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THE ACODAC SYSTEM

Scott C. Daubin, et al

Woods Hole Oceanographic Institution

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WHOI-72-87

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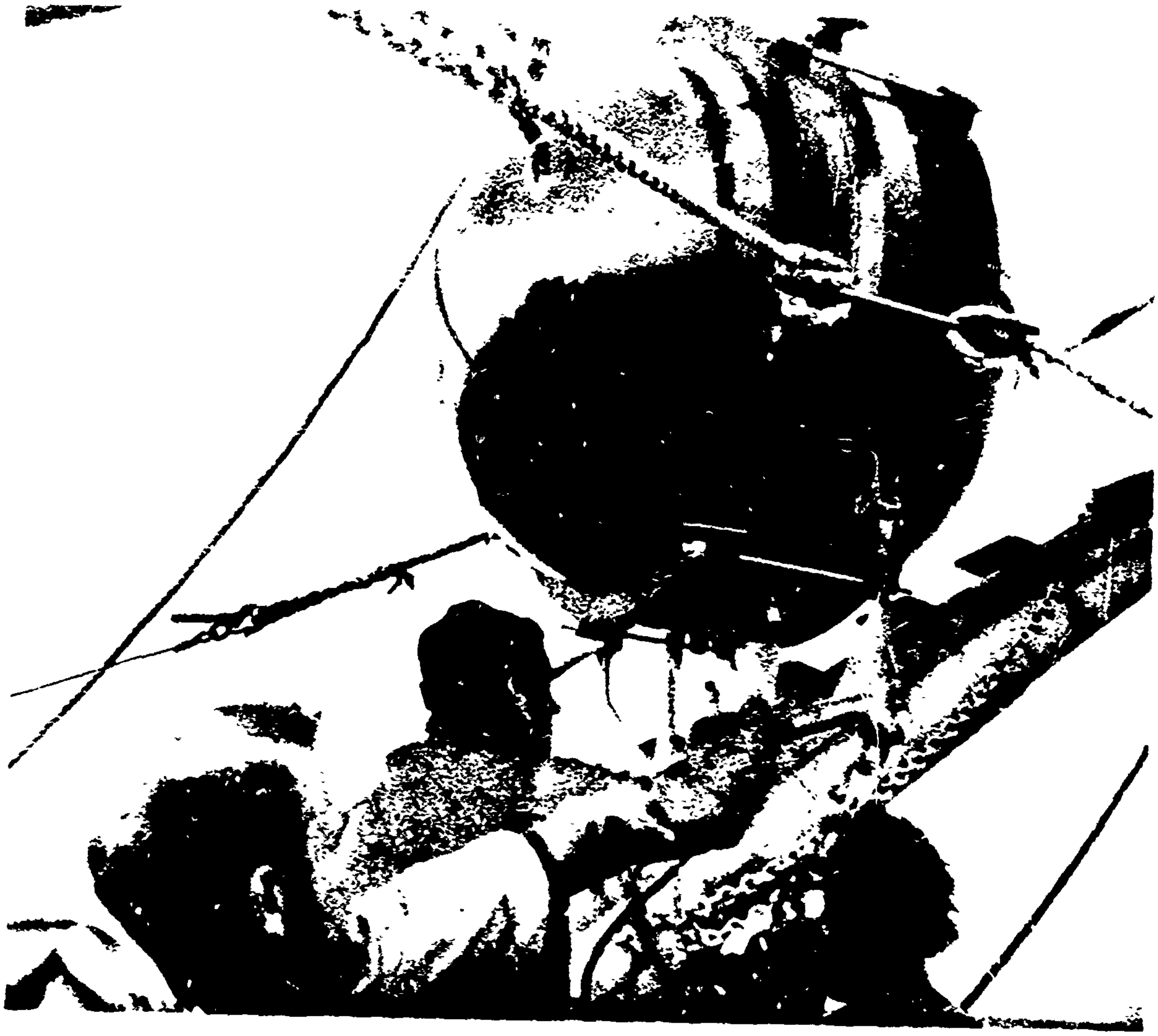
Department of Ocean Engineering

III

Frontispiece



ACODAC Launching

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The process of realization of a complex system from concept to operational hardware involves the coordinated efforts of many persons. In the case of the ACODAC system the authors hereby cite the efforts of Richard S. Brereton, Allan R. Davison, William M. Kucharski, Sidney R. McPherson, Jr. and Patrick O'Malley, for their teamwork in the laboratory and at sea often under sometimes less than confortable conditions; Dan W. Clark and his crew of whom miracles were asked and from whom miracles were delivered; Constantine D. Tollios for transforming ideas into working computer programs and raw data into reduced tables and plots ashore and afloat; William S. Shultz for his ingenuity and skill as a machinist; Captain Emerson H.Hiller and the entire crew of the R/V KNORR for magnificent service; Captain D. Murphy and the crew of the R/V NORTH SEAL for successfully conducting a novel operation; Jess H. Stanbrough, Jr. for many things, large and small, technical and non-technical; and finally Charlotte A. Muzzey for "mothering" the people, the paper and the system from beginning to end.

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1. ACODAC System

1.1 General

1.1.1 Background

The ACOustic DAta Capsule (ACODAC) system was developed to answer a long standing need in underwater acoustic instrumentation. The need was for long time series data, simultaneously acquired at a number of depths throughout the water column in the deep ocean. In solving the design problem for the system to meet the need, the following constraints were observed:

A. Measurement periods of up to one month were required in a band up to 3 kHz.

B. The data acquisition process was to be completely automatic without the involvement of men or ships. In the first place, ships are noisemakers; they generate acoustic noise which can mask the signals being sought and, through surface motion, they can induce self noise into a ship suspended array. For relatively short periods, ships can reduce their acoustic radiation by going to a "quiet ship" condition, but for long periods, this becomes an infeasible approach. Finally, ships are expensive and if it is required to make long term observations simultaneously from several sites, the cost rapidly becomes prohibitive.

C. The system was to be "adaptable", i.e., the sampling depths were to be selectable as were the sampling intervals and durations. Further, the system was to be deployable from a number of platforms; it was not to be tied to a particular ship or shipboard installation for deployment or recovery.

Table I lists the performance characteristics of the systems developed to satisfy these needs. Appendix B details the systematic organization of the ACODAC and supporting systems, but for the purpose of this report the ACODAC system is divided into the following subsystems: data acquisition, main power, electromechanical cable, instrument pressure vessel and miscellaneous components. The auxiliary systems comprise those which are needed for launching and recovery, maintenance and data processing; these include the ACODAC winch, jacking stand, tracks, miscellaneous mechanical equipment and data processing systems.

1.1.2 Program History

Woods Hole first formally proposed "An Investigation of Oceanic Acoustic Ambient Noise via Long Term Unattended In Situ Recording" in September 1969. The program's first objective was to develop an ACODAC instrumentation system and then to employ five such ACODACs in long term studies of ambient noise particularly in the low frequency (less than 300 Hz) regions and to relate observations to sources, natural and man-made, in both a deterministic and a statistical sense.

The September 1969 proposal was favorably received but not supported at that time, due to lack of available funds. When funding became available, Woods Hole submitted two supplementary proposals, one in January 1970 and one in May 1970, both of which were funded by the Office of Naval Research (ONR). The January proposal defined "an initial package of work" to proceed from 2 March until 30 June 1970. Its statement of work follows: "It is proposed to complete the preliminary design, conduct the detail design, define purchase specification, choose supplier and issue certain long lead purchase orders for the first two ACODAC units. In connection with this, necessary laboratory bench modelling will be accomplished." The work proposed in the January 1970 proposal was successfully completed. The May 1970 proposal provided "for a continued high level of activity in the program until such time as regular FY 71 funds can be made available." Its statement of work follows: "During the period 1 July through 31 October 1970, it is proposed to redefine the ambient noise program, complete the ACODAC detail design, complete specifications of all purchased hardware, issue all major purchase orders, conduct most of the breadboard circuit development and complete most of the mechanical component development. Assembly and testing of completed ACODAC units will take place after 31 October 1970." The work proposed in the May 1970 proposal was completed. A proposal submitted in September 1970 provided for "the purchase of equipment, fabrication of components, assembly and test of two complete ACODAC units together with shipboard support equipment..... and in instances of clear price advantage, purchases..... for all five units of the total program..... also for planning subsequent field observations." This work was accomplished as stated and the ACODAC system was tested at sea off Cape Cod for a three day exposure during May. The ACODAC system was approaching an operational state. The proposal of May 1971 "took the system to sea" for a series of tests and observations during the remainder of the year; it also provided for detailed laboratory analyses of the results and preparations of systems for the following year, incorporating the inevitable lessons learned through exposure to the environment. Under the "sea observations" task a series of deployments off Bermuda, Madeira and in the Mediterranean were proposed and carried out in accordance with the following table:

Location	Deployment Date	Recovery Date	Mooring
<u>Bermuda</u>			
Lat. 32-17.9 N Long. 64-29.6 W	8 Aug. 1971	20 Aug. 1971	B
<u>Madeira</u>			
Lat. 33-20.0 N Long. 19-36.1 W	[illegible]t. 1971	20 Oct. 1971	A
Lat. 33-22.8 N Long. 19-41.5 W	10 Oct. 1971	18 Oct. 1971	B
<u>Mediterranean</u>			
Lat. 36-15.7 N Long. 17-26.7 E	2 Nov. 1971	2 Nov. 1971	A
Lat. 36-17.8 N Long. 17-13.2 E	1 Nov. 1971	25 Nov. 1971	B

This report describes the system used during this phase of the ACODAC program, the associated shipboard support equipment and the operational methods employed.

DATA SYSTEM	
Number of Hydrophones	6
Recording Method	Direct Record Analog
Overall Dynamic Range (per channel)	-70 to _10DB re V/ubar in three automatically selected 27 DB ranges
Tape Speed	15/160 IPS or 15/16 IPS
Overall Frequency Response	15 to 300 Hz or 20 to 3000 Hz within ±3 DB
Recording Duty Cycle Range	1:1 to 30:1 in selectable integral ratios
Recording Time Per Cycle	1 to 128 minutes selectable
Total Recording Time (Duty cycle = 100%)	10 2/3 days or 25.6 hrs.
Total Bandwidth - Days (BW x # channels x days)	19200 Hertz-days (6 hydrophones)
OPERATIONAL CHARACTERISTICS	
Maximum Operating Pressure	9000 psi (Limited by sphere)
Acoustical Telemetry Data	Leak indication Pressure at upper end of hydrophone array Battery voltage
Location Aids	Redundant acoustic transponders
Recovery Method	Redundant acoustic releases
Recovery Aids	Acoustic pinger on capsule Dual radio beacons (27 MHz) Dual zenon flashers
POWER	
Main Power Supply	Magnesium cells, 16 kwh
Auxiliary Supply	Magnesium cells
MECHANICAL	
Sphere	38" ID x 1.25" t, 7178-T6 aluminum
Hydrophone E/M Cable	7 Conductor, 3/8" double armored cable Amergraph Type 7437SB

ACODAC Performance Specifications
TABLE I

1.2 Data Acquisition Sub-system

1.2.1 General

The data sub-system consists of all those elements which transform the acoustic pressure signal in the ocean into a magnetic recording within the instrument pressure vessel (IPV). These include the hydrophones with their preamplifiers, the transmission functions of the interconnecting connecting cable (which will be discussed under Sect. 1.4.2 below), the IPV data amplifiers with their gain control and error detection circuitry and the magnetic tape recorder. The command and control circuitry and the master clock circuitry which control the sampling program and interacts with the human operator at the surface via acoustic telemetry also comprises part of the data acquisition sub-system. A block diagram of the ACODAC data acquisition sub-system is shown in Figure 1. A photograph of the electronics package mounted in the IPV is shown in Figure 2.

1.2.2 Signal Processing and Recording

The data amplifiers interface the hydrophones with the tape recorder and incorporate an automatic gain control circuit to compensate for differences in dynamic range between the hydrophones and the recorder. They also provide inputs for injecting calibration and data annotation signals, and allow for frequency roll-off and pre-recording equalization if required.

The tape recorder is the heart of the system. It is a low speed, direct recording unit with IRIG compatible tape track configuration. This enables the data reduction to be performed with any high quality playback recorder at increased speed. The recorder was chosen for its long term recording capability in terms of the timex bandwidth product, low power drain and general suitability for field use.

The command and control system includes a time code generator, a multiple frequency generator, a calibration signal generator, the tape recorder motor control circuitry, and a master clock.

The electronics of an American Machine & Foundry Co. (AMF) Model 262 acoustic transponder/release system are also incorporated into the sphere and are tied to an acoustic telemetry system. This provides a means for determining the system depth after deployment, relocating the system for retrieval, releasing the sphere, and checking the status of the unit after deployment.

With the exception of the tape recorder, the time code generator, and the AMF release, all electrical design and fabrication was done at W.H.O.I. Of special concern in designing all circuits were power consumption and reliability. The conserve power, all devices used were selected for their low current drain. The RCA Complementa Symmetry-Metal Oxide Semiconductor (COSMOS) logic elements sed exclusively in all logic design. These devices exhibit mic tt power dissipation and have a high noise immunity. Also

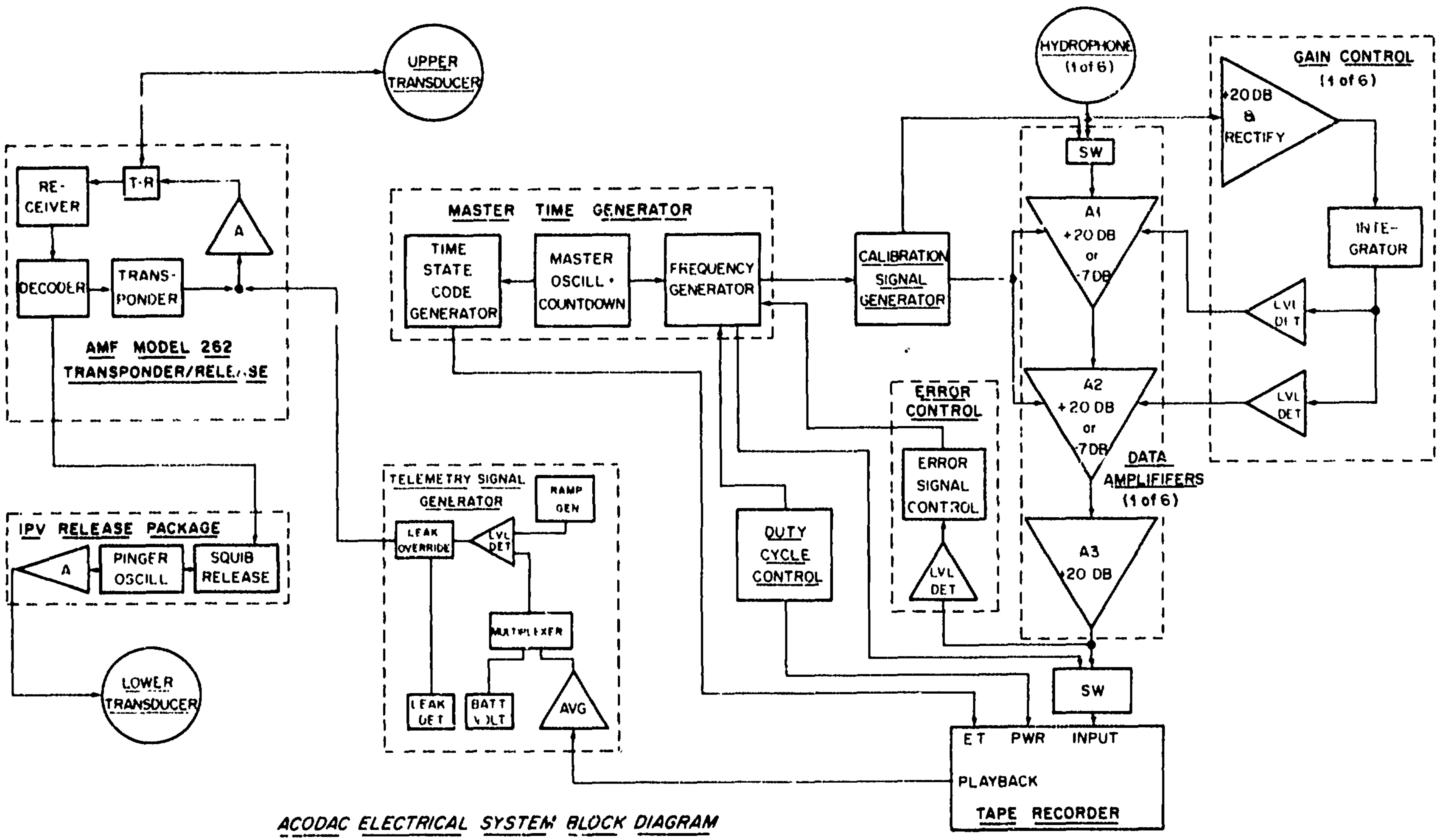


Figure 1. ACODAC Data Acquisition Sub-System Block Diagram

they are usable over a wide range of supply voltages so that it was unnecessary to provide tightly regulated power supplies. High gain discrete transistors and micropower analog integrated circuits were used when required. Extensive use of integrated circuits provided increased reliability, ease of fabrication, and compact size.

All circuits are built on double sided printed circuit boards employing high reliability connectors.

A. Tape Recorder

The original system requirements specified simultaneous monitoring of seven hydrophones for a period of thirty days. Several different methods of recording were compared in view of these requirements and the results are summarized in the following table.

Recording Method	Signal-to-Noise Ratio	Tape Speed Required for 300 Hz Bandwidth and 6 Hydrophones	Tape Required for 30 Days (1000 ft.)
Direct	24-40 db	.05 - .2 ips	10.8 - 43.0
FM	40-55 db	1 3/4 ips	380
Digital	80 db	10.5 ips	2268.0

The analog methods (Direct and FM) have the advantage that one tape channel can be devoted to each hydrophone whereas the hydrophone signals have to be sequentially sampled and recorded serially with a digital recorder. The amount of tape required for both FM and digital recording is prohibitive unless severe limitations on recording time are imposed. Therefore, direct recording was chosen although it offers a reduced signal-to-noise ratio and requires sophisticated dynamic range compression circuitry to match the hydrophone signal range to the recorder. One-half inch tape was selected since the standard IRIG configuration provides seven data tracks and two edge tracks. One data track was assigned to each hydrophone and the edge tracks were to be used to record time code and other information as required.

In selecting the recorder several factors were taken into consideration including,

(a) Recording Capacity
(b) Signal bandwidth
(c) Dynamic range
(d) Size, weight and power
(e) Suitability for unattended field use
(f) Availability and price
(g) Data format and ease of retrieval
(h) Previous performance.

The Geotech Model 17373 recorder proved to be the best compromise and was selected. It is a relatively compact unit with con-

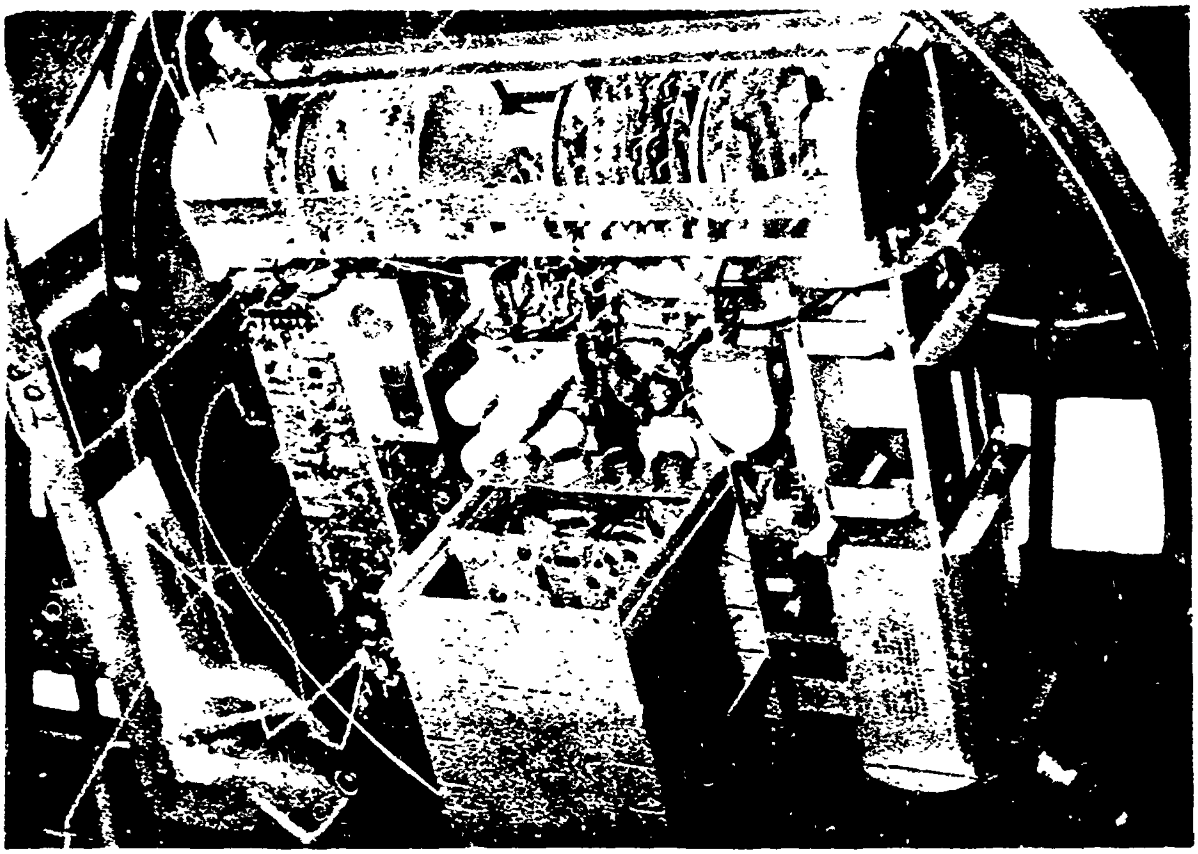


Figure 2. IPV Electronics Assembly

centric reels, a captive loop tape path, and has been used at the Woods Hole Oceanographic Institution previously for acoustic and seismic work. It can be built to run at various tape speeds and the following table summarizes its characteristics at 15/160 ips and 15/16 ips.

Geotech Model 17373 Tape Recorder

Tape Speed (ips)	15/160		15/16
Tape Capacity (1 Mil Tape)		7200 ft.	
Recording Time	10 2/3 days		25.6 hours
Size		8"x18½"x22"	
Weight		35 lbs.	
Operating Temperature Range		-6 to 60°C	
Head Configuration	IRIG Standard	7 Tracks + 2 Edge Tracks	
Speed Accuracy		±.25%	
Record Bandwidth	0-300 Hz		0-3000 Hz
Dynamic Range		30 db	
Input Sensitivity Range		.5 to 5v RMS	
Power Supply Voltage		±11 to ±14	
Power	13 watts		19 watts

To compensate for speed variations in the tape recorder which would otherwise result in loss of resolution in narrow band spectrum analysis and in loss of dynamic range, a reference frequency is impressed on the auxiliary (time code) track of the recorder. The reference frequency is beat down from the master oscillator and has the stability characteristics of the master clock. During A/D conversion operations for generating a digital time series from the analog data, the reference frequency signal triggers the sampling circuit. These control frequencies are near the upper end of the usable band, 294.17 Hz and 2941.7 Hz for the 300 Hz and 3000 Hz band machines, respectively.

B. Data Amplifiers

The data amplifiers interface the hydrophones with the tape recorder and perform the following functions.

(a) They incorporate a step-wise automatic gain control circuit which provides three gain settings separated by 27 db. This allows the 80 db dynamic range of the hydrophone to be recorded on the recorder which has only 30 db dynamic range. The average level of the input signal is monitored once each minute and the gain is then adjusted accordingly.

(b) Each amplifier also incorporates an overload detector. If the input signal should become large enough to cause the amplifiers to saturate before the gain is adjusted, the error signal is switched onto the data track in place of the data.

(c) A calibration signal input is provided where a known signal can be injected into the front end of the amplifier in place of the data signal.

A detailed block diagram of one amplifier is shown in

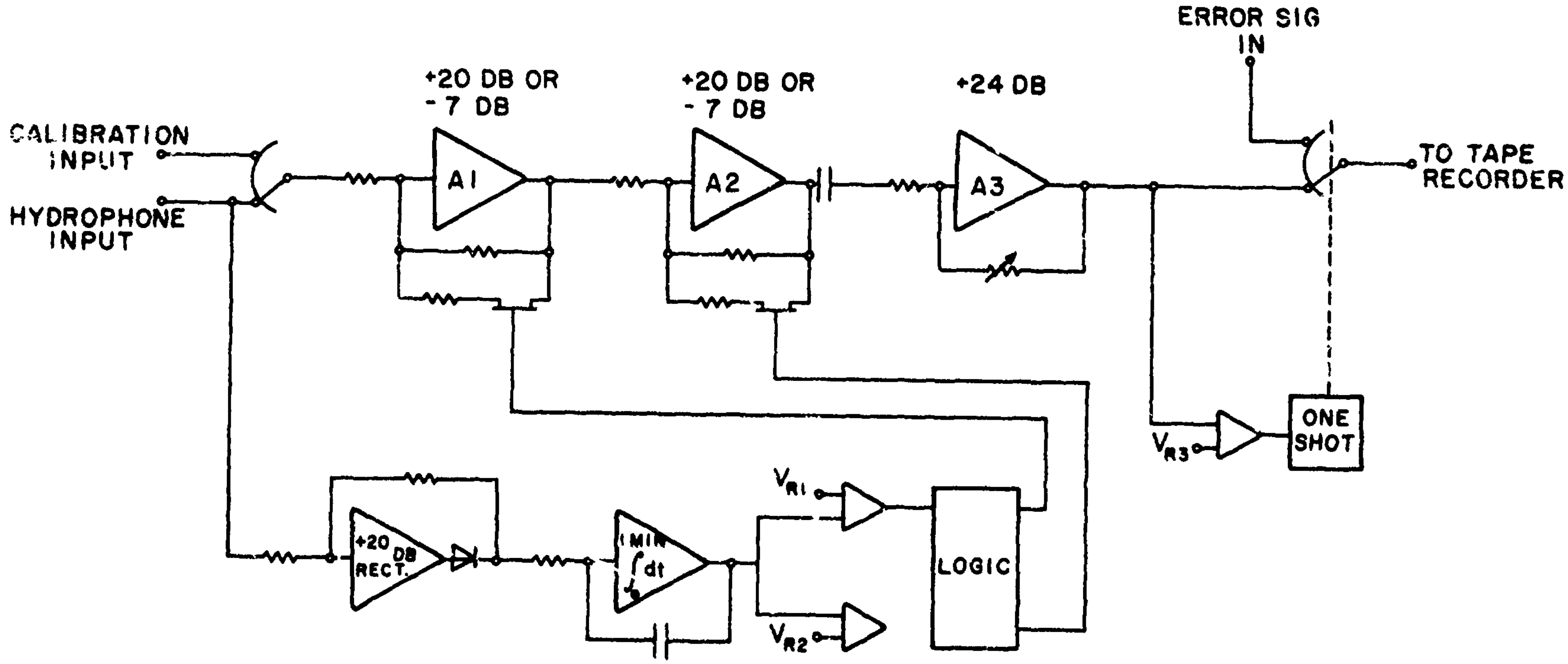


Figure 3. Data Amplifier Block Diagram

Figure 3. Each amplifier is composed of three amplifiers stages in series. Fairchild Type μA735 operational amplifiers are used in each stage for their small size, low power drain and low waveform distortion. The feedback resistor of the first two stages can be changed by field effect transistor switches which in turn change the gain. The resistor values have been selected so that the gain is either +20 db or -7 db. The third stage amplifier gain can be adjusted by a potentiometer in the feedback loop. The tape recorder is set to take signals in the range .1v to 3.0v rms, and the amplifiers are adjusted so that the output signal falls within this range. The following table summarizes the gain settings and input voltage range covered by each gain setting.

Overall Amplifier Gain (DB)	Stage Gain (DB) 1	2	3	Input Signal Range	Output Signal Range
+10	-7	-7	+24	.033 - 1.0v rms	.1 - 3.0v rms
+37	-7	+20	+24	.0015 - .045v rms	.1 - 3.0v rms
+64	+20	+20	+24	.0001 - .003v rms	.1 - 3.0v rms

The frequency response of the amplifier in all gain settings is flat from about 8 Hz to about 7.0 kHz (-3 db points). The automatic gain control circuit consists of an amplifier-rectifier, an integrator, two comparators and control logic. The input signal is amplified by 20 db and half-wave rectified to get only the negative side of the input signal. This then goes into an integrator which generates a voltage ramp that is proportional to the average input signal level. Two comparators are used to generate inputs to the control logic. Reference voltages are applied to one input of each comparator and the integrator ramp is applied to the other input. Depending on how high the ramp voltage gets in one minute the comparators are either tripped or not and the control logic then adjusts the gain of the amplifiers accordingly. All gain adjustments are made once per minute and the ramp voltage is simultaneously reset back to zero. The reference voltages are adjusted so that the gain changes are made for input signal levels of .003v rms and .045v rms as shown the previous table.

The overload detector monitors the output of the data amplifiers and when the output level is high enough to cause overload distortion of the recorded signal, the data signal is switched off and the error signal is switched into the tape recorder. When the overload condition is over, the data signal is switched back on. A one shot multivibrator is used to hold the error signal on for a minimum of .120 seconds whenever the overload is triggered. This is to insure that there is sufficient time to detect it upon playback.

A calibration signal input is provided at the front end of the amplifiers so that the data can be switched off and a known signal run through to the tape recorder periodically. A typical calibration signal involves two different frequencies and three different amplitudes. At the same time the calibration signal is being applied the automatic gain control logic circuitry is overriden and the amplifier gains are controlled by the calibration signal generator.

To monitor each amplifier gain setting at playback, two lines are run to the time code generator. The state of these lines is encoded into the time code and outputted from the time code reader.

1.2.3 Command and Control

The command and control system generally does all the "housekeeping" chores of the system. It has several main parts as defined in the following sections.

A. Master Clock and Oscillator

All frequencies and timing functions are derived from a master oscillator and its associated countdown circuitry. The oscillator is an Austron Sulzer Model 1115 high stability type operating at 5 mHz. Its stability specifications are given in the following table.

Variable	Variation	Stability
Supply Voltage	12± .6v DC	$\pm 5\times10^{-9}$
Ambient Temperature	-2½C to +25½C	$<5\times10^{-9}$
Aging (After 72 hrs.)	Over 24 hours	3×10^{-9}

A two stage countdown circuit is used - the first stage generates frequencies from 250 kHz to 1 Hz and the second stage generates frequencies with periods from 2 seconds to one hour; see Figure 4. All frequencies and timing functions used in the system are generated from these circuits and thus exhibit the same stability as the master oscillator

B. Time Code Generator

The time code uses a standard IRIG "C" format with an amplitude modulated 50 Hz carrier. The basic modulation signal is shown in Figure 5. The code is updated once per minute and has minutes, hours, and days coded into it. In addition there is a provision for "inputting" 32 data bits, twelve of which are now used to record the data amplifier gain settings. The unit was built to W.H.O.I. specifications by CGS Datametrics Corporation of Watertown, Massachusetts.

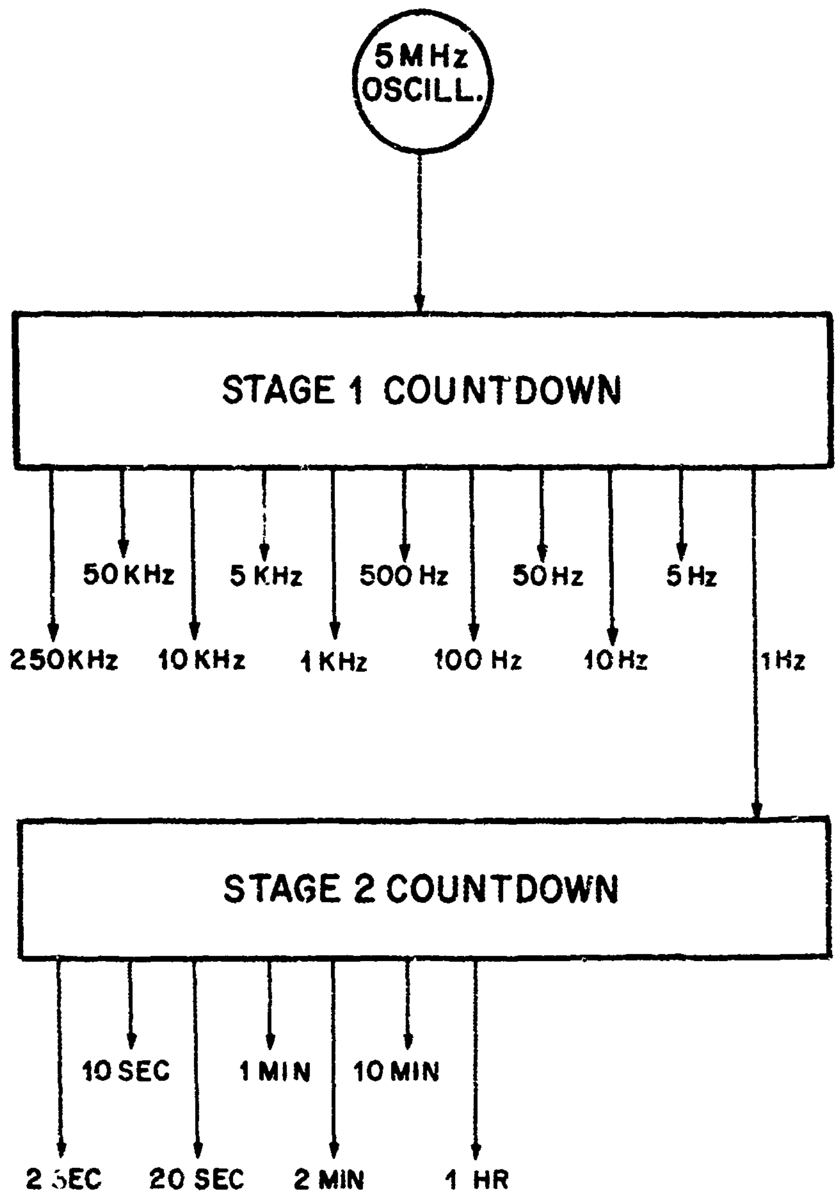


Figure 4. Master Clock

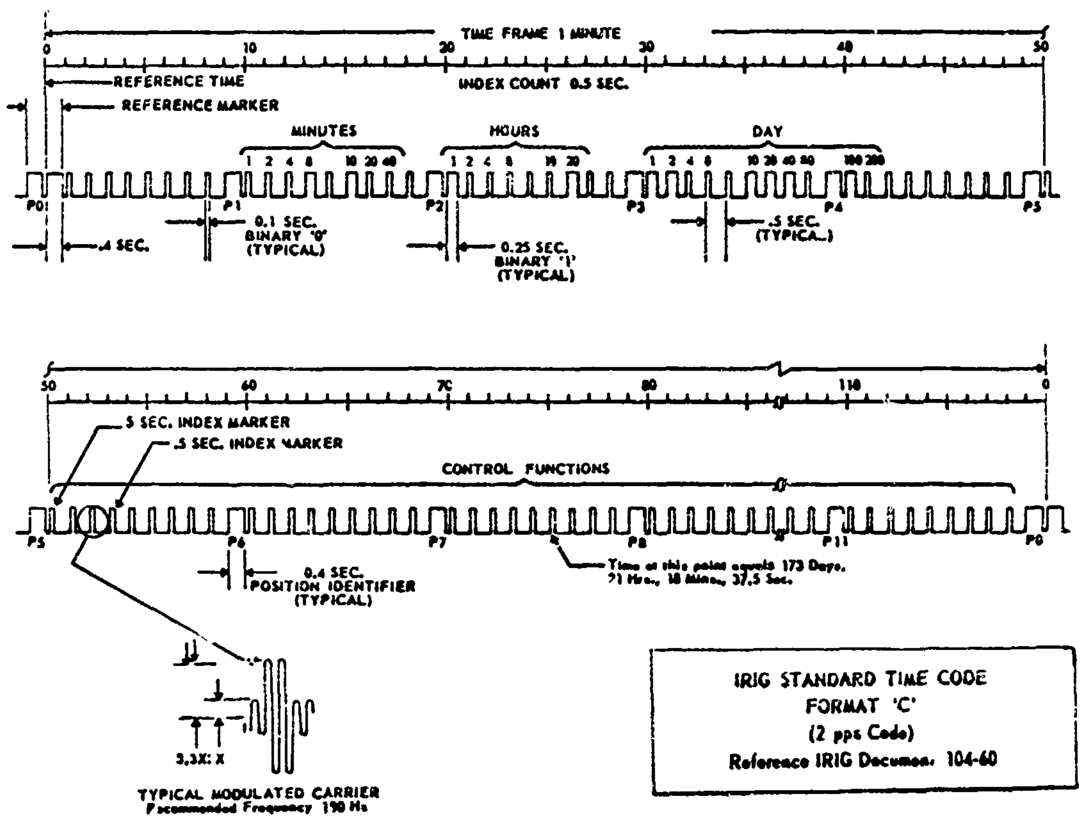


Figure 5. Time Code Format

C. Tape Recorder Duty Cycle Controller

Since the tape recorder cannot record continuously for thirty days the duty cycle controller is used to cycle the recorder on and off to extend its recording time. The basic controller allows selection of on times from one minute to 128 minutes in increments of one minute. The off time can be selected as multiple of the on time in the range 1:1 to 15:1, or can be overridden to give continuous recording. Additional circuitry was added external to the controller which extended the off time-on time ratio to a maximum of 30:1.

In order to facilitate data reduction when a duty cycle is employed a start-of-data signal is inserted on the tape prior to the beginning of data recording during each recorder cycle,

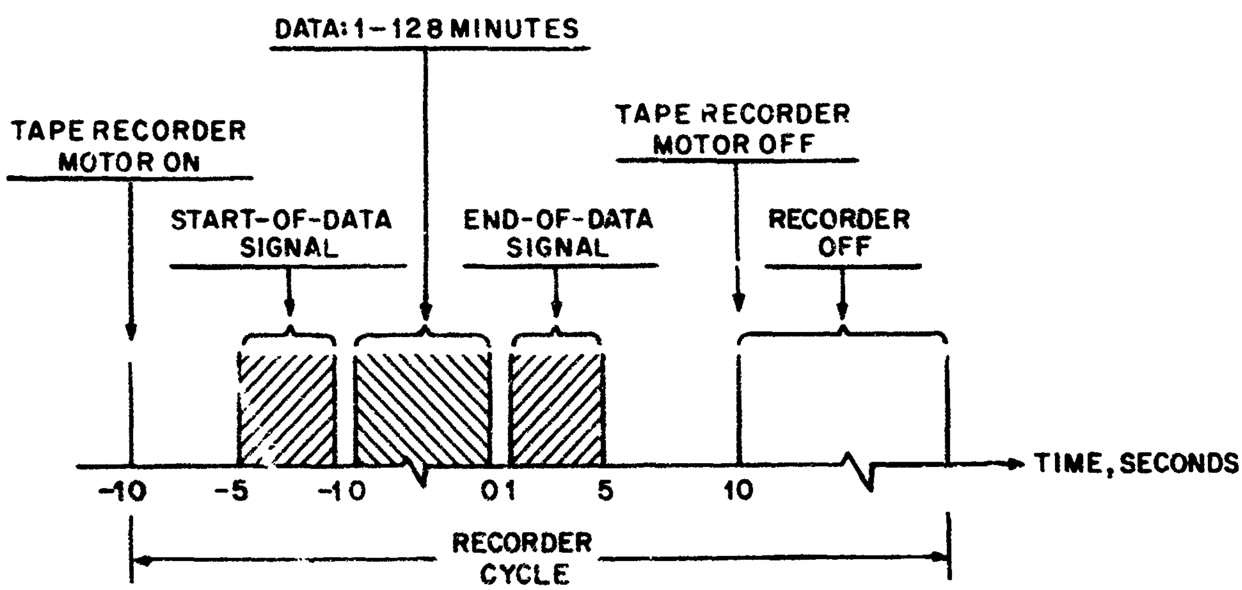


Figure 6. Tape Recorder Cycle

and an end-of-data signal is inserted at the end of the recording period. This is illustrated in Figure 6. The duty cycle controller, Figure 7, generates the logic functions to control motor turn-on, start-of-data and end-of-data signal insertion, and data recording. A hermetically sealed, latching relay is used to do the actual switching of the recorder motor control power.

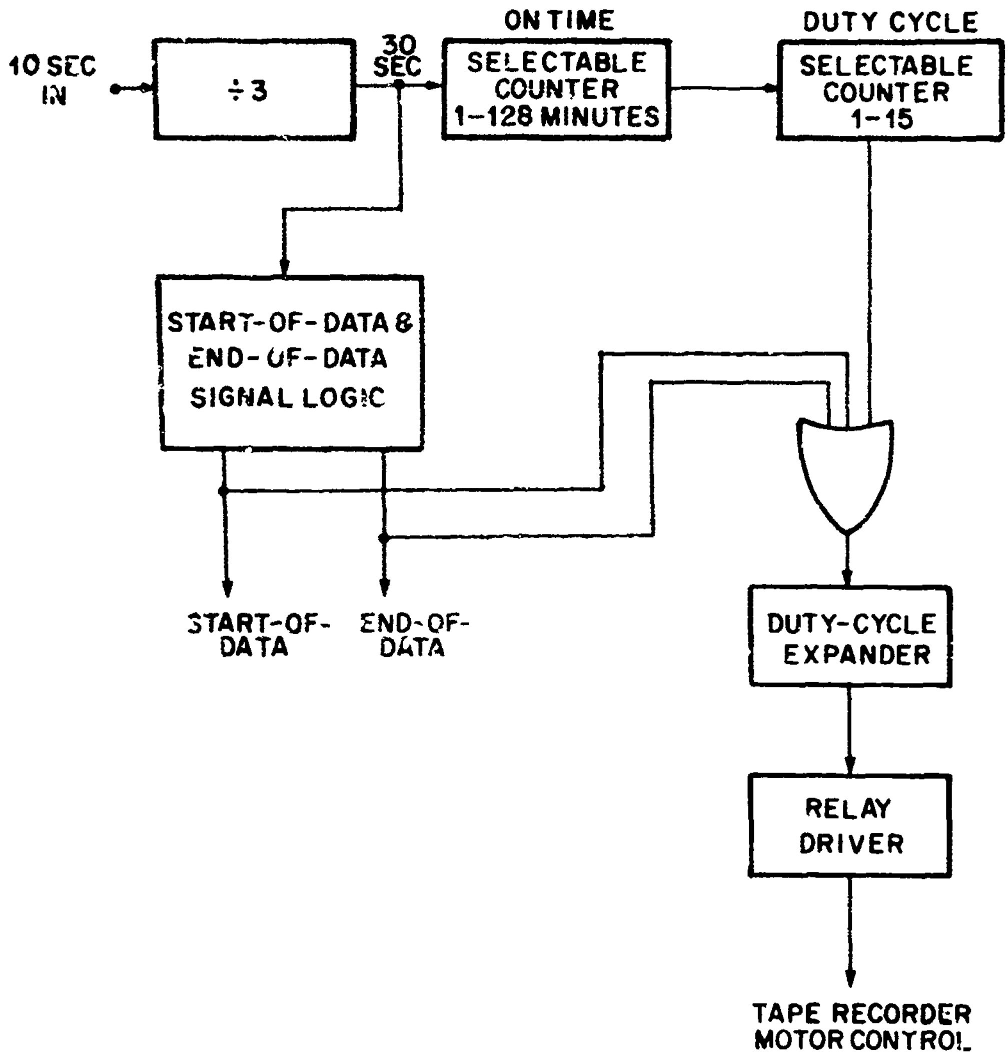


Figure 7. Tape Recorder Duty Cycle Controller

D. Delay Timer

The delay timer allows the tape recorder to be set for a delayed turn-on, see Figure 8. It can be programmed for delays ranging from 0 to 10^4 minutes (6 d 22.6 h) in ten minute increments. In this way the system can be deployed and set to begin recording at a predetermined time.

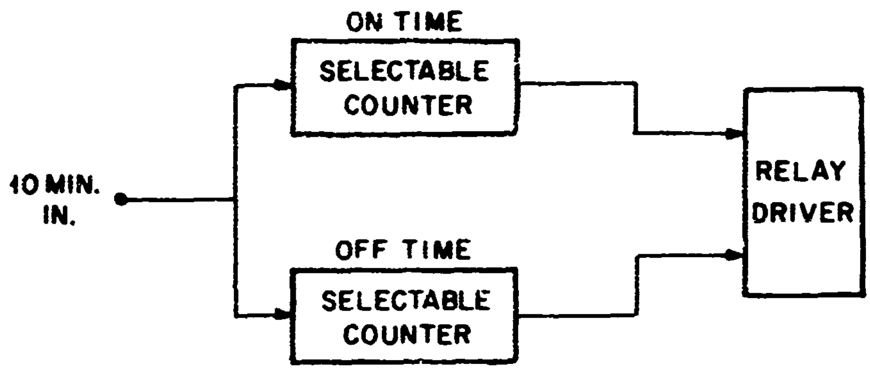


Figure 8. Delay Timer Block Diagram

E. Calibration Signal Generator

In order to determine the actual level of the playback signals in performing data reduction, a calibration signal is recorded on the tape periodically in place of the data; see Figure 9. The calibration signal consists of a sine wave stepped through three different amplitudes at two different frequencies. The three amplitudes correspond to the three gain ranges of the data amplifiers. In addition to generating the signal, the calibration signal generator also outputs logic controls to override the automatic gain control of the data amplifiers and step their gain in sequence with the amplitude of the calibration signal. In this way a simultaneous check of the amplifiers is made at the same time. The calibration signal sequence is shown in the following.

Frequency	50	50	50	200	200	200
Amplitude(dB/V)	-59.5	-32.5	-5.5	-59.5	-32.5	5.5
Data Amp Gain	+64	+37	+10	+64	+37	+10

It is applied once every six hours except when the recorder is on the off portion of the duty cycle in which case it waits until the recorder is turned on.

The sequence shown above is used in System "A" which has a 15/160 ips tape recorder. The same sequence is used for the "B" system which has a 15/16 ips recorder except that the frequencies used are 500 and 2000 Hz instead of 50 and 200 Hz.

F. Frequency Generators

The main frequency generator is used to generate the start-of-data, the end-of-data, the calibration frequencies, and the error signals. These signals are simply the sum of two discrete frequencies (except the calibration signal) and are summarized in the following table.

Signal	System "A"(15/160 ips)	System "B"(15/16 ips)
Start-of-data	150 + 200 Hz	1500 + 2000 Hz
End-of-data	75 + 150 Hz	750 + 1500 Hz
Error	75 + 200 Hz	750 + 2000 Hz
Calibration	50 Hz	500 Hz
	200 Hz	2000 Hz

The frequencies are generated from the main clock and thus are very stable. To insure that the amplitude of the calibration frequency is also stable, all logic and voltage sensitive circuitry is powered from a regulated power supply. Amplitude stability is typically ±1% over the expected input voltage range and over temperatures in the range 0°C to 25°C.

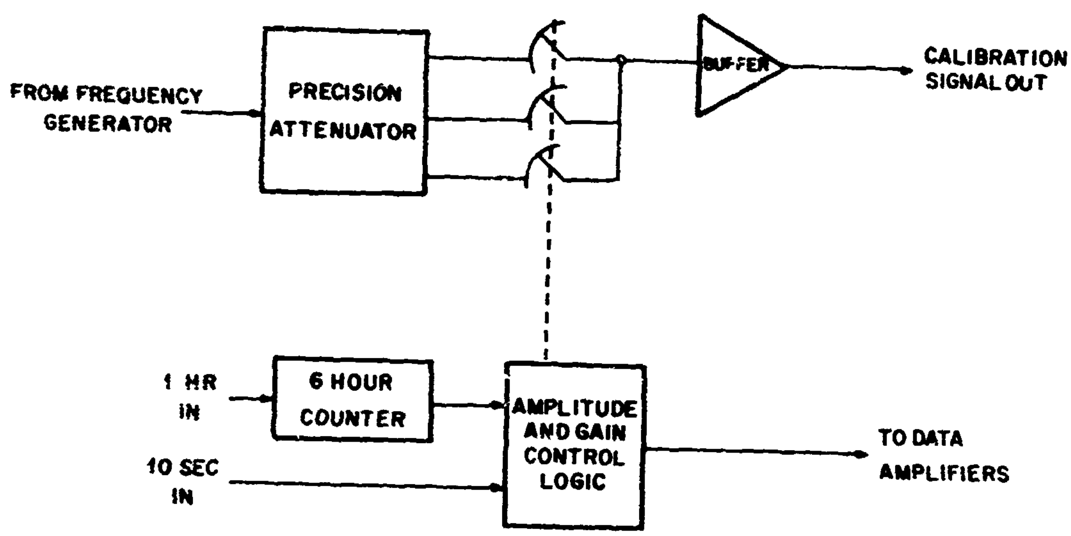


Figure 9. Calibration Signal Generator

A second frequency generator is used to generate a high frequency reference signal which is additively combined with the time code. It can be used during data reduction to eliminate the effects of tape recorder speed variations during narrow band analysis. The reference frequency is 294.17 Hz (10 kHz - 34) on the "A" system and 2941.7 Hz (100 kHz . 34) on system "B".

1.2.4 Telemetry

The purpose of the acoustic telemetry system is to provide a means of monitoring capsule status after the system has been deployed and to provide an automatic indication of any leak in the sphere. The telemetry system is composed of three main components; the telemetry signal generator, the voltage-to-time converter, and an AMF Model 262 acoustic transponder-release system.

A. Telemetry Signal Generator

In order to telemeter data back from the ACODAC system to the surface after it has been deployed a pulse position modulation scheme is employed. This is a method ideally suited for acoustic data transmission with low data rates and has been used on many instruments built at W.H.O.I. As shown in the following figure, the data are transmitted as a series of acoustic pulses. Reference pulses are sent once every four seconds and the data point is represented as a pulse somewhere between the reference pulses. The analog data level is proportional to the time between the first reference pulse of the frame and the data pulse. See Figure 10.

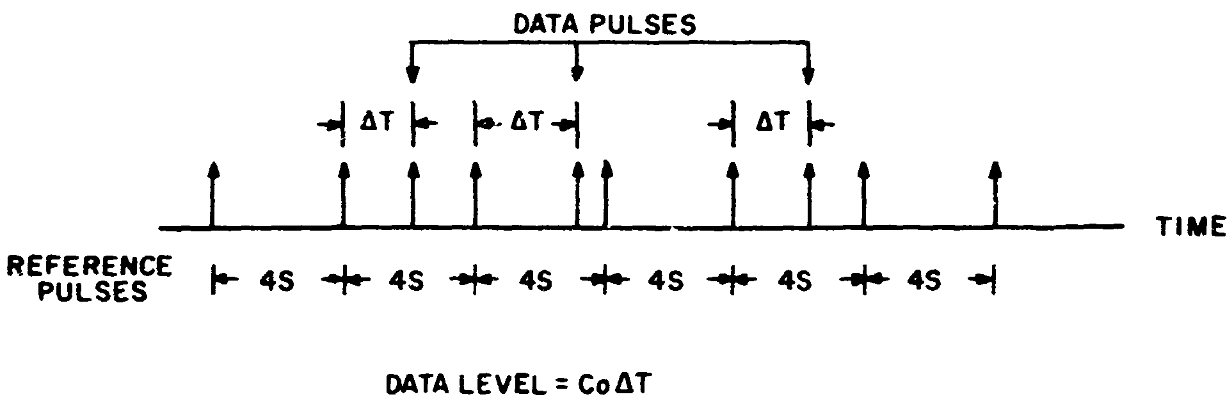


Figure 10. Acoustic Data Transmission

The functions of the telemetry signal generator are as follows:

(a) Generate the reference pulses.
(b) Provide a multiplexer so that more than one data source can be monitored.
(c) Condition the data signals to be compatible with the telemetry system.
(d) Provide a leak detection monitor.

A block diagram of the generator is shown in Figure 11. The telemetry signal is initiated on command from the AMF unit and repeats itself for 120 seconds whereupon it shuts off.

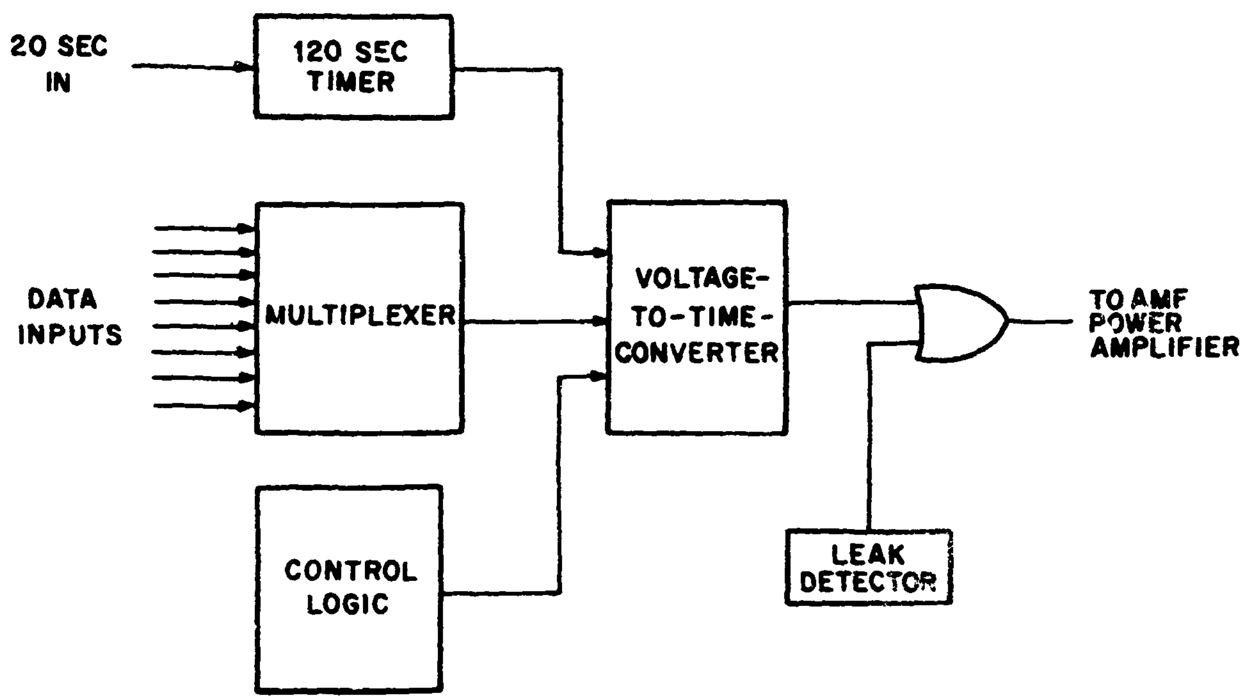


Figure 11. Telemetry Signal Generator

The three data sources are positive battery voltage, negative battery voltage and recording verification. The multiplexer has the capability of monitoring up to eight inputs but only three are used at present. The system will only take inputs in the range 0 to 5VDC so all data inputs must fall within this range. The battery voltages are run through resistor-divider networks to put them within this range, and the recording verification is monitored by taking a signal off the single playback head and rectifying and filtering it. Following the multiplexer the signals are fed to the voltage-to-time converter (Section 1.2.4 - B, below), which converts the analog input to a delayed pulse. The output of the voltage-to-time converter is then combined with the four second reference pulses to form the telemetry signal. This is then used to drive the AMF unit.

A leak detector is also included which is simply two parallel plates mounted near the bottom of the sphere. When salt water gets between them due to leakage, they are short circuited, This is used to generate the leak signal which consists of 10 pulses occurring once per second and repeated every twenty seconds.

The circuit is arranged so that the leak signal will override all other telemetry signals and will come automatically.

B. Voltage-to-Time Converter

A block diagram of the voltage-to-time converter is shown in Figure 12. A precision voltage ramp is generated once every four seconds from the master oscillator. The ramp is then applied to one input of a comparator and the analog data is applied to the other input. When the ramp exceeds the data input the comparator is triggered which in turn causes the pulser to generate an output pulse. The ramp is reset in synchronism with the reference pulses of the telemetry signal. The time delay from the reference pulse to the data pulse is then proportional to the magnitude of the data input voltage.

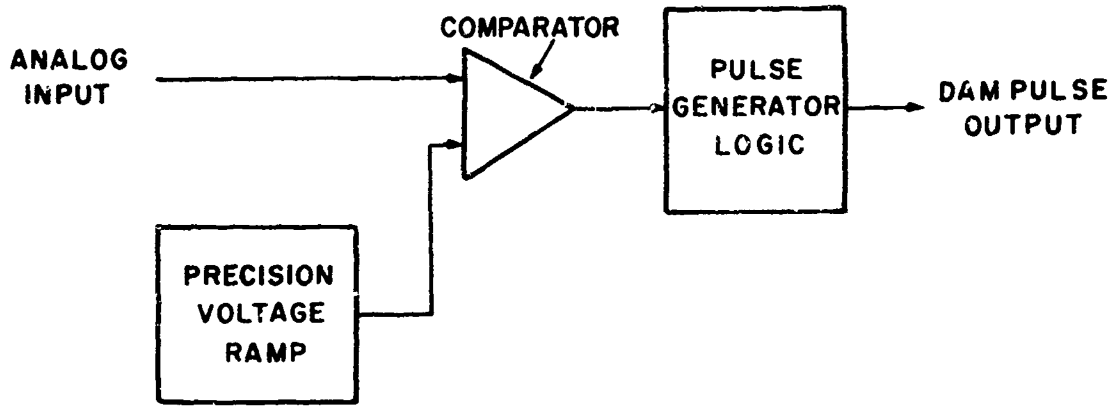


Figure 12. Voltage-to-Time Converter

1.2.5 Hydrophones

Five primary characteristics were sought in ACODAC hydrophones: (1) high sensitivity, (2) high dynamic range, (3) low self noise, (4) wide and flat frequency response and (5) insensitivity to acceleration. The hydrophone which was developed to Woods Hole specifications, included here as Appendix A, was the ITC Model 8004, produced by the International Transducer Corporation of Santa Barbara, California.

These hydrophones have an element sensitivity of about -80 db re v/ub; within the hydrophone body has a 40 db preamplifier which give an overall nominal hydrophone response of about -40 db re v/ub. Fourteen hydrophones were produced in the initial order; the precise, mid-range sensitivities of these hydrophones, based on separate element sensitivity and amplifier gain measurements by ITC, are indicated in Table II below:

Hydrophone Ser. No.	Element Sensitivity (db re v/ub)	Pre-Amp Gain (db)	Hydrophone Sensitivity @ 100 Hz (db re v/ub)
001	- 78.5	38.8	- 39.7
002	- 78.5	39.2	- 39.3
003	- 78.5	39.2	- 39.3
004	- 78.5	39.1	- 39.4
005	- 78.5	39.0	- 39.5
006	- 78.5	39.0	- 39.5
007	- 78.5	39.2	- 39.3
008	- 78.5	39.2	- 39.3
009	- 78.5	39.4	- 39.1
010	- 78.5	39.2	- 39.3
011	- 78.5	38.9	- 39.6
012	- 78.5	39.1	- 39.4
013	- 78.5	39.1	- 39.4
014	- 78.5	39.1	- 39.4

ACODAC Hydrophone Sensitivities

(ITC Model 8004)

Table II

To reduce the net acceleration response, the hydrophones were resiliently mounted within a "cage assembly" as shown in Figure 13. The natural frequency of the mounting in air is about 3.5 Hz. When fully assembled, a neoprene flow shield surrounds the hydrophone as shown in Figure 14. By providing a quiescent free-flooding volume for the hydrophone, the flow shield keeps net water motion relative to the mooring a few inches away from the boot of the hydrophone. Although no measurements were made as to the magnitude of the resulting flow noise suppression, calculations indicate that the arrangement should reduce flow noise by from 4 to 6 db.

The acceleration response of the ITC 8004 element was tested in air on a shaker table and found to exceed the 20 db suppression required by the specifications (Appendix A) in all three axes. However, the acceleration response suppression of the assembled hydrophone was not as good as that of the bare element. This effect results from a number of possible causes; among these are first the lack of symmetry in the overall hydrophone assembly and the resulting near field acoustic pressure patterns produced by its motion and second the pressure gradients within the element containment fluid due to the resilient response of the boot under accelerations. Because of residual acceleration sensitivity, it was found necessary to reduce the low frequency response of the hydrophone. The low frequency roll off of the overall hydrophone is controlled by two elements, one mechanical and the other electrical. Figure 15 shows the electrical circuit of the preamplifier. In the operating frequency range the cylindrical transducer element appears as a completely enclosed container. However, the cylindrical element is vented to the surrounding oil volume by a tiny orifice in the element. For static pressures

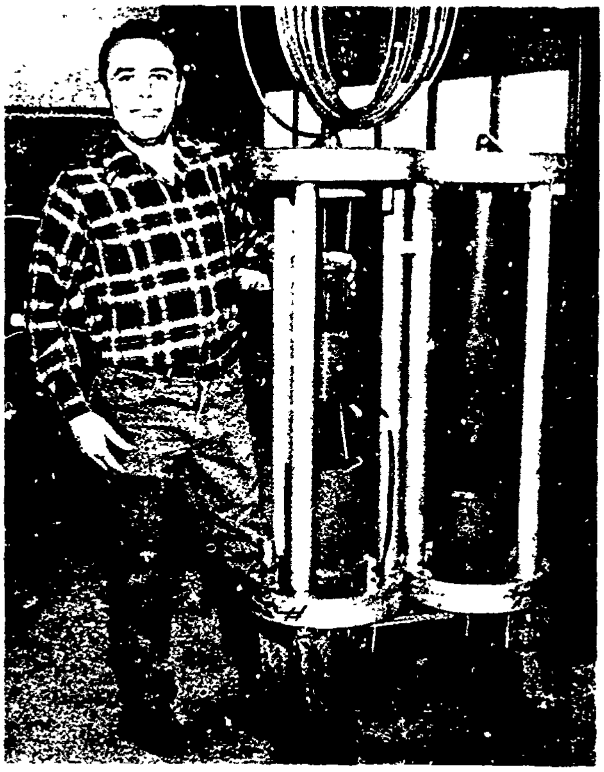


Figure 13. Hydrophone Cage Assembly (less flow shield)

Figure 14. Hydrophone Cage Assembly (with flow shield)

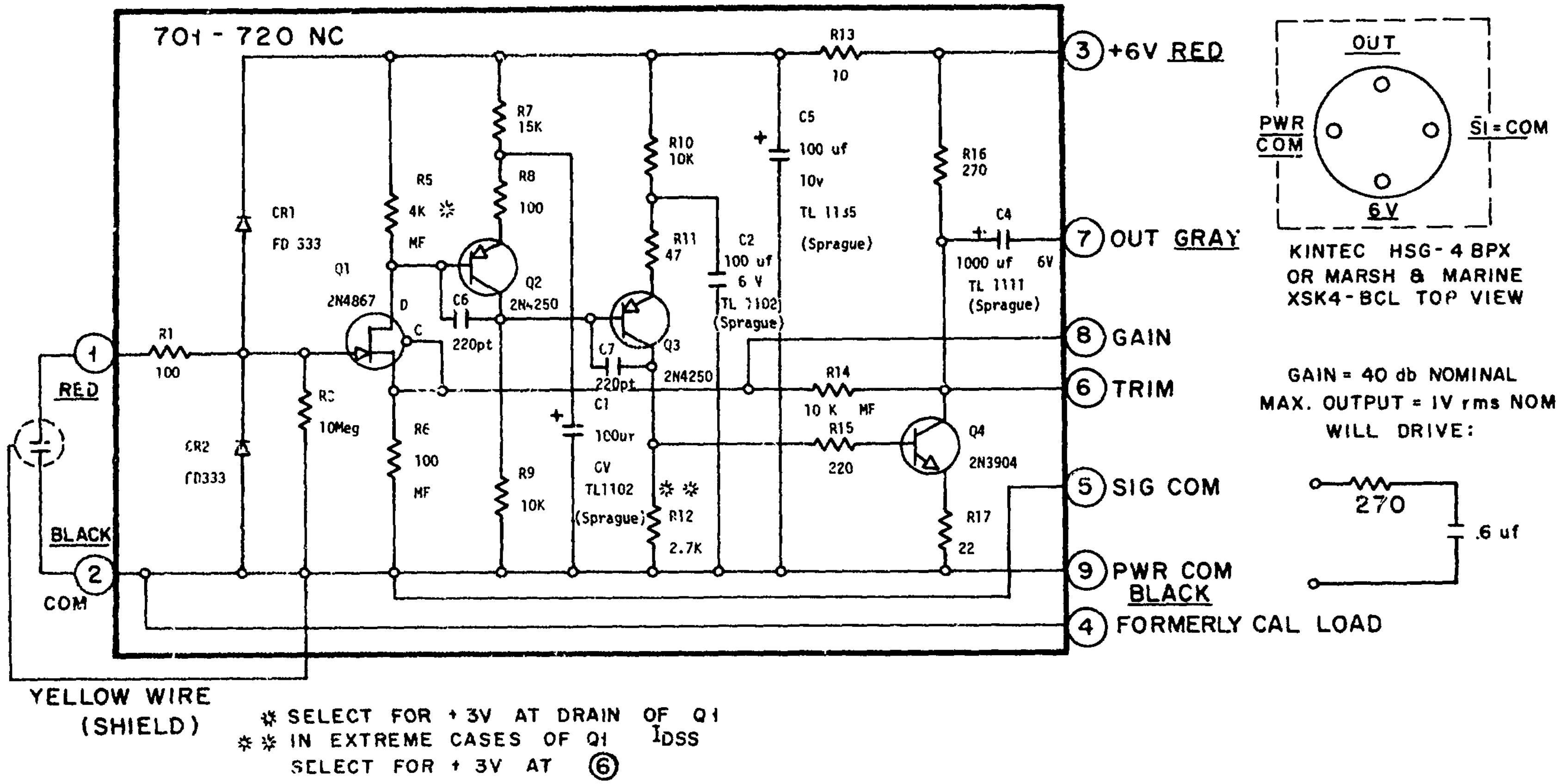


Figure 15. Hydrophone Preamplifier Schematic

there is thus pressure equilibrium between the inside and outside of the element. The diameter and length of the orifice determines the transitions frequency between the appearance of the element as a vented and nonvented volume to an acoustic pressure excitation. The lower 3 db down point frequency of the element varies as the dimensions of this orifice (diameter, a, and length, l) in accordance with the following expression $f_{\ell e} \alpha \frac{a^4}{\ell}$. The electrical signal generated in the element is divided between the capacitive reactance of the element and the input resistance to the pre-amplifier. The frequency of the 3 db down point is given by the following relation:

$$f_{\ell e} = \frac{1}{2\pi RC}$$

For an element capacitance of 1533 pico farads and an input resistance of 20 megohms f_{l_e} = 5.2 Hz. Since the orifice dimensions could not be changed it was necessary to change the value of the input resistor (R3 in Figure 15) in order to vary the low frequency roll off. Because of the "excessively high" acceleration sensitivity the low frequency 3 db down point was increased to 10.4 Hz by reducing the value of the input resistor to 10 megohms.

1.3 Main Power Sub-System

1.3.1 Circuit

A schematic of the power supply system is shown in Figure 16. The main components include the main battery, the isolation diode circuit, the auxiliary battery, and the voltage regulators.

The IPV electronics are designed to run off input voltages of +13±2V DC and -13 ±2V DC. Two voltage regulators in the electronics provide +5V DC for the time code generator logic and +9V DC for the frequency and calibration signal generators.

The main battery is composed of a series-parallel combination of magnesium dry cells (Section 1.3.2). Since each cell provides a nominal 1.6 V output, eight cells are connected in series to give 12.8 V. These series strings are then connected in parallel to provide the required capacity. Diode isolation of each series string prevents loss of power by preventing reverse current flows, and also provides fault protection should any string suffer a loss of voltage.

In order to prevent loss of time code during the change-over from the shipboard test set to the main battery at deployment, a small auxiliary battery is mounted inside the IPV to keep the system running. Also, since the magnesium cells require several seconds to develop full cell potential when an increased load is applied, the auxiliary battery carries the electrical load during these periods. It consists of 20 size "C" nickel-cadmium batteries connected in series to provide

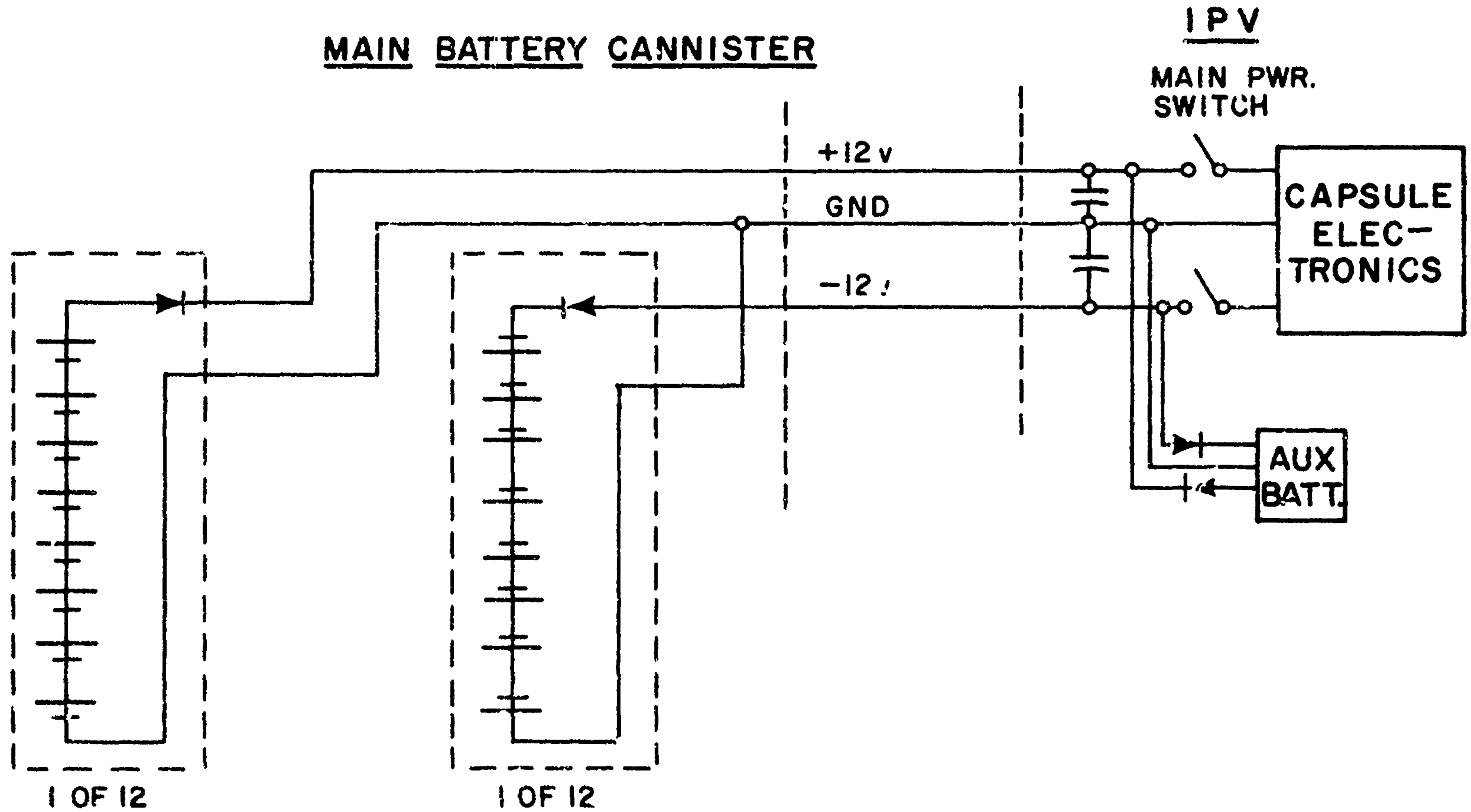


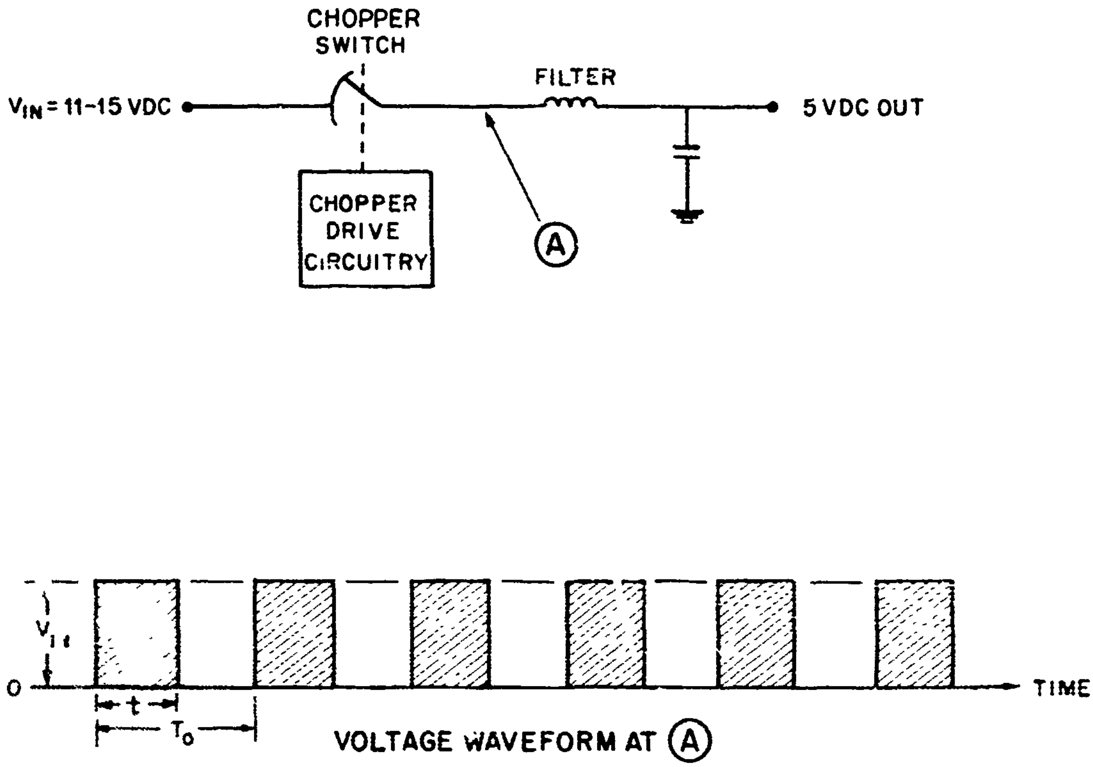
Figure 16. Main Power Supply System

+12 and -12V DC. Two voltage regulators in the electronics provide +5V DC for the time code generator logic and +9 V DC for the frequency and calibration signal generators.

The load on the 9V voltage regulator is mostly COSMOS logic circuits and the current drain is very low. Therefore a standard series regulator is used in which the excess power is dissipated in the device in the form of heat. The 5 V voltage regulator carries a sizeable load and since the time code generator operates continuously during the whole deployment a chopper regulator was used. The input voltage is chopped to produce a square wave which is then filtered to produce a lower DC output voltage. When the output current load increases, the "on" time of the chopper is increased, and likewise if the input voltage is increased without any increase in the output current requirements the chopper "on" time is decreased. A block diagram is shown in Figure 17. Ideally, no power is wasted in regulation but typically this scheme realizes 85-90% efficiency.

1.3.2 Batteries

Several types of cells were considered in designing the main battery for ACODAC. These included magnesium, nickel-cadmium, lead acid, mercury, alkaline, and silver-zinc. Table III summarizes the various types.



$$V_{OUT} = \frac{t}{T_o} V_{IN}$$

Figure 17. 5 VDC Regulator Diagram

Battery Type	Nominal Voltage	Ampere Hour Capacity	Watt Hr/Lb. @72^{o}F.	$/Watt Hr. @ 72^{o}F.	Rechargable	Low Temperature Derating
Magnesium Battery Corp. of America #6 Cell	1.6	60	43.5	.06	no	5-10%
Nickel-Cadmium Nife Corp. KA83E	2.4	830	24.5	.11	yes	5%
Lead Acid Sears Roebuck Co. "Die-Hard"	12	96	21	.02	yes	20%
Silver Zinc Yardney Power Corp. Type YS-300	1.1	300	100	Very high	yes	15%
Mercury Union Carbide Type E42N	1.35	14.0	51.5	.52	no	80%
Alkaline Rechargable Union Carbide Type 561	15	5.0	12.5	.23	yes limited	20%

Cell Characteristics

Table III

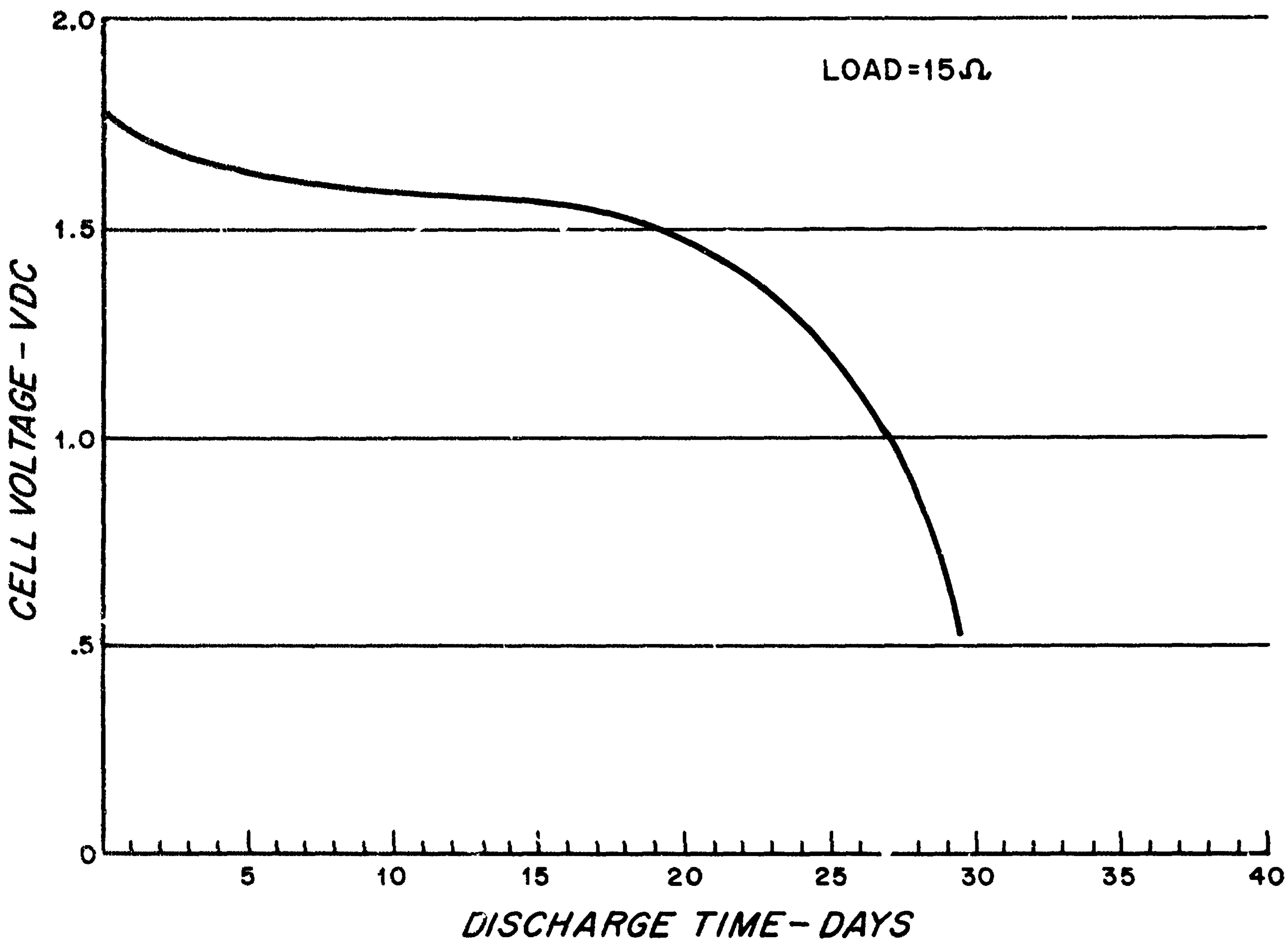


Figure 18. Discharge Test Magnesium No. 6 Cell

The table's figures are approximations and are for the basic cells without any containment structures. The magnesium cells appeared to be the best compromise based on energy capacity, cost, storage life, ease of handling and low temperature operation.

The main battery consists of 24 sets of eight #6 cells wired in series. This gives a nominal voltage of 12.8 V DC. The 24 sets are divided into two sets of 12 which are wired in parallel to form the positive and negative voltages. A discharge test curve of the No. 6 cell is shown in Figure 18. Based on a minimum allowable cell voltage of 1.38 volts, the discharge time with a 15 ohm load is 23 days - 552 hours. Assuming a conservative .100A average current drain the capacity of each cell is about 55 ampere-hours. This gives a total main battery capacity of 55x12 - 660 AH out of each leg. The magnesium cells have very good low temperature characteristics, typically 5 - 7% derating from 70°F to 32°F at low discharge rates.

The ACODAC "A" (15/160 ips recorder) system average current drain is approximately .450A out of the positive leg and .350 out of the negative leg. Likewise, the ACODAC "N" system average current drain is .180A out of the positive leg and .070 out of the negative leg. Based on a 30 day deployment there is adequate power for either system.

1.3.3 Main Battery Container

The assembled main battery container is shown in Figure 19 and the internal components are exposed in Figure 20. The container is oil filled and pressure equalized; it also provides for venting of evolved gas. The pressure equalization is accomplished through three

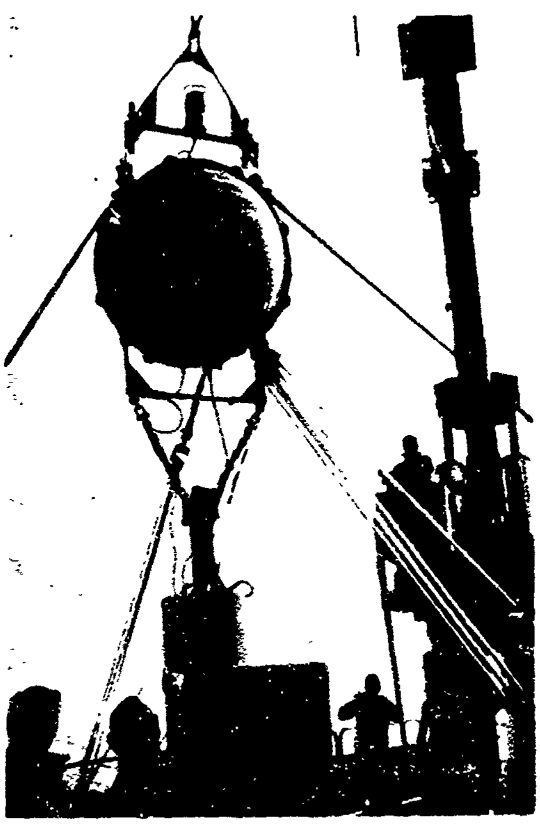


Figure 19. Main Battery Assembled

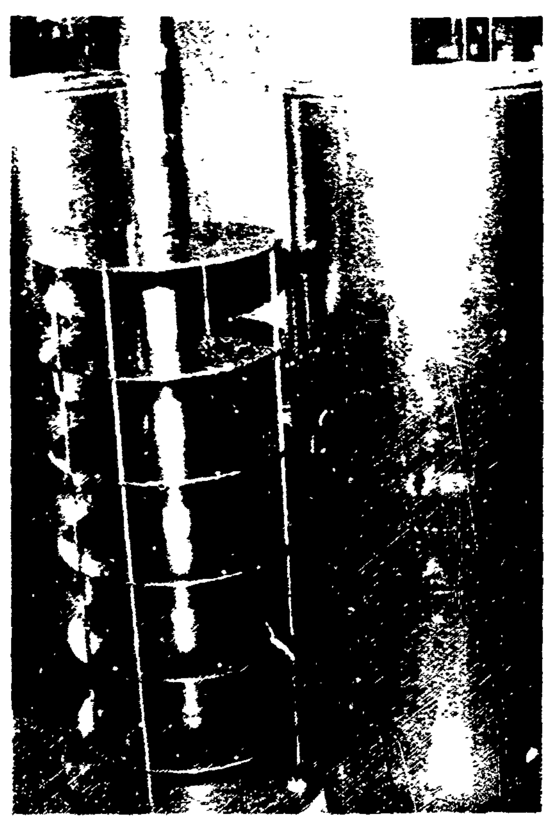


Figure 20. Main Battery Disassembled

rolling diaphragms (Bellofram 4-500-300-FCJ) which provide an oil reservoir of 153 cubic inches, more than enough to account for both the intrusion of oil into the voids of the batteries under pressure and the difference in compressibility between oil and sea water. Venting of gas is via an internal tube capped with a check valve and running from the top of the internal volume down to a low point on the battery case.

1.4 Electro-Mechanical Cable Sub-System

1.4.1 Mechanical Characteristics

Amergraph Type 7H37SB cable, manufactured by United States Steel, was used in the 1971 ACODAC deployments. This cable is formed from a double helix of galvanized improved plow steel strength members surrounding a free flooding core of electrical conductors. The following mechanical characteristics are pertinent:

Breaking Strength - - - - - - - - 11,000 lbs. (min.)
Weight in Sea Water - - - - - - - 193 lbs/1000'

The mechanical properties of stretch, torque and twist which are experienced by a cable of this type under load are expressed as follows:

A. Stretch

$$\frac{L}{L} = 1.84\times10^{-6}(T-100) \text{ ft/ft} \qquad 0 \quad T \quad 1000 \text{ lbs}$$

$$\frac{L}{L} = 1.66\times10^{-3} + 1.47\times10^{-6}(T-1000) \text{ ft/ft} \qquad 1000 \quad T \quad 2000 \text{ lbs}$$

$$\frac{L}{L} = 3.13\times10^{-3} + 1.35\times10^{-6}(T-2000) \text{ ft/ft} \qquad 2000 \quad T \quad 3000 \text{ lbs}$$

$$\frac{L}{L} = 4.47\times10^{-3} + 1.15\times10^{-6}(T-3000) \text{ ft/ft} \qquad 3000 \quad T \quad 11000 \text{ lbs}$$

B. Torque

$$= 0.106\ (T-64) \text{ inch-lbs.} \qquad T \quad 1000 \text{ lbs}$$

C. Rotation

$$\frac{\phi}{L} = 2.539\times10^{-3}(T-1148) \text{ degrees/ft} \qquad T \quad 1148 \text{ lbs}$$

$$\frac{\phi}{L} = 0 \text{ degrees/ft} \qquad T \quad 1148 \text{ lbs}$$

Several tests at breaking strength associated with the development of the load bearing mechanical connector were performed on the Woods Hole Oceanographic Institution's Baldwin Universal testing machine. In all cases, the cable developed at least the rated 11000 lbs at load before breaking.

1.4.2 Electrical Characteristics

The 7H37SB type cable has seven individual .032" stranded copper conductors cabled inside the double armoured steel jacket. One lead is used for each hydrophone to carry the signal back to the IPV, and the remaining conductor is used as a common ground for all hydrophones.

The specifications for this cable list 11.1 ohms/1000 ft. DC resistance and an interconductor capacitance of 47.5 pF/ft at 1000 Hz. Since there is a possibility of crosstalk which would seriously degrade the data, several tests were conducted to determine if the cable was suitable for use as a signal carrier. See the table and Figure 21 below.

Frequency (Hz) 1 volt RMS	Crosstalk db
50	-45 to -48
100	-37 to -57
300	-34 to -54

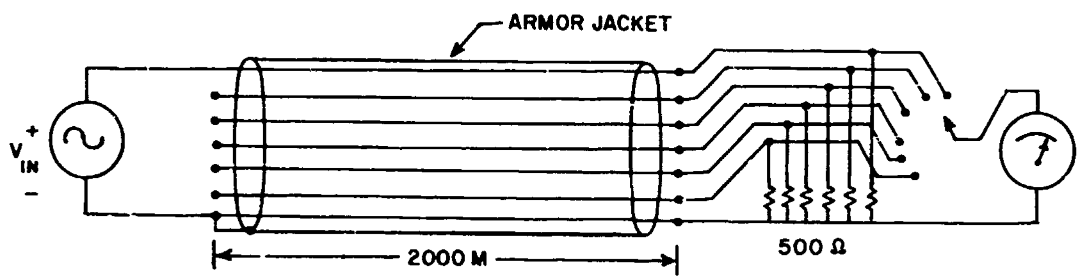


Figure 21. Cable Crosstalk Test Configuration

No tests were run for higher frequencies, but since the crosstalk is proportional to cable length and the "B" system uses only a 1200 ft. cable, the crosstalk would be about the same for frequencies to 3000 Hz. Tests were also performed at ambient and high pressure to insure that there was no degradation of performance.

Frequency (Hz) 1 volt RMS	Crosstalk db Ambient Pressure	10,000 PSI
50	-64	-64
100	-61	-65
300	-52	-58
500	-48	-54
1000	-42	-48

(Cable Length = 196 ft.)

Interconductor resistance measurement made at both ambient and 10,000 psi showed at least 15 megohms DC resistance on all readings. There is a slight attenuation of signal depending on the distance of the hydrophone from the IPV because of the relatively low input impedance of the data amplifiers and the 11 ohms/1000 ft resistance of the cable. The attenuation at 1 kHz is approximately 0.3 db per 1000 ft. This has been checked and verified in subsequent tests.

The minimum allowable signal-to-noise ratio is equal to the dynamic range of the tape recorder which is 30 db. Extrapolating the crosstalk test results of the tables above to include higher frequencies and different cable lengths gives the following worst case figures for the A and B systems

System	Conditions	Crosstalk
A	300 Hz, 10,000 ft.	-30 db
B	3,000 Hz, 1,200 ft.	-29 db

Therefore, while the two most remote hydrophones may be marginal, the cable should provide an adequate signal-to-noise ratio for all others. This, coupled with its attractive mechanical characteristics make it suitable for use in this application.

Figure 22 shows the calculated characteristic impedance and attenuation characteristics of the 7H37SB cable.

1.4.3 Mechanical Termination

A mechanical termination was required which was small yet capable of developing the full strength of the cable and which required no use of chemical or eutectic metal to assemble. The result of much development work at Woods Hole is shown in the figures. The assembled connector is shown in Figure 23 and Figure 24 shows an "exploded" view. The attachment of the connector to the end of the cable is accomplished through the use of jigs, shown separately in Figure 25 and in use in Figure 26. The spring provided bending strain relief. Aluminum anodes were crimped on the cable under the spring. These anodes worked as the load bearing wires of the cable were bright even after six weeks of intermittent exposure over a period of six months. The springs, however, were subject to hydrogen embrittlement from the gas evolved at the anodes. Most broke and were otherwise in a bad state of disintegration after the 1971 Madeira deployments.

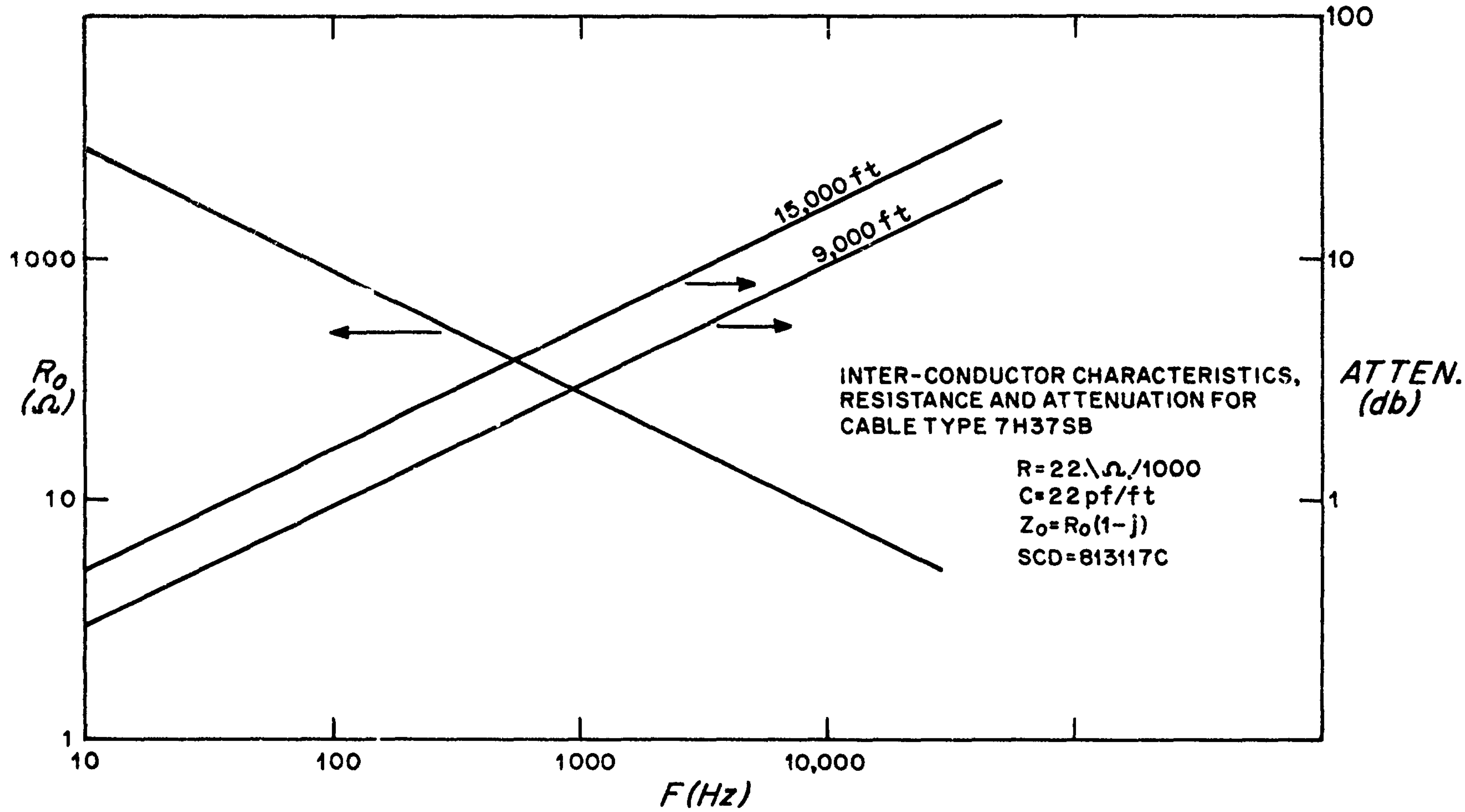


Figure 22. Transmission Characteristics of Type 7H36SB Cable

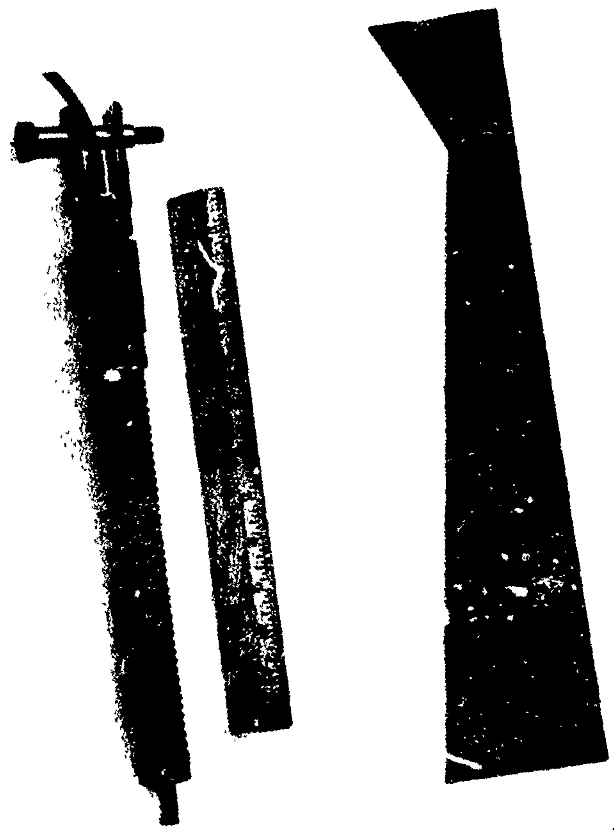


Figure 23. Mechanical Cable Termination Assembled

Figure 24. Mechanical Cable Termination Disassembled

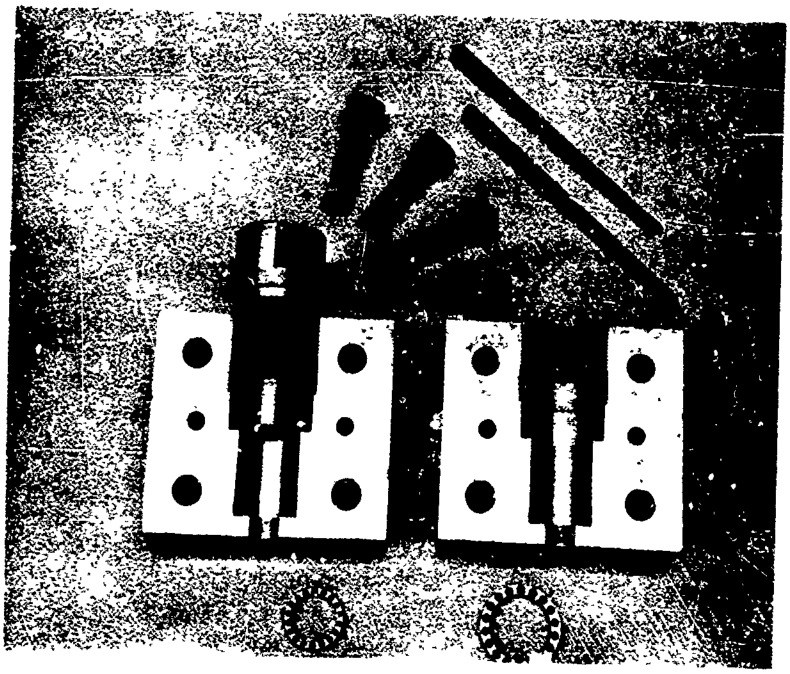


Figure 25. Assembly Jig

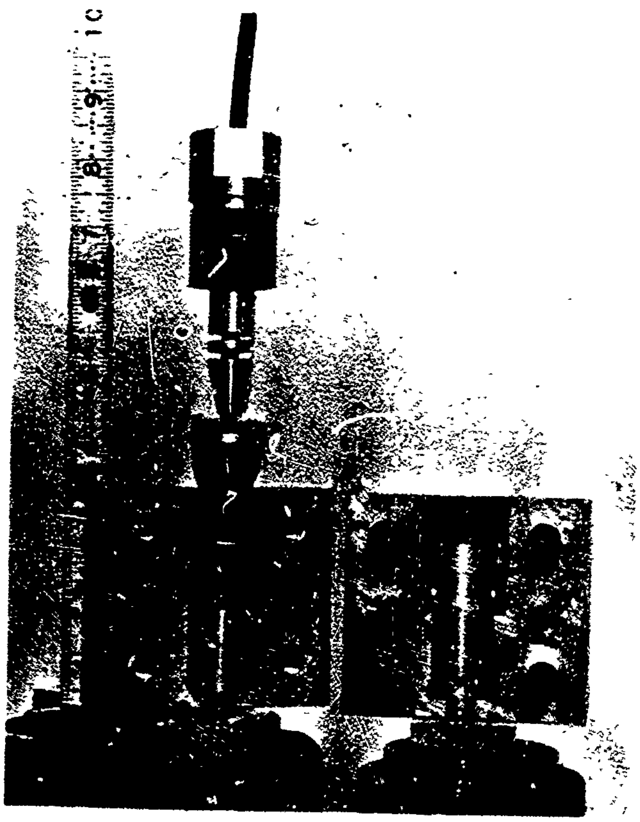


Figure 26. Assembly Jig in Use

1.4.4 Electrical Termination

The seven electrical conductors were jointly terminated in an eight pin (one pin unused) connector at each end of each length of cable. Connectors manufactured by the Marsh and Marine Division of the Vector Cable Company were used. At one end of each length of cable was a male plug (XSL-8-CCP) and at the other end was a female receptable (XSL-8CCR). A polyurethane boot joining the neoprene surface of the connector pigtail to the seven-wire bundle exiting from the mechanical termination. Figure 27 shows the mold used for this work. In the potting process each of the seven polypropylene insulated wires whose total insulated diameter equalled 0.058" was forced through a smaller hole in a polyurethane tension and spacer ring seen in Figure 28. The purpose of this ring was two-fold: first, by maintaining a squeeze on the wire it served as a secondary dam against intrusion of water and second, it maintained orderly spacing of the wires during the potting process. Note that the tension ring becomes an integrally bonded part of the boot.

1.5 Instrument Pressure Vessel (IPV)

The instrument pressure vessel consists of two 38" ID x 1.25" thick hemispheres of 7178-T6 aluminum which butt on to a 5" x 5" central ring of 7075-T6 aluminum. The assembled IPV is shown in Figure 29; its design collapse depth is 20,000 feet. The central ring supporting the internal electronics was shown in Figure 2. Nine holes penetrate the central ring radially for the following purposes:

Four internal/external tapered mounting lugs, or "ears",
Three electrical penetrations, and
Two vacuum valve penetrations.

In addition there are two blind tapped partial holes in the ring to mount magnesium anodes.

During preparations for deployment the sphere is pumped down to 28" of vacuum, then filled with dry nitrogen to one atmosphere; this gas is once more evacuated and the vessel is again filled to one half of an atmosphere with dry nitrogen. This procedure removes sufficient moisture to prevent any internal condensation in the cold depths of the ocean. A vacuum valve assembled and disassembled is shown in Figure 30. The use of the vacuum valve "T" fitting, which serves both as a wrench and as a part of the vacuum system, is shown in Figure 31.

There are two protective coatings on the IPV; the first is an electrolytic process known as Sanford Hard Coat in which the piece is immersed as an anode in an acid electrolyte. The resulting oxide layer both penetrates and coats the surface. It is quite hard, but porous; the surface is made more impermeable through the addition of a chromate to the bath. The second protective coating is an epoxy paint system manufactured by Magna Coating Chem. Corp., known as Laminar X100; this is a four part process requiring the strictest of quality control during every step. The resulting coat is quite satisfactory. The IPV with its attached bales and fittings and filled with electronics has an air weight of 1400 pounds, but displaces 1900 pounds, which gives a net buoyancy of 500 pounds.

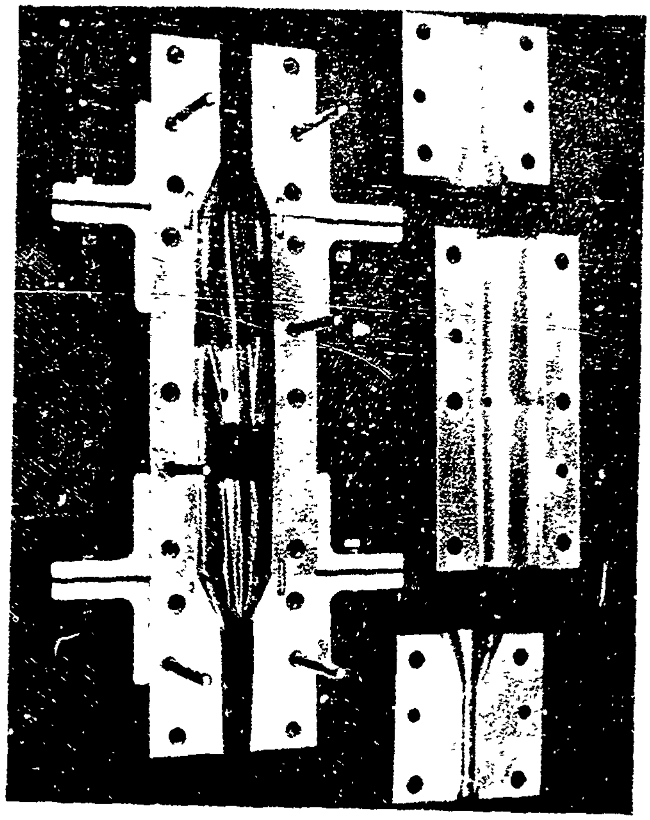


Figure 27. Electrical Termination Transition Mold

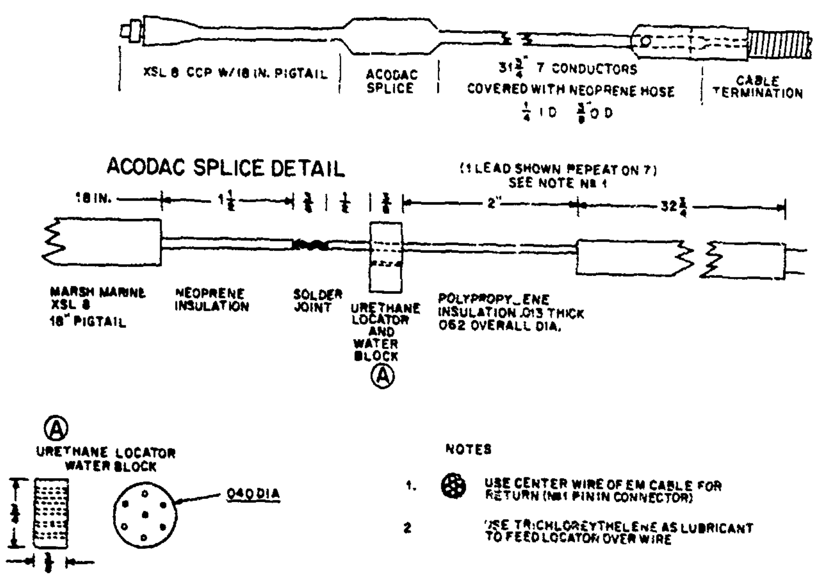


Figure 28. Water Block Locator

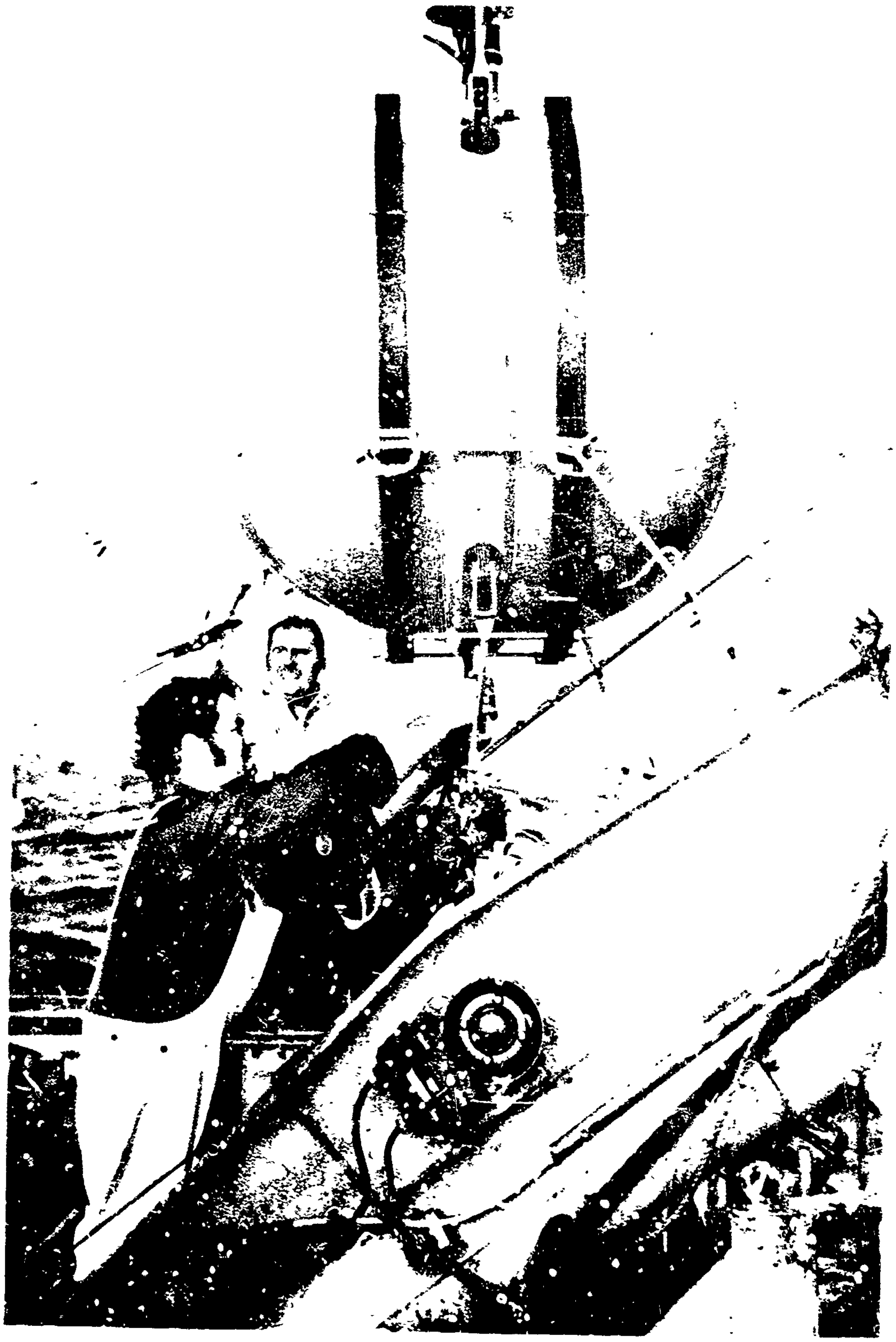


Figure 29. Instrument Pressure Vessel

1.6 Components

1.6.1 Releases

There are two types of releases used in the ACODAC system, the American Machine & Foundry Co., (AMF) Model 262 Acoustic Transponder/Release and the E, G & G Geodyne Model 855 Timed Release. The electronics portion of one 262 is housed in the IPV and is tied to an external release package via electrical cable. A second Model 262 release is tied in parallel with the Geodyne Model 855 release and is mounted at the bottom of the cable. This arrangement is shown in Figure 32.

A. AMF Acoustic Transponder/Release System

The Woods Hole Oceanographic Institution has used AMF releases in many diverse applications and has gained a great deal of experience in working with them. They have proven to be among the most reliable units available and were chosen for use on ACODAC for this reason.

There are two modes of operation of the Model 262 units, as a transponder in which it is interrogated and after a precise delay time it responds with an acoustic reply, and as an acoustic release. The shipboard equipment consists of a receiver, a coder which generates the commands, a power amplifier, and a three element transducer which serves as both a projector and receiver. In the transpond mode the receiver will give a readout of both slant range in kilometers and bearing relative to ship heading. Experience in ACODAC deployments has shown that range and bearing can be determined at separations of up to 10 KM.

The basic command signal to the release is a complex code of the five levels: (1) carrier frequency; (2) modulation frequency; (3) pulse width; (4) pulse repetition; and (5) time duration. This type of code provides command security to prevent accidental activation due to naturally occurring noise signals. The transpond command uses only the first three code levels.

Each of the Model 262 units has three command functions. One of the commands is used to activate the release, and the other two can be used to control other functions. Normally, one of these two commands is connected to a timed pinger and is used to check out all the electronics of the unit before deployment.

The Model 262 installed in parallel with the Geodyne Model 855 at the bottom of the mooring is a standard, self-contained release as supplied by AMF. The Model 262 installed in the IPV serves several functions.

(1) IPV release via an external release package
(2) IPV location in the transponder mode
(3) Telemetry activation by one of the spare command functions
(4) Transmission of the telemetry data.

Figure 30. Vacuum Valve

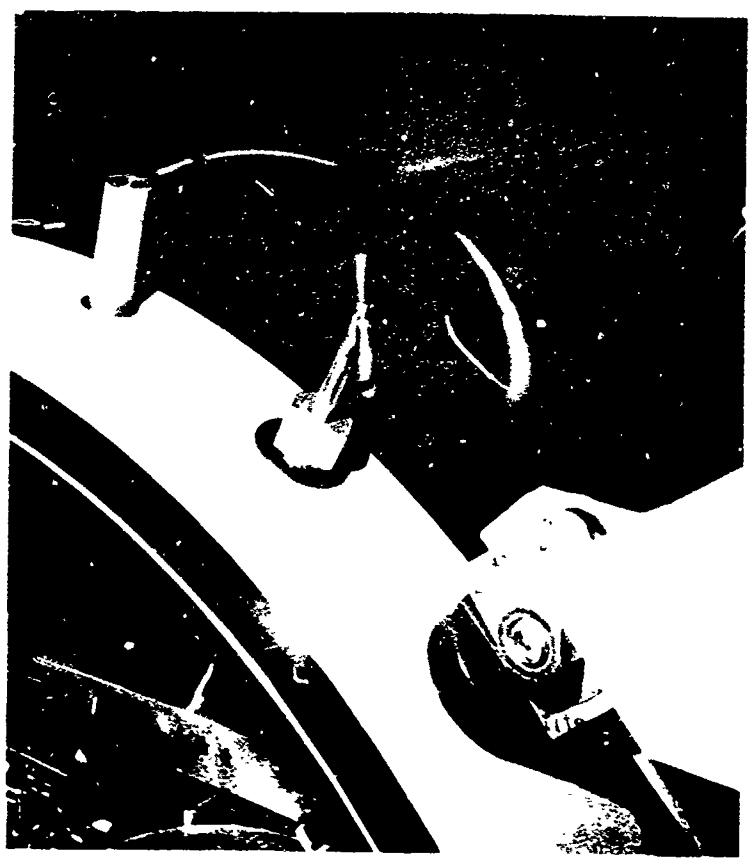


Figure 31. IPV Vacuum Connections

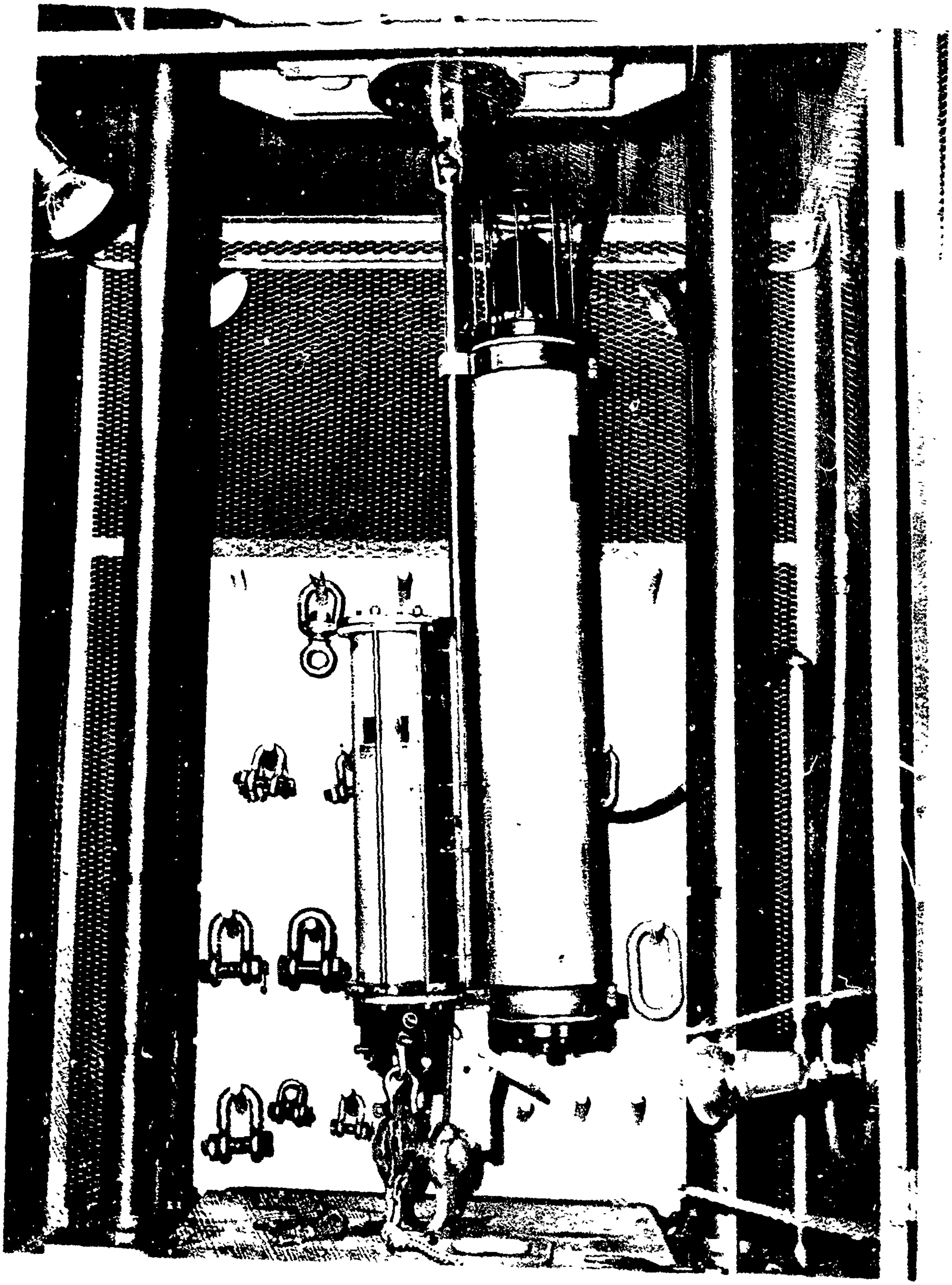


Figure 32. Parallel Releases, Acoustic and Timed

A block diagram of the IPV release system is shown in Figure 33. Command #3 is used to fire the release mechanism through two wires which connect to the external release package. The external release package contains a pinger which is activated upon release and serves to help locate the IPV. Command #1 is used to activate the telemetry system as described in Section 1.2.4. The output signal from the telemetry system is inserted into the front end of the AMF power amplifier which then transmits the data to the surface where a one channel strip chart recorder provides a data readout through the AMF shipboard receiver.

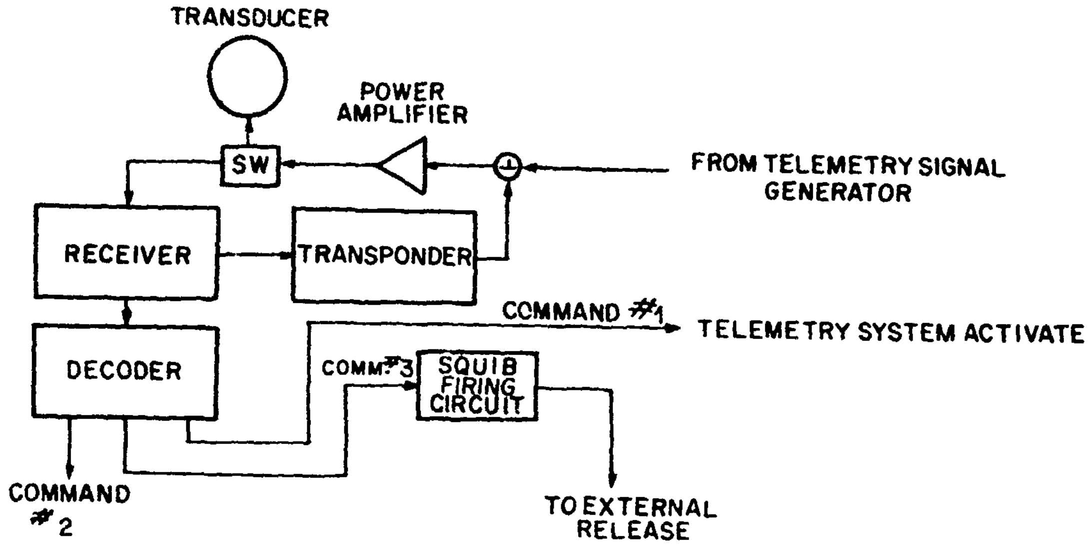


Figure 33. IPV Release System

B. Geodyne Model 855 Release

The Geodyne Model 855 release is used as a back-up release for the ACODAC system in the event the AMF acoustic releases are inoperable. A bracket was fabricated to mount the 855 in parallel with an AMF 262 release such that either one can release the mooring and both will come to the surface.

The 855 is a self-contained timed release that can be set prior to deployment to release at a specified time in the range of five minutes to one year. It contains a timer, a battery and a release firing mechanism. The timer is accurate to better than one percent and can be used to depths of 22,000 ft. and loads to 10,000 lbs.

1.6.2 Structural Components

A. Floats - In addition to the Instrument Pressure Vessel (see Section 1.5 above) which provided 500 lbs. of buoyancy, the following subsurface floats were used:

- Steel Sphere - A 48 in. steel sphere (Ocean Research Equipment Co.) providing 1400 lbs. of buoyancy up to a working depth of 500 meters was modified (Figure 34) and used in ACODAC System I.

- Glass Ball Floats - Floats of greater pressure resistance were needed for deployment at depths greater than 500 meters. A buoyancy module prototype made of two inch fiberglass spheres in a matrix of syntactic foam (Data Packaging Corporation) was fabricated, tested and submitted to a two month exposure at a depth of 1500 m. The test was unsuccessful (Appendix C). It was then decided to use glass ball floats of proven performance. These floats are made of eight 16 inch diameter sealed glass spheres (Corning), housed in orange hard polyethylene containers bolted to a frame of fiberglass angles. . This sturdy arrangement provides 340 lbs. of buoyancy at working depth of 6000 meters. To minimize the possibility of catastrophic failure by sympathetic implosion, each glass ball was tested to the rated working pressure (10,000 psi) prior to the float construction. These floats were used one at a time (Figure 35) or coupled in pairs (Figure 36).

  Instrumentation pressure vessels, steel floats, and glass ball floats, were all equipped with radio beacons and flashing lights (OAR Corp.) for ease of location during recovery.

B. Distributed Buoyancy - In addition to the floats, lumped buoyancy distributed along the line at locations determined by fixed design criteria was needed to support the array. Only glass balls or syntactic foam castings could be used to satisfy the modular and depth requirements. Because of their lower cost, known performance, and immediate availability, 16 in. sealed glass balls (Corning Glass Works) were selected. These spheres were systematically tested to a pressure of 10,000 psi prior to deployment. Approximately 3% of all the spheres tested failed. These failed balls were replaced by the manufacturer.

Most of the glass balls were assembled in pairs, each pair providing 90 lbs. of buoyancy. Figure 37 depicts the mechanical arrangement for attaching a pair of balls to a cable. Figure 38 shows a number of these pair attachments ready for launching. When not in pairs, the containers of the glass balls were simply bolted to a length of chain inserted in the mooring line.

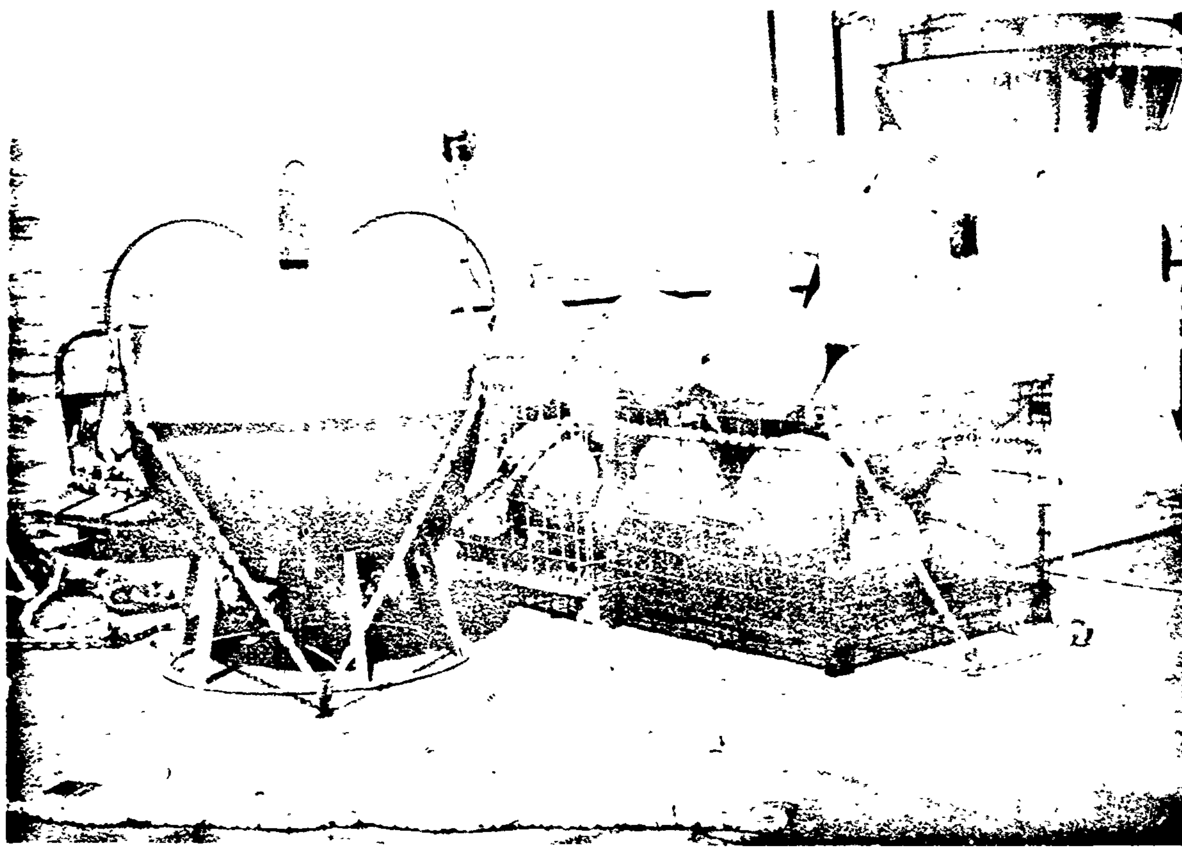


Figure 34. O.R.E. Sub-surface Buoy

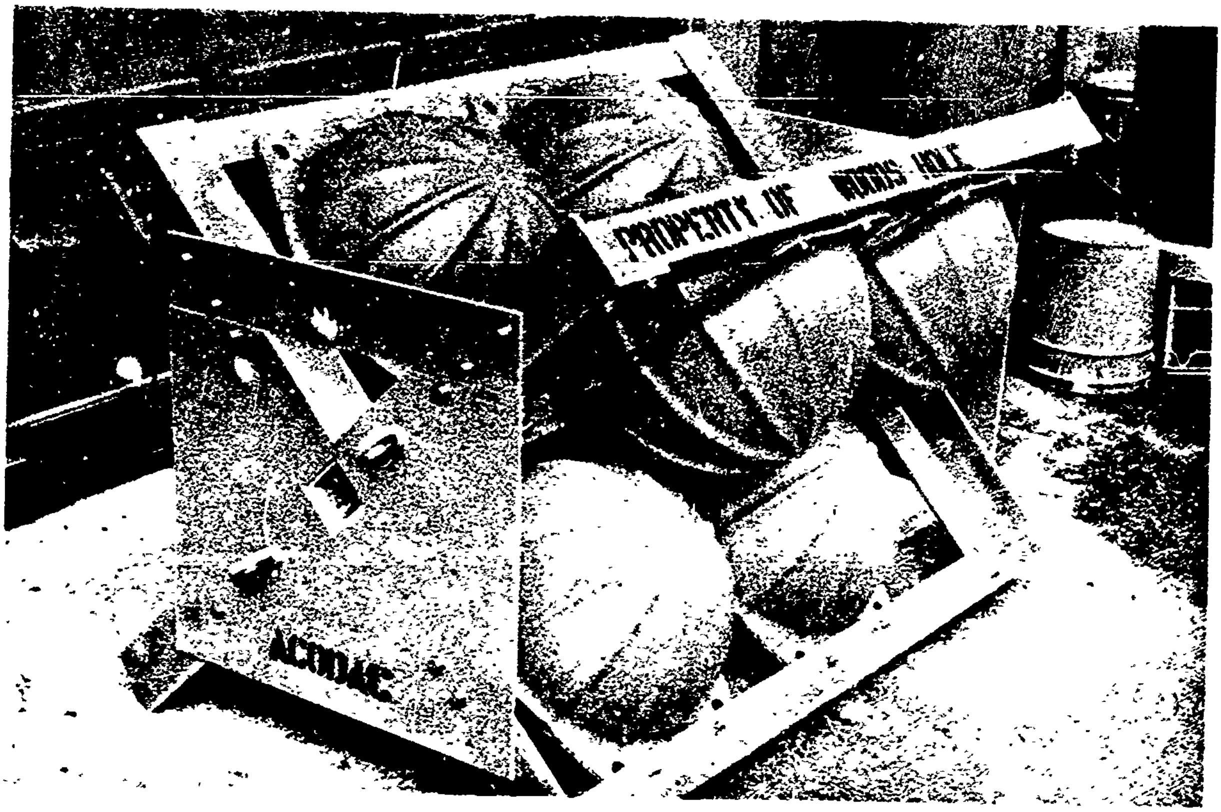


Figure 35. Single Flotation Package

Figure 36. Double Flotation Package

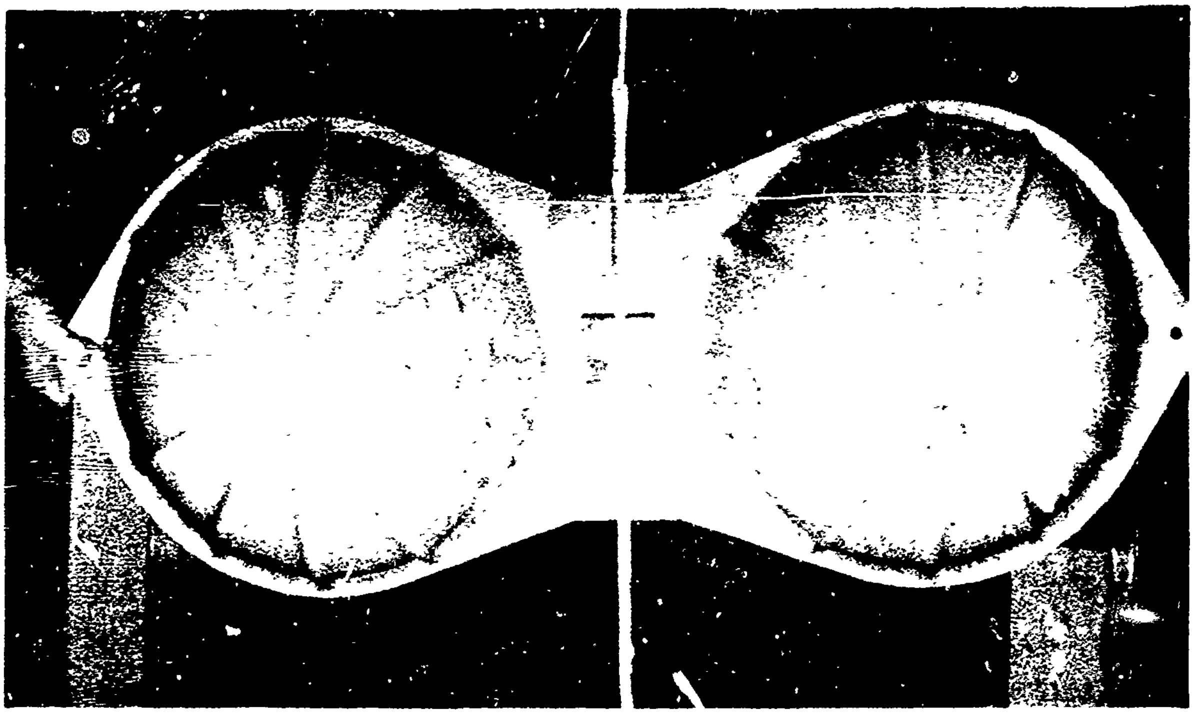


Figure 37. Distributed Buoyancy Element, Glass Ball Pair

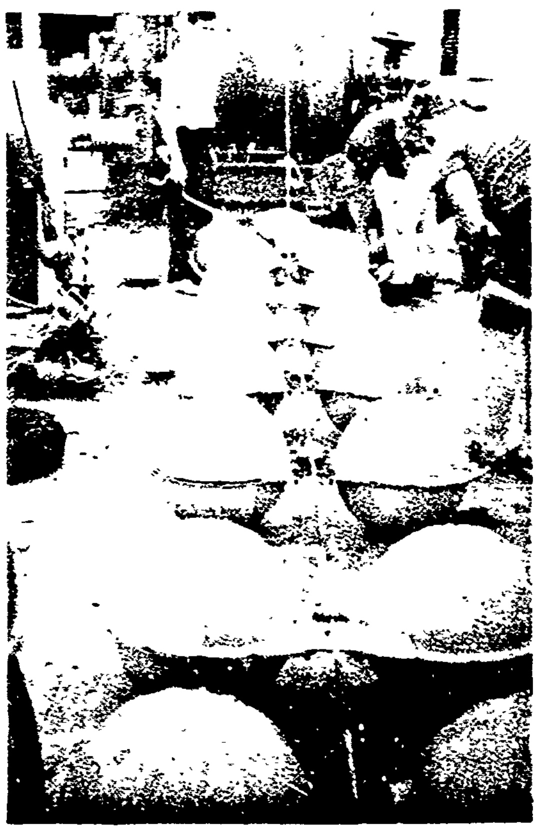


Figure 38. Distributed Buoyancy Array of Glass Ball Pairs in Hard Hats Ready for Launching

C. Mooring Line - The mooring line consisted of electromechanical cable and various segments of wire and synthetic fiber ropes. The electromechanical cable together with its terminations was discussed in Section 1.4 above; other mooring line components are discussed below.

- Wire Rope - A short length of wire rope was used as a strength member connecting the floats in the upper part of the ACODAC System I. Wire rope was selected for its resistance to fish bite attacks which are likely to occur at the depths these floats were to be set. The type of wire rope used was a 3/8" diameter 3x19 torque balanced construction, galvanized wires and plastic jacketed oceanographic rope (U. S. Steel Co.) with a breaking strength of 14,800 lbs.

- Synthetic Fiber Ropes - Lengths of synthetic fiber ropes were used in the lower part of the moorings between the deepest hydrophone and the anchor, at depths where the probability of fish attack was extremely small. The use of synthetic fiber ropes with large strength to weight ratio, results in a smaller overall buoyancy requirement to support the array. Furthermore, the elastic compliance of these ropes is of great help to damp out the dynamic loads imposed on the system during deployment and free fall.

  Two types of synthetic fiber ropes were used in the different arrays:

  - Nylon - Short lengths of standard 3/4" plaited nylon (Columbian Rope) with a breaking strength of 14,000 lbs. were used in systems where the deepest hydrophones were relatively close to the bottom.

  - Dacron - In ACODAC Systems IV and VI large lengths of synthetic fiber ropes were needed to connect the deepest hydrophone to the anchor. A rope with minimum drag to strength ratio and well established elastic characteristics was critical for maintaining the hydrophones at their prescribed depths. A special ½" diameter single braid polyester rope (D50-805 Samson Cordage Works) with a breaking strength of 14,000 lbs. was selected for this application. Tests performed and method of rope measurements are outlined in Appendix D.

D. Anchors - Dead weight anchors consisting of bundles of 1½" used anchor chain were used in all systems. The immersed weight of the bundle was 700 lbs. more than the anticipated vertical component of mooring line tension at the anchor. In order to provide additional horizontal holding power a 65 lb. Danforth Anchor was secured by 10 feet of ½" chain to the main anchor. A 96 in. drogue chute was also attached to the main anchor to slow down its free fall.

- Anchor Releases - Three anchor releases were used in each system. These are discussed in Section 1.6.1 above.

- Hardware - All mechanical connections were made by a combination of drop forged galvanized steel safety anchor shackles with stainless steel-cotter pins and pear shaped sling links. Three tons special Miller swivels were used above the releases to prevent rotation of the releases and the anchor during deployment.

2. Auxiliary Systems

2.1 General

The ACODAC system depends on several auxiliary systems for deployment, recovery, servicing and data processing. One of the initial requirements of the ACODAC program was to provide "platform flexibility", i.e. not to be dependent on a particular ship for support. When this requirement is coupled with the special needs of the ACODAC for these support functions, the decision to provide portable, but self-contained, auxiliary systems is understood. Among these portable, but self-contained systems were the winch, the jacking station, the various support vans and special equipment, such as deck tracks and the acoustic data processing system.

2.2 ACODAC Winch

2.2.1 Background

Launch and recovery of the ACODAC system imposed certain requirements which could not be met in conventional winches. Since the ACODAC operations were expected to be made from a variety of vessels of unknown power availability, it was determined that the winch should be self-contained, employing a diesel or gasoline engine. For reasons of fire hazard, reliability, and the fact that most vessels would have ample fuel supplies, the choice was made to diesel power. Other basic requirements were to develop 12,000 pounds maximum line pull and 125 feet per minute maximum line speed, ability to smoothly position rated loads at speeds down to a few inches per minute, and to store approximately 12,000 feet of 3/8 diameter electromechanical (E-M) wire. While none of the above are particularly unusual requirements individually, taken together they indicated the need of fairly large, powerful unit with very wide speed range developing better than 50 horsepower.

While the immediate use (ACODAC) was not expected to require maximum speed and line pull simultaneously, the desire for selecting a machine with flexibility to be adaptable to future applications indicated consideration of full capacity design. This was not an expensive decision to make, inasmuch as the structural design and most of the mechanical design would be dictated by the maximum load.

To develop maximum load and speed simultaneously meant essentially the selection of an engine of more horsepower and cooling systems of higher capacity. The increased cost of these components is a minor fraction of the total cost of the machine.

The most significant departure from conventional winches was the large drum, with a core diameter of 44 inches and having four (4) separate sections or "bays" for the E-M wire, and five (5) narrower "slots" for 7/16 diameter 3x19 wire rope. (See Figure 39) This complex configuration was necessary to accommodate four separate "shots" of mooring wire making up the buoy string, as well as several short lengths of wire rope used in handling the buoy string under tension.

The large drum diameter prevents excessive bending of the E-M cables and their terminations. The principle effect of this drum on the rest of the design was the very high torque requirement to produce 12,000 pounds line pull on a 48 inch average diameter. A secondary effect was that such a large drum circumference demanded very low rotating speeds to meet the minimum line speed requirements. Developing 24,000 foot pounds torque, speeds down to 0.1 rpm and up to 10 rpm, in view of other parameters mentioned above, clearly demanded a very unusual machine.

The choice of whether to build a new machine from the ground up, or to modify an existing machine was quickly answered when considered in the dual lights of the schedule and reliability. Five months from problem statement to test allowed little time for a sequential alteration program.

The chance of readily locating an existing winch suitable for modification was considered small; and predicting the extent of such modification was infeasible. It was well known that lead time on delivery of certain components could be as much as three or four months, and these could not be specified or ordered until the winch was defined. On the other hand, building a new machine would permit relatively quick definition of concept followed almost immediately by placement of orders. The concept could be as quickly revised to select components offering reduced lead time or lower cost. The ultimate reliability of the winch had to be very high considering the role it was to play in launching and recovering ACODAC. Reliability of an existing winch, if one were found, could prove to be an open question. A new design could have the necessary reliability built in.

2.2.2 Configuration and Characteristics

Figure 39 and Figure 40 depict the general configuration; Figure 40 is a photograph of the winch in action. Table IV provides overall characteristic data.

The components of the power chassis are mounted to a sub-frame of 12 inch x 50 pound beams and are protected by 3/4 inch plywood over steel framing. Numerous doors provide access and ventilation. The operator's position is between the transmission and reduction gear, offering convenience to all controls and indicators. Over this position is an expanded metal "turret" with plexiglass windows affording the operator good visibility and ventilation, as well as complete protection in the event of a snapped cable. A hinged plywood enclosure covers the turret when the winch is not in use.

Included in the operator's position is a 110 volt AC power panel, mounted above the transmission. This panel provides electricity for the overload clutch slip alarm, the two fresh water cooling circulating pumps, interior lighting, and utility outlets. The operator, from one position, may start or stop the engine, control winch speed and direction, manipulate both brakes and control the electrical functions described. He may also control the quantity of flow of cooling water through the transmission and reduction gear by means of two valves provided. Gages monitor engine speed

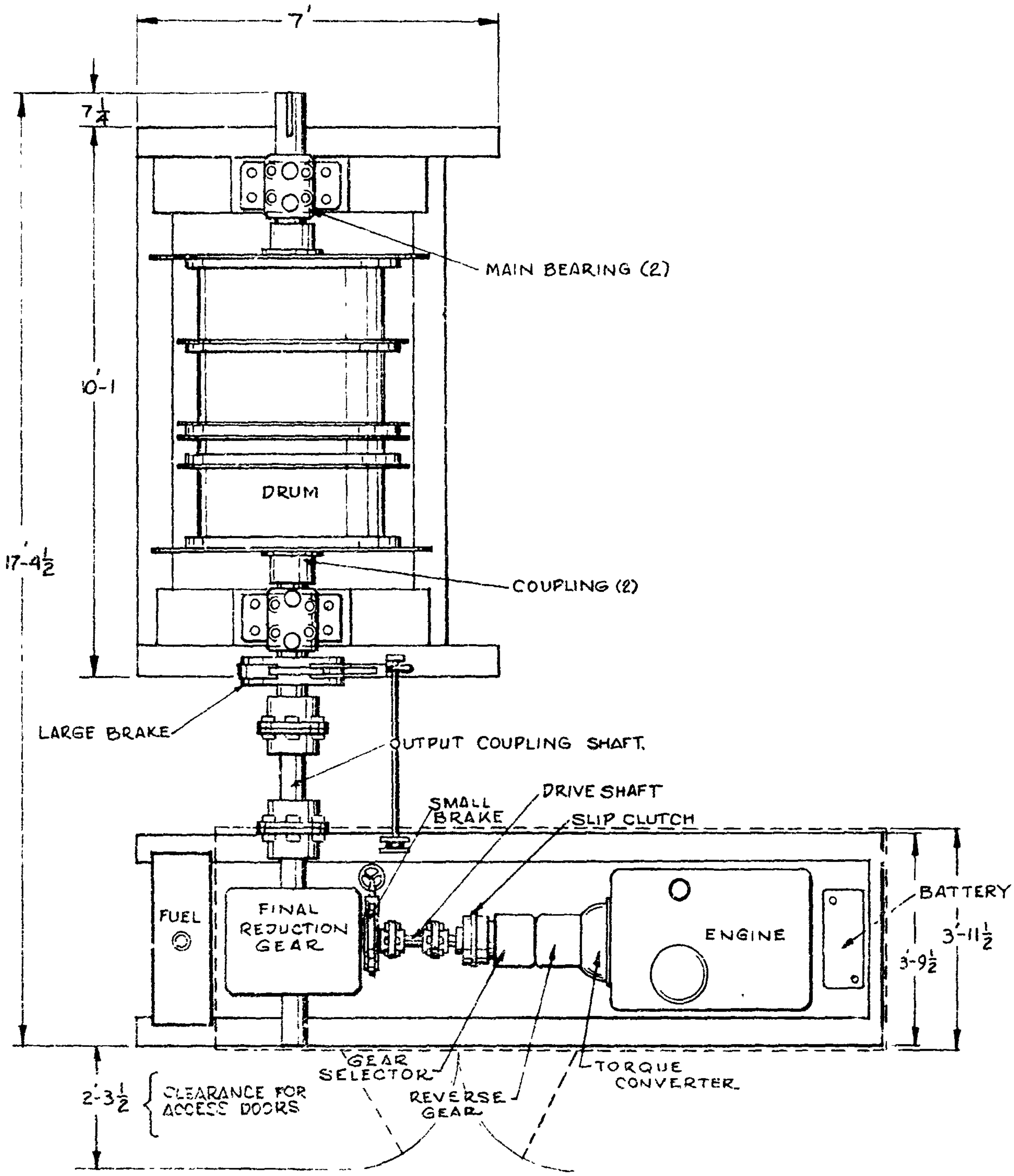


Figure 39. ACODAC Winch (Plan View)

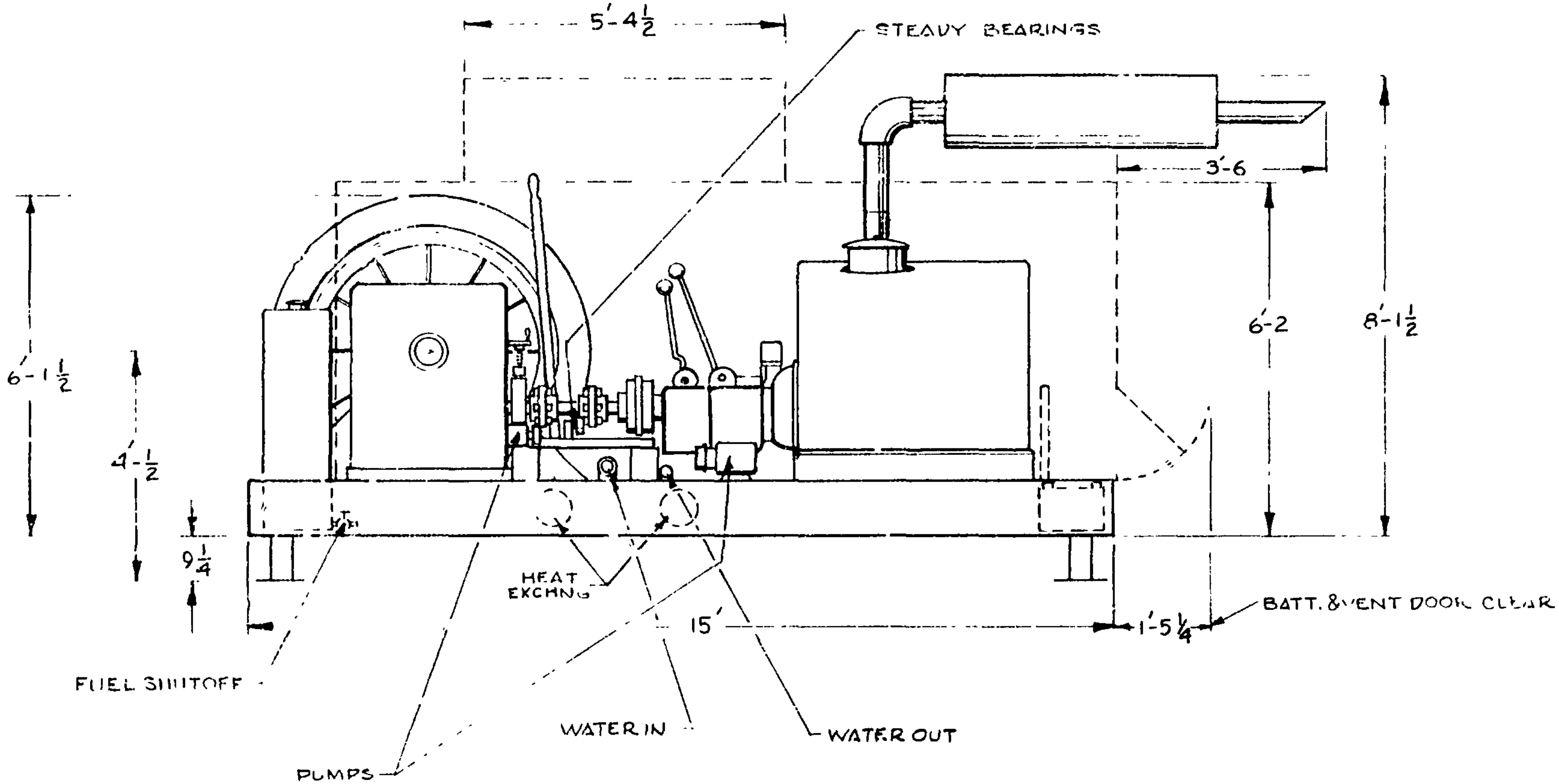


Figure 40. ACODAC Winch (Elevation View)

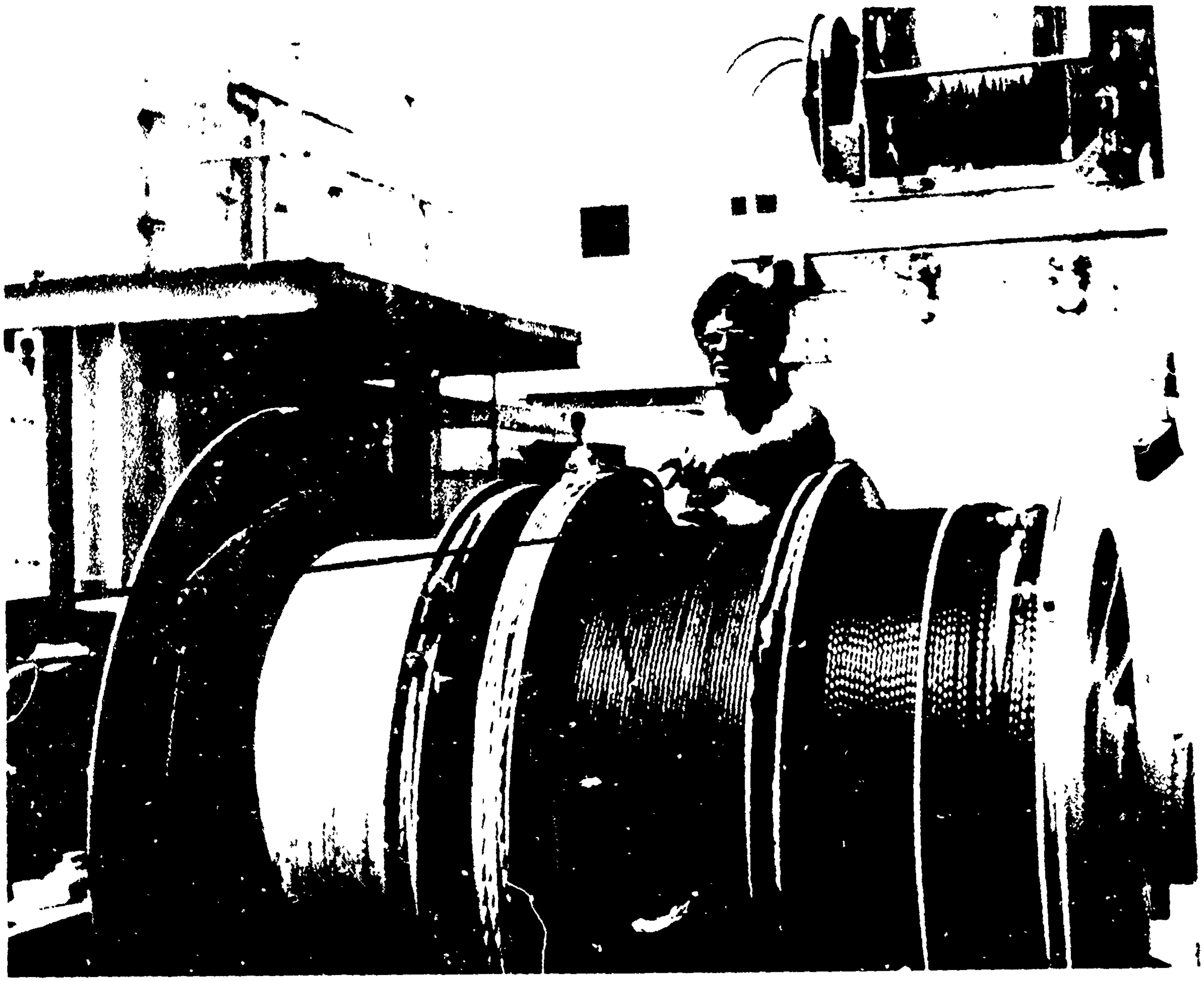


Figure 41. ACODAC Winch in Action

and conditions, and transmission temperature and pressure. Alarms provide warning in the event of engine overheating or low lube oil pressure, and for slipping in the overload clutch.

Grab handles are located in several places to provide operator support in sea conditions and a shelf has been installed to contain personal conveniences.

The bottom of the power chassis frame is covered with sheet steel to form a sort of "bilge" to collect leaking engine oil and other fluids, thereby avoiding the personnel hazard of these spilling out on deck. The "bilge" is drained through valves fitted with hose connections. The engine is equipped with an over-sized exhaust muffler designed for critical quieting.

The entire power chassis is secured to the deck through eight(8)inch long sections of five (5) inch diameter pipe. Elevating the unit in this way allows most water sweeping the deck to pass underneath easily instead of being dammed up and forcing itself into the unit.

The winch frame is also constructed of 12 inch steel beams, and is elevated above deck as is the power chassis. The frame has been designed to withstand being stood on end with a fully loaded drum without permanent deformation or serious deflection. The drum and shaft assembly may be readily removed from the frame, and the shaft may also be removed from the drum, permitting various interchanges if desirable in the future. The gear type coupling shaft connecting the power chassis to the winch permits considerable angular and axial misalignment, simplifying installation of the winch on deck and accommodating any foreseeable motions due to ship's flexibility.

The drum frame has provisions for mounting and driving a level wind device, which was designed and built, but never used because experience proved that it was not necessary. The level wind, not shown in Figure 40, provided for spooling to and from each of the 16" bays on the drum. The level wind guide could be positioned by the operator at any working position along the drum axis. The vertical rollers of the guide could be separated to permit the passage of lumps such as cable terminations.

The unusually massive appearance of this winch is a direct result of the requirement for reliability. First, this is ocean going equipment. The forces of ships roll and seas sweeping the deck combine to discover any weakness in the works of man. The loaded drum, for example, weighs over 8,000 pounds and must be held very securely to prevent damage to bearings or to itself. As time proceeds, rusting will introduce new weaknesses. This machine was designed to survive severe storms on the weather decks of any vessel on any ocean. Secondly, history has shown that it is only a matter of time before equipment such as this is overloaded, by accident or intent. In the case of the ACODAC winch, this has occurred sooner than anticipated. The power unit was accidentally dropped about six (6") inches while being loaded aboard R/V KNORR. Three months later the winch was being used to tow a 5,000 pound "fish" with towing strains on the locked drum expected to be over 15,000 pounds. In both cases, the design was adequate.

Max. line pull, running(1);	12,000 pounds
Line pull, starting(1);	6,000 pounds
Speed at rated load;	125 ft/min
Max. speed;	200 ft/min
Min. speed;	1.5 ft/min
Engine;	Detroit Diesel 3-71 Power Unit Rated 75 cont. HP @ 1800 rpm Max. Torque: 293 ft.lb. @ 1400 rpm
Transmission;	Funk Model 12,000 4 speed with torque converter and hydraulic reverse.
Overload clutch;	Hilliard double plate; slip point adjustable from 1000-12,000 pound line pull on 50" dia. drum(3).
Final Reduction Gear;	Cone-drive 12" worm, 60:1 ratio
Brakes: on drum; on worm input;	Hart, 24" dia. 400,000 in.-lb. cap. Hart, 12" dia. 50,000 in.-lb. cap.
Starting	12 volt DC (Battery)
Fuel Cap. (#2 Diesel)	Approx. 80 U.S. gals.
Weight, Total	24,000 lbs.
External Requirements:	
Raw Water(2)	20 gpm Max. @ 5 psi and 70° F Max.
Electricity;	110 V.A.C., 60 Cy., 30 A. Max.

(1) Due to worm gear characteristics whereby running efficiency is about 65%, starting efficiency is about 32%.

(2) Not required for light-load operations.

(3) Overtightening can produce much higher output pulls, with consequent damage to winch.

Characteristics of the ACODAC Winch

Table IV

2.2.3 Performance

During the first ACODAC trials in May 1971, the winch demonstrated ability to meet all operational requirement and at times was operated in excess of 200 feet per minute with reduced loads.

The combination of oversized muffler and plywood housing over the power chassis has resulted in a very quiet machine to the outside listener. The height of the exhaust pipe above deck proved to be sufficient to cause only a minimum of annoyance from noxious fumes.

In subsequent dock trials, the winch worked smoothly with an 8,300 pound payload, the heaviest which could be conveniently located. As a test of emergency conditions, this weight was lowered rapidly and the winch reversed instantly to full power. Momentary dynamic load was estimated at between 12,000 to 15,000 pounds. This test was, of course, performed under controlled conditions and with the overload clutch tightened beyond safe working load. There was no indication of damage to the winch.

2.3 Jacking Stand

A fixture necessary for shipboard as well as laboratory support operations is the jacking stand, Figure 42. This device permits disassembly and assembly of the IPV with safety and without damage to the critical mating surfaces even on a rolling and pitching ship. As seen in Figure 2, it also holds the center ring and permits inverting it for servicing the electronics.

2.4 Miscellaneous Mechanical Equipment

2.4.1 Big Sheave - A 68 inch diameter aluminum sheave was designed and fabricated for deployment and recovery purposes. The throat of the sheave was large enough to pass the mechanical terminations and the connector protector discussed below. Due to change of deployment methods this sheave saw service only during the May 1971 deployment.

2.4.2 Connector Protector - The name of the long snake-like device shown in Figure 43 describes its function which is to protect the relatively tender electrical connectors with their pigtails during the passage of the intersection of two cable lengths through the sheave described above.

2.4.3 Mechanical Connector Stopper - During launching and retrieval it is necessary to "stop off" the cable which is deployed over the stern while a hydrophone cage is inserted in or removed from the mooring. The mechanical connector stopper, Figure 44 holds the base of the end mechanical connector snugly while this process takes place.

2.4.4 Mechanical Cable Stopper - This device, Figure 45, permits stopping off the mooring at any point along the cable. It was tested without slipping to a cable tension of 2000 pounds.

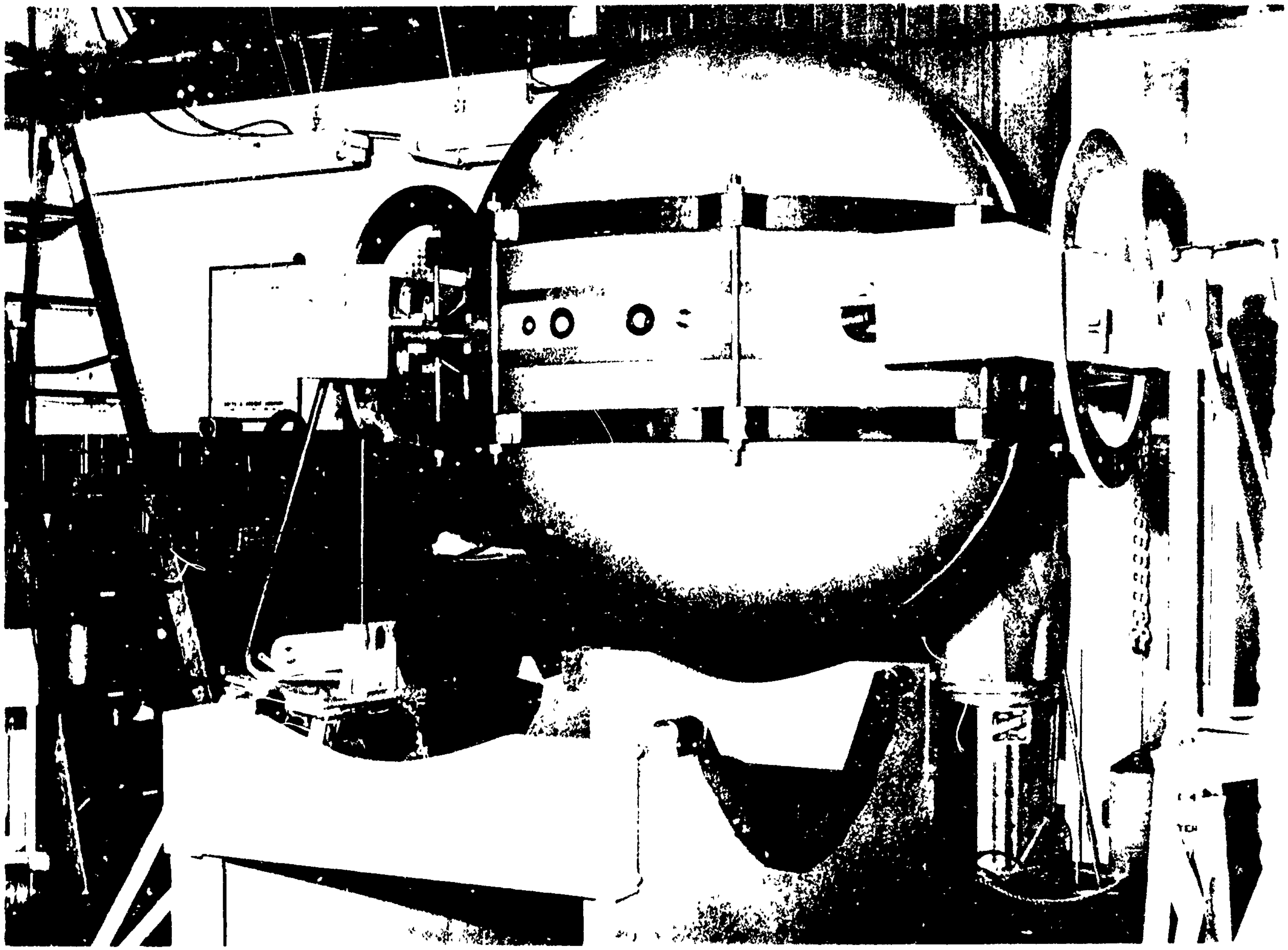


Figure 42. Jacking Stand for IPV

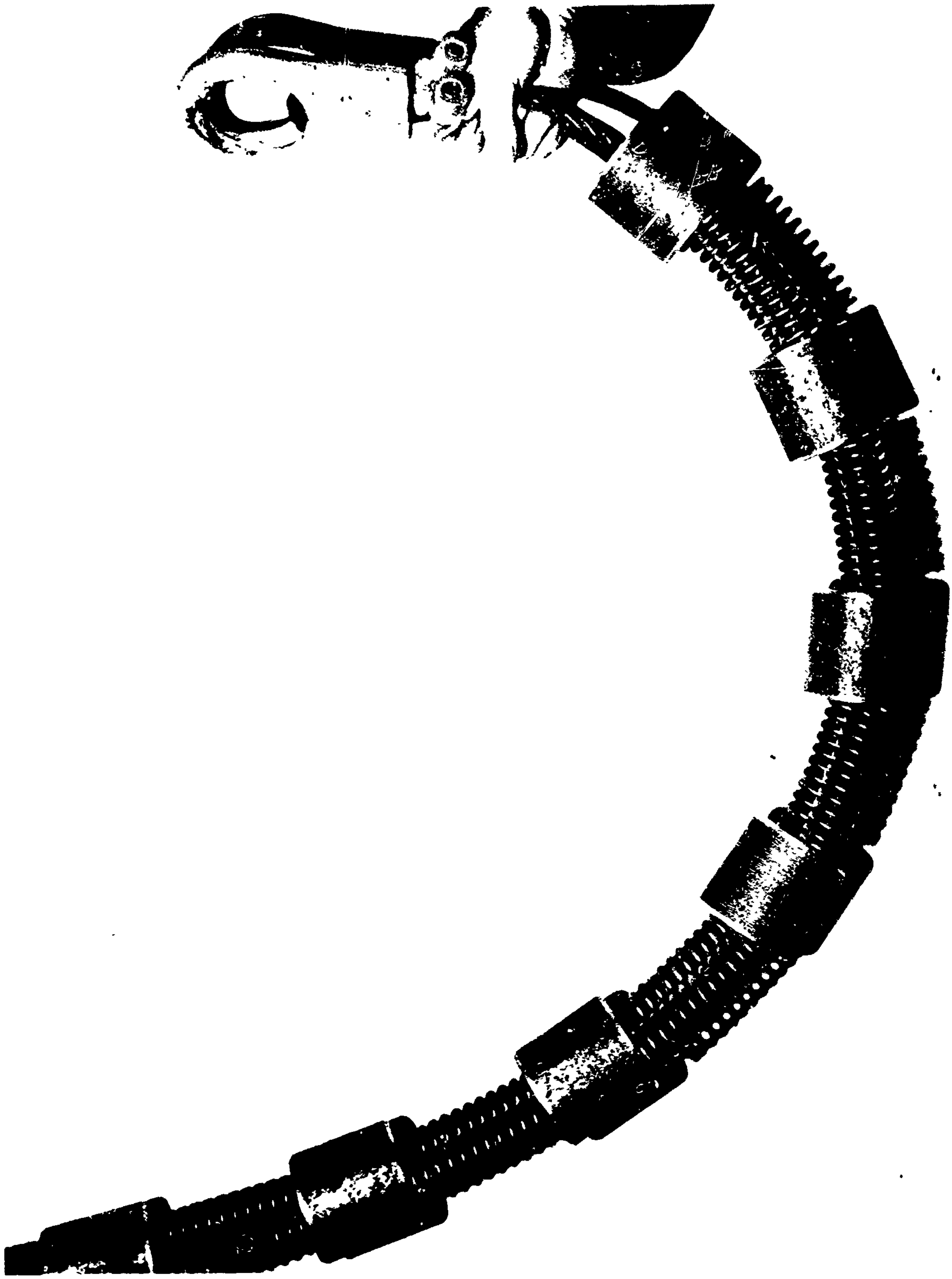


Figure 43. Connector Protector

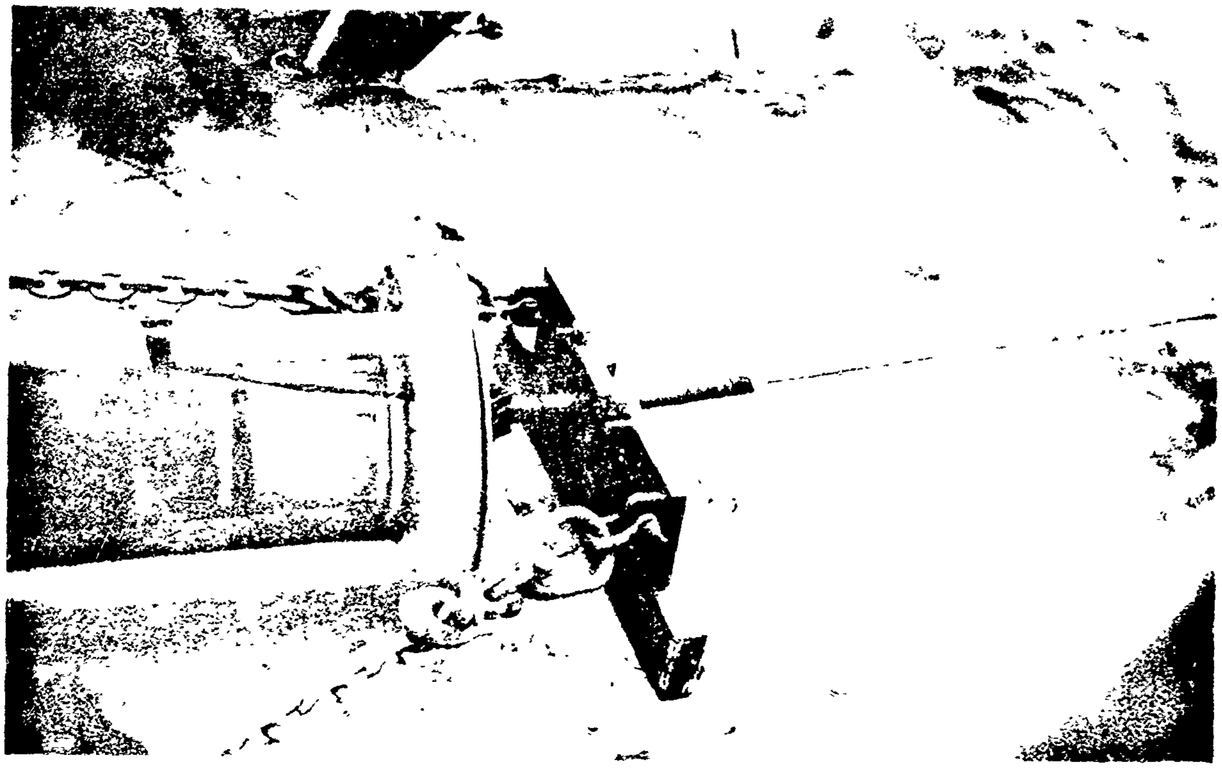


Figure 44. Mechanical Connector Stopper

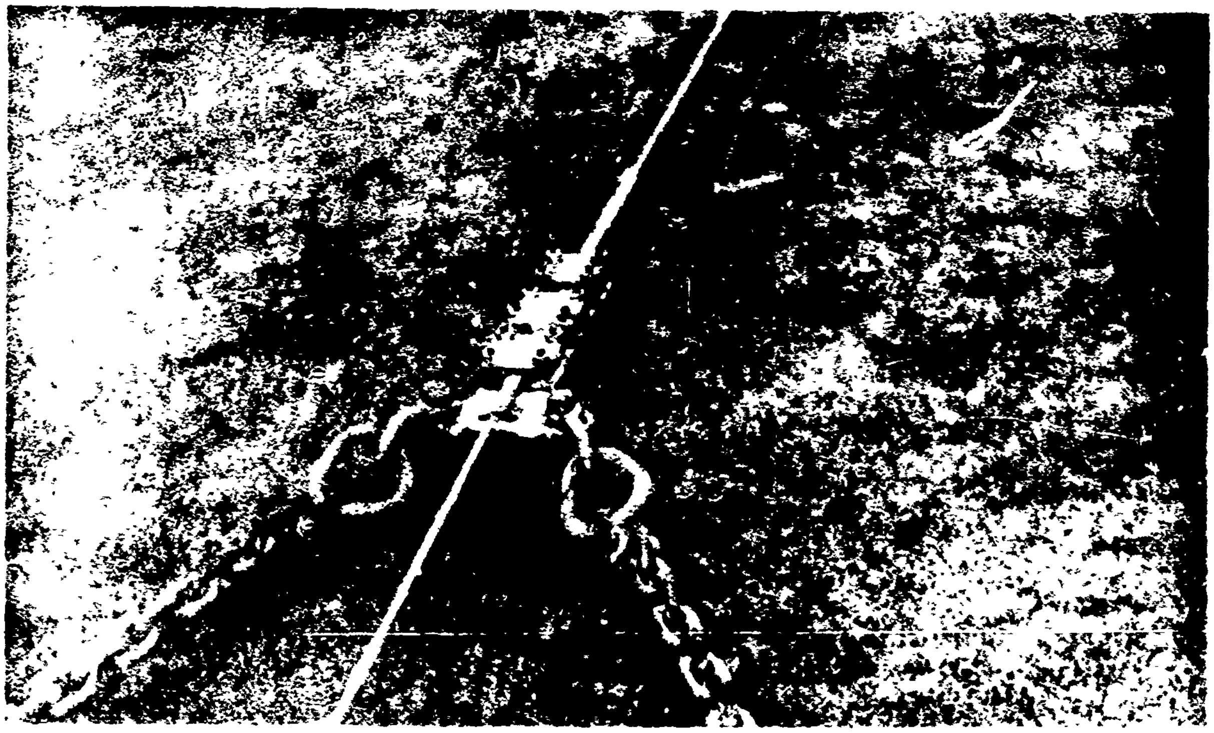


Figure 45. Mechanical Cable Stopper

2.5 NORTH SEAL Modification

The transformation of the M/V NORTH SEAL into the R/V NORTH SEAL required six weeks of concentrated effort at the Woods Hole dock. The vessel arrived on July 6, 1971 in the condition shown in Figure 46 and left on July 30, 1971, as shown in Figure 47. During this interval six vans (operations van, ACODAC van, mechanical van, living van, generator and electronics huts) were landed and fitted out, the ACODAC winch was landed, ACODAC tracks were installed, intercom systems, deck lighting and power wiring were installed and miscellaneous handling equipment such as "air tuggers" were installed.

2.6 Data Processing

2.6.1 General

Three forms of data processing are pertinent to ACODAC recordings. First, analog recording via a multi-channel graphic recorder (Brush eight channel) proved extremely useful in obtaining an overview of the data for identification of events and areas of interest for future digital processing. The data on graphic records also were reduced as part of the analysis program. The analog channels were adaptable to plot either wide band or one-third octave levels. Second, band processing for energy statistics was accomplished using a one-third octave analyzer, digitizer and digital computer working in conjunction with the ACODAC time-state decoder. Third, time series acoustic pressure processing was designed for narrow band analysis, correlation studies and shot-energy calculations.

2.6.2 Band Data Processing

The scheme employed for band processing is shown in Figure 48. This system was used on board R/V KNORR for processing after the deployments at Madeira and in the Mediterranean; it was also used ashore for post-cruise processing at Woods Hole. One third octave, as well as broad band, data in 10 second real time samples are generated through the General Radio Model 1921A analyzer and r.m.s. detector system. The sampling times are keyed to the data format on the ACODAC tape control channel which establishes the time reference; other control signals such as "start of data", "end of data", and "overload error", are generated on the data track and read through the logic control as shown. The HP 2116A computer averages seven minutes' worth of data and records on digital tape the average and variance of each of the fifteen bands of data. During a second pass the data from the digital tape are plotted (seven minute averages and standard deviations) and the statistics for each six hours of running are collected, averages for each band printed on the plot and other selected data printed out. For an example of the form of a six hour plot, see Figure 49.

2.6.3 Time Series Acoustic Pressure Data Processing

The system for this process is shown in Figure 50. The reference frequencies on the control track of the ACODAC tape control track of the ACODAC tape control the sampling times for A/D conversion. The resulting time series is used to generate power spectra, auto correlations, cross

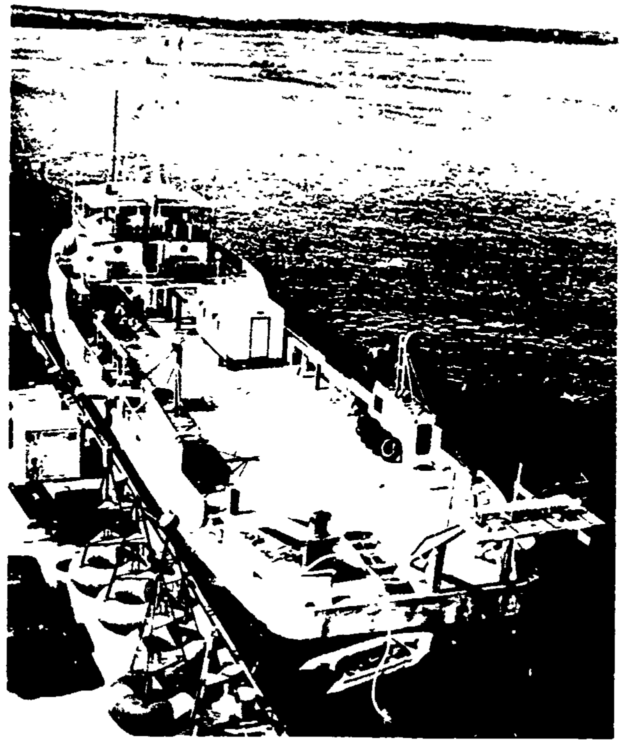


Figure 46. [illegible] SEA[illegible] [illegible]rival at Woods Hole, [illegible] 6, 1971

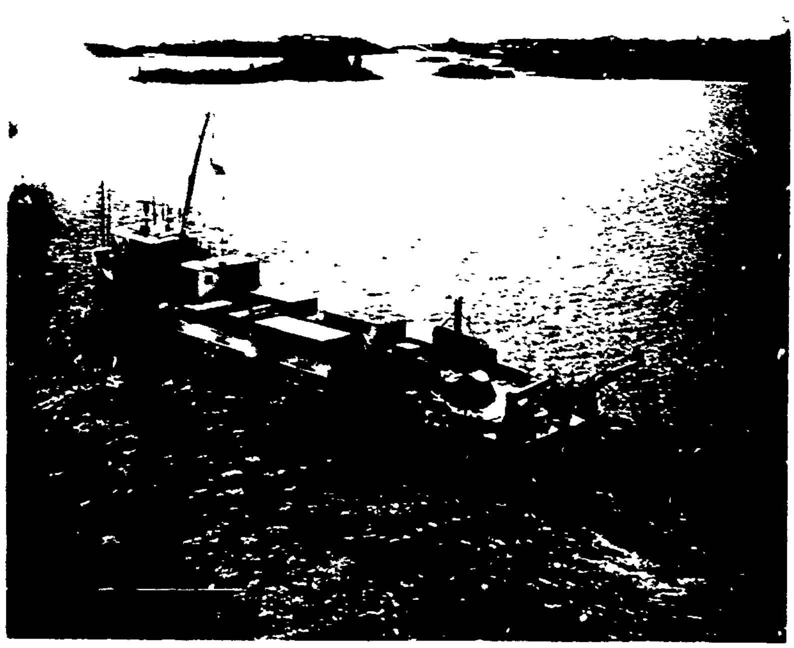
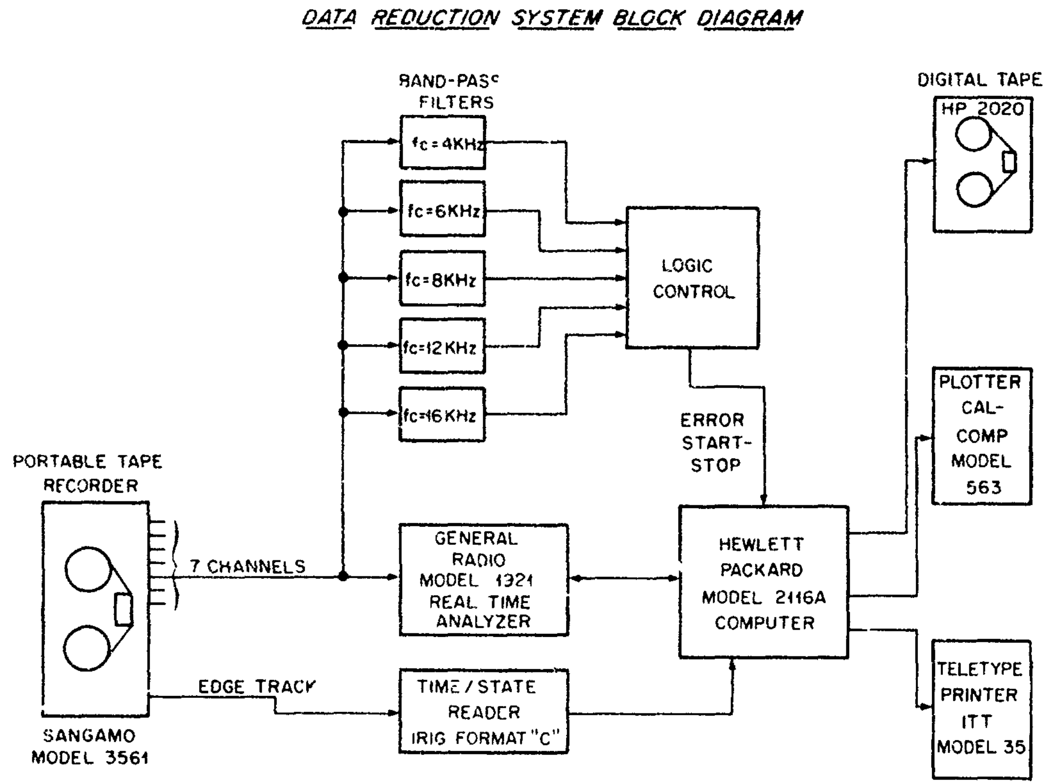


Figure 47. [illegible]ORTH SEA [illegible] Departure [illegible] Woods Hole, July 30, 1971



ACODAC DATA FORMAT

	RECORDED	PLAY-BACK
1 NO. OF CHANNELS	7 + ET	7 + ET
2. SPEED - IPS	15/160	75
3. "ON" BLOCK	7 25 MIN	5 4375 SEC
4 "DATA" BLOCK	7 MIN	5 25 SEC
5 GUARD BLOCK-		
START	10 SEC	125 SEC
STOP	5 SEC	.0625 SEC
6 CONTROL SIGNALS		
START OF DATA	150 Hz 200 Hz	12 KHz 16 KHz
END OF DATA	75 Hz 150 Hz	6 KHz 12 KHz
ERROR	75 Hz 200 Hz	6 KHz 16 KHz
CALIBRATION	50 Hz ?00 Hz	4 KHz 16 KHz

Figure 48. ACODAC Band Data Processing Diagram

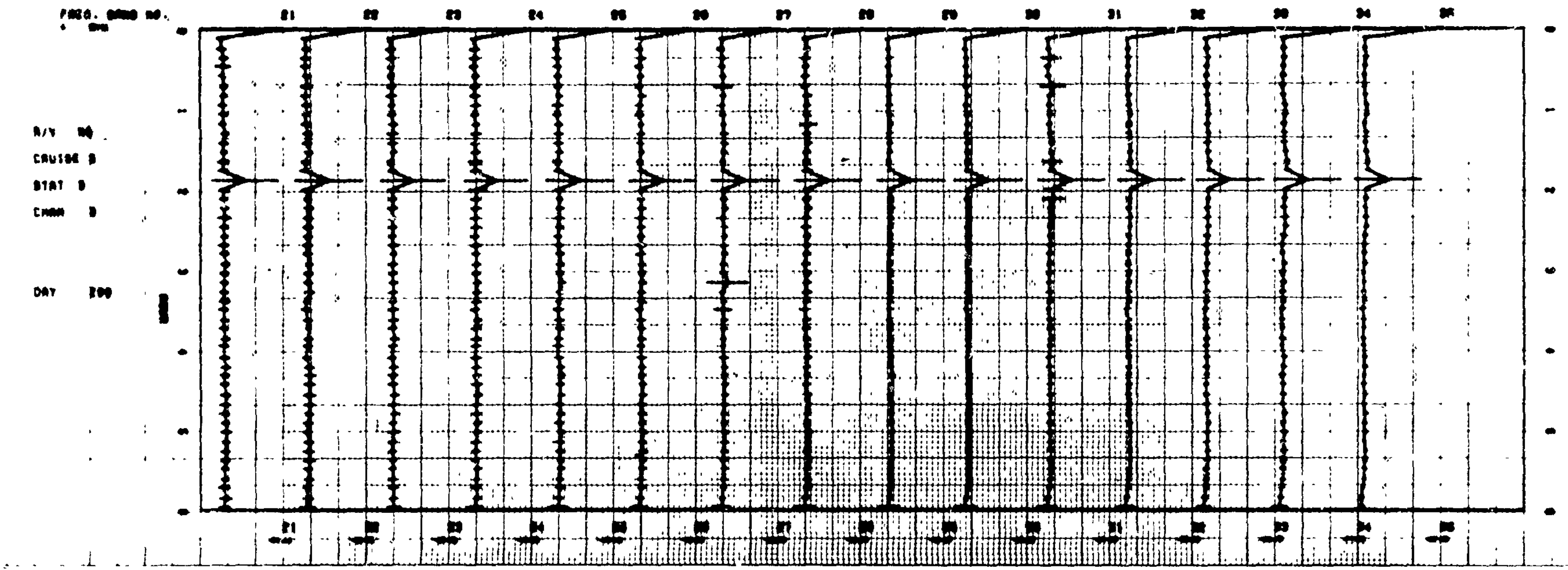


Figure 49. Six Hour Band Processing Plot

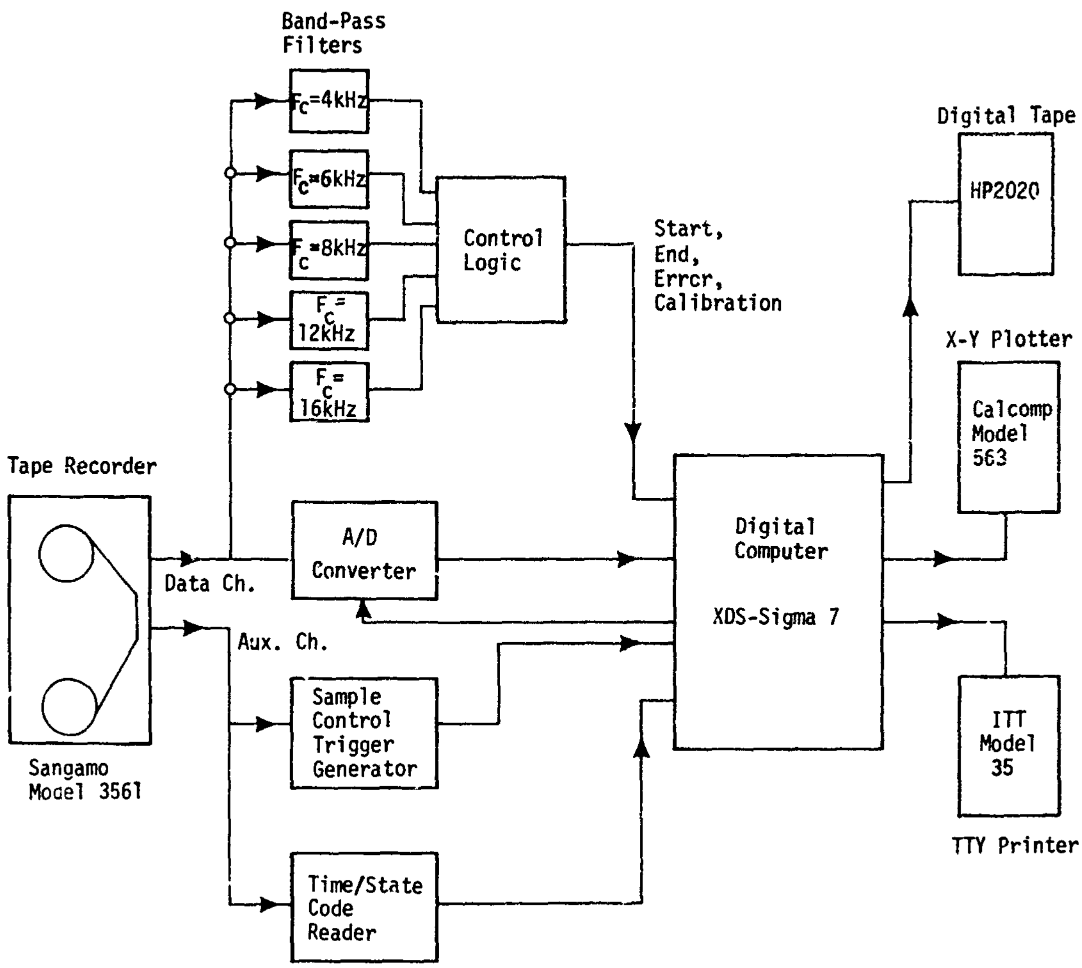


Figure 50. ACODAC Time Series Acoustic Pressure Data Processing Diagram

correlations and transient energies. The use of the control reference frequency reduces the effect of tape speed fluctuations during the recording and playback processes. As of the time of this report this system has not yet been used.

3. System Configurations and Deployment Methods

3.1 General

Six arrays were deployed in 1971. Date and place of deployment are summarized in the following table:

System Number	Date Set	Date Retrieved	Days on Station	Location	Bottom Depth Meters	Remarks
I	5/15/71	5/18/71	3	39°48.8'N 70°17.2'W	1148	Experimental
II	8/8/71	8/29/71	12	32°17.9'N 64°29.6'W	3500	Bermuda B
III	10/13/71	10/20/71	7	33°29.9'N 19°36.1'W	4470	Madeira A
IV	10/11/71	10/18/71	7	33°22.8'N 19°41.5'W	4595	Madeira B
V	11/ 2/71	11/2-IPV	23	36°15.7'N 17°26.7'E	3420	MED A
VI	11/ 1/71	11/25/71	24	36°17.8'N 17°13.2'E	3420	MED B

Design criteria, mooring analysis, and system configurations are reviewed below.

3.2 Design Criteria

The purpose of the mooring structure was to maintain at known prescribed depths a set of hydrophones connected by hard wire to a central recording station. Size and length of mooring line components, distribution of buoyancy, size and shape of anchor, had to be selected within the constraints imposed by deployment techniques, implantation requirements and recover procedures. In general the following criteria applied:

3.2.1 Structural Safety Factor

When statically loaded (mooring on station) a minimum safety factor of 5.0 (or larger) was used in all sections of wire rope and electromechanical cable. In order to minimize possible elongation due to cold flow, a larger safety factor of 10 (or larger) was selected for the synthetic fiber ropes. During launching the combined effect of dynamic and static loading could result in tension values higher than the values anticipated for the static moored case. Components were selected to insure a minimum safety factor of 2.6 (or larger) during the launching operations.

3.2.2 Launching Techniques

Three basic techniques were used to deploy the ACODAC arrays:

- Anchor first (ACODAC I).
- Anchor first with auxiliary buoy (Figure 51) (ACODAC II).

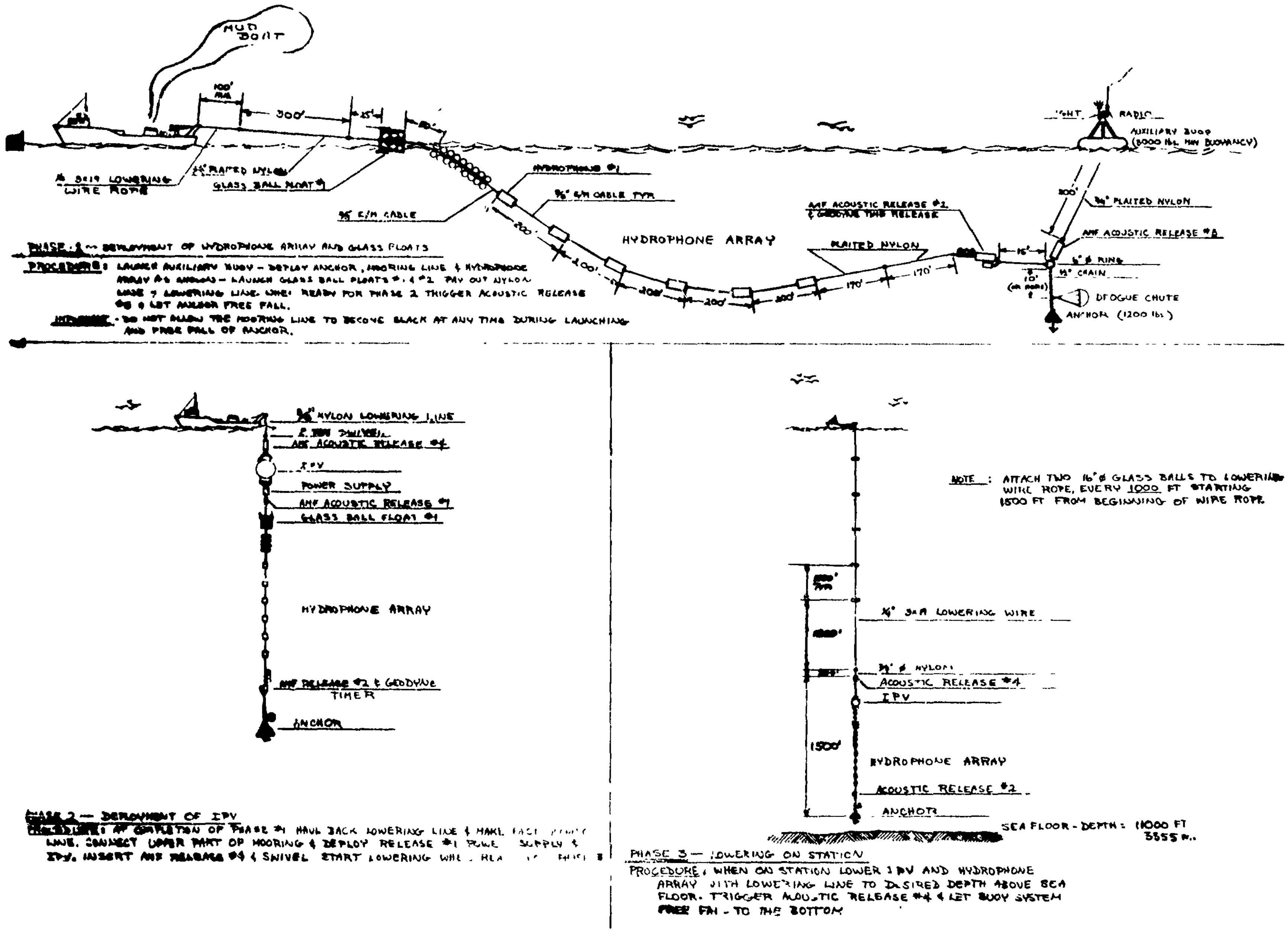


Figure 51. Launching Technique - Anchor First with Auxiliary Buoy

o "Drop and Run" technique (Figure 52) (ACODAC III, IV, V, & VI).

Analysis and selection of components had to take into consideration the launching technique used.

3.2.3 Buoyancy

Buoyancy is needed to maintain the array upright and of course for recovery of the system. Buoyancy can be provided in quantity large enough to permit recovery of failed parts (back up or redundant buoyancy) or small enough to just permit recovery of the unfailed system (normal recovery).

The ACODAC systems were designed so as to recover the Instrument Pressure Vessel and its battery pod independently of the hydrophone array. The buoyancy for the recovery of the IPV was provided by the IPV itself and two glass balls strapped to the battery pod. This part of the system had about 200 lbs. of positive buoyancy.

The pilot mooring ACODAC I, had enough reserve buoyancy distributed along the line to permit the recovery of any part of the array should the mooring line break during launching or when on station. Upon recovery the electromechanical cable became slack between the lumped buoyancy packages, and kinks developed (Figure 53). In the five subsequent systems the mooring line was made slightly negatively buoyant. During recovery the mooring line was then taut and fully submerged, thus preventing kinking. The only reserve buoyancy of the array was provided by the glass ball floats. The minimum value of this reserve buoyancy was 350 lbs.

3.2.4 Hydrophone Depth

The depths of the hydrophones were prescribed. In order to place the hydrophones as close as possible to their prescribed depth, the stretched length of the mooring line components had to be established prior to implantation for different materials and anticipated loading history. The corresponding unstretched lengths were also determined for mooring line preparation and storing purposes. All computations were based on zero current conditions.

3.3 Analysis

3.3.1 General

Stresses of the mooring line during launching and implantation and array configuration when on station were analytically investigated.

3.3.2 Launching, Anchor First

Simple mathematical models were used to investigate the resonant conditions and the tension in the mooring line as the anchor and the system components of ACODAC I were lowered to the ocean bottom. Method of computation and summary of results are presented in Appendix E.

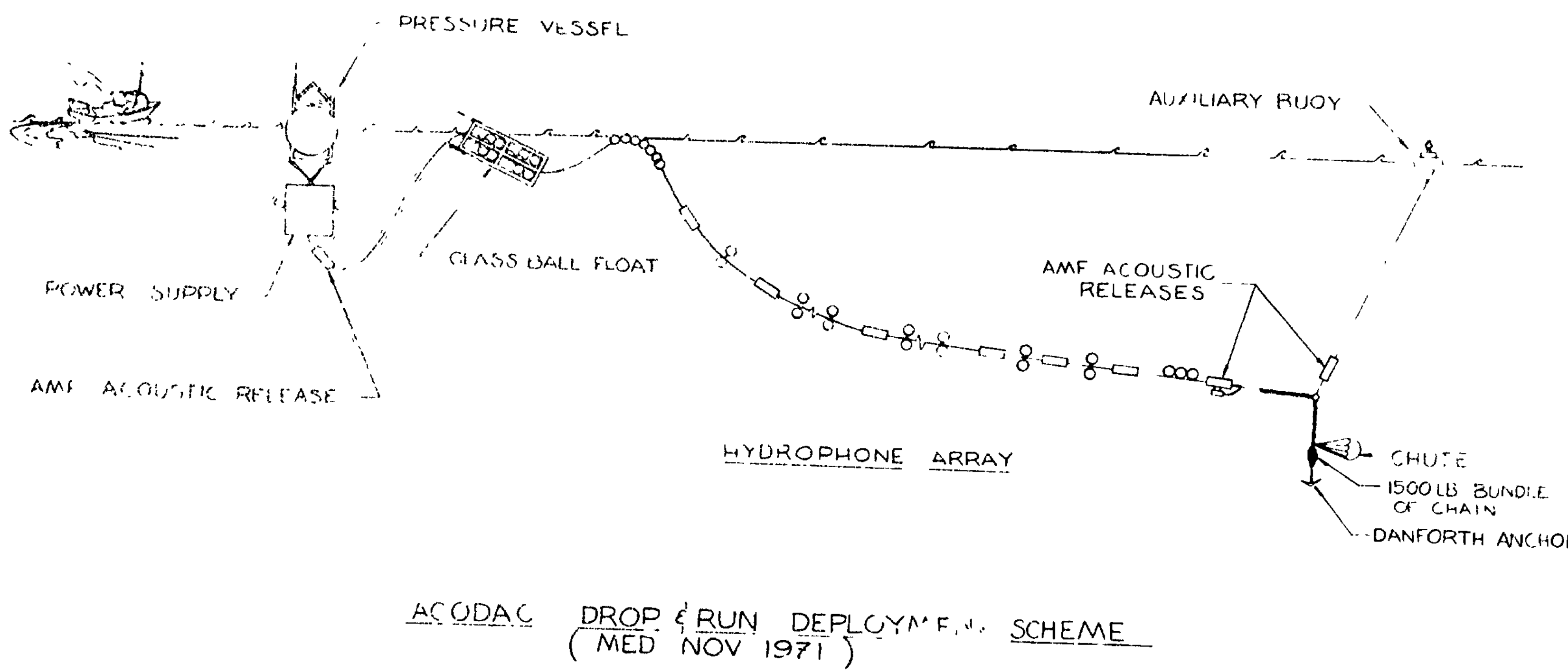


Figure 52. Launching Technique - Drop and Run

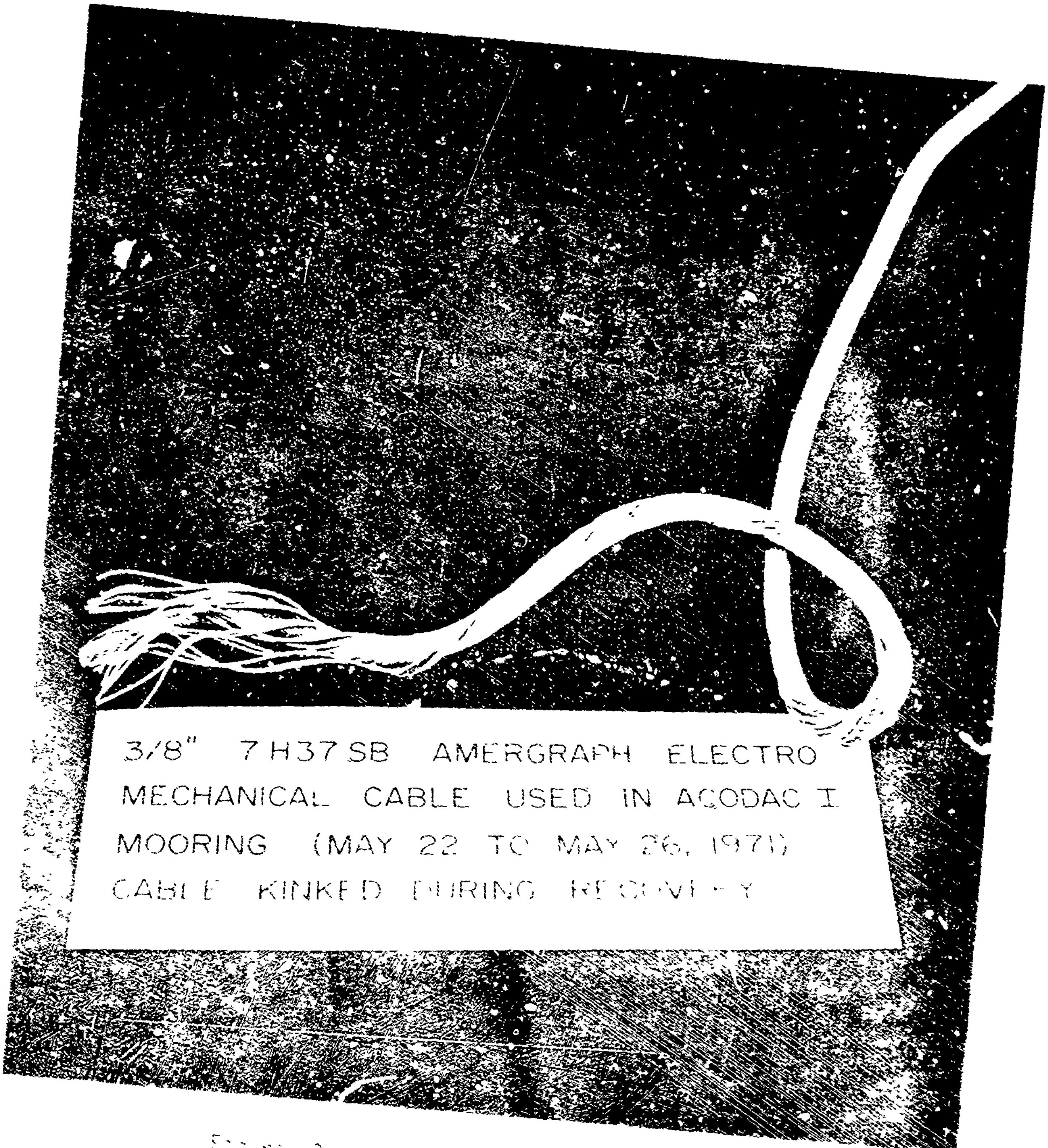


Figure 13. Kinked Electro-Mechanical Cable

3.3.3 Launching, Free Fall

Five out of six systems were allowed to free fall on station. Terminal velocity and transient conditions were studied prior to launch to ascertain that slackness and therefore possibility of cable kinks would not occur after anchor bottoming. The array was modeled in a non-linear spring mass system. The equations of motion of the system masses were numerically integrated after anchor impact starting from known initial conditions. Figure 54 shows a typical curve of mooring tension versus time obtained from computer results. Tension values below the state tension level are indicative of slackness conditions which occur in a system with little damping or elasticity (such as one without elastic nylon).

3.3.4 Static Analysis - Mooring on Station

Tension after implantation was computed at a number of locations in the mooring line. Total amount and distribution of buoyancy, perhaps the most critical factor of operational success, was carefully checked. Tension in the mooring line during recovery was also studied to make sure the line would hang straight from the float. Results of these computations are summarized on the six system configuration drawings (Figures 55 through 60..

3.3.5 Mooring Trajectory Under Steady State Currents

A study was made of the equilibrium trajectory assumed by the subsurface array when acted on by steady state oceanic currents. It was found that the arrays could be quite sensitive to current forces. However the current regimes in the deployment locations were expected to be low and therefore downstream excursion and dip of hydrophones was not a major design concern.

3.4 ACODAC System Drawings

Analytical results and design considerations were consolidated in detailed system configuration drawings showing the placement of floats and hydrophones and the type, size and length of the mooring line components (Figures 55 through 60.

A certain amount of complementary information on components' weight or buoyancy and tension levels is also indicated on these drawings. Differences in types of floats, mooring line components, depth of implantation of hydrophones, and buoyancy distribution are apparent from a review of these drawings.

3.5 Station Logs

Detailed records of the launching and recovery of each ACODAC system were maintained. The time of each event was noted as well as the condition of each component as it went over the side or was brought aboard. These logs are included here as Appendix E.

3.6 Conclusions

The rather straightforward and simple design of the systems proved to be

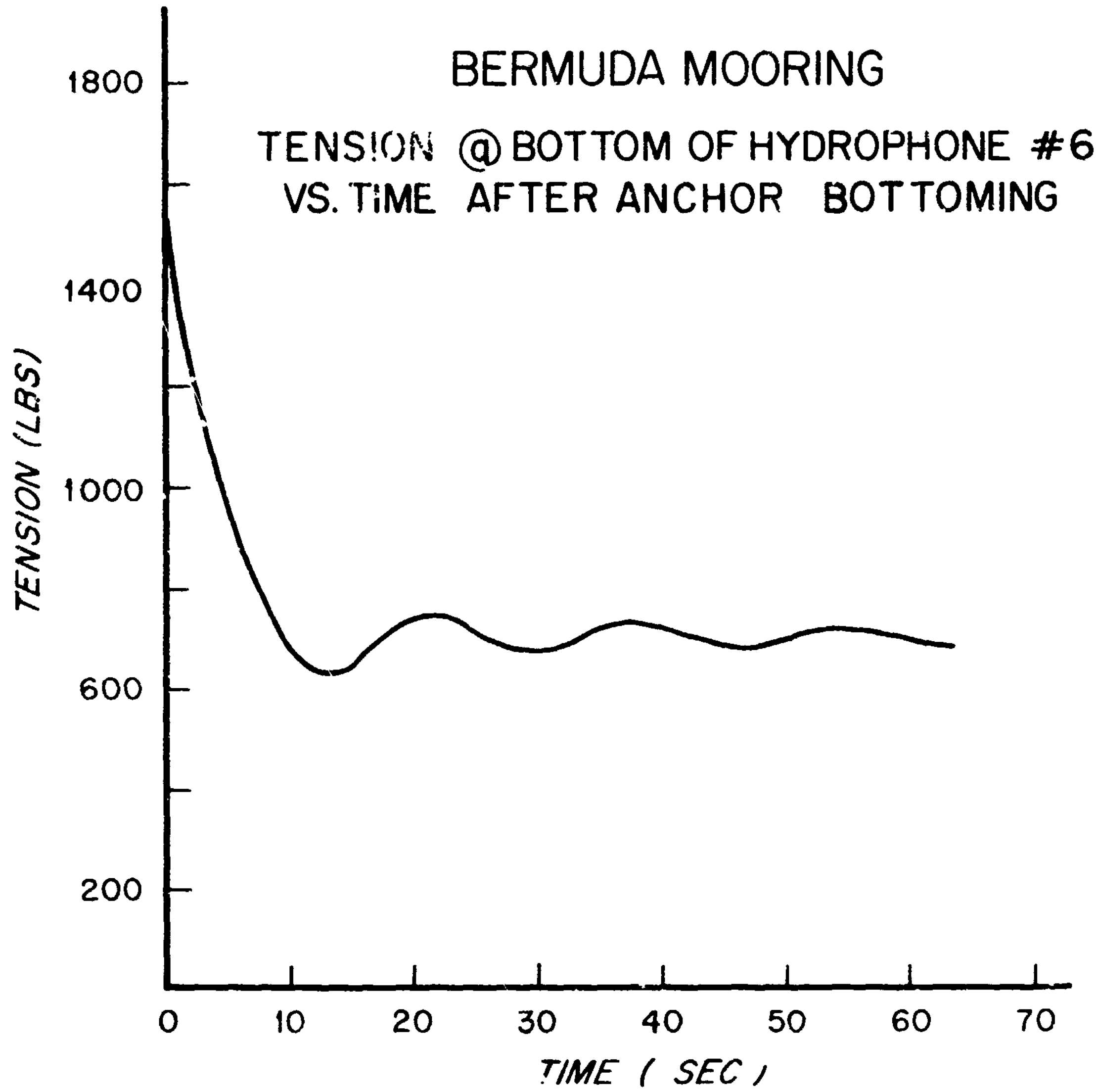


Figure 14. Tension vs Time of Bermuda Mooring After Bottoming Anchor

satisfactory. Careful preparation of components, expert handling and good weather during deployment were additional important reasons for the excellent structural performance of the systems.

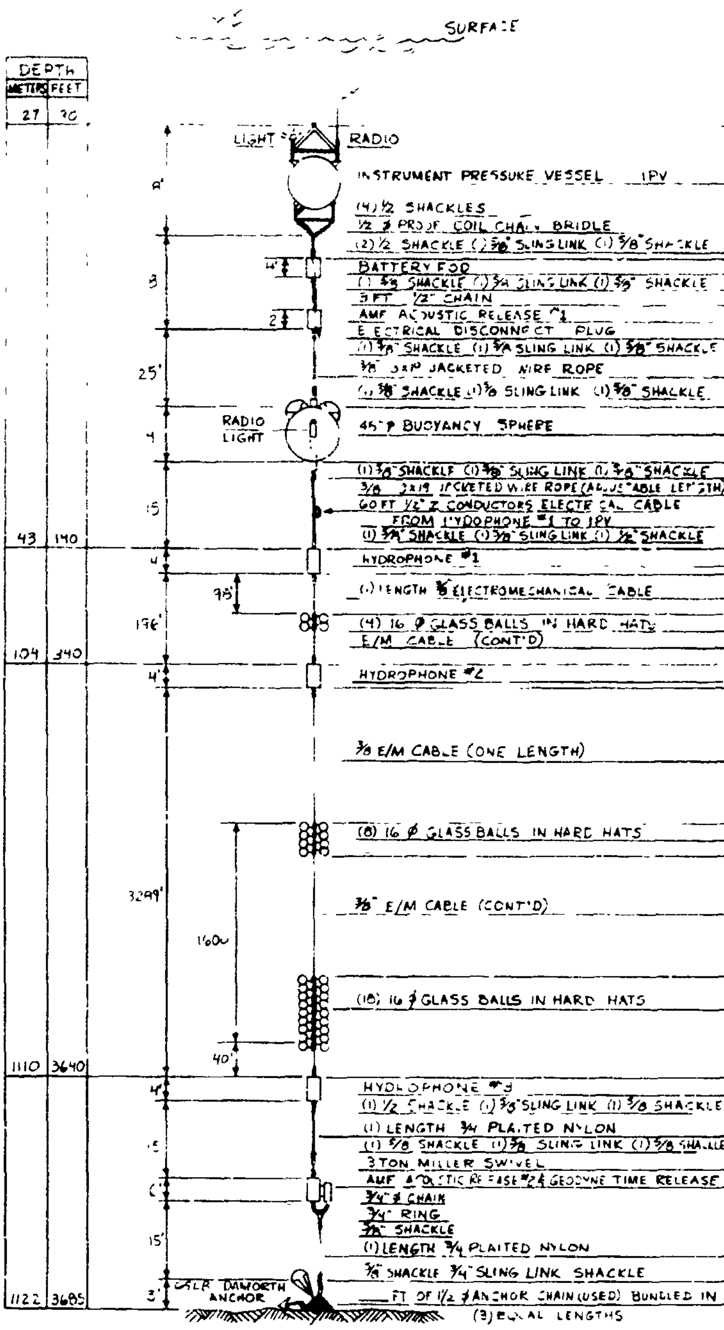
Mechanical problems associated with IPV seals and tape recorder transport operation resulted in the loss of data in the Mediterranean deployments. Electrical problems associated with the automatic gain control of the data sub-system degraded the quality of much of the data recovered at Madeira.

Deployment times were reduced from 26 hours and 18 minutes for System I off Cape Cod, to six (6) hours and 21 minutes for System V in the Mediterranean. For accuracy in emplantment deployment times need to be reduced even more; a total time of two (2) hours for deep water (15,000 feet) is considered a reasonable goal. Deployment times can be reduced by reducing the cable tension during deployment by simplifying the attachment devices for components and by unitizing the packaging of the IPV and main batteries. The basic concept of the "drop and run" deployment has proved to be sound.

The question of static cable tension needs to be considered from many viewpoints. In these deployments we used as a design goal an average static tension of about 1500 pounds. This tension was adequate for maintaining verticality of the mooring in the low current regimes encountered. In areas of high current, however, the moorings would have leaned downstream to perhaps an unacceptable degree. The natural frequency of transverse cable vibration increases as the square root of the tension; it is important for self noise purposes to keep this out of the frequency range of acoustical interest. In addition the problems of safety factor and creep arise as tension is increased. In a mooring reserve buoyancy is defined as the net upward force at any point in the line which would pertain should the line be severed at that point and all components above removed from the mooring. Because of the problems of electro-mechanical cable kinking on recovery it was not possible to provide a positive reserve buoyancy at every point on the mooring. Therefore, choice of average static tension as well as distribution of buoyant forces along the mooring is a compromise whose constraints are dictated by many considerations and which must be evaluated in light of the current environment to which the mooring will be exposed.

The experience gained from this development and the six ACODAC deployments of 1971 is being fed back into improved designs for 1972 and future years.

PURPOSE: SHORT TERM PILOT MOORING FOR EVALUATION OF DEPLOYMENT TECHNIQUES & SYSTEM PERFORMANCE
PROCEDURE: DEPLOY ANCHOR FIRST. RETRIEVE IN THIS SECTIONS - CALL INSTRUMENT PRESSURE VESSEL FIRST
SITE: APPROXIMATE SITE 31°50N & 70°00'W
DEPTH: 3685 FT 1122 METERS
EQUIPMENT: ARRAY AS SHOWN



DEPTH METERS	DEPTH FEET	COMPONENT	WEIGHT IN AIR OF COMPONENT (LBS)	WET WEIGHT OR BUOYANCY OF IMMERSED COMPONENT (LBS)	RESERVE BUOYANCY AT INDICATED LOCATION (SEE NOTE 1) (LBS)	LAUNCHING STATIC TENSION AT INDICATED LOCATION (SEE NOTE 2) (LBS)	MINIMUM STATIC TENSION DEPLOYMENT AT INDICATED LOCATION (SEE NOTE 3) (LBS)
27	90					800	
		INSTRUMENT PRESSURE VESSEL IPV	1200	+500			
		(4) 1/2 SHACKLES; 1/2 PROOF COIL CHAIN BRIDLE; (2) 1/2 SHACKLE (1) 5/8 SLING LINK (1) 5/8 SHACKLE				1166	500
		BATTERY POD	600	-240			
		(1) 5/8 SHACKLE (1) 5/8 SLING LINK (1) 5/8 SHACKLE; 3 FT 1/2 CHAIN		-10	1816	916	250
		AMF ACOUSTIC RELEASE #1	40	-20			
		ELECTRICAL DISCONNECT PLUG; (1) 5/8 SHACKLE (1) 5/8 SLING LINK (1) 5/8 SHACKLE					
		5/8 3x19 JACKETED WIRE ROPE	14	-12			
		(1) 5/8 SHACKLE (1) 5/8 SLING LINK (1) 5/8 SHACKLE			1648	884	218
		45" BUOYANCY SPHERE	[illegible]	+1400			
					448	2284	1618
		(1) 5/8 SHACKLE (1) 5/8 SLING LINK (1) 5/8 SHACKLE; 5/8 3x19 JACKETED WIRE ROPE (ADJUSTABLE LENGTH)	13	[illegible]			
43	140	60 FT 1/2" 2 CONDUCTORS ELECTRICAL CABLE FROM HYDROPHONE #1 TO IPV; (1) 5/8 SHACKLE (1) 5/8 SLING LINK (1) 1/2 SHACKLE			458	2274	1608
		HYDROPHONE #1	50	-40	498	2234	1568
		(1) LENGTH 3/8 ELECTROMECHANICAL CABLE	23	-20	5.8	2214	1548
		(4) 16 Ø GLASS BALLS IN HARD HATS	180	180	338	2394	1728
104	340	E/M CABLE (CONT'D)	23	-20	358	2374	1708
		HYDROPHONE #2	50	-40	398	2334	1668
		3/8 E/M CABLE (ONE LENGTH)	400	-315	713	2019	1353
		(8) 16 Ø GLASS BALLS IN HARD HATS	360	+360	353	2379	1713
		3/8" E/M CABLE (CONT'D)	400	-315	668	2064	1398
1110	3640	(18) 16 Ø GLASS BALLS IN HARD HATS	810	+810	ZERO	2874	2208
		HYDROPHONE #3	50	-40			
		(1) 1/2 SHACKLE (1) 5/8 SLING LINK (1) 5/8 SHACKLE; (1) LENGTH 3/4 PLAITED NYLON	5	-2			
		(1) 5/8 SHACKLE (1) 5/8 SLING LINK (1) 5/8 SHACKLE; 3 TON MILLER SWIVEL			ZERO	2832	2166
		AMF ACOUSTIC RELEASE #2 & GEODYNE TIME RELEASE	160	100			
		3/4" Ø CHAIN; 3/4" RING; 3/4" SHACKLE; (1) LENGTH 3/4 PLAITED NYLON	5	-2			
		3/4 SHACKLE 3/4 SLING LINK SHACKLE			ZERO	2730	2064
1122	3685	LB DANFORTH ANCHOR; FT OF 1/2 Ø ANCHOR CHAIN (USED) BUNDLED IN (3) EQUAL LENGTHS	3100	2730			

NOTES:

1. RESERVE BUOYANCY AT LOCATION INDICATED IS THE BUOYANCY FORCE IN LBS BETWEEN THE LOCATION AND THE ACOUSTIC RELEASE #2.
2. LAUNCHING STATIC TENSION IS DEFINED AS THE TENSION IN LBS IN THE LINE AT THE INDICATED LOCATION JUST BEFORE THE LOCATION ENTERS THE WATER SURFACE & BEFORE THE ANCHOR BOTTOMS.
3. MINIMUM STATIC TENSION AFTER DEPLOYMENT IS THE GRAVITY FORCE IN LBS AT THE INDICATED LOCATION. HYDRODYNAMIC FORCES DUE TO CURRENTS ARE NOT INCLUDED IN THIS DWG.
4. ROPE LENGTH SHOWN IS LENGTH OF ROPE IN RELAXED (NO LOAD) CONDITION.
5. DEPTH SHOWN INCLUDES STRETCH OF ROPE.
6. SHACKLES TO BE SAFETY ANCHOR TYPE, THIN HEX HEAD BOLT & STAINLESS 316 COTTER PIN (C.L. TYPE G 2130) SLING LINKS TO BE PEAR SHAPE (C.L. TYPE G-341)
7. E/M CABLE TO BE AMERGRAPH TYPE TH 375 B 3/8 Ø 11,000 LBS RBS

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OCEAN ENGINEERING DEPT

ACODAC I MOORING
SHORT TERM PILOT MOORING

Figure 55. Mooring Configuration - System I

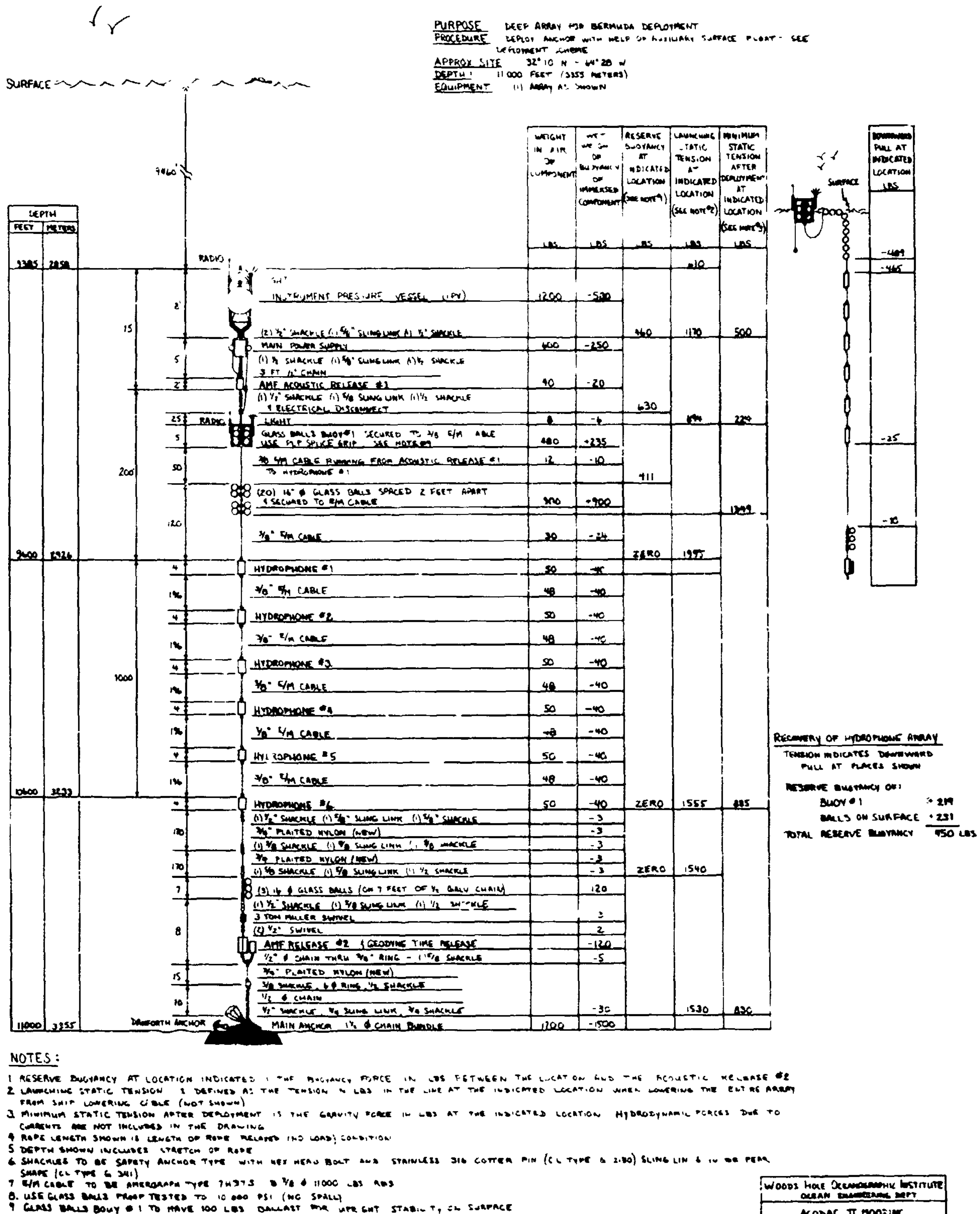


Figure 56. Mooring Configuration - System II

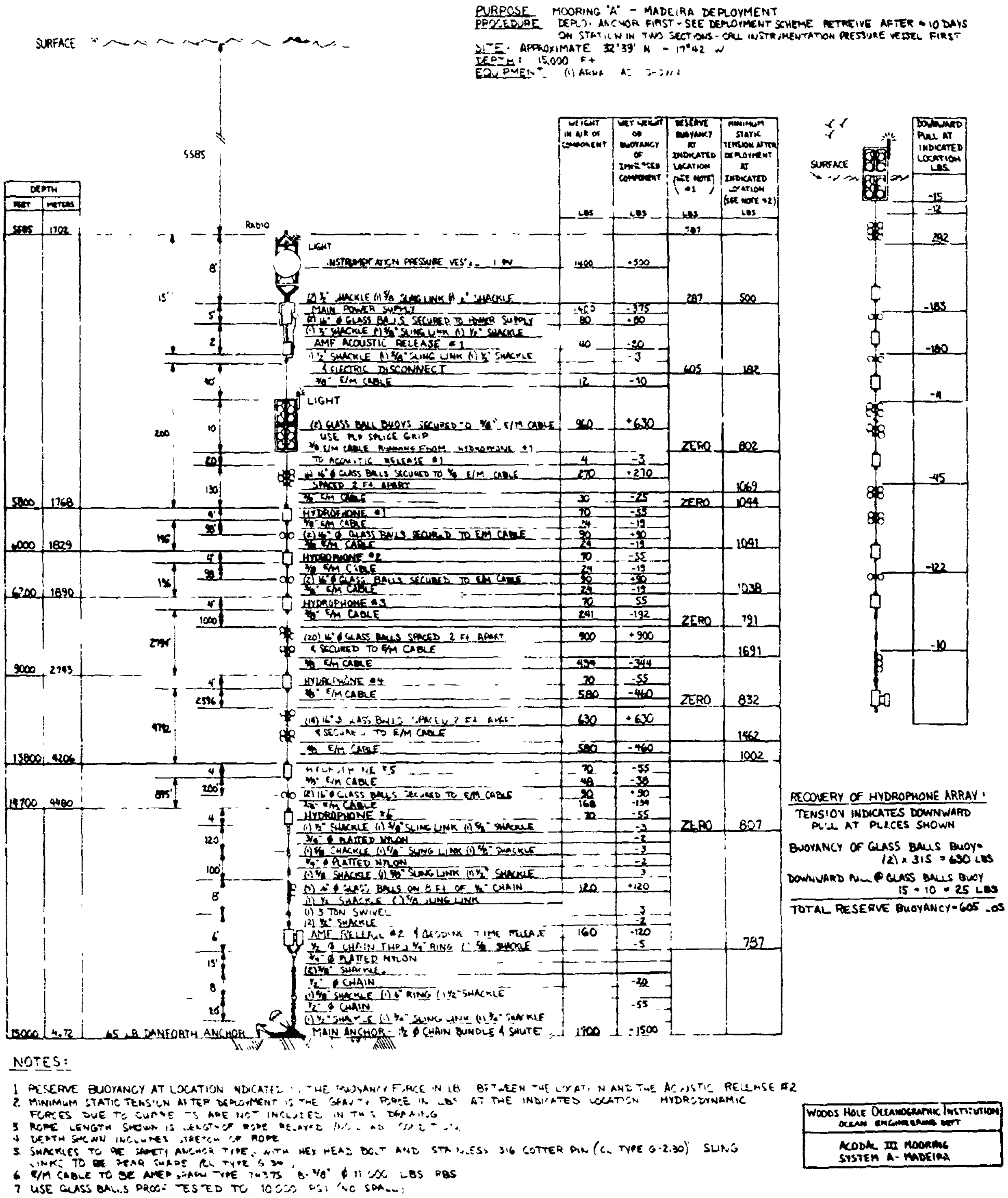
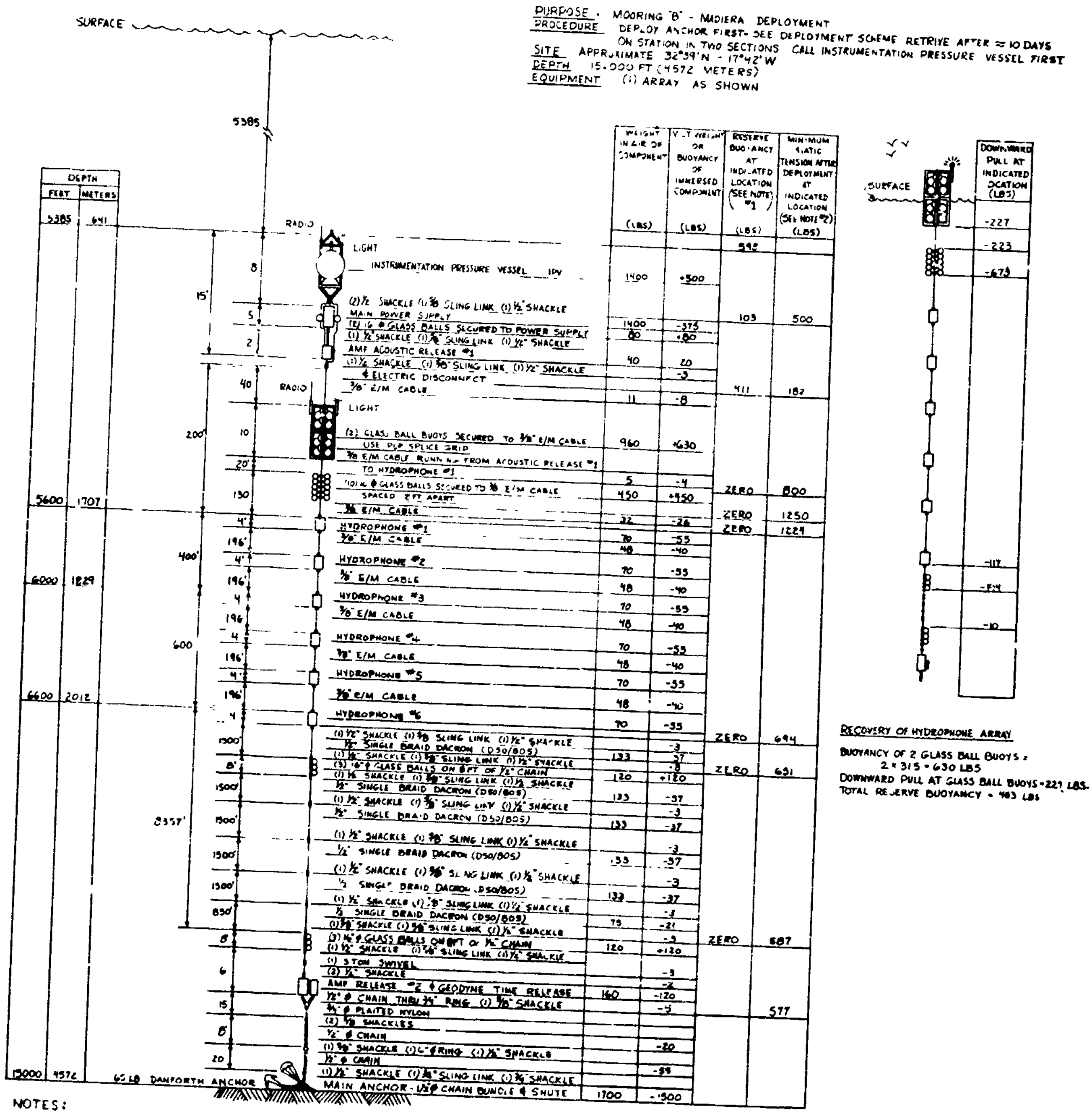


Figure 57. Mooring Configuration - System III



NOTES:

1. RESERVE BUOYANCY AT LOCATION INDICATED IS THE BUOYANCY FORCE IN LBS BETWEEN THE LOCATION AND THE ACOUSTIC RELEASE #2.
2. MINIMUM STATIC TENSION AFTER DEPLOYMENT IS THE GRAVITY FORCE IN LBS AT THE INDICATED LOCATION. HYDRODYNAMIC FORCES DUE TO CURRENTS ARE NOT INCLUDED IN THIS DRAWING
3. ROPE LENGTH SHOWN IS LENGTH OF ROPE RELAXED (NO LOAD) CONDITION
4. DEPTH SHOWN INCLUDES STRETCH OF ROPE
5. SHACKLES TO BE SAFETY ANCHOR TYPE, WITH HEX HEAD BOLT AND STAINLESS 316 COTTER PIN (CL TYPE G-2130) SLING LINKS TO BE PEAR SHAPE (CL TYPE G 341)
6. E/M CABLE TO BE AMERGRAPH TYPE 7H3TS B-3/8" Φ 11,000 LBS RBS
7. USE GLASS BALLS PROOF TESTED TO 10,000 PSI (NO SPALL)

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ACODAC II MOORING
SYSTEM B - MADEIRA

Figure 58. Mooring Configuration - System IV

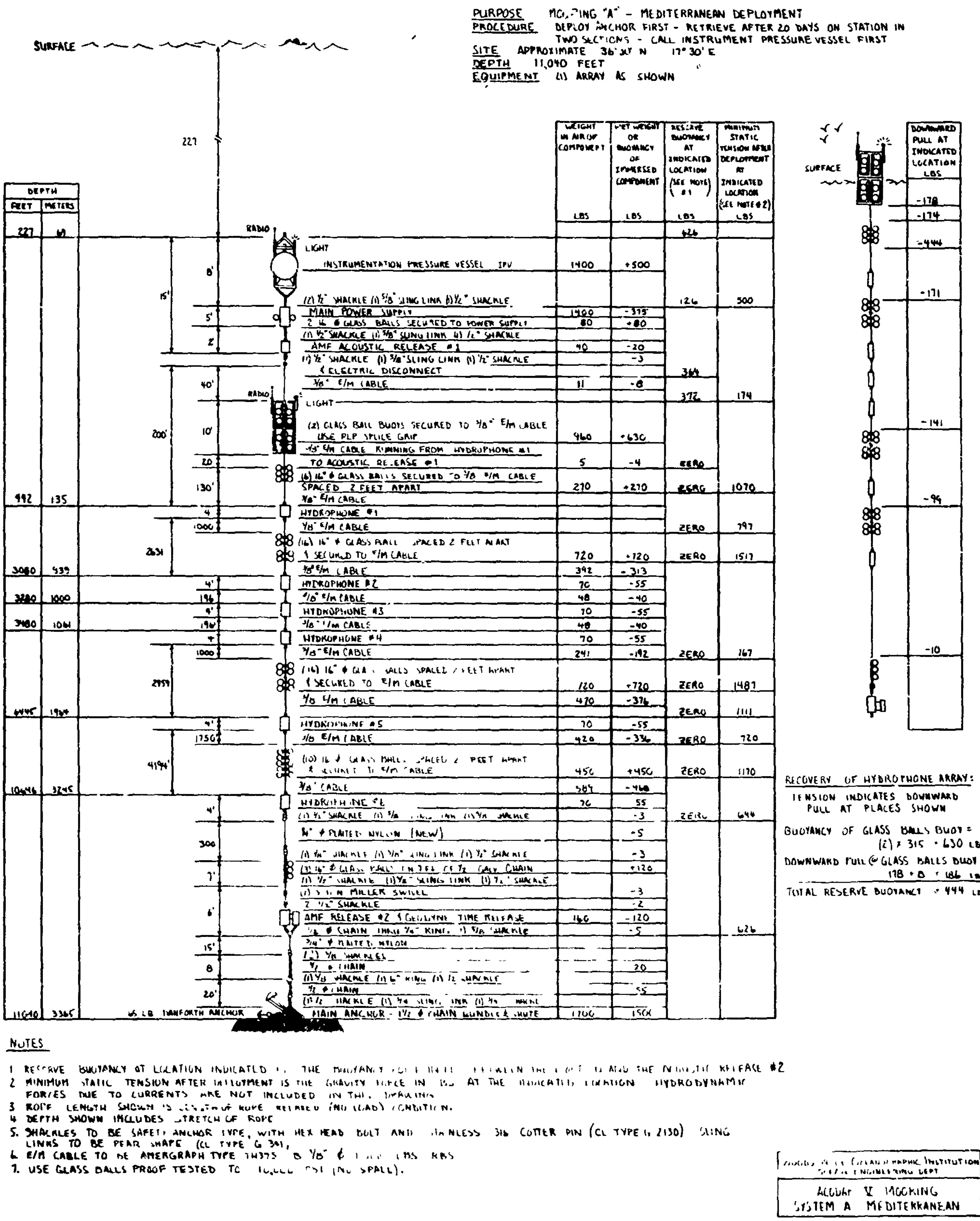


Figure 59. Mooring Configuration - System V

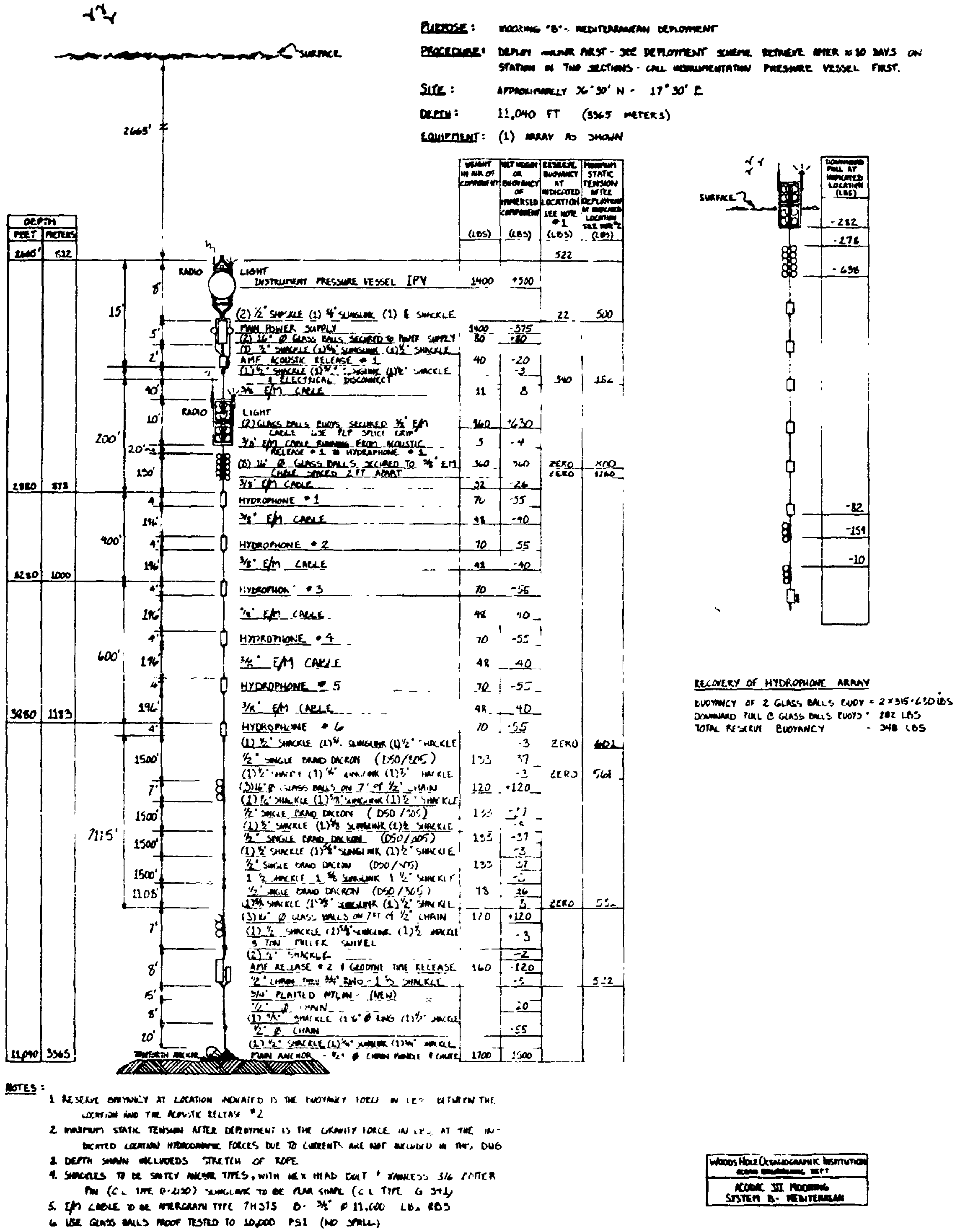


Figure 60. Mooring Configuration - System VI

Appendix A

ACODAC Data Hydrophone/Preamplifier Specifications

The following specifications refer to the data hydrophone/preamplifier assemblies for application in the Woods Hole Acoustic Data Capsule (ACODAC) program:

1.	Sensitivity:	-40 db re v/ub
2.	Frequency Range:	Flat within ±1 db between 15 Hz and 1 kHz. 3 db down points located as follows: Lower - less than 7.5 Hz Upper - greater than 1.5 kHz
3.	Ambient Pressure Range:	0 to 10,000 psig. Open circuit sensitivity between 15 Hz and 1 kHz not to change more than ± 0.5 db over range of ambient pressure.
4.	Acceleration Insensitivity:	The hydrophones shall be constructed to be insensitive to accelerations up to 1 g. Response compared to a non-cancelling hydrophone of the same sensitivity shall be down by 20 db re volts per g over the entire frequency range in any direction.
5.	Dynamic Range:	80 db
6.	Signal Voltage Levels:	With an input acoustic spectrum level varying between +10 and -70 db re 1 ub the output of preamplifier shall vary between 1 volt and 100 micro-volts rms.
7.	Temperature Coefficient:	Response over entire frequency range shall not vary with temperature by more than ± 0.1 db when the temperature varies between 0° C and 25° C.
8.	Transmission Line:	The hydrophone/preamplifier assembly will drive a two wire transmission line whose characteristic impedance is 272-j272 ohms at 1 kHz.

9. Power:	Power consumption shall be less than 0.15 watt continuous at 6 volts. DC power shall be isolated from the signal output terminals. The power system shall be isolated from ground. For a steady input signal the output signal shall not vary by more than 0.1 db with slow changes in the power supply voltage between 6.5 and 5.5 volts.
10. Mechanical Arrangements:	The hydrophone/preamplifier assembly shall fit within a cylindrical envelope 5 inches in diameter by 8 inches in length exclusive of connectors. Metal plates at each end of the assembly shall each contain 3 3/8 inch blind tapped mounting holes equally spaced peripherally. The preamplifier shall be contained within a pressure vessel which can be disassembled for trouble shooting. The pressure vessel shall mount a Marsh and Marine four pin Type XSK 4 BCL connector along its cylindrical axis. Two of the leads shall be signal leads and two leads shall be power leads. The manufacturer shall identify the leads.
11. Testing:	The manufacturer shall demonstrate by test the sensitivity and dynamic range of each hydrophone/preamplifier assembly produced. He shall demonstrate on any single unit to be chosen by the customer the adherence to all of the remaining units for all of the specification requirements.
12. Drawings:	The manufacturer shall provide outline assembly drawings showing all dimensions and materials which are exposed to sea water shall be identified.

Appendix B

ACODAC System Organization

1000 Mechanical Systems

- 1100 Containment Systems
  - 1110 Instrument Pressure Vessel (IPV)
    - 1111 IPV Hemispheres
    - 1112 IPV Central Ring
    - 1113 IPV External Structure
    - 1114 IPV Internal Structure
    - 1115 IPV Valving and Penetrators
    - 1116 IPV Sacrificial Anodes
  - 1120 Main Power Supply Container
    - 1121 Case
    - 1122 Pressure Equalizer
    - 1123 Pressure Relief
    - 1124 Fittings
  - 1130 Hydrophone Power Supply Container
    - 1131 Case
    - 1132 Pressure Equalizer
    - 1133 Pressure Relief
    - 1134 Fittings
- 1200 Support Fittings
  - 1210 Hydrophone String
    - 1211 Cable
    - 1212 Mechanical Cable Termination
    - 1213 Hydrophone Assembly Cages
    - 1214 Buoyancy Modules
    - 1215 Base Frame
    - 1216 Anchor

2000 Electrical Systems

- 2100 Data System
  - 2110 Acoustic Data System
    - 2111 Hydrophone/Preamplifiers
    - 2112 Amplifiers
    - 2113 Receiver Filters
    - 2114 Level Sense
    - 2115 Calibration Signal Generator

2120 Auxiliary Data

    2121 Pressure Transducer

2130 Control Data

    2131 Leak Detector Circuitry
    2132 Battery Voltage Monitor

2200 Recording System

    2210 Tape Recorder

2300 Command and Control System

    2310 Acoustic Telemetry

        2311 IPV Telemetry Transducer
        2312 Receiver/Demodulator
        2313 Signal Generator
        2314 Amplifier/Driver
        2315 T/R Unit

    2320 Logical Decision and Control System

        2321 Logical Decision and Control Unit

2400 Time System

    2410 Master Oscillator and Countdown System

        2411 Master Oscillator Assembly
        2412 Master Oscillator Countdown Circuit

    2420 Time/State Code System

        2421 Time/State Code Generator

2500 Power Systems

    2510 Main Power

        2511 Main Power Batteries
        2512 Main Power Interconnection
        2513 DC-DC Converters

    2520 Hydrophone Power

        2521 Hydrophone Batteries
        2522 Hydrophone Power Interconnection

    2530 Auxiliary Power

        2531 Auxiliary Power Batteries
        2532 Auxiliary Battery Interconnection

2600 Location Assist Systems

2610 RF System

2611 IPV Radio Beacon
2612 Hydrophone String Radio Beacon

2620 Visual System

2621 IPV Flasher
2622 Hydrophone String Flasher

3000 Electro-Mechanical Systems

3100 Electro-Mechanical Releases

3100 IPV Release System

3111 IPV Release Assembly

3120 Hydrophone String Release System

3121 Hydrophone String Release Assembly

3200 Pressure Proof Electrical Connectors

3210 IPV Electrical Connectors

3211 IPV Penetrators and Connectors
3212 IPV Electrical Disconnect

3220 Hydrophone String Electrical Connections

3221 Hydrophone String Penetrators and Connectors
3222 Hydrophone String Electrical Disconnect

3230 Main Power Connections

3231 Main Power Supply Penetrators and Connectors

4000 Shipboard Systems

4100 Handling Systems

4110 Launch and Recovery System

4111 Hooks and Yokes
4112 Winches
4113 Reels

4120 Deck Handling System

4121 Hemisphere Handlers
4122 IPV Cradle

4200 Conditioning and Test Equipment

4210 IPV Atmospheric Conditions System

4211 Dry Nitrogen Circulation Equipment
4212 Vacuum Equipment

4220 Test Systems

4221 Test Signal Generator and Analyzer
4222 Test Umbilical

4300 Command and Telemetry Systems

4310 Acoustic Telemetry System

4311 Telemetry Receiver
4312 Decoder/Display

4320 Acoustic Command System

4321 Command Coder
4322 Power Amplifier
4323 Transducer
4324 Range/Bearing Receiver

4330 RF System

4331 RF Receiver

4400 Shipboard Data Reduction Systems

4410 Data Recovery

4411 Tape Recorder/Reproducer
4412 Graphic Recorder
4413 Time/State Code Reader

4420 Data Processing

Appendix C

Buoyancy Material Immersion Test

Purpose of test: The purpose of thetest was to evaluate the performance of a sample of composite buoyancy material when exposed to approximately 150 atmospheres of hydrostatic pressure over a period of two months.

Description of sample: The sample was a cylinder (21"Øx24")of composite material made of fibreglas hydrospheres and syntactic foam.

- The following parameters were measured or computed before the test.

  Weight: 148 lbs.(140 lbs. of material, 8 lbs. of structure)

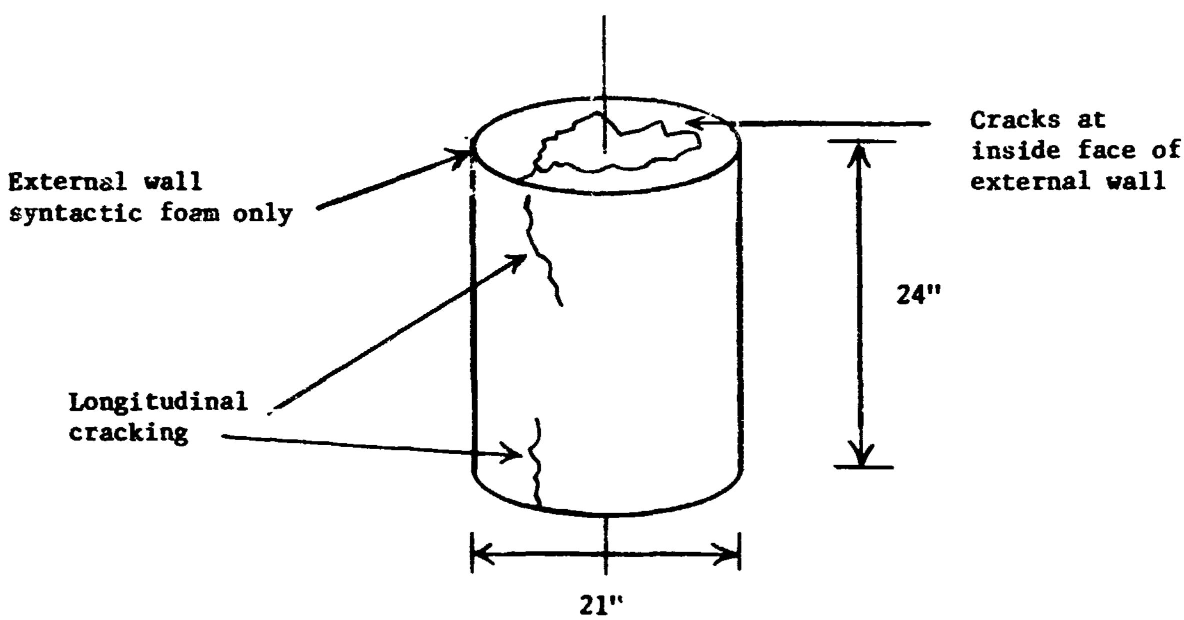
  Displacement: (4.81) cubic foot or woo lbs. of sea water

  Buoyancy: 308 - 140 = 168 lbs.

The sample was provided free of charge by the Data Packaging Corporation, Flotation Division, 205 Broadway, Cambridge, Mass. 02139.

Location of test: The sample was inserted in the mooring line of the surface mooring station number 355 @ 1500 meters below the surface. Station 355 was set October 9, 1970 at site "L" (34°N,70°W) and retrieved December 7, 1970. The sample was immersed in situ 60 days.

Test results: Upon retrieval the sample was found cracked and leaking. Cracks were circular as well as longitudinal (as shown on sketch).



22.5 quarts (5.6 gallons) of leaking water were collected and measured while underway. Upon arrival at W.H.O.I. the module was weighed and the weight found to be 200 lbs. The following parameters were thus established:

Weight of the module at time of retrieval

$W = 200 + (5.6)(0.134)(64) = 248$ lbs.

Amount of water absorbed:

$248 - 140 = 108$ lbs.

or, $\frac{108}{64} = 1.69$ cubic foot

Remaining buoyancy after exposure:

$168 - 108 - 60$ lbs.

Loss of Buoyancy

$$\frac{168-60}{168} = 64\%$$

Conclusions: These results seem to indicate that most of the hydrospheres have collapsed and that only the syntactic foam in the voids between spheres and in the outside wall have resisted the pressure thus accounting for the remaining buoyancy. The material tested is inadequate for use at 1500 meters depth. The supplier intends to open up the sample for further autopsy. Long term tests of similar material at shallower depths (1000 and 500 meters) are indicated.

Appendix D

Method of Measuring and Test Loads for Dacron Rope of ACODAC Systems IV and VI

The following is a description of a procedure to establish the quantity of synthetic fiber rope which will eventually stretch to a desired length when the load across the rope is known. Length measurements based on percent elongation are difficult to achieve when the rope cannot be measured in the same way as the sample on which the percent elongation has been established. This procedure is based on weight measurements rather than length measurements. It was suggested by P. B. Stimson and the Samson Cordage Company.

Procedure:

Step 1 Take a sample from the machine run.

Step 2 Place two marks on the sample. NOTE: the sample is under no tension whatsoever when marking.

Step 3 Place sample in tensile machine, the marks being free of splice and attachment points.

Step 4 Load the sample first to its tension during sea launching and hold for the estimated time of launch. Then decrease tension to value when on station. Measure the length exactly, say L = 5.782 ft.

Step 5 Remove sample from tensile machine. Cut sample at marks. Carefully weigh the sample - say W = 275.41 grams.

Step 6 The procedure has established that 275.41 grams of the particular rope will stretch to 5.782 ft. when loaded (in the dry) in the manner anticipated for the actual use. It can then be said that one gram of the rope will have a length (under load) of

$$\frac{5.782}{275.41} = 0.02099 \text{ ft.}$$ or that a stretched foot of rope will weigh

$$\frac{275.41}{5.782} \text{ grams} = 47.6323 \text{ grams}$$

Step 7 Establish the length needed to deploy the instrumentation at a given distance from the ocean floor. Say this distance is 7800 ft. The amount of rope needed which will stretch to this distance is

$$(7800) \text{ ft. } (47.6323) \frac{\text{gram}}{\text{ft.}} = 375{,}342.52 \text{ grams, or, } (375.34252)$$

$(2.205) = 827.63$ lbs. and this provided the rope elongates in the same manner when immersed. IF NOT then a correction must be made.

Step 8 Now comes the question of manufacturing a precise amount of rope. One way to do this could be to:

1. Produce a controlled but unknown quantity of rope (the control instrument being a clock or a meter wheel). Weigh this amount of rope. This permits to establish than the machine produces "x" gram per unit of control instrument (say 22.407 grams per second of 41.273 grams per rotation of the meter wheel).

2. The manufacturing of the amount needed will then be based on the unit th , established.

   For example, to produce 375,342.52 grams the machine will have to run $\frac{375,342.52}{41.273}$ = 9,094.1 revolutions.

Step 9 Now comes the question of cutting the rope to suitable lengths for storing on the launching drums. This can be done in the following way:

- Establish the storing capacity of the drum. Say this is 1500 ft.

- The number of lengths to cut will therefore be

$$\frac{7800'}{1500'} = 5.200$$

- The total production will have to be divided in six parts. Five equal parts each weighing

$$\frac{375,342.58}{5,2000} = 72,181.26 \text{ grams}$$

  and one part weighing

$$(72,181.26)(0.2533) = 18,283.51 \text{ grams.}$$

Step 10 The production is then divided by weight as suggested in Step 9. The sum of the weights gives a check on the total amount needed.

Step 11 The six (6) lengths can now be spliced at both ends.

Remarks:

To conclude, the total length is unknown and varies with load. The total amount (lbs. or grams) of rope is however known and also its length when loaded as anticipated. Loads on test sample of ½" single braid polyester Samson (D50-805) for ACODAC Systems IV and VI were:

Hold 1600 lbs. for 24 hours.
Down to 700 for one hour.

These loads correspond to anticipated average loading during launch anchor first, and afterwards on recovery. The accuracy of the end result depends on:

1. Conditions in which the weight of the sample and the weight of the production are established. Ideally they should be identical (same scale, same building, same temperature, same humidity, etc...).

2. Similitude between sample and production run.

3. Physical behavior of the rope when immersed in sea water.

4. Knowledge of the anticipated load when deployed.

Appendix E

Summary of Analysis of the ACODAC System I Launching Transient

The array is deployed anchor first. Tension due to static and dynamic loads during deployment are investigated, using simple models.

Method of Analysis

Static Tension: The static tension T_s is defined as

$$T_s = \sum_i W_i - \sum B_i$$

where $\sum_i W_i$ is the sum of the component/weight (immersed or not, depending on the situation) below the point studies, and is the sum of the buoyant components below that point.

Dynamic Tension: Dynamic tension is investigated in two ways:

1. Solution of the wave equation, considering the cable as a continuous elastic member supporting the anchor at one end and being forced to move with ship motion at the other end. The solution neglects the hydrodynamic drag.

2. Determination of the inertia forces and drag forces due to acceleration and speed of the upper part of the mooring. The dynamic tension is then assumed to be the sum of these two forces and is given by:

$$T_{DYN} = T_i \cos \omega t' + T_D (\sin \omega t')^2$$

(see derivation at end)

where $T_i = a \sum_i m_i$

a = acceleration of line

$\sum_i m_i$ = sum of virtual masses below point studied

$$T_D = V^2 \sum_i \tfrac{1}{2} \rho C_i A_i$$

V = speed of line, and

and $\omega t' = \cos^{-1} \dfrac{T_i}{2T_D}$

C_i and A_i are drag coefficients and areas of components below point.

This solution ignores elasticity.

Line Tension During Lowering of Anchor
(Summary of Analytical Results)

ACODAC I - W.H.O.I./O.E. May 4, 1971

	Location In Array Where Tension is Computed	Static Tension lbs.	Dynamic Tension: From Inertia Force (lbs.)	Dynamic Tension: From Drag Force (lbs.)	Dynamic Tension: Maximum Dynamic Force (lbs.)	Total Launching Tension (lbs.)	Safety Factor at Location
1	In the winch working rope, while lowering IPV, IPV in air	2500	2127	2013	2574	5074	3.94
2	In the winch working rope while lowering IPV, IPV in water	800	2338	2320	2903	3708	5.39
3	Above ORE Sphere, ORE sphere in air	3280	1496	1813	2121	5401	
4	Above ORE Sphere, ORE sphere in water	1030	1766	2121	2488	3518	4.20
5	In 3/8" Wire Rope below ORE sphere	2430	1392	1814	2310	4740	3.12
6	In 3/8" E/M Cable below hydrophone #1	2380	1383	1768	2037	4417	2.49
7	In 3/8" E/M Cable above hydrophone #3	2870	650	250	700	3570	3.08
8	In 3/4" Nylon above AMF release #2	2830	609	150	650	3480	4.08

TABLE I

Notes:

1. The static tension T_s is defined as $T_s = \sum W_i - \sum B_i$ where $\sum W_i$ = sum of weights below location and $\sum B_i$ sum of buoyant elements below location.
2. Tension from inertia force is defined as $T_i = \sum m_i a$ where a = acceleration of top of array and $\sum m_i$ sum of virtual masses below location.
3. Tension from drag force is defined as $T_D = \frac{1}{2} \rho V^2 \sum C_i A_i$ where V = speed of top of array and C_i & A_i are the coefficients of drag and projected areas of components below location.
4. Maximum dynamic force is maximum value of $T_i \cos \omega t' + T_D (\sin \omega t')^2$
5. Total tension = T_s + Tmax = T Total
6. Dynamic forces are computed assuming ship roll of 15° and roll period of seven secs.
7. Total tension below hydrophone #1 was also computed using solution of wave equation in elastic E/M cable with same excitation and mass of anchor applied at lower end - Result is: Total = 3751 lbs.

Due to complexity of problem and time allowance more rigorous analytical solutions of the launching transient are not part of this study.

Resonance: Periods of resonance for different lengths are established in two ways.

- Determination of the natural frequencies of an equivalent spring mass system.

- Results of solution of wave equation.

Results:

Total Tension - The total tension is defined as the sum of the static tension and the maximum dynamic tension. Results for different critical points and times are presented in Table 1, "Line Tension During Launching of Anchor". Safety factors for these points are also listed. The dynamic excitation was defined as

Ship roll	=	15°
Amplitude of sheave motion	=	7.75 ft.
Roll period	=	7 secs.

The critical point and time is when lowering the O.R.E. sphere in water.

Periods of Resonance: The period of resonance for different lengths of immersed cable are summarized in Table II below.

Length (ft.)	Natural Period of Spring Mass System (secs)	Natural Period from Wave Equation Theory (secs)
100'	0.76	----
1000'	2.41	0.662
3500'	4.51	2.81

Derivation of Dynamic Tension Expression

1. **Wave Equation:** The tension $T(s,t)$ in a line supporting a mass M at its lower end and having its lower end and having its upper end excited according to

$$\xi(L,t) = B \sin pt$$

is given by the solution of the elastic wave equation as:

$$T(s,t) = \mu g S + Mg + \frac{B e A}{\cos \frac{pL}{a} + \frac{Mp}{EA} a \sin \frac{pL}{a}} \left[\sin pt \left(\frac{Mp^2}{EA} \cos \frac{pS}{a} - \frac{P}{a} \sin \frac{P}{a} s \right) \right]$$

where

S	=	Distance from lower end	Ft.
L	=	Length of line	Ft.
μ	=	Line density	Slug/ft.
M	=	Virtual mass of object at lower end	Slug
E	=	Modulus of elasticity of line	PSI
A	=	Cross section of rope	IN^2
g	=	Acceleration of gravity	Ft/Sec^2
a	=	Speed of propagation of elastic wave	

$$a = \sqrt{\frac{AE}{\mu}} \qquad \text{Ft/Sec}$$

B	=	Amplitude of excitation	Ft.
p	=	$2\pi f$	

$$= \frac{2\pi}{T} \quad = \text{angular frequency of excitation} \qquad \text{rad/Sec}$$

2. Tension Based on Inertia and Drag Forces Inertial Effects:

   a. The force necessary to accelerate the line and the components is of the form

$$T_i = a \sum_i m_i$$

   The particular acceleration "a" is 6.28 ft/sec^2. The mass $\sum_i m_i$ is the virtual mass of all components below the point studied (actual mass and added mass).

   b. Drag Effects: The force necessary to pull the components at a speed V through the water is of the form

$$T_D = \frac{1}{2} pV^2 \sum_i C_i A_i$$

   where $V = 7$ ft.(sec)

   C_i = drag coefficient of component "i"

   and A_i = projected area of component "i"

   c. Summation of Internal and Drag Forces - Starting from rest, end of line going up, acceleration and speed are up, and the inertial and drag forces are downwards and add. Of particilar interest is the maximimum value of their sum. Assuming an harmonius excitation

$$\xi = B \cos \omega t$$

   then

$$V = \frac{\partial \xi}{\partial t} = -B\omega \sin \omega t$$

and $a = \frac{\partial^2 \xi}{\partial t^2} = -B\omega^2 \cos \omega t$

The drag force as a function of time is the:

$$F_D = [\ \frac{1}{2}\rho\ V^2 \sum_i C_i A_i]\ [\sin \omega t]^2 = T_D\ (\sin \omega t)^2$$

and the inertial force as a function of time is:

$$F_i = [a \sum_i m_i][\cos \omega t] = T_i\ [\cos \omega t]$$

The sum is therefore:

$$F_{(t)} = T_i \ \cos \omega t + T_D\ (\sin \omega t)^2$$

and F_{max} will occur when $\frac{\partial F}{\partial t} = \frac{\partial F}{\partial(\omega t)} = \frac{\partial(\omega t)}{\partial t} = 0$

or when

$$-T_i W \sin \omega t + 2T_D\ W \sin \omega t + \cos \omega t = 0$$

The particular time t' for maximum sum is therefore

$$\omega t' = \cos^{-1} \frac{T_i}{2T_D}$$

The force is then given by:

$$F_{max} = T_i \cos\ (\omega t') + T_D\ (\sin \omega t')^2$$

Appendix F

ACODAC Station Logs - 1971

ACODAC I:	Launching & Retrieval
ACODAC II:	" "
ACODAC III - System A:	" "
ACODAC IV - System B:	" "
ACODAC V - System A:	" "
ACODAC VI - System B:	" "

ACODAC MOORED STATION LOG

DEPLOYMENT No. = Acodac I

I. LAUNCHING OPERATION:

LOCATION SET: 39°48.8'N 70°17.2'W

DATE: May 15-16, 1971

WATER DEPTH: 1148 meters

VESSEL: Knorr #21

WEATHER: Calm

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
1	65 lb. Danforth Anchor	5/15/71 16:45	
2	2730*lbs 1 1/2" chain	16:45	*weight in water
3	15 ft. of 3/4" plaited Nylon	17:00	covered with canvas
4	*AMF Acoustic Release #2	17:00	*Serial No-113 x-WHOI-x-701084
5	Geodyne Time Release	17:00	Set to fire. May 20 @0800 Rides piggyback on AMF.
6	3 ton swivel	17:00	
7	15' of 3/4" plaited Nylon	17:00	covered with canvas
8	Hydrophone	18:40	Serial #4
9	3/8" E/M cable - one 3289 ft. length E/M cable	Start 19:00 Over 22:00	Continuous length Packages of Glass Balls

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
10	(18) 16" ϕ Glass Balls	19:40	1st ball 40 ft. above hydrophone (item #8) Balls are approx. 12' apart. (1 1/4 turn on winch drum) Cable paid out 150 ft./min.
11	(8) 16 " ϕ Glass balls	20:20	Start attachment of balls at 20:00 hr. - 600 ft. above Hydrophone (item #8) Finish paying out item #9 @ 20:45.
12	Hydrophone	24:00	Serial #5. Start attaching @ 22:00
13	196 ft. - 3/8" E/M cable	May 16	(Starts 00:01
14	(4) 16" ϕ Glass balls	00:15	
15	Hydrophone	04:15	Serial #3
16	15 ft. - 3/8" - 3 x 19 wire rope	04:15	
17	60 ft. - 7 conductors cable	08:30	Attached in/tape to item 16 & item 21 fed thru ORE. sphere.
18	48" O. R. E. sphere	08:30	To item #24
19	OAR Radio	08:30	Working - Freq. 26.995 mc
20	OAR Light	08:30	Working
21	25 ft. - 3/8" - 3 x 19 wire rope	08:30	
22	AMF Acoustic Release	08:35	Serial #102
23	3 ft. - 1/2" chain	08:35	
24	Battery Pod	08:35	
25	IPV Sphere	08:35	Electrical cables loose. 3 rope slings left on sphere.
26	OAR Light	08:35	
27	OAR Radio	08:35	
28	AMF Release	Fired 09:36	x-701083 to winch working wire - Recovery

ACODAC MOORED STATION LOG

DEPLOYMENT No. - Acodac I

II. RETRIEVAL OPERATION:

LOCATION: 39°48.8'N 70°17.2'W

DATE: May 18, 1971

WATER DEPTH: 1148 meters

VESSEL: Knorr #21

WEATHER: Calm. Fog. Visibility less than 1 mile. Fair by noon.

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
25	IPV Sphere	07:45	Release #1 fired @ 07:15 Upper balls bent during recovery.
26	OAR Light	07:45	
27	OAR Radio	07:45	Working - Monitored on ships radio.
24	Battery Pod	07:46	Electrical cable ripped off connector.
23	3 ft. - 1/2" chain	07:46	
22	AMF Acoustic Release #1	07:46	Pings on deck. Release #2 command @ 08:47 Range on ORE @ Surface ≈1200 meters
18	48" ORE sphere	09:10	
20	OAR Light	09:10	
19	OAR Radio	09:10	Working during Recovery. Antenna broke.
21	24 ft. - 3/8' - 3 x 19 wire rope	09:10	

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
17	60 ft. - 7 Conductor Cable	09:10	
16	15 ft. - 3/8" - 3 x 19 wire rope	09:15	
15	Hydrophone	09:15	Start disconnect E/M cable (item #13) @ 09:15 completed @ 09:32. Hydrophone leaks oil.
13	196 ft. 3/8" E/M cable	10:45	3/4 hr. to pass connector thru sleave.
14	(4) 16" ϕ Glass balls	10:22	3 minutes to disconnect (2) Glass ball assemblies.
12	Hydrophone	10:45	Start disconnect @ 10:25
9	3,289 ft. - 3/8" - E/M cable	10:45	Feeding connector thru sleave Reeling cable @ 11:15.
11	(8) 16" ϕ Glass balls	11:45	Large loops and kinks in E/M cable.
		12:45	Resume hauling of 2nd half E/M cable.
10	(16) 16" ϕ Glass balls	13:20	Large loops and kinks @ ball package.
8	Hydrophone	13:30	
7	15 ft. - 3/4" Plaited Nylon	13:35	
6	Swivel	13:35	Turns freely by hand.
5	AMF Acoustic Release	13:35	
4	Geodyne Time Release	13:35	279 Red, 297 Black } @ 14:00 on counter. Disarmed about 14:00

ACODAC MOORED STATION LOG

DEPLOYMENT No. Acodac II

I. LAUNCHING OPERATION:

LOCATION SET: 32°17.9'W
64°29.6'W
Bermuda

DATE: Aug 8, 1971

WATER DEPTH: 3500 meters

VESSEL: "North Seal"

WEATHER: Sea State 1 - Rain

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
1	Auxiliary Booy - Filled Toriod	8/7/71 13:37	Chain Bridle
2	OAR Radio	13:37	Working
3	OAR Light	13:37	Working
4	200 ft. - 3/4" Nylon	13:37	
5	AMF Release	13:40	Serial 112X
6	3 Ton Miller Swivel & Ring	13:40	
7	15 ft. - 1/2" chain (to ring)	14:00	
8	Drogue Chute	14:00	
9	1500 lb. Anchor	14:00	1 1/2" chain bundle
10	8 ft.-1/2"chain (to ring)	13:40	
11	15 ft. - 3/4" Nylon	13:40	covered with fire hose.
12	AMF Release	14:05	Serial 116X

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
13	Geodyne Time Release	14:05	Serial 00637 (fires 8-25-1000)
14	3 Ton Swivel	14:05	Special St. St.
15	(3) 16" ϕ Glass Balls	14:05	on 7 ft. - 1/2" ϕ chain
16	170 ft. - 3/4" Nylon	14:07	
17	170 ft. - 3/4" Nylon	14:10	
18	Hydrophone #6	14:42	(#2 cable)
19	196 ft. - 3/8" E/M cable	15:00	
20	Hydrophone #5	15:00	(#4 cable)
21	196 ft. - 3/8" E/M cable	15:15	
22	Hydrophone #4	15:15	(#5 cable)
23	196 ft. - 3/8" E/M cable	15:27	
24	Hydrophone #3	15:27	(#6 cable) Placing (2) lengths of E/M cable on winch.
25	196 ft. - 3/8" E/M cable	16:00	
26	Hydrophone #2	16:00	(#7 cable)
27	196 ft. 3/8" E/M cable	16:10	
28	Hydrophone #1	16:10	(#8 cable)
29	200 ft. - 3/8" E/M cable	16:10	
30	(20) 16" ϕ Glass balls	16:30	In yellow hard hats.
31	Glass Ball Buoy #1	16:45	
32	OAR Light	16:45	Working
33	OAR Radio	16:45	Working
	300 ft. 3/4" Nylon	17:00	Deploying line. Towing on site.
		18:19	Firing of Release 112X
		18:22	Glass Ball Buoy tows under.
		18:24	Angle from vertical $\cong 30^\circ$
		18:29	Angle from vertical $\cong 05^\circ$
		18:31	Angle from vertical $\cong 0^\circ$

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
34	AMF Release #1 on 3 ft. 1/2" chain	22:10	Serial #101
35	Battery Pod	01:00	
36	(2) 16" ϕ Glass balls	01:00	Attached to item 35
37	IPV	01:00	
38	OAR Radio	01:00	Working - freq. 21.045 mc
39	OAR Light	01:00	Working Mooring dropped in free fall.
--	Note: Speed of descent = 1.5 m/sec slowing down to 1.3 m/sec after approximately 5 minutes.		

ACODAC MOORED STATION LOG

DEPLOYMENT No. - Acodac II

II. RETRIEVAL OPERATION:

LOCATION: 32°17.9'N
64°29.6'W

Bermuda

DATE: Aug. 20, 1971

WATER DEPTH: 3500 meters.

VESSEL: R/V North Seal

WEATHER: Sea State 1. Wind westerly 5-10 kts; Mostly sunny; One Rain squall 12:45-13:45

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
-	IPV Release Command	10:18	
-	IPV on Surface	11:00	
39	OAR Light	12:27	Good condition. Working
38	OAR Radio	12:27	Working
37	IPV	12:27	Good condition. Had been brushed along port side of ship for about 10 ft. during recovery. Small paint scratch on one hemisphere.
36	(2) 15" φ Glass balls.	12:27	Attached to item #35.
35	Battery Pod	12:27	Leaking oil. First, oil slick noted around IPV on surface, prior to recovery. Oil film noted on sides of containers oozing from vent holes. Uncertain whether other oil leak exists. One possible explanation for leakage is gassing of batteries. Considerable amount of oil was deposited on deck due to this leakage

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
35	con't	12:27	making footage hazardous. Leakage continued well into Saturday morning, Aug. 21. Following battery voltages read: -13, -13, +13, +13.
34	AMF Release (IPV)	12:27	Excellent Condition
-	Mooring Release Command	13:08	
-	G. B. Buoy on Surface	13:30	
33	Oar Radio	14:15	Working. Removed from buoy frame at 14:21.
32	OAR Light	14:15	Transparent plastic housing broken when ship struck buoy during recovery.
31	Glass Ball Buoy	14:15	Buoy apparently slipped about 8" upward on PLP hairpins. Hairpins frayed open at ends. Slippage apparently due to plastic flow of PVC insert in load clamp.
30	(20) 16" ϕ Glass balls	14:30	Three pairs of balls floating, the rest submerged. Several hairpins at ball load clamps frayed. Sharp bend in E/M cable when lifting balls with crane.
29	200 ft. - 3/8" E/M cable	14:45	Several kinks in section between Glass Ball Buoy and 20 Glass Balls; one kink particularly bad. No kinks in any part of mooring that remained subsurface.
28	Hydrophone Cage #8	15:10	Anode working.
27	196 ft. - 3/8" E/M cable	15:15	Upper connector spring broken; piece saved. Subsequent informed opinion believes break due to hydrogen embrittlement caused by working of aluminum anodes about E/M cable in way of springs. In other cases where springs were broken and E/M cable visible, there were no signs of corrosion.
26	Hydrophone Cage #7	15:30	Good Condition.
25	196 ft.- 3/8" E/M cable	15:40	Connector spring broken through at

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
25	con't		base of connector.
24	Hydrophone Cage #6	15:45 ob 15:50 st	(o.b. - on board. st- stowed.) Discrepancy in cage numbers between "as launched" and "as recovered," condition is puzzling. Perhaps someone has shifted cage positions in mooring?
23	196 ft. - 3/8" E/M cable	15:55	Lower connector spring broken.
22	Hydrophone Cage #5	16:01	Good condition.
21	196 ft. - 3/8" E/M	16:08	Upper spring broken. Lower one still in one piece.
20	Hydrophone Cage #4	16:16	Good Condition
19	196 ft. - 3/8" E/M cable	16:25	Upper and lower springs broken.
18	Hydrophone Cage #2	16:27	Cable harness hanging out at lower cover.
17	170 ft. - 3/4" Nylon	16:35	Frayed point about 40 ft. from top. At first Al Davison thought this to be a splice, but found it to be definitely a fish bite.
16	170 ft. - 3/4" Nylon	16:40	Good Condition
15	(3) 16" ϕ Glass balls	16:40	
14	3 Ton Swivel	16:40	
13	Geodyne Time Release	16:40	Good Condition. Not fired.
12	AMF (bottom) release	16:40	Good Condition.

ACODAC MOORED STATION LOG

DEPLOYMENT No. Acodac III - System A

I. LAUNCHING OPERATION:

LOCATION SET: 33°29.9'N 19°36.1'W

Madeira

DATE: Oct. 13, 1971

WATER DEPTH: 4470 meters

VESSEL: "North Seal"

WEATHER: Cloudy, 10 Knt. wind, 3-4 ft seas, Afternoon clear, 20 Knt wind, 6-8 ft seas.

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
1	Toriod Buoy (Aux)	06:43	with chain bridle - (homemade) Radar reflection.
2	OAR Radio Beacon	06:43	
3	10 ft. - 3/4" Nylon	06:43	
4	30 ft. - 1/2" chain	06:43	
5	140 ft. - 3/4" Nylon	07:30	
6	AMF Release	07:30	Transponder Code #1
7	Swivel	07:30	
8	Ring	07:30	
9	Danforth Anchor	07:30	Attached with 1/2" chain to item #10.
10	1500 lb. anchor	07:30	Bundle of used chain.
11	Parachute	07:30	Attached to item #12
12	20 ft. - 1/2" chain	07:30	from anchor to ring.

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
13	8 ft. - 1/2" chain	07:30	from ring to item #14
14	15 ft. - 3/4" Nylon	07:35	with chafing protection.
15	AMF Release	07:40	Transponder GDE 21
16	Geodyne Time Release	07:40	mounted in parallel with AMF release.
17	Swivel	07:40	
18	(3) 16" ϕ Glass balls	07:40	Bolted 8 ft. - 1/2" chain.
19	100 ft. - 3/4" Nylon	07:42	
20	120 ft.- 3/4" Nylon	08:10	
21	Hydrophone #6	08:10	Serial #2
22	895 ft. - 3/8" E/M cable	08:40	
23	(2) 16" ϕ Glass balls	08:22	Attached 200 ft. from upper end of item #22.
24	Hydrophone #5	08:40	Serial #4
25	4,792 ft. - 3/8" E/M cable	09:55	
26	(14) 16" ϕ Glass balls	09:15	Attached in middle of item #25
27	Hydrophone #4	11:36	Serial #5
-	--	09:55	Launching interrupted - Reeling more E/M cable on winch drum. Resumes 11:35.
28	2794 ft. - 3/8" E/M cable	12:45	
29	(20) 16" ϕ Glass balls	12:15	Attached 1000 ft from upper end of item #28.
30	Hydrophone #3	12:45	Serial #6
31	196 ft. - 3/8" E/M cable	13:15	
32	(2) 16" ϕ Glass balls	13:00	Attached to middle of item #31
33	Hydrophone #2	13:15	Serial #7
34	196 ft. - 3/8" E/M cable	14:25	
35	(2) 16" ϕ Glass balls	13:20	Attached 60 ft. from top end of item #34.

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
36	Hydrophone #1	14:25	Serial #8
37	200 ft. - 3/8" E/M cable	14:30	
38	(6) 16" ϕ Glass balls	14:30	Attached in middle of item #37
39	Glass ball buoy	15:30	
40	OAR Light	17:30	
41	AMF Release	17:30	
42	Power Supply	17:30	
43	IPV Sphere	17:30	
44	OAR Light	17:30	
45	OAR Radio	17:30	
-	Note: Aux. buoy release fired @ 17:40 IPV sunk @ 17:58.		

ACODAC MOORED STATION LOG

DEPLOYMENT No. - Acodac III - System A

II. RETRIEVAL OPERATION:

LOCATION: 33°29.9'N
19°36.1'W

Madeira

DATE: Oct. 20, 1971

WATER DEPTH: 4470 meters

VESSEL: North Seal

WEATHER: Sea State 1, 5 Knot wind, Bright and Sunny. Barometer 30.25.

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
45	OAR Radio	09:05	Working
44	OAR Light	09:05	Working
43	IPV	09:05	Landed 09:31 VA cc = 18 1/2" Hg.
42	Power Supply	09:05	1) +8.5v 2) -11.0v 3) +11.5v 4) +12.0v 5) -11.0v.
41	AMF Release	09:06	Unfired cable to release broken off at connector on release.
40	OAR Light	09:40	
39	Glass Ball Buoy	09:40	
38	(6) 16" ϕ Glass balls	10:10	
37	200ft. - 3/8" E/M cable	10:15	Kink at buoy cleared. Balls cleared.
36	Hydrophone #1	10:20	E = 6.8v
35	(2) 16" ϕ Glass balls	10:25	

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
34	196 ft. - E/M cable	10:34	Lower connector spring broken and very corroded.
33	Hydrophone #2	10:39	E = 6.7 volts
32	(2) 16" ϕ Glass balls	10:57	
31	196 ft. - 3/8" E/M cable	10:59	
30	Hydrophone #3	11:03	E = 6.8 volts
29	(20) 16" ϕ Glass balls	11:41	
28	2794 ft. - 3/8 E/M cable	12:22	
27	Hydrophone #4	12:30	
26	(14) 16" ϕ Glass balls	14:33	
25	4792 ft. - 3/8" E/M cable	14:56	Badly bent at upper connector. Installed emergency clamp.
24	Hydrophone #5	15:00	6.75v = E
23	(2) 16" ϕ Glass balls	15:13	
22	895 ft. - 3/8" E/M cable	15:19	Upper connector spring practically gone.
21	Hydrophone #6	15:23	E = 0
20	120 ft. - 3/4" Nylon	15:24	
19	100 ft. - 3/4" Nylon	15:24	
18	(3) 16" ϕ Glass balls	15:24	
17	Swivel	15:24	
16	Geodyne Time Release	15:24	
15	AMF Release	15:24	

COMMENTS:

Acodac III - A

1.) IPV Transponding Intermittent. IPV release attempted for 50 minutes without success.

2.) 08:03 IPV surfaced.

3.) 08:03 Line on IPV

4.) 10:06 Hydrophone checks out. #2 (bottom) lowest.

5.) 13:55 Started rewinding 2,794 ft. length.

6.) Glass Ball Buoy Floating on Side. 6 additional balls showing.

ACODAC MOORED STATION LOG

DEPLOYMENT No. - Acodac IV - System B

I. LAUNCHING OPERATION:

LOCATION SET: MADEIRA
33°22.8'N
19°41.5'W

DATE: Oct. 11, 1971

WATER DEPTH: 4595 meters

VESSEL: "North Seal"

WEATHER: 3 ft. waves, Cloudy, Rain, 5-10 Knt wind.

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
1	Toroid buoy (Aux)	06:45	with chain bridle freq. 27.045 mc
2	OAR Light on buoy	06:45	
3	OAR Radio on buoy	06:45	
4	10 ft. - 3/4" Nylon	06:45	
5	30 ft. - 1/2" chain	06:45	
6	140 ft. - 3/4" Nylon	06:45	
7	AMF RELEASE	06:45	TRANSPONDER Code #2
8	Swivel	06:45	
9	Ring	06:45	
10	Danforth Anchor	07:25	Attached to item #11 with 1/2" chain.
11	1500 lbs. anchor	07:25	Bundle of used chain.
12	Parachute	07:25	Attached to Item #13.

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
13	20 ft. - 1/2" chain	07:25	from Item #11 to Item #9
14	8 ft. - 1/2" chain	07:30	from Item #9 to Item #15
15	15 ft. - 3/4" Nylon	07:30	Chaffing protection
16	AMF RELEASE	07:30	TRANSPONDER CODE #8
17	Geodyne Time Release	07:30	Mounted in parallel with AMF
18	Swivel	07:30	
19	(3) 16" ϕ Glass Balls	07:30	Bolted to 8 ft. -1/2" chain
20	850 ft. - 1/2" DACRON	07:45	
21	1500 ft. - 1/2" DACRON	08:00	
22	1500 ft. - 1/2" DACRON	08:40	
23	1500 ft. - 1/2" DACRON	09:00	
24	1500 ft. - 1/2" DACRON	09:40	
25	(3) 16" ϕ Glass balls	09:40	Bolted on 8 ft. - 1/2" chain
26	1500 ft. - 1/2" DACRON	11:04	
27	Hydrophone #6	11:04	Serial #2
28	196 ft. - 3/8" E/M CABLE	11:25	
29	Hydrophone #5	11:25	Serial #4
30	196 ft. - 3/8" E/M CABLE	11:40	
31	Hydrophone #4	11:40	Serial #5
32	196 ft. - 3/8" E/M CABLE	13:05	
33	Hydrophone #3	13:05	Serial #6
34	196 ft. - 3/8" E/M CABLE	13:25	
35	Hydrophone #2	13:25	Serial #7
36	196 ft. - 3/8" E/M CABLE	13:40	
37	Hydrophone #1	13:40	Serial #8
38	200 ft. - 3/8" E/M CABLE	13:45	Starts towing. 16:30 Ends.
39	(10) 16" ϕ Glass balls	16:50	Attached to ITEM #38

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
40	GLASS BALL BUOY	17:15	freq. 27.145 mc. Buoy spins, hauled back on board. Secured with 2 Nylon ties to prevent spinning.
41	OAR LIGHT	17:15	
42	OAR RADIO	17:15	
43	AMF RELEASE	20:20	TRANSPONDER CODE 5
44	BATTERY POD	20:20	
45	IPV Sphere	20:20	freq. 27.195
46	OAR Light	20:20	
47	OAR RADIO	20:20	

ACODAC MOORED STATION LOG

DEPLOYMENT No.- Acodac IV - System B

II. RETRIEVAL OPERATION:

LOCATION: 33°22.8'N 19°41.5'W

DATE: Oct. 18, 1971

WATER DEPTH: 4595 meters

VESSEL: North Seal

WEATHER: Sea State 2, wind and swell from S. E. sunshine, 5-10 Knot wind all day.

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
47	OAR RADIO	10:00	Working
47	OAR LIGHT	10:00	Not working. Water inside.
45	I. P. V. Sphere	10:00	Floating with list and low freeboard. VACC. = 10"Hg
44	Battery Pod	10:10	2 Missing #2 & #3. Apparently separated on launch.
43	AMF RELEASE #1	10:10	Working
42	OAR RADIO BEACON	11:46	Working
41	OAR Light	11:46	Working
40	Glass Ball Buoy	11:46	Floating on side. Radio beacon under water. Lower plate chaffed.
		12:13	Wire fouled. Apparently on rudder...CLEARED.
39	(10) 16" ϕ GLASS BALLS	12:50	Cases warped.

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
38	200 ft.-3/8" E/M CABLE	13:30	Small kink at top at G.B. Float due to twist on launch. Chaffing on pigtail.
37	Hydrophone #1	13:32	Boot pulled free at top. Little water in lower connector. Female part. E=6.7 volts.
36	196 ft. - 3/8 E/M CABLE	13:48	
35	Hydrophone #2	13:54	Boot free at bottom. CONNECTORS Good. E=6.7 v.
34	196 ft. - 3/8" E/M CABLE	14:12	Lower spring gone in places.
33	Hydrophone #3	14:16	E=6.8 v.
32	196 ft. - 3/8" E/M CABLE	14:38	
31	Hydrophone #4	14:43	E=6.8v.
30	196 ft. - 3/8" E/M CABLE	14:55	
29	Hydrophone #5	15:00	Water drops in upper connector #2. Pin on conn. bent slightly. E=6.8v.
28	196 ft. - 3/8" E/M CABLE	15:14	
27	Hydrophone #6	15:18	Possibly a drop of water in upper connector. Torn rubber boot. Probably water in connector. E=6.9v.
26	1500 ft. - 1/2" DACRON	15:55	
25	(3) 16" ϕ GLASS BALLS	15:55	
24	1500 ft. - 1/2" DACRON	16:22	
23	1500 ft. - 1/2" DACRON	16:40	
22	1500 ft. - 1/2" DACRON	16:53	
21	1500 ft. - 1/2" DACRON	17:05	
20	850 ft. - 1/2" DACRON	17:12	
19	3-16" ϕ Glass balls	17:12	
18	Swivel	17:12	
17	Geodyne Release	17:12	
16	AMF RELEASE	17:12	

COMMENTS:

Acodac IV -B

Total Recovery time 8 hrs. 48 min.

Notes:

1) Main battery packs #2 and #3 missing from assembly on recovery; apparently fell off on launch.

2) IPV seemed to have marginal free board while on surface; even with loss of 2 Battery Packs.

3) Four ounces (approx) of sea water found within IPV. Apparently vacuum valve #2 leaked again, both thru cap and needle valve.

4) Full tape had been played; Data on all channels near end of tape.

5) Glass Ball Buoy floating on Side.

ACODAC MOORED STATION LOG

DEPLOYMENT No. - Acodac V - System A

I. LAUNCHING OPERATION:

LOCATION SET: 36°15.7'N 17°26.7'E

Mediterranean (Ionian Sea)

DATE: Nov. 2, 1971

WATER DEPTH: 3365 meters

VESSEL: North Seal

WEATHER: Clear, 10 knt wind, 3-5 ft. waves.

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
1	TORIOD BUOY (AUX)	06:58	with chain Bridle - Radar reflector. freq. 27.045 mc.
2	OAR Light	06:58	
3	OAR Radio	06:58	Working
4	10 ft. - 3/4" Nylon	06:58	
5	30 ft. - 1/2" chain	06:58	
6	120 ft. - 4/3" Nylon	07:07	
7	AMF RELEASE	07:08	CODE 3
8	3 TON MILLER SWIVEL	07:08	
9	Ring	07:06	
10	20 ft. - 1/2" chain	07:06	from ITEM #9 to ITEM #12
11	96" chute	07:06	ATTACHED to ITEM #10
12	1500 lbs Anchor	07:05	with 65 lb Danforth

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
13	8 ft. - 1/2" chain	07:09	from Item #9 to Item #14
14	15 ft. - 3/4" Nylon	7:20	with chaffing protection.
15	AMF RELEASE	7:20	Code 2
16	Geodyne Release	7:20	In parallel with Item #15
17	3 Ton Swivel	7:20	
18	(3) 16" ϕ Glass balls	7:21	Attached to 7 ft. - 1/2" chain
19	300 ft. - 3/4" Nylon	7:25	
20	Hydrophone #6	7:30	Serial #8
21	4194 ft. - 3/8" E/M CABLE	08:05	
22	(10) 16" ϕ Glass Balls	07:56	Bolted to Item #21, 1750 ft. from upper end.
23	Hydrophone #5	08:20	Serial #2
24	2959 ft. - 3/8" E/M cable	08:52	
25	(16) 16" Glass Balls	08:45	Bolted to Item #24, 1000 ft. from upper end.
26	Hydrophone #4	09:04	Serial #4
27	196 ft. - 3/8" E/M cable	09:06	Towing & reeling more E/M cable on winch.
28	Hydrophone #3	10:48	Serial #5
29	196 ft. 3/8" E/M cable	10:50	
30	Hydrophone #2	11:00	Serial # 6
31	2631 ft. - 3/8" E/M cable	11:33	
32	(16) 16" Glass Balls	11:35	Bolted to Item #31, 1000 ft. from upper end.
33	Hydrophone #1	11:45	Serial #7
34	200 ft. 3/8" E/M Cable	12:22	
35	(6) 16" ϕ Glass Balls	11:50	Bolted to Item #34
36	(1) Glass Ball Float	12:22	Bolted to Item #34 freq, 27.245 mc
37	OAR Light	12:22	Working

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
38	OAR Radio	12:22	Working
39	AMF RELEASE	13:07	
40	Battery Pod	13:07	
41	IPV Sphere	13:07	freq. 26.995 mc
42	OAR Light	13:07	
43	OAR Radio	13:07	

ACODAC MOORED STATION LOG

DEPLOYMENT No. - Acodac V - System A

II. RETRIEVAL OPERATION: (IPV)

LOCATION: 36°15.7'N 17°26.7'E

Mediterranean (Ionian Sea)

DATE: Nov. 2, 1971

WATER DEPTH: 3365 meters

VESSEL: North Seal

WEATHER: Clear.

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
-	Release IPV fired @ 16:30		IPV Surfaced immediately on board with battery Pod and AMF @ 18:06. SEE COMMENTS

COMMENTS:

Acodac V - System - A

Date: Nov. 2, 1971

Note: The IPV was called to surface a few hours after setting because a leak was detected by Acoustic Telemetry. Decision was made to call rather than let it down at the risk of

(1) sinking and losing the entire gear.

(2) a short in the Bus Bar resulting in no data.

Upon opening sphere, cause of leak was traced back to faulty seal of structural penetrator (EAR).

ACODAC MOORED STATION LOG

DEPLOYMENT No. - Acodac V - System A

II. RETRIEVAL OPERATION:

LOCATION: 36°15.7'N 17°26.7'E

DATE: Nov. 25, 1971

Mediterranean (Ionian Sea)

WATER DEPTH: 3365 meters

VESSEL: North Seal

WEATHER: Clear

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
38	OAR RADIO	18:25	
37	OAR LIGHT	18:25	
36	(1) Double Glass Ball Float	18:25	Secured 18:30
35	(6) 16" ϕ Glass Ball	18:40	
34	200 ft. - 3/8" E/M cable	18:45	
33	Hydrophone #1	18:45	E=6.8v
32	(16) 16" ϕ Glass Balls	19:15	
31	2631 ft. - 3/8" E/M cable	19:30	
30	Hydrophone #2	19:35	E=6.8v. Continual stream of oil.
29	196 ft. - 3/8" E/M cable	19:45	
28	Hydrophone	19:50	E=6.8v. Spewing oil.
27	196 ft. - 3/8" E/M cablo	20:00	

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
26	Hydrophone #4	20:05	E=6.5v. Spewing oil. Bottom spring off.
25	(16) 16" ϕ Glass Balls	20:19	
24	2959 ft. - 3/8" E/M cable	20:35	
23	Hydrophone #5	20:45	E=7.4v
22	(10) 16" ϕ Glass Balls	21:04	
21	4194 ft. - 3/8" E/M cable	21:21	
20	Hydrophone #6	21:25	E=6.3v Boot Torn.
19	300 ft. - 3/4" Nylon	21:30	top 80 ft. fouled
18	(3) 16" ϕ Glass Balls	21:30	
17	3 ton swivel	21:30	
16	Geodyne Release	21:30	
15	AMF RELEASE	21:30	

ACODAC MOORED STATION LOG

DEPLOYMENT No. = Acodac VI - System B

I. LAUNCHING OPERATION:

LOCATION SET: 36°17.8'N 17°13.2'E

Mediterranean (Ionian Sea)

DATE: SET: Nov. 1, 1971

WATER DEPTH: 3365 meters

VESSEL: North Seal

WEATHER: Clear, 3 ft. seas, 5-10 Knt. wind.

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
1	TOROID BUOY (AUX)	06:58	with chain bridle. Radar reflector. freq. 27.045 mc
2	OAR Light	06:58	Not working. Bumped during launch.
3	OAR Radio	06:58	Working
4	10 ft. - 3/4" Nylon	06:58	
5	30 ft. - 1/2" chain	06:58	
6	120 ft. - 3/4" Nylon	06:58	
7	AMF RELEASE	07:15	CODE #9
8	3 Ton MILLER SWIVEL	07:15	
9	Ring	07:15	
10	20 ft. - 1/2" chain	07:15	from Item #9 to Item #12
11	96" chute	07:15	Attached to Item #10
12	1500 lbs. anchor	07:15	

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
13	8 ft. - 1/2" chain	07:15	from Iten #9 to Item #14
14	15 ft. - 3/4" Nylon	07:15	with chaffing protection.
15	AMF RELEASE	07:20	CODE #8
16	Geodyne RELEASE	07:20	In parallel with Item #15
17	3 Ton MILLER SWIVEL	07:20	
18	(3) 16" ϕ Glass balls	07:20	Attached to 7 ft. - 1/2" chain
19	1108 ft. - 1/2" DACRON	07:30	
20	1500 ft. - 1/2" DACRON	07:44	
21	1500 ft. - 1/2" DACRON	08:07	
22	1500 ft. - 1/2" DACRON	08:07	
23	(3) 16" ϕ Glass Balls	08:07	Attached to 7 ft. - 1/2" chain.
24	1500 ft. - 1/2" DACRON	08:14	
25	Hydrophone #6	08:25	Serial #8
26	196 ft. - 3/8" E/M cable	08:29	
27	Hydrophone #5	08:42	Serial #2
28	196 ft. - 3/8" E/M cable	08:50	
29	Hydrophone #4	08:55	Serial #4
30	196 ft. - 3/8" E/M cable	09:07	
31	Hydrophone #3	09:09	Serial #5
32	196 ft. - 3/8" E/M cable	09:19	
33	Hydrophone #2	09:22	Serial #6
34	186 ft. - 3/8" E/M cable	09:22	
35	Hydrophone #1	09:28	Serial #7
36	200 ft. - 3/8" E/m cable	09:30	
37	(8) 16" ϕ Glass Balls	09:40	Start towing; bolted to Item #36, 100 ft. from upper end.
38	(1) Double Blass Ball Float	12:15	Bolted to Item #36, 45 ft. from upper end.

ITEM #	DESCRIPTION	TIME OVER-BOARD	REMARKS
39	OAR Light	12:15	Working.
40	OAR Radio	12:15	Working. Antenna bent by chain bridle from towing.
41	AMF RELEASE	13:18	Code #5
42	Batter Pod	13:18	
43	IPV sphere	13:18	
44	Oar Light	13:18	
45	OAR Radio	13:18	

ACODAC MOORED STATION LOG

DEPLOYMENT No. - Acodac VI - System B

II. RETRIEVAL OPERATION:

LOCATION: 36°17.8'N 17°13.2'E

Mediterranean (Ionian Sea)

DATE: Nov. 25, 1971

WATER DEPTH: 3365 meters

VESSEL: North Seal

WEATHER: Clear

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
45	OAR Radio Beacon	09:00	Broken Antenna
44	OAR Light	09:00	Working
43	IPV	09:35	Secured by 09:40
42	Battery Pod	09:35	
41	AMF RELEASE	09:44	Working
40	OAR Radio Beacon	10:55	Bent but operating
39	OAR Light	10:55	Not working.
38	(1) DOUBLE GLASS BALL FLOAT.	10:53	E/M cable cut at both ends.
37	(8) 16" ϕ Glass Balls	11:01	
36	200 ft. - 3/8" E/M cable	11:15	
35	Hydrophone #1	11:25	E=6.7v Sig 3.5 Vp/p
34	196 ft - 3/8" E/M cable	11:40	

ITEM #	DESCRIPTION	TIME ON-BOARD	REMARKS
33	Hydrophone #2	11:45	E=7.1v Sig 3.0 vp/p
32	196 ft. - 3/8" E/M cable	13:05	
31	Hydrophone #3	13:08	E=6.5v Sig 3.0 vp/p
30	196 ft. - 3/8" E/M cable	13:10	
29	Hydrophone #4	13:15	E=ov Sig 1.0 vp/p
28	196 ft. - 3/8" E/M cable	13:20	
27	Hydrophone #5	13:25	E=6.8v Sig 2.5 vp/p
26	196 ft. - 3/8" E/M cable	13:28	
25	Hydrophone #6	13:30	E=6.3v Sig 2.0 vp/p
24	1500 ft. - 1/2" DACRON	13:42	
23	(3) 16" ϕ Glass Balls	13:57	
22	1500 ft. - 1/2" DACRON	14:10	
21	1500 ft. - 1/2" DACRON	14:17	
20	1500 ft. - 1/2" DACRON	14:32	
19	1108 ft. - 1/2" DACRON	14:38	
18	(3) 16" ϕ Glass Balls	14:39	
17	3 TON MILLER SWIVEL	14:39	
16	Geodyne Release	14:39	
15	AMF RELEASE	14:39	

COMMENTS:

Acodac VI

Operation:

Time	
06:45	Pipe putting AMF transducer over broke (weld) just as getting underway to moor. Repaired by elimination 1/2 of pipe. Seas calm so operation from lower deck (main). Put transducer in range bearing and then let go.
07:05	Rerigged and interrogating.
07:10	Underway. Course 180° - 3 Knt. AMF barge 6,750 meters.
07:25	Ship all Stop. Transducer in water.
07:34	Range @ 4950 m - resume course 180° - 3 Knt.
07:58	Release of unit accomplished.
08:13	Unit surfaced. Range 3850 m @ 45° off stern on starboard.
08:14	Course 180°.
08:23	Entire mooring was released and is now visible on surface. IPV release didn't work.
09:15	Sphere on IPV.
	Sphere - sides badly scratched from ship. Spheres have slipped down on one side as if it was not held tight by clamps. One bolt sheared off. Another bent.

Battery Pod Voltages

1)	+10:5 v	3)	+9.0 v
	- 9:0 v		-9.5 v
2)	+ 9.5 v	4)	+9.5 v
	-10.0 v		-9.5 v

COMMENTS:

Acodac VI

Hydrophones

#1 (top) Strain relief badly corroded. Mg anode apparently not effective. Steel bolt badly rusted. Corrosion in transducer connector. Hydrophone covered with oil.

#2 Connector O.K. Little oil on hydrophone.

#3 Grease. Connector O.K.

#4 Grease. Connector OK.

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IN REPLY REFER TO:

5510/1
Ser 321OA/011/06
31 Jan 06

MEMORANDUM FOR DISTRIBUTION LIST

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

Ref: (a) SECNAVINST 5510.36

Encl: (1) List of DECLASSIFIED LRAPP Documents

1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

2. The LRAPP documents listed in enclosure (1) have been downgraded to UNCLASSIFIED and have been approved for public release. These documents should be remarked as follows:

   Classification changed to UNCLASSIFIED by authority of the Chief of Naval Operations (N772) letter N772A/6U875630, 20 January 2006.

   DISTRIBUTION STATEMENT A: Approved for Public Release; Distribution is unlimited.

3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

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By direction

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

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Declassified LRAPP Documents

Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Unavailable	ACOUSTIC ENVIRONMENTAL SCENARIOS AND PREDICTIONS FOR ASW. VOLUME VII. AREA 3A SUMMER PREDICTIONS FOR PASSIVE SONAR	Maury Center for Ocean Science	721001	AD0910342	U
Unavailable	Unavailable	ACOUSTIC ENVIRONMENTAL SCENARIOS AND PREDICTIONS FOR ASW. VOLUME VIII. AREA 3B WINTER PREDICTIONS FOR PASSIVE SONAR	Maury Center for Ocean Science	721001	AD0910343	U
Unavailable	Unavailable	ACOUSTIC ENVIRONMENTAL SCENARIOS AND PREDICTIONS FOR ASW. VOLUME IX. AREA 3B SUMMER PREDICTIONS FOR PASSIVE SONAR	Maury Center for Ocean Science	721001	AD0910344	U
Unavailable	Unavailable	ACOUSTIC ENVIRONMENTAL SCENARIOS AND PREDICTIONS FOR ASW. VOLUME V. AREA 2 SUMMER PREDICTIONS FOR PASSIVE SONAR	Maury Center for Ocean Science	721001	AD0911224	U
Unavailable	Unavailable	ACOUSTIC ENVIRONMENTAL SCENARIOS AND PREDICTIONS FOR ASW. VOLUME XI. AREA 4A SUMMER PREDICTIONS FOR PASSIVE SONAR	Maury Center for Ocean Science	721001	AD0912560	U
Unavailable	Unavailable	ACOUSTIC ENVIRONMENTAL SCENARIOS AND PREDICTIONS FOR ASW. VOLUME X. AREA 4A WINTER PREDICTIONS FOR PASSIVE SONAR	Maury Center for Ocean Science	721001	AD0916556	U
MC-011 VOL. 14	Unavailable	ACOUSTIC ENVIRONMENTAL SCENARIOS AND PREDICTIONS FOR ASW. VOLUME XIV. AREA 5 WINTER PREDICTIONS FOR PASSIVE SONAR	Maury Center for Ocean Science	721001	AD0916557; ND	U
MC-011 VOL. 13	Unavailable	ACOUSTIC ENVIRONMENTAL SCENARIOS AND PREDICTIONS FOR ASW. VOLUME XIII. AREA 4B SUMMER PREDICTIONS FOR PASSIVE SONAR	Maury Center for Ocean Science	721001	AD0916610; ND	U
MCR008	Goodman, R. R., et al.	THE NEAT 1 EXPERIMENT (U)	Maury Center for Ocean Science	721001	NS; ND	U
Unavailable	Cherry, W. R.	LRAPP BEAMFORMER	Scripps Institution of Oceanography Marine Physical Laboratory	721015	ADA081876	U
ONR ACR-186	Gregory, J. B.	PROJECT LRAPP TEST BED- TECHNOLOGY USED IN THE DEVELOPMENT OF A DEEP-OCEAN STABLE PLATFORM (U)	Office of Naval Research	721024	AD052337D ~~AD052370~~; ND	U
MC-010	Unavailable	CHURCH GABBRO EXERCISE PLAN- LRAPP (U)	Maury Center for Ocean Science	721026	ND	U
WHOI-72-87	Daubin, S. C., et al.	THE ACODAC SYSTEM	Woods Hole Oceanographic Institution	721101	AD0756628; ND	U
NRLR7516	Fleming, H. S., et al.	PROJECT NEAT 1 ENVIRONMENTAL DATA REPORT (U) (USNS J.W. GIBBS)	Naval Research Laboratory	721129	NS; ND AD523746	U