UNIVERSITY OF MIAMI

ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE

TECHNICAL REPORT
June 1973

CHURCH GABBRO Technical Note
Systems Description and Performance

by
Scott C. Daubin

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UM-RSMAS 73040

F. G. Walton Smith
Dean

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ABSTRACT

This report describes the technical features of systems used in the CHURCH GABBRO exercise during November - December 1972, critiques their performance and recommends future design and operational modifications. Systems discussed include acoustic measurement (ACODAC, MABS, TABS, VLAM and Sonobuoys), acoustic sources (SUS charges Mk61-0 and Mk 82-0, CW Sources HX-231-F and VIBROSEIS), environmental instruments (SBTs, AXBTs, STD, current measurement systems, laser wave profiler) and the ships and aircraft involved.

Forty-six recommendations are set forth for design improvements or operational procedures.

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CHURCH GABBRO Technical Note

Systems Description and Performance

1. Executive Summary

1.1 Purpose

The purpose of this report is to document the systems which were employed in the CHURCH GABBRO exercise, which took place in the Caribbean Sea from 26 November until 15 December 1972, see References (22) and (23). It is intended that this note serve as a technical reference for these systems as well as a means of presenting various problems and deficiencies together with corrective recommendations in order that future exercises may benefit from this experience.

1.2 System Description

Several complex systems were employed and are described technically below. There were the major moored acoustic measurement systems: ACODAC and MABS. There were drifting measurement systems: TABS, VLAM and Sonobuoys. There were acoustic sources: SUS charges Mk 61 and Mk 82, CW sources including the piezoelectric HX 231-F and the hydroacoustic VIBROSEIS. There were environmental instruments: XBT (T-5 and T-7), AXBT, STD, SVP, current measurement arrays including a continuous deep ocean profiling system, laser wave profilers and of course usual shipboard instruments such as echo sounders with precision graphic recorders. Four ships and several aircraft participated. The ship characteristics are outlined and the critical navigation equipment described.

1.3 Conclusion and Recommendations

The overall conclusion is that the systems performed well. In spite of the temporary loss of one mooring and the inability to use its data, ACODACs provided the major part of the data they were intended to record. MABS, TABS, VLAM, and Sonobuoys, all in spite of minor problems, produced useful data from which the scientific objectives can be achieved. The biggest area of disappointment was in the performance of the CW acoustic sources, which were only operative for a small fraction of their scheduled time. However, the signals they projected when "on" were of high quality and produced useful data. SUS charge sequences were successful, more so from ship than aircraft launching. Even in view of the reliability difficulties, the T-5 XBT was a necessary and productive instrument. The four ships involved, USNS SANDS, R/V NORTH SEAL, R/V PIERCE and M/V DEARBORN all performed well; in spite of some aircraft equipment difficulties the air crews conducted their part of the exercise in an excellent manner. Forty-six recommendations, most dealing with design improvements or operational procedures, are set forth.

2. Systems Description and Performance

2.1 Acoustic Measurements Systems

2.1.1 ACODAC

A. General

The ACOustic DAta Capsule (ACODAC) system is a subsurface, moored, self recording acoustic instrumentation system designed to monitor and record acoustic signals and ambient noise at six selected depths throughout the water column. Reference (6) describes the system as it existed in 1971. During the winter and spring of 1972 various changes were incorporated by Texas Instruments Inc. and the Woods Hole Oceanographic Institution under contract to the LRAPP office of the Office of Naval Research and three additional recording and power module (RPM) assemblies were completed. The original two systems after modification are designated "Mod I"; the three new systems assembled by Texas Instruments were designated "Mod II". The performance specifications of the modified systems are presented in Table I.

B. Mooring and Array Designs

Three separate mooring designs were employed in this exercise. Double armored electromechanical cable (U.S. Steel Amergraph 7H37SB and Vector equivalent) was used in the moorings (at Positions H and D); these are termed "hard wire" systems. A multiconductor core surrounded by a polypropylene load bearing braid was used in the mooring at Position B; this is termed a "compliant" system. The two hard wire systems mounted different hydrophones both designed for acceleration insensitivity; hydrophones developed by the Westinghouse Research and Development Center were installed in the mooring at Position H and hydrophones developed by the International Transducer Corporation to University of Miami specifications were installed in the hard wire mooring at Position D and in the compliant mooring at Position B. These different system components were employed both for purposes of field evaluations as well as for inter-comparison of results. Since the three systems were widely separated they did not necessarily experience comparable current regimes; hence intercomparison for evaluation of strumming response was infeasible.

The mooring and array designs with actual depths are shown as follows:

Position	RPM	Mooring Type	Hydrophone	Reference
B	2A4	Compliant	ITC 8020	Figure 1, 2 Appendix A
D	1A1	Hard Wire	ITC 8020	Figure 3
H	2A3	Hard Wire	Westinghouse	Figure 4

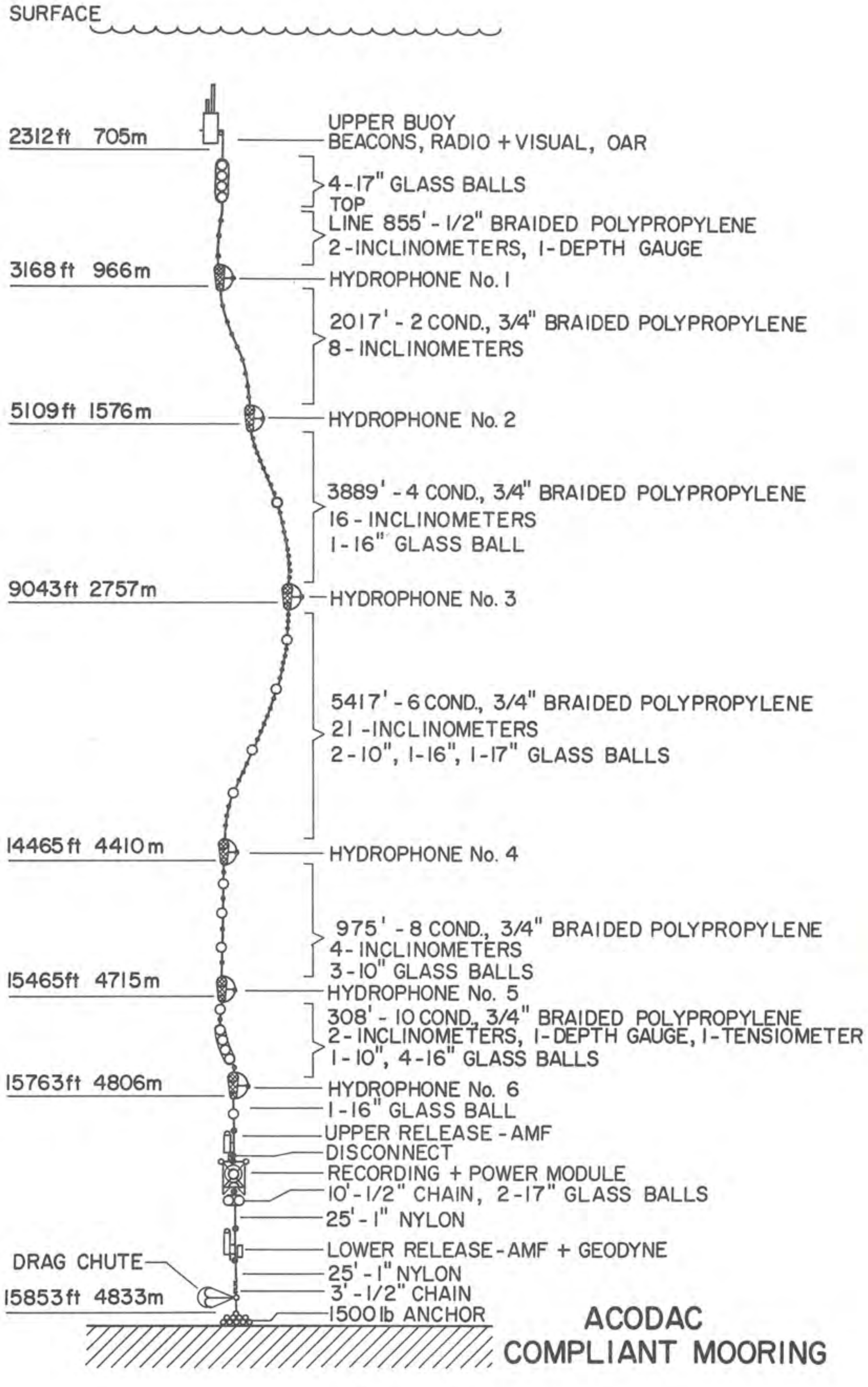
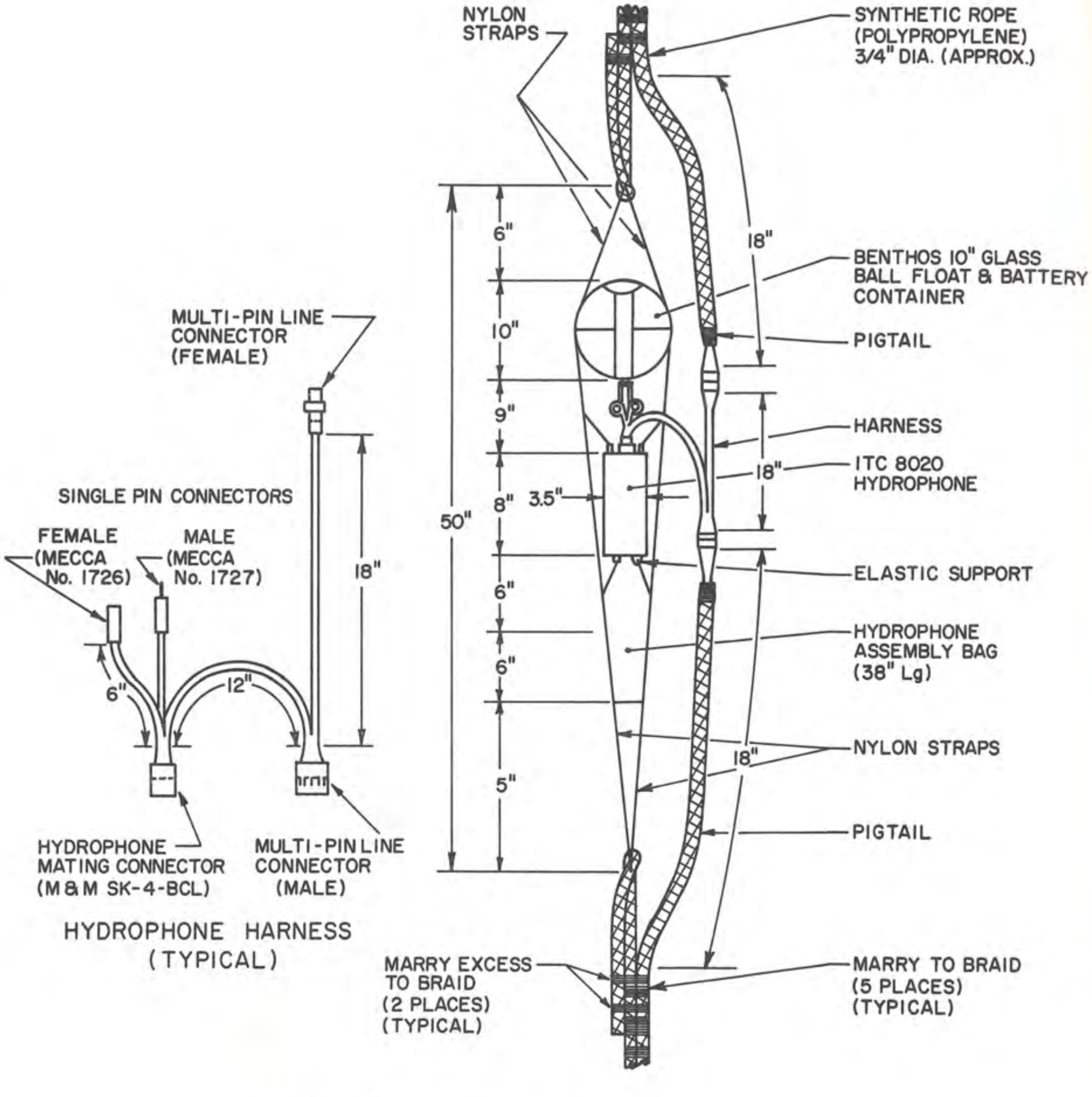
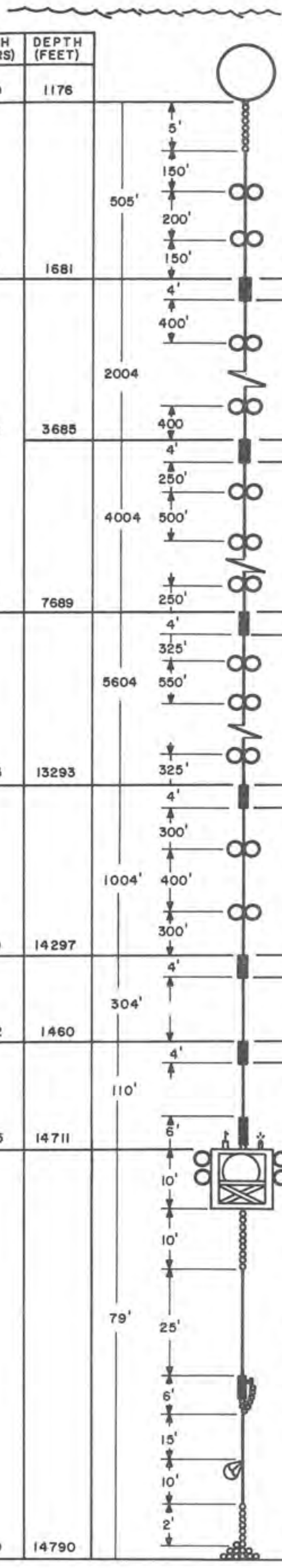

SURFACE
2312ft 705m
UPPER BUOY
BEACONS, RADIO + VISUAL, OAR
4-17" GLASS BALLS
TOP
LINE 855' - 1/2" BRAIDED POLYPROPYLENE
2-INCLINOMETERS, 1-DEPTH GAUGE
3168ft 966m
HYDROPHONE No. 1
2017' - 2 COND., 3/4" BRAIDED POLYPROPYLENE
8 - INCLINOMETERS
5109ft 1576m
HYDROPHONE No. 2
3889' - 4 COND., 3/4" BRAIDED POLYPROPYLENE
16 - INCLINOMETERS
1 - 16" GLASS BALL
9043ft 2757m
HYDROPHONE No. 3
5417' - 6 COND., 3/4" BRAIDED POLYPROPYLENE
21 - INCLINOMETERS
2 - 10", 1 - 16", 1 - 17" GLASS BALLS
14465ft 4410m
HYDROPHONE No. 4
975' - 8 COND., 3/4" BRAIDED POLYPROPYLENE
4 - INCLINOMETERS
3 - 10" GLASS BALLS
15465ft 4715m
HYDROPHONE No. 5
308' - 10 COND., 3/4" BRAIDED POLYPROPYLENE
2 - INCLINOMETERS, 1 - DEPTH GAUGE, 1 - TENSIOMETER
1 - 10", 4 - 16" GLASS BALLS
15763ft 4806m
HYDROPHONE No. 6
1 - 16" GLASS BALL
UPPER RELEASE - AMF
DISCONNECT
RECORDING + POWER MODULE
10' - 1/2" CHAIN, 2 - 17" GLASS BALLS
25' - 1" NYLON
LOWER RELEASE - AMF + GEODYNE
DRAG CHUTE
25' - 1" NYLON
3' - 1/2" CHAIN
15853ft 4833m
1500 lb ANCHOR
ACODAC
COMPLIANT MOORING

Figure 1



ACODAC COMPLIANT MOORING
HYDROPHONE ASSEMBLY ARRG'T.

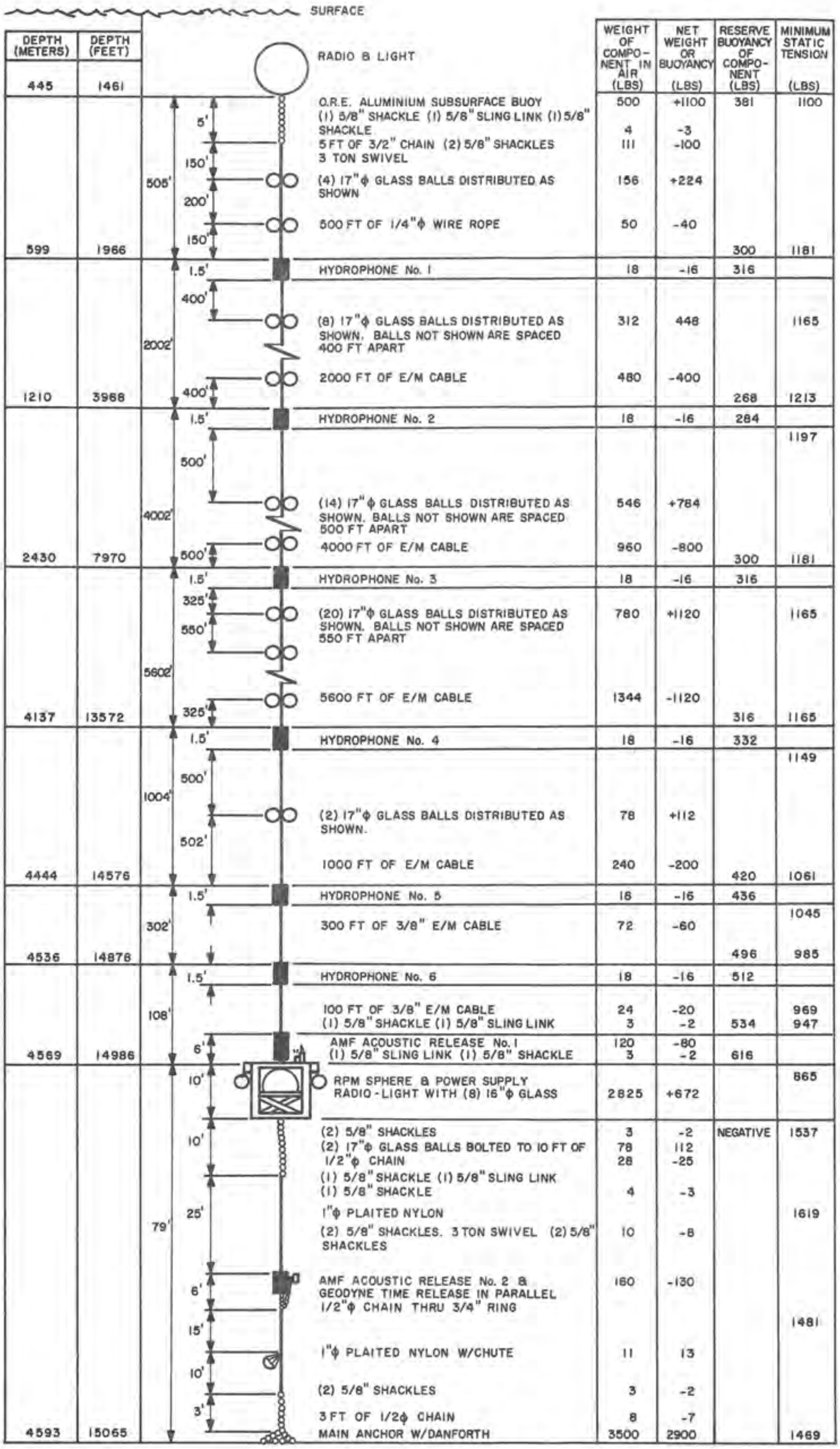
Figure 2



DEPTH (METERS)	DEPTH (FEET)	COMPONENT	WEIGHT OF COMPONENT IN AIR (LBS)	NET WEIGHT OR BUOYANCY OF COMPONENT (LBS	RESERVE BUOYANCY (LBS)	MINIMUM STATIC TENSION (LBS)
359	1176	RADIO & LIGHT O.R.E. ALUMINUM SUBSURFACE BUOY	500	+1100	399	1100
		(1) 5/8" SHACKLE. (1) 5/8" SLING LINE				
		(1) 5/8" SHACKLE	4	-3		
		5 FT 3/2"ϕ CHAIN. (2) 5/8" SHACKLES 3 TON SWIVEL	111	-100		
		500 FT 1/4" ϕ WIRE ROPE	50	-40		
		(4) 17" ϕ GLASS BALLS DISTRIBUTED AS SHOWN	156	+224		
513	1681				318	1181
		HYDROPHONE No. 1	70	-55	373	
						1126
		(8) 17" ϕ GLASS BALLS DISTRIBUTED AS SHOWN. BALLS NOT SHOWN ARE SPACED 400 FT APART	312	+448		
		2000 FT 3/8" ϕ E/M CABLE	480	-400		
1123	3685				325	1174
		HYDROPHONE No. 2	70	-55	380	
						1119
		(16) 17" ϕ GLASS BALLS DISTRIBUTED AS SHOWN. BALLS NOT SHOWN ARE SPACED 500 FT APART	624	+896		
		4000 FT OF 3/8" E/M CABLE	960	-800		
2344	7689				284	1215
		HYDROPHONE No. 3	70	-55	339	
						1160
		(20) 17" ϕ GLASS BALLS DISTRIBUTED AS SHOWN. BALLS NOT SHOWN ARE SPACED 550 FT APART	780	1120		
		5600 FT OF 3/8" E/M CABLE	1344	-1120		
4053	13293				339	1160
		HYDROPHONE No. 4	70	-55	394	
						1105
		(4) 17" ϕ GLASS BALLS DISTRIBUTED AS SHOWN	156	224		
		1000 FT OF 3/8" E/M CABLE	240	-200		
4359	14297				370	1129
		HYDROPHONE No. 5	70	-55	425	
						1074
		300 FT OF 3/8" E/M CABLE	72	-60		
4452	1460				485	1014
		HYDROPHONE No. 6	70	-55	540	
		100 FT OF 3/8" E/M CABLE	24	-20		959
		(1) 5/8" SHACKLE. (1) 5/8" SLING LINK	3	-2	562	937
		AMF ACOUSTIC RELEASE No. 1	120	-80		
4485	14711	(1) 5/8" SHACKLE. (1) 5/8" SLINK LINK	3	-2	644	
		IPV SPHERE & PWR SUPPLY. LIGHT-RADIO W(15) 16" ϕ GLASS BALLS ATTACHED	2700	+700		855
		(2) 5/8" SHACKLES	3	-2		1555
		(2) 17" ϕ GLASS BALLS BOLTED TO	78	+112	NEGATIVE	
		10 FT OF 1/2" ϕ CHAIN	28	-25		
		(1) 5/8" SHACKLE. (1) 5/8" SLING LINK.	4	-3		
		(1) 5/8" SHACKLE				
						1637
		1" ϕ PLAITED NYLON	7			
		(2) 5/8" SHACKLES. 3 TON SWIVEL. (2) 5/8" SHACKLES.	10	-8		
		AMF RELEASE No. 2 & GEODYNE TIME RELEASE IN PARALLEL 1/2" ϕ CHAIN THRU 3/4" RING	160	-130		
						1499
		1" ϕ PLAITED NYLON W/CHUTE	11	-3		
		(2) 5/8" SHACKLES	3	-2		
		3 FT 1/2" ϕ CHAIN	6	-7		
4509	14790	MAIN ANCHOR W/DANFORTH	3500	2900		1487

ACODAC MOORING
DEPLOYMENT - 17
POSITION D

Figure 3



DEPTH (METERS)	DEPTH (FEET)		WEIGHT OF COMPONENT IN AIR (LBS)	NET WEIGHT OR BUOYANCY (LBS)	RESERVE BUOYANCY OF COMPONENT (LBS)	MINIMUM STATIC TENSION (LBS)
		RADIO & LIGHT				
445	1461	O.R.E. ALUMINIUM SUBSURFACE BUOY	500	+1100	381	1100
		(1) 5/8" SHACKLE (1) 5/8" SLING LINK (1) 5/8" SHACKLE	4	-3		
		5 FT OF 3/2" CHAIN (2) 5/8" SHACKLES 3 TON SWIVEL	111	-100		
		(4) 17"ϕ GLASS BALLS DISTRIBUTED AS SHOWN	156	+224		
		500 FT OF 1/4"ϕ WIRE ROPE	50	-40		
599	1966				300	1181
		HYDROPHONE No. 1	18	-16	316	
		(8) 17"ϕ GLASS BALLS DISTRIBUTED AS SHOWN. BALLS NOT SHOWN ARE SPACED 400 FT APART	312	448		1165
		2000 FT OF E/M CABLE	480	-400		
1210	3968				268	1213
		HYDROPHONE No. 2	18	-16	284	
						1197
		(14) 17"ϕ GLASS BALLS DISTRIBUTED AS SHOWN. BALLS NOT SHOWN ARE SPACED 500 FT APART	546	+784		
		4000 FT OF E/M CABLE	960	-800		
2430	7970				300	1181
		HYDROPHONE No. 3	18	-16	316	
		(20) 17"ϕ GLASS BALLS DISTRIBUTED AS SHOWN. BALLS NOT SHOWN ARE SPACED 550 FT APART	780	+1120		1165
		5600 FT OF E/M CABLE	1344	-1120		
4137	13572				316	1165
		HYDROPHONE No. 4	18	-16	332	
						1149
		(2) 17"ϕ GLASS BALLS DISTRIBUTED AS SHOWN.	78	+112		
		1000 FT OF E/M CABLE	240	-200		
4444	14576				420	1061
		HYDROPHONE No. 5	18	-16	436	
						1045
		300 FT OF 3/8" E/M CABLE	72	-60		
4536	14878				496	985
		HYDROPHONE No. 6	18	-16	512	
		100 FT OF 3/8" E/M CABLE	24	-20		969
		(1) 5/8" SHACKLE (1) 5/8" SLING LINK	3	-2	534	947
		AMF ACOUSTIC RELEASE No. 1	120	-80		
4569	14986	(1) 5/8" SLING LINK (1) 5/8" SHACKLE	3	-2	616	
						865
		RPM SPHERE & POWER SUPPLY RADIO-LIGHT WITH (8) 16"ϕ GLASS	2825	+672		
		(2) 5/8" SHACKLES	3	-2	NEGATIVE	1537
		(2) 17"ϕ GLASS BALLS BOLTED TO 10 FT OF	78	112		
		1/2"ϕ CHAIN	28	-25		
		(1) 5/8" SHACKLE (1) 5/8" SLING LINK (1) 5/8" SHACKLE	4	-3		
		1"ϕ PLAITED NYLON				1619
		(2) 5/8" SHACKLES. 3 TON SWIVEL (2) 5/8" SHACKLES	10	-8		
		AMF ACOUSTIC RELEASE No. 2 & GEODYNE TIME RELEASE IN PARALLEL 1/2"ϕ CHAIN THRU 3/4" RING	160	-130		
						1481
		1"ϕ PLAITED NYLON W/CHUTE	11	13		
		(2) 5/8" SHACKLES	3	-2		
		3 FT OF 1/2ϕ CHAIN	8	-7		
4593	15065	MAIN ANCHOR W/DANFORTH	3500	2900		1469

ACODAC MOORING
DEPLOYMENT - 18
POSITION H

Figure 4

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	Lead Acid Storage Battery, 17.28 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

Table II below lists the pertinent characteristics for the compliant line developed to University of Miami specifications. The central electrical core was manufactured by the Electromechanical Cable Division of the U.S. Steel Corporation, Worcester, Massachusetts; the outer braid was woven by Samson Cordage Works, Shirley, Massachusetts. Figure 5 is a photograph of this cable.

C. Recording and Power Module (RPM)

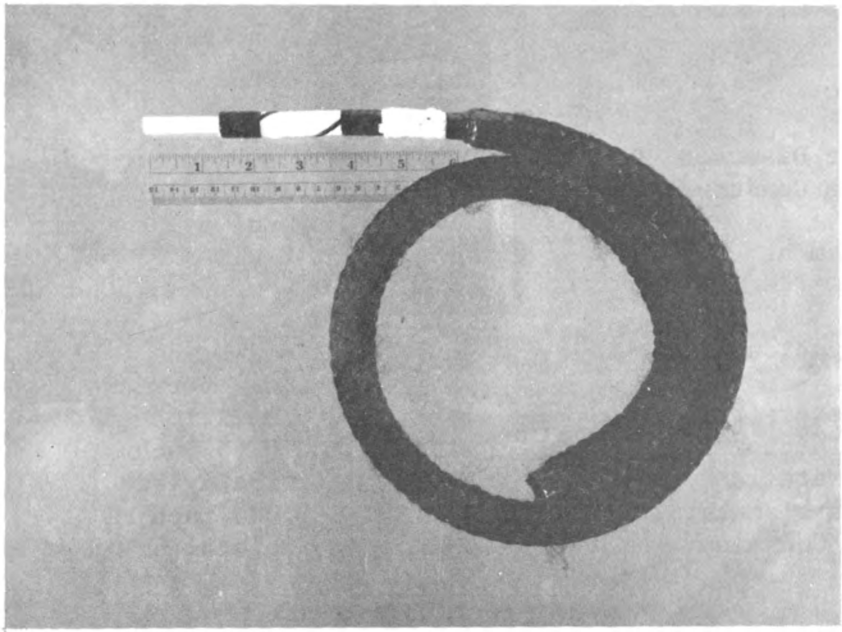
The assembled RPM is shown in Figure 6. A block diagram of the ACODAC signal processing, recording and telemetry system, most of which is contained within the RPM, is shown in Figure 7. The following discussion concentrates on changes in the system which were effected between the 1971 and 1972 deployments.

(1). Tape Recorder

To prevent tape spillage caused by accelerations, a dual system of dynamic braking of the supply reel and static braking of both the supply and takeup reels was installed. New GeoTech Model 17373 tape recorders were installed in the Mod I systems which had water in the capsules during 1971.

(2). Gain Control

Three basic changes were made in the gain control logic. Previously the system had responded only to average sound pressure level during the one minute integration time and on this level depended the gain state for the following minute; three gain states 10, 37 and 64 db provided three 30 db ranges with 3 db adjacent overlap, for a total system dynamic range of 84 db, matching the hydrophone approximately. The 3 db overlap proved not to be sufficient margin; the ambient level would frequently ride near the margin and the arrival of a transient or fade would overload the system or allow it to sink into noise. Consequently the new systems have four separate gain ranges of 10, 20, 30 and 40 db for a total system dynamic range of 60 db with a 20 db overlap between adjacent bands. The resulting margins allow for a 14 db positive transient in any band without overload as well as a 6 db fade without going into system noise. This band gain scheme together with the resulting acoustic pressure level range of the two hydrophone types are shown in Figure 8. A change in the criteria for gain changes was also made. Previously momentary overloads, although marked as such by simultaneous 75Hz and 200Hz high level signals being injected on the tape, did not automatically cause a downward gain shift during the succeeding minute as long as the average sound pressure level stayed within the bounds. In order to facilitate work with explosives a modification was made which would cause any overload during a given minute to



Compliant Cable

Figure 5

Overall:

Breaking Strength	7,000 lbs
Stretch at Break	30 %
Effective Cable Modulus	31,500 lbs
Buoyancy:	
2 conductors	9.02 lbs/Kft
4 conductors	1.13 lbs/Kft
6 conductors	-6.88 lbs/Kft
8 conductors	-14.85 lbs/Kft
10 conductors	-16.83 lbs/Kft
Type	Free flooding

Electrical Core:

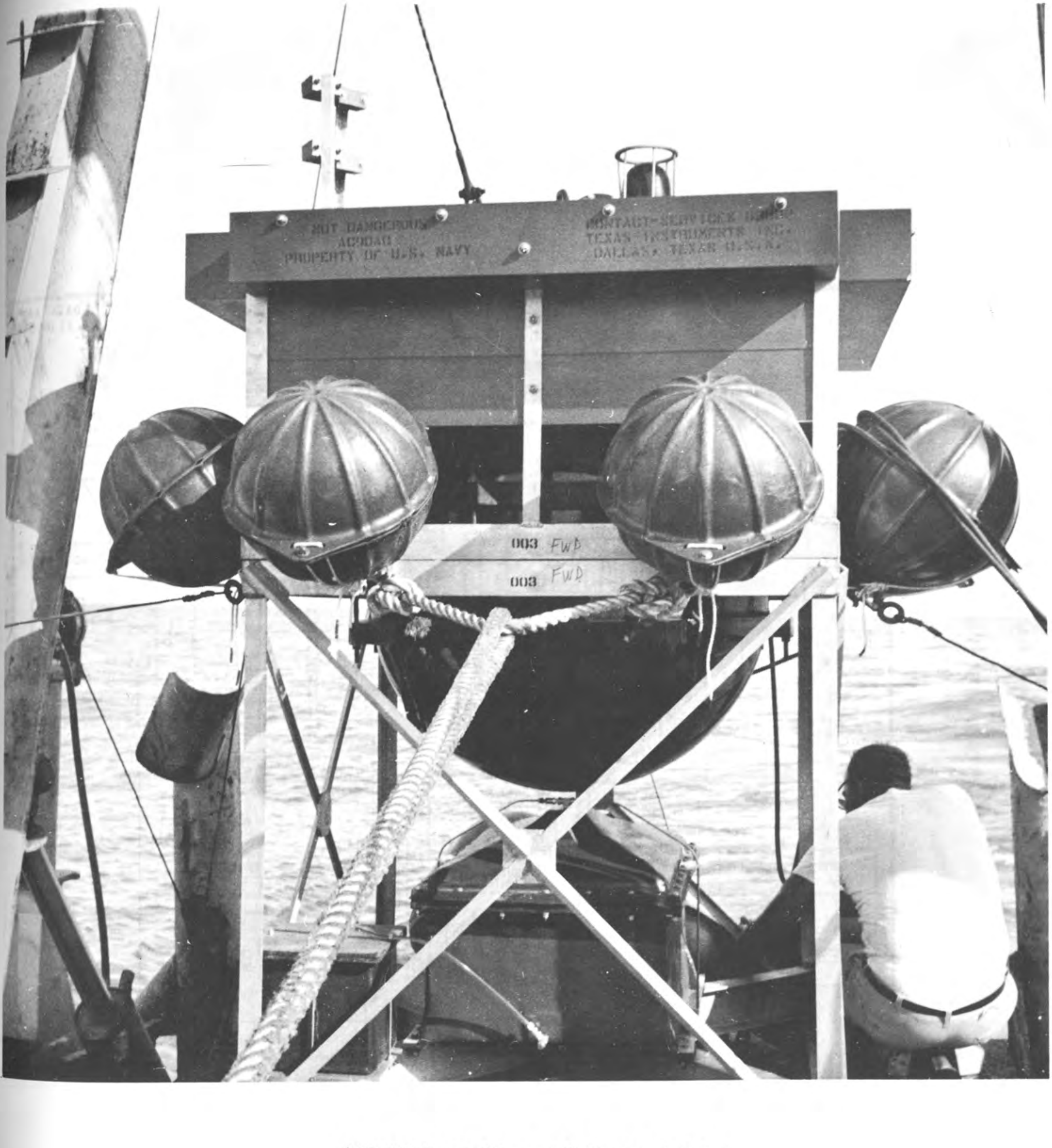
Central Core Diameter	0.300 inch
Central Core Construction	Polyethylene jacket around core of nylon fibers
Wire Arrangement	10 wires or polyethylene fillers wound around core in right hand helix, angle 45°.
Wire Construction	10 AWG #30 wires wound together to form AWG #20 equivalent
Copper Diameter (eff.)	0.032X inch
Insulation Thickness	0.0265 inch
Insulation Material	Polyethylene
Overall Wire Diameter	0.085 inch
Wire Bundle Container	Skeletal braid of nylon

Outer Braid:

Material	Polypropylene
Weight	72 lbs/Kft
Specific Gravity	0.91

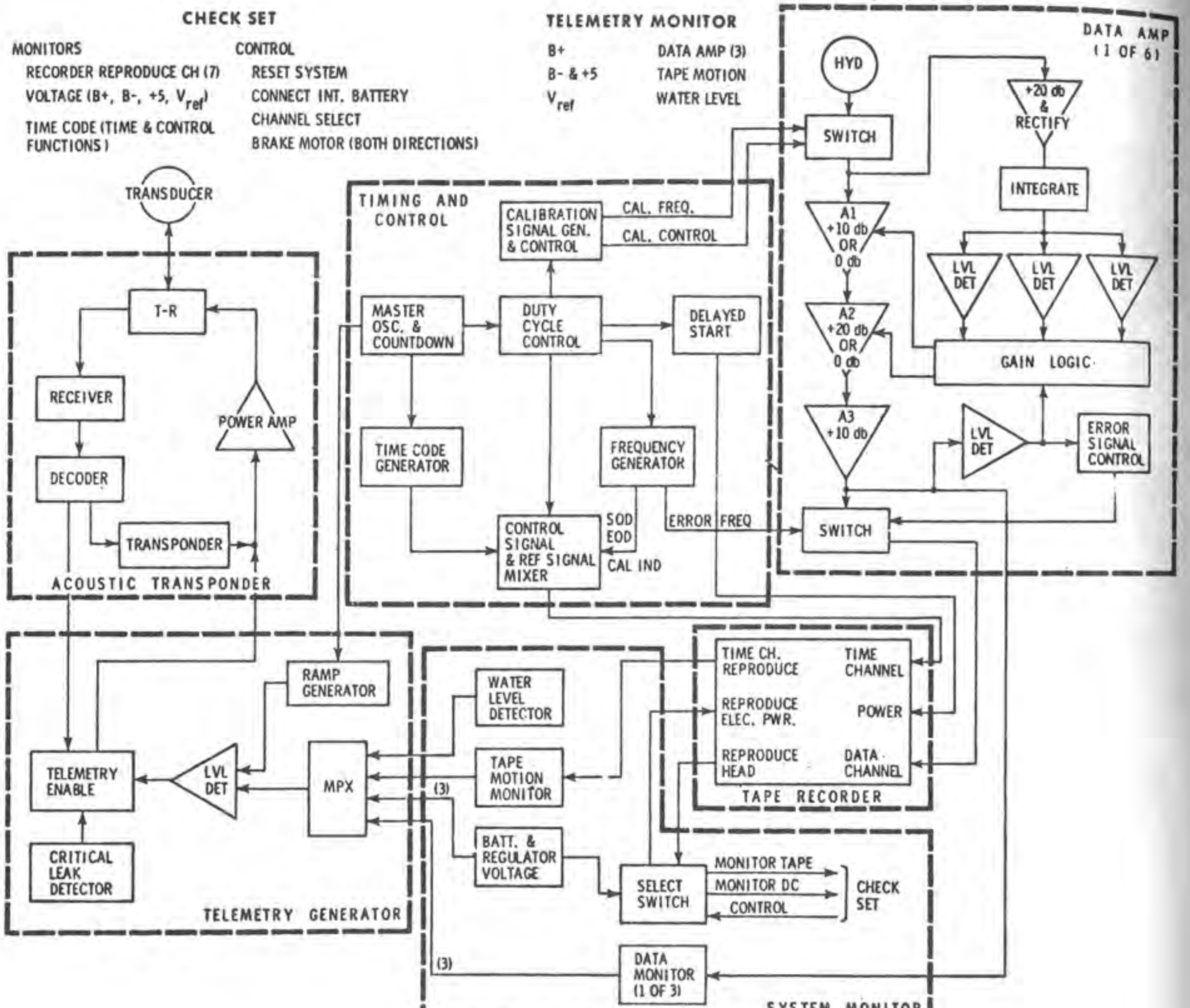
Compliant Cable Characteristics

Table II



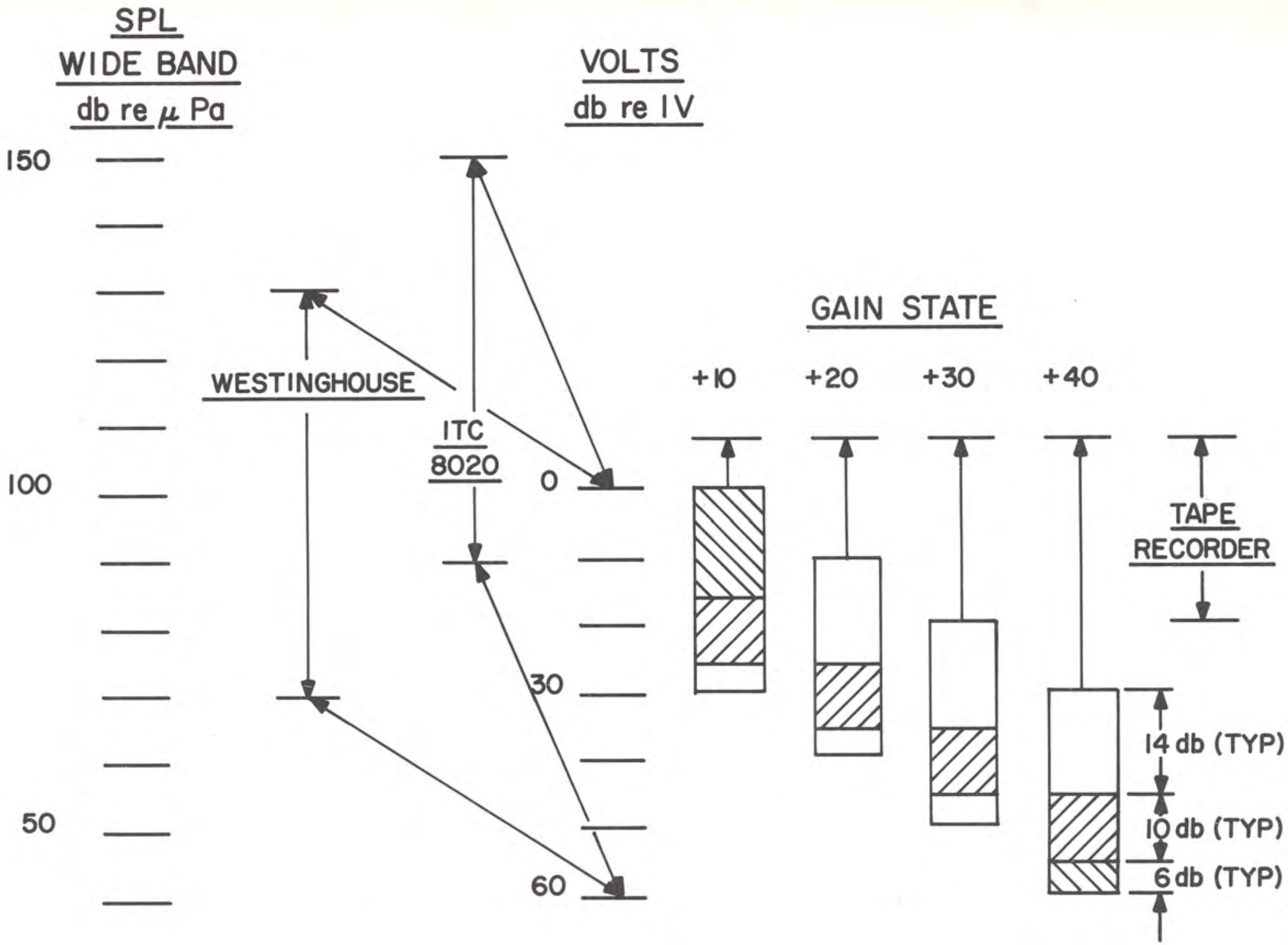
ACODAC Recording and Power Module
November 1972

Figure 6



ACODAC Signal Processing, Recording and Telemetry Systems

Figure 7



ACODAC Level Ranges

Figure 8

cause a downward gain shift during the succeeding minute. The number of minutes the system will remain in the less sensitive state is selectable between 1 and 9 in both the Mod I and Mod II units. In the Mod I unit the system on a momentary overload will at the next opportunity change gain states by one, in the Mod II unit as used in this exercise the system would change by two states if possible, otherwise to the least sensitive state.

(3). Timing and Control

The static brake mentioned above is released by the delayed start signal. All recorded control functions, except overload, have been moved from the data channels to the time code channel.

(4). System Monitor and Telemetry

After the instrument pressure vessel (IPV) has been sealed it is possible with the unit on deck to monitor the signal on each channel, system voltages, gain states, time-code generation and control function generation via an umbilical cable. Control is provided to reset the system clock, connect (or disconnect) the internal battery, select any channel for monitoring and lock (or unlock) the tape reels.

After deployment, the monitor system (via acoustic telemetry) enables the surface ship to query and receive the status of the battery and reference voltages, verify proper signal input to the tape recorder on three preselected channels, measure presence and approximate level of any water in the capsule and extract evidence that the tape had moved during the previous recording period.

(5). Telemetry Generator

The telemetry generator is activated upon receipt of a properly decoded signal from the acoustic transponder. It contains the 8-channel multiplexer and ramp generator that in combination convert the conditional voltage inputs from the system monitor to pulse position modulated time division multiplexed signals transmitted back to the ship through the acoustic transponder.

In addition, if water is detected above a critical level, an alarm circuit is activated that sends a continuing series of pulses through the telemetry system without interrogation.

(6). Acoustic Transponder

The Mod I units utilize the electronics portion of an AMF-262 acoustic release system. The AMF Model 262 is no longer in production, having been superseded by AMF-322, which is in current production. The Model 262 receives amplitude-modulated (suppressed carrier) pulses in an AGC receiver to recover the coded modulation frequency. This was found by AMF to be unreliable when used for underwater navigation purposes (only 70% of replies were received), so the 322 receiver was developed which hard-limits the received pulses, after which narrow-band filters detect the coded modulation frequency. According to AMF, this technique is 100% effective in the navigation utilization. Both receivers utilize the same deck equipment and encoding techniques, so that for ACODAC purposes they can be considered interchangeable at the assembly level. The acoustic transponders in the instrument sphere are utilized only for telemetry purposes. Additional acoustic transponders are provided for release purposes.

D. Hydrophones

(1). Westinghouse Model WX VERAY-1

The Westinghouse acceleration cancelling hydrophones used in the exercise were developed at the Westinghouse Research and Development Center, Pittsburgh, Pa. Figure 9 shows the mechanical arrangement of this hydrophone, Figures 10 through 13 show "exploded" to "assembled" photographs of the hydrophone.

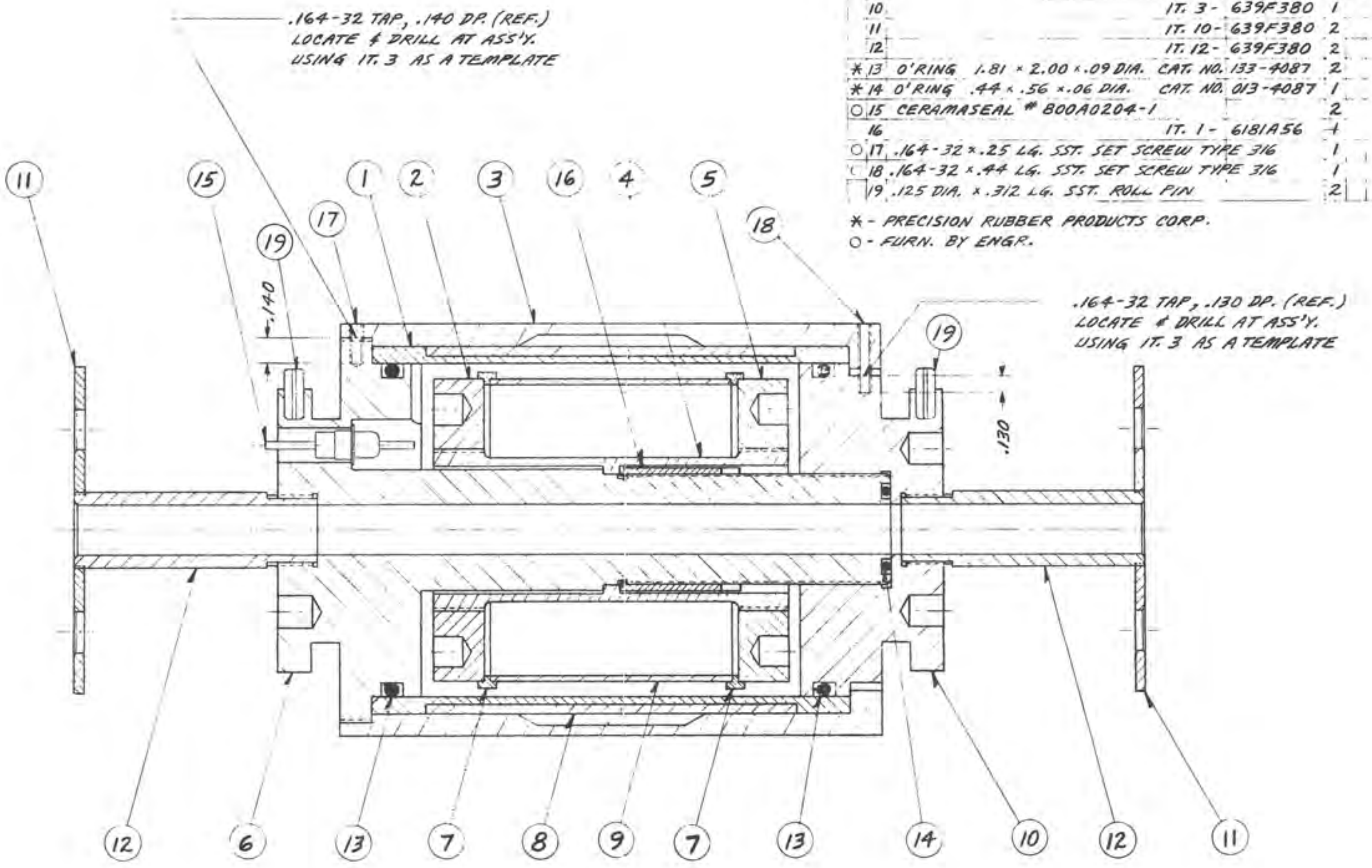
With some editing, the following paragraphs are extracted from Reference 31.

Noise Tests of FET Units

In order to determine whether Crystalonics #C413N silicon expitaxial junction N channel low noise FET units could be used in hydrophone preamplifiers, some units were passivated by the Westinghouse Research and Development Center Solid State Devices Department. The top of the aluminum cans were removed and an organic coating was added. These units were tested in the circuit shown in Figure 14. A 4Hz wide filter was used to examine the FET voltage noise over the spectrum from 10Hz to 300Hz. Figure 15 is a typical plot of the recorded output voltage. The noise at 60Hz and harmonics was large but was ignored. The units were all temperature cycled up to 150°C for 1 hour, returned to room temperature, heated to

SYM	ITEM	DESCRIPTION – MATERIAL DIMENSIONS IN INCHES	REF DWG OR PART NO.	SYM GR 1	2	3	4	5
	1	IT. 9 -	639F380	1				
	2	IT. 5 -	639F380	1				
	3	IT. 7 -	639F380	1				
	4	IT. 6 -	639F380	1				
	5	IT. 4 -	639F380	1				
	6	IT. 8 -	639F380	1				
	7	IT. 2 -	639F380	2				
	8	IT. 11 -	639F380	1				
	9	IT. 1 -	639F380	1				
	10	IT. 3 -	639F380	1				
	11	IT. 10 -	639F380	2				
	12	IT. 12 -	639F380	2				
*	13	O'RING 1.81 × 2.00 × .09 DIA. CAT. NO.	133-4087	2				
*	14	O'RING .44 × .56 × .06 DIA. CAT. NO.	013-4087	1				
○	15	CERAMASEAL # 800A0204-1		2				
	16	IT. 1 -	6181A56	4				
○	17	.164-32 × .25 LG. SST. SET SCREW TYPE 316		1				
○	18	.164-32 × .44 LG. SST. SET SCREW TYPE 316		1				
	19	.125 DIA. × .312 LG. SST. ROLL PIN		2				

* - PRECISION RUBBER PRODUCTS CORP.
○ - FURN. BY ENGR.



S.O.	CHANGE	1	2	3
D. K.			PICTORIAL CHANGE DUE TO REDESIGN AS PER ENGR. M.P. 8-26-72	ADDED IT. 19 M.P. 9-8-72

Westinghouse Hydrophone Model WX-VERAY-1

Figure 9

TOLERANCES
UNLESS OTHERWISE SPECIFIED
2 PL. DEC. ±.02
3 PL. DEC. ±.005
ANGLES ±0.5°

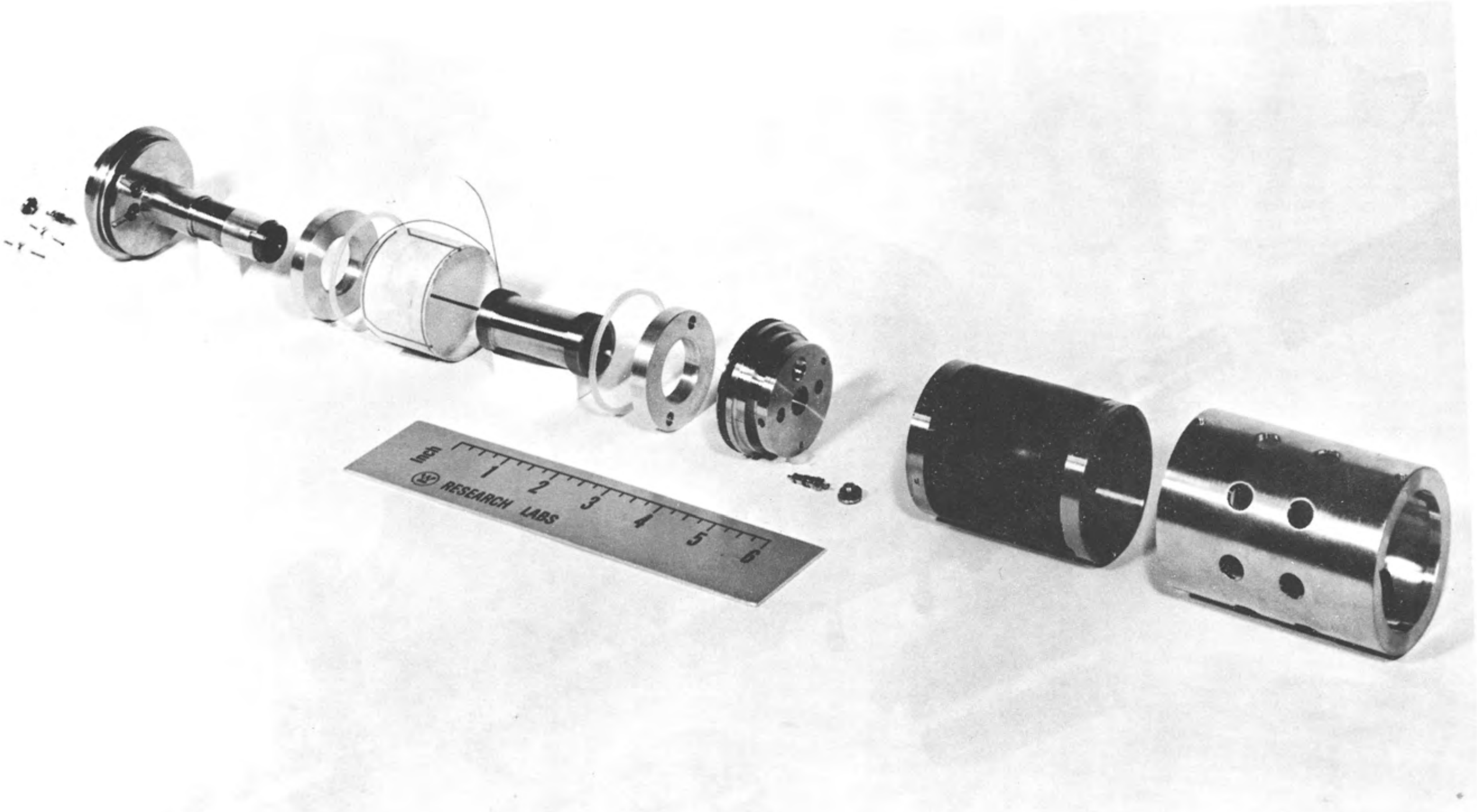
FINISH TO BE 63 UNLESS OTHERWISE SPECIFIED

GEOMETRIC CHARACTERISTIC SYMBOLS
- FLATNESS
- STRAIGHTNESS
- ROUNDNESS (CIRCULARITY)
- CYLINDRICITY
- PROFILE OF ANY LINE
- PROFILE OF ANY SURFACE
- PARALLELISM
- PERPENDICULARITY (SQUARENESS)
- ANGULARITY
- RUNOUT
- TRUE POSITION
- CONCENTRICITY
- SYMMETRY
- MAXIMUM MATERIAL CONDITION (MMC)
- REGARDLESS OF FEATURE SIZE

REF DWG

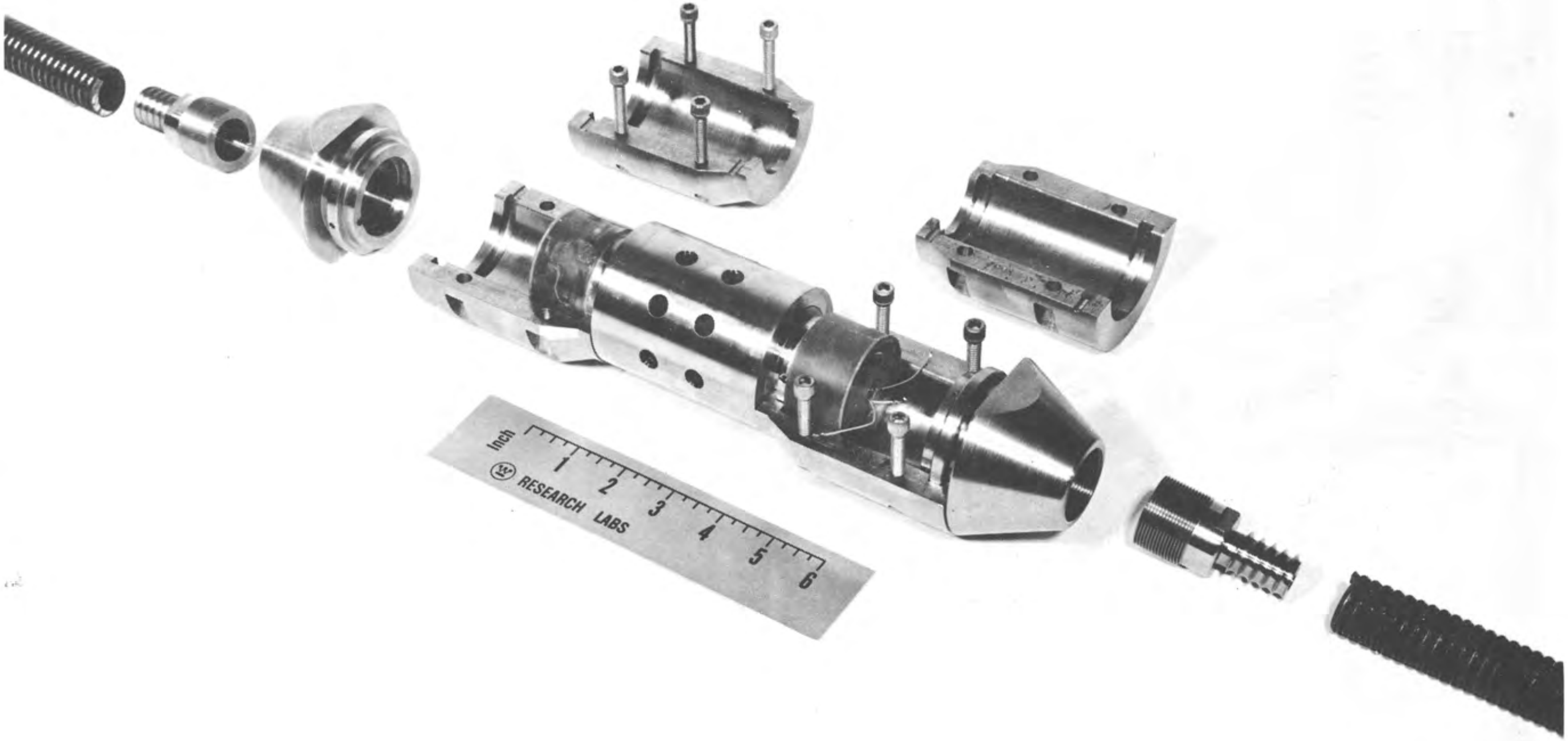
Westinghouse Electric Corporation

TITLE VERAY HYDROPHONE
ASSEMBLY
DIMENSIONS IN INCHES—SCALE & N.T.S. SUB; 1&3
DFTM. POPELLA 7/27/72 APPD G.R. Douglas 9/14/72
CHKD Michael A. Popella 9/10/72 APPD
SUPV. APPD
255 C504
RESEARCH LABORATORIES CHURCHILL BORO PITTSBURGH PA. 15235 U.S.A.



Exploded View
Westinghouse Hydrophone

Figure 10

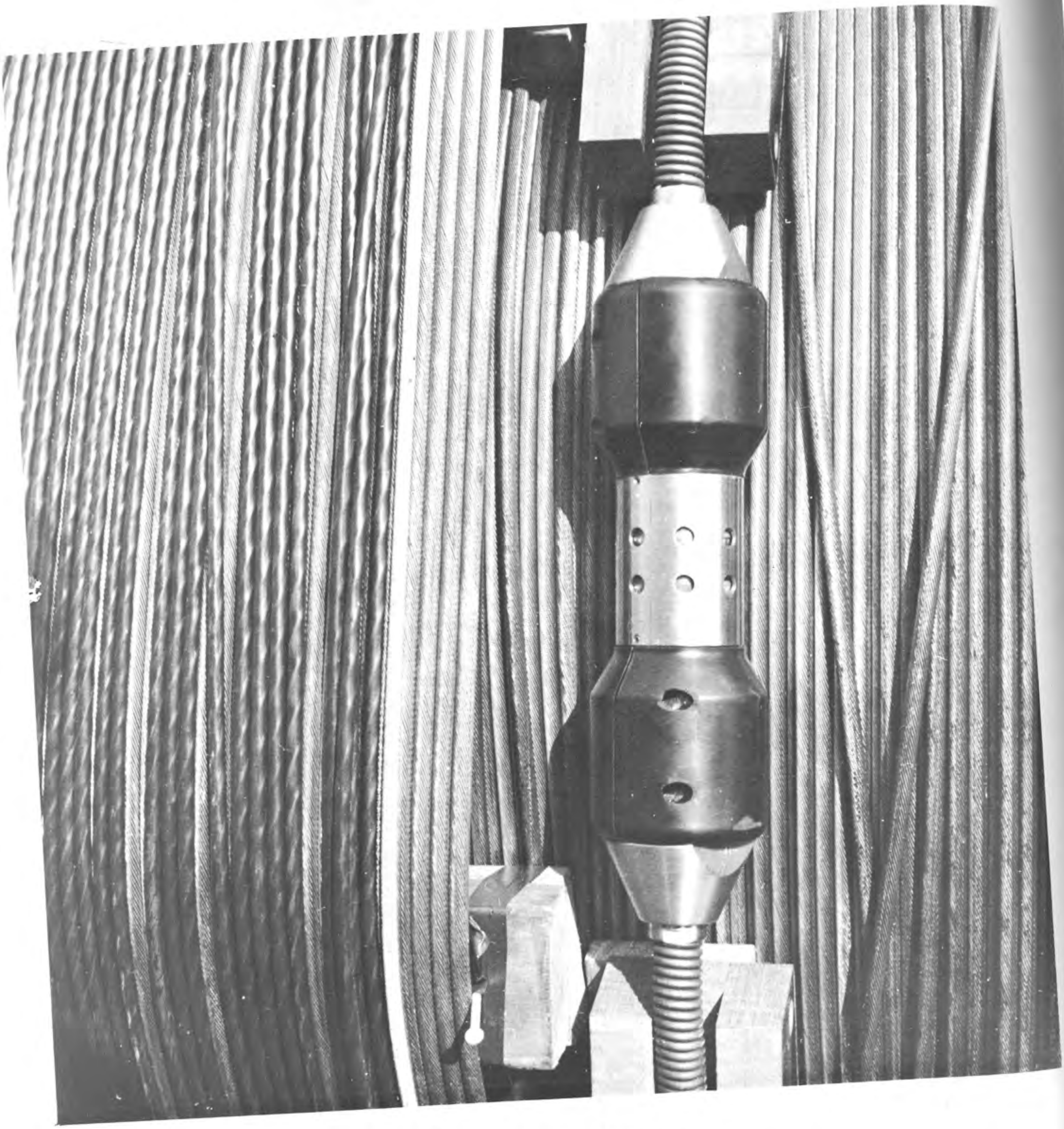


Partially Assembled
Westinghouse Hydrophone

Figure 11

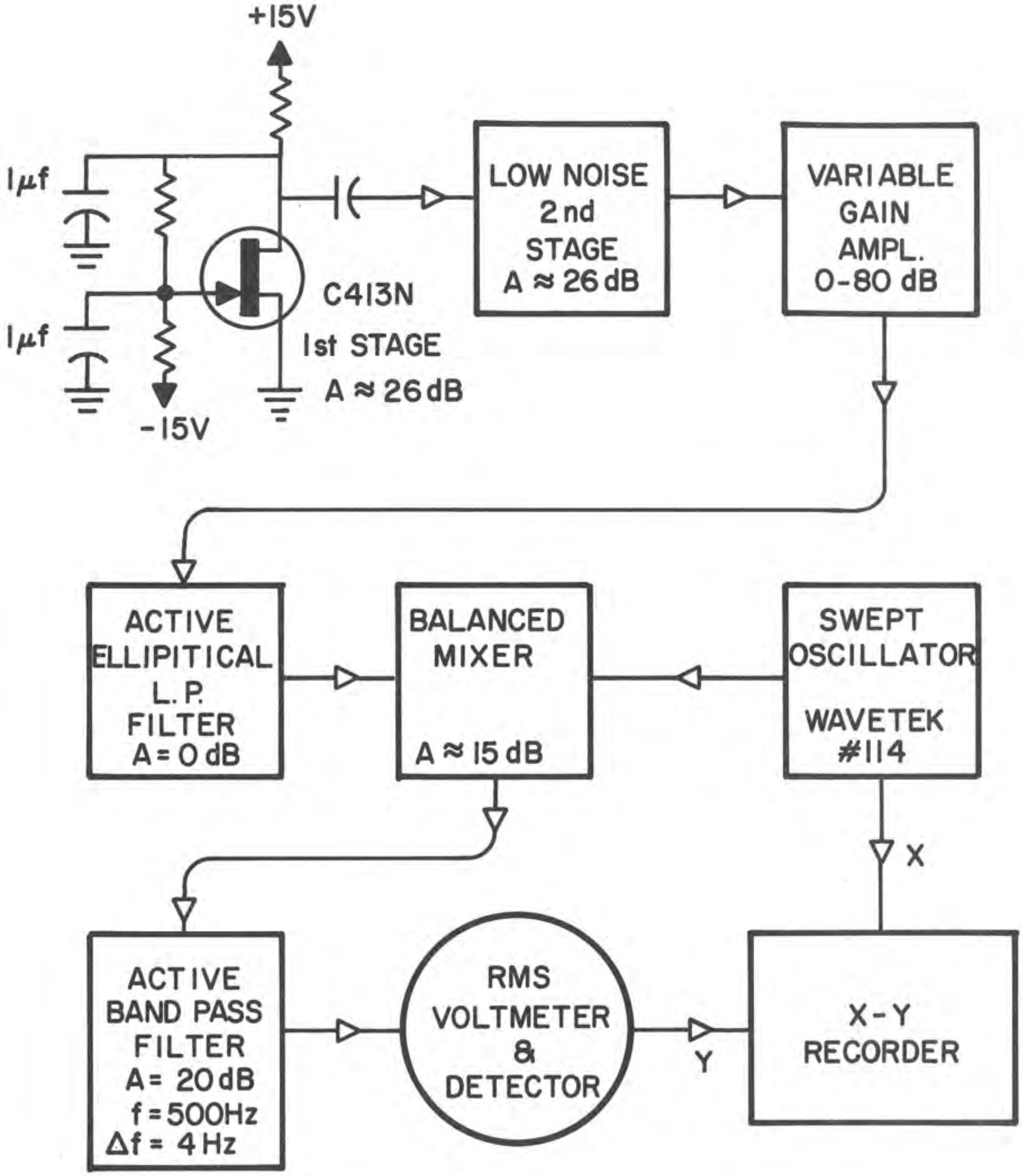
Cable Attachment Scheme
Westinghouse Hydrophone

Figure 12



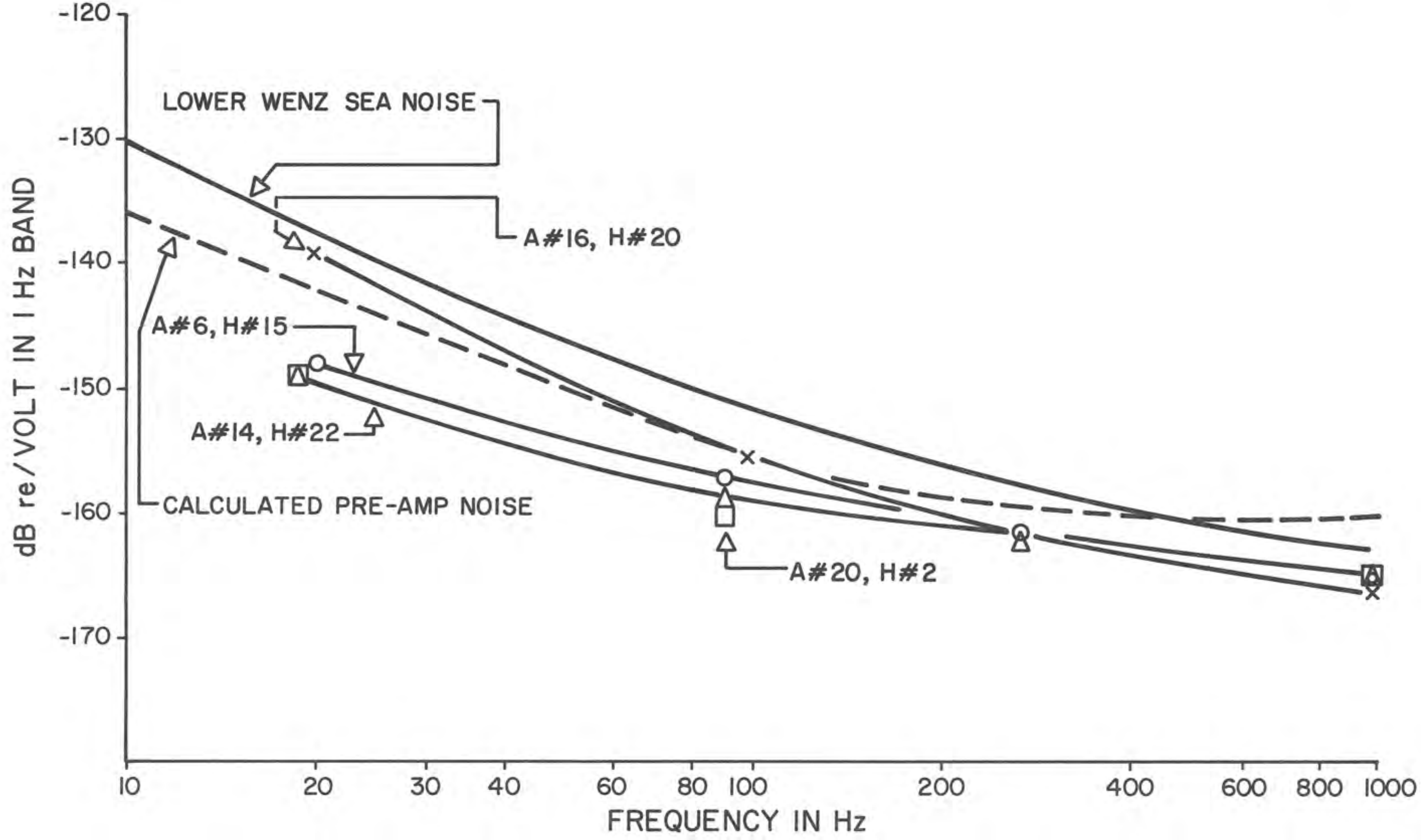
Assembled Westinghouse
Hydrophone Stowed On Drum

Figure 13



CIRCUIT FOR NOISE MEASUREMENT OF FET UNITS

Figure 14



PRE-AMPLIFIER NOISE

Figure 15

150°C for 2 hours, cooled and tested. Next, the units were placed in a bag of castor oil and were pressure cycled three times to 10,000 psi. Figure 16 illustrates a noise spectrum before and after the tests. Table III summarizes the results at 100 Hz and 200 Hz for the four units. The largest increase was 30% in voltage. This was deemed satisfactory.

Each of the complete preamplifier circuits was tested for noise before assembly to the hydrophone. A dummy RC load was used to simulate the transducer.

Calibration and Pressure Tests

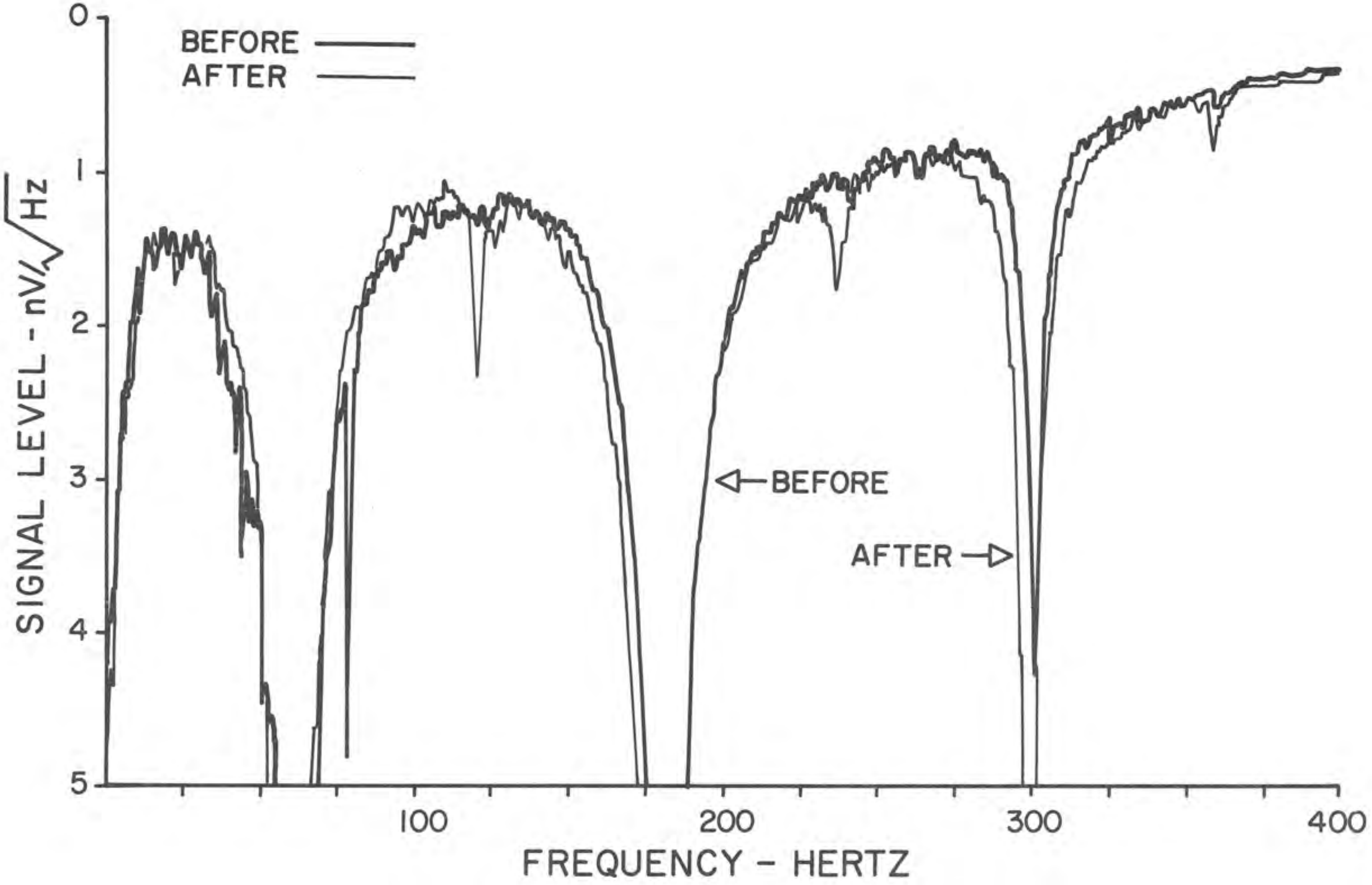
All units were subjected to an 8,000 psi test in a pressure bomb filled with oil. After the pressure test the units were calibrated in air using a 15" speaker driven by an audio oscillator. The strength of the sound field was monitored using a B&K quarter inch condenser microphone Type 4135 with cathode follower Type 2615, having a sensitivity of -71.4 db re v/μbar.

Amplifier Tests

The gain of all preamplifier units was measured by inserting a 10 μv signal at the input terminals and measuring the output voltage from the termination amplifier. A gain between 59 db and 60 db was considered satisfactory. Amplifier noise tests were made at 20, 90, 270 and 1000 Hz using a 1000 ohm resistor in series with a 4700 pf condenser connected to the input terminals, as a dummy source, in place of the hydrophone. After the amplifier units were potted and assembled to the hydrophone, noise tests were made in an anechoic chamber at 270 Hz and 1000 Hz. At lower frequencies the chamber noise masked the preamplifier noise. The gain of the number of potted amplifier units was monitored in the pressure bomb as the pressure was slowly varied from 0 to 10,000 psi and back down again. No significant change in gain occurred. The amplifier has 40 db of negative feedback so it has a stable gain even though the characteristics of some of the components change with pressure.

Amplifier Construction

Components were chosen which would stand the pressure. The circuit was designed to avoid the need for any large value capacitors so that monolithic ceramic units could be used. All resistors 1 MΩ and less consist of a metal film on a ceramic rod. The transistor units had to have the covers removed and



NOISE LEVEL OF FET # 5 BEFORE AND AFTER TEMPERATURE AND PRESSURE CYCLING

Figure 16

Calculated Input Signal Level in mV/$\sqrt{\text{Hz}}$ units

Unit No.	Case Type	Before Passivation		After Passivation		After 2 Temperature Cycles		After 3 Pressure Cycles	
		100 Hz	250 Hz	100 Hz	250Hz	100 Hz	250 Hz	100 Hz	250Hz
2	Short	2.8	2.8	2.8	2.5				
3	Short	1.6	1.5	1.8	1.5	1.8	1.5	1.5	1.3
4	Tall	1.2	0.9	1.3	1.0	1.4	1.0	1.3	1.0
5	Tall	1.0	0.8	1.4	0.9	1.3	1.0	1.3	1.0
6	Tall	1.1	0.9	1.3	0.9	1.3	1.1	1.4	1.0
7	Tall	1.2	0.9	1.5	1.0	1.5	1.1	1.5	1.2

Noise Test of Crystalonic #C413N

Table III

be passivated before they were wired into the circuits. This was done after a vacuum bake out. The polyurethane potting material was degassed in a vacuum system before it was poured around the circuit to avoid the formation of gas bubbles. It was cured in an oven under a pressure of 45 lbs. gauge.

Acceleration Tests

To determine the sensitivity of the hydrophone to accleration the hydrophone was assembled, but prior to oil filling vibration tests were made. Units were mounted so they could be vibrated axially in air using a Goodmans Industries Ltd. Type 390A force driver. The motion was monitored with a consolidated Electrodynamic Corp. Type 4-275 calibrated accelerometer with a sensitivity of -48.6 db re v/g mounted on the hydrophone case. The test was made at 100 Hz and the results are given in Table IV. The response under these conditions was found to be flat from 10 Hz to 300 Hz.

Hydrophone Sensitivity

The overall sensitivity and acceleration response of the hydrophones are shown in Table IV. The Westinghouse hydrophones were designed to measure shipping noise in the ocean. As shown in Figure 8, the ACODAC system is capable of recording signal levels from 1 mV to 1 V over the frequency range from 10 Hz to 300 Hz by using step attenuators of 10, 20, 30, and 40 db. In Reference (30) Wenz shows two solid heavy lines that give the limits of the prevailing noise in the ocean. See Figure 17. Five percent of the time the noise is below the lower curve and five percent of the time it is above the upper curve. A preamplifier that had a noise level at least 1 db below the lower Wenz curve from 10 Hz to 300 Hz was considered satisfactory. The calculated noise levels of the preamp we used was 6 db below the Wenz curve at 10 Hz and 2 db below it at 300 Hz; see Figure 15. This figure also shows the measured response of four of the amplifiers which were measured at 20, 90, 270, and 1000 Hz.

The average noise power represented by the lower Wenz curve from 10 Hz to 300 Hz is the same as the value at 50 Hz. At 50 Hz the curve has a value of

$$+18 \text{ db re } (2\times10^{-4} \text{ dynes/cm}^2) = -56 \text{ db re } 1\ \mu\text{B}$$

$$= +44 \text{ db re } 1\ \mu\text{P}$$

in a 1 Hz bandwidth. Over the 290 Hz band the noise power would increase by a factor of 290 or 25 db. Consequently, the expected ambient noise level is -31 db re 1 μB = +69 db re 1 μP. The overall

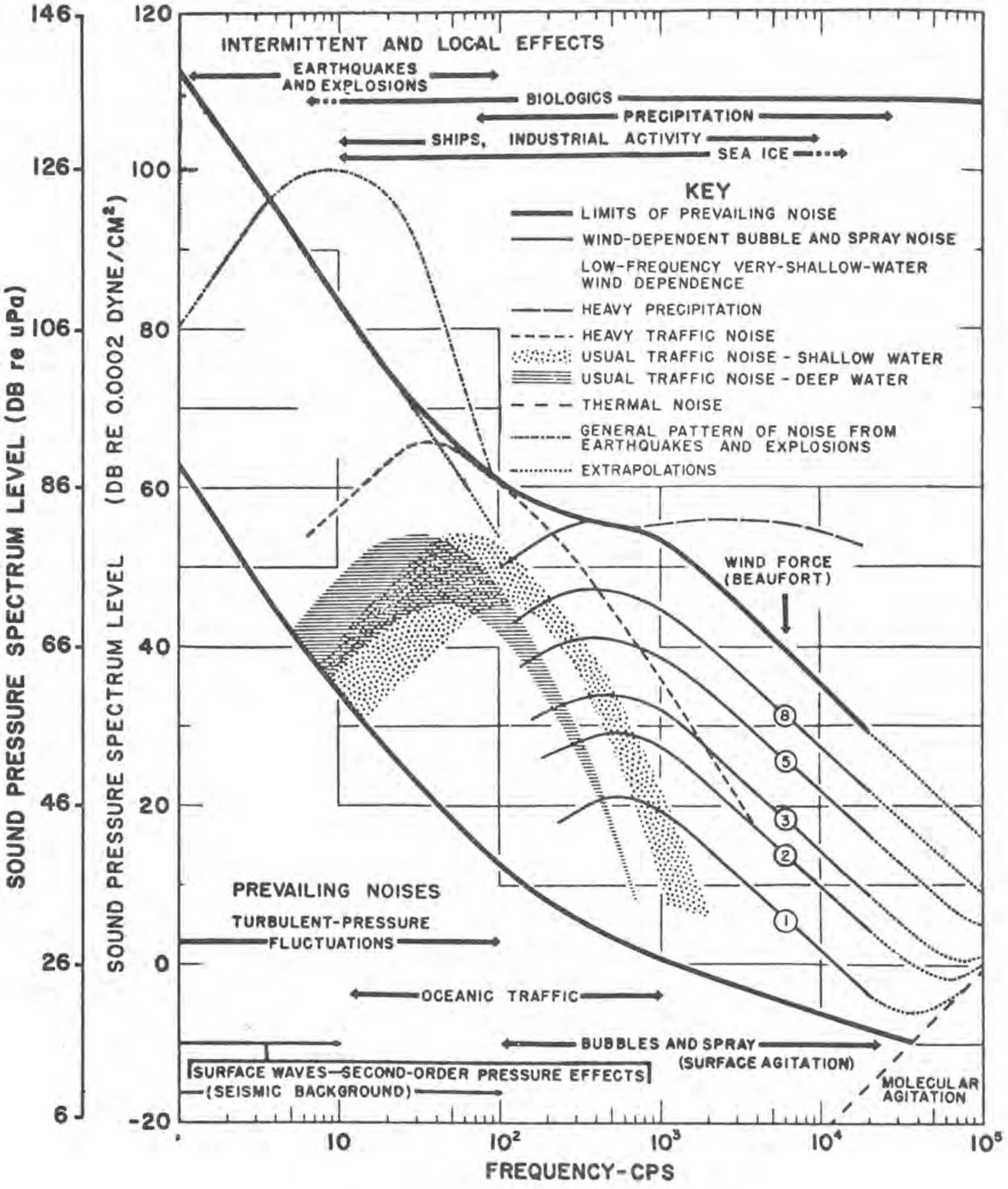
Hydrophone Location	Westinghouse Hydrophone Number	Overall Sensitivity		Acceleration Sensitivity
		Before Deployment	After Deployment	Before Deployment
		dBV/μB	dBV/μB	dBV/mg
#1 Top	2	-29	-27	-74
#2	24	-32	-32	-59
#3	15	-28	-29	-77
#4	20	-28	-38	-63
#5	22	-27	-28	-59
#6 Bottom	27	-27	-28	-58

Pre Amp Gain = 60 dB

Hydrophone Z = 5,000 pf

Calibration Data for Westinghouse Hydrophones
Used in Deployment 18, November 26, 1972

Table IV



Summary Curves for Acoustic Ambient
Noise in the Ocean
(From Wenz (1962), Reference (30))

Figure 17

sensitivity (hydrophone plus amplifier) of the Westinghouse units were about

$$-29 \text{ dbv}/\mu B = -129 \text{ dbv}/\mu P.$$

Therefore, a lower Wenz noise level over the band from 10 Hz to 300 Hz would produce a signal level of

$$-60 \text{ db re } 1 \text{ v} = 1 \text{ mv}$$

This is also the lowest level that the ACODAC system will handle; see Figure 8.

When the hydrophones are to be used to monitor explosions or other signals that contain an average power more than 60 db above the lower Wenz curve, then some additional attenuation may be desirable.

Dynamic Range

The Westinghouse system was designed to have a sensitivity of -29 dbv/μB and an output range from 1 mv to 1 v (60 db) to match the capabilities of the recording system. The amplifier has a gain of 60 db so the corresponding signal levels at the ceramic terminals are 1 v to 1 mv. The maximum amplifier output is 4 volts before saturating.

Signals from the transducer as large as 1 v will not damage the input transistor. The sensitivity of the piezoelectric element alone is

$$-89 \text{ dbv}/\mu B$$

so a signal level as great as

$$+89 \text{ db re } 1 \mu B = +189 \text{ db re } 1 \mu P$$

will not damage the Westinghouse unit. If larger signals than this are anticipated then a pair of back biased diodes can be used across the input terminals. However, this will reduce the low frequency sensitivity and also will decrease the overall signal to noise ratio of the hydrophone.

Power Converter

The preamplifier requires 30 volts at 14 milliamperes for proper operation. An additional 15 volts is required to compensate for cable voltage drop and current source simulation. Since the system power supply delivered a nominal ± 12 volts, an up-converter was designed to obtain the required 45 volts. The block diagram for the power converter is shown in Figure 18.

The basic converter consists of a multivibrator free-running at 10 kHz driving a power amplifier whose square wave output is rectified and filtered. Additional circuits provide required auxiliary functions described in the following paragraphs.

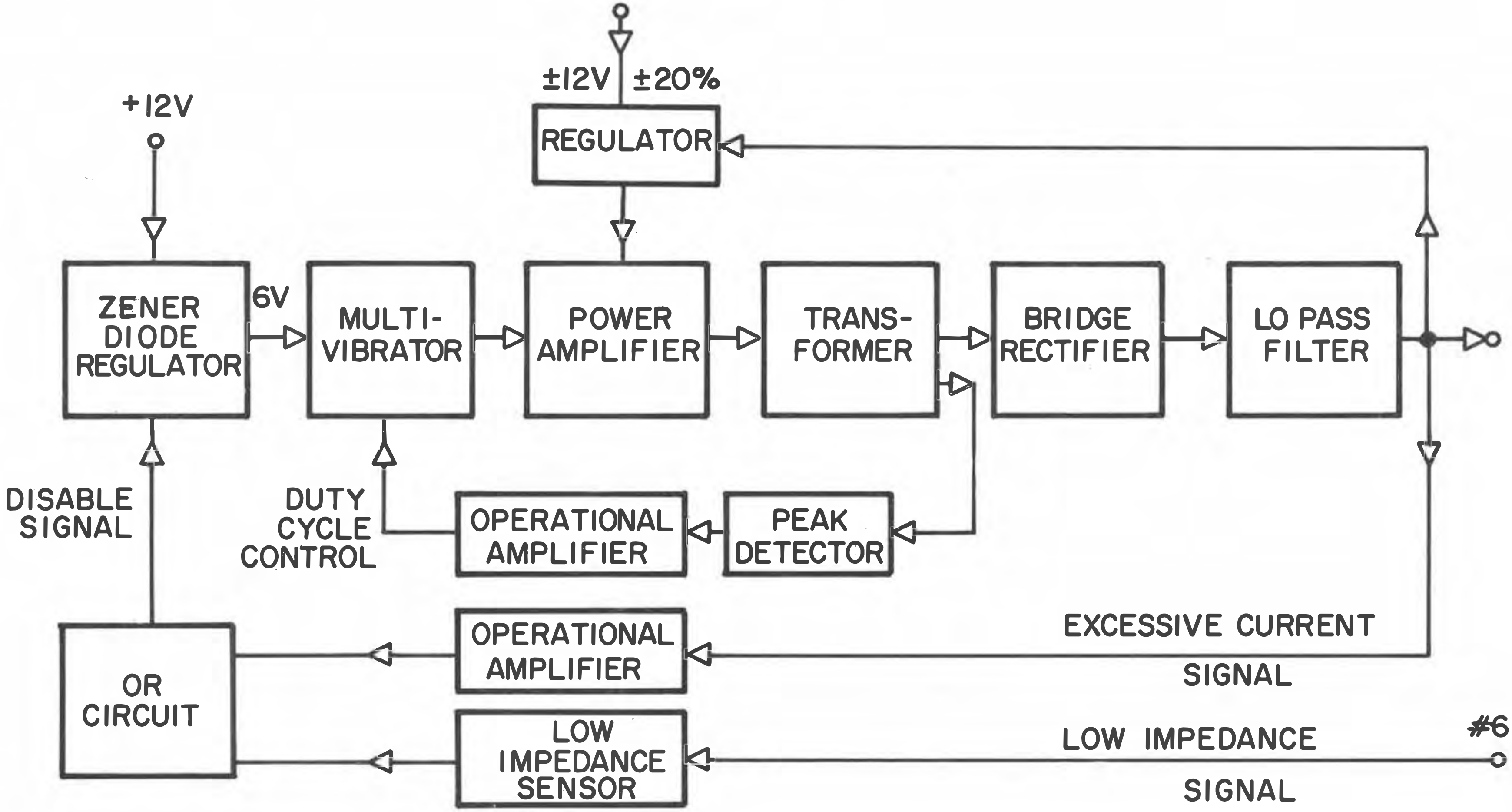
Because the system power is derived from batteries, the supply voltages drop from a high of approximately 14.5 volts to a low of approximately 10 volts as the batteries become discharged. Thus a regulator is required to maintain the amplifier system voltage at 45 volts.

Because of small differences between the positive and negative supply voltages and differing collector saturation voltages of the power amplifier switching transistors, the positive and negative "volt-seconds" applied to the transformer core are unequal. This is equivalent to applying a DC voltage component to the transformer and since the DC resistance is very small, large DC currents can flow which saturate the core. A duty cycle control circuit is included in the converter which senses unequal postitive and negative "volt-seconds" in the core and adjusts the multivibrator duty cycle so as to make them equal.

The converter is protected against excessive output current due to accidental shorts or other high load situations. If excessive current is sensed, a circuit shuts off power to the multivibrator thus removing the power amplifier drive signal and yielding zero output. Once this circuit has been activated, it must be reset by first removing and then reapplying the system power.

In ACODAC deployment number 18 the input to the impedance sensor came from the lead connected to the bottom hydrophone. In the future it would be more desirable to use the unused pin #7 on the XSL8CCP connector with the connector attached the resistance from pin #7 to ground would be very high but if the connector were to part, the salt water would reduce the impedance to 500 ohms or less.

The presence of either a low impedance signal or an excessive current signal will cause a signal from the "or circuit" to disable the diode regulator.



WESTINGHOUSE UP CONVERTER, VOLTAGE REGULATOR, AND PROTECTIVE CIRCUITS

Figure 18

(2). ITC Model 8020

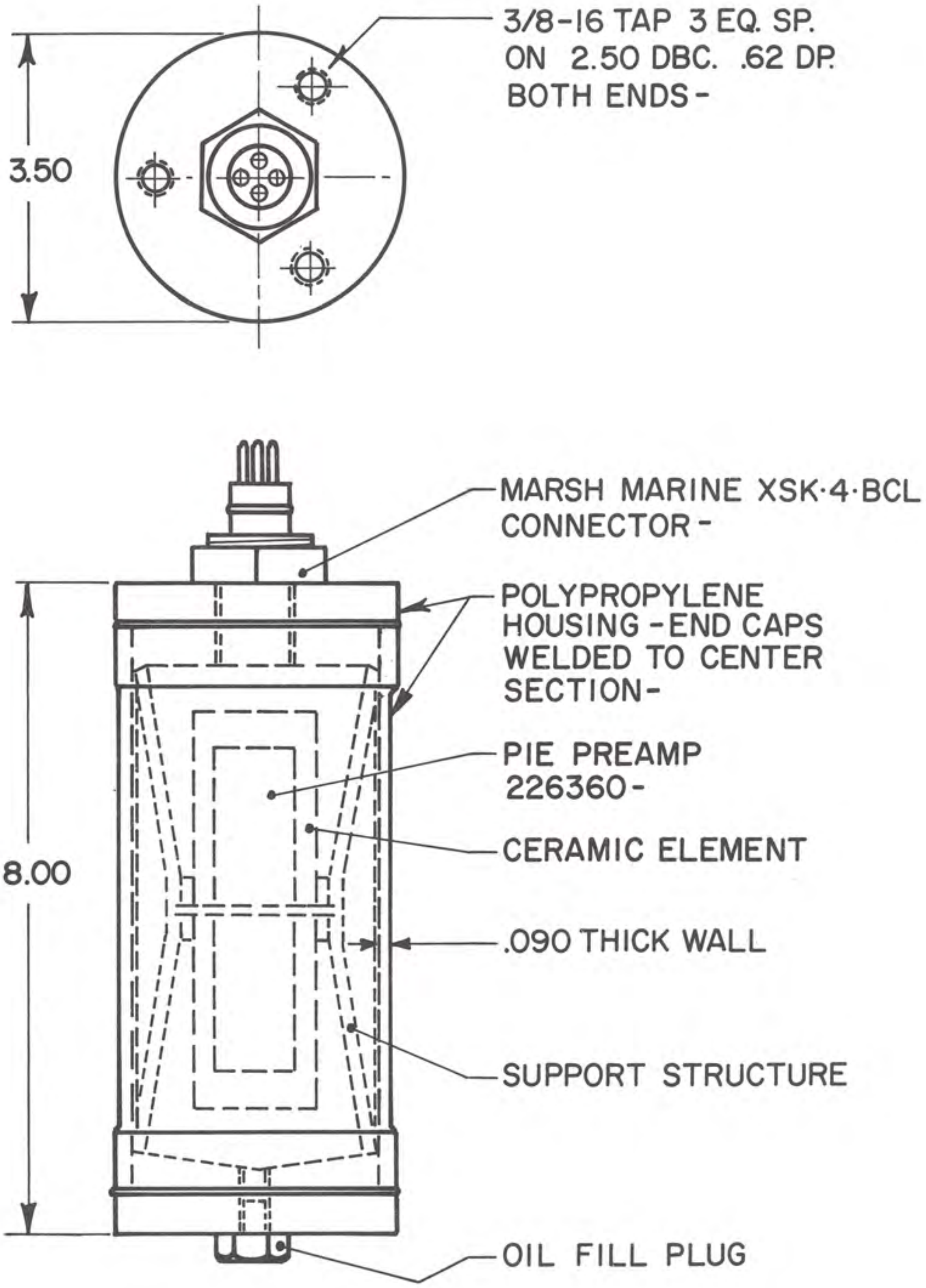
A discussion of the rationale behind the development of the ITC Model 8020 hydrophone is given by Reference (7). These units were developed by the International Transducer Corporation, Santa Barbara, California. The ITC 8020, Figure 19, was designed to overcome some of the shortcomings of the ITC 8004. First it was made as completely symmetric as possible by moving the preamp to a location inside the sensitive element. In order to accomplish this, the pressure vessel was eliminated and the electronics were designed for operation at full hydrostatic pressure. Figure 20 is a schematic of the pre-amplifier. An important consequence of the elimination of the pressure vessel is weight reduction; the ITC 8020 weighs only about 0.9 lb in sea water. This permits support by very soft elastic members (surgical tubing) which results in a very low natural frequency of the suspension and high attenuation of vibration. Second, the hydrophone walls were made much more rigid than previously.

The ITC 8020 was developed in response to University of Miami specifications; Appendix C. These were subsequently modified to require a - 150 db re v/uPa response instead of - 140. Fourteen units were produced. All units, except one, which was held as a spare, were tested at the Underwater Sound Reference Division of the Naval Research Laboratory, Orlando, Florida from 30 October through 3 November 1972. The results of this test showed a response of approximately - 150 db re v/uPa which was insensitive to temperature and pressure changes within the specified frequency range. Appendix B presents the essential data from the test report, Reference (29).

The circuit and data for the hydrophone power supply are shown in Figure 21.

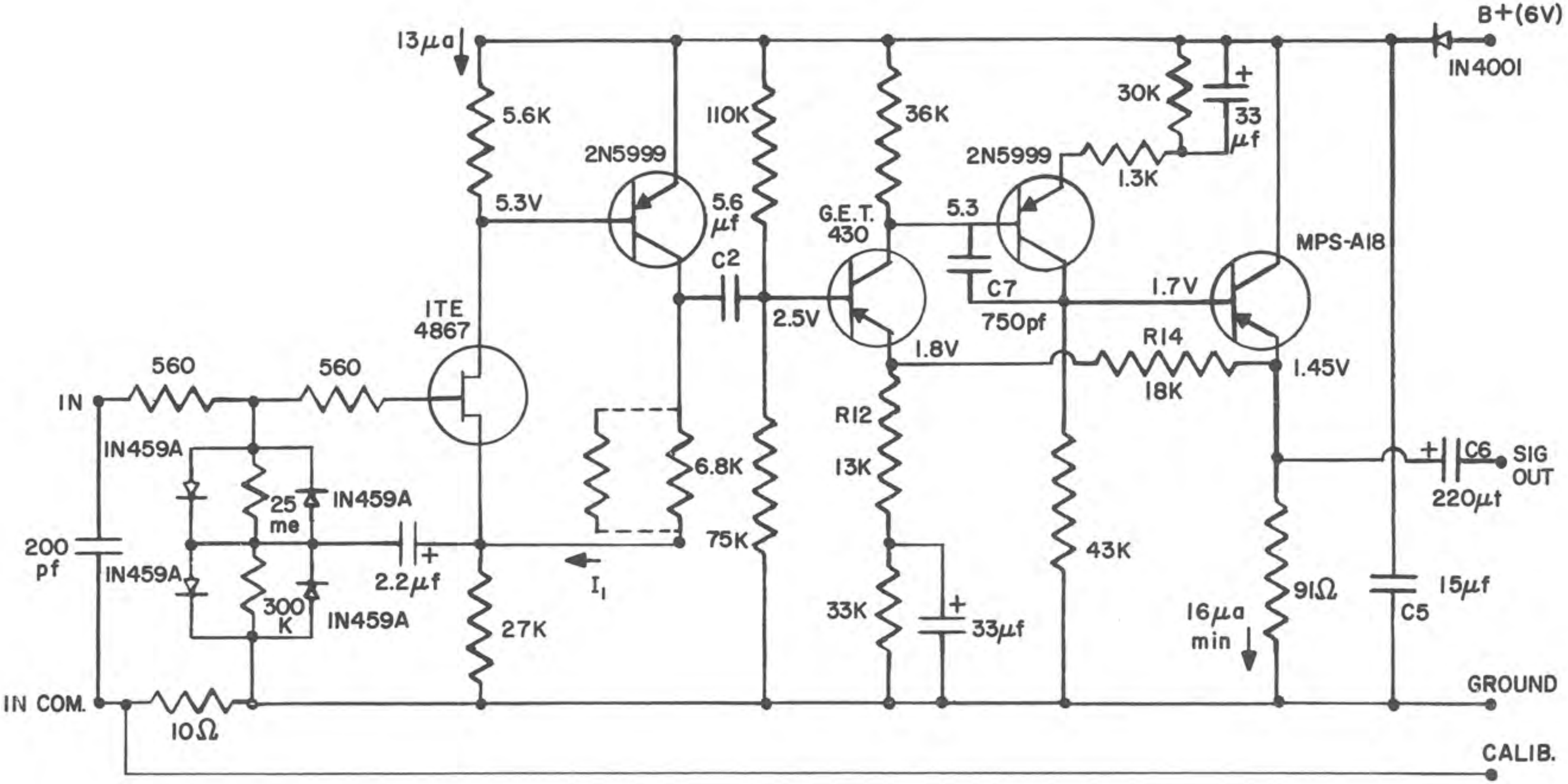
E. Deployment and Recovery

Deployment and Recovery Logs are presented in Figures 22, 23, and 24. Track charts for the deployments of the three systems are shown in Figures 25, 26, and 27. All systems were placed in water deeper than the nominal 4390 meters because sound velocities derived from XBT's dropped from NORTH SEAL indicated a deeper sound channel than anticipated. Data from Figure 4-45 of Reference (16) indicated a critical depth in the summer of 4750 meters and in the winter of 4250 meters. In planning the exercise a critical depth close to the winter value was assumed; this was an erroneous assumption. As shown in Figure 28 the actual critical depth was between 4450 and 4500 meters. The objective was to place hydrophone number 5 at the critical depth. The depths of hydrophone



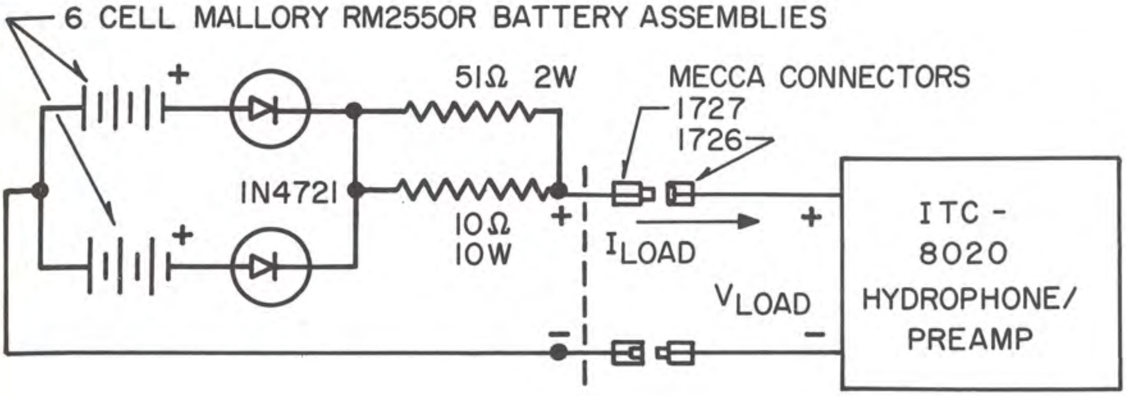
Hydrophone Model ITC 8020 Outline Drawing

Figure 19



Preamplifier for Hydrophone
Model ITC 8020

Figure 20



	"NEW" AT 22°C	"END-OF-LIFE" AT 0°C
CELL VOLTAGE	1.36 V	1.20 V
BATTERY VOLTAGE	8.18 V	7.20 V
V_{DIODE}	0.60 V	0.60 V
I_{LOAD}	21 ma	17 ma
IR	0.18 V	0.14 V
V_{LOAD}	7.40V	6.46 V

ESTIMATED LIFE (TO 1.20 V/CELL): 320 hrs × $\frac{30}{20}$ = 480 hrs

WITH CATASTROPIC FAILURE
OF ONE BATTERY

$I_{SHORT-CIRCUIT} \simeq \frac{7.5V}{10\Omega} = 750\,ma$

ITC 8020 HYDROPHONE
PRE-AMP POWER SUPPLY

Figure 21

ACODAC DEPLOYMENT AND RECOVERY LOG

Experiment CHURCH GABBRO Area NW CARIBBEAN

ACODAC System No. ______ IPV Ser. 1A1 Mooring Type Woods Hole Freq. Band 15 300 Hz

Hydrophone Type ITC 8020 Weather Clear

Sea Conditions Swell of 4' from SE

Deployment:

Deployment Method RPM last DEPL. NO. 17

	Lat.	Long.	Date/Time (GMT)	Course (°T)	Speed (kts.)
Commenced Operations	17 - 21.0 N	85 - 44.2 W	28 /1100Z	295°	0
1st Gear in Water	17 - 22.3 N	85 - 45.8 W	28 /1204Z	295°	2.1K
IPV in Water	17 - 34.4 N	86 - 01.3 W	28 /2013Z	Water Depth (M)	
Anchor Dropped	17 - 34.4 N	86 - 01.3 W	28 /2014Z		
Mooring Position	17 - 34.3 N	86 - 00.5 W	28 /2110Z		

Recovery

	Lat.	Long.	Date/Time (GMT)	Course (°T)	Speed (kts.)
Commenced Operations	17 - 33.4 N	86 - 02.3 W	09 /0830Z		
Mooring Release	17 - 33.0 N	86 - 04.3 W	09 /1000Z		
Mooring on Surface	17 - 33.0 N	86 - 04.3 W	09 /1005Z		
Mooring on Board	17 - 33.8 N	86 - 02.1 W	09 /1308Z		
IPV Release	17 - 33.6 N	86 - 02.5 W	09 /1100Z		
IPV on Surface	17 - 33.6 N	86 - 04.2 W	09 /1154Z		
IPV on Board	17 - 33.8 N	86 - 02.2 W	09 /1239Z		

Hydrophones:

No.	Depth (M)	Tape Rec. Channel	Ser. No.
1.	508	1	0002
2.	1119	2	0014
3.	2341	3	0011
4.	4053	4	0008
5.	4358	5	0015
6.	4450	6	0013

Bottom 2465 f corrected
4509 m

Time:

Event	Date/Time (GMT)
Osc. Start	/ Z
Tape Start	28 /2232 Z

Delay Interval Set 0 d 2 h 40 m

Delay Cycles Set 16

Duty Cycle 1 : 1

On Time ______ m

Off Time ______ m

Time Code Sync 28/1200 Z 11/28/72
On Recovery 12/9/72 - 1322 Z
Time Code 11 d 01 h 22 min.

Figure 22a

DEPL. NO. 17

Recovery Aids

1. Acoustic Releases

Location	Mfr.	Model	Ser. No.	Chan. No.	Freq. kH_2	Remarks
Upper	AMF	322	401	3	9	
Lower	AMF	322	403	5	11	

2. Timed Release

Location	Mfr.	Model	Ser. No.	Release Time			Set Time			Counter Set No.
				d	h	m	d	h	m	
Lower	Geodyne	855	0634	11	08	00	27	12	00	1328

Disarmed on Recovery 09 08 30

Red 293
Blue 1135

3. Radio Beacons

Location	Mfr.	Model	Ser.No.	Chan. Letter	Freq.	Remarks
Top Buoy	OAR	ST-206-1-100-PA	751	A	26.995	
RPM	OAR	ST-206-1-100-PA	752	C	27.095	
RPM	OAR	ST-206-12	534	D	27.145	

4. Flashers

Location	Mfr.	Model	Ser. No.	Remarks
Top Buoy	OAR	SF-506-1-100	288	
RPM	OAR	SF-500-1-100	343	

NOTES:

1. Channel 2 Gain Ckt. - Locked on 40 db gain.
2. Hydrophones 3 & 6 suspended by surgical tubing.

Figure 22b

ACODAC DEPLOYMENT AND RECOVERY LOG

Experiment CHURCH GABRO Area NW CARIBBEAN

ACODAC System No. ________ IPV Ser. 2A3 Mooring Type Westinghouse Freq. Band 15 300 Hz

Hydrophone Type Westinghouse Weather Clear, Vis 25 mi, W 10K from South

Sea Conditions ________

Deployment:

Deployment Method RPM last DEPL. NO. 18

	Lat.		Long.		Date/Time (GMT)	Course (°T)	Speed (kts.)
Commenced Operations	19 - 54.4 N		84 - 50.5 W		26 / 1400Z	000	0
1st Gear in Water	19 - 54.7 N		84 - 50.0 W		26 / 1415Z	000	1.0
IPV in Water	20 - 00.4 N		85 - 00.4 W		26 / 2231Z	045 Water Depth (M)	0
Anchor Dropped	20 - 00.4 N		85 - 00.4 W		26 / 2234Z	045	0
Mooring Position	20 - 00 N		84 - 58.7 W		26 / 2230Z		

Recovery

	Lat.	Long.	Date/Time	Course (°T)	Speed (kts.)
Commenced Operations	- N	- W	/ Z		
Mooring Release	- N	- W	/ Z		
Mooring on Surface	- N	- W	/ Z		
Mooring on Board	- N	- W	/ Z		
IPV Release	- N	- W	/ Z		
IPV on Surface	- N	- W	/ Z		
IPV on Board	- N	- W	/ Z		

Hydrophones:

No.	Depth (M)	Tape Rec. Channel	Ser. No.
1.	595	1	2
2.	1205	2	24
3.	2426	3	15
4.	4137	4	20
5.	4443	5	22
6.	4535	6	27

Bottom 2511 f
4593 m

Time:

Event	Date/Time (GMT)
Osc. Start	/ Z
Tape Start	29 /1504Z

Delay Interval Set 2 d 18 h 40 m

Delay Cycles Set 400

Duty Cycle 1 : 1

On Time ________ m

Off Time ________ m

Time Code Sync 1200 z 11/26/72

Figure 23a

DEPL. NO. 18

Recovery Aids

1. Acoustic Releases

Location	Mfr.	Model	Ser. No.	Chan. No.	Freq. kH_2	Remarks
Upper	AMF	322	399	1	9	
Lower	AMF	322	405	10	11	

2. Timed Release

Location	Mfr.	Model	Ser. No.	Release Time d	h	m	Set Time d	h	m	Counter Set No.
Lower	Geodyne	855	0653	13	08	00	25	18	00	1688

3. Radio Beacons

Location	Mfr.	Model	Ser. No.	Chan. Letter	Freq. Hz	Remarks
Top Buoy	OAR	ST-206-1 -100 PA	766	C	27.095	
RPM	OAR	ST-206-1 -100 PA	763	A	26.995	
RPM	OAR	ST-206-12	491	D	27.145	

4. Flashers

Location	Mfr.	Model	Ser. No.	Remarks
Top Buoy	OAR	SF-500-1 -100	342	
RPM	OAR	SF-500-1 -100	289	

Figure 23b

ACODAC DEPLOYMENT AND RECOVERY LOG

Experiment CHURCH GABRO Area NW CARIBBEAN

ACODAC System No. ________ IPV Ser. 2A4 Mooring Type compliant (UM) Freq. Band __________ ______ Hz

Hydrophone Type ITC 8020 Weather Clear, wind

Sea Conditions Sea State 3

Deployment:

Deployment Method RPM last Depl. No. 19

	Lat.	Long.	Date/Time (GMT)	Course (°T)	Speed (kts.)
Commenced Operations	18 - 50.0 N	79 - 48.5 W	30 /1755Z	267	0
1st Gear in Water	18 - 50.0 N	79 - 46.3 W	30 /1821Z	~~267~~ 240	~~0~~ 12
IPV in Water	18 - 48.7 N	79 - 52.5 W	30 /2120Z	Water Depth (M)	
Anchor Dropped	18 - 48.7 N	79 - 52.5 W	30 /2120Z		0
Mooring Position	18 - 49.0 N	79 - 52.7 W	30 /2240Z		0

Recovery

	Lat.	Long.	Date/Time (GMT)	Course (°T)	Speed (kts.)
Commenced Operations	18 - 50.2 N	79 - 53.0 W	15 /1120Z		
Mooring Release	18 - 50.2 N	79 - 53.2 W	15 /1146Z		0
Mooring on Surface	18 - 50.0 N	79 - 52.0 W	15 /1159Z	090°	1
Mooring on Board	18 - 49.5 N	79 - 51.7 W	15 /1545Z	230°	0
IPV Release	18 - 49.2 N	79 - 51.3 W	15 /1555Z		
IPV on Surface	18 - 49.4 N	79 - 51.5 W	15 /1702Z		
IPV on Board	18 - 49.4 N	79 - 51.5 W	15 /1729Z		

Hydrophones:

No.	Depth (M)	Tape Rec. Channel	Ser. No.
1.	966	1	001
2.	1576	2	004
3.	2757	3	005
4.	4410	4	006
5.	4715	5	012
6.	4806	6	009

Bottom 2642 f
4833 m

Time:

Event	Date/Time (GMT)
Osc. Start	___/___Z
Tape Start	30 /2310 Z

Delay Interval Set ___ d 2 h 40 m

Delay Cycles Set 16

Duty Cycle 1 : 1

On Time ________ m

Off Time ________ m

time code sync 1200 Z 11/30/72
on recovery 1746 Z 12/15/72
time code 15 d 5h 46m

Figure 24a

DEPL. NO. 19

Recovery Aids

1. Acoustic Releases

Location	Mfr.	Model	Ser. No.	Chan. No.	Freq. kH$_2$	Remarks
Upper	AMF	322	400	2	9	
Lower	AMF	322	404	6	11	

2. Timed Release

Location	Mfr.	Model	Ser. No.	Release Time			Set Time			Counter Set No.
				d	h	m	d	h	m	
Lower	Geodyne	855	0648	16	08	00_R	29	10	45_R	1621

Disarmed on recovery 12/15/72
time 1530 Q
red 170
black 1539

should have read:
Black 1555 Unit was slow by 4 hrs.

3. Radio Beacons

Location	Mfr.	Model	Ser. No.	Chan. Letter	Freq. mHz	Remarks
Top Buoy	OAR	ST-206 1-100PA	768	D	27.145	
RPM	OAR	ST-206-1-100PA	765	B	27.045	
RPM	OAR	ST-206-12	489	A	26.995	

4. Flashers

Location	Mfr.	Model	Ser. No.	Remarks
Top Buoy	OAR	SF-506-1-160	287	
RPM	OAR	SF-500-1-100	346	

NOTES:
1. Telemetry from RPM indicates all channels with data except #1; all voltages normal
2. IPV check on recovery indicates all voltages normal.

Figure 24b

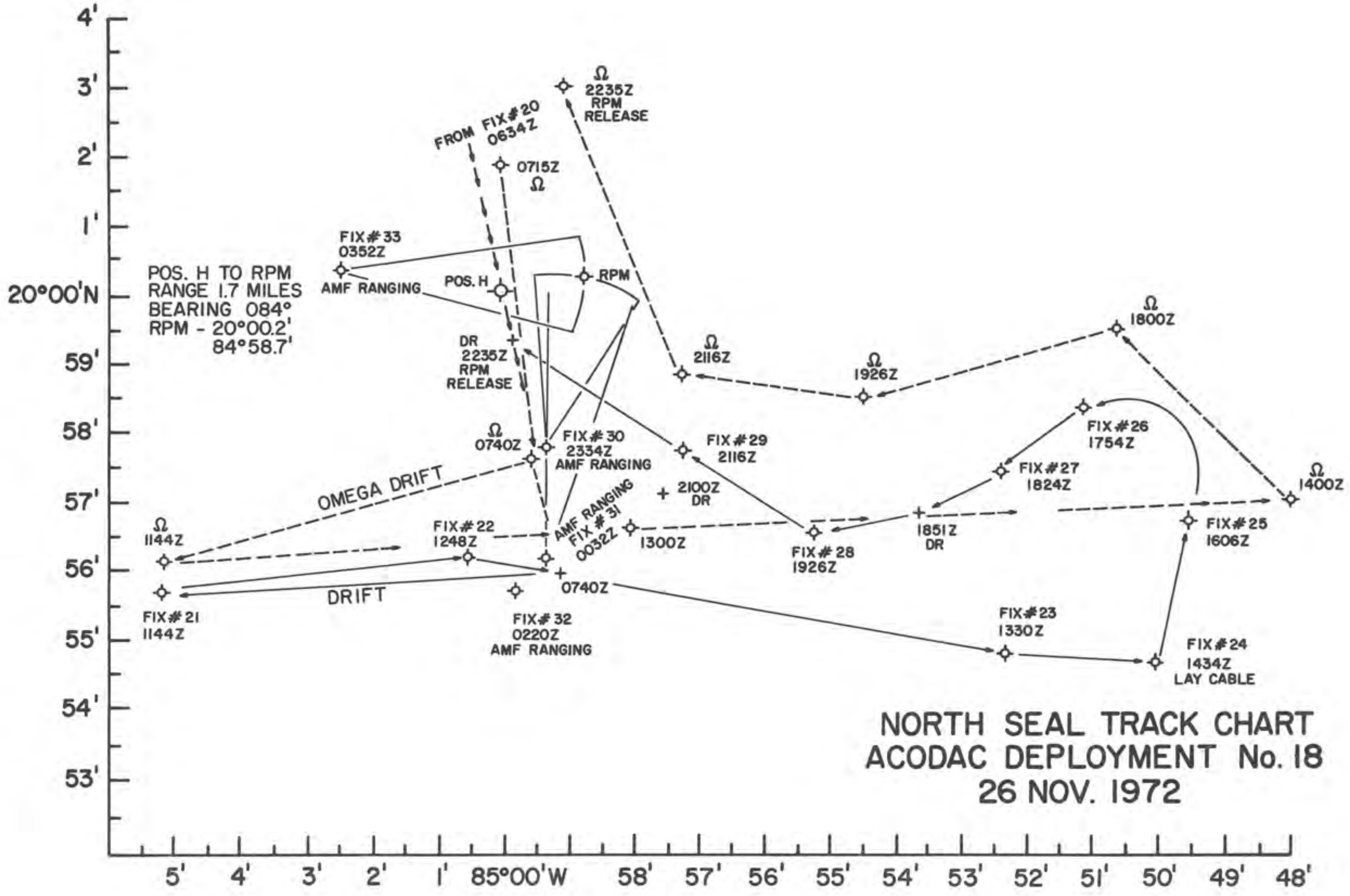

NORTH SEAL TRACK CHART
ACODAC DEPLOYMENT No. 18
26 NOV. 1972
POS. H TO RPM
RANGE 1.7 MILES
BEARING 084°
RPM - 20°00.2'
84°58.7'
4'
3'
2'
1'
20°00'N
59'
58'
57'
56'
55'
54'
53'
5'
4'
3'
2'
1'
85°00'W
58'
57'
56'
55'
54'
53'
52'
51'
50'
49'
48'
Ω 2235Z RPM RELEASE
FROM FIX #20 0634Z
0715Z Ω
FIX #33 0352Z
AMF RANGING
POS. H
RPM
DR 2235Z RPM RELEASE
Ω 2116Z
Ω 1926Z
Ω 1800Z
Ω 0740Z
FIX #30 2334Z AMF RANGING
FIX #29 2116Z
FIX #26 1754Z
FIX #27 1824Z
Ω 1400Z
OMEGA DRIFT
2100Z DR
AMF RANGING FIX #31 0032Z
Ω 1144Z
FIX #22 1248Z
1300Z
FIX #28 1926Z
1851Z DR
FIX #25 1606Z
0740Z
DRIFT
FIX #21 1144Z
FIX #32 0220Z AMF RANGING
FIX #23 1330Z
FIX #24 1434Z LAY CABLE

Figure 25

Figure 25

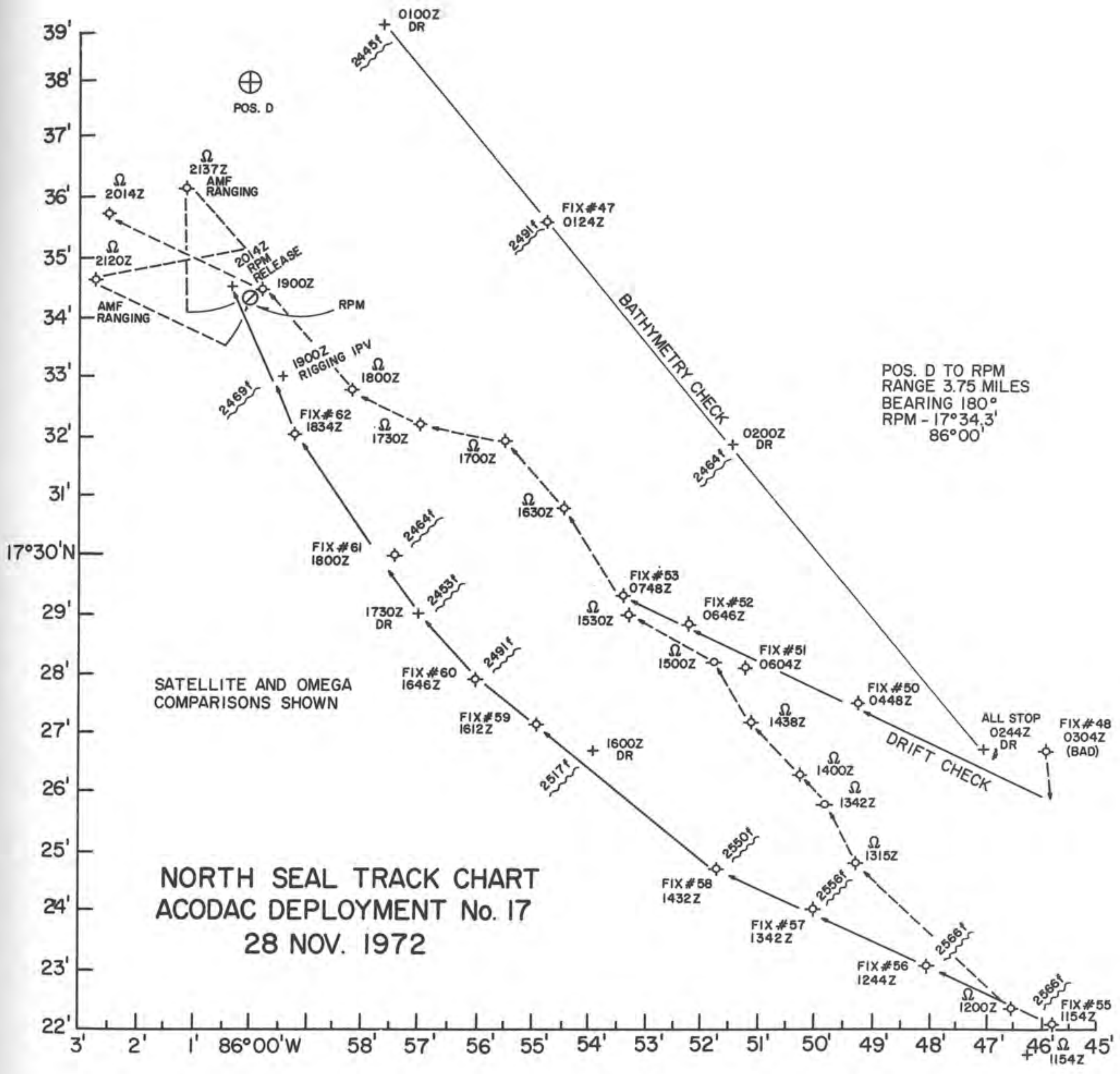


Figure 26

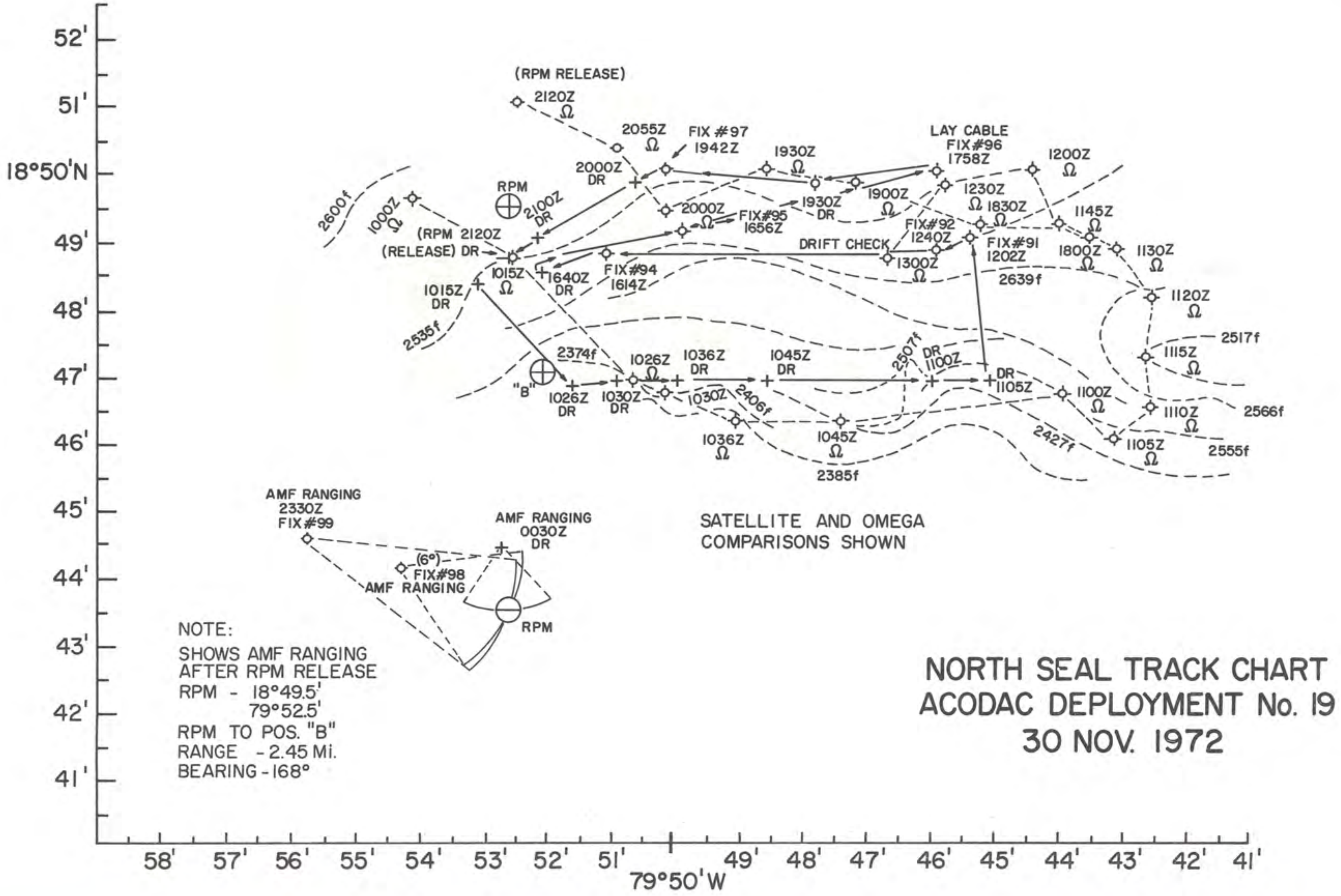
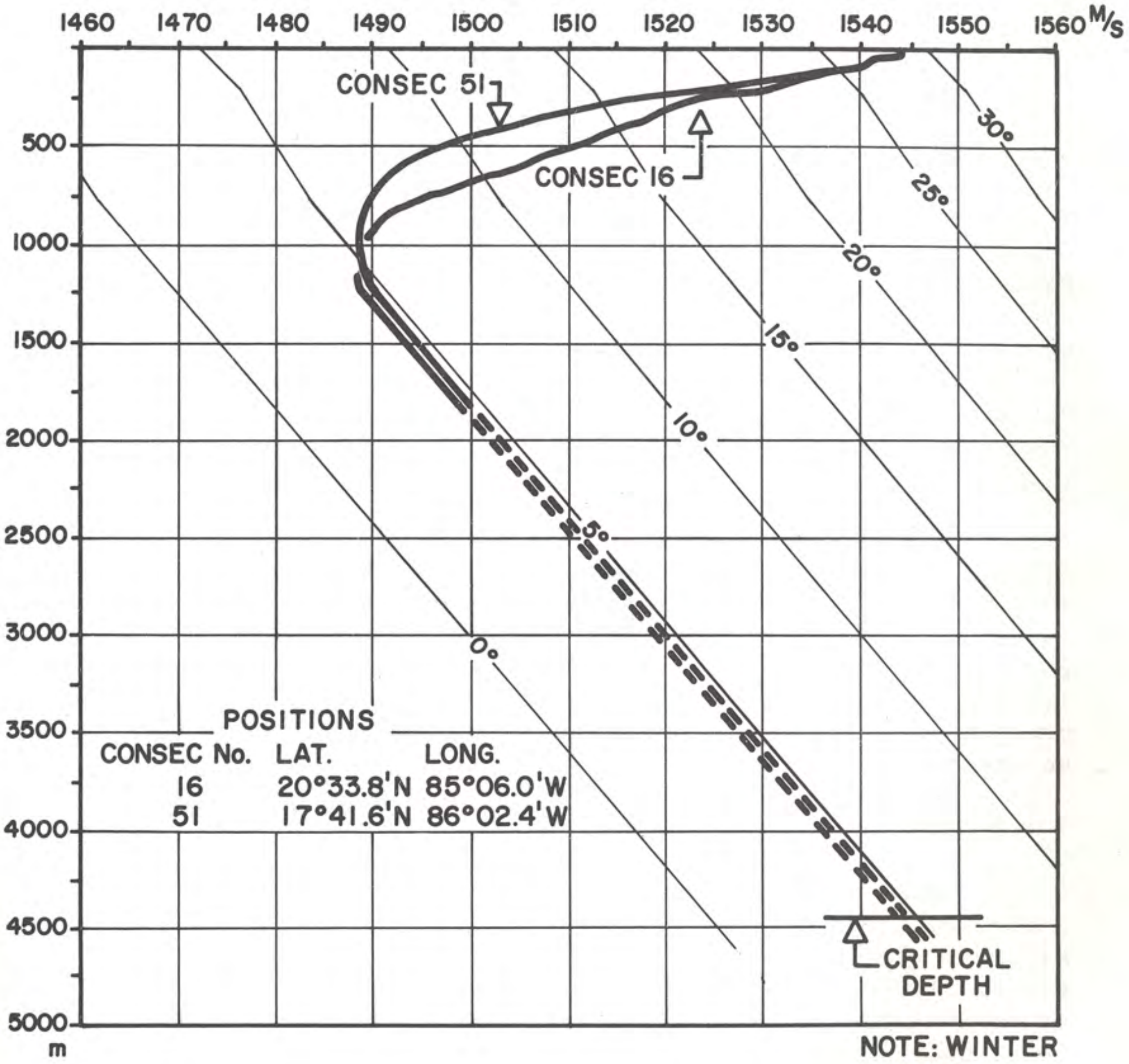

NORTH SEAL TRACK CHART
ACODAC DEPLOYMENT No. 19
30 NOV. 1972
SATELLITE AND OMEGA
COMPARISONS SHOWN
NOTE:
SHOWS AMF RANGING
AFTER RPM RELEASE
RPM - 18°49.5'
79°52.5'
RPM TO POS. "B"
RANGE - 2.45 Mi.
BEARING - 168°
52'
51'
18°50'N
49'
48'
47'
46'
45'
44'
43'
42'
41'
58'
57'
56'
55'
54'
53'
52'
51'
79°50'W
49'
48'
47'
46'
45'
44'
43'
42'
41'
(RPM RELEASE)
2120Z
Ω
2055Z
Ω
FIX #97
1942Z
1930Z
Ω
LAY CABLE
FIX#96
1758Z
1200Z
Ω
2000Z
DR
RPM
2100Z
DR
2000Z
Ω
FIX#95
1656Z
1930Z
DR
1900Z
Ω
1230Z
Ω
1830Z
Ω
1145Z
Ω
2600f
1000Z
Ω
(RPM 2120Z
(RELEASE) DR
FIX#92
1240Z
DRIFT CHECK
FIX#91
1202Z
1800Z
Ω
1130Z
Ω
1015Z
Ω
1640Z
DR
FIX#94
1614Z
1300Z
Ω
2639f
1015Z
DR
1120Z
Ω
2535f
2517f
2374f
1026Z
Ω
1036Z
DR
1045Z
DR
2507f
DR
1100Z
1115Z
Ω
"B"
1026Z
DR
1030Z
DR
1030Z
2406f
DR
1105Z
1100Z
Ω
2566f
1110Z
Ω
1036Z
Ω
1045Z
Ω
2427f
1105Z
Ω
2555f
2385f
AMF RANGING
2330Z
FIX#99
AMF RANGING
0030Z
DR
(6°)
FIX#98
AMF RANGING
RPM

Figure 27



POSITIONS

CONSEC No.	LAT.	LONG.
16	20°33.8'N	85°06.0'W
51	17°41.6'N	86°02.4'W

Sound Velocity Profiles
Derived From Temperature Profiles,
(Assuming Standard Salinity Profile)

Figure 28

number 5 were as follows: deployment no. 17 (Point D) - 4358 meters; deployment no. 18 (Point H) - 4443 meters; deployment no. 19 (Point B) - 4715 meters. The "winchless" method at deployment of the compliant array is illustrated in Figure 29.

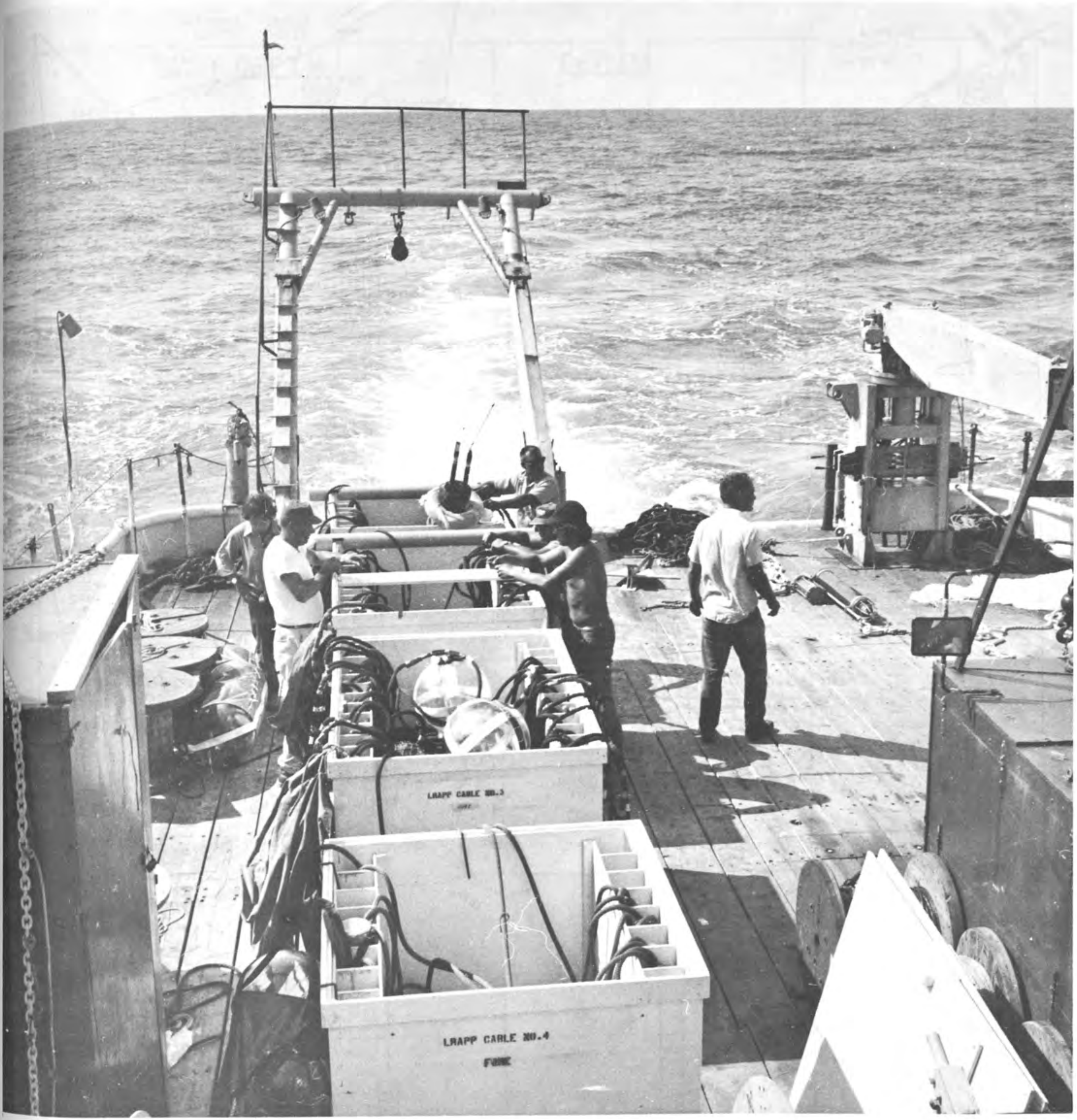
Deployment and recovery times are summarized below:

Position	Deployment No.	Deployment Time	Recovery Time
D	17	8 hr 10 min	3 hr 03 min
H	18	8 hr 19 min	-------------
B	19	2 hr 59 min	3 hr 46 min

The system at Point H was not recovered during the exercise. A detailed acoustic search for the AMF release transponders was conducted from 10 through 13 December. In addition, on 12 and 13 December VP aircraft conducted a visual and radio search (for the OAR radio beacon) in the area, concentrating on the NW octant centered at Position H, and extending past the Yucatan Straits, but also covering the entire area within 15 miles of Position H. The track chart for the acoustic search is shown in Figure 30. The entire search was fruitless, leading to the conclusion that the mooring was no longer where it was deployed. This conclusion was confirmed by the subsequent location and recovery of the entire mooring in the vicinity of Fort Lauderdale, Florida. The acoustic release had not fired; the timed release had fired, but indicated the correct number of counts for a scheduled firing on 13 December at 1200Z. Evidence from the acoustic record shows that the most probable time of breaking loose was on 7 December at about 0100Z. The most likely cause of failure was chafing of the lower section of nylon rope between the anchor and release. It is possible that the failure to burden the anchor smoothly onto the mooring during deployment could have contributed to the parting of this section of line. For a report by Texas Instruments of the failure see Reference (28).

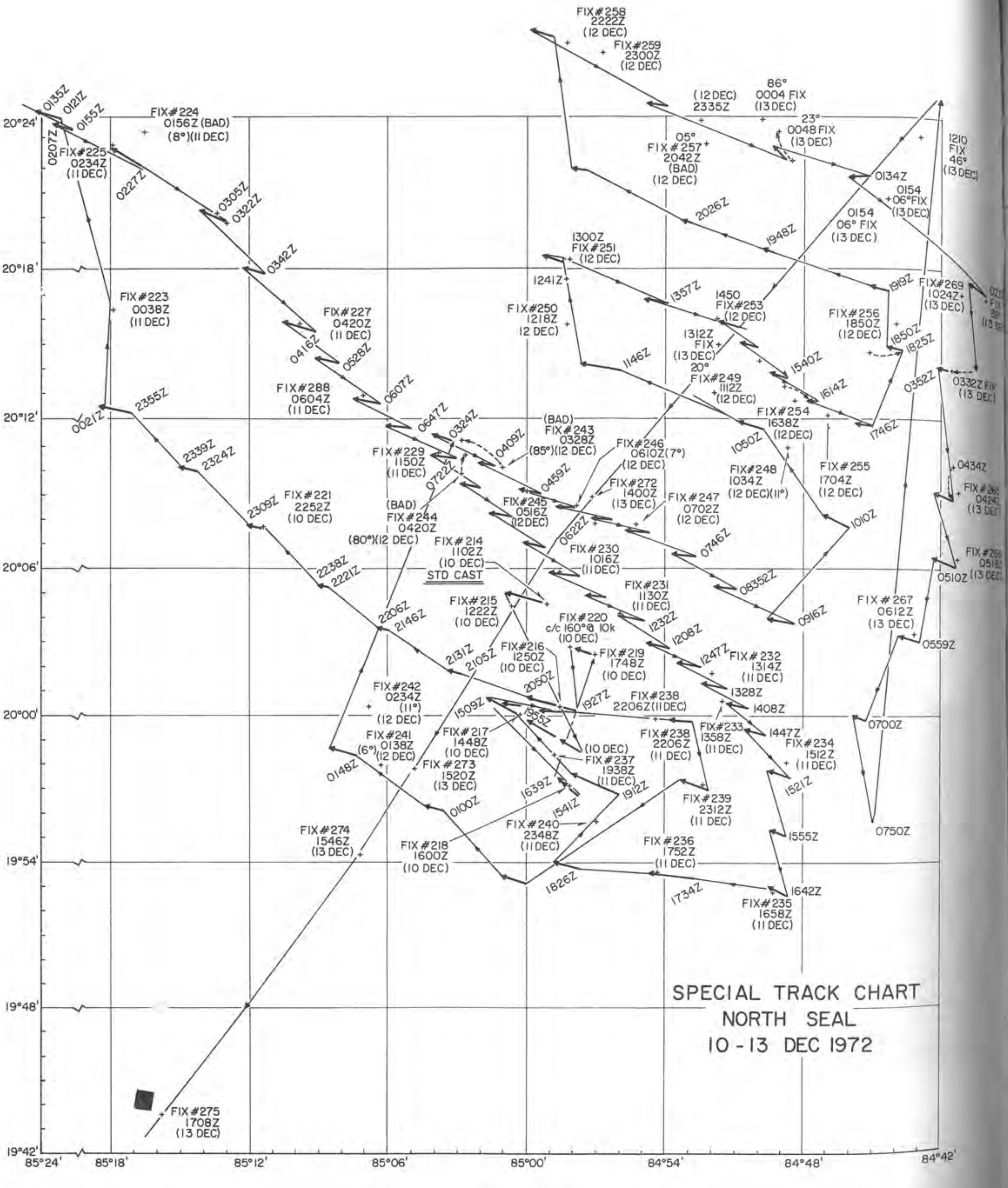
2.1.2 THE MOORED ACOUSTIC BUOY SYSTEM (MABS)

MABS is a calibrated, ship transportable system for the recording of ocean ambient acoustic noise and other underwater acoustic signals. For a description of MABS see Reference (10). As shown in Figure 31, for this exercise it consisted of four hydrophones suspended at nominal depths of 61 meters, 128 meters, 357 meters, and 966 meters. These hydrophones were suspended below a sub-surface buoy (~50 meters) which contained the electronics and logics of the system. The sub-surface buoy was an international-orange and yellow ellipsoid with dimensions 6 feet by 3.5 feet. The buoy with its integral instrumentation capsule weighed 2200 lbs. and was 1900 lbs. buoyant when submerged in sea water. It is equipped with pad-eyes for lashing to the deck. It also has two flashing lights and a radio beacon to aid in recovery. At the terminus of the 915 meters of electrical cable was approximately



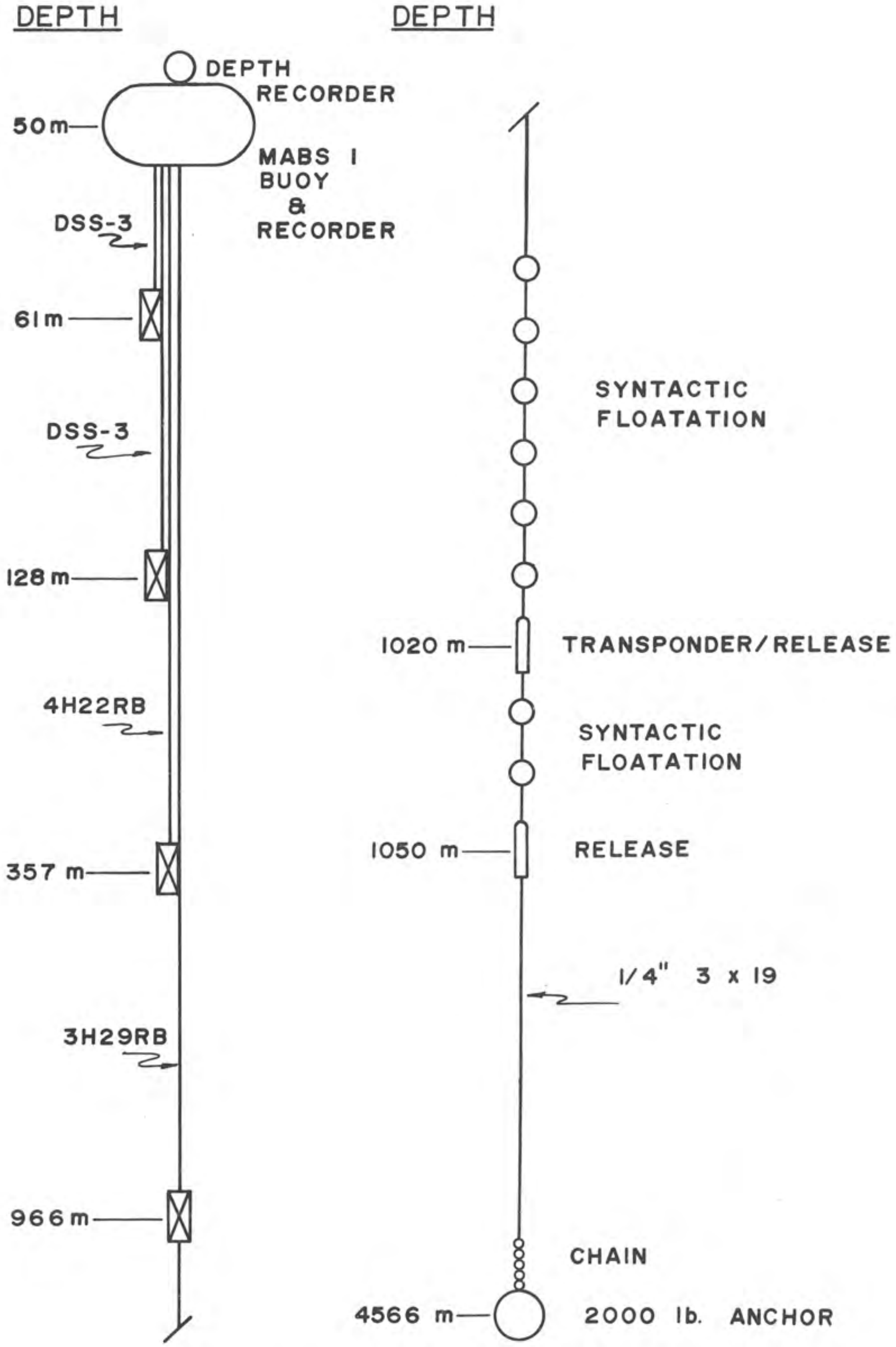
Compliant Array Ready for Deployment

Figure 29



SPECIAL TRACK CHART
NORTH SEAL
10 - 13 DEC 1972

Figure 30



MABS Configuration

Figure 31

3,660 meters of 3/8" steel wire connected to the electrical by an AMF acoustic release and transponder in series. The anchor was a 2220 lb. clump.

A five hydrophone single cable array was to have been used during the exercise; however, due to manufacturer's delays this array was not available. The make-shift four hydrophone array was used as back-up. This array had separate cables to each hydrophone. The cables were married using tie-wraps and only the areas in the vicinity of the hydrophones were faired. The hydrophones with their associated cable were calibrated against a reference hydrophone at NUSC's Millstone Quarry during the last part of October 1972.

The hydrophones used were NUS Corporation LM-3 deep sea hydrophones; see Reference (20). These were chosen because of their relatively flat frequency response between 10 Hz and 20 kHz and also because they have stable sensitivity over the extremes of pressure and temperature found in the ocean. A representative terminal sensitivity of one of these hydrophones including the internal 28 lb preamplifier and cable in -165 db/1 volt for sound pressure field of 1 uPa. The hydrophones are not generally recalibrated after an exercise because of the expense involved. However, a recalibration would be conducted if warrented by an obvious defect. The calibrations of these hydrophones have been found to be generally invariant in the past.

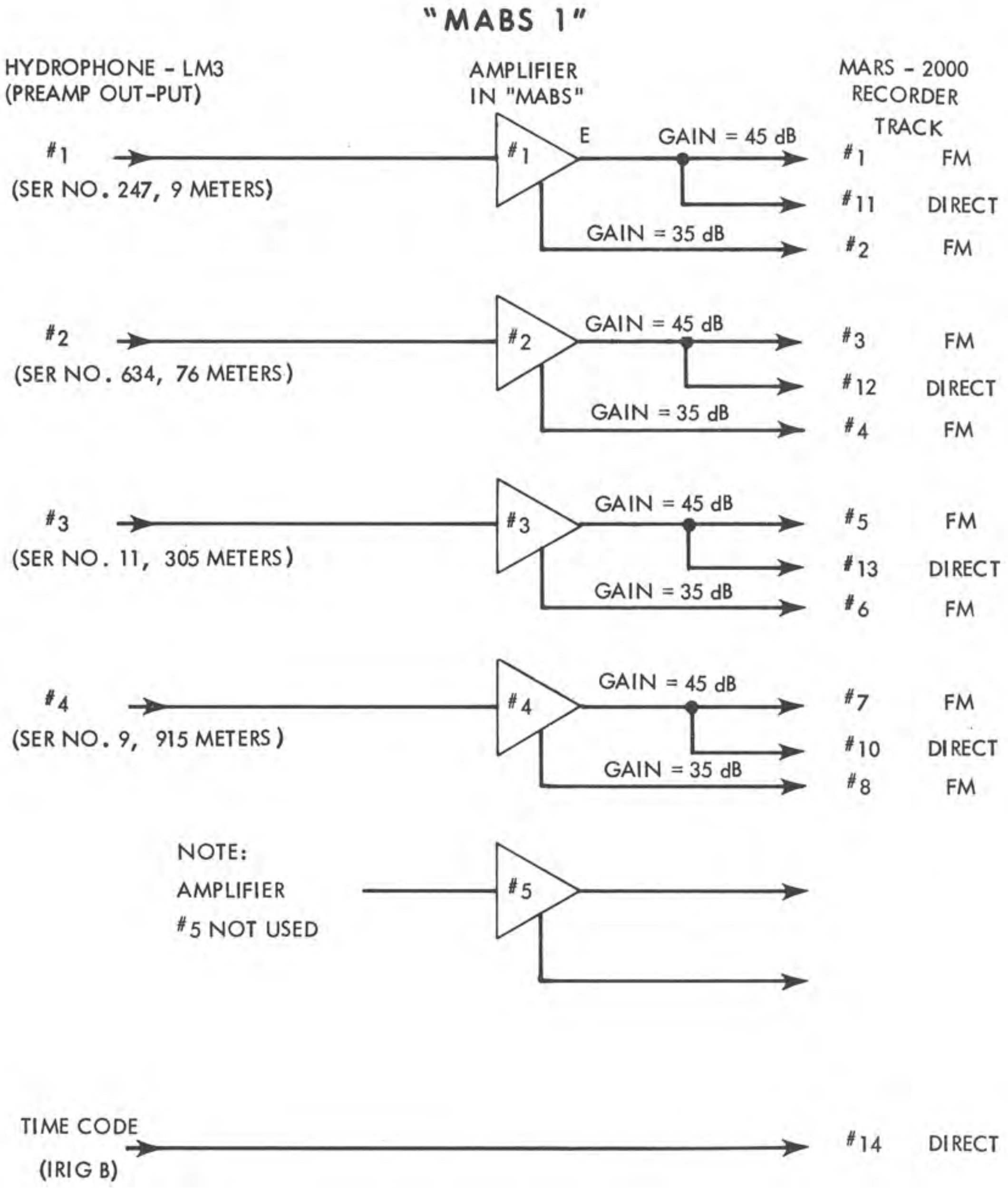
The received acoustic signals are fed onto the instrumentation capsule where they are recorded for 30 seconds every 15 minutes. Before being recorded the signals are amplified (+45 db for Hi-Gain channels and +35 db for Lo-Gain channels) as indicated in Figure 32. The recorder used is the Astroscience MARS 2000 unit using a speed of 1 7/8 IPS. This recorder has a modified carrier frequency for extended band on the FM channels.

Calibration signals injected at the input of the amplifiers were recorded for 30 seconds every four hours; see Figure 33. These calibration signals consisted of wide-band pseudo-random noise and a 1 kHz sine-wave tone.

The system deployed well except for the instrumentation sphere overturning for a short while. This later proved to be a major problem because the shallowest hydrophone parted electrically and rendered no data. Total deployment on 3 December 1972 took five hours and 24 minutes with the array in 4566 meters of water at 19°10.87'N, 76°49.9'W. A Benthos depth recorder attached to the buoy showed depth changes from 40 meters to 100 meters during the recording period. The array was retrieved on 12 December in six hours. The retrieval was complicated by some floats fouling about the ship's bow thruster.

Data Quality

The quality of data recorded by MABS is in general good. It

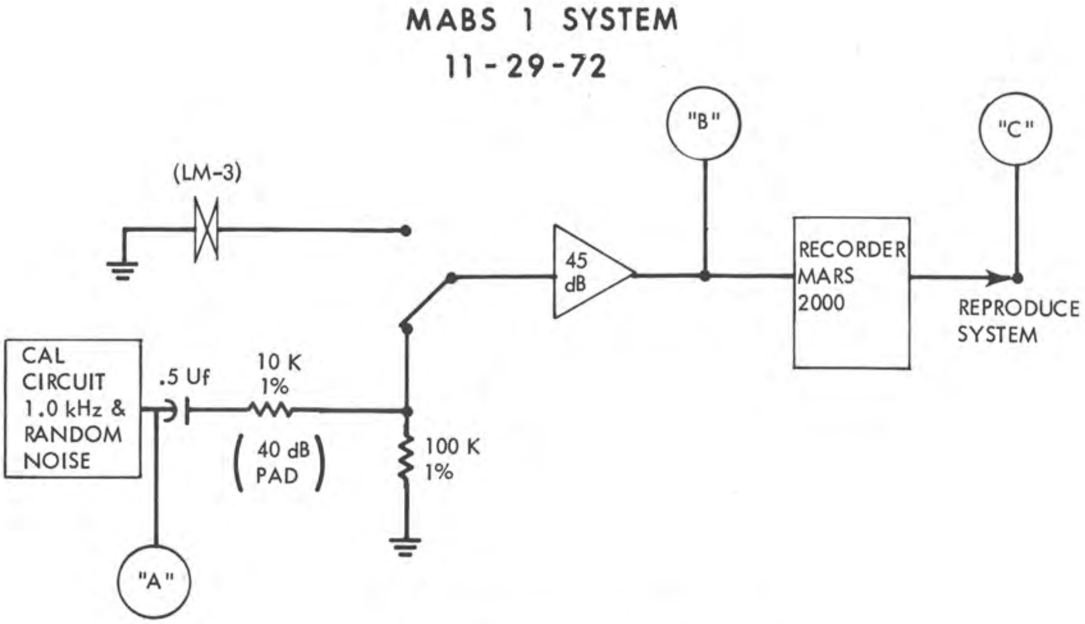


MABS Signal Processing Scheme

Figure 32

Naval Underwater Systems Center
NP24 - 49217 - 4 - 73

Official Photograph



CAL SIGNALS (dB // 1.0V)

	"A"	"B"	"C"
1.0 kHz	- 12.5 dB	- 8.0 dB	- 8.0 dB
RANDOM NOISE (BROAD-BAND)	- 12.5 dB	- 8.0 dB	- 10.25 dB
COMBINED SIGNALS (BROAD-BAND)	- 10.25 dB	- 5.25 dB	- 6.25 dB

MABS Calibration Scheme

Figure 33

recorded data for eight days and eleven hours. The shallowest hydrophone was inoperative and the deeper units were subject to intermittent low-frequency strum of 3.25 Hz which generally could be filtered out and did not distort higher frequency data. It is felt that the strum would be all but absent if the single-cable faired array had been used.

2.1.3 TELEMETERING ACOUSTIC BUOY SYSTEM (TABS)

The Telemetering Acoustic Buoy System (TABS) used during this exercise consisted of two hydrophone faired cable array suspended below a telemetering spar buoy which transmitted the received acoustic signals via R.F. link to SANDS where the data were demodulated and recorded on magnetic tape; see Figure 34. TABS was deployed for a ten hour period in the vicinity of position C on 7 December 1972 for the aircraft SUS run.

The hydrophones, which were at depths of 244 meters and 396 meters, were NUS Corporation LM-3 units that have been previously described in the MABS section of this report. The hydrophones were calibrated against a reference hydrophone in July 1972 at NUSC's Dodge Pond Calibration Facility. Prior to deployment the system was calibrated by injecting single frequency sine-wave signals of known levels at the center frequency of all the 1/3-octave bands of interest at the input to the transmitting buoy. These signals were recorded on magnetic tape as received throughout the entire receiving system. In this manner the whole system was calibrated.

TABS took less than one hour to deploy and one hour to retrieve. A radio beacon and flashing light attached to a satellite buoy facilitates recovery.

The acoustic signals received by the hydrophone of TABS were sent to SSQ-41 SONOBUOY transmitters in the spar buoy where they are modulated transmitted to the SANDS; see Figure 35. SANDS received the signals on an ARR-52 SONOBUOY receiver (High Output) where they were demodulated and then were attenuated by 25 db. The signals were then split into High and Low Gain sections (10 db difference) at the input to separate Ithaco amplifiers. From the amplifier the signals were recorded on magnetic tape (Ampex CP-100 recorder). The signals were recorded FM at 3 3/4 IPS. Signals from the reproduce mode of the recorder were then fed to 1/3-octave filters and the outputs monitored on an 8 channel Sanborn graphic recorder.

The receiver and recorder calibration systems are shown schematically in Figure 36.

TABS performed quite well during the first part of the SUS run; however, during the last two hours of the run the system became quite noisy. It has not been determined at present whether this noise was water-borne (strum, etc.) or RF interference.

Naval Underwater Systems Center
NP24 - 49221 - 4 - 73

Official Photograph

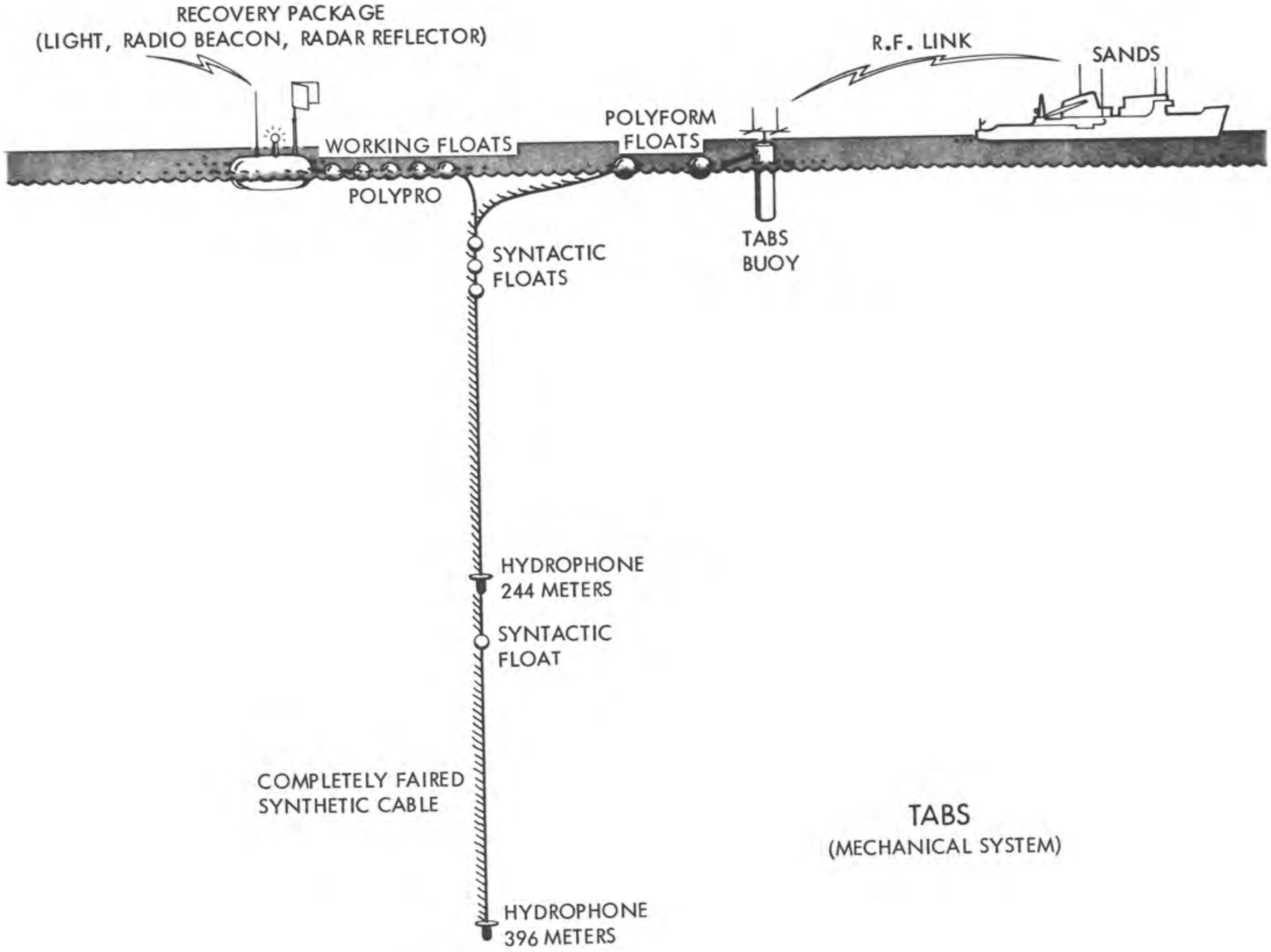
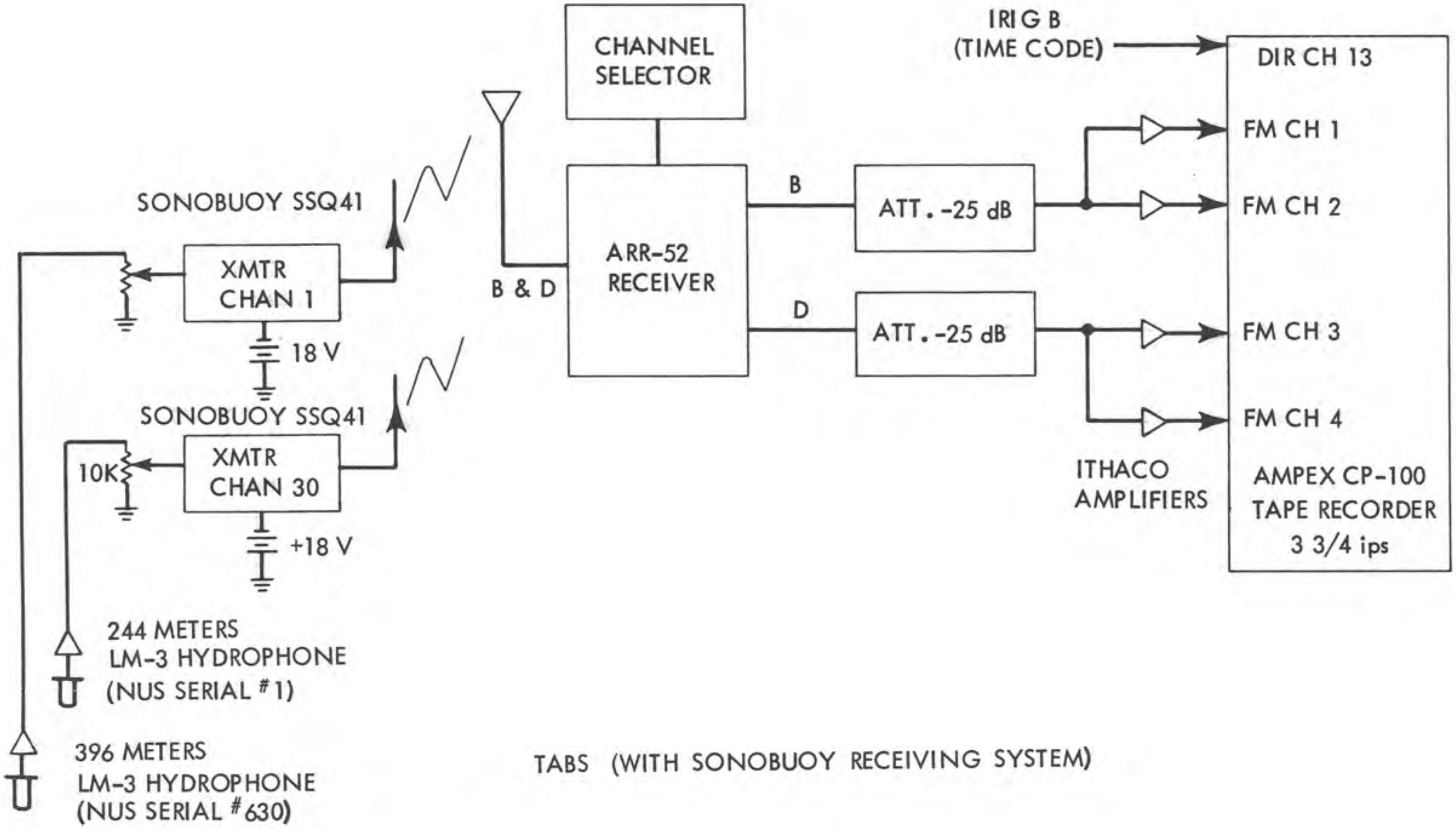


Figure 34

Figure 34

Naval Underwater Systems Center
NP24 - 49223 - 4 - 73

Official Photograph

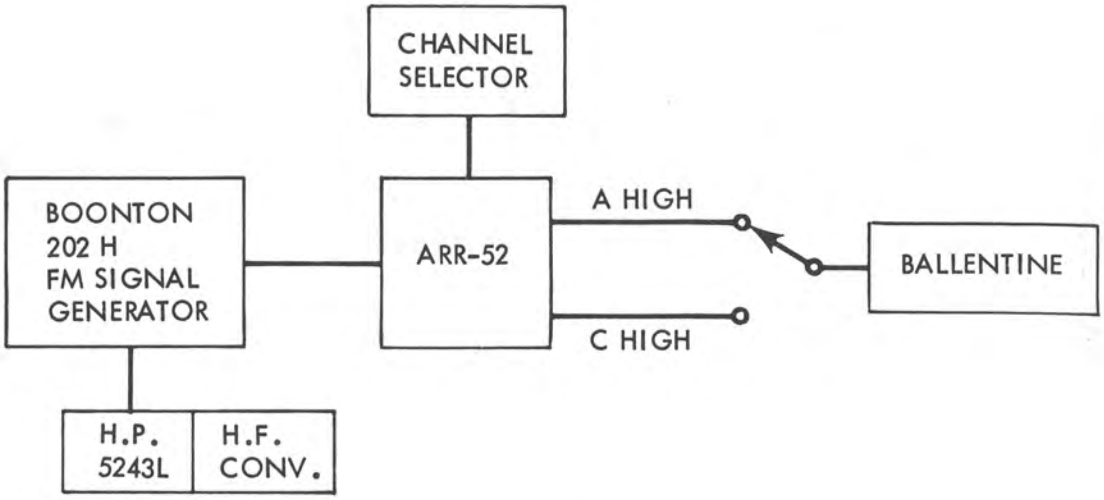


TABS (WITH SONOBUOY RECEIVING SYSTEM)

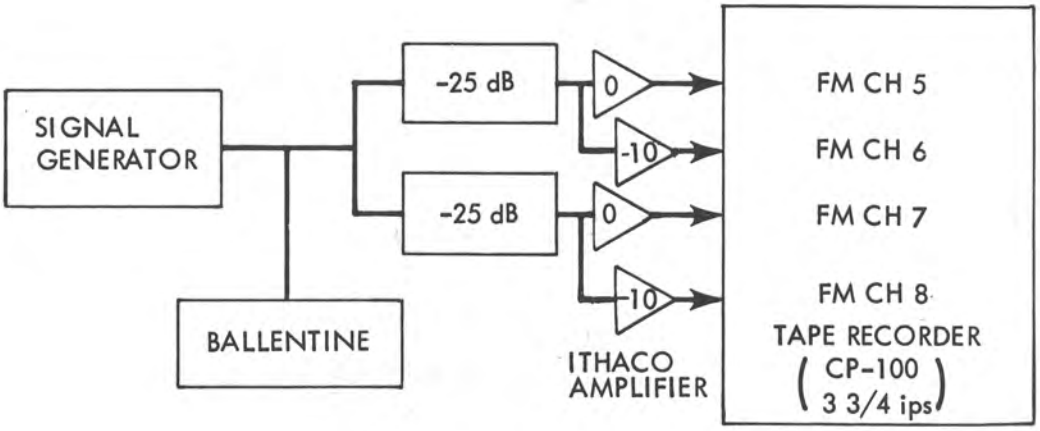
Figure 35

Naval Underwater Systems Center
NP24 - 49219 - 4 - 73

Official Photograph



RECEIVER CAL SYSTEM



RECORDER CAL SYSTEM

TABS Calibration System

Figure 36

2.1.4 VLAM

A. General

A general overview of the major components of the vertical line array measurement system (VLAM) is presented in Figure 37. For a description of the VLAM system see Reference (1), from which figures 37-42 are taken. These components comprise a general-purpose multi-channel acoustic data gathering system.

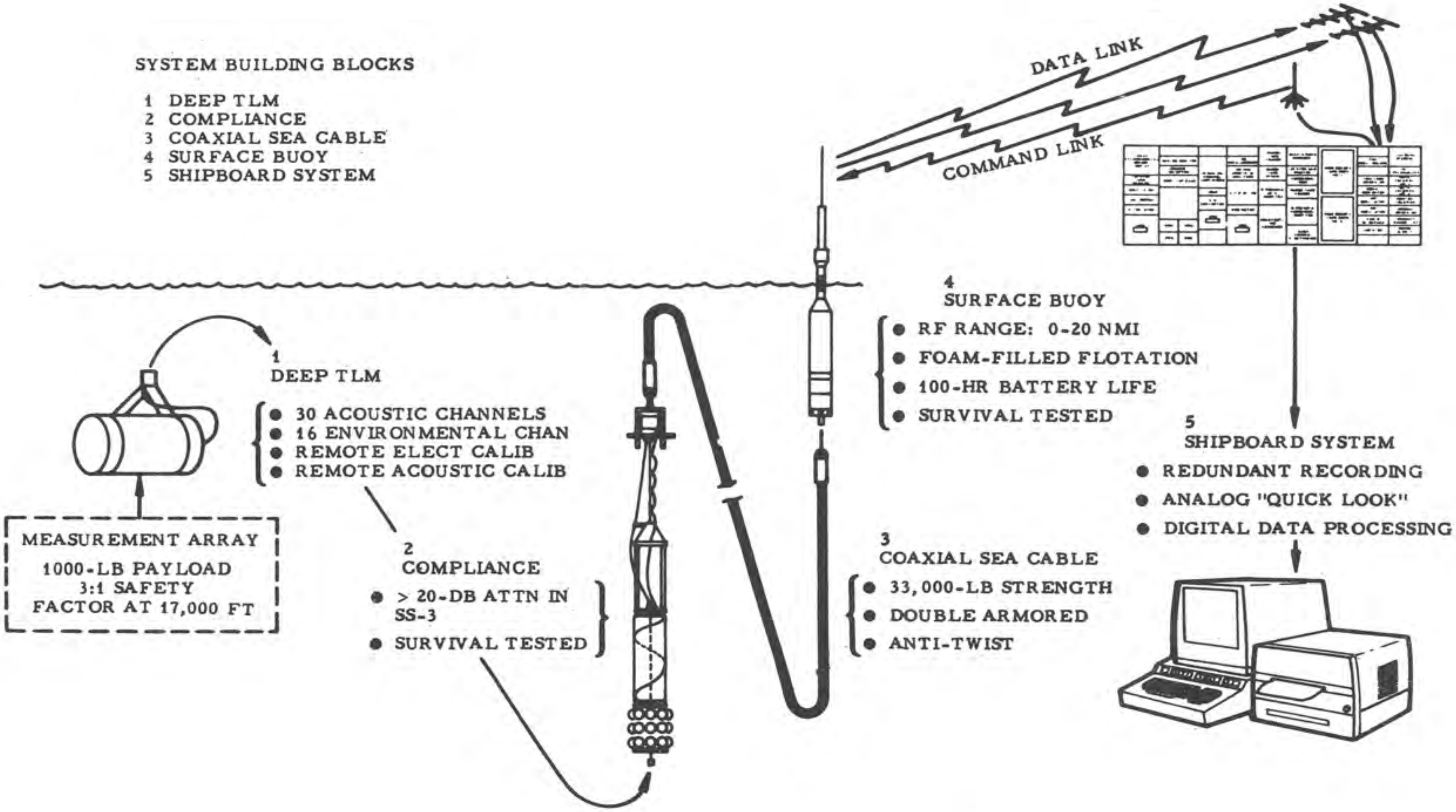
VLAM consist of an array of acoustic sensors, the deep telemetry system, a set of deep sea coaxial cables, hydrodynamic decoupling mechanisms, surface support buoys, an RF dual diversity data and command link, and a complete shipboard receiving, recording, and on-line processing system. These basic system elements may be thought of as building blocks and may be used in any combination required for a specific measurement mission. This system is deployed from the surface support buoy.

B. In-Water System

(1). General

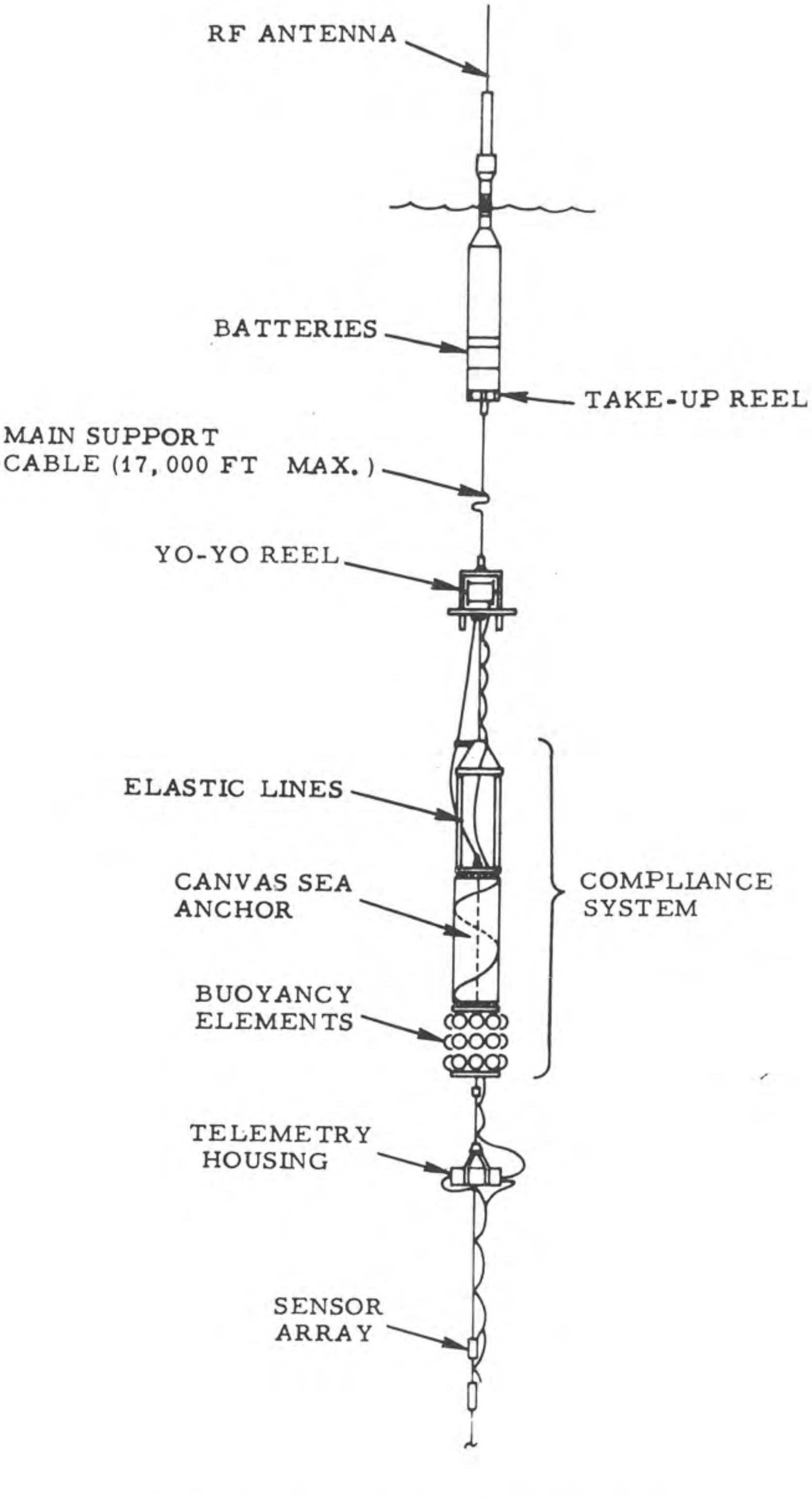
The deployed in-water system of VLAM is shown in Figure 38. It has the sensor array, which has 26 acoustic hydrophones, three two-axis tilt sensors, three high-frequency accelerometers, a velocimeter, a current sensor, depth sensor and three compasses. In addition, there are the other sub-systems that deploy the sensor array and handle the data up through the RF telemetry link to the ship board electronics.

(2). The hydrophone module is a stainless-steel assembly which houses the hydrophone and its preamplifier. The phone, of lead zirconian titanate, is a two-element acceleration balanced unit suspended by a rubber isolation within the module. The low-noise preamplifier protected within its own pressure vessel is located adjacent but out of acoustic view of the hydrophone. Connections to the preamplifier and hydrophone are via Marsh-Marine connectors. The entire module is covered with a rubber shield to reduce flow noise.



Major Components of VLAM System
(From Reference (1))

Figure 37



VLAM In-Water System Fully Deployed
(From Reference (1))

Figure 38

Hydrophone parameters follow:

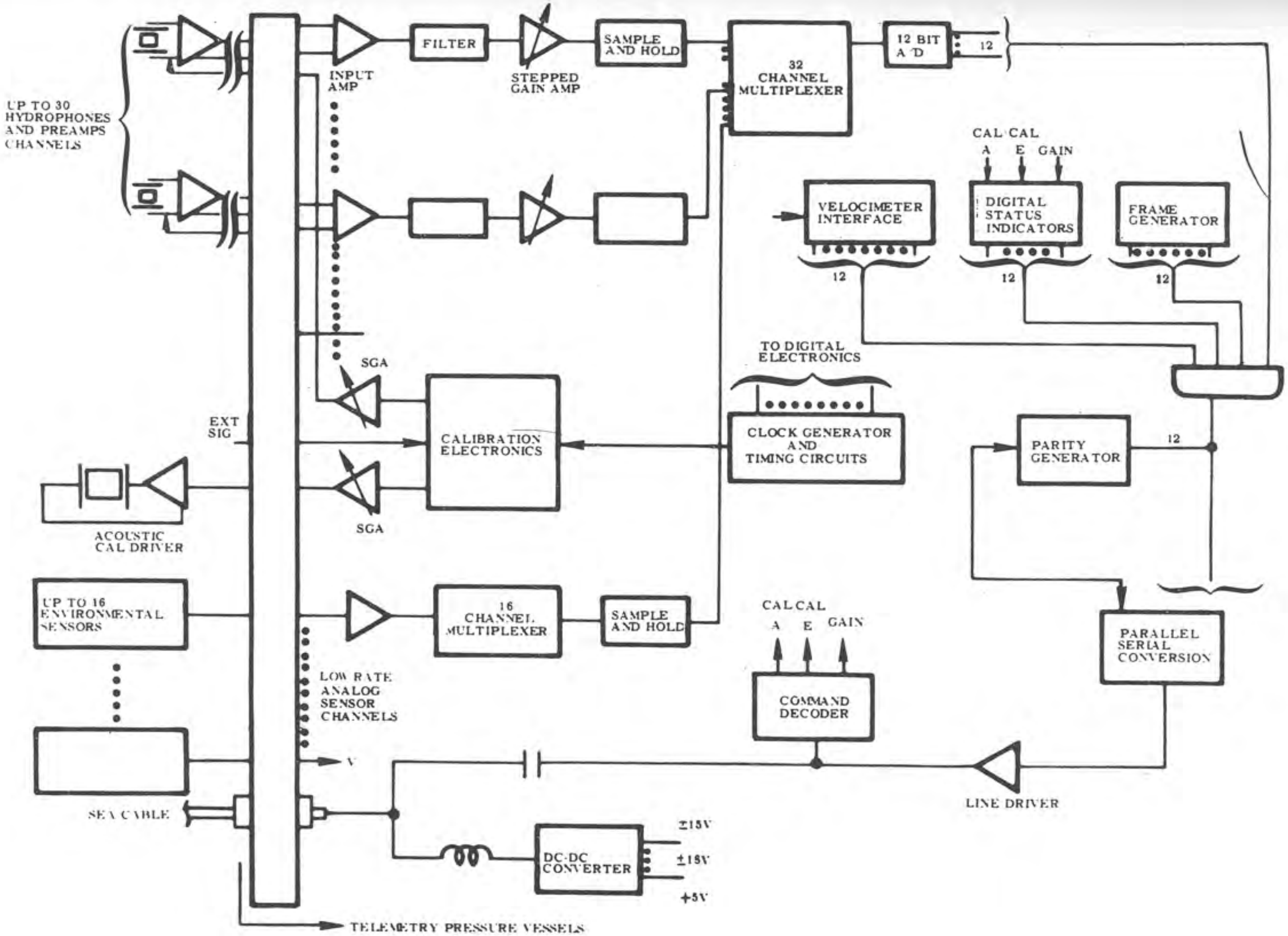
°Sensitivity	-90 dbv/μb
°Bandwidth	2 Hz to 5 kHz
°Acceleration Balanced	$\geq$40 db cancellation due to vertical and/or horizontal motion
°Directionality	Omnidirectional all planes up to 75 f_o ($\leq$0.1 db) ± 1 db up to 5 kHz
°Hydrophone Module Directionality	Omnidirectional all planes up to 75 f_o ($\leq$0.1 db)
°Depth Sensitivity	$\leq$1 db from 0 to 8000 psi
°Hydrophone to Hydrophone Amplitude and Phase Uniformity	Series opposing output $\geq$ 46 db down from series aiding output in frequency band up to 75 f_o

(3). Deep Telemetry

A 17,000 foot coaxial sea cable and a 20 mile radio link serve to connect the deep sensors with a surface-tending vessel. The system is versatile in that various combinations of cables and RF links are provided. The system can be deployed from near surface to 18,000 feet, and can be suspended either from a buoy containing the radio equipment or directly from a tending vessel, in which case only the cable link is employed. A diagram of the deep telemetry electronics are shown in Figure 39.

The system is bidirectional, with commands being sent to the deep telemetry unit (DTU) from the tending ship, and data transmitted from the DTU. Power is also multiplexed on the sea cable with all power being supplied from either the buoy (when an rf link is used), or the ship (in the case of a direct cable link).

The basic data telemetry consists of a 32 channel analog multiplexing and A/D system which will accommodate up to 30 high-rate analog hydrophone inputs. The 32nd channel is further submultiplexed to handle low-rate analog sensor inputs. In addition, the telemetry accepts low-rate digital sensor inputs directly. State-of-the-art electronics are used throughout to maintain a total system accuracy of better than 0.1 db.



Deep Telemetry Electronics
[From Reference (1)]

Figure 39

The versatility of the system is greatly increased by the cross-strapping provided, allowing the maximum number of channels to be used at the basic sampling rate, or fewer channels to be used at correspondingly higher sampling rates. Low rate and high rate channels can be intermixed to obtain maximum system efficiency.

After multiplexing, all signals are converted to a serial digital 12-bit format, with a 13th parity bit added to every data word. This serial data stream is then transmitted at a bit rate of about 1 mHz over the cable and rf links. At the receiving end, every received data word is checked for parity and sync errors, with the error rate decoded and printed out in real time, on-line. Throughout the entire data transmission and data recording path, the specified error rate of 1 bit error per 1 million bits transmitted has been exceeded in the field, with the typical error rate being about 0.3×10^{-6}.

The command link is a 4-tone coded system and allows for 15 separate commands. Commands are generated onboard ship and are decoded both at the surface buoy and the DTU. The commands provided include gain change (all hydrophone channel gains are changeable, with 2 gains being provided), enable electrical calibration, enable acoustic calibration, change rf signal strength, and turn system on and off.

(4). Compliance System

The compliance system is designed to provide isolation from both vertical motion and motion-induced flow noise sufficient to prevent masking of data for all sea states encountered up through Sea State 3.

The system, as depicted in Figure 38, is composed of three basic elements:

(1) Spring (twelve 1 1/8 inch diameter Natsyn rubber rods, 36 feet in length with a spring rate of 50 lb/ft).

(2) Mass (5 foot diameter by 20 foot long sea anchor entrapping water mass of approximately 800 slugs).

(3) Subsurface float to establish proper spring rate by adjusting static load bias.

(5). Coaxial Sea Cable

Four lengths of cable currently exist; one each of 12,000 feet and 17,000 feet and two of 3000 feet.

Equalization or reshaping of the digital data train is performed by a circuit card in either the buoy or the shipboard electronics, depending upon whether an rf-link or a direct-cable link is utilized. A special "equalizer" program has been written that will permit rapid implementation for any cable length.

Actual array depth is adjusted by reeling a predetermined amount of sea cable onto the yo-yo cable reel (Figure 38). This reel will accommodate up to 3000 feet of cable, thereby permitting a depth adjustment of between 0 and 3000 feet for any length of sea cable. A brief VLAM cable specification follows.

Diameter	0.65 inches
Weight	0.61 lb/ft in air 0.49 lb/ft in water
Breaking Strength	33,000 lbs
Attenuation at 1 mHz	1.5 db/1000 feet
Double armored, antitwist	

(6). Surface Buoy and RF Link

a. Surface Buoy

The surface buoy depicted in Figure 38 is designed to fully support the wet system for all cable lengths from 3000 ft. to 17,000 ft. Major features include a dual diversity rf-data transmission system and command receiver, a pneumatically operated telescoping antenna, battery packs for both the deep telemetry unit and the rf system, radar transponder and blinking strobe recovery aids, a pneumatic ballasting system, and a pneumatic battery equalization system. In addition to the buoy proper, there are three bolt-on additional buoyant sections to provide additional displacement for longer cable lengths; i.e., 8000-, 12,000-, and 17,000-ft. coaxial sea cables. These additional sections are used in lieu of a single large ballast chamber to preclude the possibility of losing the entire system due to inadvertent flooding of that chamber. The chamber was sized such that in the event the chamber is fully flooded, sufficient reserve buoyancy will exist to prevent loss of the system. Both the buoy and the add-on sections are filled with a closed cell foam to prevent loss due to any cause other than a catastrophic collision. That section of the buoy which pierces the air-water interface has been made as small in cross section as possible, yielding a buoy stiffness of 32 lb. per foot.

b. RF System

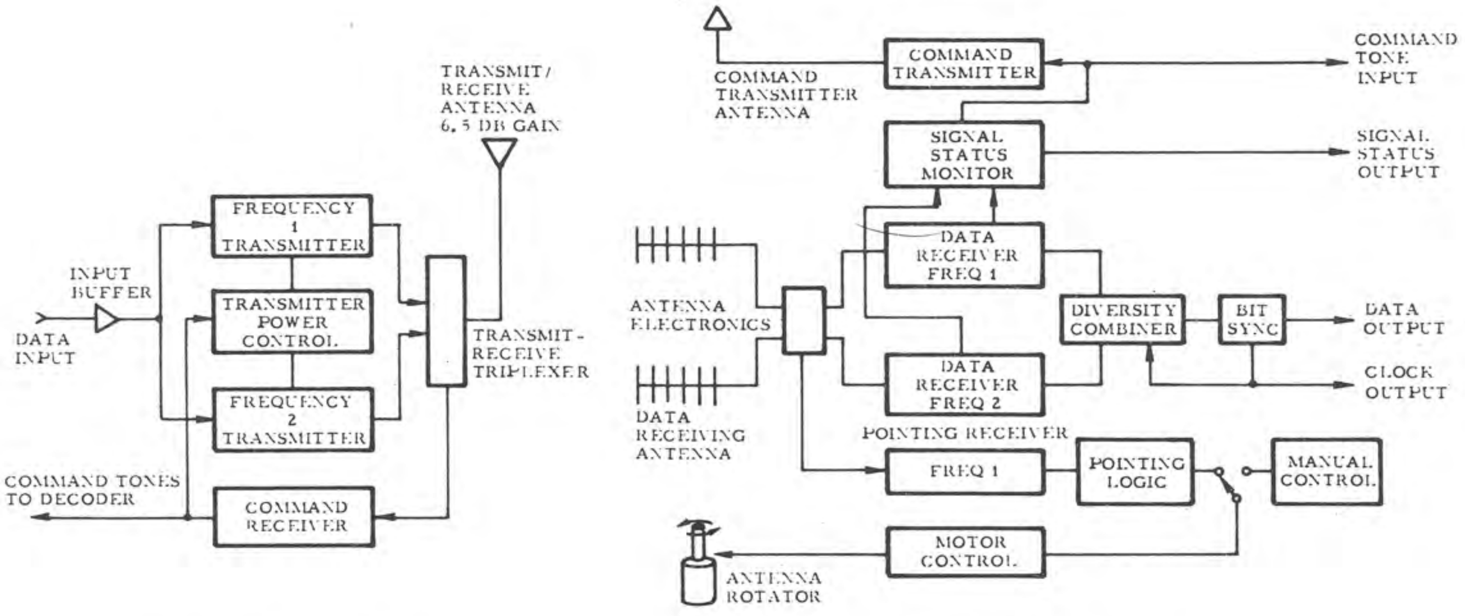
The VLAM rf system is a two way radio link between the buoy and the support ship; (1) digital data from the DTU is transmitted to the ship, and (2) command instructions, which can modify functions or operations in the buoy and DTU, are transmitted from the ship; see Figure 40.

The data channel has been designed to provide exceptionally error-free, reliable transmission. The system has a demonstrated ability (99.9 percent) to provide bit error rates of 1×10^{-6} over water paths of 18 to 20 miles. The system features dual-frequency diversity of 138 to 150 mHz with a diversity gain of 30 db. Modulation is FSK. Each of the two buoy transmitters can radiate either 50 or 350 watts of power, remotely commandable. Battery life is 25 to 100 hours depending on transmitter power.

At the ship, a fully automatic tracking antenna system employing two log periodic antennas affords a net antenna gain of 13 db.

The binary 4-tone command system operates at 220 mHz and employs narrowband frequency modulation. Like the data transmitters, it can operate at 50 or 350 watts. Its range is considerably in excess of the data link due to its inherent invulnerability to fade and multipath.

Like the DTU, the rf system should be considered a tool which can transmit large quantities of data at a high rate from an instrumentation system planted in the ocean to a monitoring ship. Since all rf components are spaced to operate from 130 to 170 mHz, frequencies may be shifted within this range if required.



BUOY COMMUNICATIONS EQUIPMENT

TRANSMITTER POWER	50/350 WATTS
BATTERY LIFE	100/25 HOURS
ANTENNA GAIN	6.5 DB
OUTAGE RATE, 20 NAUTICAL MILES	< 0.1%, K 2/3
BIT ERROR RATE	10^{-6} MAX.

SHIPBOARD COMMUNICATIONS EQUIPMENT

DUAL DIVERSITY DATA RECEIVER
ANTENNA GAINS: 13.0 DB DATA CHANNEL
2.0 DB COMMAND CHANNEL
AUTOMATIC ANTENNA POINTING SYSTEM
COMMAND TRANSMITTER OUTPUT: 50-350 WATTS

VLAM Communications Equipment
[From Reference (1)]

Figure 40

C. Shipboard Electronics

All the shipboard electronic equipment for VLAM is housed in a portable equipment van which houses nine relay racks, a 20 foot workbench, and a computer display console. A system flowchart is shown in Figure 41.

Data comes into the van from either the rf receivers or a direct cable link. The van input circuits then decode the digital data for presentation to the various analysis systems. In addition, the digital data is checked for both parity and synchronization errors, these error rates being automatically reduced to a hard copy record on-line. Every data word received is subject to these checks.

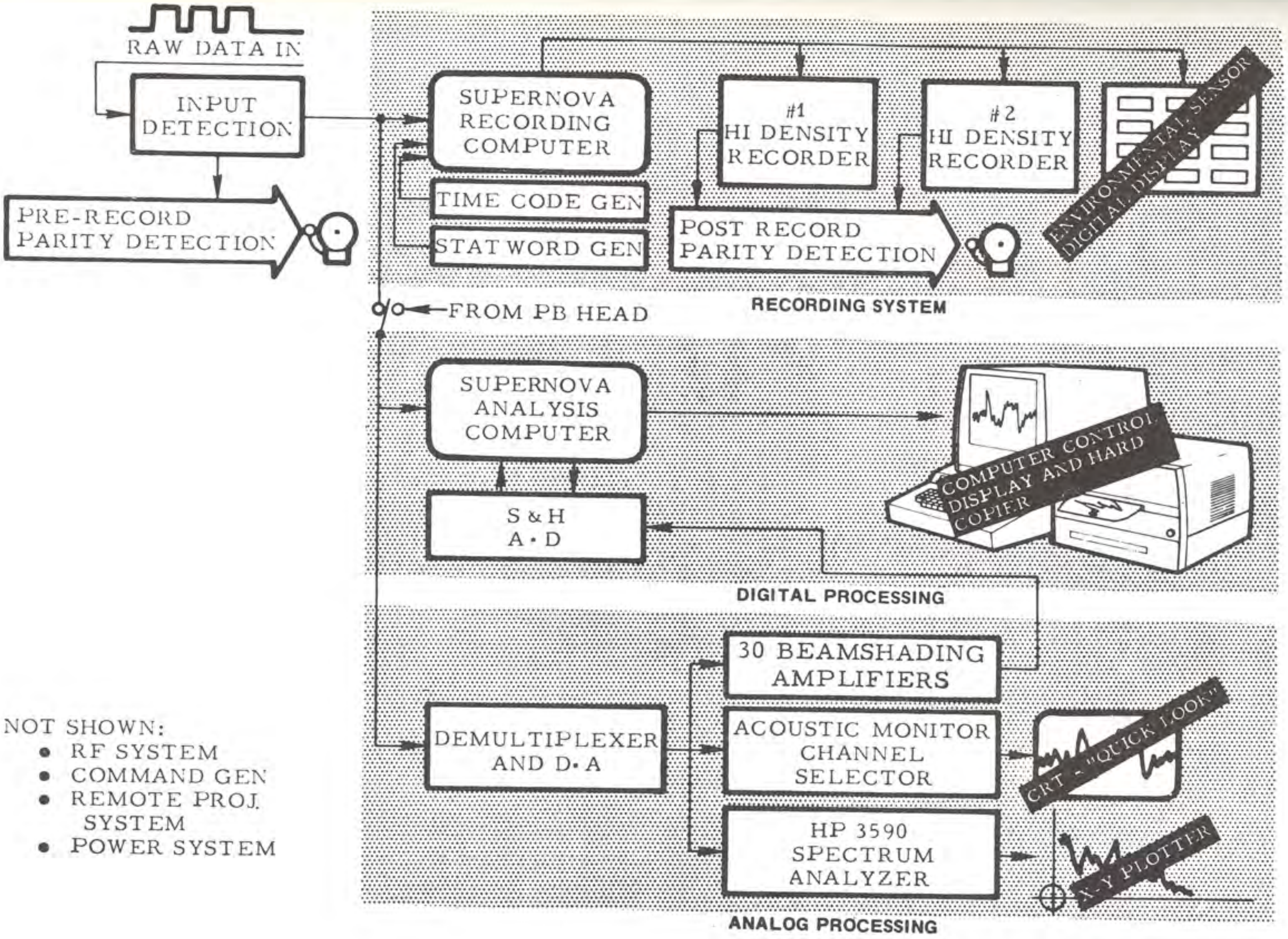
The acoustic information in the incoming data can be analyzed in either of two independent van systems. The primary analysis capability is provided by a 32K computer system which analyzes the digital data directly. Through a Tektronix CRT terminal and the interactive software provided, an analyst can:

- Perform amplitude and phase calibrations of every channel through built-in electrical and acoustic calibration electronics.
- Perform specialized narrowband or octave filtering of any channel.
- Subject any channel to FFT analysis.
- Form beams using either of the two VLAM arrays.
- Display and analyze array sensor outputs.

All of these analysis programs operate in real-time, and permit variable parameters such as filter bandwidths, integration times, beam steer angles, and output formats (various forms of graphical and tabulated results) to be selected on-line. A hard copy unit permanently records the data.

An independent parallel analysis system demultiplexes the data and presents simultaneously every channel in analog form. These signals can then be inputted to either a Hewlett Packard 3590 wave analyzer for spectral analysis or an oscilloscope for "quick look" quality assurance. A plotter is provided for a permanent record.

A second computer system in the van provides a continuous on-line, digital environmental sensor display. Twelve "nixie" tube banks continuously display the outputs of the array sensors. Included in the display are the outputs of three tilt stations (tilt plus direction), array depth, sound velocity, current direction and magnitude, battery voltage, and real-whole-time. This computer also serves as a data formatter for the recording system. Time code, the output of a



NOT SHOWN:
- RF SYSTEM
- COMMAND GEN
- REMOTE PROJ. SYSTEM
- POWER SYSTEM

Shipboard Electronics Flowchart
[From Reference (1)]

Figure 41

van status switch bank, and ASC-II code from a teletype are all meshed together with the remote DTU data in this computer and formatted for recording. Two recorders record the data simultaneously, providing a redundant capability. During the recording process, data is taken from the playback head and checked for errors identically as at the van input. Thus, good recorded data is assured at the time of recording.

D. Remote Projector Systems

Two independent VLAM projector systems exist. (See block diagram, Figure 42). Typically, these systems are used to project high level (88 to 90 db re μb) pulses of acoustic energy at two frequencies. Each system is composed of an acoustic projector, sea cable (700 ft.), a high power linear driver, and one rack of equipment containing signal generation and timing equipment. Included on each projector is a depth sensor and a sound pressure level (SPL) monitor.

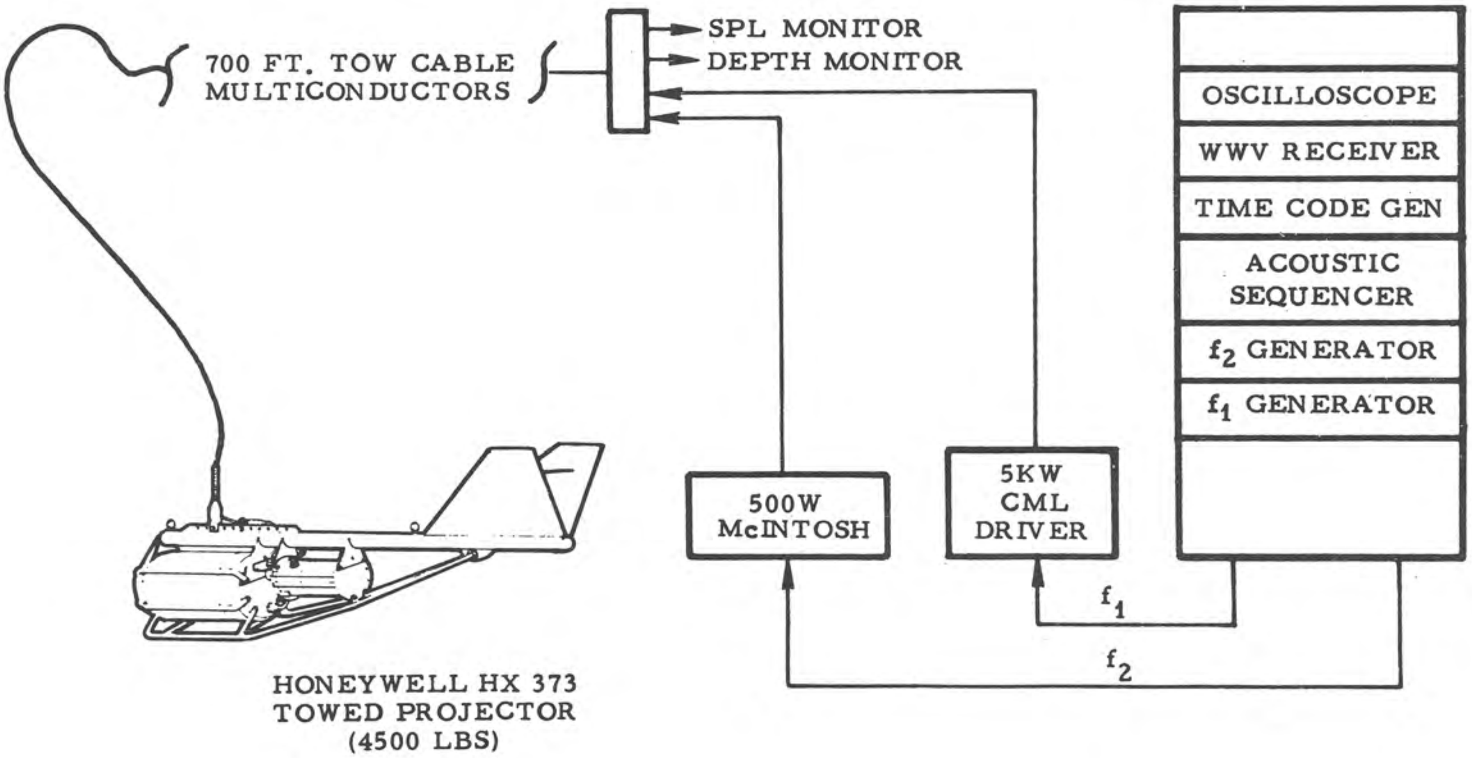
Pulse width is adjustable from 1 to 20 seconds and repetition rate from 1 to 100 seconds, both slaved to a digital clock. Since the clock can be synchronized with a WWV on-board receiver, it is possible to transmit pulses coherent within a few milliseconds. Since the system is linear, signals other than sine waves (i.e., FM slides or PRN) can be transmitted at well-defined intervals by substituting the proper signal source.

Specifications for the acoustic projector are as follows:

Source level	90 db re v/μb at 2 operating frequencies, simultaneously
Operating Frequency	11 f_o and 44 f_o
Operating Depth	To 500 feet
Maximum Towing Speed	5 knots
Weight (projector)	4500 lbs
Electronics	Single rack and drivers
Power Consumption	5 kw (1-kw output power)

E. Performance

During the exercise all systems operated satisfactorily for the deep deployment, with the exception of four hydrophones. The data from these four hydrophones were degraded because of leaky connectors. The beam forming results however, are not appreciably degraded by the elimination of these four hydrophones.



Remote Acoustic Projector System
[From Reference (1)]

Figure 42

The second planned deployment at a shallow depth was cancelled because the sea was too rough for deployment during the four day (10-13 December) period remaining.

A total of twenty six data tapes or sequences were made during the deep deployment. Each tape represents 105 minutes of continuous recorded data. A summary of data obtained is given in Table V together with a notation of errors noted. Only one tape (record No. 7-2-5) is completely unusable.

For further information on system performance and data output from the CHURCH GABBRO exercise, see References (2) and (24).

2.1.5 AN/SSQ-57A Sonobuoys

On 4 and 5 December, modified and unmodified AN/SSQ-57A sonobuoys were used to collect ambient noise and propagation loss data from aircraft in conjunction with a special aircraft data acquisition and monitoring system.

A block diagram of the monitoring and analysis system is shown in Figure 43. The entire system, independent of the AN/ARR-52A sonobuoy receiver, was calibrated prior to the flight by inserting selected calibration signals at one third-octave band frequencies between 25 Hz and 2.5 kHz. In addition, a white-noise calibration signal was passed through the system for a complete frequency calibration. The entire calibration procedure was recorded on all data tracks of the monitoring and playback system.

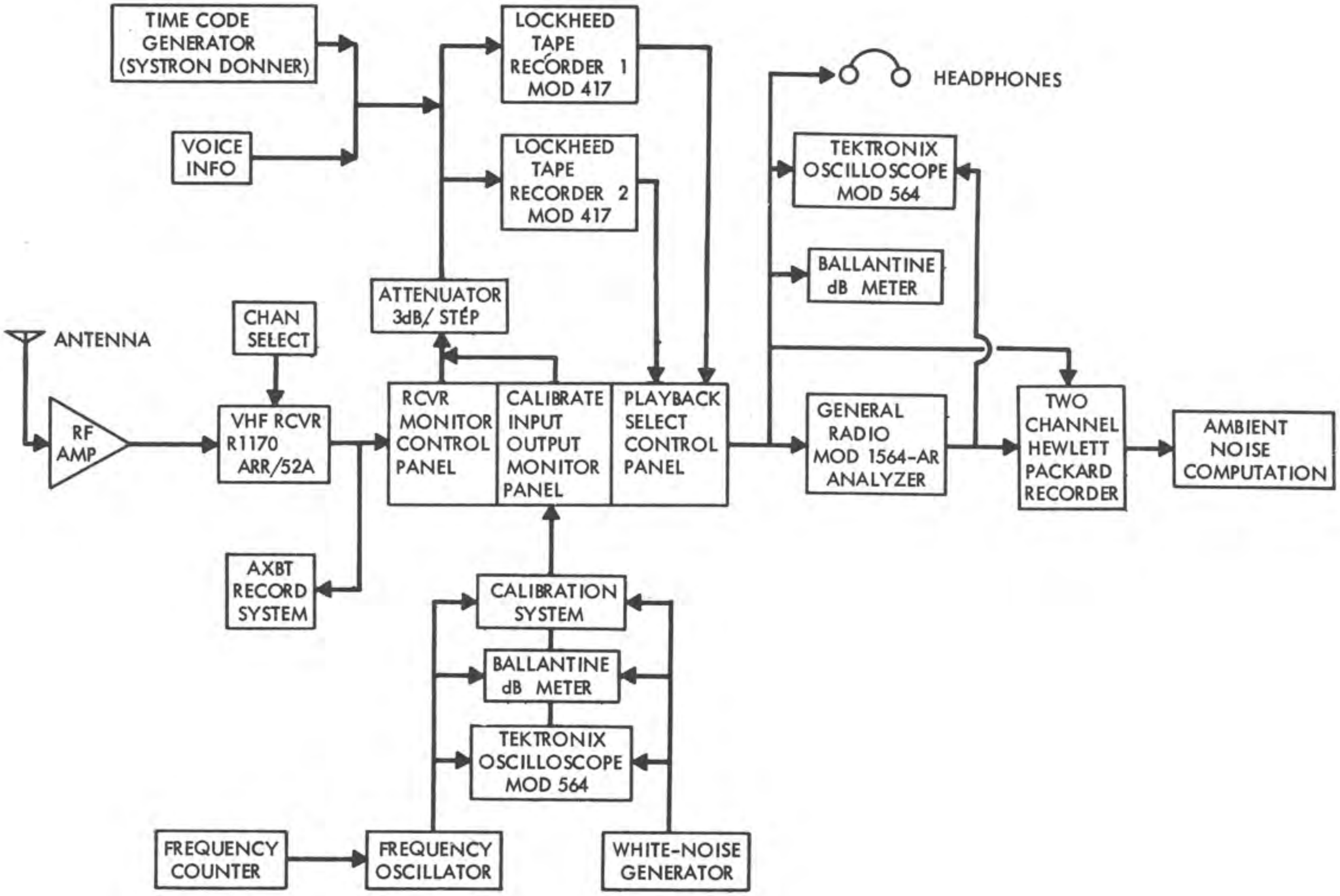
The aircraft AN/ARR-52A sonobuoy receiver system, consisting of eight VHF receivers, was calibrated by NAVOCEANO personnel at the Patuxent River Naval Air Station Avionics Facility. The receiver system was calibrated using AN/ARM-53B and AN/ARM-54A frequency modulated signal generator test sets. These tests enable frequencies at known voltage levels to modulate any sonobuoy receiver VHF channel while monitoring the high and standard audio AN/ARR-52A receiver outputs. For a ± 75 kHz deviation of an rf carrier, the standard audio output is 2 volts and the high audio output is 16 volts over the range of frequencies used in the calibration. The system levels were stepped 20 db to insure system linearity.

The standard, as well as modified, AN/SSQ-57A sonobuoys are air-launched from aircraft at speeds between 150 and 250 knots, and at altitudes between 500 and 10,000 feet. On contact with the water, the sonobuoy deploys an omni-directional hydrophone and preamplifier to a pre-selected depth of either 60 or 300 feet. A shock cord is used to isolate the surface action on the buoy from the hydrophone. In addition, the sonobuoys contain a life-selection switch of 1, 3 or 8 hours, as well as a 20 db attenuation selection switch. The

Tape	Start of Record		Range to		
No	Day	Time	PIERCE	SOURCES	ERROR
7-1-1	337	2201	0	NO	
7-1-2	338	0001	0	NO	
7-1-3	338	0201	0	NO	
7-1-4	338	0401	0	NO	
7-1-5	338	0601	0	NO	Recorder A Minor during 15 min. period
7-1-6	338	1001	0	NO	
7-1-7	338	1201	0	NO	
7-1-8	338	1401	0	NO	
7-1-9	338	2201	4.8	HX37	Recorder B Minor during 4 min. period
7-1-10	339	0001	6.0	HX37	
7-1-11	339	0201	7.5	HX37	
7-1-12	339	0401	9.1	HX37	
7-1-13	339	0601	10.5	HX37	
7-1-14	339	0801	12.5	HX37	Large during 15 min. period
7-1-15	339	1001	14.0	HX37	
7-2-1	339	1201	16.1	HX37	Large during 15 min. period
7-2-2	339	1401	18.0	HX37 SUS	Large during 15 min. period
7-2-3	339	1601	19.8	HX37 SUS	Large during last 15 min.
7-2-4	339	1801	21.8	HX37 SUS	Large during last 15 min.
7-2-5	339	2001	23.0	HX37 SUS	Whole record invalid
7-2-6	340	0001	9.0	HX37 SUS	Large during 15 min. period
7-2-7	340	0201	10.9	HX37 SUS	
7-2-8	340	0401	12.6	HX37 SUS	Large during first 15 min.
7-2-9	340	2001	6.2	NO	Large during 30 min. period
7-2-10	340	2201	8.2	NO	
7-2-11	341	0001	9.4	NO	Incorrect record level on Recorder B

VLAM Data Summary

Table V



BLOCK DIAGRAM OF AIRCRAFT MONITORING AND ANALYSIS SYSTEM

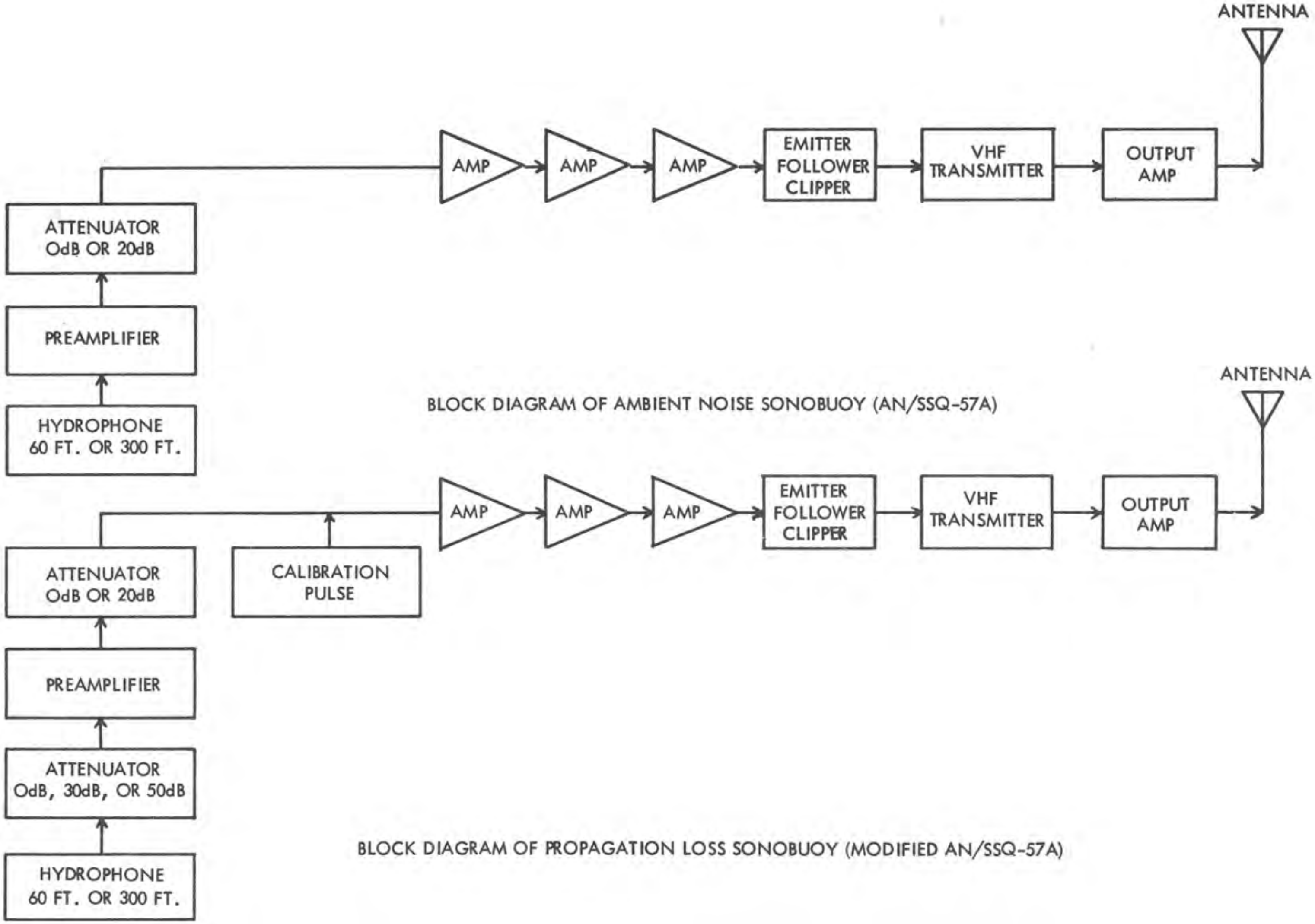
Figure 43

electronics system is capable of transmitting data as soon as a 10 volt sea water battery is activated. These buoys are described in Reference (14).

Block diagrams of both the standard and modified AN/SSQ-57A sonobuoy are shown in figure 44. Each sonobuoy consists basically of a series of attenuator or gain stages followed by a transmitter that telemeters all acoustic information detected by the sonobuoy system to a monitoring aircraft by VHF radio transmission. The sonobuoy FM transmitter operates at carrier frequencies between 162 and 174 megaHertz and consists of a reactance modulator, crystal control oscillator, frequency quadrupler, driver, and final stage RF amplifier. Each sonobuoy has a particular carrier frequency for transmission to a standard AN/ARR-52A VHF receiver onboard an aircraft. The sonobuoy receivers are capable of selecting, receiving and demodulating each RF frequency transmitted, thus enabling them to monitor one or more sonobuoys simultaneously. There are more than 30 VHF carrier frequency assignments for the sonobuoys so several buoys operating at different carrier frequencies can be simultaneously employed without mutual interference. The AN/ARR-52A sonobuoy receiver contains four FM receivers each of which can be automatically tuned to any one of the available channels.

The standard sonobuoys used for ambient noise measurements were calibrated and manufactured for the Navy by Spartan, Inc., of Jackson, Michigan under contract N00019-71-C-0116. Each sonobuoy has an individual calibration curve that is provided to the user by the Naval Air Development Center (NADC) upon request. Usable frequency range at the sonobuoy covers 10 - 3000 Hz; dynamic range is approximately 40 db. The sonobuoy frequency response is between 10 Hz and 20 kHz and is tabulated in db relative to the response of 440 Hz. At 440 Hz an acoustic pressure of +106 db relative to 1μ Pascal incident on the sonobuoy hydrophone will deviate the sonobuoy carrier ± 19 kHz.

The modified AN/SSQ-57A sonobuoys used for propagation loss measurements have essentially the same frequency characteristics as the standard ambient noise sonobuoys. However, the modified sonobuoys contain additional attenuator and gain circuitry to prevent overload conditions, as well as a calibration circuit to insure system linearity and assist in data reduction. The attenuator circuit is either 30 db or 50 db, depending upon the sonobuoy selected. The calibration pulse is produced by a multivibrator circuit that gates a phase shift oscillator to produce a two-level (25 db) calibration pulse every 15 seconds at a reference frequency of 2.35 kHz. This calibration circuit is internal to the sonobuoy electronics; the calibration signal produces pulses through the amplifier/transmitter stages and is telemetered to the monitoring aircraft where it is processed and recorded through the data acquisition system.



BLOCK DIAGRAM OF AMBIENT NOISE SONOBUOY (AN/SSQ-57A)

BLOCK DIAGRAM OF PROPAGATION LOSS SONOBUOY (MODIFIED AN/SSQ-57A)

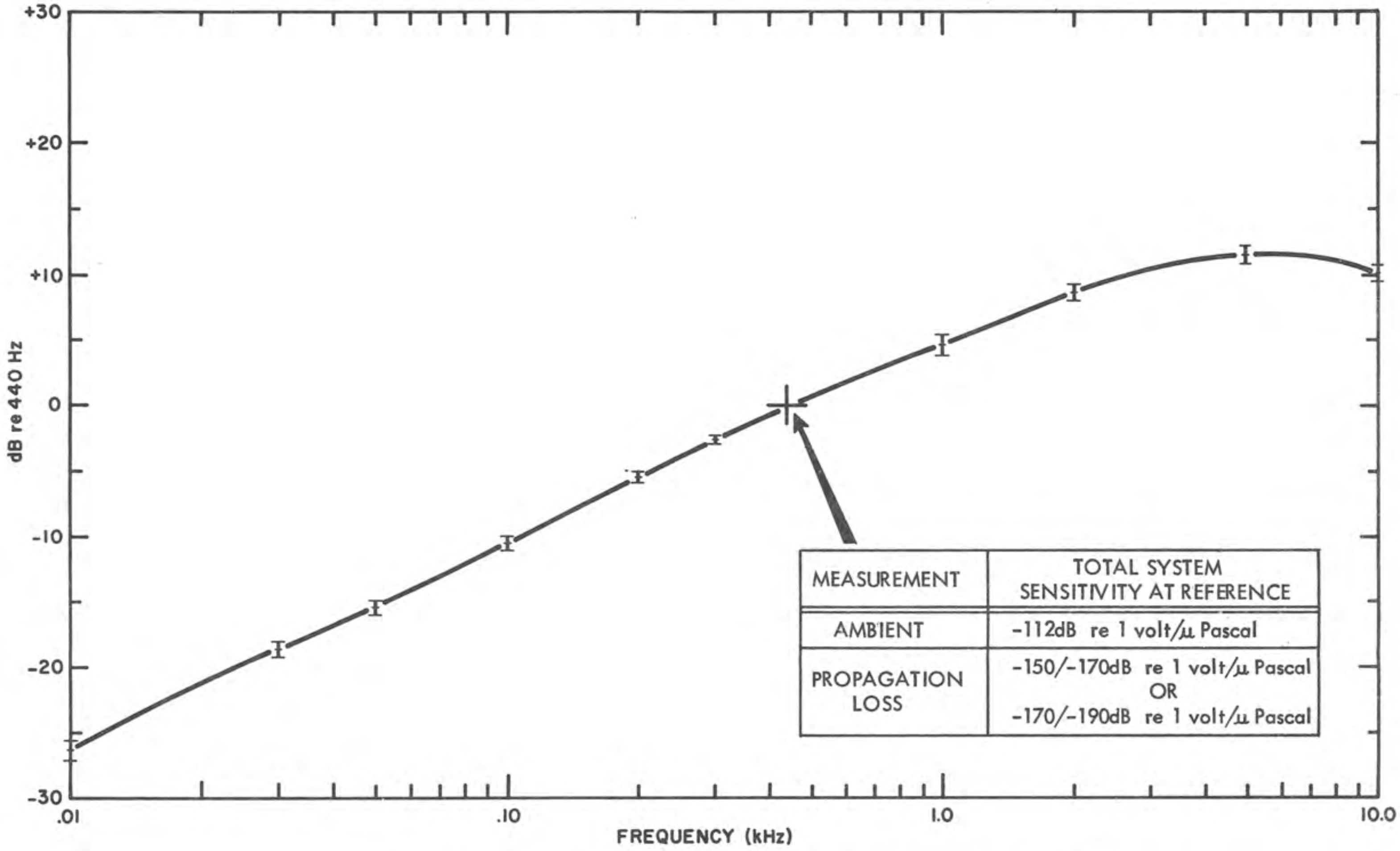
Sonobuoy (AN/SSQ-57A) Block Diagrams

Figure 44

Figure 45 shows the average frequency response and standard deviation of the response, at the calibration frequencies indicated for the modified and unmodified AN/SSQ-57A sonobuoys used in CHURCH GABBRO. Although the response curves for the two types of buoys are the same, the sensitivities are different. The sensitivity for each system at the reference frequency of 440 Hz is noted on the figure. The reference sensitivity is determined from the carrier deviation characteristics of the AN/ARR-52A receiver outputs in conjunction with the acoustic pressure/frequency deviation characteristics of the AN/SSQ-57A sonobuoy. During the present investigation the receiver standard audio outputs were monitored.

Ambient noise and propagation loss data were collected with modified and unmodified AN/SSQ-57A sonobuoys with hydrophone depths of 60 and 300 feet. As many as eight sonobuoys were monitored simultaneously for ambient noise and explosive sound source arrivals. All data were recorded broadband on magnetic tape and a preliminary examination of the monitored data was made using a General Radio model 1564-AR one-third octave/one-tenth octave analyzer, and associated analog display. No major problems were encountered with the data acquisition system.

AN/SSQ-57A sonobuoys were also deployed from SANDS during the aircraft SUS run. The sonobuoy data acquisition system aboard SANDS is similar to that for TABS and consists of AN/SSQ-57A sonobuoys, an AN/ARR-52 sonobuoy receiver, Ithaco amplifier, a CP-100 magnetic tape recorder and two Bruel and Kjaer 1/3 octave band pass filter sets; see Figure 46. Receiving and recording system calibrations were accomplished separately. The receiver was calibrated using a Boonton 202H FM generator and a frequency counter with a high frequency converter. A center frequency corresponding to a particular sonobuoy channel was selected and modulated at 1 kHz by the Boonton FM generator. This test signal was inserted into the sonobuoy receiver. Each receiver channel to be used was calibrated while monitoring the High Audio Output. The High Audio Output has a low frequency cut off of 10 Hz. The deviation of the center frequency was set at ± 75 kHz and a check was made to insure the proper amplitude of 16 volts was measured at the receiver output. The deviation was then varied from ± 75 kHz down to ± 20 kHz. This was done to check the receivers' linearity and, by graphic methods, to obtain an output level for a deviation of ± 19 kHz. Because the receiving response is flat over the audio frequencies of interest, one can utilize the output level obtained for a ± 19 kHz deviation and the factory supplied sonobuoy calibration data to obtain a graph of terminal sensitivity (db re v/uPa) vs. frequency. The High Audio Output of the receiver was used because of the increased frequency response it provided, however, this did require attenuation of the input to the tape recorder data channels of 25 db. The recorder was calibrated by sequentially inserting, at a known level, all 1/3 octave band center



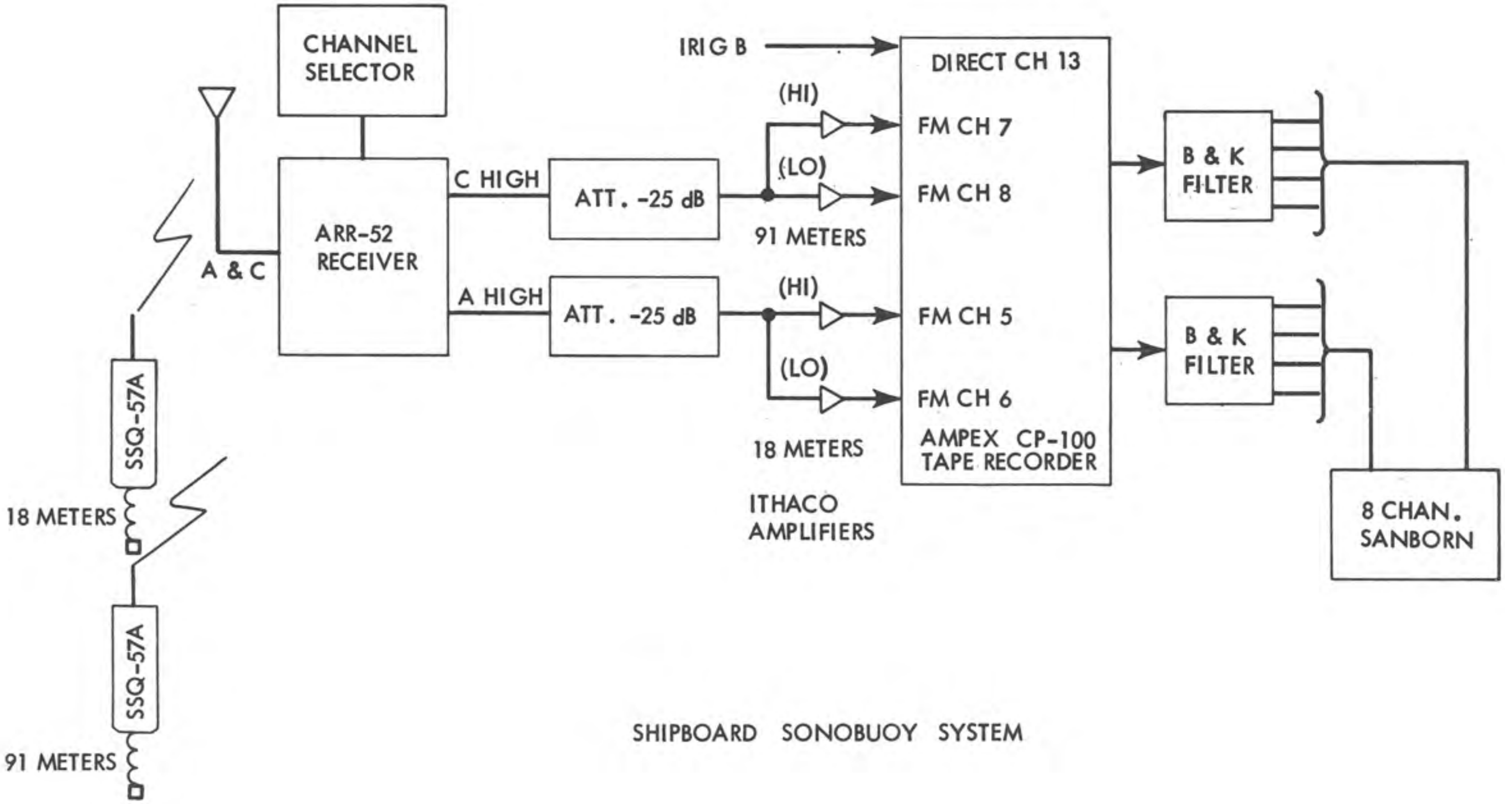
MEASUREMENT	TOTAL SYSTEM SENSITIVITY AT REFERENCE
AMBIENT	-112dB re 1 volt/μ Pascal
PROPAGATION LOSS	-150/-170dB re 1 volt/μ Pascal OR -170/-190dB re 1 volt/μ Pascal

AN/SSQ - 57A SONOBUOY FREQUENCY RESPONSE CURVE IN dB re 440 Hz

Figure 45

Naval Underwater Systems Center
NP24 - 49207 - 4 - 73

Official Photograph



SHIPBOARD SONOBUOY SYSTEM

Figure 46

frequencies, from 10 Hz to 2000 Hz, at the input of the 25 db attenuators and recording the levels on the data channels.

Both 60 and 300 foot depth sonobuoys were deployed from SANDS during the aircraft SUS run of 7 December. Both units employed the eight hour life option and the additional 20 db of attenuation. Signals were generally successfully recorded on magnetic tape. A problem with the shipboard antenna connector occurred during the run; however, very little data appear to have been lost.

2.2 Acoustic Sources

2.2.1 SUS Charges, Mk 61 - Mod 0, and Mk 82 - Mod 0

On 7 December, the VXN-8 aircraft dropped 478 Mk 61 and Mk 82 SUS for propagation loss measurements. In addition, NORTH SEAL dropped an additional 1104 Mk 82 charges on 4 and 5 December. A description of these charges and launching procedures can be obtained from References (3), (15), and (17).

2.2.2. Piezoelectric, HX 231-F

A Honeywell HX 231-F dual frequency sinusoidal source was towed by SANDS during the exercise. The HX 231-F consists of four sections with each section being a lead zirconate titanate ceramic bender bar transducer driven by a step-up auto-transformer having a turns ratio of 1:8. The physical dimensions of the HX 231-F are 32 inches in diameter, 80 inches high, with an air weight of 3,700 lbs. The maximum operating depth is 675 feet with non-operating depth to 1000 feet. Approximately 130 gallons of GE-10C transformer oil is used to fill the transducer and transformer compartment. At resonance the transducer is stress limited and the maximum voltage allowed the ceramic is 2320 V RMS; off resonance, the maximum voltage drive is 3,000 V RMS. Each element was checked at Honeywell at 4,000 V RMS. Table VI summarizes its characteristics. Figure 47 plots frequency response; HX 231-D is equivalent to HX 231-F.

The HX 231-F transducer was manufactured by Honeywell, Seattle, Washington, and delivered to the Lake Pend Oreille Test Facility in May 1972; see Reference (18). There the projector was extensively tested. The transducer was then shipped to NUSC's Lake Seneca Test Facility in New York for further calibration and testing. These tests included beam patterns at various frequencies, current and voltage transmitting responses, phase and impedance measurements, and linearity tests.

A two frequency (85.470 Hz and 128.205 Hz) harmonic sine wave generator was designed and built and used as input to drive mixed frequency. This particular HX 231-F was dockside tested in July 1972 and was again tested in shallow and deep water in the North Atlantic to confirm source level measurements using a monitor hydrophone. Also during the NORLANT Operation the source operated satisfactorily for two 12-hour periods while being "dipped". Subsequently, during that operation the source had an arc-over on one of the elements. This

PHYSICAL SPECIFICATIONS

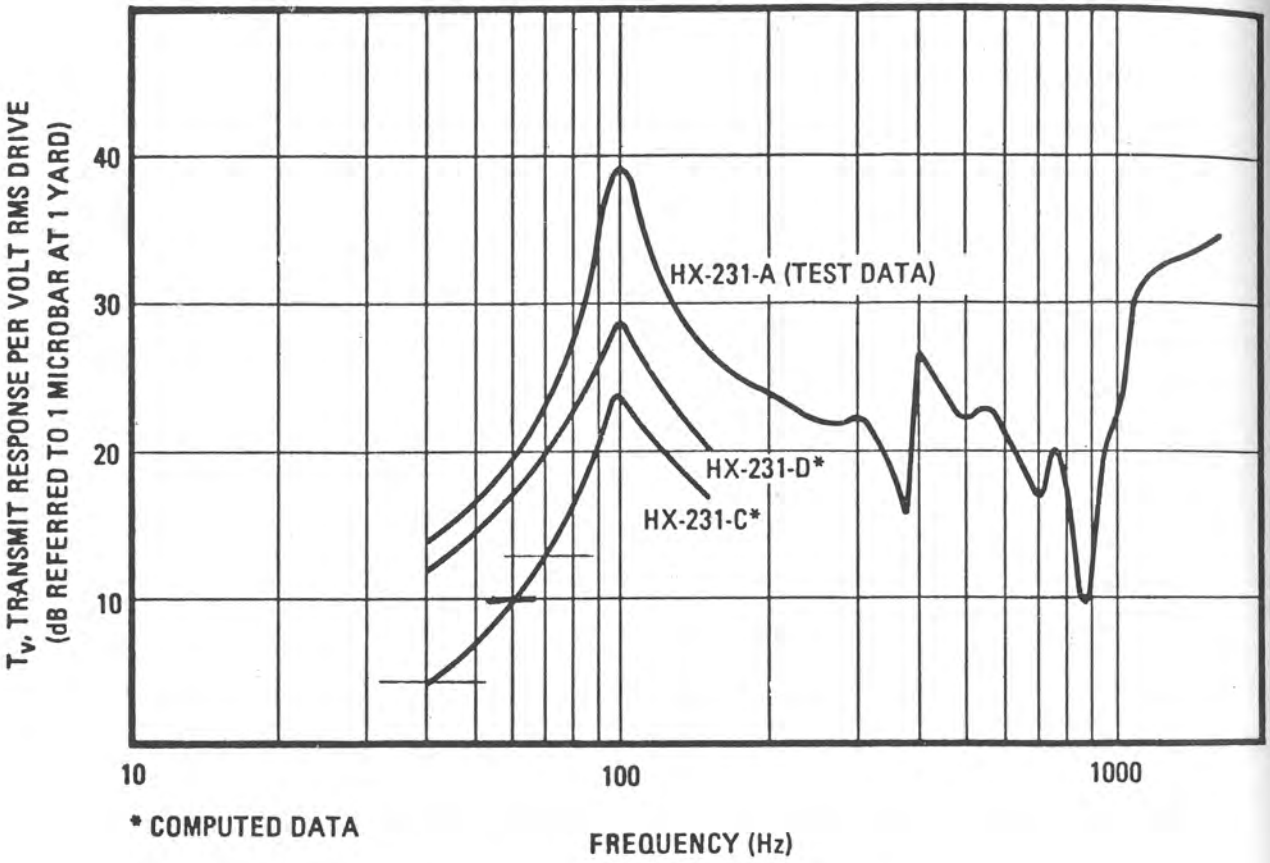
	HX-231-F
Number of modules	2
Number of bars	28
Weight in air	3700 pounds
Exterior envelope	
Length	80 inches
Diameter to contain unit	32 inches

PERFORMANCE CHARACTERISTICS

	HX-231-F
Resonant frequency	100 Hz
Maximum measured output power at f_r	—
Maximum measured source level at f_r (re 1 microbar at 1 yard)	92
Drive at maximum measured source level at f_r	—
Calculated maximum source level possible at f_r	102 dB
Directivity at f_r	Omni
Transmitting efficiency at f_r	20 percent
Measured Q_m	—
Maximum operating depth	675 feet
Input impedance at f_r	—

HX-231-F Data

Table VI



TRANSMITTING RESPONSE, HX-231 SERIES

Figure 47

breakdown was repaired before the subject exercise by replacing the faulty element.

Prior to CHURCH GABBRO the source was life tested at NUSC's Dodge Pond Facility. This test consisted of driving the source using the mixed frequency generator and a CML power amplifier for a period of 72 hours. The source was at 25 feet and operated quite well during the test. The maximum ceramic voltage was lowered to 2000 V RMS off resonance as recommended by Mr. J. White of NUSC (Code TD12).

Before the CHURCH GABBRO exercise the source was outfitted with a tow body and towing tests were planned during a shake-down cruise. However, severe weather prevented these tests at that time. Towing tests were conducted on 29 November in the Caribbean at 300 ft. depth and the source failed after about two hours. Again the problem was caused by an element arcing and shorting. This was repaired while SANDS was in port for the pre-sail conference. On 3 December at the start of the tow exercise the source had another element failure. Again this was repaired at sea. On 5 December the source was towed again and again failed. This was caused by arc-over on the terminal board (some oil may have been lost during previous repairs). The terminal board was then relocated so as to totally immerse the board in oil. In the meantime a problem had developed in the lead-in cable between the transducer and the tow cable (-660" faired cable). The cable eventually flooded and destroyed the connector to the transducer. This effectively terminated the use of the source during the exercise.

The source was powered for periods totaling 19 hours and over 155 nautical miles. This was accomplished at reduced source level (~83 db) with most of the area between Positions B and C.

The problem with the elements of the transducer appears to be a manufacturer's design deficiency. The design of the unit should be critically reviewed and a series of tests at pressure and temperature should be conducted before further usage. While towing the unit at 91 meters, SANDS was not able to make her appointed SOA of 10 knots. The SOA was actually in the order of 8 - 9 knots.

2.2.3 Hydroacoustic (VIBROSEIS)

A. Responsibilities

The DELTA Exploration Company, Inc. of Houston, Texas furnished the M/V DEARBORN outfitted with a vibrator system, operational personnel and necessary auxiliary systems such as navigation. The DEARBORN task was to tow CW sound sources at 18 m and 92 m depth simultaneously from the Yucatan Channel across the Yucatan Basin and up the Cayman Trough to the Windward Passage from 1100Z 29 November to

0300Z 13 December. Environmental measurements including XBTs were to be taken enroute.

B. DELTA's Marine Acoustic Energy Source

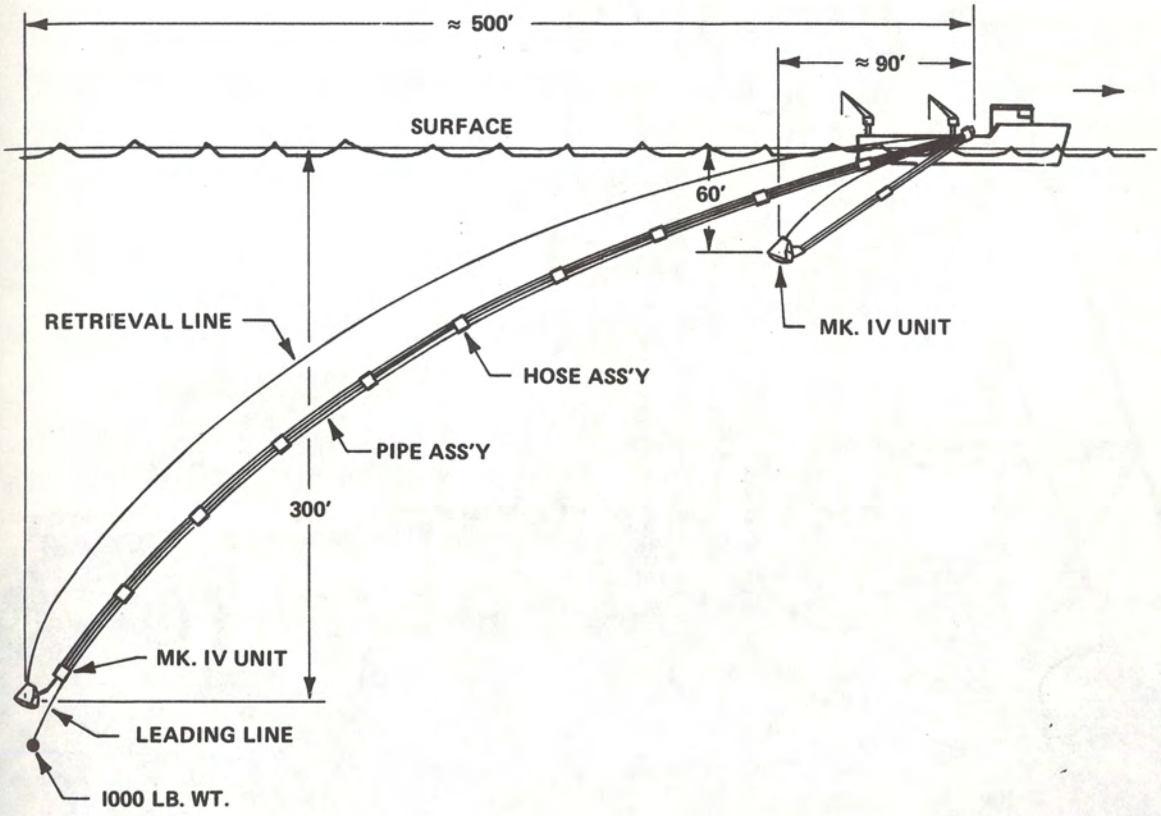
The vibrator system, known as the MK IV vibrator system has been used by Delta Exploration Company for furnishing commercial exploration services for petroleum. Techniques in operating this equipment and the equipment employed are nearly identical to standard operating practice in the off-shore seismic survey work. The portion of the system which had not been actually utilized before, was the loading apparatus required for the deep towing of the vibrator. The operation of the vibrator in depths up to 92 m was not considered to be a major technical problem since, in all cases, the average pressure in the vibrator was carefully regulated to be equivalent to the hydrostatic pressure of the vibrator. The air system also provided an accurate measure of the pressure-depth of the transducer at all times.

Figure 48 is a concept sketch showing the towing arrangement. The towing mechanism consists of the leading line, the pipe and hose assembly and the retrieval line. The required hydraulic, electrical and air circuits are routed through the pipe and hose assembly which in turn is connected to the leading line in such a manner that the whole assembly represents a faired surface. The towing forces for the transducer are taken by a wire rope assembly and the retrieving line is used to raise and lower the whole assembly.

The deck handling procedure consists of folding the pipe and hose assembly into specially prepared racks on the deck of the boat. There are special handling devices to facilitate the loading and unloading of the transducer. A complete loading or unloading operation can be completed in about two hours. Figure 49 shows deck handling devices on DEARBORN.

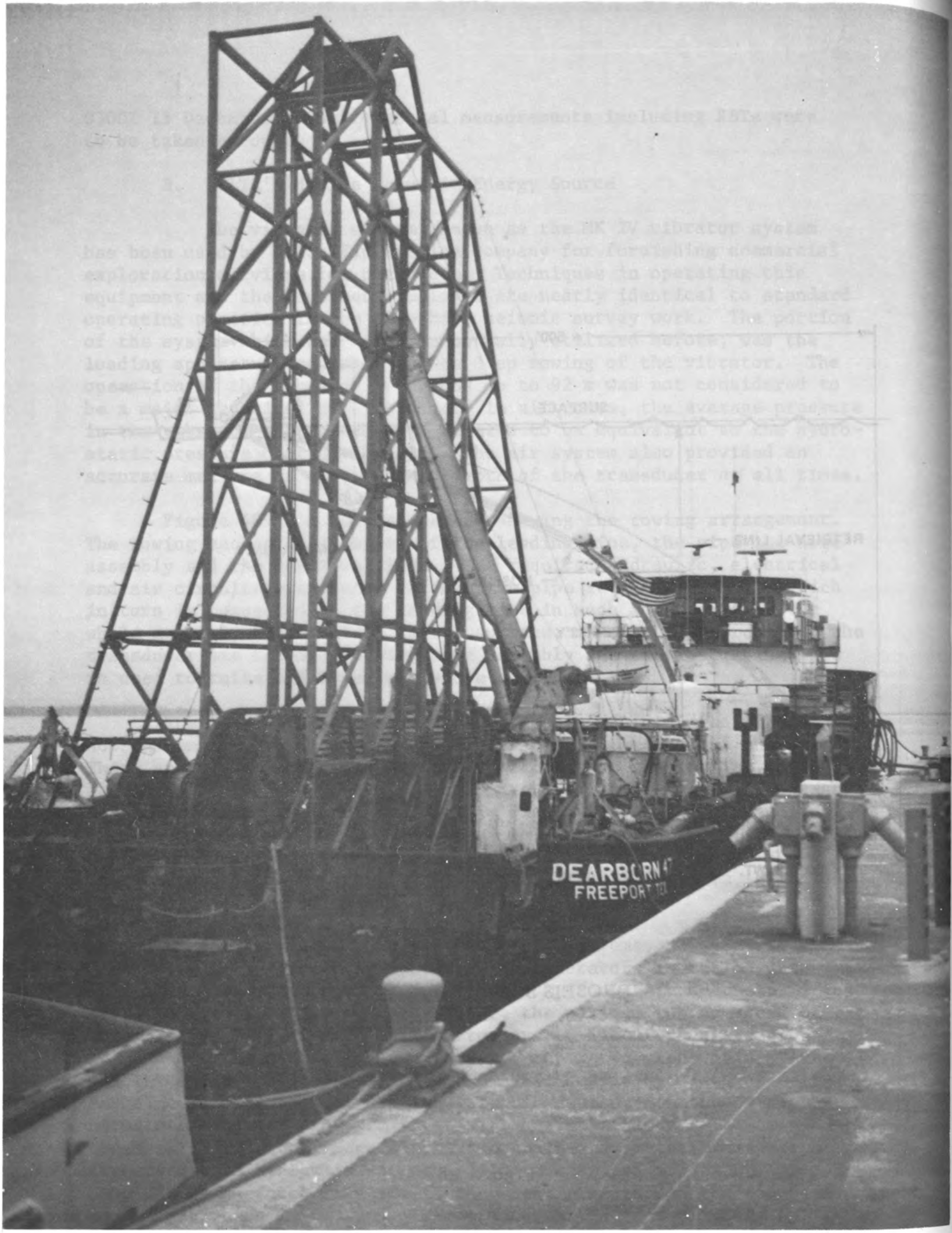
Technical literature pertaining to VIBROSEIS system is included in references (4), (5), (8), (9), (11), and (12).

Except for the mechanical handling problems, no special difficulty was expected in operating the vibrators in the hove-to condition. Because of the unpredictable hydrodynamic characteristics of the towing assembly and transducer, the maximum towing speed of the assembly was not known. The vibrator system itself consists of the transducer, the hydraulic power supply, the servo electronic system and the air control system. The hydraulic supply consists of self-contained diesel engines driving variable displacement pumps capable of maintaining constant pressures with variable flows. The transducer, the Mark IV vibrator, consists of two 48 inch diameter hemispheres connected by a hydraulic ram capable of mechanical expansion and contraction of the surfaces relative to each other to produce the acoustic pressure wave which is desired. The transducer is controlled by a



VIBROSEIS SOUND SOURCE SYSTEM, ILLUSTRATING TOWING ARRANGEMENT

Figure 48



M/V DEARBORN
Showing Structure for Handling VIBROSEIS Rig

Figure 49

four stage electro-hydraulic servo system. Figure 50 shows transducer and associated equipment.

The electronic system consists of modular units which contain circuits to process and control the feed back loops from the transducer itself. The basic input to the electronic system is the desired wave form and the system then is servoed to follow this wave form. The wave form can be any desired wave form in the 10 to 70 Hz range with degraded performance to 100 Hz. Suitable oscillators were provided to generate high quality sine waves in the desired range. A two channel oscilloscope was provided to monitor either the displacement of the transducer, which is physically related to the pressure wave developed, or to alternately monitor the hydrophones if desired. The received signal was retained on a permanent display device either in variable intensity or galvanometer mode. Figure 51 is a block diagram of the energy source.

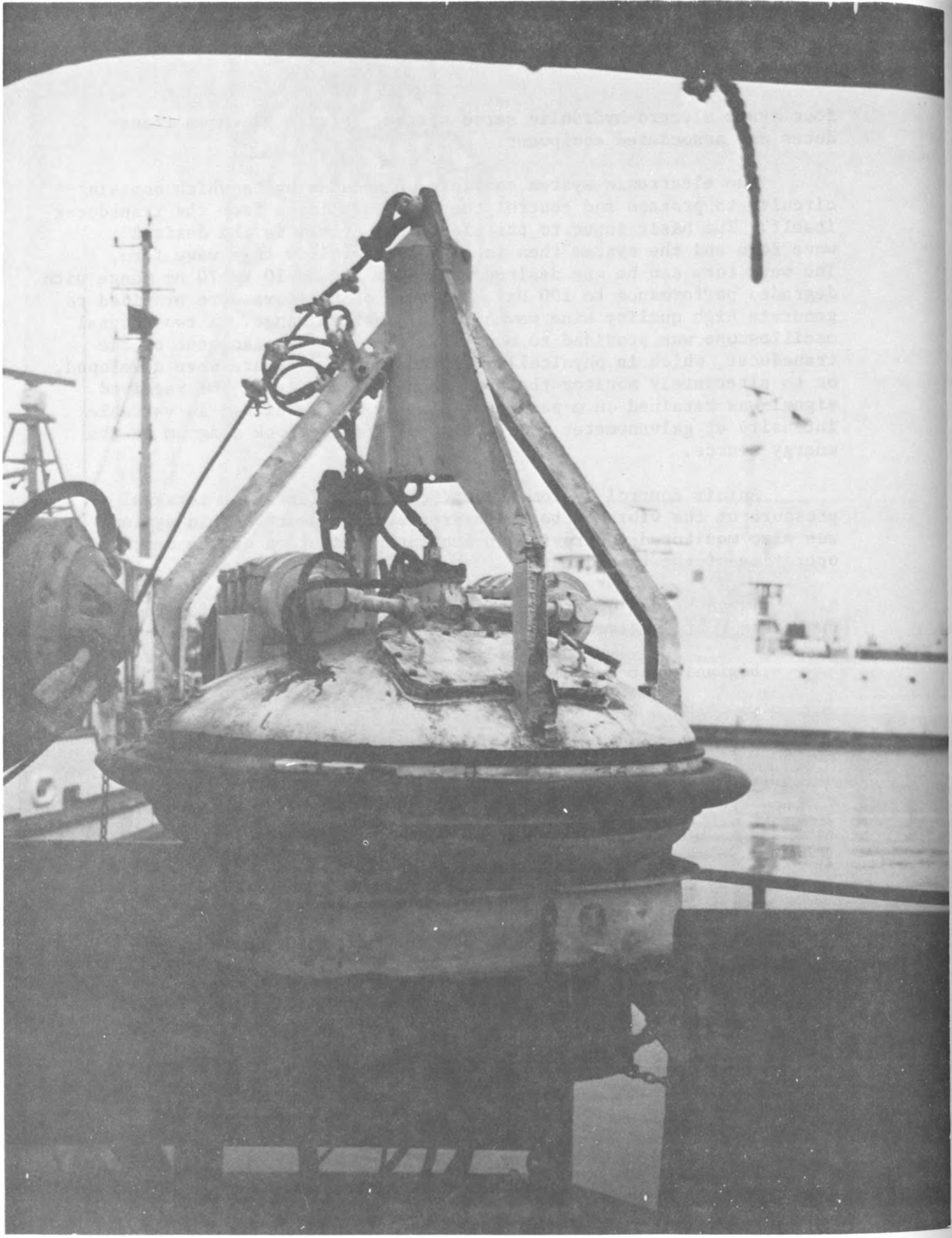
An air control system automatically equalized the internal pressure of the vibrator to the hydrostatic pressure. This system was also monitored to provide an accurate indication of the depth of operation of the transducer.

The schedule of frequencies and times of emission for each operation hour is given below:

Beginning at one minute after each hour,

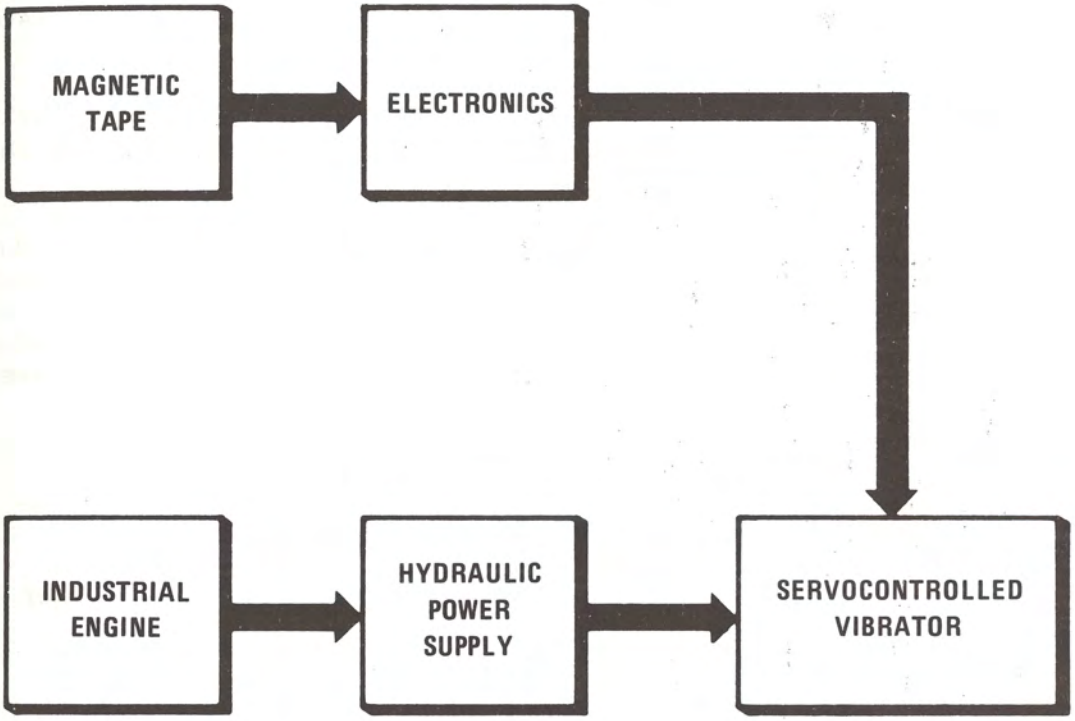
18 m depth	92 m depth	Time on
12 Hz	15 Hz	4.5 minutes
15	12	4.5 minutes
20	25	4.5 minutes
25	20	4.5 minutes
32	40	4.5 minutes
40	32	4.5 minutes
50	63	4.5 minutes
63	50	4.5 minutes
80	100	4.5 minutes
100	80	4.5 minutes
	TOTAL	45.0 minutes

Followed by 15 minutes non-emitting.



VIBROSEIS Transducer

Figure 50



BLOCK DIAGRAM OF
VIBROSEIS ENERGY SOURCE

Figure 51

C. Calibration

Acoustic calibration of two Delta Mark IV hydroacoustic projectors (VIBROSEIS) was carried out for the Office of Naval Research in an ocean area approximately eight miles south of Tudor Hill, Bermuda from 17 to 26 October 1972. The primary purpose of this test series was to measure the acoustic power levels of a shallow (60 foot) and a deep (300 foot) Mark IV projector at frequencies in the 15 to 100 Hz range while they were under tow by a surface ship. Both CW and pulsed CW transmission modes were used. The dynamic range of this equipment was measured at 40, 63, and 100 Hz while only the maximum acoustic level was measured at 15 and 20 Hz. The ability of the system to operate at various depths, the depth stability of the projector while under tow and its acoustic phase stability in the CW mode of operation was also investigated. The calibration results are summarized below. Table VII presents summary of operating characteristics of the Mark IV projector.

The acoustic calibration and the analysis of the data shows that this type system is capable of stable operation and produces substantial acoustic levels in the 90 to 107 db/μ bar at one yard range for frequencies from 15 to 100 Hz at depths to 300 feet in both a CW and a pulsed CW mode of operation. As a result of these tests and analyses, our findings are as follows:

(1). The Delta Mark IV hydroacoustic projector can be operated successfully in either a pulsed CW or continuous wave (CW) mode. In the pulse mode this equipment reaches full power in approximately one (1) cycle at frequencies in the range of 10 to 100 Hz; see Figure 52.

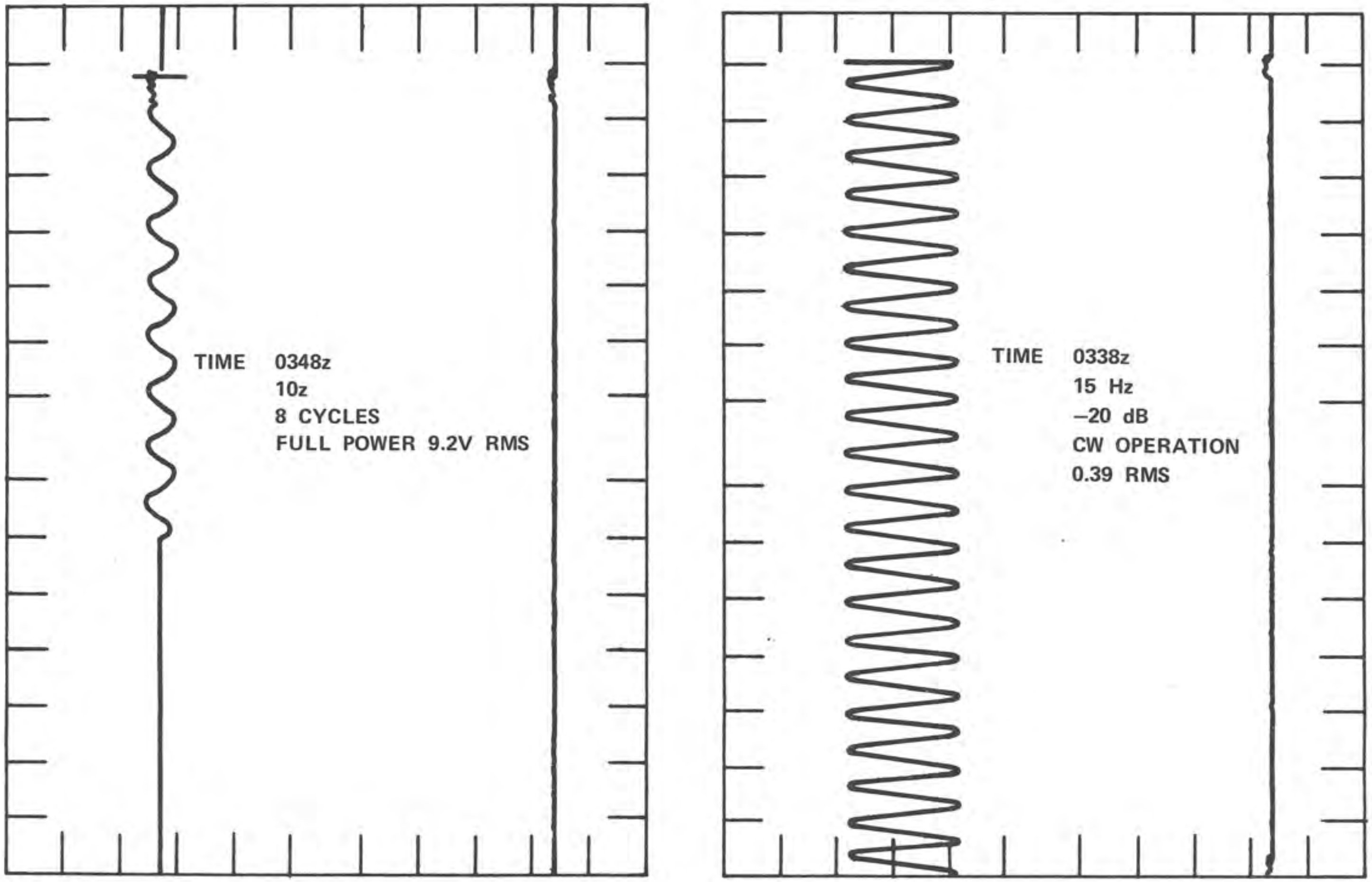
(2). To minimize multipath interference, the pulsed CW mode of operation was utilized in this calibration at frequencies of 40, 63, and 100 Hz. As shown in Figure 53 the source-receiver geometry did not permit use of this mode much below 40 Hz and CW interference pattern measurements were necessary to compute the maximum acoustic levels at 15 and 20 Hz.

(3). Maximum source level of operation for the Mark IV units varies from 90 db//μbar to 107 db//μbar over the range of 15 to 100 Hz, refer to Figure 54. Because of insufficient calibration data on the Tudor Hill Broad Band receiving hydrophone at frequencies below about 40 Hz, VIBROSEIS calibration at 20 and 15 Hz are best estimates based on extrapolation of the receiving system low frequency characteristic.

1.	Primary frequency range	10 Hz to 100 Hz
2.	Extended frequency range	∿100 Hz to 250 Hz
3.	Maximum source level over primary frequency range	90 to 107 db//μ bar
4.	Modes of operation	CW or pulse
5.	Minimum practical pulse width	2 to 4 cycles
6.	Pulse forming time	0.02 sec. at 40 Hz
7.	Distortion of acoustic signal	∿10% @30 Hz
8.	Phase stability of acoustic signal compared to driving signal generator	∿ ± 1° @40 & 63 Hz
9.	Reliability and operability	
	° 300 ft. depth	-need to be upgraded
	° 60 ft. depth	-satisfactory
10.	Towing Speed	
	° 300 ft. depth	-3 kts
	° 60 ft. depth	-6 kts

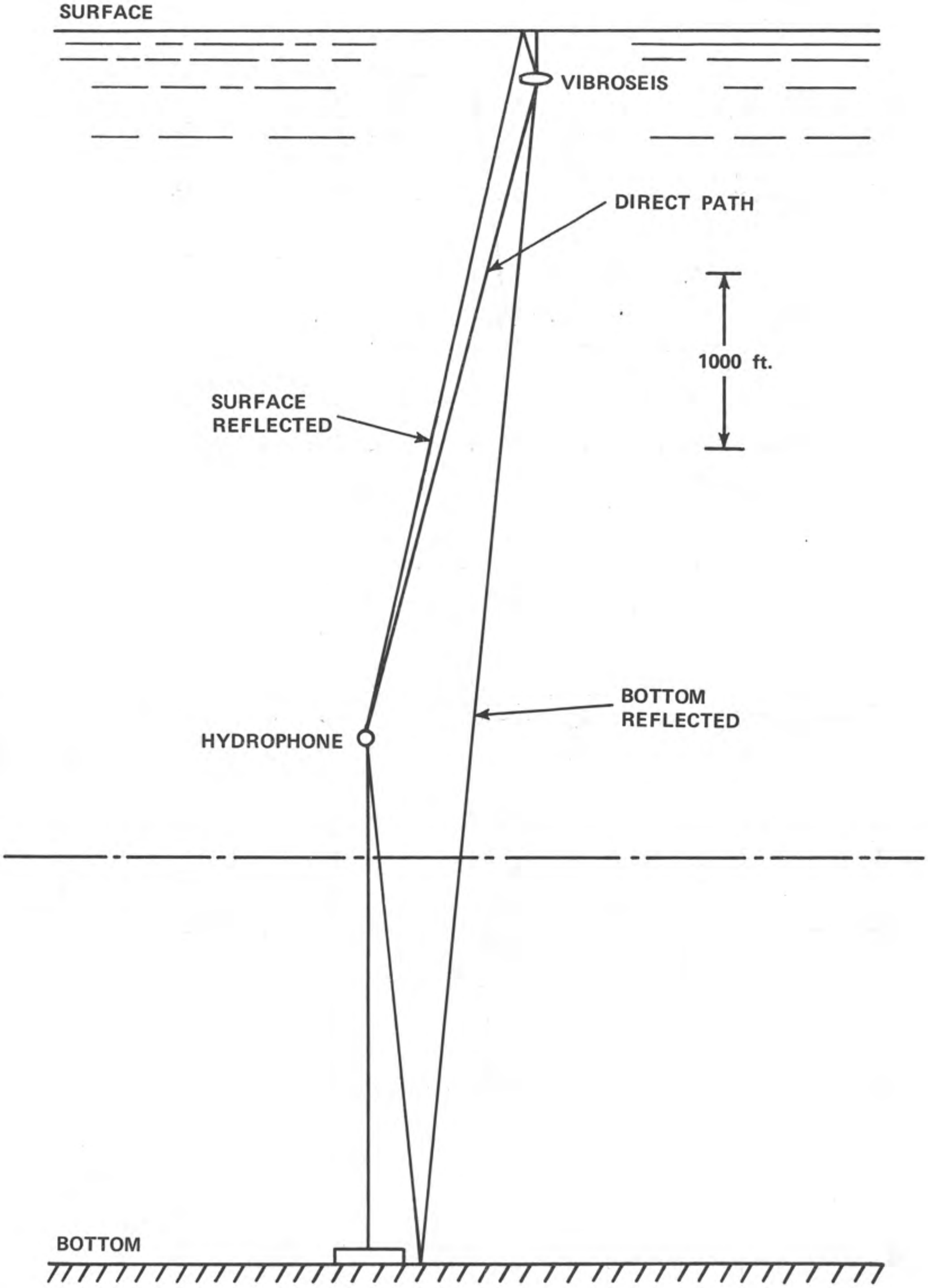
VIBROSEIS Operating Characteristics

Table VII



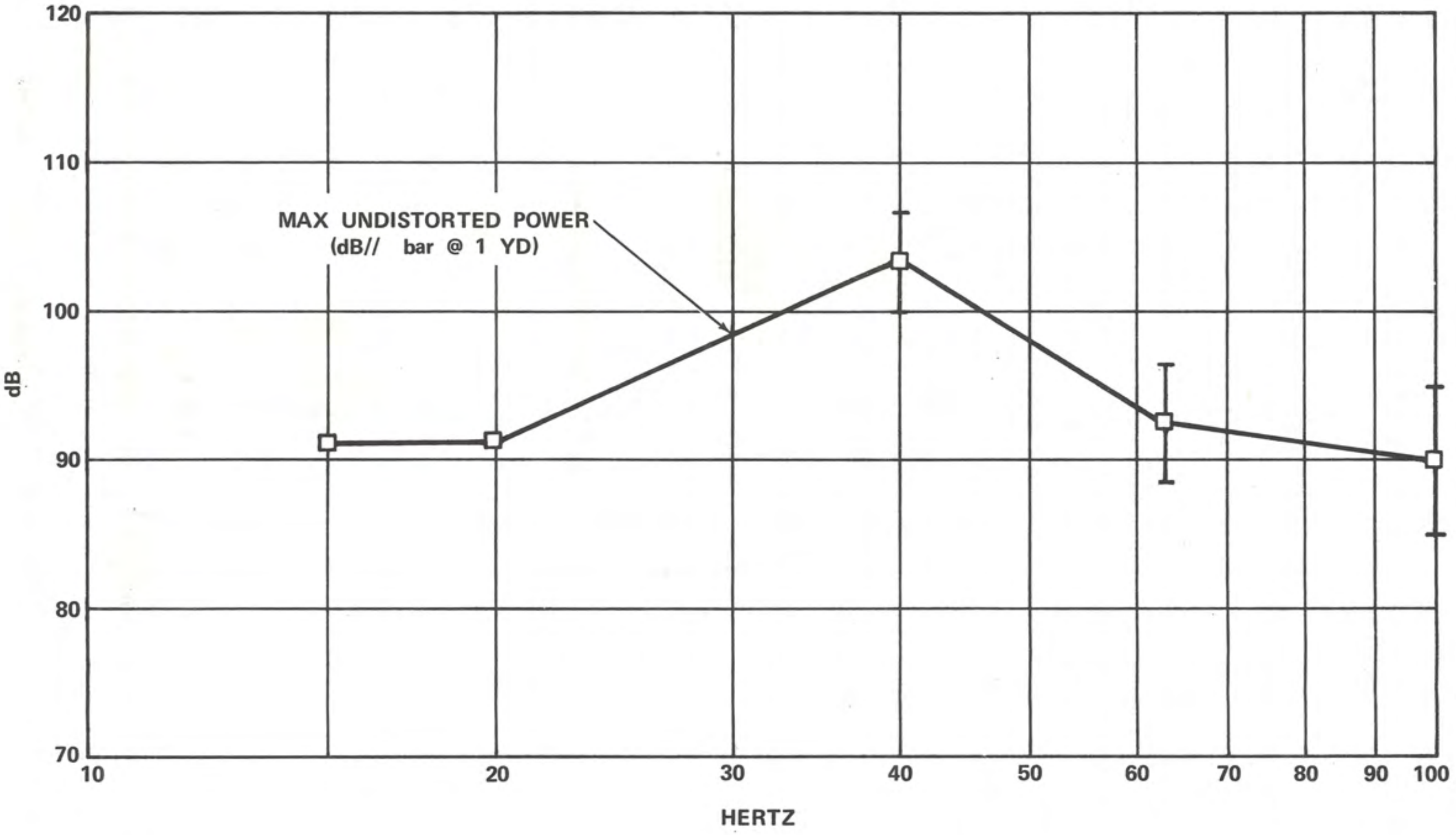
"VIBROSEIS" PISTON DISPLACEMENT AS MEASURED BY LVDT

Figure 52



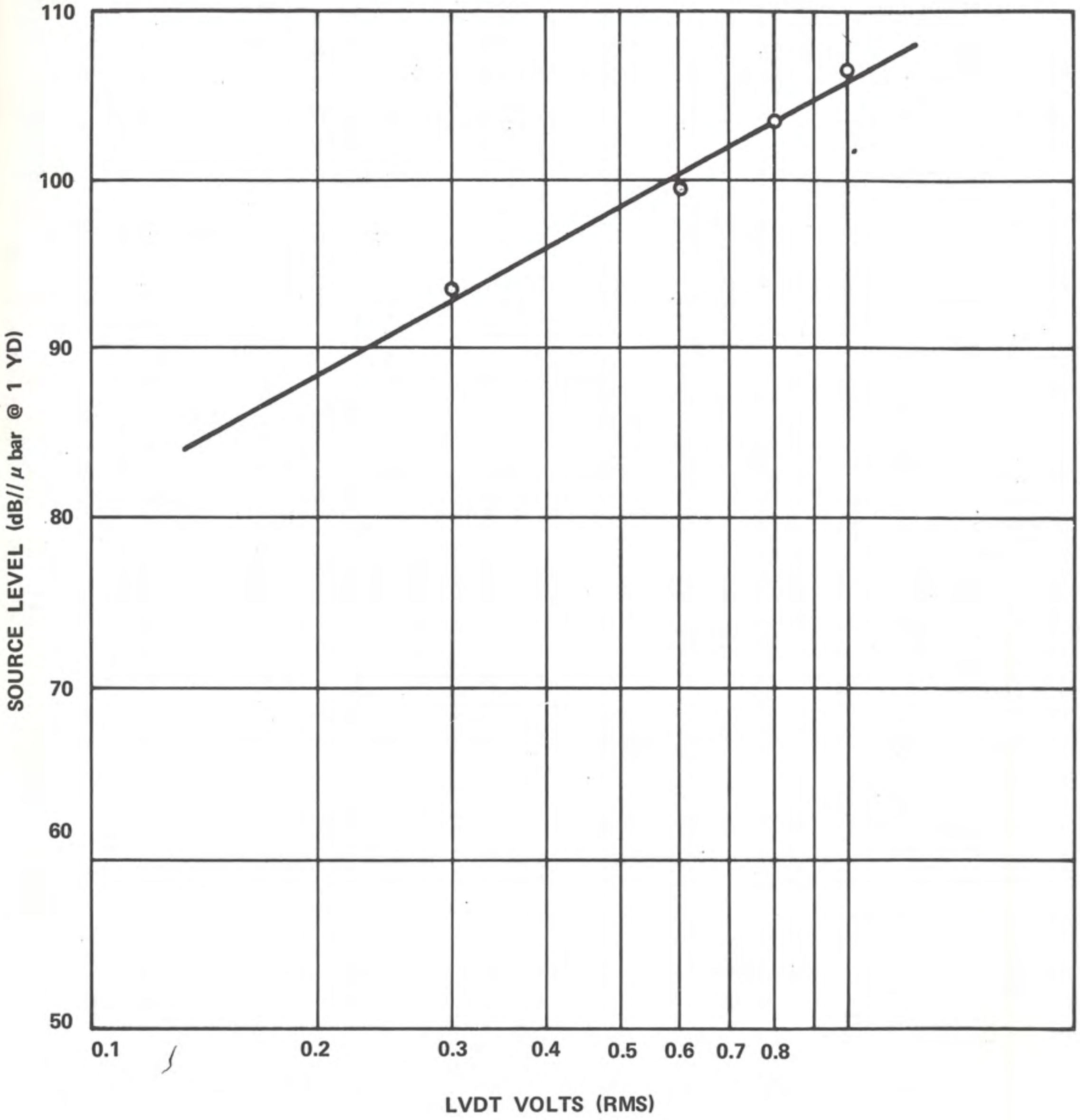
GEOMETRY OF THE TEST SHOWING THE PRIMARY ACOUSTIC PATHS

Figure 53



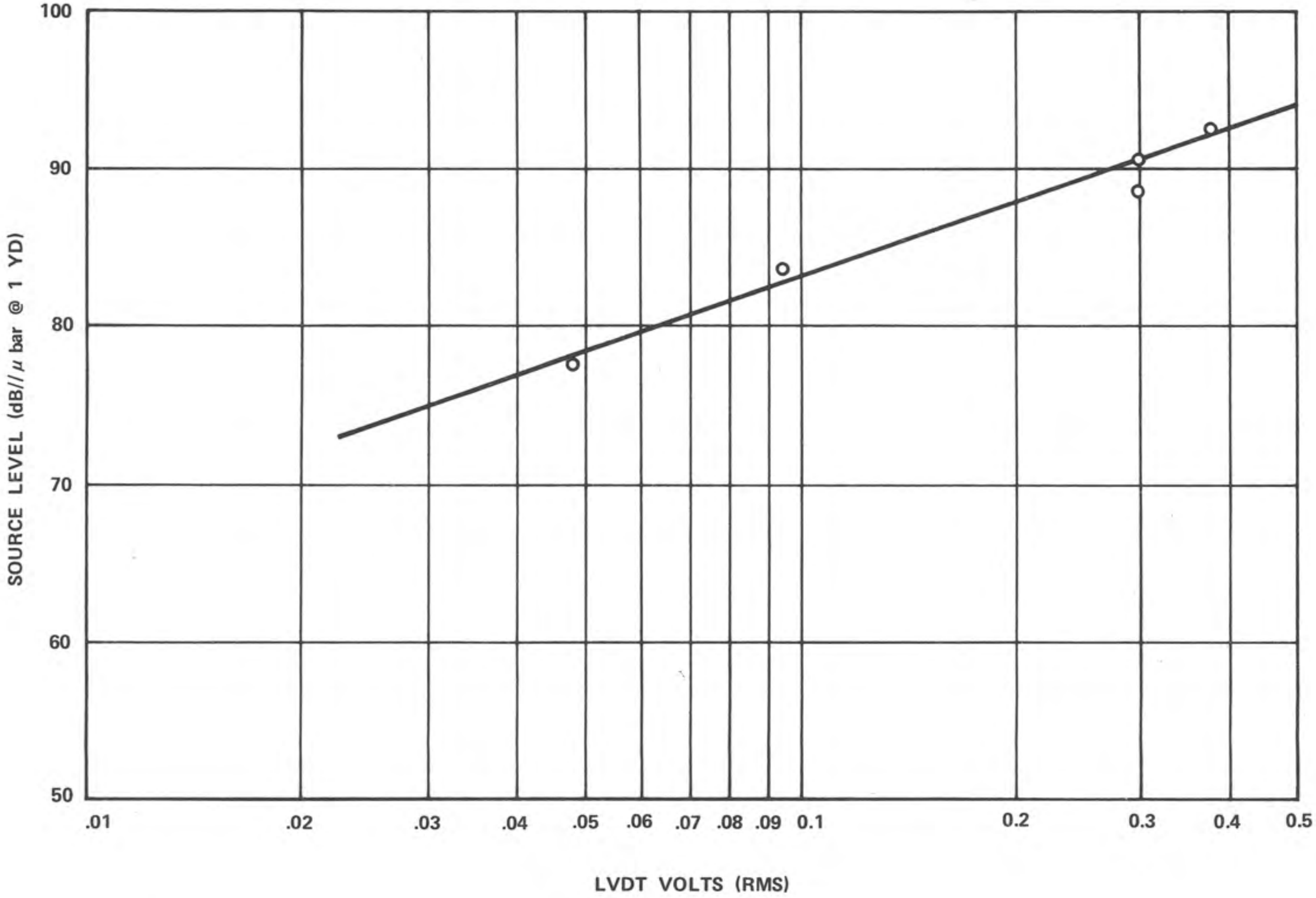
MAXIMUM UNDISTORTED SOURCE LEVEL

Figure 54



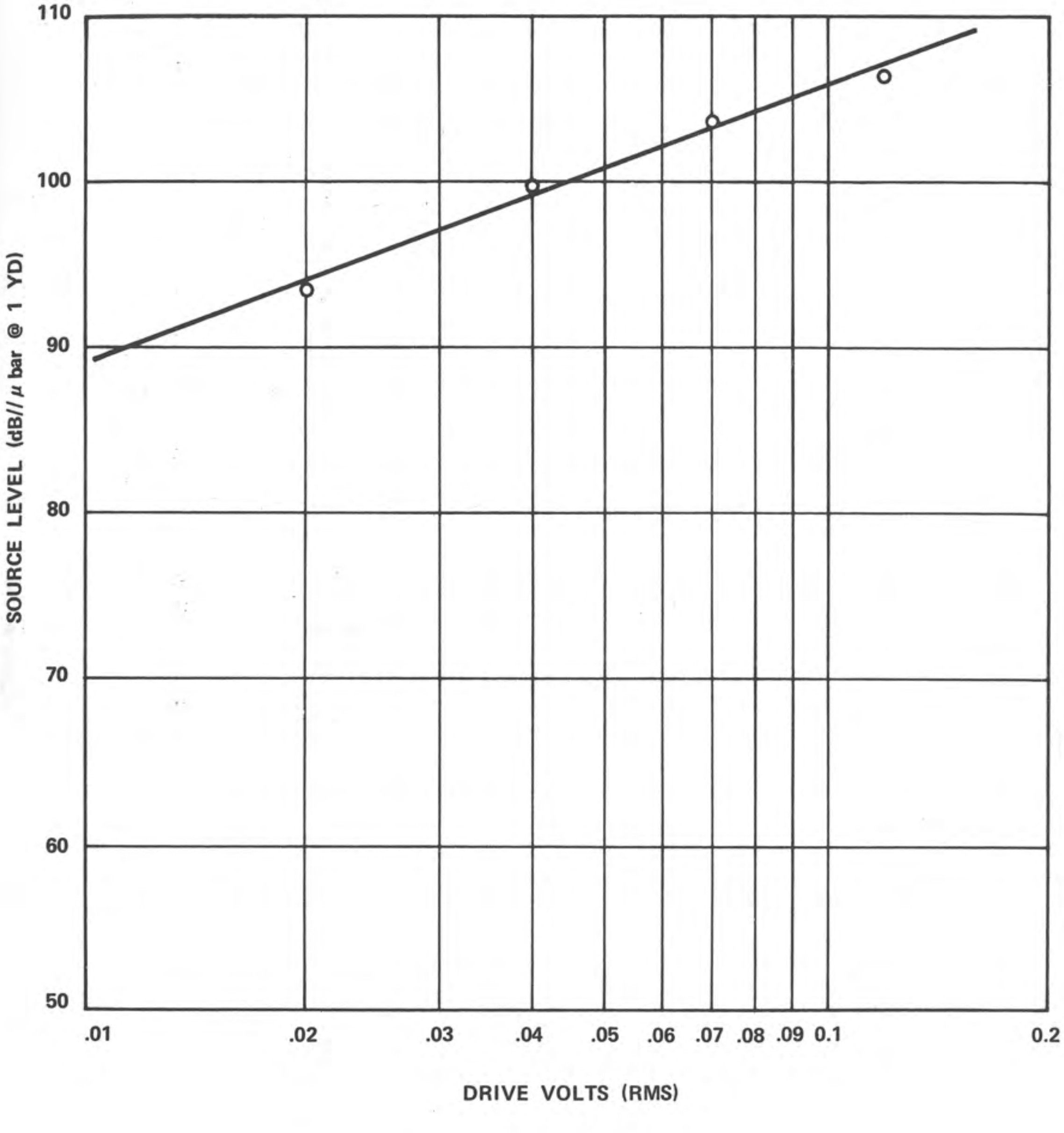
SOURCE LINEARITY WITH LVDT VOLTAGE - 40 Hz

Figure 55



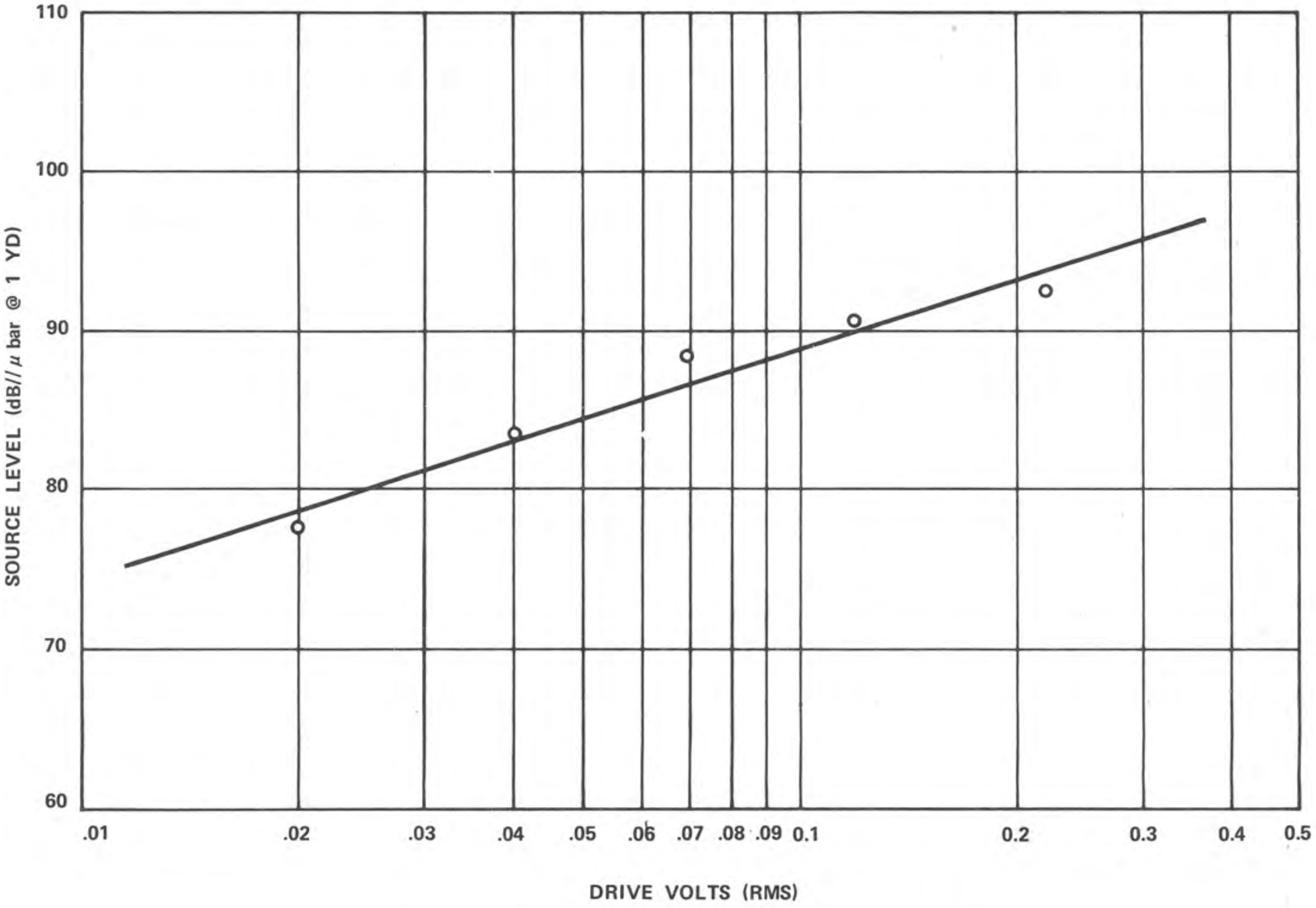
SOURCE LINEARITY WITH LVDT VOLTAGE - 63 Hz

Figure 56



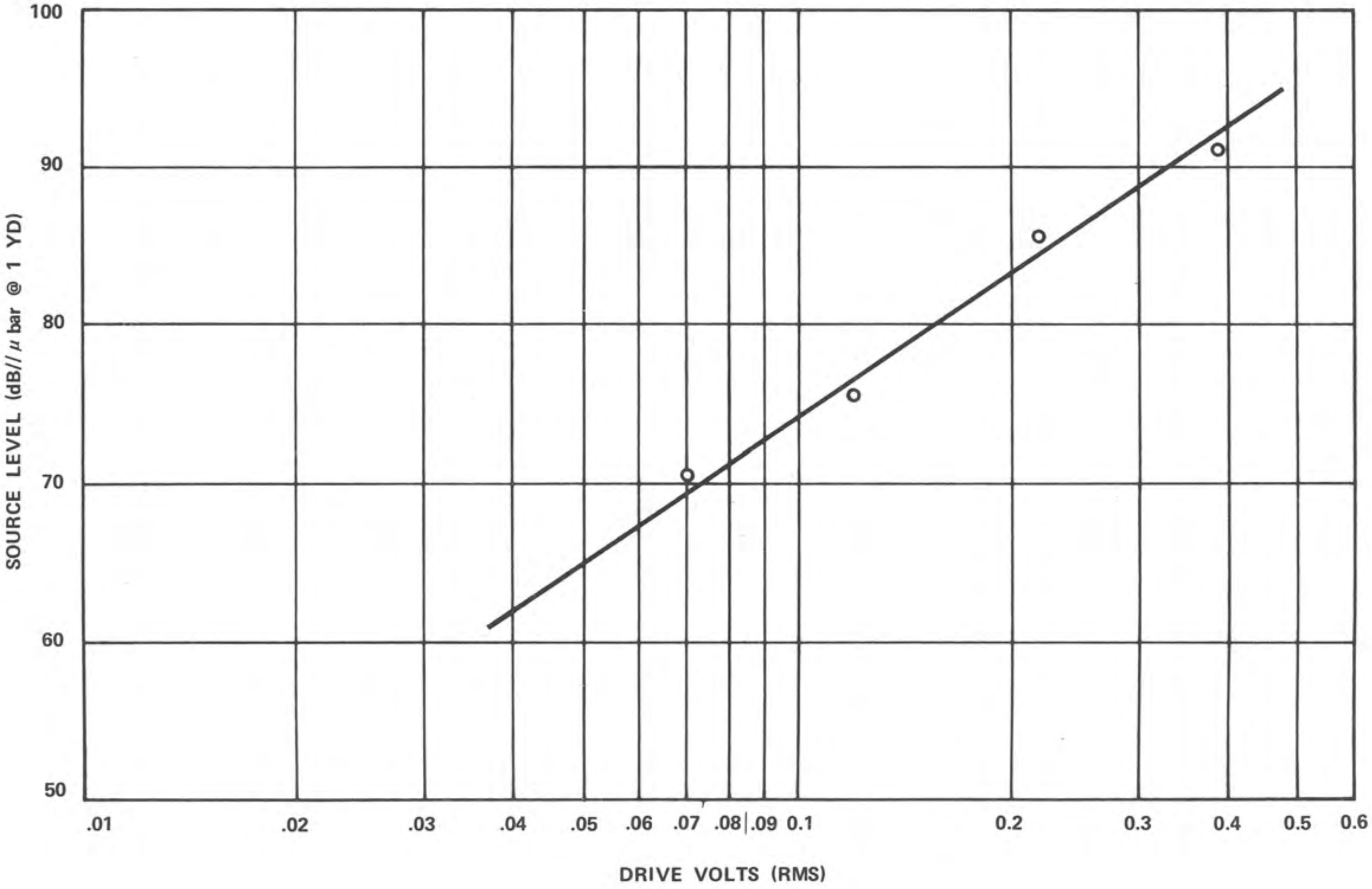
SOURCE LINEARITY WITH DRIVE VOLTAGE - 40 Hz

Figure 57



SOURCE LINEARITY WITH DRIVE VOLTAGE - 63 Hz

Figure 58



SOURCE LINEARITY WITH DRIVE VOLTAGE - 100 Hz

Figure 59

(4). Pulsed CW operation was used to obtain the dynamic range of the Mark IV projectors at 40, 63, and 100 Hz and shows that a dynamic range of 15 to 20 db is achieved at each of these frequencies. Refer to Figures 55 - 59.

(5). M/V DEARBORN traversed figure 8 patterns over station A and a CW mode of operation was used. Analysis of the data indicates a maximum source level of 91 db//1μ bar at 15 and 30 Hz. There was insufficient time to take data adequate for determining the dynamic range of Mark IV operation at these frequencies.

(6). Figure 54 shows a peak acoustic level occurs at approximately 40 Hz although these is a lack of adjacent data points to confirm this. The peak level occurs in both the pulse and CW modes and is relatively independent of Mark IV operating depth. Delta believes this high level of operation is caused by an oil column resonance in the hydraulic valve.

(7). The phase stability of the Mark IV deep unit was monitored at two frequencies in CW operation and was found to be stable to ± 1° when compared with the driving oscillator which has a stability of 1 ppm. These particular tests were brief and additional tests are necessary to determine the degree of phase stability with changing acoustic levels of operation and with changing depth caused by varying tow speeds.

(8). Although the fidelity of the LVDT signals at 10 and 15 cycles looks to be reasonably high for many forms of acoustic work, distortion may be of the order of 10% based on an early estimate; refer to Figure 52. Measurements of signal distortion can be made from the magnetic tapes.

(9). The Mark IV hydroacoustic projector is an air compensated unit and air at sufficient pressure and volume must be supplied to compensate for ambient pressure at the maximum depth of operation and for relatively rapid changes in depth while under tow and when making turns. The air supply and regulator systems may not have adequate reserve and their capabilities should be reviewed with these features plus 20 to 30 day continuous operation periods in mind.

(10). Limited tests at frequencies of 20 to 100 Hz show that VIBROSEIS operation and the radiated acoustic energy is not depth dependent in the 60 to 300 foot depth range.

(11). Inspection of Figures 55 through 59 shows that source levels below 75 to 80 db//μbar are difficult to achieve since the Mark IV unit becomes unstable at low levels. Although some mechanical improvements to the system can be made or the hydraulic pressure may be reduced, alterations such as these generally affect operation in other ways such as signal distortion at the upper end of the band. However, the smaller 30 inch Mark III projector is available, can operate from 20 Hz to beyond 100 Hz at levels approaching 100 db and may be capable of satisfactory operation at levels below 65 db//μbar.

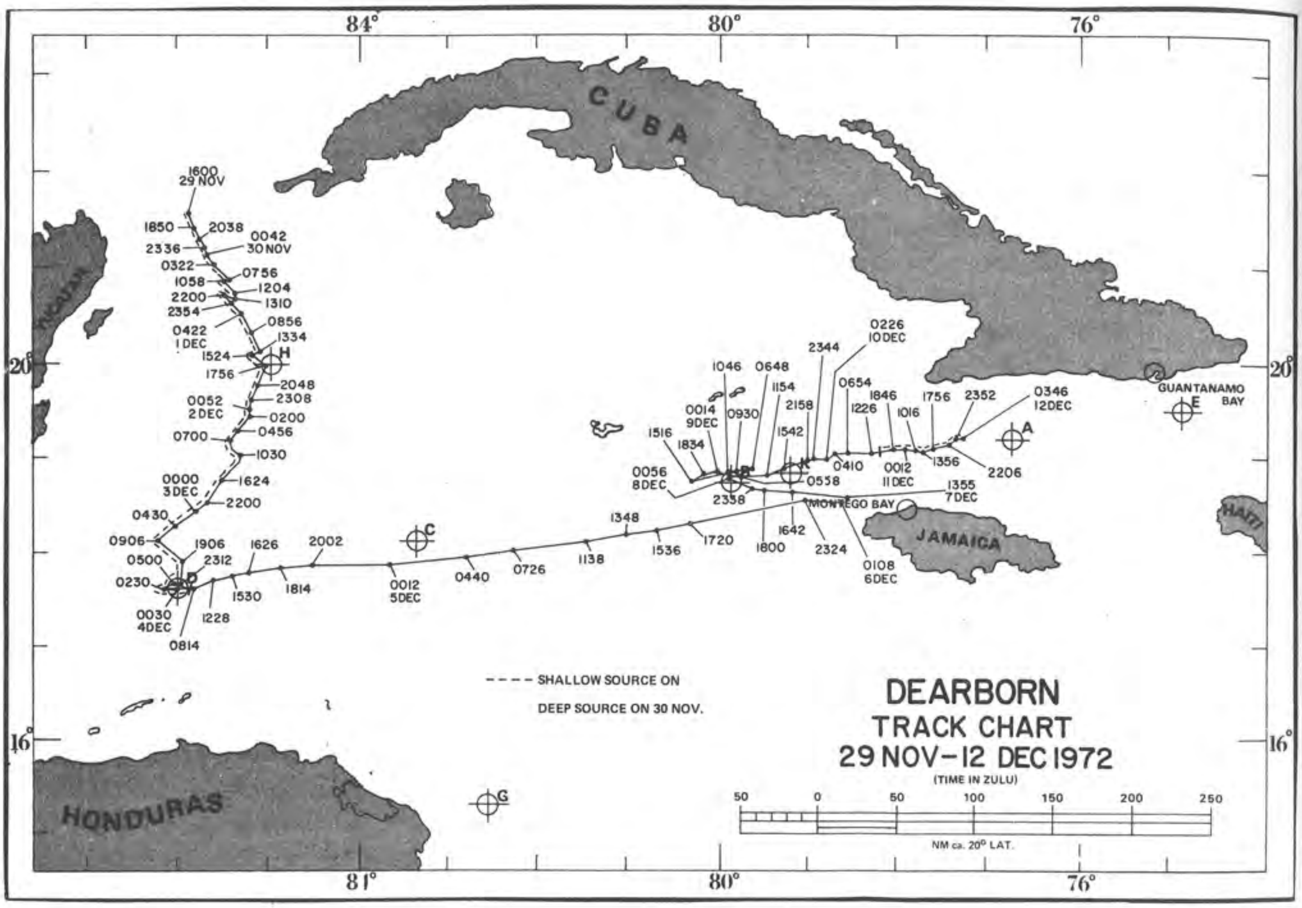
D. Performance

DEARBORN arrived on station 48 hours prior to the time the source was to begin operation for the purpose of deploying and checking functioning of the sources. In rigging the deep source, a cable clamp slipped free allowing the stowage reel to fall to the deck causing damage to the equipment. Repairs were made and the experiments were begun on 29 November, approximately as scheduled. The deep source functioned for 28 minutes on 30 November. Less serious problems were encountered with the shallow source. Loss of hydraulic oil and the interruptions resulting from attempts to operate the deep source resulted in the shallow source being operated between nine and 23 hours per day between 30 November and 4 December. By 4 December, the supply of hydraulic oil for operating the shallow source was nearly expended. Five barrels had been lost overboard during high seas and approximately two barrels per day were being consumed by the source equipment.

On 4 December, the OTC/TD directed the DEARBORN to suspend operations and proceed to Montego Bay to obtain hydraulic oil and to attempt to repair the sources. On 7 December the DEARBORN proceeded to the vicinity of position B to resume operations. Due to high seas, the shallow source was not deployed until 10 December. The continuing high seas precluded any further attempts to deploy the deep source.

The track of the DEARBORN and locations while the sources operated are shown on Figure 60. Source operating periods are given in Table VIII.

In summary, both sources were scheduled to operate simultaneously for 12 1/2 days. The deep source operated for only 28 minutes. The shallow source operated for approximately five days.



DEARBORN Track Chart

29 Nov - 12 Dec 1972

Figure 60

Source	Shallow (60 feet)			Deep (300 feet)		
		Length			Length	
Date	Period	Hours	Minutes	Period	Hours	Minutes
29 Nov (COMEX)	1400 - 1744	3	44			
	2101 - X	2	59			
30 Nov	X - 0746	7	46			
	1007 - 1124	1	17			
	2302 - 2330	0	28	2302 - 2330	0	28
1 Dec	0201 - 1300	10	59			
	1524 - X	8	36			
2 Dec	X - 0901	9	01			
	0945 - 1818	8	33			
	1916 - 2048	1	32			
	2340 - X	0	20			
3 Dec	X - 2310	23	10			
4 Dec (Exercise Suspension)	0530 - 0701	1	31			
SUBTOTALS		79	56		0	28
7 Dec (Resume Exercise)						
8 Dec						
9 Dec						
10 Dec	1501 - 1718	2	17			
	1723 - 2217	4	54			
	2337 - X	0	23			
11 Dec	X - 0205	2	05			
	1020 - 1124	1	04			
	1129 - 2145	10	16			
	2201 - X	1	59			
12 Dec	X - 0346	3	46			
SUBTOTALS		26	44		0	0
Exercise Totals		106	40		0	28

Source Operating Periods

Table VIII

2.3 Environmental Instruments

2.3.1 Expendable Bathythermographs

A. General

Two different types of expendable bathythermographs (XBTs) were used in CHURCH GABBRO, both manufactured by the Sippican Corporation. Sippican Model T-7 probes have a maximum depth capability of 760 meters, while Model T-5 probes go to a maximum depth of 1830 meters. The same launching and recording equipment is used for both probes; only the recorder paper must be changed. Specifications and a description of the system are provided in Reference (26).

B. T-7 (760 meter) Probes

A total of 369 T-7 probes were deployed during CHURCH GABBRO as shown in the following table.

CHURCH GABBRO T-7 XBT Deployments

SHIP	TOTAL DROPPED	GOOD (760 m)	FAIR (200-760 m)	POOR (0-200 m)
NORTH SEAL	108	89 (82%)	14 (13%)	5 (5%)
DEARBORN	73	40 (55%)	12 (16%)	21 (29%)
PIERCE	27	23 (85%)	2 (7%)	2 (7%)
SANDS	161	114 (71%)	9 (6%)	38 (24%)
TOTAL	369	266 (72%)	37 (10%)	66 (18%)

The T-7 probes performed better than the figures in this table would indicate; many of the failures were caused by problems unrelated to the probe itself, such as radio interference and wire abrasion on the ships hull. This latter problem was particularly serious on DEARBORN, where the launcher location caused XBTs to strike the side of the ship under certain wind and sea conditions. In addition, many XBTs became entangled in the acoustic projector cable during towing operations on SANDS and DEARBORN. These two factors raised the failure rates for these two ships considerably.

C. T-5 (1830 meter) probes

During CHURCH GABBRO, 176 T-5 XBTs were deployed, primarily from DEARBORN and NORTH SEAL. Their performance is summarized below.

CHURCH GABBRO T-5 XBT Deployments

SHIP	TOTAL DROPPED	GOOD (760 m)	FAIR (200-760 m)	POOR (0-200 m)
NORTH SEAL	49	21 (43%)	16 (33%)	12 (24%)
DEARBORN	118	43 (36%)	34 (29%)	41 (35%)
PIERCE	-0-	-	-	-
SANDS	9	2 (22%)	-0-	7 (77%)
TOTAL	176	66 (38%)	50 (28%)	60 (34%)

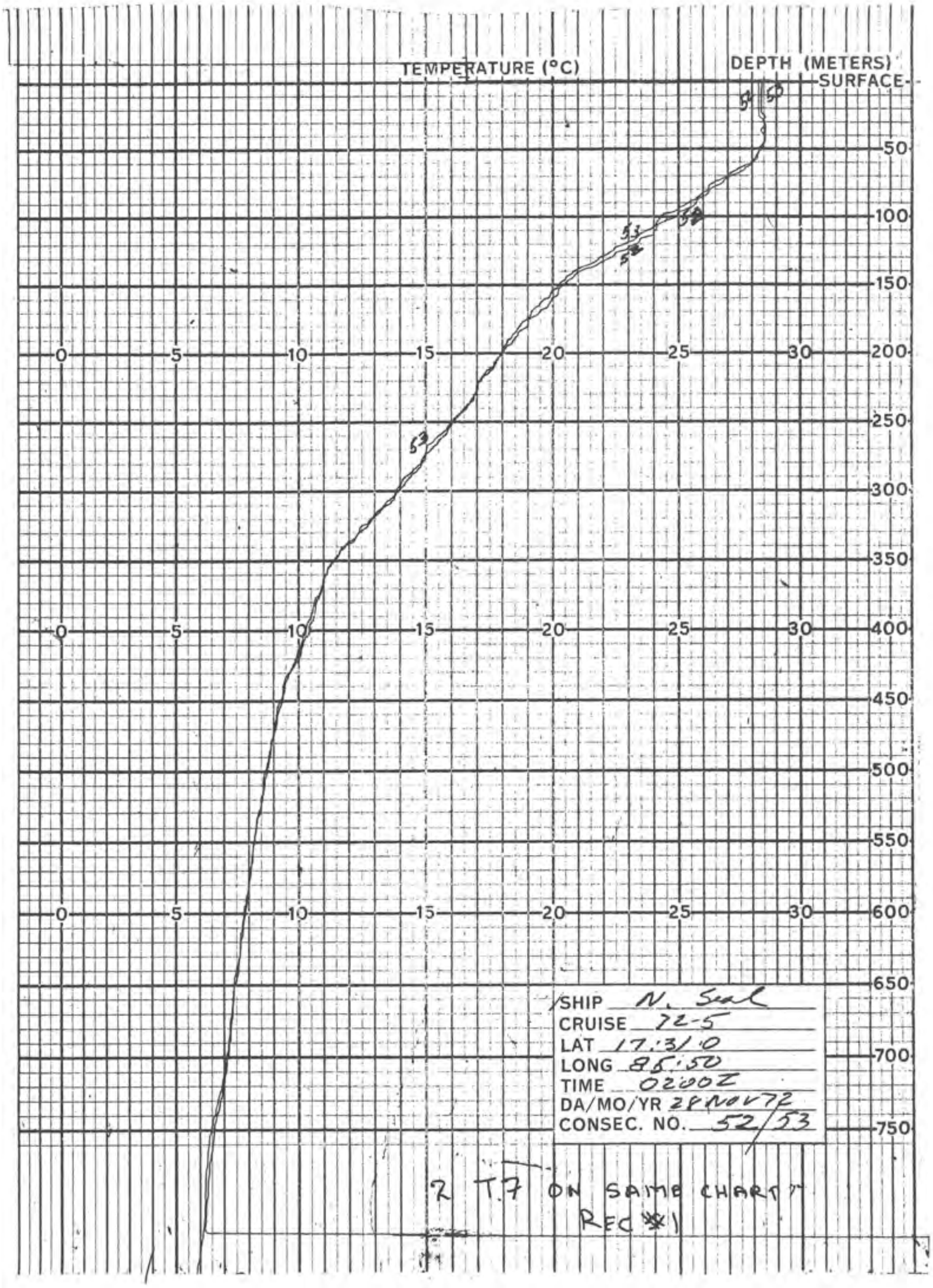
T-5 operations were plagued with the same difficulties listed for T-7s above. In addition, Sippican has experience some difficulties with quality control on T-5 production, and the probes used in CHURCH GABBRO were known to have a failure rate that was higher than is usually acceptable. It was felt, however, that the value of the data gained by employing T-5s, even with a high dud rate, far outweighed the inconvenience attendant to the repeated failures. Sippican has offered to replace the faulty probes as soon as production of the T-5 resumes.

D. Intercomparison Test

On 28 November 1972 NORTH SEAL conducted intercomparison tests of XBTs. Sequential T-7s, sequential T-5s and sequential T-7 and T-5 probes were dropped with their traces marked on the same chart. Time interval between successive drops was about five minutes. Records of the double T-7 trace and the T-7/T-5 traces on T-7 paper are shown in Figures 61 and 62. The two T-7s exhibit good repeatability, differences in the traces could reasonably be explained by statistical differences in the medium. The puzzling aspect of the T-7/T-5 experiment however, is the very coincidence of the traces as seen in Figure 62. The T-5 should sink faster than the T-7 as seen from the T-5 and T-7 depth scales both of which are indicated in the figure. This trace coincidence most probably indicates one of two conditions:

(a). The sinking rate of either the T-7 or the T-5 probe was outside of specification; either the T-7 was sinking too fast, the T-5 was sinking too slow or perhaps both conditions applied.

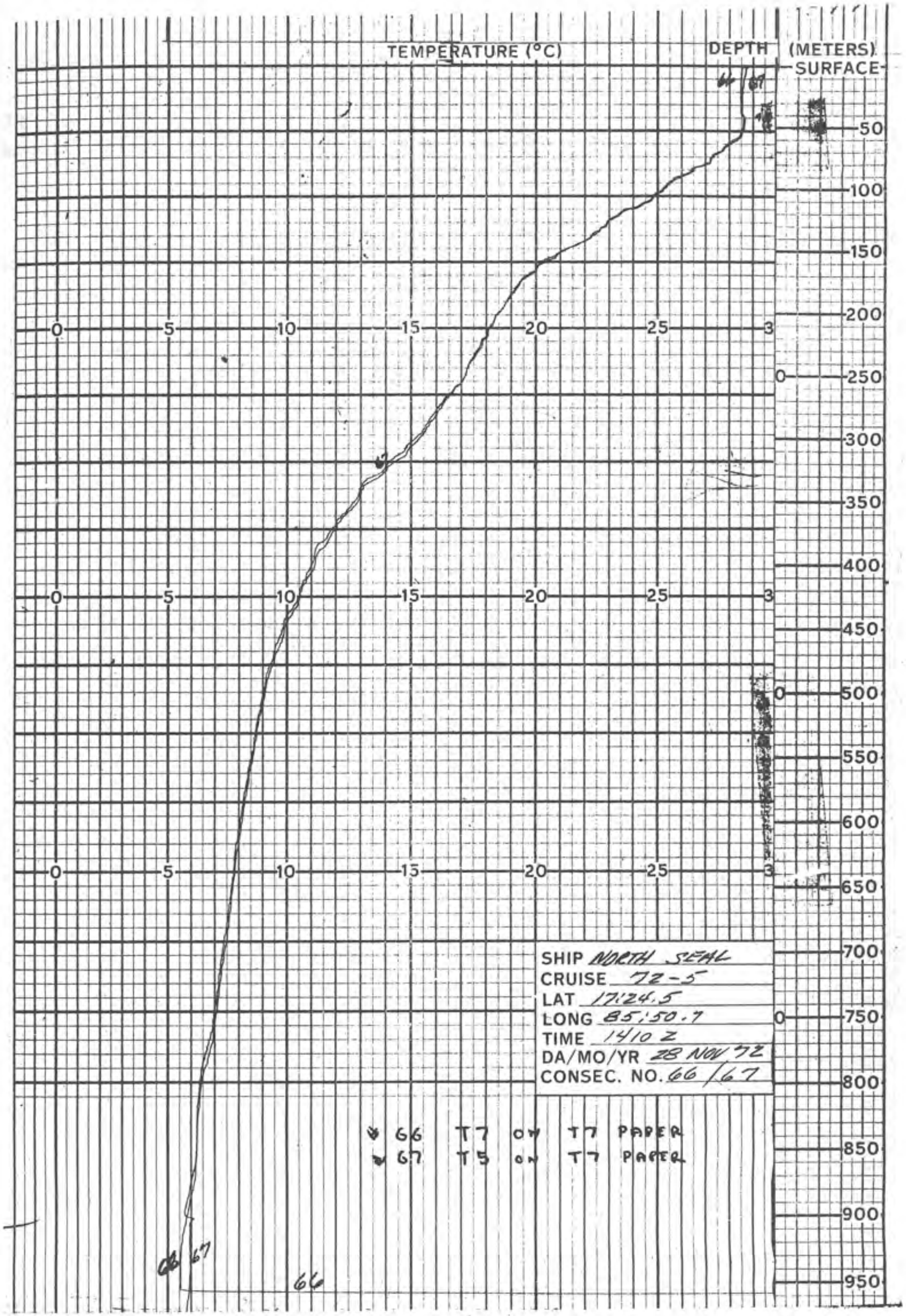
(b). An internal wave was in progress; the entire thermocline was increasing in depth between the trace made by the first (T-7) and the second (T-5) probe.



SHIP N. Seal
CRUISE 72-5
LAT 17:31.0
LONG 85:50
TIME 0200Z
DA/MO/YR 28 Nov 72
CONSEC. NO. 52/53

XBT T-7/T-7 Intercomparison
Test Record

Figure 61



SHIP NORTH SEAL
CRUISE 72-5
LAT 17:24.5
LONG 85:50.7
TIME 1410 Z
DA/MO/YR 28 NOV 72
CONSEC. NO. 66/67

66 T7 ON T7 PAPER
67 T5 ON T7 PAPER

XBT T-7/T-5 Intercomparison
Test Record

Figure 62

2.3.2 Airborne Expendable Bathythermographs

A total of 115 AN/SSQ-36 sonobuoys, or airborne expendable bathythermographs (AXBTs) were dropped by VP-16 and VXN-8 during CHURCH GABBRO. Each flight dropped between 7 and 12 probes, except for the 4 December VXN-8 flight, where 22 buoys were deployed in an intensive analysis of the thermal structure in one area.

Seven buoys failed completely, and on another 18 drops the signal faded out before reaching maximum depth. It is believed that these buoys were probably at the end of their shelf life; weakened batteries probably caused the weak RF.

All AXBT traces from one VP-16 flight on both 4 and 6 December had to be discarded because they were recorded improperly. These 21 buoys were dropped from the "back-up" P-3, which only carried an older, quarter-inch tape recorder, instead of the usual one-inch machine. Apparently the drive speed was not exactly 7 1/2 ips, and the data are biased to an unknown degree.

2.3.3. Salinity/Temperature/Depth (STD) Measuring Systems

A. General

Two STD models manufactured by Bissett & Berman, San Diego, California were employed from NORTH SEAL. One of these was a Model 9060 self contained, internally recording system and one was a Model 9040 with deck readout. The advantage of the former is that no electrical conductors are required in the support cable and the advantage of the latter is that it is possible to monitor the profile as it is being taken.

B. Model 9060 (Self-contained)

This system is rated at 2000 meters. The following performance specifications apply:

Variable	Accuracy	Resolution
Salinity	± 0.05 ppt	0.02 ppt
Temperature	± 0.1° C	0.05° C
Depth	± 0.25% full scale	0.01% full scale

This unit performed very poorly during the exercise; no satisfactory traces were obtained. The trouble was subsequently traced to a faulty internal electrical connector.

C. Model 9040 (with Deck Readout)

This system is rated at 3000 meters. The specifications are comparable to those for the Model 9060. In general this system performed satisfactorily with two exceptions. First, there was a loss of depth synchronization in the strip chart recorder trace. This was most probably due to slippage of the drive clutch. Second, when the raising or lowering rate exceeded about 100 meters/minute the recorder stylus in both the temperature and the salinity channels would execute side slewing motions from the read value to zero and back. It is assumed that this is a local instability in the deck terminal equipment caused by too rapid a change in signal frequency which does not permit sufficient signal integration at a quasi-stable frequency to achieve a reading. This condition cannot be called a malfunction because the instruction book specifically cautions against raising or lowering at a rate greater than 130 meters/second.

D. Confirming Water Samples and Temperature Measurements

SANDS was scheduled to make a Nansen cast, but due to excessive drift and large wire angle the cast was never successfully completed.

2.3.3 Sound Velocity Profiling (SVP) System

USNS SANDS was asked to obtain ten separate SVP's during the exercise. All ten SVP's were successfully obtained, although one cast was aborted at a depth of 1700 meters due to a cable problem. Profiles were obtained during both the downcast and upcast. The rate of descent/ascent was .33 meters per second between the surface and 1500 meters and one meter per second from 1500 meters to the deepest part of each cast.

The SVP sensing unit consisted of both an NUS Corporation velocimeter model TR-4B serial number 241 last calibrated at NUS in September 1972 (accuracy; one part in ten thousand) and an NUS high accuracy depth sensor serial number 1265 last calibrated in September 1972 (accuracy; one part in 1000); see Reference (21). These units were connected to the ship by .219 four conductor cable. The frequency outputs of both devices were converted to velocity in meters/second and depth in meters. These outputs were then recorded on both hard copy printer paper and punched paper tape. Wave forms were constantly monitored onboard.

A diagram of the SVP system appears in Figure 63.

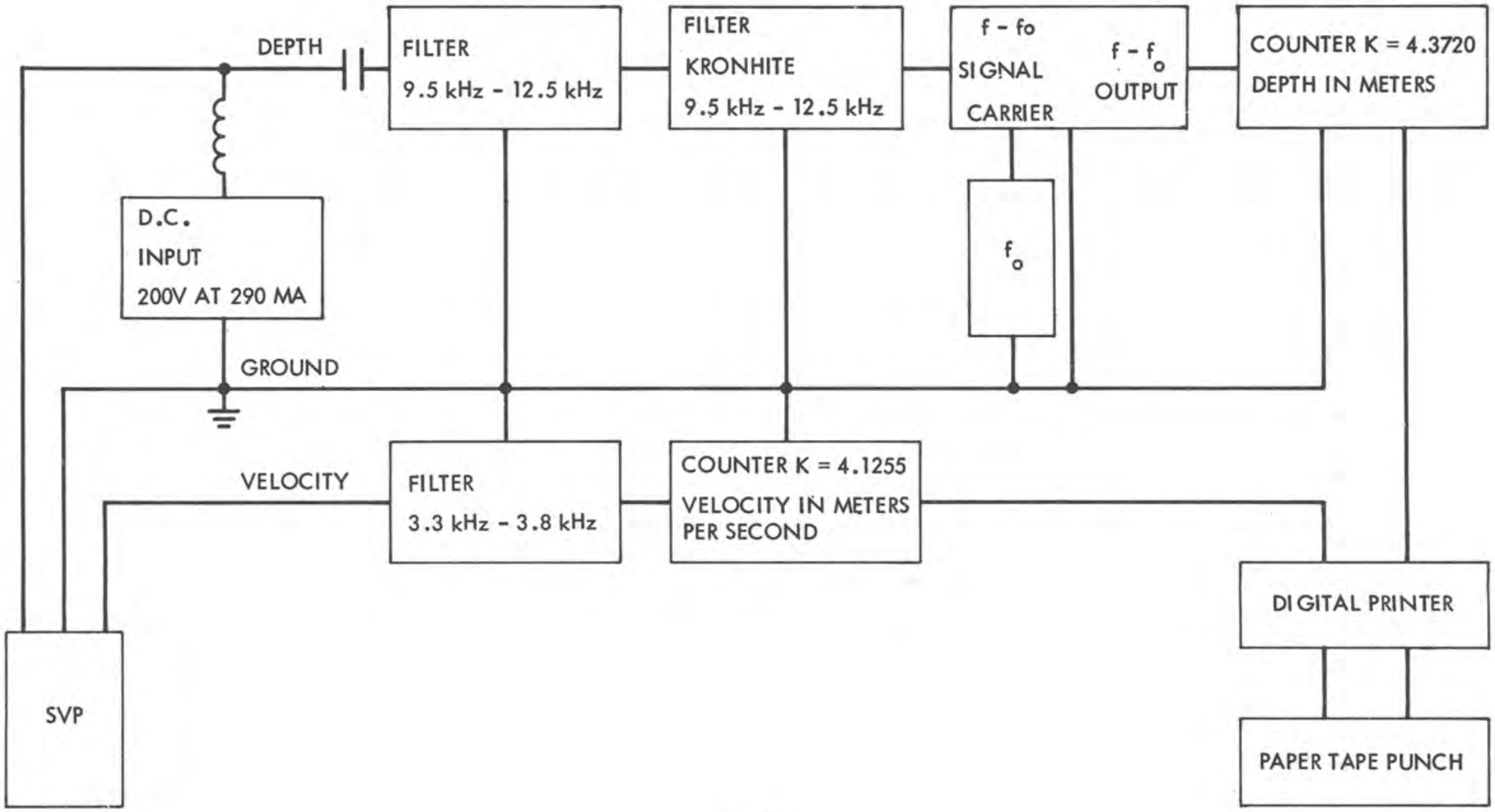
2.3.4 Current Measurement Systems

A. General

Two types of current measurement systems were used: a discrete depth system using Savonius rotor current meters and continuous profiling system using recording inclinometers which measure tilt angle and azimuth.

Naval Underwater Systems Center
NP24 - 49213 - 4 - 73

Official Photograph



SANDS
SVP BLOCK DIAGRAM

Figure 63

B. Discrete Depth System

A system for measuring currents at six discrete depths was installed at Point A. The instruments employed were Geodyne Current Meters Model A101; they were placed at the following depths: 30, 92, 244, 396, 610, and 1830 meters.

The system has a threshold which is no less than 0.1 know. Because the deep currents at the measurement site were very weak, for the majority of the time the only statement which could be made was that the currents were less than 0.1 knot.

C. Continuous Profiling System

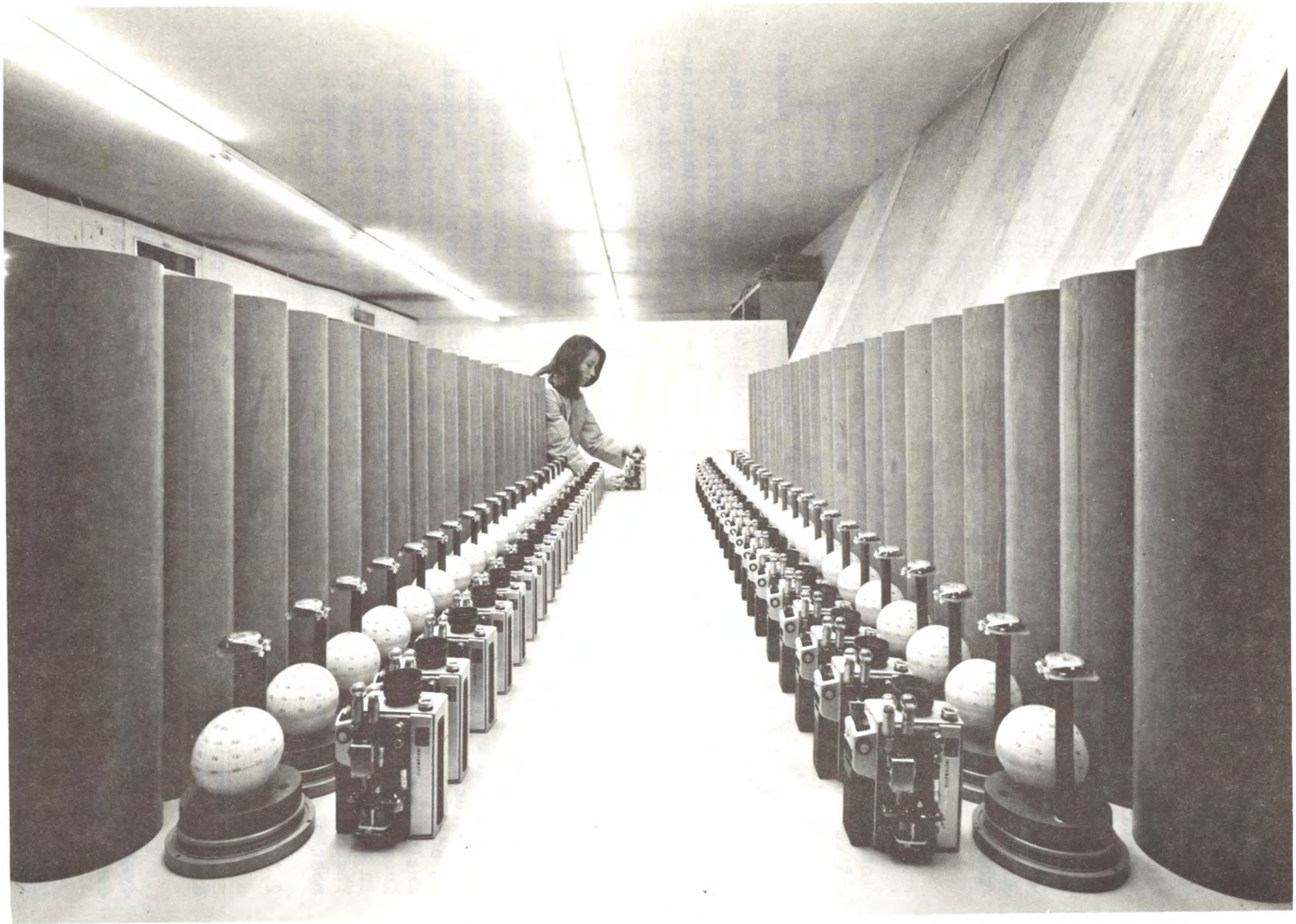
The continuous profiling current measurement system was integral with the ACODAC compliant mooring at Position B. A total of 53 recording inclinometers, General Oceanics Model 2012 were spaced at intervals of about 75 meters along the entire array; in addition two recording pressure gauges, General Oceanics Model 3050, were placed one at the top and one at the bottom of the mooring, where also a recording tensiometer, General Oceanic Model 4050, was located. See Appendix A for a detailed description of the instrument locations. Figure 64 shows assembled and disassembled views of a recording inclinometer. These units have a selectable recording interval; in this exercise one photographic record was obtained every five minutes.

The general performance of the system was very good. Out of the 56 instruments on the line, 8 failed to operate; unfortunately the recording tensiometer was among these. However, the loss of the recording tensiometer information, which is redundant in any event, does not prevent derivation of profiles. The reduction of data required longer than anticipated; a total of 327 simultaneous data sets, each constituting the base data for a continuous profile, have been reduced. In addition, a considerable effort has been devoted to improving the analysis computer program. This measurement was the first successful long term measurement of continuous profiles over such a depth range in the deep ocean. A sample of the profile data is shown in Figure 65. The high degree of sensitivity of this instrument system is apparent; most of the profile is less than 5 cm/sec (approximately 0.1 knot).

2.3.5 Laser Wave Profiler

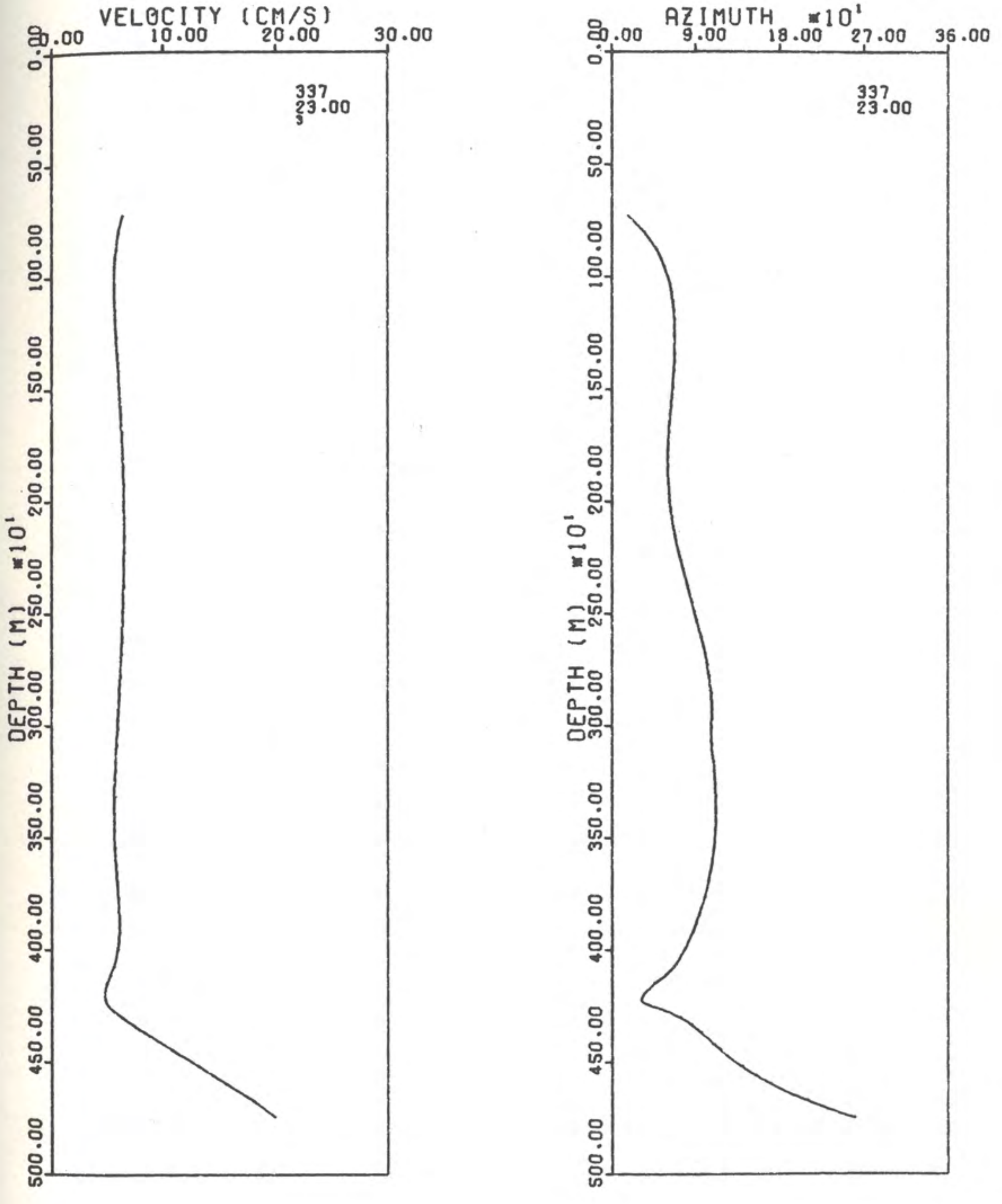
Wave height measurements were made on 4 and 5 December from a Geodolite Model 3A laser mounted on the VXN-8 aircraft.

Figure 66 is a block diagram of the laser wave profile system. The system, its performance, and calibration results are described in Reference (25).



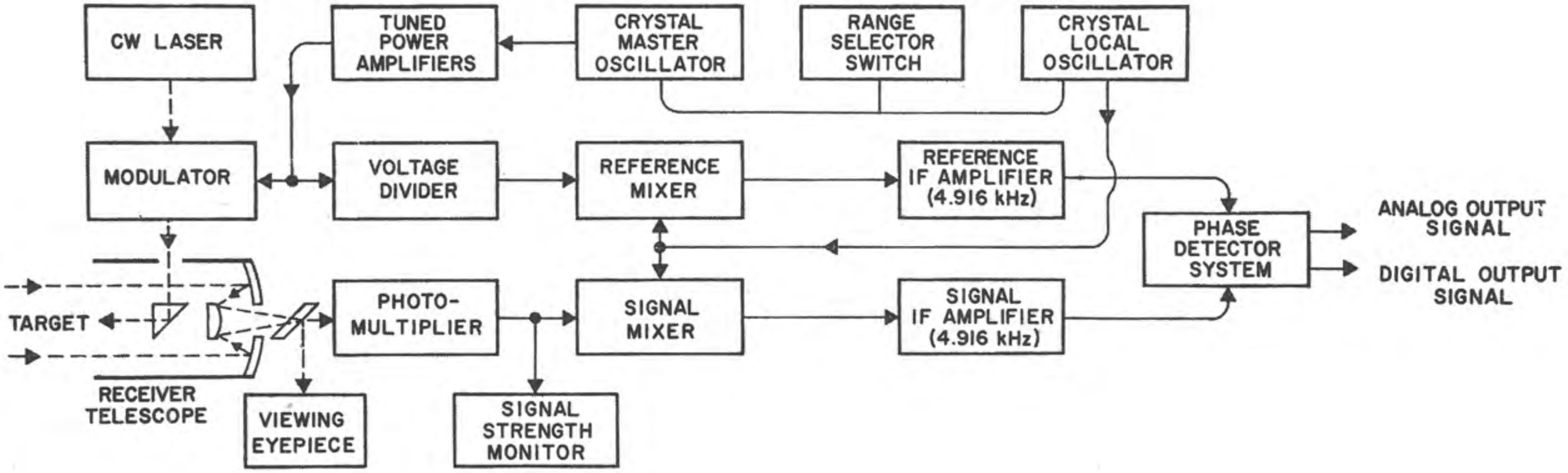
Recording Inclinometer
General Oceanics Model 2012

Figure 64



Sample Current Profile

Figure 65



Laser Wave Profile System

Figure 66

The following lists the specifications of the Geodolite 3A laser.

Range (in clear air): Greater than 10,000 feet in sun
Greater than 15,000 feet at night

Resolution and Accuracy: ± 0.1 foot or 1 in 10^4, whichever is greater.

Transmitter System

Source: Helium-neon CW Gas Laser
Power: Typically 24 milliwatts at the laser
Beam Divergence: Less than 10^{-4} radians

Receiver System

Type: 8 inch diameter reflecting telescope
Full Scale Range Steps: Choice of 10, 100, 1000, 10,000, 100,000 feet
Response Time: 1, 2, 5, 10, 20, 50, or 100 milliseconds
Output #1: 0 to +10.0 volts full scale, with full scale voltage equivalent to the full scale range step
Output #2: 0 to ± 1.4 volts for magnetic tape recording

Input Power: 115 ± 10 volts, 50 to 400 Hz, 400 VA

Mechanical

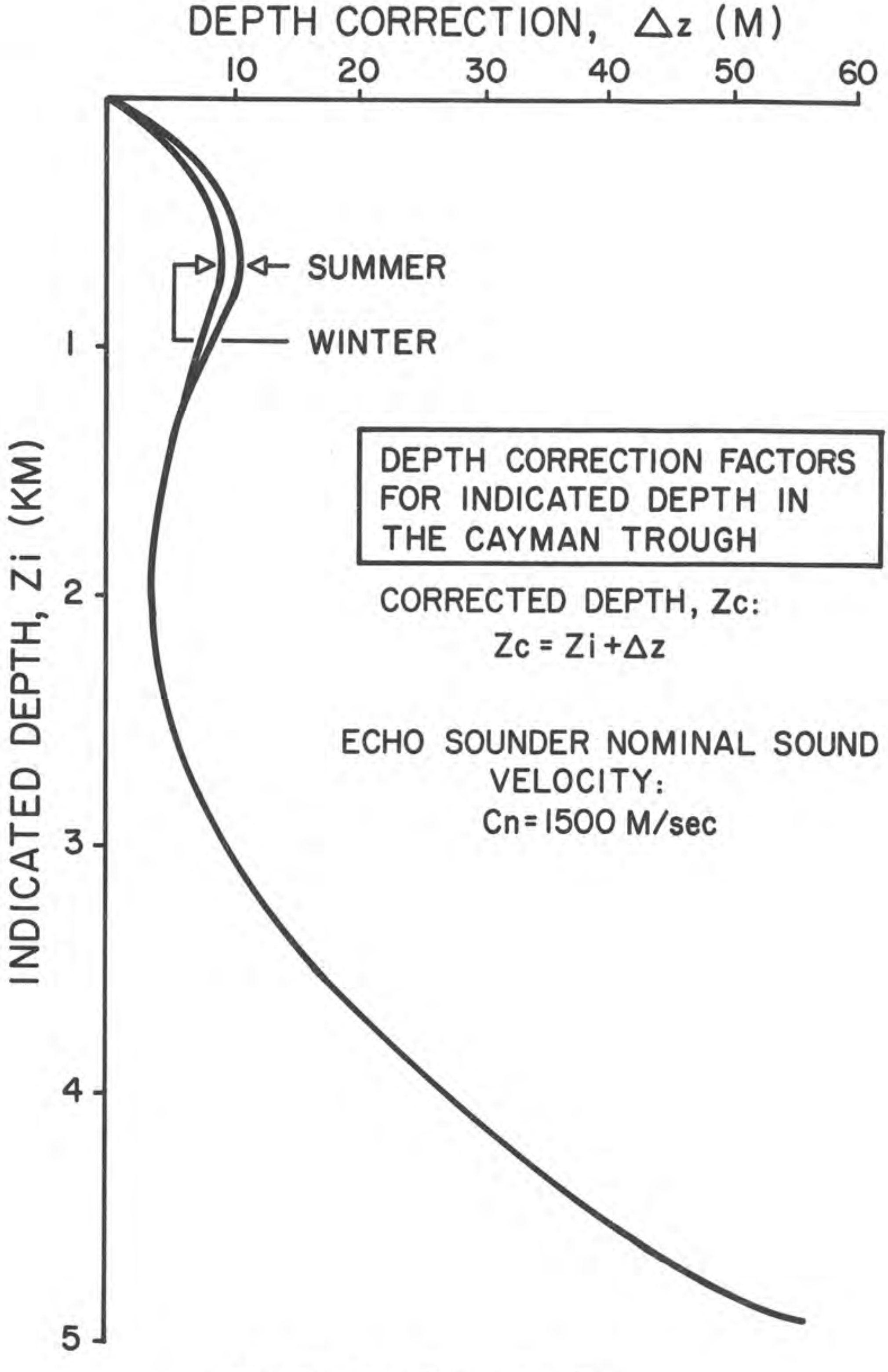
Weight: Telescope Assembly approximately 110 lbs.
Control Unit approximately 38 lbs.

Mounting: Vertical frame with vibration isolating mounts

2.3.6 Echo Sounders

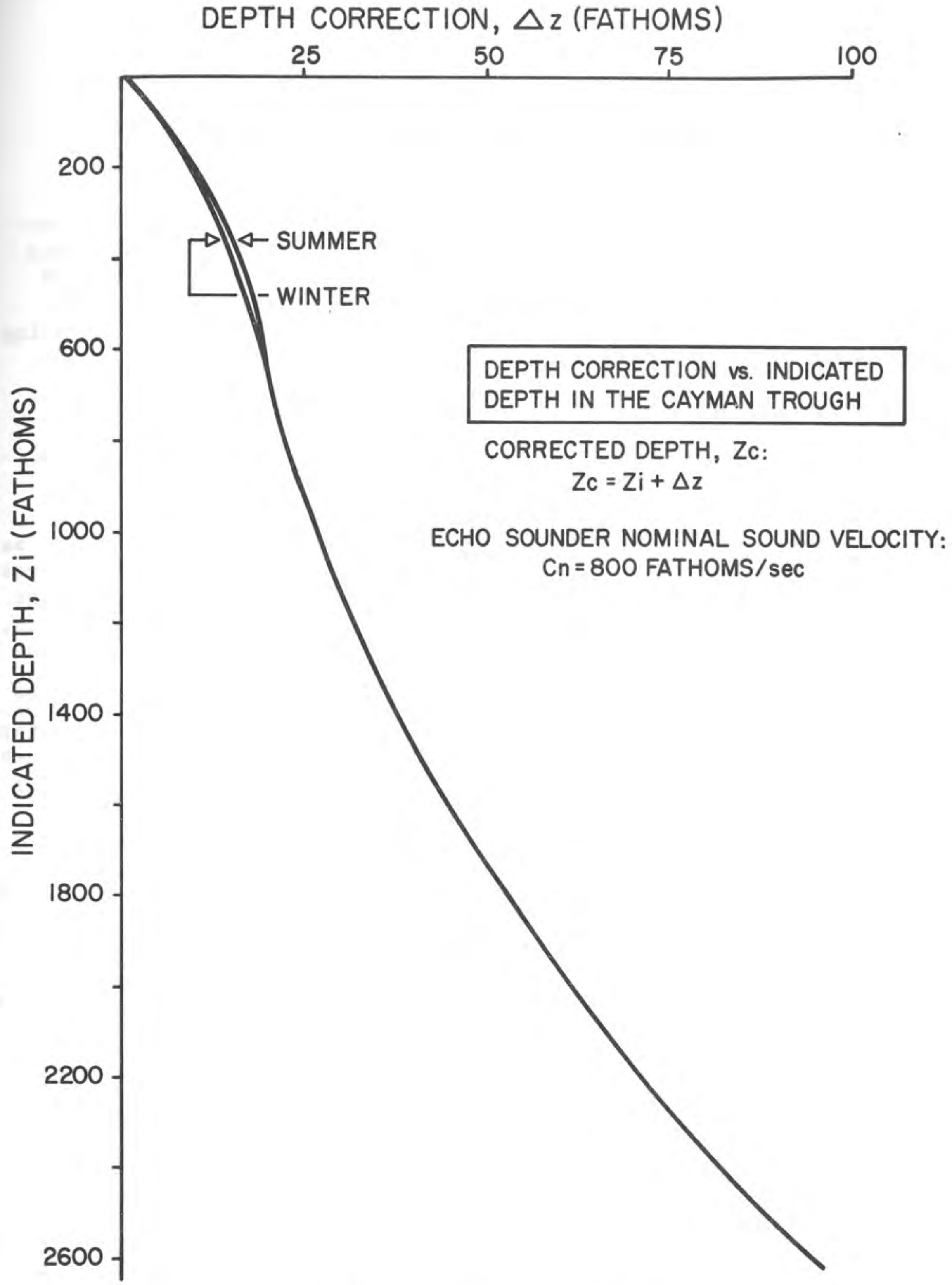
SANDS, NORTH SEAL and DEARBORN were equipped with echo sounders and Gifft Recorders. For purposes of uniformity soundings were not corrected on the bathymetric records; the correction task was assigned to NAVOCEANO in connection with the reduction of the bathymetric data.

However, for operational purposes it is often necessary to know the corrected depth. Figures 67 and 68 which plot depth correction based on historical average sound velocity profiles for the Cayman Trough area were found useful and agreed closely with the interpolated data from Matthews' Tables, Reference (13).



Echo Sounding Correction Chart
(C_n = 1500 meters/second)

Figure 67



Echo Sounding Correction Chart
(C_n = 800 fathoms/second)

Figure 68

2.4 Vehicles

2.4.1 Ships

A. General

Four ships were used in the exercise; these were: R/V SANDS a member of the AGOR-3 class, and three members of the offshore supply vessel 165 foot class, R/V NORTH SEAL, M/V DEARBORN and R/V PIERCE. SANDS is a general purpose oceanographic vessel; NORTH SEAL is specially fitted out for LRAPP work, particularly deployment and recovery of ACODACs; DEARBORN is specially fitted out for handling and towing the hydroacoustic source; PIERCE is specially fitted out for handling VLAM.

B. Navigation

Precise navigation is one of the most important elements of a successful environmental acoustics program. It assumes even greater importance when dealing with moored, submerged systems such as ACODAC or MABS. The satellite navigator is undoubtedly one of the most significant advances in positioning at sea since the invention of the sextant. SANDS, NORTH SEAL and DEARBORN all had satellite navigators, each vessel with a different model. SANDS had an SRN-9A model which failed during the exercise due to malfunctioning of the frequency standard. NORTH SEAL had a Magnavox Model 706CA which performed well during the exercise except for intermittent, unexplained shutdowns when the entire program would "blow". Such events required reloading of the program, a time consuming task. DEARBORN had a Satellite Positioning Company, SCS-100 system.

Omega was used on all vessels as a backup and interpolative system; on SANDS it became the primary navigation system because of the failure of the satellite navigator. Omega skywave corrections in this part of the ocean for this time of the year are apparently not well known, because omega positions would exhibit considerable unprogrammed wander from the satellite fix location. A special omega program for use with the Hewlett Packard 9810 computer was developed at sea aboard NORTH SEAL. This program accomplishes the following:

a. Converts omega readings into latitude and longitude, or alternatively into miles E-W and N-S of a fixed datum.

b. Using known position information (as from a satellite fix) and current omega readings, solves for skywave corrections which constrain the omega fix to the satellite fix.

With this program, omega and the satellite navigator become a self-complimentary system, providing continuous information but with fix precision updated at the frequency of each satellite fix.

In addition all vessels included the usual navigation instruments such as loran, radar and shallow depth sounders.

C. Communications

Exercise communications was poor in NORTH SEAL where the wrong crystals had been procured prior to the operation. The correct crystals were obtained and flown to Jamaica where an attempt was made to install them. The local Jamaican technician who was installing the crystals succeeded in burning out the power transformer of the transceiver. Using a duplicate transceiver NORTH SEAL communicated on general marine frequencies during the exercise.

NUSC outfitted SANDS with three separate transceivers for single side-band and AM communication, and also a UHF transceiver was available. The three side-band transceiverswere one RF communications 301 unit with a 1 KW linear amplifier and an automatic antenna coupler/tuner and two crystal controlled Collins KWM-2A units with 500 watt linear amplifiers. The UHF gear consisted of crystal controlled TED-3 gear.

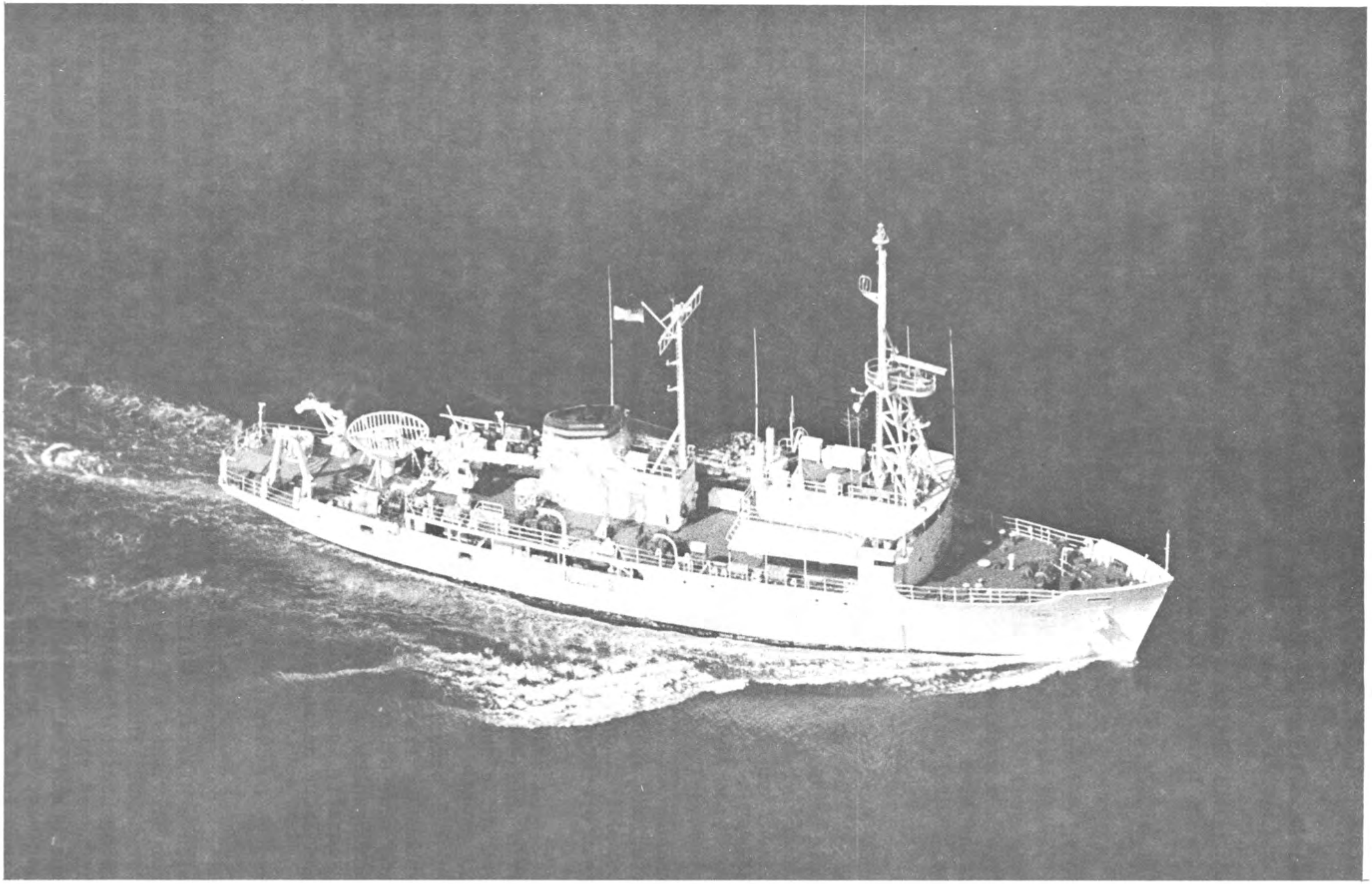
Communications from and to SANDS were generally excellent throughout the exercise. There were nighttime periods when other Navy stations appeared on the assigned frequencies; however, in general, communications could always be understood. SANDS radio communication gear operated without any breakdown during the exercise.

A standard VHF ship-to-shore channel was used to communicate from bridge-to-bridge with participating vessels while at close range and while near port.

Communications between DEARBORN and EXCON on assigned primary and secondary frequencies was unreliable due to interference both atmospheric and from other stations. in comparing this observation with that of SANDS which enjoyed good communications, the cause might be found in the generally longer ranges between DEARBORN and EXCON than between SANDS and EXCON during the exercise.

D. Vessels

USNS SANDS (T-AGOR-6), Figure 69, a research vessel staffed with a Military Sealift Command civilian crew served as the platform for all tasks assigned to NUSC during the exercise. See Table IX for SANDS' characteristics. SANDS lost no time during the exercise due to mechanical breakdowns for inability to meet schedules. It should be noted that the top speed of SANDS under average conditions is 10 knots and that during the exercise there were times when she could not meet her assigned SOA because of head-seas and winds. In future operations consideration should be given to this drawback.



USNS SANDS (T-AGOR-6)

Figure 69

Characteristic	Data
Length	208 ft.
Beam	37 ft.
Draft	19 1/2 ft.
Gross Tonnage	1200 tons
Deck Space	
Main Deck	1316 ft.
01 Level	800 ft.
Electronics Lab Space	1240 ft.
Storage Space	400 ft.
Electrical Power	750 KW
Air Conditioning	30 tons
Bow Thrusters	1 ea. 150 h.p.
Main Propellers	One each
Main Engines	1200 shp (2)
Speed	11 knots

SANDS' Characteristics

Table IX

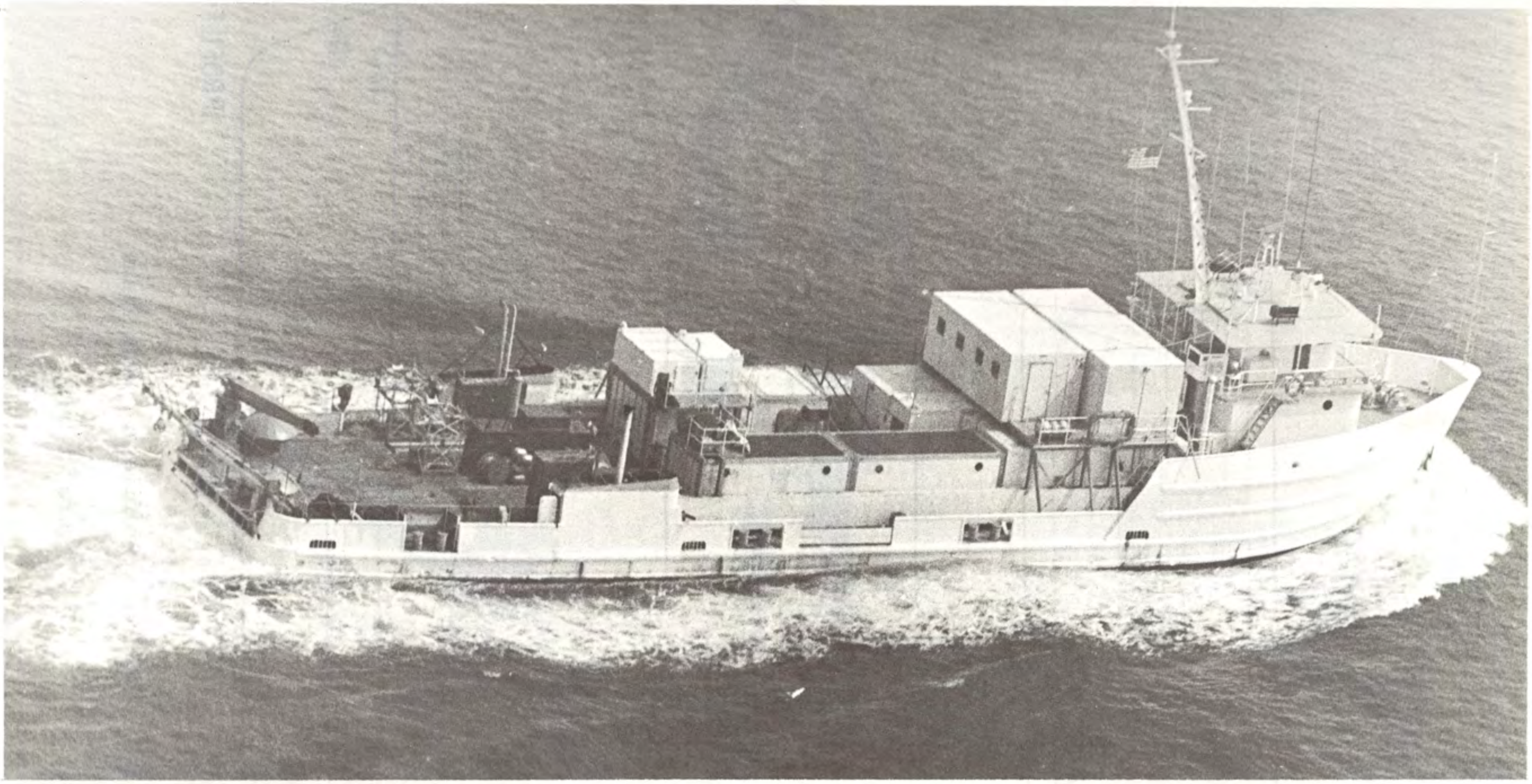
SANDS served as platform for the deployment and retrieval of several major systems including MABS, TABS, NAVOCEANO current measuring string, HX 231-F towed source, and velocimeters. All tasks were well accomplished except the MABS retrieval which was complicated by a fouling around the bow thruster of some float assemblies. This problem was caused by a combination of pilot error and weather conditions.

In general SANDS performed her tasks well despite having crowded deck space and a rather tight schedule. Her crew was competent and most willing to perform assigned tasks as well as any unforeseen extra activities even though at times extremely long working hours were required.

R/V NORTH SEAL, Figure 70, is a privately owned and operated vessel under contract to MSC via Texas Instruments, Inc. for work of the LRAPP office of ONR. The vessel has been especially outfitted for LRAPP work, especially deploying and recovering long, vertical acoustic arrays. NORTH SEAL's characteristics are outlined in Table X; Figure 71 is an outline drawing of profile and deck plans. Mechanically NORTH SEAL performed very well during the exercise.

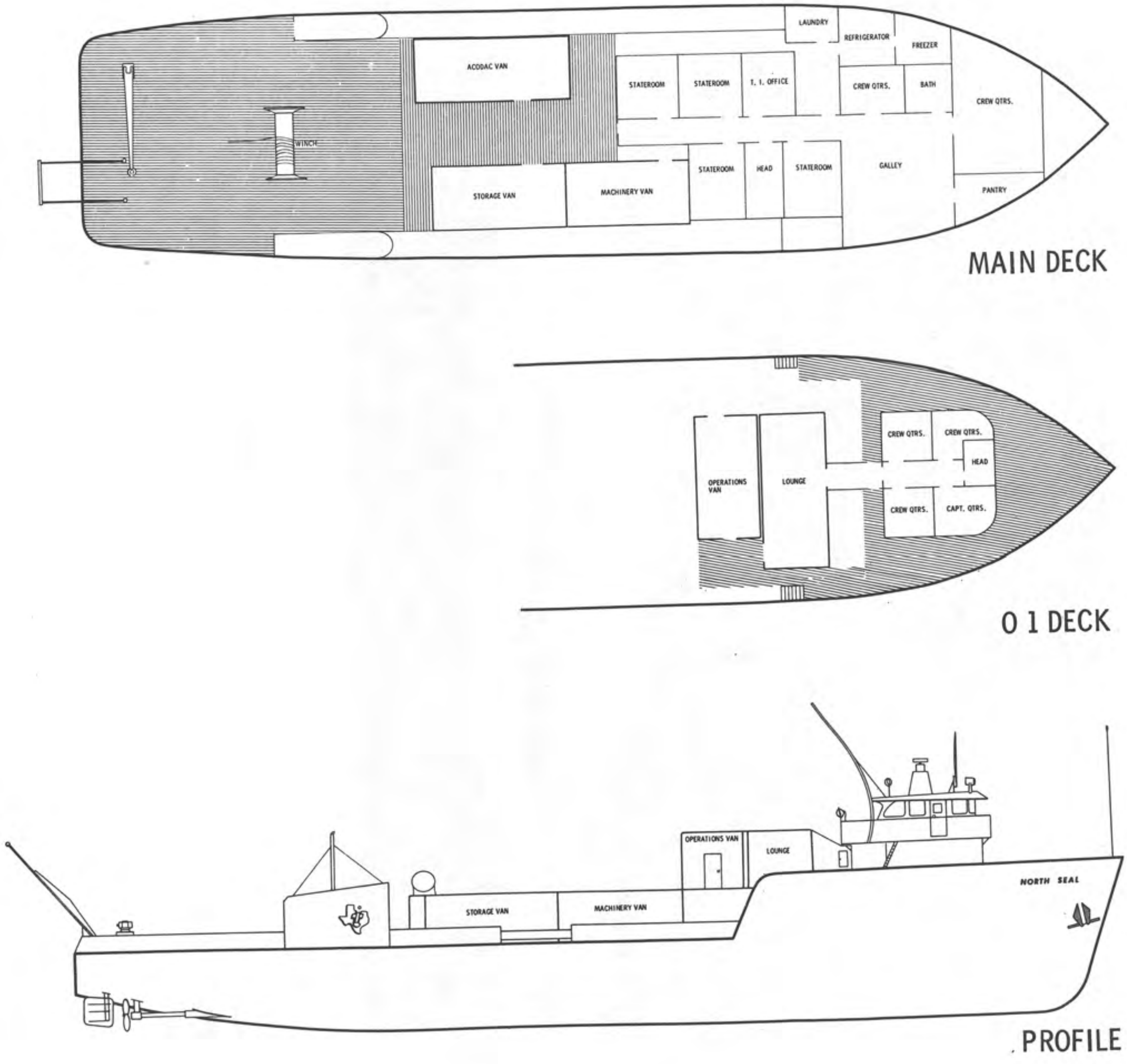
Certain aspects of NORTH SEAL's special configuration are worthy of note. First, the raised wooden, false deck which was installed between the 1971-72 operating seasons has been an unqualified success. Previously the afterdeck had been wet, slippery and sometimes covered by 3 to 6 inches of water while deploying or retreiving moorings. Not only was this condition uncomfortable, but it was also unsafe. The false deck solves the problem by immediately draining away any water which comes aboard over the transom. Some improvements could be made in access to the space between the main deck and the false deck and in the provision of more adequate tie down holes, but these are minor deficiencies compared to the advantage of this arrangement which permits one to keep dry while working on a low freeboard vessel. Second, the handling equipment has become quite effective. The air tuggers, crane A-frame and ACODAC winch work together as a team. As with most converted land cranes the training torque of the crane is extremely marginal; operators have to be careful not to apply side loads because of potential failure of the training pinion or gear. Third, assigning storage space for glass balls on top of the ACODAC van has proved effective; previously balls were stored between the false deck and the main deck and were subject to damage from the constant mass of moving water in that area. Fourth, NORTH SEAL has demonstrated the utility of the concept of special purpose, portable vans which can transform a general purpose into a special purpose vessel.

M/V DEARBORN and R/V PIERCE are also special purpose vessels. DEARBORN's characteristics are outlined in Table XI and PIERCE's characteristics are outlined in Table XII. Figure 72 shows PIERCE with VLAM deployed.



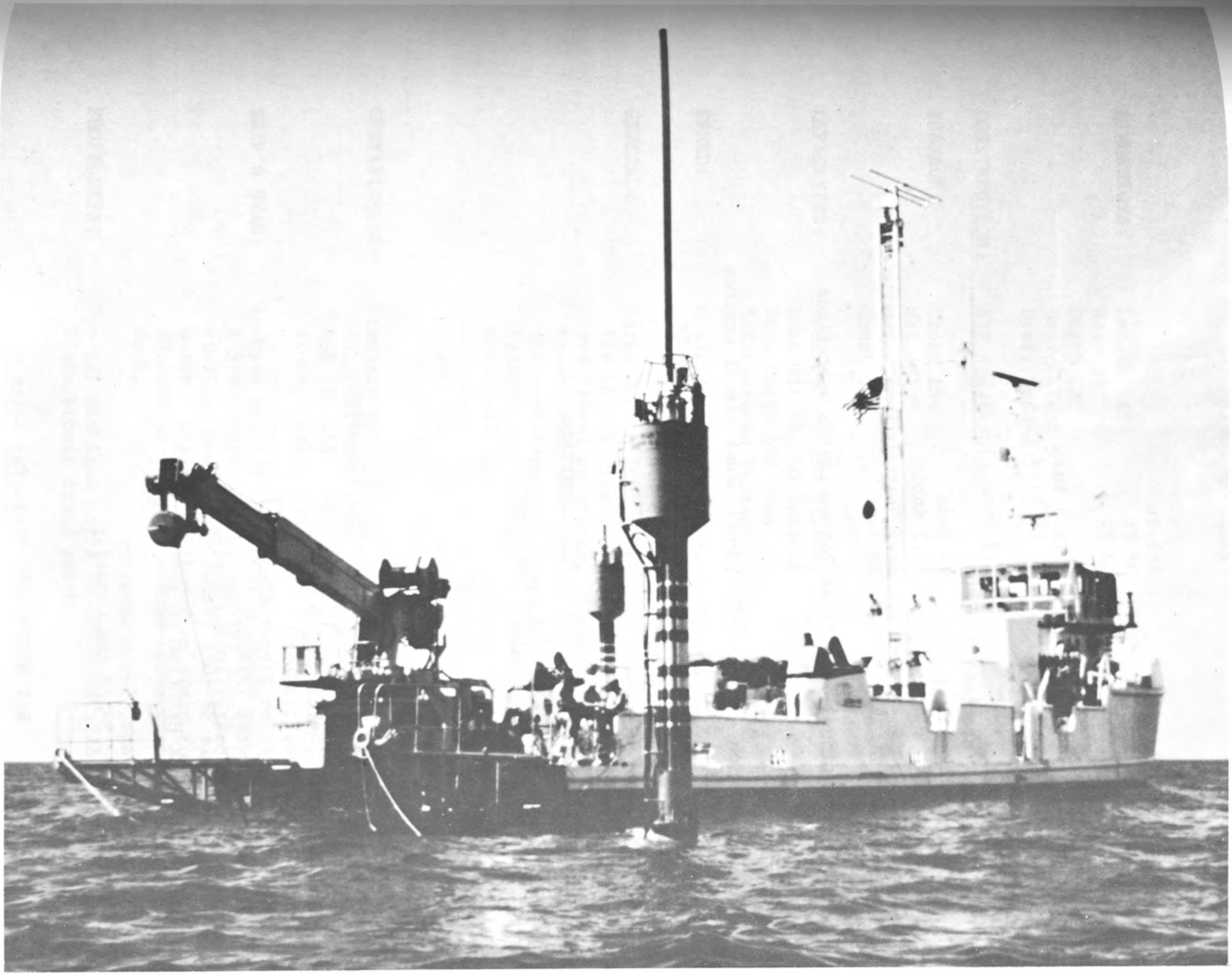
R/V NORTH SEAL

Figure 70



R/V NORTH SEAL Profile and Deck Plans

Figure 71



R/V PIERCE with Fully Deployed VLAM System

Figure 72

Length Overall	165 Ft
Maximum Beam	38 Ft
Depth	12 Ft
Draft*	
Light	6 Ft 5 in.
Loaded	10 Ft 9 in.
Clear Deck Area	3540 Sq Ft
Gross Tonnage	293 Tons
Deck Loading (present) configuration)	93 Tons
Speed	12.5 Knots
Range @ 12 Knots	7500 Miles
Endurance	30 days

*ABS international load lines for worldwide operations

MACHINERY

Ship Propulsion - two 775-hp (continuous) diesel engines (Caterpillar)
Electrical Generation - three 60-KW, 3-phase, 60-Hz generators

PERSONNEL

Accommodations for as many as 12 scientists

NAVIGATION - COMMUNICATIONS EQUIPMENT

Gyrocompass (Sperry)
Autopilot (Sperry)
Long-range Radar
Hi-resolution Radar (Decca)
Radio-telephone
Single-sideband High-frequency radio (Collins)
Distress Radio, Battery Powered
Satellite Navigation (Magnavox)
Omega Navigator (Tracor)
Automatic Direction Finder (Bendix)
Shallow Fathometer (Simrad)
Precision Fathometer (Ocean Sonics)

SCIENTIFIC DECK HANDLING EQUIPMENT

Articulated Crane, 5-ton Capacity
4-Ft 'A' Frame, 5-1/2 ton Capacity

R/V NORTH SEAL Characteristics

Table X

SUPPLY VESSEL
165 FOOT
2800 HP CLASS

DIMENSIONS:	Length 165' Beam 38' Depth 13' Draft Light 9' Draft Loaded 11'
CONSTRUCTION:	All Steel Welded
TONNAGE:	Gross 194 Net 131 DWT 625 Canal 902
CAPACITIES:	Fuel Oil 61,610 Gallons Lube Oil 1,100 Gallons Deck Cargo 600 Tons Refrigerated Storage 250 Cubic Feet
SPEED:	Cruising 12 Knots Fuel 90 GPH Maximum 14 Knots Fuel 120 GPH
GENERAL:	Cargo Deck - 109' X 36'. Six (6) staterooms for ship's crew. Extra accommodations for additional personnel, lounge, built in bunks, innerspring mattresses, centrally heated and air conditioned by 7 1/2 ton unit, necessary lockers and storage for crew and additional personnel, galley has all stainless steel equipment, including freezer, cooler, electric stove, stainless steel double sink to meet U.S. public health standards.
CERTIFICATES:	Standard certificates for ocean service, ABS International load line, USCG admeasurement, A-1 (E) all oceans classification, communications, health and derat.
SHIP'S GEAR:	Anchors two (2) bow 1000# Danforth and 1000' of 1 3/8" anchor chain, one (1) double wildcate windlass powered by twenty (20) HP electric motor. Rolling tailboard on stern to handle 30,000# anchors, fire hose connections on main deck.
PROPELLERS:	Two (2) Michigan style WH 78" X 70", four (4) blade bronze fixed pitch.

M/V DEARBORN Characteristics

Table XI

RUDDERS:	Two (2) balanced spade rudders for good maneuvering at low speeds. Powered by two, (5) HP hydraulic motor and ram assembly.
MAIN ENGINES:	Two (2) D-399 Caterpillar diesel engines with Lufkin reverse gear, rated at 1425 HP each.
GENERATORS:	Two (2) 100 KW, 60 cycle, powered by Caterpillar D-333 diesel engines
PUMPS:	One fuel oil transfer, Roper One fuel oil cargo, Roper One ballast and fire, 20 HP 490 GPM Marlow One ballast and fire, 10 HP 300 GPM Marlow One Deming Sanitary water pump One Deming potable water pump
NAVIGATION:	Radar, Kelvin Hughes Intercommunications two (2) way system with stations in engine room, bridge and galley Recording fathometer Auto direction finder, Raytheon Auto pilot, Decca-Arkas Steering system Arbetrol Magnetic compass Dual voltage navigation lighting system Loran A-C
RADIOS:	Single sideband 30 channel AM marine set Raytheon Auto direction finder 8 band shortwave/longwave receiver
ENGINE CONTROLS:	Pilot house controlled, throttle and clutches. Stern steering station with throttles and clutches Alarm system
AIR COMPRESSORS:	Two (2) high pressure Quincy 5 HP for ship's use.

Table XI (Continued)

Length	158 feet
Beam	30 feet
Draft	10.5 feet
Freeboard	1 foot 8 1/2 inches
Gross Tonnage	180
Drive	Twin Screw
	2-675HP Diesel Direct Drive
Electrical Power	2-60 KW generators
Lab Space	340 Sq. Feet
Deck Space	2,000 Sq. Feet
Speed	11.5 Knots
Endurance	≈3,000 nmi
Equipment	Decca Radar RM314
	RM460
	Gyro - SIRUS MicroTechica
	LORAN - LOR200
	Raytheon Recording Fathometer
	Single Side Band Radio
	Decca ARGUS Autopilot

R/V PIERCE Characteristics

Table XII

2.4.2 Aircraft

A. General

In CHURCH GABBRO, aircraft were used to collect several different types of data, including:

- density of surface shipping;
- ambient noise and propagation loss measured with SSQ-57A sonobuoys;
- wave height profiles measured with a laser profiler;
- temperature structure to a depth of 330 meters measured with SSQ-36 AXBTs;
- surface wind speed and direction measured by the use of smoke flares; and
- meteorological observations.

In addition, on 7 December one aircraft acted as an acoustic source platform by dropping SUS charges for propagation measurements.

The techniques employed in conducting these programs are discussed elsewhere in this report; however, the performance of the aircraft and its equipment obviously affects the quality of the data collected. These are addressed below.

B. Navigation

Very few electronic aids to aircraft navigation exist in the CHURCH GABBRO area. At the low altitudes (10,000 feet for less) typical of all CHURCH GABBRO flights, no LORAN reception was possible at any time. The radio beacon on Swan Island gave a single line of position in some areas, but this was of only limited utility.

Navigation was primarily by radar from land masses and dead reckoning (DR) in between. In the eastern end of the area, Cuba and Jamaica provided fairly accurate radar fixes. Along the far western and southwestern edges, the island of Cozumel (Mexico), Swan Island, and the Bahia Islands (Honduras) were used. Unfortunately, the balance of the area was out of radar range of land, and was navigated strictly by DR, sometimes for several hours.

Even under the best of conditions, the accuracy of DR navigation is usually not more than 5-15 miles; under poor conditions, errors of 15 to 30 miles are possible. Conditions during CHURCH GABBRO ranged from fair to good on most flights. Navigational accuracy is therefore estimated to be ± 15 miles for those flights that operated for long periods out of radar contact with land.

C. Communications

No serious problems were experienced in aircraft communication. All aircraft remained in continuous contact with the Operational Control Center located at the Naval Air Station, Guantanamo Bay, Cuba. Air-to-air communication was occasionally difficult, but presented no serious problems. Air-to-ship communication was attempted several times with no success.

D. Readiness

Air operations were conducted by Patrol Squadron Sixteen (VP-16), Oceanographic Development Squadron Eight (VXN-8), and the Naval Research Laboratory (NRL) Squadron. VP-16 flew three missions each on 4 and 6 December, and stationed four P-3 aircraft at Guantanamo Bay, with one airplane as backup. VXN-8 flew single missions on 2, 4, 5, and 7 December with a single P-3, and NRL flew single missions on 2, 4, 5, and 6 December with one P-3.

In general, aircraft operations were highly successful, with most mission objectives obtained. The only serious shortcomings were caused by equipment malfunction; the more significant were:

- one of the VP-16 aircraft (P3#2) assigned to a surveillance mission on 4 December suffered the loss of an engine, and diverted to Jacksonville for repairs. This forced the use of an older backup P-3 with poorer equipment. This backup aircraft was plagued with equipment malfunctions on both 4 and 6 December, including, total loss of radar, poor inertial navigator performance, and a malfunctioning tape recorder.
- On 4 December, another VP-16 surveillance mission (P3#3) had to be modified when the on-top indicator failed.
- On 6 December, the "replacement backup" aircraft sent from Jacksonville suffered a fuel leak prior to takeoff. This forced the continued use of the other backup airplane with its inoperative equipment.
- Also on 6 December, the VP-16 aircraft assigned as P3#3 suffered a partial failure of their radar.

The VXN-8 aircraft suffered no major equipment breakdowns, but some problems were encountered during the 7 December SUS charge flight.

The SUS were dropped by hand through the aircraft sonobuoy chute at one-minute intervals, using a Systron-Donner Time Code Generator that was periodically chacked against WWV. The task was rather repetitive, and several SUS were dropped at the wrong time due to crew fatigue.

The large quantity of SUS charges to be dropped presented weight, volume, and storage problems on the aircraft. All scientific equipment, spare parts, and other equipment not required for the flight had to be removed from the aircraft before takeoff. Only a limited number of AXBT buoys could be carried, and crew size had to be limited. The P-3 SUS stowage racks hold only 100 charges, so the balance had to be distributed as uniformly as possible throughout the rest of the airplane. One man was required full time to move the ammunition cases, unpack the charges, and stow the empty containers. This caused a formidable logistical problem in the cramped and busy cabin of the P-3.

In addition, the limitations on manpower available caused some difficulty in keeping up with the AXBT drops, SUS drop schedule timing, and the navigational, meterological, radar, AXBT, and SUS drop log book.

3. Conclusions and Recommendations

3.1 General

CHURCH GABBRO was a complex experiment employing many sophisticated systems. In order to improve capability to conduct future exercises of this type it is necessary to exploit this opportunity for performance evaluation of the systems involved. Since systems evaluation was one of the objectives of this exercise, it is the purpose of this section to distill those lessons learned from this exposure of the hardware to the real ocean world to the end that future exercises shall be more efficient and more effective.

3.2 Acoustic Measurement Systems

3.2.1 ACODAC

A. General

The general performance of the ACODAC systems was very good. Since the inception of the system in 1970 and its first deployment in May of 1971 many improvements and refinements have been made and several design alternatives have been developed. The paragraphs below discuss future "tuning" which might be accomplished to improve even more the system's effectiveness.

B. Mooring Integrity

The physical integrity of the mooring is of course the first requirement for a successful deployment. The temporary loss of the Position H system (deployment no. 18) was probably caused by too sudden transfer of anchor to the line, somehow bringing nylon in permanent contact with a metallic chaffing surface.

- Recommendation - Special care should be taken to burden the anchor smoothly and smartly to the main mooring.

Evidence of sudden collapse of glass balls and otherwise failure of others emphasize the importance of the integrity of these buoyancy elements.

- Recommendation - All glass balls used in a mooring, particularly the deep parts of the mooring, should be inspected for evidence of incipient failure, such as spalling, before deployment.

- Recommendation - All glass balls used for buoyancy in ACODAC moorings should be tested hydrostatically to 10,000 psi.

C. Dynamic Range

The present system dynamic range of 60 db is marginal for receipt of both shot signals and ambient noise.

- o Recommendation - Increase overall dynamic range of system from 60 db to 72 db by decreasing gain state overlap from 14 db to 10 db. This would provide a gain state arrangement as shown in Figure 73, which is to be compared with the present arrangement shown in Figure 8. A hydrophone with sensitivity - 150 db re v/uPa would then sample the range of wide band sound pressure level of 84 to 156 db re uPa, which is to be compared with the range of the present arrangement, 90 to 150 db re uPa.

- o Recommendation - For special purposes investigate possibility of exclusive assignment of hydrophone channels either to shot or noise measurement.

D. System Transfer Function

In a complex system where several groups have responsibilities for sub-system design and development overall system integration control is essential. The difference in measurement SPL range of ACODAC systems employing ITC hydrophones and those employing Westinghouse hydrophones is traceable to a breakdown in technical communication and lack of system integration.

- o Recommendation - For all experiments employing ACODACs insure that system integration is accomplished.

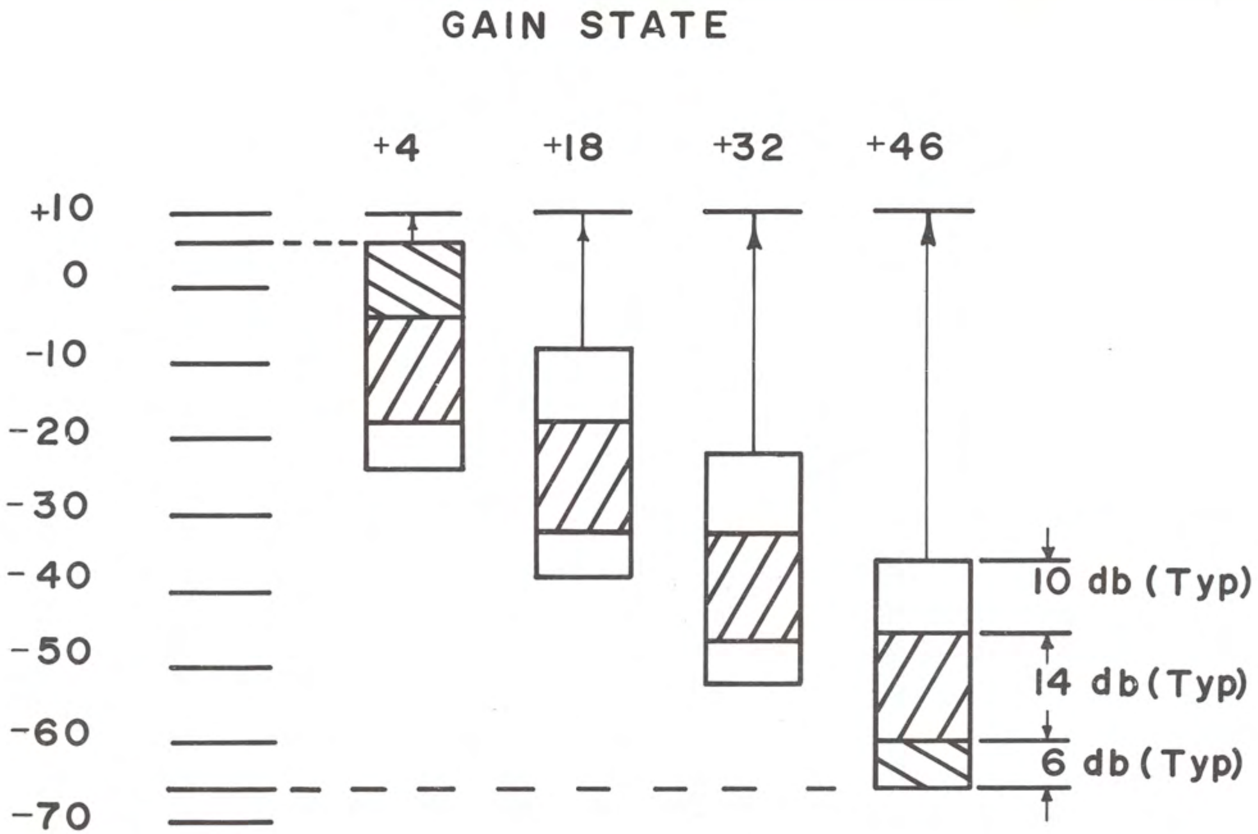
The best proof of the system transfer function is a test of the complete system from hydrophone through cable to RPM and on to the recorder. In addition to direct transfer function, this test can also measure cross-transfer functions, i.e. cross talk.

- o Recommendation - In preparation for future ACODAC experiments, conduct complete system transfer function tests.

E. System Intercomparison

One objective of the CHURCH GABBRO exercise was to compare the performance of three systems of different designs. The wide geographic separation of the systems made direct quantitative comparisons meaningless. Such tests are important in that they offer a means of separating system self noise from measured ambient noise.

- o Recommendation - Conduct a series of intercomparison tests with geographically contiguous systems to derive the self noise function of each system as a function of environmental variables such as current.



Proposed ACODAC Gain States
For 72 db Dynamic Range

Figure 73

F. Hydrophones

The Westinghouse and ITC hydrophones were calibrated by different procedures at different locations.

- o Recommendation - Calibrate Westinghouse and ITC hydrophones by the same procedures at the same location, preferably at the same time. USRD of NRL, Orlando, Florida offers best facilities for such a test.

None of the ACODAC hydrophones have been tested in water for acceleration response at the Marine Physical Laboratory, Scripps Institution of Oceanography, by the method of Reference (27).

- o Recommendation - Conduct in water acceleration response tests of the ITC 8020 and Westinghouse WX-VERAY-1 hydrophones.

G. Signal Processing System

The electronics within the RPM contain a Duty Cycle Control and a Time Code Generator, both of which receive inputs from the Master Oscillator and Countdown; see Figure 7. Loss of synch between the duty cycle control and the time code has been observed.

- o Recommendation - Insure synchronization by operating the Duty Cycle Control from the Time Code Generator.

H. Launch Time

The time of launching the ACODAC system has been reduced dramatically from the original 27 hours of the first deployment to present times on the order of 4 to 6 hours. In general, the longer the launch time the less accurate the placement and the greater the probability of losing the array to a passing ship.

- o Recommendation - Design ACODAC moorings for fast deployment; objective should be two hours total time from top buoy in water to anchor drop.

3.2.2 MABS

A. General

The general performance of MABS in this exercise was good. Data quality and quantity were good. The loss of the top hydrophone and intermittent strumming of the three deep phones marred performance, but not seriously. Filtering during data reduction always removed the strumming signal from the data on the two middle hydrophones and most of the time for the lowest phone. However, during some periods strumming on the lowest phone became intense enough to destroy the data in all bands. The strumming was generally at 3.25 Hz.

B. System Configuration

The mooring was a "jury" rig of four separate electrical cables married to a strength member. This undoubtedly contributed to the strumming problems.

- o Recommendation - Use regular MABS cable in which electrical and strength members form an integral unit.
- o Recommendation - As per usual practice on MABS, use fairing to reduce strumming.

C. Deployment and Recovery

The capsizing of the MABS buoy during deployment and consequent loss of the upper hydrophone were caused by a tending line fouling in a sheave.

- o Recommendation - Insure that all deck personnel are well trained and alert and that gear is properly tended; in particular see that all running lines are "free for running" prior to deployment.

3.2.3 TABS

A. General

TABS performed very well. Deployment and recovery were well done. Data were good except at end of run when the system became noisy.

B. Self Noise

The system noise referred to above could not be isolated to a particular component or part.

- o Recommendation - Insert a periodic calibration signal in the TABS buoy electronics to calibrate the entire system from that point through the RF link and the shipboard recorder.

3.2.4 VLAM

A. General

The performance of the VLAM was good; data are of sufficient quantity and quality to derive the vertical directionality results sought. One of the two scheduled deployments was not made due to weather.

B. Leaky Connectors

Data from four hydrophones were unusable due to leaky electrical connectors. Underwater connector technology has reached the point where leaky connectors are unnecessary and should not be tolerated.

- o Recommendation - Review the connector installation on the entire system; redesign or replace as necessary to eliminate the problem of leaky connectors.

C. Sea State Limitation

VLAM deployment possibility is sensitive to sea state, thus limiting the a priori assurance that a scheduled deployment can actually be made.

- o Recommendation - Review entire system design with the objective of improving VLAM handleability in rough weather. Consider deploying from stable platform such as FLIP; this would have added benefit of removing necessity of RF data link.

D. At Sea Reel Interchange

Phase II of the experiment could not immediately follow Phase I because of the need to return to port to interchange cable reels.

- o Recommendation - Provide means for carrying aboard and interchanging cable reels at sea.

3.2.5 Sonobuoys AN/SSQ-57A

A. General

Sonobuoy performance was very good.

B. Overloading on Shots

At moderate to close ranges SUS signals would generally overload sonobuoy circuits.

- o Recommendation - Consider insertion of additional 20 db of selectable attenuation to improve sonobuoy utility in exercises involving SUS runs to close range.

3.3 Sound Sources

3.3.1 SUS Charges

A. General

SUS charge operation was successful. Due to the peculiar geometry of the exercise area, reverberation times as long as 90 seconds were observed.

B. Reliability

NORTH SEAL experienced 22 failures out of 1104 charges dropped; for a failure rate of 2%. This failure rate was not high enough to affect the utility of the data.

- o Recommendation - Do not exceed a 2% failure rate for exercises of this type; if feasible attain a 1% failure rate, or less.

C. Signal Level

The Mk 61 and Mk 82 charges used contained a main charge of 1.8 lbs of TNT. At the first convergence zone and then closer than about 20 miles, these charges tended to saturate ACODAC receiving systems. It would be useful to reduce the charge weight within 20 miles of a receiving site, thus removing the stringent dynamic range requirements which now exist.

- o Recommendation - Use a reduced charge weight for ranges at the first convergence zone or less.

3.3.2 Piezoelectric Source, HX 231-F

A. General

The overall performance of this source was disappointing; the source was powered only for 19 hours out of a total of 138 hours scheduled, and this at a reduced power level. However, when the source was "on", the signal quality was good.

B. Operational Reliability

After a 72 hour trouble free life test at Dodge Pond, the unit failed three times shortly after being deployed from SANDS. The first two of these failures were caused by the arcing over of an element, and the last by arcing over of a terminal board in the unit. A flooded cable resulted in a final failure which put the unit out of action for the duration of the exercise.

- o Recommendation - Review the HX 231-F design and change as necessary in order to ensure reliable operation at rated power levels while being towed.

3.3.3 Hydroacoustic Source, VIBROSEIS

A. General

The net overall performance of both VIBROSEIS sources was poor; the deep source was "on" for only 28 minutes and the shallow source for 106 hours and 40 minutes out of 304 hours scheduled.

B. Mechanical Design

The problems with the sources apparently stemmed from failure of mechanical fittings on hydraulic lines between the ship and source. These failures could have been associated with the fall of a storage reel on deck during the initial rigging.

- Recommendation - To achieve reliable operation review and revise as necessary design of the rigging for system deployment and the hydraulic connections.

3.4 Acoustic Releases

3.4.1 AMF Model 322 Acoustic Release and AMF Model 200 Acoustic Command System

A. General

The AMF Model 322 acoustic releases performed well during the cruise. Prior to ACODAC system deployment, the transpond function of each acoustic release was verified in water by suspending the unit from a wire at about 300 meters. There was no failure to respond to a release command; however, there were problems in ranging (transponding) at slant ranges in excess of 5 km. Responses at ranges greater than this were intermittent; in order to "back up" the AMF Model 200 Acoustic Command System it was necessary to extinguish the echo sounder and listen with earphones through the Gifft Recorder to identify the faint transpond return. Many ranges were estimated by manually timing the audible return. It was almost always possible to hear the returns even when the automatic ranging circuitry of the Model 200 unit did not indicate a signal. However, the bottom echo would often be confused for a transpond return. These observations suggest that the Model 200 unit was transmitting sufficient acoustic power, but the receiver circuitry was too selective.

B. Long Range Detection

- Recommendation - AMF should review the design of the entire system to improve the reliability of signal detection at long ranges.

C. Pre-Deployment Tests

- o Recommendation - Continue practice of checking transpond function of releases suspended under the ship on a wire prior to deployment of the unit on the moored system.

3.5 Environmental Instruments

3.5.1 Expendable Bathythermograph (XBT)

A. General

The T-5 (1830 meter) probe's statistical performance was poor as expected (62% "not good"); however for this type of exercise it is essential to obtain large numbers of temperature profiles past the main thermocline. The T-5 unit is the only one with the depth capability to reach past the SOFAR axis. The reliability of the T-7 (760 meter) probe was still not acceptable (28% "not good").

B. T-5 Reliability

Although lacking in reliability, the T-5 probes are nevertheless essential for this type of environmental acoustics exercise.

- o Recommendation - Solve the design or quality control problems which limit T-5 reliability and get this probe back in production as soon as possible.

C. T-5/T-7 Intercomparability

NORTH SEAL's T-5/T-7 trace overlay test brought forth unanswered questions regarding the depth accuracy of either one or both of these instruments.

o Recommendation - Repeat the trace overlay a sufficient number of times to obtain statistical significance. If results confirm NORTH SEAL's original results, a manufacturer's test program should be undertaken to resolve the problem.

D. Operational Failures

Many XBT failures were caused by faulty operational procedures, e.g. dropping to windward when the vessel had way on or dropping to leeward when lying to.

- o Recommendation - Insure that all operations personnel are properly trained in XBT procedures.

3.5.2 Aircraft Expendable Bathythermograph (AXBT)

A. General

The performance of these systems was only fair. These probes had a maximum depth of 310 meters which limited their usefulness in defining the sound channel, but provided useful information of the spatial distribution of shallow thermal structure.

B. Systems Integration

Many of the problems could have been prevented by thorough systems integration and calibration of the aircraft. Problems such as a lack of a proper tape recorder destroyed the usefulness of much of the data.

- Recommendation - For future exercises ensure that all components of the system are proper and that the overall system is properly calibrated.

3.5.3 Salinity/Temperature/Depth (STD) Systems

A. General

The overall performance of the STD systems was only fair.

B. Model 9040

The dual channel strip chart recorder of the Model 9040 would frequently lose depth synchronization due probably to a slipping clutch.

- Recommendation - Readjust, repair or replace clutch to prevent slippage.
- Recommendation - During the cast tape record the signal on the in water cable for a permanent record and subsequent laboratory playback. The tape recording could either be in analog or digital form; in the latter case a digital record of the frequency monitors would be made.

C. Model 9060

Faulty internal electrical contacts prevented this unit from making a single successful cast.

- Recommendation - Repair or replace the faulty components.

D. Confirming Water Samples

There were no confirming water samples or reversing thermometer temperature measurements. SANDS' Nansen cast was unsuccessful due to large wire angle; even if successful, it would have not directly confirmed STD measurements due to large separation in space of time of the measurements.

- o Recommendation - Acquire an electrically actuated rosette sampler such as the General Oceanics Rosette Multi-Bottle Array Model 1015.
- o Recommendation - Acquire a shipboard laboratory salinometer such as Plessy Environmental Systems Model 6230.

3.5.4 Sound Velocity Profiling (SVP) System

A. General

The performance of the SANDS SVP system was excellent. Data were of acceptable quantity and quality.

B. Redundant Systems Measurements

For this form of exercise the sound velocity profile is the single most important environmental variable. It therefore must be measured accurately. Sound velocity profiles can be derived from STD results or XBT results combined with salinity profiles as well as by direct measurement via the SVP. These independent methods provide a redundancy which can provide a check of the internal consistency of the data.

- o Recommendation - Cross check the SVP results from these independent, redundant methods.

3.5.5 Current Measurement Systems

A. General

Current measurements are important to this type of exercise. First, they provide information as to the hydrodynamic environment of the vertical array for evaluation of the possibilities of strumming. Second, they provide input data into the overall oceanographic assessment.

B. Continuous Profiles

Continuous profiles at the actual measurement site will provide useful data for the design of operational midwater acoustic arrays.

- o Recommendation - Continue to measure currents by the inclinometer line integral with the ACODAC array, i.e. the compliant array.

3.5.6 Laser Wave Profiler

A. General

The results of the laser wave profiler were disappointing. Apparently the weather was too good on the day of its use, i.e. the sea was so calm that the sun glitter injected a noise into the system through which the signal could not be read.

B. System Design

- Recommendation - Review the design of the system to improve its discrimination against sun glitter.

C. Operational Scheduling

- Recommendation - For future operations investigate feasibility of using laser wave profiler at night.

3.6 Vehicles

3.6.1 Ships

A. General

The overall performance of the ships in this exercise was excellent.

B. Navigation

This type of environmental acoustics requires precise, weather independent navigation. A combination of satellite navigator and omega provide a powerful combination for the necessary precise navigation.

- Recommendation - Provide ships with modern satellite navigators, such as the Magnavox MX-706CA.
- Recommendation - Use omega and satellite navigator to complement one another. Use omega to interpolate between good satellite fixes; use satellite fixes to provide updated skywave correction for omega.

C. Communications

Communication equipment was adequate, but NORTH SEAL was unable to communicate on assigned primary and secondary channels due to wrong crystals.

- Recommendation - In this type of exercise set event for complete communications check sufficiently in advance of cruise to rectify any problems which may arise.

D. Vessels

NORTH SEAL's configuration is well suited to her tasks.

- o Recommendation - For any future vessel assigned to handle ACODAC use NORTH SEAL configuration as a model, particularly with respect to the arrangement of winch, A-frame, crane, air tuggers, tracks and vans.

The false, wooden deck provides a dry fantail and improves the efficiency and safety of all weight handling and rigging operations.

- o Recommendation - Consider installation of a false deck in any low freeboard research vessel which works over the stern.

One of the outstanding weaknesses of NORTH SEAL equipment is the low side load capability of the crane.

- o Recommendation - Strengthen training gear train and provide emergency training brake on NORTH SEAL crane.

Deployment or recovery of a long system such as ACODAC or MABS is a complex operation, requiring a skilled, experienced and careful deck force.

- o Recommendation - Inspect all running and static cables prior to an exercise of this type; provide adequate spares.

3.6.2 Aircraft

A. General

In general aircraft performance was good; crews worked hard and were eager to do a good job, but were sometimes hampered by inadequate equipment.

B. Navigation

Aircraft navigation needs to be improved for purposes of SUS track maintenance as well as shipping surveillance.

- o Recommendation - Provide aircraft navigation systems comparable in accuracy to omega; consider inertial systems.

C. SUS Droppers

SUS schedules require precise drop times at small time intervals for hundreds of drops covering periods of 8 to 10 hours.

This repetitive task can become so burdensome that drops are mistimed or missed completely.

- Recommendation - Provide an automatic SUS dropper which will drop the charges on a preset interval schedule without manual intervention other than to load the magazine.

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APPENDIX A - ACODAC COMPLIANT MOORING ARRAY DESIGN

NOVEMBER 1972

Unit		Distance (ft.) From Top	Distance (ft.) From Bottom	Buoyancy (lbs.)	Tension (lbs.)
Section 0 (0 Conductors, 800')					
1.	Surface buoy	0.0	13,613.0	+2.0	
2.	4-17" Glass Balls	30.0	13,583.0	+224.0	
3.	1-16" Glass Ball	50.0	13,563.0	+45.0	
4.	Depth Gauge #1	100.0	13,513.0	-3.1	
5.	Inclinometer	546.5	13,066.5	-3.1	
6.	Inclinometer #2	801.5	12,811.5	-3.1	
	Cable			+4.5	+266.2#
Section 1 (2 Conductors, 2000')					
7.	Hydrophone #1	907.5	12,705.5	+4.8	
8.	Inclinometer #3	1058.5	12,554.5	-3.1	
9.	Inclinometer #4	1311.5	12,301.5	-3.1	
10.	Inclinometer #5	1563.0	12,050.0	-3.1	
11.	Inclinometer #6	1816.0	11,797.0	-3.1	
12.	Inclinometer #7	2075.5	11,537.5	-3.1	
13.	Inclinometer #8	2324.5	11,288.5	-3.1	
14.	Inclinometer #9	2574.0	11,039.0	-3.1	
15.	Inclinometer #10	2823.0	10,790.0	-3.1	
	Cable			+4.0	+250.2
Section 2 (4 Conductors, 4000')					
16.	Hydrophone #2	2924.0	10,689.0	+4.8	
17.	Inclinometer #11	2968.0	10,645.0	-3.1	
18.	Inclinometer #12	3217.5	10,395.5	-3.1	
19.	Inclinometer #13	3468.5	10,144.5	-3.1	
20.	Inclinometer #14	3720.0	9,893.0	-3.1	
21.	Inclinometer #15	3971.0	9,642.0	-3.1	
22.	Inclinometer #16	4222.5	9,390.5	-3.1	
23.	Inclinometer #17	4474.0	9,139.0	-3.1	
24.	Inclinometer #18	4725.0	8,888.0	-3.1	
25.	1-16" Glass Ball	N.A.		+45.0	
26.	Inclinometer #19	4984.0	8,629.0	-3.1	
27.	Inclinometer #20	5226.0	8,387.0	-3.1	
28.	Inclinometer #21	5475.0	8,138.0	-3.1	
29.	Inclinometer #22	5721.5	7,891.5	-3.1	
30.	Inclinometer #23	5968.5	7,644.5	-3.1	
31.	Inclinometer #24	6216.0	7,397.0	-3.1	
32.	Inclinometer #25	6464.5	7,148.5	-3.1	
33.	Inclinometer #26	6711.5	6,901.5	-3.1	
	Cable			-18.0	+228.4

APPENDIX A - ACODAC COMPLIANT MOORING ARRAY DESIGN

NOVEMBER 1972

Unit		Distance (ft.) From Top	Distance (ft.) From Bottom	Buoyancy (lbs.)	Tension (lbs.)
Section 3(6 Conductors 5400')					
34.	Hydrophone #3	6813.0	6,800.5	+4.8	
*35.	Inclinometer #28	7040.5	6,572.5	-3.1	
36.	1-17" Glass Ball	N.A.	N.A.	+56.0	
37.	Inclinometer #29	7291.5	6,321.5	-3.1	
38.	Inclinometer #30	7543.0	6,070.0	-3.1	
39.	Inclinometer #31	7794.5	5,818.5	-3.1	
40.	Inclinometer #32	8045.0	5,568.0	-3.1	
41.	Inclinometer #33	8296.5	5,316.5	-3.1	
42.	Inclinometer #34	8547.5	5,065.5	-3.1	
43.	1-10" Glass Ball	8686.5	4,926.5	+10.0	
44.	Inclinometer #35	8797.0	4,816.0	-3.1	
45.	Inclinometer #36	9046.0	4,567.0	-3.1	
46.	Inclinometer #37	9293.5	4,319.5	-3.1	
47.	Inclinometer #38	9542.5	4,070.5	-3.1	
48.	Inclinometer #39	9791.0	3,822.0	-3.1	
49.	Inclinometer #40	10,041.0	3,572.0	-3.1	
50.	Inclinometer #41	10,284.0	3,329.0	-3.1	
51.	Inclinometer #42	10,541.5	3,071.5	-3.1	
52.	1-16" Glass Ball	10,671.5	2,941.5	+45.0	
53.	Inclinometer #43	10,791.0	2,822.0	-3.1	
54.	Inclinometer #44	11,039.0	2,573.5	-3.1	
55.	1-10" Glass Ball	11,167.5	2,445.5	+10.0	
56.	Inclinometer #45	11,288.5	2,324.5	-3.1	
57.	Inclinometer #46	11,536.5	2,076.5	-3.1	
58.	Inclinometer #47	11,786.5	1,826.5	-3.1	
59.	Inclinometer #48	12,033.5	1,579.5	-3.1	
	Cable			-81.0	+208.1

* Note: No Inclin. #27 due to short cable.

Section 4 (8 Conductors 1000')					
60.	Hydrophone #4	12,230.0	1,383.0	+4.8	
61.	Inclinometer #49	12,260.0	1,353.0	-3.1	
62.	1-10" Glass Ball	12,380.5	1,232.5	+10.0	
63.	Inclinometer #50	12,507.0	1,106.0	-3.1	
64.	1-10" Glass Ball	12,629.5	983.5	+10.0	
65.	Inclinometer #51	12,755.5	857.5	-3.1	
66.	1-10" Glass Ball	12,880.5	732.5	+10.0	
67	Inclinometer #52	13,004.0	609.0	-3.1	
	Cable			-22.0	+208.5

APPENDIX A - ACODAC COMPLIANT MOORING ARRAY DESIGN

NOVEMBER 1972

Unit		Distance (ft.)		Buoyancy (lbs.)	Tension (lbs.)
		From Top	From Bottom		
Section 5 (8 Conductors 300')					
68.	Hydrophone #5	13,205.0	408.0	+4.8	
69.	1-10" Glass Ball	13,229.0	384.0	+10.0	
70.	Inclinometer #53	13,254.5	358.5	-3.1	
71.	1-10" Glass Ball	13,393.0	220.0	+10.0	
72	Depth gauge #2 and Inclinometer #54	13,507.0	106.0	-6.2	
73.	Tensiometer	13,515.0	98.0	-28.1	
74.	4-16" Glass Balls	13,522.5	90.5	+180.0	
	Cable			-8.7	+367.2
Termination					
75.	Hydrophone #6	13,533.0	80.0	+4.8	
76.	1-16" Glass Ball	13,536.0	77.0	+45.0	
77.	AMF Release & Disconnect	13,539.0	74.0	-82.0	
78.	RPM	13,546.0	67.0	+700.0	
79.	AMF Release & time release	13,578.0	35.0	-106	
80.	Chain	13,611.0	2.0		
81.	Anchor	13,613.0	0.0		+929.0

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APPENDIX B

Sensitivity Test Results
ITC Model 8020 Hydrophone

(Excerpted from USRD Calibration Report No. 3483)

Naval Research Laboratory
UNDERWATER SOUND REFERENCE DIVISION
P.O. Box 8337, Orlando, Florida 32806

HJH/hs
K03-30.101/4336
18 December 1972

CALIBRATION REPORT No. 3483

Subj: ITC Model 8020 transducers serials 1 and 2, 4 through 9, and
11 through 15; calibration of

Ref: (a) International Transducer Corp. Purchase Order A03947 of
14 Dec 1972

Encl: (1) Table 1
(2) Drawings USRD 73926 through 73928 and 62785

1. Calibration measurements were made on the subject transducers as arranged in a telephone conversation of 3 May 1972 between Dr. Scott Daubin of the University of Miami and Dr. W.L. Paine of the USRD, and in accordance with a measurement outline furnished by Mr. R.F. Dutton of the International Transducer Corporation, who was present to specify and observe the measurements. Funds for the service are authorized by reference (a).

2. Free-field voltage sensitivity in the frequency range 10 to 1000 Hz was measured in the Low Frequency Facility at the temperatures 3 and 23°C and hydrostatic pressure to 6895 kPa.

3. Free-field voltage sensitivity of serial 5 was measured in the Lake Facility in the frequency range 0.1 to 10 kHz at the temperature 25°C. Directivity patterns were measured in the XY and XZ planes at 1 kHz. The results are shown on the drawings of enclosure (2).

4. Measurements in the Low Frequency Facility were made with sound propagated parallel to the Z axis. Orientation in the Lake Facility was as described for a cylinder on drawing USRD 62785. A cross marked on the transducer case served as the +X-axis reference; the cable was in the +Z direction.

H J Hebert
H. J. HEBERT

Copy to:
ITC (Mr. R.F. Dutton)(1)
University of Miami (Dr. Scott Daubin)(1)
USRD (Code 8280)(1)
NRL Wash (Code 2620)(1)
(Code 1240)(1)

Table 1

FREE-FIELD VOLTAGE SENSITIVITY
(Decibels re one volt per micropascal)

ITC Model 8020 Transducers

Open-circuit voltage at end of 9-m cable
Unbalanced
(Sensitivity values negative)

Freq (Hz)	Serial 1		Serial 2	Serial 4		Serial 5	
	3°C	23°C	3°C	3°C		3°C	
	6895 kPa	6895 kPa	6895 kPa	689 kPa	6895 kPa	689 kPa	6895 kPa
10	150.3	150.4	150.5	150.9	150.8	150.5	150.1
20	150.1	150.2	150.3	150.7	150.4	150.1	149.8
50	150.1	149.9	150.2	150.7	150.4	150.0	149.8
100	150.1	149.9	150.0	150.5	150.4	150.0	149.8
200	150.1	149.9	150.0	150.5	150.4	150.0	149.8
500	150.8	149.9	150.5	151.3	150.4	150.0	150.1
800	150.6	149.9	150.7	151.3	150.8	150.0	150.1
1000	151.5	148.5	151.0	151.8	151.7	150.1	150.1

Freq (Hz)	Serial 6		Serial 7				
	3°C		3°C		23°C		
	689 kPa	6895 kPa	689 kPa	6895 kPa	3.5 kPa	689 kPa	6895 kPa
10	150.3	150.4	150.4	150.4	150.2	150.0	149.9
20	150.2	149.8	149.9	150.0	149.8	149.5	149.5
50	150.1	149.8	149.9	149.9	149.8	149.4	149.5
100	150.1	149.8	149.9	149.8	149.8	149.4	149.4
200	150.1	149.8	149.9	149.8	149.8	149.4	149.4
500	150.1	150.4	150.5	149.8	149.8	149.4	149.4
800	150.1	150.3	150.4	150.8	149.8	148.8	149.5
1000	149.4	150.2	150.6	151.4	148.4	148.4	148.4

Freq (Hz)	Serial 8			Serial 9			Serial 11
	3°C		23°C	3°C		23°C	3°C
	689 kPa	6895 kPa	6895 kPa	689 kPa	6895 kPa	6895 kPa	6895 kPa
10	150.4	150.5	149.7	150.7	150.8	150.1	150.9
20	150.0	150.1	149.8	150.5	150.3	149.9	150.6
50	149.8	150.0	149.8	150.5	150.3	149.8	150.5
100	149.8	150.0	149.8	150.5	150.3	149.8	150.5
200	149.8	150.0	149.8	150.5	150.3	149.8	150.5
500	149.8	150.0	149.8	150.5	149.8	150.3	151.3
800	150.0	150.9	150.0	151.3	150.9	150.3	151.3
1000	150.7	151.0	148.6	151.0	151.0	149.3	151.6

(continued)

Table 1 (continued)

Freq (Hz)	Serial 12			Serial 13			Serial 14	Serial 15
	3°C		23°C	3°C		23°C	3°C	3°C
	689 kPa	6895 kPa	6895 kPa	689 kPa	6895 kPa	6895 kPa	6895 kPa	6895 kPa
10	150.1	150.2	149.8	150.3	150.8	150.4	150.9	151.4
20	149.6	149.7	149.5	150.3	150.4	149.9	150.9	151.1
50	149.5	149.5	149.5	150.3	150.4	149.9	150.9	151.0
100	149.4	149.4	149.5	150.3	150.4	149.9	150.9	151.0
200	149.4	149.4	149.5	150.3	150.4	149.9	150.9	151.0
500	150.2	148.6	149.5	150.8	149.8	149.9	150.9	151.3
800	150.5	150.1	149.6	150.7	151.4	150.2	150.9	151.3
1000	150.2	150.8	148.4	150.5	151.6	148.8	150.9	152.1

Naval Research Laboratory
UNDERWATER SOUND REFERENCE DIVISION
P. O. Box 8337, Orlando, Florida 32806

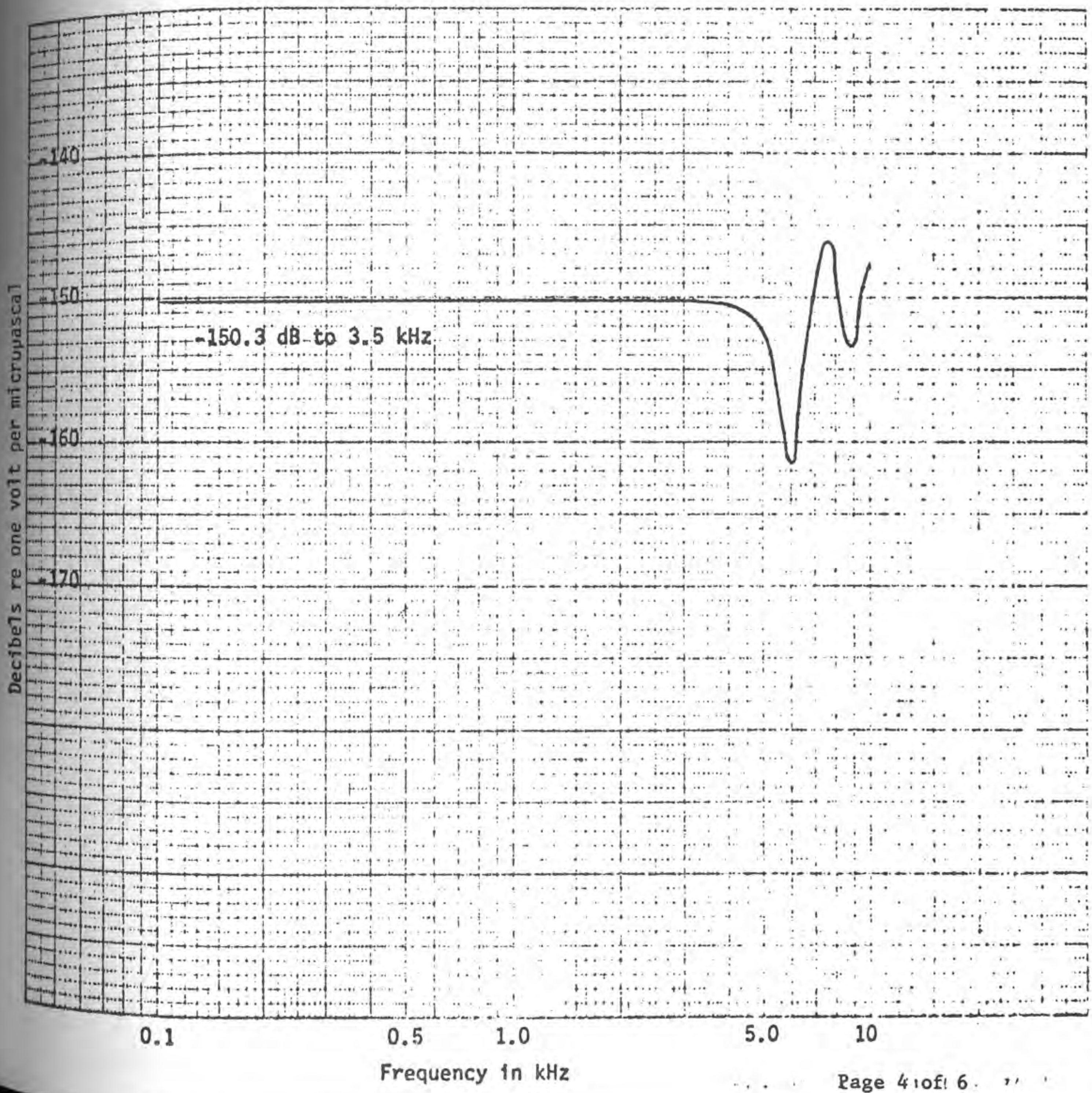
USRD No. 73926
4336

Date Nov 1972

FREE-FIELD VOLTAGE SENSITIVITY
ITC Model 8020 Transducer Serial 5
Open-circuit voltage at end of 9-m cable

Water temp 25

[illegible]



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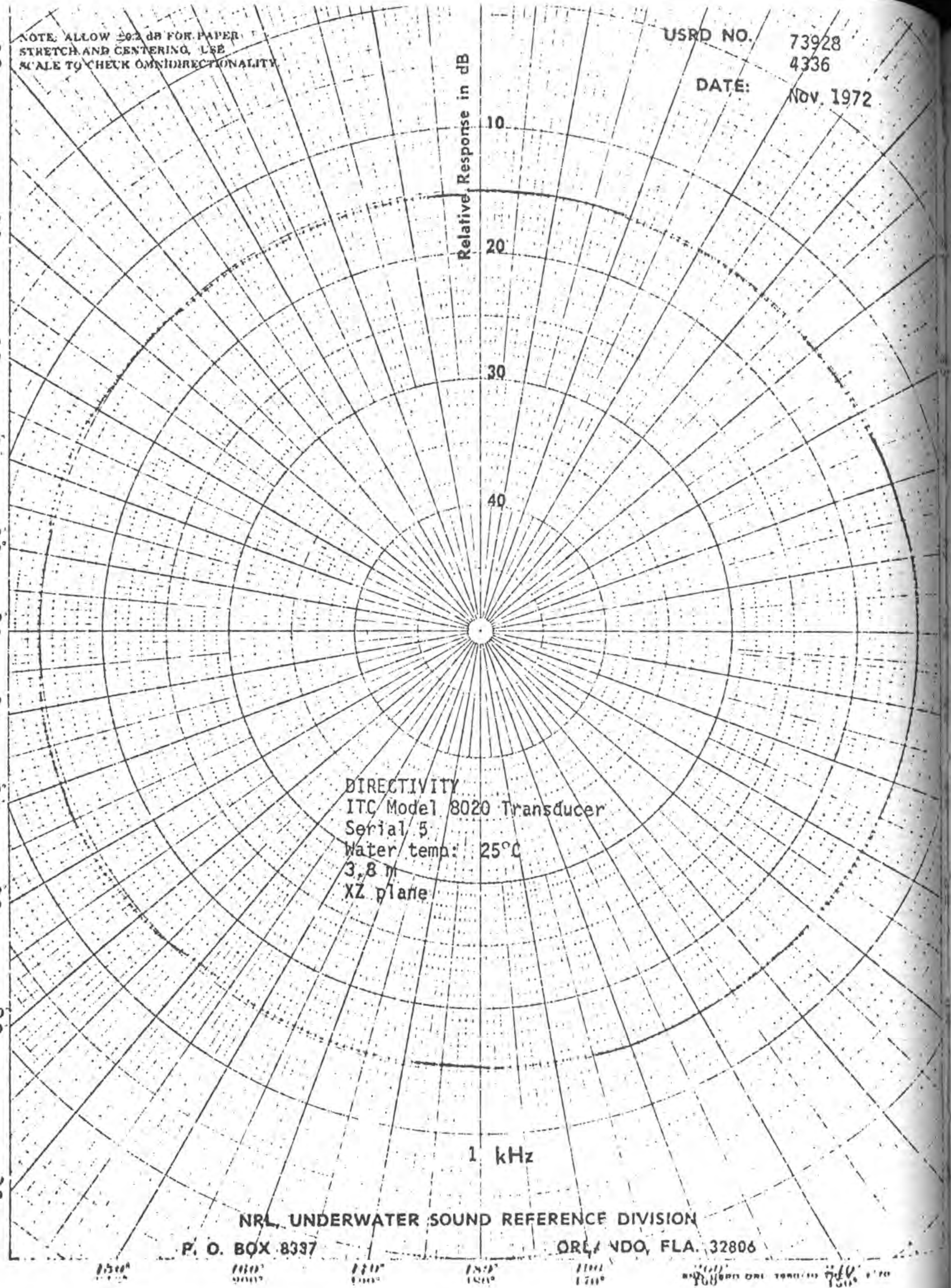
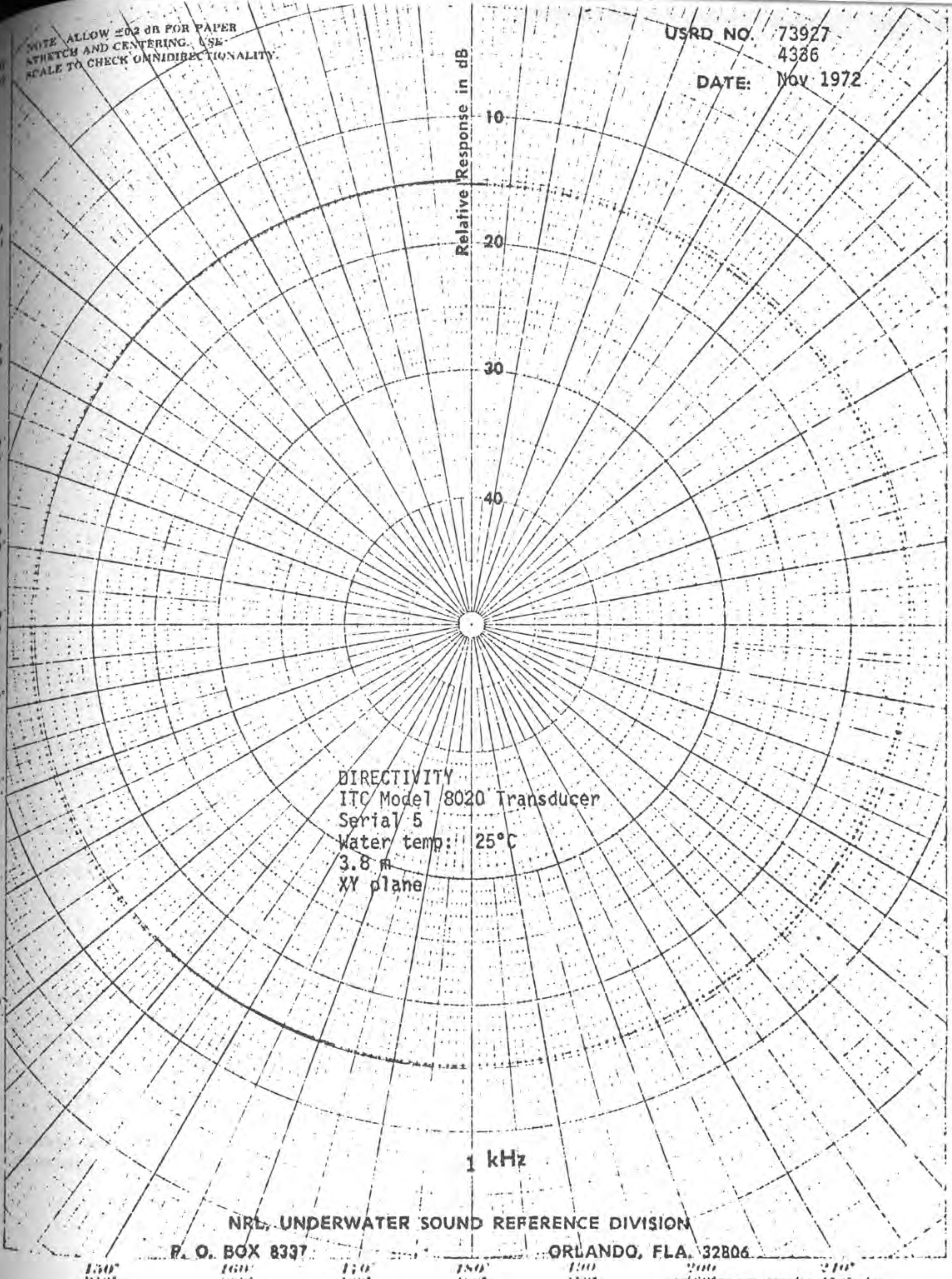


DIRECTIVITY
ITC Model 8020 Transducer
Serial 5
Water temp: 25°C
3.8 m
XZ plane



USRD NO. 73927
4386
DATE: Nov 1972

DIRECTIVITY
ITC Model 8020 Transducer
Serial 5
Water temp: 25°C
3.8 m
XY plane

APPENDIX C

ACODAC Acceleration Cancelling Hydrophone Specifications

May 1, 1972

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

Item	Requirement
1. Sensitivity:	The element sensitivity shall be at least - 80 db re v/ub. The overall sensitivity of the hydrophone (element plus preamplifier) shall be at least -40 db re v/ub.
2. Frequency Range:	Flat within ± 1 db between 15 Hz and 1 kHz. The 3 db down points shall be located as follows: Lower - less than 7.5 Hz, Upper - greater than 1.5 kHz.
3. Ambient Pressure Range:	The hydrophone shall be operable over a range of pressures from 0 to 10,000 psig. The open circuit sensitivity between 15 Hz and 1 kHz shall not change more than - 1 db when ambient pressure is varied from 0 to 10,000 psig.
4. Acceleration Insensitivity:	The hydrophones shall be insensitive to accelerations up to 1 g. The acceleration response shall be less than - 10 db re ub/mg at 10 Hz.
5. Dynamic Range:	The dynamic range shall be at least 80 db.
6. Temperature Effects:	Response over the entire range of frequency and depth shall not vary with temperature by more than ±½ db when the temperature varies between 0°C and 25°C. The hydrophone shall not be damaged by continuous exposure to temperatures up to 65°C.
7. Transmission Line:	The hydrophone will drive a two wire transmission line whose characteristic impedance is 275 - j275 ohms at 1 kHz.

8. Power:	Power consumption shall be less than 0.15 watt continuous at 6 volts. 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.
9. Pressure Compensation:	The sensitive element and the preamplifier shall be exposed to ambient pressure. Components shall be chosen and assembled with this requirement in view.
10. Materials	The hydrophone case shall be made from non-metallic materials whose acoustic and mechanical properties are satisfactory under the environmental conditions described in items 3 and 6 above. The hydrophone manufacturer shall choose the materials subject to the specific approval of the University of Miami.
11. Mechanical and Electrical Arrangement:	The hydrophone shall fit within a cylindrical envelope 3.25 inches in diameter by 7.5 inches in length exclusive of connectors. The end caps at each end of the hydrophone shall each contain three 3/8 inch blind tapped mounting holes equally spaced peripherally. One end cap of the hydrophone shall mount a Marsh and Marine four pin Type XSK 4 BCL connector along the cylindrical axis. The connector shall be physically constrained from rotating. When viewing the connector from outside the following pin assignments shall be made: large index pin - common; 1st clockwise pin - signal; 2nd clockwise pin - calibration; 3rd clockwise pin - 6 volt dc power for preamplifier.
12. Tests:	The specification requirements of items 1 through 8 above shall be demonstrated by the manufacturer by test on each unit produced. It shall be demonstrated that each hydrophone remains within the specification requirements after five (5) pressure cycles from 0 to 10,000 psig. The manufacturer shall provide complete test reports within 30 days at delivery of the hydrophones.

14. Documentation:	Within 30 days after delivery the manufacturer shall provide assembly drawings showing all dimensions and materials. Electrical schematic of the preamplifier as well as test reports shall be provided at the same time.

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13. ABSTRACT

This report describes the technical features of systems used in the CHURCH GABBRO exercise during November - December 1972, critiques their performance and recommends future design and operational modifications. Systems discussed include acoustic measurement (ACODAC, MABS, TABS, VLAM and Sonobuoys), acoustic sources (SUS charges Mk61-0 and Mk 82-0, CW Sources HX-231-F and VIBROSEIS), environmental instruments (XBTs, AXBTs, STD, current measurement systems, laser wave profiler) and the ships and aircraft involved.

Forty-six recommendations are set forth for design improvements or operational procedures.

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