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MOORED ACOUSTIC BUOY SYSTEM (MABS): SPECIFICATIONS AND DEPLOYMENTS

Peter C. King, et al

Naval Underwater Systems Center
Newport, Rhode Island

5 January 1973

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NAVAL UNDERWATER SYSTEMS CENTER

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13. ABSTRACT

The Moored Acoustic Buoy System (MABS) is a self-recording, 1700-ft long, vertical array of five hydrophones designed to measure underwater acoustic signals. The submerged, self-contained, programmable system records calibrated acoustic data that are stored on magnetic tape for analysis after recovery. MABS is capable of recording either continuously for 30 h or intermittently for up to 30 days. The calibrated acoustic signals are recorded as a function of depth in the frequency band from 3 to 5000 Hz, with a system self-noise threshold 10 dB below Knudsen Sea State 0. Analytical models and at-sea experience have demonstrated the advantages of using the anchor-last technique for MABS deployment: it provides accurate anchor placement, is a fast, uncomplicated procedure, and requires a minimum of personnel. After two trial deployments, MABS was operationally deployed in the Mediterranean Sea during the Ionian-Mediterranean Exercise (IOMEDEX) and recorded high quality calibrated ambient-noise and continuous wave (CW) signals in the band from 3 to 5000 Hz.

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Anchor-Last Technique						
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ICMEDEX (Ionian-Mediterranean Exercise)						
BERMEX (Bermuda Exercise)						
Santa Cruz Exercise						
Subsurface Buoy						
Hydrophone Array						
MABS Mooring						
MABS Winch						
MABS Environmental Sensors						
Environmental Sensor Specifications						

ABSTRACT

The Moored Acoustic Buoy System (MABS) is a self-recording, 1700-ft-long, vertical array of five hydrophones designed to measure underwater acoustic signals. The submerged, self-contained, programmable system records calibrated acoustic data that are stored on magnetic tape for analysis after recovery. MABS is capable of recording either continuously for 30 h or intermittently for up to 30 days. The calibrated acoustic signals are recorded as a function of depth in the frequency band from 3 to 5000 Hz, with a system self-noise threshold 10 dB below Knudsen Sea State 0.

Analytical models and at-sea experience have demonstrated the advantages of using the anchor-last technique for MABS deployment: it provides accurate anchor placement, is a fast, uncomplicated procedure, and requires a minimum of personnel. After two trial deployments, MABS was operationally deployed in the Mediterranean Sea during the Ionian-Mediterranean Exercise (IOMEDEX) and recorded high quality calibrated ambient-noise and continuous wave (CW) signals in the band from 3 to 5000 Hz.

Successful deployments in waters 3000 to 11,000 ft deep indicate the versatility of MABS. Among its other advantages are that it provides a quiet hydrophone platform and, during its deployment period, eliminates the need for a support vessel and is not affected by weather.

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INTRODUCTION

The Moored Acoustic Buoy System (MABS), shown in figure 1, is a moored, self-contained, programmable, acoustic data-acquisition system. It is designed to record calibrated acoustic signals as a function of depth in the frequency band from 3 to 5000 Hz in deep ocean areas. A master clock and logic circuit control the duration of each data sample and the time between data samples. Provision is made for unattended measurement periods ranging from 30 h to 30 days. The system is suitable for use in the deep sea anywhere in the world.

The nucleus of MABS is a subsurface buoy that provides buoyancy, protection, and support for the underwater instrumentation capsule (IC). Suspended beneath the subsurface buoy is an array of five hydrophones, spaced along 1770 ft of multiconductor, electromechanical cable. The lower end of the array cable is attached to the mooring system that can be adjusted to the depth of the water at the deployment site. The MABS IC contains the circuitry and the processing equipment for automatic, programmable, acoustic data acquisition; the calibration circuit, the master clock, and the logic circuit; and a magnetic tape recorder. The hydrophone array is suspended beneath the capsule and forms a part of the mooring system.

MABS is deployed by the anchor-last technique; that is, the subsurface buoy, hydrophone array, and mooring system are streamed on the surface astern of the deployment vessel, the mooring wire is cut to suit the measured water depth, and then the anchor is allowed to free fall to the bottom. Thereby, the subsurface buoy is dragged to its prescribed depth. Special provisions were made in the mooring to maintain at least 100 lb of tension on MABS during launch and recovery and to return the lower end of the mooring cable to the surface, following an acoustic command from the support ship, during recovery. The system is completely self-contained, with its own deck-mounted, self-powered winch. The winch includes a specially configured reel that carries the assembled array and mooring wires. MABS deployment and recovery times are approximately 90 min each; therefore, the system can be recovered, serviced, and redeployed in one day.

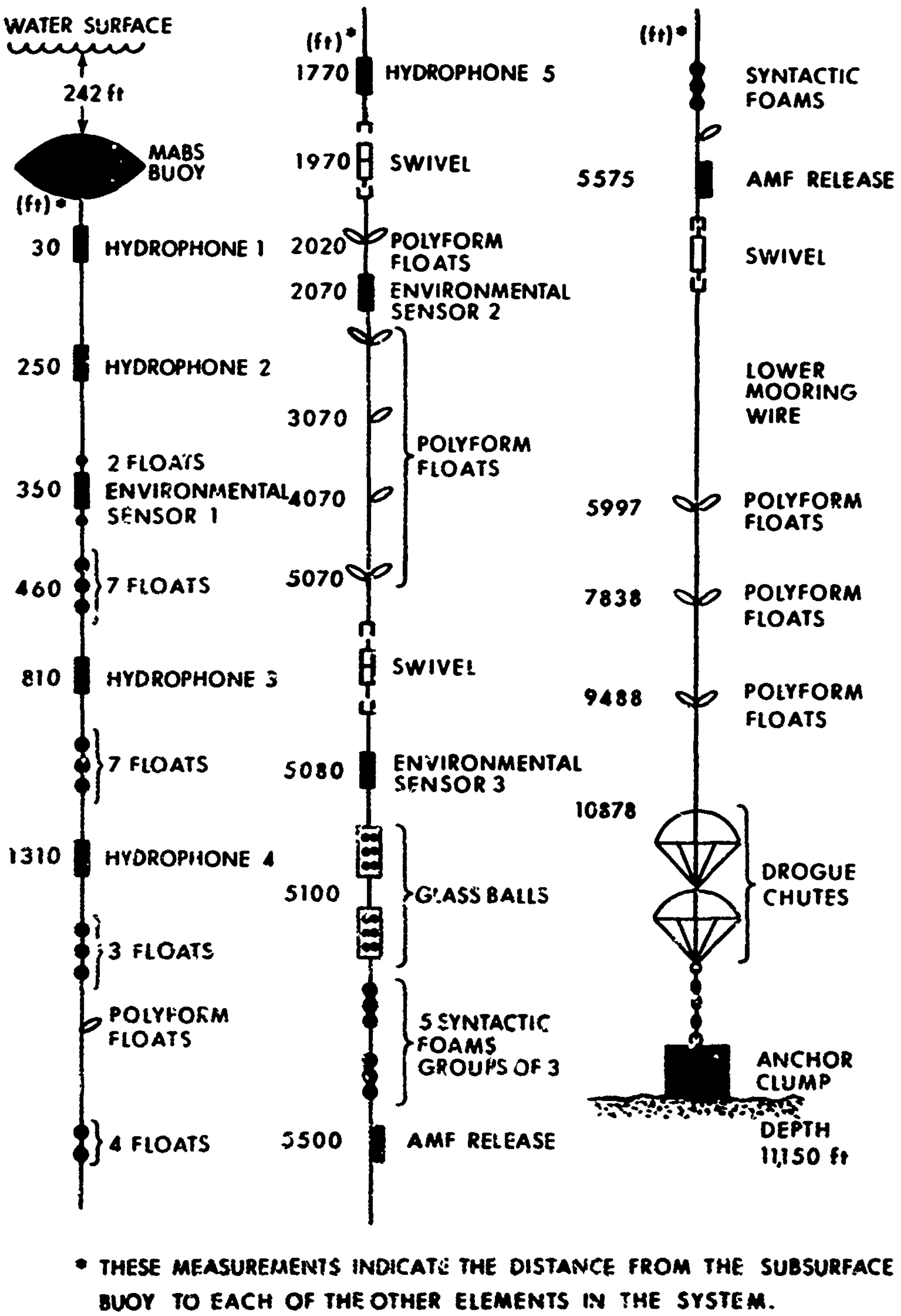

Figure 1. MABS

Since MABS is used to measure ambient noise, special attention was directed toward designing a quiet hydrophone platform. In addition, because reliability was also of utmost concern, a proven design was chosen for both the array and the mooring. The system was extensively tested in the laboratory and at sea. Tests were conducted of the individual components and of the assembled hydrophone array. Also, trial deployments took place in the Santa Cruz Basin and in the Bermuda waters. These tests and subsequent operational deployments fully demonstrated the success and utility of the MABS approach for automatically collecting calibrated underwater acoustic signals over lengthy periods of time.

SYSTEM SPECIFICATION AND DESCRIPTION

The original MABS' specifications required that, within a six-month time frame, a reliable, mechanically quiet, self-contained, single mooring, multiple hydrophone, subsurface buoy system be designed, fabricated, and tested, This system was to be portable, complete with its own winch, and readily deployable from a variety of support vessels. Also, it had to be able to support an 1800-ft array of five hydrophones and an accompanying recording system, and to function unattended for one month. Although the immediate application for MABS was for ocean areas with soundings of 11,000 ft, the system had to be capable of deployment in waters of any depth. The MABS time frame required that only existing or immediately available components be used; and the reliability factor necessitated a proven design, testing throughout the assembly process, and ocean testing of operational aspects and performance. Moreover, MABS operational limitations on maintenance and inspection of instrumentation after deployment necessitated special emphasis on array design to avoid system malfunctions.

MABS was designed around an existing 15-in.-diameter, 40-in.-long, cylindrical precision-tape recorder and other electronics. POSAC Z3B-SP hydrophones, available at the Naval Underwater Systems Center (NUSC), were used as the array elements. Only "well-logging" cable was readily available for the array itself; however, its use imposed special considerations for handling and deployment because it tends to hockle when tension is relaxed. A Rochester 7-H-4 seven-conductor, No. 20 AWG, rubber-insulated, double-armored cable was chosen — it was available with a fairing that reduces cable flutter and strumming. Rubber insulation was chosen in preference to polypropylene to avoid the stress cracking associated with polypropylene and the interface problems between plastic, metal, and rubber connectors. This cable's 0.464-in. diameter and 0.28-lb/ft weight in water were undesirable factors, but these parameters could be tolerated in an array only 1800 ft long.

DEPLOYMENT TECHNIQUE

Past at-sea experience indicated that array problems, such as cable hockling, could be most effectively avoided if the complete system were deployed and recovered under minimal tension. This meant that the weight and the dynamic loads of the anchor and the deployed gear could not be supported by the cable during deployment. Therefore, the anchor-last technique was chosen because, by allowing the anchor to free fall to the bottom, no dynamic loads from the ship's motion would be placed on the cable.

However, before the final decision to use the anchor-last technique could be made, the anchor swingback and the cable tension that would (1) position a MABS subsurface buoy at a depth of 200 ft and (2) avoid severe subsurface buoy overshoot during deployment, with the consequent danger of IC collapse, had to be determined. Array configurations and cable tensions during free fall were computed for various current conditions and are shown in figures 2 and 3. These figures show, respectively, the array configuration during deployment and the tension on the cable. Results of this analysis predicted no impulse loads on the cable; a smooth MABS deployment during anchor free fall, with little overshoot; and a very large anchor swingback.* For a 7000-ft-deep mooring, swingback could average 3765 ft $\pm$ 1264, depending on the ocean current. Therefore, it was considered practical to use the anchor-last technique for MABS deployment, provided the system could be streamed on the surface following a bottom contour line.

Past experience using the anchor-last technique for both taut-line moored surface buoy and subsurface systems has been reported by Berteaux and Walden[1] and by Fowler.[2] In particular, Fowler reported 18 successful moorings in 13,000 ft of water, whereby a 1200-lb, buoyant subsurface buoy was placed at 300 ft. Each mooring consisted of 3/16-in., 3 x 19 stranded steel wire, a 1500-lb anchor, and descent drogue chutes. The moorings for the systems described in references 1 and 2 used positive lower sections and American Machine and Foundry (AMF) releases for recovery. No serious problems with cable hockling were reported for either system. These were encouraging results; however, neither system used the troublesome well-logging cable dictated for the MABS design by "off-the-shelf" availability.

According to the test results concerning cable hockling obtained by Vachon,[3] the probability of cable hockling would be minimized if 100 lb of tension could be maintained on the cable during deployment and recovery. Tension of this

* G. T. Griffin, Informal communication.

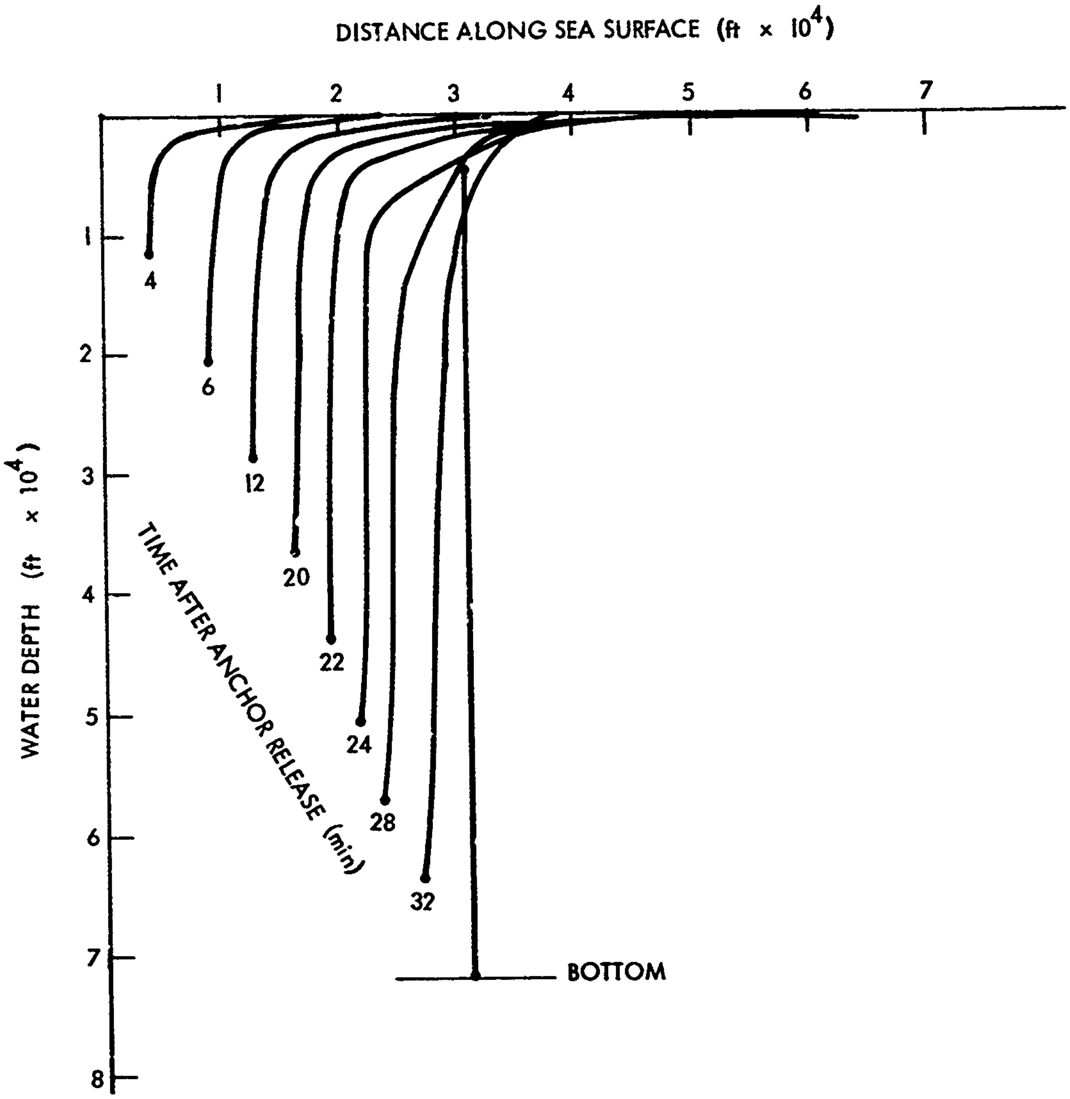

Figure 2. MABS Configuration During Launch Using Mean Ocean Current Profile

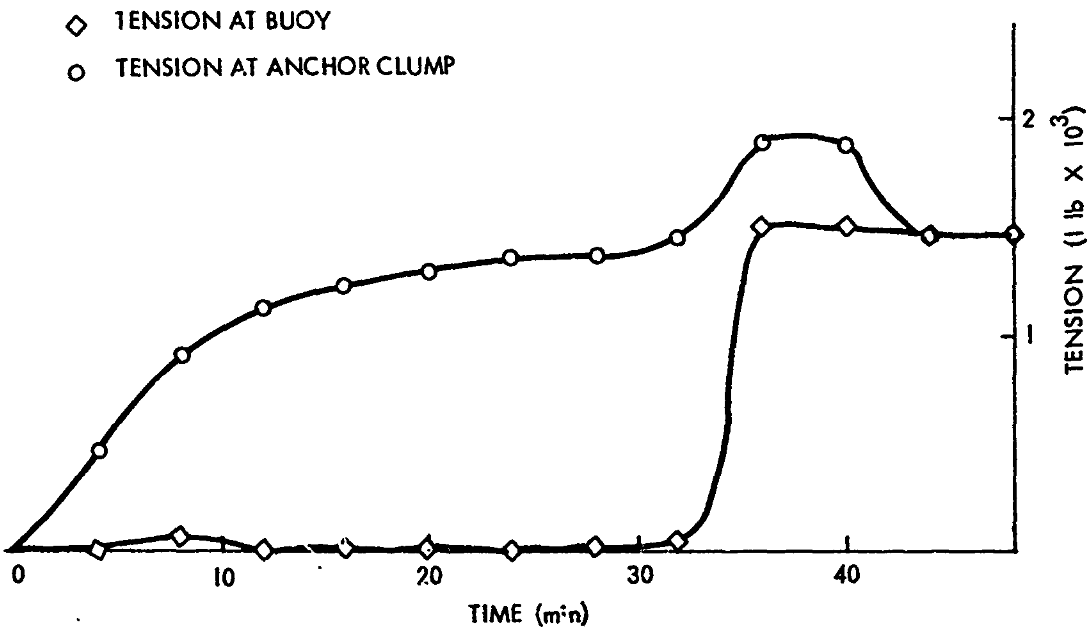

Figure 3. Tension versus Time Plot

magnitude would be automatically introduced into MABS during deployment because of the drag of the array and subsurface buoy as they are streamed on the surface behind the deployment vessel prior to anchor drop. During recovery, the necessary tension could be maintained by suspending 3000 ft of 3/8-in. wire rope directly underneath the array. These measures proved successful in eliminating cable hockling during the at-sea operations.

SUBSURFACE BUOY

The subsurface buoy, shown in figure 4, is an oblate spheroid composed of 22-lb/ft^3 density, composite, syntactic foam, with an internal aluminum frame and a major axis of 6 ft. It provides buoyancy, support, and protection for the IC (pressure vessel), which is carried in a well in the center of the buoy. The buoy is fitted with lifting eyes, deck skids, cavities to mount lights, and a radio beacon for recovery purposes. The buoyancy material has a maximum operating depth of 3000 ft, which is five times deeper than that of the IC, and has sufficient buoyancy to support the array if the IC were to leak or fail. A 25-lb foam section of the buoy was held at 1000 lbf/in.^{2} for 8 days in the NUSC pressure facility with no degradation in buoyancy. All joints on the buoy are insulated and silenced by means of delrin bushings.

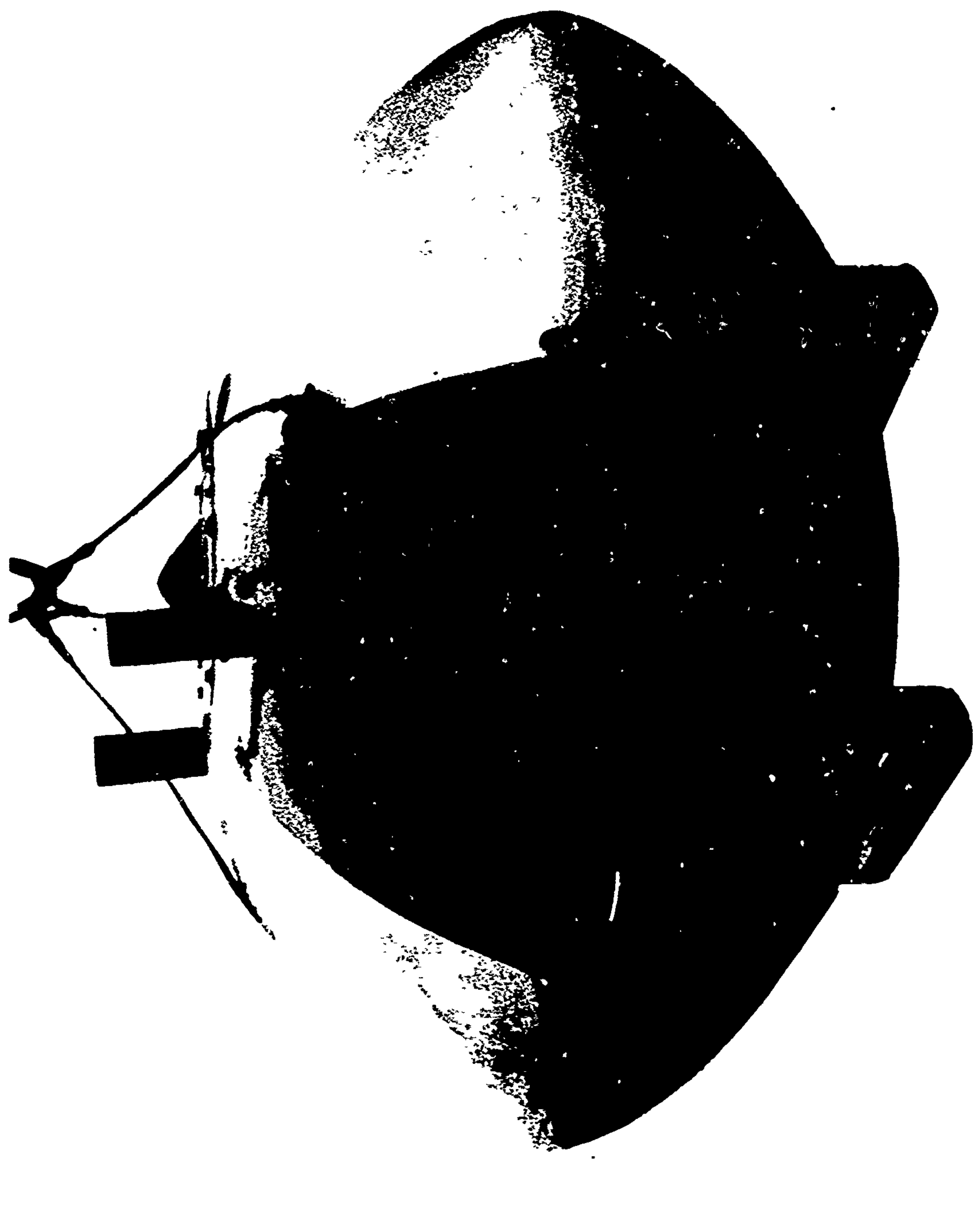

Figure 4. MABS Subsurface Buoy

SUBSURFACE BUOY SPECIFICATIONS

The subsurface buoy, which is designed to withstand rough handling at sea and is able to right itself if capsized during deployment, has the following specifications:

Displacement	4200 lb
Weight with IC	2500 lb
Buoyancy	1700 lb
Dimensions, oblate spheroid	6 x 3-1/2 ft
Color, striped	orange and yellow
Flotation	Composite, syntactic foam 22 lb/ft^3
Frame	1/8-in. wall, 6061T6 sheet aluminum
Lifting	3-point, permanently attached sling
Array attachment	Single pad eye and cable well
Instrument capsule (IC):	
Collapse depth	750 ft
Dimension cylinder	44-1/2-in.-long x 16-in.-diameter
Connector	12-pin (D. G. O'Brien)
Material	Schedule 30 steel pipe
Buoy Fabricator	Flotation Products, West Warwick, R.I.

ELECTRICAL

During the summer of 1970, an in-house project to provide hardware for the continuing investigation of ambient noise over a long time interval was initiated at NUSC. This led to the acquisition, on a no-cost basis, of a sound-survey, tape recorder capsule, built in 1961 by Lockheed Electronics Company under contract to the Office of Naval Research. The heart of this system was a seven-track 1/2-in. magnetic tape recorder built by Shepherd Industries. This tape recorder formed the nucleus for the present MABS recording system.

As originally configured, MABS was a self-contained instrument package capable of sequentially sampling acoustic data from four hydrophones suspended below the package in a cabled array. Each sample consisted of 25 s of data from each hydrophone and an additional 25 s of a single frequency calibration signal. The interval between data samples was fixed at 2 h and controlled by an Accutron Cycle Timer. Sufficient battery power and magnetic tape were included to permit one month of unattended operation.

With the advent of the Ionian-Mediterranean Exercise (IOMEDEX) of the Long Range Acoustic Propagation Program (LRAPP), a number of improvements were incorporated into MABS to meet the requirements for this exercise and to improve its overall performance. The changes included greater flexibility of sample interval and the addition of a fifth hydrophone, a time code generator (TCG), and a random noise calibration generator. In addition, the tape speed was reduced from 3-3/4 to 1-7/8 in./s.

OPERATION

All timing for MABS operation (see figure 5) is derived from a crystal oscillator that is part of a miniature TCG. The TCG also provides Inter Range Instrumentation Group (IRIG) B time code for indexing the data on magnetic tape. Timing pulses derived from the TCG are counted in the control circuit until a predetermined number of pulses, corresponding to the required elapsed time between data samples, have been counted. Start commands then energize the other functions of the instrument in order to begin a data sample. The hydrophone switching logic also derives timing pulses from the TCG and controls the switching on and off of each data channel. When all seven channels have recorded information, the hydrophone switching logic sends a command to the control circuit to stop the tape recorder and turn off power to all but the time-keeping circuits.

Each of the five hydrophones "feeds" a separate balanced pair of conductors in the MABS array cable, but no impedance matching or amplification is performed in the array itself. Consequently, no pressure housing is needed for the hydrophone packages and the reduction in their complexity and size allows them to be mounted permanently as an integral part of the cable. Each hydrophone signal is amplified in the IC by a high input impedance, low noise preamplifier system, with a gain of 80 dB. A 10-dB range of gain adjustment in each channel compensates for hydrophone and cable variations and provides equal midband acoustic sensitivity for each channel. The five hydrophone signals, as well as the TCG and calibration signals, are buffered by the post-amplifier before being recorded. The post-amplifier provides adjustable gain or attenuation to optimize the dynamic range of the recording system for expected acoustic levels, which vary with geographic location.

The calibration generator consists of a binary random noise generator, with a frequency spectrum from dc to 5 kHz that is flat to within $\pm 1/2$ dB. The generator drives a low pass filter that rolls off frequencies above 5 kHz at a rate of 18 dB per octave. The noise signal is linearly mixed with a precise 1-kHz sine-wave signal. The noise signal provides amplitude calibration levels at all frequencies of interest and the sine-wave signal gives amplitude and frequency calibration at 1 kHz.

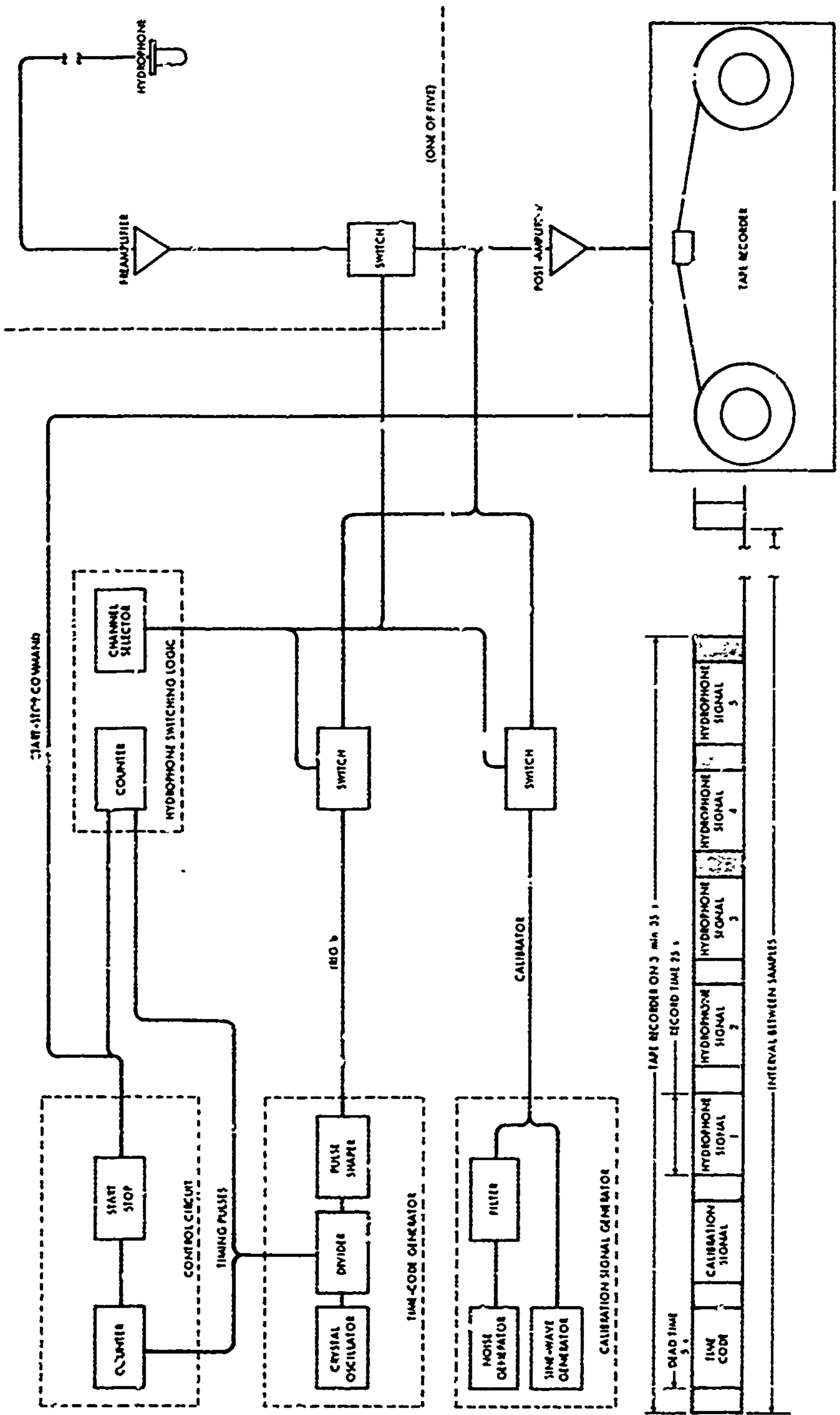

Figure 5. MABS Electrical System Block Diagram

CALIBRATION

Absolute acoustic calibration of the MABS hydrophone system was handled in a somewhat different manner from that usually employed. Actually two methods of absolute calibration were used. For the first method, the hydrophone array was calibrated to determine the open-circuit receiving sensitivity of each hydrophone and its pair of conductors in the array cable. When connected to the subsurface buoy, the hydrophone and cable drive a very high input impedance preamplifier that does not load down the hydrophone cable combination and affect the calibration. For the second method, each hydrophone was calibrated for open-circuit receiving voltage sensitivity. Then they were each connected to the array cable and a known voltage was generated across a calibration resistor that was inserted at the hydrophone in series with the low side of the cable pair. The combination of measurements in the second case, which is equivalent to the single measurement in the first case, is suitable for checking the condition of the array during field operations. Because the calibration signals recorded during operation are applied after preamplification, any changes in gain in the preamplifiers during a period of deployment would affect the absolute acoustic calibration of the system. Therefore, highly stable components must be used in this portion of the circuit, and test procedures have indicated a gain stability of ±0.2 dB under operating conditions.

The tape recorder has a standard seven-track head but only one record amplifier. Variations in coil impedance for the different tracks in the record head result in slight differences in frequency response and level when the amplifier is switched from track to track. Since only a single record amplifier is used, it can not be adjusted to compensate for the track-to-track variation. Therefore, to compensate for this variation, a segment of a calibration signal is recorded as a part of each sample and all data are corrected to this signal that is recorded on each track within a few minutes of the data.

RECORDING SYSTEM SPECIFICATION

The recording system for MABS has the following specification:

Tape Recorder:	
Manufacturer	Shepherd Industries, Fairfield, N. J.
Model	Transport type, AT-03A
Transport Functions:	Stop Record Reproduce Fast forward Rewind Track switching

Speed:	
Operating	3-3/4 in./s and 1-7/8 in./s ±1%
Fast forward and rewind	2-1/2 min for 3600 ft of tape
Flutter and wow:	0.9% peak to peak, 10 to 160 Hz
Voltage input	28 V nominal, operates 25 to 39 Vdc
Current input:	
Surge	11 A
Fast forward and rewind	6 A
Operating	3 A
Voltage output of regulated power supplies	+12 V, 0.49 A; -12 V, 0.49 A
Reproducing heads	7-track IRIG standard
Recording and reproduction:	Records and reproduces on seven tracks (one is used for each pass), with rewind and track switching accomplished automatically by photocells and clear leader strips at the beginning and end of the tape. The recorder stops automatically after rewinding the seventh pass.
Recording amplifier:	
Frequency response	±5 dB, 20 Hz to 5 kHz
Input level	100 mV to 1 V rms
Input impedance	Exceeds 10,000Ω
Time Code Generator (TCG):	
Manufacturer	CGS/Datametrics, Watertown, Mass.
Model	SP-105-514
Frequency standard	1-mHz crystal
Frequency stability	1 x 10^{-7} per 24 h, after temperature stabilization
Signal outputs	Time-code format: IRIG-B time code, modulated on a 1-kHz carrier frequency, with day of year and time of day in hours, minutes, and seconds.
Buffered pulse outputs	1 pulse per second, 1 pulse per minute, 1/10 pulse per minute, and 1 pulse per hour.
Size	6-1/4 in. long, 4 in. high, 2-7/8 in. wide
Weight	16 oz

Power requirements	+5 Vdc ±0.25, 500 to 600 mW
Hydrophones:	
Manufacturer	Harris Division of General Instrument Corporation, Westwood, Mass.
Model	Z3B-SP (POSAC)
Nominal sensitivity	-196 dB//1V/1μPa ±2 dB,* 10 Hz to 10 kHz
Preamplifiers:	
Manufacturers and models	Ithaco, Ithaca, N. Y., Model 144F, and Analog Device, Cambridge, Mass., Model 153J
Gain	80 dB ±2.5
Stability	±0.2 dB
Input impedance	1000 MΩ shunted by 15 pF max.
Power	Plus and minus 12 V at 8 mA max.
Frequency response	±0.5 dB, 10 Hz to 10 kHz
Post-amplifier:	
Manufacturer	Analog Device, Cambridge, Mass.
Model	153J
Gain	0 dB ±15, adjustable
Stability	±0.2 dB
Power	Plus and minus 12 V at 2 mA
Frequency response	±0.5 dB, 10 Hz to 10 kHz

Sample Interval (switch selectable):
Adjustable over the range:
4 to 9 min in 1-min intervals
10 to 90 min in 10-min intervals
1 to 9 h in 1-h intervals

Sample Length (see figure 5):
Fixed, consisting of 25 s of acoustic data from each hydrophone, 25 s of time code, and 25 s of calibration signal.

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*One micropascal, equal to 10^{-5} dynes per square centimeter, has been adopted by NUSC as the standard reference pressure for acoustic measurements in liquids, superseding the microbar (1 dyne per square centimeter). The effect of the change in reference is a translation of 100 dB in level; e.g., 90 dB//1 μB = 190 dB//1 μPa.

Battery Supply:	
Main Battery Pack	19 Silvercells, type LR-85, 28 V at 100 Ah, Yardney, Pawcatuck, Conn.
TCG Battery Pack	4 Silvercells, type LR-85, 7 V at 100 Ah
Amplifier Battery Pack	2 Gell-cells, type 1245, 12 V at 4.5 Ah, Globe, Milwaukee, Wis.

All batteries are recharageable.

System Operation Life:	
Recording time	30 h, limited by Amplifier Battery Pack
Deployment time	30 days, limited by TCG Battery Pack

RECORDING CHARACTERISTICS

Figure 6 is a 2-Hz-bandwidth-spectrum analysis of MABS operation, recorded and reproduced at 1-7/8 in./s. The tape overload point is set at +3 dB//1 V; from 100 Hz to 5 kHz, the sine-wave and white-noise calibration signals indicate a frequency response of ± 2 dB. The input to the preamplifier was terminated with a capacitor in order to simulate the hydrophone and system noise. (The reproduce-system noise is also shown in figure 6.) The noise spikes in the MABS noise curves are a result of the servo system used to drive the tape capstan.

Because the effect of standard tape recorder wow and flutter on various methods of data analysis is difficult to ascertain, measurements were made of the wow and flutter induced frequency smear bandwidth in the record-reproduce process. The measurements made at 3-3/4 in./s indicate that the bandwidth of the induced smear (bandwidth determined at the -15-dB points) is insignificant at data frequencies below 500 Hz, but at a frequency of 1 kHz, the bandwidth increases to about 3 Hz. These values will be greater for slower tape speed; however, for any frequency, the bandwidth should be no more than doubled when the tape speed is halved to 1-7/8 in./s.

HYDROPHONE ARRAY

The MABS hydrophone array,* shown in figure 7, consists of five 2-in.-diameter by 8-in.-long hydrophones, spaced along the length of 1770 ft of 7-H-4 rubber-insulated, double-armored, faired cable. The hydrophones are hard-rubber mounted in 5-in.-diameter by 14-in.-long steel, slotted, coaxial cages

*Two separate hydrophone arrays were fabricated and one was designated as a spare.

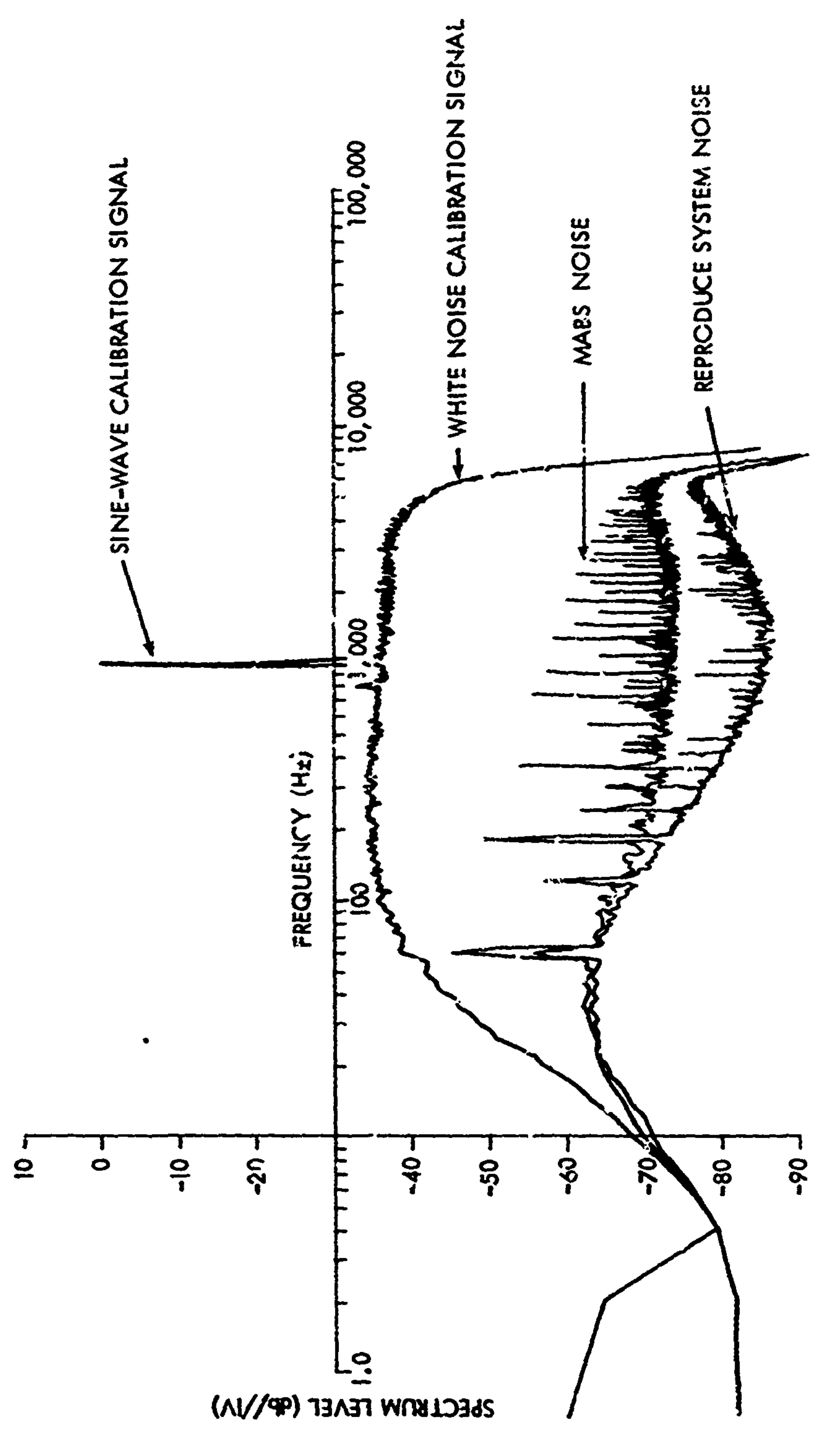

Figure 6. MABS Performance

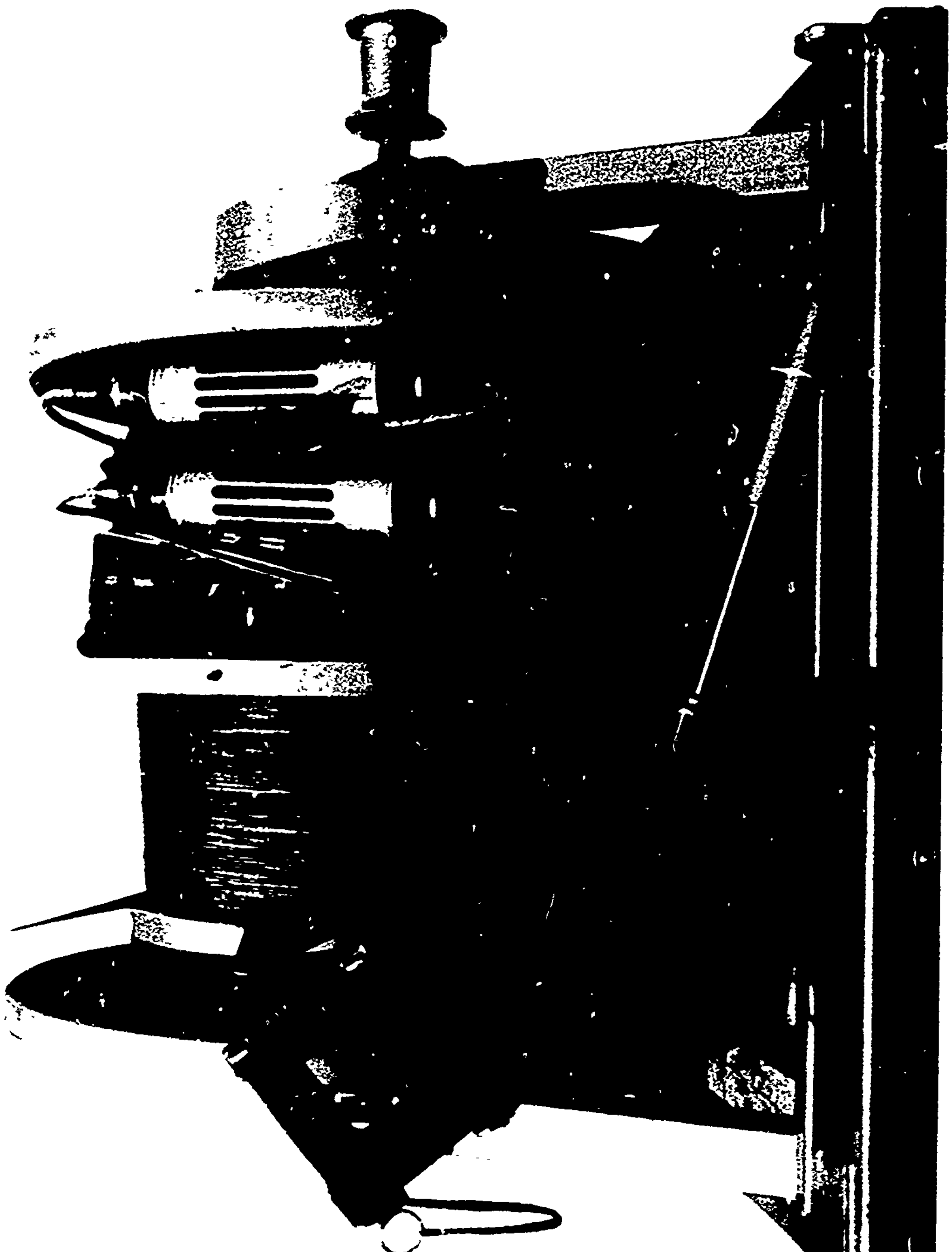

Figure 7. MABS Array on Winch

(see figure 8) that are end-fitted with special Preform Line Products (Cleveland, Ohio) Dyna-Grips. No provision is made for flexure other than the bending inherent in the grips that allows the array to be wrapped easily around the 40-in.-diameter MABS winch. However, this does impose the constraint that the cage can only be wound onto the drum under, at most, 500 lb of tension. In addition, the complete array must be wound on a reel no larger than 4 x 9 ft, which will fit inside the NUSC pressure vessel for testing.

The mechanical joints at the top and at the bottom of the MABS array are silenced and insulated by means of delrin bushings. During deployment, the weight of the array is offset by the addition of special, coaxial, syntactic foam floats that are attached to the array cable.

Each hydrophone is connected by single-pin Mecca (Houston, Texas) connectors to a pair of rubber-insulated conductors. The individual conductors inside the cable are only interrupted at the hydrophone they are servicing; the remaining conductors, free of splices, bypass the station inside a conduit pipe. All permanent joints are vulcanized rubber molds.

The array was fabricated and assembled in the Preform Line Products plant in Cleveland, Ohio. After each rubber conductor mold was completed, it was tested for continuity and insulation resistance in a salt-water bath under zero pressure. The completed array was then reeled onto a special reel and retested in the NUSC pressure tank at 1000 lbf/in.^{2} for 24 h. Next, the five hydrophones were inserted into the array and the completed system was tested at the maximum operating pressure that it would be exposed to in the ocean. During these tests, no defects were found in either array.

HYDROPHONE ARRAY SPECIFICATIONS

The components that form the hydrophone array have the following specifications:

Hydrophones	5 each, 2-in.-diameter x 8-in.-long, 2-lb air weight
Cable	
Type	7-conductor, No. 20 AWG
Insulation	0.030-in. rubber
Diameter	0.464 in.
Weight in water	0.268 lb/ft
Breaking strength	16,000 lb
Armor	double round wire armor
Fairing	polyurethane ribbon type

Figure 8. MABS Hydrophone Cage

Hydrophone cage:

Dimensions and weight	cylinder, 5-in.-diameter x 14-in.-long; 29 lb
Material	1/4-in. galvanized steel
Array overall length	1770 ft
Max. operating depth	3400 ft

MABS MOORING

The mooring for MABS is composed of three major parts:

a. the 3000-ft upper mooring cable that serves the dual function of providing a recoverable mooring cable plus ballasting the array to produce 100 lb of tension in the array cable to avoid hockling during the initial recovery period;

b. the center buoyancy and release section that, when activated, returns the lower end of the mooring to the surface for recovery;

c. the expendable lower mooring section consisting of the length of wire required to reach the bottom, two in-line anchor descent drogue chutes, and a 2300-lb clump anchor.

These sections are connected by modified Miller swivels to reduce cable hockling.

The upper mooring cable is 3/8-in., 3 x 19 stranded construction US Steel torque-balanced wire rope with a polyethylene jacket and a rated breaking strength of 14,800 lb. This high breaking strength was selected because of the possibility of cable hockling.

The center mooring section is composed of syntactic foam and redundant AMF releases. The 38-lb/ft^3 density, 1200-ft operating depth, syntactic foam is cast in "watermelon" form on 10-ft x 1/2-in.-steel pendants that are constructed with mating male and female ends. Three floats, each producing 50 lb of buoyancy, are cast on each pendant. They are then added in series to produce the required buoyancy. Their shape and flexibility make these pendants and attached floats easy to handle.

Two AMF releases are used to achieve redundancy — the lower one is activated first and the upper one is only used if the first one fails. They are hooked in series and separated by one buoyancy pendant for handling ease. The upper release is also a transponder, which allows the mooring to be located and its integrity verified by acoustic means.

The lower mooring section consists of 5/16-in., 3 x 19 stranded wire rope, two 8-ft-diameter, vane-type, coaxial drogue chutes, and a 2300-lb steel clump anchor. The chutes can each support 2000 lb and are coaxially mounted to ensure a symmetrical anchor descent of approximately 300 ft/min.

MOORING SPECIFICATIONS

The mooring for MABS has the following specifications:

Upper mooring cable	3000 ft 3/8-in., 3 x 19 stranded torque-balanced wire rope
Upper mooring cable breaking strength	14,800 lb
Buoyancy modules	syntactic foam, 130 lb, positive buoyancy
Releases	two AMF
Expendable lower mooring wire	5/16-in.-diameter, 3 x 19 stranded wire rope
Expendable lower mooring wire strength	10,300 lb
Drogue chutes	two 8-ft-diameter, Pioneer Parachute Co., Manchester, Conn.
Anchor	steel clump, 2300 lb

MABS WINCH

A completely self-contained, diesel/hydraulic driven winch with a specially configured large capacity reel was chosen (see figure 9). The winch is compact and can be easily welded to the deck in a few hours. The large reel is divided into four sections. The two outside sections will each hold the hydrophones of one array and the two center sections will each contain a complete mooring system and array cable. Thus, the winch can be loaded in port with an assembled array, mooring, and spares.

WINCH SPECIFICATIONS

The winch can be set for any line pull tension and has fingertip speed control. It was purchased complete with capstan, level wind, and fabric cover from Pengo Hydra-Pull Corp., Fort Worth, Texas, and has the following specifications:

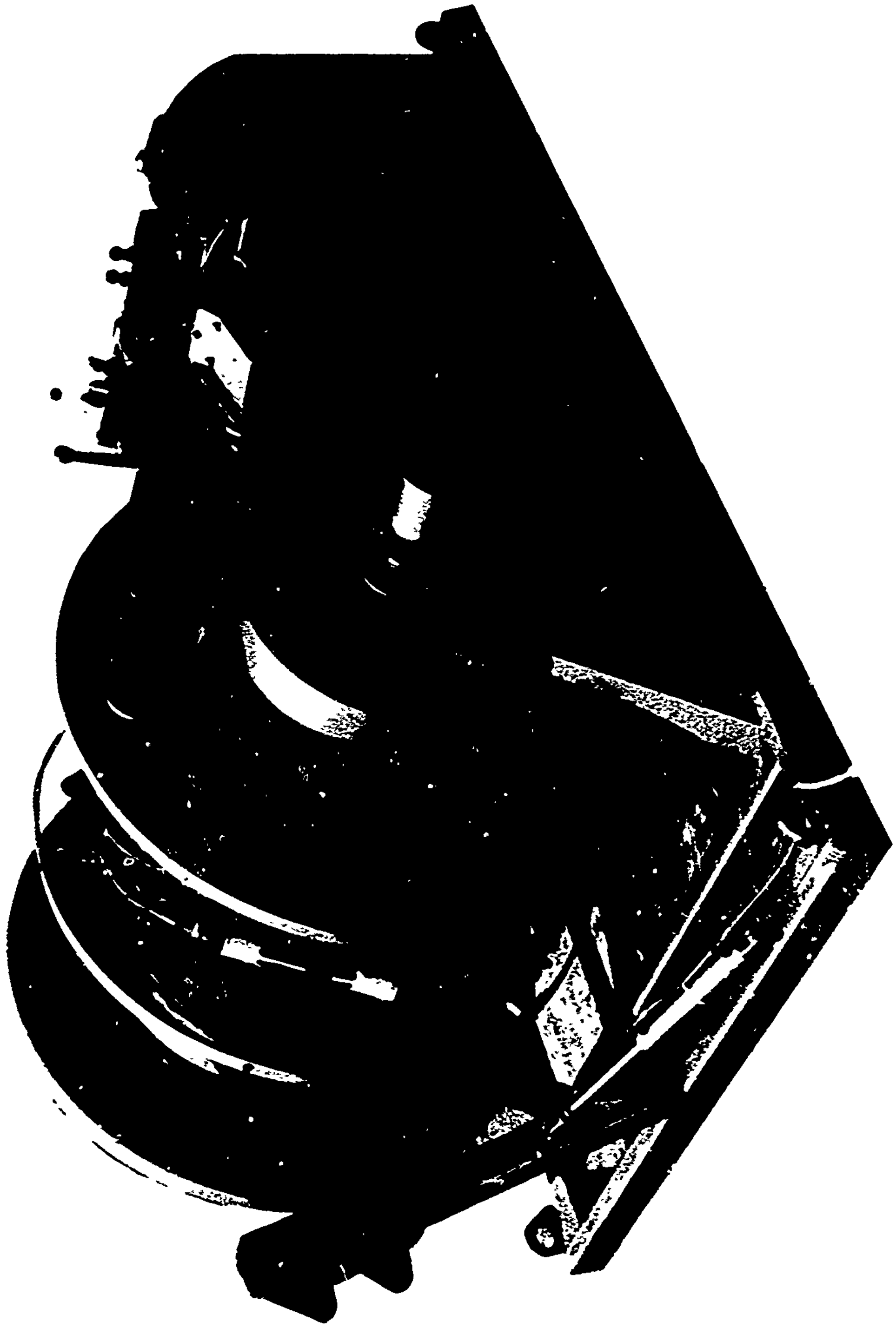

Figure 9. MABS Winch

Max. line pull:	
high gear	8000 lb
low gear	12,000 lb
Line speed:	
high gear	140 ft/min
low gear	88 ft/min
Dimensions	10 x 7 ft
Weight	5500 lb
Reel size	60 x 56 in., removable
Engine	30 hp, diesel, air-cooled

DEPLOYMENT AND RECOVERY

As described previously, MABS is deployed by the anchor-last technique. The major advantage of this technique is that the high tension generally encountered during anchor lowering can be avoided. However, two disadvantages are (1) wire length errors can occur that will affect the depth of the subsurface buoy and (2) since control of the system is lost once the anchor is released for its free fall to the bottom, cable kinking and buoy plunge overshoot can occur.

These possible hazards plus the requirement that the subsurface buoy must be accurately placed 200 ft below the surface in 11,000 ft of water produced considerable concern in the early stages of deployment design. It was, therefore, decided that the mooring system should be analyzed for deployment configuration, tension on the cable, and anchor swingback and the analytical model validated by an at-sea deployment of a prototype.

The results of these analyses and tests led to the selection of the parameters cited in the following description of the deployment and recovery procedures (also see table 1). Analyses indicated that MABS would experience an anchor swingback of over half the total system length, as shown in figure 2, if the current were in a direction from the anchor to the buoy. (An anchor swingback of 3000 ft has been measured.) Thus, it was apparent that an accurate survey of the sea bottom preceding each deployment and precise navigation along selected depth contours during anchor drop would be necessary to achieve the specified 200-ft buoy depth. (The survey generally requires about 4 h and navigation is provided by a combination of loran and satellite.)

DESCRIPTION

Prior to each deployment, a MABS procedure was written that identified the sequence of operations and related it to cable out, time, distance along the ship's track, and water depth, as in table 1.

For a typical 7000-ft-deep mooring, deployment would begin with the ship sailing along a 30,000-ft-long deployment track. An inflatable safety buoy, capable of supporting the entire system in the event the mooring wire was too short, and 400 ft of polypropylene line would be put overboard first. Next the subsurface buoy would be deployed and released. Array deployment would then proceed at an average of 50 ft/min, with stops to attach in-line flotation. The upper mooring wire would be played out at 100 ft/min and the lower wire at 150 ft/min. Major items, such as the subsurface buoy, the central buoyancy section, and the clump anchor, require from 5 to 10 min each for deployment. Deployment of the entire system would average about 100 ft/min, with a total elapsed time of approximately 90 min. The complete system would be stretched out on the surface of the sea prior to anchor release. Thus zero-tension nodes would be avoided during anchor free fall.

The ship speed during these operations would be approximately 170 to 200 ft/min, which would generally produce a tow speed of 1/2 to 1 knot and cable tension from 50 to 300 lb. Greater cable tensions caused by the cable's weight are avoided by attaching a number of 175-lb-buoyancy, inflatable, Polyform floats along the cable. The floats would be pulled down and automatically collapse under pressure. Therefore, they could not influence the mooring until the recovery process was initiated, when they would reinflate and assist in that process.

Once the system is deployed, the ship would remain next to the surface safety buoy until the ship's position (and, thereby, the subsurface buoy's position) was determined by satellite navigation. Then a rubber boat would be launched and the crew would detach the safety buoy from the subsurface buoy and, in the process, measure the depth of the latter to within 5 ft. For recovery, the ship would return to the location and acoustically activate the lower release and the subsurface buoy would appear 1 min after release. Then the ship would be maneuvered close to the lower buoyancy section that should appear on the surface 100 to 200 yd upwind from the subsurface buoy, approximately 13 min after release. Then MABS would be recovered in the reverse order of deployment, thereby reloading the winch in the proper order for the next deployment. A crew of six was required to deploy and recover MABS, only half the number usually required for such a system.

Table 1. MABS Deployment Procedure

Sequence of Operations		Cable Out (ft)		Time (min)		Ship's Track (K ft)		Water Depth Along Ship's Track (fm)		Remarks
Desired	Actual	Desired	Actual	Desired	Actual	From Start	To Anchor Drop	Desired†	Actual	
Safety Buoy										
Subsurface Buoy				10		0	30			
H_1 H_2*		250		15		1	29			
E_1 3F		350		20		2	28			
4F		600		25		3	27			
H_3 2F		810		30		4	26			
4F		1060		35		5	25			
H_4 3F		1310		40		6	24			
4F		1560		45		7	23			
H_5 3F-PF		1770		50		8	22			
2F		1970		55		9	21			
E_2 PF		1970		30		10	20			
		2470		65		11	19			
PF		2970		70		12	18			
		3470		75		13	17			
PF		3970		80		14	16			
		4470		85		15	15			
		4670		90		16	14			
E_3 PF		4670		95		17	13			
		4970		100		18	12			

Sequence of Operations		Cable Out (ft)		Time (min)		Ship's Track (K ft)		Water Depth Along Ship's Track (fm)		Remarks
Desired	Actual	Desired	Actual	Desired	Actual	From Start	To Anchor Drop	Desired†	Actual	
2 PF 4 B		5010		105		19	11			
AR		5015		110		20	10			
AR B-PF		5030		115		21	9			
				120		22	8			
		5530		125		23	7			
		6030		130		24	6			
		6530		135		25	5			
CC		6550		140		26	4			
Anchor		6575		145		27	3			
				150		28	2			
				155		29	1			
Drop Anchor				160		30	0			

*Code	Component
H	Hydrophone
E	Sensor Package
F	Syntactic Foam with Preformed Grip
PF	Polyform Float
B	Wire-Rope Pendant with Cast Syntactic Floats
AR	Acoustic Release
CC	Drogue Chute Assembly

†The desired water depth is recorded following the predeployment survey conducted at each site.

Although the deployment parameters could be closely predicted and repeated, the recovery time was neither predictable nor repeatable. Elapsed time for recovery varied from 58 to 223 min maximum, depending to a large extent on the maneuvering characteristics of the support ship.

SPECIFICATIONS

The following specifications were predicted for an 11,000-ft mooring;

MABS crew	6
Support ship	400-ft^2 deck space; 3000-lb lift, maneuverable
Navigation	real time $\pm$ 1/4 nmi
Deployment time	90 min
Recovery time	90 min
Average ship speed	1.7 knots
Average speed of cable winch	100 ft/min
Time required for buoy to submerge after anchor release	33 min
Anchor swingback	3000 ft
Buoy depth error	$\pm$30 ft

AT-SEA OPERATIONAL EXPERIENCE WITH MABS

To date MABS has been deployed in the Santa Cruz Basin, California, in June 1971; Bermuda in August 1971; and in the Mediterranean Sea for IOMEDEX in November 1971.

SANTA CRUZ EXERCISE

The Santa Cruz Exercise tested the MABS design concept for both acoustic and mechanical performances, with special emphasis on the deployment technique. A prototype system instrumented to meet the objectives was used. Delco's Santa Cruz Acoustic Range Facility (SCARF) was chosen as the deployment test site because it had facilities to test the acoustic and mechanical performances. SCARF's three-dimensional tracking range, accurate to within 10 ft, was used to track the deployment vessel, Delco's R/V SWAN; measure anchor swingback;

and, after deployment, compare ambient noise recordings from both bottom-mounted and suspended hydrophones with the MABS recorded data.

SWAN also served as the support ship. Its stern, well-equipped for buoy deployment, trained crew, and good maneuverability provided an excellent platform for prototype testing.

The MABS was loaded on SWAN on 7 June 1971. Following a predeployment survey at SCARF, deployment commenced at 1000 and required 88 min. Then the ship departed the area and left MABS unattended for a 3-h ambient-noise recording period. It returned at 1551 and recovered the system in 58 min.

The data gained during this deployment provided answers to most of the deployment and operational questions, such as the amount of overshoot, descent velocity, and anchor swingback. A 24-ft overshoot and an average descent velocity of 300 ft/min were measured, and the final depth of the buoy was 230 ft — 30 ft deeper than planned. The anchor swingback was 1/5 the total system length. No hockling or malfunctioning was observed.

BERMUDA EXERCISE (BERMEX)

During the Bermuda Exercise (BERMEX), MABS was used to gather ambient-noise data, thereby operationally verifying the instrumentation that was to be used in IOMEDEX. MABS was deployed from R/V NORTH SEAL — a supply-type ship rigged explicitly for IOMEDEX. This was the first field test of the completed MABS.

The deployment site, 1 nmi from an existing vertical array whose data are cabled back to the NUSC Tudor Hill Laboratory in Bermuda, was chosen because it allowed comparison of the ambient-noise measurements recorded by the two systems. The mooring at this site was in 7000 ft of water. As a result of this choice, the anchor had to be dropped on an 8.5° slope. Moreover, this steep slope and the 200-ft ±100 buoy-depth requirement limited the width of the drop zone to 1200 ft. A very precise bottom survey was conducted by using the Bermuda based NASA radar positioning for real-time navigation. The bottom contours were plotted, the ship's course was selected, and the system was deployed using the deployment parameters determined from the Santa Cruz operation.

The deployment required 83 min, and the subsurface buoy came to rest at 230 ft — 30 ft deeper than planned. Anchor swingback was 2520 ft, which agreed well with predictions. Figure 10 is a plot of the ship's tracks showing the launch zone, event lines, contours, and the anchor's final position. This operation went very smoothly and validated the deployment predictions that would be used for IOMEDEX.

MABS was left unattended for 13 days and was recovered on 19 August. The recovery operation required 100 min. One minute after the lower release was commanded to release, the subsurface buoy surfaced. Thirteen minutes later (right on schedule), the lower buoyancy elements appeared 200 yd upwind from the subsurface buoy. The ship then maneuvered its stern close to the lower buoyancy section and took it under tow in order to separate the subsurface buoy and the lower buoyancy section, thereby preventing the cable bight, suspended 2500 ft in the water, from hockling. From 100 to 200 lb of tension were maintained in the cable as the array was brought aboard. No indication of cable hockling was observed.

Unfortunately, no acoustic data were obtained during the recording period because of a malfunction in the tape recorder and, therefore, no comparison of the two arrays was possible. The fault in the tape recorder was traced to a short circuit caused by the tape reel rubbing against the wire when the recorder doors were closed. All previous life tests of the recorder had been performed with the recorder doors open for periodic inspection and measurements, which accounts for the late discovery of this problem.

IONIAN-MEDITERRANEAN EXERCISE (IOMEDEX)

The Bermuda operation proved that NORTH SEAL was an excellent vessel from which to deploy MABS. However, because of the multiplicity of tasks required of this ship in IOMEDEX and the ease of moving MABS from one ship to another, it was decided to deploy MABS from USNS SANDS, which had become available to the project. Although SANDS was not the best vessel for this purpose, because of her relatively poor maneuverability and high free board, no major problems were expected

Most of MABS equipment was loaded aboard SANDS at NUSC. However, the arrays, recorder, and pressure vessel were held at NUSC for calibration and system testing in 30 ft of water and then flown to the Naval Air Station at Sigonella, Sicily. There again, the equipment underwent system testing from 28 October to 4 November.

From 4 to 5 November, MABS was completely reassembled aboard SANDS in Augusta Bay, Sicily. During this period, a project requirement changed the emplantment site. The water depth at the new site was 4500 ft deeper and necessitated the addition of 4500 ft of wire, 600 lb of fixed buoyancy, and 900 lb of

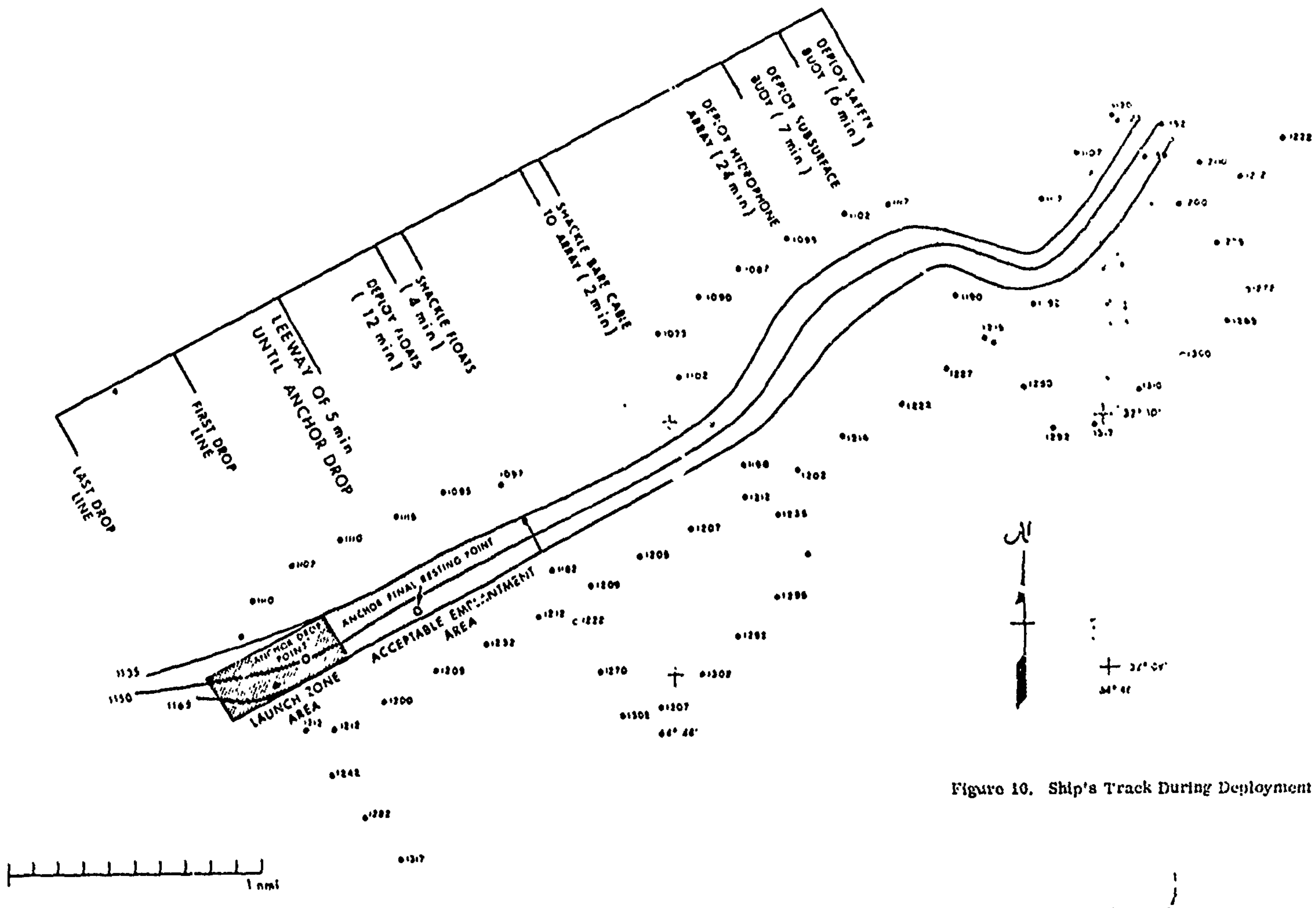

Figure 10. Ship's Track During Deployment

inflatable buoyancy to MABS. Unfortunately, there was only enough extra mooring wire in spare parts to permit one deployment in the deeper water. Therefore, the deployment period was changed to 19 days, instead of two 1-week deployments, and the interval between recording samples was changed from 20 to 30 min in order to gather data over the longer deployment period.

SANDS arrived at the deployment site on the morning of 6 November. Since there was not enough time for a complete bathymetric survey, an emplantment course was chosen from existing bathymetry plus some bathymetry supplied by Naval Research Laboratory (NRL) personnel aboard R/V KNORR, which had arrived in the area ahead of SANDS. An additional constraint on the deployment was the desire to place MABS as close as possible to a previously deployed array.

No problems were encountered during deployment, even though it was conducted at night. The estimated and actual deployment parameters agreed remarkably well. The subsurface buoy depth was 12 ft shallower than the planned 200-ft deployment and the anchor was 300 yd from its target. After the MABS position was determined by using the satellite navigation and the safety buoy was removed, SANDS departed for other operations, with a scheduled return for recovery on 25 November.

On 14 November, SANDS was informed by radio that a buoy closely resembling the MABS subsurface buoy had been sighted adrift, approximately 142 nmi from the deployment site. SANDS arrived in the area late on the 14th, proceeded directly to the MABS deployment site, and interrogated the acoustic transponder in the lower mooring section. The transponder's reply indicated that it was still at the proper depth and location. However, it could not be determined whether or not the subsurface buoy had broken free from the mooring lines above the transponder and lower buoyancy. Therefore, since two-thirds of the tape in the recorder was now spent and no more information could be received from the beach concerning the drifting buoy because of poor radio communications, it was decided to take advantage of the good weather and recover MABS prior to SANDS departing the area.

On the following morning, the anchor was released in a Sea State 1 condition. The subsurface buoy surfaced approximately one minute after release, 300 yd off the port quarter. This location was predicted by acoustic ranging on the acoustic transponder prior to release. Thirteen minutes after release, the lower buoyancy section arrived on the surface, approximately 75 yd up wind from the subsurface buoy. Approximately 45 min were required to maneuver SANDS into position to pick up the line attached to the lower buoyancy section by the rubber boat crew. This section had become entangled on its way to the surface — a condition probably caused by the use of the different density buoyancy sections required by the deeper water depth encountered in this deployment. The ship's crane had to be used to bring MABS lower buoyancy section aboard.

During this operation, the ship remained dead in the water and drifted past the subsurface buoy. Consequently, the array crossed over itself between the two lower hydrophones, ultimately fouled, and produced a kink in the cable, which caused a short circuit in the array between the last two hydrophones.

During this IOMEDEX deployment, 6 to 14 November, MABS recorded 8-1/2 days of acoustic data at a sample interval of 30 min. The preamplifier gain settings selected before deployment placed the acoustic data at a near optimum value within the dynamic range of the system.

Since a spare hydrophone array was carried with the MABS equipment, a second deployment was possible, provided 3947 ft of mooring wire could be obtained at SANDS next port of call. Suitable wire was found among the Woods Hole Oceanographic Institution (WHOI) spares aboard NORTH SEAL and was transferred to SANDS and then onto the MABS winch in Augusta Bay on 16 November. MABS was then redeployed for a 7-day recording period. This deployment required only 81 min but the recovery took 132 min, 52 min of which were spent maneuvering SANDS into position to pick up the lower buoyancy section. The subsurface buoy was moored at a depth of 320 ft during this deployment. This was 110 ft deeper than expected and the error factor for this deployment was approximately four times that for previous moorings. This can probably be accounted for by an "in the field" wire-counting error during wire transfer from NORTH SEAL to SANDS.

This deployment, from 17 to 24 November, provided an additional 5-1/4 days of data at the rate of a sample every 20 min. The recording terminated a day and a half early because of the premature discharge of the main battery pack. This problem was caused by the inadvertent failure to check the battery electrolyte level in the rush to prepare MABS for the unexpected second deployment. The same gain settings used in the first deployment were used in the second, and, again, all recorded data were of good quality.

MABS ENVIRONMENTAL SENSORS

During IOMEDEX, three environmental sensors were attached to MABS at depths of 592, 2312, and 5312 ft for the first mooring, and one was attached at 2290 ft for the second mooring. Primarily, these instruments were to measure MABS performance as a hydrophone platform, but they also measured the time variations of several oceanographic variables that affect system performance.

Each sensor recorded one stability reference channel and the following eight environmental measurements: water-current speed, water-current direction relative to the instrument, compass orientation of the instrument housing, X and Y inclinations of the instrument from the vertical, hydrostatic pressure, water temperature, and conductivity.

The nine data channels were sample (strobed) once every 5 min (12 times per hour). A single strobe of the nine channels required approximately 4 s; therefore, the measurements represented virtually instantaneous values.

Each sensor contained a 400-ft continuous loop, 1/4-in. incremental magnetic tape recorder on which data were recorded in Binary Coded Decimal (BCD) format. For the given sampling rate, maximum tape capacity equaled about 50 days of operation. Before deployment, the instruments were turned on and synchronized aboard the emplantment vessel, and were allowed to operate uninterrupted until the final recovery of the MABS array.

ENVIRONMENTAL SENSOR SPECIFICATIONS

The environmental sensors used in the array have the following specifications:

Current speed:	
Range	0.05 to 8 knots
Starting speed	0.05 knot
Resolution	0.05 knot
Accuracy	±0.05 knot at 1 knot or less, ±0.1 knot above 1 knot
Current direction (combination of compass and vane):	
Resolution	2.8°
Accuracy	±6°

Conductivity:		
Range	0 to 60 mmho/cm	
Accuracy	±0.02 mmho/cm	
Temperature:		
Range	-2° to +30°C	
Accuracy	±0.1°C	
Inclination:		
Range	+45° to -45°	
Accuracy	±0.3°	
Pressure:		
Serial No.	Range	Accuracy
D-185	0 to 500 lbf/in^2	±1% full scale
D-186	0 to 3000 lbf/in^2	±1% full scale
D-187	0 to 7500 lbf/in^2	±1% full scale

PROPOSED MABS MODIFICATIONS AND IMPROVEMENTS

Thus far, no major problems have been encountered during the at-sea operations using MABS. However, its design was mechanically conservative so that a reliable system could be developed in the relatively short time frame of six months. The following changes are being considered for future MABS development:

a. Buoy depth specifications should be changed to 300 ft ±200, with the cable deployed in a large negative bight, which will reduce anchor swingback. The lower mooring wire can be cut to the appropriate length when the desired bottom depth reading appears on the fathometer trace. With the anchor swingback reduced, the anchor will fall closer to the anchor drop point, thereby making the navigational requirements for MABS less critical.

b. Rubber boat operations should be avoided by eliminating the safety buoy. If this is done, (1) a pressure sensor will be required on the subsurface buoy to determine its depth and (2) a stronger pressure vessel will be needed to protect the buoy from damage in case of severe overshoot. Also a recovery line for hoisting MABS aboard should be installed on the subsurface buoy. An easily maneuverable ship that can come alongside the lower buoyancy section quickly and get a line on this section directly from the ship should be used.

c. The mooring wire can be safely reduced to 1/4-in., 3 x 19 stranded construction, which would lighten the entire system, thereby reducing the amount of system buoyancy required.

d. The upper mooring wires could be lengthed to 8000 ft of 1/4-in., 3 x 19 stranded construction, with a reciprocal shortening of the lower mooring wire. Since the upper mooring wires are recoverable, this will result in more economical operations.

e. Since MABS, in its present form, deflects only 59 ft from the vertical in 7000 ft of water when subjected to a 0.4-knot current from top to bottom and, according to analytical studies, only 22 ft when exposed to a general ocean current, less fixed buoyancy could be used along the system. This would speed up deployment and recovery.

f. The MABS crew could be reduced to four persons if adequate deck space and handling equipment were provided.

SUMMARY

MABS was constructed for a specialized application and set of objectives. Its immediate application was in ocean areas with soundings of 11,000 ft. MABS was designed to be a reliable, self-contained, single-mooring subsurface buoy system that would also be portable, complete with its own winch, and readily deployable from a variety of support vessels. These objectives were met. Moreover, it is apparent that MABS has more widespread applications. Considerable attention was paid to time, handling ease, and mobility problems during the at-sea operations. The intent was to isolate these for comparison with values derived for other mobile data acquisition systems, such as instrumentation suspended from spar buoys, surface ships, and free-diving, depth-seeking buoys.

It is the opinion of the authors that, within the realm of limited recording systems, quickly deployable, moored, subsurface buoy systems (such as MABS) enjoy several operational and performance advantages. For the acoustic system, it provides a quiet hydrophone platform that places the sensors where they are desired and holds them in place. Operationally, it frees the costly support vessel while it samples the uncontaminated acoustic field at a preprogrammed rate. Lastly, it functions independently of weather conditions during its deployment.

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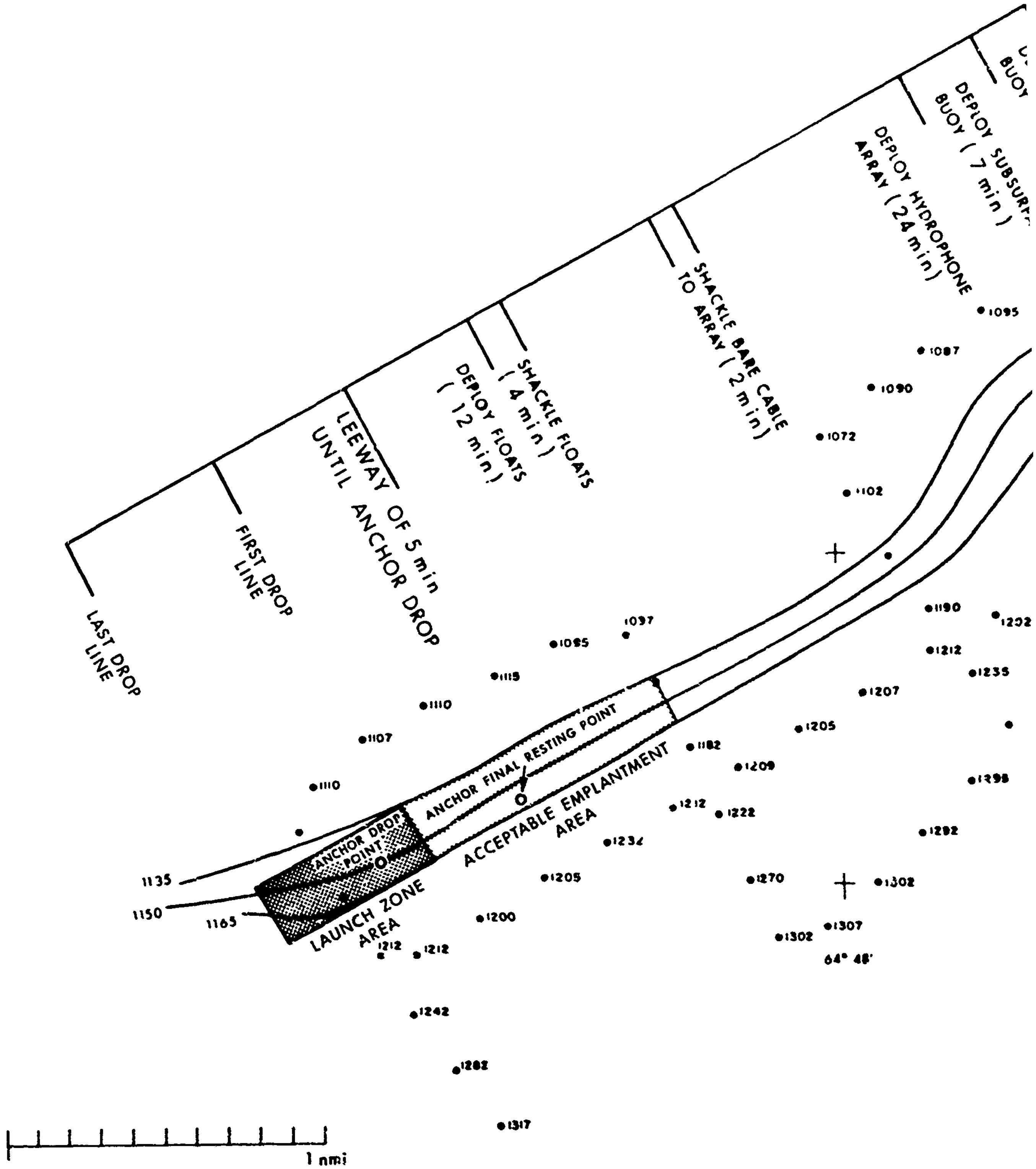

BUOY
DEPLOY SUBSURFACE BUOY (7 min)
DEPLOY HYDROPHONE ARRAY (24 min)
SHACKLE BARE CABLE TO ARRAY (2 min)
SHACKLE FLOATS (4 min)
DEPLOY FLOATS (12 min)
LEEWAY OF 5 min UNTIL ANCHOR DROP
FIRST DROP LINE
LAST DROP LINE
ANCHOR FINAL RESTING POINT
ANCHOR DROP POINT
ACCEPTABLE EMPLANTMENT AREA
LAUNCH ZONE AREA
1135
1150
1165
64° 48'
1 nmi

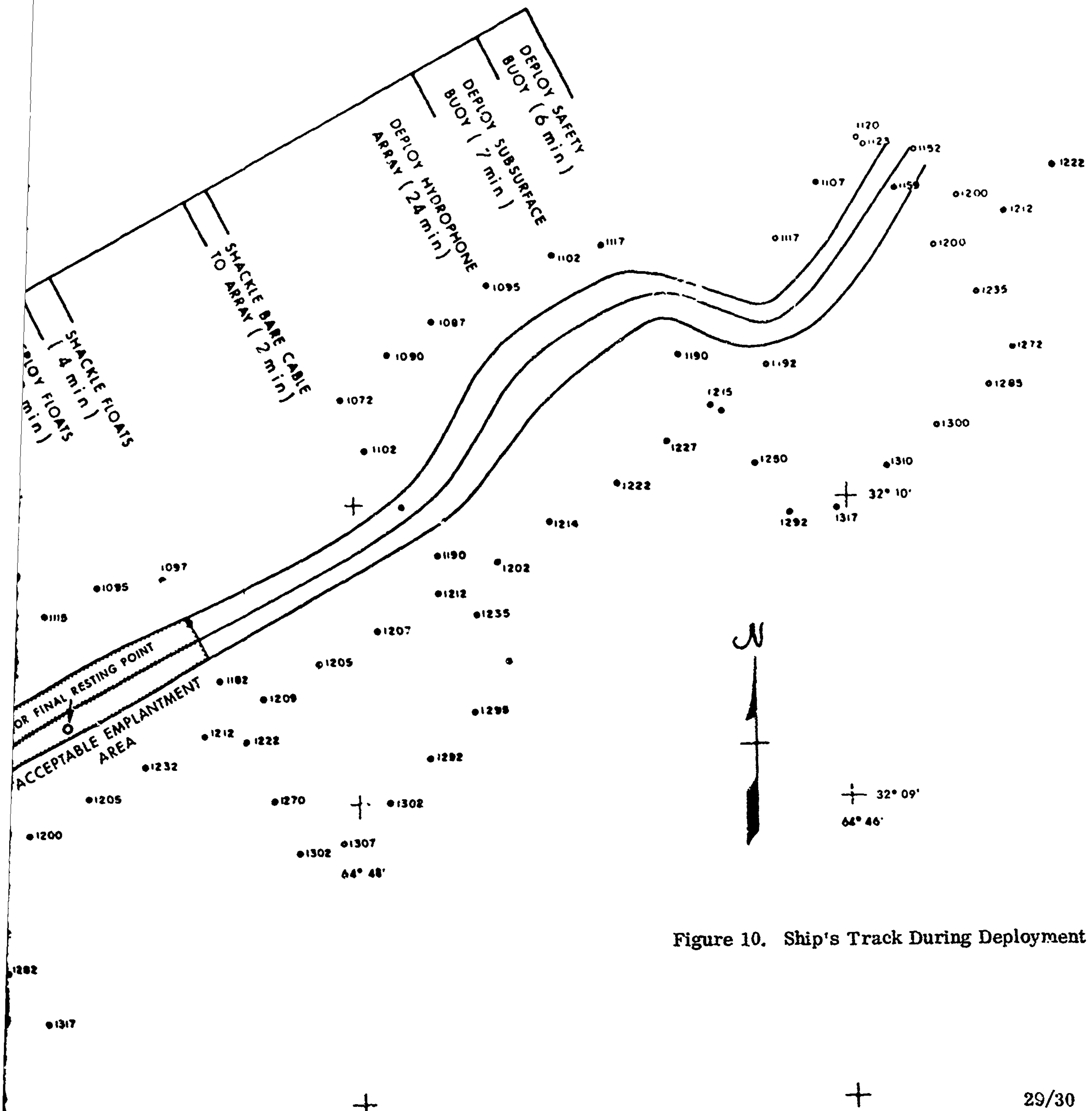

Figure 10. Ship's Track During Deployment

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Ref: (a) SECNAVINST 5510.36

Encl: (1) List of DECLASSIFIED LRAPP Documents

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

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

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

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Brancart, C. P.	TRANSMISSION REPORT, VIBROSEIS CW ACOUSTIC SOURCE, CHURCH ANCHOR EXERCISE, AUGUST AND SEPTEMBER 1973	B-K Dynamics, Inc.	730101	AD0528904	U
Unavailable	Daubin, S. C., et al.	LONG RANGE ACOUSTIC PROPAGATION PROJECT. BLAKE TEST SYNOPSIS REPORT	University of Miami, Rosenstiel School of Marine and Atmospheric Science	730101	AD0768995	U
NUSC TR NO. 4457	King, P. C., et al.	MOORED ACOUSTIC BUOY SYSTEM (MABS): SPECIFICATIONS AND DEPLOYMENTS	Naval Underwater Systems Center	730105	AD0756181; ND	U
MC-012	Unavailable	CHURCH GABBRO SYNOPSIS REPORT (U)	Maury Center for Ocean Science	730210	ND	U
Unavailable	Hecht, R. J., et al.	STATISTICAL ANALYSIS OF OCEAN NOISE	Underwater Systems, Inc.	730220	AD0526024	U
Raff rept 73-2	Bowen, J. I., et al.	EASTLANT SHIPPING DENSITIES	Raff Associates, Inc.	730227	ND	U
Unavailable	Sander, E. L.	SHIPPING SURVEILLANCE DATA FOR CHURCH GABBRO	Raff Associates, Inc.	730315	AD0765360	U
Unavailable	Wagstaff, R. A.	RANDI: RESEARCH AMBIENT NOISE DIRECTIONALITY MODEL	Naval Undersea Center	730401	AD0760692	U
Unavailable	Van Wyckhouse, R. J.	SYNTHETIC BATHYMETRIC PROFILING SYSTEM (SYNBAPS)	Naval Oceanographic Office	730501	AD0762070	U
MCPLAN012	Unavailable	SQUARE DEAL EXERCISE PLAN (U)	Maury Center for Ocean Science	730501	NS; ND	U
Unavailable	Marshall, S. W.	AMBIENT NOISE AND SIGNAL-TO-NOISE PROFILES IN IOMEDEX	Naval Research Laboratory	730601	AD0527037	U
Unavailable	Daubin, S. C.	CHURCH GABBRO TECHNICAL NOTE: SYSTEMS DESCRIPTION AND PERFORMANCE	University of Miami, Rosenstiel School of Marine and Atmospheric Science	730601	AD0763460	U
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USRD Cal. Report No. 3576	Unavailable	CALIBRATION OF FLIP-CHURCH ANCHOR TRANSDUCERS SERIALS 15 AND 19	Naval Research Laboratory	730716	ND	U