

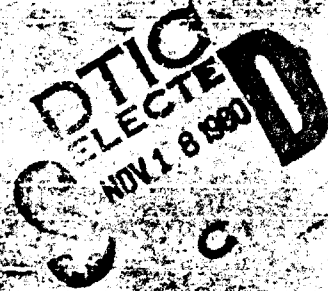
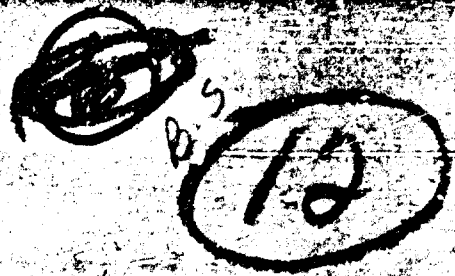
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LEVEL

COASTAL SURVEILLANCE

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U. S. Coast Guard Research and Development Center
Avery Point Groton, Connecticut 06340



1 APRIL 1980

FINAL REPORT

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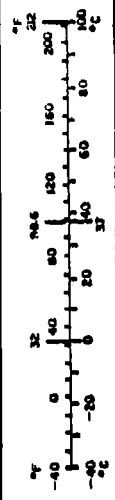
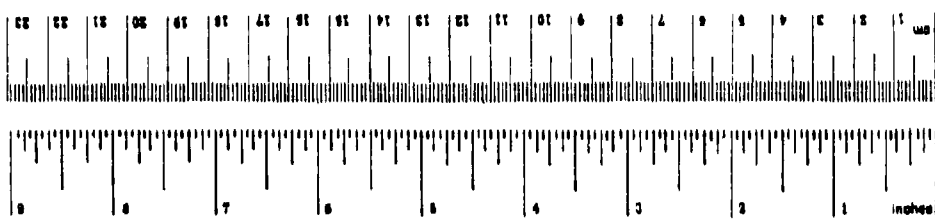
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16. Abstract <p>This final report gives an account of a one-year effort performed during FY79 under the Coastal Surveillance Project. The objective of the project was to define the operational and technical parameters and evaluate the performance of equipment which could be used for remote surveillance of harbors and near coastal shallow water areas. The effort consisted of two parts: Problem Definition and Hardware Evaluation. In Problem Definition, contacts were made with technical groups and Coast Guard field units to define applicable technology and Coast Guard needs. This led to the design of a prototype Coastal Surveillance System consisting of four elements: radar, sonobuoy, infrared devices and a radio scanner. In Hardware Evaluation, three devices were selected for test and evaluation: a modified Navy sonobuoy AN/SSQ-41, an Army night vision device AN/TAS-6 and a commercially available thermal imaging system (Pyroelectric Videcon Model 84). Testing of the sonobuoy system was conducted at three locations with different depth and bottom topography. Detection ranges of three different size target vessels at three different speeds were determined when the vessel proceeded toward the sonobuoy ("acquisition" range) and when it receded from the buoy ("loss" range). For initial planning estimates and feasibility studies, a detection range of 1500 yards is recommended for the sonobuoy. The AN/TAS-6 night vision device has good potential as a coastal surveillance device while the Pyroelectric Videcon was found to hold little promise for coastal surveillance use.</p>					
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures		Approximate Conversions from Metric Measures		
Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
m	meters	39.37	inches	in
km	kilometers	0.6214	miles	mi
cm	centimeters	2.54	inches	in
mm	millimeters	0.03937	inches	in
dm	decimeters	3.281	feet	ft
hm	hectometers	1.094	yards	yd
mm	millimeters	1.1	miles	mi
AREA				
m ²	square meters	1.196	square yards	sq yd
km ²	square kilometers	0.3861	square miles	sq mi
m ²	square meters	1.2	square feet	sq ft
ha	hectares (10,000 m ²)	2.471	acres	ac
km ²	square kilometers	0.4	acres	ac
MASS (weight)				
g	grams	0.03523	ounces	oz
kg	kilograms	2.2	pounds	lb
tonnes (1000 kg)	tonnes (1000 kg)	1.1	short tons	st
VOLUME				
ml	milliliters	0.03381	fluid ounces	fl oz
l	liters	1.057	quarts	qt
kl	kiloliters	1.359	gallons	gal
m ³	cubic meters	35.23	cubic feet	cu ft
km ³	cubic kilometers	1.357	cubic yards	cu yd
TEMPERATURE (exact)				
°C	Celsius temperature	1.8 (times add 32)	Fahrenheit temperature	°F



1 liter = 1.057 quarts. For other exact conversions and more detailed tables, see NBS Mon. Publ. 28, Units of Weight and Measure, Page 82-26, SI Listing No. C13.10.28.

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Justification	
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Distribution / _____	
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1.0 OBJECTIVE

The objective of the Coastal Surveillance Project was to define the operational and technical parameters and evaluate the performance of equipment which could be used for remote surveillance of harbor and near coastal shallow water areas.

Efforts toward the Problem Definition portion of the project have been pursued concurrently along two parallel but interrelated paths; namely, definition of Coast Guard needs and definition of applicable technology. The result of Problem Definition led to the design of a Coastal Surveillance System; the elements or subsystems of which were then selected for test and evaluation.

2.0 PROBLEM DEFINITION

In order to obtain information on Coast Guard needs, Office of Research and Development personnel visited and consulted with personnel of the following Coast Guard commands: CCGDSEVEN, COMLANTAREA, CCGDNINE, CCGDFIVE, CCGDONE, and Group Portland Maine. Due to time constraints, visits were not made to PACAREA and the West Coast Districts. Specifically, these visits were made to identify potential operation scenarios where a detection and tracking surveillance system would be useful and to determine local law enforcement problems that could be solved using technology.

In order to obtain information on applicable technology, contacts were made with the following technical groups: Woods Hole Oceanographic Institution, U.S. Army Night Vision Laboratory, Naval Underwater Systems Center, Naval Electronic Systems Engineering Activity, Naval Electronics Systems Command, Naval Mobile Inshore Undersea Warfare Group Two and The Sparton Corporation.

Details of these visits and contacts with the technical groups and the Coast Guard operating units were documented in reference (1). As a result of these efforts, a prototype of a Coastal Surveillance System consisting of four elements or subsystems was designed:

- a. A radar-equipped van was located so as to provide radar coverage of the area under surveillance. Antenna height is to be such that a 20-foot steel hull boat may be acquired and tracked at ranges of at least five miles. This van is the VTS Data Collection Trailer with its radar and recording equipment which is described in reference 2.
- b. A sonobuoy network where one or more sonobuoys are deployed will transmit to a receiver mounted in the radar van. The AN/SSQ-41 sonobuoy and the AN/ARR-52 receiver were modified for use.
- c. A Night Observation Device Long Range (NODLR), AN/TAS-6, was borrowed from the U.S. Army Night Vision Laboratory, Fort Belvoir and installed in the radar van.
- d. A five-band scanning receiver, Bearcat 250, was installed in the radar van. This allows the operator to scan the many possible frequencies the intruder may use as well as to select any frequency that prior intelligence reveals the intruder may be using.

This Coastal Surveillance System was specifically designed for the operational scenario in an area not normally traversed by marine traffic. The presence of traffic would be an indication of illegal activities. Therefore, the function of the system is to detect marine traffic without being detected. It operates in the following manner:

- a. The system is set up with the sonobuoys, NODLR and scanner operating. Each of these passive devices provides input to the operator.
- b. The radar, an active device, is kept on standby until a target is detected by one of the other elements.

c. At that time, it is activated and, upon confirmation of the target, friendly forces are vectored to a rendezvous with the target.

As a result of the discussion held with the CG commands, three sites which met this operational scenario were identified. They are Pemaquid Point, Cape Elizabeth and Owls Head; all within Group Portland. Other sites which do not need the total system but required certain elements (i.e., sonobuoys and NODLR's) are the four inlets in CCGDFIVE and the areas within CCGNINE for both drug interdiction and fisheries enforcement.

3.0 HARDWARE EVALUATION

The Hardware Evaluation portion of this project was not intended to test and evaluate the performance of the total coastal surveillance system as described in the preceding section. Two of its subsystems (namely, Navy's Sonobuoys and Army's NODLR) were selected for test and evaluation as they represented technologies which had not been utilized in Coast Guard applications. The Coast Guard radar system in the VTS Data Collection Trailer was used in the testing as the primary device for target range determination. A commercially available thermal imaging device (Pyroelectric Videcon Model 84) was added later in the test program for evaluation.

Testing of sonobuoys took place in two test sites: Avery Point, Groton, Connecticut, in the proximity of Coast Guard R&DC, and Race Point, Cape Cod, Massachusetts. The Race Point site was selected as a "simulated site" which would emulate the environmental characteristics of possible operational sites such as Pemaquid Point in Group Portland, Maine. Water depths, current, bottom conditions, radar antenna height above the water and accessibility were all considerations in choosing the simulated site.

In all tests, the three devices (Sonobuoy, NODLR and Pyroelectric Videcon) were operated by minimally trained novices. The testing was simultaneously conducted on all the devices. For the sake of clarity they will be described separately.

3.1 Pyroelectric Videcon Model 84

The Pyroelectric Videcon is a commercially available thermal imaging system developed and marketed by ISI Group Inc., Albuquerque, NM. The device resembles a small television camera and works in a similar fashion. The primary difference being that the lens, transmitting faceplate, and tube target are specially made for detecting the infrared spectrum instead of the visual spectrum. The device displays only changes in the infrared image on the transmitting faceplate. Thus the viewer sees only targets with relative motion across the field of view. Relative motion may also be the result of panning the camera. An alternative method, though not available during the testing, is to chop the incoming signal with a mechanical device. This will produce an image of stationary items without moving the camera.

The camera assembly weighs approximately six pounds and includes a small viewfinder but not a power supply. The output signal is suitable for a videotape recorder or direct television input. The manufacturer's specifications are contained in appendix B and reference (3) provides an excellent background on the system.

The Pyroelectric videcon camera was tested by observing traffic in the New London harbor area. The primary mode of operation was panning the camera because the range and speeds of targets did not result in sufficient relative motion for imaging. The device achieved only minimal range, detecting small vessels (20-40 feet) at 400 yards and less. Due to this limited range, detailed testing was not undertaken. Because of time and funding limitations, use of a higher power lens or a chopper which might have improved the range was not considered.

3.2 AN/TAS 6 Night Vision Device

The AN/TAS 6 Night Vision Device is an infrared telescope developed by the U.S. Army for use by artillery spotters. The performance characteristics and range capabilities of the device are classified. Physically, the device weighs approximately twenty pounds and is intended for tripod or mobile mounting. It is battery operated and requires a supply of high pressure ultra pure nitrogen. Both are available in field use sizes that do not add significantly to the weight. Magnification is selectable at either three or nine power. The device is a field proven, operational piece and is "GI Proof." Personnel from the U.S. Army's Night Vision Laboratory estimated unit production costs to be \$48,000.

The AN/TAS 6 Night Vision Device was tested by observing the test vessels during passes at the sonobuoy while located at Avery Point and by observing traffic at Race Point, MA. Systematic range testing was not undertaken because of the security classification of such results. In most cases, it performed exceptionally well, detection of a 42-foot inboard generally surpassed three miles from a 20-foot height of eye. Detection of 14 and 23-foot fiberglass vessels exceeded two miles. Device limitations were noted but are subject to classification. This information is available on a need-to-know basis from: Director, Night Vision and Electro-Optics Laboratory, Fort Belvoir VA. Based on the experience gained during testing, this device could be useful in the hands of a trained observer located at a good vantage point. Such a person would provide positive detection of a vessel with the capability of observing some activities on the vessel at a range of 0.8 miles.

3.3 Sonobuoy

The sonobuoy used during this evaluation was a standard U.S. Navy air deployable sonobuoy modified to provide a thirty-day on-station time and a bottom mooring capability. The modifications were performed by Woods Hole Oceanographic Institution and are explained in detail in their contractor's report, included as appendix A. The nature of the modification was to repackage the sonobuoy electronics into a buoy capable of being moored in moderate open ocean environments and containing an adequate power supply for 30 days of operation. Appendix A also describes the performance characteristics of the system. Probably the most notable of these are the frequency response, 20-5,000 Hz, and the line-of-sight-nature of the transmitter.

The mooring system used (figure 1) was intended to (1) minimize motion at the hydrophone, (2) be easy to deploy, (3) be easy to recover major components, and (4) be able to replace the hydrophone without moving the mooring. To minimize transmission of buoy motion to the hydrophone, the two were connected by a 3/8" flexible tether. Data transmission was via a heavy duty coil cord similar to a telephone cord. The hydrophone was housed in a metal cage. Below the hydrophone the mooring was 1/2" nylon line which is much stiffer than the tether. Between the hydrophone and subsurface float, part of the nylon line was run through a plastic pipe. This was included to prevent the mooring from becoming tangled in times of slack current. Just below the subsurface float, a mechanical release device was installed to allow recovery of the upper mooring parts. The total length of mooring was designed

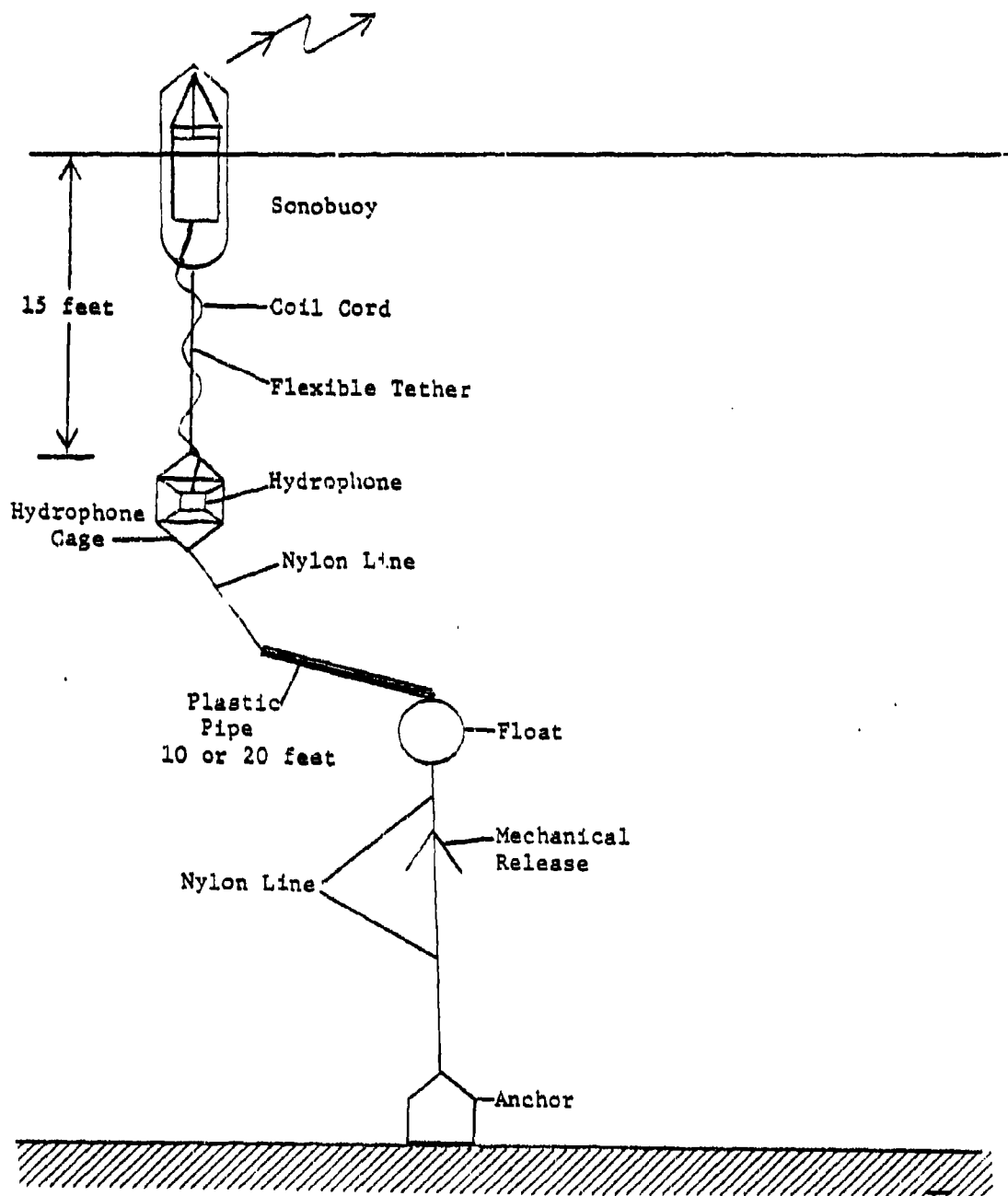


Figure 1. Sonobuoy Mooring Schematic

to allow retrieval of the hydrophone without retrieving the mooring. Two, three-hundred-pound cast iron sinkers were used as anchors. The buoy transmitted directly to a standard Navy sonobuoy receiver. The receiver signal was passed through a deep notch, adjustable band-pass filter to an amplifier and speaker.

Late in the test program a suite of electronics equipment for analysis and visual display of underwater acoustic signals was obtained from the Naval Underwater Systems Center, New London, Connecticut. Two parallel systems were provided, both based on high-speed real-time spectrum analysis of the audio signal. Both systems used a gain controlled signal as an input to a spectrum analyzer. Figure 2 illustrates the hookup.

The method used by the Schlumberger System was to sample and hold a segment of the audio signal, perform a spectral analysis and file the result digitally. Subsequent samples were then taken. The display provided is a continuously updated average of the result of these analyses.

The method using the Federal Scientific Spectrum Analyzer was to sample and hold a segment of the audio signal, perform a spectral analysis and output an analog analysis to a storage scope. As each subsequent analysis was outputted to the storage scope, it was cycled by a display controller and a small D.C. voltage bias was added. Thus, each analog trace of a sample would appear just above the previous sample. Done repeatedly using amplitude modulated intensity, this method displays a bright area on the scope at the dominant frequencies. In addition, the display controller can be set to start the display only after detecting a certain level across a given frequency band. The display must be visually averaged by the operator to determine the nature of the signal.

All equipment was mounted in a mobile trailer equipped with a DECCA Marine Model RM-424 Radar. The Radar was used as the primary range measuring device. Specifications on the radar and trailer are available in reference (2). A microwave transponder positioning system (autotape) was also used as backup for range measurement:

The mode of operation during the testing was to move the test vessel to a predetermined position out of range of the sonobuoy. When the area was clear, the vessel started toward the buoy. Detection was determined by an alerted operator listening to the audio signal transmitted by the sonobuoy. As needed, the operator could adjust his filters to assist detection. At the command of the audio operator, a radar fix was taken in the van and an autotape position was recorded by the test vessel crew. This determined the "acquisition" range. The vessel then continued past the sonobuoy until the signal was lost. Another radar fix and autotape position were taken at the time of signal loss. This determined the "loss" range. During the tests at Race Point, the electronic detection equipment was operated in parallel with the audio operator. Separate fixes on vessel positions were taken for electronic detection acquisition and loss locations.

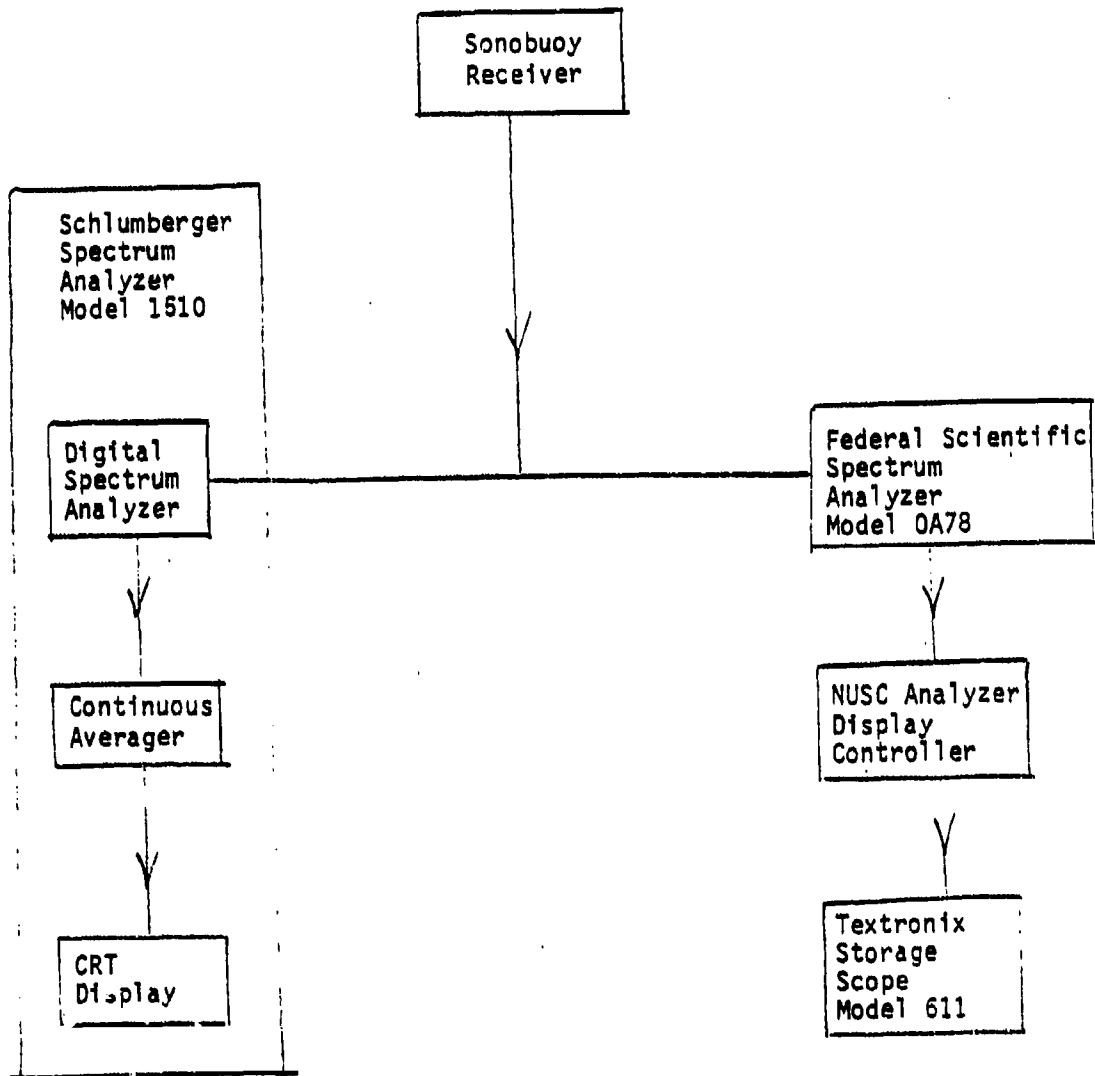


Figure 2. Electronic Detection Equipment Schematic

3.3.1 Sonobuoy Testing Program

Unlike the infrared viewing device, the detection range of the sonobuoy was expected to vary significantly with vessel speed, vessel size, bottom topography and perhaps depth and direction of heading. In order to provide a more complete picture of performance, a variety of situations were tested. Specifically, three types of vessels were considered as potentially interesting to the Coast Guard and each was tested at a typical slow, cruise and full speed. They were:

1. Fourteen-foot whaler with a 40 HP outboard using speeds of 5, 10 and 14 knots.
2. Twenty-three foot fiberglass speedboat, inboard-outboard engine using speeds of 5, 15 and 30 knots.
3. Forty-two foot steel hull, twin screw inboard, using speeds of 5, 12 and 17 knots.

Variation in depth and bottom topography were provided by mooring the buoy at three different locations. In total, five different sets of data were taken at three different depths with three cases of an open path and two cases with underwater obstructions.

1. New London Harbor Location

The first location for anchoring the sonobuoy was in 45 feet of water, two miles south of Avery Point (point A on figure 3). As seen from figure 3, the bottom is a flat area with a soft mixture of mud and sand. A total of 68 passes were made and the range of target acquisition and loss were observed. Passes were made from several (usually four) directions and occasionally at non-intersecting courses. In most cases, the weather was very calm. All three vessels were tested at three engine speeds. Passes were made in groups of four using the same vessel and speed but differing directions. Each group of passes required one to four hours depending on traffic and speed.

2. Black Ledge Location

During the second testing period, the sonobuoy was anchored in approximately 25 feet of water near Black Ledge, (point B on figure 3). In this location, severe bottom topography allowed the testing for blocking of the signal and for shallow water ranging. Test passes were planned so that approaches and departures occurred both to the open side and the shielded side of the buoy. Target acquisitions or losses in the vicinity of point 1 on figure 3 provided information on cases where an underwater obstruction exists, reaching within 9 feet of the surface. Fixes in the vicinity of point 2 represents unblocked signals in 25 feet of water. Point 3 fixes show ranges with underwater obstructions reaching to within 14 feet of the surface. Thus, the testing at Black Ledge provided three separate data sets. A total of 81 test passes were made using all three boats at all speeds. During nearly all tests at Black Ledge, the weather was very calm. Passes were made in groups of four using the same vessel and speed but differing paths.

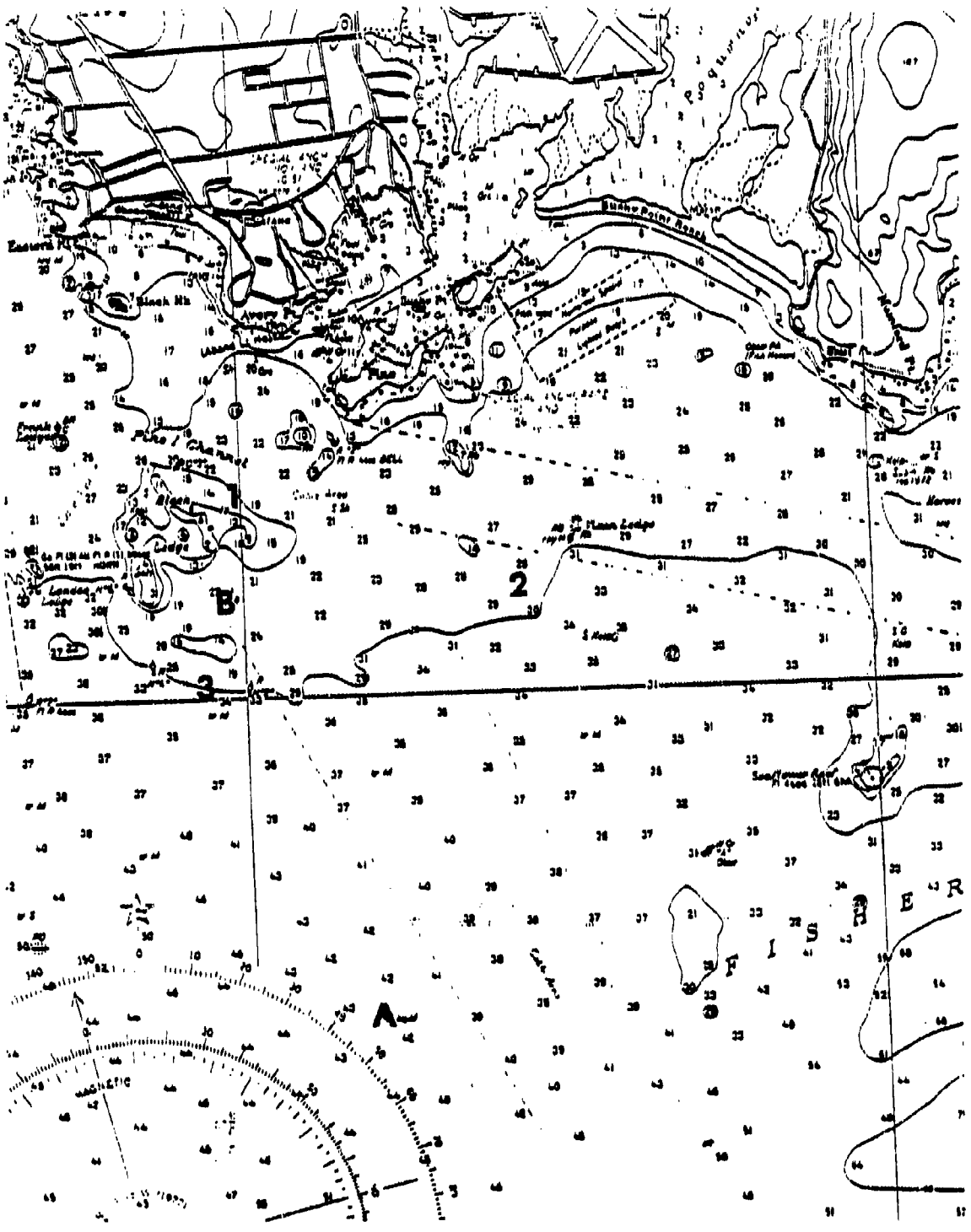


Figure 3. New London Harbor Operating Area

3. Provincetown, MA Location

During the third testing period, the sonobuoy was anchored in approximately 200 feet of water off Race Point, Cape Cod, MA (42°06.5'N 70°15'W) point C on figure 4. As seen from figure 4, the bottom topography was relatively flat and the site was open to the ocean. A total of 26 test passes were made approaching from different angles. Only the 23-foot inboard-outboard and the 42-foot inboard were used at this site because the open sea conditions were considered too hazardous for the 14 foot whaler. High and medium speeds were run with the 23-footer and all speeds were run with the 42-footer. Most of the cases were run under moderate to moderately severe conditions, since winds of 10-20 knots were nearly continuous in the area. One afternoon of calm weather was encountered. Passes were made in groups of four using the same vessel and speed but differing directions. Each group required one to four hours depending on traffic and speed.

3.3.2 Analytic Consideration

Although there is limited information on shallow water range testing of sonobuoys, an analysis of expected important factors can be made. Using the passive-sonar equation:

$$\begin{array}{ccccccc} \text{SL} & - & \text{TL} & = & \text{NL} & - & \text{DI} & + & \text{DT} \\ \text{Source} & & \text{Transmission} & & \text{Noise} & & \text{Directivity} & & \text{Detection} \\ \text{Level} & & \text{Loss} & & \text{Level} & & \text{Index} & & \text{Threshold} \end{array}$$

and ignoring the directivity index since only one hydrophone was used, the Detection Threshold (proportional to maximum range) is

$$\text{DT} = \text{SL} - \text{TL} - \text{NL}$$

The Source Level (SL) here refers to the radiated noise of the target vessel which is, of course, governed by the vessel type and speed. Noise Level (NL) is primarily controlled by environmental noise (wind, breaking waves, mooring noise, etc.) and by radiated noise from other vessels (traffic). In general, machinery noise and propeller noise dominate the spectra of radiated noise. Machinery noise originates as mechanical vibration of the many and diverse parts of a moving vessel. This vibration is coupled to the sea via the hull of the vessel. The machinery noise of a vessel may usually be visualized as possessing a low-level continuous spectrum (hull structural vibration) containing strong line (tonal) components at the fundamental frequency and harmonics of the vibration-producing process. Propeller noise, with its origin in the flow of water about the propeller, creates tonal components in addition to the continuous spectrum of cavitation noise. Thus, detection of the target vessel depends on the selection of frequency range and processing bandwidth for optimizing the Detection Threshold (maximum signal to noise ratio).

As for Transmission Loss, reference 4 provides three equations which describe these losses in shallow water at "short", "intermediate" and "long" ranges. The correct equation is selected by comparing the expected ranges with a parameter:

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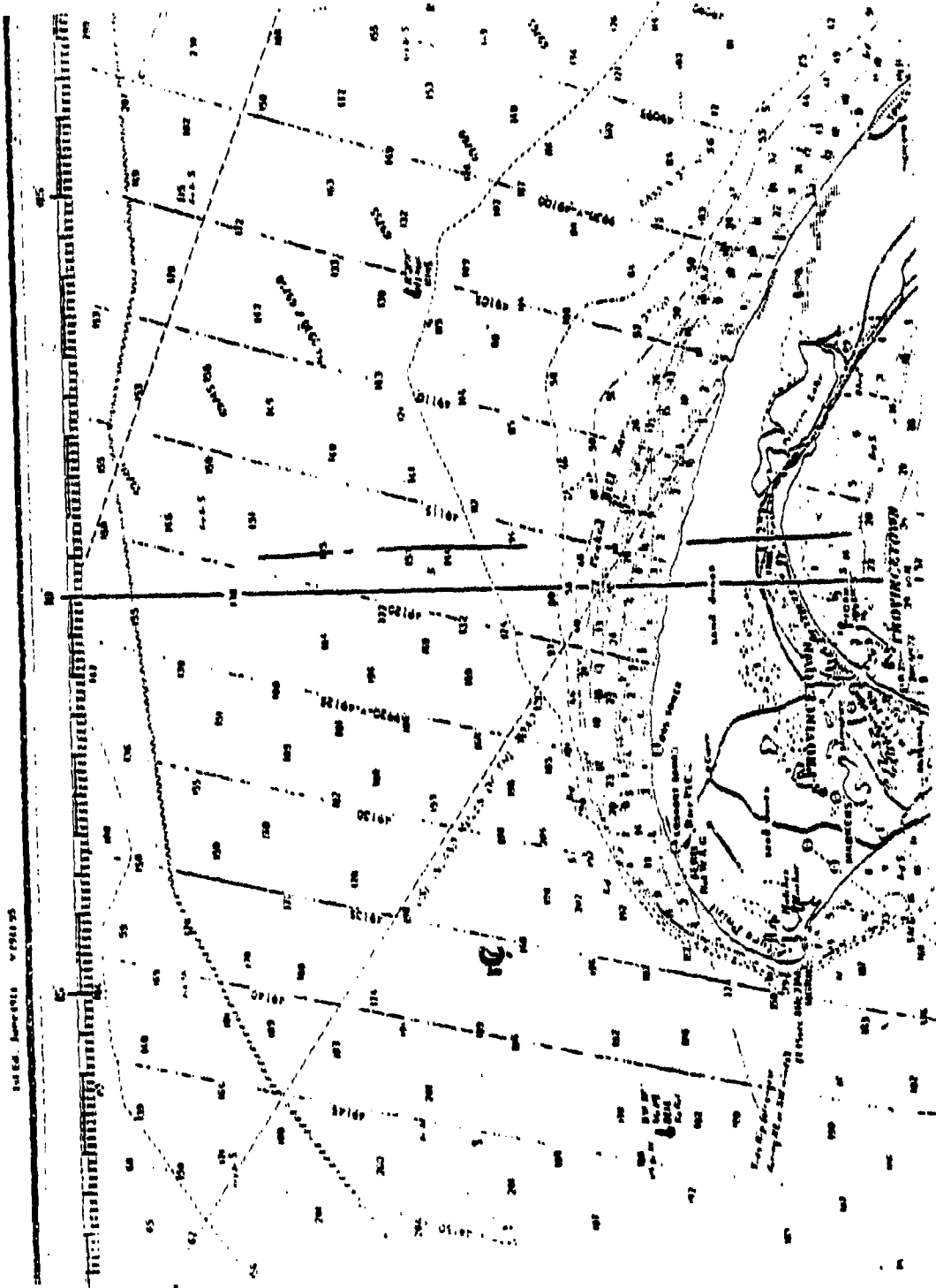


Figure 4. Race Point Operating Area

$$H = \frac{(2(D + L))}{4}^{1/2} \text{ kiloyards,}$$

where D is the water depth in feet and L is the isothermal layer depth in feet. Since even at the shallowest depth, 25 feet, H is larger than the observed ranges of 1,500 yards, the proper equation for transmission loss in decibels is the "short" range equation:

$$TL = 20 \log r + 60 + \alpha r - k_L,$$

where r is the range in kiloyards
 α is the absorption coefficient of sea water in decibels per kiloyard
and k_L is a "near-field anomaly," in decibels, given in reference 4

The first two terms account for spherical spreading. For the conditions of interest here, the terms involving absorption coefficient and the near-field anomaly are small compared to 60 and are independent of depth. Thus, transmission loss is primarily controlled by spherical spreading and is not affected by depth. Furthermore, since spherical spreading is the controlling feature, signals should be subject to blockage by obstacles in the transmission path.

Summarizing, we can expect at "short" ranges that factors affecting the Source Level (vessel size and speed), the Noise Level and Transmission Loss (range) to be the variables of interest. Depth and direction (acquisition/loss) should not be significant variables.

3.3.3 Results

The analysis of data in this investigation primarily involves the determination of detection range and the determination of factors which affect the range. As stated previously, the factors tested were vessel type, vessel speed, depth and underwater obstructions. In addition, by virtue of the experimental run pattern, differences between acquisition (incoming range) and loss (outgoing range) were tested.

Before detailing the significance of the various factors, some comments about the data should be made. For all the test cases run in areas with no obstruction, the average range was 1457 yards. They varied from zero, one stormy day at Race Point, to 3000 yards, one quiet night in New London Harbor. The standard deviation during any burst of four runs was normally 300 to 400 yards. The maximum average of any burst was 2100 and the minimum was 850. Figure 5 illustrates a typical group of data. Approximately 90% of the detections were made at greater than 1000 yards. In other words, spacing of devices at one mile intervals should provide a detection probability of at least 90% of the intrusions (since not all intrusions are necessarily proceeding through a path which is equi-distant from each device). The significant effects discussed in the following section are not of a magnitude that should change this predicted spacing. The magnitude of the variability from run-to-run, however, may be of operational concern. This variability seemed most related to transient background noises. During testing near New London Harbor, signals were often masked by or confused with other vessels. Such problems often caused hour-long delays especially in slow speed tests. Although incidental traffic is not of concern for most

Vessel 23' I/O

Speed High

Location New London Harbor

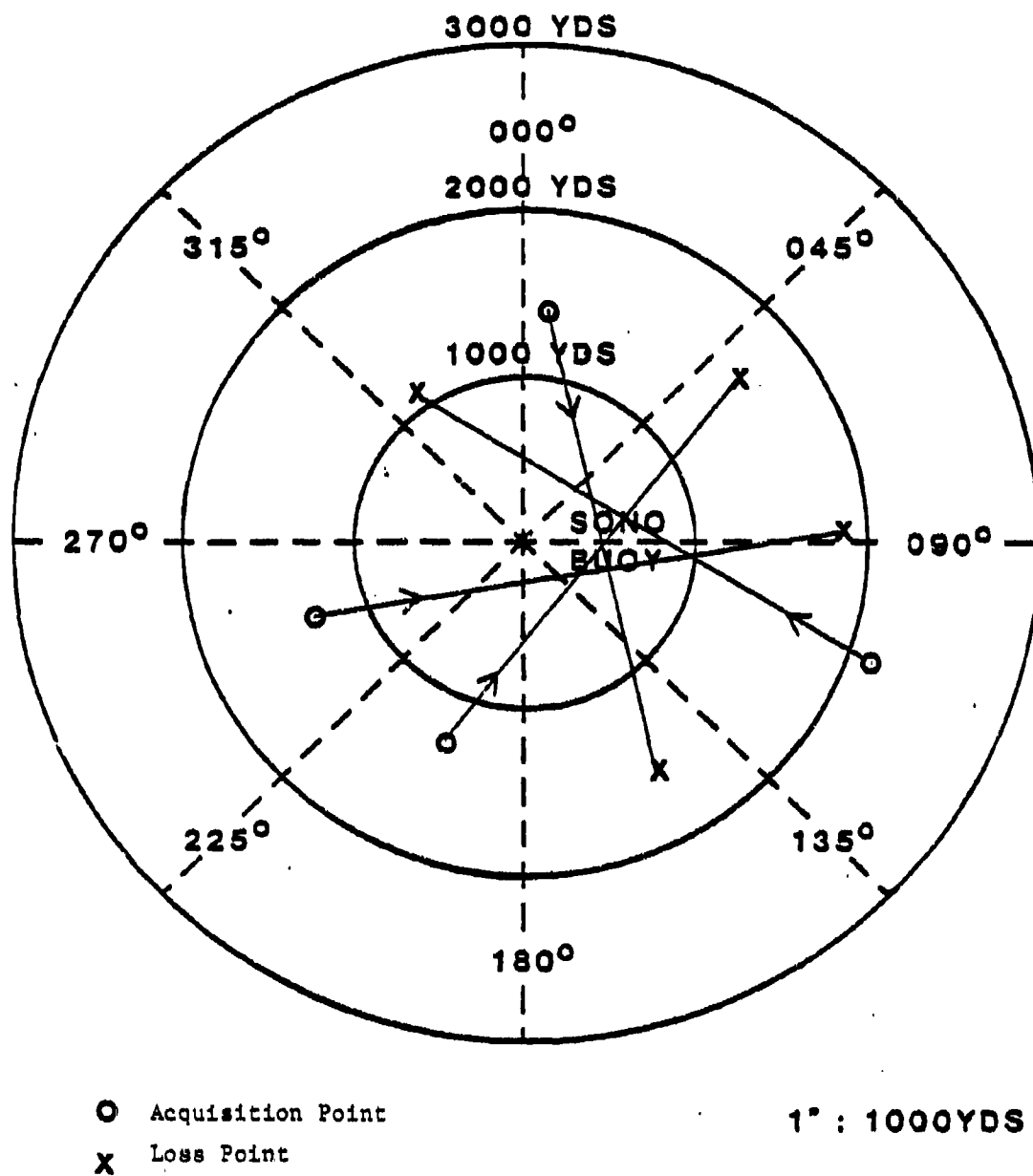


Figure 5. Typical Burst of Four Passes

applications, a similar problem was encountered while testing at Race Point. Occasionally, for periods of several minutes, reception of vessel signals was completely obscured by what may have been waves breaking near the buoy or mooring noise. In short, there may be times in an operation where detection of a vessel will not be possible.

The method used to determine the factors affecting range is described in reference 5. This method is derived from two level factorial experimental designs and determines the significance of the effect of a variable. A significance level of 95% was used in all cases. Test runs were grouped in specific ways to provide comparisons of the different levels. Thus, all runs for any two vessels for any two speeds, for any two locations and both acquisition and loss could be evaluated to determine which factors caused significant effects. With three test vessels, three test speeds, and five test depths (two different blocking conditions and three open water conditions), many comparisons can be made. Table 1 shows the comparisons that were calculated and highlights the significant factors.

Results of data analysis indicate that significant differences (at 95%) do not exist between acquisition range and loss range. The variation due to the other variables (table 1) is not as apparent:

Speed:

At first appraisal, it appears that speed is a significant factor in slightly more than half of the cases illustrated. This is somewhat misleading. If cases involving underwater obstructions (Black Ledge locations 1 and 3) are not considered, nearly all other cases show a positive effect for speed, i.e., greater speed, greater range. Vessel speed was therefore judged a significant factor.

Vessel Type:

Vessel effect provides an additional complication to that encountered in the speed effect. While nearly all of the cases involving obstructions show no effect of vessel type, the other cases show both positive and negative effects. The negative effects are confined to comparisons between the 23-foot inboard-outboard and the 42-foot inboard. Comparisons involving the 14-foot outboard all show positive effects. This means that the greatest ranges were achieved with the 23-foot inboard-outboard, but ranges for both the 42-foot inboard and the 23 foot inboard-outboard were greater than the 14-foot outboard. Thus vessel size cannot be said to have a positive or negative effect on range, but it was a significant variable. It does seem likely that the 23-foot inboard-outboard may have more distinct line frequencies that enhanced detection.

Depth:

Evaluation for depth indicates that significant differences between the three depths were generally not observed.

Blocking:

Table 1 shows that underwater obstructions clearly affected detection range. In fact, comparison of Black Ledge locations 1 and 3 show that the depth of the ledge with respect to the hydrophone was important. The reduction of range due to the blocking was so great that the effect of speed and vessel type were generally obscured.

3.3.4 Electronic Detection Equipment

The electronic detection equipment described earlier (figure 2) was evaluated during testing at the Race Point location. In addition, tapes of runs performed during the Black Ledge testing were replayed into the systems. In each case, detection range by operator's ear exceeded that of the electronic equipment. The average range achieved at the Provincetown site was 905 yards for all runs at which detection was confirmable. On many occasions, no indication of a vessel was given. In general, the electronic detection equipment performed nearly as well as the operator's ear in periods of low noise but deteriorated rapidly with increases in ambient noise.

3.3.5 Comments by Operators

The personnel working as operators for the sonobuoy provided a good spectrum of potential watchstanders. At various times, the task of detecting the vessel was assigned to eight different people ranging from a Lieutenant Commander to a Fireman. Although not supportable conclusions, their observations are important to evaluation of the equipment.

1. Experience both in listening to sonobuoy signal and in observing local sound conditions is extremely important in detecting vessels.
2. Detection of vessels cannot be a part-time job for a watchstander. It requires constant attention and concentration.
3. The range predicted by the experiment is probably higher than would be achieved operationally. The knowledge that a boat is coming in the next few minutes increases the operator's concentration and thus the range of detection. If a remote listening station is used, this may result in many false alarms.
4. The weather conditions, stormy wind and waves, encountered at Provincetown greatly increased ambient noise. Discrimination of the signal from the noise required much greater judgment in such cases, despite the fact that similar ranges were achieved.
5. The mooring used for the sonobuoy did not perform as expected. Even low current stretched the upper flexible section so tight that the mooring could not be changed. On other occasions, it became tangled in itself. Although the automatic gain control made it difficult to identify mooring noise from other background noise, it seemed that self-generated mooring noise was an important component.

TABLE 1
Significant Factor Analysis

	Speed			Vessel			Location					Significant Factors			
	Low	Medium	High	14' Outboard	23' I/O	42' Inboard	B.L. #1	B.L. #3	B.L. #2	N.L. Harbor	Provincetown	Speed	Vessel	Depth	Blocking
1	X		X	X		X	X					0	0		
2	X		X	X		X	X					0	0		
3	X		X	X	X	X						0	0		
4	X		X	X	X	X						0	0		
5	X		X	X	X	X						0	0		
6	X		X	X	X	X						+	+		
7	X		X	X	X	X						+	+		
8	X		X	X	X	X						+	+		
9		X	X	X	X	X						+	+		
10	X		X	X	X	X						+	+		
11	X		X	X	X	X				X		+	+		
12	X		X	X	X	X				X		+	+		
13		X	X	X	X	X					X	0	0		
14	X		X	X	X	X						+	+		+
15	X		X	X	X	X			X			+	+		
16	X		X	X	X	X						+	+		
17	X		X	X	X	X						+	+		
18		X	X	X	X	X						+	+		
19	X		X	X	X	X	X	X				+	+	0	0
20	X		X	X	X	X	X	X				0	+		+

KEY

- X Variables for the case being tested, arranged so that variables expected to produce greater range are to the right. (i.e., greater speed, larger vessel, less blocking or greater depth are to the right)
- + Positive factor effect. Result of comparison is as expected and are significant with 95% confidence.
- Negative factor effect. Result of comparison is opposite of that expected and are significant with 95% confidence.
- 0 Statistically significant effect not discernable with 95% confidence.

Example

Case number 18 is as follows. The 23-foot I/O is compared to the 42-foot inboard at medium and high speed for Black Ledge #2 and Provincetown. The comparison showed that higher speeds produced greater range, the 23-foot I/O was tracked at greater ranges and depth differences did not significantly affect range. Blocking was not tested since neither location experienced this condition.

4.0 CONCLUSIONS

As a result of this study, the following conclusions were reached.

1. For initial planning estimates and feasibility studies a detection range of 1500 yards should be used for the sonobuoy.
2. The sonobuoy generally behaved as expected with respect to vessel type, speed, depth, and blocking. That is to say, noisier vessels and higher speed vessels will be detected at greater ranges. Depth of the water is not important (at least between 25 and 200 feet), but underwater obstacles are.
3. Sonobuoy detection of a vessel by a novice observer is very much dependent on background noise. Separating one vessel from another requires expert operators.
4. Improved mooring designs might contribute marked improvements in the ranges achieved.
5. Electronic detection equipment used in this experiment was not as effective as the alert human ear but: a) might perform as well as a bored watchstander, b) might have uses in low noise areas. This conclusion should not be extended to electronic equipment in general.
6. The AN/TAS 6 Night Vision Device has good potential as a coastal surveillance device.
7. The Pyroelectric Videcon holds little potential for Coast Guard surveillance.

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APPENDIX A

CONTRACTOR REPORT OF SONOBUOY MODIFICATION

Purpose: These buoys were developed to provide the U.S. Coast Guard R&D facility with a readily deployable system to monitor small craft traffic in shallow depths by acoustic means. In essence, the buoys are adaptations of standard U.S. Navy air-deployed sonobuoys and function similarly.

Operation: In use the buoy is moored to the bottom using appropriate anchors and non-metallic line. The upper part of the mooring is composed of a pennant, supplied with the buoy, which terminates at its lower end in a shielded hydrophone assembly.

Acoustic signals, picked up by the hydrophone, are amplified in the buoy and caused to modulate a wideband FM (Frequency Modulated) radio transmitter. Signals from the transmitter are radiated by a totally enclosed antenna to a shore monitoring station having line-of-sight to the buoy.

External: The buoy is fabricated entirely from fiberglass. It is cylindrical with a conical top. Nominal body diameter is 12.5" and overall height is 78". The bottom end of the buoy is hemispherical with a 5/8" thick fiberglass pad to provide a mooring attachment point. Adjacent to the pad is a short electrical pendant for connection to the hydrophone cable. Penetration of the buoy hull is by means of a tapered gland.

The top of the buoy is removable at a flange 24" from the top. This flange is gasketed and held by twelve 1/4-20 stainless bolts. Removal of the top cone allows access to the buoy interior for servicing the electronics. This gasket should be coated with silicone compound (DC-4).

The cone is orange gel-coated with an 8" high circumferential band of "Scotch lite" relectorized tape. Do not paint the cone as metallic oxides or flakes in paint can effectively reduce the R.F. radiation from the antenna and or detune it.

Internal Structure: Internally buoy contains a 6" aluminum central tube running from the deck, 8 inches below the flange coupling, to the top of the poured ballast. A 1/4" thick aluminum alloy annular ring joins the center 6" tube to a 24" high expanded aluminum screen on the inside of the fiberglass body. The space between the 6" tube and the expanded metal has been poured full of foam-in-place polyurethane foam. This foam provides structural rigidity, holding the expanded metal screen against the outer fiberglass hull, and provides some auxiliary floatation in the event of a leak.

The expanded aluminum screen provides an effective R.F. ground to the surrounding water due to the large coupling capacitor thus formed.

The bottom ballast consists of 100 pounds of steel punchings in an epoxy slurry poured in place. A channel from the electrical penetrator to the center well is provided for the electrical lead to the hydrophone.

Electronics: The buoy electronics consists mainly of the electronic components of a standard Navy sonobuoy. As these buoys are purchased by the Navy for one-shot usage, no provision for schematics or manuals has been made. A "typical" schematic is shown. Some modifications to the original sonobuoy electronics have been made: 1) The timer and scuttling mechanism and

circuitry have been removed or disabled and 2) the input stage has been modified to adapt a different hydrophone/preamplifier to the system, 3) in two units a salt water "bilge alarm" has been added.

Essentially, any standard "B" size sonobuoy electronic package can be mounted in the buoy. The main constraints being on battery power. In the buoys supplied, all electronic packages are from Magnavox buoys. These buoys operate at a nominal supply of 16 volts DC at 100 to 120 ma drain. Other sonobuoy manufacturers use other supply voltages, usually 11-12 volts at much higher current drain (over 200 ma) and consequently much lower efficiency.

The electronics consists of two circuit boards; one for all audio functions and one for timing and R.F. (transmitter). DO NOT ADJUST ANY SLUGS OR CONTROLS ON THE R.F. BOARD. These are critically tuned stages and realignment is nearly impossible without the factory test set-up to allow for housing and stray capacitance, etc.

The audio board usually has one or two potentiometers, depending on type. These are for purposes of setting modulation limits and gain (if a second). The span of the potentiometers is so small as to be of no significant use other than final adjustment to specifications. At the lower end (with antenna upright) of the audio board the hydrophone is connected. Two wires are used, a ground and high lead which is carrying both audio up and power down to the preamplifier. The drain load resistor for the F.E.T. preamplifier is on the board and it is this which has been altered to provide the proper operating point for the preamp (see sketch).

Frequency response of the electronic system depends on the parent buoy type. The SSQ-57 and SSQ-41B buoy has a rising response extending to 20kHz while the SSQ-41A rises to 4-5 kilohertz then falls off rapidly. Curves are shown for both as originally configured. In practice, without effective filtering at the receiving location, the extended high frequency response will usually hopelessly overload the ear with a hiss which masks target sounds.

Hydrophones: Hydrophones supplied, while differing slightly in appearance, are essentially identical in function and performance. Each is composed of a ceramic ring transducer and a one or two stage F.E.T. preamplifier. These hydrophone/preamplifier combinations are essentially flat in response from 10Hz to 20 kHz. Any desired modification of the system response can be made at the audio board in the buoy. All hydrophones are standard sonobuoy types with a heavier cable and polyurethane jacket added. These units will withstand 1000 foot depths.

The hydrophones are suspended on silicone rubber cords in the center of a stainless steel "cage" which serves to carry the mooring strains past the hydrophone without introducing vibration. These cages may be covered with a thin, perforated PVC shield over which a 1/4" thick layer of open-cell polyurethane foam has been stretched. This serves to minimize flow noise due to water rush by the mooring much as the "wind screen" on a microphone in air.

Electrical connection from the hydrophone is by means of a coiled, neoprene-jacketed, 2-conductor cable wrapped spirally around a 1/16" diameter Natsyn rubber cord. This provides an electrical link as well as a compliant strain bearing member to the surface buoy. Such an arrangement isolates extraneous noises generated by motion of the surface buoy from the

hydrophone. Most particularly, vertical motions, since they tend to move the hydrophone up and down, causing a pressure change to which the hydrophone responds, are attenuated.

Mechanical termination of the strain member is by means of a molded urethane rubber clevis at either end. Compliance of this assembly is up to almost three times original length. The clevis ends will recover from up to 400 ppounds tension (tested separately) although the rubber may not.

The upper end of the coil cord is terminated in an underwater pluggable 2-wire connector (electro-oceanics type 51F2M-1). This connector mates with the short cable which comes through the gland on the bottom of the surface buoy. These connectors will pull apart if the mooring strain is excessive. The coil cord coming upward should be secured to the urethane clevis termination to prevent the gradual creep of the coil cord downward with buoy motion from pulling the connectors apart. This connector must remain free to pull apart under excess strain or the gland will pull out of the bottom of the buoy flooding it.

Batteries: Provision is made for mounting up to 14 lithium cells of 30 ampere-hour capacity. Various series-parallel combinations of these cells will power almost any sonobuoy electronics package. In the configuration supplied, they are arranged in two paralleled series strings of six cells. With a nominal terminal voltage of 2.8 volts per cell, the battery then supplies (2 8x6) or 16.8 volts to the buoy electronics. Total capacity is 60 ampere-hours. Total life of a buoy with fresh batteries, assuming 100 ma drain is about 25 days, (.1 amp drain x24 hours divided into 60 ampere hours = 25 days) + or - depending on temperature.

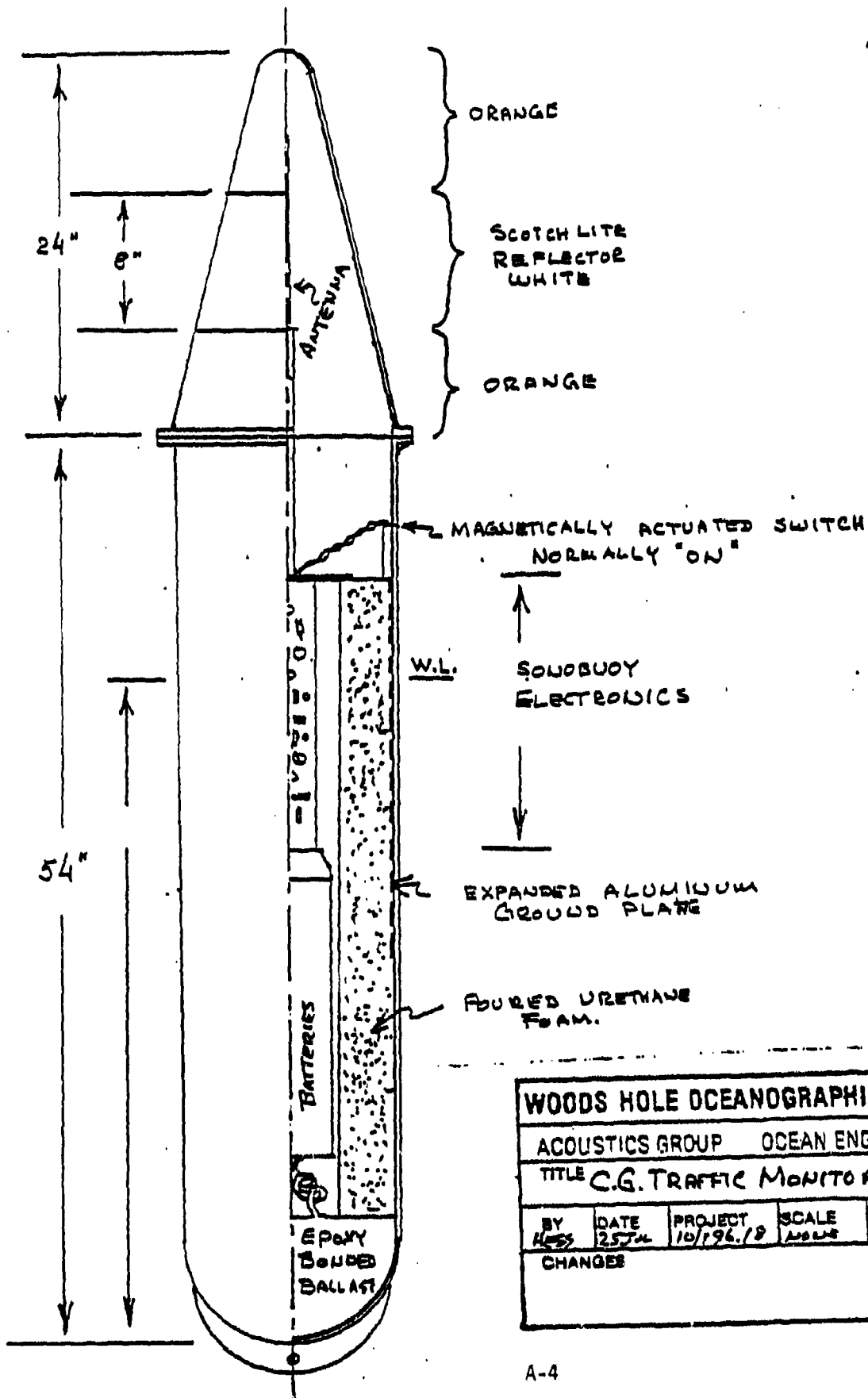
The battery stacks are assembled with soldered wire jumpers eliminating corroded joints or noisy spring contacts. Each set of six cells has a series diode (1N5818) in the output lead to protect the stack from possibly violent rupture in the event of a shorted or low cell causing the other battery stack to discharge into it. This is a low forward drop (Shottky) type diode.

NOTE: Even a momentary short of the output leads will destroy this diode.

The lithium cells are manufactured by Power Conversion, Inc., Mount Vernon, New York. Part number is 660-5AS.

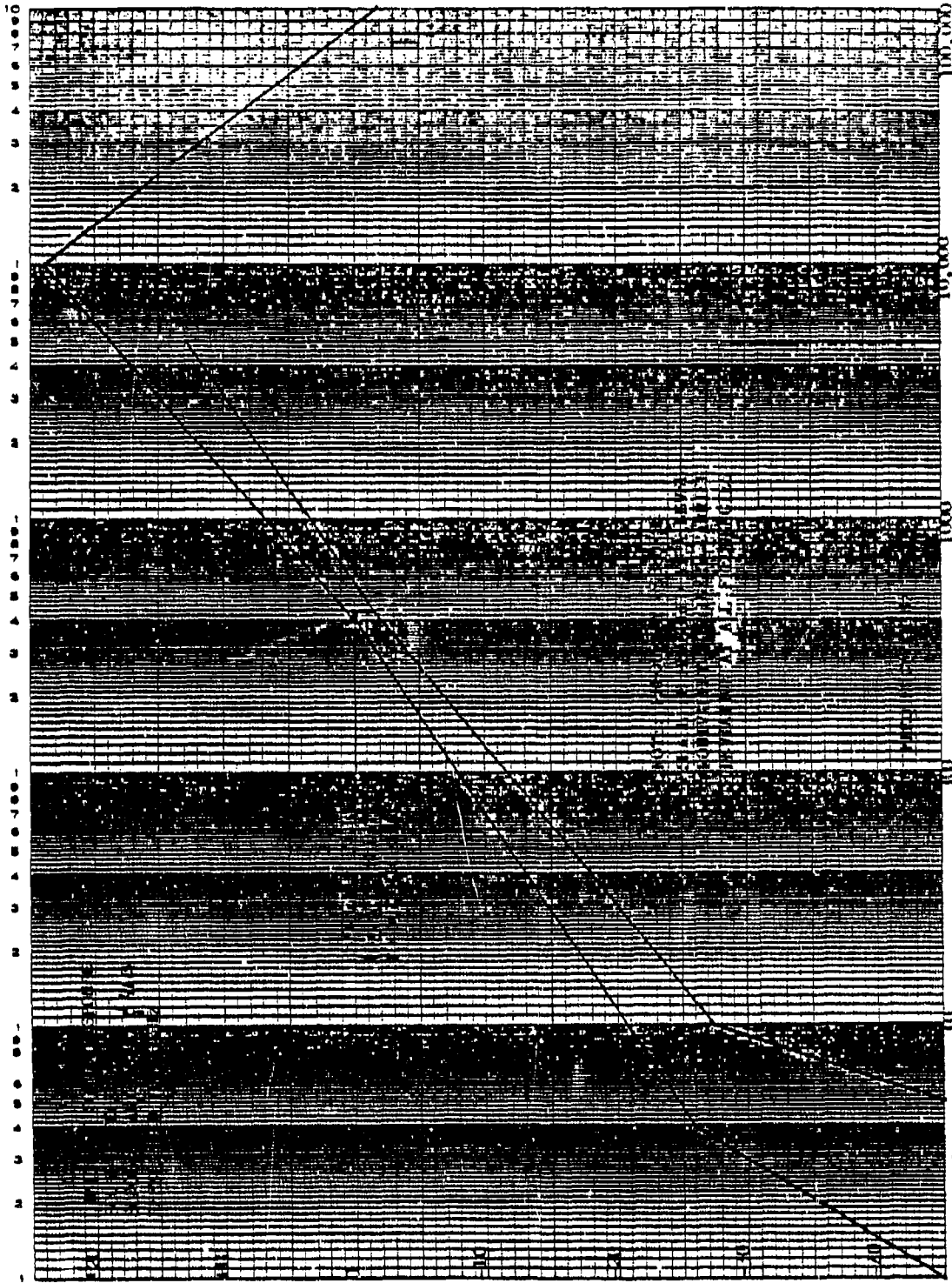
Power Switching: On-off switching is by means of a magnet-activated normally-closed glass reed switch inside the buoy just above the aluminum internal deck. It is held open (buoy transmitter off) by means of a magnet applied to the outer surface of the buoy. The buoy can be turned off while still in the water without opening it up.

For prolonged shutdown or storage, the top cone of the buoy should be removed and the short cable going from the reed switch to the electronics package unplugged. If storage is to be in excess of two weeks or so, batteries should be removed to prevent damage from cell leakage.



WOODS HOLE OCEANOGRAPHIC INSTITUTION				
ACOUSTICS GROUP		OCEAN ENGINEERING DEPT.		
TITLE C.G. TRAFFIC MONITOR (MECK)				
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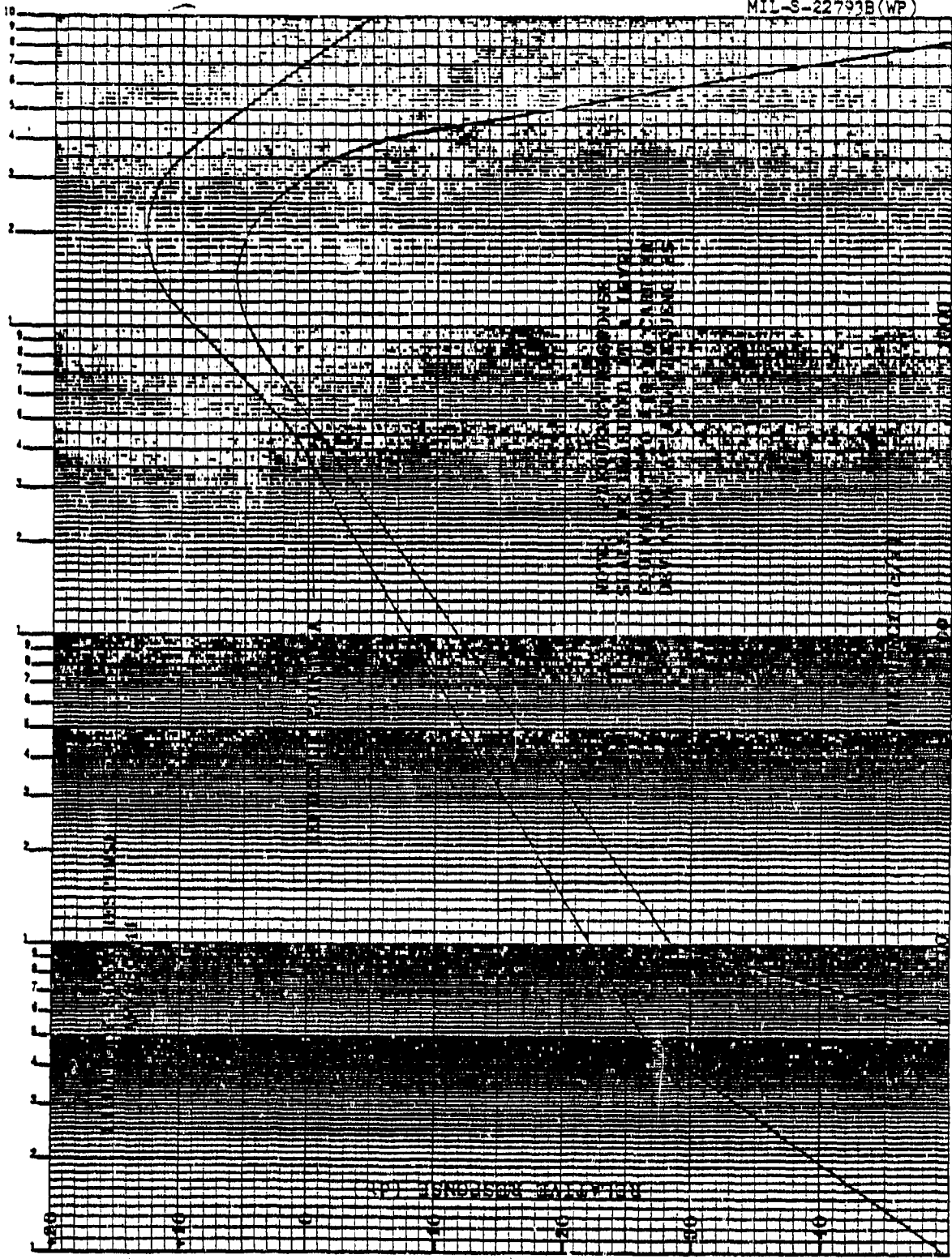
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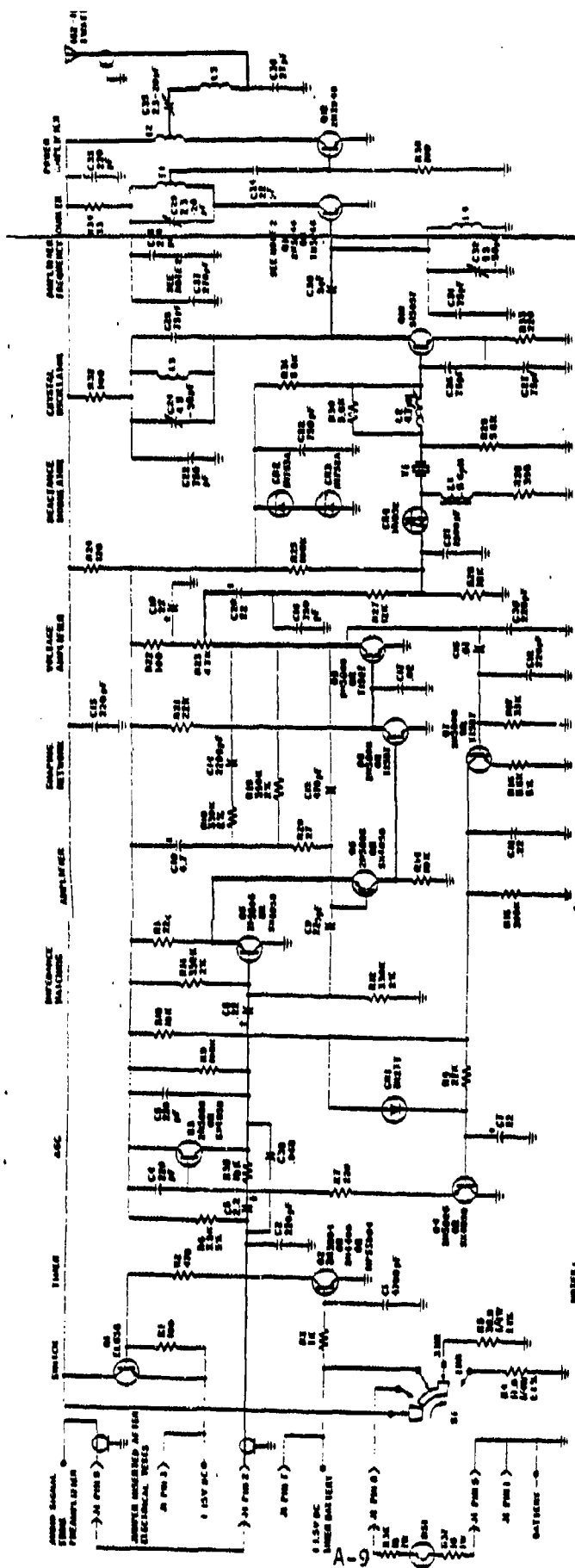
U. S. GOVERNMENT PRINTING OFFICE: 1967: 303-216-2210

FIGURE 3
15 June 1967

K-E SEMI-LOGARITHMIC 48 6012
4 CYCLES X 10 DIVISIONS PER INCH
RUFFEL & SEIBER CO.



3014



UNLESS OTHERWISE INDICATED, VALUES FOR RESISTORS ARE EXPRESSED IN OHMS (R = 1,000 OHMS AND K = 1,000,000 OHMS) AND CAPACITORS IN MICRO FARADS (M = 1,000,000 FARADS AND P = 1,000,000,000 FARADS). CAPACITORS LISTED ONLY UNDER TRANSMITTER ARE IN TYPE 252/100.

A-7

Figure 4-2. AM/SSQ-41A monobwoy schematic diag:
4-5/4-61
UNCLASSIFIED

APPENDIX B
SPECIFICATIONS FOR PYROELECTRIC VIDECON

VIDEOTHERM

MODEL 84

THERMAL IMAGING SYSTEM

SPECIFICATIONS

Size: 4.20" Wide x 4.20" High x 9.20" Long
(10.67 cm W x 10.67 Cm H x 22.8 Cm L)

Weight: Camera, 2.036 lbs. (924 Gm)
Pistol Grip, .268 lbs. (122 Gm)
Lens, 1.90 lbs. (861.8 Gm) Typical for
50mm, f/0.74
Viewfinder, 1.56 lbs. (710 Gm)

Power: 4.26 Watts, .385A from a +12 V dc source
(either from VideoTherm Power Unit, Video
Tape Recorder, or Battery Belt)

Construction: Completely Solid State with CMOS Integrated
circuits on glass epoxy boards.

Scanning: 2:1 Interlaced, 525 Lines, 60 fields, 30
frames per second (US Standard)

Vertical Sweep Rate: 60 Hz

Horizontal Sweep Rate 15,750 Hz

Sync & Blanking Waveforms: EIA-RS-330, 2:1 Interlaced

Camera Tube Types: "Hard" Pyroelectric Vidicons such as
Thomson/CS TH-9851 and TH-9855

Resolution: Limited by tube selection. Typically 238
TV Lines with high thermal contrast scene.

Scan Size: 18 x 24mm Nominal-fully adjustable

Scan Failure Protection: Automatic through High Voltage shut down

Low Voltage Power Supply: Fully regulated

High Voltage Power Supply: Fully regulated for G1, G2, G3, & G4

Beam Current: Internally set from Regulated Power supplies