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FINAL REPORT

NOTICE

Technical Report Documentation Page

1. Report No. CG-D-47-76	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: COMPARATIVE EVALUATION OF VISUAL DISTRESS SIGNALS		5. Report Date: 13 August 1976
		6. Performing Organization Code
7. Author(s): Marvin K. Niemiller		8. Performing Organization Report No.
9. Performing Organization Name and Address: Commanding Officer, Naval Weapons Support Center, Applied Sciences Department (5045), Crane, Indiana 47522		10. Work Unit No. (TRAIS): 761285.4
		11. Contract or Grant No.: MIPR Z-70099-5-54369
12. Sponsoring Agency Name and Address: Commandant (G-DST), U.S. Coast Guard, Washington, D.C. 20590		13. Type of Report and Period Covered: FINAL
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This program involved the comparative evaluation of the standard issue lifejacket light (one-cell flashlight) and two currently available chemiluminescent devices for use in emergency signaling. The two chemiluminescent devices were a commercially available single ampule device (Cyalume) and a double ampule device previously developed by NAVWPNSUPPCEN Crane.

17. Key Words	18. Distribution Statement
Visual Distress Signals Chemical Lights	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	92	

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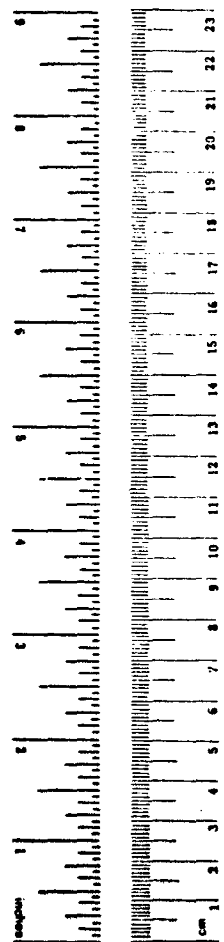
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

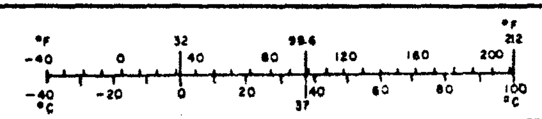
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



SUMMARY

The Naval Weapons Support Center, Crane, was tasked by the U. S. Coast Guard Headquarters through the Office of Research and Development, Search and Rescue Projects Branch (G-DST-1/62 TRPT), to conduct a comparative evaluation of visual emergency signalling equipment. This program specifically applied to the standard issue lifejacket light (one-cell flashlight) and currently available chemiluminescent devices.

Two chemiluminescent devices were evaluated during this program. One was a single ampule, commercially available, device manufactured under the trade name Cyalume. The second device was a double ampule device supplied by NAVWPNSUPPCEN Crane.

The laboratory test phase of this program did not positively identify one device as being superior. The commercial chemical light was superior in light output and had a lower initial procurement cost. This device, however, was deficient in long-term storage tests. The double ampule chemical light was superior in ability to withstand long-term storage and had a light output level comparable to the currently used flashlight. The double ampule design also had the highest initial procurement cost of the devices tested in this program. The one-cell flashlight had the advantage of being reuseable, but had reliability problems with the switch, was bulkier than the chemiluminescent devices, and was subject to deterioration with prolonged storage.

Field testing of these devices was originally scheduled for December 1975 in Puerto Rico. Unfortunately, the lack of support equipment time due to search and rescue requirements and some adverse weather conditions prevented completion of this field test as planned. Although only a limited amount of data was obtained, it was concluded that the commercial chemical light was an easier target to acquire than either of the other two devices.

Field testing of the devices was rescheduled and conducted in May 1976 at St. Petersburg, Florida. The data obtained from this testing confirmed that the commercial chemical light had the highest visibility/detection range and was the easiest target to acquire. The double ampule chemical light and the one-cell flashlight proved to be essentially equivalent in terms of visibility/detection range.

When the field test was rescheduled for May 1976, NAVWPNSUPPCEN Crane was also requested and funded to conduct laboratory light output measurements on several sea-water activated devices. These measurements were to supply supplemental information only and a detailed analysis of these devices was not required. In addition, supplemental field test data was obtained on several devices as requested. The supplemental laboratory and field test data are included in this report so that all of the data developed during this program is readily accessible in one report. The supplemental data developed is given in Appendices A and B.

This program has shown that chemiluminescent devices are comparable, if not superior, to the one-cell flashlight as a visual signalling device. The larger (6 inches in length) commercial chemical light offers an increased visibility range and a lower initial procurement cost. The double ampule chemical light offers increased long-term storage capability. It was concluded that either of the chemical lights evaluated will be superior in use, overall, to the one-cell flashlight.

It is recommended, however, that a total cost effectiveness study be conducted prior to a firm commitment to use either of these chemical lights. Information concerning procurement quantities, use rates, and length of storage should be developed for this study. The double ampule chemical light may prove more cost effective, if long-term storage is considered a requirement, while a high use rate may indicate that the commercial unit is more cost effective.

PREFACE

This comparative evaluation program was conducted for the Coast Guard Search and Rescue Division under the direction of the Office of Research and Development. Personnel involved in this program included CWO William Collier and LTJG Rick Glover (G-DST-1/62 TRPT). The assistance and cooperation of these and other Coast Guard personnel, at the headquarters and local level, throughout the entire program were greatly appreciated. The technical expertise, assistance, and cooperation of Mr. C. W. Gilliam, NAVWPNSUPPCEN Crane, who provided the technical assistance and guidance for the light measurement setup and significant chemiluminescent information throughout the program, is also greatly appreciated.

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INTRODUCTION

OBJECTIVE:

The objective of this program is to comparatively evaluate the presently used one-cell lifejacket light (flashlight) and various available chemical lights.

SCOPE:

This program encompasses the comparative testing of chemical lights and the one-cell flashlight.

Experimenatl chemical light devices were not considered for testing in this program. The time delay before procurement and expenditure of funds to bring these devices to production status were considered contrary to the immediate program objectives.

Similarly, complete field testing and analysis of each device in all search and rescue situations were not attempted due to time and funding limitations.

BACKGROUND:

Search and rescue operations at night are dependent upon the light level, capability of the survivor to assist, signalling devices available for the search. The currently issued one-cell flashlight is subject to frequent failures and is considered to be less than ideal as a personnel signalling device.

The chemical light was developed as an expendable survival light, but has been used in other applications, such as UNREP (Underway Replenishment) line markers, droppable aircraft markers, etc.

The chemiluminescent devices produce low level light by a chemical reaction between two liquids. The liquids are kept separated by one or two sealed glass ampules, depending on the device, until ready for use. Flexing of the sealed plastic tube encasing the chemicals breaks the glass ampule(s) and allows the chemicals to react and give off light.

Chemical lights do not produce a flame, heat or fumes, and are safe to use in explosive atmospheres. They can be activated with only one hand, if necessary, and provide a positive light source in wind, foul weather, and underwater.

The chemical components will degrade, if exposed to light, and will cause skin irritation in direct contact. Chemical lights are supplied with protective packaging to prevent exposure to light, and skin irritation can be easily avoided by washing the contact area with soap and water.

The state of the art in chemiluminescent devices has continued to advance and some devices are being commercially produced. Thus a source of supply is readily available. The potential reliability, the variety of applications, and the lower cost of the chemical lights were with basis for initiating this program.

TECHNICAL APPROACH

The comparative evaluation program was accomplished in two phases. The first phase was the Laboratory Test Program and the second phase was the Field Test Program. The Field Test Program was contingent upon satisfactory completion of the Laboratory Test Program.

TEST DEVICES:

Two flashlight designs, manufactured under the same specification, were tested in this program. The two designs, Figure 1, differed in physical appearance only. The one-cell flashlights were obtained from the regular stock inventory to insure a random sample selection. Batteries for the flashlights were also procured from regular stocks to give a random sample distribution.

Two types of chemical lights were tested in this program. The commercially available chemical lights (trade name Cyalume) are available in two sizes. The smaller unit (4 inches in length) is available from Navy stocks and has been assigned FSN 9G6260-106-7478. The larger unit (6 inches in length), Figure 2, is not in the supply system, but can be readily procured through normal outside purchasing procedures. Both commercial units are single ampule designs. With this design, only one of the chemical components is contained in a glass ampule, hence the term single ampule. It was decided to test the larger unit (6 inch size) in this program because of the increased light output and, therefore, visibility offered by the larger unit.

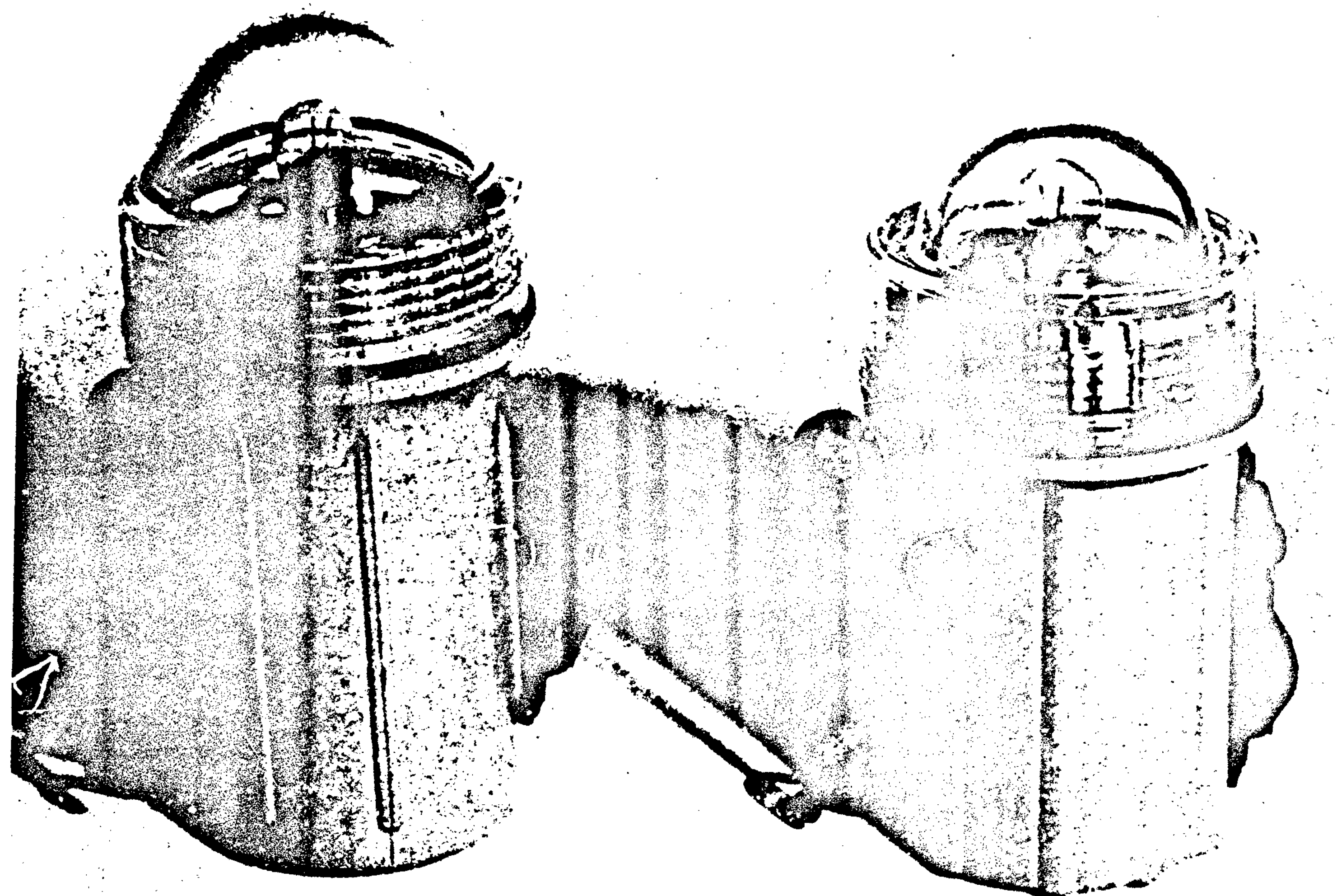

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FIGURE (1) - ONE-CELL FLASHLIGHT

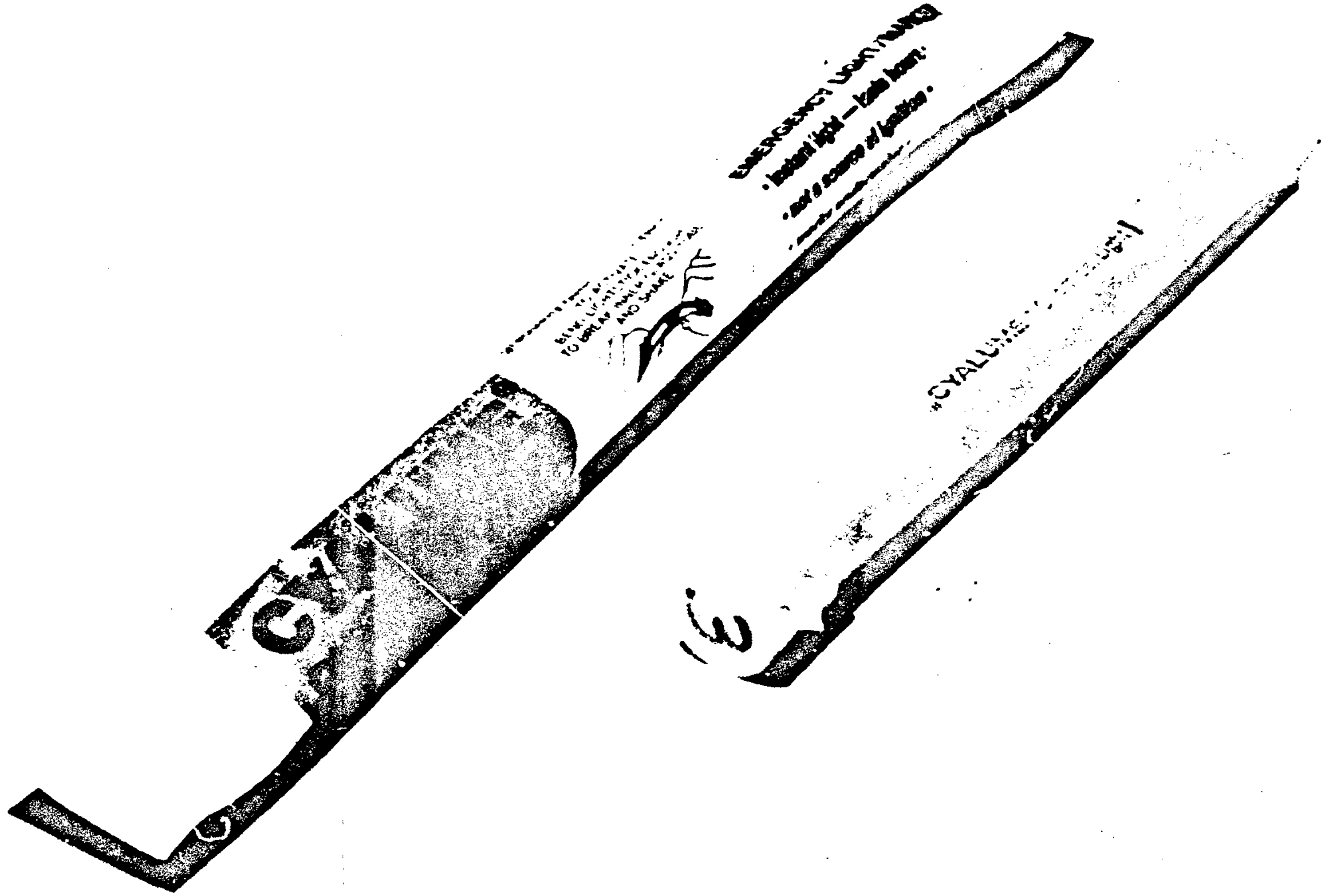


FIGURE (2) - COMMERCIAL CHEMICAL LIGHT

The second type of chemical light tested in this program was a four inch double ampule unit (Figure 3). Both of the chemical components are contained in glass ampules in this device. This design is commonly referred to as a double ampule design. This unit was developed and documented by NAVWPNSUPPCEN Crane when earlier single ampule designs were found to deteriorate with environmental exposure. A six inch double ampule design has been produced, but hardware is not presently available to manufacture these units.

Although the size difference between the two chemical lights does not allow a direct comparison of the estimated visibility range, the two designs can be comparatively evaluated on the effects of environmental conditioning. Since both designs utilize the same chemical components, a six inch unit of either design will yield the same light output and estimated visibility range.

LABORATORY TEST PROGRAM:

The relative effectiveness of the test devices was determined by measuring the light output of the devices and calculating an estimated visibility range. Unconditioned units of each type served as the control sample and provided baseline data for comparative analysis between the devices.

In service use, the devices will be exposed to various storage and environmental conditions. A variety of environmental tests (14-Day Temperature and Humidity, High and Low Temperature Storage, and Salt Spray) was selected to determine the ability of each device to function

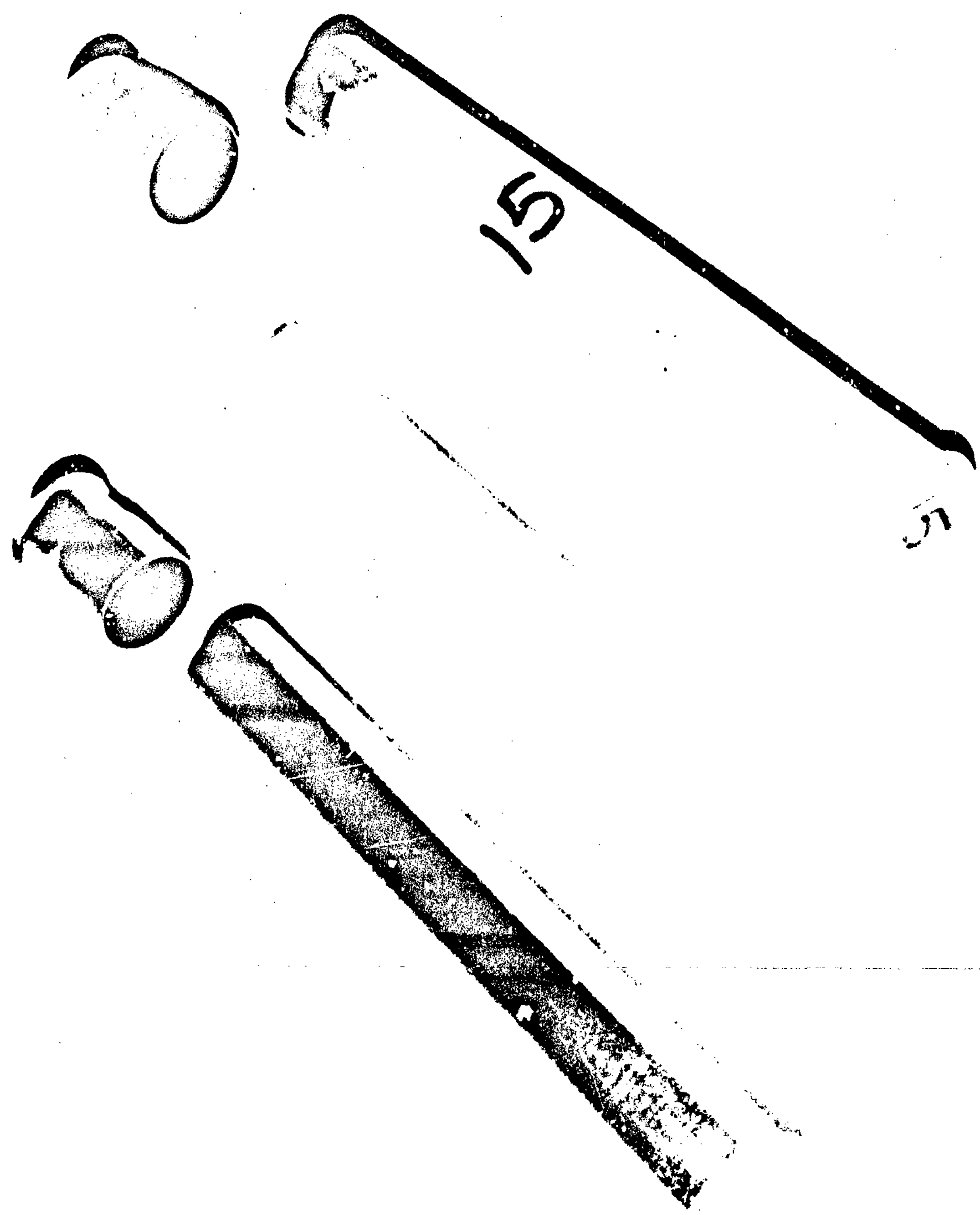


FIGURE (3) - DOUBLE AMPULE CHEMICAL LIGHT in anticipated storage and use environments. The Laboratory Test Program outline is shown in Figure 4.

MEASUREMENT OF LIGHT OUTPUT:

The basic difference between the test devices is that the chemical lights are volume emitters while the flashlight is a point source. This difference required that the light output be measured by two different methods. For the chemical lights, the light output was measured in brightness, or intensity, the standard method of light measurement for volume emitters. The light output of the one-cell flashlights was measured in candlepower.

Although two different light output measurements were required, the physical setup for these measurements was basically the same, as shown in Figures 5 and 6. To obtain maximum data retrieval, the test equipment design incorporated a rotating sample table to allow output data to be taken at two minute intervals for each device. Sequencing of the table rotation, recording of the data, and the data printout were all computer controlled. The differences in the two test setups were in the sensing head, signal amplifier and the number of samples that could be tested at one time. Computer control of the operation allowed continual data retrieval over a period of 5 hours plus rapid analysis and printout of the data. The computerized data system was also used to produce the graphic displays of the light output data. The large volume of light output data both numerical and graphic, necessitated forwarding this information in a separate report (CG-D-48-76). Numerical summaries and some selected output graphs are used in this report to illustrate the performance of the test devices.

The brightness measurements of the chemical lights were mathematically converted to an estimated visibility range by the following equations:

(1) Conversion of light output measurement to candlepower

$$I = (\text{AREA}) \times \frac{(\text{FT. LAMBERTS})}{\pi}$$

where I = candlepower

Area = surface area of emitting material in surface feet

Ft. Lamberts = measured output of chemical light

$\pi = 3.1416$

(2) Estimated visibility range.

$$E_t = \frac{I}{d^2} (e^{-\sigma d})$$

where E_t = threshold illumination[1] = 2.8×10^{-9} lumens/ft^2

σ = estimated atmospheric conditions constant for 5 mile visibility range = $\frac{2.9}{(5280 \text{ ft.})(5 \text{ Miles})}$

I = candlepower

e = base of nature logarithms

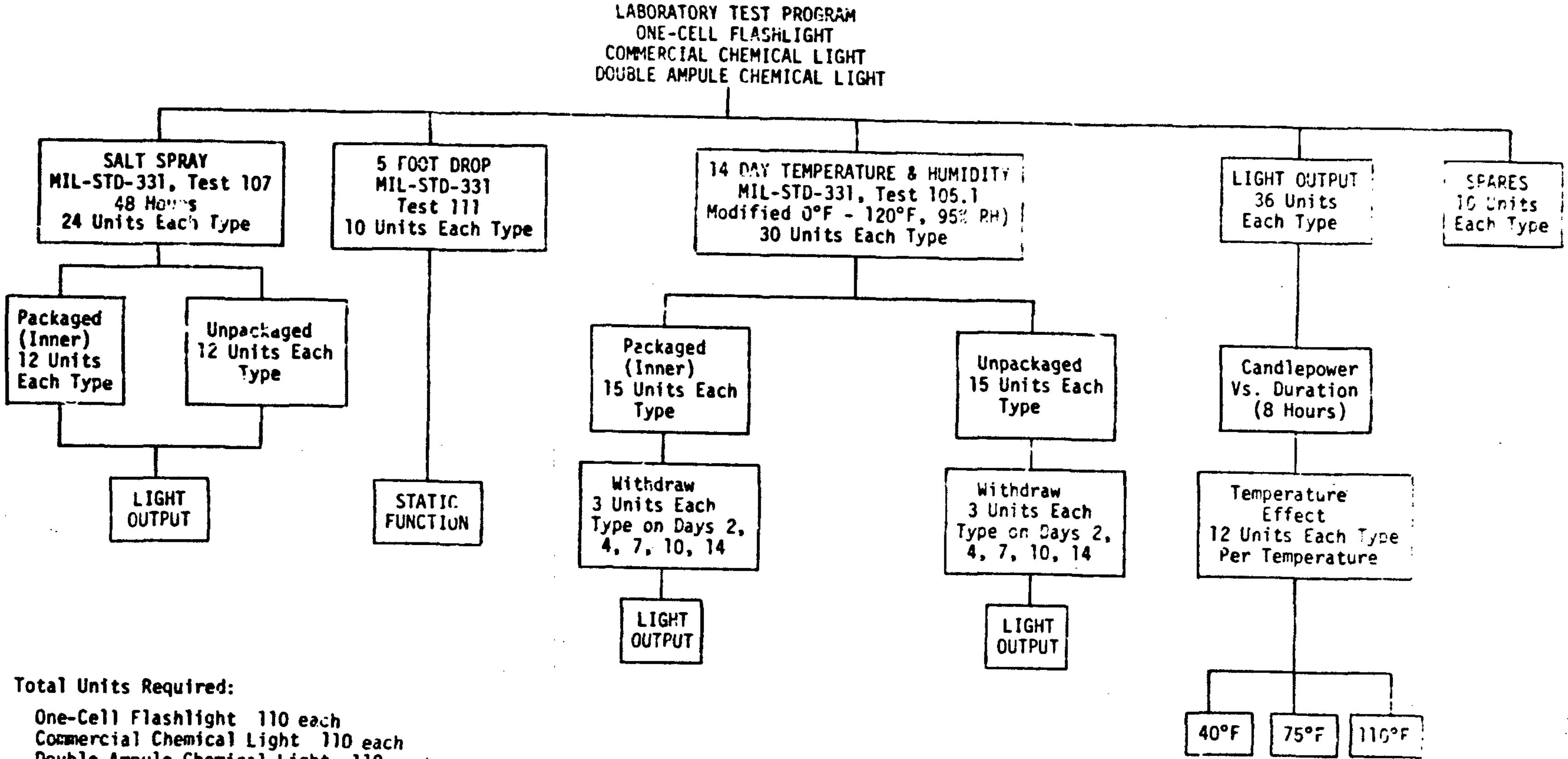
d = estimated visibility range

The light output of the one-cell flashlights was measured directly in candlepower. The estimated visibility range was calculated using equation (2) above.

[1] J. Kaufman (ed.), "IES Lighting Handbook", 5th Edition, Illuminating Eng. Soc., New York, 1972.

FIGURE 4

COMPARATIVE EVALUATION OF EMERGENCY
VISUAL SIGNALING DEVICES



Total Units Required:

One-Cell Flashlight 110 each
Commercial Chemical Light 110 each
Double Ampule Chemical Light 110 each

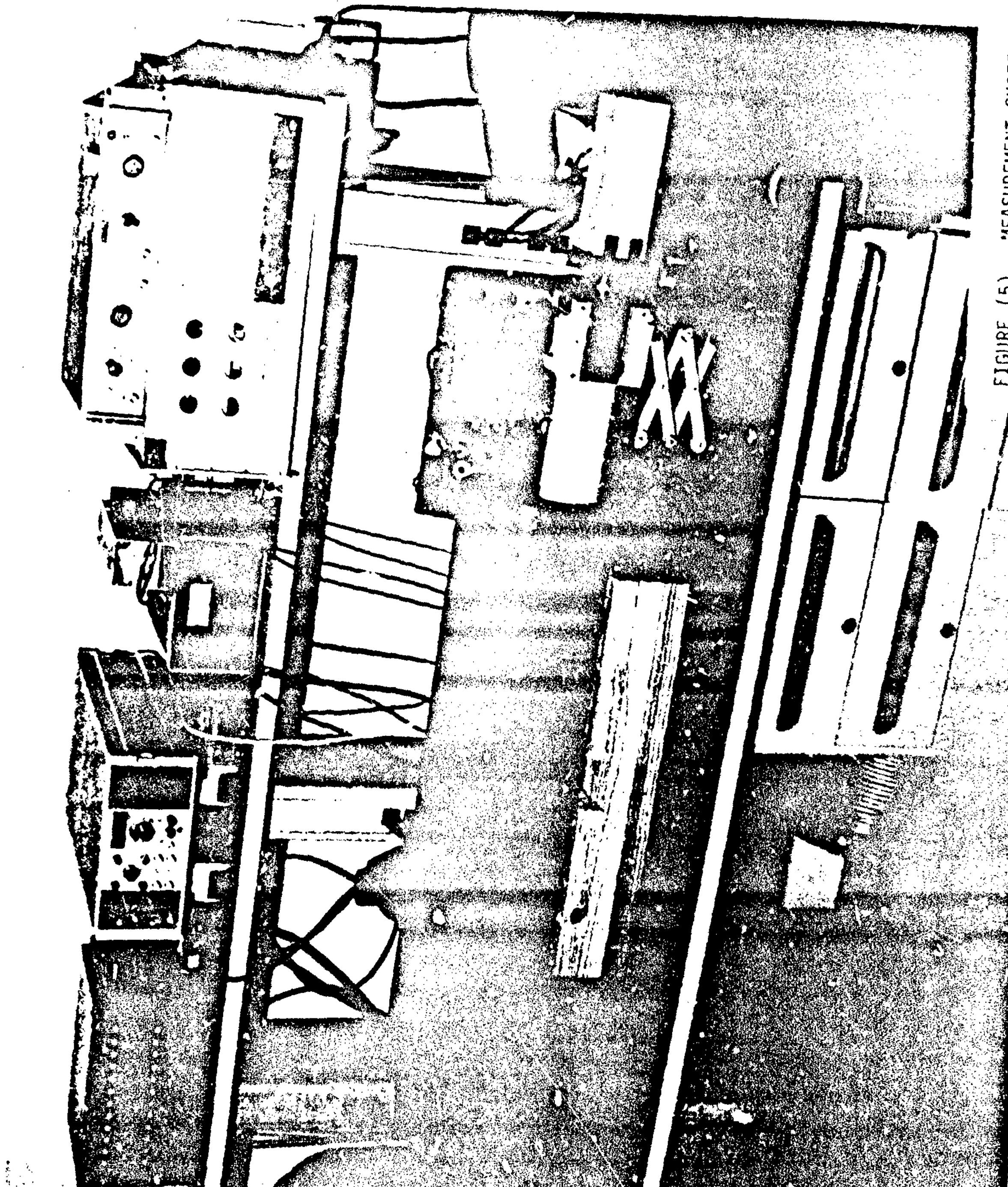


FIGURE (5) - MEASUREMENT SYSTEM FOR CHEMICAL LIGHTS

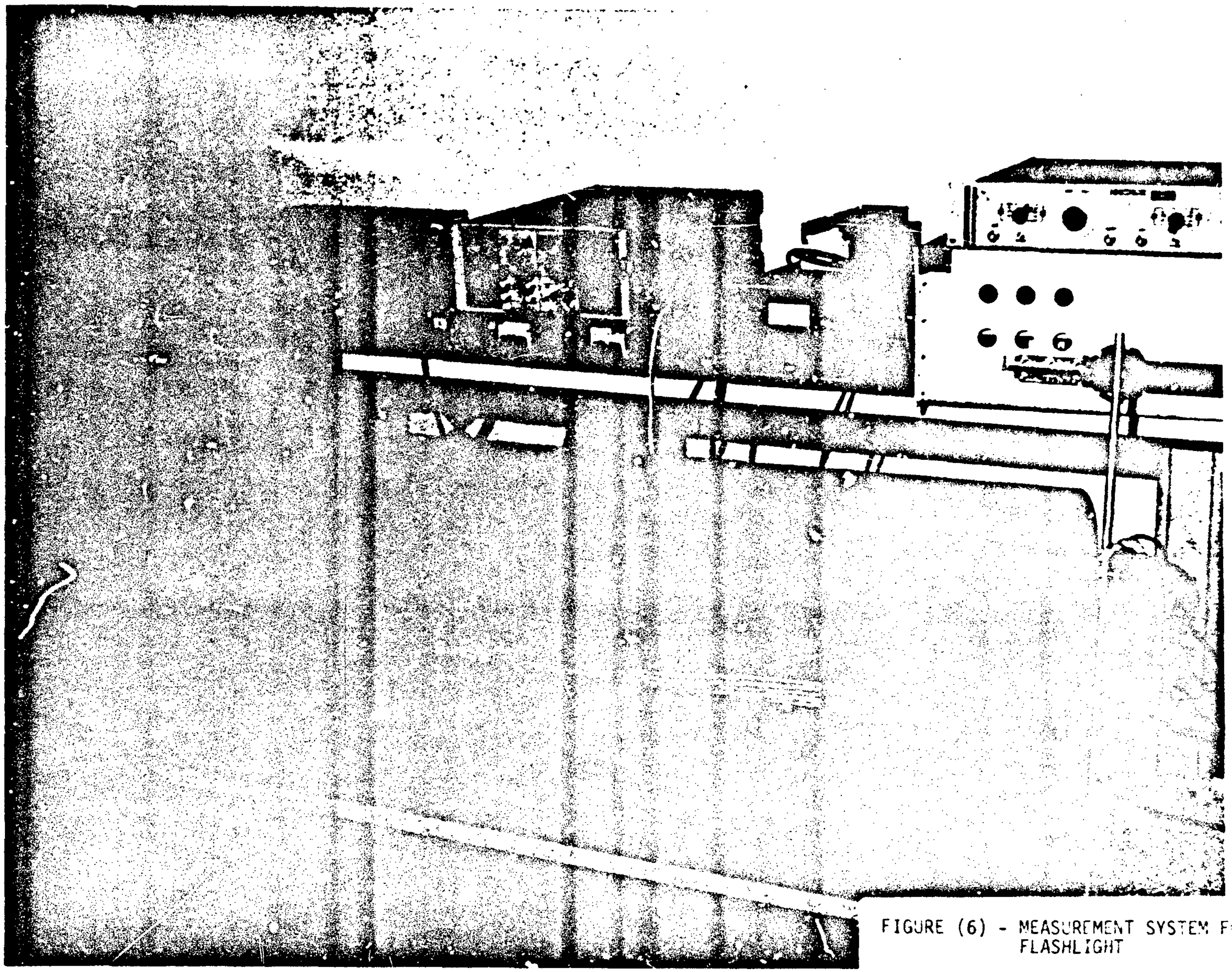


FIGURE (6) - MEASUREMENT SYSTEM FOR FLASHLIGHT

The parameters selected for determining the estimated visibility range were a 5 mile meteorological visibility and a 90% probability of acquiring the target (test device). These parameters, in turn, determined the threshold illumination and atmospheric conditions constant (σ) for the estimated visibility range calculation.

The 5 mile meteorological visibility was selected because most areas where the test devices can be employed are nominally above this range; thus, the realistic rather than "ideal" use condition is simulated. The 90% detection probability was selected because of the use of the devices in rescue signalling, where a high probability of detection is desirable. The combination of relatively low meteorological visibility and high detection probability results in a conservative estimated visibility range for these devices. Valid search sweep widths can, therefore, be established, based on these conservative range estimates, so that valuable field test and eventually SAR search time is not wasted on looking for a target that cannot be seen.

As previously noted, the estimated visibility range for the one-cell flashlight was calculated directly from the candlepower measurements obtained. The estimated visibility range for the chemical lights required the conversion of the brightness measurements to an estimated candlepower which was then used to calculate the visibility range. In order to utilize this calculation, it must be assumed that the chemical light is an "ideal" volume emitter; i.e., the light is brightest at the center (thickest section) and diminishes to nothing at the edges. A cursory check of both types of chemical lights revealed that they were not ideal volume emitters; the plastic tube and broken glass ampules reflect the emitted light and both chemical lights show emission at the edge of the signal. Accordingly, a candlepower measurement test was conducted with the chemical lights. This test confirmed that the chemical lights were not "ideal" volume emitters and showed that the estimated visibility range was actually higher than the range calculated by the brightness conversion equations (the range given on the data printouts). A comparison of the candlepower and brightness estimated visibility ranges shows that the brightness range (range given on the data printouts), multiplied by a factor of 1.5 would correct the non-ideal nature of the chemical lights and approximate the candlepower estimated visibility range. An exact correlation between the two estimated visibility ranges can be made with regression analysis. However, the data available is not in the proper format (candlepower and brightness measured simultaneously) to permit regression analysis. It is felt, however, that the estimated visibility ranges, either based on brightness or corrected for non-ideal volume emitter, are realistic.

FIELD TEST PROGRAM:

The Field Test Phase of the overall program was conducted after completion of the Laboratory Test Program when none of the test devices demonstrated a clear superiority in all areas of analysis.

The Field Test Program included both coastal and open sea testing with searches conducted from both surface vessels and aircraft. Acquisition ranges obtained from the field test were compared with the laboratory data to determine if a correction factor was required before establishing sweep widths.

Several inexpensive flotation devices were fabricated for the field test. The flotation devices were designed to hold the test units above the water surface at the approximate distance a survivor would position the unit.

LABORATORY PROGRAM TEST RESULTS

The laboratory test program results for each of the devices are discussed in the following paragraphs:

One-Cell Flashlight:

General. Two flashlight designs were tested during this program. The two designs were manufactured under the same specification and differed only in physical appearance. No significant difference was observed in the performance of either design, with both designs having an estimated visibility range of 5400 feet. Prior to committing units to environmental and/or light measurement tests, each unit was checked for operability. The units were checked by installing a battery and determining whether or not the flashlight worked. Specific battery outputs were not measured since the user would not have access to similar equipment and a random battery output distribution was desired for the various tests. During this pre-test check, an unexpectedly high number of defective batteries was found (13.8 percent of the batteries checked were unsatisfactory). Since the batteries were manufactured in 1974, it was concluded that the shelf life of the flashlight would be approximately one year with the battery installed. A summary of the Laboratory Test Results is given in Table 1.

Control. No statistically significant temperature effect was found by analysis of the output and visibiility range data obtained at the various test temperatures. A typical light output graph is shown in Figure 7. A general decrease in the visibility range of 200-500 feet was observed with a 45° look angle at the flashlight. However, statistical analysis of the test data did not show a statistically significant decrease in the visibility range because of the look angle. The failure to show significance was the direct result of the high sample variance (caused by the randomness of the battery outputs) and the relatively small sample size. It is felt that a statistically significant decrease in the visibility range, because of the look angle, would be shown with the testing of additional samples.

Temperature and Humidity (Packaged). The packaged condition means that the flashlights were conditioned as received from the manufacturer (no battery installed). Since the cardboard overpack, in which each flashlight is packaged, provides no structural or sealing properties to the flashlight, the cardboard was removed prior to conditioning to facilitate handling of the units. The bulbs and switches of all of the flashlights were checked prior to conditioning to insure that they were in satisfactory working order. Three flashlights were withdrawn following 2, 4, 7, 10 and 14 days of conditioning. Batteries were installed in the flashlights and the units were tested for light output. Statistical analysis of the output data did not show a significant difference between the various withdrawal periods; however, this determination was influenced by the small sample size. Figure 8 is a typical light output graph for units following this conditioning. Two of the flashlights developed bad switch contacts during the first 10 days of conditioning. The switch contacts were improved so that testing could be completed to determine if the conditioning had any detrimental effect on the bulb. No detrimental effect was observed. A third unit had a switch contact failure during testing and no light output readings were obtained for the last 285 minutes of the test. Figure 9 shows the effect of poor switch contact on the light output.

Temperature and Humidity (Unpackaged). These units were tested the same as the "packaged" units, except that batteries were installed prior to the conditioning. Three of the packaged units were withdrawn following 2, 4, 7, 10 and 14 days of conditioning. Three of the flashlights developed defective switches during the conditioning. The switch contacts were improved to permit testing of the batteries. Statistical analysis of the results did not reveal any significant effect of the various amounts of conditioning on the flashlights. This indicates that the flashlight affords some protection from environmental conditions to the battery. Figure 10 is a typical light output graph for units after this conditioning.

Salt Spray (Packaged and Unpackaged). These two test conditions are combined for this discussion because the results are essentially the same. Statistical analysis did not show a significant difference between the results of either test condition and the control units despite the apparent differences in the averages. The high variability in the individual unit output is the reason that significance was not shown.

Five Foot Drop Test. The results of this test, designed to simulate a use environment, were considered unsatisfactory. Only 4 of the 10 units tested functioned following this test. All of the failures were the result of the bulb filament breaking from the shock of the impact. In addition, all of the units suffered lens damage (cracked or broken) which would seriously compromise the units' ability to withstand prolonged storage.

TABLE I

FLASHLIGHT OUTPUT SUMMARY

Conditioning			Samples	OUTPUT (CP) AT TIME (Minutes) 2	10	30	60	120	180	240	300	Estimated Visibility Range (Ft) At Time (Minutes) 10	30	60
Control	+40°F	Head-on	8	.209	.184	.168	.159	.134	.120	.114	.109	5826	5642	5497
		45°	4	.162	.147	.136	.122	.105	.095	.085	.080	5358	5202	4998
	Ambient	Head-on	8	.172	.145	.136	.126	.114	.096	.090	.081	5300	5175	5048
		45°	4	.147	.133	.118	.110	.090	.030	.070	.062	5150	4928	4781
	+110°F	Head-on	8	.210	.186	.171	.155	.136	.119	.109	.102	5820	5659	5465
		45°	4	.184	.163	.138	.128	.108	.092	.082	.075	5594	5257	5054
Temperature & Humidity	2 days	Head-on	2	.208	.187	.165	.145	.120	.110	.090	.080	5890	5625	5356
Packaged		45°	1	.227	.208	.182	.16	.14	.12	.11	.10	6143	5834	5613
	4 days	Head-on	2	.172	.166	.142	.120	.100	.085	.080	.070	5534	5228	4917
		45°	1	.109	.138	.123	.11	.08	.07	.06	.06	5252	5023	4733
	7 days	Head-on	2	.198	.180	.162	.145	.120	.105	.080	.070	5812	5578	5378
		45°	1	.112	.060	0	0	0	0	0	0	3760	0	0
	10 days	Head-on	2	.228	.205	.183	.165	.140	.125	.105	.095	6110	5847	5617
		45°	1	.123	.104	.082	.07	.06	.06	.05	.05	4709	4295	4201
	14 days	Head-on	2	.073	.043	.039	.035	.025	.025	.020	.015	3250	3101	2902
		45°	1	.175	.156	.134	.12	.10	.08	.07	.06	5506	5198	4964
Temperature & Humidity	2 days	Head-on	2	.124	.120	.112	.105	.090	.080	.075	.070	4970	4830	4696
Unpackaged		45°	1	.095	.089	.078	.07	.06	.06	.05	.05	4420	4201	4024
	4 days	Head-on	2	.114	.114	.096	.085	.075	.065	.060	.060	4849	4507	4298
		45°	1	.099	.090	.080	.07	.06	.06	.05	.05	4458	4234	4028
	7 days	Head-on	2	.152	.138	.122	.105	.090	.085	.070	.060	5162	4946	4730
		45°	1	.143	.135	.124	.12	.11	.09	.09	.08	5204	5044	4898
	10 days	Head-on	2	.210	.180	.152	.125	.110	[illegible]	.090	.085	5777	5394	4997
		45°	1	.148	.135	.122	.11	.10	.09	.08	.07	5212	5014	4840
	14 days	Head-on	2	.079	.072	.065	.060	.045	.045	.045	.035	4052	3893	4846
		45°	1	.119	.114	.102	.09	.07	.07	.06	.06	4872	4675	4465
Salt Spray Packaged		Head-on	8	.195	.179	.156	.136	.110	.092	.078	.069	5768	5469	5212
		45°	4	.085	.078	.064	.052	.042	.035	.028	.022	3886	3261	3086
Salt Spray Unpackaged		Head-on	8	.133	.118	.123	.098	.080	.068	.061	.049	4717	4981	4562
		45°	4	.081	.074	.068	.060	.052	[illegible]	.048	.042	3446	3344	3237

FIGURE 7

TYPICAL FLASHLIGHT LIGHT OUTPUT

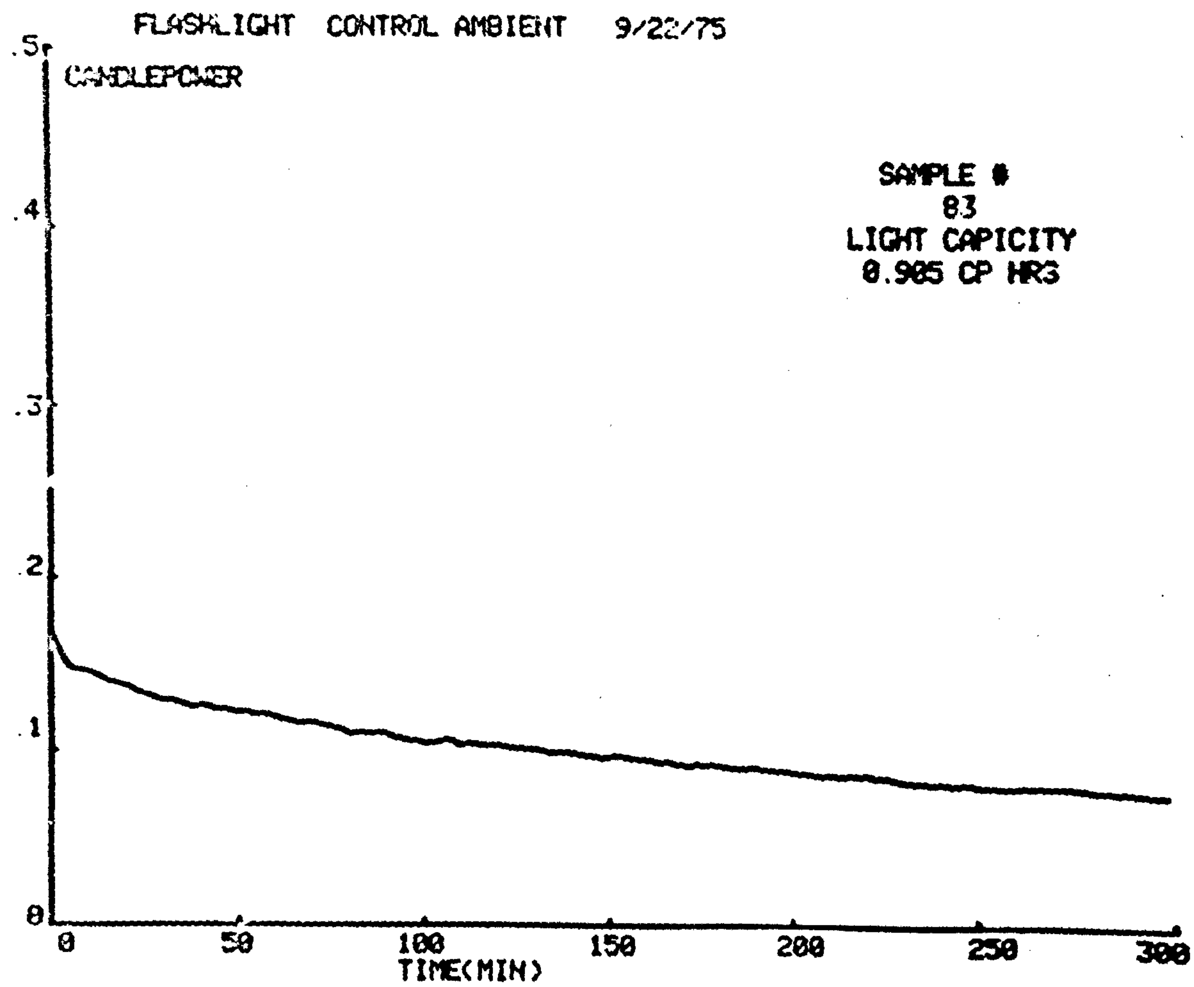


FIGURE 8

TYPICAL FLASHLIGHT LIGHT OUTPUT
AFTER PACKAGED TEMPERATURE AND HUMIDITY CONDITIONING

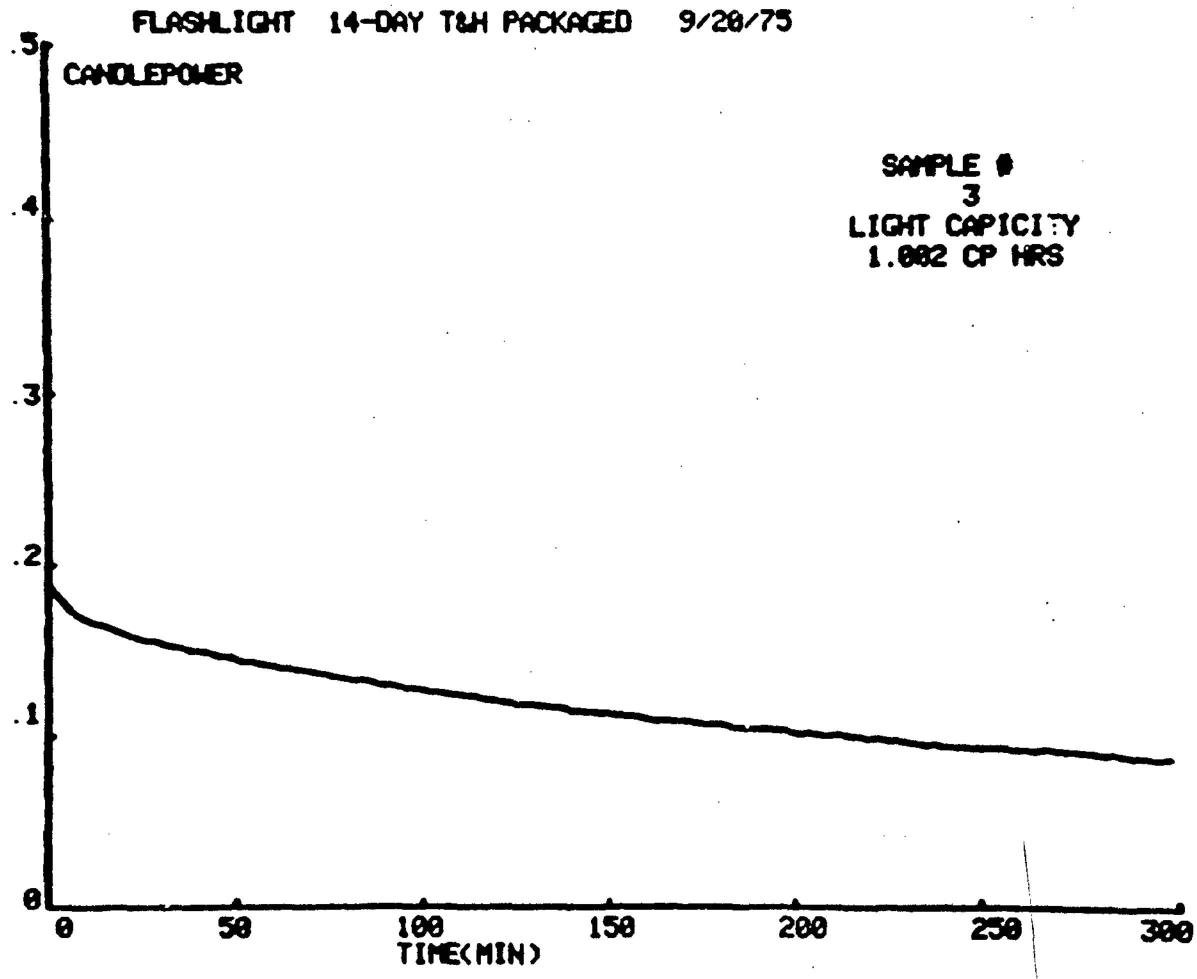


FIGURE 9

EFFECT OF POOR SWITCH CONTACT
ON FLASHLIGHT LIGHT OUTPUT

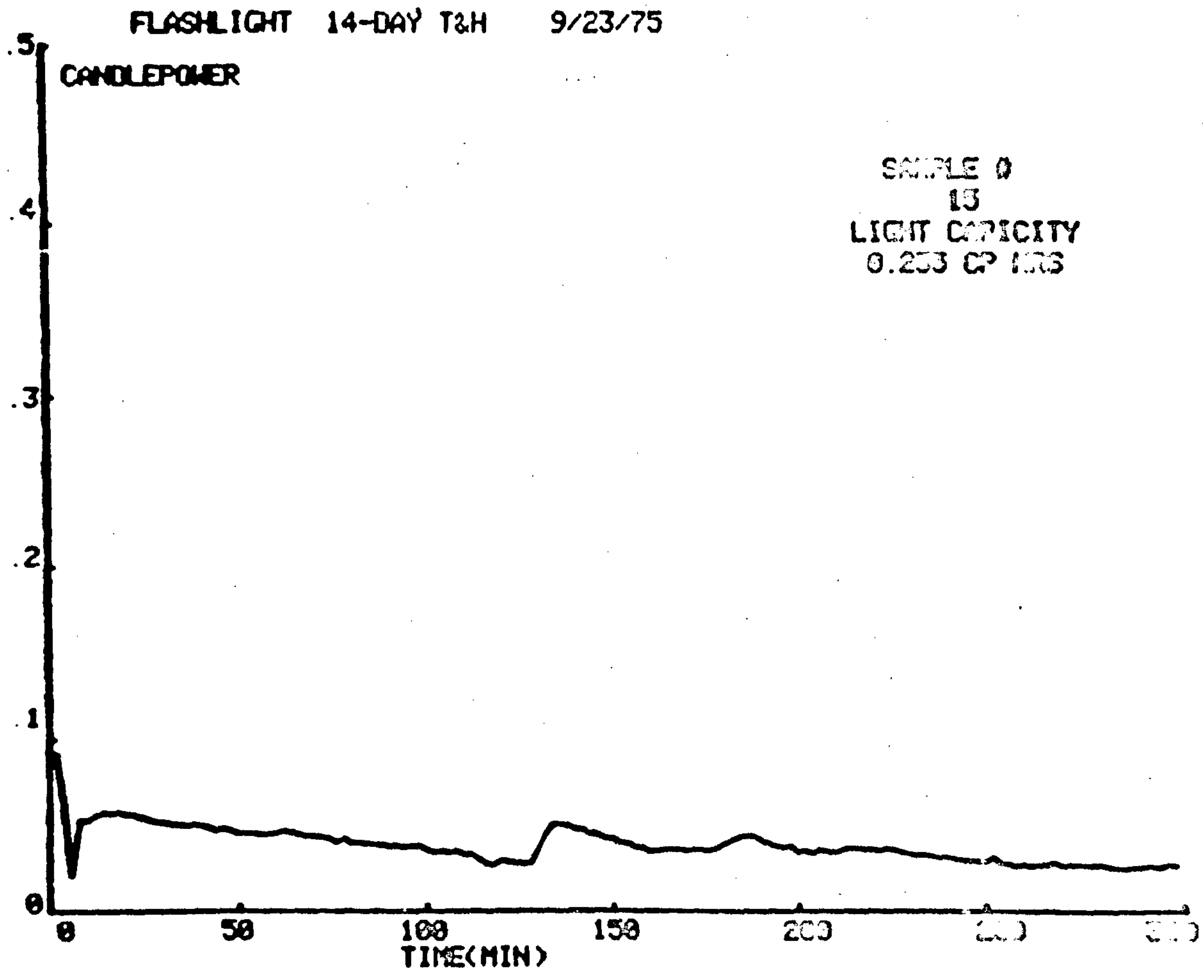
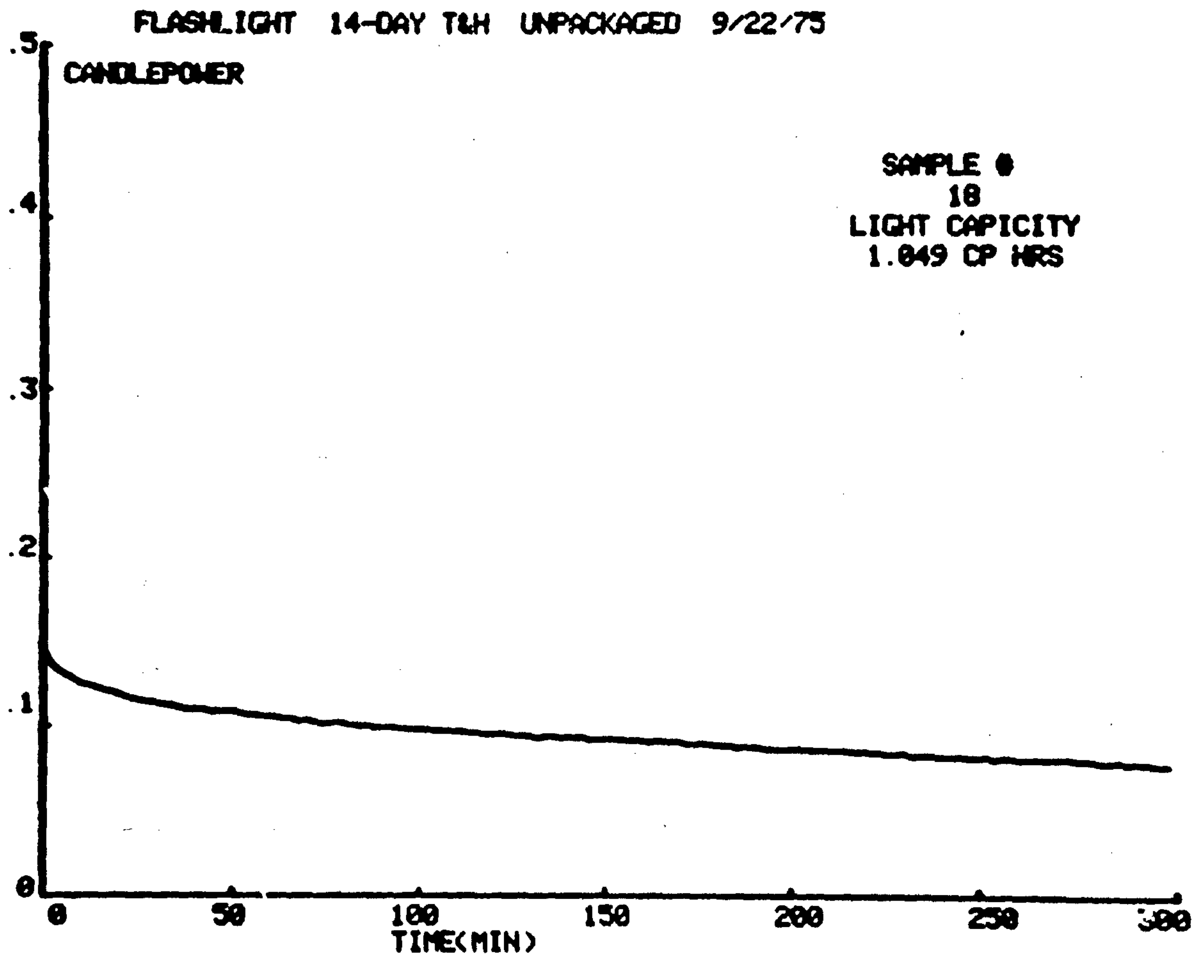


FIGURE 10

TYPICAL FLASHLIGHT LIGHT OUTPUT
AFTER UNPACKAGED TEMPERATURE AND HUMIDITY CONDITIONING



COMMERCIAL CHEMICAL LIGHT:

General. The larger 6 inch commercial chemical light was tested in this program because of the increased visibility offered by the larger sized unit. The estimated visibility range (corrected) for this unit is 7900 feet, which is approximately 50% farther than the other two devices. However, based on the test results, this device will not withstand prolonged exposure to moderate environmental conditions. A summary of the Laboratory Test Results is given in Table 2.

Control. The results of testing the control units show that the output of the single ampule chemical light is significantly affected by temperature; i.e., the lower the temperature, the lower the initial light output. The light output of units at +40°F was lower than the output of the ambient units for approximately the first 30 minutes after activation. After 30 minutes, the light output was approximately the same for the units from the two test conditions because the cold conditioned units had slowly warmed to room temperature. Although the initial light outout was reduced by the lower temperature, the time of useful light output was not lengthened because the units had warmed to room temperature. Figure 11 shows the light output of a typical unit tested at ambient temperature, while Figure 12 shows the lower initial output caused by lower temperature. When used at ambient temperatures (approximately 70°F) this device has the highest estimated visibility range (7900 feet).

Temperature and Humidity (Packaged). The commercial chemical lights were placed in this environmental conditioning in their foil protective overpack. Three units were withdrawn following 2, 4, 7, 10 and 14 days of conditioning and tested for light output. A significant decrease in output was observed after 7 days of conditioning, as shown in Figure 13. Statistical comparison of the results with the control sample (ambient) revealed a statistically significant decrease in output after 2 days of conditioning. Although the outputs and visibility ranges after 2 days of conditioning may not be significantly different from a practical viewpoint, these results demonstrate that the commercial chemical light will not withstand environmental exposure in its foil-protective packaging.

Temperature and Humidity (Unpackaged). These units were subjected to the same environmental conditioning as the packaged units. The foil protective packaging was removed prior to starting the environmental conditioning. Samples were withdrawn and tested at 2, 4, 7, 10, and 14 day intervals. Analysis of this data shows that a significant decrease in output occurs as a result of this conditioning regardless of the withdrawal time, as shown in Figure 14. These results show that the unit is incapable of withstanding environmental exposure for any period of time without the foil protective packaging.

Salt Spray (Packaged and Unpackaged). The results of these two test conditions are discussed collectively because the results are essentially the same. Analysis of the test results revealed a statistically significant decrease in light output when compared with the control (ambient) sample. Although the output decrease may not be significant from a practical standpoint (Figure 15), it does indicate a weakness of the unit to withstand moderate use environments.

Five Foot Drop (Packaged and Unpackaged). The commercial chemical lights satisfactorily passed this test in the packaged condition (none of the units activated). One of the 5 units tested without the foil packaging activated when subjected to this test and, thus, failed the requirements of the test.

TABLE 2

COMMERCIAL CHEMICAL LIGHT
OUTPUT SUMMARY

Conditioning		Samples	Output (FL/CM) At Time (Minutes)								Estimated Visibility Range (Ft) At Time (Minutes		
			2	10	30	60	120	180	240	300	10	30	60
Control	+40°F	12	18.03	18.53	17.29	12.54	6.31	3.39	1.87	1.28	4860	4730	4158
	Ambient	12	25.92	20.28	16.78	12.03	6.12	3.36	1.81	1.21	5033	4674	4089
	+110°F	12	33.77	31.11	25.23	14.72	6.00	3.89	2.71	2.72	5930	5477	4436
Temperature & Humidity	2 days	3	20.10	15.07	13.00	10.07	5.83	3.30	1.73	0.90	4473	4218	3799
Packaged	4 days	3	19.67	14.53	13.00	10.16	6.00	3.40	1.87	0.97	4415	4222	3816
	7 days	3	10.73	12.90	12.67	9.90	6.07	3.57	2.00	1.20	4204	4170	3774
	10 days	3	11.63	10.67	12.53	10.03	6.60	3.93	2.27	1.30	3778	4130	3794
	14 days	3	0.13	0.87	3.70	6.57	7.13	5.50	3.53	3.07	966	2242	2967
Temperature & Humidity	2 days	3	18.77	14.23	12.10	9.53	5.87	3.30	1.83	0.97	4375	4099	3714
Unpackaged	4 days	3	3.23	9.47	11.93	10.67	6.87	4.07	2.43	1.33	3705	4072	3894
	7 days	3	13.23	13.57	12.70	10.23	6.30	3.60	2.07	1.03	4292	4178	3826
	10 days	3	0.53	1.63	4.00	6.03	6.10	4.63	3.53	2.37	1713	2560	3057
	14 days	3	0.00	0.00	0.17	0.73	0.40	1.77	1.33	1.80	0	334	1183
Salt Spray - Packaged		12	19.14	18.08	15.78	11.93	6.88	3.84	2.11	1.07	4811	4562	4076
Salt Spray - Unpackaged		12	20.64	17.96	14.91	11.49	6.80	3.85	2.14	1.04	4799	4458	4012

NOTE: Estimated Visibility Range is based on 5 mile meteorological range and 90% probability of target acquisition. The chemical light is assumed to be an ideal volume emitter.

FIGURE 11

TYPICAL AMBIENT TEMPERATURE LIGHT OUTPUT
OF COMMERCIAL CHEMICAL LIGHT

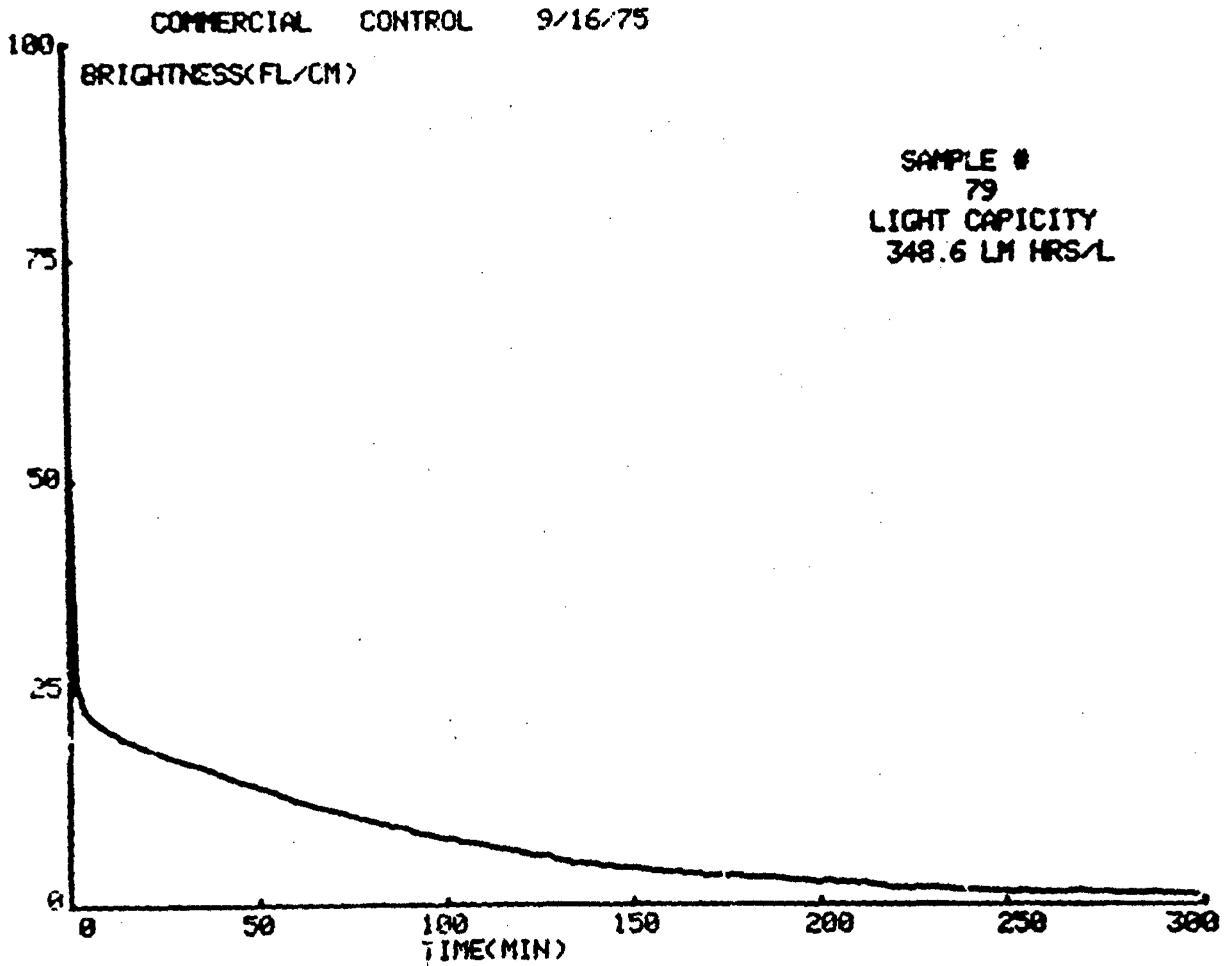


FIGURE 12

TYPICAL LOW TEMPERATURE LIGHT OUTPUT
OF COMMERCIAL CHEMICAL LIGHT

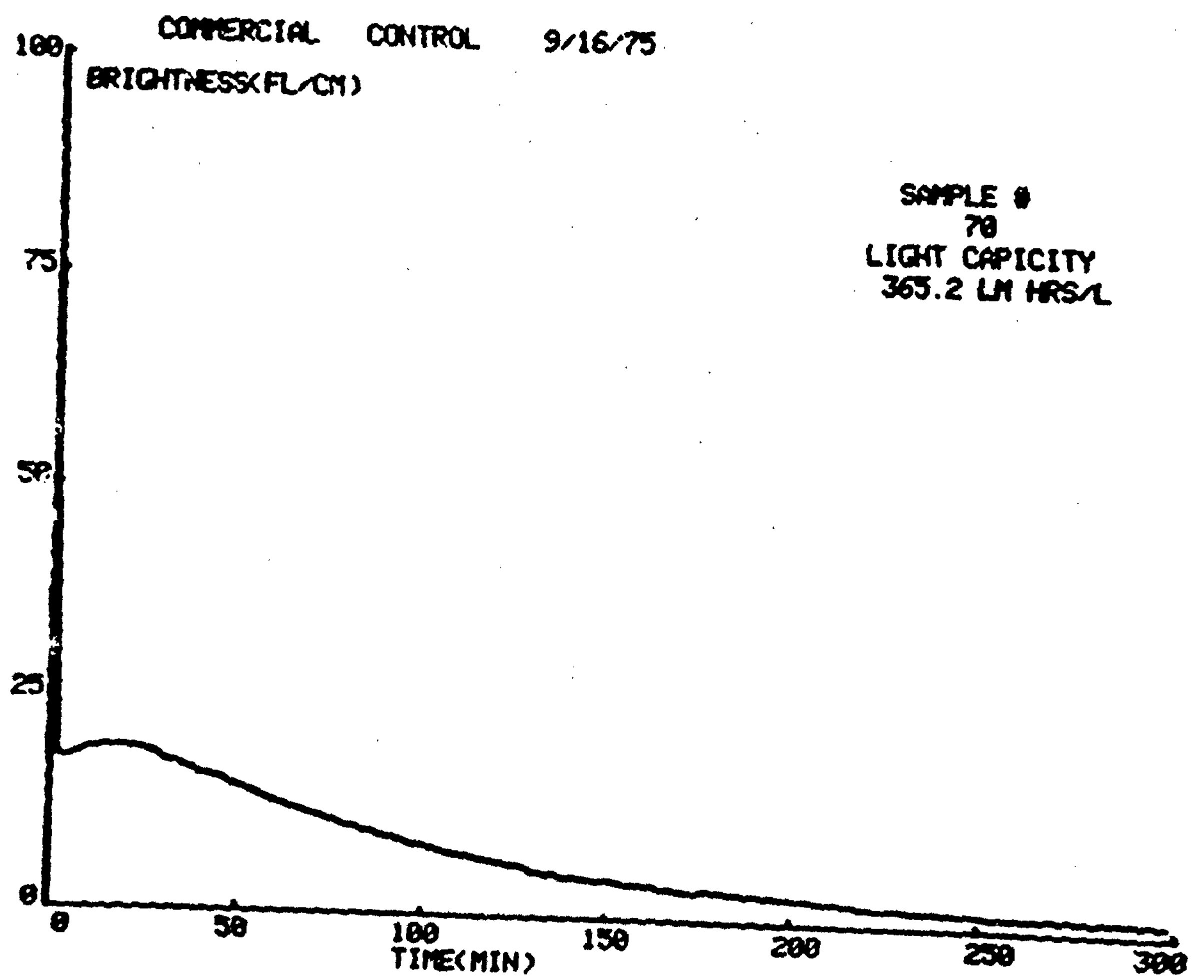


FIGURE 13
EFFECT OF TEMPERATURE AND HUMIDITY CONDITIONING
ON LIGHT OUTPUT OF PACKAGED COMMERCIAL CHEMICAL LIGHT

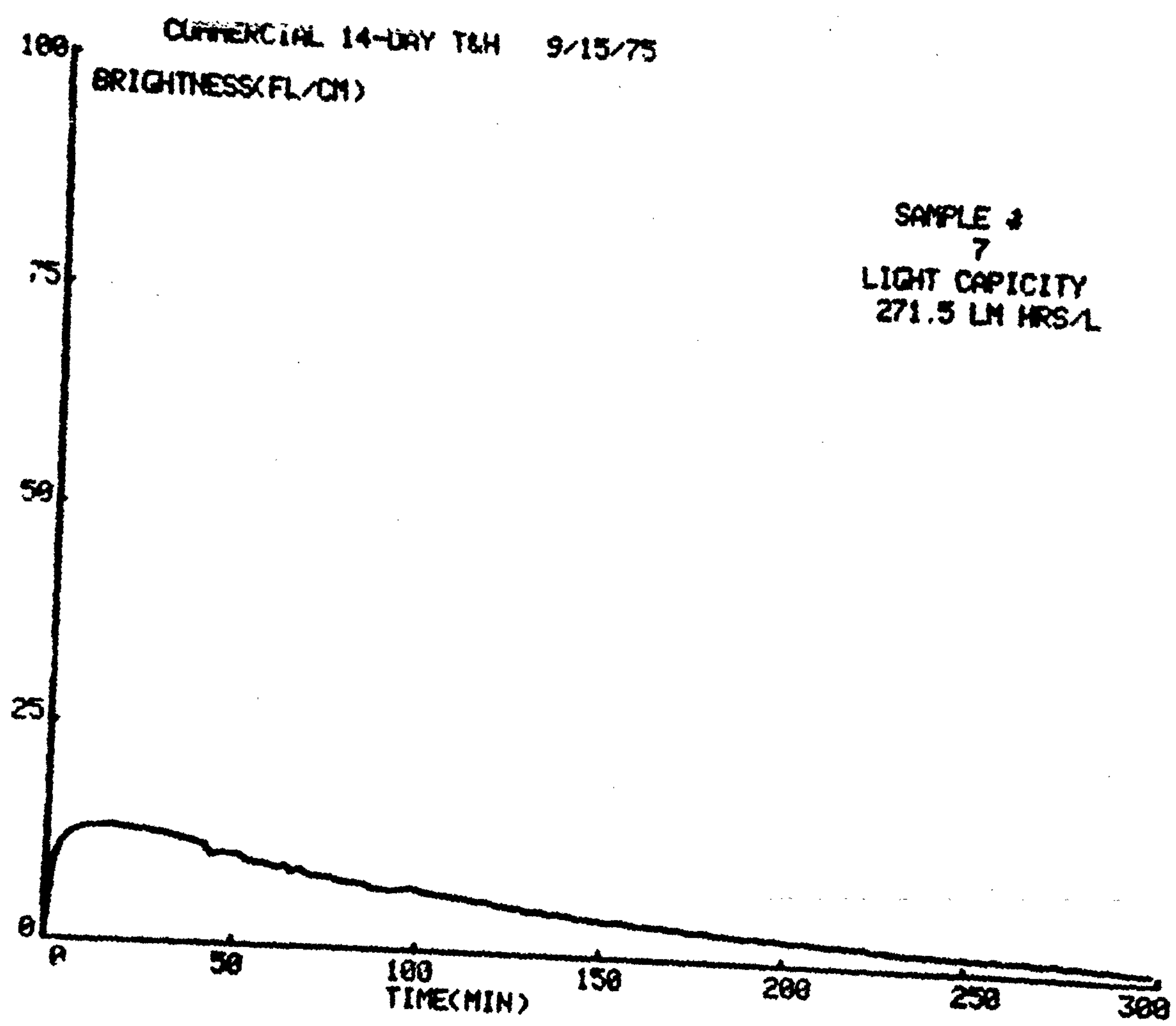


FIGURE 14

EFFECT OF TEMPERATURE AND HUMIDITY CONDITIONING
ON LIGHT OUTPUT OF UNPACKAGED COMMERCIAL CHEMICAL LIGHT

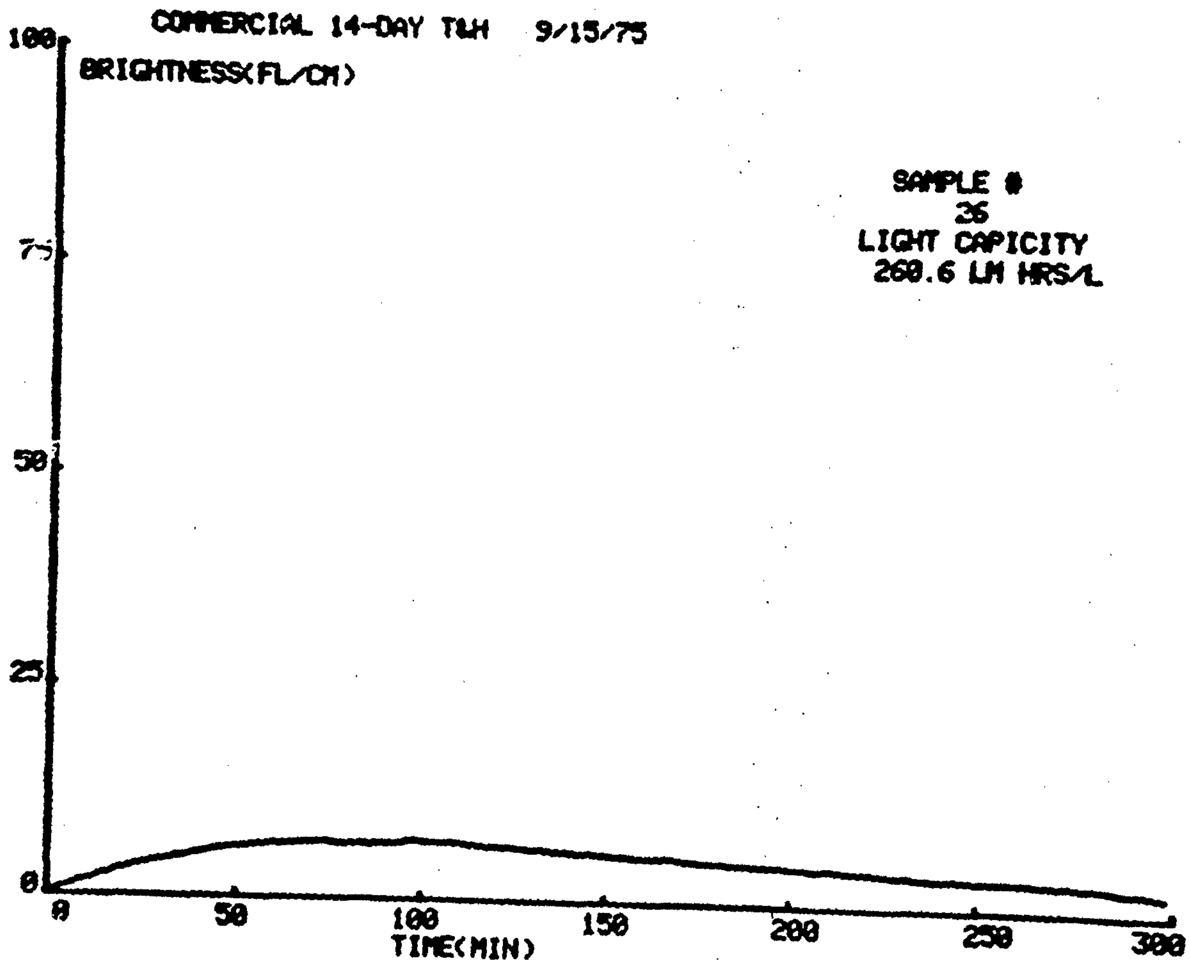
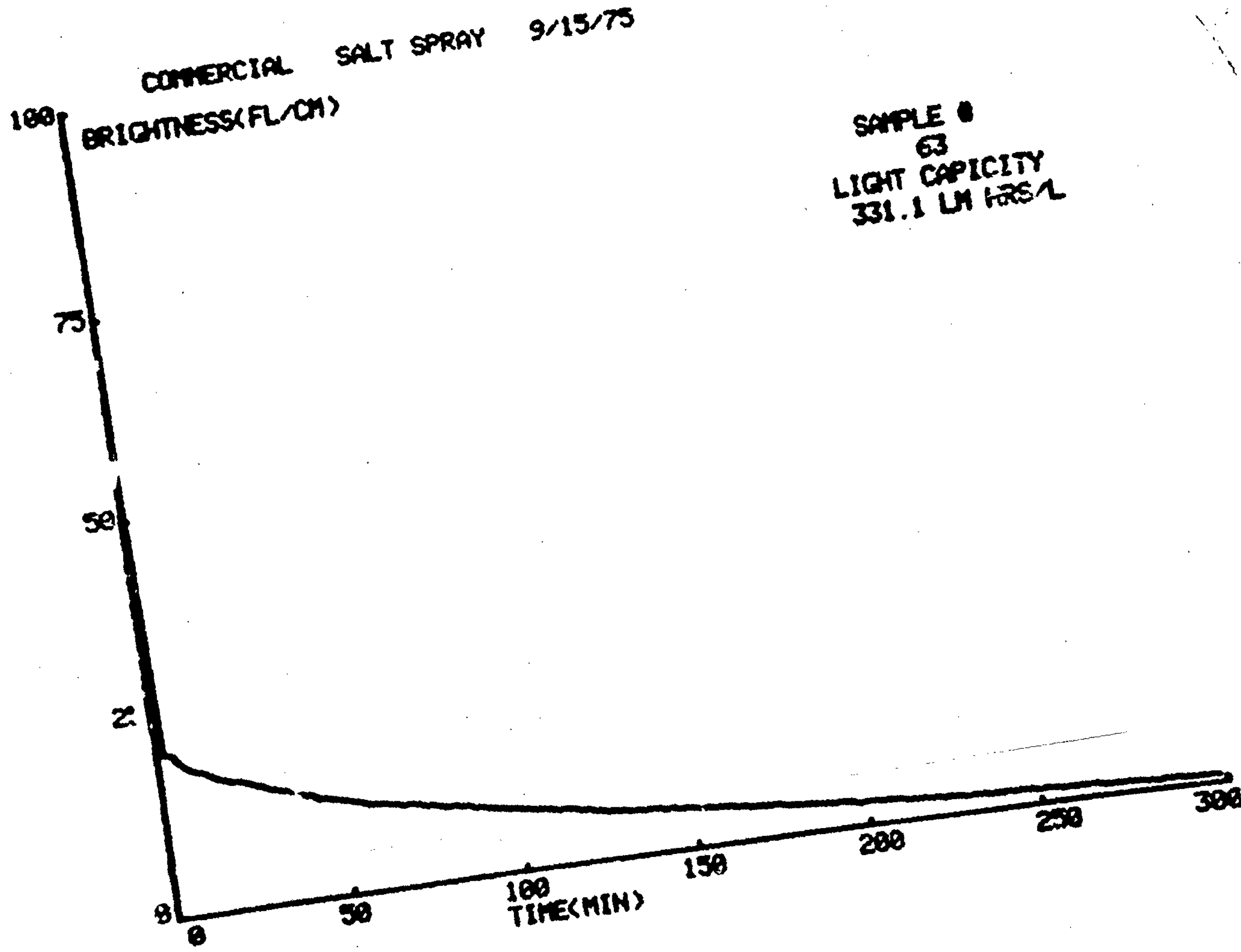


FIGURE 15

EFFECT OF SALT SPRAY ON LIGHT OUTPUT
OF COMMERCIAL CHEMICAL LIGHT



DOUBLE AMPULE CHEMICAL LIGHT:

General. The double ampule chemical lights tested in this program were the 4 inch (smaller) size. A 6 inch size unit has been previously produced, but hardware was not available to manufacture units for this program. Although the smaller size double ampule unit does not allow a good direct comparison of the estimated visibility range with the larger commercial chemical light (4800 feet vs. 7900 feet), it does allow a comparative determination of the environmental characteristics of the units. In this respect, the double ampule chemical light proved superior to the other two devices tested. A summary of the Laboratory Test Results is given in Table 3.

Control. Statistical analysis of the light output results has determined that there is no significant temperature effect on the light output. This is illustrated in Figures 16, 17, and 18.

Temperature and Humidity (Packaged). These units were subjected to the same environmental conditioning as the other test devices. The units were subjected to this conditioning in the metal protective tube designed for the units. Three units were withdrawn and tested following 2, 4, 7, 10, and 14 days of conditioning. Comparative analysis of the light output measurements with the ambient control data also shows that there was no significant effect upon the light output caused by this conditioning, as shown in Figure 19. Additional analysis of the data has also shown that there was no significant decrease in light output caused by exposure to this environmental conditioning for various lengths of time.

Temperature and Humidity (Unpackaged). These units were subjected to environmental conditioning without their protective metal tubes. Three units were withdrawn and tested following 2, 4, 7, 10, and 14 days of conditioning. Analysis of the light output data determined that there was no significant decrease in light output as a result of the varied conditioning times (Figure 20). Comparative analysis between the ambient control data and the packaged temperature and humidity data also showed that there was no significant difference in light output levels as a result of this conditioning.

Salt Spray (Packaged and Unpackaged). These test results were combined for this discussion because of the similar results obtained. Comparative analysis of this light output data with the control ambient data and the environmental conditioning data showed no significant difference in the light output levels (Figure 21).

Five Foot Drop (Packaged and Unpackaged). The units tested in the protective metal tube satisfied the requirements of this test, i.e., they did not activate. Without the protective tube, two of the five units tested activated and, thus, failed the requirements of the test.

TABLE 3

DOUBLE AMPULE CHEMICAL LIGHT
OUTPUT SUMMARY

Conditioning		Samples	Output (FL/CM) At Time (Minutes)								Estimated Visibility Range (Ft) At Time (Minutes)		
			2	10	30	60	120	180	240	300	10	30	60
Control	+40°F	12	25.48	16.37	8.75	4.56	3.69	2.46	2.01	1.68	3133	2386	1782
	Ambient	12	25.38	15.06	7.77	4.52	3.47	2.40	1.92	1.62	3029	2268	1775
	+110°F	12	27.92	20.29	9.39	4.98	3.93	2.34	1.48	1.46	3393	2435	1819
Temperature & Humidity	2 days	3	22.33	16.23	8.57	5.03	2.97	2.13	2.00	1.93	3130	2368	1868
Packaged	4 days	3	33.17	18.50	9.80	5.07	3.50	2.57	2.33	1.83	3380	2512	1871
	7 days	3	32.67	18.33	9.53	5.57	3.50	2.57	2.30	2.10	3296	2483	1953
	10 days	3	30.73	16.90	9.20	5.30	3.43	2.40	2.43	1.73	3184	2445	1913
	14 days	3	39.43	20.67	9.47	4.63	4.27	3.37	1.07	1.33	3466	2477	1797
Temperature & Humidity	2 days	3	28.80	15.40	7.70	4.60	2.93	2.00	1.90	1.63	3055	2257	1789
Unpackaged	4 days	3	27.80	16.00	8.43	5.10	2.70	1.80	1.70	1.37	3108	2350	1872
	7 days	3	33.23	18.43	9.57	5.43	3.40	2.43	2.30	1.90	3297	2481	1925
	10 days	3	30.50	16.90	9.47	5.40	3.03	2.07	1.97	1.83	3182	2478	1932
	14 days	3	40.77	23.07	10.03	5.20	3.60	1.30	1.37	0.27	3631	2539	1894
Salt Spray - Packaged		12	24.14	18.45	10.32	6.23	3.43	2.53	2.34	1.64	3300	2569	2050
Salt Spray - Unpackaged		12	27.63	16.89	9.62	5.63	[illegible]	2.37	2.22	1.49	3178	2493	1962

NOTE: Estimated Visibility Range is based on 5 mile meteorological range and 90% probability of target acquisition. The chemical light is assumed to be an ideal volume emitter.

FIGURE 16

TYPICAL LOW TEMPERATURE LIGHT OUTPUT OF
DOUBLE AMPULE CHEMICAL LIGHT

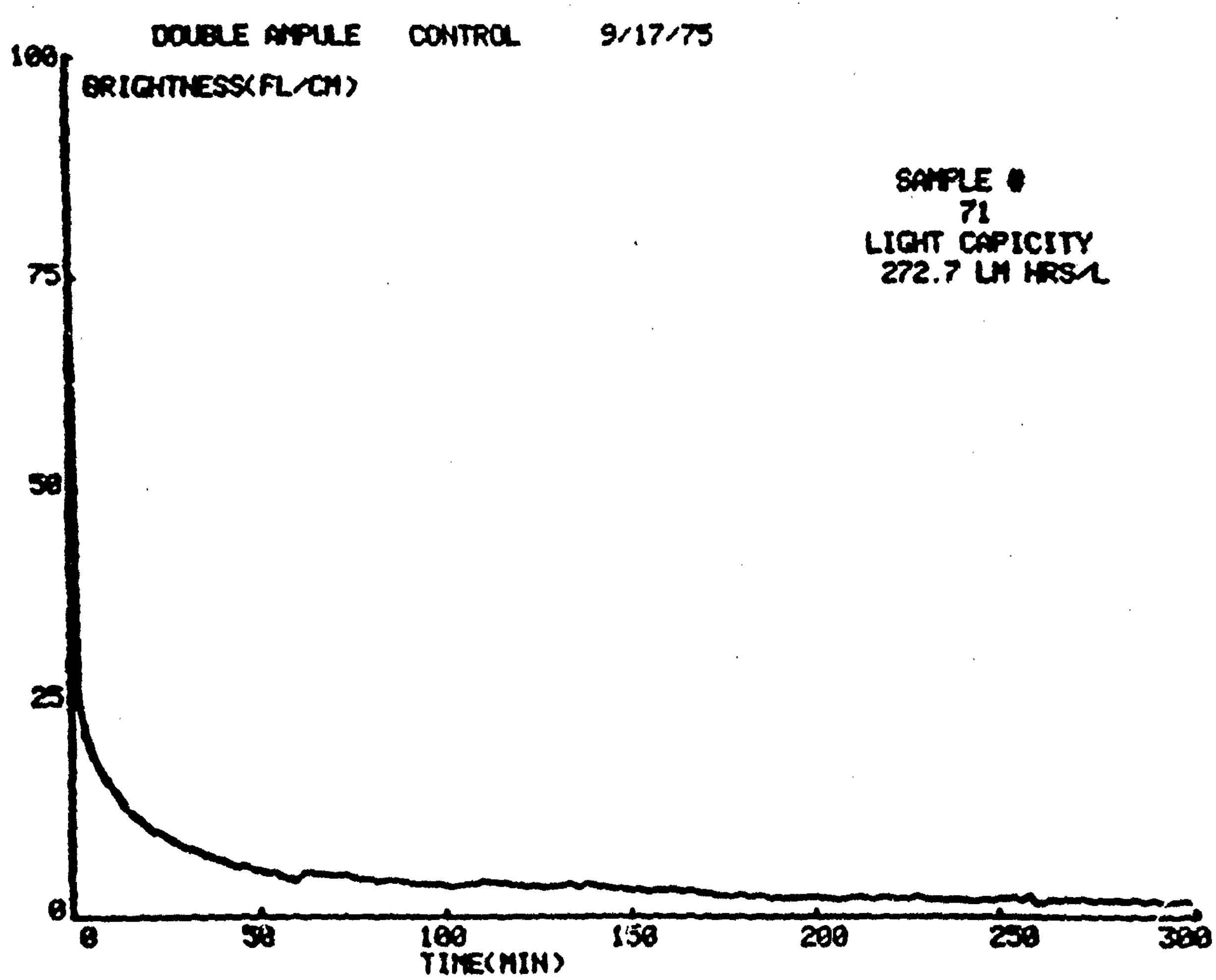


FIGURE 17

TYPICAL AMBIENT TEMPERATURE LIGHT OUTPUT
OF DOUBLE AMPULE CHEMICAL LIGHT

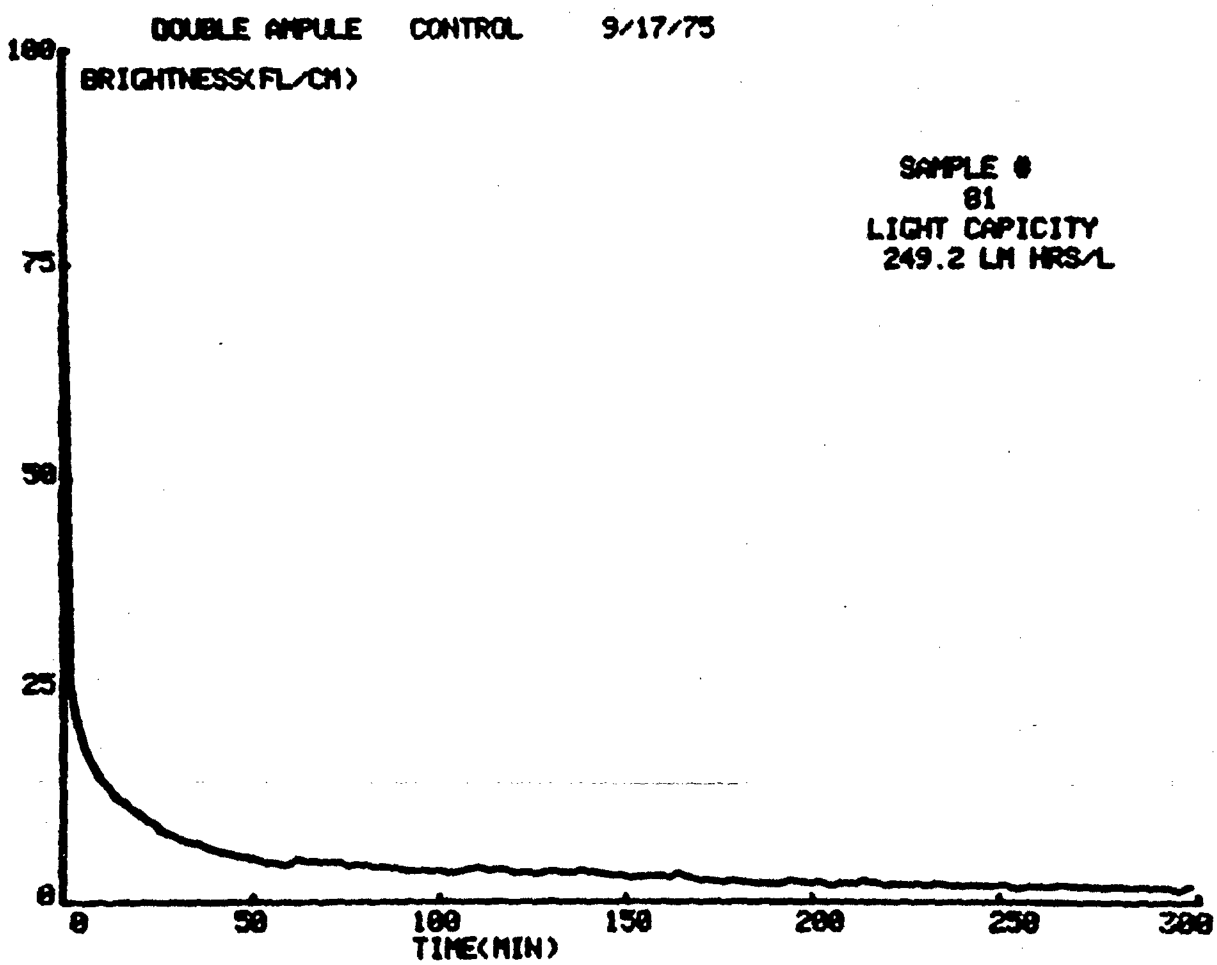


FIGURE 18

TYPICAL HIGH TEMPERATURE LIGHT OUTPUT
OF DOUBLE AMPULE CHEMICAL LIGHT

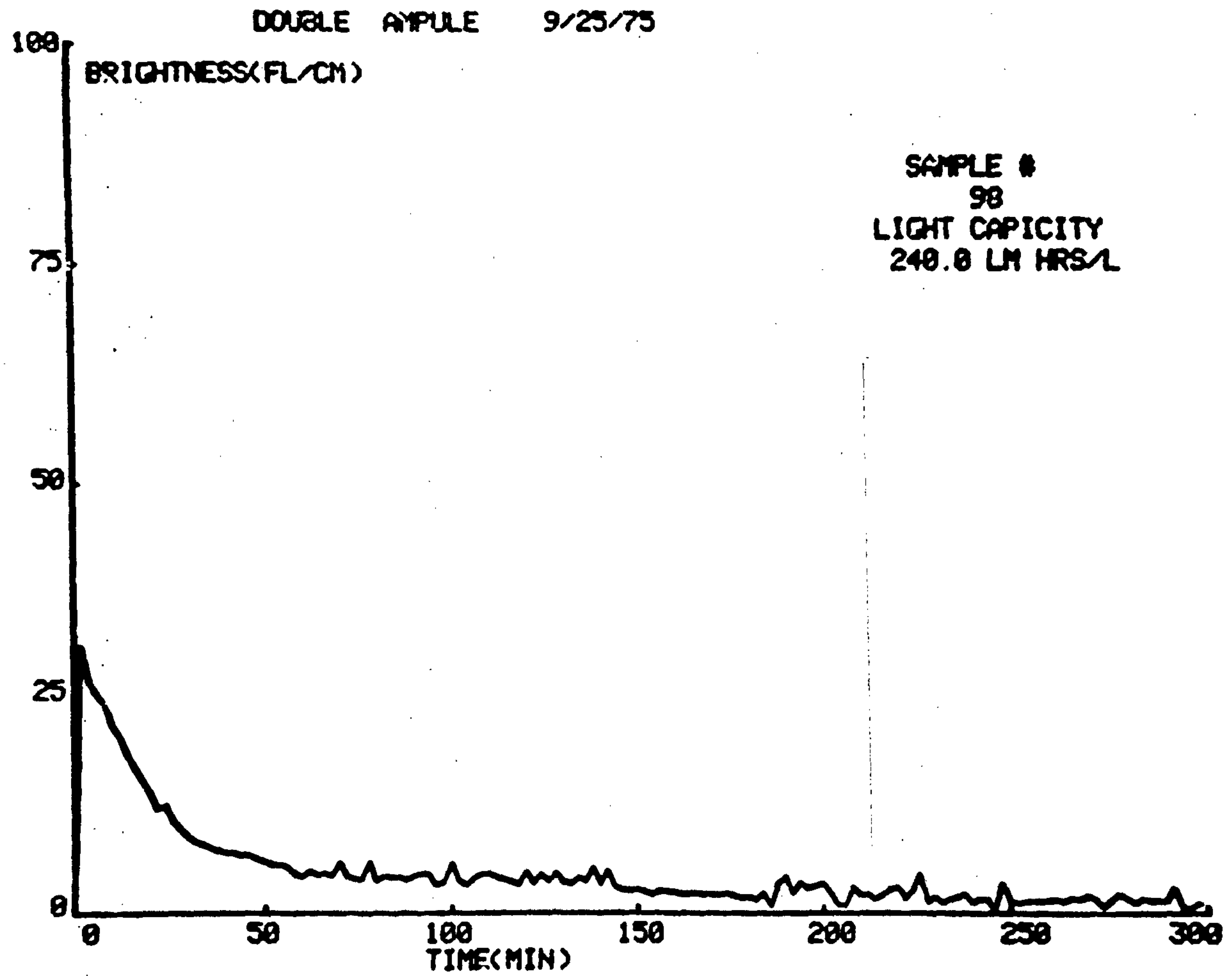


FIGURE 19
EFFECT OF TEMPERATURE AND HUMIDITY CONDITIONING
ON LIGHT OUTPUT OF PACKAGED DOUBLE AMPULE CHEMICAL LIGHT

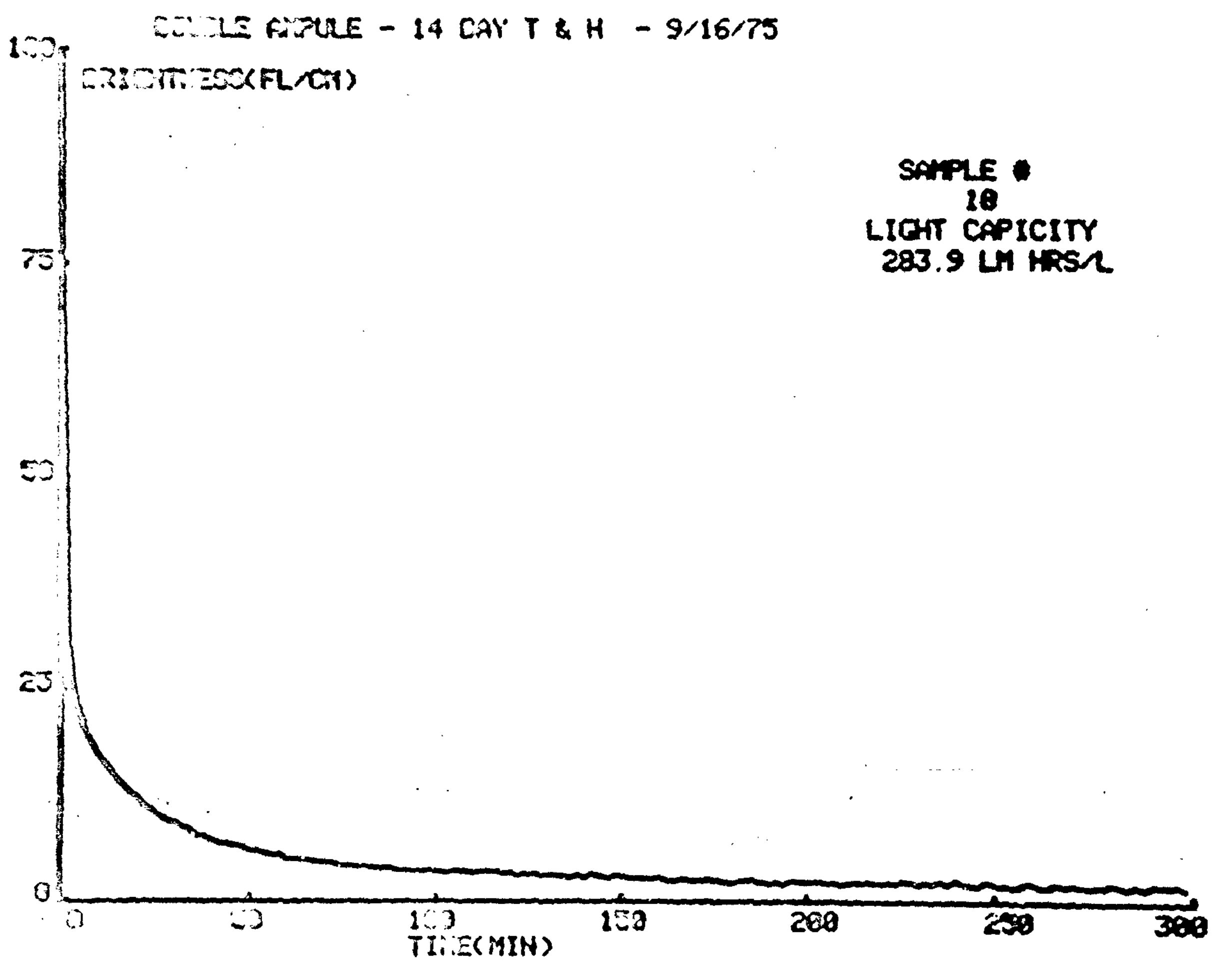


FIGURE 20

EFFECT OF TEMPERATURE AND HUMIDITY CONDITIONING ON LIGHT OUTPUT OF UNPACKAGED DOUBLE AMPULE CHEMICAL LIGHT

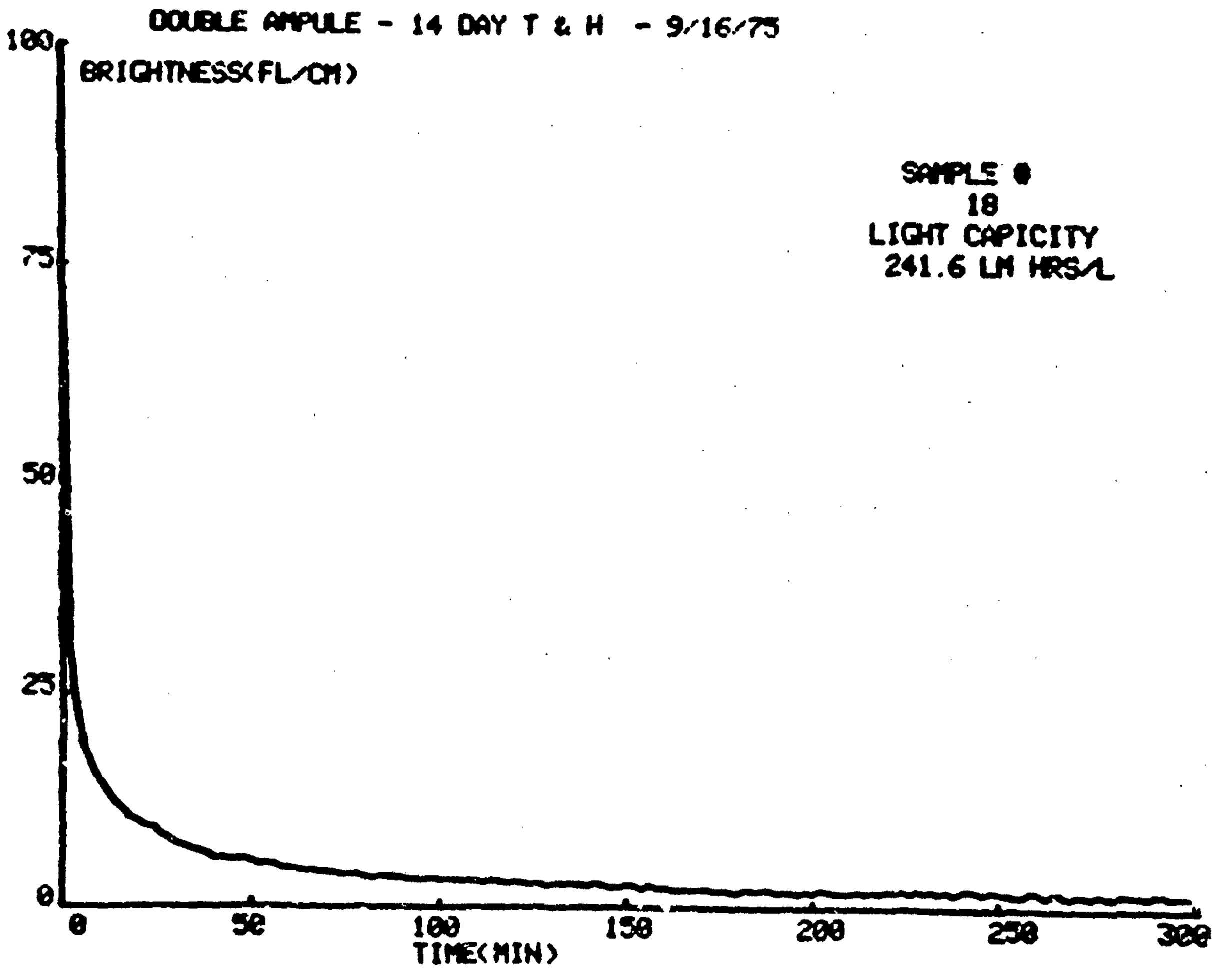
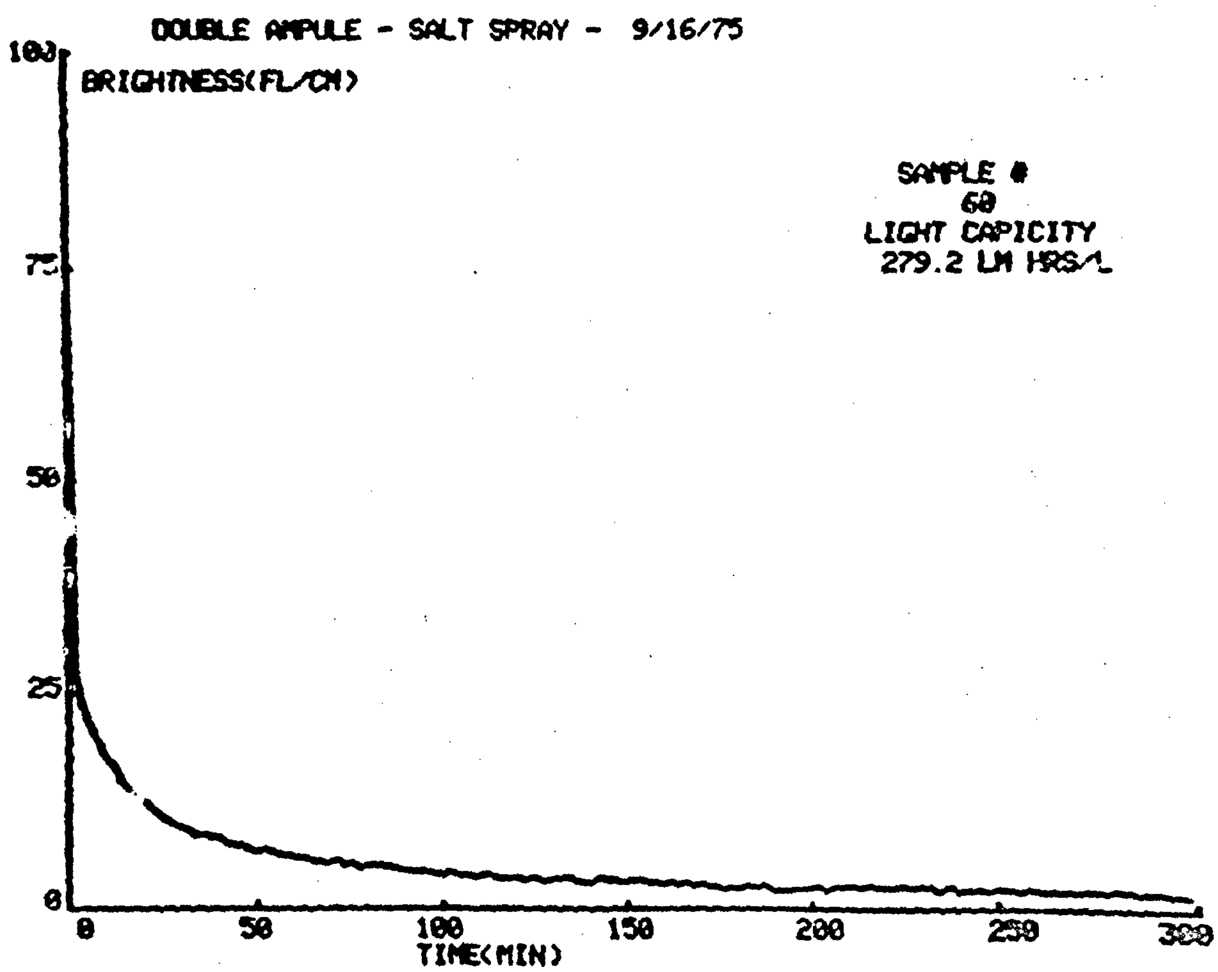


FIGURE 21

EFFECT OF SALT SPRAY ON LIGHT OUTPUT
OF DOUBLE AMPULE CHEMICAL LIGHT



LABORATORY TEST PROGRAM SUMMARY

Based on the light output measurements, estimated visibility ranges, and general performance of devices during the laboratory test program, specific advantages and disadvantages were determined for each of the devices. A summary of the general characteristics of each device is given in Figures 7, 8, and 9. The advantages and disadvantages determined by the Laboratory Test Program are as follows:

One Cell Flashlight:

Advantages:

(1) With the battery installed, this is the easiest device to activate.

(2) Capable of being shut off, thus extending the service life of the unit in use.

(3) Higher estimated visibility range after 3 or more hours of continuous operation due to the slower decay of the battery compared to the chemical lights.

(4) The unit is reuseable with replacement of the battery and/or bulb.

Disadvantages:

(1) An inventory of replacement components (batteries and bulbs) is required to extend the service life.

(2) Visible from only 180°.

(3) Periodic maintenance checks are required to insure operability.

(4) The reliability of the switch is suspect.

(5) The logistics are more complicated. (Storage, shipment and handling are required for three components. Assembly, testing of each component, and maintenance are required for continued operability).

COMMERCIAL (SINGLE AMPULE) CHEMICAL LIGHT:

Advantages:

(1) Once removed from its protective foil wrap, this device is the second easiest to activate.

(2) Visible for 360°.

(3) Highest estimated visibility range for the first hour of operation.

(4) Lowest initial unit cost of the devices tested in tnis program.

(5) Simplified logistics requirements.

Disadvantages:

(1) Will not withstand moderate environmental conditions. Because of this, a significant inventory turnover can be expected in order to maintain a satisfactory quantity of serviceable units, thus increasing the yearly operating costs.

(2) Exposure to light will reduce the units' light output due to degradation of the chemicals.

(3) The device is not reuseable and cannot be turned off once activated.

DOUBLE AMPULE CHEMICAL LIGHT:

Advantages:

(1) Only device capable of withstanding prolonged environmental exposure without a significant decrease in light output.

(2) Visible for 360°.

(3) No maintenance or replacement requirement.

(4) Simplified logistics requirements.

Disadvantages:

(1) Most difficult of the devices to activate due to the two glass ampules. which provide environmental integrity. However, the device can be activated with a one-hand operation.

(2) Exposure to light will reduce the units' light output due to degradation of the chemicals.

(3) This device is not reuseable and cannot be turned off once activated.

ONE-CELL FLASHLIGHT
CHARACTERISTICS

OPERATING LIFE:	Approximately 14 hours continuous operation.
COST:	G.T. Price Mfg., \$1.62 (\$1.53 flashlight + \$0.09 battery) Fulton, Mfg., \$0.95 (\$0.86 flashlight + \$0.09 battery) Listed price is \$0.99 without battery
SIZE:	G.T. Price Mfg., length - 3 3/4 in., diameter (max) - 2.1 in. Fulton - 4.4 in., diameter (max) - 2.1 in.
WEIGHT:	G.T. Price = 0.34 lbs. (with battery) Fulton = 0.37 lbs. (with battery)
EASE OF OPERATION:	Easy one-hand operation of standard flashlight switch.
RELIABILITY:	Estimated at least 84% at the 90% confidence level based on 8 defective switches of 90 units tested.
ENVIRONMENTAL FACTORS:	Suitable for marine and aircraft environments. Device is sealed and no special storage environments are required.
MAINTENANCE:	Device will require checking and probable battery replacement once or twice a year. Occasional bulb replacement would be required.
REUSEABILITY:	Device can be reused until battery is depleted. With replacement of battery or bulb, as required, hardware can possibly be used indefinitely, if switch is operable. Switch allows selective use of the device. Operating life is extended because of switch-off design.
LIGHT OUTPUT VS TIME:	Light output decreases in a linear fashion with decreasing battery output.
LIGHT OUTPUT VS TEMPERATURE:	No significant temperature effect was observed. However, battery output is known to decrease significantly at extremely low temperatures.
SHELF LIFE:	Storage life would be indefinite without the battery installed. With the battery installed, shelf life would be that of the battery, approximately 1 year.

OTHER FACTORS: Performance of the flashlight is directly related to the battery. Flashlight is a directional device and does not have the same visibility from all look angles. Flashlight cannot be used as an air dropped target marker.

COMMERCIAL CHEMICAL LIGHT CHARACTERISTICS

OPERATING LIFE:	Six to seven hours.
COST:	$0.78 for six inch device, $0.39 for four inch device.
SIZE:	Length = 6 inches, Diameter = 0.6 inches Length = 4 inches, Diameter = 0.5 inches
WEIGHT:	Six inch device = 0.04 lbs.; four inch device = 0.02 lbs.
EASE OF OPERATION:	Device can be activated with one-hand operation. Protective foil packaging may present some difficulty in removing if only one hand is available.
RELIABILITY:	Device is 100% reliable, except following prolonged environmental exposure.
ENVIRONMENTAL FACTORS:	Device is suitable for use in a marine or aircraft environment. Device will not withstand prolonged storage with temperature fluctuations and high humidity.
MAINTENANCE:	None
REUSEABILITY:	Device cannot be reused. Once activated, chemical reaction cannot be "turned-off" and restarted.
LIGHT OUTPUT VS TIME:	Light output decreases expotentially with time.
LIGHT OUTPUT VS TEMPERATURE:	Light output is lower at lower use temperatures.
SHELF LIFE:	Undetermined. Devices are significantly affected by storage environment and individual unit variation. Six month maximum indicated under moderate storage conditions.
OTHER FACTORS:	Chemical components will degrade with exposure to light. Devices should be kept in foil packaging until use is required. Device cannot be checked to determine if chemical are still reactive prior to use. Volume emitter; light output is the same at all look angles. Device is a very good air dropped target marker.

DOUBLE AMPULE CHEMICAL LIGHT CHARACTERISTICS

OPERATING LIFE:	Six to nine hours
COST:	$2.50 for 10,000 units; $1.50 for 50,000 units (estimated costs). Cost may be reduced by replacement of metal packing tube with plastic tube.
SIZE:	Length = 5 3/4 inches, diameter = 0.56 inches
WEIGHT:	0.03 lbs.
EASE OF OPERATION:	Can be activated with one hand. Protective packaging can be opened and removed with one hand. Slightly more difficult to activate than the commercial light due to additional glass ampules protecting chemicals.
RELIABILITY:	100%
ENVIRONMENTAL FACTORS:	Suitable for marine and aircraft environments. No environmental storage requirements.
MAINTENANCE:	None
REUSEABILITY:	Device cannot be reused. Once activated chemical reaction cannot be stopped and restarted.
LIGHT OUTPUT VS TIME:	Light output decreases expotentially with time.
LIGHT OUTPUT VS TEMPERATURE:	Light output is lower at lower use temperatures.
SHELF LIFE:	Indefinite. Laboratory tests indicate minimum of 5 years.
OTHER FACTORS:	Chemical components will degrade with exposure to light. Devices should be kept in protective metal tube until use is required. Device cannot be checked to determine if chemicals are still reactive prior to use. Volume emitter; light output is the same at all look angles.

SUPPLEMENTAL LABORATORY TEST DATA:

In addition to the three devices tested during this program, the light output of several types of sea-water activated lights was also measured. These measurements were taken for supplemental information only. It was not the intent of this additional testing, nor was sufficient data available, for any comparative analyses.

The sea-water activated lights exhibited a greater light output than the two chemical lights or the one-celled flashlight. The greater light output resulted from the larger power supply and bulb of these lights. The light output, however, was shown to be directional. The limited supplemental data obtained and a brief discussion of the data are given in Appendix A.

FIELD TEST PROGRAM:

Field testing of the devices was originally scheduled for the second week of December 1975 in Puerto Rico. Unfortunately, adverse weather conditions and the lack of support equipment time due to search and rescue requirements prevented completion of the scheduled field test program.

A trial test was conducted, however, approximately two miles from the entrance to San Juan harbor. From this trial test, it was learned that the devices would have to be tested singly in order to obtain valid range data on each device. The trial test also confirmed that sufficiently accurate target acquisition ranges could be obtained from the helicopter navigational computer. A visibility detection range of approximately 3/4 mile was obtained during the trial test. This range was obtained between 45 and 60 minutes after activation of the devices.

Field testing of the devices was conducted from 10-19 May 1976 near Clearwater, Florida. Personnel and equipment for these tests were provided by Coast Guard Group, St. Petersburg, Coast Guard Air Station, St. Petersburg and Coast Guard Station, Clearwater. The assistance and cooperation of these personnel was invaluable in completing this program.

The actual testing of the devices consisted of actuating a device, attaching it to a float which simulated a person floating in the water, finding the device, and recording the visibility/detection range. The helicopter ranges were obtained from the on-board navigation computer, while the boat ranges were computed from the engine r.p.m. and the runout time until the signal disappeared.

The range data obtained during the field testing is given in Tables 4, 5, and 6 for the commercial chemical light, the double ampule chemical light and the one-cell flashlight, respectively. From the range data obtained, summary plots were made of the visibility ranges for each device. The summary plots are shown in Figure 22 (one-cell flashlight), Figure 23 (commercial chemical light), and Figure 24 (double ampule chemical light). The maximum visibility ranges from the aircraft and the boat are shown on each of these plots. It can readily be seen that, in most cases, the boat visibility range for a device was greater than the aircraft detection range. This occurred solely because of the test methods available to obtain the range data. The boat visibility ranges represent the maximum surface range in that the "target" was constantly in sight during the range determination. The aircraft detection ranges, however, represent the condition of looking for the target; thus the target had to become sufficiently visible from its' surroundings to be detected. The boat visibility ranges, therefore, reflect more of an ideal situation, while the aircraft detection ranges reflect more of an actual search and rescue situation.

Two factors affecting the visibility range of the devices became readily apparent during the field tests. These factors were backlighting and wave direction. The field tests were conducted 2-4 miles offshore from Clearwater, Florida and backlighting was obtained from the east,

TABLE 4

FLASHLIGHT
FIELD TEST RESULTS

TEST DATE	TEST CONDITIONS	AIRCRAFT HEADING(°)	LOCATION RANGE (miles)	TIME FROM ACTIVATION (minutes)	OBSERVATION DIRECTION FROM BOAT	VISIBILITY RANGE Yards	VISIBILITY RANGE Miles	REMARKS
May 10, 1976	Target 1-1/2-2 miles from shore,	350	0.3	76				Pilot's remark "best so far"
	full moon, ground haze, sea state	150	0.5+	80	W	1700	0.97	
	2, A/C altitude 500 feet	290	0.5	83	E	400	0.23	
		Unknown	0.2	87				
May 12, 1976	Target 4 miles from shore, full moon,	A/C computer not functioning			E	1000	0.57	
	clear, sea state 0 (calm)	properly and no data obtained.			S	1375	0.78	Very directional signal;
					W	950	0.54	light disappears and comes back on
May 17, 1976	Sunset 2014, wind SW @ 5 mph,				N	1050	0.60	
	target 4 miles from shore, no moon	090	---	114	S	500	0.28	
	light haze, swells 3-5 ft into beach,	270	0.5?	118	E	175	0.10	
	A/C altitude 500 ft, water 78°F				W	900	0.51	
May 19, 1976	Sunset 2015, wind NW @ 6-8 mph, target	270	0.5	71	S	not seen		Target confirmed at 0.3 mile
	3 miles from shore, sea state 2-3	090	0.5	73	W	800	0.45	Losing target in swells
	with moderate chop, no moon	180	0.8	76	N	310	0.18	
	light haze, A/C altitude 400 feet	360	0.5	79	E	1000	0.57	

TABLE 5

COMMERCIAL CHEMICAL LIGHT
FIELD TEST RESULTS

TEST DATE	TEST CONDITIONS	AIRCRAFT HEADING(°)	LOCATION RANGE (miles)	TIME FROM ACTIVATION (minutes)	OBSERVATION DIRECTION FROM BOAT	VISIBILITY Yards	RANGE Miles	REMARKS
May 10, 1976	Target 1-1/2-2 miles from shore, full moon, ground haze, sea state 2, A/C altitude 500 feet.	180	0.3	Unknown	W	900+	0.51	A/C thought this was a white light, possibly a flashlight
		360	0.3	Unknown	E	800	0.45	
		090	0.1	Unknown				
		270	0.5	Unknown				
May 12, 1976	Target 4 miles from shore, clear, full moon, sea state 0 (calm)	A/C computer not functioning properly and no data obtained.			S	2100	1.19	
					W	2200	1.25	
					E	1250	0.71	
May 17, 1976	Sunset 2014. wind SW @ 5 mph, target 4 miles from shore, no moon, slight haze swells 2-5 ft into beach, no weights attached to float, A/C altitude 500 feet, water 79°F	090	---	5	N	1250	0.71	Flew by target, target to left of A/C
		270	0.9	8	S	1250	0.71	
		360	---	14	E	350	0.20	Flew by target; target to left of A/C
		360	1.5*		W	1750	[illegible]	*Range with A/C going away from target; looking 180°
		180	1.2	16				
		360	0.4	22				
May 19, 1976	Sunset 2015, wind NW @ 6-8 mph target 3 miles from shore, sea state 2-3 with moderate chop, no moon, light haze, A/C altitude 400 feet	[illegible]	0.25	2	S	1000	0.57	
		[illegible]	0.7	4	W	not seen		Suspect float turned from boat blocking visibility
		[illegible]	0.7	6	N	825	0.47	
		360	0.7	[illegible]	E	825	0.47	

TABLE 6

DOUBLE AMPULE CHEMICAL LIGHT FIELD TEST RESULTS

TEST DATE	TEST CONDITIONS	AIRCRAFT HEADING(°)	LOCATION RANGE (miles)	TIME FROM ACTIVATION (minutes)	OBSERVATION DIRECTION FROM BOAT	VISIBILITY Yards	RANGE Miles	REMARKS
May 10, 1976	Target 1-1/2-2 miles from shore, full moon, ground haze, sea state 2, A/C altitude 500 feet	100	0.2	Unknown				
		320	0.6	Unknown	W	1350	0.77	
		270	0.2	Unknown				
		090	0.1	Unknown				
		180	0.2	Unknown				
May 12, 1976	Target 4 miles from shore, full moon, sea state 0 (calm), clear	A/C computer no functioning properly and no data obtained.			E	1075	0.61	
					S	1550	0.88	
					W	1650	0.94	
May 17, 1976	Sunset 2014, wind SW @ 5 mph, target 4 miles from shore, no moon, slight haze, swells 3-5 ft into beach, no weights attached to float, A/C altitude 500 ft, water 73°F.	360	---		N	500	0.23	Flew by target; target to left of A/C
		180	1.2(0.6?)	4	S	1400	0.80	Probable computer error - not updated
		090	0.5	8	E	700	0.40	
		270	---		W	1050	0.60	Flew to boat due to light reflection
		180	0.4	16				
May 19, 1976	Sunset 2015, wind NW @ 6-8 mph, target 3 miles from shore, sea state 2-3 with moderate chop, no moon, light haze, A/C altitude 400 feet	180	0.1	12	S	500	0.28	
		090	---		W	625	0.36	
		270	---		N	810	0.46	Light reported but disappeared - no range data
		360	0.2	20	E	1100	0.62	
		245	0.5					
		270	0.2	94	S	400	0.23	Very poor mark
		90	0.1	97	W	300	0.17	
		360	0.2	99	N	425	0.24	
		180	C.2	101	E	300	0.17	

FIGURE 22

FLASHLIGHT

SUMMARY PLOT OF FIELD TEST DATA

Visibility/Detection Range From:

+——+ Aircraft
0----0 Boat

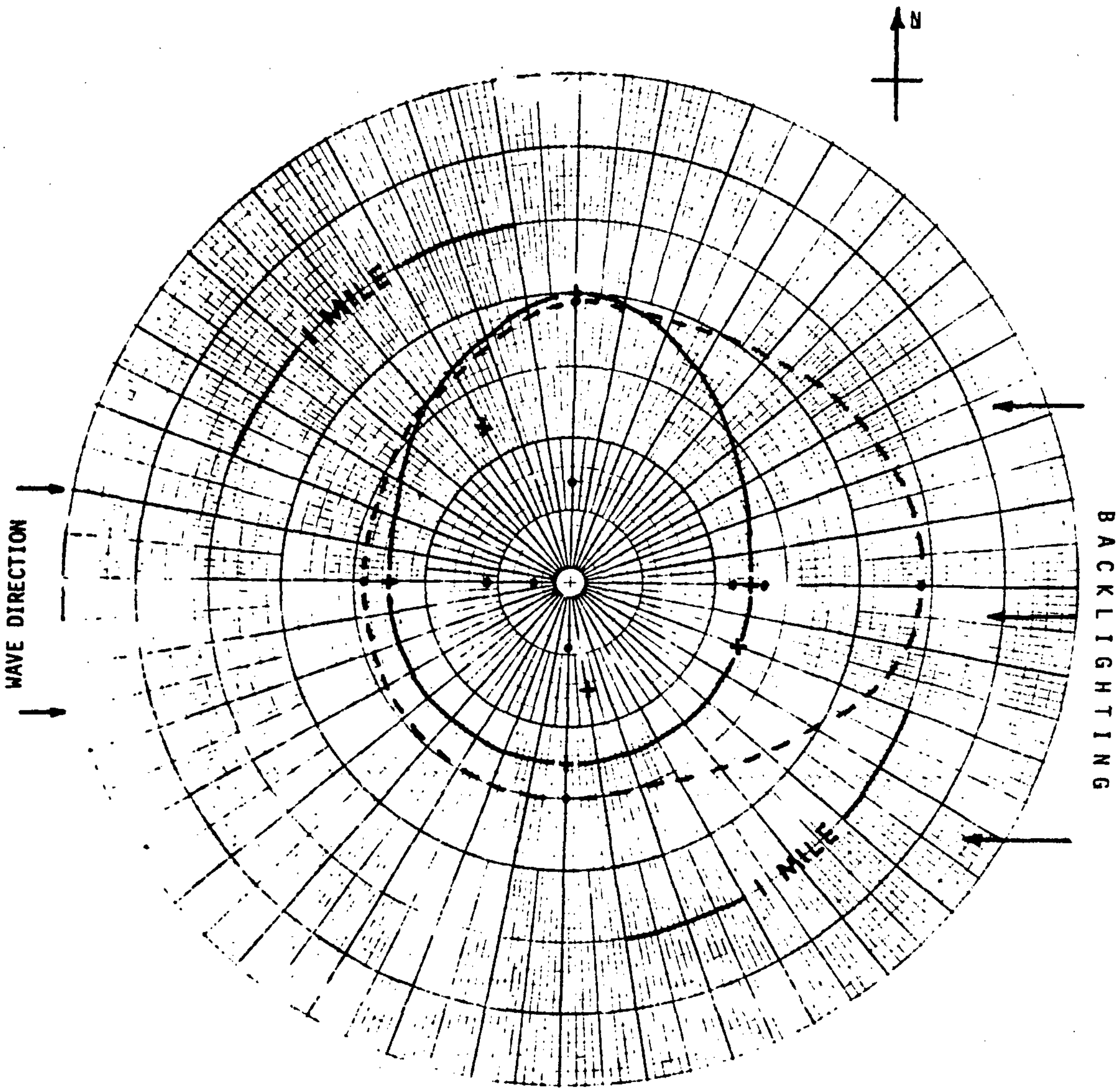


FIGURE 23

COMMERCIAL CHEMICAL LIGHT

SUMMARY PLOT OF FIELD TEST DATA

Visibility/Detection Range From:

+——+ Aircraft
0----0 Boat

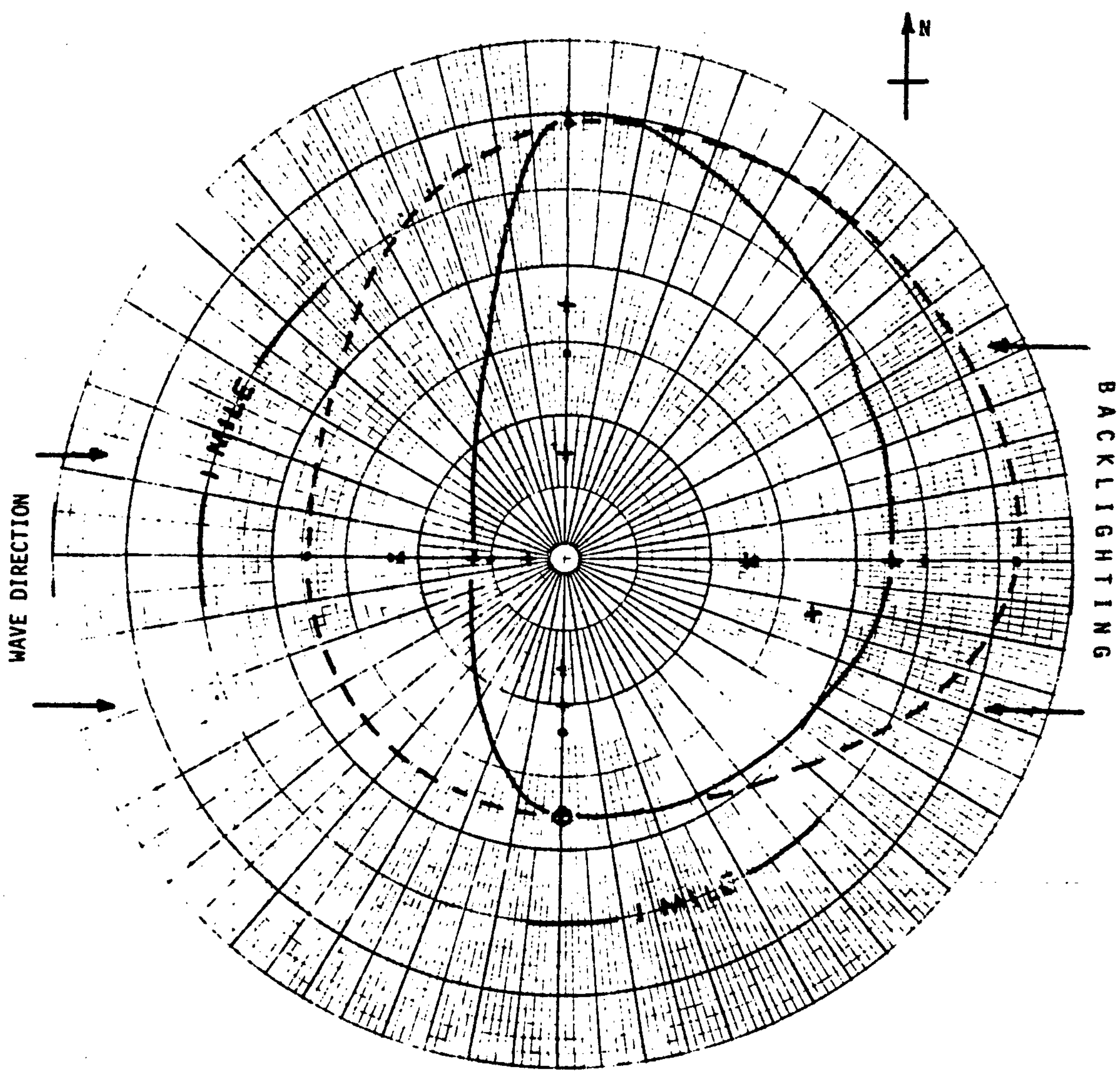


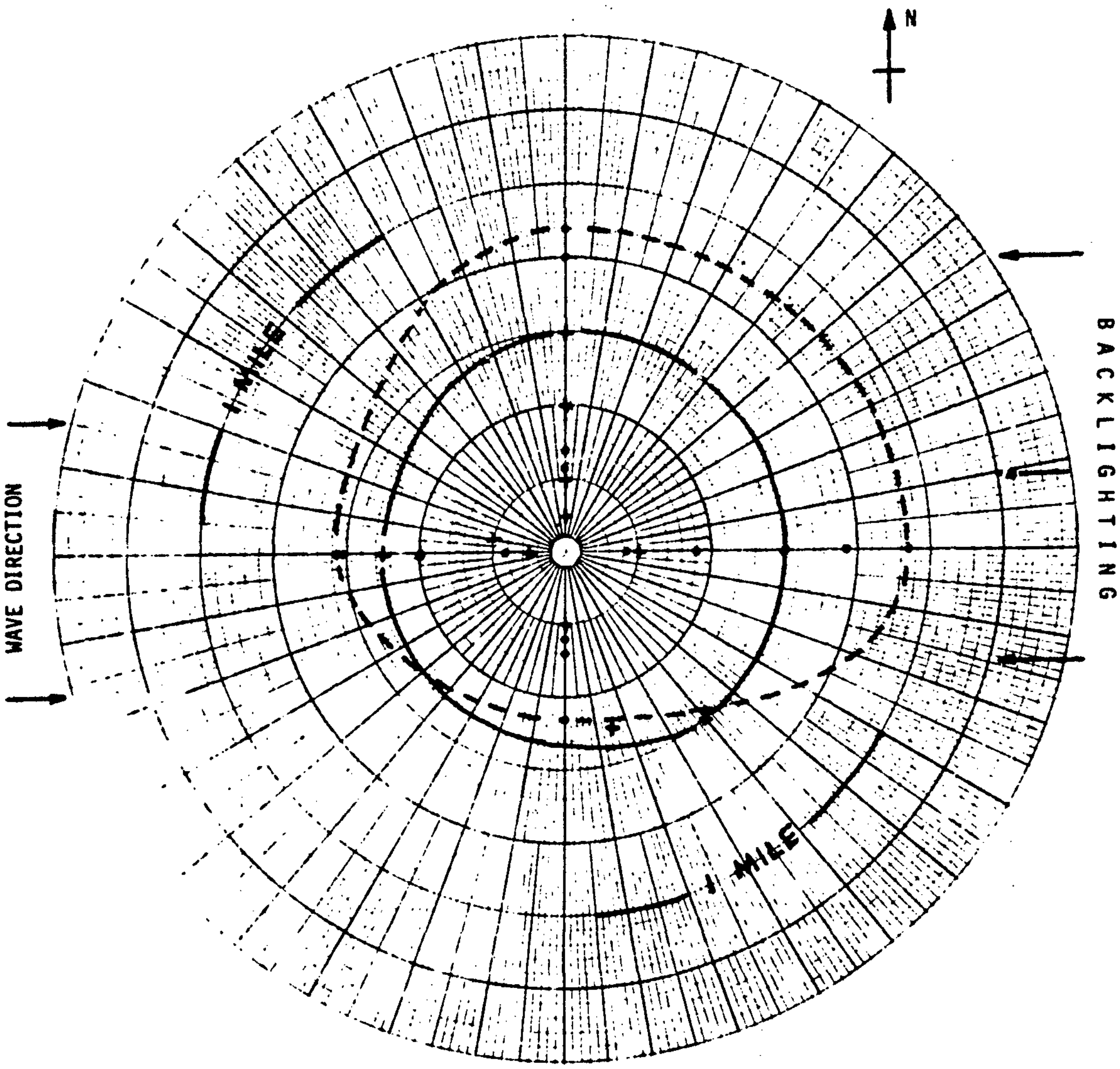
FIGURE 24

DOUBLE AMPULE CHEMICAL LIGHT

SUMMARY PLOT OF FIELD TEST EATA

Visibility/Detection Range From:

+——+ Aircraft
0----0 Boat



as shown on the summary plots. During the early tests of this program, a full moon was rising in the east and increased the backlighting. There was no moon during the later tests and, in general, visibility ranges were greater. The wave direction during the tests was from the west (open sea) to the east (into shore). Minor variations in the wave direction occurred due to changing wind direction and the proximity of the test site to the Clearwater Channel, but, in general, the wave direction was from west to east.

The effects of backlighting and wave direction are readily apparent when looking at the summary plots of the visibility ranges. All visibility ranges from west of the target were considerably reduced by these factors. Observations from north or south of the target were made down the trough of the waves; thus, a longer "look" time was available to the observer and longer ranges were obtained. Observations from east of the target were not affected by backlighting. The backlighting and wave direction factors affecting visibility are not new findings, but are noted to fully explain the test data obtained.

One night of the field test program was devoted to testing the devices in Tampa Bay. No significant quantitative data was obtained during these tests because of the high amount of backlighting and large number of lighted marker buoys in the test area. It was concluded from these limited tests that none of the devices provides a positive identification point under these adverse search conditions. However, the larger chemical lights will provide a satisfactory reference point for close-in rescue coordination.

Several conclusions can be made from the field test data obtained. These conclusions are:

a. The commercial chemical light (6 inch) has a greater visibility/detection range than the one-cell flashlight.

b. The double ampule chemical light (4 inch) has a visibility/detection range comparable with the one-cell flashlight.

c. The field test visibility ranges correspond approximately with the visibility ranges predicted from the laboratory test data.

(1) Commerical chemical light - maximum lab range - 1.50 miles
maximum field test range -
1.2 miles (A/C), 1.25 miles (Boat)

(2) Dougle ampule chemical light - maximum lab range - 0.91 miles
maximum field test range -
0.6 miles (A/C), 0.94 miles (Boat)

(3) One-cell flashlight - maximum lab range - 1.16 miles
maximum field test range -
0.8 miles (A/C), 0.97 miles (Boat)

d. None of the devices provides a positive identification point in conjested search areas, although all of the devices could serve as a point reference for close rescue work.

In summary, the field test program demonstrated that the chemical lights will perform satisfactorily as a rescue signal. The larger chemical light (6 inch commercial) demonstrated a greater visibility range than the one-cell flashlight.

SUPPLEMENTAL FIELD TEST DATA:

In addition to these devices, three other signalling devices were tested during the field test program. These devices were two prototype chemical light units and the standard strobe light. The additional devices were tested only to supply supplemental visibility/detection range information. The visibility/detection range information obtained and a brief discussion of the results are given in Appendix B.

CONCLUSIONS

The Laboratory Test Program and the limited Field Test Program did not establish any of the devices as superior to the others in all of the areas analyzed. This program did show that the chemical lights are at least comparable, if not superior, to the one-cell flashlight as a signalling device. The chemical lights also provide an easy to use, air-droppable marker for aircraft use.

The program results indicate that the six-inch single ampule chemical light will provide a better rescue light than the flashlight because of its higher initial visibility. The faster drop-off in light output of the chemical lights is partially compensated for by the fact that several of the smaller chemical lights can be carried in the space required for the bulkier flashlight. The chemical lights could be activated over a period of time, providing a good signal for many hours.

Although the single ampule chemical light offers advantages in initial acquisition range, versatility, durability, and initial procurement cost, serious consideration was given to the inability of this design to withstand prolonged storage. Indications from the laboratory tests are that degradation of the chemical components will occur between three and nine months after procurement with storage in a moderate environment. It may be possible to delay this degradation with storage in a controlled environment, but degradation will eventually occur. Because of this, consideration must be given to future replacement costs, whether or not the units are expended.

The double ampule chemical light eliminates this storage degradation problem. However, without knowing procurement quantities and use rate, an accurate cost estimate for procuring the double ampule chemical light cannot be made. It is felt, however, that the double ampule design would prove more cost effective over a prolonged period due to its ability to withstand environmental storage conditions.

RECOMMENDATIONS:

Based on the program results, it is recommended that a feasibility program be initiated within the Coast Guard for further analysis into the use of chemical light devices. This program should utilize one or more activites as data acquisition points. These activities should record the number of devices expended, time of storage prior to use, storage environment, general performance of the device, use applications, etc. From this data, use rate and storage life data can be generated for cost effectiveness analysis and logistics requirement determinations.

It is also recommended that only the larger six-inch chemical lights be utilized in this program because of their increased visibility. Because of their immediate availability, the six-inch single ampule commercial chemical light would be satisfactory for this program. By using this device, the initial procurement cost will be minimized and the expected field storage life of this device can be more accurately determined. It is felt, however, that the double ampule design will provide the best cost effectiveness with continuous use because of its indefinite storage life.

APPENDIX A

SUPPLEMENTAL
LABORATORY TEST DATA

SUPPLEMENTAL LABORATORY TEST DATA

Following completion of the field test program, NAVWPNSUPPCEN Crane conducted laboratory light measurement tests on two types of sea-water activated lights. Both of the lights tested are powered by sea-water activated batteries. The sea-water activated lights tested were:

1. "Survivor Locator Light", Marine Resources, Inc., Fern Park, Florida
2. "Rescue Lite", Chromalloy Electric Division, Hollywood, Florida

The data on these lights is limited because of the small number of units available and the time limitations for completing this program. The light output data for these signals is given in Tables A1 and A2. Graphic displays of the light output of each signal are given in Figures A1 through A12.

Testing of the devices was planned to consist of pre-conditioning at 0°F, +70°F (ambient), or +120°F followed by testing in sea-water at temperatures of +32°F, +65°F (ambient), and +80°F. Pre-conditioning of the devices was completed as planned; however, testing of the devices was accomplished only in sea-water at +32°F and +65°F because of a procedural error. On Tables A1 and A2, the first two units listed were pre-conditioned at +120°F, the middle two units at +70°F (ambient), and the last two units at 0°F. The sea-water temperature for the test is given on each table.

The light outputs measured show considerable variability between the units. However, the limited number of samples tested does not allow statistical analysis to determine the specific causes for this variability. Some factors considered to affect the light output are pre-conditioning temperature, test water temperature, and general condition of the battery. Both types of units tested have poor battery seals and the effectiveness of the batteries is dependent upon storage conditions.

Light distribution measurements were conducted on a "Rescue Lite" signal following the light output measurement. The light distribution determined for this signal is shown on Figures 13, A14, and A15. These measurements determined that the light output was directional and concentrated in the vertical and horizontal planes with very little output in between.

Two other sea-water activated devices ("Neptune NQ-1", C&S Associates, Concord, California and "Life Lite", Toto Electric Co., Ltd, Tokyo, Japan) were available, but could not be tested. Both devices have pulsating light outputs, which could not be recorded with the computer data program developed for this program. The development and checkout of additional computer analysis program was considered unwarranted in view of the overall program goals and limited time available.

The sea-water activated lights have greater light outputs and greater visibility ranges than the chemical lights or the flashlight due to the larger power supplies available. Although specific cost data is not available, all of these units are considerable more expensive than the chemical lights or flashlight.

TABLE A1

LIGHT OUTPUT DATA

7/7/76 SURVIVOR LOCATOR LIGHT 32 DEG F BATH

MAX BEAM CANDLEPOWER MEASURED AT 1.50 FEET
WITH A 1.5 INCH DIAMETER PHOTOPTIC COLOR CORRECTED PHOTOCELL.

CANDLEPOWER VS TIME(MIN)

SAMPLE#	2	10	30	60	90	120	150	180	210	240	270	290
1	0.427	0.465	0.462	0.49	0.50	0.52	0.51	0.51	0.51	0.51	0.51	0.53
2	0.467	0.513	0.507	0.53	0.53	0.52	0.54	0.56	0.57	0.64	0.66	0.67
3	0.511	0.520	0.530	0.58	0.62	0.61	0.59	0.59	0.59	0.63	0.64	0.63
4	1.152	1.246	1.321	1.34	1.27	1.26	1.31	1.26	1.26	1.26	1.29	1.30
5	0.608	0.626	0.663	0.67	0.69	0.70	0.72	0.74	0.75	0.75	0.75	0.77
6	1.089	1.111	1.155	1.16	1.17	1.21	1.25	1.28	1.25	1.26	1.27	1.25

ESTIMATED SIGHTING RANGE AT 5 MI VISIBILITY

SAMPLE#	10 MIN	30 MIN	60 MIN
1	8211.	8313.	8369.
2	8489.	8937.	8600.
3	8577.	8776.	8843.
4	11324.	11530.	11586.
5	9060.	9255.	9310.
6	10929.	11063.	11068.

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TABLE A2

LIGHT OUTPUT DATA

7/8/76 RESCUE LITE ROOM TEMP BATH

MAX BEAM CANDLEPOWER MEASURED AT 1,50 FEET
WITH A 1,5 INCH DIAMETER PHOTOPTIC COLOR CORRECTED PHOTOCELL.

CANDLEPOWER VS TIME(MIN)

SAMPLE#	2	10	30	60	90	120	150	180	210	240	270	298
7	3,535	3,589	3,566	3,68	3,78	3,81	3,75	3,43	3,85	3,71	3,24	3,12
8	0,840	0,871	0,900	0,86	0,84	0,80	0,78	0,77	0,76	0,77	0,81	0,78
9	0,146	0,164	0,137	0,14	0,13	0,13	0,13	0,13	0,13	0,13	0,12	0,12
10	1,200	1,259	1,288	1,31	1,21	1,20	1,17	1,14	1,09	1,04	1,03	1,03
11	1,336	1,390	1,393	1,36	1,37	1,33	1,32	1,30	1,29	1,28	1,27	1,27
12	1,629	1,750	1,790	1,70	1,64	1,64	1,64	1,64	1,61	1,62	1,61	1,61

ESTIMATED SIGHTING RANGE AT 5 MI VISIBILITY

SAMPLE#	10 MIN	30 MIN	60 MIN
7	15301.	15355.	15400.
8	10118.	10224.	10060.
9	5403.	5240.	5219.
10	11301.	11441.	11509.
11	11710.	11717.	11641.
12	12340.	12533.	12441.

FIGURE A1

+120°F CONDITIONING

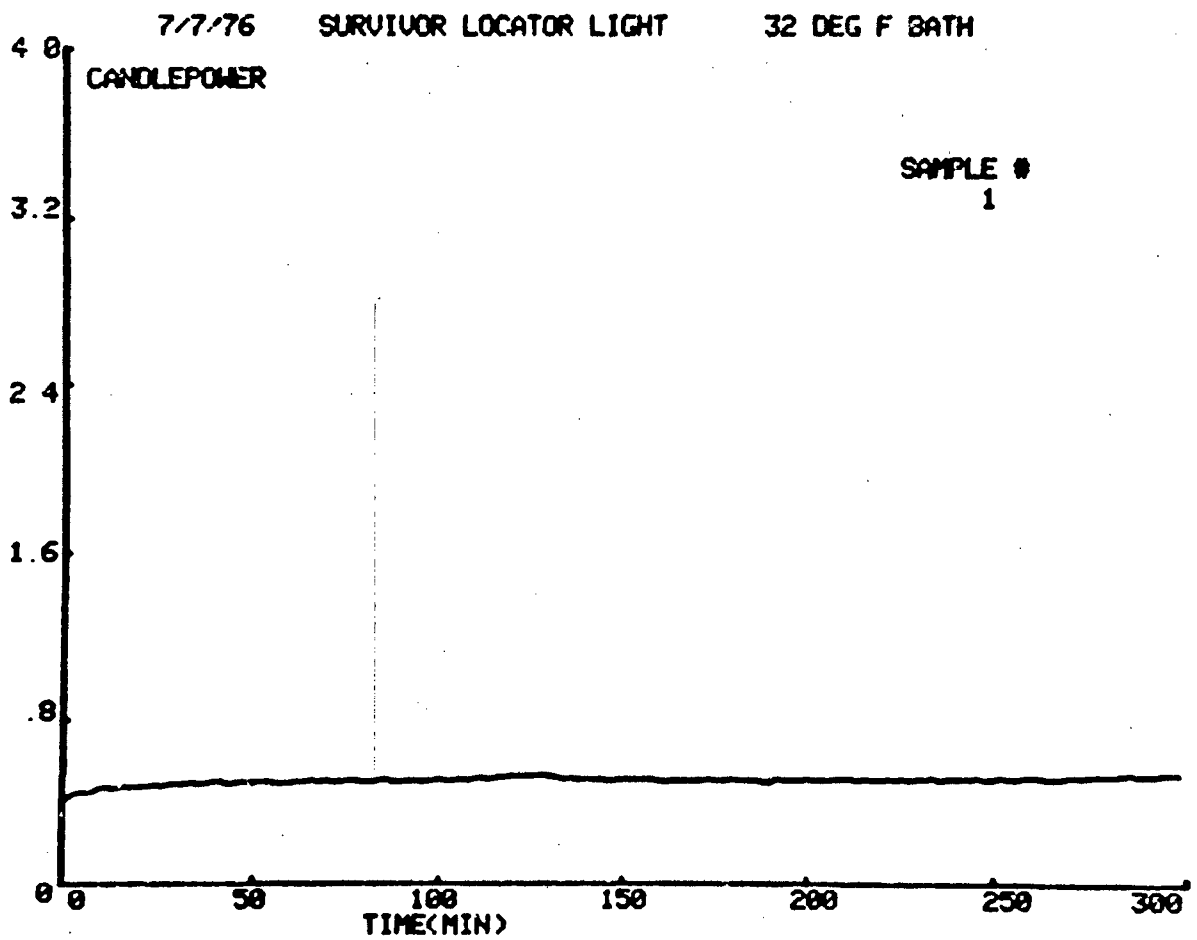


FIGURE A2

+120°F CONDITIONING

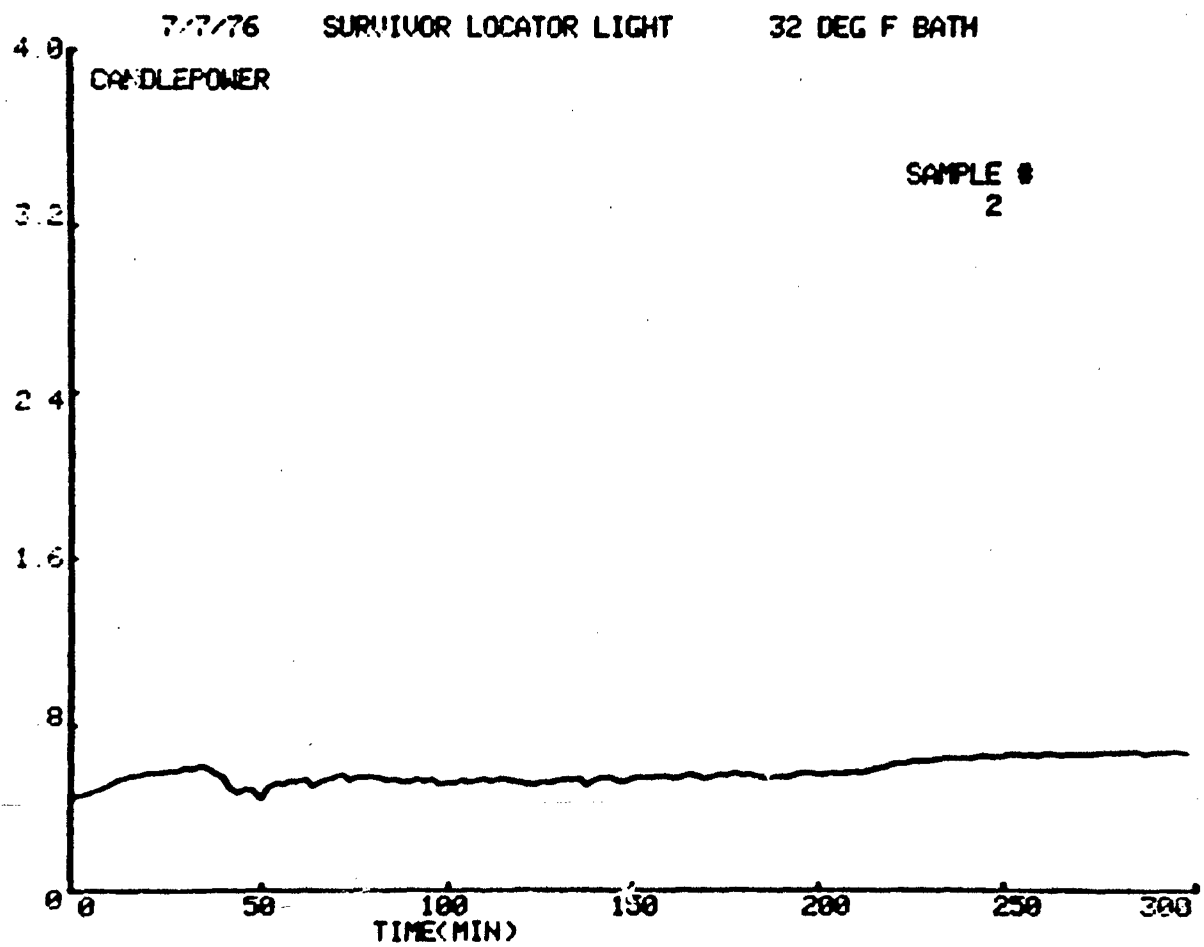


FIGURE A3

+70°F CONDITIONING

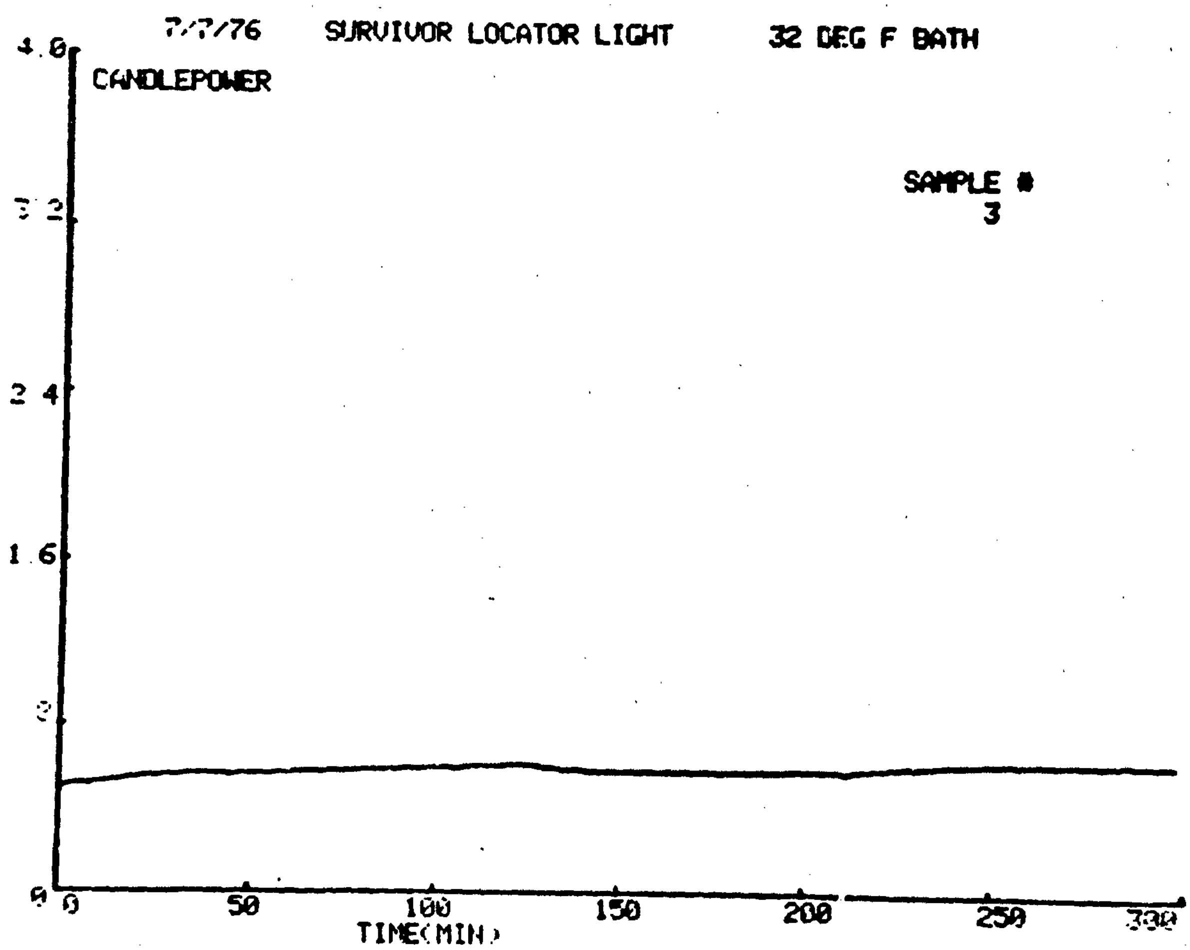


FIGURE A4

+70°F CONDITIONING

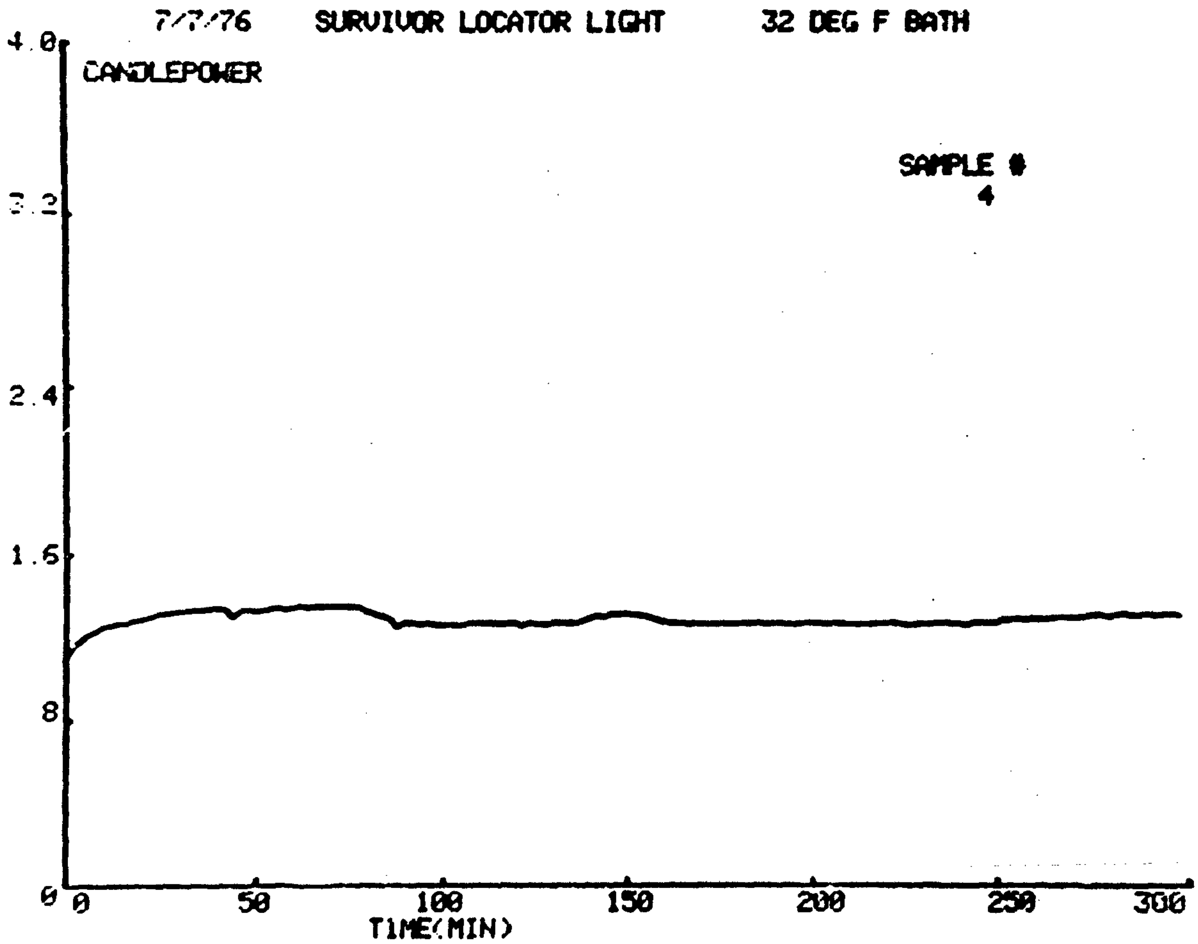


FIGURE A5

0°F CONDITIONING

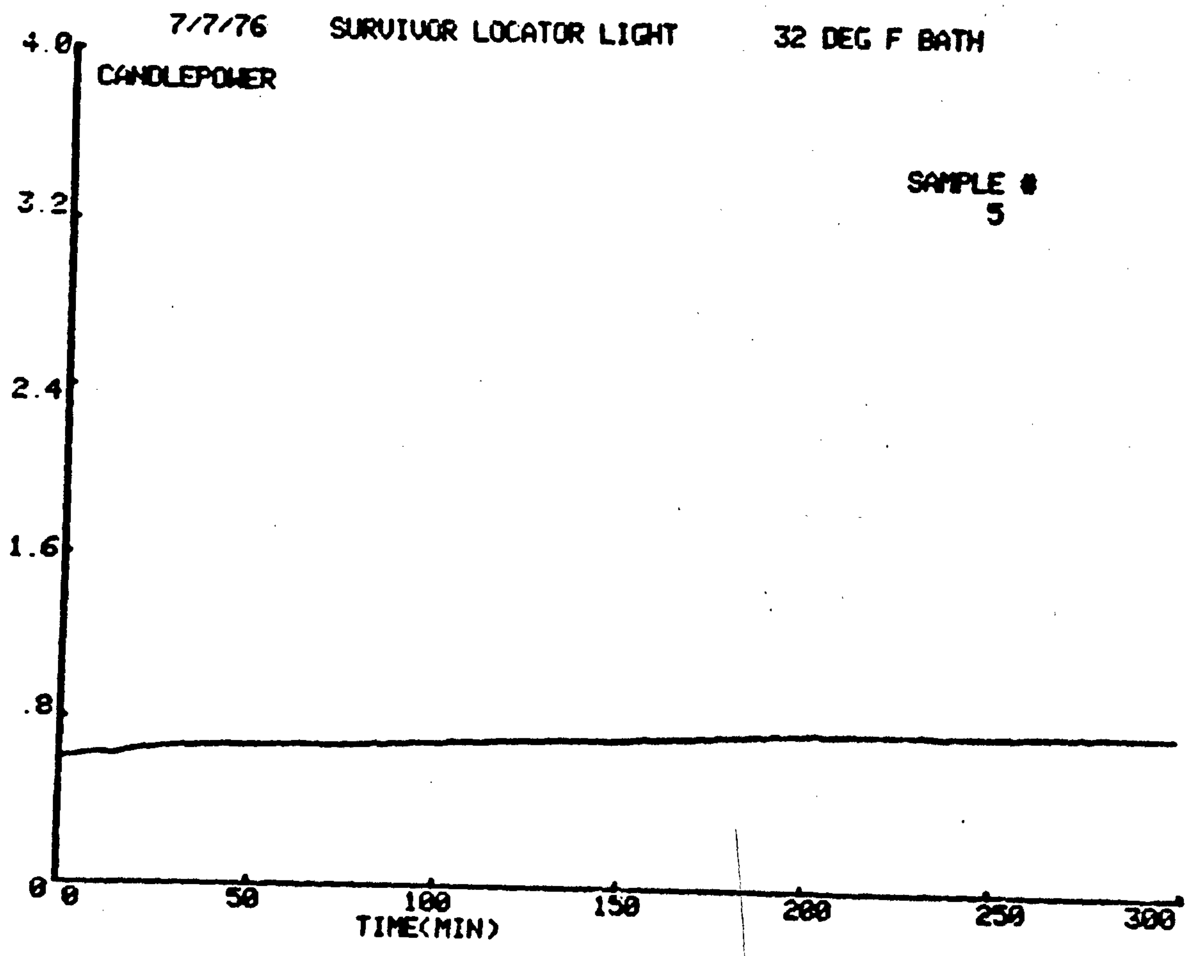


FIGURE A6

0°F CONDITIONING

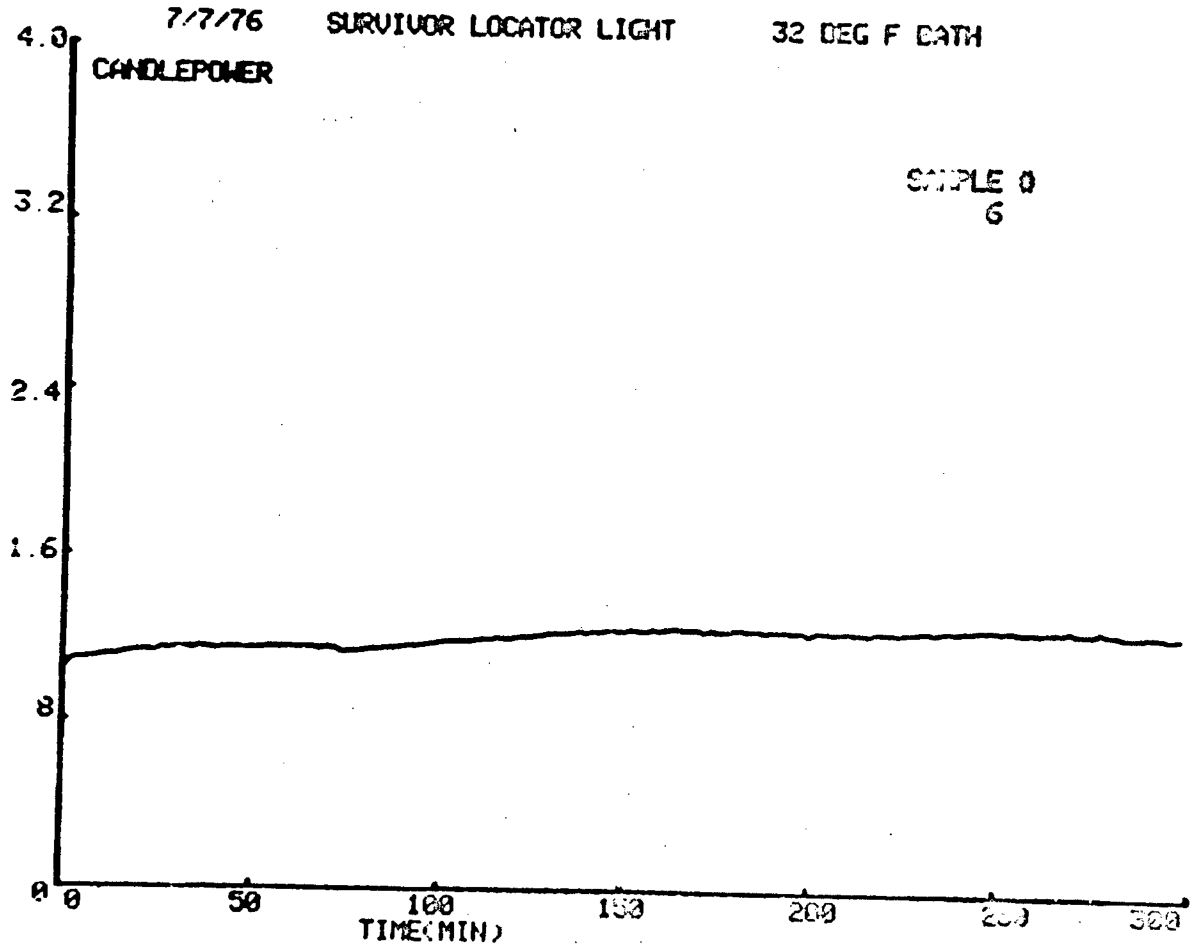


FIGURE A7

+120°F CONDITIONING

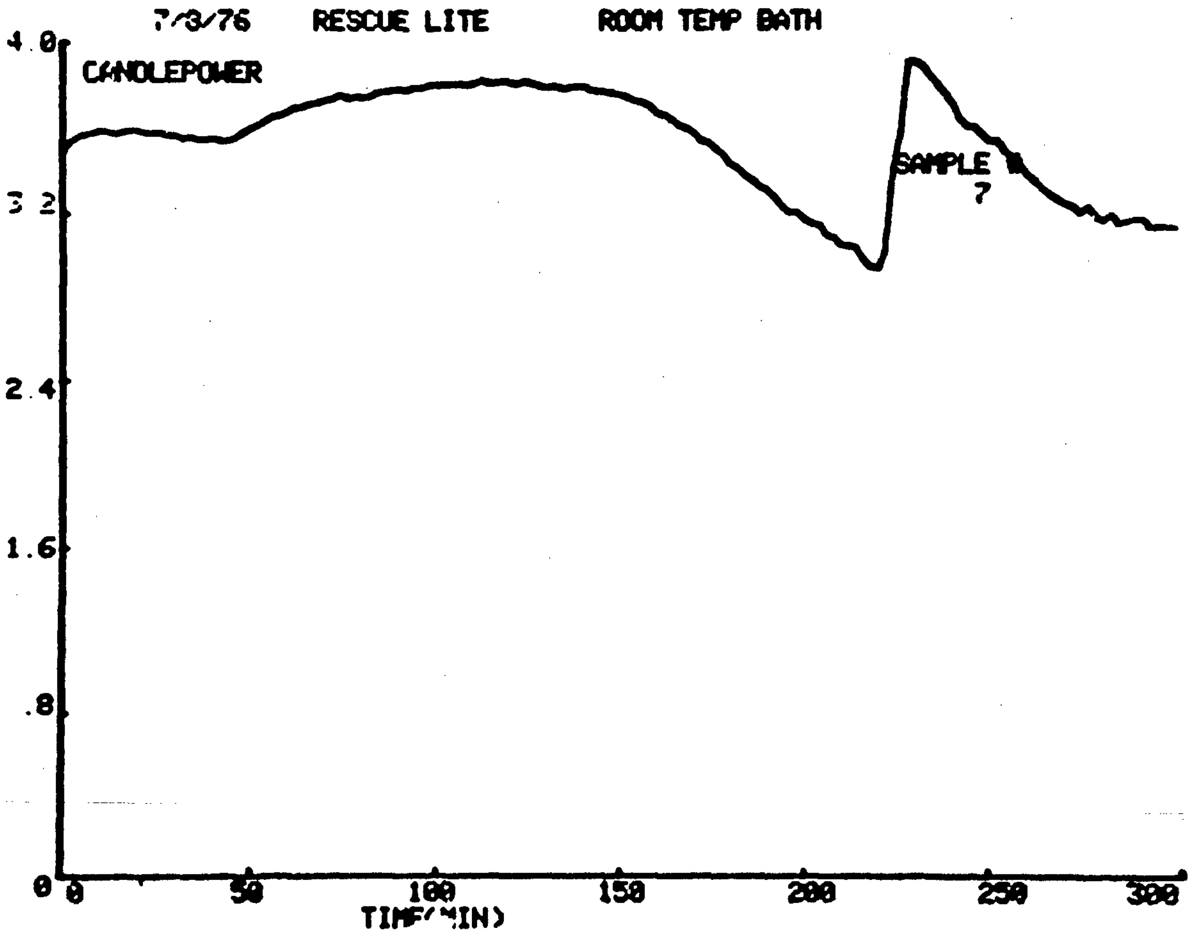


FIGURE A8

+120°F CONDITIONING

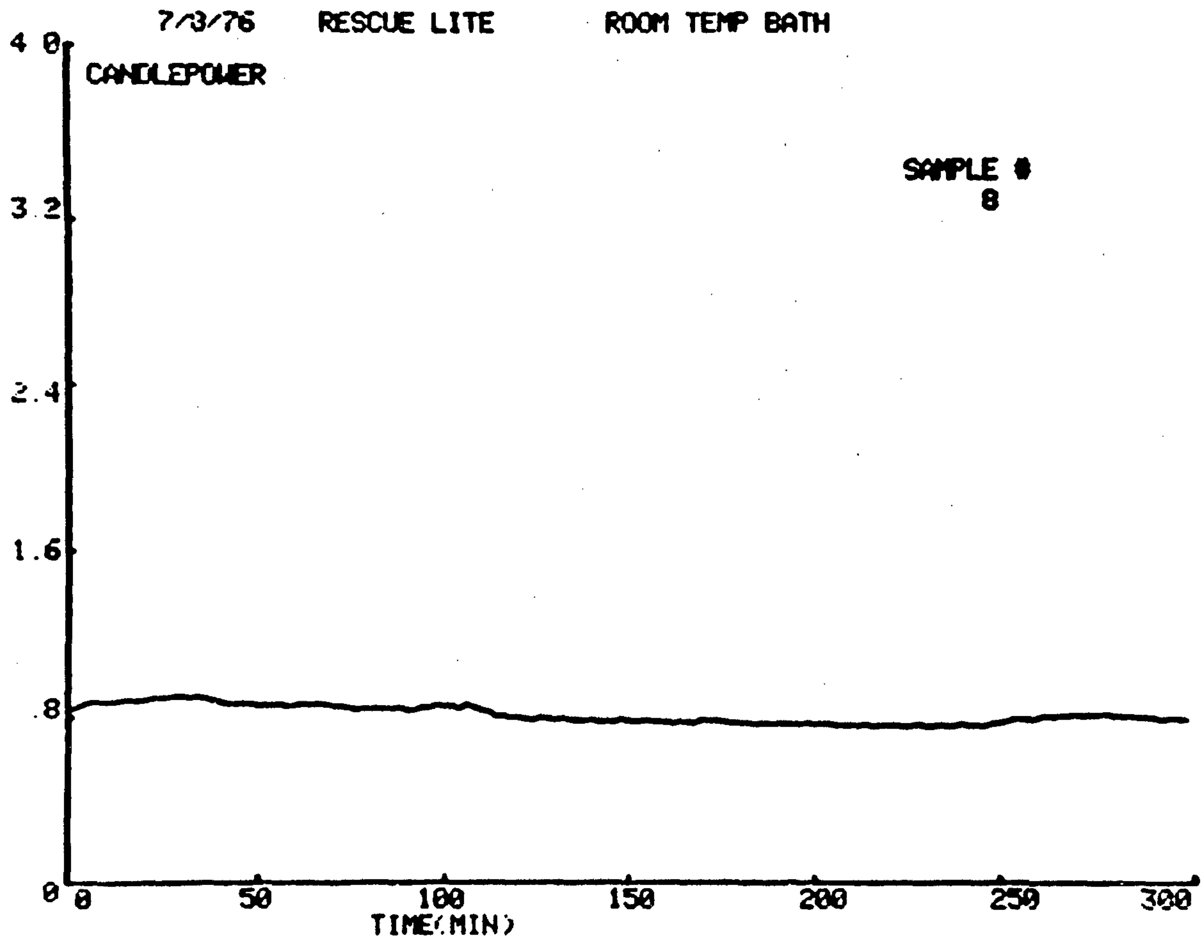


FIGURE A9

+70°F CONDITIONING

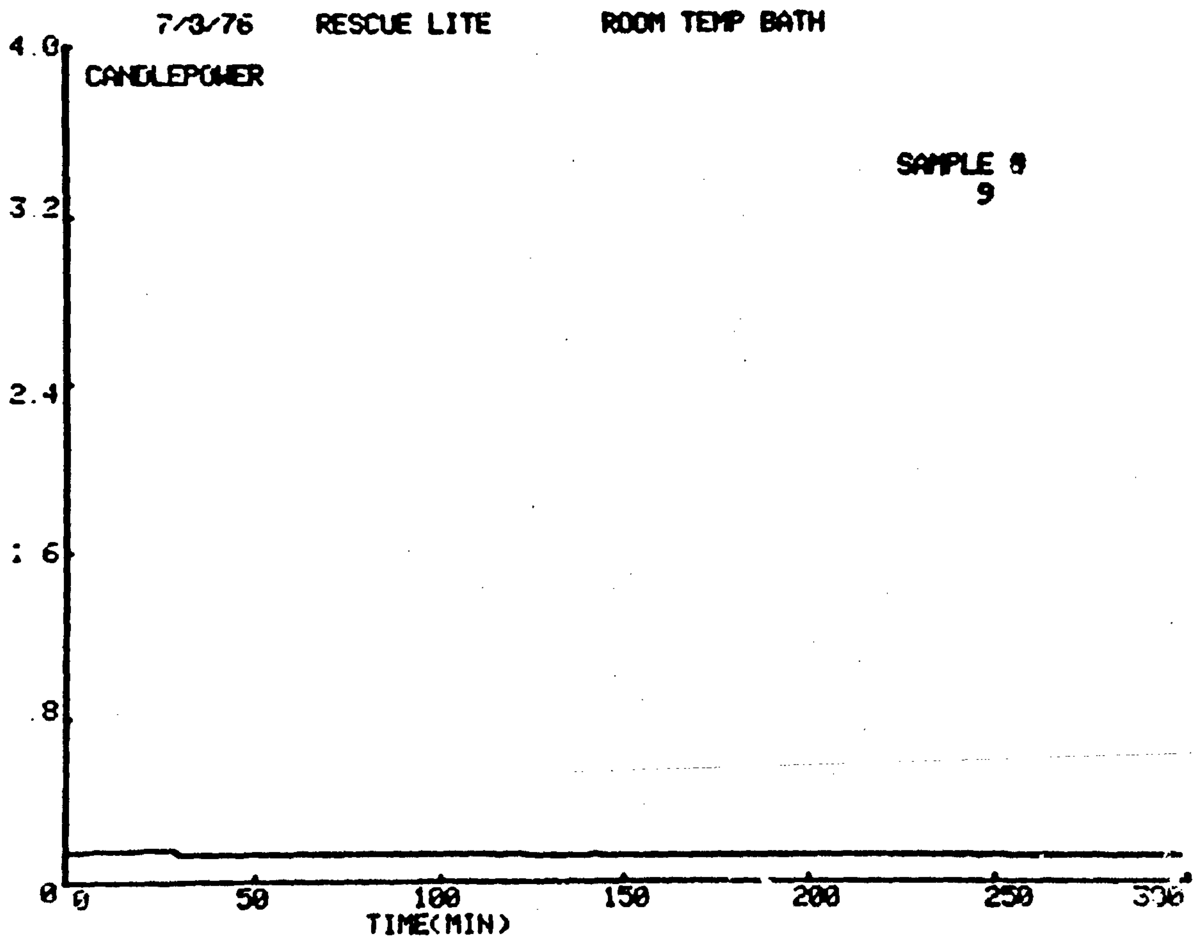


FIGURE A10

+70°F CONDITIONING

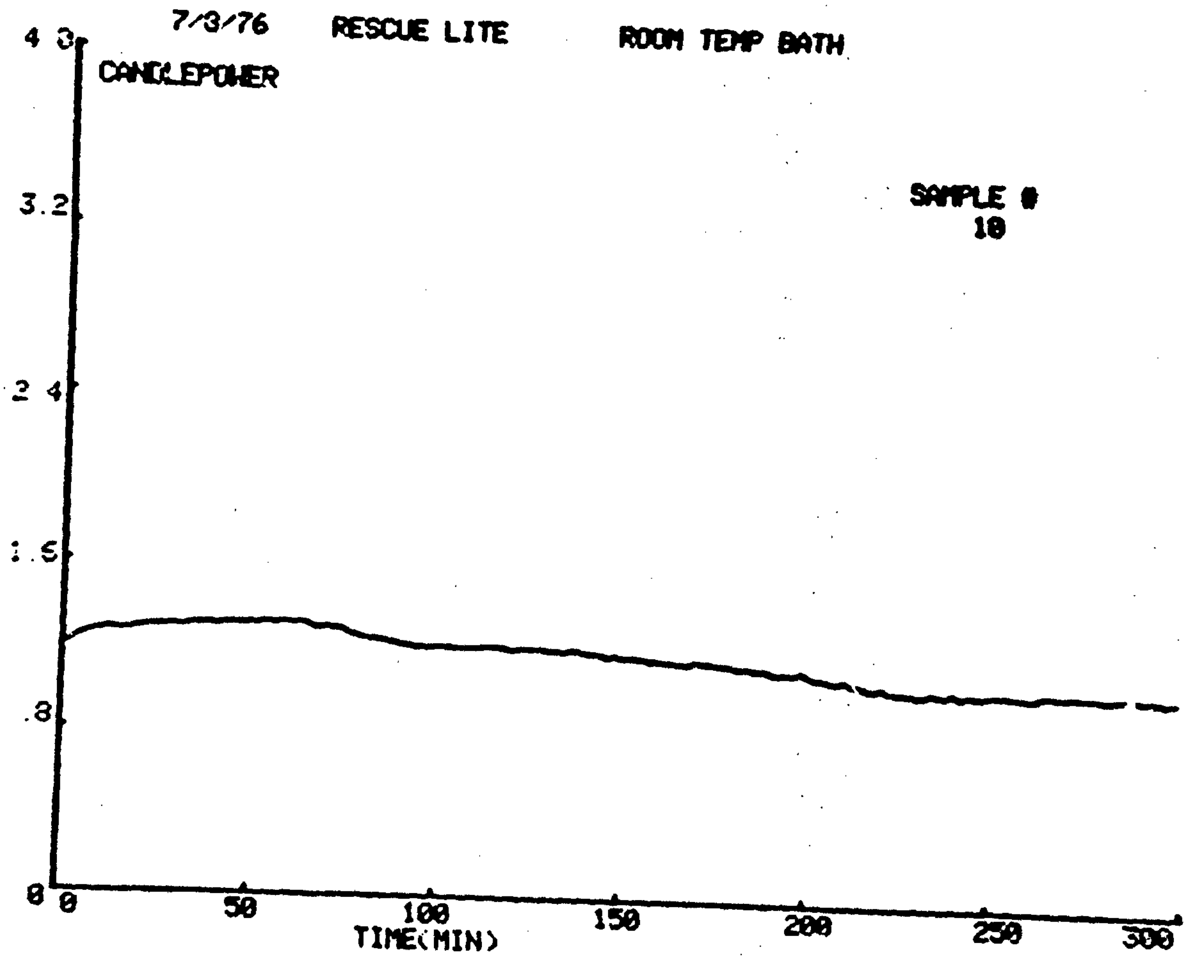


FIGURE A11

0°F CONDITIONING

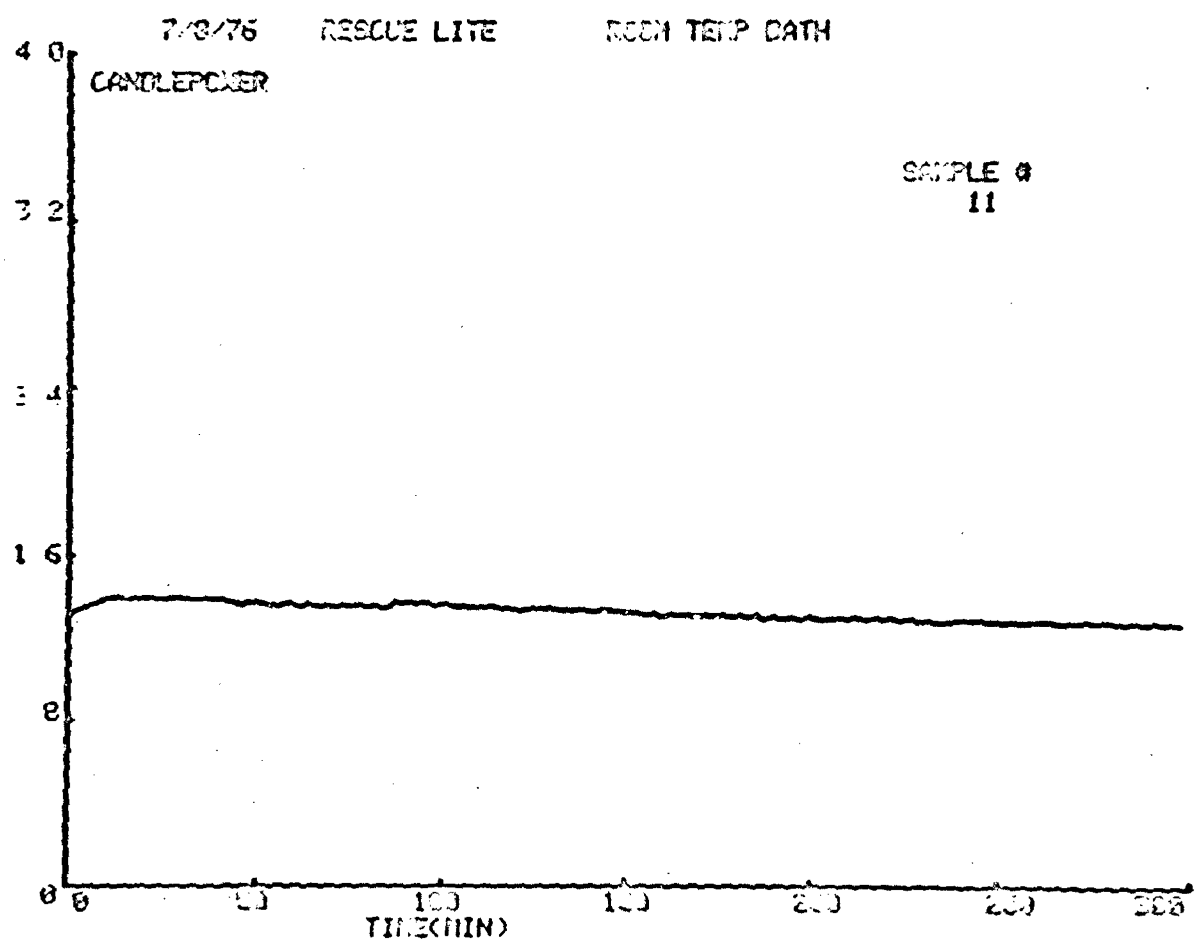


FIGURE A12

0°F CONDITIONING

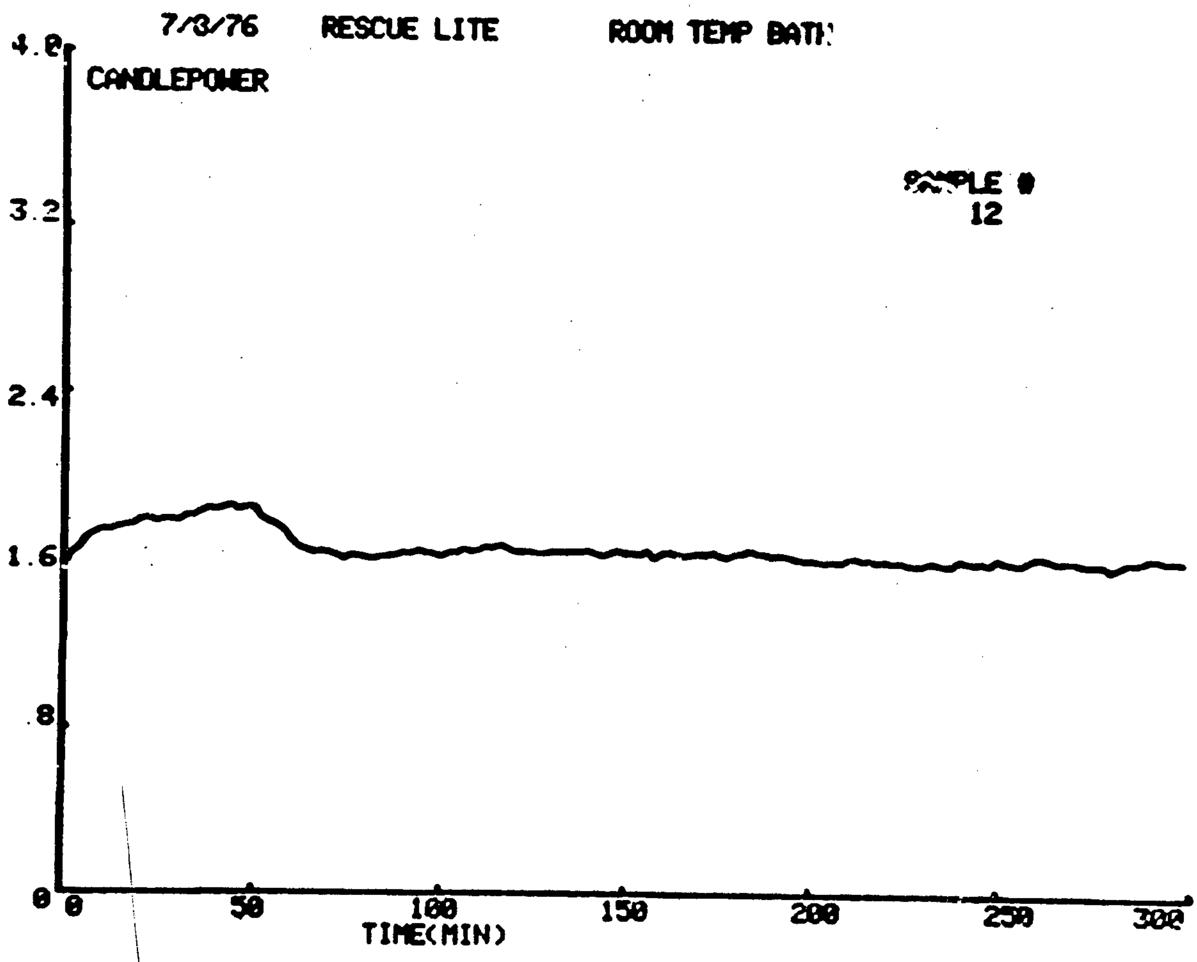
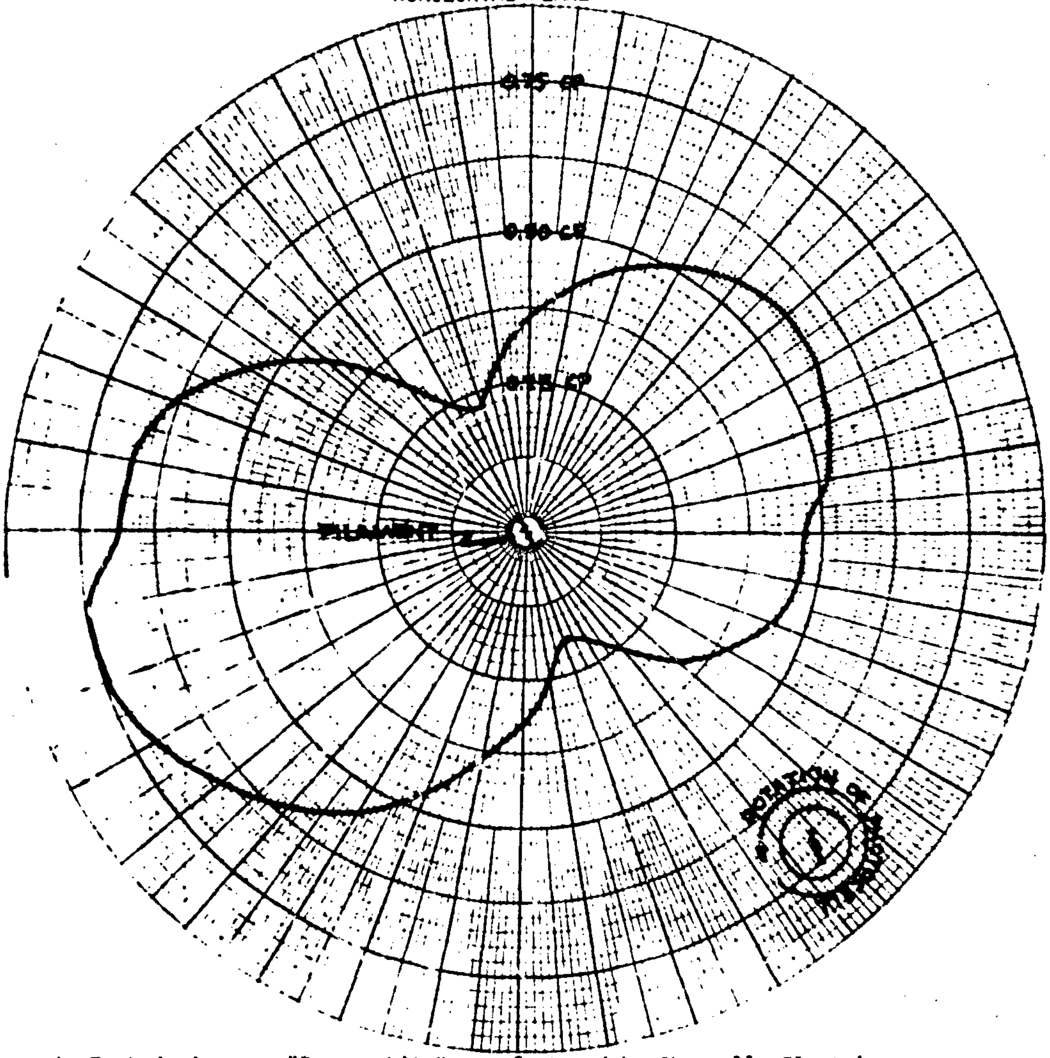


FIGURE A13

TYPICAL SEA-WATER ACTIVATED DEVICE*

LIGHT OUTPUT DISTRIBUTION

HORIZONTAL PLANE



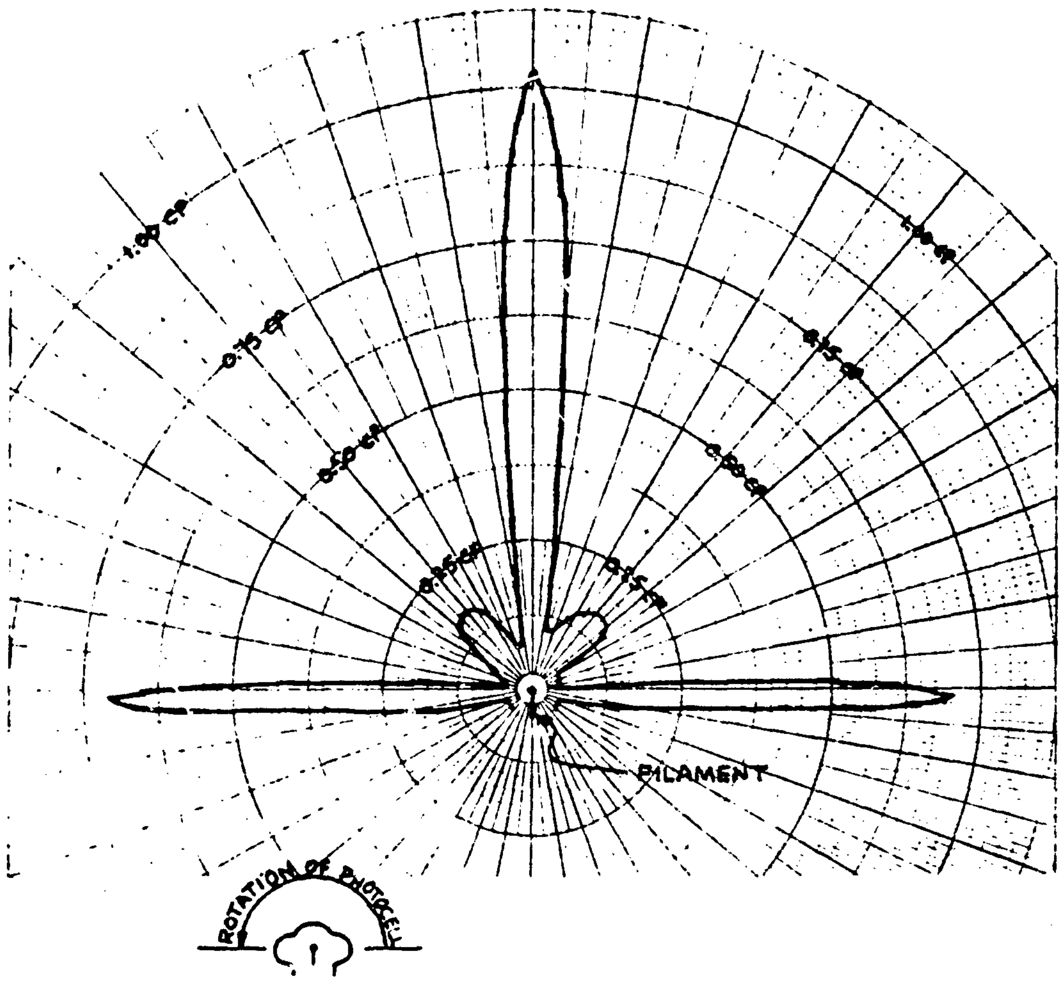
* Test device was "Rescue Lite" manufactured by Chromally Electric Division, Hollywood, Florida

FIGURE A14

TYPICAL SEA-WATER ACTIVATED DEVICE*

LIGHT OUTPUT DISTRIBUTION

VERTICAL PLANE - ACROSS FILAMENT



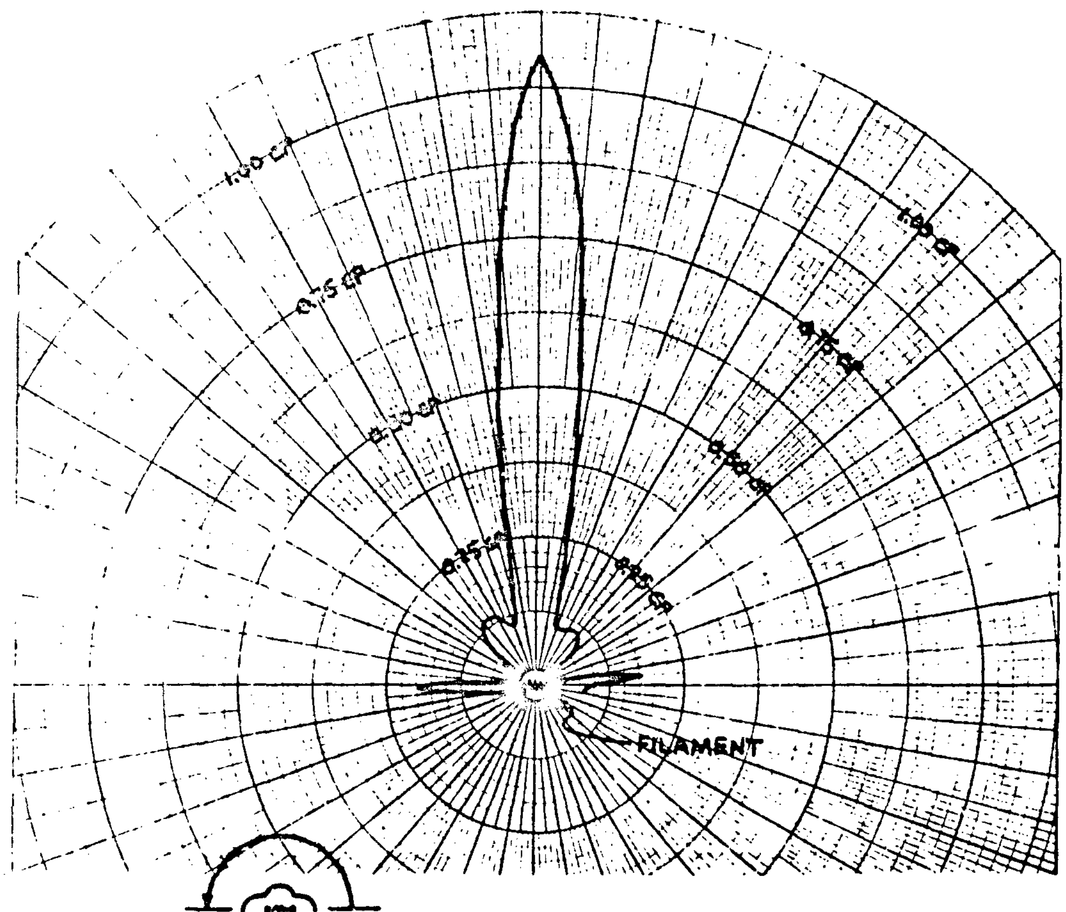
* Test device was "Rescue Lite" manufactured by Chromally Electric Division, Hollywood, Florida

FIGURE A15

TYPICAL SEA-WATER ACTIVATED DEVICE*

LIGHT OUTPUT DISTRIBUTION

VERTICAL PLANE - ALONG FILAMENT



* Test device was "Rescue Lite" manufactured by Chromally Electric Division, Hollywood, Florida

APPENDIX B

SUPPLEMENTAL

FIELD TEST DATA

SUPPLEMENTAL FIELD TEST DATA

In order to obtain a maximum amount of information from the field test program, three other signals were tested in addition to the three devices discussed in this report. These additional signals included a five-inch double ampule chemical light and a floating double ampule chemical light in prototype development by American Cyanamid Company. A third signal tested was the standard strobe light. The data obtained for these signals is given in Tables B1, B2, and B3.

The floating double ampule unit was the better of the two chemical lights. This unit has more chemiluminescent material and a more transparent plastic case than the five-inch double ampule chemical light and these factors account for the visibility range difference. The floating double ampule chemical light had an increased visibility range over the one-cell flashlight while maintaining the environmental stability of the double ampule design.

The standard strobe light had the highest visibility range of all devices tested. The higher visibility range was expected because of the high light output of the strobe light. The intermittent flashing of the light was also felt to be an aid in its' location.

The summary data plots, Figures B1, B2, and B3, also show the effects of backlighting and wave direction on the visibility range, as previously discussed.

TABLE A1

FLOATING DOUBLE AMPULE CHEMICAL LIGHT (American Cyanamid)
FIELD TEST RESULTS

TEST DATE	TEST CONDITIONS	AIRCRAFT HEADING(°)	LOCATION RANGE (miles)	TIME FROM ACTIVATION (minutes)	OBSERVATION DIRECTION FROM BOAT	VISIBILITY Yards	RANGE Miles	REMARKS
May 10, 1976	Target 1-1/2-2 miles from shore, full moon, ground haze, sea state 2, A/C altitude 500 ft.	280	0.4	Unknown				
		090	0.2	Unknown	E	500	0.28	
		180	0.1	Unknown	W	1200	0.68	
		340?	0.5	Unknown				
May 12, 1976	Target 4 miles from shore, full moon, clear, sea state 0 (calm)	A/C computer not functioning properly and no data obtained.			W	1775	1.01	
					E	1200	0.68	
					S	1500	0.85	
May 17, 1976	Sunset 2014, wind SW @ 5 mph, target 4 miles from shore, no moon, light haze, swells 3-5 ft into beach A/C altitude 500 ft, water 78°F	246	1.3	1	N	1250	0.71	
		320	0.8	9	S	2100	1.19	Flew by target, target to left of A/C
		100	---	14	E	350	0.20	
		250	1.0	17	W	2300	1.31	
		180	1.1	21				

TABLE A2

5" DOUBLE AMPULE CHEMICAL LIGHT (American Cyanamid)
FIELD TEST RESULTS

TEST DATE	TEST CONDITIONS	AIRCRAFT HEADING(°)	LOCATION RANGE (miles)	TIME FROM ACTIVATION (minutes)	OBSERVATION DIRECTION FROM BOAT	VISIBILITY Yards	RANGE Miles	REMARKS
May 10, 1976	Target 1-1/2-2 miles from shore, full moon, ground haze, sea state 2, A/C altitude 500 feet	360	---					
		180	---					
		342	0.4	17	E	825	0.47	
		160	---		W	1350	0.77	
		010	0.3	26				
		270	0.3	29				
		095	0.2	32				
		270	0.5	36				
May 12, 1976	Target 4 miles from shore, full moon, clear, sea state 0 (calm)	A/C computer not functioning properly and no data obtained.			N	1250	0.71	
					E	700	0.40	
					S	1100+	0.63	
					W	1125	0.64	
May 17, 1976	Sunset 2014, wind SW @ 5 mph, target 4 miles from shore, no moon, light haze, swells 3-5 ft into beach, A/C altitude 500 ft, water 78°F	180	0.2	9	S	350	0.20	Sighted earlier but no A/C range confirmed
		090	0.8?	Unknown	N	1750	0.99	
		090	0.6	Unknown	E	900	0.51	Unconfirmed A/C sighting
		270	0.5	Unknown	W	2100	1.19	A/C leaving target
		360	1.3?	Unknown				
May 19, 1976	Sunset 2015, wind NW @ 6-8 mph, target 3 miles from shore, sea state 2-3 with moderate chop, no moon, light haze, A/C altitude 400 ft	360	0.5	3	S	800	0.45	
		180	0.6	5	N	800	0.45	
		270	0.6	8	E	425	0.24	
		090	0.5	10	W	1250	0.71	

TABLE A3

STROBE LIGHT
FIELD TEST RESULTS

TEST DATE	TEST CONDITIONS	AIRCRAFT HEADING(°)	LOCATION RANGE (miles)	TIME FROM ACTIVATION (minutes)	OBSERVATION DIRECTION FROM BOAT	VISIBILITY Yards	RANGE Miles	REMARKS
May 10, 1975	Target 1-1/2-2 miles from shore, full moon, ground haze, sea state 2, A/C altitude 500 feet	360	2.0	Unknown	E	not seen		Target apparently hidden by swells
		270	visible from shore		S	4000	2.27	
May 17, 1976	Sunset 2014, wind SW @ 5 mph, target 4 miles from shore, no moon, light haze, swells 3-5 ft into beach, A/C altitude 500 ft, water 78°F	A/C had departed test site; no A/C data obtained			N	1250	0.71	
					S	900	0.51	
					W	3000	1.70	Swells reflecting light
					E	30	0.02	
May 19, 1976	Sunset 2015, wind NW @ 6-8 mph, target 3 miles from shore, sea state 2-3 with moderate chop, no moon, light haze, A/C altitude 400 feet	180	1.0	Unknown	S	0	0	Losing signal in swells
		360	3.7*	Unknown	W	1600	0.91	*Comment: target must get up on crest to be seen; regular flashing @ 2.5 miles
		090	0.5	Unknown	N	1600	0.91	Seen and lost several times; 1.0 miles max.
		270	2.4	Unknown	E	950	0.54	Good signal

FIGURE B1

FLOATING DOUBLE AMPULE CHEMICAL LIGHT

SUMMARY PLOT OF FIELD TEST DATA

Visibility/Detection Range From:

+——+ Aircraft
0----0 Boat

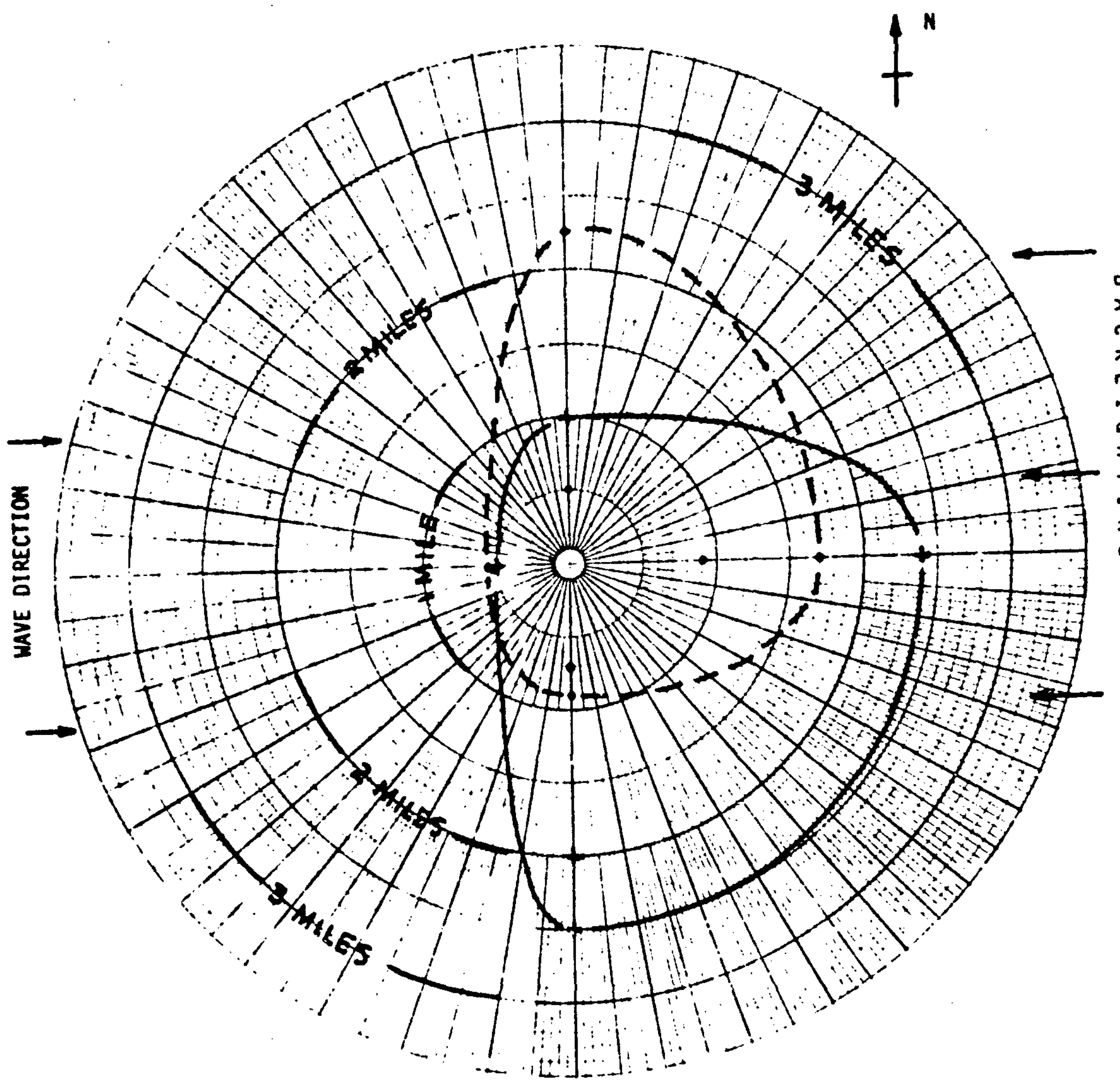


FIGURE B2

5 INCH DOUBLE AMPULE CHEMICAL LIGHT

SUMMARY PLOT OF FIELD TEST DATA

+——+ Aircraft
0----0 Boat

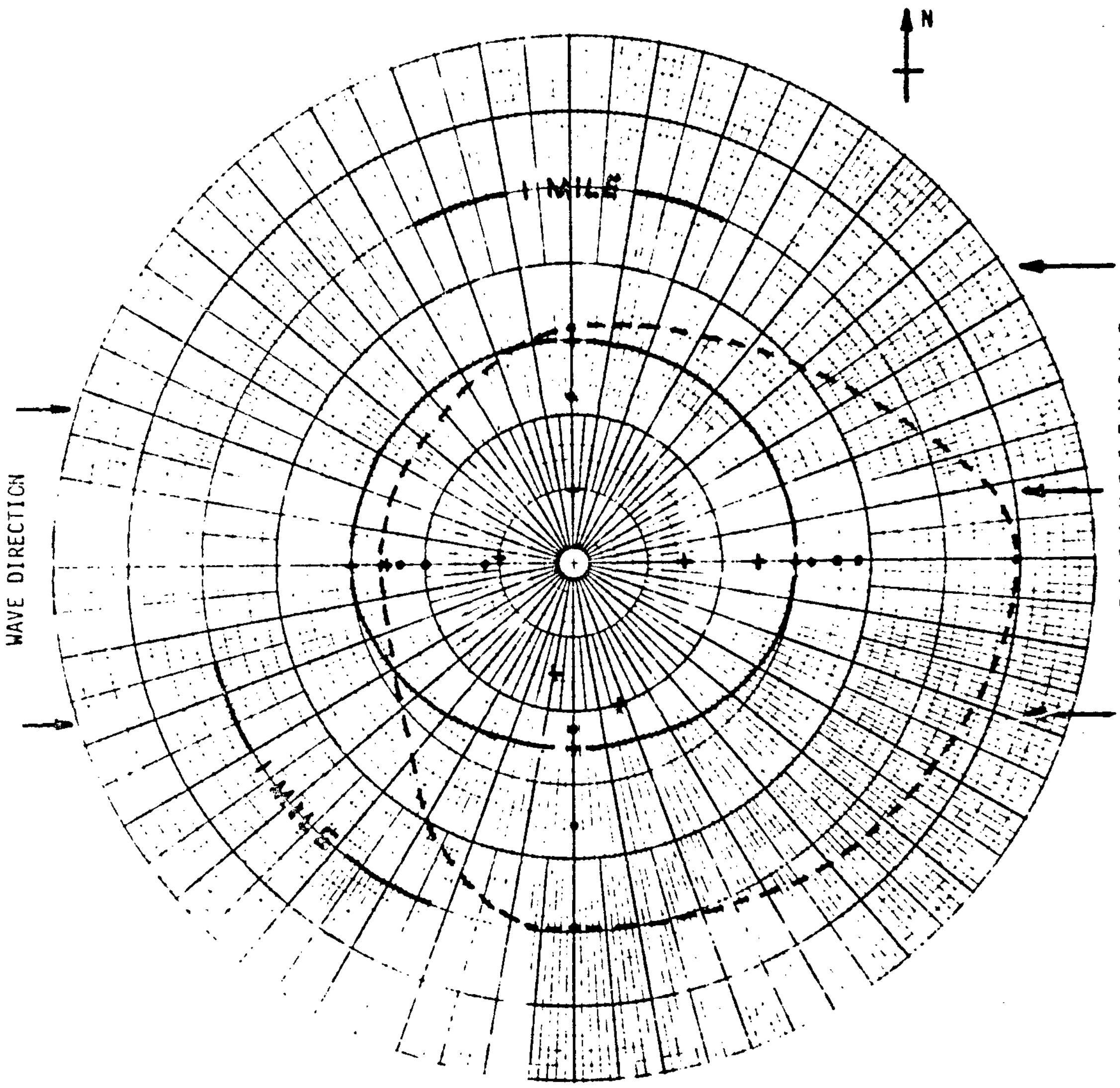


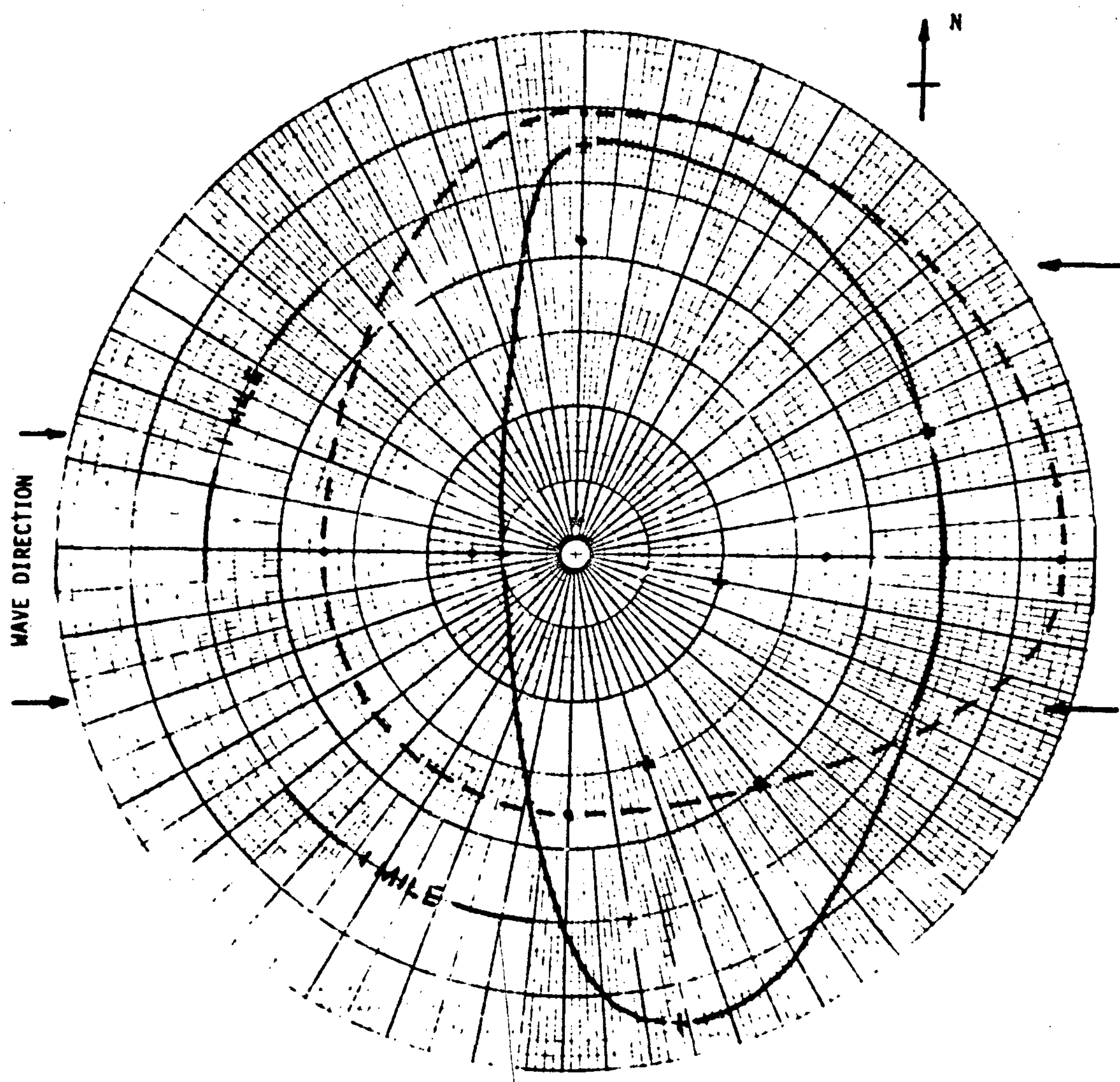
FIGURE B3

STROBE LIGHT

SUMMARY PLOT OF FIELD TEST DATA

Visibility/Detection Range From:

+——+ Aircraft
0----0 Boat



*U.S. GOVERNMENT PRINTING OFFICE : 1977 0-731-011/24