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PRELIMINARY INVESTIGATION OF TEMPORAL AND CHROMATIC METHODS OF MARKING CHANNELS

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16. Abstract

This report summarizes the results of initial research designed to determine the best methods for marking straight lighted channels. Two methods were examined: regulated time flashing (temporal) and color flashing (chromatic). In the temporal method all (30) test observers chose the ordered systems (sequential and simultaneous) superior to the unordered systems (random, random-sequential, and random-simultaneous). Within the test conditions for ordered systems, sequential flashing was chosen best. In the chromatic method a two color combination for channel marking was chosen best: a white-red system against a lighted background and a green-red or white-red system against a dark background. This preliminary work shows an advantage to ordered temporal systems of marking channels as well as the advantage of a two color system. The results of this research could provide guidance for design of future channel lighting systems.

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PREFACE

Grateful acknowledgment for assistance is given to the Chief of Aids-to-Navigation School Branch and its staff, the officers and men of the Coast Guard Cutters Dallas and Red Beech, and the Coast Guard Training Center. The three commands provided observers for the experiments, and the Aids-to-Navigation School Branch provided needed laboratory space and technical assistance.

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1.0 INTRODUCTION

Throughout the United States the shorelines along waterways and harbors are polluted with lights of every description. This pollution forms an intrusive background against which navigational aids must be observed. It has made the recognition of channels marked by lighted buoys or structures extremely difficult.

In order to improve the identification of straight lighted channels, a psychophysical experiment was designed using a Channel Lighted Buoy Model (CLBM). The CLBM presents, in small scale, the appearance of lighted aids marking a channel by displaying lights whose position, color, and flash characteristics may be altered (see Figure 1). In the experiment observers simultaneously viewed two situations on the CLBM and stated their preference. Two methods of lighting were examined by thirty test observers: time regulated flashing (temporal method) and color flashing (chromatic method). Within the temporal method, simultaneous, sequential and random flashes were displayed. The chromatic method demonstrated color flashes in various combinations of white, red and green. When testing the color flashing method, the random lighting system was used. When testing the time regulated flashing method, the color white was always employed. No intercomparison between the temporal and chromatic methods were attempted. The data for the paired comparison observations were reduced to show the relation preferences in the two methods. Finally, some conclusions are drawn concerning the possible future for innovations in navigational channel lighting.

2.0 METHOD

A straight channel model consisting of three pairs of equally spaced buoys (Fig. 2) was used to evaluate sets of temporal and chromatic lighting methods. These methods were evaluated against dark and lighted backgrounds.

The temporal methods evaluated were: simultaneous (SIM) flashing, sequential (S) flashing, random (R) flashing, and the combination of random-sequential and random-simultaneous (R-S and R-SIM). In the simultaneous method, all lights in the channel flashed at the same instant. In the sequential method, the lights flashed in sequence by pairs down the channel, away from the observer (Fig. 3). In the random method, each buoy displayed a consistent characteristic controlled by its own timing device, independent of all other lights. When using the random-sequential and random-simultaneous flashes, the left side of the channel flashed in the random method while the right side flashed in the sequential or simultaneous method. Table 1 gives the specific details concerning the temporal flashing methods.

The four chromatic methods evaluated were:

1. All lights displayed a flashing white light.
2. Channel lights on the right-side displayed flashing red while the left-side displayed a flashing white .
3. The left-side lights flashed green and the right side flashed white.
4. Green lights flashed on the left side and red flashed on the right.

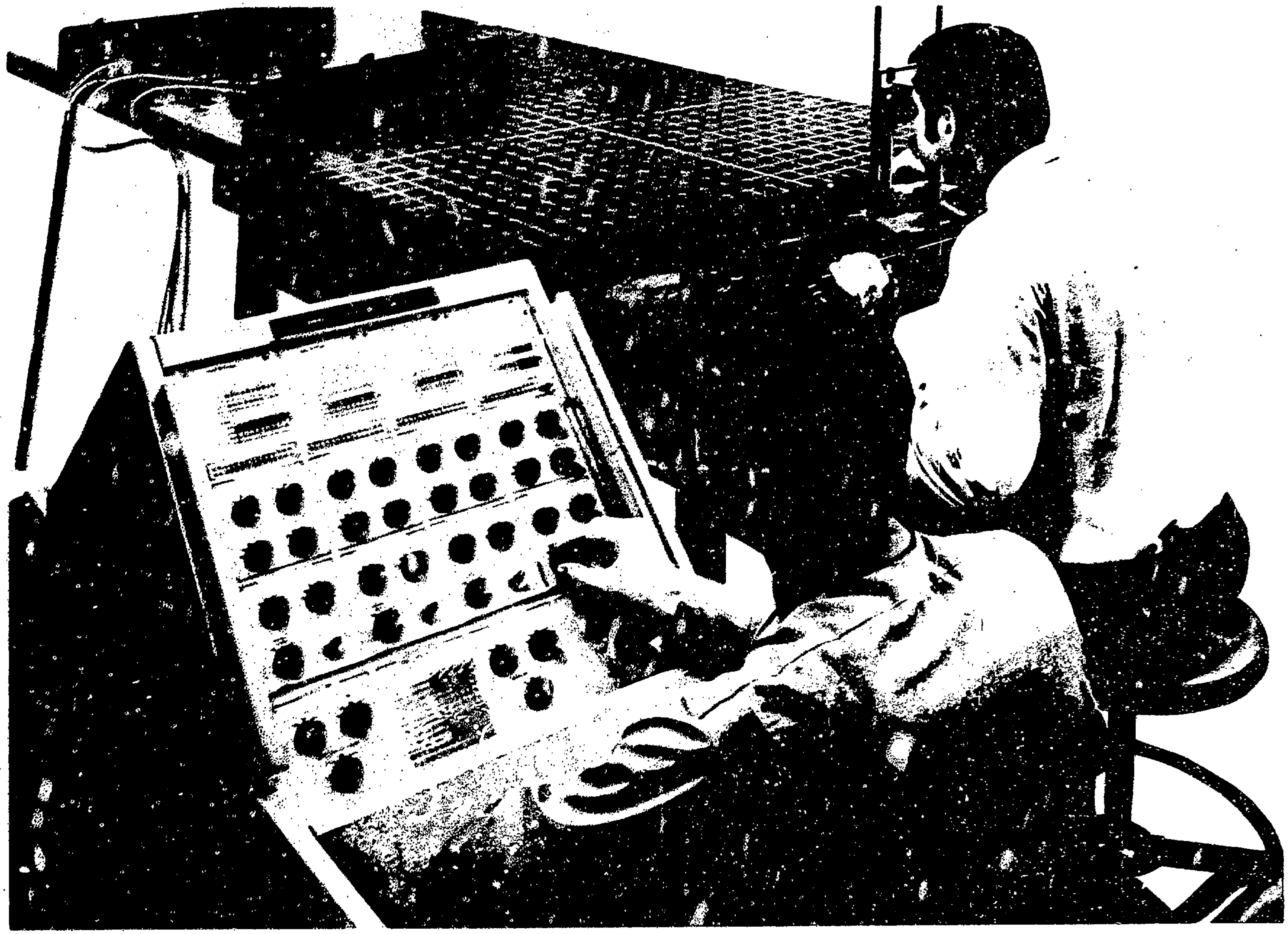

Figure 1 - The Channel Lighted Buoy Model in Operation

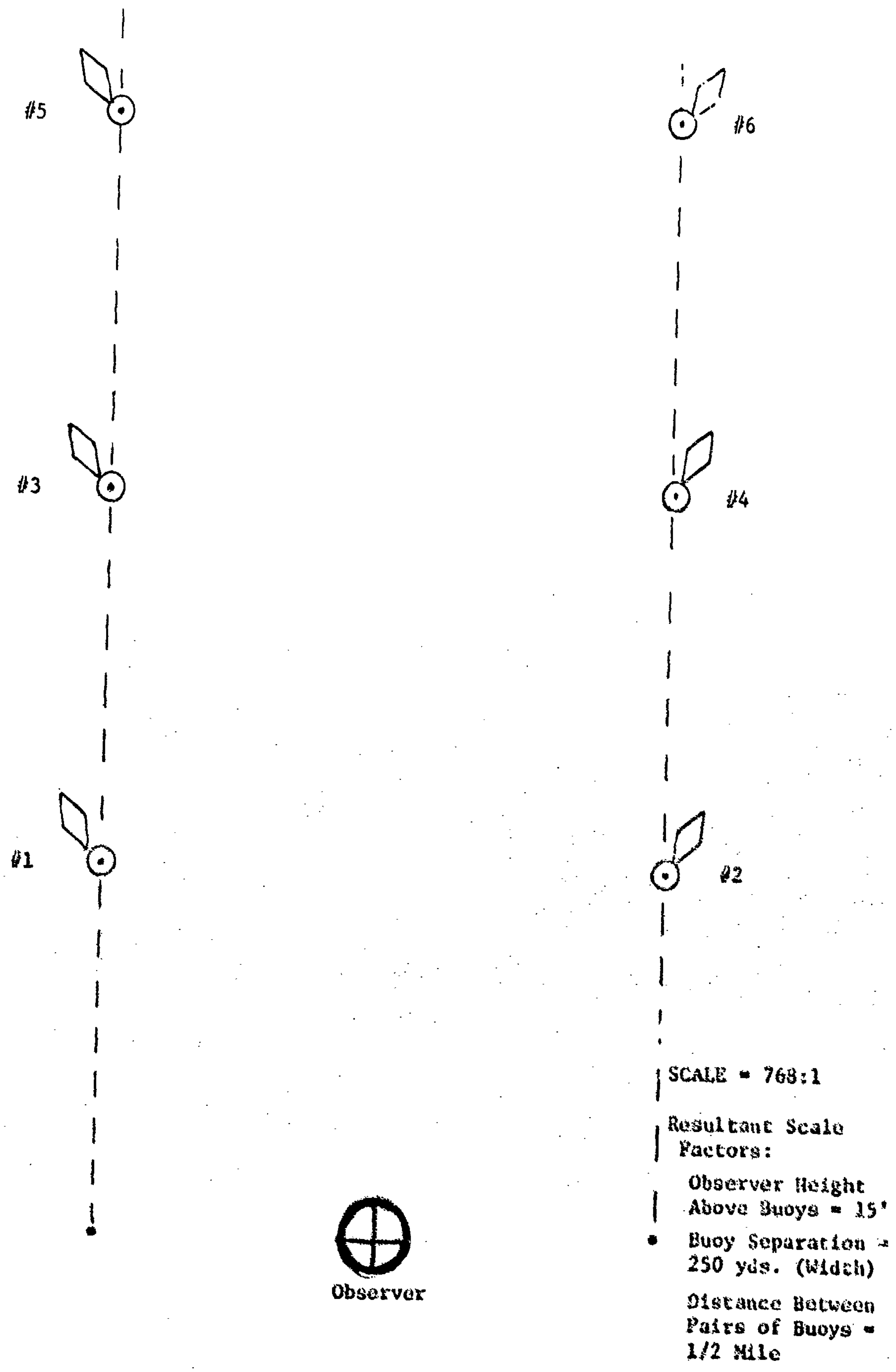

Figure 2
Channel Configuration used for Experimental Evaluations

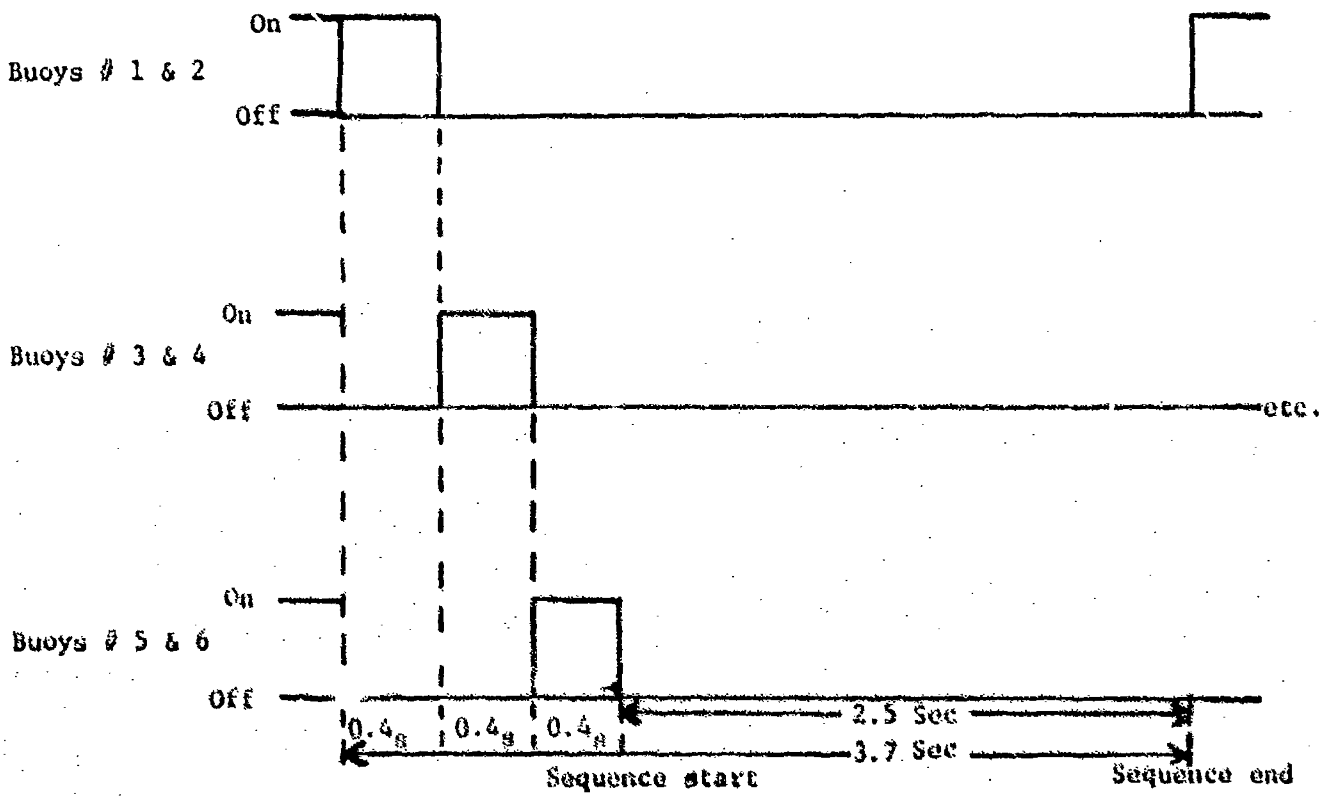

Figure 3
Temporal Characteristics for the Sequential Method

TABLE 1

Temporal Characteristics of the S, SIM, and R Methods Used in the Experimental Evaluation

	Sequential	Simultaneous	Random
Flash Duration*	0.4 sec.	0.4	0.4
Eclipse Time*	3.3 sec.	4.6	3.6
Duty Cycle*	10.8%	8%	10%
Intersequence Internal+	0.0 sec.		
Sequence Off Time+	2.5 sec.		

*Represents characteristics of individual lights
+Represents characteristics of an ordered method

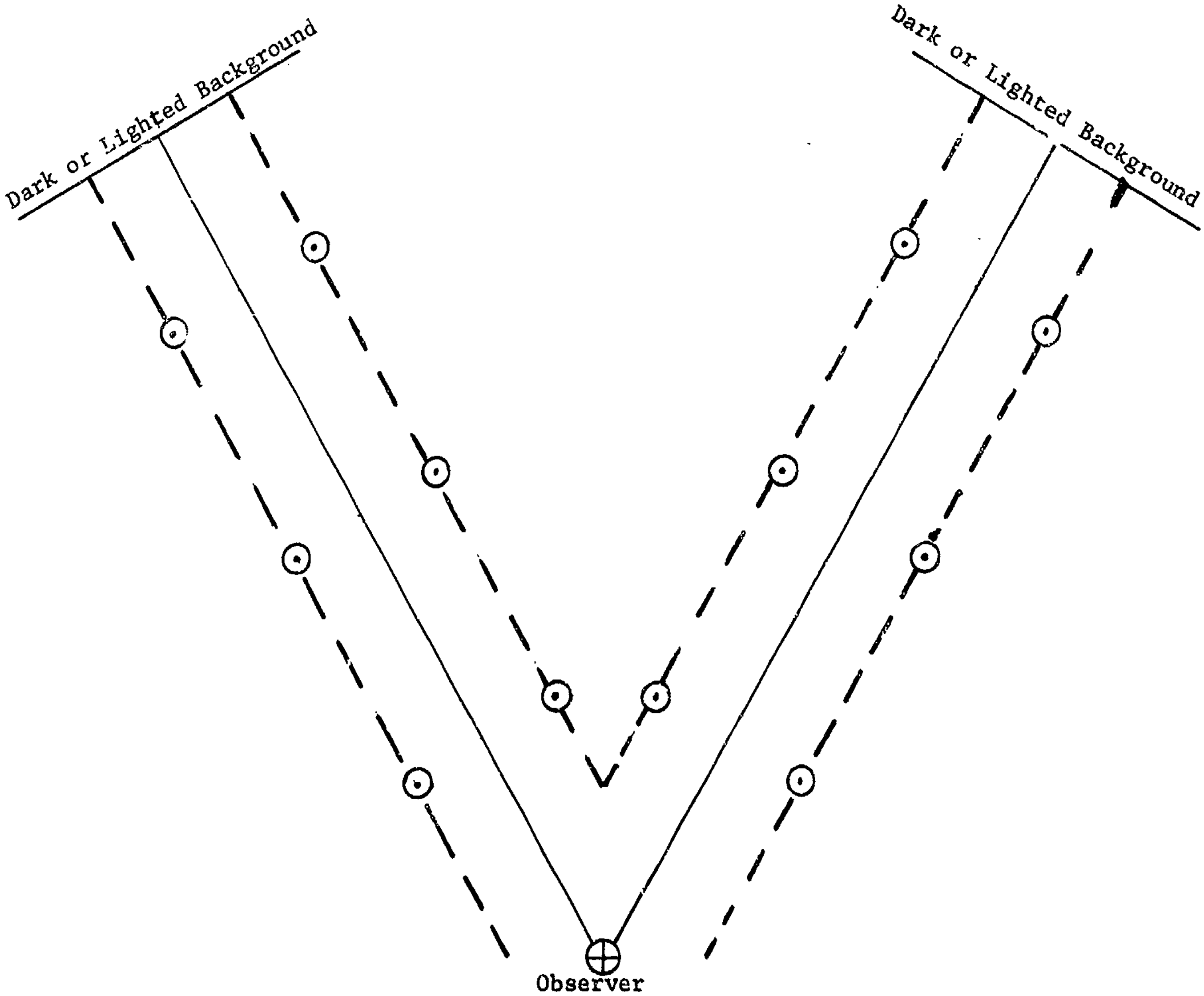

Figure 4
CLBM Display Used For The Method Of Paired Comparison

All lights in the four chromatic methods displayed the same 0.4 second flash with a 3.6 second eclipse. Color flashings were operated in the random temporal method. All methods had a duty cycle of approximately 10%, thus eliminating the affects of battery life from the evaluation.

The experimental procedure for gathering evaluation data used a forced-choice technique in the Method of Paired Comparison. Using this decision analysis technique, an observer viewed displays on the Channel Lighted Buoy Model which showed lighting situations on two identical straight 6-buoy channels (Fig. 4). While watching 2 different lighting situations simultaneously, the viewer made a forced choice decision as to the best system for marking the channel.

Before an experimental session began, each observer acquired a knowledge of the channel configuration and the number of buoys marking the channel.

Observers were given detailed, tape recorded instructions to ensure identical briefing. After being told he should select the best lighting method, the observer was allowed to set his own standard of preference. Observation time was unlimited. Immediately following his selection, the observer was allowed to rest while the experimenter prepared the next display. This procedure continued until the observer had viewed sixteen displays, ten with the regulated time flashing methods and six with the color flashing method (Table 2). No intercomparison between temporal and chromatic methods were made. Both lighted and dark backgrounds were used in the displays: seventeen observers viewed lighted backgrounds (Tables 3 and 6), thirteen observers viewed the dark backgrounds (Tables 4 and 7). The viewers' choices were recorded and totaled upon completion of the experiment (Tables 5 and 8).

The lighted background consisted of a backlighted diffusing panel behind a black perforated fiber board sheet. The perforation was patterned after a slide of dense background lighting in Baltimore Harbor. Thus, the background was essentially a horizontal band of light with some vertical excursions (ie. bridges and buildings), predominately white in color with some green, red, and blue.

The modules were adjusted visually for equal intensity of white and colored lights. The closest lights in each display were slightly more intense than the background while the last four lights in each channel definately appeared less intense than the background.

TABLE 2

Display #		Method Displayed on Left Channel (For Mixed Methods) (Left Side - Right Side)	Method Displayed on Right Channel (For Mixed Methods) (Left Side - Right Side)
1		R - S	R
2		SIM	R - SIM
3	(In displays 1-10 all	R	S
4	lights displayed a white flash)	SIM	R - S
5		S	R - SIM
6		R	SIM
7		R - S	S
8		R - SIM	R
9		S	SIM
10		R - SIM	R - S
11		G - W	W - R
12	(In displays 11-16 all	W	G - R
13	lights flashed in the random	G - W	W
14	temporal method)	W - R	G - R
15		W	W - R
16		G - R	G - W

Code: R-Random; S-Sequential; SIM-Simultaneous; R-S,-Random-Sequential; R-SIM,-Random-Simultaneous; W-White; G-W,-Green-White; W-R,-White-Red; G-R,-Green-Red

3.0 DATA ANALYSIS

By using the classical Method of Paired Comparison, data reduction techniques[2,3] resulted in scale values for the stimuli observed. These techniques were used to obtain values for both the temporal and chromatic lighting methods (Tables 3 through 8).

The scale values obtained are a measure of observer preference for the lighting methods. These scale values should not be misunderstood. They provide no measure of an absolute value of observer preference, but rather a relative value of observer preference between two situations. They locate the response to a stimulus on a psychological continuum relative to the response for all other stimuli tested. The separation between two scale values, or the scale difference, is a measure of observer preference for one stimulus over the other. In the case of the temporal and chromatic lighting methods the scale value of the most preferred method was equated to 100 and the scale value of the least preferred was equated to 0.

The average variabilities in the data obtained, enabled calculation of the minimum significant scale separation (MSS) for each scale[2,4]. These minimum significant scale separations are presented in each of Tables 3 through 8.

TABLE 3

Scale Values for the Temporal Methods Evaluated
Against a Lighted Background by 17 Observers

Lighting Method		Scale Value (0-100)
Sequential	(S)	100.0
Simultaneous	(SIM)	74.8
Random-Sequential	(R-S)	9.0
Random-Simultaneous	(R-SIM)	7.0
Random	(R)	0.0

Minimum Significant Separation = 12.8

TABLE 4

Scale Values for the Temporal Methods Evaluated
Against a Dark Background by 13 Observers

Lighting Method		Scale Value (0-100)
Sequential	(S)	100.0
Simultaneous	(SIM)	49.3
Random-Sequential	(R-S)	11.3
Random-Simultaneous	(R-SIM)	6.0
Random	(R)	0.0

Minimum Significant Separation = 7.7

TABLE 5

Scale Values for the Temporal Methods Evaluated Against Both Backgrounds by 30 Observers

Lighting Method		Scale Values (0-100)
Sequential	(S)	100.0
Simultaneous	(SIM)	69.4
Random-Sequential	(R-S)	9.1
Random-Simultaneous	(R-SIM)	5.0
Random	(R)	0.0

Minimum Significant Separation = 10.4

TABLE 6

Scale Values for the Chromatic Methods Evaluated Against a Lighted Background for 17 Observers

Lighting Method		Scale Values (0-100)
White-Red	(WR)	100.0
Green-Red	(GR)	82.5
Green-White	(GW)	14.3
White	(W)	0.0

Minimum Significant Separation = 9.7

TABLE 7

Scale Values for the Chromatic Methods Evaluated Against a Dark Background for 13 Observers

Lighting Method		Scale Values (0-100)
Green-Red	(GR)	100.0
White-Red	(WR)	96.0
White	(W)	16.7
Green-White	(GW)	0.0

Minimum Significant Separation = 12.1

TABLE 8

Scale Values for the Chromatic Methods Evaluated
Against Both Backgrounds for 30 Observers

Lighting Method		Scale Value (0-100)
White-Red	(WR)	100.0
Green-Red	(GR)	87.4
Green-White	(GW)	1.1
White	(W)	0.0

Minimum Significant Separation = 11.5

4.0 RESULTS

The separations between the least beneficial ordered method (SIM) and the most beneficial non-ordered method (R-S) are 65.8 and 38.0 for lighted and dark backgrounds respectively. Since the minimum significant separations (MSS) for the lighted and dark backgrounds are 12.8 and 7.7 respectively, it is apparent that a significant benefit is obtained by the use of ordered timing for both backgrounds. Since all methods containing random timing are grouped within the MSS for the lighted background, they must, within the limits of this experiment, be considered equivalent. For the dark background there exists a separation between R and R-S which is greater than MSS but relatively small.

There exists for both backgrounds a significant scale separation between the sequential and simultaneous methods of coding, 25.2 in the case of a lighted background and 50.7 for a dark background. These scale separations indicate the sequential method is the more preferred under these test conditions. A condition, where both the flash length and the eclipse length of the simultaneous method were reduced to produce a duty cycle more nearly equal to that of the sequential method, could change the results. More experimentation would be required to optimize the various parameters, but it is evident that the ordered methods are superior to the unordered.

Data for the chromatic methods indicate a two color system with lateral significance is advantageous. From the scales of Tables 6 and 7, it can be seen that the red-green and white-red methods are selected "best" by a majority of the observers. The MSS's are 9.7 and 12.1 for the lighted and dark backgrounds respectively. For the lighted background, the white-red method is first on the scale with a significant separation of 17.5 over the red-green method. For the dark background, the two methods are within the MSS and are equivalent within the experimental limits. The white and white-green methods finish low on both scales. There does not appear to be any advantage to the green lights tested. These green lights appear visually as an unsaturated green resembling that obtained from a high transmittance green filter previously used on marine signal lanterns.

5.0 CONCLUSIONS

Within the obvious limitations of a relatively short experiment, the advantage of synchronizing or sequencing channel lights has been shown. An extensive evaluation of these two methods would be required to identify the optimum method. The effect of the direction of sequencing must be studied to determine how this direction may effect an observer's preference. The advantage of a two color system has been shown. It may be inferred that a two color system with ordered temporal coding could offer an even greater advantage.

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