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EVALUATION OF IDENTIFICATION BEACONS FOR AIRPORT EMERGENCY VEHICLES

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JANUARY 1974

FINAL REPORT

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16. Abstract

The purpose of this effort was to determine the effectiveness of several newly developed identification beacons for airport emergency vehicles. Fourteen different light bar configurations were tested on the National Aviation Facilities Experimental Center (NAFEC) airport during various environmental conditions and a human appraisal of the different combinations was performed for suitable airport use. The results lead to conclusions as to which signal characteristics are most effective for use within the aircraft movement areas of airports.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

PURPOSE.

The purpose of this effort was to evaluate the performance of several widely used and commercially available emergency vehicle lighting devices. From this study, conclusions were to be drawn as to the relative effectiveness of the various system characteristics (color, flash rate, source type, etc.) for use in development of emergency vehicle lighting for use within the aircraft movement area of airports.

BACKGROUND.

Many articles have been written concerning emergency vehicle lighting systems including those intended for use on airports. The point stressed in these articles is that present specifications and standards may be obsolete in part or in whole due to recent state-of-the-art developments in light sources, filter materials, etc.

The Port Authority of New York and New Jersey requested that an evaluation be made of the several newly developed emergency vehicle lighting systems. It was determined that such an evaluation could best be accomplished at the National Aviation Facility Experimental Center (NAFEC) which led to 3 months of test and evaluation ending with this report.

Requirements for lighting of emergency vehicles on airports are given in Advisory Circular 150/5210-5 entitled Painting, Marking and Lighting of Vehicles Used on Airports. Attachment B to Annex 14 of the Aerodromes Manual states the International Civil Aviation Organization (ICAO) recommended practices and standards for emergency vehicle lights. Various state and local authorities in the United States have either developed their own standards for emergency vehicle lighting or have adapted standards proposed by the Society of Automotive Engineers, ICAO, or the Federal Aviation Administration (FAA).

Although there are a variety of standards and specifications published, no uniform and concise guidance for choosing satisfactory airport emergency vehicle lighting equipment has been developed. Little information is available for determining specific technical requirements such as light color, effective intensity, flash rates, etc.

DESCRIPTION OF EQUIPMENT.

Fourteen light combinations (systems) were tested, encompassing representative types of light sources presently manufactured for use on emergency vehicles. Included were flashing, rotating, reflecting, capacitor-discharge (strobe), and oscillating lights in various color combinations. Figure 1 gives a complete description of the light bar configurations and color combinations that were tested.

DISCUSSION

TEST PROCEDURES.

Day and night tests were performed on each of the light bars (figure 1). Each combination of lights (figures 2, 3, and 4 are examples) was mounted on similar vehicles for the tests and driven over a pre-established course on the NAFEC airport as shown in figure 5. Test observers at six locations on the airport completed questionnaires (figure 6), and the results were tabulated by computer and plotted on graphs (figures 7 and 8). Each bar configuration was judged for its effectiveness under typical airport traffic conditions such as passing close to lighted aircraft, through flood-lighted areas and so forth. Test vehicle speed, angle of approach, and departure were varied as well as the background and ambient lighting conditions. Various weather conditions were encountered during the course of the testing and were considered as an additional variable. Configurations which initially proved to be lacking in effectiveness were eliminated from further consideration and/or evaluation. Seventy-three questionnaires were completed by test observers of diverse backgrounds which included: air traffic controllers, pilots, engineers, technicians, police, and firemen. The questionnaire was developed to obtain a comparative evaluation of the various light combinations under test rather than to merely give an "acceptable/not acceptable" rating to each variation. The criteria used for each configuration tested and for which opinions or ratings were obtained are as follows:

- A. Visibility of the complete light combination.
- B. No interference with similar airport lights.
- C. Combination of color for individual lights making up the complete configuration.
- D. Acceptability of colors as a group (pleasing to the eye).
- E. Overall distinctiveness of the group.
- F. Depth perception.
- G. Motion detection.
- H. Comparison value (distinguishing emergency vehicles from maintenance vehicles, etc.).

Even though various airport authorities have in the past used airport emergency vehicles for other than airport use, only lighting requirements that pertain to the aircraft movement areas of airports were considered in this evaluation.

Three representative light bars were subjected to laboratory testing. Taken into account were such parameters as the transmission factor of the filters used on all colored lights and the effective intensity. The technique used to determine the effective intensity of the lights was that found in the FAA Specification FAA-E-1100 and was based upon the classical Blondel-Rey equation given in that specification. Photometric measurements were made on three representative light bars with a vacuum photo diode, a Biomation Model 802 Transient Recorder, and a Wang Series 700 Programming Calculator which integrated the area under the light curve, plotted it in graph form, and provided a single value measure of the effective color intensity. The results of these tests are given in appendix A of this report.

TEST RESULTS.

The test observers were essentially in agreement on the following:

1. All lights that gave off less than 360° of light (directional) were less effective than omni-directional lights.

2. For effective intensities of the same magnitude:

- The RED color was most preferred for all conditions;
- the YELLOW color performed best under daylight conditions, but could be confused with the yellow lights on service vehicles;
- the BLUE color was most effective during hours of darkness but was significantly less effective under daylight conditions; and
- CLEAR lamps possessed good intensity characteristics both day and night but lacked the quick-identification factor or uniqueness of colored lights.

The 14 light bar configurations tested (listed in figure 1) were identified by numbers used in the two sets of graphs (figures 7 and 8) which show a comparison of the lights tested. In figure 7 individual criteria are shown, and in figure 8 a comprehensive rating is shown by taking the mean of the individual criteria rating for all configurations. This criteria mean takes into consideration every criteria rating that was given each configuration and is defined as that which is the middle rating of a number of ratings. The mean of each bar of lights for each individual criteria (figure 7) was computed and the configurations with the highest mean value in each criteria were as follows:

	Criteria	Configuration Rating		
		Highest	Second	Third
A.	Visibility	1	12	9
B.	Interference	1	12	8
C.	Color Combination	9	12	14
D.	Pleasing to the eye	12	9	14
E.	Distinctiveness	1	12	9
F.	Depth Perception	9	12	14
G.	Motion Detection	9	14	12
H.	Comparison Value	9	12	14

The three highest rated configurations on each graph were plotted with wide graph bars for emphasis.

With regard to power consumption, present-day vehicle batteries and alternators are taxed to their limit and those lighting systems having the minimum power requirements are to be preferred. The units involved required the following current drain:

Configuration	Approximate Current Drain (Amperes)
2, 3, 4, 6, 7	3.5
1, 5, 8, 10, 13	9.0
14	11.5
9, 11, 12	15.0

It may be possible to considerably reduce the current drain with only minimal reduction of efficiency by utilizing lower wattage lamps; however, such modifications were not tested within the scope of this effort.

Although 14 different light bars were evaluated, the results of the computer tabulation clearly indicated that the configuration variation was not as important a factor as was the intensity and conspicuity of the lights. Configuration 12 received consistently high ratings for each criteria.

CONCLUSIONS

It is concluded that:

1. Of the colors tested, the RED light is the most satisfactory for airport emergency vehicle use in that it was the only color adjudged satisfactory under both day and night conditions.

2. The rotating or oscillating incandescent lamp is the most effective source for providing flashing light of both sufficient intensity and duration. The characteristically short duration of the capacitor-discharge light source proved to be detrimental to its use for this identification function.

3. BLUE supplemental flashing lights provide some measure of added conspicuity at night. Their value under daytime conditions is minimal.

4. Passive elements such as mirrors, reflectors, etc., may provide an added measure of conspicuity with no increase in current or power drain on the vehicle's electrical system.

1.  CENTER - Strobe light with 360° RED filter and CLEAR strobe light directed by reflectors upwards and outwards.
EACH END - Strobe lights with YELLOW filter facing forward and RED filter facing backwards.

2.  CENTER - Strobe light with 360° RED filter.
EACH END - Strobe lights facing forward ONLY with RED filters.

3.  CENTER - Strobe light with 360° RED filter.
EACH END - Strobe lights facing forward ONLY with YELLOW filters.

4.  CENTER - Strobe light with 360° RED filter.
EACH END - Strobe lights facing forward ONLY with BLUE filters.

5.  CENTER - Strobe light with 360° BLUE filter and CLEAR strobe light directed by reflectors upwards and outwards.
EACH END - Strobe lights with YELLOW filters facing forward and RED filters facing backwards.

6.  CENTER - Strobe light with 360° BLUE filter.
EACH END - Strobe lights facing forward ONLY with BLUE filters.

7.  CENTER - Strobe light with 360° BLUE filter.
EACH END - Strobe lights facing forward ONLY with RED filters.

8.  CENTER - Strobe light with 360° RED filter and CLEAR strobe light directed by reflectors upwards and outwards.
EACH END - Strobe lights with 360° BLUE filters.

9.  EACH END - Two rotating lights, back-to-back, with three reflecting mirrors reflecting backward from the vehicle. Lights and reflectors enclosed by a RED filter and lights synchronized by a chain drive.

10.  EACH END - Two rotating lights, back-to-back, one RED and one CLEAR.

11.  CENTER - Four rotating lights with RED filters.
EACH END - Strobe lights with YELLOW filters facing forward and RED filters facing backwards.

12.  CENTER - Four rotating lights with RED filters.
EACH END - Strobe lights with 360° BLUE filters.

13.  CENTER - Four rotating lights with RED filters.

14.  CENTER - Two rotating lights with RED filters.
EACH END - Strobe lights with 360° BLUE filters.

FIGURE 1. LIGHT BAR CONFIGURATIONS

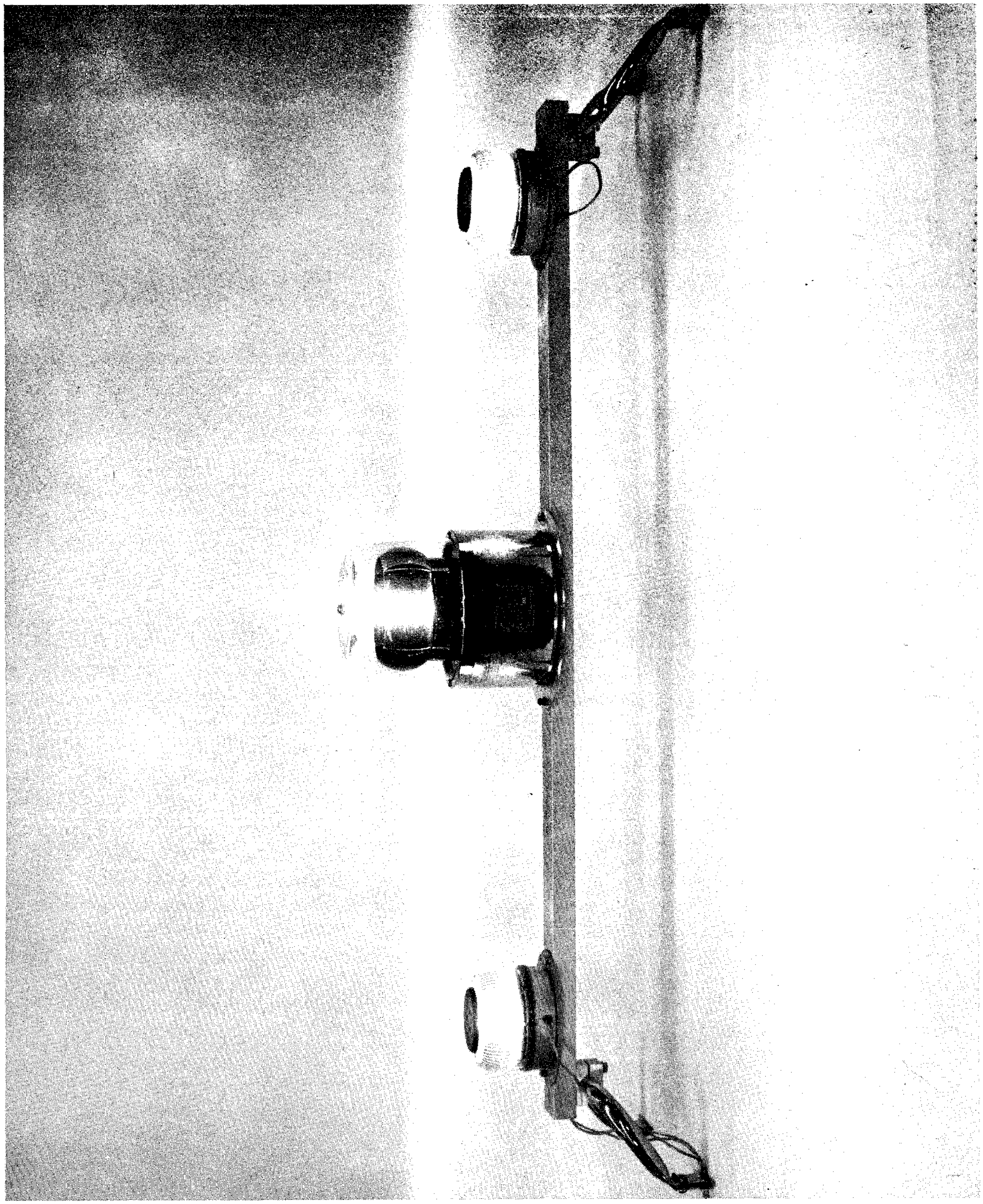


FIGURE 2. LIGHT BAR CONFIGURATION (TYPICAL OF FIGURE 1, CONFIGURATION 8)

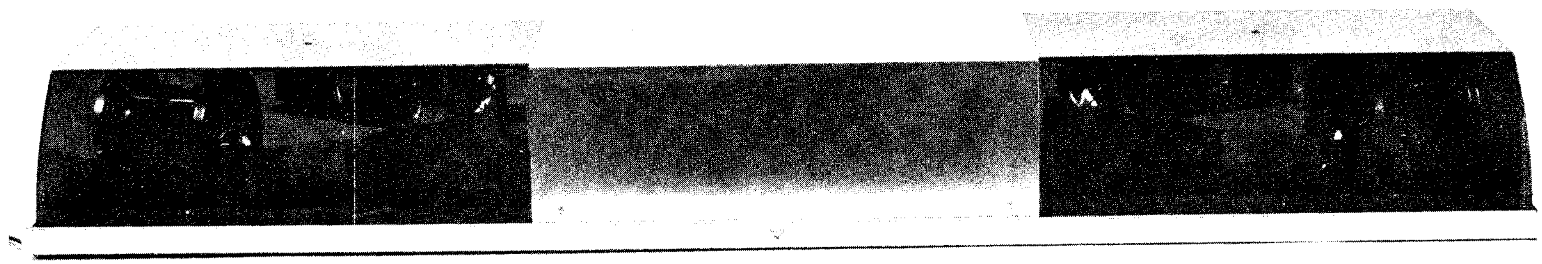


FIGURE 3. LIGHT BAR CONFIGURATION (TYPICAL OF FIGURE 1, CONFIGURATION 9)

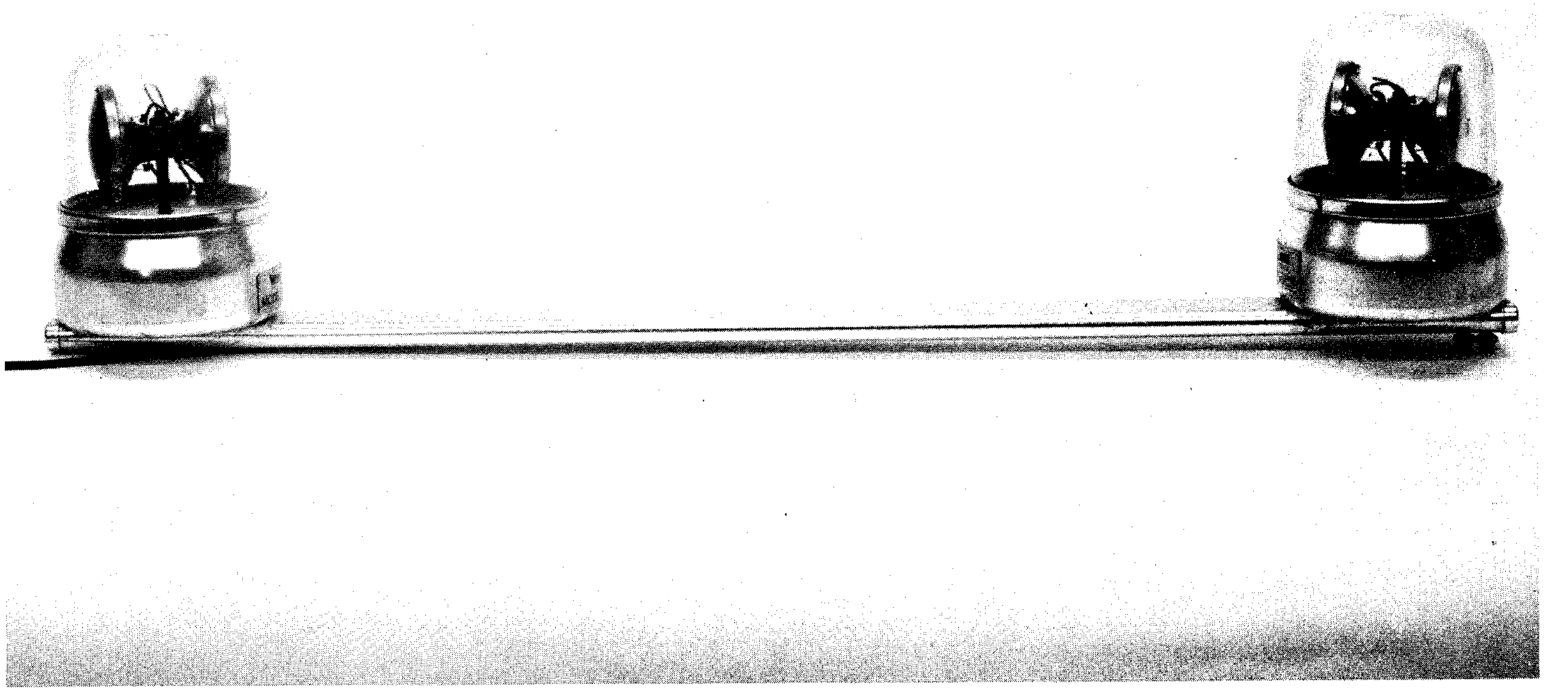


FIGURE 4. LIGHT BAR CONFIGURATION (TYPICAL OF FIGURE 1, CONFIGURATION 10)

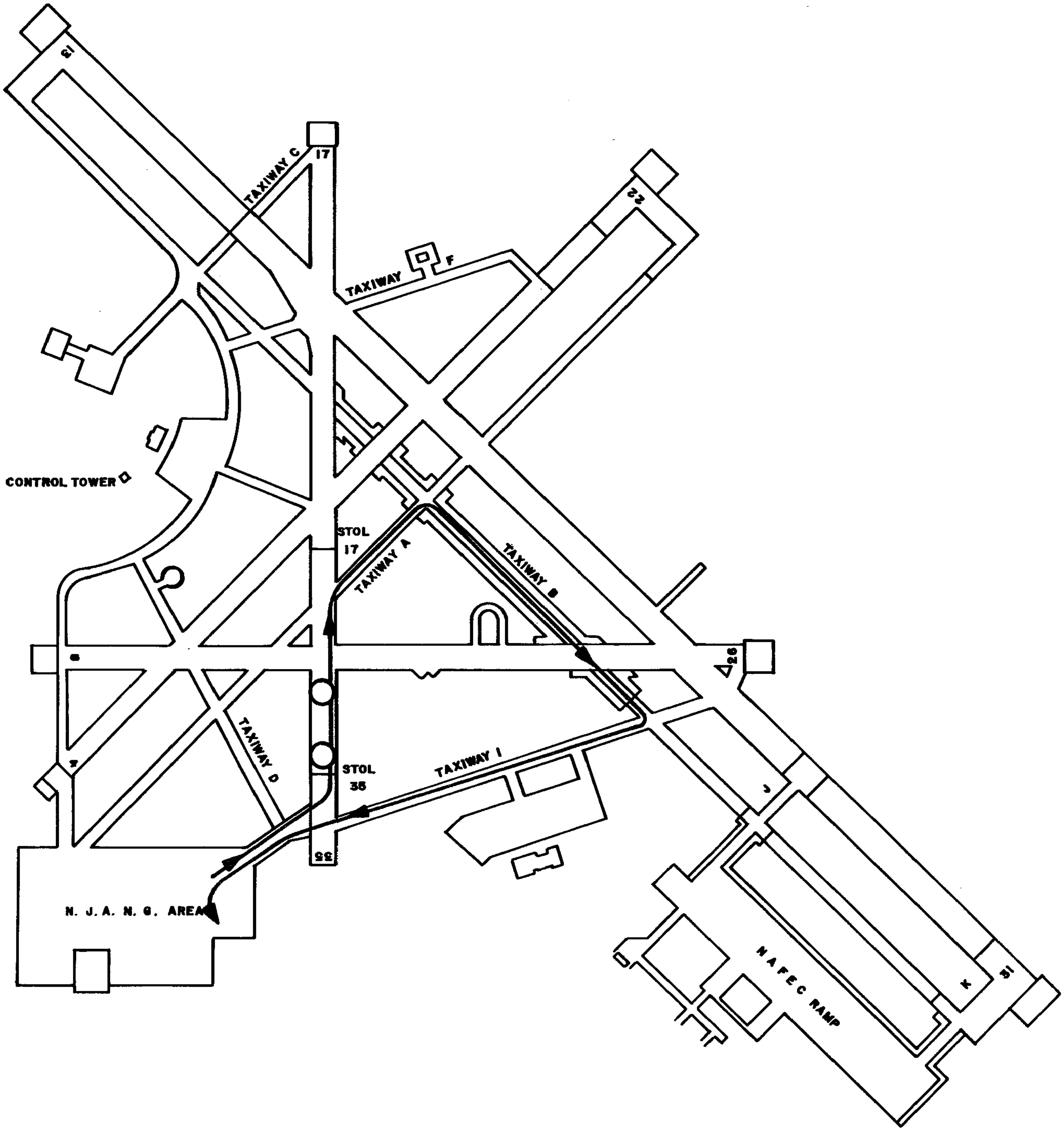


FIGURE 5. VEHICLE IDENTIFICATION BEACON TEST COURSE

EMERGENCY VEHICLE LIGHT TEST

Date __________. Time __________. Day __________? Night __________? Weather __________?

This test is not intended to be made easy and it may require considerable judgment on your part. Therefore use a pencil in case you want to change your mind.

In order to give you some basis for comparison, a truck with the present emergency lights on it will be shown first.

Consider all viewing angles, all weather conditions, and all possible airport conditions such as airport and aircraft lights, etc.

The bar of lights may or may not be shown in numerical order as time is required to change the lights. We will be in radio contact with all parties during the tests. The vehicle will make the same manuever for each test which will include standing, moving slowly, circling and moving rapidly.

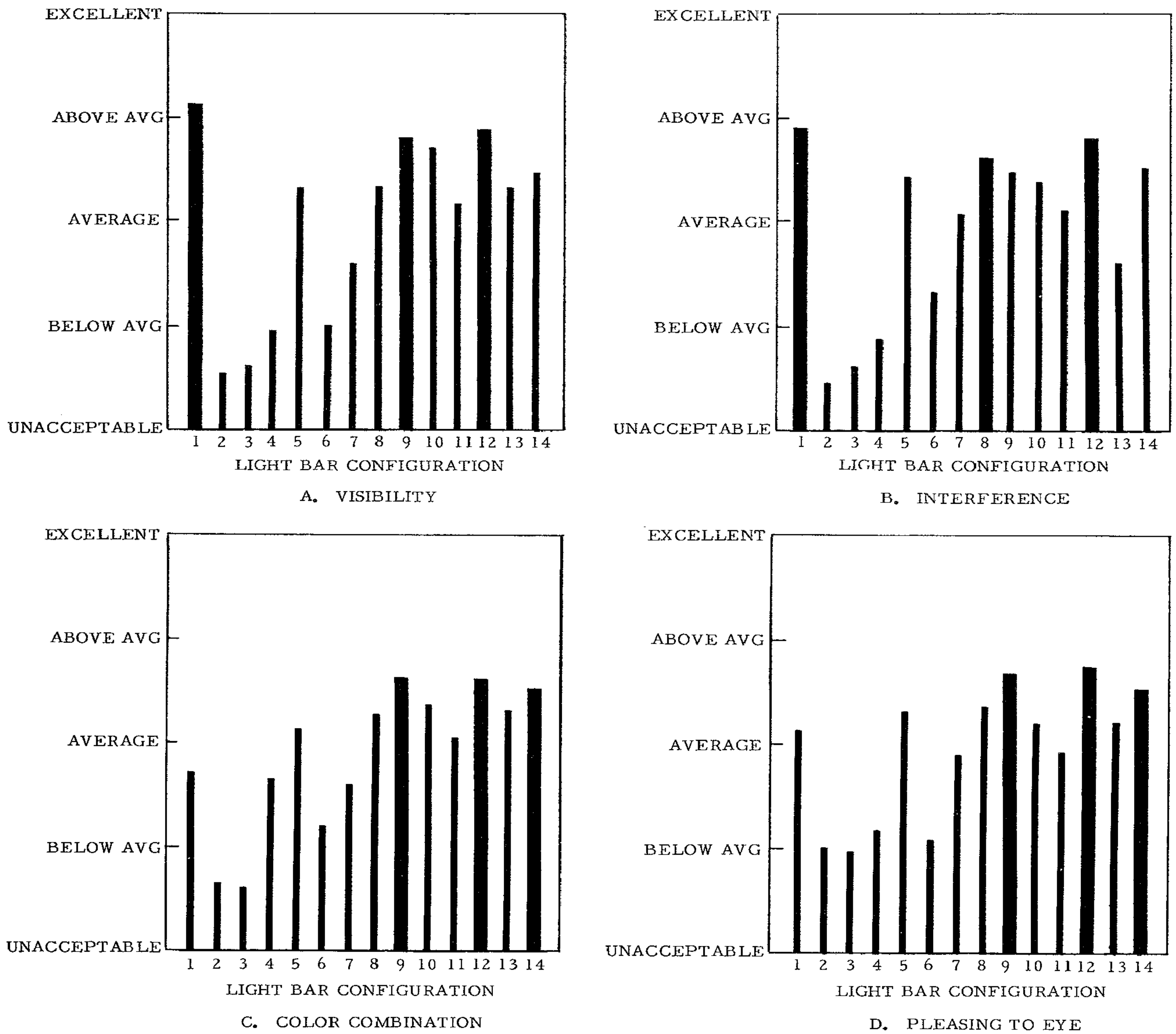
Rate by: Numbers 1 through 5. Number 1 means excellent. Number 5 means unacceptable.

How do you rate:	LIGHT BARS 1	2	3	4	5	6	7	8	9	10	11	12
A. The visibility of the light combination? (Consider combination as a whole, not individual lights.)												
B. The lack of interference with similar airport lights? (Consider no interference as being excellent.)												
C. The color combination (individual lights)? (Rate individual lights that make up the whole combination.)												
D. The acceptability of the colors as a group? (Is it pleasing to the eye?)												
E. The overall distinctiveness of the lights as a group? (Does this combination "hit" you between the eyes or do you slowly pay attention.)												
F. The depth perception with this combination? (How well can you judge the distance of the lights from you?)												
G. The motion of the vehicle? (Can you detect when the vehicle is moving slowly?)												
H. How well this combination clearly distinguishes it as an emergency vehicle as compared to maintenance vehicles, etc.?												

What light bars did you find not suitable __________?
What color combination, would you prefer for emergency vehicles?
Remarks __________.

FIGURE 6. EMERGENCY VEHICLE LIGHT TEST QUESTIONNAIRE

FIGURE 7. INDIVIDUAL TEST VARIABLES OF QUESTIONNAIRE RESULTS (Sheet 1 of 2)



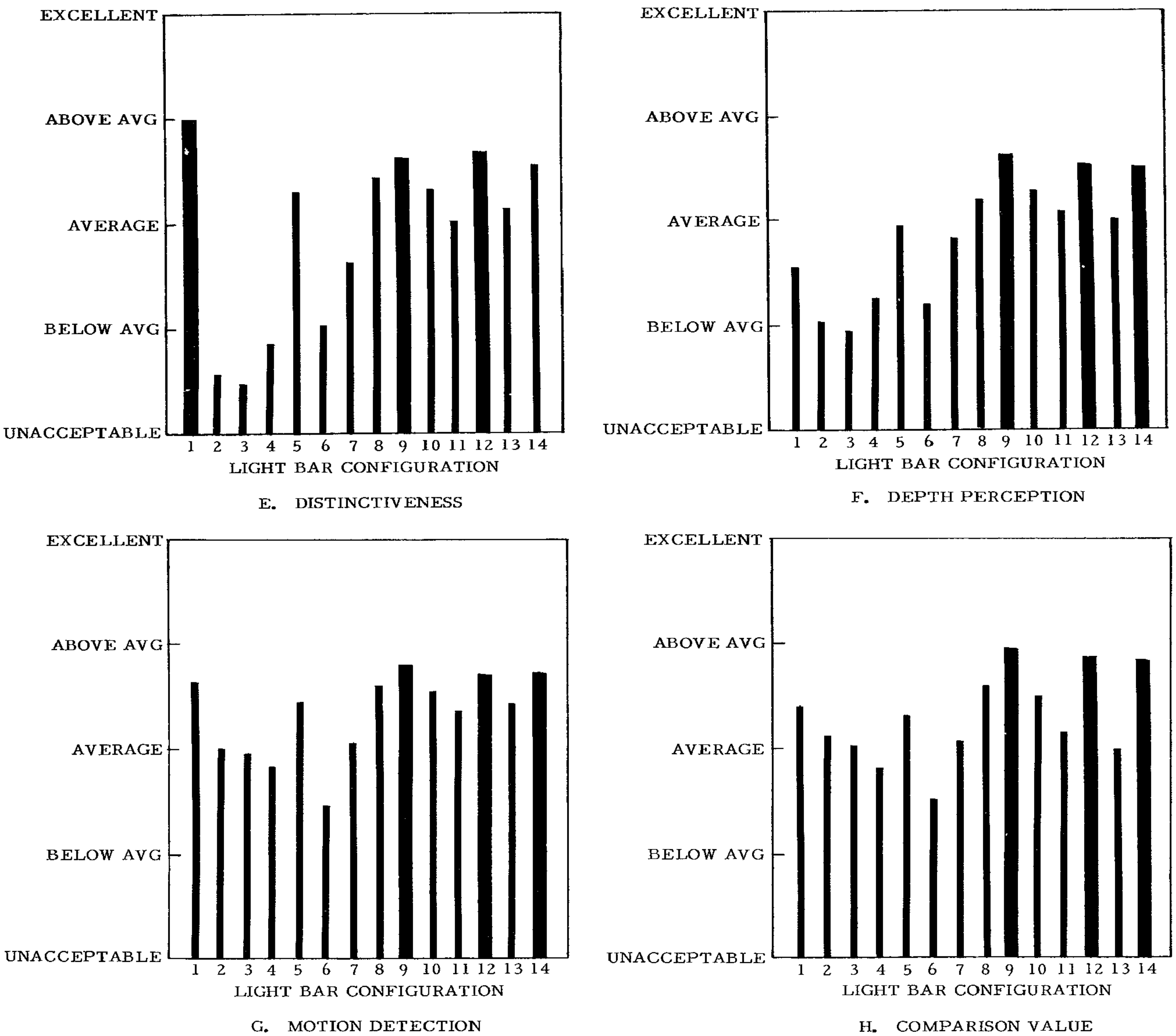


FIGURE 7. INDIVIDUAL TEST VARIABLES OF QUESTIONNAIRE RESULTS (Sheet 2 of 2)

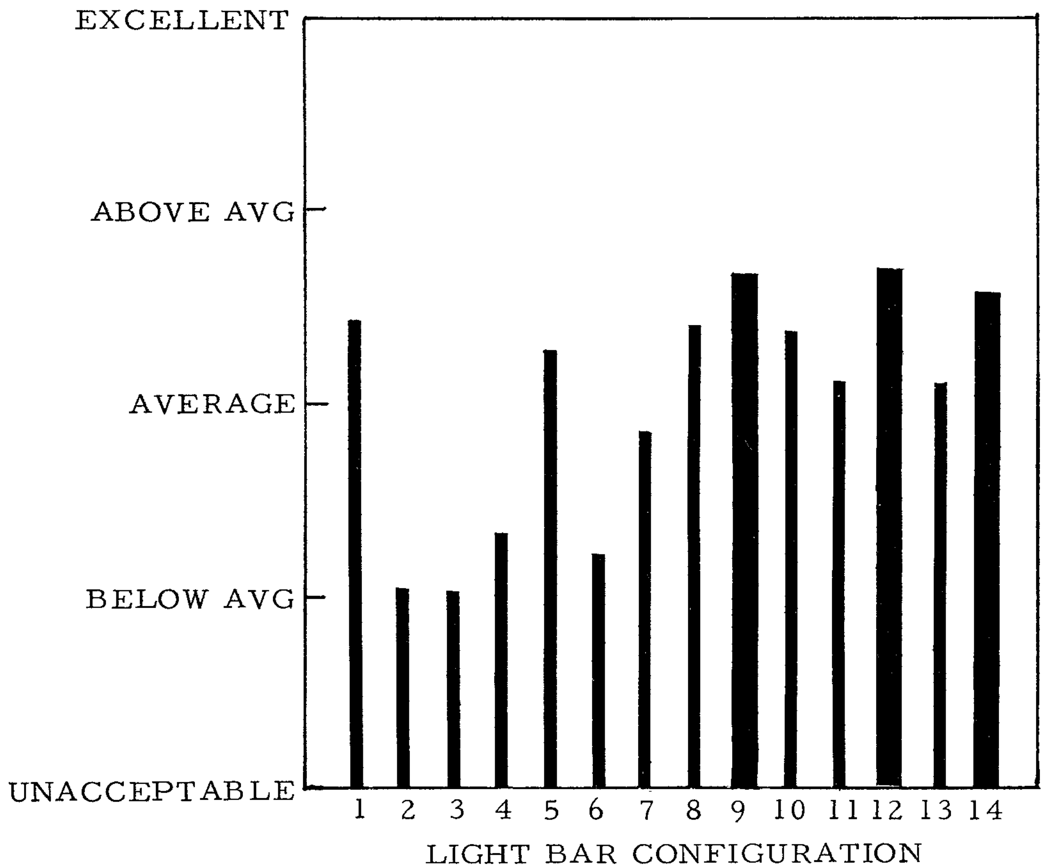


FIGURE 8. SUMMARY (FIGURE 7) OF QUESTIONNAIRE RESULTS

APPENDIX A

EFFECTIVE INTENSITY MEASUREMENTS OF THREE VEHICLE LIGHT BARS

Project 071-312-000
Report No. P-4-73,
Dated September 27, 1973

GENERAL.

This report presents the results of photometric measurements of the effective intensity of the individual sources of three light bars for emergency vehicle identification.

MATERIAL SUBMITTED.

Three fixtures described as follows:

No. 8. Three Xenon flash tube units. End units have blue (blue-green) 360° lens, center unit has 360° lower red sector with 360° upper clear sector.

No. 9. Rotating incandescent spot lamps, one pair on each end. Bilateral symmetry, counter rotation synchronized through common chain drive. Each rotating lamp pair has three stepped metal mirrors reflecting forward and three reflecting backwards. Red filter housing cover all optical components.

No. 10. Each end has two rotating lamps, back to back; one red, one clear.

SERVICES REQUESTED.

Measure the effective intensity of the submitted light bars.

BACKGROUND.

Of the seven base units (meter, kilogram, second, ampere, kelvin, mole, and candela) in the modernized metric system, the candela is unique in that it purports to quantify a nonphysical quantity by means of a physical artifact. The candela is defined as the luminous intensity in the perpendicular direction of 1/600,000 of a square meter of a blackbody at the freezing point of platinum.

Luminous intensity is nonphysical in that it is a quantity perceived by an indivdual as a part of his visual response to radiant energy. This perception is highly variable and leads to various definitions of scales of candela.

To generate working definitions of particular candelas, a mathematical relationship for luminous flux is used. The magnitude of the unit of luminous flux is defined as: "One lumen is the luminous flux in a unit solid angle of one steradian by a point source having a uniform intensity of one candela."

The mathematical relationship is:

$$\phi_v = K_m \int_o^\infty \phi_{e,\lambda} \; V(\lambda) \; d\lambda \qquad (1)$$

where ϕ_v is the luminous flux; $\phi_{e,\lambda} = \frac{d\phi e}{d\lambda}$ is the spectral concentration of radiant flux; $V(\lambda)$ is a visibility function chosen on the basis of some particular psychophysical experiments; and K_m is chosen so that for ϕ_e,λ for a blackbody at the freezing point of platinum and the particular visibility function, the numerical result is consistent with that resulting from other visibility functions and the base unit. The numerical consistency of the units, however, is practically the exception rather than the rule.

Two visibility functions that are of major importance are the photopic and the scotopic. The photopic scale of units factor is designated as $V(\lambda)$ and is representative of the spectral sensitivity of the central 2° field of vision over some range of light adaptation. The scotopic scale of units factor, designated $V'(\lambda)$, is meant to be representative of the spectral sensitivity of peripheral vision of dark-adapted young eyes. These two visibility functions are depicted in figure A-3. (See principles of light measurements, publication CIE No. 18 (E-1.2) 1970.)

Lights which move or suggest motion or flash are more prominent than fixed lights giving the same luminous energy at the eye. The Blondel-Rey integral equation expresses the intensity of a flashing light in the candela rating of a steady light which appears equally bright when both are centrally fixed in the field of vision. The intensity of the apparently equally bright steady light is called the effective intensity of the flashing light, Ie:

$$I_e = \int_{t_1}^{t_2} I \, dt \; / \; \underline{a} + t_2 - t_1 \qquad (2)$$

where I is the instantaneous intensity; t_2 and t_1 are the time in seconds at which the instantaneous intensity is equal to the effective intensity and the value of Ie is a maximum (see C. A. Douglas and T. H. Projector (Illuminating Engineering, Vol. 52, No. 12, December 1957)); a has the value 0.2 seconds at threshold perception. (See T. H. Projector (Illuminating Engineering, Vol. 52, No. 12, December 1957) for a discussion of experiments which show a decrease in the value of a for illuminance levels above threshold.)

TEST METHODS.

Figure A-1 is a block diagram of the measurement system used to obtain the data. The luminosity filter, in combination with the photodiode sensor have a spectral sensitivity which closely matches $V(\lambda)$, the photopic visual response, so that for most sources tested, the calculation indicated in Equation (1) is avoided for the photopic scale. A standard lamp of known intensities (on the photopic scale) is placed a measured distance from the sensor diffusing glass and a linear calibration factor determined over the range of illumination required for the test. The output of the sensor is recorded on an instrument whose technical specifications are shown in figure A-2. A programmable calculator performs a numerical integration of Equation (2), using the recorded values of time and instantaneous intensity.

For some of the fixtures, a factor was estimated for relating scotopic intensity to photopic intensity measured (figure A-3). Time was not available to obtain all data necessary for an analytic measurement of the scotopic intensity in accordance with Equation (1).

The purpose of including an estimated scotopic scale intensity is that there may be circumstances where peripheral dark-adapted vision is important. A deep-red light that is quite perceptible when vision is directed toward it may be difficult to find when vision is not directed toward it. The estimate assumes the Blondel-Rey equation is applicable to peripheral scotopic vision. All light bars were operated at 12 VDC.

RESULT OF TESTS.

See tables A-1 through A-5 and figures A-4 and A-5.

TABLE A-1. EFFECTIVE INTENSITIES FOR CONFIGURATION 8

Elevation Angle In Degrees	Effective Intensity (Candelas) Red and Clear On Photopic Scale	Individual Blue On Photopic Scale	Individual Blue On Scotopic Scale
-10	33	-	-
- 8	35	-	-
- 7	39	39	179
- 6	44	46	212
- 5	50	52	239
- 4	57	68	313
- 3	73	98	451
- 2	94	137	630
- 1	104	156	718
0	114*	182*	837*
1	104	169	777
2	64	115	529
3	51	64	294
4	41	37	170
5	40	26	120
6	36	-	-
8	29	-	-
10	21	11	51
15	9	-	-
20	25	25	-
32	110(Clear)	43	-

NOTE: *Maximum effective intensity.

TABLE A-2. EFFECTIVE INTENSITIES FOR CONFIGURATION 8 END LAMPS WHEN EQUIPPED WITH RED LENS HOUSING AND WHEN EQUIPPED WITH YELLOW LENS HOUSING

Elevation Angle In Degrees	Effective Intensity (Candelas) Red On Photopic Scale	Red On Scotopic Scale	Yellow On Photopic Scale
-7	26	1	92
-6	30	2	103
-5	39	2	103
-4	54	3	113
-3	68	4	125
-2	79*	4*	129
-1	76	4	162
0	69	4	278
1	43	2	337*
2	26	1	273
3	18	1	199
4	14	1	129
5	12	1	102

NOTE: *Maximum effective intensity.

TABLE A-3. EFFECTIVE INTENSITIES FOR CONFIGURATION 9 (WITH 60-WATT LAMPS AND RED FILTER)

Elevation Angle In Degrees (Azimuth 0°)	Effective Intensity (Candelas)*		
	Direct Beam Average On Photopic Scale	Direct Beam Average Scotopic Scale	Individual Reflections Average On Photopic Scale
-4	70	3	11
-2	262	12	34
0	320**	14**	76
2	316	14	84**
4	237	11	56
6	86	4	20

Azimuth Angle In Degrees (0° Elevation)	Effective Intensity (Candelas)*	
	Direct Beam Average On Photopic Scale	Individual Reflections, Average On Photopic Scale
± 4	320	63
± 8	320	54
±12	320	37
±16	320	23
±20	316	7

NOTE: *These effective intensity values are calculated by treating the flashes as individual isolated sources. No established basis was available for calculations at distances and conditions where all flashes are seen both individually and as a sequential and spatial pattern.

**Maximum effective intensity.

TABLE A-4. COMPARISON OF EFFECTIVE INTENSITY OF CONFIGURATION 9 WHEN LAMPED WITH 30-WATT GE NO. 4416 LAMPS AND WHEN LAMPED WITH GE NO. 4464 60-WATT LAMPS.

Average Photopic Effective Intensity (Candelas)

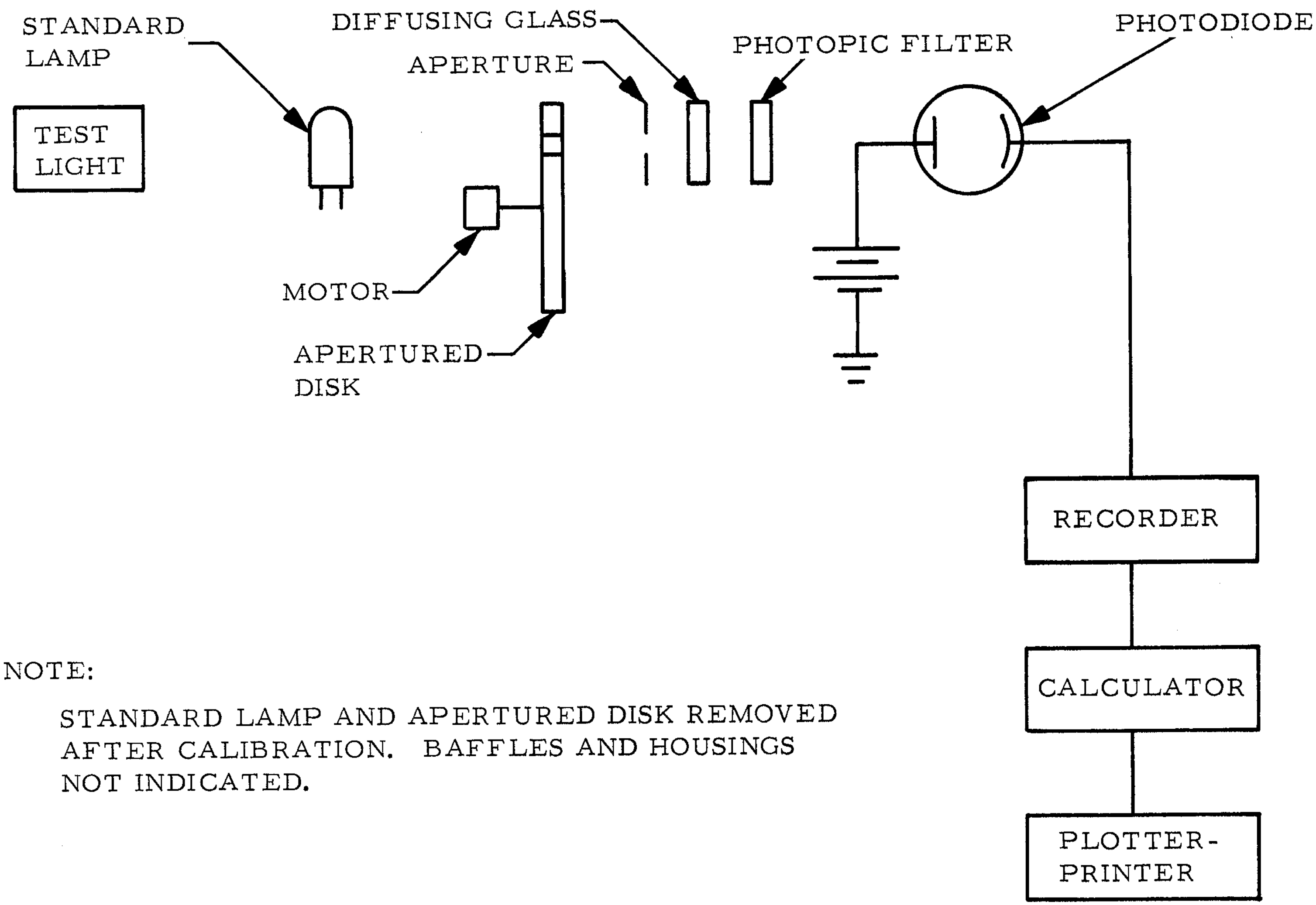
Elevation Angle In Degrees, Azimuth Normal	Direct Beam 4416	Direct Beam 4464	Reflections 4416	Reflections 4464
0	200	320	41	76
+6	14	86	9	20

TABLE A-5. EFFECTIVE INTENSITIES FOR CONFIGURATION 10

Individual Flashes (Candelas)

Elevation Angle In Degrees	Clear On Photopic Scale	Red On Photopic Scale	Red On Scotopic Scale
-6	-	12	1
-5	153	21	1
-4	305	42	2
-3	491	64	3
-2	660	81	3
-1	793	91	4
0	862*	97*	4
1	852	94	4*
2	739	86	4
3	587	72	3
4	410	53	2
5	219	32	1
6	-	15	1

NOTE: *Maximum effective intensity.



NOTE:

STANDARD LAMP AND APERTURED DISK REMOVED AFTER CALIBRATION. BAFFLES AND HOUSINGS NOT INDICATED.

FIGURE A-1. BLOCK DIAGRAM OF MEASUREMENT APPARATUS

TECHNICAL SPECIFICATIONS

INPUT CHARACTERISTICS

Input Impedance	1 megohm ‖ 50 pf.
Input Range	10 mV to 50 V full scale.
Input Resolution	0.4% or 1 part in 256 for full scale input.
Input Offset	±1.5 X full scale input range. Light indication when part of signal is offscale.
Maximum Input Level	±100 V.
Frequency Response	DC to 500 KHz all ranges (3 db point; AC coupling provides low frequency cutoff of 2 Hz).
Sweep Time, Sweep A or B	500 μsec to 20.0 sec for the first 1000 words.
Sweep Time, External	External advance of sweep. Pulse of +5 V to 0 V, risetime <100 nsec, advances memory one step. Rate continuously variable from 2 μsec to 500 μsec per address. If delay of more than 500 μsec occurs between advance pulses, all further pulses will have 2000 μsec latency.
Internal Calibration	Signal provided to record independent of the sweep time selected. Useful for setup of scope display or YT recorder.

TRIGGERING CHARACTERISTICS

Modes of Operation	
Auto	Sweep is initiated every 100 msec in the absence of a trigger (useful primarily during setup).
Normal	Sweep initiated by each acceptable trigger.
Single	Sweep initiated by each acceptable trigger only after arming by pushbutton switch or by remote arm input.
Trigger Selection	
Source: Internal	Trigger obtained from input signal.
External	External trigger required.
External ÷ 10	External trigger input attenuated by 10.
Slope	Positive or negative selectable.
Level	0 to ±5 V adjustable.
Trigger, Internal or External	
Pulse Width	>100 nsec.
Pulse Height	>400 mV.
Trigger Coupling	
DC	DC coupling.
AC Slo	20 Hz to 30 kHz.
AC	15 kHz and above.
Trigger Delay	0 to 10X sweep time (nominally) to a maximum of 10 sec, continuously variable.
Modes of Operation	
Trigger Holdoff	Next trigger (Normal mode) not acceptable until after delay period set with 10 turn control.
Delayed Sweep	Sweep start is delayed from trigger by the delay period set with 10 turn control.
Pretrigger Recording	Recording is continuous until trigger is received, at which time delay period starts. End of delay period stops recording process so that signal received prior to end of trigger plus delay period is held in memory.
Switched Time Base	Sweep Time A is used for initial portion of sweep. Switch to Sweep Time B after delay selected on 10 turn delay control. Sweep Times A and B are set independently. Change-over point continuously variable
Delay Stability (short term)	±1% of sweep time or 1% of delay, whichever is greater.

FUNCTIONAL CHARACTERISTICS

A/D Converter	8 bit, 50 Hz to 2 MHz word conversion rate, depending upon sweep time selected.
Time Base	10 MHz crystal controlled oscillator

OUTPUT INTERFACE

Output Signal	
Analog X Axis	1 V full scale ±1.5 V offset.
Display Expand	X1, X5, X10.
Analog Y Axis	1 V full scale ±1.5 V offset
Digital Information	8 bit parallel TTL level, positive true.
Digital Address	10 bit parallel TTL level, positive true
Switched Time Base Point	1 bit TTL level, positive true.
Input Range, Sense	6 line parallel, 0 to +2 V, positive true, 1 K source impedance, 10 K minimum load.
Input Range, Control	6 line parallel, 0 to +4 V, maximum source impedance 500 Ω.
Sweep Time A, Sense	7 line parallel, 0 to +2 V, positive true, 1 k source impedance, 10 K minimum load.
Sweep Time A, Control	7 line parallel, 0 to +4 V, maximum source impedance 500 Ω.
Sweep Time B	Not available digitally.
Output Sweep Speed	
Analog Y Axis	2 msec for oscilloscopes, 100 sec for YT recorder.
Analog X Axis	2 msec only.
Digital	2 μsec to 500 μsec/address, 2 msec latency for asynchronous rates slower than 500 μsec/point. Digital output starts at fast rate. If delay of more than 500 μsec occurs between command pulses, all further points will have 2 msec latency.

DIGITAL INTERFACE SIGNALS

Output Command	TTL, +5 V to 0 V and held at 0 V to provide digital output operation.
Flag Output	
Level	TTL, 0 to +4 V, risetime <100 nsec.
Pos. Transition	New data available in output buffer
Neg. Transition	Command has been received and should be removed.
Word Command	
Level	TTL, +5 V to 0 V, risetime <100 nsec.
Neg. Transition	Requests next word to be placed in buffer.

MISCELLANEOUS

Operating Temp. Range	0-55°C
Power	100-130 or 200-260 V AC, 50 W, 50-60 cycles.
Size	Height 5.25 inches, width 8.5 inches, depth 17 inches.
Weight	18 lbs., shipping weight 25 lbs.

FIGURE A-2. TRANSIENT RECORDER TECHNICAL SPECIFICATIONS

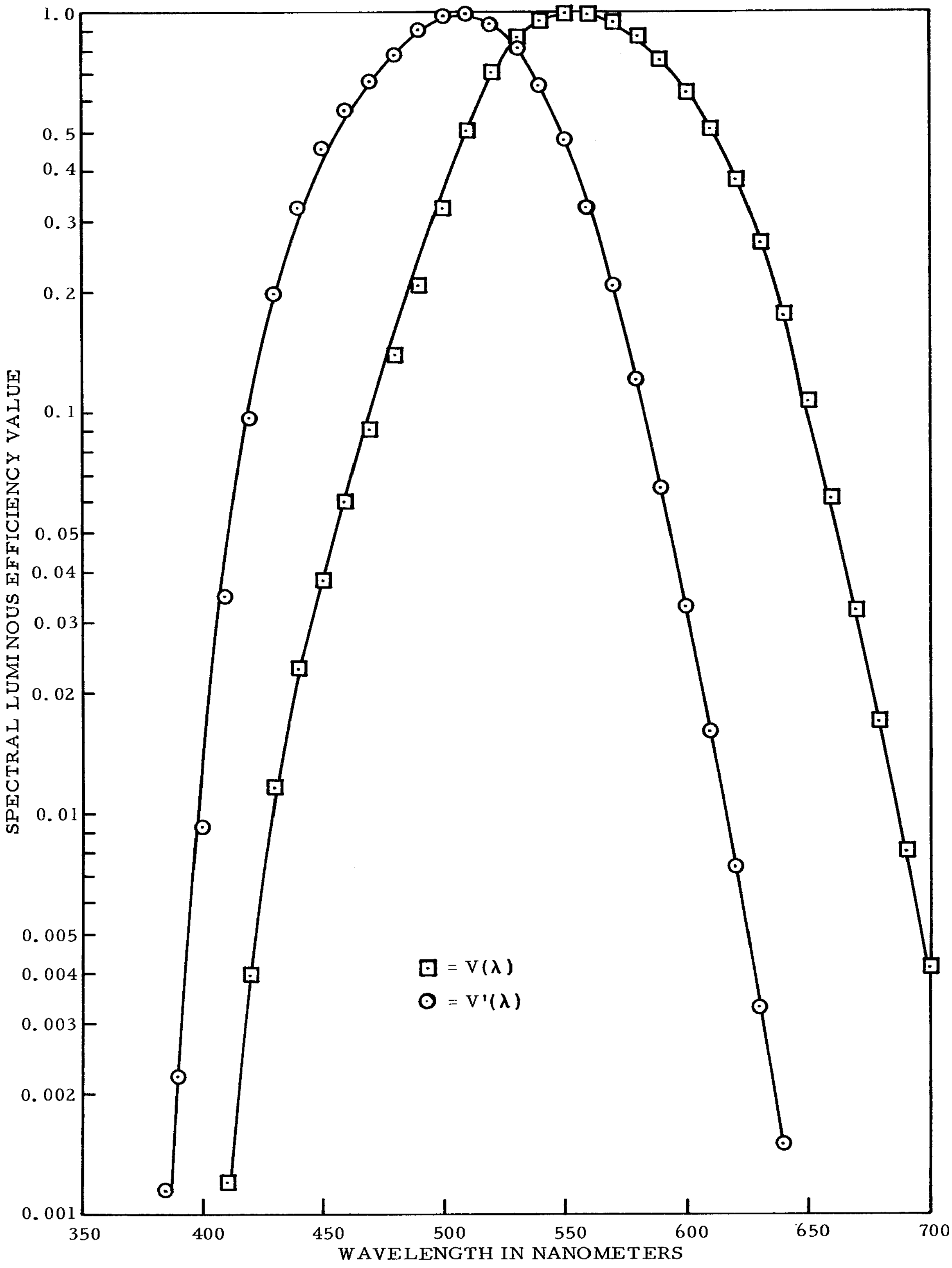


FIGURE A-3. PHOTOPIC AND SCOTOPIC VISIBILITY SPECTRUM

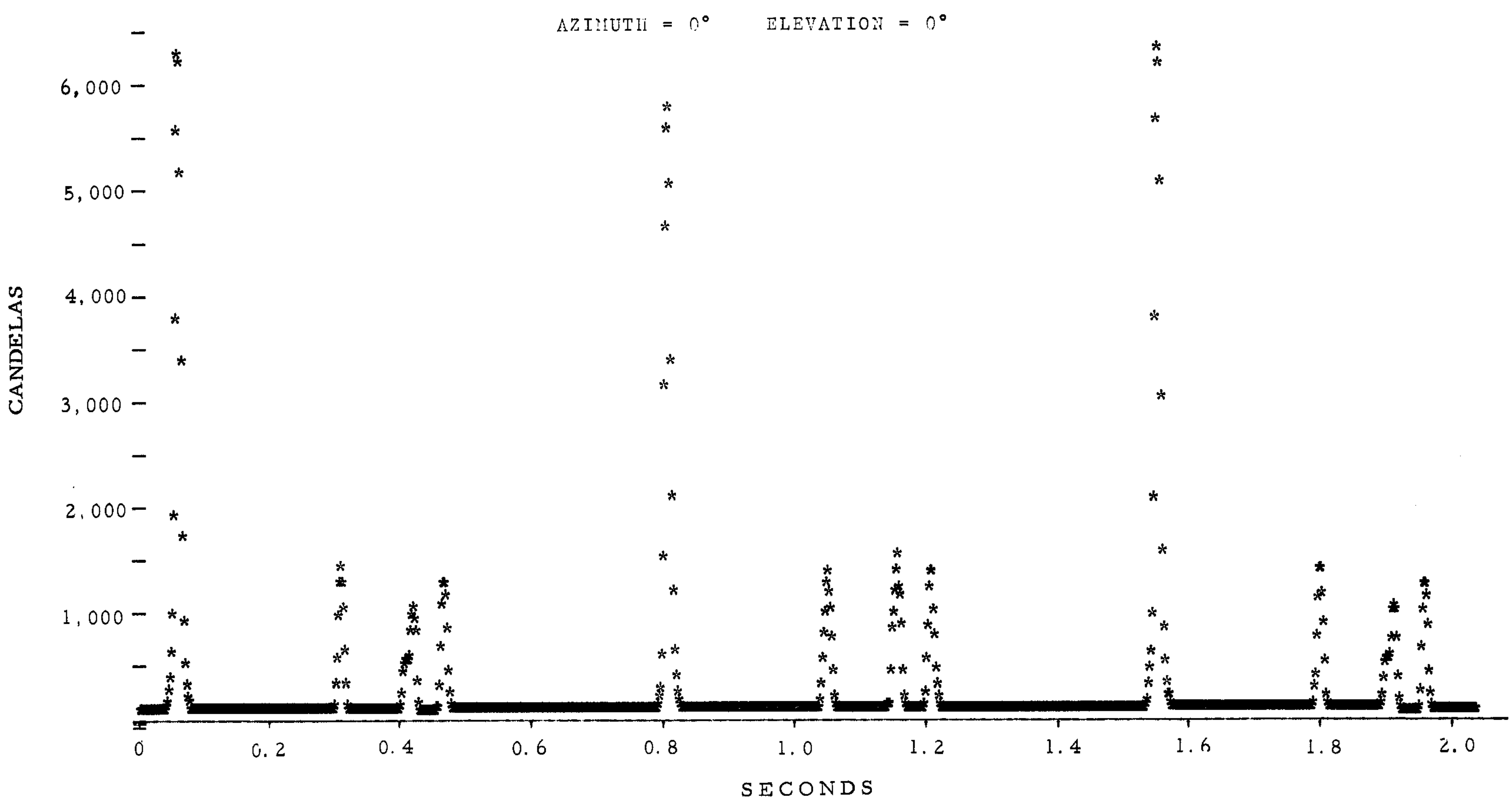


FIGURE A-4. COMPLETE PRESENTATION OF ONE SIDE OF CONFIGURATION 9 LIGHT INTENSITY SPECTRUM

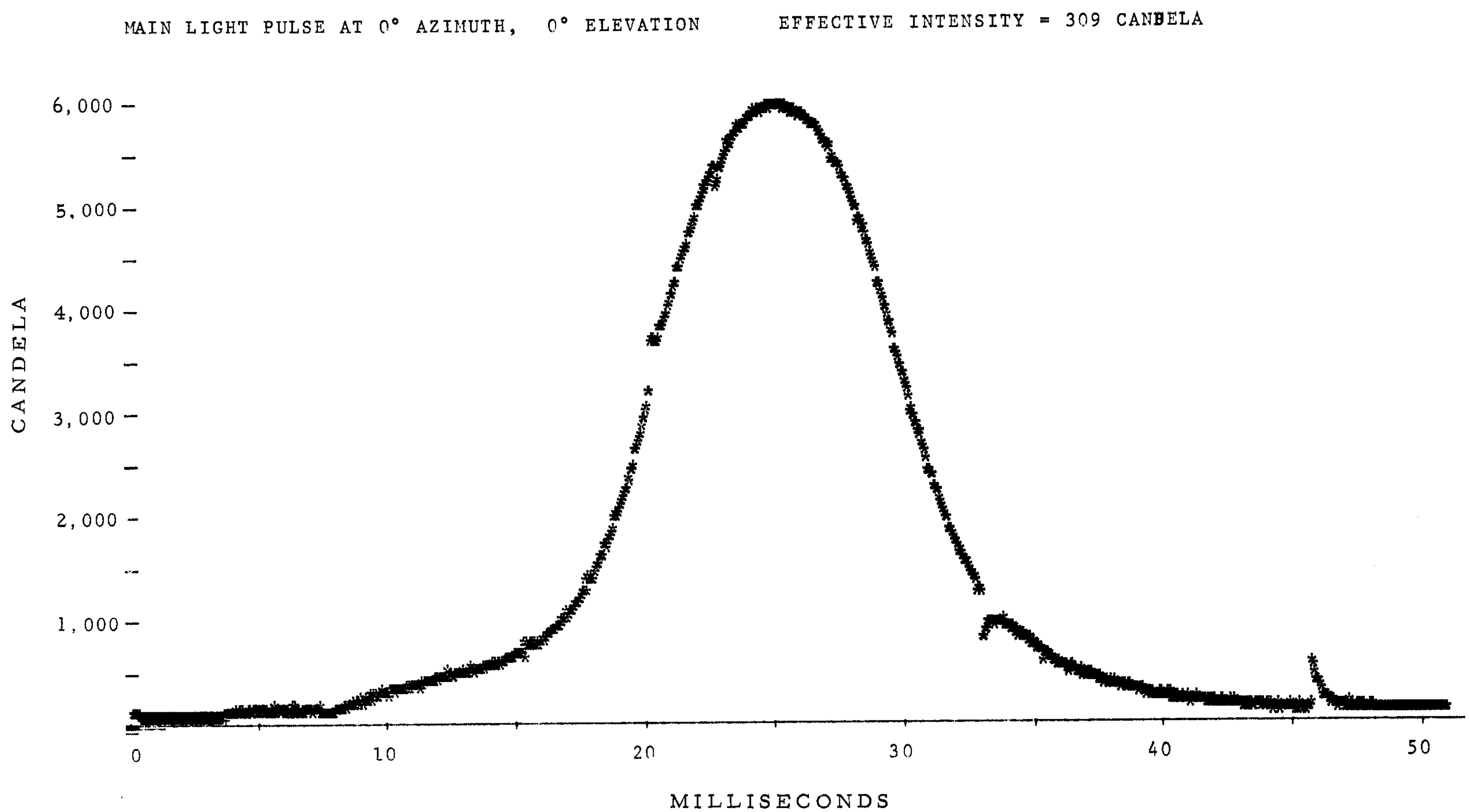


FIGURE A-5. TYPICAL MAIN LIGHT PULSE OF CONFIGURATION 9 LIGHT INTENSITY SPECTRUM