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NAVY DEPARTMENT

Report on

PHOTOMETER FOR NIGHT VISUAL RANGE OF LIGHT LOCK OPENINGS

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ABSTRACT

A low brightness photometer, and the calibration thereof, is described for the purpose of measuring the night visual ranges of light lock openings.

CHAPTER 1

INTRODUCTION

A light lock is a passage way between a lighted compartment and the exterior designed to permit personnel to pass through as readily as possible and to permit as little light as possible to pass out. The light emerging from the external opening of the light lock must be less than a certain value in order that the opening be invisible beyond a specified "safe" distance, otherwise the light lock fails to fulfil its intended purpose. The maximum distance that the opening can be seen at night is called the "visual range". In the investigation of the design of light locks at this Laboratory in co-operation with the Bureau of Ships a photometer was developed for the measurement of the visual range of the light lock opening. This report describes the photometer and the calibration and manner of use of the photometer.

CHAPTER 2

VISUAL RANGE PHOTOMETER

The visual range photometer is the low brightness photometer described by the University of Rochester[1] with minor modifications. It employed a radio-active luminous button as a source of comparison illumination. The button obviated the use of a battery operated light and may be expected to hold its calibration for a year. A photograph of the photometer is shown in Plate 1. The photometer was arranged to cover the brightness range of about 0 to 1500 milli-micro-lamberts (mμL). It was calibrated in the accepted manner by comparison with the illumination from a tungsten lamp at a temperature of 2360° Kelvin.

The visual range of an illuminated area at night depends mainly on the brightness, shape and size of the area, the brightness and color of the area and of the background, the clearness of the atmosphere and the eye-sight of the observer. It was assumed that the area was the color of tungsten light, that the background was black and that the atmosphere was perfectly clear. The visual range in meters of a rectangle 2.5 cm wide and 10 cm long as a function of the brightness of the rectangle against backgrounds of various brightnesses was observed by the University of Rochester[2]. Nine observers were used; the individual values are given in columns 2 to 10, Table 1, and the averages of these columns in column 11. The values of column 11 are plotted in the curves of Plate 2. From these curves the visual ranges k of the 2.5 x 10 cm rectangle were read off for several values of target brightness and are tabulated in Table 2.

It is convenient to express the visual range in terms of the area of the illuminated target. In so doing the assumption is made that targets of the same area but different shapes are equally visible. The assumption is true to a close approximation provided the shapes do not differ too extremely from squares or from the rectangle of 1:4 aspect of the Rochester data. Then

$$R = KA^{\frac{1}{2}} \qquad (1)$$

where R is in yards, A is in square feet and K is in the third column of Table 2.

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1. "Measurements of the brightness of the night sky", Institute of Optics, University of Rochester. Project OEMsr-265 of Section C-6, NDRC, about 1942 (undated).

2. "Visibility of targets at low levels of illumination", Institute of Optics, University of Rochester, Project OEMsr-160 of Section D-3, NDRC, about 1942 (undated).

[redacted]

K is the visual range of a target of area 1 square foot. It is related to k, the visual range in meters of a 2.5 x 10 cm rectangle, by

$$K = (1.0936/0.0269^{\frac{1}{2}})\ k$$

$$= 6.66\ k\ ,$$

where 1.0936 is the number of yards in a meter and 0.0269 square feet is the area of a 2.5 x 10 cm rectangle.

From the brightness calibration of the photometer and from Table 2 the photometer scale was laid off in values of K. A full sized drawing of the scale is shown in Plate 3. The photometer was then used to determine the night visual range of an illuminated area against a black background in the following way,

> Take the reading K when the photometer is adjusted to match the brightness of the illuminated area. The visual range in yards of the illuminated area is K times the square root of the area in square feet.

For example, if the photometer reading was K = 125 for an area of 12 square feet, the visual range of the area was

$$125 \times 12^{\frac{1}{2}} = 433 \text{ yards.}$$

Suggested procedure. If the light lock is installed on a vessel which cannot be moved away from disturbing artificial illumination at night, build a light-tight room or tent, with interior surfaces black, over the opening with sufficient space so that the observer can make observations from a distance of at least about 6 feet from the opening. With the illumination in the compartment turned on the observer makes 5 photometer readings each at about 6 points distributed over the opening. The average of these is the value of K which, together with the effective area of the opening in square feet, gives the visual range.

If the vessel is at sea or in a place where there is no disturbing external artificial illumination the readings may be made in the open on any moonless night. In this case readings are taken without any illumination in the compartment, their average (if different from zero) being subtracted from the average of the readings taken with the compartment illuminated.

It is scarcely necessary to remark that the observer must be completely dark adapted, which requires nearly an hour in the dark if he has been exposed to full daylight and about 30 minutes if he has been in a normally lighted room.

[redacted]

CHAPTER 3

VARIOUS DETAILS

Accuracy of low brightness photometry. If the "safe" visual range that one is concerned with is, say, 500 yards and if one has light lock openings of area 8, 12, 16 and 20 square feet, one has from Eq. (1) values of K 177, 145, 125 and 111, and hence from Table 2 values of target brightness 185, 125, 94 and 66 $m\mu L$, respectively. These are fairly low brightnesses; they are the brightnesses of a clear, starry, moonless, night sky. Thus one is concerned with the measurement of rather low brightness, and the visual method of measurement by means of the photometer of Plate 1 is not capable of yielding a very high accuracy. However, it is the best portable photometer of the visual type known at the present time. No non-visual photometers suitable for the purpose exist; they could be developed, but not quickly or easily.

Investigation in the laboratory of the photometer of Plate 1 with the K scale of Plate 2 used by 12 experienced observers and 6 inexperienced observers, all with normal eyes, gave the following results:

(a) If a series of 5 readings are taken an individual reading may deviate from the average by 15 percent for an experienced observer and by 30 percent for an inexperienced observer.

(b) An average of 5 readings may be expected to be correct within ±10 percent for an experienced observer and ±20 percent for an inexperienced observer.

(c) After 3 or 4 periods of an hour in using the photometer an inexperienced observer may be said to be "experienced", provided he has enough of the vague quality known as "intelligence" or "commonsense".

(d) An observer must have normal ability to see in the dark, he must not be "night blind". Whether he is color blind or not makes no difference; whether he is 20 or 40 years old makes no difference.

Since the possibility exists that some observers can use the low brightness photometer more consistently than others, the suggestion has been made that a test plate be provided, for example, another luminous button, of known brightness which the observer can use to test his photometer readings. The suggestion has not been tried out, and it is not known whether the suggestion is necessary or helpful. At any rate the suggestion is not harmful.

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Accuracy of visual range. People differ in their ability to see in the dark. The University of Rochester data of the several observers given in Table 1 show this. The data of Table 1 were repeated in a number of cases at this Laboratory; the average values of the last column of Table 1 were confirmed for average good observers, and it was concluded that they refer in general to observers with average good eye sight. At the same time a few observers were found with exceptionally good eye sight at night whose visual ranges were about 60 percent greater than the average values of Table 1 in some cases. At present there is no exact information about the number of persons of exceptionally good eye sight in a group of persons with good eyesight. The question has been mentioned to the Medical Research Laboratory, Submarine Base, New London, Connecticut.

Accuracy of the visual range to be expected from the photometry of the light lock. From the two preceeding paragraphs the accuracy to be expected in the value of the visual range R determined from the suggested procedure of Chapter 2 may be estimated. R is open to an error of $\pm$ 10 percent due to error in the use of the photometer, and to an error of about 60 percent due to an exceptionally keen sighted observer; the maximum error being therefore 80 percent. This means that if the value of R determined from the photometer calibrated in accordance with Table 2 was 500 yards, the actual value of R might be 450 to 550 yards to good observers and might be 900 yards to an exceptional observer. However, there are several reasons why the actual value is probably less than these estimates. The estimates refer to ideal quiet laboratory conditions of total darkness of background and surroundings. Actual conditions in the open make for visual ranges less than those of the laboratory, because of motion, weather and lack of total darkness. This last effect is brought out in Table 3, taken from Reference 2. The Table shows, for example, that the target of brightness 166 $m\mu L$ has a visual range of 25.7 meters if the background is black and a range of 12.6 meters if the background is of brightness 17.8 $m\mu L$. The brightness of the deck or sides of a dark colored ship was observed to range from 10 to 30 $m\mu L$ on moonless nights.

It was concluded that the result obtained from the photometer was sufficiently conservative to yield a "safe" visual range without introducing any further safety factors. If one should contemplate further safety factors he might find that he had got himself to the point of permitting so little light to escape from the light lock that he was unable to measure it. In such case he had better discard the photometer entirely and require merely that no light be permitted to escape.

Openings of various shapes. Eq. (1) and Table 2 refer to the visual ranges of squares and of rectangles for which the ratio of width to length is less than 4. For areas of other shapes, as irregular, long thin rectangles, etc., the visual ranges are in general equal to or less than, but not greater than, the ranges given by Eq. (1) and Table 2.

Effect of a man in the light lock. If the light lock is so constructed that a man in light colored clothes at certain positions in the lock diverts considerable light to the outside, he may increase the visual range in certain directions disastrously.

Non-uniform illumination of the light lock. If the light lock opening has certain areas that are brighter than others Eq. (1) may be used to determine the visual range of the bright areas, or a weighted average value of K may be used. No exact formula has been worked out for the general case of irregular illumination.

Colored illumination. If the illumination of the compartment behind the light lock is yellowish or greenish the photometer of Plate 1 with the calibration of Plate 3, which referred to tungsten light, may be used. If the illumination is highly colored, as red or blue, a special calibration must be worked out for the particular color, which may require a special photometer for each color.

Effect of binoculars. Because of their magnification binoculars increase the visual range of a luminous area and because of their light attenuation they decrease the visual range. The effect of binoculars can be worked out from the curves of Plate 2. Consider 6 power binoculars of assumed light transmission 60 percent used to view the 2.5 x 10 cm rectangle of brightness 100 mμL. From Plate 2 the unaided eye visual range of the rectangle is 19.3 meters. In the binoculars the brightness of the rectangle is 60 mμL and the unaided eye range is, from Plate 2, 14.5 meters. The binocular range is 6 x 14.5 = 87 meters, which is 87/19.3 = 4.5 times the unaided eye range. If the 40 percent of the light lost in the binoculars is scattered over the field the binocular range is less than the 87 meters just calculated.

[redacted]

Table 1. Visual range in meters of 2.5 x 10 cm rectangular target against black background, data of Reference 2.

Target brightness				Visual range in meters of observers a to i						
mμL	a	b	c	d	e	f	g	h	i	Average
16.3	7	11	8	8	9	12	5	7	11	8.5 meters
33.9	12	13	15	11	12	12	9	-	12	11.0
74.1	16	16	20	16	17	14.5	14	12	16	16.4
166	25	20	23	31	29	30	19	23	20	25.7
339	44	33	33	40	42	39	27	40	36	37.2
750	53	50	51	63	63	61	47	54	43	54.5
1580	88	53	81	80	86	86	50	80	71	72.8

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Table 2. Visual range of 2.5 x 10 cm and of 1 square foot target against black background.

Target brightness $m\mu L$	Visual range k of 2.5 x 10 cm	Visual range K of 1 square foot
16.3	8.5 meters	56 yards
20	9.0	60
30	10.5	70
40	12.0	80
50	13.2	88
60	14.5	96
70	15.8	105
80	17.1	113
90	18.2	121
100	19.3	128
110	20.3	135
120	21.3	142
130	22.3	148
140	23.2	154
150	24.1	160
200	28.0	186
250	31.7	211
300	35.0	233
400	40.6	270
500	45.5	303
600	49.4	328
700	52.8	351
800	56.0	373
900	58.6	390
1000	61.0	406
1100	63.2	421
1200	65.2	434
1300	67.2	447
1400	69.2	461
1500	71.2	473

[redacted] L

Table 3. Visual range in meters of 2.5 x 10 cm rectangular target against various backgrounds, data of Reference 2.

Target brightness	Visual range in meters for background brightness from 0 to 100 mμL					
mμL	0	1.78	17.8	31.6	56.2	100 mμL
0	–	1.6	4.7	5.8	7.0	8.4 meters
16.3	8.5	6.5	0.5	3.0	5.0	6.8
33.9	11.0	9.7	4.1	0.8	3.0	5.6
74.1	16.4	13.3	6.6	4.8	2.0	3.2
166	25.7	21.2	12.6	10.1	7.3	3.9
339	37.2	31.6	21.4	18.3	14.8	11.0
750	54.5	46.0	31.3	27.4	23.3	19.1
1580	72.8	66.5	46.2	40.9	35.5	30.1

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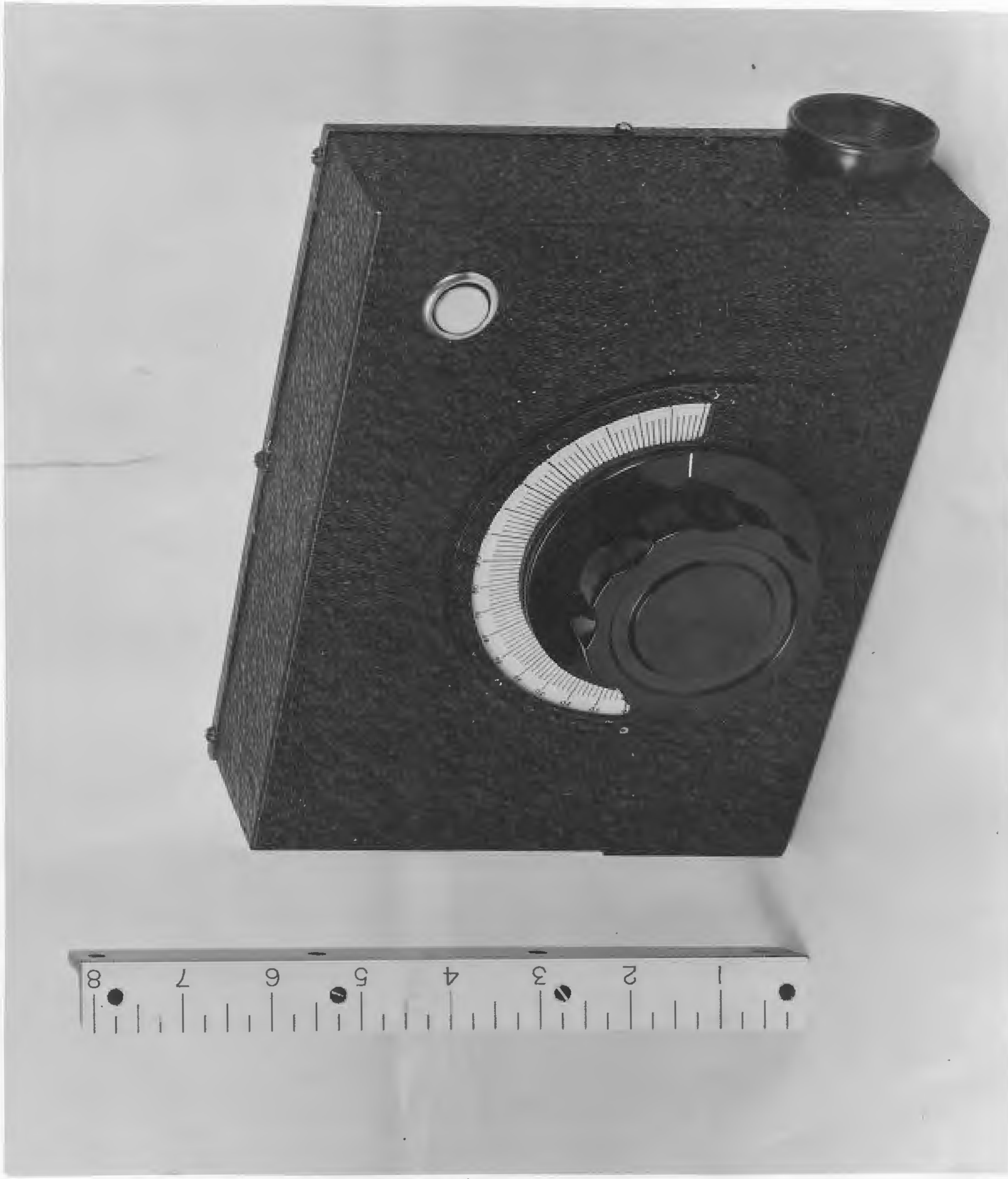

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PLATE I

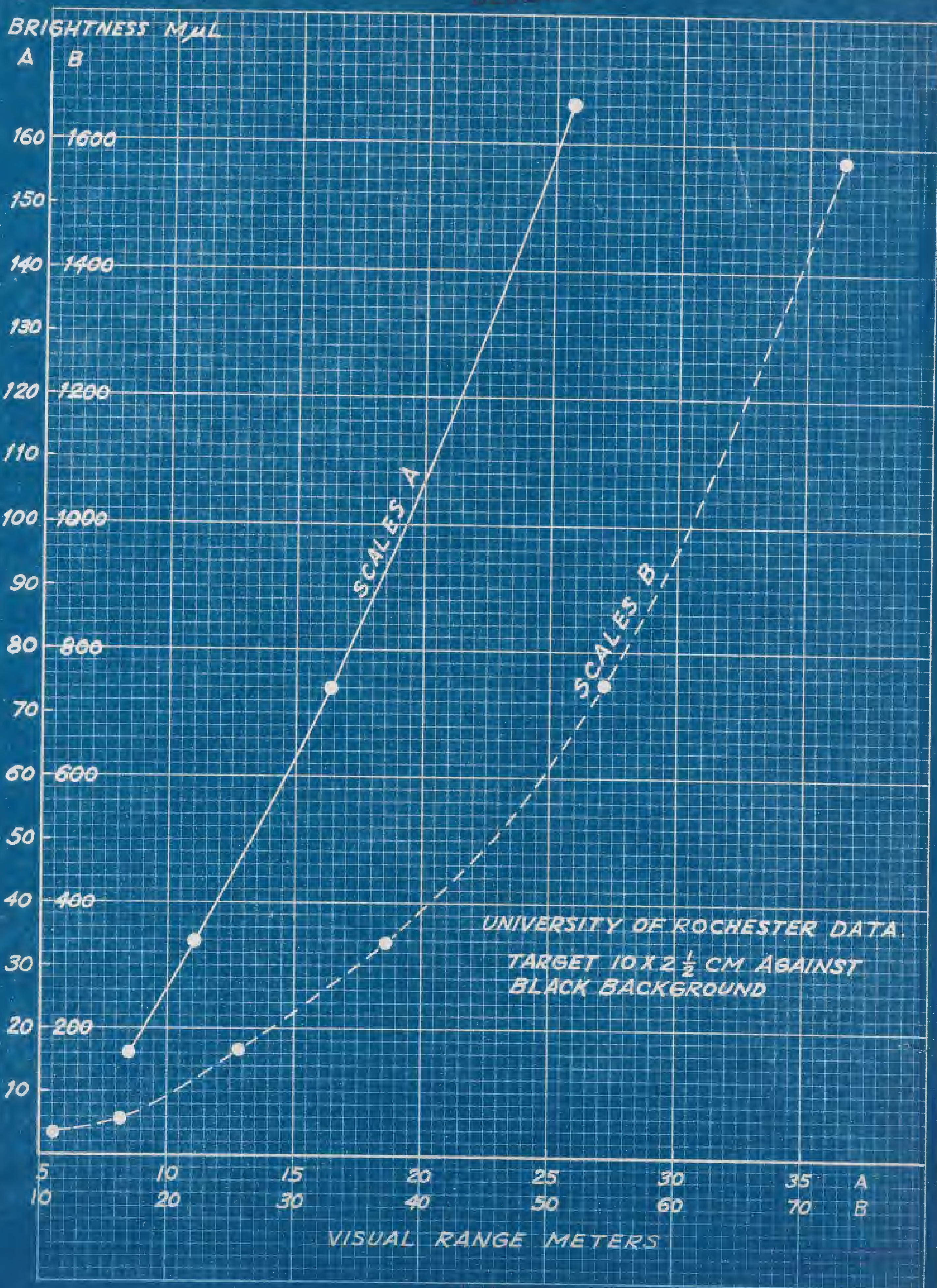
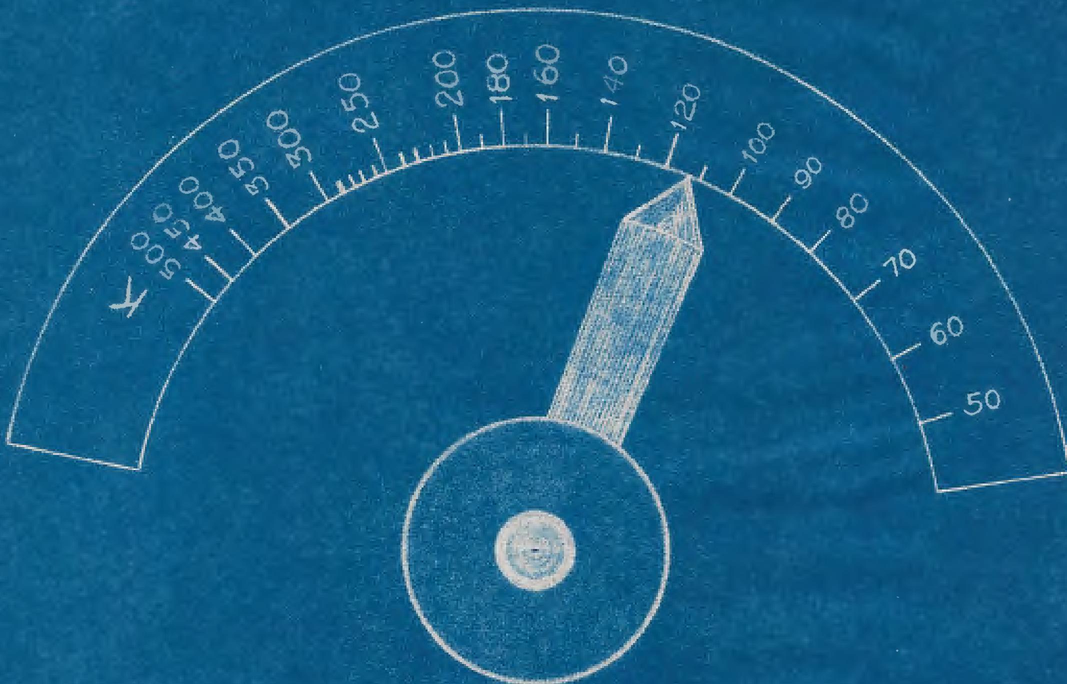

BRIGHTNESS MμL
A B
160 1600
150
140 1400
130
120 1200
110
100 1000
90
80 800
70
60 600
50
40 400
30
20 200
10
SCALES A
SCALES B
UNIVERSITY OF ROCHESTER DATA.
TARGET 10 X 2 ½ CM AGAINST BLACK BACKGROUND
5 10 15 20 25 30 35 A
10 20 30 40 50 60 70 B
VISUAL RANGE METERS

PLATE 2



VISUAL RANGE IN YARDS =
K TIMES SQUARE ROOT OF
AREA IN SQUARE FEET

PLATE 5