

A COMPARISON OF DIFFERENT TYPES OF LIGHT BULBS BY
USE OF THE PRECISION PHOTOMETER.

by

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This thesis undertakes to set forth and explain the methods used and the results obtained from testing three types of light bulbs by use of a precision photometer.

First we will look into a few general principles of photometry. If we have two sources of light of equal brightness casting their rays on a screen, the illumination produced is inversely proportional to the square of their distances from the screen. To compare the illuminating powers of two sources of light, they are placed so that they produce equal illumination on the screen. When this condition has been secured their illuminating powers vary as the squares of their distances from the screen. This is the basic principle on which all photometers operate. As a formula it may be stated thus:

$$I_x = I_s \frac{dx^2}{ds^2}$$

Where:

I_x is the candle power of the unknown source of light.

I_s is the candle power of the standard source of light.

ds is the distance from screen to standard light.

dx is the distance from screen to unknown light.

The measurements herein recorded were made with a Lummer-Brodhun contrast photometer. This type is one of the most sensitive of all photometers. The photometric field appears as two semi-circles with their diameters coinciding.

In each semi-circle there is a trapezoid. When a photometric balance has been obtained, the trapezoids are of equivalent brightness, also the two semi-circles: in addition, the contrast between one trapezoid and its semi-circle equals the contrast between the other trapezoid and its semi-circle. The photometer is thus very sensitive save where there is a considerable difference in the colors of the two sources.

The photometer was suitably mounted on a long table which was provided with a framework of small pipe. A dark cloth was hung over this framework to exclude any outside light which might have gained entrance into the room. On the table are two parallel horizontal bars, about three hundred and fifty centimeters in length. Three carriages mounted with flanged wheels travel on these bars. The center carriage carries the photometric screen. The other two carriages carry the standard bulb and the bulb being tested. All the carriages are adjustable so that the screen and the bulbs may be put in the same horizontal plane. In the experiments performed it was desirable to revolve the bulb being tested and thus obtain average values for the vertical distribution curves. In order to do this, a special piece of apparatus was used to replace one of the carriages. This consists of an arrangement to revolve the bulb about an axis passing through the base and tip of the bulb. The axis about which the bulb revolves is so

pivoted that it may be revolved in a vertical plane about the bulb itself, that is, the bulb may be tilted in a vertical plane and readings taken at different angles. Thus as the bulb spun around its axis could be moved and the average light for that angle of movement would fall on the screen for comparison purposes. A small compound D.C. motor furnishes the power for revolving the bulb. Resistance in the armature circuit is used to properly reduce the speed to about 180 R.P.M.

In taking the readings the standard bulb was brought to the voltage at which it was calibrated by means of a variable resistance in series with it. In a similar manner the other bulb was brought to the desired voltage. The unknown bulb was set rotating at the desired angle. The screen was then placed at a fixed distance from the rotating bulb, and by means of an arm the carriage with the standard was moved until a balance was obtained on the screen. The distance, dx , was read off the scale on the parallel bars, with suitable correction. The distance, ds , was found in a very ingenious manner (which did not originate with the author of this thesis). To the bottom of the carriage with the standard was fastened a block of wood. An arm, A, (see Fig. 2), was pivoted to this block in such a manner that it could move in a horizontal plane. A pencil was fastened on the end of the arm next the screen. On the board between the parallel bars a sheet of paper was clamped. The carriage was moved

by the arm until a balance was secured, and a mark was made on the paper with the pencil. Again the screen was balanced and so on until about six marks were on the paper. Now the carriage carrying the standard was set at a known distance from the screen and a long mark was made with the pencil. The distance from this base line to the average of the marks on the paper was then obtained. This distance was either added or subtracted, as the case might be, to the base line distance, the result being d_s . After one reading the axis of the revolving bulb was moved ten degrees and another reading taken and so on until eighteen (0 to 180 degrees) readings were taken. From these the points on the vertical distribution curves were calculated by use of the formula already mentioned.

The vertical distribution curves give the distribution of light, but it is desirable to know something further concerning the bulbs tested. The Rousseau diagram gives an easy method of determining the mean spherical candle power as well as the efficiency. In its construction advantage is taken of the proportionality of the areas of the zones of a sphere to their respective altitudes. The values of the altitudes of the zones subtended by equal angles are laid off to scale along the vertical axis of the diagram as shown. On the horizontal lines the values of the candle power in the direction of the corresponding angles are laid off to scale. The area enclosed by the

curve and the vertical will represent the total luminous value of the source of light. The value of this area in terms of the product of the scales to which the curve was plotted divided by the sum of the ordinates will give the mean spherical candle power (M.S.C.P.). This multiplied by 4π will give the flux in lumens. The efficiency of the bulb is the watts per M.S.C.P.

Three bulbs were tested in the manner already outlined. A tungsten (type B Mazda), a type C Mazda, and a carbon bulb were used for these tests. The type C Mazda was of the mill type, and so was less efficient than the regular bulb of that type. The regular type C had such a long neck that it could not be used with the revolving apparatus. Three secondary standards, and a working standard were used. Throughout the thesis any one of these is referred to simply as a standard. It must be remembered that none of them are really standard, primary being meant by this. The standards used were as follows:

Carbon - 16 cp. at 106.6 volts.

Carbon - 16 cp. at 109.0 volts at 180 R.P.M.

Tungsten - 61.6 at 118.0 volts.

Tungsten - 53.33 at 110.0 volts.

The carbon standard was used for making the tests on the carbon bulb. The tungsten working standard at 53.33 was used for the other measurements, thus avoiding a color contrast.

VOLTMETER CALIBRATION

Standard Voltmeter Reading	Correct Voltage	Simplex Voltmeter Reading
109.4	110.0	114.0
108.4	109.0	113.0
106.0	106.6	111.0

Note: The reading at 118.0 volts with the tungsten standard was made with the standard voltmeter at 117.4 volts. The error in the standard voltmeter was approximately 0.6 volts for the range covered in this thesis.

Calibration of Working Standard

Secondary Standard	I_s (Cp.)	d_s (Cm.)	d_x (Cm.)	$I_x = \frac{d_x^2}{d_s^2} I_s$ (Cp.)	
Carbon	16	65	118.2	52.96	
Stationary					
Carbon at 180 R.P.M.	16	65	117.0	51.70	
				52.33	Average
Tungsten	61.6	80.7	75.1	53.33	

The calibration of a tungsten bulb by a carbon standard at lower voltage was unsatisfactory due to the color contrast. The calibration of tungsten by tungsten was considered most accurate, so the value of 53.33 Cp. was used. The value for the calibration by carbon standards is included merely for comparison.

The two carbon standards (secondary) were calibrated by the Electric Testing Laboratories. Later the tungsten standard (61.6 Cp. at 118.0 volts) was secured from this same company. From it the value of 53.33 Cp. for the working standard (tungsten) was obtained by calibration as shown above.

DATA:

Type B Mazda (Tungsten) - I_x and I_s at 110 volts.

Position of Lamp Tested	Position on Diagram (Degrees)	I_s (Cp.)	dx (Cm.)	ds (Cm.)	$I_x = \frac{dx^2}{ds^2} I_s$ (Cp.)
80	10	53.33	45.7	115.7	8.37
70	20	"	65.7	102.8	21.6
60	30	"	75.7	96.2	33.0
50	40	"	75.7	86.3	41.1
40	50	"	85.7	90.7	47.5
30	60	"	85.7	85.8	53.1
20	70	"	"	82.6	57.4
10	80	"	"	79.8	61.5
360	90	"	"	79.6	61.7 90 %
350	100	"	"	81.0	59.9
340	110	"	"	82.9	57.1
330	120	"	"	85.8	53.2
320	130	"	"	90.1	48.2
310	140	"	75.7	84.0	43.3
300	150	"	75.7	91.9	36.2
290	160	"	75.7	106.0	27.3
280	170	"	60.7	109.1	16.4
270	180	"	50.7	126.2	8.60

At 115.0 volts:

360	90	53.33	85.7	75.6	68.6
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0.525 Amperes at 115 Volts = 60.40 Watts

M.S.CP. at 110 volts = 49.6

M.S.CP. at 115 volts = $49.6 + 0.90 (\%) = 55.2$ Efficiency = $60.40 + 55.2 = 1.10$ Watts per Candle Power.

DATA:

Mill Type C Mazda - I_x and I_s at 110 volts.

Position of Lamp Tested	Position on Diagram (Degrees)	I_s (Cp.)	dx (Cm.)	ds (Cm.)	$I_x = I_s \frac{dx^2}{ds^2}$ (Cp.)
80	10	53.33	80.7	120.0	24.2
70	20	"	85.7	112.3	31.1
60	30	"	"	99.0	40.0
50	40	"	"	103.8	36.3
40	50	"	"	105.1	35.5
30	60	"	"	105.1	35.5
20	70	"	"	105.0	35.6
10	80	"	"	103.9	36.3
360	90	"	"	105.9	34.9
350	100	"	"	104.3	35.9
340	110	"	"	103.8	36.3
330	120	"	"	103.5	36.5
320	130	"	"	100.8	38.5 88.5%
310	140	"	"	98.7	40.2
300	150	"	"	96.7	41.9
290	160	"	"	94.7	43.7
280	170	"	"	94.6	43.8
270	180	"	"	95.6	42.9

At 115 volts:

320	130	53.33	85.7	94.8	43.5
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0.447 Amperes at 115 Volts = 51.40 Watts

M.S.CP. at 110 volts = 36.9

M.S.CP. at 115 volts = $36.9 \div 0.888 (\%) = 41.7$

Efficiency = $51.40 \div 41.7 = 1.23$ Watts per Candle

Power.

DATA:

Carbon Bulb - I_x and I_s at 106.6 volts

Position of Lamp Tested	Position on Diagram (Degrees)	I_s (Cp.)	dx (Cm.)	ds (cm.)	$I_x = I_s \frac{dx^2}{ds^2}$ (Cp.)
80	10	16.0	65.7	102.5	6.55
70	20	"	70.7	93.3	9.19
60	30	"	70.7	82.9	11.6
50	40	"	80.7	86.5	14.0
40	50	"	"	80.8	16.0
30	60	"	"	77.7	17.3
20	70	"	"	74.0	19.1
10	80	"	85.7	77.2	19.7
360	90	"	"	76.3	20.2
350	100	"	"	78.1	19.3
340	110	"	"	78.7	19.0
330	120	"	"	80.9	18.0
320	130	"	"	85.6	16.0
310	140	"	80.7	84.9	14.5
300	150	"	75.7	85.3	12.6
290	160	"	75.7	91.8	10.9
280	170	"	70.7	93.0	9.24
270	180	"	65.7	88.0	8.91

74.0%

At 115 volts:

360 90 16.0 125.7 96.5 27.15

0.495 Amperes at 115 Volts = 56.95 Watts

M.S.CP. at 106.6 volts = 16.95

M.S.CP. at 115.0 volts = 16.95 + 0.74 (%) = 22.9

Efficiency = 56.95 + 22.9 = 2.49 Watts per Candle

Power.

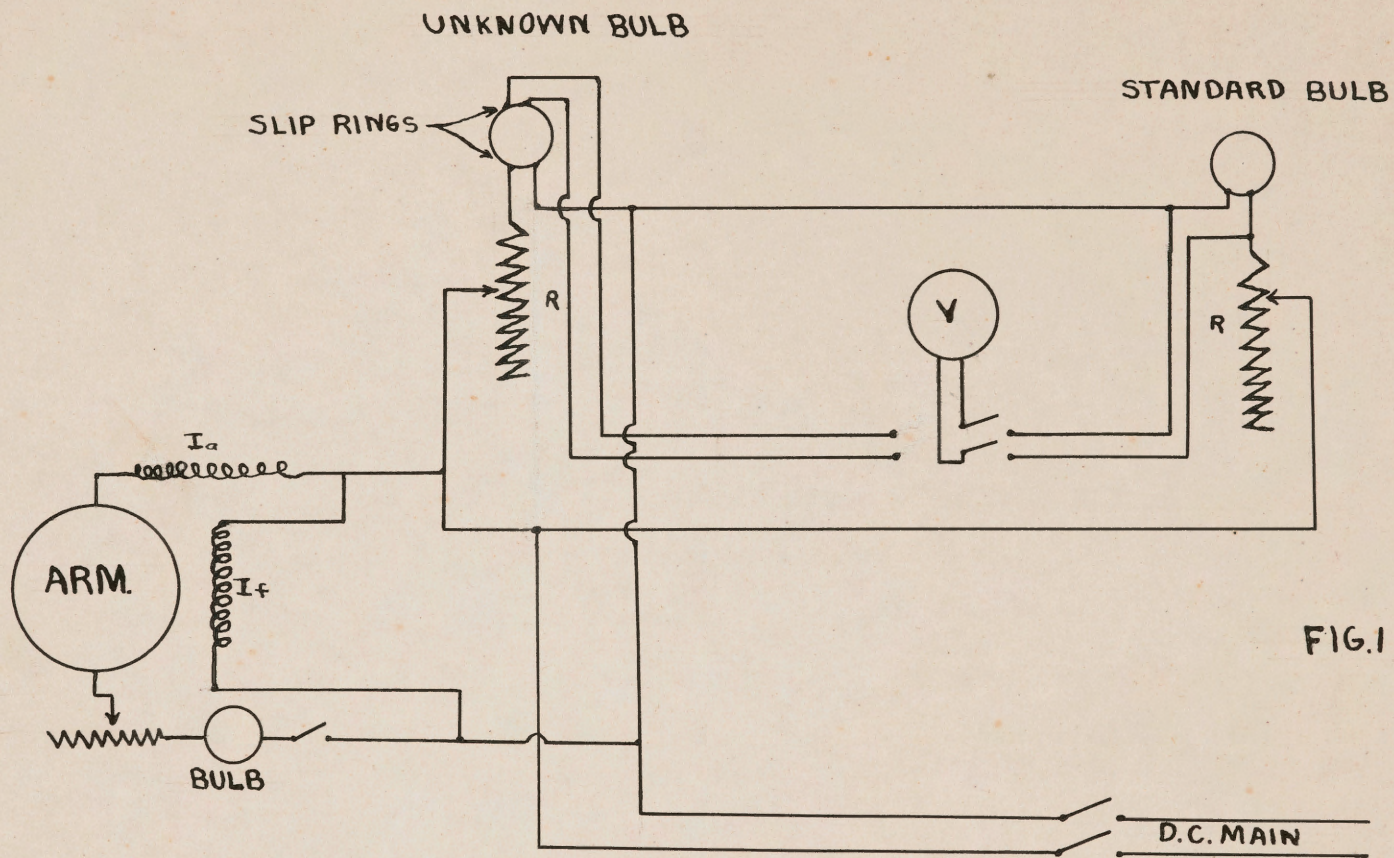


FIG.1

WIRING DIAGRAM - PRECISION PHOTOMETER

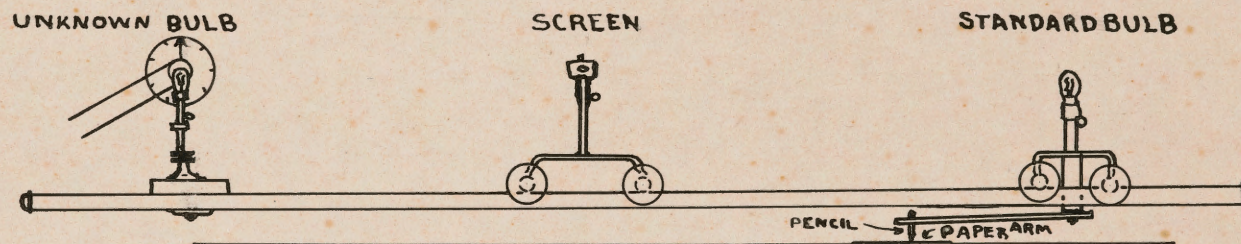
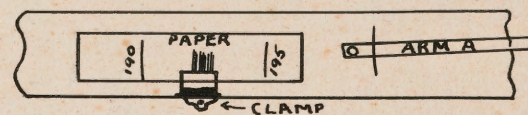


FIG. 2



METHOD OF TAKING READINGS

CARBON BULB

1s AND 1x AT 106.6 VOLTS

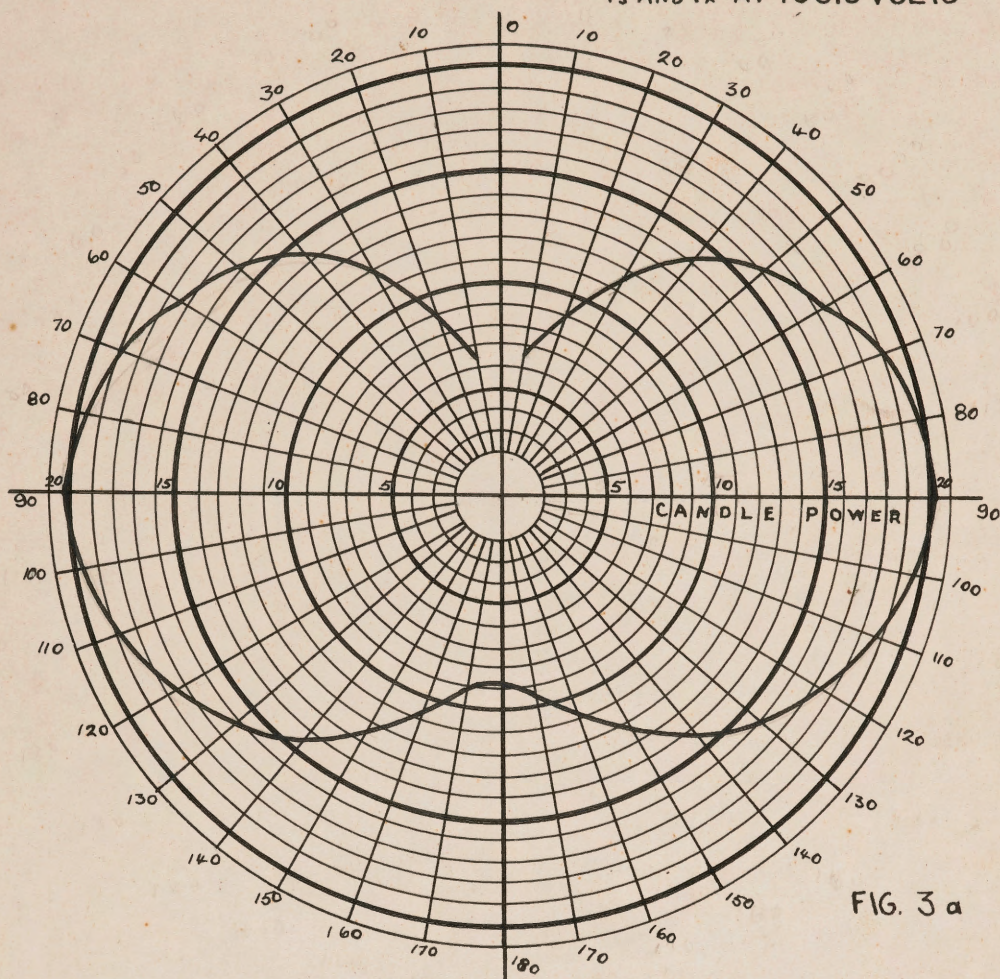
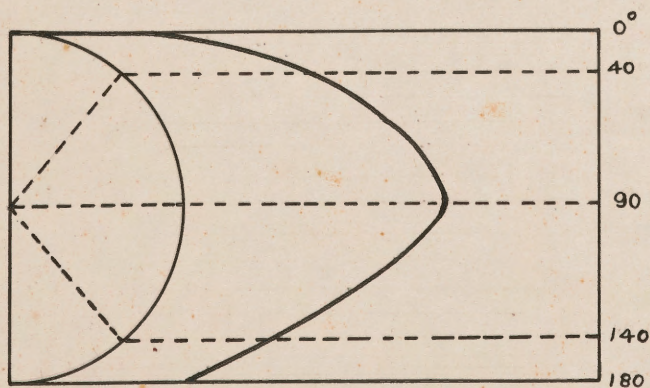


FIG. 3 a

VERTICAL DISTRIBUTION



CANDLE POWER

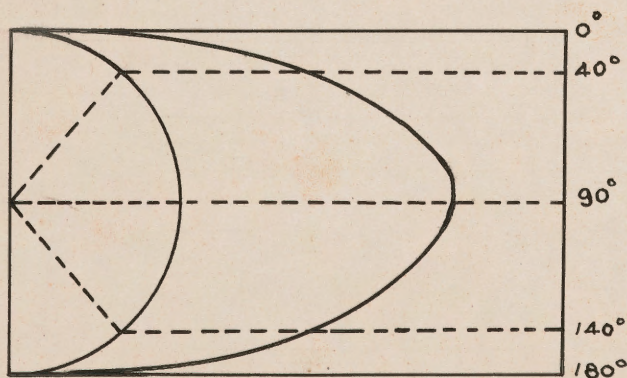
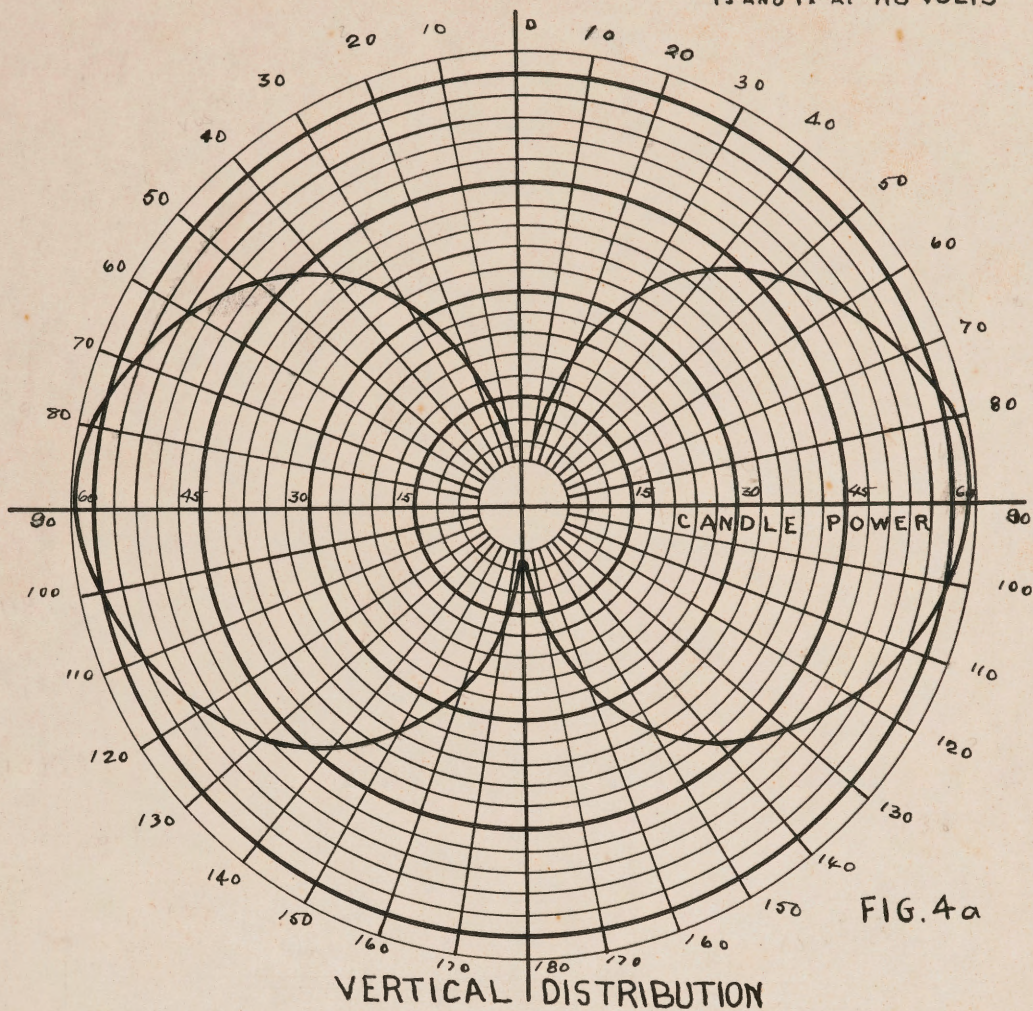
ROUSSEAU
DIAGRAM

M.S. C.P = 16.95

FIG. 3 b

TYPE B MAZDA

15 AND 1X AT 110 VOLTS



ROUSSEAU
DIAGRAM

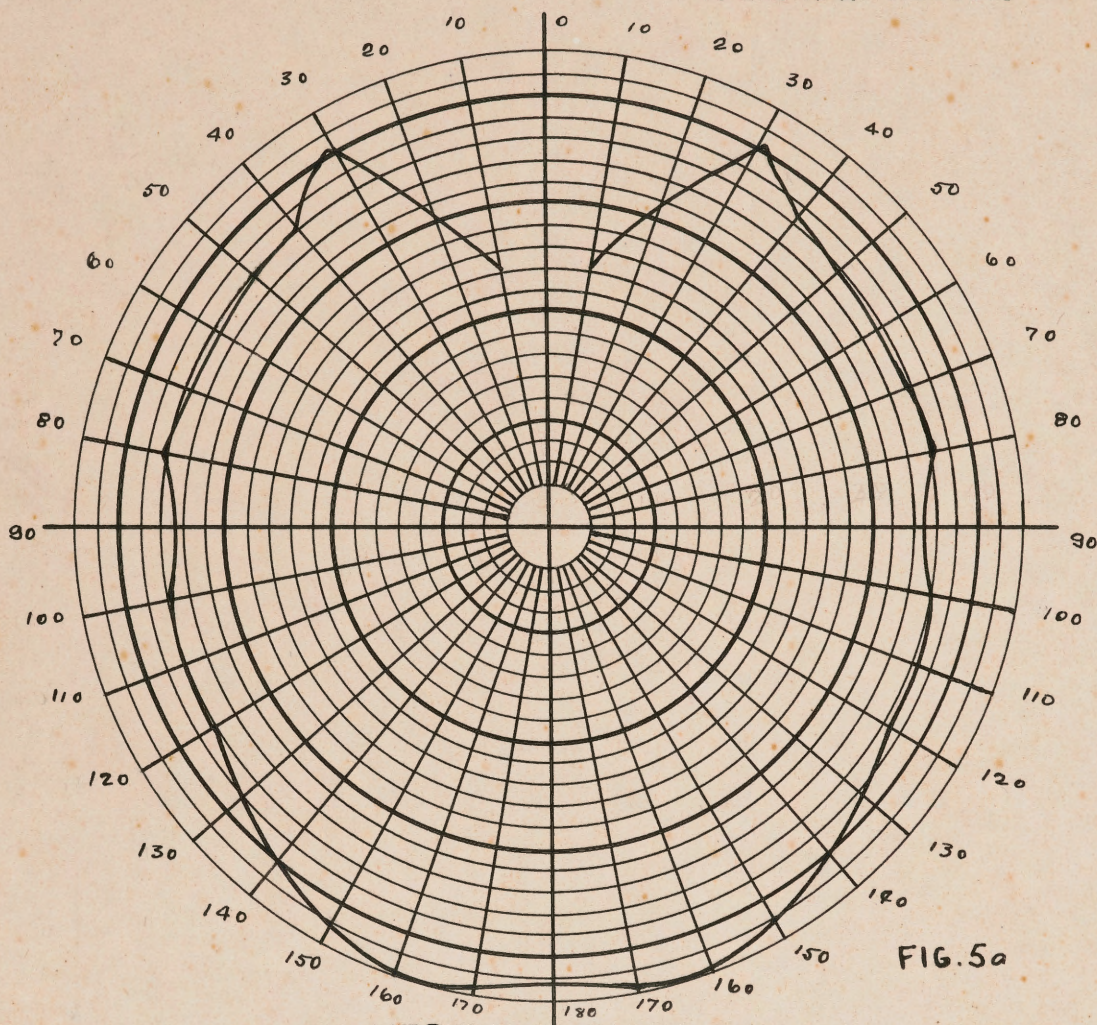
M.S.C.P. = 49.6

CANDLE POWER

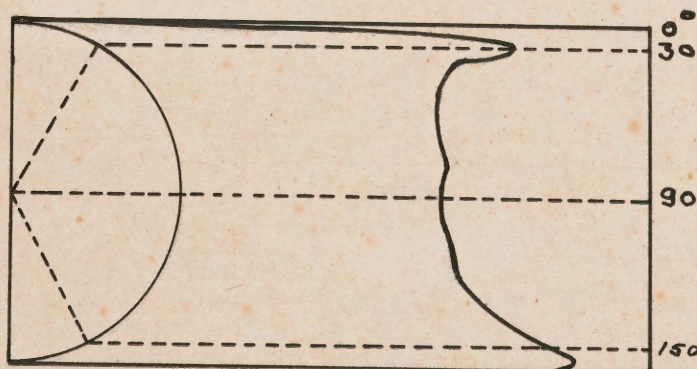
FIG. 4b

MILL TYPE C MAZDA

1S AND 1X AT 110 VOLTS



VERTICAL DISTRIBUTION



ROUSSEAU
DIAGRAM

M.S.C.P. = 36.9

CANDLE POWER

FIG. 4b

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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