

AUTOMOBILE HEADLIGHT LENSES

A THESIS

PRESENTED BY

HIRSCH EPSTEIN

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

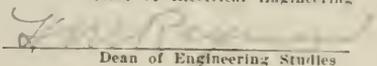
IN

ELECTRICAL ENGINEERING

MAY 27, 1920

APPROVED:

Professor of Electrical Engineering



Dean of Engineering Studies

Dean of Cultural Studies

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V. GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

P R E F A C E .

The purpose of this thesis is to obtain a complete survey of the automobile headlight problem of today. The following pages contain facts and data which has been taken from authorities on the subject and from laboratory tests done by myself. The discussion is both theoretical and practical in order to determine what could be expected from an automobile headlamp.

The writer desires to express his appreciation of the assistance rendered by Prof. E.H. Freeman and also wishes to acknowledge his indebtedness to Mr. J. Whyte for his aid in obtaining the necessary data.

Hirsch Epstein.

Chicago, Illinois,

May 25, 1920.

29102

A U T O M O B I L E H E A D L I G H T
L E N S E S .

TABLE OF CONTENTS

	Page.
Preface	2
PART ONE	
Introduction	4
PART TWO	
Glare As Encountered By The Automobile Driver	7
PART THREE	
State Laws Governing Headlights	13
PART FOUR	
Theoretical And Practical Discussion Of The Parabolic Reflector And Light Source	22
PART FIVE	
Various Devices On The Market	43
PART SIX	
Conclusion	56
Bibliography	61

AUTOMOBILE HEADLIGHT LENSES.

PART ONE

INTRODUCTION.

The first object in equipping automobiles with projectors was, of course, to light the road ahead for the driver. It is desirable that the driver of an automobile be able to see his way for several hundred feet in advance, and since he must provide his own lamps and direct the light for lighting the roadway, it becomes necessary to project a beam of high intensity. It was the effort to accomplish this, as well as to give ease of control, that brought about the rapid change from oil and acetylene units to the electric system employing closely coiled low voltage filaments in deep projectors, giving both accurate control and high efficiency.

If there were but one automobile and a lonely road, the headlight problem might be considered solved. But the higher intensity lighting equipments have, in solving the problem of

lighting the road, introduced a new and serious problem in that they temporarily blind the driver or pedestrian who happens to come within their angle of action. This problem must be considered from the point of view of the driver behind the headlights as well. There are also pedestraains and the occupants of unlighted vehicles, whose safety depends upon the ability of the automobile driver to see them in sufficient time to avoid running them down.

Automobile headlights are limited by cost and appearance to sizes under one foot in diameter, and the size can be considered as a constant in a consideration of the glare problem. The luminosity of the background under worse conditions is zero, the complete darkness of the country road, and it is likely to be for sometime, until all roads are artificially illuminated at night. Therefore, the luminosity of the background is also a constant so far as the present problem is concerned. There remains

then only one thing controllable; the luminous intensity.

There is likely to be a great difference of opinion as to the limit of intensity which would be fairly safe and yet endurable. It is unfortunate that it is difficult to devise a consistent method for the measurement of interference with vision, making it possible to determine the relation between glare effect and candle power for some fixed road condition. If the background is entirely dark, as often occurs in country driving, there seems to be interference with vision even with the lowest intensity, dimmed light sources. In reducing the intensity, the glare vanishes completely only when the candle power reaches zero. When the background is not dark, there can be considerable intensity with out marked interference.

PART TWO

GLARE AS ENCOUNTERED BY THE AUTOMOBILE DRIVER.

The effect of glare has become a subject of vital importance. Glare is due to lack of accommodation due to the impossibility of accommodating to a bright spot and a dark field at the same time. It is the direct cause of strained brightness accommodation. There are various kinds of glare, but in headlights we only deal with spot glare and veiling glare.

Contrast or spot glare arises from brightness localized in a field of much lower or much higher luminosity. The retina tends to accommodate itself to that part of the field of view upon which the attention is centered. Vision is at best when contrasts are about 1:20. It is accomplished with effort at contrasts as low as 98 : 100 provided the general illumination be sufficient, and without sensible discomfort, if contrasts be less than 1 : 100. Contrasts as high as 1 : 10,000 are not rare, in window frames

TABLE 1. #

	Relative brightness level. 1000. ml.	Preceptible percentage difference. .0176	Relative retinal sensitivity. 1
1. Bright daylight in the open.			
2. Interiors in full daylight.	10.	.030	59
3. Interiors artificially illuminated. .1		.123	1430
4. Night street illumination.	.001	.79	22300

Taken from reference #1.

against open sky, illuminates against their backgrounds. These constitute contrast glare.

Since the sensation of brightness varies enormously with the brightness of the field of view, any data of glare is incomplete unless the temporary sensibility be specified. Glare has been considered from the standpoint of the four following different levels of accommodation given in Table 1.

The percentage difference is the difference in brightness that is just perceptible (from data of A.Konig) expressed as a fraction of the whole. This data is to be regarded as tentative only. Such data gives a basis for the quantitative estimation of glare under various conditions. For example, assuming the glare data correct, an area so bright as to be blinding in broad daylight must be about 60 times as bright as that which is blinding in an interior in the daytime and 22,000 times as bright as a surface which is blinding at night out of doors. In

general, no protective glasses can afford any relief from contrast glare. The sole remedy is to reduce the contrasts causing it. It will be recalled that a headlamp which is glaring at night time can hardly be noticed in the daytime. The important criterion of glare is not the discomfort to the eyes of the driver but it is the question whether the driver can see beyond the light he is facing. This is very important on the state roads since there are a large number of automobiles on pleasant summer evenings going in both directions, and there is a great deal of difficulty caused by glare. Between the distances of 40 and 700 feet of two approaching automobiles, each driver is unable to see where he is going, when each car has headlamps without protective devices.

Another condition of interest is when the observer is behind the headlamp. In this case, the condition is different from that of an observer in the distance trying to distinguish

The first of these is the fact that the
the first of these is the fact that the
the first of these is the fact that the

the first of these is the fact that the
the first of these is the fact that the
the first of these is the fact that the

the first of these is the fact that the
the first of these is the fact that the
the first of these is the fact that the

the first of these is the fact that the
the first of these is the fact that the
the first of these is the fact that the

the first of these is the fact that the
the first of these is the fact that the
the first of these is the fact that the

the first of these is the fact that the
the first of these is the fact that the
the first of these is the fact that the

the first of these is the fact that the
the first of these is the fact that the
the first of these is the fact that the

the signal light. An automobile driver uses the light for illuminating the roadway and, if a considerable portion of the light be scattered by fog, rain, smoke, or dust, it is difficult to see thru the illuminated veil. This is called veiling glare. A greenish-yellow glass does, however, slightly reduce this glaring effect.

The cause of glare in automobile headlights is treated later after a discussion of the parabolic reflector.

The physiological basis of glare is some sort of conflicting tendency among the sets of nerves controlling retinal adaptation. It is well known that the eye is extremely sensitive after having been subjected to darkness for half an hour. In the normal eye the pupil contracts automatically to protect the retina from excessive brightness and expands to admit more light to the retina when required. The diameter varies from about 2 to 8 mm. On a sudden exposure to a bright light, the pupil will contract in about one second and upon sudden increase in darkness

of the field, it will expand to about 5 m.m. in about 2 seconds and then continue to expand slowly to the limit. The limit to brightness to just not cause a blinding for an eye adapted to the darkness of night is about .1 lambert when viewed steadily, about .3 lambert for an object in the field, but not viewed directly and perhaps 20 lamberts for an object flashing by the axis of vision. The brightness of approaching headlights is from 5 to 500 lamberts, the lighted road from .01 to .1 millilambert and actual sensibility about 1/10 its maximum value. It is obvious that if the candle power of the light source be reduced and thereby the illumination on the roadway, that a great contrast in illumination will result, and the pupil has to automatically expand in rather quick time owing to the comparatively slight range of illumination. Thus when the intense beam of approaching headlamps suddenly enter in the field of vision, the eyes of both drivers are blinded instantaneously, for it will

take a second for the puple to contract. A decided loss of seeing ability lasting nearly a minute will result. While the eye is in a seriously blinded condition and consequently unable to see persons or objects on the road, holes and bumps in the road and even the borders of the road itself. This is why laws and regulations regarding glare must be adopted.

PART THREE

STATE LAWS GOVERNING HEADLIGHTS.

Agitation caused by powerful headlamps has gradually increased until we are threatened with drastic legislation. Attempts by authorities to eliminate glare completely by means of laws have, in some cases, resulted in the almost complete elimination of road illumination. In a number of cases accidents have resulted from this lack of illumination and in one or two instances the laws have not been enforced or have been declared invalid on account of this fact.

The most complete law regarding automobile headlight regulations is that of the state of New York. A brief discussion of this law is as follows:

The light from the lamp should be sufficient to reveal any person or object on the road straight ahead of such motor vehicle for a distance of at least 200 feet, is deemed to be complied with if the following conditions are

fulfilled:

No headlamp or headlamp control device shall be sold by a dealer that is not accompanied by a printed sheet of instructions describing the device in detail, its method of mounting and adjustment, type and candle power of lamp to be used and any other adjustment that may be necessary to insure its conformity with the requirements of this act.

Two pairs of the samples of the device are tested. The reflectors used in connection with laboratory tests shall be of standard high grade manufacture of 1.25 inches in focal length. The incandescent lamps used shall be of standard high grade manufacture also. A pair of testing reflectors mounted similarly to the headlamps in a car, shall be set up in a dark room at a distance not less than 60 feet from a vertical white screen. If a testing distance of 100 feet is taken, the reflectors shall be set 28 inches apart from center to center, and if a shorter

distance is taken, the distances between reflectors shall be proportionally reduced. The axes of the lamps shall be parallel and horizontal, or tilted in accordance with the manufacturer's adjustment. The intensity of the combined light shall then be measured with each pair of samples in turn, with reflectors fitted with a pair of each of the following types of bulbs:

- (1) Vacuum type - 6-8 volts, 17 m.s.c.p., G-12
- (2) Gas filled type, 6-8 volts, 20 m.s.c.p., G-12.

The lamps shall be adjusted to give their rated candle power. Measurements shall be made at the surface of a screen placed as mentioned above:

- "A" In the median vertical plane parallel to the lamp axes, on a level with the lamps.
- "B" In the same plane 1° of arc below the level of the lamps.
- "C" In the same plane 1° of arc above the level of the lamps.
- "D" Four degrees of arc to the left of this plane

LEGAL TEST POINTS.

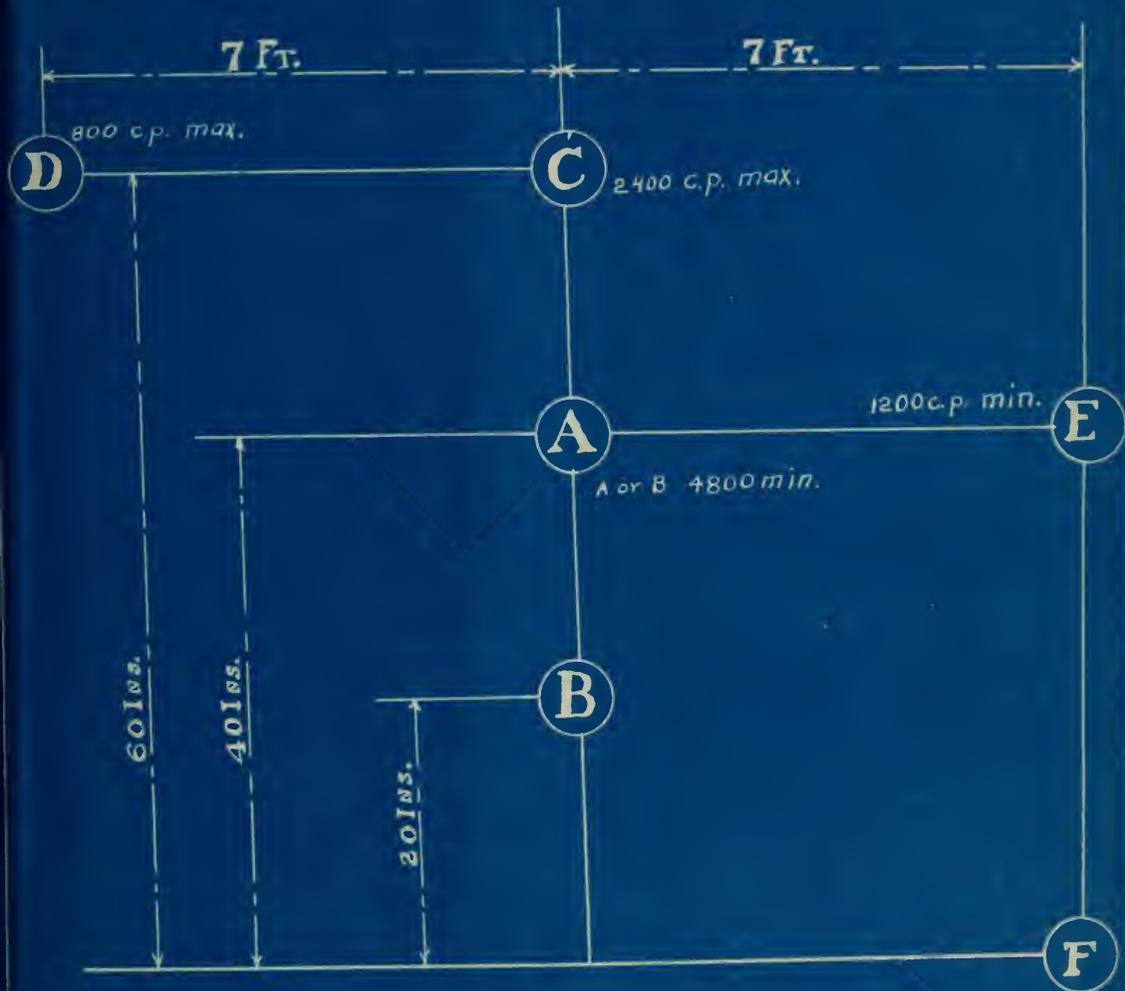


FIG. 1

STATE LAWS RELATING TO LIGHTS ON VEHICLES.

The following States have definite specifications regulating the apparent candle power of the headlight beam in various positions. These regulations practically divide the illumination into two zones of light; one above the 40 inch line, which is regulated by maximum specifications, and one below the 40 inch line, which is regulated by minimum specifications, to insure safe driving light.

STATE	A or B		C		D		E	
	Dist. ahead	Hgt. from ground	Ap. C.P.	Dist. ahead	Hgt. from grd.	Dist. left from grd.	Ap. C.P.	Dist. Right from grd.
CAL.	200 ft	0'-40"	1200 min	100 ft	60"	7 ft	800 max	
CONN.	200 ft	0'-40"	4800 min	100 ft	60"	7 ft	800 max	
N. Y.	200 ft	0'-42"	1200 min	100 ft	60"	7 ft	800 max	
Penn.	200 ft	0'-42"	1200 min	100 ft	60"	7 ft	800 max	
PHOENIX Ariz.	200 ft	0'-40"	1200 min	100 ft	60"	7 ft	800 max	
WISC.	100 ft	0'-40"	4800 min	100 ft	60"	7 ft	800 max	

The following is a condensed specification of the lighting laws of the States where no attempt is made to specify beam candle power.

- ALABAMA _____ MISSOURI _____ Two white lights visible 500 feet ahead of vehicle. No direct rays above 42 inches. Non-glare devices necessary. Bulb candle power, 36 maximum.
- ARKANSAS _____ MICHIGAN _____ Lights equipped with efficient dimming device.
- ARIZONA _____ Two white lights shining at a reasonable distance ahead of a vehicle. No State legislation; local legislation only.
- COLORADO _____ DELAWARE _____ Two white lights visible 200 feet ahead of a vehicle and efficient means to prevent glare.
- DIST. OF COLUMBIA _____ DIST. OF COLUMBIA _____ Light visible for 200 feet ahead of vehicle and dimming devices approved by Commissioner of Motor Vehicles.
- FLORIDA _____ IOWA _____ Light visible 500 feet ahead of vehicle. No direct light rays above 42 inches from ground at a distance of 75 feet. Bulb candle power, 32 maximum.
- ILLINOIS _____ INDIANA _____ Two white lights visible 200 feet ahead of a vehicle and equipped with efficient non-glare devices.
- INDIANA _____ IOWA _____ Light visible 500 feet ahead of vehicle. No direct light rays above 42 inches from ground at a distance of 75 feet. Bulb candle power, 32 maximum.
- IDAHO _____ IDAHO _____ Two white lights visible 200 feet ahead of vehicle.
- KANSAS _____ KANSAS _____ Two white lights visible 300 feet ahead of vehicle and equipped with efficient lenses or dimming device.
- KENTUCKY _____ KENTUCKY _____ White lights visible 200 feet ahead of vehicle. No direct light rays above 42 inches from ground at a distance of 75 ft.
- LOUISIANA _____ LOUISIANA _____ White lights visible 200 feet ahead of vehicle.
- MAINE _____ MAINE _____ No direct light rays above 42 inches from ground at a distance of 75 feet. Bulb candle power, 24 maximum.
- MARYLAND _____ MARYLAND _____ Two white lights visible 200 feet ahead of vehicle. No direct rays to left of axis of vehicle above 42 inches from ground at a distance of 75 feet. Bulb candle power, 32 maximum.
- MASSACHUSETTS _____ MASSACHUSETTS _____ White light 150 feet ahead and 10 feet on either side of vehicle. No direct light rays above 42 inches from the ground at a distance of 50 feet.
- MINNESOTA _____ MINNESOTA _____ Two white lights visible 200 feet ahead of vehicle.
- MICHIGAN _____ MICHIGAN _____ Lights equipped with efficient dimming device.
- MISSISSIPPI _____ MISSISSIPPI _____ White light visible at least 200 feet ahead of vehicle.
- MISSOURI _____ MISSOURI _____ Two white lights visible 500 feet ahead of vehicle. No direct rays above 42 inches. Non-glare devices necessary. Bulb candle power, 36 maximum.
- MONTANA _____ MONTANA _____ Two white lights visible 200 feet ahead of vehicle and equipped with non-glare device.
- NEW JERSEY _____ NEW JERSEY _____ No direct rays of light higher than 84" above roadway at any distance, unless diffused.
- NEW HAMPSHIRE _____ NEW HAMPSHIRE _____ Light visible for 200 feet ahead of vehicle and dimming devices approved by Commissioner of Motor Vehicles.
- N. CAROLINA _____ N. CAROLINA _____ Two white lights on front of car.
- N. DAKOTA _____ N. DAKOTA _____ No direct light rays above 42 inches from ground at a distance of 75 feet.
- NEVADA _____ NEVADA _____ Two white lights visible a reasonable distance ahead. No direct rays of light above 42 inches from ground.
- NEBRASKA _____ NEBRASKA _____ No direct light rays above 42 inches from ground at a distance of 75 feet.
- NEW MEXICO _____ NEW MEXICO _____ No direct light rays above 42 inches from ground at a distance of 200 feet.
- OHIO _____ OHIO _____ No direct light rays above 42 inches from ground at a distance of 200 feet.
- OREGON _____ OREGON _____ Two white lights visible 200 feet ahead. Direct rays to strike ground 75 feet in front of vehicle.
- OKLAHOMA _____ OKLAHOMA _____ No glaring or blinding light permitted. Light must reveal objects 150 feet ahead and 10 ft to left or right. No direct light rays above 42 inches from ground at a distance of 75 feet.
- VERMONT _____ VERMONT _____ Light visible 200 feet ahead of vehicle. No direct light rays above 42 inches from the ground at a distance of 75 ft.
- VIRGINIA _____ VIRGINIA _____ One white light throwing a bright light at least 100 ft. ahead of vehicle.
- WASHINGTON _____ WASHINGTON _____ No dazzling light above 42 inch level. Bulb, 27 candle power.
- WYOMING _____ WYOMING _____ White light visible 500 feet ahead of vehicle. Adequate dimming device.
- WEST VIRGINIA _____ WEST VIRGINIA _____ At least one lamp in front. Glass so constructed as to prevent glaring light.

and 1° of arc above the level.

"E" Four degrees of arc to the right of this plane on a level with the lamps.

"F" Four degrees of arc to the right of this plane on the ground.

The apparent candle power of either "A" or "B" shall not be less than 1,200; "C" shall not exceed 2,400; "D" shall not exceed 800; and "E" shall not be less than 800. Figure 1 shows the graphical arrangement of these positions.

The various states have passed or are now about to pass laws regulating the use of headlights. The rules laid down are practically the same for each state, differing only in some of the minimum or maximum values. Figure 2 gives a brief statement of the regulations passed by each state. In figure 1 each test point is given a candle power value which is the minimum or maximum allowed by any state. A device satisfying these values will be passed by every state.

Points "C" and "D" are known as glare points

THE UNIVERSITY OF CHICAGO
DEPARTMENT OF THE HISTORY OF ARTS
AND ARCHITECTURE
1100 EAST 58TH STREET
CHICAGO, ILLINOIS 60637
TEL: 773-936-3700
WWW.HA.UCHICAGO.EDU

since the intensity of the light in this area must not be above a certain candle power. The candle power of the bulb allowed to be used with any device is governed by these two glare points. The candle power readings of the various points are taken with the bulbs as described above. Knowing the maximum value allowed, by direct relationship the size of the bulb for any device is calculated. This is done for the spiral and "V" shape filaments, since these types are the most common, The largest bulb allowed in any device is 24 m.s. candle power. If the test indicate that a device unacceptable with either of the test lamps, it will come within the specifications with lamps of a lesser candle power.

One of the diffusing device manufacturers restricted to 10 candle power bulbs because of the glare limit, afterwards securing the approval of the Secretary of State to use 17 candle power lamps had advertized that this particular device

THE UNIVERSITY OF CHICAGO
DEPARTMENT OF CHEMISTRY
5708 SOUTH ELLIS AVENUE
CHICAGO, ILLINOIS 60637

RECEIVED
MAY 15 1964

FROM
DR. J. H. GOLDSTEIN

TO
DR. R. F. W. WILSON

RE
NMR SPECTRA OF
POLYMER SOLUTIONS

ACKNOWLEDGMENT
The author wishes to thank the National Science Foundation for their generous support of this work.

REFERENCES
1. J. H. Goldstein, *J. Chem. Phys.*, **28**, 236 (1958).
2. R. F. W. Wilson, *J. Chem. Phys.*, **30**, 1000 (1959).

having been approved for use with a maximum of 17 candle power resulted in such a wonderful road light that auto owners would certainly not be justified in using another lens with a higher candle power lamp and the consequent greater power demanded. The inference was that the state authorities had passed upon this advertiser's device as being adequate for road illumination with the 17 candle power bulb, so why use any other device which must be inferior if it is approved for use with 24 candle power bulbs. It should be made clear that all low candle power ratings were in attempt to keep the glare within permissible limits.

The effectiveness of the law depends upon the manner in which it can be enforced by the average officer. In seeking simplicity and freedom from highly technical requirements it is unwise to allow regulations to drift into vagueness. The automobilist wants to know precisely the limitations of the law. While he has every

intention of complying with the law he also wants the best road illumination that the law will permit. The specifications "must not glare or dazzle" is most vague. The principles of the limitation of light zone has been endorsed by various organizations. It is most effective from the user's point of view because it reduces glare with the least loss of useful light and in most applications increases the amount of light upon the roadway. limiting the light zone will not prevent glare when the car is passing over an uneven road, or over the top of a hill.

One of the greatest factors of safety in night driving is the projection of light some distance in front of the car. It acts as a warning to others approaching the highway from intersecting roads that an automobile is coming in another direction. The projection of light at the side of the road when the automobile is making a turn is a warning to others around the turn that a car is approaching.

THE UNIVERSITY OF CHICAGO
DIVISION OF THE PHYSICAL SCIENCES
DEPARTMENT OF CHEMISTRY
5708 SOUTH EAST ASIAN AVENUE
CHICAGO, ILLINOIS 60637
TEL: 773-936-3700
FAX: 773-936-3701
WWW: WWW.CHEM.UCHICAGO.EDU

Suppose we take it for granted that a device will accomplish the desired results. Objects of considerable size such as vehicles, pedestrains, and etc. must be quickly detected by a relatively small proportion of their total surface, e.g., a vehicle by its wheels, a horse by its legs and vertical obstructions along the roadway by their bases. At the same time signboards, detour, and warning signs and the like will not be seen at all since these are at present usually well above the $3\frac{1}{2}$ foot mark. On the other hand opposing headlights will not blind the eyes of the driver and the chance pedestrain will not be confused as he attempts to cross the roads. If there is a fog, the driver can see much better than formerly, the luminous screen caused by the diffusion of light by the fog^{is} no longer interfering with sight, as it is largely below the line of vision. Night driving under these conditions will never be as agreeable as when many of the visual aids revealed by the upward light were present. The

perfect lamp will permit the use of lamps of greatly increased candle power, so that the results will be a vast improvement over the former method of illumination.

The practical problem presented by the regulation of the use of high-powered head lamps is apparently an extremely difficult one, judging by the general unsatisfactory results which has been obtained up to the present time in endeavoring to secure road illumination without presenting intolerable glare to persons facing the head lamp. Only by the close application of a thorough knowledge of the process of vision and the requirements of headlighting may a satisfactory compromise be effected.

PART FOUR

THEORETICAL AND PRACTICAL DISCUSSION OF THE
PARABOLIC REFLECTOR AND LIGHT SOURCE.

Assuming the mirror to be ideal in form, the linear equation of the parabolic curve is either

$$y^2 = 4Fx$$

the rectangular form, figure 3, or

$$P = \frac{2F}{1 + \cos a}$$

the polar form, figure 4.

Using the equation $y^2 = 4Fx$, the slope of the line drawn tangent to the parabola at point p is, figure 5,

$$\frac{dy}{dx} = \frac{2F}{y} \tan C.$$

The slope of the normal to the curve at this

point is $-\frac{dx}{dy} = -\frac{y}{2F} = \tan e$.

From the figure, light emitted from the focus

follows the line OP and $\tan a = \frac{y}{F-x}$.

$$a + c + d = 180.$$

$$\tan(a+c) = \tan(180-d) = \tan d.$$

Then $\tan d = -\frac{2F}{y}$

$$d' = d$$

... ..
... ..
... ..

... ..
... ..

$$x^2 + y^2 = z^2$$

... ..

$$x^2 + y^2 = z^2$$

... ..

... ..

... ..

... ..

$$x^2 + y^2 = z^2$$

... ..

$$x^2 + y^2 = z^2$$

... ..

$$x^2 + y^2 = z^2$$

$$x^2 + y^2 = z^2$$

... ..

$$x^2 + y^2 = z^2$$

$$x^2 + y^2 = z^2$$

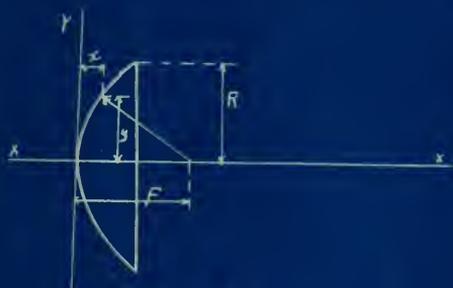


Fig. 3

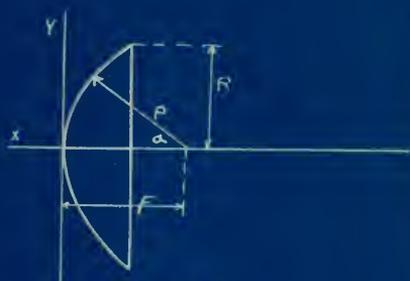


Fig. 4

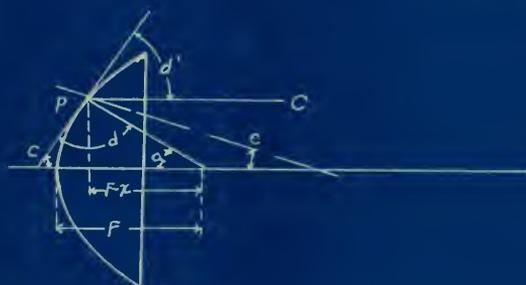


Fig. 5

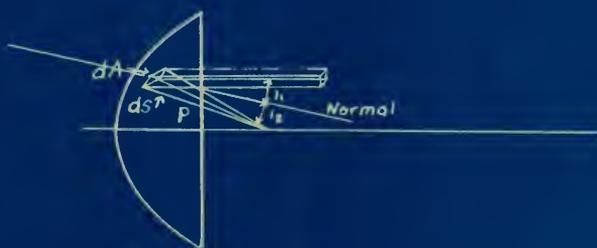


Fig. 6

and therefore, as $\tan c$ and $\tan d$ are numerically equal,

$$d' = c$$

and the reflected ray PC is parallel to the axis. A beam of light made up of rays such as PC would form a true cylinder of unvarying diameter. Each ray would pursue an independent path parallel to all other rays.

It may be shown that the flux intensity in any section of the beam db, Fig. 6, is equal to the flux intensity at a distance p from the source before reflection takes place.

Let a small area dA on the surface of the mirror be illuminated from a point source at the focal point. The cone of light striking this area has an angle of incidence i' , as shown in Fig. 4. The spherical area of this cone at the radius p is

$$ds = dA \cos \zeta'' \quad \text{square inches.}$$

The right section of the reflected beam has an area

$$db = dA \cos \zeta' \quad \text{square inches.}$$

$$\zeta' = \zeta'' \quad \text{degrees.}$$

THEORETICAL
PARABOLIC MIRROR & POINT SOURCE
BEAM DISTRIBUTION

From Reference #2

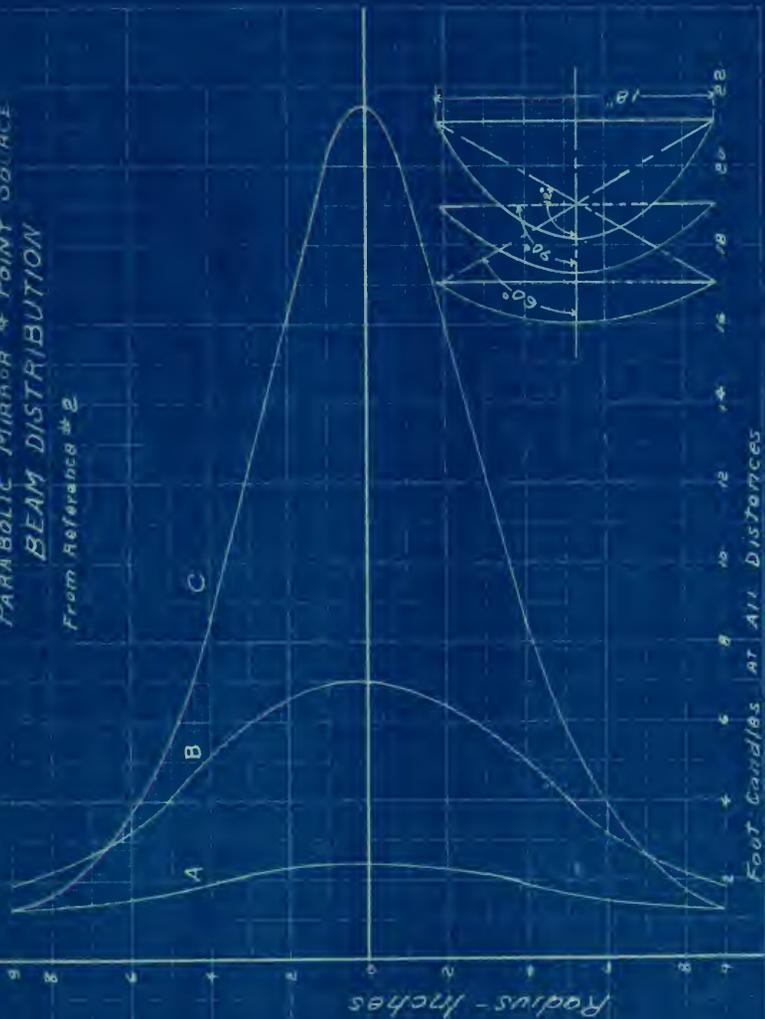


Fig. 7

$db = ds$ square inches.

The area db and ds contain the same quantity of light dQ and, therefore, the density is the same.

The intensity of radiation at radius p is

$$E = \frac{I}{p^2} \quad \text{foot-candles.}$$

$$p^2 = y^2 + (F-x)^2$$

$$= 4Fx + F^2 - 2Fx + x^2$$

$$= (F+x)^2 \quad \text{inches.}$$

$$E = \frac{I}{(F+x)^2} \quad \text{foot-candles}$$

and with a mirror having a coefficient of reflection m the beam intensity is

$$E = \frac{mI}{(F+x)^2} \quad \text{foot-candles.}$$

In Fig. 7 the beam intensities are plotted for a source having a uniform intensity of one candle in three typical 18 inch mirrors. The angular opening of the mirrors are measured from the axis, 60° , 90° , and 120° .

In solving for the beam characteristics of a spherical source in a parabolic mirror, it is necessary to make the assumption that the distance across the mirror is very small in comparison to the distance out along the axis of

the beam where the intensities are to be calculated.

The illumination

$$E = \frac{4\pi m I F^2}{s L^2} \tan^2 \frac{1}{2} a, \text{ foot candles.}$$

s- area of a great section of the spherical source.

I- intensity of the source.

m- coefficient of reflection of the mirror.

L- distance from focal point to point in beam,
in feet.

This is one form of the equation for the central density of a beam from a spherical source and a parabolic mirror. With a fixed focal length, the intensity varies as the square of the tangent of half the angle a , or given a fixed angular opening, the intensity varies as the square of the focal length.

Also
$$\frac{I}{s} = B,$$

the brilliancy in candles per square inch.

$$E = \frac{4\pi m B F^2}{L^2} \tan^2 \frac{1}{2} a, \text{ foot candles.}$$

This equation is particularly valuable as it shows that the intensity at the center of the beam de-

The first part of the document is a letter
to the President of the United States

dated the 1st day of January 1862

and is a copy of the original
document as it was received

by the Secretary of State

on the 1st day of January 1862

and is a copy of the original
document as it was received

by the Secretary of State

on the 1st day of January 1862

and is a copy of the original
document as it was received

by the Secretary of State

THEORETICAL
 PARABOLIC MIRROR + SPHERICAL SOURCE
 BEAM DISTRIBUTION
 From Reference # 2

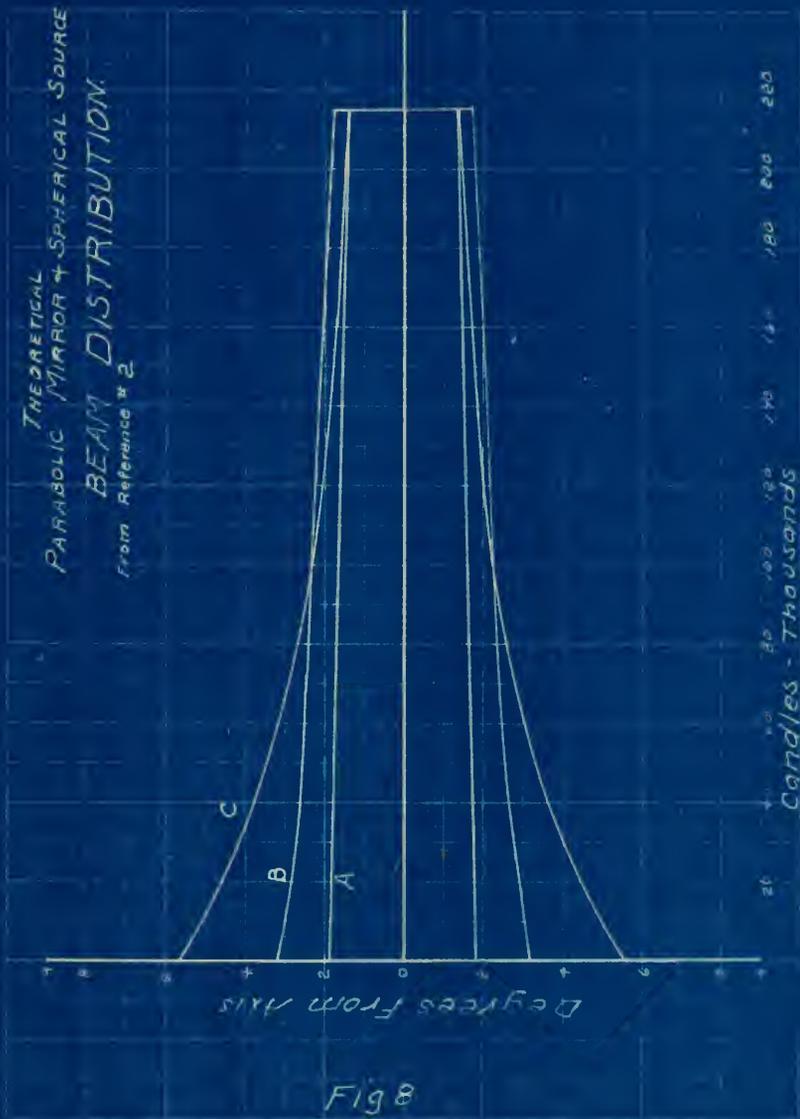


Fig 8

pendes upon the brilliancy of the light source and is independent of the size of the luminous sphere. However, this assumes that there is no interference of the reflected light by being stoped by the luminous sphere in the center of the beam.

The above equation may be written

$$E = \frac{\pi m B R^2}{L^2} \quad \text{foot-candles.}$$

The focal length does not enter into the equation and this brings out the highly interesting fact that all parabolic mirrors having the same diameter should give the same illumination at points on the axis. The difference in action between a shallow and deep reflector is shown in Fig. 8, where the beam intensities of three 18 inch mirrors of different focal lengths are plotted. The same source having a uniform brilliancy of 1,000 candles per square inch and a diameter of .5 inche, is used in all three cases.

The two latter equations, by a simple transformation may be used to calculate the candle

intensities on the axis.

$$I_B = 4 \pi m B F^2 \tan^2 \frac{1}{2} \alpha, \quad \text{candles}$$

and $I_B = \pi R^2 B m \quad \text{candles.}$

The last equation states that the intensity of a searchlight beam is equal to the product of the brilliancy of the source, the plane area of the mirror and the coefficient of reflection.

The intensities at points not on the axis of the beam may be found by the use of the above equation and the following relations.

The apparent angular radius of the source viewed from the central point on the mirror is

$$e_o = \tan^{-1} \frac{r}{p_o} = \tan^{-1} \frac{r}{F} \quad \text{degrees.}$$

At other points on the mirror we have as a good approximation

$$e = e_o \frac{p_o}{p} \quad \text{degrees.}$$

The light incident upon the center of the mirror has the greatest spread and is distributed throughout the entire beam. The light from the edges of the mirror is concentrated within a smaller angle and this light forms the center

ANGULAR WIDTH OF BEAM FROM
DIFFERENT RADII ON MIRROR
Parabolic Mirror and Spherical Source
From Reference *E

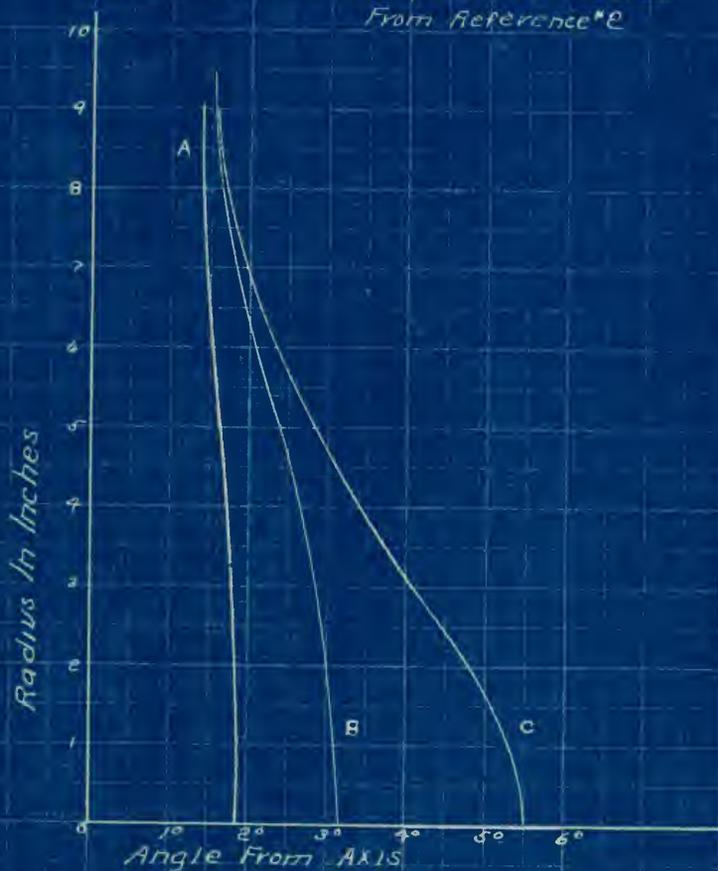


Fig 9

of the beam. By noticing the angle of spread at different parts of the mirror, the area covered by any section may be readily obtained. Values of the above equation for the three mirrors are given in Fig. 9. The angle of spread of the beam, b , is equal to the angle subtended by the source, e .

The curves in Fig. 9 may be interpreted as follows: Suppose an observer at a considerable distance from mirror C and slowly approaches the axis of the beam. When he reaches a point 5.5° from the axis, the center of the mirror will become visible. At a point 5° from the axis the luminous spot will be 1.7 inches in radius. The luminous area will continue to grow until the observer reaches a point of 1.38° from the axis when the entire mirror will be covered. From this point to a similar point 1.38° on the opposite side of the axis, the area A and the total apparent beam intensity will remain constant, and from this point the luminous area

The first part of the report is devoted to a general
description of the country and its resources. It
then proceeds to a detailed account of the
various branches of industry and commerce,
and concludes with a summary of the
state of the country at the present time.
The second part of the report is devoted to
a description of the various branches of
industry and commerce, and to a
summary of the state of the country
at the present time. The third part
of the report is devoted to a
description of the various branches
of industry and commerce, and to
a summary of the state of the
country at the present time.

will appear to decrease until the observer steps out of the beam at 5.5° . These figures only apply to this particular reflector and luminous source.

It is rather difficult to actually observe the action of the luminous spot on the mirror as outlined above on account of the great distance at which the observer must stand. At an insufficient distance the mirror will first appear luminous at the center and the edges nearest the observer. These two spots will merge and form an oval area that gradually approaches the size of the mirror as the observer comes up to the axis of the beam.

If foot-candle readings are taken very close to the surface of the mirror of Fig. 8, the illumination curves will be found to approach the point source curves in form. The two sets of curves represent the conditions at opposite ends of the beam. Between these two extremes of distances, zero and infinity, they undergoes a gradual transformation, and it is this region

THE UNIVERSITY OF CHICAGO
DIVISION OF THE PHYSICAL SCIENCES
DEPARTMENT OF CHEMISTRY
5708 SOUTH CAMPUS DRIVE
CHICAGO, ILLINOIS 60637
TEL: 773-936-3700
WWW: WWW.CHEM.UCHICAGO.EDU

of transformation that our practical interest is centered.

The intensity of the beam has been shown to be proportional to the area of the mirror, that is, with a given source all parabolic mirrors have the same brilliancy. From the above equation

$$\frac{I B}{\pi R^2} = m B \quad \text{candles per sq. in.}$$

The beam candles divided by the area of the mirror gives mirror brilliancy,

$$B_m = m B \quad \text{candles per sq. in.}$$

and it is at once evident that the beam has a maximum and constant candle intensity at all points receiving light from the entire mirror. Once the intensity reaches a constant value the inverse square law may be used to calculate illumination at other distances, within what is called the inverse square region, the shaded area in Fig. 14. Fig. 15 shows some laboratory tests. It was sometimes found that the apparent candle power would increase with the distance.

The angle which the boundaries makes with the axis maybe calculated directly.

$$b_1 = \tan^{-1} \frac{r}{R} \quad \text{degrees}$$

where p , is the distance from the focus to the edge of the mirror and the distance at which these boundaries cross the axis is

$$L_0 = \frac{R}{12} \cot b_1 \quad \text{feet.}$$

This may be put in the following form.

$$L_0 = \frac{R(F + \frac{R^2}{4F})}{12r} \quad \text{feet.}$$

It can be shown that there is considerable freedom of movement allowed to the light source without changing the central beam intensity. This intensity has been shown to depend directly upon the brilliancy of the source, and from this we could infer that the size and shape of the source affects only the width and side intensities of the beam. This is only true for a source like a sphere which eliminates light from every point. This relationship is misunderstood with regard to the commercial filaments. If a spiral filament, for example, were

THE STATE OF NEW YORK
IN SENATE
January 10, 1907.

REPORT
OF THE
COMMISSIONERS OF THE LAND OFFICE
IN RESPONSE TO A RESOLUTION
PASSED BY THE SENATE
MAY 10, 1906.

ALBANY:
J. B. LIPPINCOTT COMPANY,
PRINTERS.

1907.

ALBANY: J. B. LIPPINCOTT COMPANY, PRINTERS.

1907.

ALBANY: J. B. LIPPINCOTT COMPANY, PRINTERS.

1907.

ALBANY: J. B. LIPPINCOTT COMPANY, PRINTERS.

constructed to occupy the same outside dimensions as one on the market today, but have more actual surface by having the filament more compact and the brightness in each case be the same, this new filament will give off a beam of much more intensity. The light on the axis comes from those rays of the source that pass thru the focal point. It follows that the source may have any size, shape or position whatever, without changing the central beam intensity, providing only that every line from the mirror thru the focus will touch the light source.

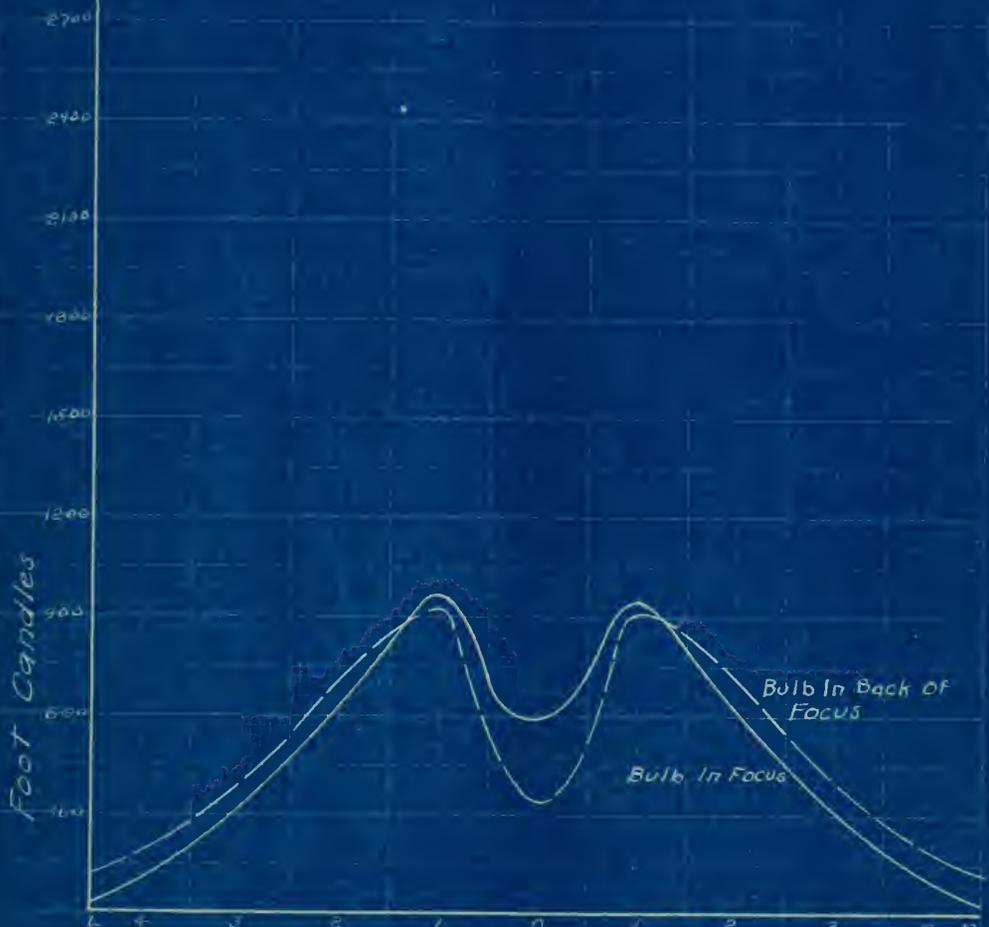
A disk so placed so that its luminous side is at the focal point and facing the mirror, is the ideal case of the carbon arc. The intensity on the axis of the beam is, Fig. 16,

$$I_B = \pi R^2 B_m \quad \text{candles.}$$

For points not on the axis the line of reasoning is not so simple as for the sphere. It has been assumed that the disk is luminous on one side only.

DISTRIBUTION OF BEAM INTENSITY AT LENS

10 M.S.C.P. Bulb #102 #1
Spiral Filament



Inches Out From Center Of Beam
Dia. Of Reflector, 9"
Focus, $\frac{5}{16}$ "

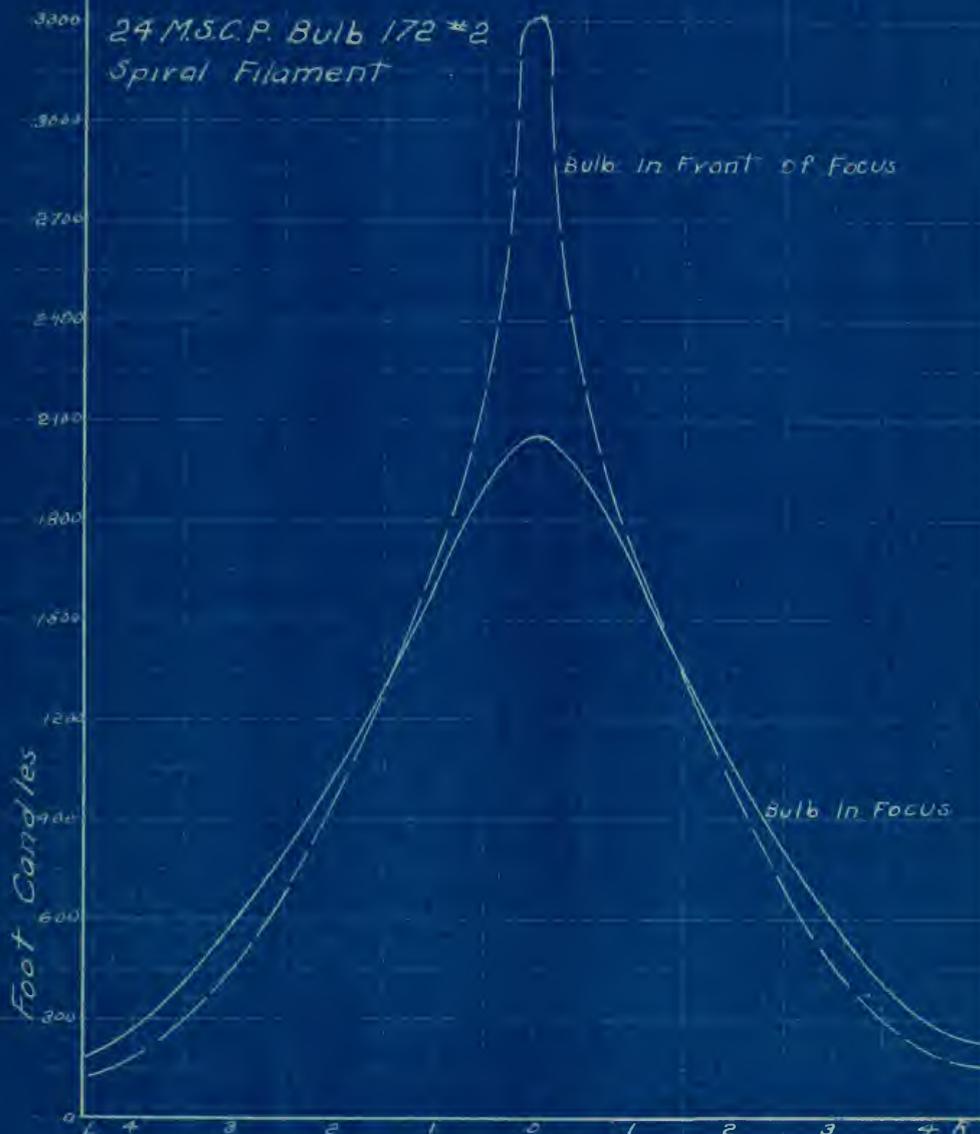
Fig. 10

May 1820
H. Epstein

DATA #2.

Distribution Of Beam Intensity At Lens

24 M.S.C.P. Bulb 172 #2
Spiral Filament



Inches Out From Center Of Beam
Dia. Of Reflector, 9"
Focus, $1\frac{5}{8}$ "

Fig. 11

May 1920

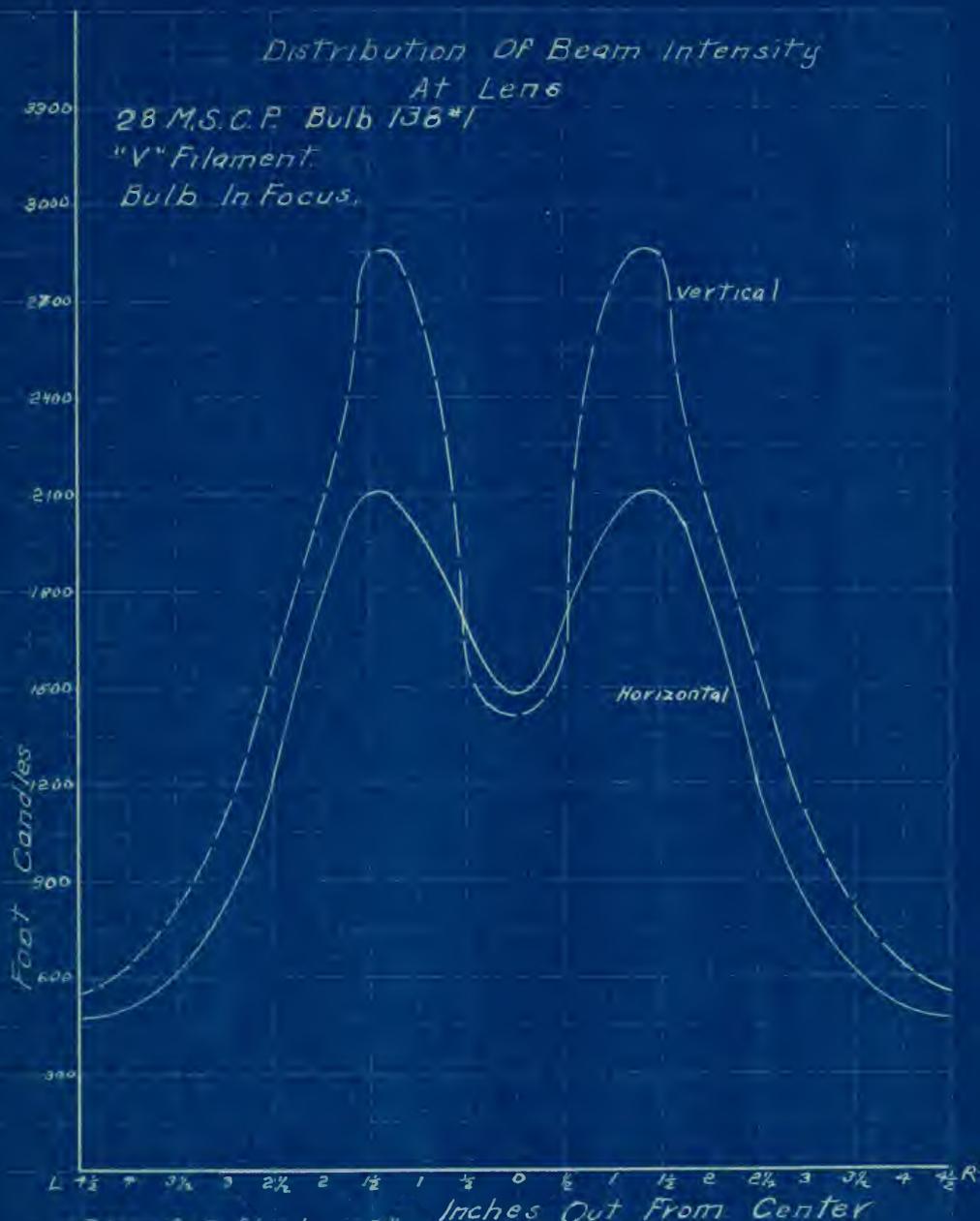
H. Epstein

Distribution of Beam Intensity
At Lens

28 M.S.C.P. Bulb 138*1

"V" Filament.

Bulb In Focus.



Dia. of Reflector, 9"

Focus $\rightarrow 1\frac{5}{16}$ "

Inches Out From Center

SEE Data # 3.

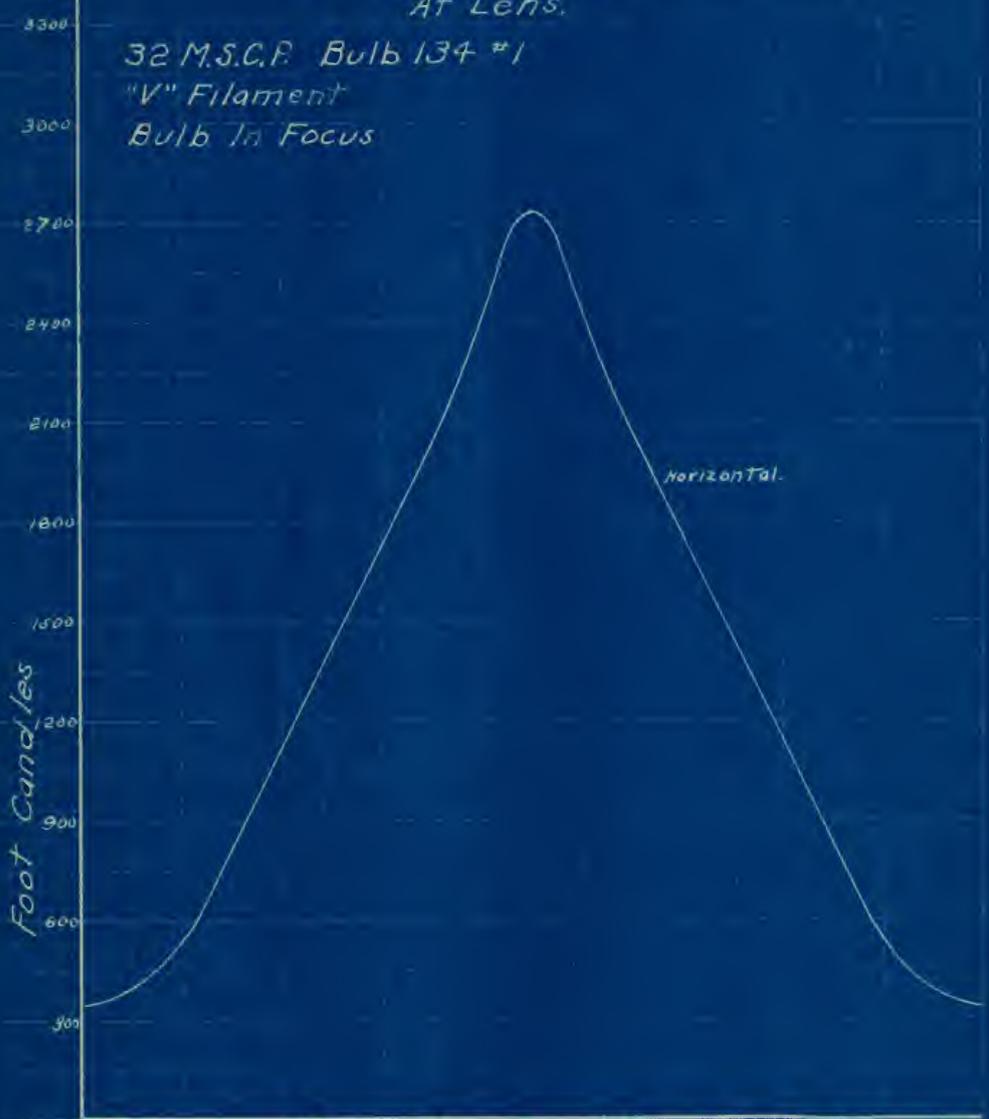
Fig. 12

May 1937

H. E. Jones

Distribution Of Beam Intensity
At Lens.

32 M.S.C.P. Bulb 134 #1
"V" Filament
Bulb In Focus



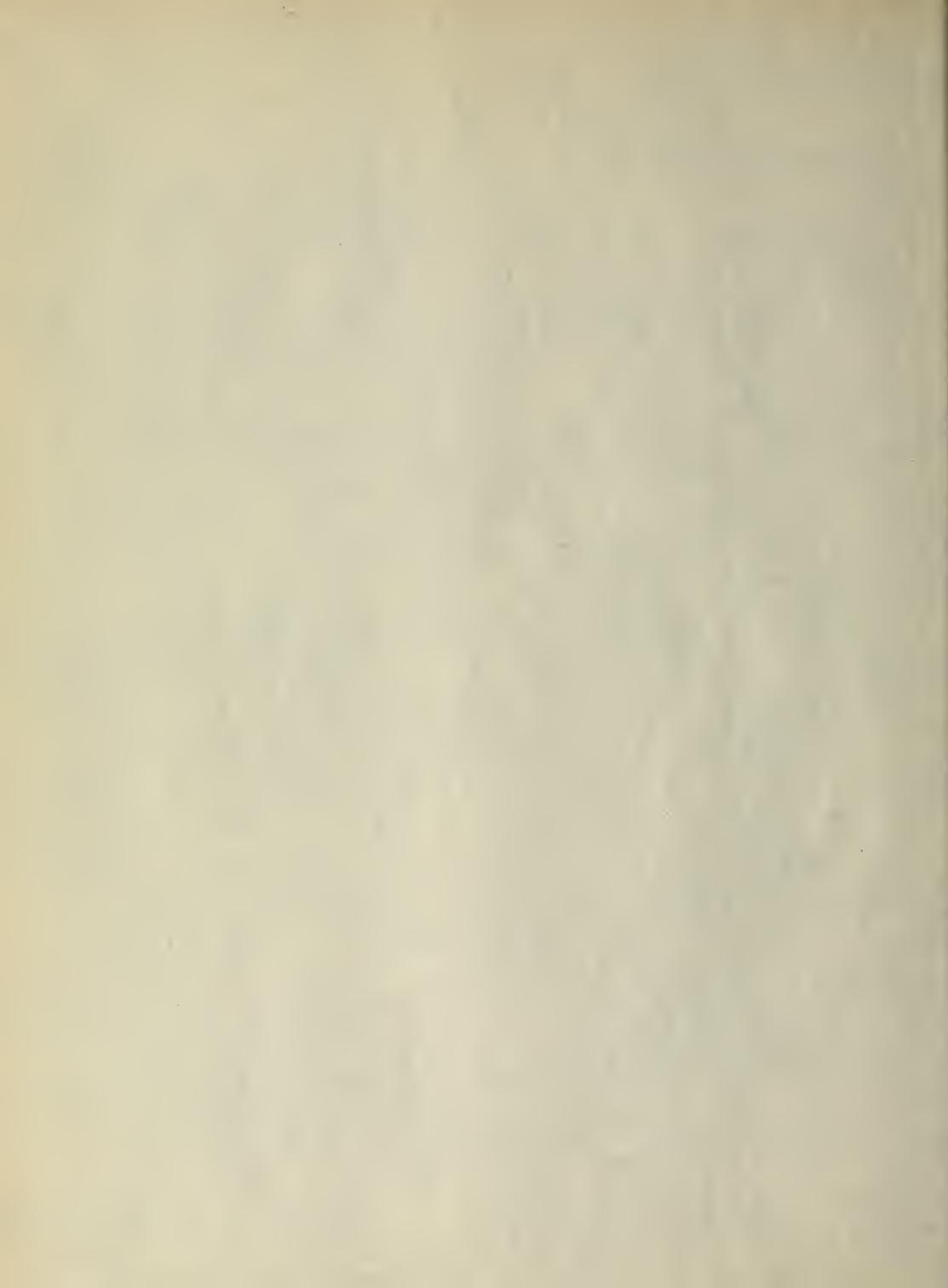
L Inches 4 3 2 1 0 1 2 3 4 R
Inches Out From Center

Dia. Of Reflector, 9"
Focus, $1\frac{5}{16}$ "

Fig 13

May 1920
H Epstein

Data # 5



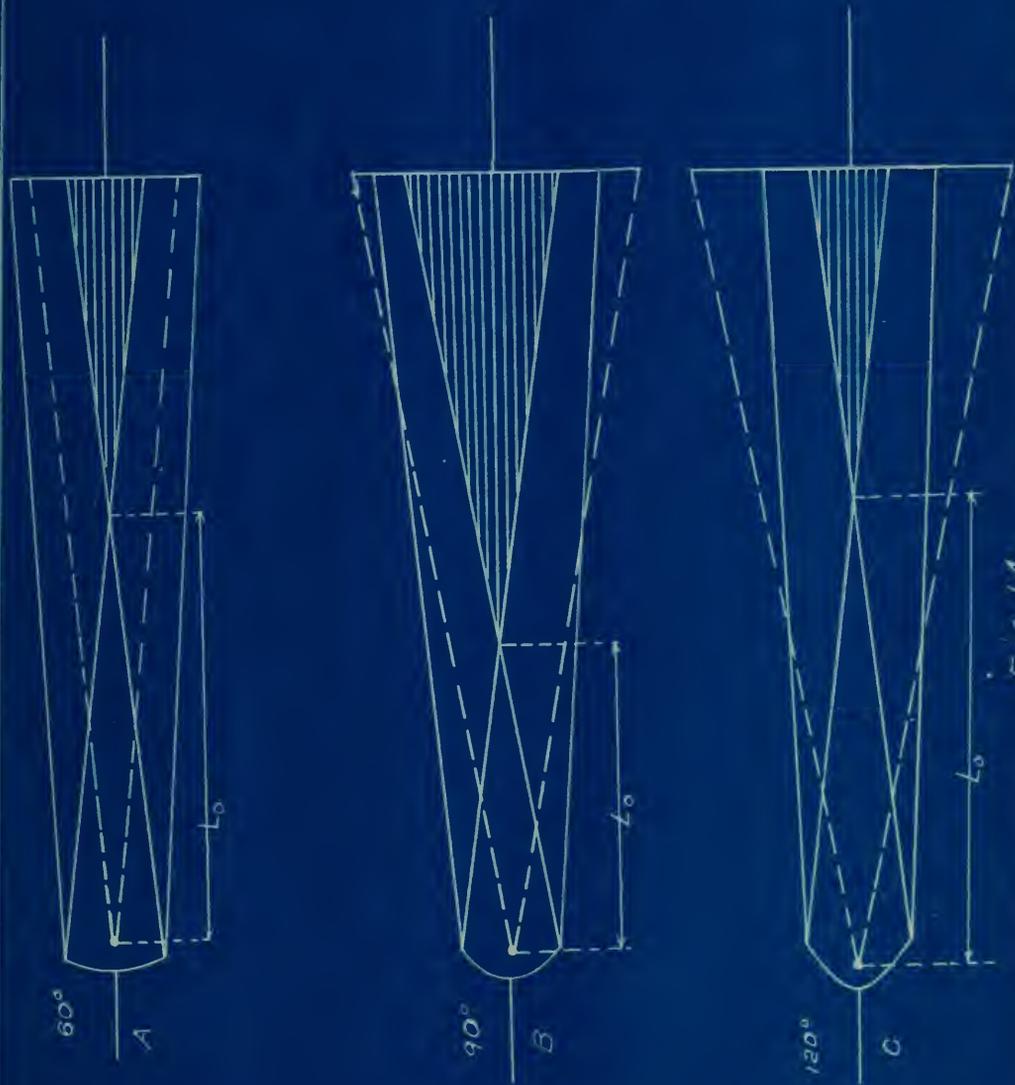
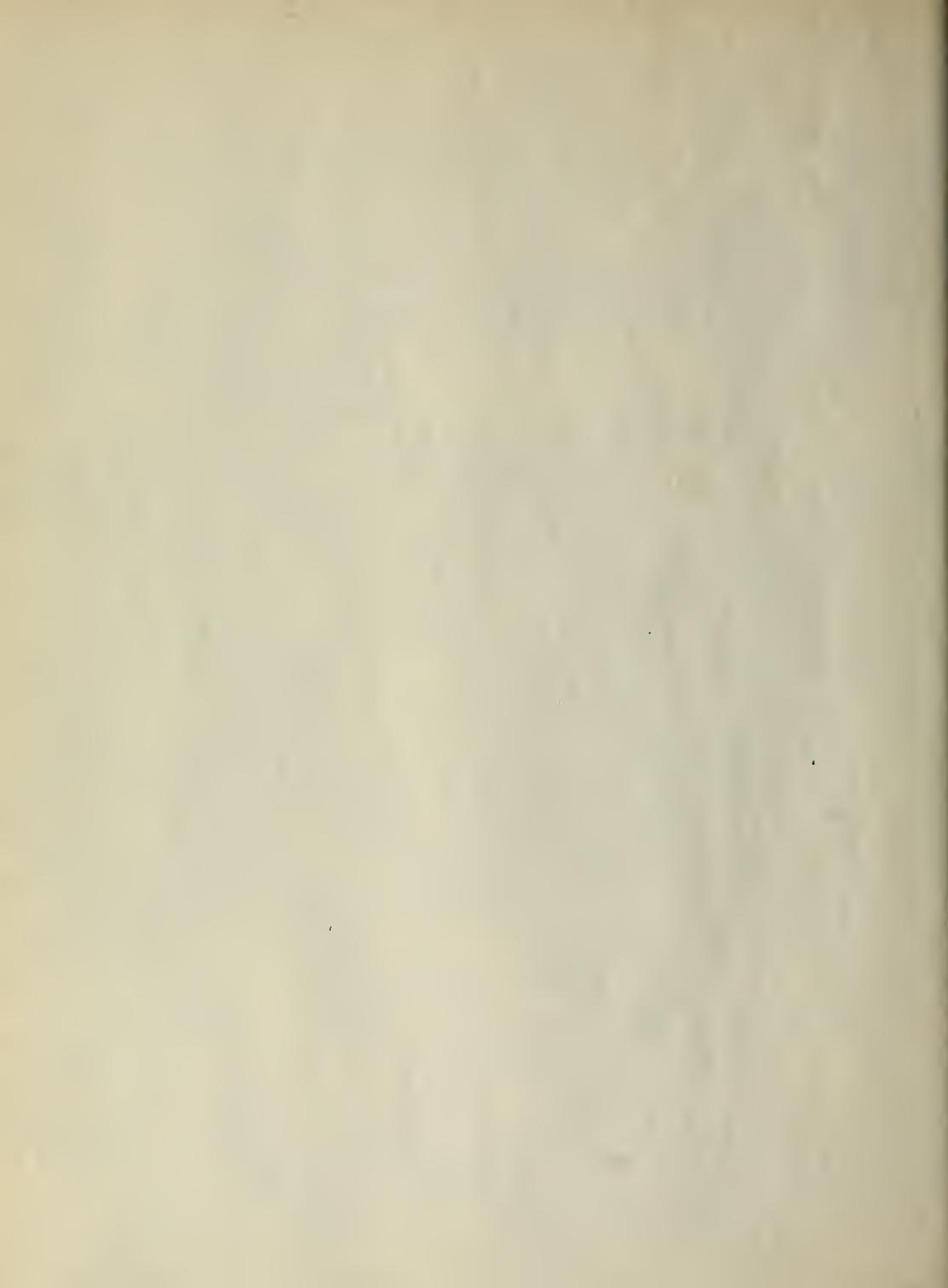
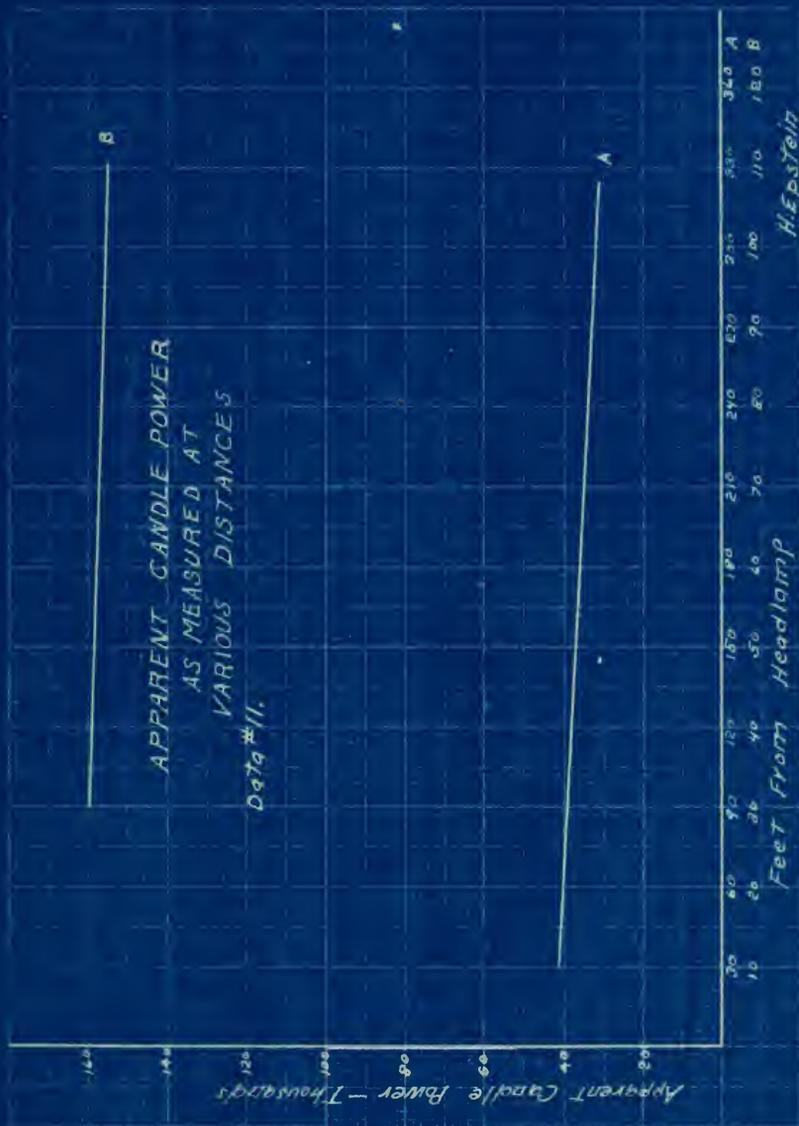


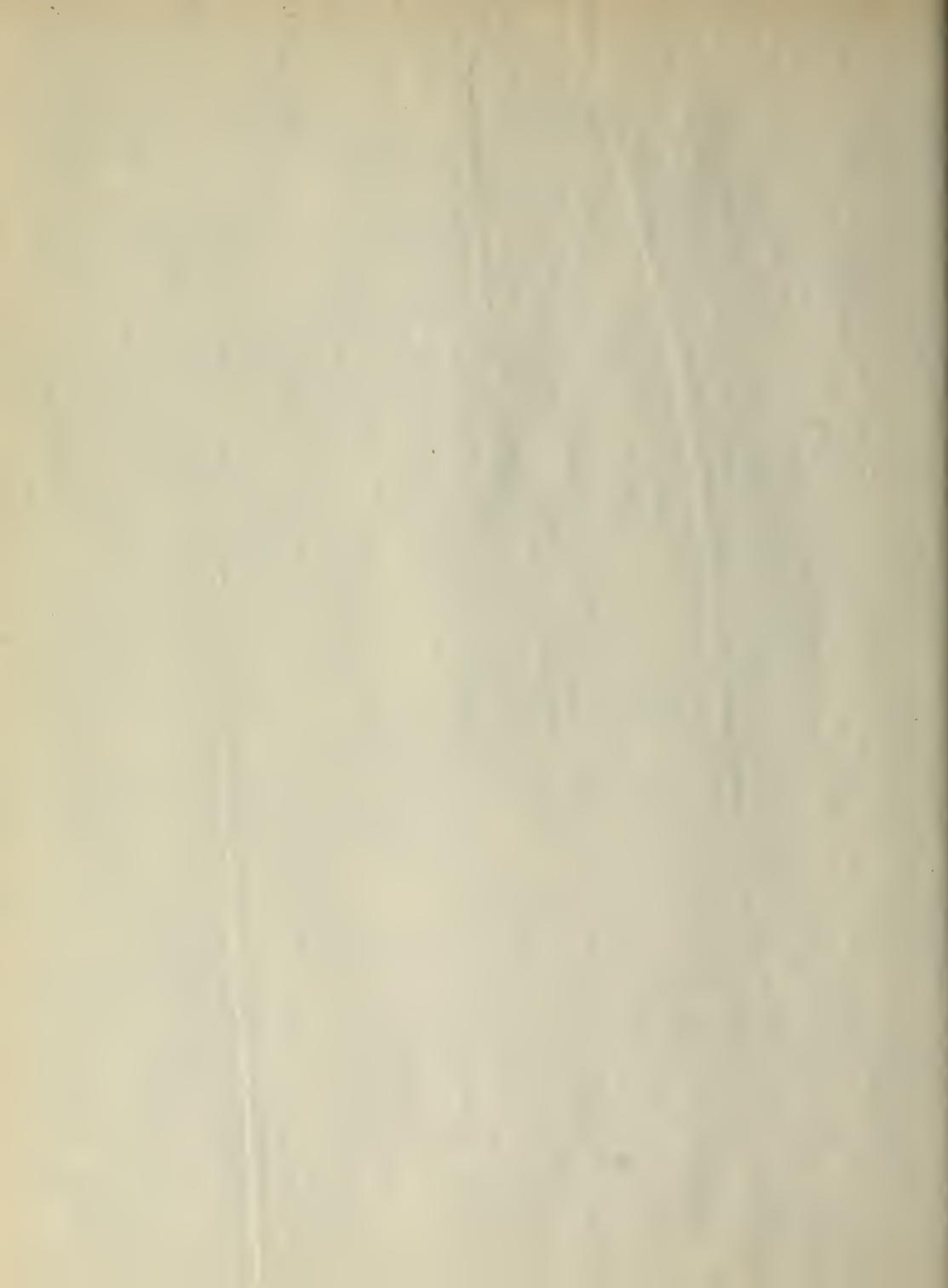
Fig. 14





H.E. Pfeiffer

FIG. 15



THEORETICAL
 PARABOLIC MIRROR + DISK SOURCE
 BEAM DISTRIBUTION
 Reference #2

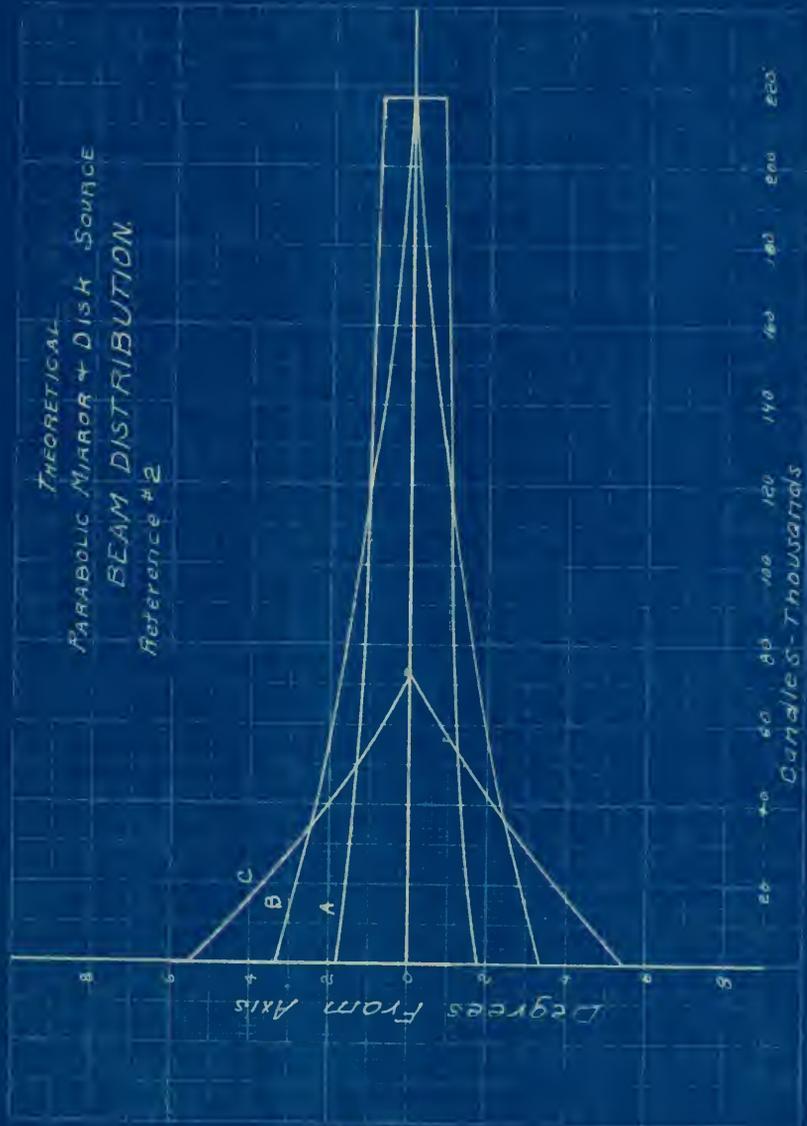
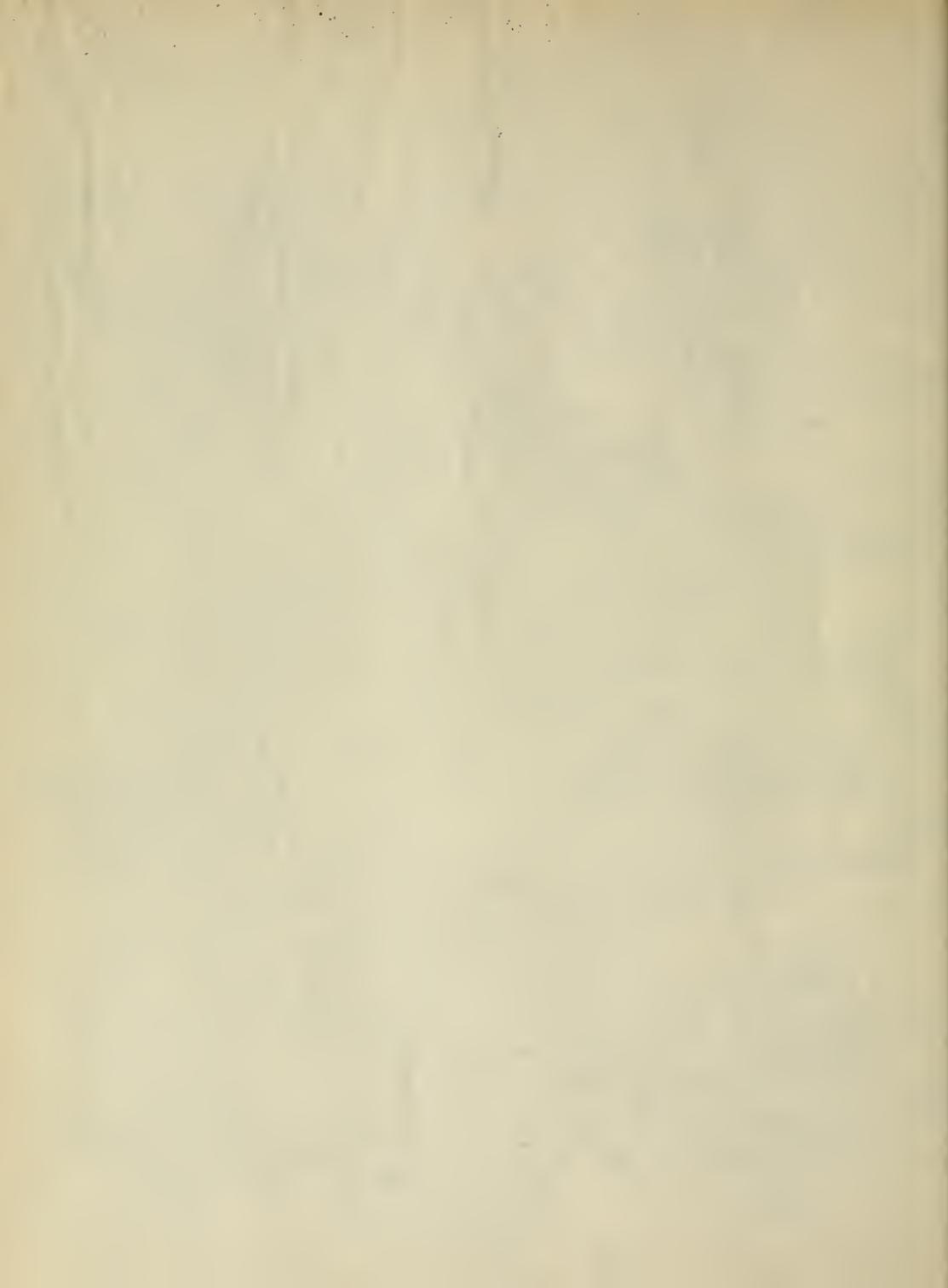


FIG. 16



A wider angular opening than 180° is not effective, since the projected area becomes zero at 90° from the axis. The effective diameter of reflector C is reduced to $2A$. The distance from the focus at which the inverse square region begins is in this case

$$L'_0 = \frac{R(F + \frac{R^2}{4F})}{12r \cos \alpha}$$

The above discussion is mostly theoretical which is far from the actual conditions as they really exist, yet it gives a general idea of what can be expected.

To determine the distribution of the intensity of the beam as it comes out of the reflector, using a bulb as the source, the photometer was placed in the center of the beam in a plane which would coincide with the lens, were it in place. No lens was used in this test. The photometer was then moved horizontally and the intensities at various points were determined. At each test the current flowing thru the bulb was its normal value and the photometer read directly in foot-candles.

The 22nd March 1944 (Wednesday) 1944
Dear Mr. [Name] [Address]
[Address]
[Address]
[Address]
[Address]

Yours faithfully,
[Signature]
[Name]

The above is a copy of the letter
sent to you on [Date] by [Name]
of [Address] and is for your
information only.

It is requested that you should
return the original to the
[Name] at [Address] as soon as
possible. The original is
being held by the [Name] at
[Address] and will be
returned to you as soon as
possible. The original is
being held by the [Name] at
[Address] and will be
returned to you as soon as
possible. The original is
being held by the [Name] at
[Address] and will be
returned to you as soon as
possible.

With the bulb in focus the intensity increased as the center was approached. With some bulbs there seems to be an interference effect and the highest intensity appears to be from 1" to $1\frac{1}{2}$ " away from the center of the beam, Fig. 10 to 13 with corresponding data. In all of these tests the same reflector was used. When the bulb is placed in back of focus, the rays diverge and the intensity increases toward the edges of the reflector while it decreases in the center. When the bulb is ahead of focus, the reverse is true; the center increases in intensity while the edges decrease. The beam is more uniform, when a spiral filament is used than when a "V" shaped filament. But the "V" filaments produce a sharper beam as it is more nearly concentrated.

As the focus of the reflector is a point, it is evident that only one point of the filament of the bulb can occupy this position, and rays emanating from this point, after reflection, will proceed in lines parallel to the axis of the



Fig. 17

reflector. Rays from all other points of the filament will be reflected from the reflecting surface at an angle to the axis. This is the reason why each point on the reflector reflects the image of the filament and sends out a cone of light. The cones emanating from points on the reflector near the apex have bases of considerable area while those reflected from points near the edge have small bases, Fig. 17. The resulting beam is a blending of these cones and the illumination produced depends entirely upon the form and area of the filament.

The first important operation, after placing the bulb in the socket is the focal adjustment. This adjustment depends upon the form of the reflected cone of light desired. It is impossible for practical purposes to determine which point of the filament is the center with respect to the focal point of the reflector. A good way is to throw an image of the reflected light upon a screen or other plane surface perpendicular to the axis of the lamp at a distance not less than



Back of Focus
FIG. 17



Ahead of Focus
FIG. 18



IN Focus

FIG. 19

fifteen feet.

Starting with the filament of the lamp, placed back of the focal point, that is some point between the focus and reflector, we have an image with a black spot in the center, Fig. 17. This adjustment is undesirable because the light distribution upon the road is such that black spots are visible. The majority of the rays in this case are useless, because the wide angle of projection carries them to a considerable extent off the sides and up into the air. With the filament placed in front of the focus, Fig. 18, the results are similar except that the beams now converge, where in the first case they diverge. The light going up into the air now comes from the bottom of the reflector where in the first instance it came from the top part of the reflector. When the filament is placed in focus, Fig. 19, the image will have the smallest diameter and the "light center of gravity" of the filament is then in focus. The image will be much larger

than the reflector as the rays are not strictly parallel. With a good 9 inch reflector the image will have a diameter of about 6 feet at 100 feet from the lamp. For all practical purposes it may be assumed that the rays from any part of the reflector are parallel because no definite angle could be given to them. The beam as a whole diverges with an angle of about 2 degrees.

Automobile headlight equipments use lamps ranging from 4 to 50 candlepower; although special lamps have been made to produce intensities of higher candle power. The ordinary parabolic headlamp focused for maximum concentration will give from 10,000 to 100,000 apparent beam candle power or higher. With a 28 candle power lamp it is possible to obtain a beam of 80,000 candle power.

The filament winding has a very material effect upon the uniformity of light distribution throughout the beam. The centering of the filament with the respect to the base is extremely

FILAMENT IMAGES



FIG. 20



FIG. 21



FIG. 22



FIG. 23

important, as a crooked base or a crooked stem may throw the filament to one side by a fraction of an inch and seriously distort the beam. The glass bulb by reflection produces one or more images inside of the bulb. These images do not coincide with the filament, if the latter is not centered correctly, and in some cases they throw off a considerable amount of light. These images then produce the effect of a light source which is out of focus and cause glare. The majority of bulbs on the market produce these images, Fig. 20 to 23. The smaller the dimensions of the actual light source, the more powerful and narrower will be the beam obtained. We have to deal with light sources that are irregular in shape, and so the shape of the resulting beam is greatly modified.

It is sometimes thought that light emerging from the bulb produces glare. To test this fact, that part of the bulb which produced stray light was coated with silver. The entire angle of the

bulb is now made use of since this coating acts as a spherical reflector. The light now issued from the reflector is more directive and there is less side illumination. This is very good where the beam is to be controlled with accuracy. But this did not reduce the glare and besides this stray illumination is very desirable. The glare does not come from the bulb, it comes from the reflector itself and is due to the unparallel rays. This is obtained by an imperfect reflector and due to part of the filament being out of focus.

The maximum beam or driving light is supposed to be at least 200 feet in front of the car. This means a drop in the beam of 40 inches in 200 feet, or an angle of \tan^{-1} or \sin^{-1} .

$$\frac{40}{200 \times 12} = .0167 \text{ or } 0^{\circ} 56'.$$

That is to say that the top of the maximum beam is 56' below the horizontal. Assuming that a man is 60 inches tall, then he is looking at an angle of 56' above the horizontal. This makes a

total angle of $1^{\circ}52'$. If there are any imperfections in the reflector, or the filament out of focus to cause any of the rays to shift more than $1^{\circ}52'$, glare will be the result and it cannot be avoided regardless of the lens.

The light coming from the edge of the reflector is the most controllable beam. The reason for this is that any point on the filament makes an angle of least divergence from the focus, when reflected from the edge of the reflector. As the center of the reflector is reached, points on the filament away from the focus point makes an appreciable angle variation. The brightest spot is wanted at about 1° below the horizontal line. If the light coming out of the reflector be cut up in horizontal slices, the beams from the top and bottom will be the most controllable. So these beams should be used for the driving light, and the center slice for the light near the car. More glare comes from the spiral filament than from the vacuum type, because the spiral filament occupies more volume; and glare is only due to

the light that comes from the reflector into the eye due to parts of the filament being out of focus. During the use of reflectors, they are polished by hand and in doing so they are scratched and this increases the spread.

For a fixed position of light source with respect to the eye the degree of glare experienced is a function of

- (1) brightness of the source; and
- (2) total flux of light directed toward the eye from the source.

It is interesting to note that in a test done by Ward Harrison (See reference #1) that in the opinion of the observers in his experiment a clear bulb, gas filled lamp of approximately 100 candle power was not considered so objectionable as a lamp of double the candle power in an opalized bulb although the brightness of the former was of the order of 3,000 candle power per square inch and of the latter but 16 candle power per square inch.

The most common misconception in regard automobile headlights is the opinion that the elimination of the upper half of the reflector will obviate all upward reflected light. This is only true in the case of the diverging beam, whereas should the source be moved forward, producing a converging beam, the obscuration of the top of the reflector would eliminate the lower half of the beam. Another misconception is that lenses increase light. They may increase light in certain directions, but they transmit no more light than a flat glass, and frequently much less.

Although there are very many variables that are a function of glare, it is correct to assume that the glare increases with increase of candle power, but it is very difficult to say in just what proportion. It is only necessary to determine a limit to the candle power that is just unbearable.

PART FIVE

VARIOUS DEVICES ON THE MARKET.

To overcome the dazzling glare over two thousand methods have been developed, some of which are now in actual use. The main principles of theory and design of some of the most common seen at present may be considered:

- 1. Dimming the light source.
- 2. Auxiliary light sources.
- 3. Tilting the headlights.
- 4. Parabolic reflectors with devices placed in the path of the reflected light.
 - A. Diffusing glasses.
 - B. Diffracting glasses.
 - C. Opaque screens.
 - D. Lenses.
 - E. Prismatic glasses.
 - F. Blinds or slats.
 - G. External reflectors.
 - H. Changing the color of the light.

5. Parabolic reflectors with devices placed between light source and reflector.
 - A. Bulb caps.
 - B. Metal reflectors or shields.
 - C. Glass prismatic refractors.
6. Special light sources.
 - A. Various types of filaments.
 - B. Treated bulbs.
7. Reflectors of special design.
 - A. Tilted axis.
 - B. Offset or double focii.
 - C. Ellipsoid.
1. By dimming the light source is meant reducing the current flowing thru the bulb. This reduces glare by lowering its candle power, but the general illumination is greatly reduced and is a very poor method of control.
2. In city driving or when an approaching driver is seen in the country, the main lights are turned off and auxiliary lights are turned on. These lights are smaller and are located near the upper

THE HISTORY OF THE UNITED STATES OF AMERICA
FROM 1763 TO 1876
BY CHARLES A. BEAMAN
VOLUME I
CHAPTER I
THE EARLY HISTORY OF THE COLONIES
THE DISCOVERY OF AMERICA
THE EARLY SETTLEMENTS
THE STRUGGLE FOR INDEPENDENCE
THE CONSTITUTION
THE UNION
THE CIVIL WAR
THE RECONSTRUCTION
THE PRESENT
THE FUTURE

part of the reflector, throwing a small downward beam upon the road. It necessitates an extra lamp circuit and does not give enough illumination.

3. Tilting the headlamps may be temporarily or permanent. The Adams-Bagnall Tilting Device makes use of an electrically operated mechanism in the housing of the lamp. When an approaching driver is seen, the mechanism is operated by the driver with a push button and this tilt can be adjusted at will.

Headlamps having their bulbs in focus with plain glass fronts and tilted with an angle of about 1° give a good road illumination. The only disadvantage is that it does not give a wide enough distribution and it is difficult to see the edge of the road.

4. Devices which are placed in the path of the reflected light are the most popular and economical method of control. These are divided into two general classes, diffusing and deflecting. Diffusion is obtained by the use of small lenses

or prisms , either clear or frosted. The diffusion has the effect of reducing the beam intensity and contributing the light so gained to the illumination of objects contained within a much wider angle. Deflecting light is accomplished by the use of prismatic glass fronts that tend to redirect all or a part of the reflected light. The redirection of the light in some devices not only keep it within the zone in which glare is not objectionable, but also distributes it over a greater width of road. There is a great diversity in opinion as to which of the two methods is most advisable. Each has their advantages and disadvantages.

The advantages of the diffusion principle are:

1. Focusing not necessary.
2. Aiming of lamps not important.
3. Does not increase its glaring effect upon rough roads.
4. Gives better illumination for turning a corner.

The first thing I noticed when I stepped
 out of the car was the smell of the sea.
 It was a fresh, salty breeze that
 seemed to wash away all my worries.
 I had been thinking about the
 meeting all day, but now it felt
 like a distant memory. The sun was
 just setting, and the sky was a
 beautiful mix of orange and blue.
 I took a deep breath and felt
 a sense of peace that I hadn't
 felt in a long time. The waves
 were crashing against the shore,
 and the sound was so soothing.
 I had found a little piece of
 heaven in the most unexpected
 place.

The sunset was so beautiful, I
 couldn't believe I had missed it.
 I had been so busy with work,
 but now I was here, in the
 middle of it all. The colors were
 so vibrant, and the light was
 just what I needed. I had
 been so stressed, but now I
 felt like I had found a new
 way to breathe. The world was
 so beautiful, and I was so
 lucky to be here.

Disadvantages:

1. Glare varies greatly with change in candle power
2. No distant illumination of road.
3. No warning beam in front of car.
4. The diffused light forms a veil for distant objects.

The advantages of the light zone or deflecting principle are:

1. Distant road illumination.
2. No glare near the car.
3. Most efficient light distribution on the road.
4. Change in candle power of bulb does not greatly increase the glare.
5. It has a warning beam for cross roads.

Disadvantages.

1. Exact focusing absolutely necessary.
2. Causes momentarily glare when car is passing over rough roads or top of hill.
3. Harder to see warning signals as signs.

It is evident that from the above discussion

[Illegible Title]

[Illegible text block 1]

[Illegible text block 2]

[Illegible text block 3]

[Illegible text block 4]

[Illegible text block 5]

[Illegible text block 6]

[Illegible text block 7]

[Illegible text block 8]

[Illegible text block 9]

[Illegible text block 10]

[Illegible text block 11]

[Illegible text block 12]

[Illegible text block 13]

[Illegible text block 14]

[Illegible text block 15]

[Illegible text block 16]

[Illegible text block 17]

[Illegible text block 18]

[Illegible text block 19]

[Illegible text block 20]

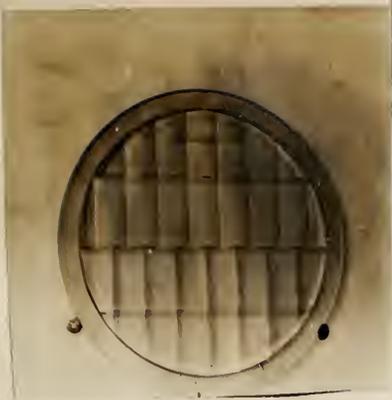


FIG. 24
Patterson Lens



FIG. 25
Liberty Lens



FIG. 26
Lee Knight Lens



FIG. 27
Legalite Lens



FIG. 28
Controllite Lens

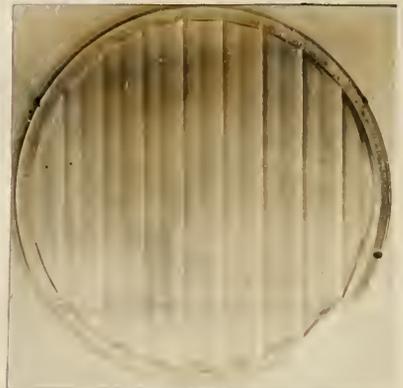


FIG. 29
Bausch & Lomb Lens



FIG. 30
SHALER LENS

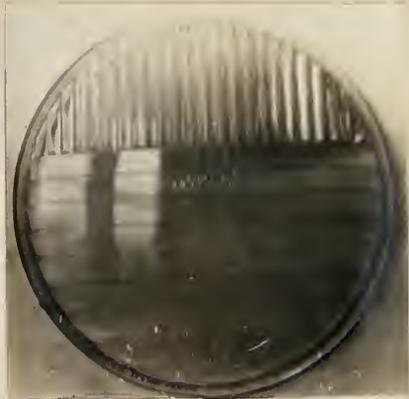


FIG. 31
McKEE LENS



FIG. 32
MACBETH EVANS LENS



FIG. 33
CORNING LENS

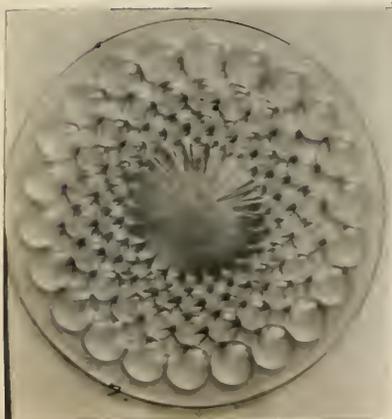


FIG. 34
WARNER LENS

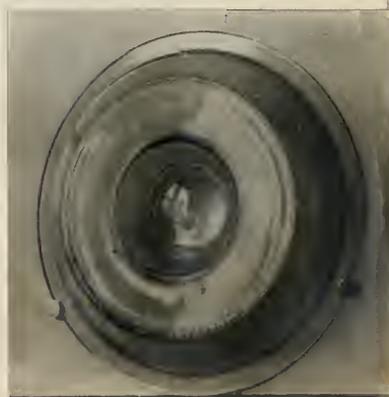


FIG. 35
DILLON LENS

that the deflecting type of control is the more suited for country driving. For city driving the same kind of control should be used except that a resistance should be inserted into the circuit so as to reduce the candle power of the bulb.

The Patterson Lens, Fig. 24, 36, and 51, has horizontal prisms across the surface of the glass which deflects the light downward toward the ground. The angles of the various prisms are not the same. It also has vertical cylinders which distribute the light sideways producing a wider beam. This lens illuminates the road very satisfactorily. Fig. 67 shows the horizontal distribution curves of this lens for various levels, the readings being taken 100 feet away and Fig. 58 shows its vertical distribution.

The Liberty and Lee Krite Lenses, Fig. 25, 52, 59; 26 and 41, are of similar construction, varying only in some of the optical dimensions.

The Legalite and Controllite Lenses, Fig. 27, 43, 54, 60; 28, 39, 55, 62 and 69, have just a

large number of small horizontal prisms. This has the same effect as tilting the headlamp. They produce very intense but narrow beams. The Legalite Lens has two vertical prisms which slightly widens the beam.

The Bausch and Lomb Lens, Fig. 29 and 38, has vertical cylinders which widens out the horizontal diameter. This beam is very wide but not long.

The Shaller Lens, Fig. 30, 49, 53, and 70, is constructed to have its bulb slightly in back of focus. Fig. 53 and 70 were taken with the bulb in focus. Each lens illuminates three distinct areas on the road. When both lenses are in operation, the light spots blend into one illuminated area. The illumination is not even, and when one bulb burns out it is difficult to see the road.

The Macbeth Evans Lens, Fig. 32 and 47, is of the same general construction as the Liberty Lens, but has a green absorbing shield over the top. This shield is for the purpose of reducing

glare and is very ineffective. It just reduces the road illumination.

The yellow Corning lens, Fig. 33, 40, and 61, has horizontal prisms across the surface of the glass. The reflected light is bent downwards. The prisms in the center are molded in the form of cylinders in order to distribute the light sideways producing a slightly wider beam. The beam is of yellow light and is supposed to have several advantages. Below is an abstract giving one's opinion on yellow light.

Abstract of paper read at Toledo meeting of C.E.R.A. Nov. 23, by Mr. K.W. Makall.

*Headlights which produce yellow light has not been found to reduce glare except that directly traceable to the lesser intensity of the headlight, due to the absorption of the glass. So far as my tests are concerned I cannot find there is any bases for the claim that a light of this characteristic will penetrate fog, dust, smoke, or mist to any greater degree than will white

THEY ARE IN THE MIDDLE OF THE ROAD

PATTERSON LENS

TOP HALF

BOTTOM HALF

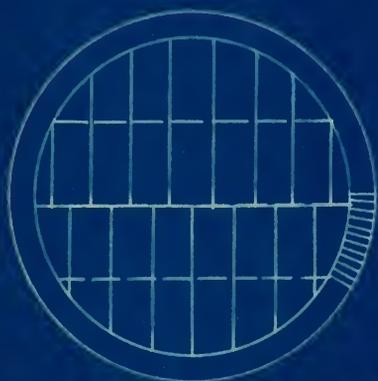


FIG. 36

WARNER LENS

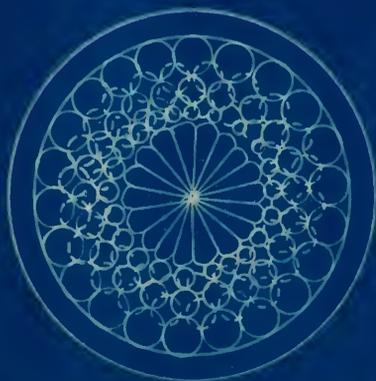
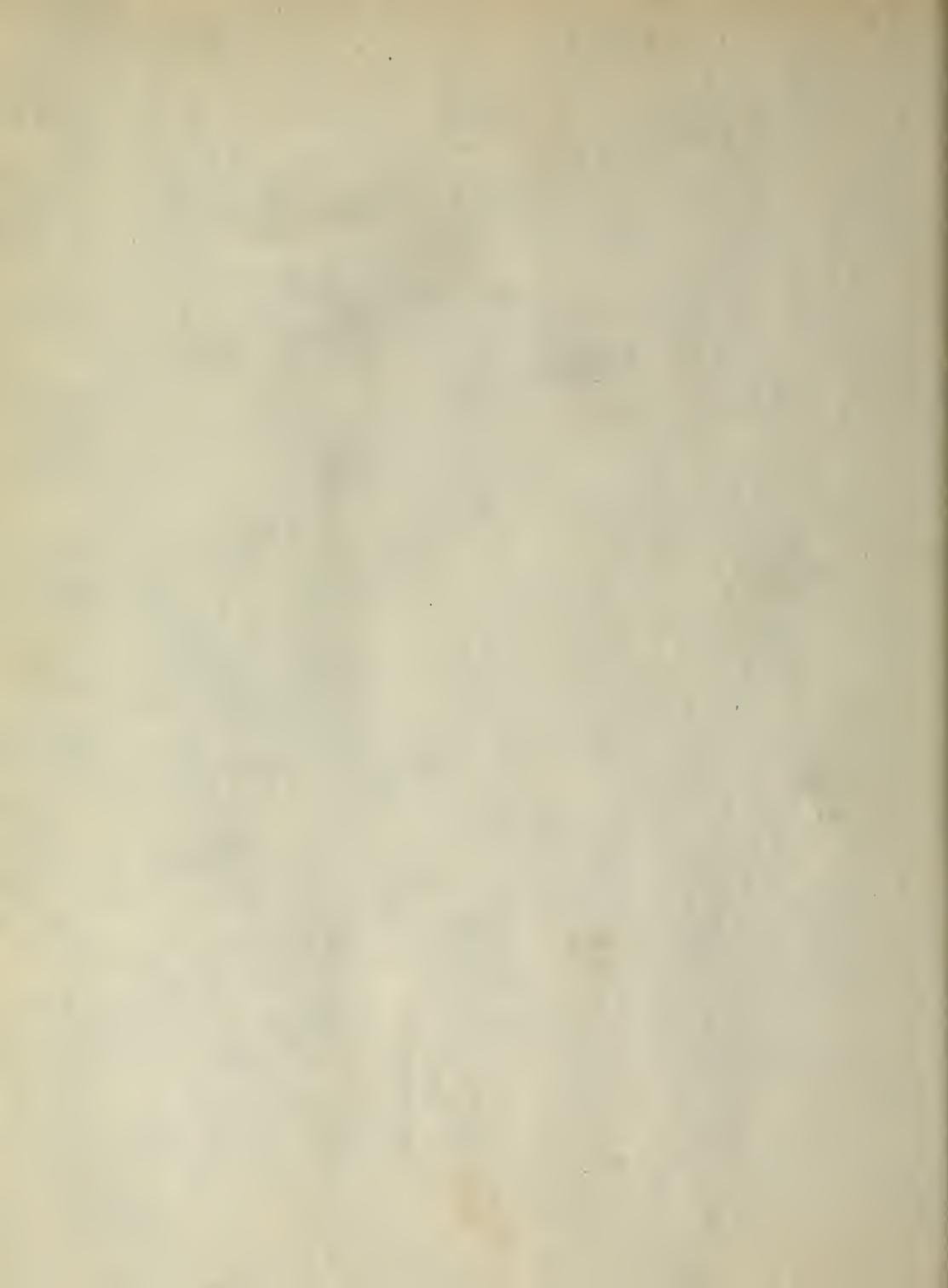
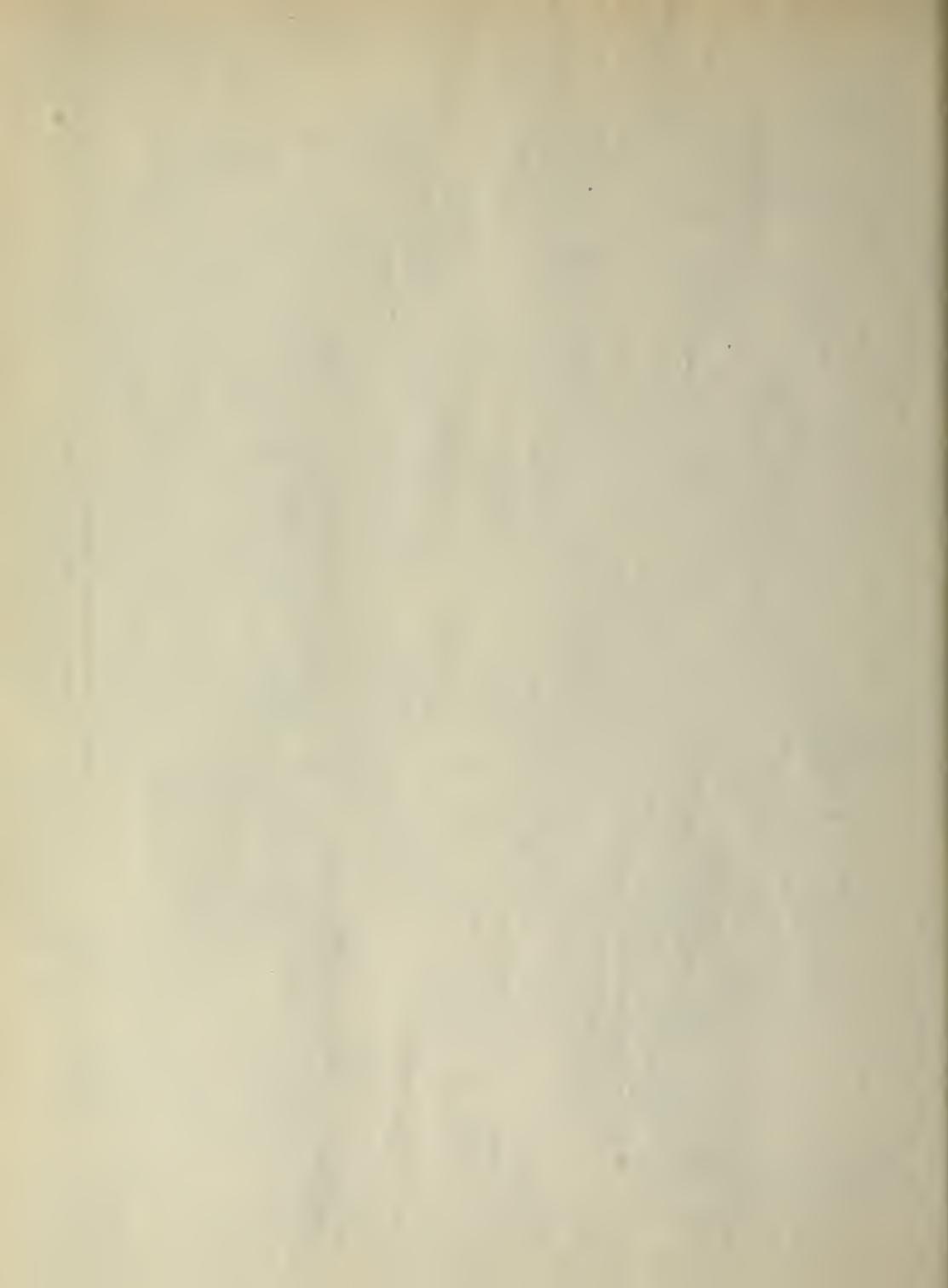
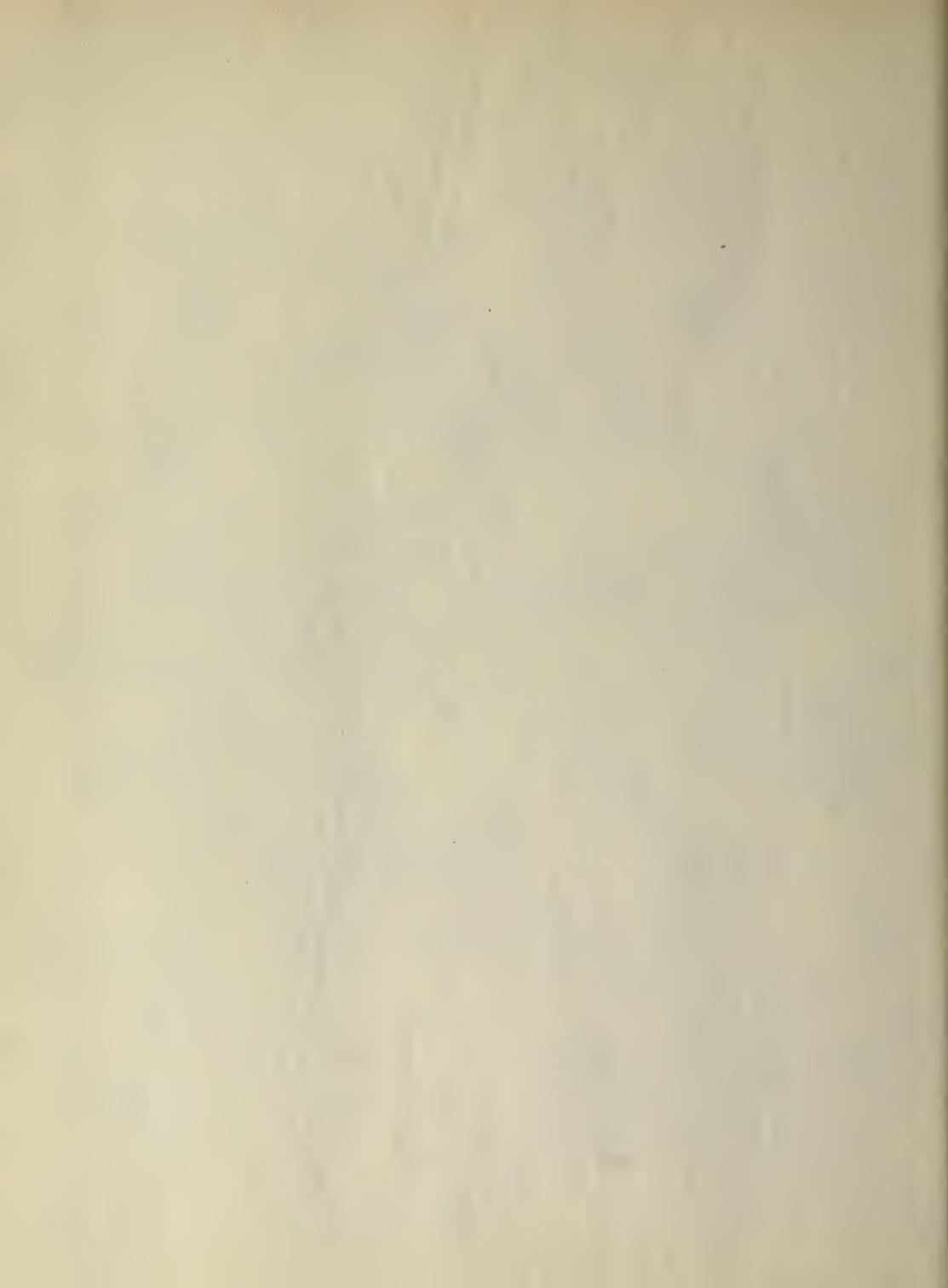


FIG. 37







LEGALITE



FIG. 42

DILLON LENS

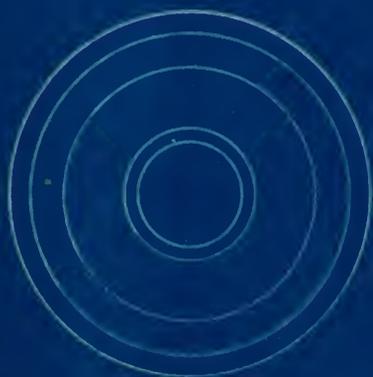


FIG. 43

MATISSE CONCAVE LENS

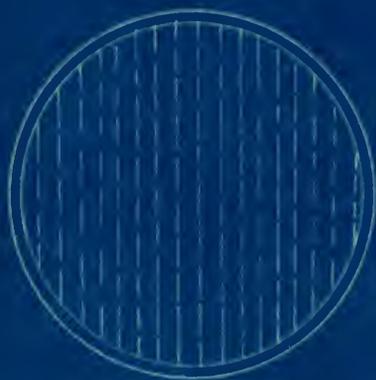


FIG. 44

TOTALUX

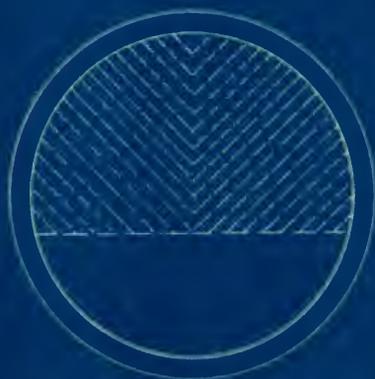


FIG. 45

Parab-o-Light LENS



FIG. 46



Macbeth Evans Lens

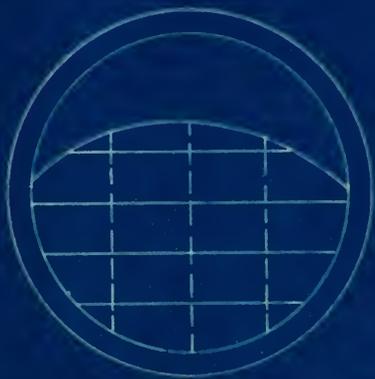


FIG. 47



McKEE LENS

section thru AB

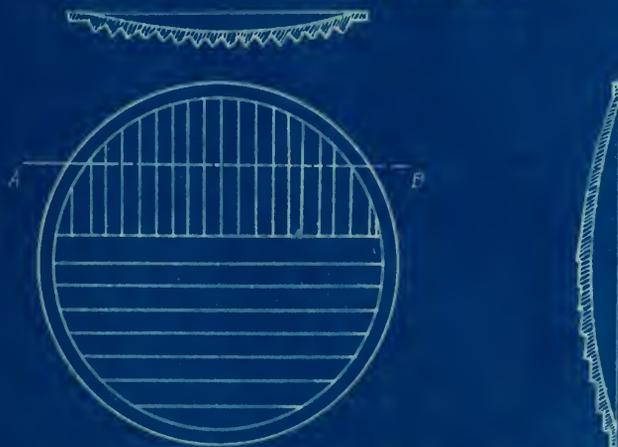


FIG 48

SHALER LENS

section thru AB

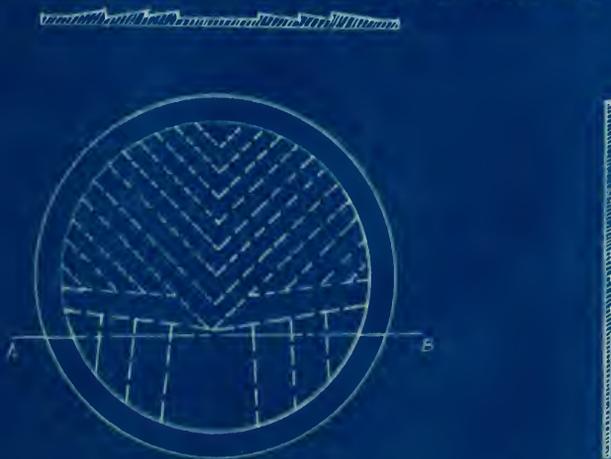


FIG 49

light of equal intensities. There is this about yellow light which appears to be advantages, and that is when driving thru a rain storm or a heavy fog, the diffraction halation or back glare is some what reduced. There is, however, no scientific data on this point."

A greenish-yellow light will penetrate the atmosphere better than a white one, but the difference is not noticeable with the ordinary eye.

The Warner Lens, Fig. 34, 37, 56 and 68, is of the diffusing type. It consists of a multiplicity of small lenses aver the entire front and back. It gives a wide angle of distribution, but it does not give a far driving light.

The Dillion Lens, Fig. 35, 43 and 57, has the same characteristics, but instead of using lenses, its surface is moulded rough.

There are a great number of different kinds of lenses, but those above are the princqple ones and illustrate the principles in use.

5. The Lennon cap is a hemispherical metal cap with a nickel-plated surface. The concave

surface acts as a spherical mirror and produces an image of the filament in front of the actual filament. The filament should be placed in front of the focus with the cap on the lower side of the bulb. A downward beam will be produced.

The Franco Lens, a similar device, consists of curved prisms partially surrounding the lamp which are intended to be so located that all of the light striking one half of the reflector must pass thru these prisms, This acts as if the filament was moved ahead of focus and the light is thrown on the ground. If all adjustments were correct, the beam candle power is some what reduced and the beam spread increased.

6. Various types of filaments designed to give a definite spread has been put on the market, but they are not much in actual use. Sometimes the bulbs are frosted or are coated to give off a yellow light. Frosting the bulb increases the glare as it produces a larger luminous source-- when the bulb is in the focus position.

7. Satisfactory results can be obtained by the use of a modified reflector, composed of two half paraboloids, the axis of the upper one being so inclined or displaced as to throw the light toward the ground. In another form, the bulb is partly surrounded by a reflector of peculiar design, so arranged as to cutt off the light or deflect it so that it will be thrown upon the road. Both of these devices increase the illumination of the roadway at a point where it is desired, but it does not spread the beam of light. The first device is somewhat costly to manufacture. Care must be taken to see that the filament is properly focused.

The Ames Headlamps are of several varieties, and depend for their operation upon the use of spherical and ellipsoidal surfaces for the upper reflecting surface. Some of these headlamps have the electric lamp mounted at an angle of 40 degrees to the horizontal and locating the filament entirely above the focus. This feature allows a

considerable latitude in the location of the filament.

The Matisse Headlamp makes use of a silvered glass reflector, having ground surfaces. The concave surface is spherical and the convex parabolic. It produces a very concentrated beam by reason of its long focal length, namely $2\frac{1}{4}$ inches. Its diameter is 10 inches and its depth $3\frac{1}{2}$ inches. The filament produces a concentrated beam of high power approximately 1° below the reflector axis. In front of the lamp is placed a spherical mirror which produces an image above the filament. This headlamp produces two beams, both of which may be adjusted so that practically all of the reflected light is below the horizontal axis.

The Edwards Headlight is a combination consisting of a parabolic lower and an ellipsoidal upper part. This device, if perfectly made, would give no light above the horizontal, not even the direct light from the filament. Proper adjustment requires that the filament be placed a little

more than its axial length back of the parabolic part. The ellipsoid is arranged to have one of its foci at the proper position of the filament and the other thru which the intercepted rays are directed at a point on the axis of the lamp just back of the plane of the front glass.

The Rand Reflector is composed of two half paraboloids split horizontally in the center, having a common focal point. The upper half is inclined downward at an angle of 2 to 7 degrees. Both halves throw downward beams.

The offset reflector is two half reflectors, the division being made horizontally. The lower half has a focal length greater than the upper by the length of the filament. The entire filament is behind the focus for the lower reflector and ahead of focus for the upper. Both halves throw downward beams.

There are a number of devices which combine several principles. The disadvantages of these are; first, that they are costly; second, they require

a knowledge of illuminating engineering to make the proper adjustments; and third, the adjustment in a number of cases is not lasting.



Patterson.

FIG. 51



Liberty

FIG. 52



FIG. 53



FIG. 54



FIG. 55



FIG. 55 A



FIG. 56



FIG. 57

PART SIX
C O N C L U S I O N .

Most of the anti-glare devices give some help when properly adjusted and when the headlamp is properly in focus. Conditions can easily occur, and frequently do, where thru improper adjustment the glare reducing device fails entirely, or even increase glare. This is often due to ignorance, on the part of the car driver, of the principles of the headlights. A good device should function for two purposes. It should reduce the glare and distribute the light most efficiently. With a good driving light a brighter glaring light can be endured.

It is not good to eliminate the direct rays from the filament. This helps to illuminate the surroundings near the car and it does not cause any glare at all. There are a number of devices using this principle.

The shape of the filament has an affect upon the distribution given off by the lenses. In

general the spiral filament is easier to work with as they give an evenier distribution. With the same size candle power bulbs and with the filaments in focus, various results may be obtained from different filaments. Experience has shown that readings in any given plane of an incandescent beam can rarely be checked. The difficulty lies in the overlapping filament images that give the beam its molted appearance.

The mazda bulbs of today have been designed to occupy such a space as to give the proper spread for so called good road illumination, when located at the focal point of the reflector. This spread was taken with out the use of any lens. To design a good lens, the unmodified beam should not be spreaded but have parallel characteristics. So it is necessary to redesign the bulbs, if it is to be used with lenses. Also, if bulbs were constructed so that the distance between the tip of the butt and the filament were the same for various candle power bulbs, the headlamp could

be constructed so that the bulb would be stationary. The chances of the filament being in focus would be much greater with this arrangement.

There is some diffusion caused by the glass. The glass used is of a cheap grade, ~~and~~ is relatively poor optically, and it diffracts the light. Due to the low intensity which is used for headlamps, as compared with searchlights, this has little effect. Dust or dirt on the lens reduces the light a considerable extent.

A number of advertisements of non-glare devices use photographs to show the road illumination. Unless these photographs have been made under the same conditions, namely, of atmosphere, length of exposure, size of diaphragm, speed of lens, and type of photographic plate employed, they will be useless for the purpose of comparison. It is possible to get almost any desired result upon a photographic plate with proper manipulation.

It has been found that the shorter wave

lengths of light energy are absorbed more rapidly by the earth's atmosphere than the longer wave lengths. This has found to be the case by recent tests on search lights. An automobile headlight will have the maximum transmission thru fogs if the light is composed of wavelengths from .5300 to .5900 microns. This is a greenish-yellow light. The amount of light returned to an observer near the headlamp varies inversely as the sixth or seventh power of the rays.

Drivers call for a far reaching light. The illumination necessary to see a person clothed in dark cloth is .15 foot-candles. This beam should strike the ground at a distance of about 300 feet, making it necessary to have at least 13,500 apparent candle power. The general shape of the illuminated area should be as shown in Fig. 73.

This high candle power is sufficient, but there are a number of different types of roads and the characteristics of road surfaces have

an affect. Some roads after a rain possess a very high specular reflecting quality and it is impossible to see the road well. Strictly each type of road needs a specific type of distribution of light. On a rough road the driver drives his car slow and so he does not need a far driving beam. On a smooth road, where automobiles travel fast, the driver is looking far ahead of his car and so needs a far driving light. For a lamp to cover all conditions, it must give off a great deal of light and illuminate the road evenly from the car to 500 feet in front of it. This means a large bulb and on account of glare it is not feasible.

REFERENCES

- #1. "Glare Measurements". Ward Harrison,
Trans. I.E.S., No. 1, 1920.
- #2. " The Parabolic Mirror", Benford,
Trans. I.E.S., vol. 10, p. 907.

BIBLIOGRAPHY.

- "Present Practice in Automobile Headlighting",
S.C. Rogers, Trans. I.E.S., 1917, p. 158.
- "Automobile Lighting From The Lighting View Point",
E.L. Clark, Trans. S.A.E., 1916, p. 153.
- " General Report On Glare",
Trans., I.E.S., 1915, p. 987.
- "A Survey of the Automobile Headlamp Situation",
W.F. Little, Trans. I.E.S., 1917, p. 123.
- "Road Illumination by Means of Automobile Headlamps",
H.P. Gage, Trans., I.E.S., 1917, p.179.

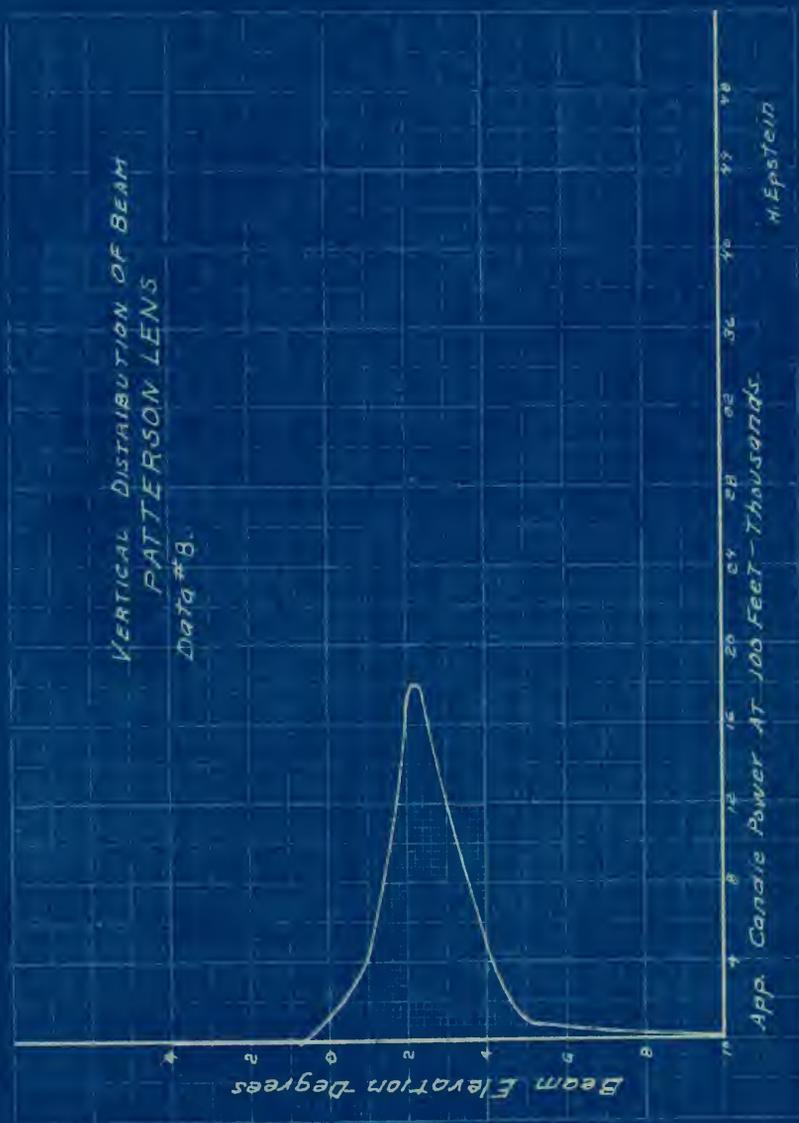
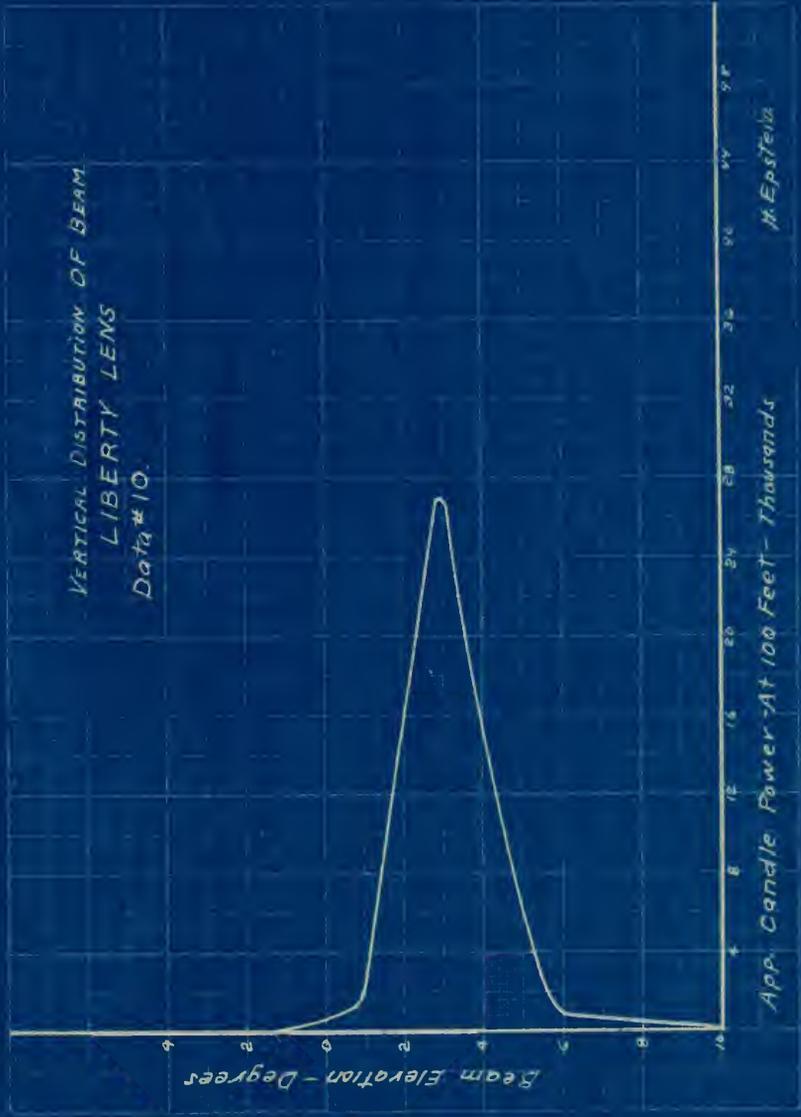


FIG. 58

VERTICAL DISTRIBUTION OF BEAM
LIBERTY LENS
Data #10.



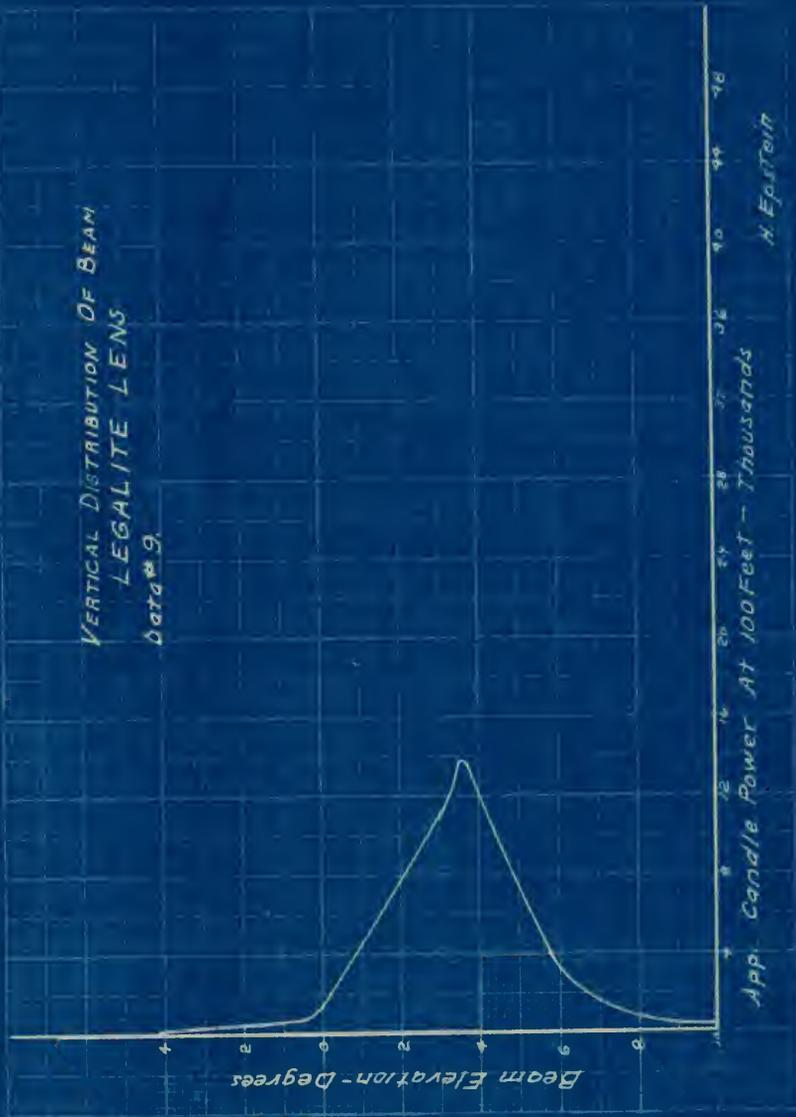
M. Epstein

App. Candle Power - At 100 Feet - Thousands

Beam Elevation - Degrees

FIG. 59

VERTICAL DISTRIBUTION OF BEAM
LEGALITE LENS
Data # 9.



App. Candle Power At 100 Feet - Thousands
H. Epstein

FIG. 60

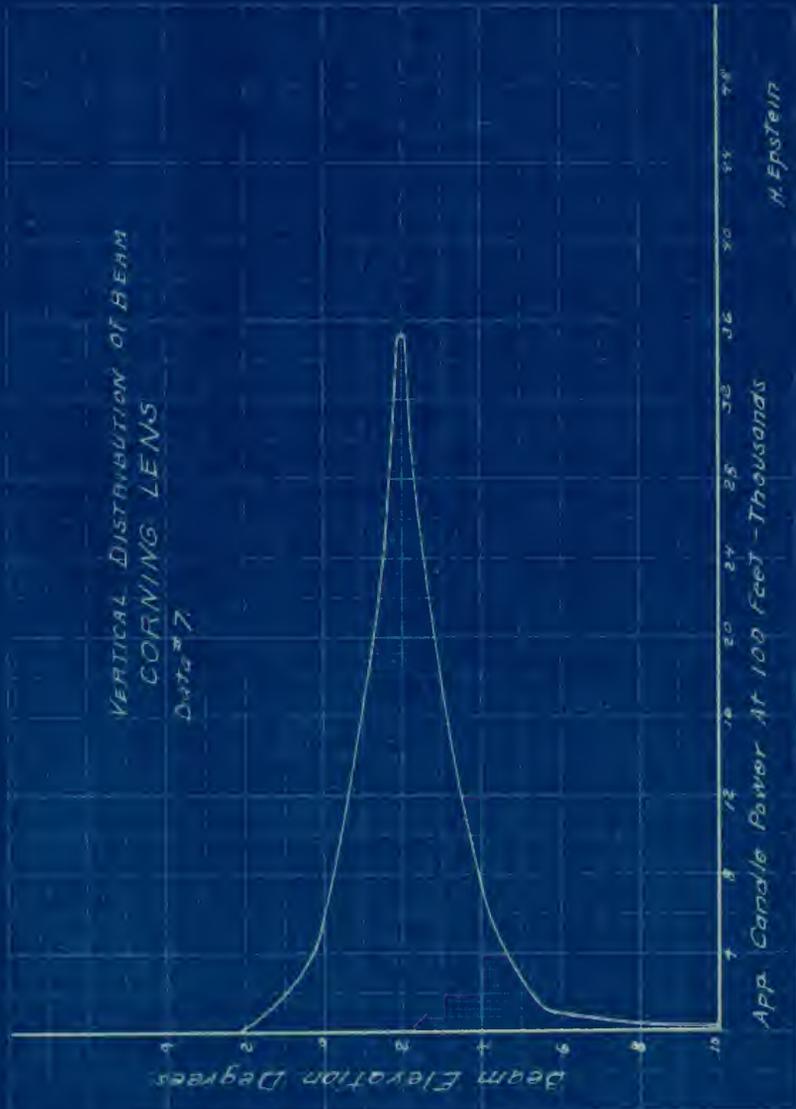
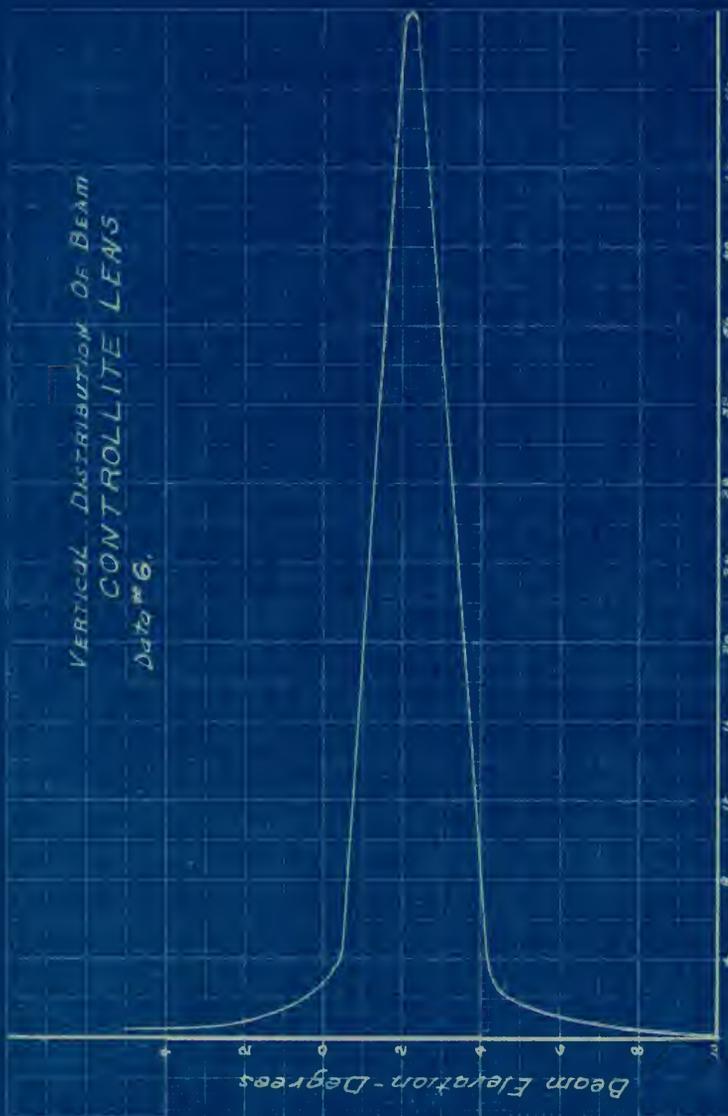


FIG. 61

VERTICAL DISTRIBUTION OF BEAM
CONTROLLITE LENS

Data # 6.



App. Candle power At 100 Feet - Thousands

M. Epstein

FIG. 62

LIGHT DISTRIBUTION IN VERTICAL AXIS
DEVICES PLACED BETWEEN LIGHT SOURCE
AND PARABOLIC REFLECTOR

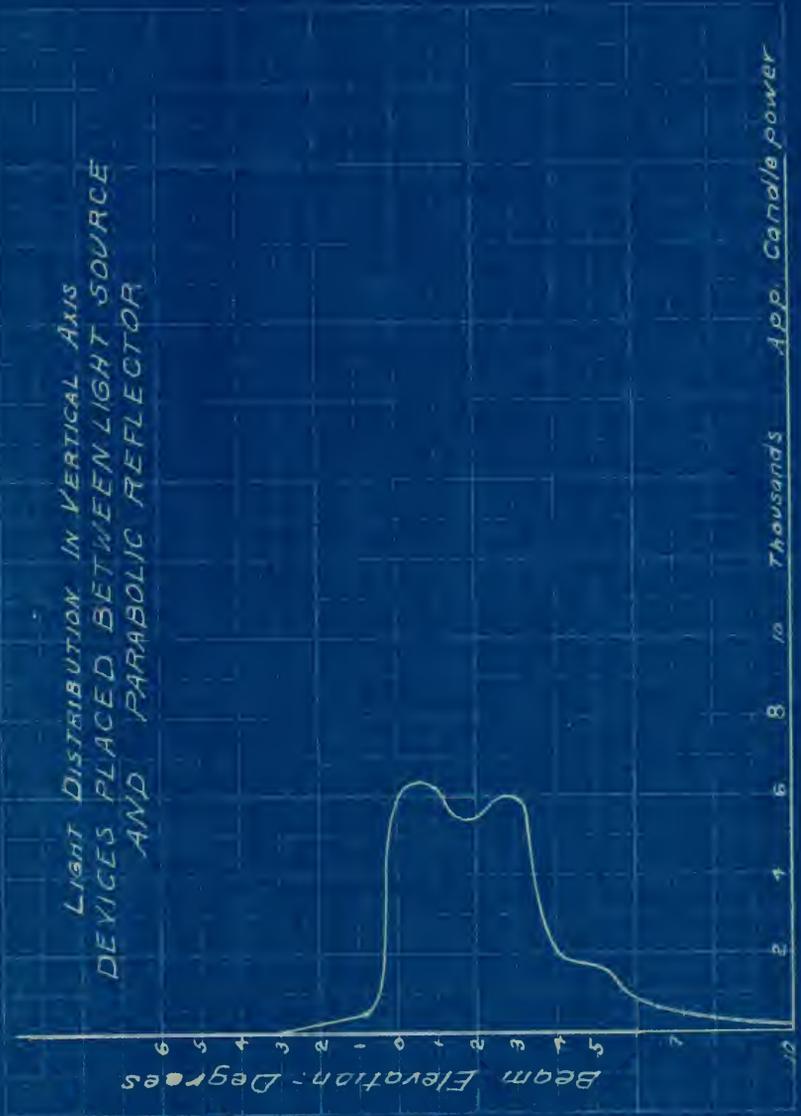


FIG. 63

LIGHT DISTRIBUTION IN VERTICAL AXIS
DEVICES PLACED BETWEEN LIGHT SOURCE
AND PARABOLIC REFLECTOR

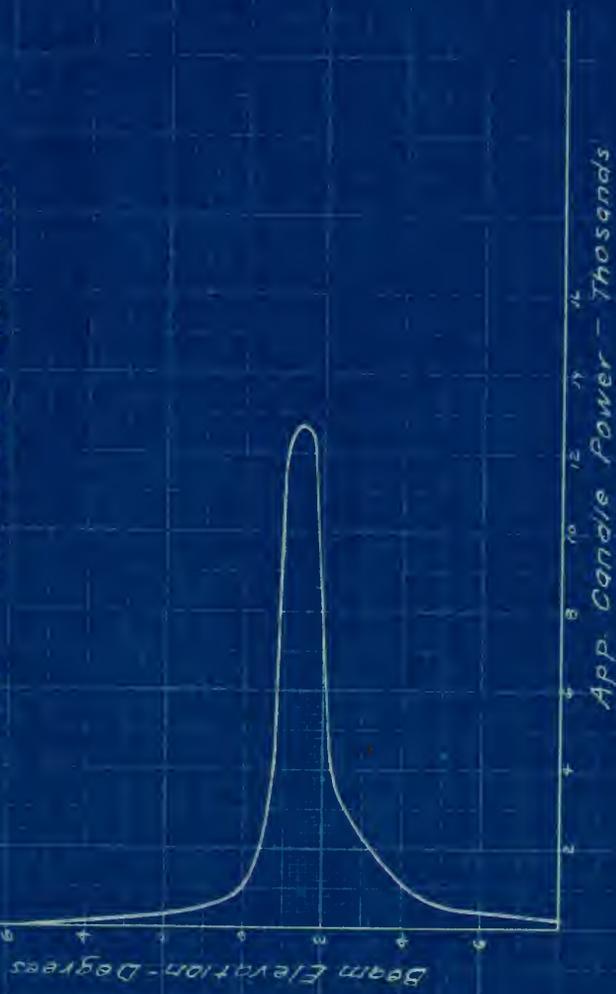


FIG. 64

LIGHT DISTRIBUTION IN VERTICAL AXIS
SPECIAL DESIGNED REFLECTOR.

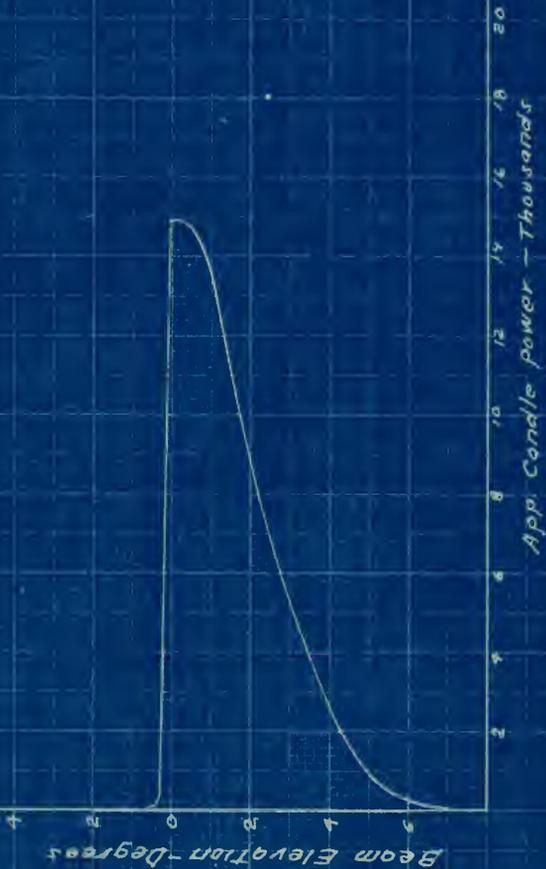


FIG. 65

LIGHT DISTRIBUTION IN VERTICAL AXIS
SPECIAL DESIGN OF REFLECTOR

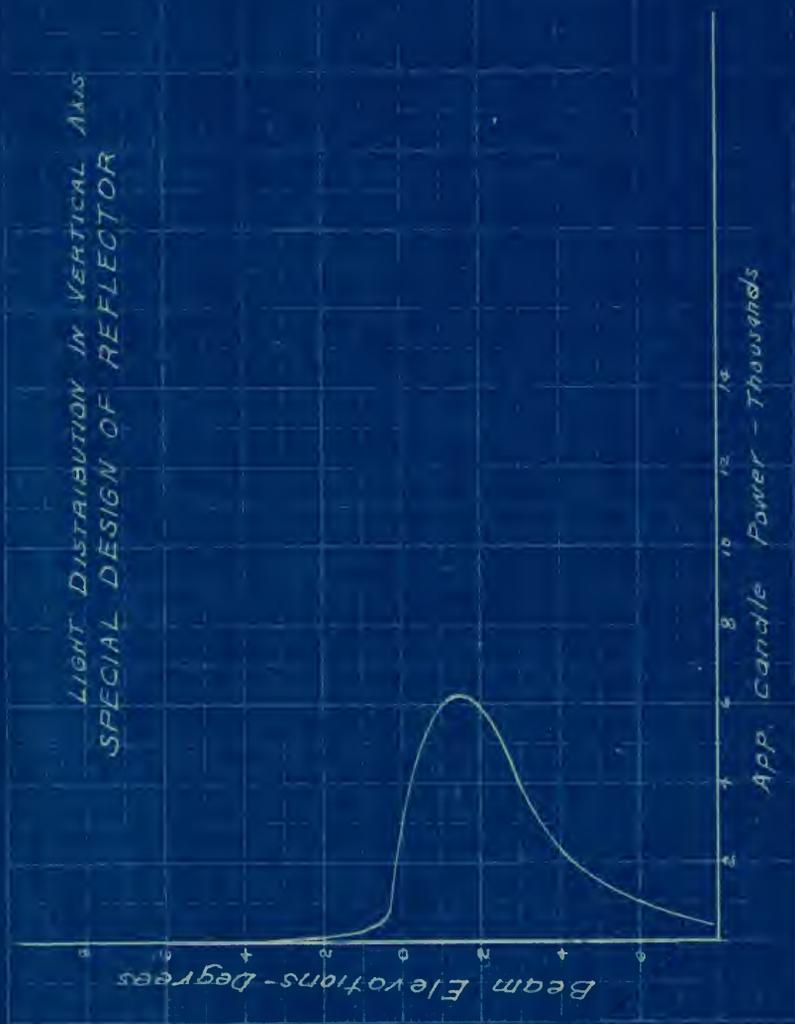


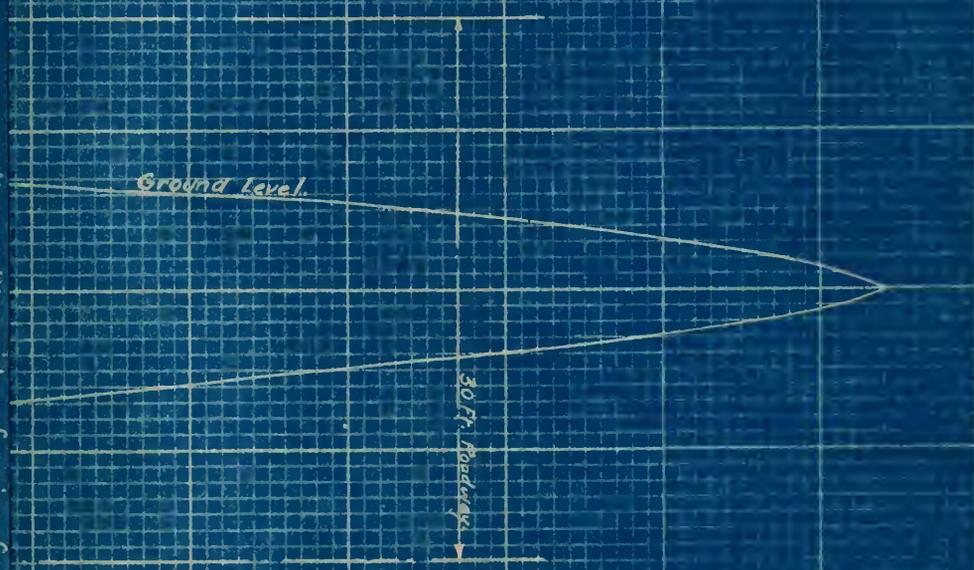
Fig. 66



Fig. 73

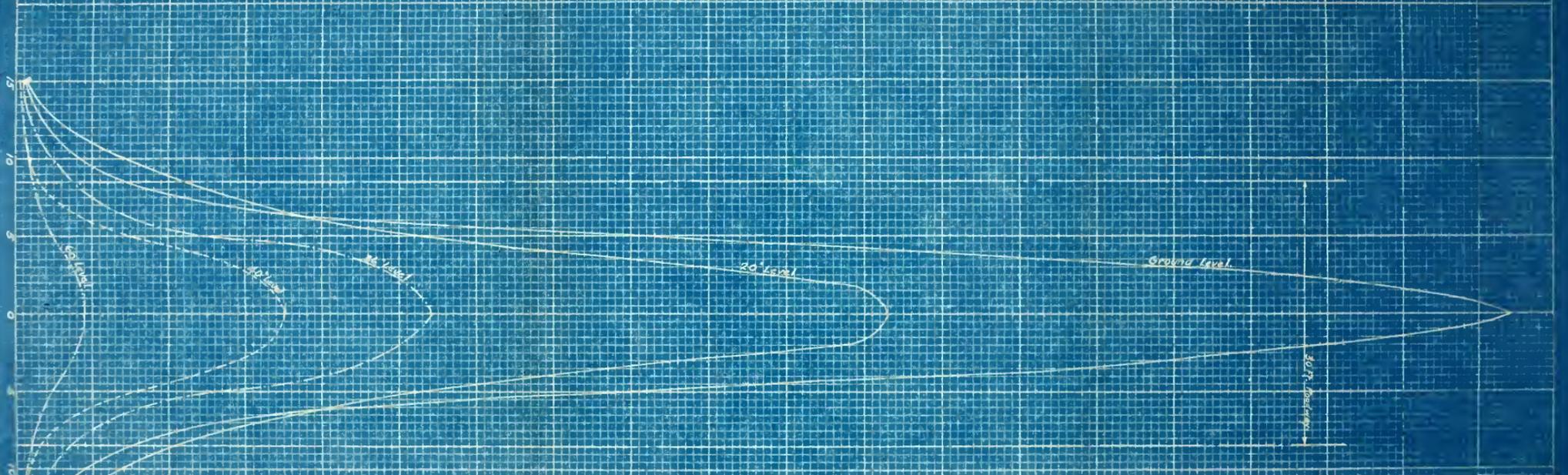
14000 15000 16000 17000 18000 19000

Degrees angularity on either side of axis of vehicle.



1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000

Feet
10
20
30
40
50
60
70
80
90
100



Diagrams, respectively on either side of this horizontal line.

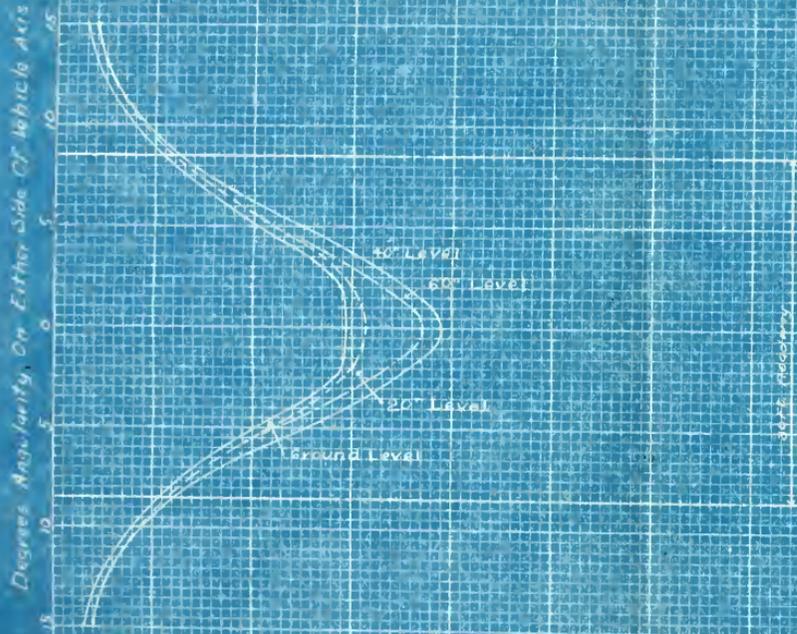
LIGHT DISTRIBUTION
ZATERSCHN LENS
 FOCUS, SEMI-ANGLE

data #17
 FIG 67

DATA #19

FIG 68

Appendix III
Candle Power At 100 Feet



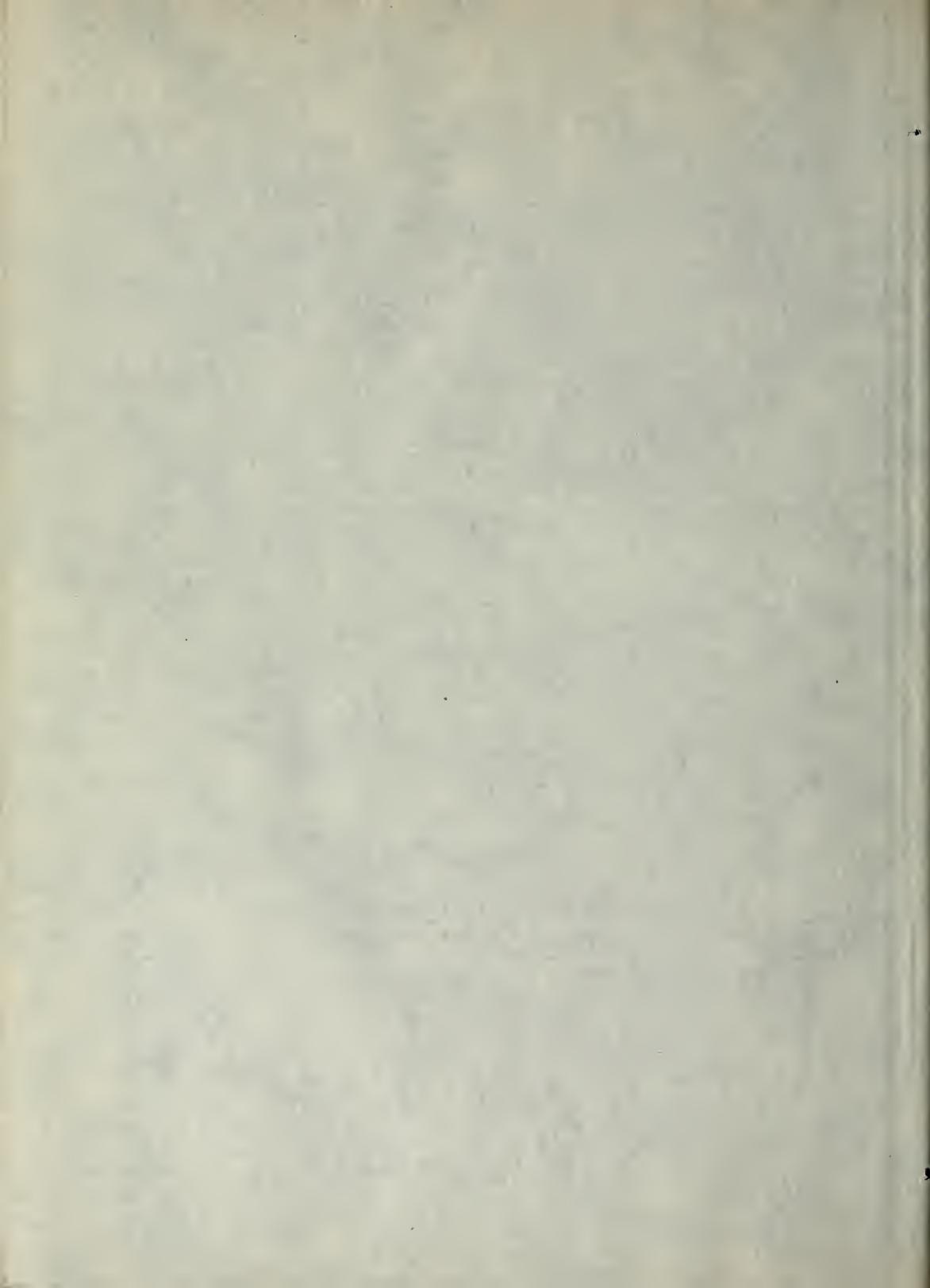
LIGHT DISTRIBUTION
WARNER LENS
P&P Bulb

March 19
Fig 68

Distance measured on either side of axis of vehicle

Distance from center of vehicle





20	11760	12600	13440	14280	15120	15960
70	20860	22350	23840	25330	26820	28310
0	34580	37050	39520	41990	44460	46930
30	48440	51900	55360	58820	62280	65740
30	57540	61000	64460	67920	71380	74840
50	62300	66750	71200	75650	80100	84550
95	75610	81225	86840	92455	97470	102885
30	93940	100650	107360	114070	120780	127490
00	112000	120000	128000	136000	144000	152000

30.2' Reading

LIGHT DISTRIBUTION (AT LAMP LEVEL)
UNMODIFIED BEAM

D. P. MATH

Bulb (°F)	Apparent Brightness Measurements For Various Bulb Distances																		
10	340	720	220	380	220	590	580	1190	1340	1490	1630	1780	1930	2080	2230	2380	2530	2680	2830
12	140	280	470	590	730	890	1040	1190	1340	1490	1630	1780	1930	2080	2230	2380	2530	2680	2830
15	240	340	740	380	1230	1820	1920	2170	2470	2770	3070	3370	3670	3970	4270	4570	4870	5170	5470
18	340	1320	1930	1340	2610	3320	3320	3620	4110	4410	4710	5010	5310	5610	5910	6210	6510	6810	7110
20	410	1420	1430	1640	2090	2440	2440	2890	3480	3680	4080	4480	4880	5280	5680	6080	6480	6880	7280
21	440	1480	1430	1780	2230	2680	2680	3130	3720	3920	4320	4720	5120	5520	5920	6320	6720	7120	7520
24	540	1630	1725	2130	2680	3230	3230	3680	4270	4470	4870	5270	5670	6070	6470	6870	7270	7670	8070
26	570	1620	2630	2630	3330	4030	4030	4580	5170	5370	5770	6170	6570	6970	7370	7770	8170	8570	8970
32	680	1670	2480	3290	4090	4890	4890	5440	6030	6230	6630	7030	7430	7830	8230	8630	9030	9430	9830

Degree irregularity on either side of axis of vehicle.

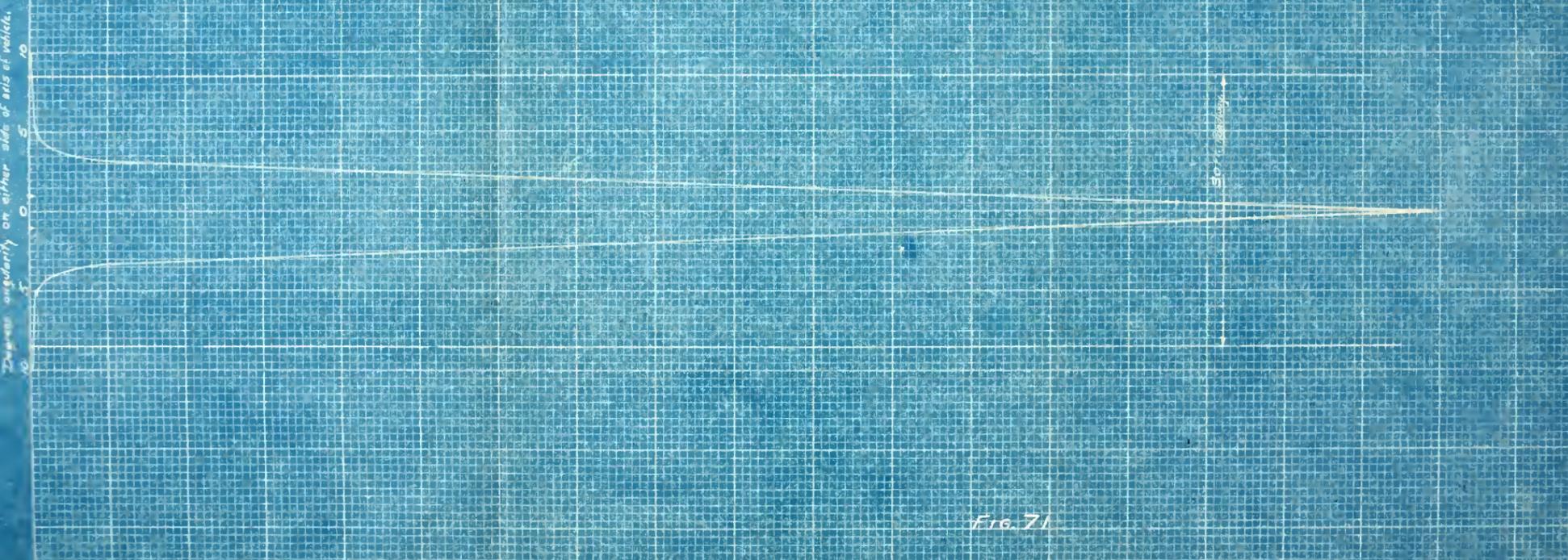


Fig. 71

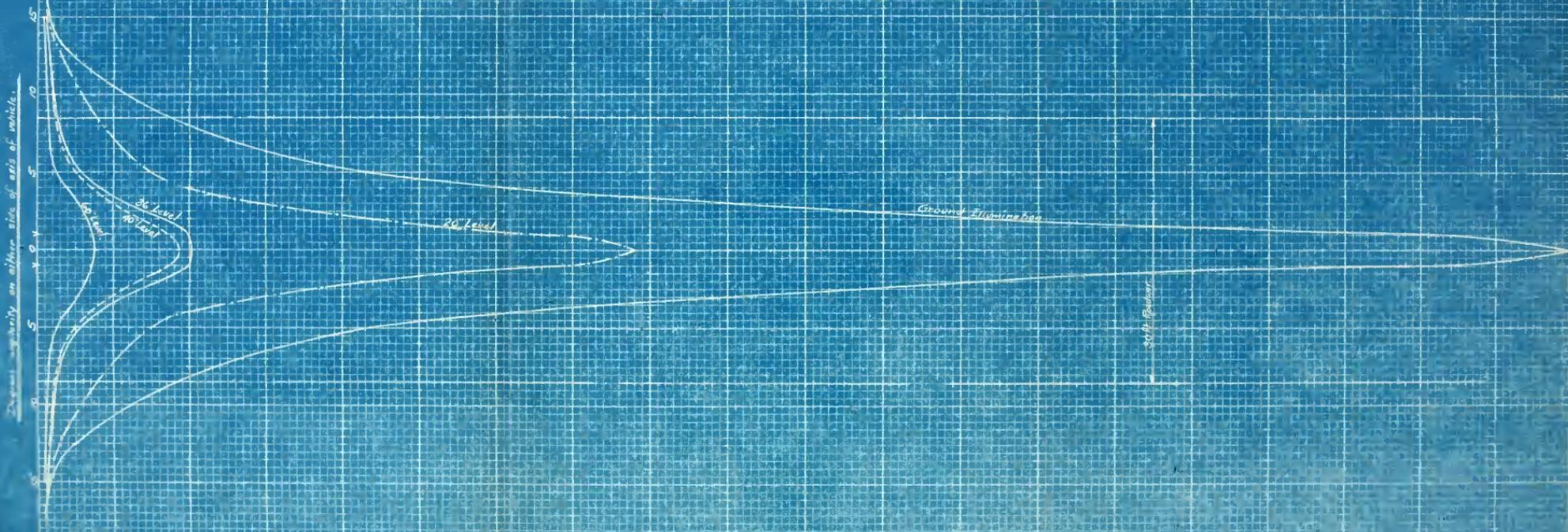
2800	3000	3200	3400	3600	3800	4000
3850	4125	4400	4675	4950	5225	5500
5180	5550	5920	6290	6660	7030	7400
6650	7125	7600	8075	8550	9025	9500
7700	8250	8800	9350	9900	10450	11000
8400	9000	9600	10200	10800	11400	12000
10290	11025	11760	12495	13230	13965	14700
14000	15000	16000	17000	18000	19000	20000
18900	20250	21600	22950	24300	25650	27000

30 ft. Spacemat

LIGHT DISTRIBUTION

LENS #2 LIBERTY

10.	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
12.	275	550	825	1100	1375	1650	1925	2200	2475	2750	3025	3300	3575	3850	4125	4400	4675	4950	5225	5500
15.	350	700	1050	1400	1750	2100	2450	2800	3150	3500	3850	4200	4550	4900	5250	5600	5950	6300	6650	7000
18.	425	850	1275	1700	2125	2550	2975	3400	3825	4250	4675	5100	5525	5950	6375	6800	7225	7650	8075	8500
20.	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000
21.	550	1100	1650	2200	2750	3300	3850	4400	4950	5500	6050	6600	7150	7700	8250	8800	9350	9900	10450	11000
24.	700	1400	2100	2800	3500	4200	4900	5600	6300	7000	7700	8400	9100	9800	10500	11200	11900	12600	13300	14000
26.	800	1600	2400	3200	4000	4800	5600	6400	7200	8000	8800	9600	10400	11200	12000	12800	13600	14400	15200	16000
32.	1350	2700	4050	5400	6750	8100	9450	10800	12150	13500	14850	16200	17550	18900	20250	21600	22950	24300	25650	27000



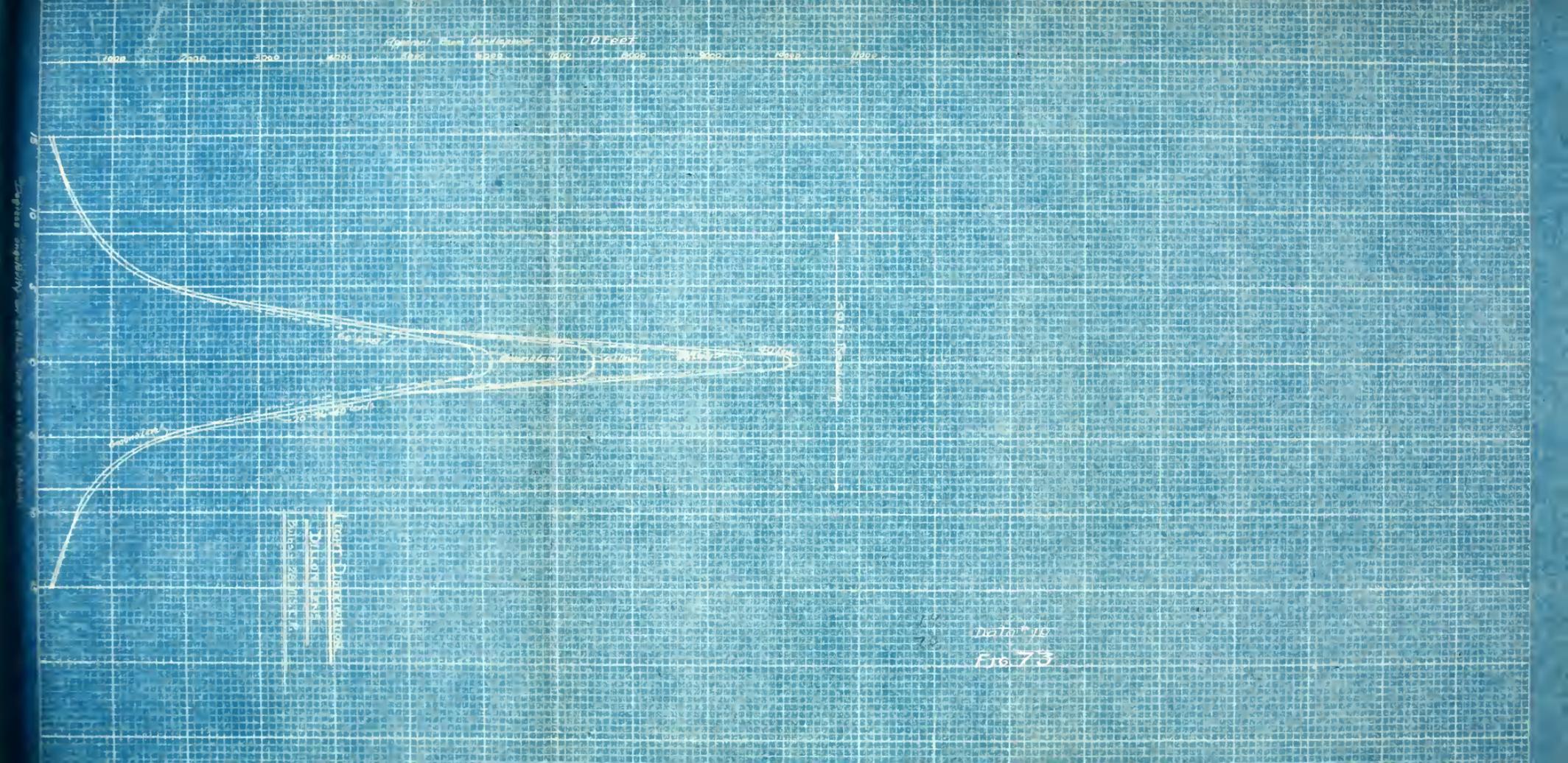
Data 7/18

Fig. 72

Light Distribution
 U.S. DEPT. OF LIBERTY

Copyright, 1918, by U.S. Dept. of Liberty. 40% 10 - 1 Error

Vertical text columns, likely bleed-through from the reverse side of the page. The text is dense and illegible due to the high resolution and orientation.



1000
100
10
1
0

0 100 200 300 400 500 600 700 800 900 1000

N

P

1000
100
10
1
0

0 100 200 300 400 500 600 700 800 900 1000

N

P

10 14000 15000

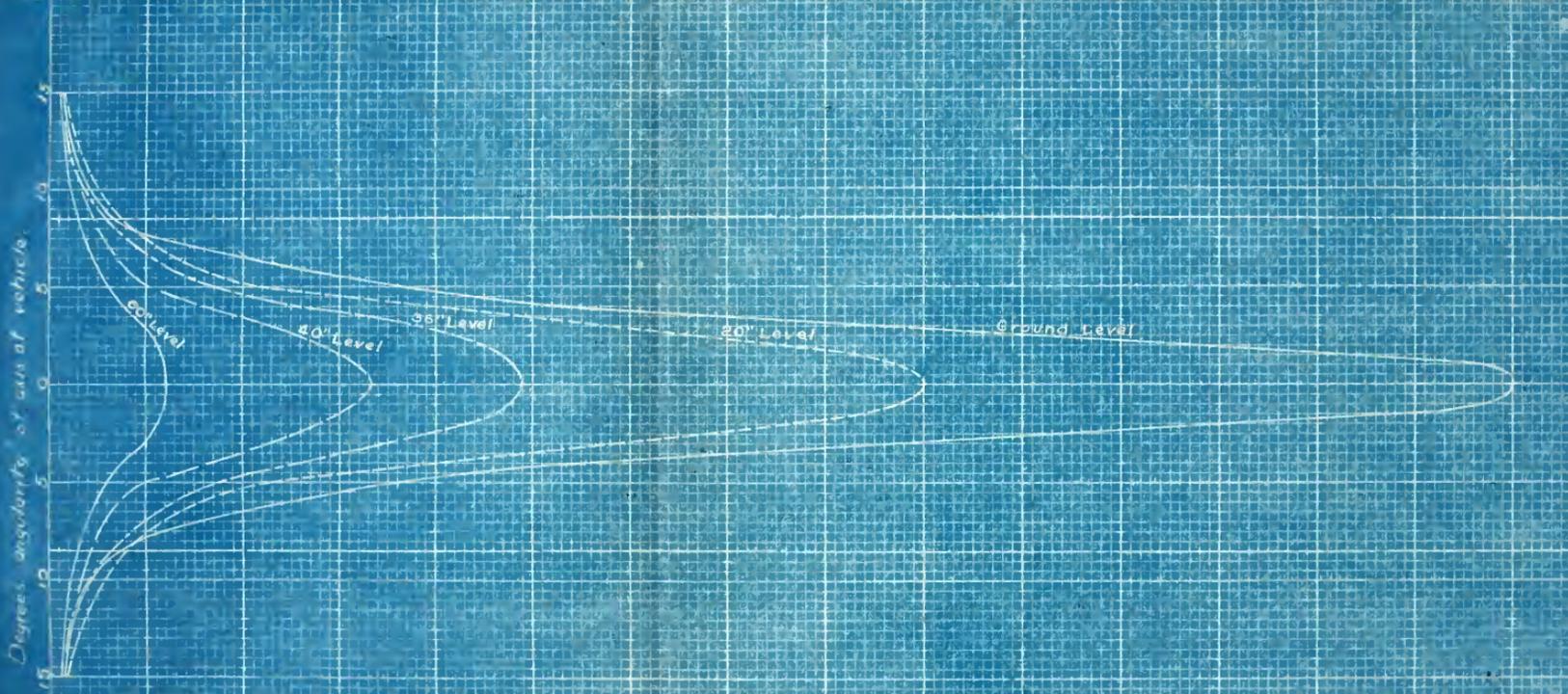


10 m. roadway

Whit
ENS

Apparent Available Power At 104 Feet Feet

1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000

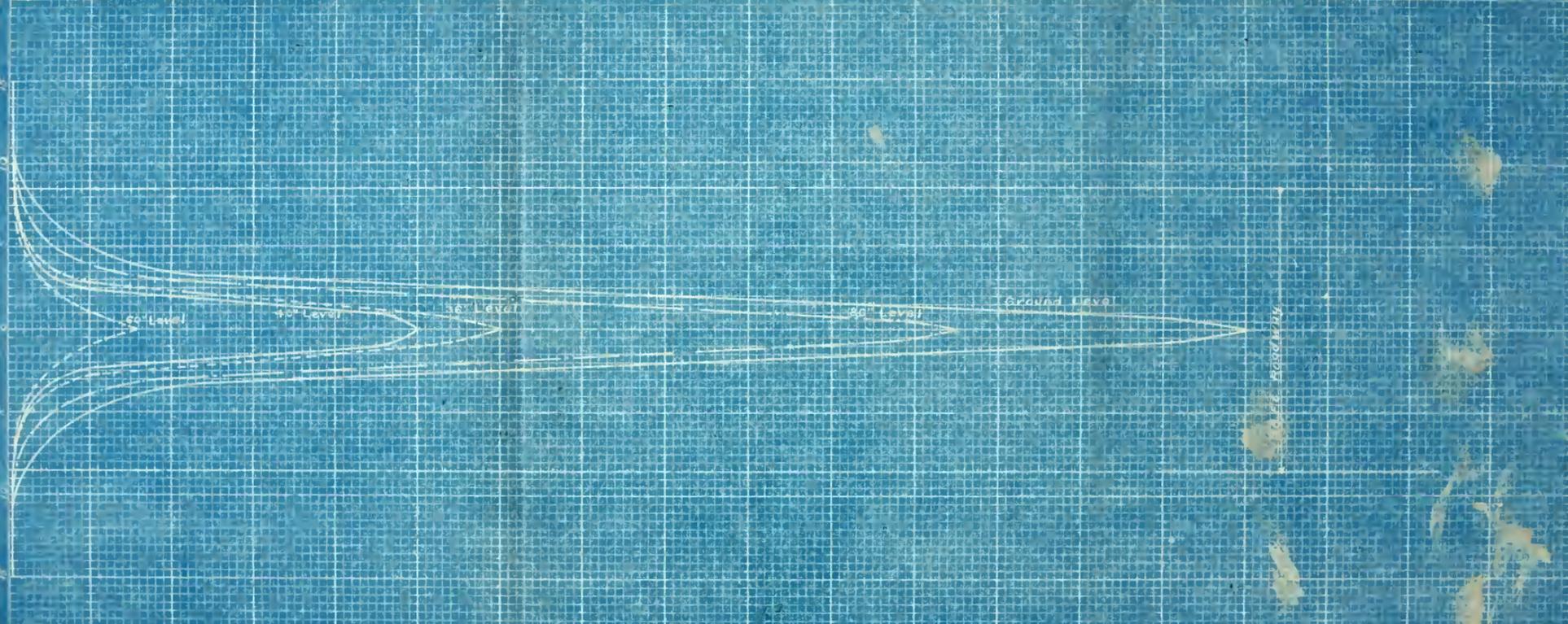


Army Distribution
RESERVE ENGINEERS

Fig. 74

8 c.p. bulb

Apparent Candle Power At 100 Feet



1887 DISTRIBUTION
 CONTROLLING LENS
 Data # 12
 Fig. 75

