THESIS

on

INVESTIGATION OF THE GLARE
OF AUTOMOBILE HEADLIGHTS

Submitted to the

OREGON STATE AGRICULTURAL COLLEGE

In partial fulfillment of
the requirements for the
Degree of

MASTER OF SCIENCE

by

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May, 1930

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ACKNOWLEDGMENT.

The writer wishes to express his sincere appreciation to Dr. W. B. Anderson, Professor of Physics at the Oregon State Agricultural College, for his guidance in this investigation, and for his assistance in the preparation of this thesis.

INVESTIGATION OF THE GLARE OF AUTOMOBILE HEADLIGHTS

INTRODUCTION.

National practices and the regulation for automobile headlighting are necessarily determined to a large extent by the character of the road, density of traffic, general character of automobile drivers, etc. In the United States a great diversity of these conditions is encountered. Some of the roads are straight and some are crooked. An automobile on a straight road requires a beam with considerably less horizontal spread than one on a road with curves in it. The speed at which an automobile is driven is a factor in determining the width of the beam. The driver of an automobile going fifty miles per hour requires a narrower beam than the driver of one going twenty miles per hour in order to see far enough ahead to recognize all obstructions, danger signs, and signals in ample time to avoid an accident.

The angles of horizontal and vertical spread of the headlight beams have been investigated by Dickerson and Allen. They have, on the basis of their extensive analysis, devised what appears to be the ideal system of illumination required for safety.

First from the point of view of the driver himself on roads free from opposing traffic:

(a) Vertical spread six degrees, brightest in the center.

(b) Horizontal spread varying with speed from fifteen degrees for maximum speeds to ninety degrees width for speeds of twenty miles per hour.

(c) Axis of the beam horizontal for conditions permitting speeds of over thirty miles per hour, and gradually depressed for lower speeds to about one and one half degrees.

(d) Candlepower sufficient for visibility of the objects the size of an automobile at least five hundred feet away for the six degree by fifteen degree beam in absence of other illumination, with the same or greater bulb candlepower in beams of wider spread.

Second from the point of view of both drivers when vehicles are meeting:

(a) Vertical spread about four degrees, brightest at the top and shading off at the bottom.

(b) Horizontal spread from forty degrees at thirty miles per hour to sixty degrees or more at twenty miles per hour.

(c) Beam depressed so that the top is about two degrees below horizontal.

(d) Intensity corresponding to the same bulb candle-power as used for (d) above.

DEFINITION OF GLARE

The limited knowledge pertaining to glare and its effects has naturally resulted in no standard definition of the term. Numerous definitions have been given but no two are exactly alike. Some people define glare as any intrinsic brilliancy which causes dazzling and pain to the eye. The value, however, depends somewhat upon the individual. The above definition is not sufficient. If we look at the filament of an incandescent lamp in the evening a dazzling effect is experienced, but if we look at it during the day this effect is absent. As we come out into the bright sun from a motion picture theater, discomfort and interference with vision is experienced. Again, if a light is placed in front of a white screen, even at night, little glare is experienced when looking at it, but when viewed before a blackboard, the glare effect is intense. Both contrast and illumination, therefore, determine largely the glare effect, as is easily shown. When looking at a lamp against a white screen which makes the general illumination high, or when studying the lamp in the bright sun, the nerves of the eye are less sensitive, and also the light flux entering the eye is greatly reduced, because of the contraction of the pupil. However, in looking at a light in front of a blackboard the nerves of the eye are rested and therefore more sensitive, and the pupil has enlarged to take in the dark background, which has very little illumination. Thus glare occurs chiefly if a rested or sensitive eye experiences simultaneously a high intrinsic brilliancy and sharp contrast.

Nutting in the "Journal of the Franklin Institute," No. 3, March 1917, gives curves for the so-called threshhold sensibility or the least brightness which is painful to the eye. His curves show that as long as the intrinsic brightness of the glare source does not exceed about ten meter-candles, glare occurs when the contrast ratio, the ratio of the brightness of the glare source to that of the object in view, exceeds 1000 to 1, but when the brightness is raised to 10,000 meter-candles, the ratio drops to 10 to 1. It appears that if the brightness is further increased, the brightness itself is glaring.

Glare of automobile headlight may be defined as light entering the eye which is dazzling to the eye, and hinders the visibility of the road and objects in front of the automobile. This glare appears to depend upon the surface brightness of the objects in the field of vision, the luminous flux at the eye from the glare source, and the angle the glare source makes with the visual axis.

THE PURPOSE OF THE PRESENT INVESTIGATION.

The purpose of this investigation was to study the glare of automobile headlights and its effects with the hope of finding some means of improving visibility in night driving. This study included:

(1) The effect of glare on speed of vision.

(2) The effect of dimming the headlights.

(3) The reduction of glare as its angle with the visual axis increased.

REPORTS ON AUTOMOBILE HEADLIGHTS.

The International Committee on Illumination received reports in 1928 from various committees concerning the headlight situation in their respective countries. The following countries were represented; Britain, France, Holland, Germany, Japan, Switzerland, and the United States. These committees reached the following conclusion:

(1) A concentrated beam directed downward is not favored on account of contrast produced; neither is too great a degree of spread. A horizontal spread of 6 degrees to 12 degrees, and a vertical spread of 4 degrees to 6 degrees are recommended. The axis should be inclined less than 1/2 degree below the horizontal.

(2) Strongly diffusing beams are deficient in range, and increase the area of glare.

(3) A downward directed beam is favored in fog. Also, if all the energy could be concentrated in the red or yellow end of the spectrum, it is probable that a better driving light in fog would result.

(4) Glare may be avoided;

 (a) By dimming. This is not desirable because of the time required by the eye to adapt itself to the sudden change in intensity.

 (b) By tilting downward the beam of full intensity:

  1. By mechanical tilting of the projector. This is undesirable because of the great illumination of the roadway near the car and because of mechanical difficulties.

 (c) By using two filaments of equal candlepower, one placed slightly above the other. The upper filament produces the tilted beam.

 (d) By using two filaments of unequal candlepower. The filament of lower candlepower produces the tilted beam.

The different committees disagreed as to the relative merits of the two filaments of equal candlepower and the two of unequal candlepower. It is believed by some that using two filaments of equal candlepower has the disadvantage of producing too great an intensity near the car.

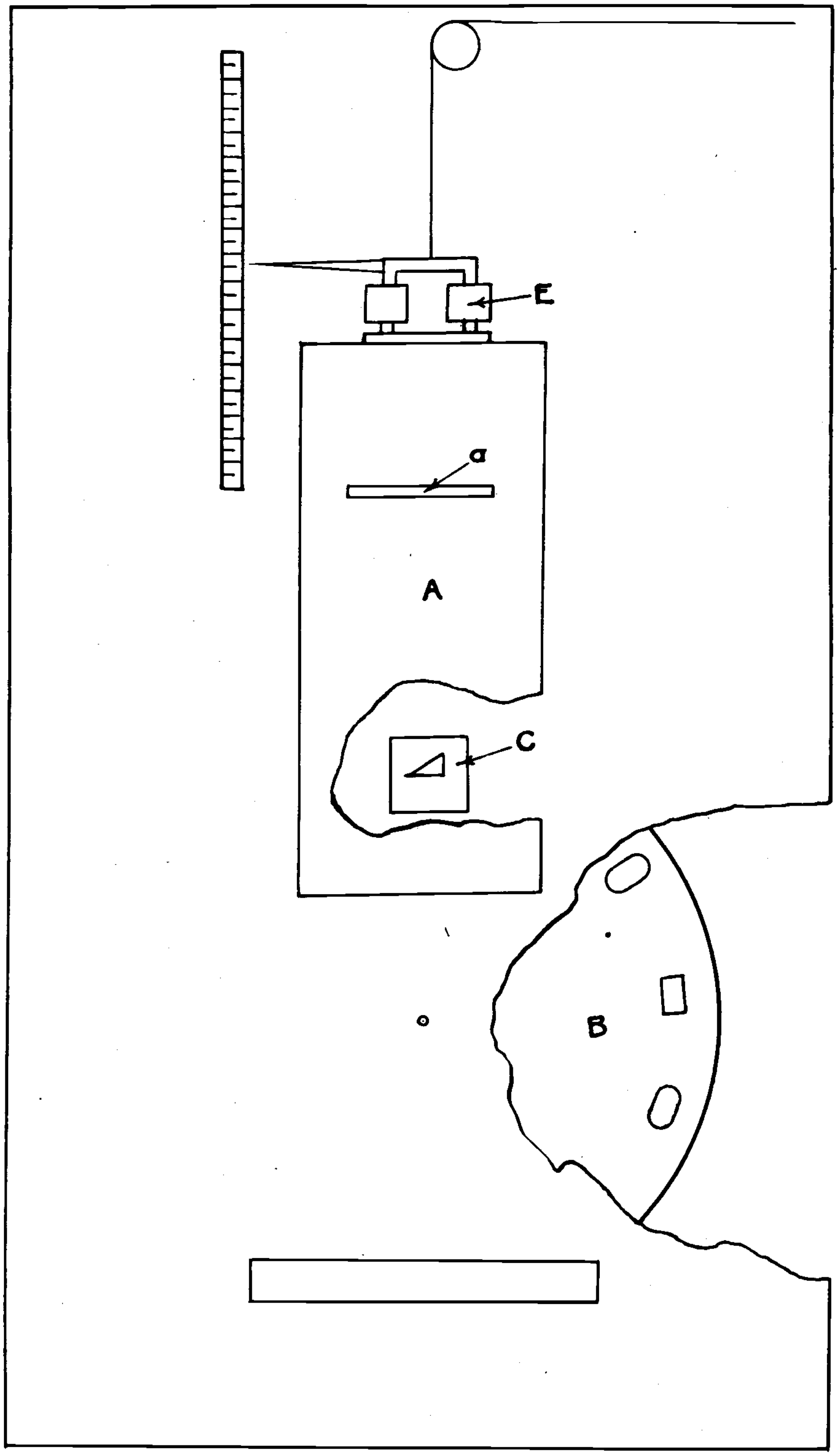
EFFECT OF GLARE OF SPEED ON VISION

The test-objects, a rectangle, two ellipses (one vertical and one horizontal), and a cross used in this part of the investigation are shown in Fig. I. Each of these test-objects subtended at the eye an angle of 12.6 minutes. They were printed on white paper and pasted on a disc B of gray beaver board at equal distances from its center. This disc was mounted against the back of a vertical beaver board screen of gray in which a small hole C was cut. The disc could be rotated about a horizontal axis through its center, thereby bringing any desired test-object to view at the hole in the screen.

Speed of Vision Without Glare

Except for the very small illumination received from the glare source by reflection from the walls which were plaster of a tan color, the test-objects were illuminated by a 100 watt frosted Mazda C lamp in a metal reflector. The glare source was a 21 candlepower Model A Ford headlight placed 13.7 feet from the observer. The test-objects were likewise the same distance from the observer. A rectangular piece of beaver board A of a gray color with a horizontal slot a, 1 centimeter in width was dropped past the test-object, allowing the test-object to be in view only during the time it took the slot to pass the object. Knowing the distance of fall, and the width of the slot, the time of exposure to view could be calcu-

FIGURE I



lated. A similar piece of beaver board with a 2 centimeter slot was used when a comparatively long time of exposure was necessary.

The observer was seated at the designated distance in front of the test-object. The piece of beaver board A was suspended by an electromagnet E with the center of the slot 30 centimeters above the test-object. The illumination of the screen and hence of the test-object was 7.3 foot-candles. The glare source was not used in this first part of the work. The observer, to insure that his eyes would be focused on the test-object during the brief time it was rendered visible by the falling slot, looked through a ring placed close to the test-object and directly in line with it, and then released A by pressing a key.

Two trials were given at each position, and if the observer could not then recognize the test-object, A was lowered one centimeter at a time, thereby lengthening the time of exposure. Two trials were given at each position because of the possibility that the eyes were not properly focused, or were fatigued, or the mind of the observer was temporarily diverted. This operation was repeated until all four objects had been recognized. In no case did the observer have any knowledge as to which test-object would be shown. In this way the minimum time required to recognize each test-object was obtained and found to be practically the same for all four. By repeating the work several times, usually on different days, the average minimum time required to recognize any test object when illuminated by a beam of 7.3 footcandle intensity was found to be 0.00425 seconds.

Speed of Vision with Glare

The glare source was then placed at various angles with the visual axis, and the minimum time of exposure necessary to recognize the test-objects with 7.3 foot-candles illumination was found. The data are given in Table I. Curves obtained from these data are shown in Fig. II. It will be noted that glare decreases very rapidly with the departure of the glare source from the visual axis until an angle of five degrees is reached. Outside this region the glare does not play much part in the quickness of the eye to make out details. Because the distance from the center of the headlight to the center of the test-object was used in determining the above angle, the difference in glare effect at two degrees and at three degrees will be greater for the short distances from the glare source to the observer was used in this investigation than it would be for long distances on the road. At two degrees the rim on the side near the test-object will reflect light which will give considerable glare for short distances, consequently this angle that the glare source makes with the visual axis will virtually be less than two degrees as measured.

FIGURE II

SPEED OF VISION WITH GLARE

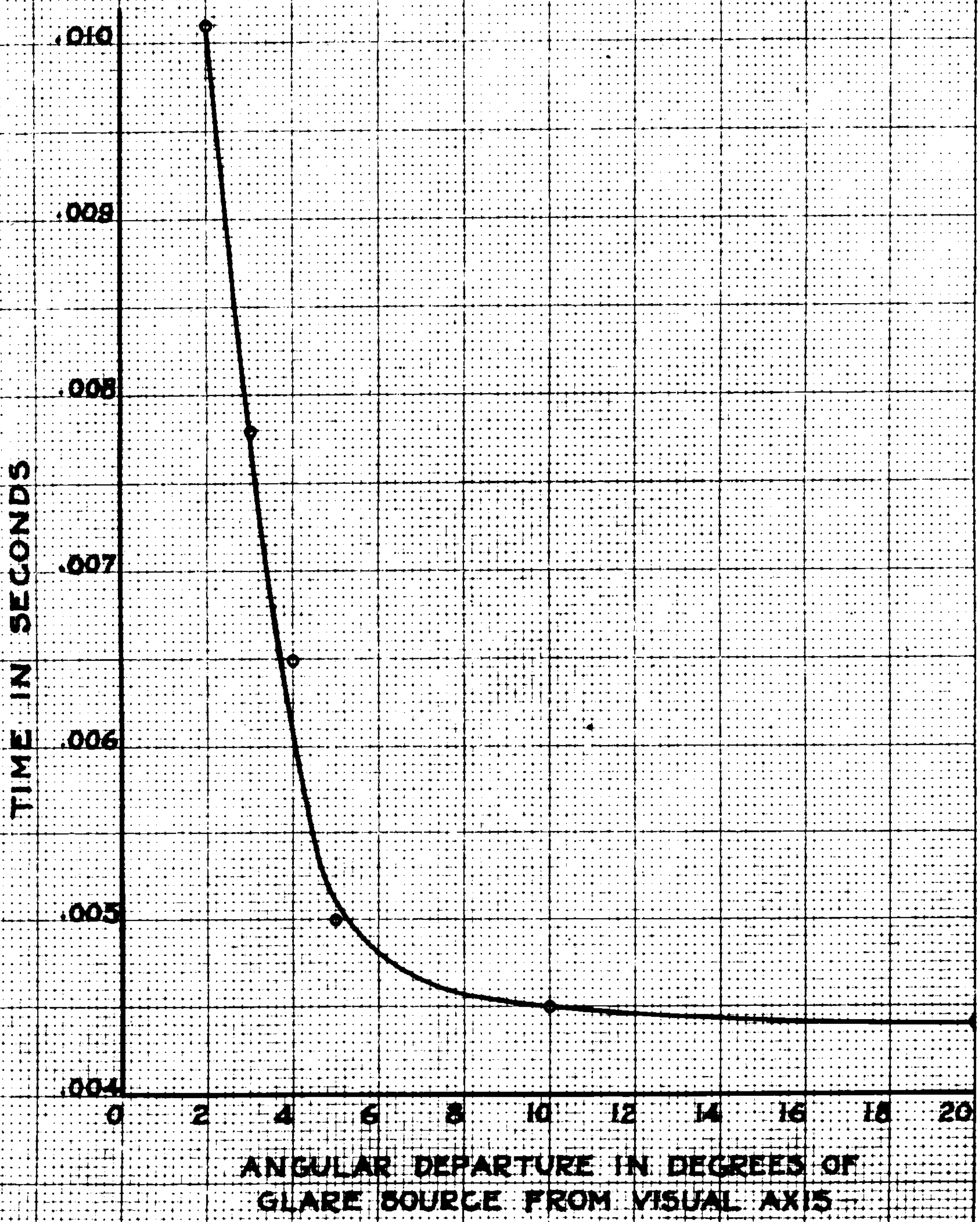


TABLE I
EFFECT OF GLARE ON SPEED OF VISION

Angle with visual axis	Type of glare source	Intensity of glare source at eye, Foot candles	Illumination of test-object, Foot candles	Time of exposure seconds
2°	21 Candlepower Model A Ford headlight	19	7.3	..011
3°				.0076
4°				.0066
5°				.0052
10°				.00461
20°				.00434

DIMMING THE HEADLIGHTS TO AVOID GLARE

It is quite generally believed that dimming the headlights is one method of avoiding glare. The International Committees on Headlights agreed, however, as previously stated, that this is an unsatisfactory method. In this investigation, as described below, tests were made to obtain quantitative data bearing on the question. The data obtained, Table II, show that dimming the lights does not aid either driver of two passing cars, provided the intensities of both are reduced an equal percentage of their total intensities.

The work was done in the laboratory. A right triangle, subtending an angle of 25.2 minutes at the eye, was used for the test-object. It was printed in black ink on white drawing paper, 0.75 x 1.5 inch, and clamped on a vertical rod at the same level as the eyes of the observer. The glare source was first placed at an angle of two degrees, and then five degrees from the visual axis. The test-object was illuminated with a 100 watt Mazda C lamp, and with light from the glare source reflected from the walls. The observer was seated at a distance of 13.5 feet from the test-object, and the same distance from the glare source.

It was thought at first that the reduction in visibility due to the glare source could be measured in terms of the increase in illumination necessary for the perception of the test-object. The observer was to determine the threshold illumination without glare and then with glare. In determining this threshold illumination, or the minimum illumination required for the perception of the test-object by means of a variable rheostat connected in series with the Mazda C lamp. This method was not successful. It was found much easier to obtain consistent results for the threshold illumination by approaching this illumination from higher values instead of from lower values.

Due to the tiring effect of the glare upon the eyes the object disappeared for a time and then reappeared. Errors due to this erratic behavior were minimized by slowly decreasing the illumination of the test-object until the latter disappeared, and then decreasing it some more when the object reappeared. Finally, the test-object disappeared permanently.

TABLE II
EFFECT ON GLARE OF DIMMING THE HEADLIGHTS

	Angle with visual axis	Type of glare source.	Intensity of glare source at eye, Foot candles.	Illumination of test-object Footcandles
Observer #1	2°	32 Candlepower	38.10	5.3
	2°	Model T Ford	19.1	2.63
	5°	headlight	38.1	0.488
	5°		19.1	0.244
	2°	32 Candlepower	39.37	5.60
	2°	Model A Ford	19.68	2.90
	5°	headlight	39.37	0.94
	5°		19.68	0.436
	8°		39.37	0.31
	8°		19.68	0.15
Observer #2	2°	32 Candlepower	39.37	12.0
	2°	Model A Ford	19.68	6.1
	5°	headlight	39.37	1.86
	5°		19.68	.91
	2°		39.37	12.0
	2°		10.0	3.0
Observer #3	2°	32 Candlepower	39.37	2.7
	2°	Model A Ford	19.68	1.48
		headlight		

The "minimum illumination" I of the test-object that could be used and still make the objects visible was obtained by using for the glare source a 32 candlepower Model A Ford headlight. The potential across the terminals of the lamps were held at 6.1 volts. This potential was used because the voltage drop is slightly greater than 6 when the generator is operating. The value of I and intensity of the light flux a were measured. The voltage across the glare lamp was then decreased until a was reduced one-half and I was again determined. The process was repeated for only one observer with a reduced to one-fourth the original value.

A 32 candlepower Model T Ford headlight was tested in the same manner. This model gave the same intensity at the eyes as the 32 candlepower model A, and, therefore, the same glare effect.

Since, as shown above, <u>decreasing</u> the intensity of the glare source and the illumination source by the same fraction does not reduce the glare, it might seem that increasing them by the same fraction would not <u>increase</u> the glare. It would be an advantage, therefore, to increase the candlepower of the automobile headlights above that which is used in practice today. A driver could then have better illumination upon the road at all times and still not be affected to any greater extent by the glare from an oncoming car. However, this relationship between the glare source and illumination source might not hold true if lamps of a very high candlepower, say 300 candlepower, were used. Automobile lamps greater than 32 candlepower could not be obtained to make any tests on this problem. Curves for the threshold illumination with the glare source making various angles with the visual axis are shown in Fig. III.

COLOR TESTS

Tests were made with yellow light to see if the glare was as serious as with white light when using the same angle, 2°, from the visual axis and the same intensity, 30.48 footcandles, in each case. A yellow filter was placed against the lens in front of a 32 candlepower lamp. The potential across the terminals of the lamp was set at 6.1 volts. For the white light test a 32 candlepower lamp was used in the same reflector but with a Model T lens because it gave a greater intensity at the eye than the Model A for the same voltage drop. The potential was reduced to 5.1 volts in order to have the same light flux entering the eyes of the observer as with the yellow light. This reduction in voltage, however, gave a greater percentage of the total light from the longer wave length end of the spectrum than if the potential were maintained at 6.1 volts, but the change was assumed to cause no very serious discrepancy in the results. The data obtained, as shown in Table IV, seem to indicate that the filter merely reduced the amount of light flux entering the eye.

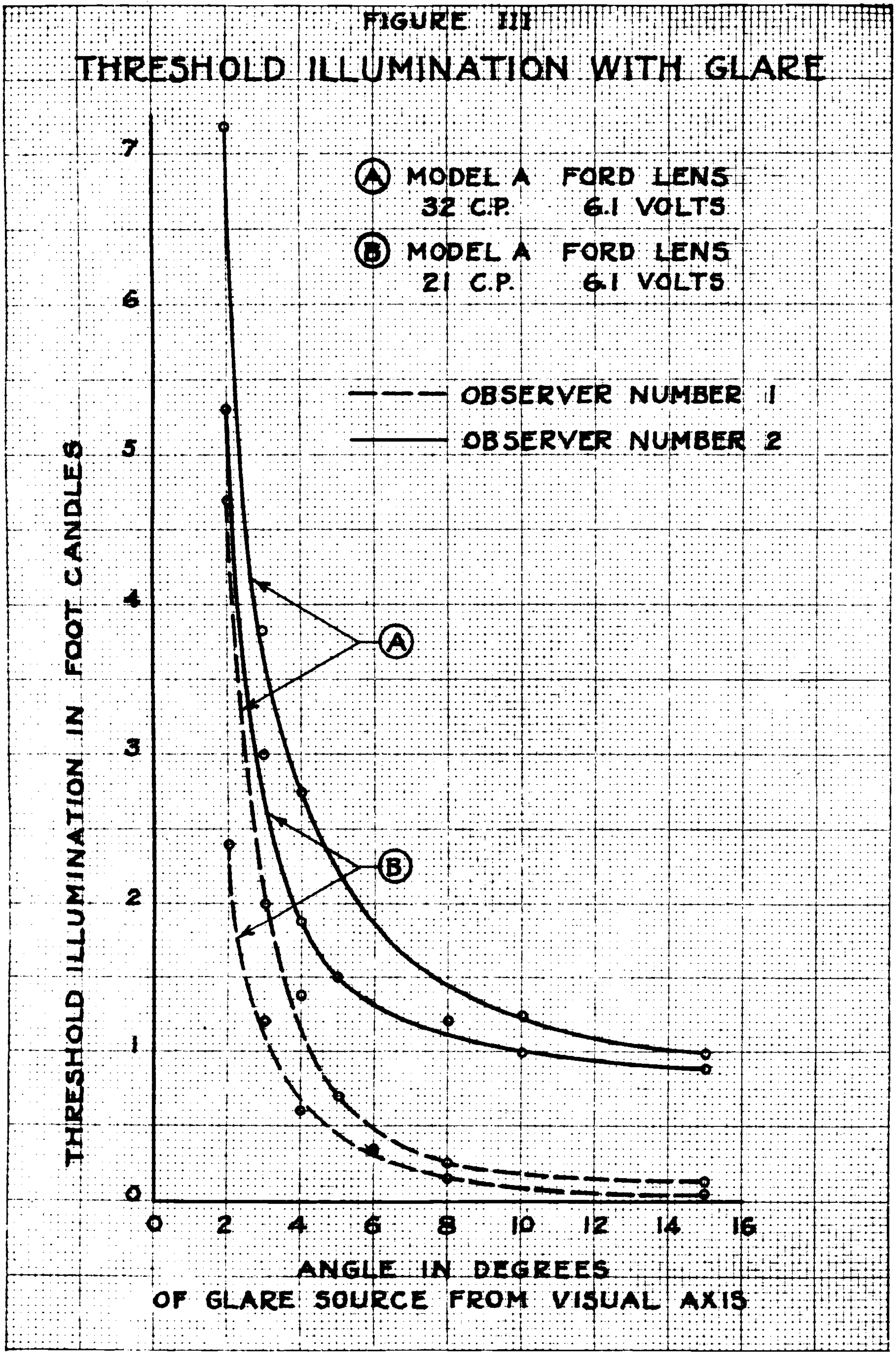


FIGURE III
THRESHOLD ILLUMINATION WITH GLARE
(A) MODEL A FORD LENS
32 C.P. 6.1 VOLTS
(B) MODEL A FORD LENS
21 C.P. 6.1 VOLTS
OBSERVER NUMBER 1
OBSERVER NUMBER 2
THRESHOLD ILLUMINATION IN FOOT CANDLES
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14
16
A
B
ANGLE IN DEGREES
OF GLARE SOURCE FROM VISUAL AXIS

DISTRIBUTION CURVES OF HEADLIGHTS

Distribution curves of the 32 candlepower Model A Ford and 21 candlepower Chevrolet headlights are shown in Fig. IV. It will be noted that the greatest intensity of the two beams are at the centers, and from two degrees on either side the intensity decrease very rapidly.

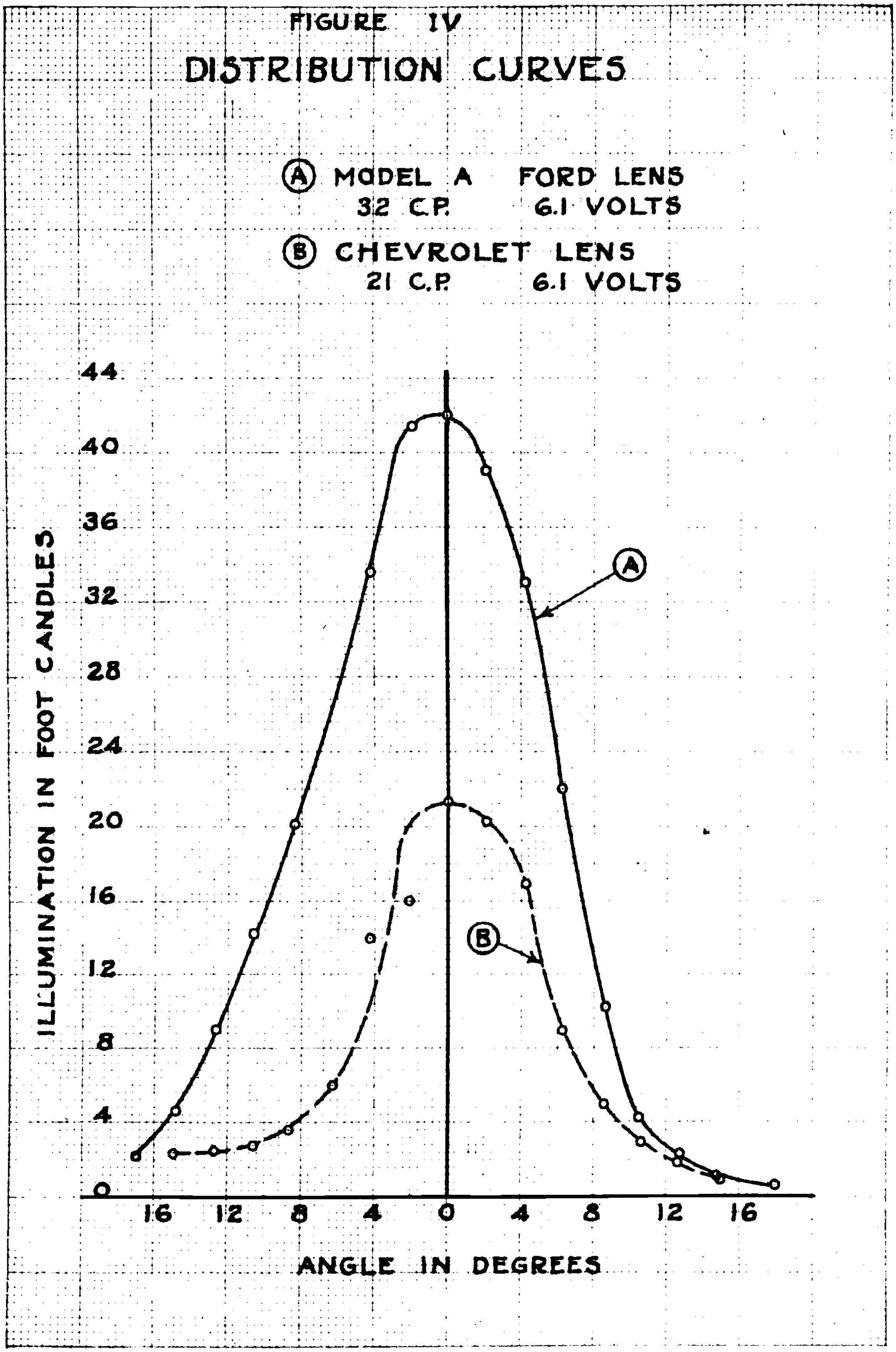


FIGURE IV
DISTRIBUTION CURVES
(A) MODEL A FORD LENS
32 C.P. 6.1 VOLTS
(B) CHEVROLET LENS
21 C.P. 6.1 VOLTS
ILLUMINATION IN FOOT CANDLES
44
40
36
32
28
24
20
16
12
8
4
0
16
12
8
4
0
4
8
12
16
A
B
ANGLE IN DEGREES

TABLE IV
DATA SHOWING THE EFFECT OF GLARE FROM LIGHT IN DIFFERENT REGIONS OF THE SPECTRUM.

Angle of glare from the visual axis	Color of light.	Intensity of glare source at the eye Foot Candles.	Maximum Ill. of test-object and not see Foot Candles	Type of glare source.	Voltage across lamp.
Observer #1					
2°	White	30.48 Foot Candles	3.70	32 Candle-power Model T Ford.	5.4
2°	Yellow	30.48 Foot Candles	3.65	32 Candle-power Model A Ford.	6.1
Observer #2					
2°	White	30.48 Foot Candles	7.2	32 Candle-power Model T Ford.	5.4
2°	Yellow	30.48 Foot Candles	7.1	32 Candle-power Model A Ford.	6.1