DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
George K. Burgess, Director

MOTOR-VEHICLE HEADLIGHTING

CIRCULAR OF THE BUREAU OF STANDARDS, No. 276

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FOREWORD

For several years the Bureau of Standards has been cooperating with engineering societies and other agencies interested in improved headlighting for motor vehicles. Acknowledgment is hereby made of the cordial spirit of cooperation displayed in this work, particularly by the American Automobile Association, the motor vehicle lighting committee of the Illuminating Engineering Society and the lighting division of the standards department, Society of Automotive Engineers.

To the motor vehicle lighting committee of the Illuminating Engineering Society belongs the credit for formulating the "Specifications of laboratory tests for approval of electric headlighting devices for motor vehicles." These specifications, which have been approved by the American Engineering Standards Committee as a "Tentative American Standard," represent the current practice in approval of headlight devices by many States and they have served as a means for creating a uniform list of approved and legalized devices.

The bureau is also indebted to the following organizations, which have loaned illustrations for this circular: C. A. Shaler Co.; Motor Life; Chevrolet Motor Co.; National Lamp Works, General Electric Co.; American Flatlite Co.; Edmunds & Jones Corp.; American Automobile Association; Ford Motor Co.; and motor vehicle lighting committee of the Illuminating Engineering Society.

The circular has been prepared by R. E. Carlson, mechanical engineer.

MOTOR-VEHICLE HEADLIGHTING

ABSTRACT

The requirements for good road lighting are discussed and the construction and operation of present-day types of electric head lamps explained. Few so-called "antiglare" devices have been found to be really effective, and the most practical solution to the headlighting problem under present conditions is the proper adjustment of lighting devices by manufacturers and sales agencies on new cars and careful maintenance of such adjustments by owners and drivers. The latest specifications for gas head lamps as approved by the Society of Automotive Engineers are given. Gas head lamps are used on trucks.

The methods used at the Bureau of Standards for making laboratory tests on electric headlighting devices are briefly described. State laws and regulations are discussed, and suggested paragraphs for a State law presented. Instructions for the adjustment of head lamps are made clear by photographs, and the uniform list of devices approved by the Eastern Conference of Motor Vehicle Administrators is given. The need for educational work is mentioned and suggestions made for local community work. The brief bibliography includes the principal articles which have appeared on this problem. The Appendix contains the specifications under which tests for approval of types of devices by State officials are made. These specifications have been approved by the American Engineering Standards Committee as a Tentative American Standard.

CONTENTS

I. INTRODUCTION

The unprecedented increase in registration and use of motor vehicles in the United States from about 1,000,000 in 1912 to over 17,000,000 in 1924 has created many serious traffic problems. It is the purpose of this circular to discuss one of these problems, namely, motor-vehicle headlighting.

The necessity for improved illumination for night driving is generally recognized, and for many years a sound and practical solution has been diligently sought by engineers, scientists, and the motoring public. The problem is a difficult one, and it is doubtful whether any simple and satisfactory solution can be found. The National Conference on Street and Highway Safety held in Washington, December 15 and 16, 1924, adopted the following recommendations on the subject of headlights:

> Present lighting regulations should be more rigidly enforced as a necessary beginning in arriving at any improved night-driving condition on the highways.
>
> The study of proper road illumination, combined with the minimizing of undesirable glare, should be given immediate further consideration with a view to determining whether it may not be possible to improve the regulations now in force.

It is understood that in accordance with this recommendation the research committee of the Society of Automotive Engineers is planning a further study of the problem of road illumination.

Whatever the final solution may be, it is certain that present conditions can be improved if motorists are given a better understanding of the principles involved, and appreciate the advantages of having their own lights in good condition. Car manufacturers can furnish equipment, the adjustment of which is simpler and more permanent. National associations of automotive interests can render a public service by sponsoring the educational work necessary to show car drivers, first, "why" and, second, "how" to adjust head lamps. The individual car driver can help himself as well as others by adjusting his own lights. It is hoped that the information contained in this circular may help to remove the danger and discomfort now associated with night driving.

FIG. 1.—*Night photograph taken from the tonneau of a car*

Shows what can be achieved in obtaining a good driving light that is safe for the driver and the motorist traveling in the opposite direction when headlights are properly adjusted

II. REQUIREMENTS OF AUTOMOBILE HEADLIGHTING

For safety and comfort when driving a motor car at night the road ahead should be adequately lighted. The illumination should be sufficient to make clearly visible any substantial object on the road up to 200 or 300 feet ahead of the car, so that the driver can see any obstruction in time to apply the brakes and bring the car to a stop if necessary. With brakes in average condition, tests have shown that a distance of 50 feet is needed to stop a car moving at 20 miles per hour, while a distance of approximately 175 feet is required to bring a car to a stop from 35 miles per hour. To this 175 feet must be added an extra 25 feet, which represents the distance the car travels while the driver is endeavoring to apply the brakes after actually seeing an object on the road. This reaction time of the driver varies with different individuals but averages approximately one-half second.

In addition to extending out ahead of the car, the road illumination should be as free from dark spots as possible and should clearly light up the ditches and obstructions at the roadside.

To prevent glare and discomfort to other users of the road, the present approved practice is to confine the main part of the headlight beam below a horizontal plane passing through the two head lamps and parallel to the road. Most cars have the head lamps mounted from 30 to 40 inches above the road, so that on a level stretch of road the top of the main headlight beam ahead would not rise above this height. This requirement is intended to direct the light onto the road and keep the brilliant concentrated portion of the beam from rising high enough above the ground to interfere with the vision of approaching motorists.

FIG. 2.—*Sketch representing a side view of a properly adjusted headlight beam*

Shows the position of the main concentrated beam which does not rise above the horizontal. In all practical devices there is considerable light outside the main beam; some of this is used for illumination at the sides of the road and immediately in front of the car

Figure 1 is a night photograph taken from behind the windshield of an automobile and is an example of the type of road illumination which can be obtained by the use of suitable equipment properly adjusted.

When seen from the side of the road, a properly adjusted headlight beam would have the form shown in Figure 2.

As a result of several years' work by the motor vehicle lighting committee of the Illuminating Engineering Society, there are available Specifications of Laboratory Tests for Approval of Electric Headlighting Devices for Motor Vehicles. These specifications, approved by the American Engineering Standards Committee as a Tentative American Standard, are referred to in the section on laboratory tests and are printed in the Appendix, together with the standards of recommended practice of the Society of Automotive Engineers. The specifications indicate the distribution of light required and are used by many States as a basis for approval of headlight devices. Good road light is a primary requisite for safe and comfortable night driving, but it is difficult to control the high-intensity beams required, so that light will be available where needed and no light thrown where its presence is objectionable. The present system of headlighting

unavoidably produces glare under some circumstances. For example, unevenness in the road surface throws the beam up and down, and the vertical sweep of the beam caused by the passage of a car over the brow of a hill can not be avoided with present-day equipment. The most practical remedy for the latter difficulty appears to be more general use of devices which tilt the beam downward when desired. If, however, each driver has good driving light from his own car, the glaring effect of the lights of the approaching car is much reduced under any circumstances.

III. DEVELOPMENT OF TYPES

In the early days of the automobile very little was required of headlights beyond serving as car markers. Motor-car use at night was uncommon, and lamps were only provided to enable the motorist to proceed home in case of being detained after dusk. The lamps used were similar to those mounted on the horse-drawn vehicles and burned oil.

The development of the motor car into a more reliable means of transportation broadened its field of use and made necessary better lamp equipment for driving at night. The acetylene-gas burner was adapted to automobile use by mounting it in front of a spherical mirror and suitably protecting it against the elements. Gas was furnished from a generator using calcium carbide and water whose rate of flow was controllable, thereby affording a means of adjusting the amount of light produced at the burners. The gas generator required considerable attention and was later superseded by an acetylene-charged tank which when empty could be exchanged for a new one. This system is still extensively used on motor trucks, which generally employ magneto ignition and do not carry storage batteries.

The application of the storage battery to the motor car made the electric head lamp feasible. The early types made no attempt to control the form of the beam through use of lenses or special reflectors. A plain glass was provided for protecting the reflector, which was generally paraboloidal in form. While the electric lamp and bare reflector gave ample distance light for driving, the distribution across the road was not satisfactory, and the brilliancy of the unmodified beam when misdireted caused discomfort to the occupants of passing cars. To reduce the glare, various diffusing devices were tried, such as frosted bulbs, ground front glasses, and diffusing lenses. If these devices produced enough diffusion to diminish the glare, they also reduced the amount of light projected on the road, and as a consequence decreased the effectiveness of the lighting equipment. The present types of head lamps, which modify the reflected beam so as to keep the main portion below a horizontal

plane parallel to the road and spread it out to cover evenly a considerable area of road surface, are the outgrowth of years of effort to secure good road illumination without excessive glare.

IV. ELECTRIC HEAD LAMPS—CONSTRUCTION AND OPERATION

1. THE ASSEMBLED HEAD LAMP

The complete head lamp assembly consists of a metal housing to which the reflector, lamp socket, focusing mechanism, lamp door, and lens are attached. The housing is provided with a bracket for mounting the lamp on the vehicle. The details of construction and methods of mounting vary with different manufacturers, but the general characteristics of the component parts are described below. Figure 3 shows a modern type of head lamp disassembled.

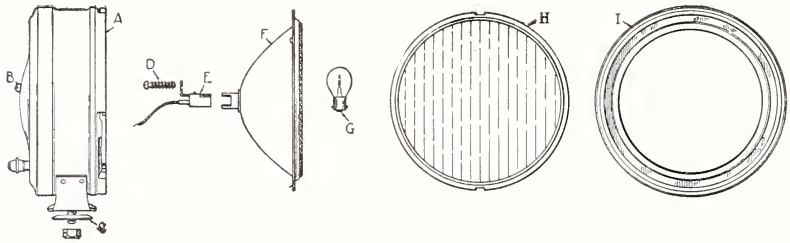


FIG. 3.—*Modern type headlamp disassembled*

A, lamp housing
B, focusing screw (when assembled)
C, adjustable mounting
D, focusing screw
E, lamp socket
F, reflector
G, lamp (bulb)
H, lens
I, headlamp door

2. LAMPS

Light is furnished by an electric incandescent lamp having a very compact and carefully positioned V-shaped coiled filament. Automobile lamps use the bayonet-type base and are made with single- or double contact for use, respectively, on grounded or insulated return circuits of 6 to 8 or 12 to 16 volts. Although furnished in 21 and 32 candlepower sizes, the 21 candlepower, 6 to 8 volt single contact type, is most generally used. The following standard for the manufacture of automobile-type lamps is taken from page B–3, Volume I, of the Society of Automotive Engineers Handbook:

The light center length for all incandescent lamps used in head lamps for either electric or gasoline propelled vehicles shall be $1\frac{1}{4} \pm \frac{3}{64}$ inches, as measured from

the center of the filament field to the bulb side of the lock pins in the base. The longitudinal axis of the lamp filament at the focal point shall not deviate more than $\frac{3}{64}$ inch from the axis of the lamp base.

3. REFLECTORS

The purpose of the reflector is to gather up as much as possible of the light emitted by the lamp and project this forward where it is required. The most generally used type of reflector is paraboloidal in form and equipped with a focusing mechanism which permits the

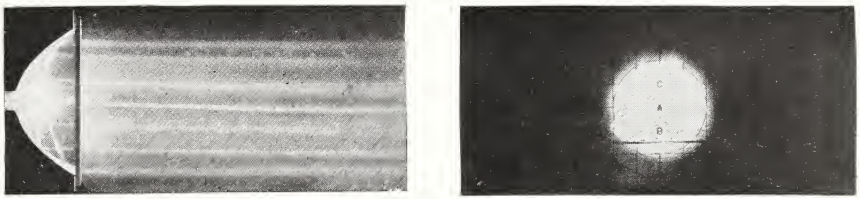


FIG. 4

Rays from reflector with light source at the exact focus

Cross section of the beam with the light source at the exact focus

lamp filament to be placed at the focus of the reflector. A well-known characteristic of the parabolic reflector is that if a point source of light be placed at the focus the light rays emitted by the source and striking the surface will be reflected parallel to the axis extending from the reflector center through the focus. This action is well shown by Figure 4 in which the light source is at the focus of

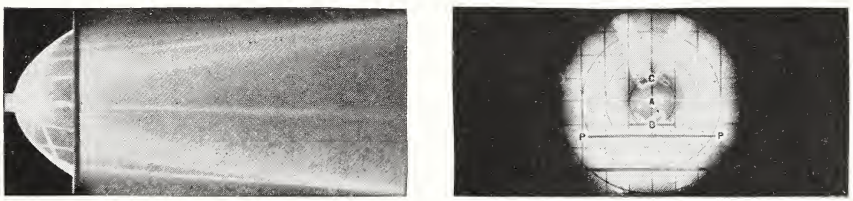


FIG. 5

Rays from reflector with light source back of focal point

Cross section of the beam with light source back of the focal point

a parabolic reflector. The light source used is the filament of an automobile lamp which has an appreciable size, so that some parts of this filament lie outside the exact focal point, thus causing a slight deviation from a perfect cylindrical beam.

When the light source is placed slightly behind the focal point, a diverging beam results as shown by Figure 5. This beam has a dark center and when thrown on a wall or road the pattern will show a dark spot.

If the light source is ahead of the focal point, a beam is produced similar to that in Figure 6. The light rays from opposite sides of the reflector cross and then diverge, leaving the central portion of the beam dark, thus causing a dark spot when thrown on the wall or road.

From the foregoing it will be noted that moving the lamp backward from the focal point toward the reflector causes the beam to

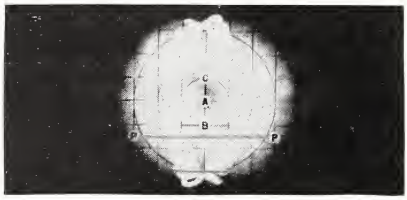


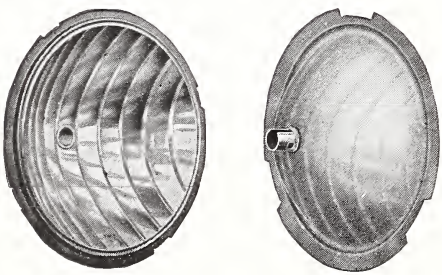
FIG. 6

Rays from reflector with light source ahead of the focal point

Cross section of the beam with light source ahead of the focal point

diverge, while moving the lamp ahead causes the light rays to cross and then diverge. This behavior of the light beam affords an easy means of placing the lamp at the focal point of the reflector by moving it backward or forward until the light pattern on a wall or screen 25 feet or more distant is of the smallest possible size and of uniform brightness. A black spot at the center of the pattern indicates that the lamp is out of focus.

Reflectors are usually stamped out of light sheet brass and then placed in an electrolytic bath, where they are given a light coating of silver. The inner or reflecting surface is given a high polish by buffing on a wheel. In head-lamp construction care must be taken to protect this silvered surface against rain and dust. Only a small amount of light is projected forward when the reflecting surface becomes tarnished or rusted, and when in this condition it should be resilvered or the entire reflector replaced by a new one.



Front view Rear view

FIG. 7.—*Special reflector which requires no spreading lens*

Although the parabolic reflector requires a lens to modify the cylindrical beam and spread it out fanwise over the road surface, some specially made reflectors accomplish this result through the use of vertical flutes stamped into the surface during manufacture. An example of this type is shown in Figure 7. A plain glass is used in the head lamp door for protection of the silvered surface. Other

special reflectors modify the beam to give better distribution without a lens by employing reflecting surfaces of varying curvature which depart from the parabolic shape.

An elliptical reflector, which, however, also uses a lens, is shown in Figure 8.

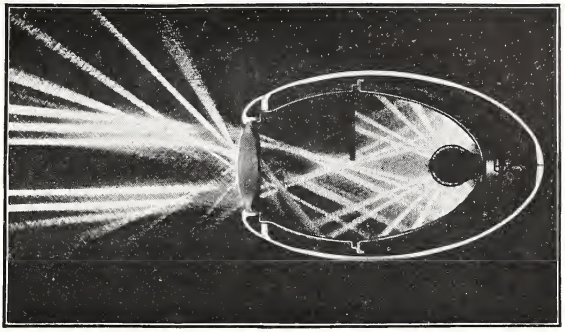


FIG. 8.—*This smoke box photograph illustrates paths of light rays from source of light to elliptical reflector and through the lens*

4. FOCUSING DEVICES

To permit proper positioning of the lamp (bulb) so as to bring the filament to the focal point of the reflector, most head lamps are equipped with some form of focusing mechanism. The most commonly used types are shown in Figure 9.

In (A) the focusing screw is located at the rear part of the lamp housing and is threaded into a projection on the lamp socket which

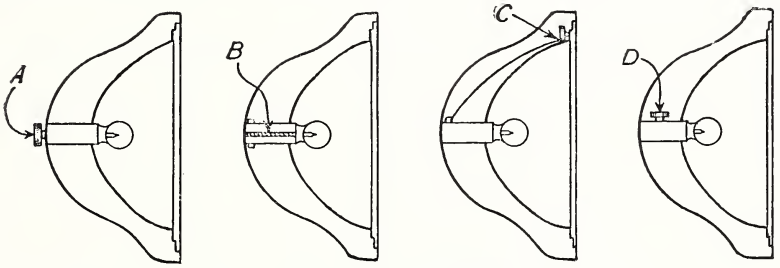


FIG. 9.—*Types of focusing devices*

slides in a supporting socket attached to the reflector. In (B) the lamp (bulb) is held in place by a ratchet device. The lamp (bulb) can be moved forward or backward by grasping it and either turning or pressing sidewise to disengage the ratchet and then pushing or pulling the lamp socket into the next notch. In (C) the adjusting screw is located in the rim of the reflector and is connected to the mov-

able lamp socket. In (D) the lamp socket is held in place by a set screw which when loosened permits the lamp to be moved.

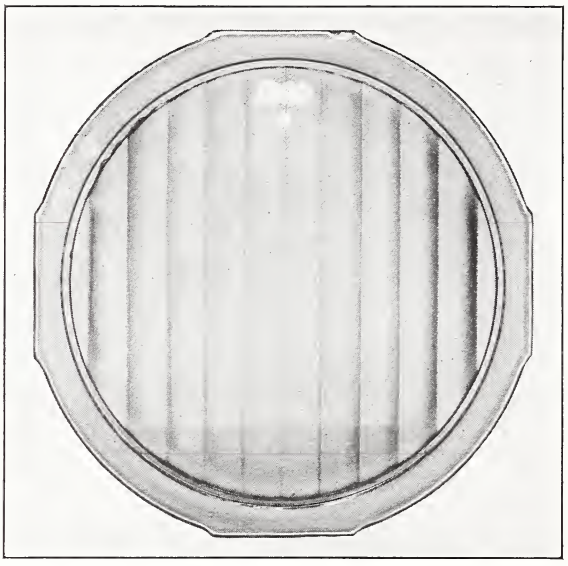


FIG. 10.—*A type of lens which spreads the beam sidewise*

The focusing devices shown by (A) and (C) represent the best current practice and afford the easiest means of proper adjustment. As a result of improvements in the manufacture of lamps greater uniformity is being obtained, which it is believed will make focusing devices unnecessary and permit the use of a fixed-focus type of reflector.

FIG. 11.—*Beam pattern from bare reflector*

5. LENSES

The cylindrical light beam produced by a parabolic reflector with the lamp properly focused is too concentrated and narrow to give proper distribution of light on the road. Moving the light source out of focus will produce a diverging and wider beam which causes glare and, as stated above, produces dark spots, which result in nonuniform illumination. A lens is therefore required with the parabolic reflector

to spread out and properly distribute the beam in such a manner as to produce more uniform lighting and confine the principal portion of the beam below a horizontal plane parallel to the road surface.

There are two classes of lenses in general use. Lenses of the first class, as shown by Figure 10, are made with vertical flutes and spread the beam fanwise horizontally. When one of these is placed in front of a beam from a bare reflector, such as is shown by the pattern in Figure 11, a beam pattern as shown by Figure 12 is produced. The action of these vertical flutes is shown by Figure 13, in which the observer is directly above the head lamp looking down toward the road.

Lenses of the second class, as shown by Figure 14, employ vertical flutes for spreading sidewise, combined with horizontal prisms for bending the beam or portions of it downward. The action of these horizontal prisms is shown by Figure 15.

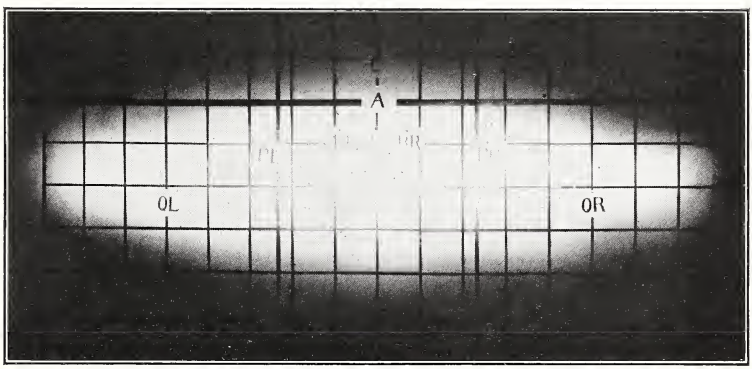


FIG. 12.—*Beam pattern shown in Figure 11 modified by spreading lens*

Various shapes of beam patterns are produced by the different lenses, depending upon the arrangement of the flutes and prisms. Figure 16 shows the patterns produced by two different lenses when the head lamps were properly adjusted and the light thrown on a shaded screen.

6. BEAM CONTROL

Although lenses or special reflectors produce beams of proper characteristics, it is necessary to direct these beams suitably along the road before good lighting is obtained. For this reason head-lamps are usually attached to the car by adjustable brackets, so that the lamp housing can be rotated vertically and horizontally and then locked in the desired position. A standard form of adjustable bracket mounting is shown on page B–1a of Volume I of the Society of Automotive Engineers Handbook.

In addition to the adjustment of the beam afforded by moving the head-lamp housing, some devices are equipped with a movable

reflector which can be controlled by the car operator while driving. The entire reflector or a part of it is so mounted as to permit of rotation in a vertical plane, thus permitting the driver by a suitable mechanical or electromagnetic control to lower the beam when other cars approach. The same effect is also obtained by the use of double-filament lamps in some devices recently developed.

FIG. 13.—*Spreading the rays of light by passing them through vertical flutes*

Each pencil of light is spread out fanwise on leaving the flutes

For country driving dimming the headlights when meeting another car should be discouraged because of the element of danger involved. Under normal driving conditions the driver's eyes are adjusted for good road illumination. When the lights are dimmed, suddenly reducing the road light, a few seconds must elapse before the eyes can readjust themselves to the new conditions. During these few seconds, the driver is unable to see clearly and may collide with the oncoming car, run into pedestrians walking along the

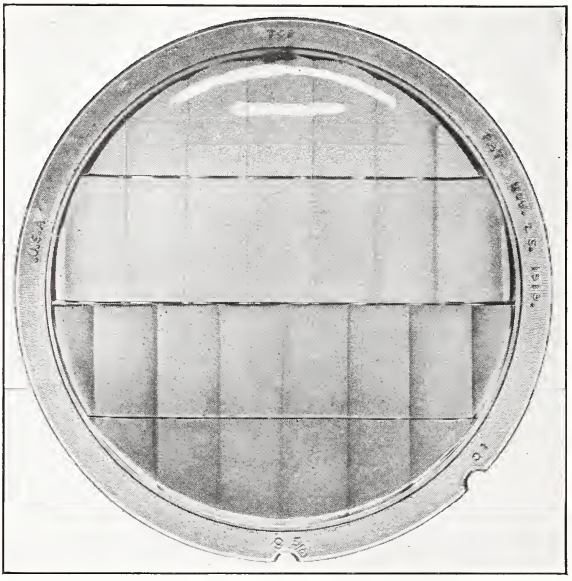


FIG. 14.—*Combination lens*

Vertical flutes spread beam sidewise and horizontal prisms bend beam downward

FIG. 15.—*Bending a ray of light by passing it through a horizontal prism*

roadside, or get off the road into the ditch. In addition, the lights on the approaching car seem unduly bright because no road illumination beyond them is available to reduce the contrast with the background.

It is believed that the use of some form of beam control is far superior to the present practice of "dimming" when meeting another

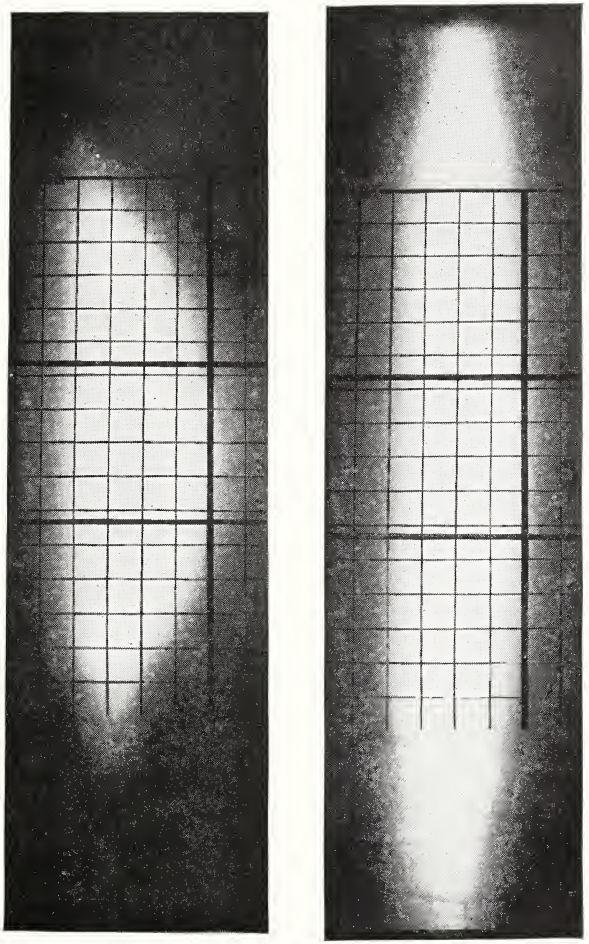


FIG. 16.—*Screen pattern from two types of lenses properly adjusted*

car on the road. When the beam is lowered its intensity remains unchanged, and ample light is available to clearly define the road and ditches. In the "up" position the control mechanism should be so adjusted that the main part of the beam can not be raised above a horizontal plane.

7. SPOTLIGHTS

When properly used, the spotlight is a helpful auxiliary to the standard headlight equipment. When meeting another car, the beam from the spotlight should be directed to the right of the center line of the car and well below the horizontal, so as to strike the road or ditch. Some State laws specify the distance ahead of the car at which the spotlight beam must strike the road, and others require the use of a spotlight lens. There is an unfortunate diversity among State laws in this respect, and an effort is being made to obtain the adoption of uniform requirements.

8. ANTIGLARE DEVICES

Most of the so-called "antiglare" devices do not fulfill the requirements indicated by the title. These devices consist usually of a metal hood or screen, louvres, or some form of shield to be fitted to the reflector or lamp. In numerous tests made at the Bureau of Standards it has been found that nearly all devices in this class reduce the amount of light available for lighting the road and do not materially affect the glare which results from the headlight beam being aimed too high or improperly focused.

The definition of glare is given as "A brightness within the field of view of such a character as to cause discomfort, annoyance, or interference with vision." As a result of extensive tests by the Illuminating Engineering Society, it was found that the average eye under ordinary conditions of driving could tolerate a light intensity of 800 candles, and that higher intensities caused discomfort. Improper aim of beam, or lamps out of focus, permit enough light to rise above the horizontal to cause interference with the vision of pedestrians and the drivers of oncoming cars. Few antiglare devices correct these conditions, and most of them simply reduce the effectiveness of the reflectors in lighting the road.

V. GAS HEAD LAMPS

The extensive use of acetylene gas head lamps on motor trucks has indicated the desirability of formulating some standard specification representing the best current practice. The following has recently been adopted for this purpose by the Society of Automotive Engineers and conforms with the generally accepted requirements for this type of headlight equipment.

1. CONSTRUCTION

The head lamps shall be of substantial construction to withstand the shock and wear of ordinary usage. They shall be equipped with $\frac{5}{8}$-foot burner, a 6-inch concave mirror, and a clear, plain front glass.

Burners.—A $\frac{5}{8}$-foot burner is one that consumes $\frac{5}{8}$ cubic foot of gas per hour at normal gas pressure.

Mirrors.—Nominal 6-inch mirrors are ones that measure approximately 6 inches on the curved reflecting surface and from $5\frac{1}{8}$ to $5\frac{5}{8}$ inches in diameter straight across the reflecting surface, according to the curvature. They shall be of curved plate glass at least $\frac{3}{16}$ inch plus $\frac{1}{64}$ minus 0 inch thick; or of molded glass, ground and polished and at least $\frac{3}{16}$ inch thick. They shall have a focal length of not less than $2\frac{1}{8}$ inches and not more than $2\frac{1}{2}$ inches from the reflecting surface.

Front Glass.—The front glass shall be of clear, plain glass $\frac{1}{8}$ inch plus or minus $\frac{1}{64}$ inch thick.

2. MARKS OF IDENTIFICATION

Each lamp must bear a distinctive designation prominently and permanently indicating the maker or name and type of the lamp. Each burner must be clearly marked to show the cubic feet of gas consumed per hour at normal gas pressure.

3. MOUNTING

Head lamps shall be securely mounted so that the axes of the main light beams will be parallel to the axis of the vehicle or tilted downward in the vertical plane not more than 3°.

4. OPERATION

Head lamps shall be maintained in proper operating condition with the mirrors and front glasses clean, and the burners secured so that the center of the gas flames shall be at the focus of the mirrors. The gas pressure shall be regulated to produce the maximum flames having a flat top, which will produce a light of approximately 21 mean spherical candlepower.

VI. LABORATORY TESTS

The Bureau of Standards has no specific authority for the approval or disapproval of any headlight device for use in any State, and the responsibility for such action is usually vested by law in some State official, ordinarily the commissioner of motor vehicles. Many State laws require a laboratory test prior to the approval of any headlight device, and the various States have had tests made in such laboratories as they found most convenient. The Bureau of Standards has at times acted as the official testing agency for some State officials and is sometimes called on to make tests as a referee in cases of disagreement. For this reason a brief description is given of the method followed at the bureau in making laboratory tests.

1. SPECIFICATIONS

Formal tests are regularly made in accordance with the Illuminating Engineering Society's 1922 Specifications of Laboratory Tests for Approval of Electric Headlighting Devices for Motor Vehicles, which were approved as a Tentative American Standard on November 11, 1922, by the American Engineering Standards Committee.

These specifications are reprinted in toto in the appendix. The required light distribution in the beam is indicated by the candlepower values at the various test points located as shown by Figure 20, on page 26.

These specifications represent minimum requirements for the road light, and most devices now approved exceed these requirements considerably.

2. APPARATUS REQUIRED

Standard parabolic reflectors of proper size.

Standardized 21-candlepower gas-filled automobile lamps.

Head lamp mounting with suitable mechanism for accurate rotation vertically and horizontally.

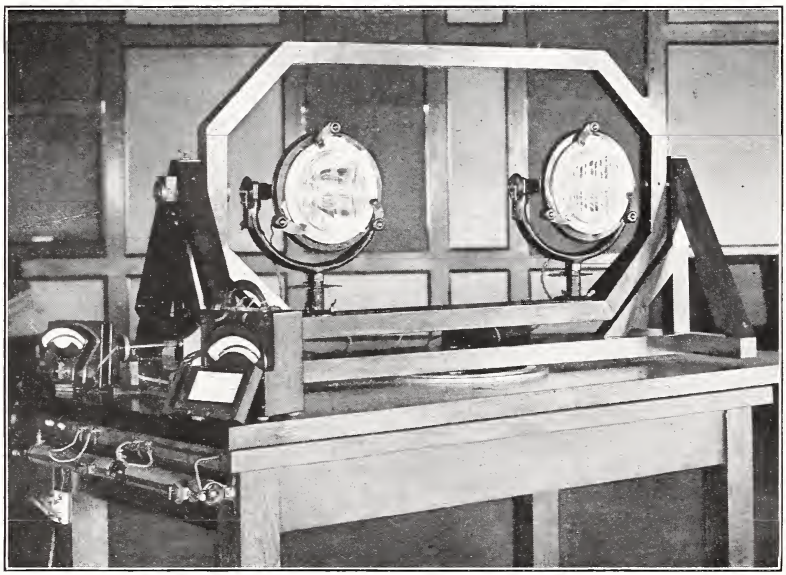


FIG. 17.—*Adjustable mounting for head lamps used in making laboratory tests*

Ruled focusing screen with white surface.

Voltmeter, ammeter, shunts, and resistance units.

Portable photometer.

A dark hall or tunnel is required, having sufficient length to permit placing the photometer at 60 to 100 feet from the head lamps.

3. PROCEDURE

The incandescent lamps are aged to insure uniform performance and then standardized in the integrating sphere by which the mean spherical candlepower is determined for given current values. The head lamps are mounted on an adjustable framework, as shown by Figure 17.

The lamps are inserted, the devices to be tested attached to the head lamps and adjustments made in accordance with the manufacturer's standard instructions.

To prolong the useful life of the standard lamps, the current is adjusted to produce a candlepower of 14 instead of the normal rated 21 candles. It has been found that by running the lamps at 14 candles and multiplying the readings by the ratio of 21/14, or 1.5, results can be obtained identical with those made when the lamps are operated at 21 candles, excepting cases where the devices have a notable color.

The photometer, which is recalibrated before each series of tests, is set up 100 feet from the head lamps, and a portable focusing screen is placed midway between the photometer and the head lamps. This screen has a hinged door located in line with the photometer and the lamps, which permits taking readings in any selected portion of the beam and keeps the remainder of the beam or reflected light from reaching the photometer. From an examination of Figure 20, on page 26, it is apparent that photometer readings are necessary at the several test points located in different parts of the beam. To obtain these readings, the photometer could be moved to each of these points, the head lamps being fixed, or the photometer could be fixed and the head lamps moved. The latter method is followed in tests at the Bureau of Standards, and the vertical and horizontal rotation of the head lamps is accurately controlled by suitable adjusting mechanism, as shown in Figure 17. Measurements of apparent beam candlepower are made at all test points, corrected to the 21-candlepower basis, and compared with the values indicated in the specifications.

VII. ADJUSTMENT INSTRUCTIONS

The adjustment of automobile headlights is simple and can be easily and quickly accomplished by the average car driver. The first step is to position the lamp bulbs so as to place them at the focal points of the reflectors. This adjustment is called "focusing" and is covered more fully under the section on reflectors. After the lamps have been properly focused the next step is to aim the beams so that the light will be projected on the road ahead of the car. The following cuts show how to adjust headlights.

1. PLACING CAR

See Figure 18.

2. FOCUSING BULBS

See Figure 18.

3. AIMING AND TILTING LAMPS

See Figure 18.

4. ADJUSTMENT CHART

For garage use, a portable adjustment screen is very convenient. The chart shown in Figure 19 can be mounted on a light framework and placed in front of the car. This portable screen allows the main

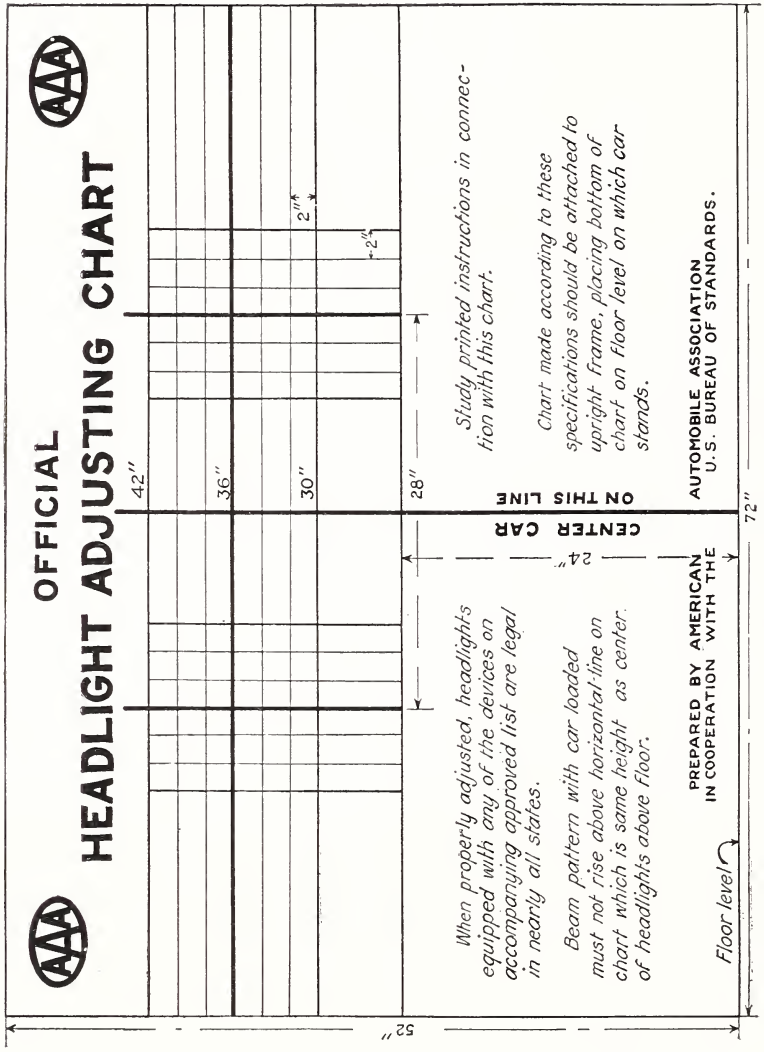


FIG. 19.—*Adjustment chart*

driveway, or aisle, of the garage to be used for headlight adjustment, thus making it unnecessary to set aside for this purpose garage space which could otherwise be used for storage or repair work.

ADJUST YOUR HEADLIGHTS

Simple Instructions for Adjustment to Give Better Road Light and Minimize Glare

Prepared by the United States Bureau of Standards

With the cooperation and approval of the National Automobile Chamber of Commerce, the Society of Automotive Engineers, the Illuminating Engineering Society, the Motor and Accessory Manufacturers Association, The National Automobile Dealers Association, The American Automobile Association, American Petroleum Institute, Rubber Association of America, Automotive Electric Service Association, and other trade and service associations.

1. PLACE CAR

Like this on level floor in front of shaded wall or screen

A—Height of lamp centers

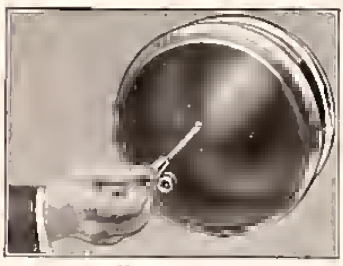
B—Distance between lamp centers

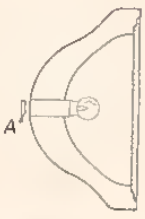
Have car loaded or allow for it when tilting. Loading raises light beams

2. FOCUS BULBS

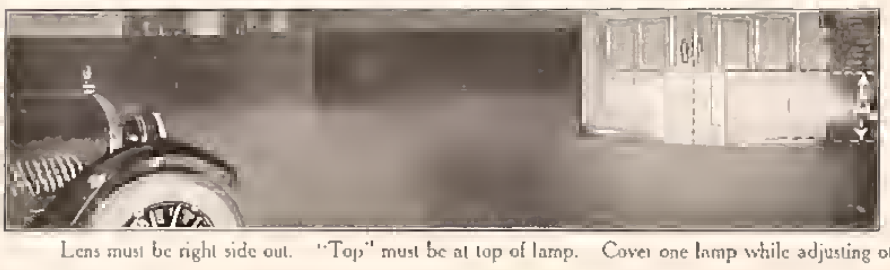
Outside Focusing Adjustment

(Lens must be on)





Turn screw to give horizontal beam pattern with narrowest vertical spread

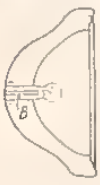


A—Narrowest vertical spread. Right lamp

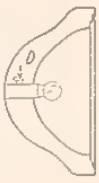
Lens must be right side out. "Top" must be at top of lamp. Cover one lamp while adjusting other

Inside Focusing Adjustment

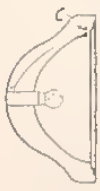
(Lens must be off)



Push or turn lamp to move ratchet



Loosen set screw



Turn screw in rim

Adjust until beam pattern looks like this with lens off

Lens on left lamp
Good focus

3. AIM AND TILT LAMPS

Loosen lamp mounting

Turn lamps horizontally until beams extend straight forward

A—Center left beam

B—Center right beam

Good Adjustment with car loaded

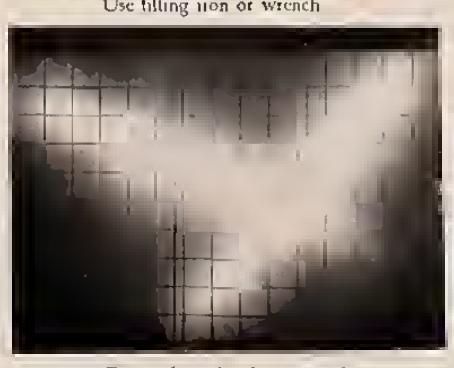
A—Height of lamp centers above floor.

Tilt lamp upward or downward. Bring beam pattern below horizontal

Cars Without Adjustable Lamp Brackets

Use tilting iron or wrench

Good Adjustment of both lamps with car loaded



Proper focus but lens twisted

Proper focus but aimed too high. Will glare

A—Height of lamp centers above floor

5. UNIFORM APPROVED LIST OF HEAD-LAMP DEVICES

Headlight devices on the following list have been approved by the Eastern Conference of Motor Vehicle Administrators and when properly adjusted are legal in most States. This list, dated March 1, 1925, was furnished the Bureau of Standards by the chairman of the conference lighting committee.

Alpheco.
Bausch & Lomb.
Bausch & Lomb Star.
Benzer type A.
Brown Universal (reflector).
Conaphore type F (clear and amber).
DB (Dodge Bros. 8⅝-inch only).
Deglarescope.
Dillon type I.
E. & J. type 20 (head lamp).
Flat-Lite Standard (reflector).
Flintex.
Ford H (8⅛-inch only).
Guide Ray type A (head lamp).
Guide Tilt Beam (head lamp).
Guide Tilt Ray (head lamp).
Holophane No Tilt.
Hudson (8⅛-inch only).
Johnson.
Lee Knight.
Liberty.
Liberty tpye D.
Lincoln Projector.
Macbeth type D.
McKeelite.
Miro-Tilt (head lamp).
Monogram.
Osgood B 23.
Patterson.
Parab-O-Lite type FW.
Smith.
Spreadlight.
Standard.
Twin Beam (head lamp).

MOTOR CYCLES

Conophore type F.
McKeelite.
Monogram.
Patterson.
Spread light.
Standard.

Acetylene head lamps when equipped with 6-inch, clear, bright, spherical mirrors, and burners which consume five-eighths cubic foot of gas per hour, giving 21 candlepower, may be used with plain glass lenses.

VIII. EDUCATIONAL WORK

As stated before, good laws and good equipment are helpful, but without the car drivers' cooperation they can not remedy unsatisfactory headlighting conditions. The statement below gives the results of head-lamp tests made at the Bureau of Standards on some 400 cars of 58 different makes equipped with 47 different types of headlighting devices. Notwithstanding the fact that 72 per cent of these cars were equipped with devices included in the "Conference approved list," only 5½ per cent of the total number of cars had lights in good condition. From the statement it will be noted that nearly 75 per cent of the head lamps were improperly focused. The percentage recorded as "glaring" represents the lamps which, in the judgment of the observers who made the tests, would have thrown a troublesome amount of light in the eyes of an approaching driver on a level road. It is merely an estimate but is believed to be conservative.

Résumé of head-lamp tests

[Percentage of cars having head lamps in condition noted]

	Per cent
Equipment in good condition	5. 5
Lenses:	
Dirty	52. 8
Broken	4. 3
Loose in head lamp	3. 8
Twisted in head lamp	35. 8
Reflectors:	
Dirty	38. 8
Rusty	6. 7
Dented	1. 7
Lamps (bulbs):	
Out of focus	73. 2
Blackened	5. 3
Too high candlepower	. 3
Too low candlepower	6. 7
Head lamps:	
Not parallel	23. 6
Not correctly tilted	46. 7
No outside focus adjustment	8. 4
Glaring	54. 0

From a study of these results it is obvious that an intensive educational campaign is needed to impress upon the car driver that he can help himself and other car drivers by adjusting his own equipment. Car manufacturers are being urged to supply headlights which can be more easily and permanently adjusted, and through the action of the Eastern Conference of Motor Vehicle Administrators law enforcement is being placed on a more uniform basis, but marked improvement can not be expected until the motoring public realize their responsibilities and give some attention to their own headlights.

Improvement in any locality can be obtained by a well-planned and energetic educational campaign designed, first, to provide adjustment facilities; second, to get motorists to use these facilities; and, third, to insist on strict law enforcement for those motorists who do not voluntarily comply.

To start such a campaign, the leading men in the community representing garages, car dealers, motor clubs, safety committees, enforcement officials, chambers of commerce, civic clubs, etc., should be called together in conference and the problem outlined and discussed. Garages should be equipped with adjustment charts and their personnel instructed how to adjust head lamps. After the facilities for adjustment have been provided an intensive publicity campaign should make known this fact to the motoring public. Motor clubs should advise their membership to have their lamps adjusted. Safety committees should send out and put up posters calling attention to the fact that "glaring head lights are dangerous

and unlawful." Car dealers should adjust the lamps on all new and used cars delivered. The law-enforcement officials should advertise broadly the requirements of the law and the plan of enforcement. A campaign of this scope participated in by all classes interested in trying to make night driving safer and more comfortable will bring results. From a national viewpoint a considerable amount of educational work is already under way. Adjustment of head lamps by the individual motorist combined with good laws and good equipment will surely greatly improve the present intolerable headlight situation.

IX. STATE LAWS AND REGULATIONS

1. EASTERN CONFERENCE OF MOTOR VEHICLE ADMINISTRATORS

Many States have enacted motor-vehicle laws which differ considerably from the laws and regulations adopted by adjoining or near-by States. When motoring through several States these nonuniform regulations are not only confusing, but are often the cause of law violation. In an attempt to secure uniform enforcement of motor-vehicle laws the motor-vehicle commissioners of 10 or 12 Eastern States have formed what is termed the "Eastern Conference of Motor Vehicle Administrators." Through this informal organization the administrative officers of the States composing the conference secure the benefits accruing from mutual counsel and, in so far as may be possible under their State laws, endeavor to place their law enforcement on a uniform basis. In connection with head-lamp requirements, this conference has issued a uniform list of devices which are accepted as legal in all of the conference States. This list is given under the section on adjustment, page 19.

2. SUGGESTED PARAGRAPHS FOR A STATE MOTOR-VEHICLE LIGHTING LAW

Space does not permit the inclusion of a digest of all the State laws relating to motor-vehicle lighting. The sections that follow are intended to suggest a type of motor-vehicle lighting law in which the basic principles only are specified in the act but which authorizes the motor-vehicle administrator to issue such supplementary rules and regulations as may be necessary. It should be understood that no attempt is made here to present a complete law.

Motor Vehicle Act of ———— ————

(*a*) COMMISSIONER OF MOTOR VEHICLES.—The office of commissioner of motor vehicles is hereby created. The commissioner is hereby authorized to appoint with the consent and approval of ———— all deputies, inspectors, and traffic officers necessary to carry out the provisions of this act. With the approval of ————, the commissioner is hereby authorized to make such

rules and regulations pertaining to motor-vehicle lights and their approval as are not inconsistent with the specific provisions of this act. (Include qualifications for office, salary, appointment, term, etc.)

Pertaining to lights on motor vehicles

(*b*) Lights, When Required.—Every motor vehicle, driven or operated upon the public highways of the State during the period from one-half hour after sunset to one-half hour before sunrise, and at any other time when there is not sufficient light to render clearly discernable a person, vehicle, or other substantial object on the highway 200 feet ahead, shall be equipped with and have lighted, when running, two head lamps mounted on the front of the vehicle, one on each side and fitted with lamps of equal candle power not exceeding 21 candles. The head lamps shall be of the type approved by the commissioner of motor vehicles, as provided in subdivision — of this section. In addition to the head lamps, one lighted lamp shall be mounted on the rear of such vehicle. This lamp shall be so mounted and equipped as to display a red light, visible from the rear at a distance of —— feet and also to illuminate by white light the number plate carried on the rear of such vehicle in such manner as to render the numerals thereon legible for at least 50 feet in the direction from which the vehicle is proceeding. The term "head lamp" as used herein shall denote a light located upon the front portion of a vehicle the rays of which are projected forward, other than a side light or spotlight. Motor vehicles may also be equipped with two side lights, but no more. The term "side light" shall include any light upon a motor vehicle the rays of which project forward, other than headlights, spotlights, or parking lights covered by section (*g*). No electric lamp rated greater than 4 candlepower shall be used in any side light.

(*c*) Construction, Arrangement, and Adjustment of Head Lamps.—The head lamps shall be so constructed, arranged, and adjusted that they will at all times mentioned in section —, and under normal atmospheric conditions produce ample driving light for the use of the vehicle operator, but will not project a glaring or dazzling light to persons approaching such light or to persons whom such lights may approach. When the vehicle is being operated on a street or highway not sufficiently lighted so as to reveal any person, vehicle, or other substantial object on the street or highway 200 feet ahead, the head lamps shall give sufficient light so as to make clearly discernible any such person, vehicle, or substantial object on the road 200 feet ahead of the motor vehicle.

(*d*) Approval of Head-lamp Devices.—No head lamp shall be used upon any motor vehicle operated upon the public highways unless such head lamp is equipped with a lens or other device of a type approved by the commissioner of motor vehicles, or has as a whole been so approved. The approval shall be contingent upon the device satisfactorily passing tests made in accordance with specifications representing the best current practice, which specifications shall be prescribed by the commissioner. Tests shall be made by a qualified and disinterested testing agency. (Insert details covering cost of test, procedure in case of disagreement, etc.).

Headlighting devices heretofore approved may be used when arranged, adjusted, and operated, as required by Section — of this act, upon motor vehicles in this State while such certificates of approval are in force. Any such certificate, however, heretofore or hereafter issued may be revoked after a hearing of which the person or corporation named therein, or his or its successor in interest, shall have been given reasonable notice and an opportunity to appear and be heard, upon the ground that the device does not comply with the provisions of this act and the rules and regulations of the commissioner of motor vehicles, and the

decision of the commissioner of motor vehicles revoking such certificate shall be final; such revocation, however, of a lens or other headlighting device heretofore or hereafter approved shall not take effect until six months after the decision of the commissioner of motor vehicles revoking same.

(*e*) Sale of Head Lamps or Head-Lamp Devices.—From and after ——— —, ———, it shall be unlawful to sell or offer for sale any head lamp or head-lamp device for use on motor vehicles in this State unless it is of a type approved by the commissioner of motor vehicles under the provisions of this act. Each device when sold must be accompanied by a printed instruction sheet describing the device, the method of mounting and adjustment, and giving any other information necessary to insure conformity with the provisions of this act.

(*f*) Inspection by Officers.—The operator of every motor vehicle shall permit any police officer or motor-vehicle inspector, examiner, or other person exercising police powers to inspect at any reasonable time the headlighting equipment of such motor vehicle and to make such tests as may be necessary to determine whether the provisions of this act are being complied with.

(*g*) Parking Lights.—Whenever any vehicle is standing on a public highway, and not in motion, the operator thereof shall light and keep lighted either the lamps herein required for a moving vehicle or one light visible from both the front and rear, which shall be carried at the left side of the vehicle and shall show a white or yellow light when seen from the front and a red light when seen from the rear, visible at a distance of — feet.

The following suggested rules and regulations agree closely with those now in force in the State of New York and are presented here to indicate the type of regulations which the motor-vehicle commissioner is authorized to issue in order to supplement the provisions of the law.

3. SUGGESTED RULES AND REGULATIONS

In pursuance of the authority conferred on the commissioner of motor vehicles by section — of the motor vehicle act of —— ——, the following rules and regulations concerning head lamps on motor vehicles are hereby adopted:

1. No motor vehicle shall be entitled to be registered or licensed in this State unless the same is equipped with two head lamps and lenses or special reflectors of a type which has been approved by the commissioner of motor vehicles.

2. No motor vehicle shall be operated day or night upon the public highways of the State unless equipped with two approved head lamps with bright and clear reflectors free from rust, and they shall at all times when operated on the highways at night give sufficient light to make clearly visible all vehicles, persons, or substantial objects upon the roadway ahead of the car within a distance of 200 feet.

3. Every lens or other device, the type of which has been approved by the commissioner of motor vehicles, shall be applied and adjusted in accordance with the requirements of the certificate approving the type and use thereof. Lenses must not be twisted or turned in the head lamps. Every lamp, bulb, or light used in any head lamp on a motor vehicle shall be of 21 rated mean spherical candlepower.

4. The operator of every motor vehicle shall permit any police officer, State police, inspector, or other person having police powers to inspect the headlighting equipment of such motor vehicle at all reasonable times and to make such tests as

may be necessary to determine whether the provisions of the highway law relating to head lamps on motor vehicles and of these rules and regulations are being complied with.

5. No electric headlighting device will be approved which does not comply with the 1922 specifications of the Illuminating Engineering Society nor until after it is submitted and passes a laboratory test as provided by subdivision — of section — of the motor vehicle act, and such device must be capable of conforming to the requirements of the law and of these rules and regulations as to production and distribution of light.

Notwithstanding a favorable report on such test, the commissioner of motor vehicles reserves the right to refuse approval of any device which, in his opinion, is liable for any reason to prove unsafe or unsatisfactory in actual use.

6. Motor cycles shall be equipped with and shall display one lighted lamp on the front, and, if operated with a side car, two lights in front. A single red light shall show from the rear. Motor-cycle lights must avoid dangerous glare and dazzle and give sufficient illumination to make clearly visible all vehicles, persons, or substantial objects within the traveled portion of the highway for a distance of 200 feet.

7. Acetylene head lamps when equipped with 6-inch, clear, bright, spherical mirrors and burners which consume five-eighths cubic feet of gas per hour, giving 21 candlepower, may be used with plain glass lenses. Head lamps shall be securely mounted so that the axes of the main light beams will be parallel to the axis of the vehicle or tilted downward in the vertical plane not more than 3°, and in other respects the lamps must conform to the provisions of the law covering dazzling or glaring lights.

8. These rules and regulations as to quantity of light do not apply to parked cars or to the operation of cars on well-lighted streets.

9. The headlamp devices in the following list have been tested in accordance with section 5 of these rules and are approved for use in this State.

(Insert here the list of devices tested and approved. See uniform approved list prepared by Eastern Conference of Motor Vehicle Administrators.)

X. SELECTED BIBLIOGRAPHY

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XI. APPENDIX

1. SPECIFICATIONS OF LABORATORY TESTS FOR APPROVAL OF ELECTRIC HEADLIGHTING DEVICES FOR MOTOR VEHICLES[1]

[Approved by American Engineering Standards Committee as Tentative American Standard, November 11, 1922]

DEFINITION

By headlighting device is meant either the integral and complete lamp or a device intended to modify in a suitable manner the beam of the ordinary type of headlighting equipment.

(A) Tests of Devices Used in Pairs.—*Samples for test.*—The samples submitted to the testing authority shall be representative of the device as manufactured and as marketed. They shall be accompanied by printed instructions for their use as issued by the manufacturer of the device The samples submitted shall include as much of the accessory equipment peculiar to the device (except batteries) as is necessary to operate the device in its normal manner. In the case of front glasses the samples shall be one pair each of $8\frac{5}{32}$ (or Ford size), $8\frac{1}{2}$, 9, and $9\frac{1}{2}$ inch diameter when practicable.

Reflectors and incandescent lamps.—In the case of devices to be used in connection with standard parabolic reflectors, the reflectors used in making the laboratory tests shall be of standard high-grade manufacture 1.25-inch focal length with clean and highly polished surfaces, and as nearly truly paraboloidal in form as practicable, and as approved for this purpose by the National Bureau of Standards.

The incandescent lamps used in connection with the laboratory test shall be of standard manufacture and as approved for this purpose by the National Bureau of Standards. In the case of devices involving the use of special incandescent lamps, such lamps, together with any necessary accessories, shall be submitted.

Marks of identification.—Each device submitted must bear a distinctive designation prominently and permanently indicating the name and type of the device. Special incandescent lamps submitted in connection with devices shall bear the manufacturer's normal, clear bulb rating.

Adjustment of devices.—The testing authority shall adjust the device in accordance with the printed instructions issued by the manufacturer, which instructions

[1] Prepared under the direction of and issued by the Illuminating Engineering Society, 29 West Thirty-ninth Street, New York, N. Y.

must be adequate for practical purposes. An exact description of the adjustment made for test shall be given in the report.

Focal adjustments of incandescent lamps.—The following designations of the focal adjustments of the incandescent lamp in the parabolic reflector are adopted:

Principal focus.—The beam, with bare reflector or plain front glass, is nearly parallel and of the smallest possible diameter.

Rear focus.—The beam, with bare reflector or plain front glass, diverges as much as possible without having a dark center.

Front focus.—The beam, with bare reflector or plain front glass, converges and crosses near the lamp and then diverges as much as possible without having a dark center.

Special focus.—A special focal adjustment is allowed only when it can be clearly defined and described.

Photometric Tests.—The tests shall be as follows:

Test 1.—A pair of testing reflectors, mounted similarly to the head lamps on a car, shall be set up in a dark room at a distance of not less than 60 feet nor more than 100 feet from a vertical white screen. If a testing distance of 100 feet is

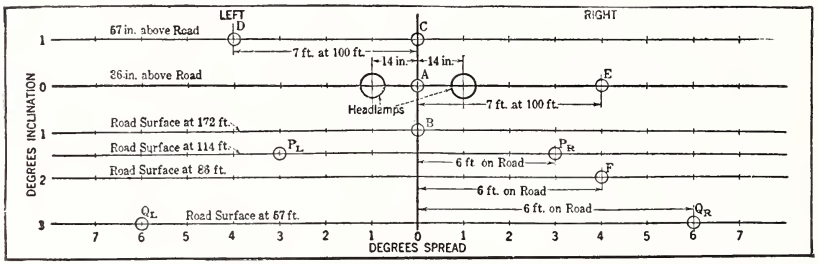

FIG. 20.—*Diagram of test positions*

A, 1,800 cp minimum, 6,000 maximum
B, 1° right and left 7,200 minimum
C, 800 cp minimum, 2,400 maximum
D, 800 cp maximum
P_L to P_R 5,000 minimum
Q_L to Q_R 2,000 minimum

taken, the reflectors shall be set 28 inches apart from center to center, and if a shorter testing distance is taken, the distance between reflectors shall be proportionately reduced. The axes of the lamps shall be parallel and horizontal or tilted in a vertical plane in accordance with manufacturer's adjustment. The intensity of the combined light shall then be measured with each pair of samples in turn, with the reflectors fitted with a pair of incandescent lamps of the gas-filled type, 6 to 8 volts, 21 spherical candlepower rating. The lamps shall be such as will give their rated candlepower when operated at their rated efficiency. They shall be operated at their rated candlepower.

Measurements shall be made at the following points at the surface of the screen:

A. In the median vertical plane parallel to the lamp axes, on a level with the lamps.

B. In the median plane 1 degree of arc below the level of the lamps.

C. In the median plane 1 degree of arc above the level of the lamps.

D. Four degrees of arc to the left of the median plane and 1 degree of arc above the level of the lamps.

P_L and P_R. One and one-half degrees of arc below the level of the lamps and 3 degrees of arc to the left and to the right, respectively, of the median plane.

Q_L and Q_R. Three degrees of arc below the level of the lamps and 6 degrees of arc to the left and to the right, respectively, of the median plane.

A diagram of test positions is shown in Figure 20.

All pairs of samples tested under the conditions prescribed above shall conform to the following specifications for observed apparent candlepower:

Point A, not less than 1,800 candlepower nor more than 6,000 candlepower.

Point B, not less than 7,200 candlepower, and there shall not be less than 7,200 candlepower at any point on the horizontal line through B, 1 degree to the left and to the right of B.

Point C, not over 2,400 candlepower, and not less than 800 candlepower.

Point D, not over 800 candlepower.

Points P_L and P_R, at each of these points and at every point on the line between them, not less than 5,000 candlepower.

Points Q_L and Q_R, at each of these points and at every point on the line between them, not less than 2,000 candlepower.

> NOTE.—The above testing directions are drawn specifically to cover the case of devices accessory to parabolic reflectors of 1¼-inch focal length. In the case of other classes of devices where these directions evidently can not be applied literally, their intent must be adhered to, and the testing positions and candlepower limitations shall govern in all cases.

Test 2.—A single pair of samples taken as an average representative of the device as manufactured, shall be submitted to a complete test with the same testing equipment as specified for test 1. This test shall show light distribution characteristics by actual measurements made in accordance with the best laboratory practice.

Distribution of Samples.—One pair of the samples submitted shall be retained at the testing laboratory for the purpose of future reference and as samples of construction.

(B) TESTS OF DEVICES USED SINGLY.—Motorcycle head lamps are used singly and not in pairs and have commonly a reflector of smaller diameter and shorter local length. Hence, devices for use in connection with them are not included in the same classification as those for other motor vehicles. For the laboratory tests of such devices two samples of representative sizes shall be submitted. They shall be tested with representative motorcycle head-lamp reflectors. The numerical limitations of apparent candlepower for test 1 with one lamp only shall be as follows:

Point A, not less than 1,800 candlepower.

Point B, not less than 3,600 candlepower, and there shall not be less than 3,600 candlepower at any point on the horizontal line through B, 1 degree to the left and to the right of B.

Point C, not more than 2,400 candlepower.

Point D, not more than 800 candlepower.

Points P_L and P_R, at each of these points and at every point on the line between them, not less than 2,500 candlepower.

Points Q_L and Q_R, at each of these points and at every point on the line between them, not less than 1,000 candlepower.

Test 2 shall be made with one lamp and not with two.

Other deviations from the details of procedure are obviously made necessary because of the fact that single devices instead of pairs are subjects of test.

Reports.—The report of the test shall be rendered in duplicate to the State authority and shall be signed or initialed not only by the expert making the test, but also by an executive officer of the institution making the test.

2. SOCIETY OF AUTOMOTIVE ENGINEERS, RECOMMENDED PRACTICE

Laboratory Test for Desirable Illumination.—The following illumination values are intended as an objective in designing new electric headlamps, not as legal restrictions. The points at which the values are specified are the same as those given in the preceding specifications except that the S_L and S_R points are 4 degrees of arc below the level of the lamps and 12 degrees to the left and to the right of the median plane.

Point A, not less than 2,000 candlepower nor more than 6,000 candlepower.

Point B, not less than 25,000 candlepower, and there shall not be less than 25,000 candlepower at any point on the horizontal line through B, 1 degree to the left and to the right of B.

Point C, not over 2,400 candlepower and not less than 800 candlepower.

Point D, not over 800 candlepower.

Points P_L and P_R, at each of these points and at every point on the line between them, not less than 10,000 candlepower.

Points Q_L and Q_R, at each of these points and at every point on the line between them, not less than 4,000 candlepower not more than 8,000 candlepower.

Points S_L and S_R, not less than 500 candlepower.

Washington, November 19, 1924.