GLARE from PASSING BEAMS of AUTOMOBILE HEADLIGHTS

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SYNOPSIS

Measurements of glare intensity from the lower (dipped) beams of vehicle headlights were made at sites in Texas, Maryland, New Jersey, and in the District of Columbia in the summer of 1952. The results show that in the two states which had well-established vehicle-inspection procedures (New Jersey and the District of Columbia), glare was slightly less than in Maryland, which had no inspection, and in Texas where inspection had just begun. At all places, a few very-badly adjusted headlamps were met.

Although glare from lower beams was found to be reasonably low, the situation as regards deterioration was less satisfactory. With the help of the Bureau of Public Roads, measurements were made, at two inspection stations in Washington, of the maximum intensities of the country beams of vehicles as presented for inspection. It was found that the light output of many lamps had deteriorated badly; but because the candlepower limit at inspections was so low, few of these deteriorated lamps were rejected. Combining these results with those of the glare survey in Washington, rough calculations were made which indicated that, because of the large deterioration allowed, the distance a Washington driver can see when meeting another motorist at night is, for many such meetings, only a fraction of what it might be if all lamps were maintained as new.

Counts made on rural roads in Texas showed that 20 to 25 percent of drivers met refused to dip (change to lower beam). It is not known whether the same high proportion is met elsewhere, but it appears probable that most of the glare nuisance in the United States is due to this reluctance to use the lower beam.

FOR some time past, research has been going on at the Road Research Laboratory, England, with particular reference to British conditions, to find ways of reducing dazzle (glare) and improving visibility when vehicles meet at night. One of the conclusions is that an important first step might be to encourage or enforce in Britain the use of a standard headlight, such as the sealed beam now in almost universal use in the United States. It is therefore of interest to know how American headlights compare with British, particularly as regards glare. When the author visited the United States in 1952 as a Commonwealth Fund Fellow, the opportunity was taken to obtain American data with which to make the comparison. Measurements of the glare intensity from the lower beams of headlights were made in a number of states, and some information on the maximum intensity in the upper beams was also collected. It is intended later to obtain comparable data in Britain. This report describes the apparatus constructed for the American measurements and the results.

DATA OBTAINED

Measurements of dazzle intensity, that is, of the intensity directed towards the eyes of a driver by the headlights of an oncoming vehicle, were made in Texas, Maryland, New Jersey, and Washington, D. C. New Jersey and the District of Columbia have well-organized state-run vehicle-inspection stations, whereas Maryland has no inspection and Texas has only just started a garage-operated scheme (1952). If vehicle-inspection is effective, less glare is likely to be found in Washington and New Jersey than elsewhere; the measurements were expected to give information on this matter.

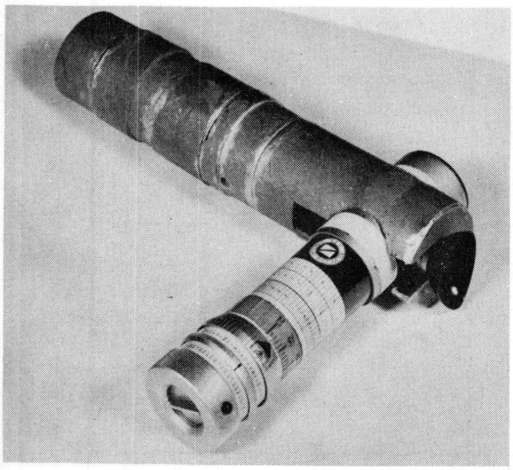

Figure 1. Glare meter.

The measurements of glare intensity were made with an S.E.I. photometer, fitted with the attachment shown in Figure 1. The photometer is an instrument for measuring the luminance (brightness) of a surface by matching it visually with a spot of known brightness. The attachment consists of a lens, A, which is directed towards the headlamp whose intensity is to be measured (see Fig. 2). A diffusing screen, B, placed some distance within the focal length of the lens, receives a defocussed image of the headlamp. The brightness of this image, which at a given distance is proportional to the intensity, is measured with the S.E.I. photometer, and from a calibration curve the intensity may be deduced. The distance of the diffusing screen from Lens A is such that, at 300 ft. (the usual viewing distance), the images of the two headlamps overlap and a single reading of combined intensity can be made. Fuller details of the instrument and of the method of calibration are given in the appendix.

All the observations were made from a stationary car parked about 350 ft. from a traffic light. The distance of the vehicle from the stop line was measured with a "Rolatape", a rubber-tired wheel, 2 ft. in circumference, equipped with a revolution counter, and mounted at the end of a "lazy-tongs" handle, so that it could be wheeled along the road. Particulars of the sites are given in Table 1.

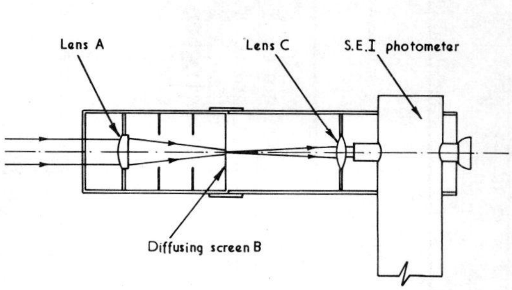

Figure 2. Section of the attachment to the S.E.I. photometer.

"The effect of glare, both as regards disability and discomfort, depends more on the ratio of glare intensity to intensity directed towards the object than on the absolute value of the glare intensity, (1) and it

TABLE 1

Date	Place	Number of Obser-vations	Distance of Observer	Street Width	Viewing Angle*	Remarks
			ft.	ft.	deg.	
13 and 14.5.52	Kilgore, Texas	54	302	40	3	Level road
10.7.52	Kilgore, Texas	39	316	40	4	Level road
3.8.52	Washington, D.C. I Street and 16th	59	348	36	2.8 in one lane	Slope of about 0.8° increasing the depression of beams.
4.8.52	I Street at 18th	30	350	36	As at 16th	Level road
8.8.52	K Street at 18th	55	370	45	3.3 in one lane 4.6 in one lane	Slope of about 0.7° decreasing depression of beams.
14.8.52	L Street and 17th	36	330	About 30	1	One-way street: Level: room for one lane of traffic only.
15.8.52	Aberdeen Maryland	20	333	42	3.6 in one lane 5.3 in other lane	Level road
16.8.52	Frederick Maryland	72	352	30	2.8	Level road: One line of cars
17.8.52	Trenton New Jersey	53	310	35	3.8	Level road: One line of cars: slight bend in road.
18.8.52	Trenton New Jersey	53	388	37	4.6	Level road: only one lane visible

*The viewing angle is the angle between the longitudinal axis of the car being observed and a line from the observer to a point midway between the headlamps.

would therefore have been desirable to have measured the intensities directed along the road towards the object. This was not possible;instead, measurements were made of the maximum candlepower of the upper beam, which might be expected to be proportional to the value sought. A large number of values of the maximum candlepower of the upper beam were obtained for the author by the Traffic Research Department of the Bureau of Public Roads, who recorded the results of routine inspection tests at the two vehicle-inspection stations in Washington, D. C. Thanks are due to the Bureau of Public Roads for permission to include the results in this paper. The maximum candlepowers of the upper beams were recorded for 1,200 cars and trucks by means of Kent-Moore "Robot" headlight-testing machines. When in use, the Robot is placed in front of the headlamps and a large lens inside the instrument gathers the light and focusses it on a photocell. A meter calibrated to read directly in candlepower is connected to the cell. At Washington testing stations, the meters are calibrated frequently by means of a standard sealed-beam headlamp. An undesirable feature of the instrument is that the candlepower scale is nonlinear and difficult to read accurately at the upper end.

RESULTS

The results of the surveys are shown in Figure 3, which comprises five diagrams; the first three relate to conditions in Washington, D. C., and New Jersey, where well-conducted vehicle-inspection programs are in operation; the last two refer to Maryland, which has no inspection, and to Texas, where inspection by appointed garages had been in progress for a few months only when the measurements were made.

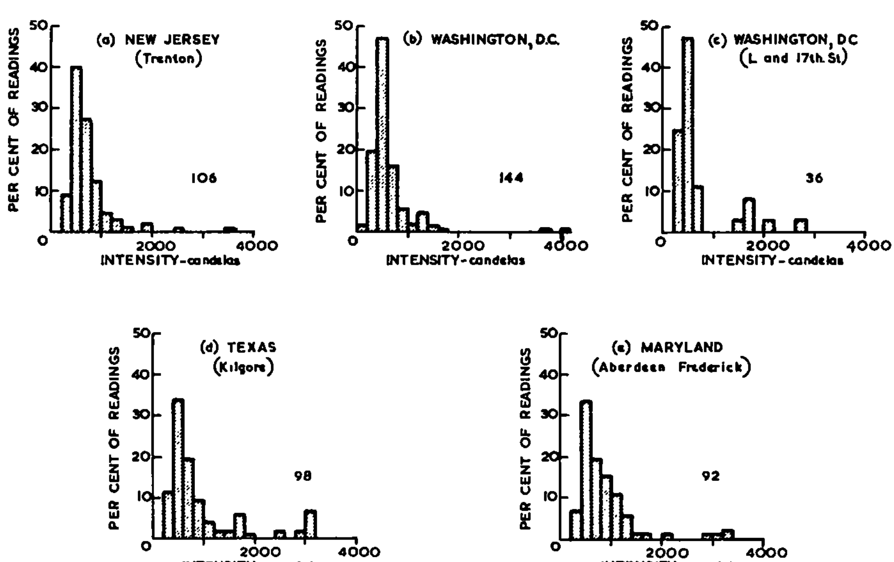

Figure 3. Glare intensities in the United States: (a), (b), and (c), states having inspection; (d) and (e), no inspection (Maryland) or inspection just started (Texas).

All the results show a low level of glare, the most frequently measured intensities at all sites lying between 400 and 600 candelas.* Even more important, perhaps, than the low level of glare is the shape of the frequency diagram, with 60 or 70 percent of the readings concentrated between 400 and 800 candelas. This suggests good aiming.

A visual comparison of the diagrams suggests that there was less glare in those states which had vehicle inspection than in those which had no inspection, and this indication is confirmed by calculations which show that significantly more vehicles with dazzle intensities over 800 candelas were observed in Maryland and Texas than in New Jersey and Washington, D. C. The differences might have been more easily detectable had it been possible to measure all glare intensities from the same position in relation to the axis of the vehicle; at many sites, however, it was uncertain which of two lanes the vehicle under observation was in, and some scatter must have been introduced into the results because of this fact. At the L Street site, a one-way street in Washington, D. C., the observations were all made on one lane of traffic from a position much nearer to that lane than was usual in other tests; the results are therefore given separately in Figure 3(c).

Although the general level of dazzle in the United States was found to be low, there was an appreciable proportion of badly adjusted headlights, even in states having inspection; in Washington for example, 10 percent were over 1,000 candelas; in Maryland, about 25 percent were over 1,000 candelas.

Another feature of the results which should give rise to concern is the extent of the deterioration of the intensities of the upper beams, which are an indication of the condition of the lamps as a whole. Figures for the maximum intensities of the upper beams, as measured in Washington inspection stations by the procedure already described, are given in Figure 4. It will be seen that there was a considerable deterioration from the design candlepowers of the upper beams (for a pair 64,000 at 6.4 volts, or probably about 52,000 for the test conditions). Since these figures were obtained at inspection stations and since the rejection limit in Washington is low (5,000 candlepower for each lamp) the state of vehicle headlights in use on the roads may well be worse than these figures suggest. Assuming them to be representative, however, the effect of this deterioration on the seeing distances of Washington motorists has been roughly calculated, making use of the data in Figures 3(b) and 4, in the following way. The glare intensities were assumed to be the same at all distances and to be given by Figure 3(b); this overestimates glare at the shorter

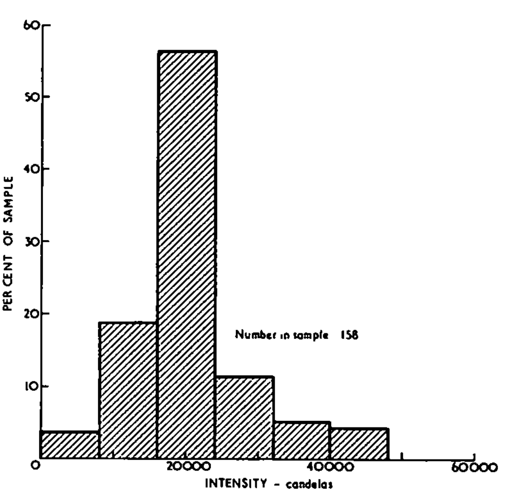

Figure 4. Maximum combined intensities of two upper beams, measured at Washington, D. C., inspection stations.

*The new international candle, virtually the same as the American standard candle.--Ed.

distance. The upper-beam maximum candlepowers were assumed to be as in Figure 4. Misaim of the beam was neglected and the intensity directed along the road towards the object to be detected was derived from Figure 4 by assuming that it was a constant fraction (1/10) of the maximum intensity in the upper beam. This fraction was estimated from the isocandels diagrams for new lamps and therefore the procedure implied that deterioration had not affected the beam pattern, a reasonable assumption for sealed headlights, and that the relative intensities of the upper and lower beams were as given by the design values for new lamps. This last assumption may be inaccurate. Making these assumptions, rough calculations of the resulting distribution of seeing distances were made by a method recently developed at the Road Research Laboratory, (2) based on practical measurements of seeing distances. The results are set out in Figure 5. The meaning of this figure may be stated in the following way. If a large number of Washington vehicles, picked at random, meet at night an equal number also randomly picked, and all vehicles use their lower beams, approximately 3 percent of the drivers are likely to have seeing distances in the range 0 to 50 ft., 22 percent 50 to 100 ft., 64.5 percent 100 to 150 ft., 10 percent 150 to 200 ft., and 0.5 percent 200 to 250 ft. To compare with these figures, it has been calculated that if all lamps had the candlepower they were designed to produce, and were correctly aimed, all drivers would have a seeing distance of 152 ft. Therefore, because of deterioration, one quarter of the seeing distances are less than two thirds of what they might be, if everything were perfect, and 10 percent are slightly greater. Considerable improvement might be expected to result from a tighter control on deterioration, and it also appears likely that the causes of deterioration would repay investigation.

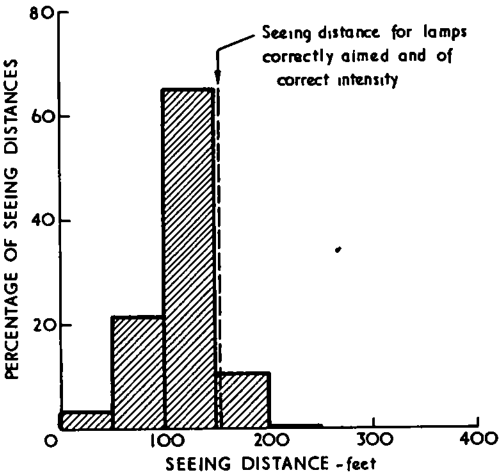

Figure 5. Calculated seeing distances for Washington, D. C.

The investigations described in this note have shown that glare from the lower beams of American vehicles is slight, but in the course of the work it was noticed that many American drivers refused to "dip" their headlights (change to lower beam) or left it far too late. Two counts, made on rural roads in Texas, showed that 20 to 25 percent of all drivers met kept their upper beams on, or did not change until they were very near. Unfortunately, no observations were made in any other states, and it is not known whether the same high proportion is met elsewhere. Even if the proportion in other states is lower, it still seems likely that most of the dazzle nuisance in the United States of America is due to this reluctance to use the lower beam. This is in contrast to the situation in Great Britain where glare is mainly due to misaim and deterioration, and only to a minor extent to refusal to change to lower beam (3).

REFERENCES

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2. V. J. Jehu, "A Method of Comparing the Performance of Vehicle Meeting Beams." Road Research Laboratory Note No. RN/1597/VJJ, July 1951. (Unpublished.)

3. Road Research Laboratory, Department of Scientific and Industrial Research. "Interim Measures for the Prevention of Dazzle on Roads." Road Research Technical Paper No. 14. London, 1948. (H. M. Stationery Office, England.)

APPENDIX

The Glare Meter

The glare meter used for the measurements described in this paper was designed to fulfil the need for a small portable instrument requiring no elaborate apparatus or electrical supplies, and capable of being brought into use quickly whenever a suitable opportunity occurred. The basis of the meter is the S.E.I. visual photometer with which the luminance (brightness) of a surface can be measured. The instrument consists of a small telescope of unit magnification, which is pointed at the object. In the center of the field of view is a comparison spot, whose brightness can be matched to that of the object by adjusting a calibrated rheostat fitted with a logarithmic scale. At comparatively short distances the intensities of a headlamp or pair of headlamps may readily be determined with an instrument of this type by using it to measure the luminance of a white surface of known luminance factor placed at a known distance from the lamp or lamps. If the luminance factor of the surface is β , and the measured luminance at a distance d is α foot lamberts, then the intensity in candelas is

$$c = \frac{\alpha}{\beta} d^2$$

For the purpose of the investigation, however, this simple arrangement had to be modified to (1) provide increased sensitivity in order to be able to measure small intensities and to work at large distances, and (2) screen off unwanted light from street lamps and other headlights. The way this was done is shown in Figures 1 and 2.

Lens A in Figure 1 is directed towards the lamp to be measured and produces a rectangular defocussed image on the diffusing screen, B. The brightness of this image, as seen through the diffusing screen, is then measured with the S.E.I. photometer, through auxiliary Lens C. Lens A has a focal length of 2.75 in. and is fitted with a rectangular stop measuring 0.75 in. by 0.375 in. It is placed at a distance of 2.45 in. from the diffusing screen, on which it produces a rectangular image about 0.08 in. long; the luminance of this image is found to be about 40 times greater than that of a perfectly diffusing plate illuminated directly by the lamp being measured.

The optical components are mounted in a stout cardboard tube, which can be firmly attached to the S.E.I. photometer in the manner shown in Figure 1. The tube is divided into two parts at the paper screen, and is provided with suitable internal baffles to intercept stray light.

Before use, the cardboard tube is adjusted so that the comparison spot of the photometer is centered on the diffusing screen which is marked to enable this to be done. This ensures that the same part of the screen is always used.

The glare meter was generally used at a distance of about 350 ft., and both lamps of a vehicle were measured at once. This was readily done, since at distances greater than 250 ft., the images of the two headlights overlap enough for a single measurement of combined luminance to be made. Reference to a calibration curve for the appropriate distance then gives the intensity.

The glare meter was calibrated in the United States with a car headlamp, operated on its upper beam, as light source. A white plate of known luminance factor was set up at 300 ft. from the lamp and five measurements of its luminance were made. Five measurements were then made with the dazzle meter from exactly the same position. This procedure was repeated from different positions with respect to the axis of the beam. Intensities of several thousand candelas had to be used in this method of calibration, and it had the disadvantage that extrapolation of the results had to be made.

In a second method, by which another calibration was later made at the Road Research Laboratory, a headlamp, whose light output could be varied over the range of intensity encountered in the glare measurements, was viewed from a distance of 300 ft., and the readings were compared with those of a photoelectric light meter of known calibration. The resulting calibration curves were used for the analysis of the glare results. They refer to two headlamps and therefore include a correction to take account of the imperfect diffusing properties of the paper screen, which result in the combined reading being 10 percent less than the sum of the two readings taken separately.

The standard error of a single reading of the meter is estimated to be 10 percent.