A Substitute for Road Tests of Automobile Headlights

GEOFFREY GRIME, Road Research Laboratory,
Department of Scientific and Industrial Research,
United Kingdom

A method of comparing vehicle headlights is described, in which the opinions of drivers are obtained under controlled conditions on a test track. The method is intended both to supplement the usual tests in which the distances at which objects are recognized are determined and to replace road trials, where many conditions are uncontrolled.

Tests with headlamps providing passing beams of four different types are also described. On both wet and dry roads, a pair of new British twin-dipping headlamps was preferred to other lamps tested, although a pair of lamps of a continental make was almost as well liked. Assessments of glare indicated that it was judged to be higher on wet roads than on dry ones, and that a glaring intensity of 400 to 500 candelas from each of the headlamps was easily tolerated on dry roads.

Suggestions are made for further investigations of glare on dry and wet roads.

THE standard experimental method of testing vehicle headlights is that described by Roper and Howard (1) in which a car is driven along a straight track to meet another equipped with similar headlights and the distance at which a test object can be seen is determined. Such tests give a series of distances at which objects are detected in the presence of glare from a similar opposing headlamp. They do not indicate whether the beam gives the driver confidence in his ability to place his vehicle on the road, and to judge this quality in the beam, road tests are often advocated.

The usual way of making road tests of a headlamp is to use the lamp in the ordinary course of driving on the public roads and to form an opinion of its merits without making any measurements. A serious objection to this as a method of test is that it is not fair to judge a lamp by its performance when meeting anything but a similar lamp, and this is not possible on the road. The object of the present paper is to describe a substitute for road tests, carried out on a test track in such a way as to approximate road conditions; the results of a series of comparisons of headlights in the passing condition are also given; and some conclusions are drawn concerning the desirable distribution of light in the beam. No novelty is claimed for these conclusions, which are in general agreement with views put forward by Nelson (2) in 1945.

The method of test described in the paper has recently been used in international comparisons of headlights carried out under the auspices of the International Commission on Illumination.

METHOD OF TEST

The original tests were carried out on part of the concrete perimeter track of London Airport, made available by permission of the Air Ministry Works Directorate. Two lengths of track were used on different occasions, and the dimensions and layout of one of them are shown in Figure 1. It was chosen to provide a reasonable length of straight track and two curves; one curve had a radius of curvature of 300 feet and the other of 400 feet. From previous work it was known that on trunk roads in Buckinghamshire about 99 percent of the curves had radii greater than 400 feet; the curves were therefore more severe than would normally be met on trunk roads near London. The track was level and there was a vertical concrete curb on one side of the track and no curb on the other. The verges were flat and grassy and there were no hedges or trees. Obstacles consisting of rectangles of sacking on wooden

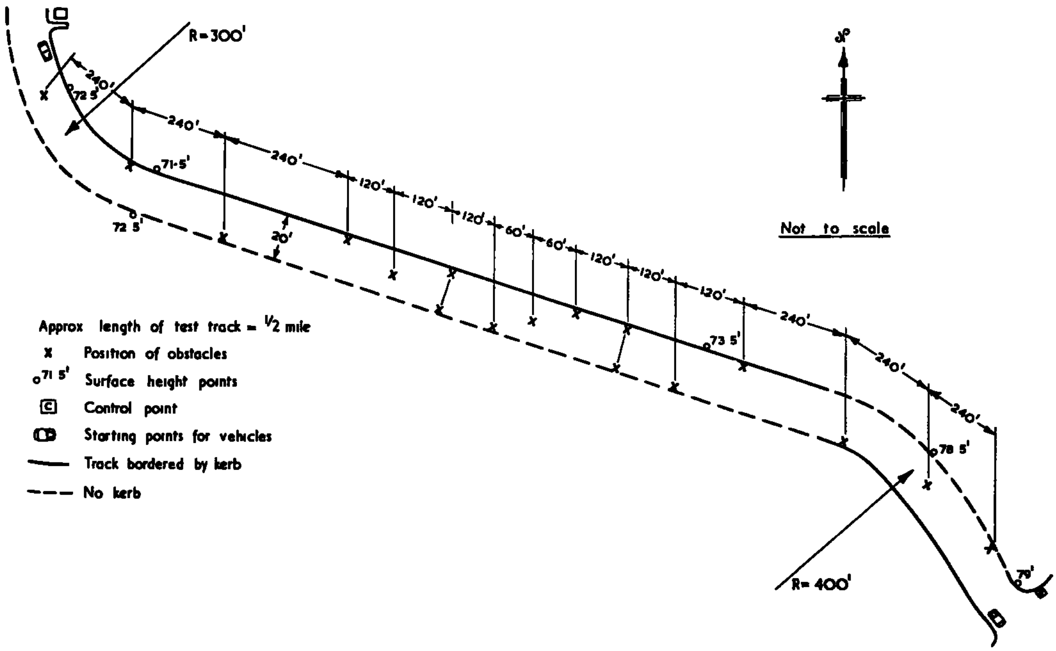

Figure 1. Plan of track used for final tests.

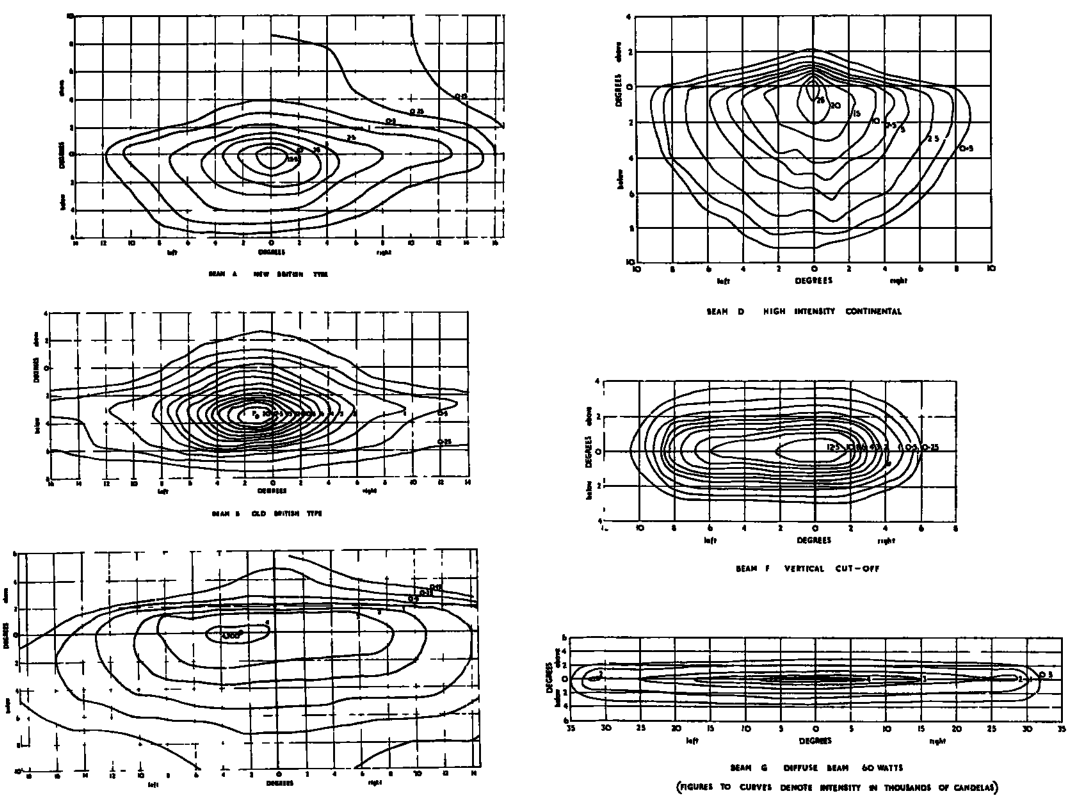

Figure 2. Light distribution curves; left, Beams A, B and C; right, Beams D, F and G.

frames were set up in three lines, one at each side of the road and one in the middle, with the spacings shown in Figure 1. Those placed at the side of the road were 2 feet wide by 4 feet 4 inches high; those centrally placed were 5 feet high but were only 9 inches wide. All had reflectivities, at normal incidence, of about 9 percent.

TABLE 1

PARTICULARS OF BEAMS COMPARED IN THE TESTS

Reference letter	Type	Maximum intensity (candelas)	Adjustment
A	Asymmetric, twin dippers, new British type	13000 (each lamp)	Main Beam ½ deg down (Peak 3 deg down and 3 deg left)
B	Asymmetric, single dippers, old British type	25000	Main beam ½ deg down
C	Symmetrical, twin dippers, continental type	4000 (each lamp)	Cut-off set 1 deg down (Peak 3 deg down and 2 5 deg left)
D	Symmetrical, twin dippers, continental type	28000 (each lamp)	Cut-off set 1 deg down (Peak 2 deg down)
E	Symmetrical, twin dippers, continental type (type D under-run)	11000 (each lamp)	Cut-off set 1 deg down (Peak 2 deg down)
F	Asymmetric, vertical cut-off, single lamp	14000	Peak 2 deg down, cut-off set straight ahead
G	Diffuse beam similar to K 24-watt bulb, single lamp		Peak 3 deg down
H	Diffuse beam, similar to K 36-watt bulb, single lamp		Peak 3 deg down
K	Diffuse beam, 60-watt bulb, single lamp	4000	Peak 3 deg down

Two test cars carried the lamps to be compared, which were arranged so that a change could be made from one lamp to another by turning a switch. Although all lamps were mounted at the same height, it was not practicable to have the alternative lamps in exactly the same lateral positions, but this is unlikely to have affected the results appreciably. The lamps were mounted with their centers 3 feet above the ground.

The observers actually drove the cars during the tests; all but two were unconnected with the planning of the tests and did not know, at any rate for some time, which lamps were being tested.

The test procedure, evolved after preliminary experiment, was for each driver to make eight runs, four as observer and four as driver, using, say, Lamps X and Z, in the order X Z Z X X Z Z X. The driver was told to drive over the course at 30 mph. After eight runs he recorded his preference for either X or Z, both with and without opposing glare. In many of the later tests, he also recorded his estimate of the degree of dazzle for both X and Z, choosing one of the following degrees of glare: none, slight, dazzle, or excessive dazzle. The tests were made on wet and dry surfaces; the wetting was done by means of a water tanker on those nights when there was no rain.

SYSTEMS COMPARED

The comparisons were confined to passing systems, i. e., the dipped headlights or special lamps used when two vehicles meet. The passing beam is probably more important from the point of view of safety than the driving beam; a glare survey (3) carried out by the laboratory in 1947 showed that on British trunk roads the passing system was in use for about four times as long a time as the main driving beam; the conditions of seeing are also more critical when it is in use, since the distances at which objects on the road can be seen are much less in the presence of glare from opposing lamps than when the road is clear.

Excluding systems using polarized light, passing-systems may be divided into four main types: (1) those with a horizontal cutoff, and symmetrical light distribution, as used on the continent of Europe; (2) the asymmetric type with no pronounced horizontal cutoff, as used in the United States and Britain; (3) those with a vertical cutoff, throwing light only on the nearside of the road; and (4) the noncutoff type with a widely diffused beam of low intensity.

The lamps tested comprised examples from each class. Particulars are given in Table 1, and distribution curves are given in Figure 2. In view of the interest at present shown in the relative merits of American and continental types, the main comparison was between examples representing these systems, but a considerable amount of information was also obtained on Items 3 and 4 (above).

It is, of course, also possible to combine the four main types to produce others, but none of these hybrid types has yet been thoroughly tested.

RESULTS AND CONCLUSIONS

Table 2 gives the results of the opinion tests, and Table 3 the judgements of glare. Because of the comparatively small number of observers (a maximum of 12 for any test condition) the differences between lamps are rarely statistically significant.

It will be noted that in Table 3 only two degrees of glare are recorded; this gives a clearer picture of the results than

TABLE 2

COMPARISON OF PASSING BEAMS AGAINST A AS STANDARD

Lamp compared with A (New British Type)	Dry Road				Wet Road			
	Without Glare		With Glare		Without Glare		With Glare	
	Preferred lamp	Score*	Preferred lamp	Score	Preferred lamp	Score	Preferred lamp	Score
B (Old British type)	A	8/11	A	8. 5/11	A	11/12	A	9/12
C (Low intensity continental)	C	7/12	A	6. 5/12	No preference	6/12	A	7/12
D (High intensity continental)	No preference	6/12	A	9/12	D	8/12	A	10/12
E (D under-run)	A	6 5/12	A	8/12	No preference	6/12	A	9/12
F (Vertical cut-off)	A	2/2	A	2/2	No preference	1 2	A	2/2
G (Diffuse beam 24 watt)					A	3/4	A	4/4
H (Diffuse beam 36 watt)	No preference	2/4	A	4/4	No preference	2/4	A	4/4
K (Diffuse beam 60 watt)	K	3/4	A	3/4				

*The score is the number of drivers who voted for the preferred lamp divided by the total number of drivers voting (Half-votes arise from drivers having no preference).

that obtained by including all the four degrees of glare, although in making the observations it is easier to choose from four than from two possible degrees. In future experiments it would be advisable to use the description "negligible dazzle" instead of "no dazzle", since there was always a small amount of glare from the opposing lamp, and drivers found difficulty in deciding when to use the term "no dazzle."

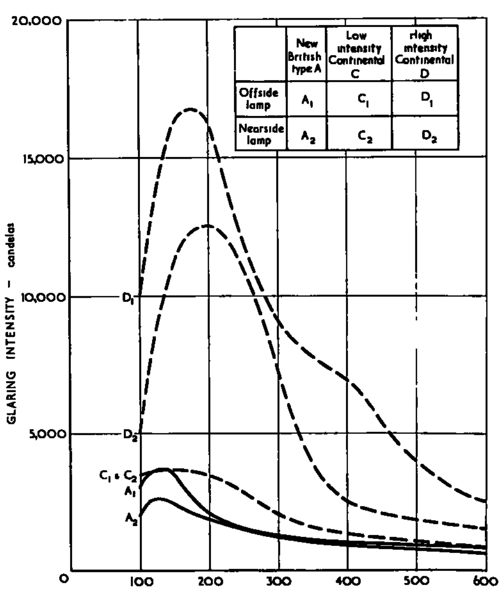

Figure 3. Intensity directed towards the road surface so as to be reflected at the angle for mirror reflection towards the driver.

The distances at which a target, 18 in. high and having a luminance factor of 7 percent, might be expected to be seen have been calculated for the first five beams by a method developed at the Road Research Laboratory (4, 5). The target was assumed to be placed centrally in the path of the car and 10 feet behind the opposing car. The calculated seeing distances are A, 150 feet; B, 170 feet; C, 140 feet; D and E, about 250 feet. The larger calculated distances of D and E depend upon the small central areas of high intensity which were a feature of the particular lamps tested.

The main conclusions from the tables and from the tests as a whole were:

1. The new British twin-lamp passing system, A, was preferred in almost all the trials, and particularly on wet roads, where glare was prevalent. The continental system, C, was judged to be nearly as good under all conditions, and it would not be possible on the basis of these tests, to choose between the two. It may be noted that the peak intensity of A was three times that of C.

2. It is sometimes stated that, when driving with the continental lamps in the dipped position, the sharp horizontal cut-off is quite noticeable, giving the impression of driving into a wall of blackness. No effect of this kind was noticed in these tests and drivers were generally

unable to tell whether they were using a continental beam or the new British beam. None of these continental lamps had a really sharp cutoff, however, and it is possible that the effect may be observed with lamps of other continental makes.

TABLE 3

PERCENTAGE OF DRIVERS WHO GAVE THE ASSESSMENT "DAZZLE" OR 'EXCESSIVE DAZZLE"

	A (New British type)	B (Old British type)	C (Low intensity continental)	D (High intensity continental)	E (D under-run)	G (Diffuse beam 24 watt)	H (Diffuse beam 36 watt)	K (Diffuse beam 60 watt)
Dry	6	27	15	50	8		25	50
Wet	19	33	25	92	50	100	67	

3. System A represents an improvement on the old single-lamp British system, B, particularly as regards glare and comfort in driving on wet roads.

4. The tests with Lamp E, which had a vertical cutoff, confining all the light to the left-hand side of the road, were discontinued because it was impossible to see the test objects in the middle of the road, and on two runs on a wet road, a target was knocked down.

5. The diffuse Systems F, G, and H, which only differed in the wattage of the bulb, gave pleasant driving conditions when no opposing car was present, but were more glaring than System A, particularly on wet roads.

6. With every passing system for which a glare assessment was made, the glare on the wet road was judged to be higher than on the dry road.

The last conclusion is in accordance with common experience and is probably due to two factors: first, the luminance of a wet road surface viewed from the driver's seat due to his own headlamps is several times lower than that of the same road when dry. On this particular road the dry surface was seven times brighter at 40 feet, five times at 60 feet, and three times brighter at 80 feet than the same wet surface. Discomfort glare from a given glare source has been shown by Hopkinson (6) to increase as the brightness of the background decreases. Background brightnesses used by Hopkinson were somewhat higher than those for wet roads, and the conditions differ in other ways, but there is no reason to suppose that the same general trend does not apply. The second factor is the brightness of the streak on the wet road surface, which itself acts as a glare source. The tests furnish some evidence that this second factor is of importance, since there was an indication that the symmetrical beams (C, D and E) were more prone to dazzle on wet roads than the asymmetrical ones. The symmetrical ones have a greater intensity in a direction likely to be reflected from the wet road surface to the eye of the oncoming driver than the asymmetrical, as is shown in Figure 3. (The intensities in this figure are only approximate, since they depend very much on the lateral separation of the vehicles.)

7. Except for the new British type, A, the amount of glare was considerable. For the old British single lamp, B, the proportion of people judging this lamp to be dazzling on dry roads was one in four.

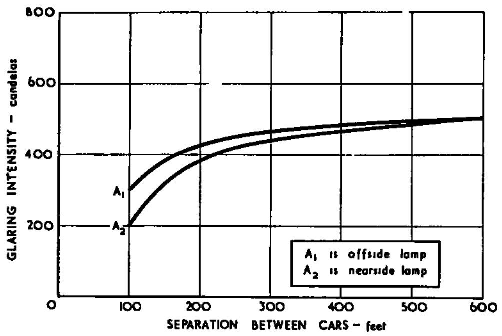

Figure 4. Intensity towards the opposing driver's eye for Beam A (new British type).

8. Some information concerning the intensity considered glaring may be obtained from the tests with Beam A. Eleven out of sixteen drivers classed this beam as giving slight dazzle on dry roads; four thought it gave no dazzle. On dry roads the glaring intensity appears to have been reasonably satisfactory. The variation of glaring intensity for each lamp with distance between the cars is given in Figure 4; this shows that 400 to 500 candelas from each lamp can easily be tolerated.

9. In the course of the tests many beams were compared which are not described in this paper. Among them were some very-narrow beams, and it was observed that the driver's preferences were influenced considerably by the distribution of light in the beam. Broad beams, which lit up the curb and grass verges and the road near the car, were preferred to narrower but otherwise similar beams, possibly because with the broad beams the driver knew his exact

position on the road. In the tests described in this paper, several drivers remarked unfavorably on the restricted width of continental Beam D; on the other hand, continental System C, which has a wide and uniform beam of low peak intensity, was well liked.

A review of the tests as a whole suggests that more investigations might usefully be made of glare on dry and wet roads. The conditions on dry roads present the simpler problem, and it might be possible to carry out laboratory experiments to determine the glaring intensities corresponding to various degrees of dazzle under different conditions of background and target luminance. On wet roads there is the additional complication of the image of the glaring light in the wet road. From other work at the Road Research Laboratory (7, 8), it appears likely that glare is less troublesome on roads with an open-textured surface (large texture depth) than on smooth roads. Not only is there less glare from the bright streak, but the road reflects more light back to the driver so that the beam from the headlight is defined well enough to give the driver confidence. The relation between the luminance coefficients of the surface and beam distribution of the passing system for least glare and best and most comfortable vision require investigation.

ACKNOWLEDGMENT

This paper was prepared at the Road Research Laboratory of the Department of Scientific and Industrial Research, United Kingdom, and is published by permission of the Director of Road Research.

REFERENCES

1. Roper, V. J. and E. A. Howard. Seeing with motor car headlamps. Trans. illum. Engng Soc., (U. S. A.), 1938, 33 (May) 417.

2. NELSON, J. H. The automobile headlamp: a study of the beam distribution needed for motor vehicle driving lights. Trans. illum. Engng Soc., Lond., 1945, 10 (3), 49-76; Discussion, 76-81.

3. ROAD RESEARCH LABORATORY. Interim measures for the prevention of dazzle on roads. Department of Scientific and Industrial Research, Road Research Technical Paper No. 14. London, 1948 (H. M. Stationery Office).

4. JEHU, V. J. A method of comparing the performance of vehicle meeting beams. Department of Scientific and Industrial Research, Road Research Laboratory Note No. RN/1597/V. J. J. (Unpublished.)

5. HARRIS, A. J. Design of the meeting beam of the automobile headlight. Highway Research Board, Bulletin No. 68. Washington, D. C., 1953 (National Research Council, Division of Engineering and Industrial Research, 1953), pp. 40-53.

6. HOPKINSON, R. G. Discomfort glare in lighted streets. Trans. illum. Engng Soc. Lond., 1940, 5 (1), 1-24.

7. CHRISTIE, A. W. The influence of texture depth on the appearance of a lighted street when the surface is wet. Department of Scientific and Industrial Research, Road Research Laboratory Note No. RN/1529/AWC. (Unpublished.)

8. CHRISTIE, A. W. The influence of texture depth on road surface brightness as seen by a driver in the light of his headlamps. Department of Scientific and Industrial Research, Road Research Laboratory Note. No. RN/1457/AWC. (Unpublished.)