# Night Legibility Distances of Highway Signs

TERRENCE M. ALLEN, Highway Research Engineer,
Virginia Council of Highway Investigation and Research [1]

● TRAFFIC SIGNS have always played a significant role in the convenience and safety of drivers on the highways. On limited-access facilities, which are now entering a period of great expansion, the motorist is forced to rely to a greater degree on signs. To perform its function effectively, a sign must have good legibility at night as well as in the daytime. The increased need for overhead signs and the need for larger letter sizes make new demands on reflectorized materials. The use of illuminated signs is increasing. There is need for data on the legibility of reflective materials in these applications, and for a comparison of their legibility to that of artificially illuminated signs. It is to this problem that this study addresses itself.

In previous studies, the night legibility of signs has been studied in the laboratory (1), and the photometrics of reflectorized materials on the highway have been outlined (4). When the results of these two studies are combined theoretically, it is possible to predict the distance at which signs can be read on the highway, given the type and size of lettering, the illumination conditions surrounding the sign, and laboratory photometric measurements of the reflective material. In this way design standards can be developed, and the performance of a new material can be evaluated without extensive field study.

However, it is important that the results of laboratory studies be checked in the field before they are used in practice. Therefore the purpose of the present study was to validate in the field both phases of the laboratory work.

Full evaluation of the theoretical considerations will require extensive analysis, and will be reported in a later paper. This paper presents the practical results which were obtained, and their implications for sign design and usage at the present time.

As in all previously reported studies, only "pure legibility" (the distance at which people can read a sign) was studied. Although such factors as glance legibility, target value, and attention value are important (2) they were outside the scope of this research. Only white or silver letters on a black background were investigated. The effect of color of background is a topic of importance because of effects color may have on target value or attention value of signs. However, previous studies (5, 6) have demonstrated that the effect of background color on "pure" legibility is small so long as the brightness contrast between letters and background is not reduced too much. The results of this study, therefore, would have been nearly the same if colored backgrounds had been used, providing that the colored backgrounds were not too high in brightness.

Three types of reflective material were studied in letter sizes of eight to eighteen inches. In addition to night observations on reflective materials, observations were made on a sign with four levels of artificial illumination. Daytime legibility distances were also recorded to provide a baseline for night legibility data.

## PROCEDURE

The experiment was conducted on a straight flat section of rural highway near the University of Virginia. Deviations in horizontal and vertical alignment were less than 7/10 of a ft. An overhead sign was mounted near one end of the section, and a roadside sign near the other. Observers sat in the front seat beside the driver, and had no task but reading the signs. The car approached the test sign at about 15 mph. As soon as the observer could read the test sign he spoke the message word. When the sign was read correctly, a recorder seated in the back seat read the distance from a foot-odometer or from stakes at the side of the road.

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[1] The data for this research was collected while the author was with the Council of Highway Investigation and Research. The paper was completed while the author was employed by the Highway Traffic Safety Center at Michigan State University.


Figure 1. Overhead test sign.

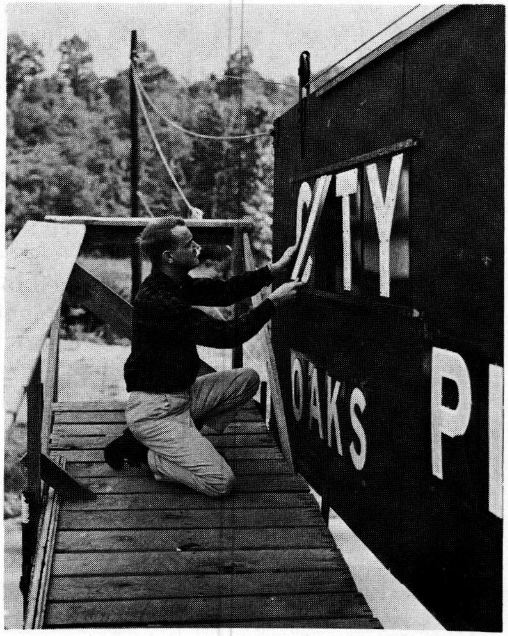


Figure 2. Placing letters on test sign.

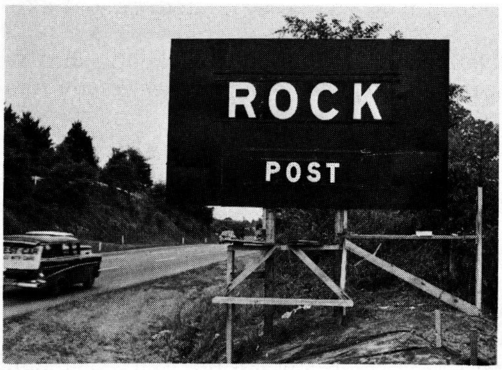


Figure 3. Roadside test sign.


Figure 4. Test car approaching sign.

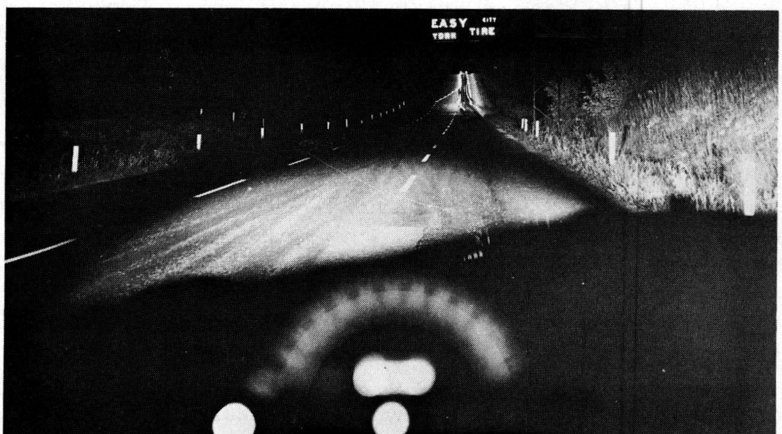


Figure 5. Driver's view of test sign at night.

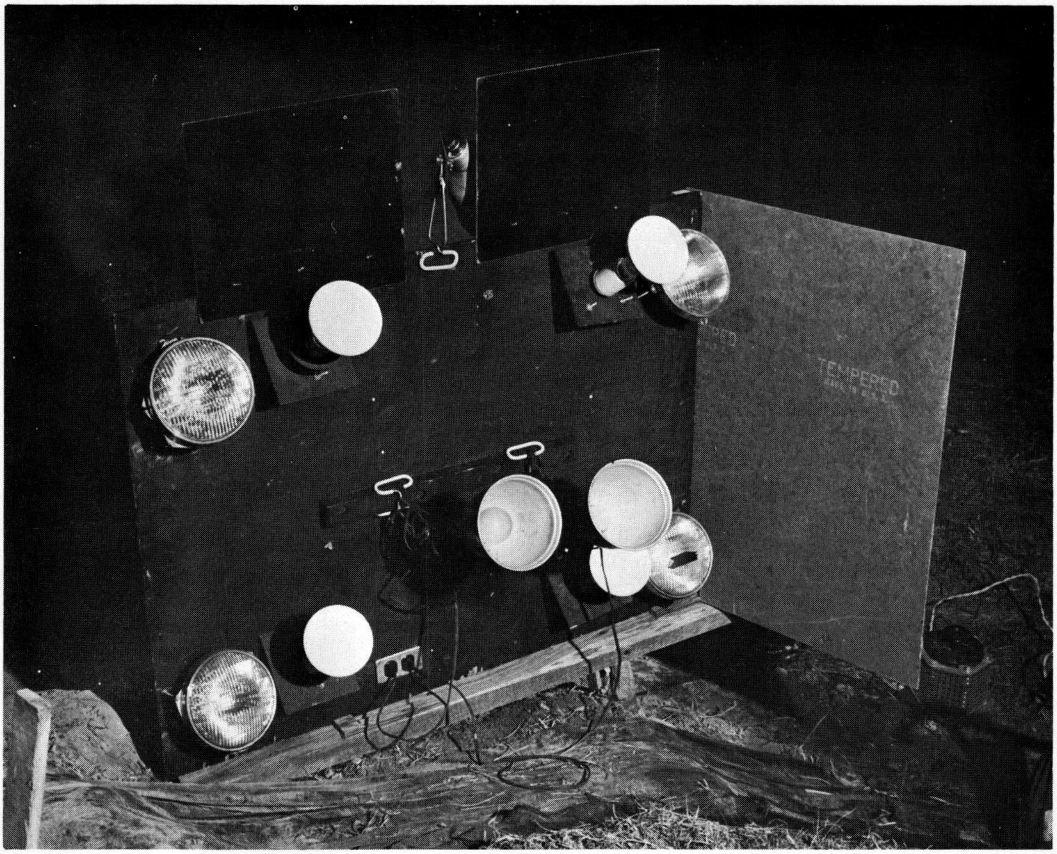


Figure 6. Bank of lamps for illuminated sign.

Test signs were viewed against a dark field at night, and observers had no glare from headlights of other cars. Near the center of the section of roadway, a restaurant was located on one side and a service station on the other. Although some glare was introduced by their lights, no better location was available.

Test Signs. Sign position should have no effect on the distance at which a sign is legible in the daytime, and should have no effect on the night legibility of an illuminated sign under the conditions studied. For reflective materials, however, since they depend upon illumination from headlamps, night legibility is very significantly affected by sign position. Both signs were positioned to be representative of sign positions on the Interstate System. The overhead sign was located over the travelled lane, with the center of the sign 20 ft above the pavement. The center of the roadside sign was 12 ft above the level of the pavement and 20 ft to the right of the pavement edge.

Figure 1 shows the overhead sign, which was mounted on pulleys on spanwires over the pavement. In order that message difficulty not affect results differentially, it was necessary that messages be changed after each test run. After each run, the sign was pulled over to the scaffold and a new set of messages was put in place. Figure 2 shows the letters being put in place. Each letter was mounted on hardboard with margins to give the proper spacing between letters. Figure 3 shows the roadside sign, upon which letters were mounted in the same way.

Test Car. The test car is shown in Figure 4, and Figure 5 shows the driver's view of the overhead sign at night. Typical G. E. No. 5040 headlamps were used with standard aiming. Voltage was controlled at the standard voltage for these lamps. Observations were made with both upper and lower beams.

Illuminated Sign. For the artificially illuminated sign four levels of illumination

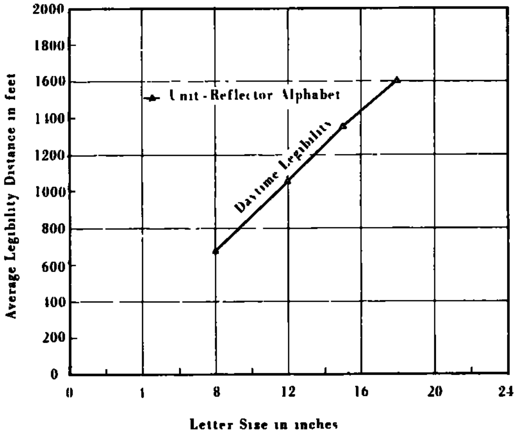


Figure 7. Daytime legibility distances.

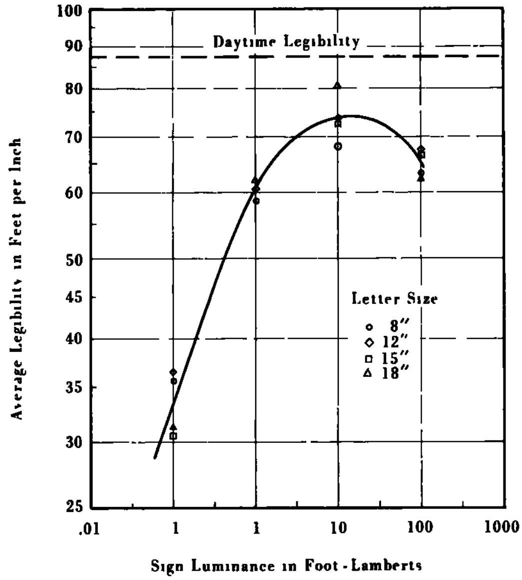


Figure 8. Legibility of artificially illuminated sign.

were used, yielding luminances of the letters of 0.1, 1, 10, and 100 ft-lamberts. It was found that conventional illumination fixtures would not yield such a wide range of levels of illumination, and their illumination was not sufficiently even for the purposes of this experiment. Therefore, the bank of tungsten lamps shown in Figure 6 was constructed. Since the effect of illumination would not be affected by sign position (and it was desired to save the overhead sign for use with reflective materials) the effect of sign illumination was studied with the roadside sign. Light from headlamps had negligible effect on the luminance of the white paper letters.

Reflective Materials. Three reflective materials were included in the experiment. These included the two materials which have been used most extensively on limited-access facilities, and a new material intended for such use. The materials were as follows:

1. Flat Sheeting - cut-out letters of a silver reflective sheeting consisting of glass spheres embedded beneath a flat outer surface.
2. Unit Reflectors - white metal letters in which round plastic reflector "buttons" are embedded.
3. Plastic-Covered Sheeting - a high-brightness silver beaded sheeting covered by a sheet of clear plastic which was sealed

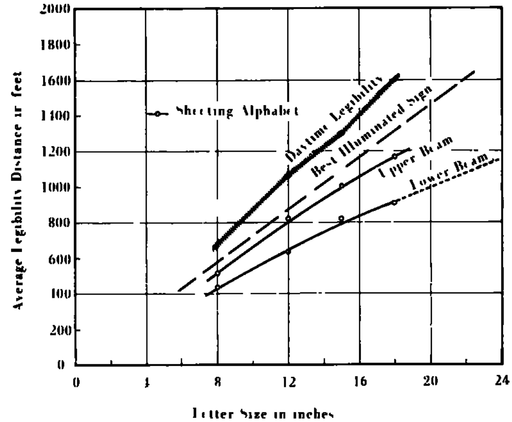


Figure 9. Legibility distances for flat sheeting on overhead sign.

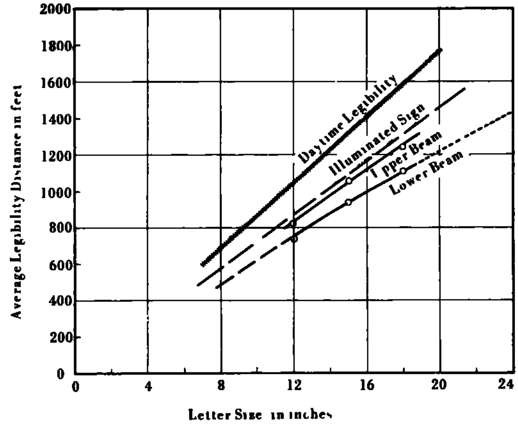


Figure 10. Legibility distances for plastic-covered sheeting on overhead sign.

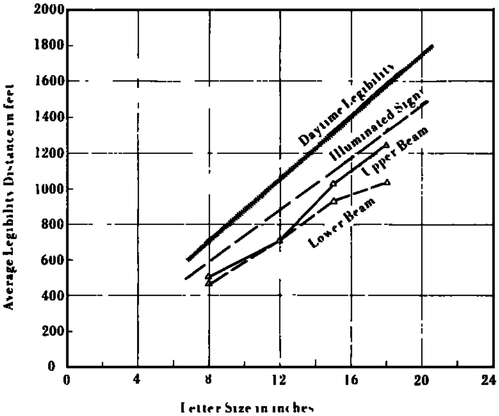


Figure 11. Legibility distances for unit-reflector letters on overhead sign.

to the sheeting by a means of a white plastic strip around the edge of the letter.

Alphabets. Each reflective material was used in the capital-letter alphabet recommended by the manufacturer. The flat sheeting material used an alphabet which was essentially the standard Series E, except that the stroke-width was 0, 20 in. per in. of letter height instead of 0.172 in. per in. of letter height. It is nearly identical to the alphabet previously studied by Forbes et al. (3). This same alphabet was used for the artificially-illuminated sign. The plastic-covered sheeting also used this same alphabet; however, the effective stroke width at night was 0. 14 in. per in. of letter height, because the plastic edging of these letters was not reflectorized. The alphabet of the unit-reflector letters was slightly narrower, but it also has a stroke-width of 0. 20 in. per in. of letter height.

It would have been desirable to have all materials identical in alphabet, so that all differences in results would be due to differences in reflective material. Although this was not possible, it was possible to equate the alphabets so that differences in alphabets would have negligible effect on results; this was done by modifying the recommended spacing between unit-reflector letters. The unit-reflector letters were slightly narrower, and the recommended spacing between letters was considerably less - resulting in about 10 percent less required sign space. The spacing between unit-reflector letters was increased so that the sign space required for the two alphabets would be approximately the same. In accordance with the manufacturer's recommendation, the additional spacing was added as a constant to each space between letters; ⅒ in. per in. of letter height was added to the recommended spacing between the unit-reflector letters. The manufacturer's recommended spacing for the sheeting letters was used without modification. Results to be presented later in this report showed that the desired result had been achieved—the daytime legibility of the two alphabets was almost identical.

Messages. Words to be used in messages were chosen so that a minimum of letters would be needed. In order that words could not be recognized by their length alone, all words were of the same length. Twelve messages of approximately equal legibility were used: FORK, TROY, ROCK, POST, PIKE, TIRE, CITY, LAST, EASY, CLAY, STAY, and OAKS. These messages were possible using only ten letters of the alphabet, ACEIKORSTY, plus letters which could be made by masking portions of these letters. The letters used accounted for 70 percent of the letters in a sample of 150 place names along Virginia's proposed Interstate routes.

Observers. The 48 test observers, 36 males and 12 females, ranged in age from 17 to 63, with an average age of 33. None were acquainted with the reflective materials used. Those who normally wore glasses when driving wore their glasses during the tests. Their far visual acuities with both eyes, measured by the Bausch and Lomb Ortho-Rater, ranged from 20/25 to 20/14 with an average acuity of 20/18.

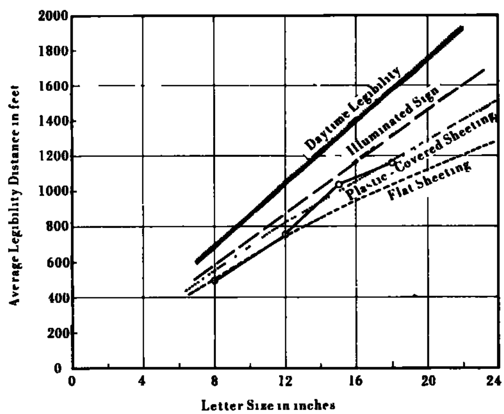


Figure 12. Unit-reflector letters on roadside sign with lower beams, and estimated curves for flat sheeting and plastic-covered sheeting.

Each observer was used for both day and night observations.

Design of Experiment. The experiment was designed to permit an accurate statistical analysis. Half the subjects made night observations first, and half made day observations first. Each subject viewed each combination of material, letter size, headlamp beam, etc. The order in which each subject viewed each material, sign position, headlamp beam, and message was determined by an incomplete block design.

## RESULTS

A total of 2,880 observations were obtained. Average legibility distances were computed using a log transformation to give proper weight to extreme observations. Since the car was travelling 15 mph., the car travelled some distance between the time the observer read the sign and the time that the recorder read the distance. If no correction were made, all legibility distances would be slightly too short. The combined reaction time in this case was estimated to be 0.7 sec, during which time the car travelled 15 ft. A correction of 15 ft was therefore added to all average legibility distances.

Daytime Legibility. Figure 7 shows the average legibility distance for each letter size in the daytime for the two alphabets. Since results were essentially the same for the overhead and roadside signs, the points shown are the average of both sign positions. It is clear that there was no significant difference between the alphabets when the spacing between unit reflector letters was augmented so that they require the same amount of sign space as the sheeting letters. For both alphabets, the average legibility distance was 88 ft per in. of letter height.

Illuminated Sign. Results for the artificially illuminated sign are shown in Figure 8. Results were plotted in a different form in order to illustrate the basic relationship between level of illumination and night legibility: when illumination is too low, legibility distance is low; as illumination is increased to an optimum value, the legibility distance reaches a maximum; when illumination is so high that the letters are too bright, legibility is less than the maximum. It is clear that the optimum luminance was in the neighborhood of 10 ft-lamberts. Similar results were found by Forbes and Holmes (2). A luminance level of about 10 ft-lamberts is obtained from many fluorescent fixtures now in use. It is clear that 100 ft-lamberts (such as is obtained with some internally illuminated signs) was too bright for this alphabet in the conditions studied.

However, the conditions of this experiment must be borne in mind. Observations were made in a dark rural area, without glare from headlights of oncoming cars. It is safe to predict that a much higher level of illumination will be required in urban areas in which the surrounding illumination is much higher, and where bright glare sources are in the field of view. There is need for legibility data collected under such urban conditions. Also, this experiment used white Series E letters, with strokewidth 0.20 letter height, on a dark background. Although results should be similar for any letters which have a stroke approximately equal to the enclosed dark space, quite different results would be obtained with a narrower stroke width. A discussion of the effect of stroke width on the required sign brightness can be found in a previous paper (1).

Figure 8 also illustrates the relation between daytime legibility and night legibility. The dashed line at the top of the figure shows daytime legibility results for comparison. Even with optimum illumination, night legibility distances were about 15 percent less than day legibility distances. Similar results were found by Forbes and Holmes (2).

Reflective Materials on Overhead Sign. Results for flat sheeting material on the overhead sign are shown in Figure 9. Smooth curves consistent with theory have been drawn through the points obtained from results for upper beams and for lower beams.

Daytime legibility results are shown for comparison. The dashed line in Figure 9 shows the results obtained from the illuminated sign with a luminance of ten ft-lamberts. This dashed line estimates the best night legibility that could be obtained with a sign with optimum illumination. A "perfect" reflective material could give results as high as this dashed line but could not exceed it. The dashed line, therefore, can be used in evaluating the results for reflective materials.

With upper headlamp beams, flat sheeting on the overhead sign could be read nearly as far as the best-illuminated sign. However, for lower headlamp beams, flat sheeting was significantly less than the "perfect" illuminated sign - from about 25 percent less for 8-in. letters to 30 percent less for 18-in. letters. The lower beam curve has been extrapolated to 24-in. letters. Although no observations were made with 24-in. letters, the extrapolation should not be seriously in error. It gave an estimate of 35 percent less than the best-illuminated sign.

Results for plastic-covered sheeting on the overhead sign are shown in Figure 10. The upper beam results were very close to the best possible as shown by the dashed line. (No points are shown for 8-in. letters because this material was not available in that size.) For lower beams, legibility distances were about 15 percent less than the best-illuminated sign. The extrapolation to 24-in. letters gives an estimate 20 percent below that for the best-illuminated sign.

Figure 11 shows the results obtained for unit-reflector letters on the overhead sign. For this material no smooth curves could be drawn, because there was no fixed relation between letter size and the reflectors used in the letters. Legibility distances for lower beam were 20 percent less than "perfect" for 8-in. and 12-in. letters, 16 percent less for 15-in. letters, and 22 percent less for 18-in. letters.

On the roadside sign, legibility observations were made with only one type of material, and with lower beams only. These results, for unit-reflector letters, are shown in Figure 12. Legibility distances on the roadside sign were considerably better - only 6 percent less than the "perfect" illuminated sign for 12-in. letters, and 12 percent less for 18-in. letters.

Although the other materials were not tested on the roadside sign, curves estimated from theory were added to Figure 12 for comparison. These curves show an increase over the results for the overhead sign, similar to the increase obtained for unit-reflector letters. This was in accordance with the common knowledge that reflective materials give better performance on roadside signs than on overhead signs. However, the difference between overhead and roadside signs should not be overemphasized. Note that for lower beams and letter sizes above 12 in., the curve for flat sheeting on the roadside sign (Figure 12) is not as high as the results for the two brighter materials on the overhead sign (Figures 10 and 11).

## DISCUSSION

A note of caution is needed regarding conclusions based on extrapolated curves and the theoretical curves of Figure 11. Although they are not believed to be seriously in error, conclusions based on small differences should be avoided. Also, differences between the best-illuminated sign and reflective materials may be slightly too large.

Use of the curves for design purposes would be seriously in error. They are based on observers with average vision riding slowly beside the driver, straining their eyes to read familiar messages. The data would be more meaningful if presented as the distance at which drivers with normal 20/20 vision can see the letters clearly. The data of Forbes et al. (3) makes possible such an estimate. Using a similar alphabet to the ones used in this study, observers with approximately 20/20 vision read scrambled letters at about 56 ft per in. of letter height. (Also, one minute of visual angle, the theoretical basis for 20/20 vision, corresponds to 57 ft per in. for these alphabets.) The average daytime legibility distance in this study was 88 ft per in. of letter height. Therefore, the letter sizes on the graph should be increased roughly 50 percent to be seen clearly by a driver with 20/20 vision. It may be helpful for the reader to renumber the horizontal axis of Figures 9-12 accordingly.

It should also be pointed out that the experiment was done under ideal conditions. All materials were new, clean, and dry. There was no rain or fog, and dew was not allowed to collect on the signs. No headlamps or luminaries caused glare in the observers' eyes, and the signs were viewed against a dark background. Further research is needed to determine the necessary allowances for these factors.

Results make possible the definite conclusion that in a dark rural area where no unfavorable conditions of alignment exist, overhead signs using reflective materials can give satisfactory performance. Results do not bear out the common conclusion that all overhead signs must be artificially illuminated and no roadside signs must be artificially illuminated. Results suggest that either of the brighter materials, when used on an overhead sign, can give legibility distances as high as the flat sheeting material on a roadside sign. It is suggested that consideration be given to the use of reflectorized overhead signs in rural areas where there are no unfavorable conditions of highway alignment or surrounding illumination; and that consideration be given to the use of illuminated roadside signs where unfavorable conditions exist.

## ACKNOWLEDGMENTS

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