DEPARTMENT OF TRAFFIC

ARNOLD VEY, *Chairman*

LEGIBILITY DISTANCES OF HIGHWAY DESTINATION SIGNS IN RELATION TO LETTER HEIGHT, LETTER WIDTH, AND REFLECTORIZATION

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SYNOPSIS

A previous paper by one of the authors analyzed sign efficiency into (1) pure legibility (long time), (2) glance legibility (short glance), (3) target value and (4) priority value, the latter two factors dealing with attention getting characteristics. This report deals with an extensive study of the first factor, pure legibility, of standard series B (narrow letters) and series D (wide letters), black on white destination signs. Letter heights from 6 to 24 inches were used.

A total of about 400 people acted as observers and made about 4600 individual observations. Charts show maximum legibility distance in relation to height and width of letter, reflectorization and illumination (day vs. night). The determination for each size, width and type of letter depended on a group of from 50 to 276 observations.

The wider letters showed greater effectiveness than the narrower ones, but both widths lost approximately 15 per cent of their legibility distance under night conditions (floodlighted). Rough practical norms for day conditions and "normal" vision gave 50 ft. per in. of letter height for the wide and 33 ft. per in. for the narrow letters. It is suggested that these values should be reduced in practice to take account of the poor vision of many drivers known to be on the highways.

The results also indicated the advantage of floodlighted signs at any location where a lighted background is encountered. Reflectors reduced the daytime legibility of the letters only in the largest sizes, and the reflectorized letters were as effective as the floodlighted ones at night against a dark background.

It is suggested that glance legibility tests will probably reduce the legibility distances somewhat, and that a correction factor may be developed, to correspond more closely to brief glimpses of signs often necessitated by heavy traffic.

If the results are applied to give the motorists 10 seconds warning at a speed of 50 miles per hour, *at least* a 10 inch series D or a 12 inch series B letter is needed for night conditions.

A number of traffic officials and others interested in traffic engineering have come to the opinion that methods of improving the effectiveness of certain types of highway signs should be studied. Varying opinions are found as to what characteristics make a highway sign seen most easily and the standard manual on Uniform Traffic Control Devices represents an attempt to standardize and crystallize the best opinion on this subject.

There is, however, still a wide field in which lack of agreement is characteristic. Specifically; is it more effective to use a 6-in. high series D letter or a 10-in. series B? The latter is relatively narrower and hence can be fitted in where the wider letter could not. This problem is especially pertinent for long names on destination signs. Another specific question is whether or not floodlighted signs are more efficient and can be read farther than reflectorized signs, again thinking of the destination sign. A problem which arises on newer highways due to an increase of design speed is that of the oversized sign which is recommended by the Standard Manual when conditions warrant. What size of letter should be indicated to give a certain amount of warning or legibility distance? Can the legibility of smaller letters be multiplied up on a proportional basis to obtain legibility distances for large signs? And what distances can be used for letters of various proportions?

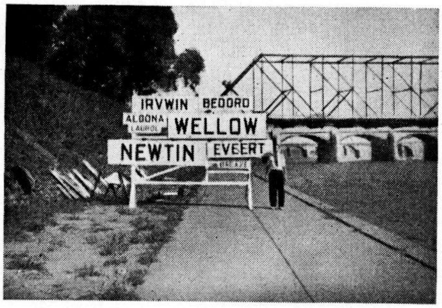
A method for the analysis of highway sign efficiency which will answer these questions has been worked out and demonstrated to be practical in a previous paper.[1] Four basic factors of sign efficiency were derived as follows: legibility, glance legibility, target value, and priority value. This analysis followed in rough fashion other analyses that had been made in the field of advertising, but with modifications to meet the highway problem.

Pure legibility was used to indicate the maximum distance at which sign copy could be read under optimum conditions, *i. e.,* with no distraction and unlimited time. Glance legibility indicated the distance at which a sign could be read under quick glance conditions, such as those where a driver must attend to other cars and has just a fleeting glimpse of the sign. Target value indicated that characteristic of a sign which makes it stand out as different from other signs and objects. Priority value was applied to the characteristic which causes one sign to be seen first from among a number of other very similar or identical signs.

The present paper reports a more extensive study of the first factor, *i. e.,* pure legibility distance, of standard black on white destination signs, relating two-letter widths and letter height to legibility distance under day and night conditions. It is hoped that studies of other factors may be carried out later by ourselves or others.

Method

A large number of observations were obtained using standard destination signs under both night and day conditions with reflectorized and unreflectorized letters. Figure 1 shows how eight different signs



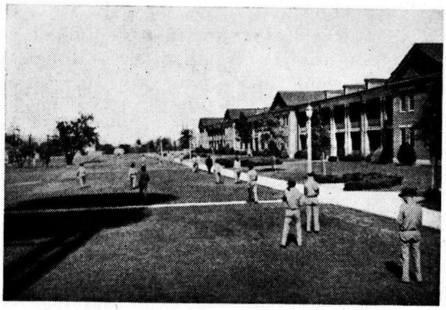


Figure 1

Upper—Series D Signs Mounted for Day Test.

Lower—Observations in Progress, Illustrating Scatter of Different People on the Same Sign.

were mounted at one time. The observers were first stationed at a distance of about 1400 feet where they were unable to read any of the signs. They then approached the signs and recorded the letters seen and the distance at which they were first able to read them. Distances were chalked on the pavement at 20-ft. intervals. By this modification of the previous technique it was possible to utilize

[1] Forbes, T. W., A Method for Analysis of the Effectiveness of Highway Signs. *Journal, Applied Psychology,* 1939.

the observers in groups of 30 or 35 and thus expedite the amassing of a large number of observations. The observers were on foot and three supervisors checked to insure proper recording.

Test Signs

Six-letter words were painted in black on white boards. Words were chosen from the vicinity of the Pennsylvania Turnpike to add realism to the test and each six-letter word included one misspelling in order to guard against guessing by the observers. This precaution proved important since some 400 faulty observations (in which the misspelling was not recorded) had to be thrown out from the approximately 5000 total obtained. Five variations of each test word were thus obtained. This allowed the use of a different series of test words for each group of observers. In this fashion it was possible to present to each group a new test in spite of discussion of the tests by members of the same organization.

Six letter heights were used in the plain letter for each of two widths (series D and series B). Three letter heights were provided in the reflectorized series D letter. The reflectors used were of glass and for the 6-in. letter were 0.5 in. in diameter; for the 12 and 18-in. letter they were 0.7 in. in diameter.

Letter Proportion and Spacing

Letter dimensions and proportions were obtained from working drawings for series B and series D letters as listed in the Manual for Uniform Traffic Control Devices.[2] For convenience these dimensions are shown in Table 1.

Since spacing is known to be of importance it was desirable that the spacing used should be definitely specified. In determining the spacing several alternatives from usual practice appeared. Constant spacing was discarded because it gives a poor balance and therefore poor appearance. A varied spacing was obtained which had been derived for practical use[3] and which was satisfactory as to appearance, but involved some 50 combinations of letters and spacing.

In order to make this system more practical, it was necessary to reduce the spacing to a simpler basis, which could be used in the sign shop. This was done by approximating the spacing and by expressing all spacings in terms of *adjacent strokes,* rather than *adjacent letters.* Thus three spacings resulted as follows: spacing between (1) parallel strokes, (2) a slanting and a vertical stroke, and (3) strokes slanting toward each other.

On this basis it was found practical and fairly easy to lay out lettering for the sign painter and the results were always predictable. This spacing attempts to equalize somewhat the area between letters due to different letter shapes. Table 2 gives the detail of the three spacings together with illustrations of their applications.

For night observations the upper half of the signboard containing unreflectorized signs was floodlighted. This was done by mounting seven 50-watt goose-necked lamps to shine directly on the test signs. Power was obtained from the batteries of two cars in order to obtain easy mobility and to be able to operate where power was not available from city lines. A switch was supplied to cut off the floodlights when observing reflectorized signs under headlights alone. Illumination intensity as measured by a Weston light meter ranged from 5 to 15 foot-candles. A reflection factor of about 0.3 was indicated after the signs had become somewhat dirty from use and handling, so that an average brightness of about 3 footlamberts was estimated to be not far wrong.

[2] Obtained from the Public Roads Administration, Washington, D. C.

[3] By the Signal Service Corporation.

TABLE 1
PENNSYLVANIA TURNPIKE COMMISSION
Dimensions for Stencil Letters and Numbers for Large Signs

Height inches	Stroke inches	WIDTH-INCHES											
		I	1	EF LT	BCDGHN OPQRSUZ 23567890	4	J	K	V	M	AY	W	X
SERIES "B"													
4	1/2	1/2	5/8	1 1/2	1 11/16	1 15/16	1 19/32	1 3/4	1 27/32	1 15/16	2 1/8	2 3/16	1 27/32
6	3/4	3/4	15/16	2 1/4	2 1/2	2 7/8	2 3/8	2 5/8	2 3/4	2 7/8	3 1/8	3 1/4	2 3/4
8	1	1	1 1/4	3	3 3/8	3 7/8	3 3/16	3 1/2	3 11/16	3 7/8	4 1/4	4 3/8	3 11/16
10	1 1/4	1 1/4	1 9/16	3 3/4	4 3/16	4 13/16	4	4 3/8	4 5/8	4 13/16	5 1/4	5 7/16	4 5/8
12	1 1/2	1 1/2	1 7/8	4 1/2	5	5 7/8	4 3/4	5 1/4	5 1/2	5 7/8	6 1/4	6 1/2	5 1/2
18	2 1/4	2 1/4	2 7/8	6 3/4	7 1/2	8 3/4	7 1/8	7 7/8	8 1/4	8 3/4	9 3/8	9 3/4	8 1/4
24	3	3	3 3/4	9	10	11 1/2	9 1/2	10 1/2	11	11 1/2	12 1/2	13	11
SERIES "D"													
4	11/16	11/16	7/8	2 7/16	2 11/16	2 15/16	2 1/2	2 3/4	3	3 3/32	3 11/32	3 1/2	2 11/16
6	1	1	1 1/4	3 5/8	4	4 3/8	3 3/4	4 1/8	4 1/2	4 5/8	5	5 1/4	4
8	1 3/8	1 3/8	1 3/4	4 7/8	5 3/8	5 7/8	5	5 1/2	6	6 3/16	6 11/16	7	5 3/8
10	1 11/16	1 11/16	2 3/16	6 1/16	6 11/16	7 5/16	6 1/4	6 7/8	7 1/2	7 3/4	8 3/8	8 3/4	6 11/16
12	2	2	2 1/2	7 1/4	8	8 3/4	7 1/2	8 1/4	9	9 1/4	10	10 1/2	8
18	3	3	3 3/4	10 7/8	12	13 1/8	11 1/4	12 3/8	13 1/2	13 7/8	15	15 3/4	12
24	4	4	5	14 1/2	16	17 1/2	15	16 1/2	18	18 1/2	20	21	16

For reflectorized signs the headlights of a car were trained upon the three signs on the lower half of the signboard. The car proceeded abreast of the group of observers so that the light was always roughly at the point of observation. For the majority of observations a 1938 Chrysler was used with newly replaced headlight bulbs, giving approximately 50,000 beam candles. The hot spot was aimed directly ahead and depressed so as to strike 32 in. above the ground 200 ft. ahead of the vehicle when loaded. (Top of hot spot about 1.4 deg. below the horizontal.) Observers stood on the rear bumper so that a loaded condition was obtained. The signs were directly in front of the car and therefore illumination should have been somewhat better than ordinarily obtained on the shoulder. However, the hot spot did not fall directly on the signs at any point, a condition similar to that under which most signs are seen on highways.

TABLE 2

SPACING SYSTEM FOR STANDARD CODE LETTERS

Code letter	Spacing between	Illustration	
X	Parallel strokes.	||	OBN
		// \\	AV
	F, L, J and parallel stroke.	F/ L\	LVJ FA
Y	Sloping and vertical stroke.	/| |/	VBAKD
	T, E, F, L and vertical stroke.	_|‾	EFB LT
Z	Opposite sloping strokes.	/\ \/	VY KA
	T, E, F, L and opposite sloping stroke.	_/‾	TVLAJ

NOTE: Spacing is measured between two nearest points of adjacent letters.

Letter height	Spacing								
	Series "B"			Series "C"			Series "D"		
	X	Y	Z	X	Y	Z	X	Y	Z
6	7/8	5/8	1/2	1 1/8	7/8	5/8	1 5/16	1 1/16	3/4
8	1 1/8	7/8	5/8	1 1/2	1 3/16	13/16	1 13/16	1 7/16	1
10	1 3/8	1 1/8	3/4	1 13/16	1 7/16	1	2 3/16	1 11/16	1 3/16
12	1 11/16	1 5/16	15/16	2 1/4	1 3/4	1 1/4	2 11/16	2 1/16	1 1/2
18	2 1/2	2	1 3/8	3 3/8	2 5/8	1 7/8	4	3 1/8	2 1/4
24	3 3/8	2 5/8	1 7/8	4 1/2	3 1/2	2 1/2	5 3/8	4 1/8	3

The mounting of the signs was such that the highest portion of the reflectorized signs was between five and six feet above the road, and the lowest approximately three feet in an attempt to obtain mounting heights somewhat similar to those ordinarily found and indicated as standard by the Manual.

Personnel

Some difficulty was experienced in obtaining sufficient personnel and for that reason the total number of observers is smaller than had been planned originally. It was found possible to hold each group of observers about one-half hour, which was the time required for a complete set of observations, on eight series D and five series B signs. The observers consisted of engineering office personnel, members of the national guard, and enrollees of an army medical school. The ages of the last two groups tended toward the lower end of the scale, and both groups would be expected to have better vision than some drivers on the road. This factor was accounted for later.

Groups were scheduled in a fashion as convenient as possible for the personnel.

Results

A total of 4,623 observations was obtained from 412 different persons divided between day and night groups. Each plotted point in the curves is based on from 50 to 276 observations as shown on each distribution.

The various observers were able to read a given test sign at widely different distances, as would be expected. Thus, for a given letter height (see Fig. 2 as an example) the legibility distances showed ranges of from 300 to roughly 700 ft. It was therefore necessary to present the results in the form of a frequency distribution.

For our purposes, the most reliable measure obtainable from such distributions is probably the median, or middle case, and this value has therefore been indicated and a median trend line shown. Similarly the 80 percentile values, *i. e.*, the distance at which 80 percent of the group were able to read the sign, has been determined and its trend line indicated. These 80 percentile values are probably of most interest for the determination of practical sign legibility distances. Furthermore, 95 percentile points have been indicated in order to show the distances for those with the poorest vision. These 95 percentile points are not of as great statistical reliability since a much larger sample would be required to determine accurately the points at the extremes of the distribution.

Figures 2 to 6 show the results for the wider, or series D letter, while Figures 7

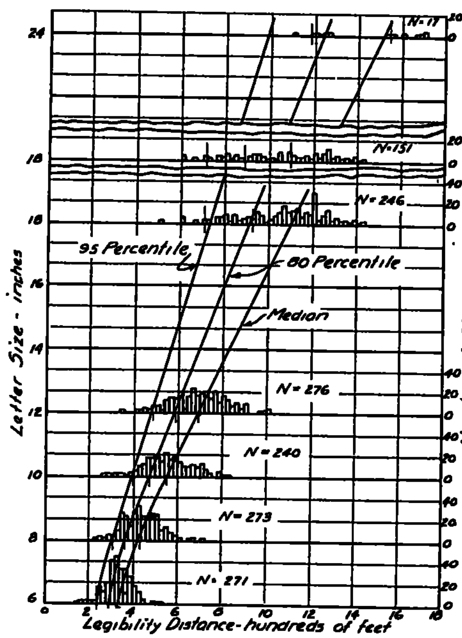


Figure 2. Daylight Legibility, Black on White, Series D Letters, Unreflectorized

and 8 show those for the narrower, or series B letter. Each figure represents observations made by the same group of people on the six-letter test words for letter sizes of 6, 8, 10, 12, and 18 inches, as indicated. One very small group of observations is shown in Figure 2 for 24-in. letters. It was unfortunately impossible to obtain more observations with this size sign.

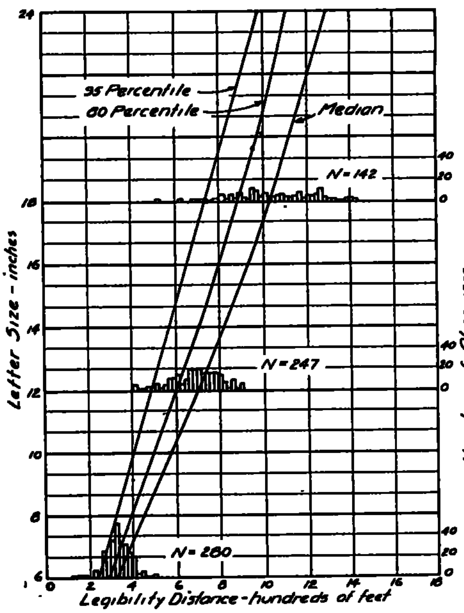


Figure 3. Daylight Legibility, Black on White, Series D Letters, Reflectorized

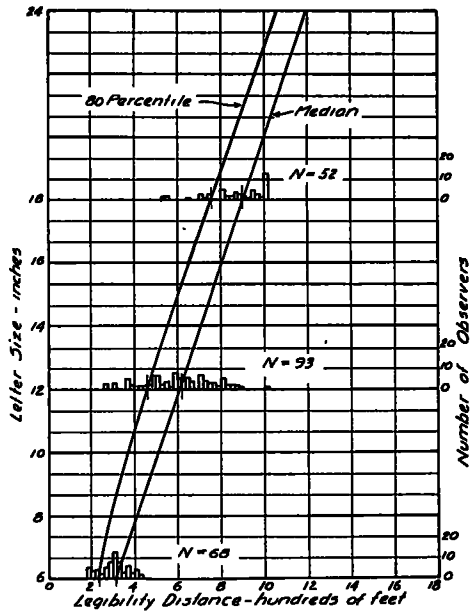


Figure 5. Night Legibility, Headlights, Black on White, Series D, Reflectorized. Dark Field, Scattered Street Lights.

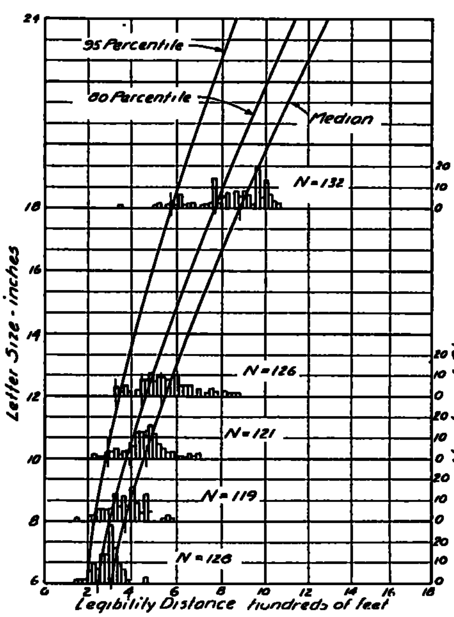


Figure 4. Night Legibility, Floodlights, Black on White, Series D Letters, Unreflectorized. Illumination 5-15 Foot Candles, Average Brightness 3 Foot Lamberts.

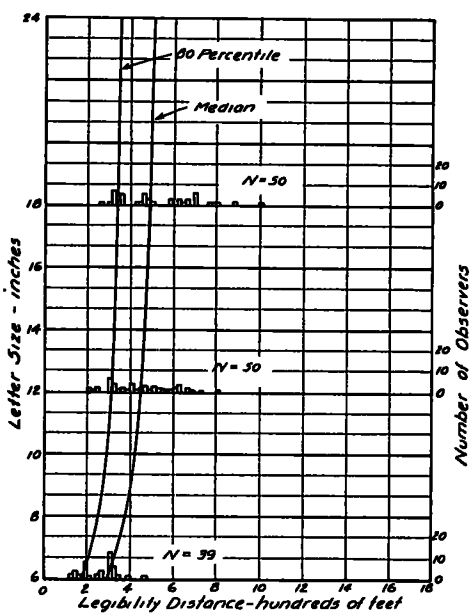


Figure 6. Night Legibility, Headlights, Black on White, Series D Letters, Reflectorized. Lighted Field, 3 Foot Lamberts. Scattered Street Lights.

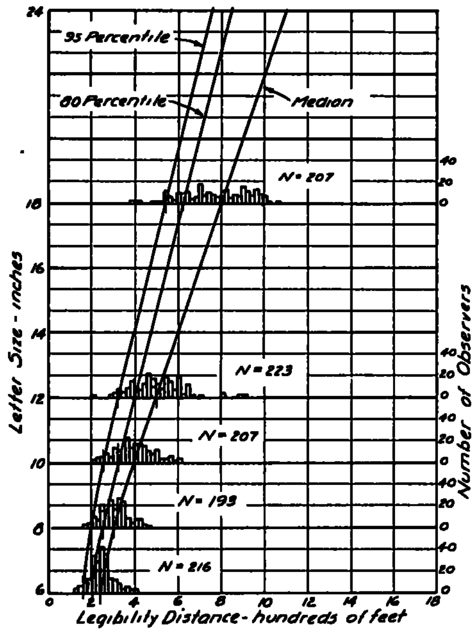


Figure 7. Daylight Legibility, Black on White, Series D Letters, Unreflectorized

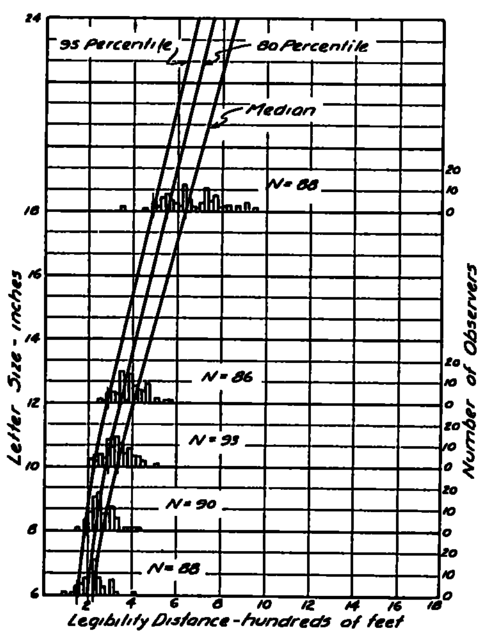


Figure 8. Night Legibility, Floodlights, Black on White, Series B Letters. Illumination 5-15 Foot Candles, Average Brightness 3 Foot Lamberts.

Trend Indices

It will be seen that the medians fall in a very consistent fashion and that the trend varies slightly from a straight line. The 80 percentile trends are generally similar to those for the medians, but show a shorter legibility distance to the extent of from 50 to about 200 feet. The 95 percentiles show a greater variation from the median than the 80 percentile, as would naturally be the case, and also a poorer conformity of the plotted points through the trend line, indicating poorer reliability for this measure.

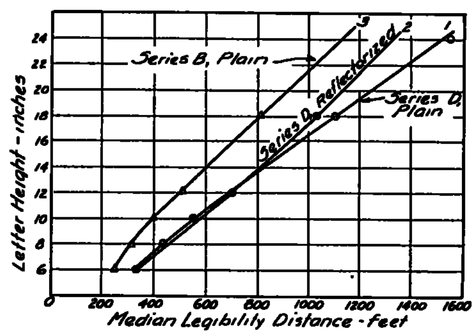


Figure 9. Effect of Width and Reflectorization, Daylight Median Values. Series D, Wider Letters. Series B, Narrower Letters.

Therefore, for purposes of comparison of letters under different conditions, medians will be used, whereas practical legibility distances will be based on 80 percentile figures. The range of vision represented will be shown later to give a further reason for choice of the 80 percentile as a base for practical values.

Day Legibility

The results for the different letters under day legibility conditions are summarized in Figure 9. As shown by the medians, the narrow letters (series B) gave from 100-300 feet less legibility distance than the wider letters for the range of letter sizes compared. The reflectorized letters showed practically no difference in legibility from the plain or unreflectorized letters in the smaller letter sizes.

Night Legibility

The night observations again show a similar relationship between the wide and narrow letters as indicated by the medians in Figure 10. Here again it will be seen that the narrow letters gave from 80 to 250 feet less legibility distance, when unreflectorized letters are compared.

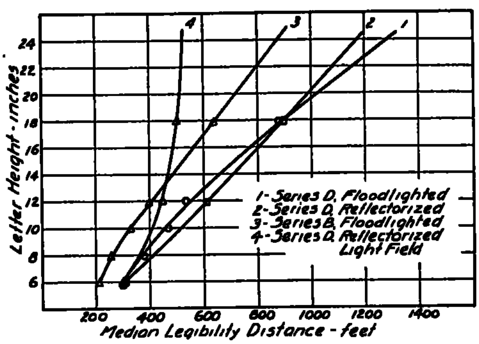


Figure 10. Effect of Width and Reflectorization at Night. Median Values

Day versus Night Legibility

When the legibility distances for the wide letters are compared on a day and night basis, it appears, as shown in Figure 11, that the floodlighted letters gave from 25 to 200 feet less legibility (8 to 20 per cent). Similarly for the narrower, or series B letters, the loss under floodlighting at night was from 30 to 150 feet of legibility distance (12 to 20 per cent). It will be noted that the loss was proportionally greater for the higher letters and longer distances, a result which is probably explainable as due to low effective brightness of the signs at long distances at night.

Effect of Reflectorization

As previously noted, it was possible to reflectorize only series D letters, and therefore conclusions must be limited to results from the wide letters. With this reservation, however, the effect of the reflectors in the black stroke of the letter was negligible under day conditions up to the 12-in. size (see Figure 9). For the larger letters (18-in.) there appears to have been some loss in legibility distance.[4] This is understandable since reduced contrast would be more deleterious at a long distance where the effective brightness of the signs is very much reduced.

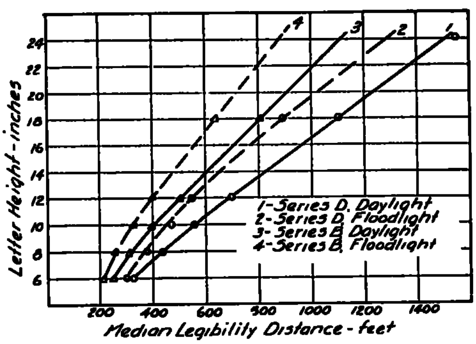


Figure 11. Comparison of Night and Day Legibility. Median Values

The night legibility of the reflectorized letters, when viewed under headlights and in a dark field, was approximately the same as for our floodlighted letters for the same height and width (see Figure 10). The condition referred to as "dark field" includes some scattered street lights of low wattage but no field of light close to the sign.

On the other hand, the same reflectorized letters under the same headlights lost from 30 to 50 per cent of their legibility distance when viewed against a low-intensity light field directly above them. The light field consisted of the lighted signs of approximately three foot-

[4] This was not due to the smaller number of cases as shown by comparison with the insert in Figure 2 which represents the smaller group on plain letters.

lamberts brightness. The reduction occurred in the two larger sizes as shown in Figure 10. Apparently any increase in size above 12 inches under these conditions resulted in very little increase of effective distance. This points out the need for greater intensity of reflected light if the signs are to be viewed against any lighted background, providing the irradiation from the greater intensity does not offset its advantage. Conversely, reflectorized signs would seem to be most effective in locations where a dark background is to be expected a large proportion of the time.

Practical Distance Values

In order to determine from our observations the practical distance at which signs of a given letter height and width are legible to the driving public, it is necessary to make some estimate of the vision of our observers as related to that found on the highway. Such an estimate was attempted by giving the ordinary Snellen eye test (chart) to two groups of observers. Their records for the 6-in. test words were then compared with their record on the Snellen test. Figure 12 shows a comparison of the Snellen and the sign observations and indicates the method of deriving the visual scale represented by the 6-in. letters in daylight.

In order to determine a point corresponding to 20/20 vision, the median of the 20/20 group (eye test) was assumed to correspond to the score of this median person on the 6-in. letters. Other acuities were then figured on a proportional basis and the scale plotted as shown. Its approximate correctness is indicated by the rough correspondence of the range of eye test scores and of computed vision for the two small groups. Unfortunately some individuals were transferred from groups 4 and 5 before the eye test was given, so that group 1 gives the more reliable index.

By this procedure, it was indicated that our 80 percentile point represented approximately 20/20 vision, and our 95 percentile approximately 20/30 vision. In other words, the vision of our observers was better than average in eye test terms.

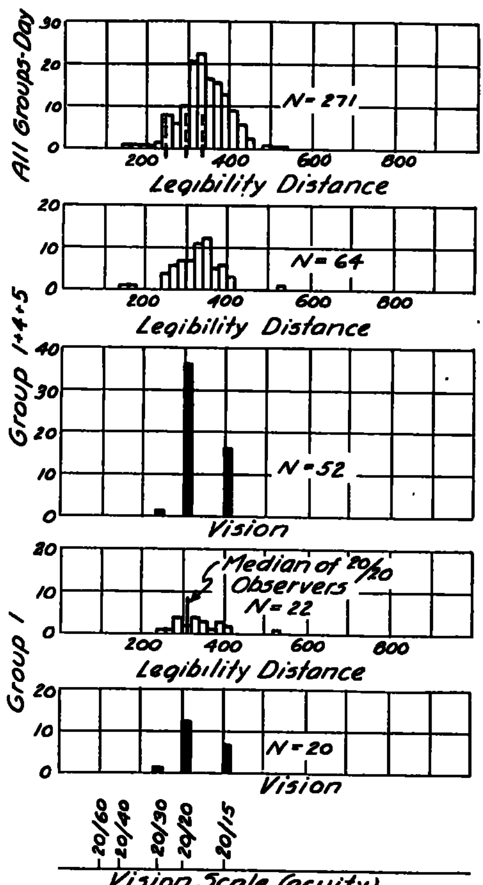


Figure 12. Eye Tests and Legibility Distance Snellen Tests on Two Subgroups of Observers Related to Their 6-Inch Legibility Distance. Visual Scale Derived from This Comparison Indicates Range of Vision Represented in Total Group of Day Observers.

Median of 20-20 Eye Test Group Equated to Corresponding 6-Inch Legibility Distance. Visual Scale Computed Proportionally from This Point.

This was to be expected, since our army and national guard observers were a selected group and since the engineering office personnel undoubtedly had better visual correction than many whose job does not call for use of the eyes on close work. On the basis of these results, our 80 percentile distances may be taken as representing 20/20 vision and should be used rather than the medians in order to be conservative.

However, it should be remembered that 20/40 vision (50 per cent vision) is used to qualify drivers in a number of states and therefore a certain proportion of drivers of this type is to be expected on any highway. Distances corresponding to 20/40 vision can be determined by

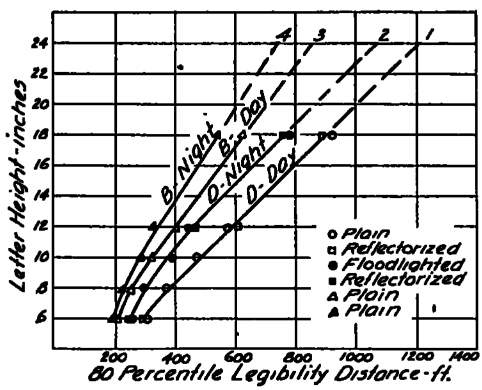


Figure 13. Practical Legibility Values Corresponding to 20/20 Vision, 80 Percentile Figures.

taking 50 per cent of the distance shown on our chart in Figure 13.

In deriving the practical values shown in this figure the plain and reflectorized values for the wide or series D letter under day conditions have been thrown together. Similarly, the floodlighted and reflectorized values for night observations have been lumped in order to give a single approximate line of relationship. (Although the medians indicate that the difference between plain and reflectorized letters is a real one, nevertheless, for practical purposes the 80 percentiles may be considered roughly the same, as will be seen from the scatter of the points around the line.) Curves for the series B 80 percentiles are also included. It will be remembered that the 80 percentiles are from 50 to 200 feet shorter than the median values.

Comparison by Letter Width

One of the original questions which was posed in the introductory paragraphs may now be answered from Figure 13. The values shown indicate that under day conditions, the narrower 10-in. series B is slightly more effective in terms of legibility than the 6-in. series D, and the 8-in. series B is approximately 80 per cent as effective as the 6-in. series D letters. A similar relationship is found for night conditions.

On the other hand, during the day an 18-in. series B letter shows approximately the same maximum legibility as a 12-in. series D, while under night conditions the 18-in. series B is about 22 per cent more effective than the 12-in. series D. Or, stated in another way, at night the 12-in. series D and the 15-in. series B are approximately equal. Any other comparisons may be made in similar fashion as desired.

Practical Importance of Nonlinearity

As noted above, for practical purposes the relationship of letter height and width to legibility distance may be stated in terms of approximate straight lines. Actually, a curvilinear characteristic is noticeable between 6 and 10-in. values. The variation represented by the points on the curve, when translated into terms of visual angle, correspond to slight fractions of one minute of arc. In fact, as shown in Figure 14, the variations between the night and day values (series D) falls between a theoretical constant minimum visual angle of 1 min. and a constant angle of 1.5 min. Variations in acuity have been demonstrated from 0.5 to 7.0 min. due to a difference in brightness which would correspond to part of our range.[5] Any such variation must be the resultant of complex reactions of the eye and is beyond the scope of this paper, except that it indicates our variations to be reasonable.

The practical importance of a curved characteristic relationship between letter size and legibility distance is obvious if an attempt is made to project the relationship found with small test letters to make it apply to larger sized letters. If brightness or other relationships result

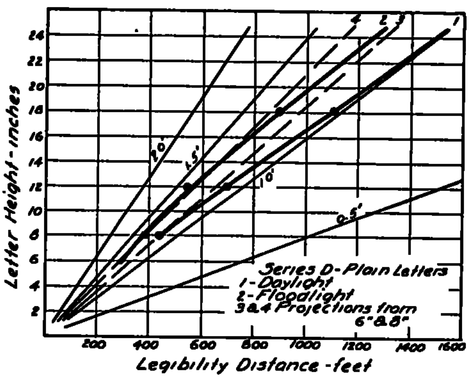


Figure 14. Error from Projection. Dotted Lines Indicate Projected Values from Small Letters Alone on the Assumption of a Linear Relationship.

Lines Marked 0.5′, 1.0′, 1.5′ and 2.0′ Represent Theoretical Values Assuming the Indicated Minimum Constant Visual Angle.

in a curvilinear relationship, it becomes much more difficult to extrapolate the curve for larger signs and makes it necessary to know the characteristic curvature fairly definitely.

It will be noted that if only the smaller sized letters had been employed the relationship might easily have been interpreted as linear. The error which would have occurred from the extrapolation of such a linear trend line is shown in Figure 14.

However, the use of smaller letters for test purposes is much easier and more convenient and would be possible if the curved characteristic is known.

DISCUSSION

Obviously many other factors which were not included in our situation will affect the practical distance at which signs are read under traffic conditions on the highway. A few other points also deserve brief consideration.

Vision of Driver

We have considered the vision of our observers as related to one of the usual eye test norms and have thereby corrected our results to correspond to 20/20 vision. There remains the question of what proportion of the drivers on the highway actually have average vision and what proportion have various degrees of poorer vision. Reliable data on this subject are scarce, but one report[6] shows out of a total of 35,040 drivers tested at automobile shows, safety conventions, etc., that about 7.3 per cent had a vision corresponding to about 20/33, and 24.2 per cent had vision corresponding to 20/25 (60 and 80 per cent vision respectively). If all those had been ruled off the road whose vision was poorer than 20/40, or 50 per cent vision, the figures would be reduced by about 1 per cent. If we disregard the question of whether or not those tested at such gatherings represent a true sample of drivers on the highway, these figures would suggest that a vision figure of not better than 20/30 should probably be used. As previously noted, this would correspond roughly to our 95 percentile points.

[5] Ferree, C. E., & Rand, G. "The effect of intensity of illumination on the acuity of the normal eye and eyes slightly defective as to refraction." *American Journal of Psychology*, Vol. 34, p. 244, 1923.

[6] Allgaier, E., American Automobile Association, "Interrelationships of Driver Test Scores," Research Report No. 11, 1939.

However, the choice of a given value seems inadvisable due to the many aspects involved and we have therefore preferred to merely indicate our 80 percentile values as corresponding to 20/20 vision ("average" or "normal" vision).

An application of the findings on sign legibility may be of importance in relation to the question of eyesight standards for drivers. Other organizations are working on this question.

Glance Legibility

Other factors tending to modify the legibility values obtained are those of familiarity, comfortable vision, and glance legibility. Familiarity with the sign can be shown to increase its effective reading distance, while the driver who does not strain his eyes, but waits for a comfortable distance (of an unfamiliar sign), would read at a shorter distance than the maximum value which we have obtained. However, these two factors are somewhat imponderable and cannot be easily included in a reproducible measure.

The third factor, glance legibility, is probably the most important of the three, since it is involved where distractions arise from other traffic and where blocking out by other cars allows the driver only a short duration glance at the signs. The preliminary study showed that this factor is measurable and that it probably results in a shortening of the practical legibility distance. It is to be hoped, therefore, that a further study, perhaps by other investigators, may be carried out in which a correction or multiplier factor may be derived for expressing glance legibility as a proportion of the pure legibility distances which we have measured. Such a factor would be convenient since the long time "pure legibility" values are easier to measure than the short time values.

Relation to Glare

The light field which caused a reduction of from 30 to 50 per cent in the legibility distance accruing to the larger reflectorized letters should be carefully distinguished from the intensities ordinarily thought of as glare in connection with headlighting. As previously noted, our intensities of illumination were from 5 to 15 foot-candles with a reflection of approximately $\frac{1}{3}$ of this amount. Therefore, the average brightness toward the eye of the floodlighted signboard which constituted our light field was approximately three footlamberts as compared to 2000 candlepower from a point source, which has been shown by others to cause a 50 per cent reduction of visibility of a gray figure under headlights.[7] The latter visibility, however, was from 200 to 300 feet under bright headlights and the illumination of the object was therefore many times higher than the intensity of the light from the reflectors in our signs at from 500 to 900 feet. On this basis, the blanking effect of the relatively low brightness which was found in our study is understandable.

The relatively great loss in effectiveness due to the light field calls attention to the value of floodlighted signs in any location where a light field of any intensity or extent is met. However, on an open highway where dark conditions prevail for a great proportion of the time, the values for the reflectors would seem to be equally good. Although headlights present a high intensity, the short time during which they are ordinarily facing the driver would mean that their effect on reflectorized sign legibility would be of short duration except under dense traffic conditions.

[7] Reid, K. M., "Seeing on the Highway." *Proceedings*, Highway Research Board, Vol. 17, p. 420, 1937.

Relation to Fifty Foot Rule

A rule of thumb which is in use by some of those in the practical sign field, gives 50 ft. of legibility distance per inch of letter height. It will be noted that our results show a good correspondence to this rule for the wider series D letters under day conditions, but roughly 15 per cent shorter distance than this for night conditions. The series B letters, on the other hand, result in more nearly 33 ft. to the inch under day conditions, and again with a 15 per cent loss at night.

Speed and Warning Distance

On the basis of the pure legibility values, however, it is interesting to note the size of letter indicated if a certain warning time and speed are assumed. Assuming a value of 10 sec. warning, which has been suggested by some experts, and a conservative speed of 50 miles an hour, a distance of 750 ft., or an 18-in. series D sign (night values) is indicated. On the same assumption, but with the sign placed 400 ft. ahead of the hazard as recommended by the Manual for Control Devices, a 10-in. series D, or a 12-in. series B sign is indicated for night conditions. The curves in Figure 13 also point out dramatically that the night condition is the critical one from the point of view of sign legibility.

SUMMARY

1. A study of pure legibility distances has been made using standard black on white destination signs with 6 to 18-in. letters of two widths (series B and series D). Total observations numbered approximately 4,600 and the total number of observers 412. Each plotted point on trend curves was derived from distributions of from 50 to 276 observations. A technique was used which eliminated guessing by observers. Test conditions included day and night, reflectorized and unreflectorized signs, floodlights and headlights.

2. Specified spacings were developed by a simplification of a more complex spacing. Spacings were specified in terms of adjacent strokes rather than letter combinations. This system proved practical for laying out signs.

3. Since median values are most reliable, they were used as an index for comparing trends and relative values. However, our 80 percentile values were shown to correspond roughly to average, or 20/20 vision, and were therefore used for deriving practical distance values.

4. Curves were presented which allowed a comparison of the relative efficiency of the different letters used in terms of pure legibility, e.g., at night a 12-in. series D letter gave approximately the same legibility distance as the 15-in. series B.

5. Reflectors reduced the daytime legibility of the smaller letters very little but showed some effect on the 18-in. letters.

6. The night legibility of the reflectorized signs against a dark background was approximately the same as for the floodlighted signs. However, when the floodlighted signs were left illuminated to a brightness of about three footlamberts, a reduction of 30 to 50 per cent in the legibility distance of the larger reflectorized letters occurred. This brightness corresponds to the less bright display signs and is very much lower than the brightness of oncoming headlights. The value of floodlighted signs where constant light backgrounds occur is indicated, although reflectorized signs seem as legible with a dark background.

7. Our observers represented better vision than the average, and therefore consideration was given to the poorer vision to be expected on the highway. A point corresponding to any given vision value can be obtained from the 20/20 curves presented. The distance values

shown may be of use to those who are setting standards of vision for drivers.

The distance values obtained indicate the use of at least 10-in. D or 12-in. B letters if 10 sec. warning is to be given the driver at 50 miles per hour at night.

8. The demonstration of a nonlinear relationship between letter size and distance is of importance if projection of values is attempted from tests on the smaller letter sizes. It has been generally assumed that such projections can be made on a linear basis. Our results indicate that the relationship which may appear linear in the smaller values, may be actually curvilinear. In this case the curve must be known in order to project.

9. In a previous paper by one of us, other factors of import to sign efficiency were derived, and it is to be hoped that studies will be made of these. It is probable that glance legibility will be somewhat shorter than the pure legibility values here reported and it is suggested that a correction factor will be derived eventually by which glance legibility may be obtained from the pure legibility values.

10. Analysis of sign efficiency in this general fashion will furnish a scientific basis for the development of highway signs to meet the increasing demands of modern highways.

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