# The Effect of Letter Width and Spacing on Night Legibility of Highway Signs

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This study was undertaken to determine the effect that spacing between letters of words, used in highway signs, had on their nighttime legibility. More than 2,500 observations were made by 36 observers while driving an automobile at 30-mph. White reflectorized letters, 10 in. high, were displayed on a black nonreflectorized background. Three different alphabets were used. Two of these, the Standard Series C with narrow letters and the wider Series E, were cut from reflective sheeting. The third alphabet, identified as Series ED and similar in width to the Series E, was designed by a manufacturer using 1¼-in. diameter plastic reflectors to form the letters. The spacings between letters were increased as the lengths of the six test words were extended from normal to 20, 40, and 60 percent above normal.

As interletter spacing was increased, the legibility distances also increased for all three alphabets until word lengths were 40 percent above normal. The resulting gain is legibility at this point was 15 percent for Series C, 16 percent for Series E, and 7 percent for Series ED. Beyond the 40-percent increase in word length, legibility leveled off or declined.

When word lengths were normal or no more than 10 percent above normal, test signs with the series ED alphabet were found to have greater legibility. At wider spacings, the Series E alphabet was superior.

As might be expected, the 10-in. Series E alphabet was legible at a greater distance (118 to 142 ft) than the narrower 10-in. Series C alphabet at corresponding letter spacings. On a percentage basis, the differences in legibility favoring the Series E alphabet ranged from 23 percent to 27 percent. A word with letters of the Series C alphabet is shorter in length than one with letters of the Series E for a given spacing, and a comparison of legibility distance per inch of word length showed that the Series C alphabet was somewhat superior to the Series E. Also studied was the probable effect of increasing the letter height of the narrower alphabet until the legend area equaled that of the wider alphabet. At the point of equivalent legend area and spacing, the two alphabets proved to be equally legible.

The study findings point to the importance of sign proportions and provide an improved means for efficient determination of legend design. Where vertical dimensions restrict sign letter heights to something less than desirable, increased spacing between letters can help to compensate for the loss of legibility distance that would otherwise occur.

● IN recent years, increasing use has been made of white reflectorized letters on a dark background for large highway destination signs. Although there are some conflicting reports, the weight of the evidence indicates that, for night legibility of large letters, this combination is superior to dark letters on a white reflectorized background. Consequently, a design using white reflectorized letters on a dark background was selected for signs recently installed on the Pentagon road network just outside of Washington, D. C. Standard alphabet designs for highway signs developed by the Bureau of Public Roads were employed.

The letter spacings used for the design of these signs were originally devised from limited tests and study of previous researches dealing with letter spacing and legibility, all with black letters on a white background. The spacing values were selected so that the white areas between successive letters in a given word would appear equal.

It was surmised that the color and reflectorization reversal on the new signs might have a significant effect on night legibility if the letter spacings were not changed. Furthermore, a recent laboratory study (*1*) had shown that white reflectorized letters on a black background may improve in legibility if the letter spacing is somewhat wider than that used with black on white. No definitive research looking toward the establishment of optimum spacings between letters had been conducted under actual roadway driving conditions.

The present study, therefore, was initiated to investigate the effect on nighttime legibility of increasing the spacing between white reflectorized letters on a black background.

### STUDY CONDITIONS

The study site was a 1500-foot-long parking lot, unused at night, substantially straight and level, and with a bituminous surface. The area was without illumination except for a few fixed street lights in the distant background. Thus the conditions were not unlike those found on unlighted urban freeways or rural highways near cities.

Studies were conducted during March and April of 1955, observations starting after dark and continuing until 11 p.m. or midnight. Generally, the weather was fair and no moon was present, although some data for 4 of the 36 observers were recorded during a light rain, and the observations of 2 others were recorded in the presence of a quarter moon. The light rain and moon had no apparent effect on the results obtained.

Observers were 36 male employees of the Bureau of Public Roads and of the D. C. Department of Vehicles and Traffic. They ranged in age from the middle twenties to the late sixties, and 20 wore eyeglasses. The participants were chosen largely because of their willingness to work in the evening hours, rather than for any particular physical ability or characteristic.

All but 2 of the 36 observers drove one of three 1951 Pontiacs. A fourth Pontiac, 4 years older, was used by the remaining observers.

The test vehicles were equipped with the improved "50–40" sealed beam headlamps to simulate the best possible seeing conditions. The headlamps were checked periodically for proper aim. The new "50–40" headlamps are now legal in all states and all vehicles in production are being equipped with them.

A test panel, 6 feet long by 4 feet high, was mounted at one end of the parking lot with the lower edge 4½ feet above the pavement. Space was provided for two 4-letter words placed one above the other with a 10-inch clearance between lines. Individual letters 10 inches in height were combined to form the test words. Because individual letters were used on the panel, the spacing between letters could easily be varied to suit the requirements of each observation. Narrow guide strips were placed below the words to indicate the letter position for each test condition. The guide strips were not reflectorized or visible during the test runs.

### SCOPE OF STUDY

Three different alphabet designs were observed. Figure 1 shows the word NAVY displayed in each alphabet.

Series "C" and Series "E" alphabets, 10 inches in height, were chosen because they are representative of those commonly appearing

Series C

Series E

Series ED

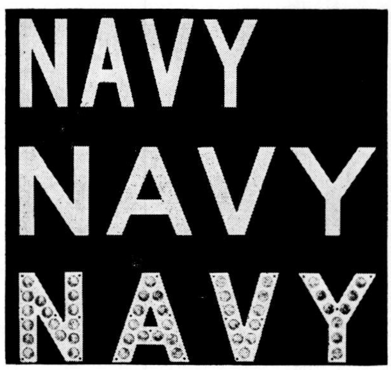


**Figure 1. Comparison of Series C, E, and ED alphabets at normal spacing.**

on highway destination signs. These two alphabets were cut from reflective sheeting. The sheeting employed reflects nearly as much light at incidence angles of 20° or 30° as it does head on.

In a third alphabet, identified in this study as Series "ED," 1¼-inch diameter plastic reflectors formed the 10-inch high letters. The brightness of these units was considerably greater than the sheeting used for the Series "C" and "E" alphabets. Series "E" and Series "ED" alphabets were quite similar in form, although the Series "ED" alphabet was designed by the manufacturer.

TABLE 1

CHARACTER (LETTER OR NUMERAL) WIDTH AND NORMAL SPACING OF 10-INCH SERIES C AND E STANDARD ALPHABETS AND 10-INCH SERIES ED (MANUFACTURER'S ALPHABET)

| Character | Standard Alphabets | | | | Manufacturer's Alphabet | | |
|---|---|---|---|---|---|---|---|
| | Character width | | Edge code† | | Character width of series ED‡ | Margin spacing | |
| | Series C* | Series E* | Left | Right | | Left | Right |
| | *inches* | *inches* | | | *inches* | *inches* | *inches* |
| A | 6.25 | 10.00 | III | III | 9.00 | 1.1 | 1.2 |
| B | 5.47 | 7.97 | I | II | 7.38 | 2.2 | 1.5 |
| C | 5.47 | 7.97 | II | III | 7.38 | 1.2 | 1.4 |
| D | 5.47 | 7.97 | I | II | 7.38 | 2.2 | 1.3 |
| E | 5.00 | 7.34 | I | III | 6.75 | 2.2 | 1.4 |
| F | 5.00 | 7.34 | I | III | 6.75 | 2.2 | 1.0 |
| G | 5.47 | 7.97 | II | II | 7.38 | 1.2 | 1.4 |
| H | 5.47 | 7.97 | I | I | 7.38 | 2.2 | 2.3 |
| I | 1.41 | 1.72 | I | I | 2.12 | 2.2 | 2.3 |
| J | 5.00 | 7.50 | III | I | 6.75 | .8 | 2.3 |
| K | 5.47 | 8.12 | I | III | 7.62 | 2.2 | .9 |
| L | 5.00 | 7.34 | I | III | 6.75 | 2.2 | .9 |
| M | 6.48 | 9.22 | I | I | 8.50 | 2.2 | 2.3 |
| N | 5.47 | 7.97 | I | I | 7.38 | 2.2 | 2.3 |
| O | 5.78 | 8.28 | II | II | 7.62 | 1.2 | 1.3 |
| P | 5.47 | 7.97 | I | II | 7.38 | 2.2 | 1.3 |
| Q | 5.78 | 8.28 | II | II | 7.62 | 1.2 | 1.3 |
| R | 5.47 | 7.97 | I | II | 7.38 | 2.2 | 1.3 |
| S | 5.47 | 7.97 | II | II | 7.38 | 1.2 | 1.1 |
| T | 5.00 | 7.34 | III | III | 6.75 | .9 | 1.0 |
| U | 5.47 | 7.97 | I | I | 7.38 | 2.2 | 2.3 |
| V | 6.09 | 9.06 | III | III | 8.12 | 1.1 | 1.2 |
| W | 7.50 | 10.47 | III | III | 9.38 | 1.1 | 1.2 |
| X | 5.86 | 8.59 | III | III | 7.62 | 1.1 | 1.2 |
| Y | 6.25 | 10.00 | III | III | 9.00 | 1.0 | 1.1 |
| Z | 5.47 | 7.97 | III | III | 7.38 | 2.0 | 2.1 |
| 1 | 2.03 | 2.97 | I | I | 3.12 | 2.0 | 2.3 |
| 2 | 5.47 | 7.97 | II | II | 7.38 | 1.2 | 1.1 |
| 3 | 5.47 | 7.97 | III | II | 7.38 | 1.3 | 1.5 |
| 4 | 6.09 | 9.22 | III | III | 8.25 | 1.2 | 2.0 |
| 5 | 5.47 | 7.97 | I | II | 7.38 | 1.1 | 1.2 |
| 6 | 5.47 | 7.97 | II | II | 7.38 | 1.3 | 1.2 |
| 7 | 5.47 | 7.97 | III | III | 7.38 | .9 | 1.0 |
| 8 | 5.47 | 7.97 | II | II | 7.38 | 1.2 | 1.3 |
| 9 | 5.47 | 7.97 | II | II | 7.38 | 1.2 | 1.3 |
| 0 | 5.78 | 8.28 | II | II | 7.62 | 1.2 | 1.3 |

* Stroke width for Series C, 1.41 inches; Series E, 1.72 inches.

† Edge codes determined, with minor exceptions, as follows: Code I indicates side of character has vertical outline; Code II, curved outline; and Code III, diagonal or open-faced outline. For measurements and sample calculations, see tables 2–3.

‡ Stroke width for Series ED, 2.12 inches. Reflectors measure 1¼ inches in diameter.

TABLE 2

NORMAL SPACING BETWEEN 10-INCH LETTERS OF ALPHABETS WITH COMBINATIONS OF CODES I, II, AND III FOR ADJACENT EDGES

| Examples of Letter Combinations | Edge Code Combinations | Letter Spacing* | |
|---|---|---|---|
| | | Series C | Series E |
| | | *inches* | *inches* |
| HI, JL | I-I | 2.11 (HI, JL; NO, PB) | 2.58 |
| NO, PB | I-II or II-I | | |
| NA, FL | I-III or III-I | 1.69 (NA, FL; GO, RC; ST, ZO) | 2.06 |
| GO, RC | II-II | | |
| ST, ZO | II-III or III-II | | |
| FT, LA, VY | III-III, not parallel | 1.12 | 1.37 |
| EX, LT, WA | III-III, parallel | .56 | .68 |

* Measured horizontally between nearest points.

All three alphabets were made from materials with retrodirective properties, i.e., a tendency to reflect a large portion of the light back to the source regardless of the angle of the incident light. The sheeting from which Series "C" and "E" alphabets were cut is composed of minute glass spheres, while the plastic units used for Series "ED" letters develop their reflection from the interior corners of cubes.

From each of the three alphabets, six test words were composed—BALK, FARM, NAVY, STOP, ZONE, and DUCK. These six words use 19 different letters of the 26 in the alphabet and require a variety of letter forms to adjoin each other.

Each of the six words was displayed in three alphabet designs and four different spacings for each of the 36 observers. The base or normal spacing was determined by using the Bureau of Public Roads' spacing chart for Series "C" and "E" and the manufacturer's recommendations in the case of Series "ED." These are tabulated in Tables 1 and 2. A sample calculation for determining the length of a word with normal spacing is given in Table 3. To increase interletter spacings, word lengths 20 percent, 40 percent, and 60 percent greater than "normal" were chosen and the individual letters arranged within that length to produce a satisfactory appearance.

These 72 alphabet-word-spacing combina-

TABLE 3
SAMPLE CALCULATION FOR DETERMINING LENGTH OF THE WORD NAVY IN 10-INCH LETTERS OF THE SERIES E AND ED ALPHABETS WITH NORMAL SPACING

| Letter | Width of Letters | Edge Code | | Margin Spacing | | Combination of Codes for Adjacent Edges | Spacing Between Letters | Length of Word |
|---|---|---|---|---|---|---|---|---|
| | | Left | Right | Left | Right | | | |
| **Solution for Series E** | | | | | | | | |
| | *inches* | | | *inches* | *inches* | | *inches* | *inches* |
| N | 7.97 | I | I | | | }I-III | 2.06 | |
| A | 10.00 | III | III | | | }III-III, parallel | .68 | |
| V | 9.06 | III | III | | | }III-III, not parallel | 1.37 | |
| Y | 10.00 | III | III | | | | | |
| Total........... | 37.03 | | | | | | 4.11 | 41.14 |
| **Solution for Series ED** | | | | | | | | |
| N | 7.38 | | | 2.2 | 2.3 | | } 3.4 | |
| A | 9.00 | | | 1.1 | 1.2 | | } 2.3 | |
| V | 8.12 | | | 1.1 | 1.2 | | } 2.2 | |
| Y | 9.00 | | | 1.0 | 1.1 | | | |
| Total........... | 33.50 | | | | | | 7.9 | 41.4 |

tions were displayed on the panel two at a time. The two combinations used for each panel were changed at the half-way point in the test. In this manner, each combination of alphabet, word, and spacing appeared half the time with a word and spacing combination from each of the other two alphabets. The panel displays were systematically chosen so that each word appeared two or three times with every other word. The order of panel presentation was selected initially at random for each half of the test runs, and then the order was advanced for each observer so that each alphabet, word, and spacing combination appeared about the same number of times near the beginning, middle, and end of the test sequences. Also, each combination was shown about the same number of times in the upper position on the panel as in the lower position.

In short, each combination of alphabet, word, and spacing received as favorable treatment as any other, and the 36 observers read the 72 combinations in conformance with a plan designed to minimize every foreseeable bias. This resulted in a total of 2592 balanced observations.

In addition to these 72 combinations that were displayed two at at a time, the 24 combinations of Series "E" were displayed one at a time for 29 of the 36 observers. Only 6 of the 24 combinations were displayed for any single observer, however.

Figure 2 illustrates the breakdown of the 2592 observations. For 10-inch Series "E" words, 216 of the 864 observations were made at each of four different word lengths. The same breakdown was also used for Series "C" and "ED" words. Similar procedures were applied to each succeeding subgrouping of the total observations although the breakdown for only one "box" is shown in Figure 2.

Visual acuity for each observer was determined from his test results for all three alphabets and six words at normal spacing. The mean legibility distance for these 18 combinations was the visual acuity score for a given observer. All 36 observers were ranked according to their visual acuity scores and then divided into three visual acuity groups of 12 observers each. This grouping was used in analyzing the effect of visual acuity on legibility.

### TEST PROCEDURE

Each observer was instructed to drive along the course at an estimated speed of 30 miles per hour, but to focus his attention on the sign panel rather than on the speedometer. He was shown a typewritten list of the six test words before the test began, but was not informed of their order of presentation or about details of alphabet and spacing. Normally, two cars made test runs in close sequence, beginning at one end of the course some 1500 feet from the sign panel. The first driver was allowed to proceed 600 to 900 feet

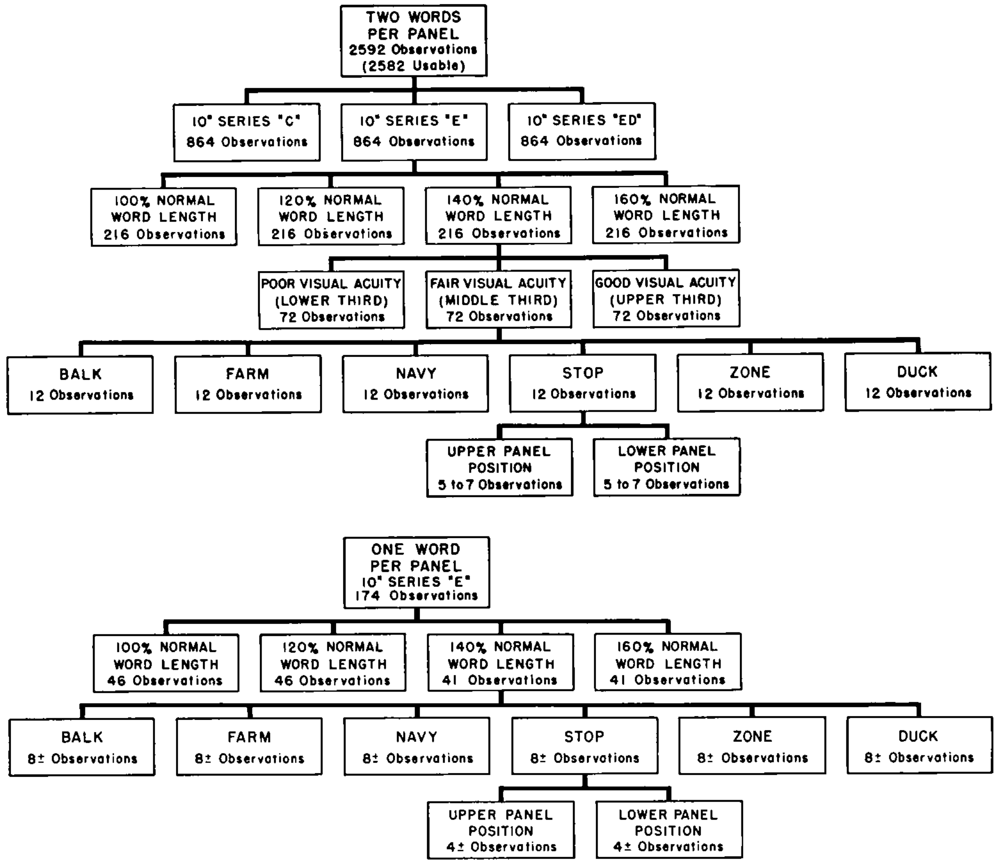


**Figure 2. Number of observations for each alphabet, spacing, visual acuity group, word, and panel position.**

down the course before the second driver started, so as to minimize interference in the legibility observations. The driver made the observations and a recorder sat in the rear seat. No one else was in the car and all runs were made using low beam of the headlamps.

As soon as the driver-observer could read either of the two words, he called it aloud, and the recorder noted the distance from the panel to the nearest 25 feet by referring his position to coded markings on the course. Similarly, the second word was read as soon as legible and the distance recorded. After both words had been read, the observers continued past the sign panel and drove back to the beginning of the course. Two new words were then placed on the panel. During each circuit of the course, which consumed about 2½ minutes, each observer usually saw the headlamps of the other car although not while actually reading the signs. Thus the effect on the eye of light from intermittent opposing headlamps was introduced to a limited extent, but care was taken to avoid any direct glare.

Observers were instructed to drive so that the left edge of the car was in line with a row of parking stall markings. This resulted in a simulated vehicle placement in the center of a 12-foot lane with the near edge of the sign panel 6 feet from the right shoulder.

The instructions discouraged guessing by observers and few combinations were read incorrectly. At times it was possible to expose the incorrectly read combinations for a second observation, and as a result only 10 observations of the 2592 were not usable.

Figure 3 shows the words NAVY and FARM from the observer position in a car 800 feet from the sign panel. Beside the left curb, coded course markers spaced 50 feet

**Figure 3. Appearance of sign panel from a distance of 800 feet.**

apart were used by the recorder to identify the point at which the observer read each combination. High beam of the headlamps was used in Figure 3 so that a clear picture would result. Actual test runs were made using low beam, however, and Figures 4, 5, and 6 were taken with low beam of the headlamps.

Figure 4 shows these two words as they appeared from 600 feet away, Figure 5 from 400 feet, and Figure 6 from 200 feet away. Figure 7 is a closeup of the panel. NAVY is formed with Series "ED" letters at the widest spacing (word length 60 percent greater than normal). FARM is formed using Series "C" letters at normal spacing.

### LEGIBILITY DISTANCES DETERMINED

For each of the 36 observers, an average legibility distance was calculated from all 72 observations. These values varied from less than 300 feet to nearly 900 feet, a ratio of over 3:1. Figure 8 shows this relationship. Over two-thirds of the observers had average values between 500 and 800 feet, but the distribution was somewhat skewed in the lower direction with one-ninth of the observers having average distances below 400 feet. When highway signs are designed, the capability of these drivers with poor visual acuity deserves special consideration. It will be seen that observers wearing glasses did not perform quite so well as a group as those without glasses.

#### *Word Lengths Increased*

For all three alphabets, increasing the spacing first produced greater legibility, then a leveling off or an actual decrease in legibility, as shown by Figure 9.

The mean legibility distance for the narrow Series "C" alphabet at normal spacing was 478 feet. Legibility increased to 549 feet at

**Figure 4. Appearance of sign panel from a distance of 600 feet.**

word lengths 40 percent greater than normal; but the 60 percent increase in word length resulted in only 5 feet more of legibility distance.

The wider Series "E" alphabet produced a mean legibility distance of 596 feet at normal spacing. A 40 percent increase in word length resulted in a mean legibility distance of 691 feet while the 60 percent increase in word length actually reduced the legibility distance 10 feet.

For Series "ED," similar in form to the Series "E" alphabet but of a different reflectorizing material, the mean legibility distance was 614 feet at normal spacing. Legibility increased to 657 feet at word lengths 40 percent greater than normal, but the 60 percent increase in word length resulted in a 13-foot decrease in the mean legibility distance.

As Figure 9 clearly shows, Series "E" and Series "ED" should not be displayed at word lengths that are much more than 40 percent greater than normal, for at these wider spacings an actual decrease in legibility resulted. Little was gained by displaying Series "C" at spacings beyond the 40 percent point.

Percentagewise, the increases in legibility with increased spacing were nearly identical for Series "C" and Series "E," as shown by Figure 10. An increase in word length of 40 percent over normal increased legibility 15 percent for Series "C," and 16 percent for Series "E," but only 7 percent for Series "ED."

*Effect of Visual Acuity*

As noted earlier, highway signs should be designed for the driver with poor vision rather than for the average driver. The data were analyzed to determine whether drivers with poor, fair, and good eyesight showed similar and proportionate changes in their legibility patterns as letter spacings were increased.

Figure 11 shows mean legibility distances for each of the three visual acuity groups. In the case of Series "C," mean legibility distances for the poor visual acuity group were at least

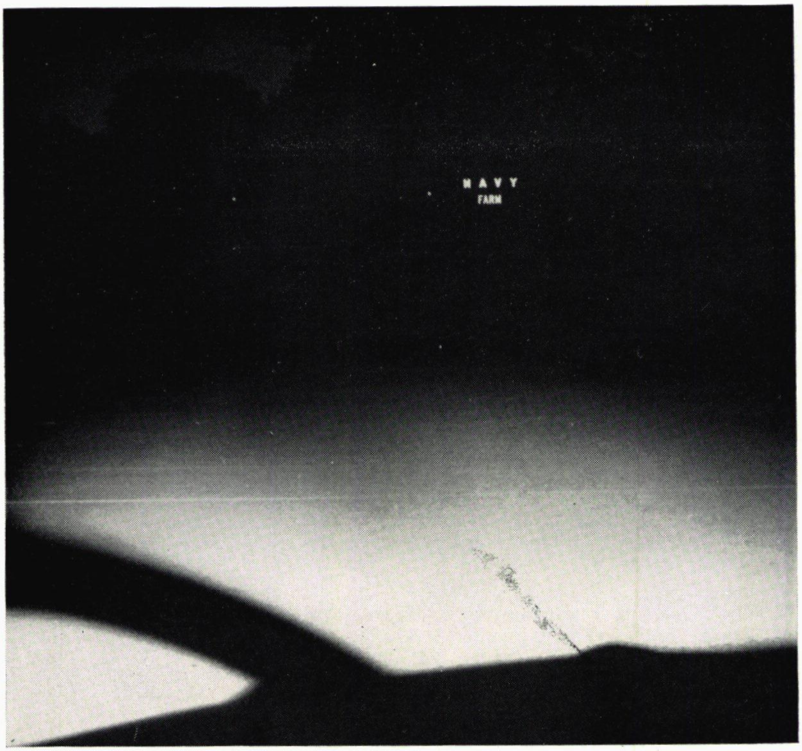


**Figure 5. Appearance of sign panel from a distance of 400 feet.**

250 feet below those of the good visual acuity group. For Series "E" and Series "ED," the differences between the poor group and the good visual acuity group were over 300 feet. In general, it will be seen that the patterns of legibility are very much the same for all groups.

These relationships are shown on a percentage basis in Figure 12. A 40 percent increase in word length resulted in a 12 percent increase in legibility of Series "C" for the poor visual acuity group, 19 percent for the fair group, and 13 percent for the good group. Series "E" percentage increases for the three groups were 17 percent, 13 percent, and 18 percent, respectively; while for Series "ED" the percentages were 6 percent, 9 percent, and 5 percent, respectively.

The poor visual acuity group was within 1 percent of the value for all three groups combined for Series "E" and "ED," and within 3 percent for Series "C." Because of this close agreement and the fact that relative values only are of principal importance in much of this study, the three groups were combined for most of the analysis.

*Frequency Distributions*

Figure 13 shows the frequency distribution for Series "C" at four different spacings. Much of the variation for a given spacing was due to differences between observers but individual words, sequence of observation, and panel position also contributed.

Figure 14 shows a similar distribution for Series "E" and Figure 15 for Series "ED." At the "tail" ends of the distribution, the small number of observations shows up in considerable fluctuations between individual spacings. At normal spacing, the lower 15 percentile value for Series "C" was 350 feet, for Series "E," 400 feet, and for Series "ED," 450 feet. This compared closely to the mean legibility distances for the poor visual acuity group of 351 feet, 414 feet, and 449 feet, respectively.

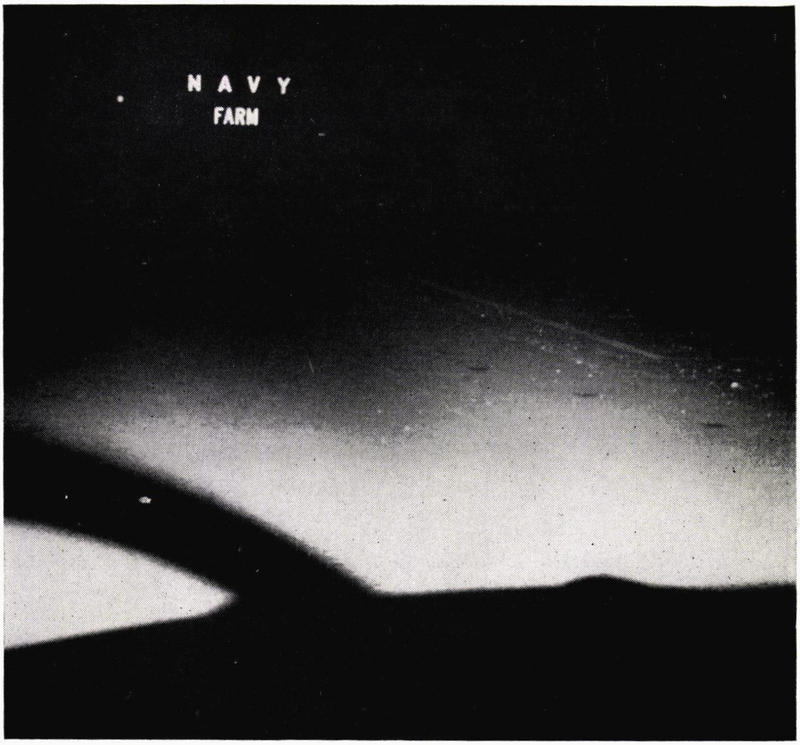


**Figure 6. Appearance of sign panel from a distance of 200 feet.**

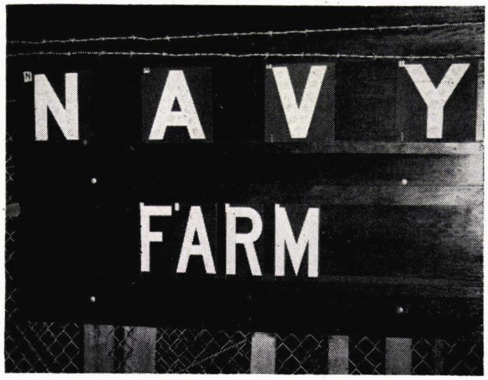


**Figure 7. Closeup view of the sign panel.**

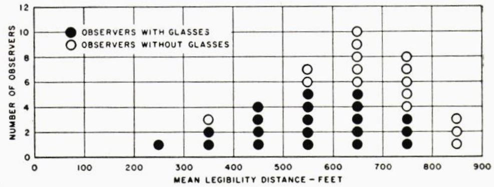


**Figure 8. Observations of 36 observers distributed according to the mean legibility distances.**

*One Word vs. Two Words Per Panel*

When two words are placed on a single panel, each can have some effect on the legibility of the other. The 174 observations of Series "E" words placed on the panel one at a time give a general indication of this effect, as shown by Figure 16. The number of observations of "one word per panel" for a given visual acuity group and spacing was not the same. To correct for this, equal weight was given to each visual acuity group and spacing regardless of the number of observations within each category.

As the corrected curve in Figure 16 shows, observations made with only one word per panel resulted in legibility distances ranging from 46 feet to 123 feet greater than for two words per panel. When only one word at a time was displayed, legibility showed a more rapid gain as spacing was increased, and continued to improve beyond the 40 percent increase in word length.

*Legibility of Six Test Words*

Of the six words tested, STOP was consistently read at the greatest distance. Undoubtedly, this was due in part to the familiarity of this word to the average driver because of its use on the standard STOP sign. In addition, the letters are so arranged that a rather distinctive open shape results.

In the case of Series "C," BALK was the least legible at all spacings. The remaining words had about the same legibility, with DUCK slightly below the rest as shown by Figure 17. DUCK and BALK have somewhat similar shapes and the difficulty in distinguishing between them may have accounted for their diminished legibility. BALK was also near the bottom in legibility for both Series "E" and Series "ED" as shown by Figures 18 and 19; while DUCK was slightly above average for Series "E," and slightly below average for Series "ED."

Figure 20 shows the percentage increase in legibility of individual words with an increase in word length. Series "C" had the most consistent pattern for the six words and Series "ED" the most erratic pattern, with FARM in Series "ED" letters actually showing a decrease in legibility as spacing increased.

*Effect of Panel Position*

Upper or lower position on the panel had little effect on legibility as shown by Figure 21. Series "C" and "E" were both more legible when placed on the lower portion of the panel, i.e., approximately 5 feet above the roadway surface. Series "ED" was more legible in the upper position, which was roughly 7 feet above the roadway surface. The average difference in legibility was generally less than 20 feet for any one of the three alphabet series, and has no significant implications for sign designers.

A possible explanation for the difference in legibility of words in the two panel positions is that Series "ED" is made from a material with greater apparent reflectance than optimum for the low-beam illumination and other conditions of the test; while Series "C" and Series "E" are made from materials with less apparent reflectance than the optimum. Thus

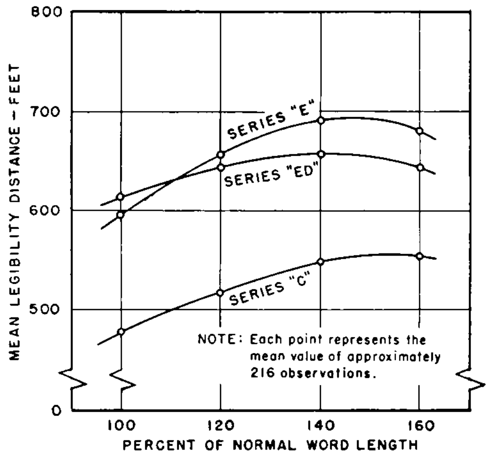


**Figure 9. Legibility distances for Series C, E, and ED alphabets as affected by the spacing between letters in test words.**

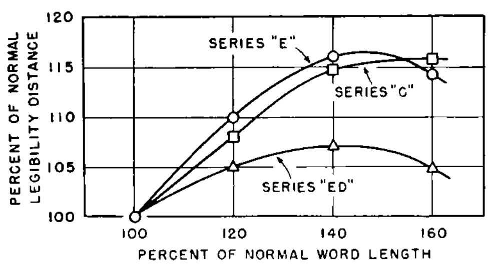


**Figure 10. Percentage change in legibility distanc s for Series C, E, and ED alphabets as affected by the spa-ing between letters in test words.**

the upper panel position for Series "ED" may in this case be better than the lower one because it receives less incident light from the headlamps and the apparent reflectance is less. With Series "C" and Series "E," the converse applies.

## COMPARISON OF SERIES "E" AND "ED" ALPHABETS

One of the more interesting comparisons made involves the relative legibility values obtained with the Series "E" and "ED" alphabets. These were of similar design, except that Series "E" letters were cut from reflective sheeting, and Series "ED" were constructed of plastic reflector units. As Figure 9 shows, at normal spacing Series "ED" was legible 18 feet farther than Series "E," while at word lengths 20 percent greater than normal, the legibility distance for Series "ED"

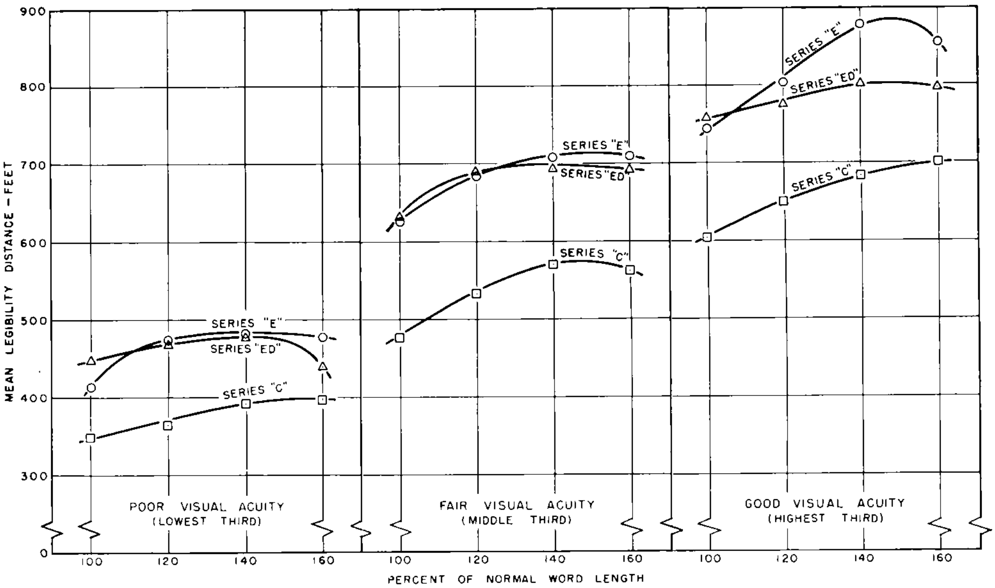


**Figure 11. Legibility distances, according to visual acuity groups, for Series C, E, and ED alphabets as affected by the spacing between letters in test words.**

was 10 feet less than Series "E," and at word lengths 40 percent and 60 percent above normal, Series "ED" legibility was 34 feet and 37 feet less, respectively.

A characteristic of the letter design in the Series "ED" alphabet is that it results in slightly greater word lengths than those of standard Series "E." Figure 22 shows the mean legibility distance expressed in terms of feet of legibility per inch of word length. This tends to equalize the minor differences in word length between the two alphabets. Again Series "ED" is superior at normal spacing and Series "E" at the wider spacings. The highest values, obtained with the Series "C" letters, will be discussed later.

In the final analysis, the most useful value for comparative purposes is the height of Series "E" letter that results in a legend area per letter equal to Series "ED" at each of the four spacings. In order to obtain this, it is first necessary to know how the legibility of Series "E" changes with letter height.

A study reported by Forbes *et al.* (*2*) contains data that makes possible this determination. That study used a white Series "E" alphabet on a black background. Night observations were made by stationary observers and the signs were artificially illuminated. The spacing between letters was greater than the normal spacing of our study and, in addition, the stroke width was about 16 percent greater than the standard. If the six words used in the present study had been similarly composed, they would have occupied 11 percent greater word length than "normal."

The median legibility distances for 8- and 12-inch capital letters forming "place names with knowledge" were 690 feet and 1060 feet, respectively. Thus, in this range of letter height, each inch increased the legibility distance an average of 92½ feet, and the calculated legibility of a 10-inch letter is 875 feet. In the present study, the corresponding median value was 640 feet, and the mean legibility distance was 630 feet.

The difference in results arises from several factors, principal among which are the driving observers, the display of two words per panel, and perception-reaction requirements. These are additive in their effect and help to account for the difference in legibility distances recorded. Because the results of these parallel studies are reasonably comparable, it is feasible to demonstrate the relative effects that letter height and spacing have on sign design.

The incremental value of 92½ feet per inch of letter height, mentioned above, was derived from a word length 11 percent greater than normal in the present study. Proportionate ratios were computed for other word lengths, and these ratios were used to determine mean legibility distances for Series "E" words of heights above and below 10 inches.

For equal legend area per letter, a 10.05-inch Series "E" letter is equivalent to a 10-inch Series "ED" letter at corresponding spacings. Figure 23 shows the mean legibility distances for this size letter expanded by the method described. At normal spacing, the legibility of the 10-inch Series "ED" is 14 feet greater than the 10.05-inch Series "E," while at word lengths 20 percent, 40 percent, and 60 percent greater than normal, Series "ED" has 15 feet, 39 feet, and 42 feet less legibility.

### COMPARISON OF SERIES "C" AND "E" ALPHABETS

As Figure 9 shows Series, "E" has an advantage over Series "C" of between 117 feet and 142 feet in legibility distance at the various spacings. Series "E," however, occupies considerably more sign area and if mean legibility distance per inch of word length is considered, Series "C" has the advantage, as shown by Figure 22.

Of greater interest, perhaps, is the resulting legibility when the two alphabets occupy equal legend area per letter and are displayed at the same relative spacing. A Series "E" letter 8.34 inches high will occupy the same legend area as a 10-inch Series "C" letter at corresponding spacings. The mean legibility distances for the 8.34-inch letter height were calculated using the procedure outlined earlier.

The results of this calculation are shown in Figure 24. It may be seen that the Series "C" alphabet has an advantage over the Series "E," where the legend area is taken into account. The differences are small, however, and since the curves were derived from two separate studies, a fairer statement would be that Series "C" and Series "E" are equally efficient users of sign space.

The Manual on Uniform Traffic Control Devices (*3*) in a recent revision has recommended that the narrower Series "A" and "B" letters not be used for reflectorized signs. The present study, however, indicates that Series "C," next in width, has no disadvantage

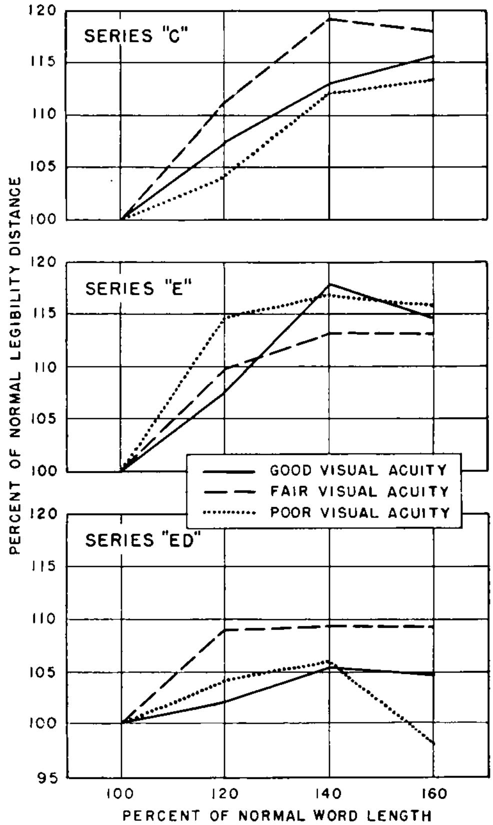


**Figure 12. Percentage change in legibility distances, according to visual acuity groups, for Series C, E, and ED alphabets as affected by the spacing between letters in test words.**

when compared with the wider Series "E" alphabet. It is conceivable, therefore, that at least for night legibility of white reflectorized letters on a dark background, letters even narrower than Series "C" may also be as efficient as Series "E." This finding may or may not hold for daytime viewing.

The effect of irradiation or spreading of the stroke width of white reflectorized letters may account for the close agreement in legibility of the 10-inch Series "C" and 8.34-inch Series "E." A narrower stroke width for Series "E" might produce improved night legibility.

To obtain, with Series "C" letters, a legibility distance equivalent to that of Series "E" letters at comparable spacings, a greater letter height must be used. Words with 10-inch Series

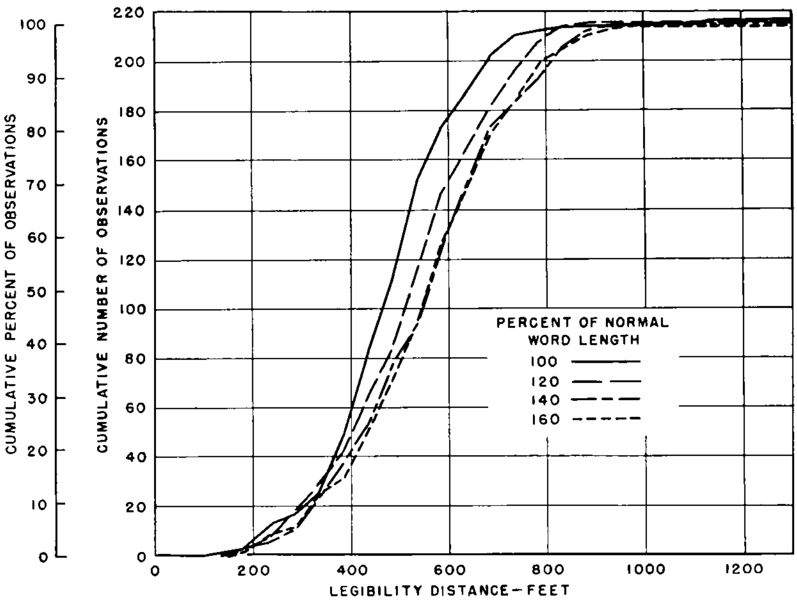


**Figure 13. Cumulative distribution of legibility distances for the Series C alphabet as affected by the spacing between letters in test words.**

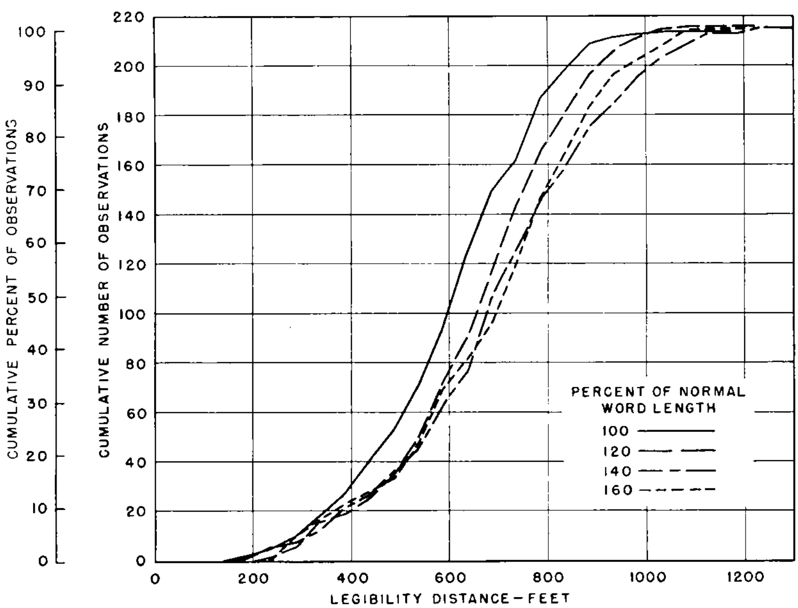


**Figure 14. Cumulative distribution of legibility distances for the Series E alphabet as affected by the spacing between letters in test words.**

"C" letters are only about as legible as those with 8½-inch Series "E" letters. The legibility equivalent of a 10-inch Series "E" letter would be a Series "C" letter about 12 inches high. An obvious feature of this relationship is the saving in the vertical dimension of a sign where short, wide letters are used in preference to tall, narrow letters.

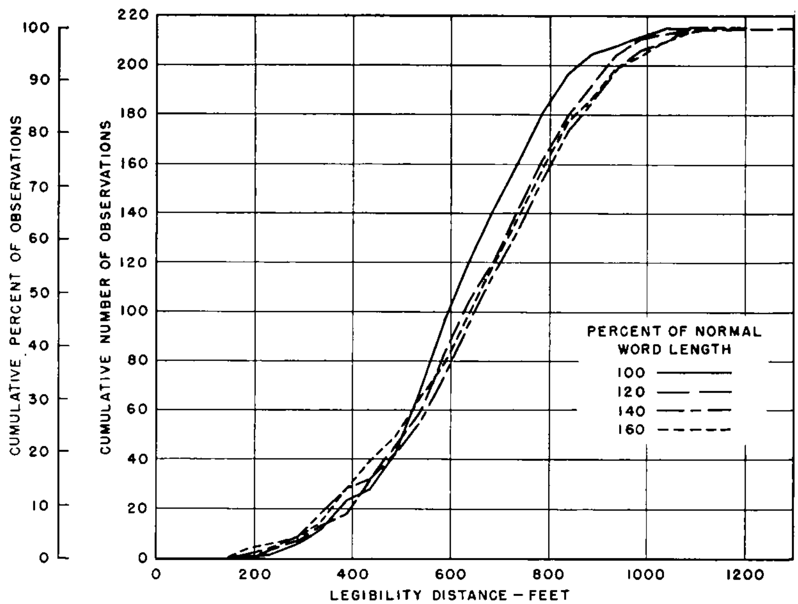


**Figure 15. Cumulative distribution of legibility distances for the Series ED alphabet as affected by the spacing between letters in test words.**

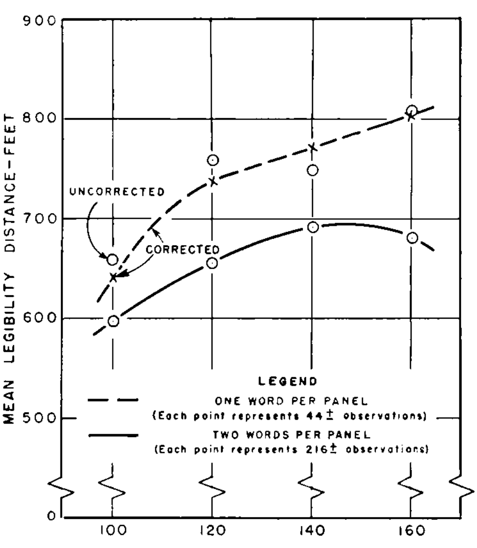


**Figure 16. Legibility distances, according to the number of words displayed on panel, for Series E alphabet as affected by the spacing between letters in test words.**

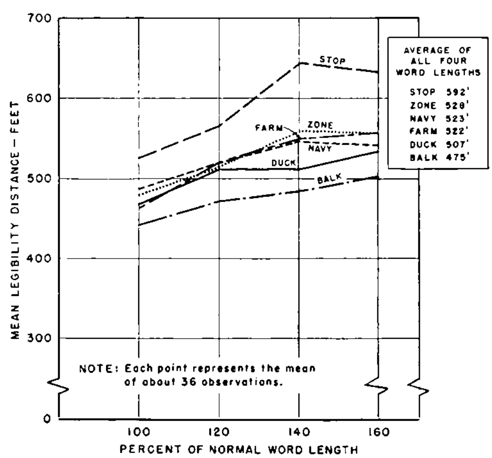


**Figure 17. Legibility distances for each test word of the Series C alphabet as affected by the spacing between letters in test words.**

## ALTERNATIVE METHODS OF IMPROVING LEGIBILITY

It has been shown that for a given alphabet, additional spacing between letters will increase legibility. The question still remains, however, as to whether legibility should be increased in this fashion or by increasing the letter height.

Again by use of the data contained in the Forbes study (*2*), it is possible to compare the two alternatives, as in Figure 25. Here, it may be seen that a 10-inch Series "E" word at a

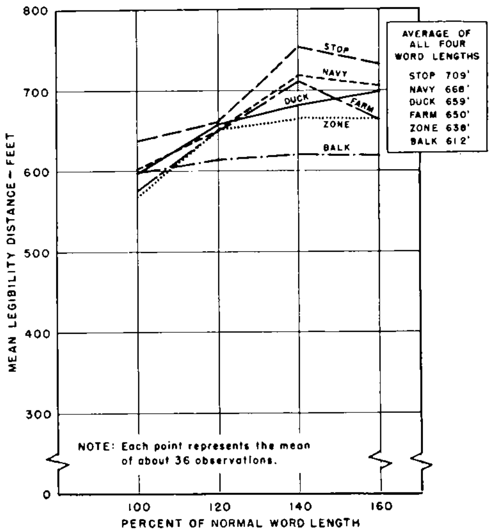


**Figure 18. Legibility distances for each test word of the Series E alphabet as affected by the spacing between letters in test words.**

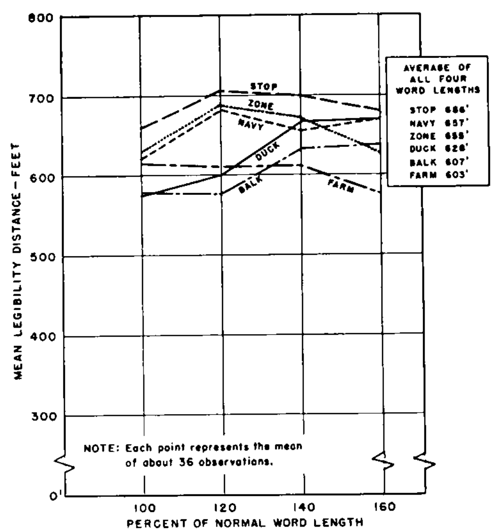


**Figure 19. Legibility distances for each test word of the Series ED alphabet as affected by the spacing between letters in test words.**

length 20 percent greater than normal occupies about the same legend area per letter as an 11-inch word at normal spacing, but gives slightly less legibility. An increase of 40 percent in word length increases the legibility distance somewhat less in proportion to that attainable by increasing the letter height. Be-

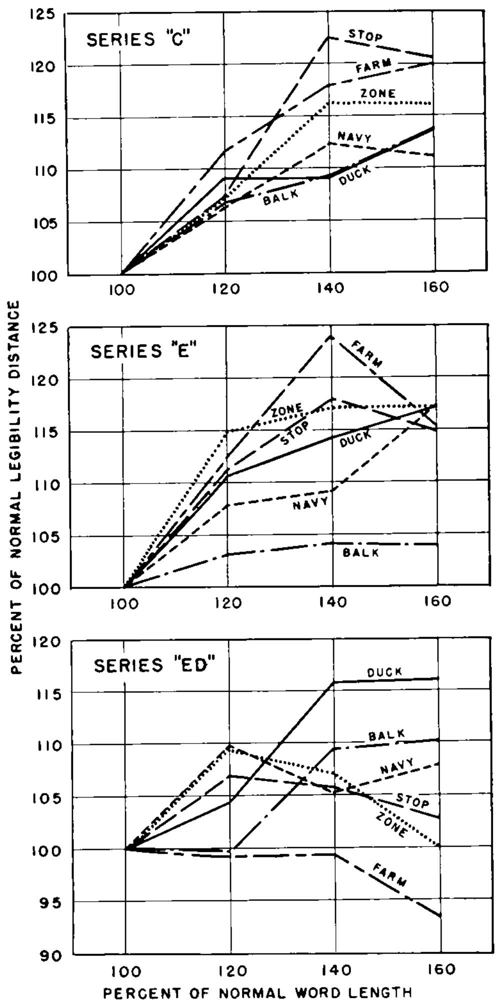


**Figure 20. Percentage change in legibility distances for each test word of Series C, E, and ED alphabets, as affected by the spacing between letters in test words.**

yond 40 percent, of course, legibility declines rapidly; thus the use of these wider letter spacings is undesirable.

In general, it is desirable that the initial sign layout be made at normal spacing, using the width of alphabet and letter height required for the legibility desired. In the development of a final design, the opportunity to introduce additional interletter spacing can often be used to advantage. Where two or more lines of sign copy are to be used, one line seldom fills the entire sign width. Increased spacing may be used for this line, thus

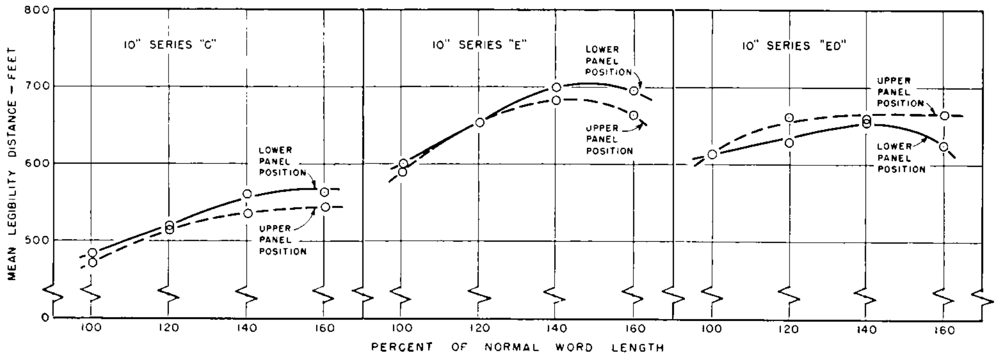


**Figure 21. Legibility distances, according to panel position, for Series C, E, and ED alphabets as affected by the spacing between letters in test words.**

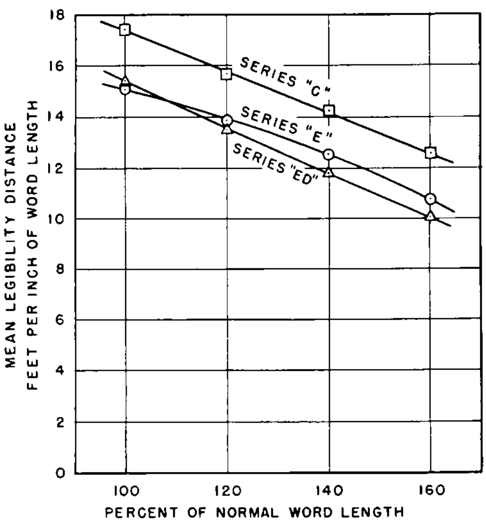


**Figure 22. Legibility distances (in feet per inch of word length) for Series C, E, and ED alphabets as affected by the spacing between letters in test words.**

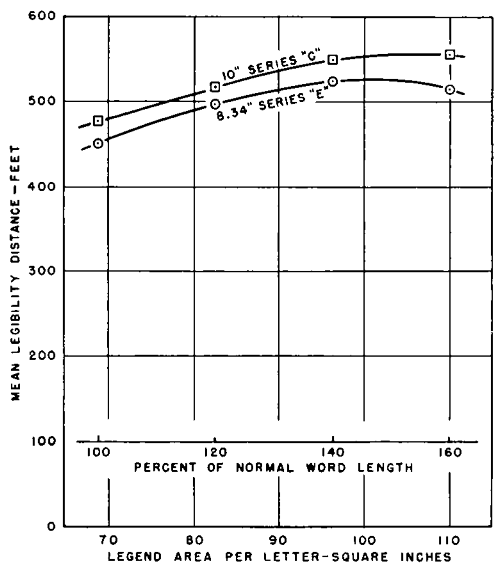


**Figure 24. Legibility distances for Series C and E alphabets (letters adjusted in height to produce equal legend areas) as affected by the spacing between letters in test words.**

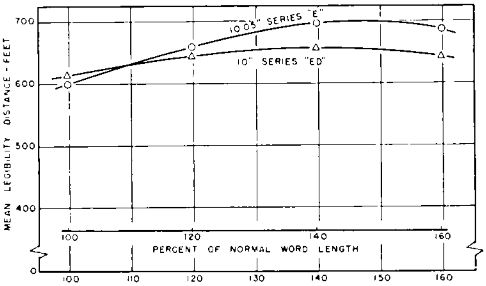


**Figure 23. Legibility distances for Series ED and E alphabets (letters adjusted in height to produce equal legend areas) as affected by the spacing between letters in test words.**

increasing legibility with no increase in the size of sign panel required. For signs on overhead structures, or for overhead signs at other locations, the vertical dimension of the sign may be limited and a comparatively small letter height may be required. In such instances, the common practice has been to shrink the total dimensions. Actually, the widest practicable alphabet (Series "E" or even Series "F") and up to 40 percent more word length can be utilized to good advantage. Similarly, where the horizontal sign dimensions are restricted, the narrower Series "C"

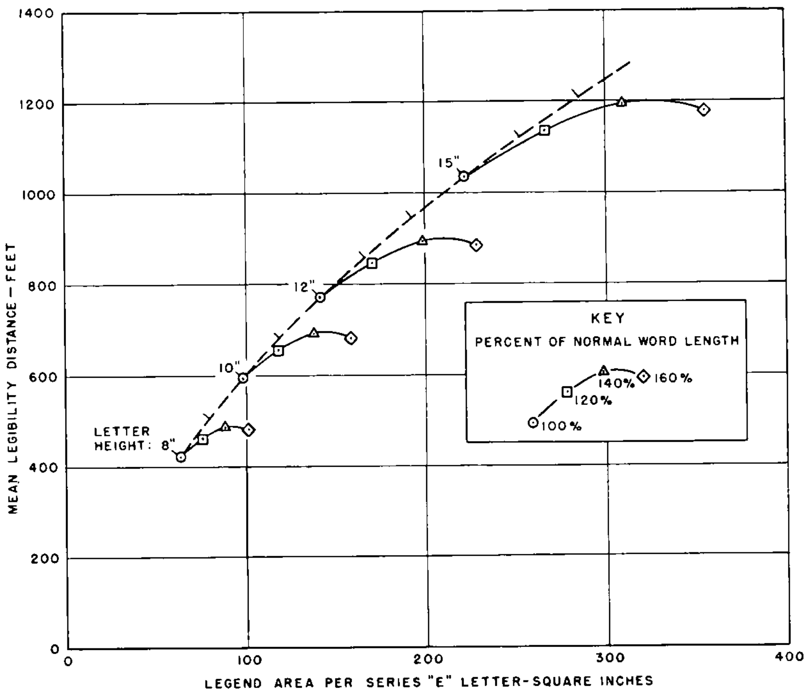


**Figure 25. Legibility distances for Series E alphabet as affected by the height of letters and the spacing between letters in test words.**


**Figure 26. Typical ground sign with 12-inch letters and normal spacing.**

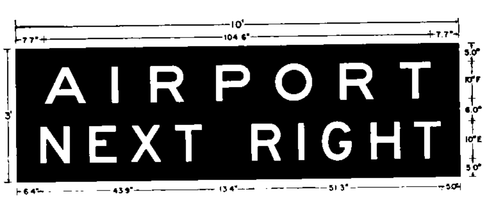


**Figure 27. Overhead sign with 10-inch letters and extended spacing.**

letter can be employed at normal spacing, and legibility increased by using a greater letter height.

APPLICATION OF TEST RESULTS

A sign found near many cities having large airports is AIRPORT, NEXT RIGHT. Figure 26 shows a possible design for such a sign. Series "C" and "E" letters are used in this example, 12 inches high and at normal spacing. These would probably be the desired proportions under normal conditions for a ground sign where adequate distance is available for advance warning and the average running speed is about 50 miles per hour.

With expressways handling heavy volumes of traffic, overhead signs are often necessary. Vertical clearances might be restricted if the sign were placed on an overhead structure. In that event, the sign could be stretched out as shown in Figure 27. The vertical dimension then is reduced from 4 feet to 3 feet, and the horizontal dimension increased from 8 feet to 10 feet.

AIRPORT is comprised of Series "F" letters 10 inches high and the spacing is increased so that the word length is 40 percent greater than normal. This results in a word that has substantially the same legibility as the ground sign, which had Series "E" letters, 12 inches high, and at normal spacing. Similarly, NEXT RIGHT uses Series "E" letters, 10 inches high at a word length 20 percent greater than normal. The resulting legibility is better than could be obtained from the ground sign, which had Series "C" letters, 12 inches high and at normal spacing.

## CONCLUSIONS

The following conclusions may be drawn for the nighttime legibility of 10-inch white reflectorized letters on a dark, nonreflectorized background under simulated roadway conditions, and with low beam of the headlamps:

1. Definite improvements in legibility result from moderate increases above the spacings normally used between sign letters. If interletter spacings are increased until the word length is 40 percent greater than normal, the mean legibility distance increases 15 percent above normal for Series "C" words, 16 percent for Series "E," and 7 percent for Series "ED."
2. An increase of approximately 40 percent over the normal word length is about the limit for realizing additional legibility through greater interletter spacing. Words lengthened more than 40 percent above normal gain little or nothing in legibility. With Series "E" and "ED" letters, word legibility actually declines, and the increase with Series "C" is only slight.
3. Mean legibility distances recorded for the 36 observers were 478 feet for Series "C" words, 596 feet for Series "E" and 614 feet for Series "ED," all measured at normal letter spacing. The 15 percentile values ranged from 27 to 33 percent lower, being 350, 400, and 450 feet, for Series "C," "E," and "ED," respectively.
4. Words formed with the Series "ED" letters have slightly superior legibility to those containing Series "E" letters when word lengths are normal or no more than 10 percent in excess of normal. At wider letter spacings, words with Series "E" letters are more legible. Since letter design details and reflectance characteristics both differed between the Series "E" and "ED" alphabets, a true evaluation of the independent contributions of these two factors to legibility was beyond the scope of this study.
5. Legibility distances for Series "E" words are 118 feet to 142 feet greater than for Series "C" at the various spacings. Series "C," however, occupies less word length for a given spacing and, judged on the basis of legibility distance per inch of word length, it is somewhat superior to Series "E." The two alphabets are equally legible when displayed at corresponding spacings and when Series "E" letters are reduced in height so that the legend areas are the same.
6. A display of two words rather than one on a sign tends to reduce the distance at which any single element of the message is legible. Additional words on the sign would further reduce legibility.
7. The responses of observers grouped according to their visual acuity are similar. Legibility curves determined for these groups, though of a different magnitude, follow remarkably consistent patterns.
8. A change from 5 to 7 feet in the vertical position of a sign legend above the roadway has little effect on the legibility distance.
9. More consideration of sign proportions is warranted in the development of sign design. Where vertical dimensions are restricted, and dictate use of letter heights less than those desirable, increased word lengths can help to compensate for the loss of legibility distance that would otherwise occur.
10. Within the limitations of appearance and need for emphasis, the horizontal spacings between sign letters should more commonly be increased to take advantage of portions of the sign area otherwise unused.

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2. Forbes, T. W., Moskowitz, K., and Morgan, G., "A Comparison of Lower Case and Capital Letters for Highway Signs," Highway Research Board, 1950, pp. 355–373.
3. "Revisions to the Manual on Uniform Traffic Control Devices for Streets and Highways," U. S. Government Printing Office, Washington 25, D. C., 1954, p. 1.