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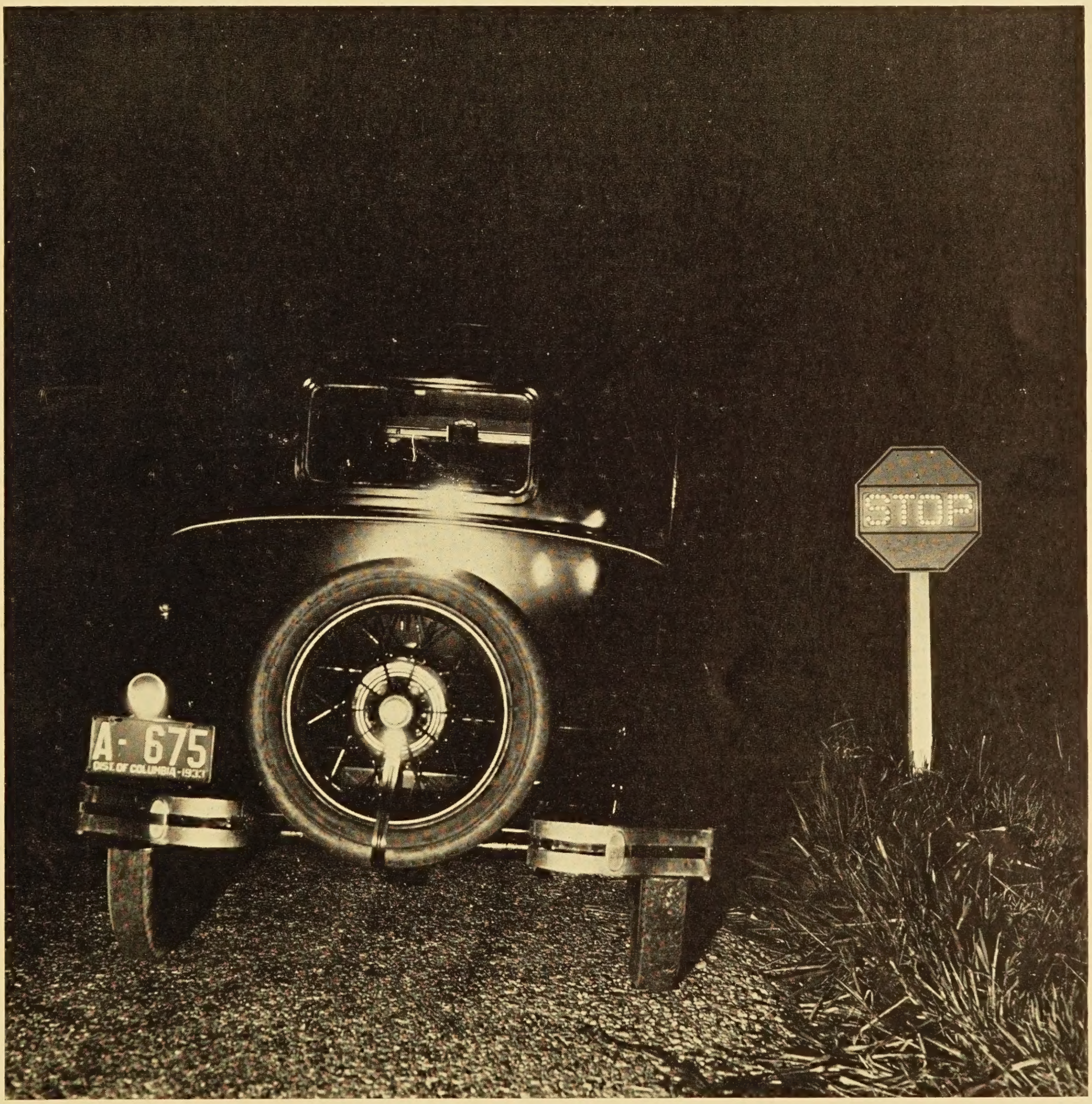

REFLECTING BUTTONS ON HIGHWAY SIGNS ADD TO SAFETY OF NIGHT DRIVING

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G. P. St. CLAIR, *Editor*

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The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to the described conditions

In This Issue

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THE COMPARATIVE VISIBILITY OF STANDARD LUMINOUS AND NONLUMINOUS HIGHWAY SIGNS

REPORT OF INVESTIGATIONS BY THE UNITED STATES BUREAU OF PUBLIC ROADS, IN COOPERATION WITH THE NATIONAL BUREAU OF STANDARDS

Prepared by F. W. MILLS, Highway Engineer, Division of Highway Transport, U.S. Bureau of Public Roads

THE REPORT of the subcommittee on traffic control and safety of the American Association of State Highway Officials, rendered at the annual meeting held in Pittsburgh, November 17 to 20, 1930, included the following recommendations:

STANDARDIZATION OF LUMINOUS SIGNS

Since it is uncertain what color and size of reflector buttons and color of background should be used on the reflector signs when made as a combination day and night sign, and due to the variable focal length of buttons that may be used on these signs, it is recommended that the Bureau of Public Roads consult with the Bureau of Standards in conducting a series of tests to learn of the most appropriate combination to use with the view of making any necessary changes in the present designs. One of the most important questions is the color of the background most appropriate for use with reflector buttons, keeping in mind both day and night visibility. For instance, is a sign with reflector buttons set in a black panel on a white background more efficient than one having buttons in a white panel on a black background, or is some other combination of color better? Also, the focal length and size of buttons as well as the number of buttons for a specific size of letter should be determined.

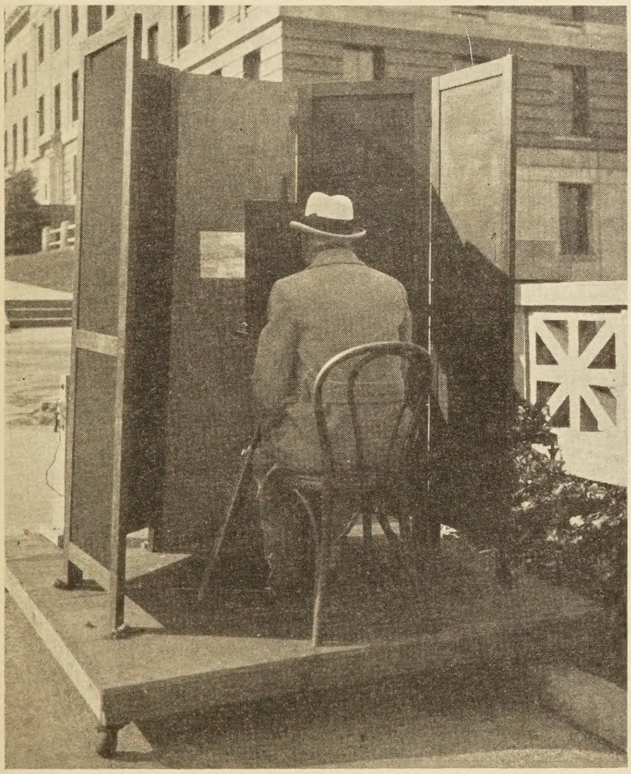

FIGURE 1.—OBSERVER'S STATION AT EYEPIECE OF TACHISTOSCOPE.

At the annual meeting of the American Association of State Highway Officials, held on September 28, 1931, it was resolved that:

The executive committee of the American Association of State Highway Officials appoint a special sign committee to act as a subcommittee of the regular association committee on traffic control and safety, and that this sign committee be made generally representative over all parts of the country so far as possible in a group of not more than five members; that the members of this committee shall be drawn preferably from those members who are directly in contact and responsible for the installation and maintenance of highway signs and markers.

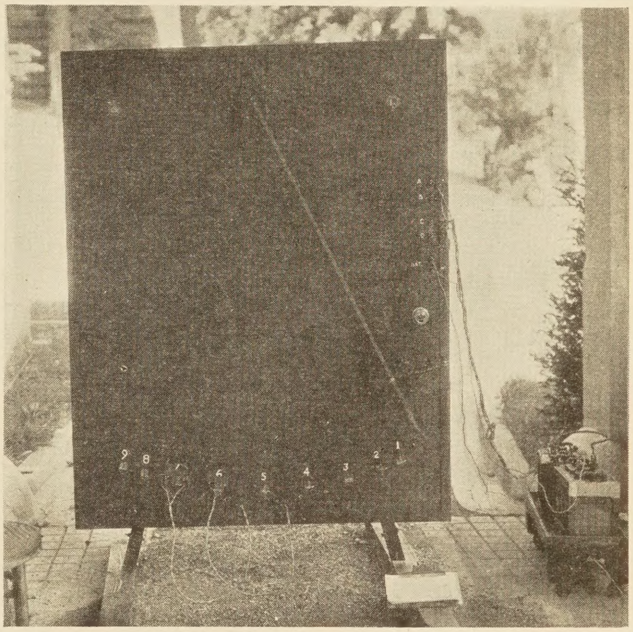

FIGURE 2.—PENDULUM FOR REGULATING TIME OF OBSERVATION.

The executive and publicity committee of the National Conference on Street and Highway Safety, at a meeting in New York City on June 23, 1931, adopted the following:

After further discussion it was voted that the executive committee of the National Conference on Street and Highway Safety favors the combination of the two codes in one publication and the setting up of a joint committee representing the American Association of State Highway Officials and the conference to formulate such a combined code and that Colonel Barber represent the conference in dealing with the highway group in the appointment committee.

Pursuant to these resolutions, a joint committee consisting of eight members representing the National Conference on Street and Highway Safety and seven members representing the American Association of State Highway Officials was created and the first meeting was held in Washington on March 24, 1932.

In harmony with the previous recommendation of the subcommittee on traffic control and safety, the joint committee was authorized: (1) To make such revisions as may seem necessary to harmonize or combine the two codes; (2) to make such additions as will produce a single and complete code for both rural and municipal use and to complete, in cooperation with the Bureau of Public Roads and Bureau of Standards, investigations recently inaugurated covering the use of reflecting elements; and (3) to introduce into the series of standard signs such other signals as may be indicated by the results of the investigation.

In accordance with the second item of this authorization the project covered by this report was inaugurated, to be carried out under the leadership of Drs. J. Franklin Meyer and M. G. Lloyd for the Bureau of Standards and Mr. F. W. Mills for the Bureau of Public Roads.

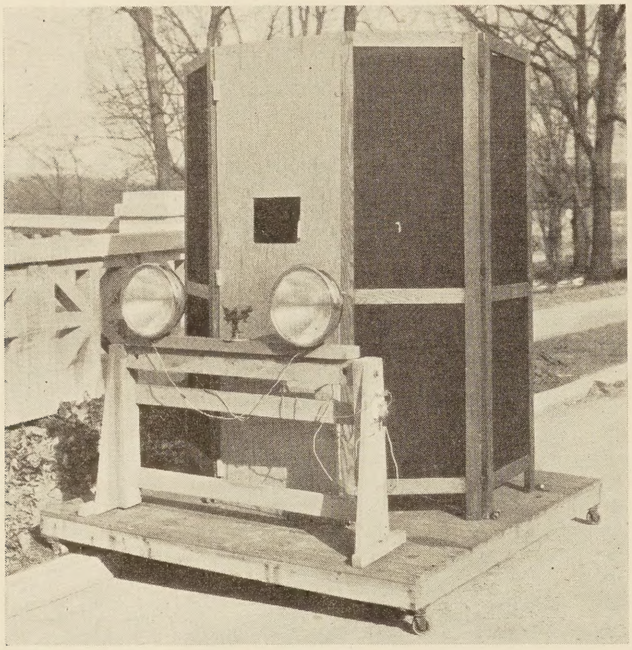

Figure 3.—Equipment for Night Observations.

Broadly considered, the scope of the investigations covered three principal phases: First, personal observations of standard signs having different color combinations as between background and legend, letters of various standard sizes without reflector buttons being used for this purpose; second, night observations of signs equipped with reflector buttons; and third, daylight observations made on the same signs to determine what effect there is, if any, on legibility, thus furnishing a basis for comparing their legibility with that of the signs not equipped with reflector buttons. The tests extended over a period that included summer as well as winter climatic conditions and offered an opportunity to view the signs in bright sunlight, during rains, snow, and fog, and against the changing natural background.

TACHISTOSCOPE DEVISED FOR REGULATING TIME OF OBSERVATION

Previous investigations in this field apparently did not consider the essential element of personal acuity as registered by time intervals. It therefore devolved upon the Bureau of Standards to design an apparatus by means of which the periods of free observation could be accurately measured and the time interval changed at will. Several general schemes were considered, such as the use of shutters similar to camera diaphragms, but these were lacking in simplicity and portability, or restricted the field of vision in a greater or less degree. A tachistoscope, meeting these requirements, was finally designed at the Bureau of Standards. It consisted of two major units, (*a*) a screened eyepiece with two shutters moving in parallel vertical planes, and (*b*) an A frame or easel supporting a pendulum by which the time interval is regulated and controlled. The screened eyepiece or observer's window is set up on an ordinary tripod with adjustable legs and carries the two shutters in front of an eye shade. The shutters are held in place by magnets. Figure 1 shows an observer seated before the eyepiece of the tachistoscope.

The A frame supporting the pendulum is approximately 5 feet high and 4½ feet across the base. It is held vertical by a hinged strut at the back, thus forming a complete tripod. The front of the frame carries a 5- by 4-foot weatherproofed sheet of wall board reinforced with battens to prevent warping. A 3- by 4- by 6-inch block situated at the top of the frame and protruding through the wall board provides a support and carrier for a pendulum one meter in length. The pendulum rod extends 25 centimeters below the bob so that in swinging it operates contacts which open the circuits of the two magnets at the observing window and releases the shutters. These contacts are carried on brass brackets affixed to the face of the wall board in the arc described by the pendulum. The contacts consist of a simple spring arrangement so constructed that when touched by a swinging pendulum the circuit is opened. One contact controls the opening shutter and the other the closing shutter of the observer's window. The contacts are attached to the bracket by a thumb screw and can be adjusted to any desired time interval from 0.1 to 1.0 second or more. Figure 2 shows the pendulum and contacts.

In order to minimize or entirely overcome the element of surprise, the switch controlling the movement of the pendulum, and consequently of the shutters, is operated by the observer. It was early recognized that the observer must also become used to the noise due to shutter movement; accordingly, in each case the apparatus was operated several times by the observer until all involuntary winking or other distraction was overcome and tolerance established. It was also foreseen that in the course of a long series of observations the sequence in which the signs were displayed might become known to the observer and the reading obtained be by memory or by suggestion. This possibility was eliminated by reversing the order of display and sequence of changes in the signs and also the time periods during which they were observed.

It is believed that the investigation has been as exhaustive as possible and that the results obtained lead to definite conclusions regarding relative efficiency within the scope permitted.

For night operations, two standard automobile headlights were mounted in front of the observation screen. A small telescope with cross hairs, by means of which the light beams could be directed so as to fall upon the signs, was attached to the cross arm between the head lights (fig. 3).

In choosing the field for the operations, great care was taken in selecting a section of roadway which would present the average background encountered on the average highway. The main driveway at the Bureau of Standards in a large measure met this consideration. It runs directly east and west, so that the sunlight was directly behind the sign during the morning hours and fell directly on the sign in the late afternoon with all penumbral phases during the day. Morning shadows were thus compensated for by afternoon sunlight. The roadway was of concrete near the sign in the far distance and of asphalt in the observer's immediate foreground. A low concrete retaining wall and a concrete building were on the observer's left and brick buildings and vegetation immediately in the rear and to the right. Observations were taken at 200, 300, 350, 400, and 500 feet. Figures 4 and 5 show the general appearance of the area in which the tests were made.

In selecting the observers, an attempt was made to obtain a complete cross section of actual and potential automobile drivers. Many observers were obtained from the local employment agency through the interested cooperation of the American Automobile Association. The majority held drivers' permits but care was taken to select a due proportion of nondrivers. For the daylight operations, approximately 28 percent were female and 72 percent male and ages ranged from 17 to 70 years. Three observers claimed to be colorblind but were not excluded on that account.

DAYLIGHT OBSERVATIONS ON NONLUMINOUS SIGNS

The nonreflecting signs used for daylight observations were of three shapes with standard dimensions (24-inch diameters): (1) Octagon; (2) square; and (3) square with diagonals vertical (diamond). The ground colors were standard Federal yellow, black, and white. Black letters were used on the yellow and white backgrounds and white letters on the black backgrounds. All letters were of standard height and stroke. In making up the various legends, separate letters were painted on heavy bristol board and attached to the signs as needed. This permitted transposition of the same letters or the use of different-sized letters on the same sign to check the accuracy of the previous reading.

All observations were made on signs of standard dimensions and design, adopted by the American Association of State Highway Officials. The hue and shade of the paint used for ground color on the yellow signs conform to the colorimetric requirements of rule 53 of the sectional committee on colors for traffic signals of the American Standards Association. These requirements have been adopted by the American Association of State Highway Officials as standard specifications and the shade is informally known as "Federal yellow." The three associated elements of sign recognition, that is, shape, color, and legend, were reported on and recorded separately.

A 3-way telephone system connecting the recorder at the observation button with the operator at the pendulum and the manipulator making the sign changes was installed. The recorder would indicate to the pendulum operator the time interval required and to the sign manipulator the desired change of the sign. In order that the observer should not be apprised of the character of the change or of the time interval, this information was conveyed either in code or by a previously arranged sequence of operation. When the proper adjustments had been made, the observer pressed a push button releasing the shutters. He was then required to inform the recorder whether or not a sign had been seen during the interval of free sight and, if so, its shape, color, and legend. The sign or its legend was then changed. The change might consist of a transposition of letters or the display of an entirely different sign. The transposition of letters or legend was particularly interesting in that it is apparent that if an observer could not read a 6-inch letter in a 0.5-second interval, it might be possible and frequently was so to read an 8-inch letter in the same interval and at the same distance. Obviously the large direction arrow might assist or even suggest recognition of the CURVE sign, but if the CURVE is changed to TURN and a large R or L substituted for the arrow, it will serve as a check on the accuracy of the previous read-

SUPERIORITY OF YELLOW BACKGROUND FOR DAYLIGHT VISIBILITY DEMONSTRATED; THREE-FOURTHS-INCH REFLECTING BUTTON FOUND EFFICIENT FOR NIGHT DRIVING

The findings in this investigation of standard luminous and nonluminous highway signs are briefly summarized as follows:

1. *Daylight observations on nonluminous signs.*—All evidence points to the definite conclusion that the standard yellow background with black letters or design, under all conditions reasonably to be expected in either urban or rural driving, is much superior to black on white or white on black. In addition to the greater readability of the legend the yellow background has a greater signal value, being more arresting to the average observer and more conspicuous by contrast with the average natural or artificial background. By the adoption of a definite shade and hue it should be possible to prohibit the use of this distinctive shade for any roadside advertisements or signs other than official highway signs.

2. *Night observations on nonluminous signs.*—While these observations were not in any way conclusive, the inadequacy of daylight signs for night driving was clearly indicated. The effect of a snow background was especially noted.

3. *Night observations on luminous signs.*—Observations were made with three sizes of reflector button, 0.95-inch, 0.76-inch, and 0.58-inch, under conditions simulating both rural and city driving. The conclusion was reached that the colorless button with a diameter of 0.76-inch and a minimum spacing between buttons of 1 inch, center to center, is, in general, the most efficient. For rural use the 0.58-inch button has a superior long-range signal value, but is less readable than the unit of larger diameter.

4. *Daylight observations on luminous signs.*—The effect on distinctness in daylight of inserting reflecting buttons in the letters is not serious at a distance of 200 feet, even though approximately 50 percent of the area of the letter is taken up by colorless buttons. The difference in the effect on black and on white letters is negligible.

5. *Recognition by shape of sign.*—The practice of outlining highway signs with reflector buttons, so that the road user may recognize a potential hazard at a distance by the distinctive shape of the sign plaque alone, is worthy of further development. The use of symbols, except for the arrows indicating curve or direction, is not considered as effective as outlining the sign with buttons.

ing, the color, shape, and time period not having been changed.

For the tests of nonreflecting signs 70 observers were used who made a total of 4,563 observations at the various distances from 200 to 500 feet. The time intervals for legibility of the legend ranged from 1.0 to 0.6 second. This apparently was the shortest interval in which the legends could be distinctly read, the readability, of course, diminishing with the distance. The time intervals 0.5, 0.4, and 0.3 second were included to determine whether the observer could still see a sign at all and, if so, its shape, color and legend.

The contention that when two colors are used the background should be of the darker color is not in this instance conclusively borne out because the superiority of white on black over black with yellow background obtains only at 200 feet. One explanation of the apparent difficulty in reading black on white is that sun glare on the high gloss white background obscures the black letters and this is apparently verified when it is noted that the percentages of difference decrease appreciably as the distance is increased. At 400 feet both black and white combinations are equal and at 500 feet there is but 1 percent in favor of the white on black. At all distances, except 200 feet, however, black on yellow has the advantage of from 5 percent to 12 percent over either of the other combinations.

Figure 4.—General View of Main Driveway at Bureau of Standards, With Observer's Station in Foreground.

AVERAGES OF ALL OBSERVATIONS INDICATE SUPERIORITY OF BLACK ON YELLOW

The average of the observations at all distances and for all time intervals establishes the following relative values: Readings of the black on white combination were 57 percent correct; of the black on yellow combination 66 percent correct, and of the white on black combination 59 percent correct. Figure 6 shows the variation in the percentage of correct readings with the distance of the sign from observer's station. The data are given in tabular form in table 1. Figure 7 gives the percentage of correct readings for each of the various signs and time intervals used, and for each of the distances from the observer.

In analyzing this tabulation, it is interesting to note that at 200 feet, white on black, i.e., white letters on black background, had a distinct advantage over black on white and a slight superiority over black on yellow. At 300 feet the superiority is to a small extent reversed with respect to the black and white combinations, being 2 percent in favor of the black on white, but at 350 feet it is again 5 percent the other way.

Table 1.—*Percentage of correct readings at each station, averaged for all time intervals*

Distance from observer	Color combination	Percentage of correct readings
Feet		
200	Black on white	85
	Black on yellow	91
	White on black	93
300	Black on white	62
	Black on yellow	71
	White on black	60
350	Black on white	62
	Black on yellow	72
	White on black	67
400	Black on white	38
	Black on yellow	48
	White on black	38
500	Black on white	35
	Black on yellow	48
	White on black	36

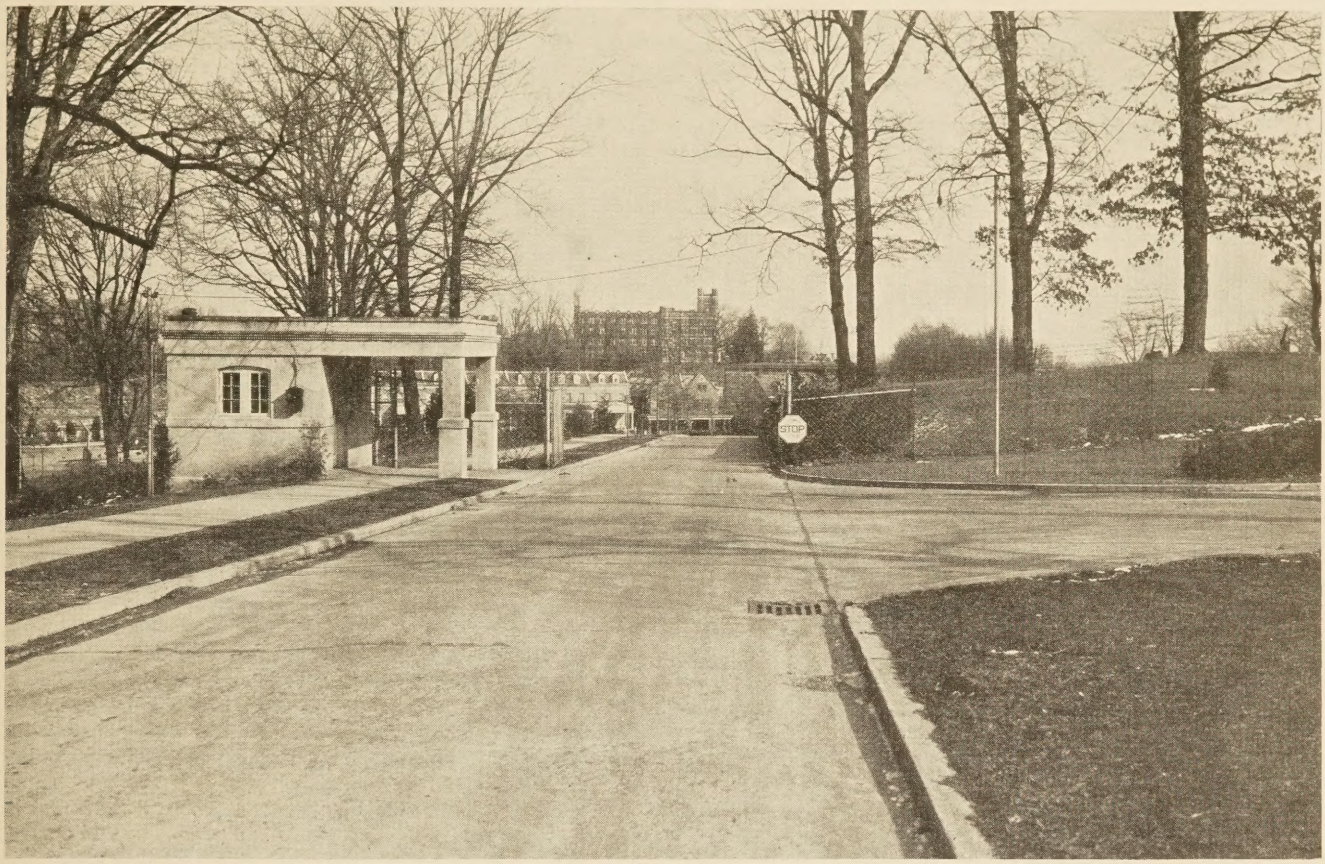

FIGURE 5.—WINTER VIEW FROM OBSERVER'S STATION.

DATA ON MEAN AND EXTREME DISTANCES ANALYZED

The previous discussion deals only with general averages of correct recognition of the signs, including all transpositions of the legend and time periods down to 0.6 second. A more complete analysis of the correct percentages obtained at the mid or critical distance and at the extreme stations (200 and 500 feet) follows. The data obtained with signs placed at these stations are given in tables 2 and 3.

The 350-foot distance apparently is the critical point beyond which there is an abrupt falling off in readability of the signs. At this station, 17 observers (6 female and 11 male) made 777 observations. Separating these according to time intervals and observing the SLOW sign (letters 8 inches in height with 1$\frac{3}{16}$ inches stroke) at 1.0 second, we find that the black on white shows 78 percent, black on yellow 83 percent, and white on black 72 percent correct. The STOP sign (6-inch letters) at 0.8 second shows: Black on white 64 percent,

TABLE 2.—*Comparative visibility at mean distance (350-foot station)*

Sign	Size of letter	Time interval	Color combination	Percentage of correct readings
		Seconds		
			Black on white	78
SLOW	8 by 1$\frac{3}{16}$ inches	1.0	Black on yellow	83
			White on black	72
			Black on white	64
STOP	6 by 1 inch	.8	Black on yellow	78
			White on black	77
			Black on white	52
CURVE	6 by $\frac{7}{8}$ inches	.7	Black on yellow	64
			White on black	65
			Black on white	62
ZONE	5 by $\frac{5}{8}$ inches	.6	Black on yellow	64
			White on black	63
			Black on white	56
SLOW	8 by 1$\frac{3}{16}$ inches	.6	Black on yellow	71
			White on black	63

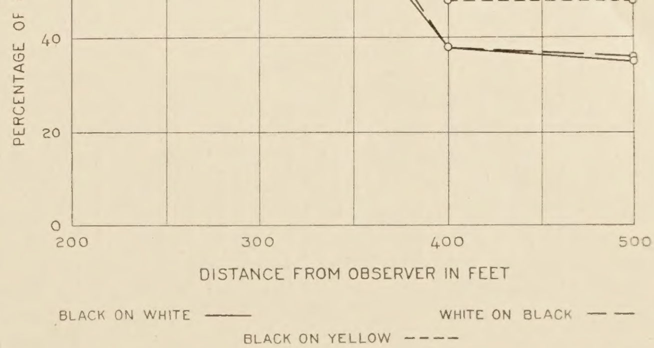

FIGURE 6.—PERCENTAGE OF CORRECT READINGS OF NON-LUMINOUS SIGNS IN DAYLIGHT AT VARIOUS DISTANCES FROM OBSERVER. AVERAGE FOR ALL TIME INTERVALS AT EACH STATION.

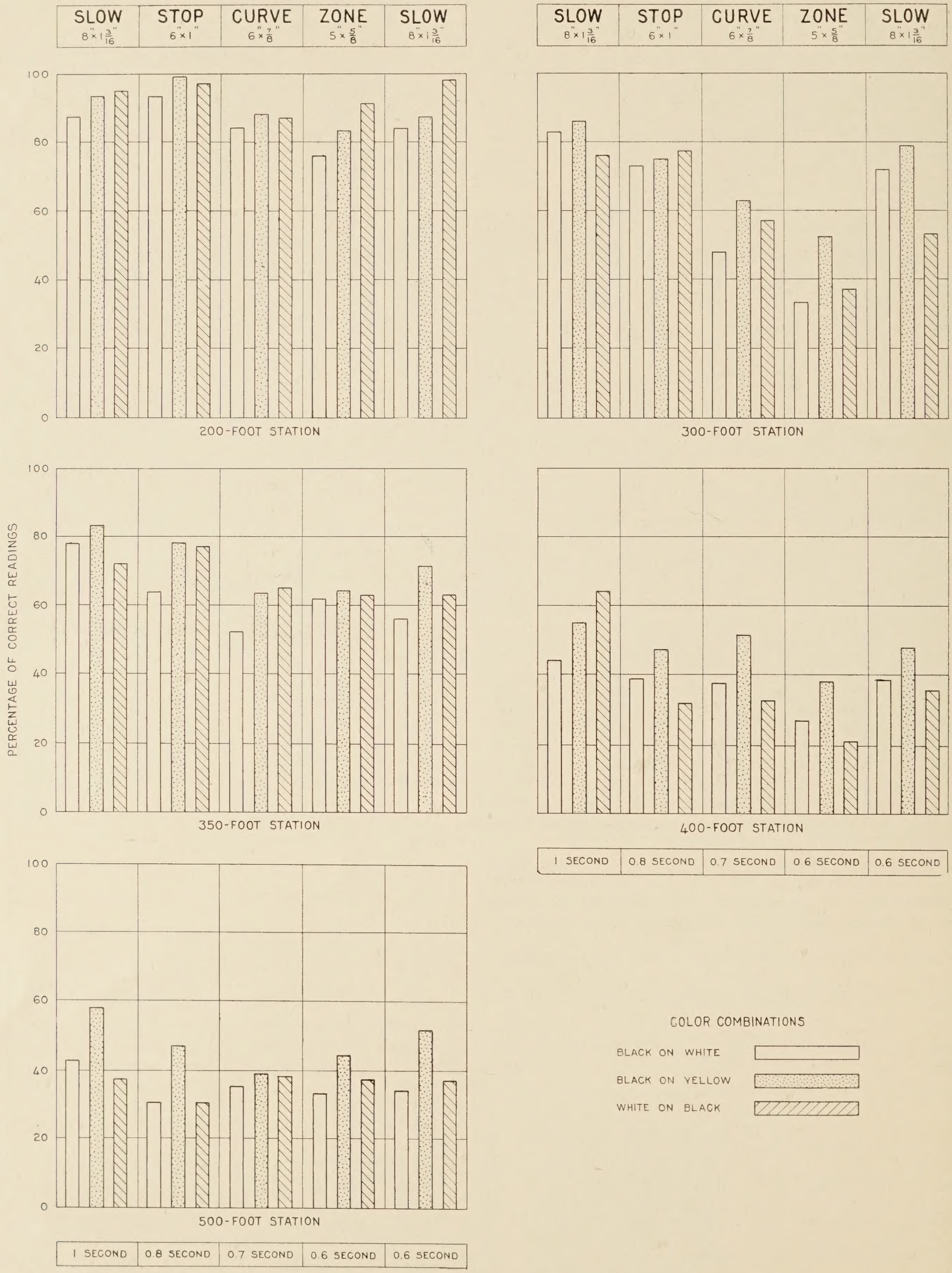

Figure 7.—Percentage of Correct Readings of Nonluminous Signs in Daylight at Various Distances from Observer and for Various Lengths of Time of Observation.

black on yellow 78 percent, and white on black 77 percent correct. The CURVE sign (letters 6 inches in height with ⅞-inch stroke) at 0.7 second shows: Black on white 52 percent, black on yellow 64 percent, and white on black 65 percent. With the SCHOOL ZONE sign (letters 5 inches in height and ¾-inch stroke) at 0.6-second interval, the percentages are: Black on white 62 percent, black on yellow 64 percent, and white on black 63 percent correct.

At this point the accuracy of the observer's reading was checked by again using the 8-inch letters on the SLOW sign. Except for the black on yellow the percentages obtained do not verify anticipations of increased legibility for the larger letter, for at the same time interval (0.6 second) the readings were: Black on white 56 percent, black on yellow 71 percent, and white on black 63 percent correct.

As in the general averages previously referred to, black on yellow still maintains its first place with white on black and black on white following in that order, the percentages at this station being 62 percent for black on white, 72 percent for black on yellow, and 67 percent for white on black.

The data are not broken down into time intervals showing the relative percipiency as between male and female drivers but the arithmetical average obtained at all intervals may be enlightening. The 6 females made 297 observations and the 11 males made 480 observations at the critical station (350 feet) with the following results:

FEMALE OBSERVERS

	Percent correct
Black on white	47
Black on yellow	64
White on black	57

MALE OBSERVERS

	Percent correct
Black on white	76
Black on yellow	79
White on black	77

Possibly the relatively low female average can be attributed to the fact that, of the 6 observers, 3 were nondrivers and therefore presumably unfamiliar with the signs. All of the 11 males, on the other hand, held driving permits.

At the extreme distances, the following results were obtained: At 200 feet the minimum distance, a total of 684 observations were made by 12 observers, 3 female and 9 male. The time intervals were 1.0, 0.8, 0.7, and 0.6 second and the sign copy as before. At 1 second, black on white registered 87 percent, black on yellow 93 percent, and white on black 95 percent correct. At 0.8 second, black on white registered 93 percent, black on yellow 99 percent, and white on black 97 percent correct. At 0.7 second, correct registration for black on white was 84 percent, black on yellow 88 percent, and white on black 87 percent. At 0.6 second, with the 5-inch letter, black on white registered 76 percent; black on yellow 83 percent, and white on black 91 percent correct. Again at 0.6 second, with the 8-inch letter, a marked increase in the correct readings is noted, giving for black on white 84 percent, black on yellow 87 percent, and white on black 98 percent correct. The difference in percentages in favor of the white on black as against the black on white is again pronounced, and white on black is superior also to black on yellow, except for the 6-inch letter at 0.8 second and the 5-inch letter at 0.7 second. In comparing again the visual acuity of the females with that of the males, quite the reverse of the condition at 350 feet is noted, in that for all the time intervals the females registered 90 percent for black on white; 93 percent for black on yellow, and 95 percent for white on black, as against 81 percent, 88 percent and 91 percent, respectively, for the males.

TABLE 3.—*Comparative visibility at extreme distances*

200-FOOT STATION

Sign	Size of letter	Time interval	Color combination	Percentage of correct readings
		Seconds		
SLOW	8 by 1 3/16 inches	1.0	Black on white	87
			Black on yellow	93
			White on black	95
STOP	6 by 1 inches	.8	Black on white	93
			Black on yellow	99
			White on black	97
CURVE	6 by ⅞ inches	.7	Black on white	84
			Black on yellow	88
			White on black	87
ZONE	5 by ⅝ inches	.6	Black on white	76
			Black on yellow	83
			White on black	91
SLOW	8 by 1 3/16 inches	.6	Black on white	84
			Black on yellow	87
			White on black	98

500-FOOT STATION

Sign	Size of letter	Time interval	Color combination	Percentage of correct readings
SLOW	8 by 1 3/16 inches	1.0	Black on white	42
			Black on yellow	58
			White on black	37
STOP	6 by 1 inches	.8	Black on white	30
			Black on yellow	47
			White on black	30
CURVE	6 by ⅞ inches	.7	Black on white	35
			Black on yellow	39
			White on black	37
ZONE	5 by ⅝ inches	.6	Black on white	33
			Black on yellow	44
			White on black	37
SLOW	8 by 1 3/16 inches	.6	Black on white	34
			Black on yellow	52
			White on black	37

At the maximum distance, 500 feet, at which station 11 observers made 600 observations, the following data were obtained. On the large SLOW sign at 1.0 second, 42 percent correct for black on white, 58 percent for black on yellow, and 37 percent for white on black was registered. At 0.8 second, with the STOP sign having 6-inch letters, the black on white shows 30 percent, black on yellow 47 percent, and white on black 30 percent correct. At 0.7 second with a 6-inch letter having a narrow stroke (⅞-inch) the correct readings were: Black on white 35 percent, black on yellow 39 percent, and white on black 37 percent correct. The increase in percentage of correct readings for the black on white and white on black combinations is probably due to the fact that the large CURVE symbol (arrow) was displayed on the CURVE sign, thus introducing an element of suggestion to the observer. Changes on this sign consisted of substituting large letters R or L for the arrow or TURN for CURVE. At 0.6 second the ZONE sign was first used and the changes or transpositions consisted of interchanging the words HOSPITAL and SCHOOL. These letters are 5 inches in height and correct registration was: Black on white 33 percent, black on yellow 44 percent, and white on black 37 percent.

It is interesting to note that at this point several observers were asked if the copy was clearly read or if the identification was made from the picture as outlined by the length of the words. A number of observers claimed that they actually read the words but perhaps a greater number identified the sign by reading the shorter word and guessed at the longer. Comparing the readings of the ZONE sign at 0.6 second against the 8-inch letter of the SLOW sign at the same interval, we find an increase of 1 percent in efficiency of the larger letter over the smaller in the case of black on white and 8 percent in the case of the black on yellow, while the white on black registered no difference.

RESULTS OBTAINED BY OTHER INVESTIGATORS DISCUSSED

As previously indicated, exhaustive investigations of sign color combinations have been made in university and commercial research laboratories and by State highway departments, but apparently this is the first time that there has been an opportunity for estimating personal percipiency or reaction of the road user as measured by a definitely controlled time interval or factor. In effect, the percentages quoted confirm deductions made in some of the laboratory tests although these may have dealt primarily with the visibility of color used on automobile tags and not exclusively with highway signs.

From the investigations made last year by Prof. A. R. Lauer, of the department of psychology, Iowa State College, under the auspices of the National Research Council, it appears that yellow for backgrounds is better than orange; but Professor Lauer's deductions that light backgrounds are always better than dark was not completely verified. In connection with the studies made in the office of the New Jersey Traffic Commission at Trenton, Mr. A. H. Vey reports that it appears that white on a black background gave from 15 to 20 percent greater distance legibility. No such superiority of white on black over black on white is indicated in these tests. Mr. Vey further expresses the opinion, however, that black on white is more adaptable under certain conditions, which will depend upon the background; and will probably give better service. He suggests that any objections to the black background might be overcome to a large extent by designing a wide white border around the sign.

In his treatise on Color and Its Application, 1921, Mr. M. Luckiesh, quoting a report from Le Courrier du Livre, gives the combination black on yellow as first and white on black as tenth in his list of 13 color combinations. The customary black on white is sixth. This rating is borne out by these investigations only as applying to the black on yellow. On the other hand, in an unpublished investigation of automobile license tags made by the National Bureau of Standards, it developed that the black on yellow combination was fourth in the list of 25 combinations investigated. Black on white was eighth and white on black was eleventh. These three combinations gave 93.2, 91.1, and 87.7 percent, respectively, of correct readings.

These ratings, while supporting in a measure the present investigations, are not necessarily conclusive in that the time interval of free sight was not considered, nor was any attempt made to relate the observing time to the distance at which the tags were legible.

RAPIDITY OF RECOGNITION OF SHAPE, COLOR, AND LEGEND

The rapidity with which the average individual observer could select or pick out a sign from its surrounding background and recognize its shape, color, or legend was tested at time intervals of 0.5, 0.4, and 0.3 second. In only a negligible number of instances and at the minimum distance were observers able to identify the sign by any of these characteristics at intervals shorter than 0.3 second. The SLOW sign with an 8-inch letter and the STOP sign with a 6-inch letter were used for this purpose. In all, 600 observations were made by 50 observers. The average percentages of correct readings, combining all three factors and including all distances, are given in table 4.

Here the superiority of the black on yellow is again apparent, except at the 0.5-second time period, where black on white has a 3-percent advantage. This superiority is most pronounced at the minimum of 0.3 second.

TABLE 4.—*Percentage of correct readings of shape, color and legend combined, at short time intervals; average for all distances*

Sign	Size of letter	Time interval	Color combination	Percentage of correct readings
	Inches	*Seconds*		
STOP	6	0.5	Black on white	78
			Black on yellow	75
			White on black	60
SLOW	8	.4	Black on white	54
			Black on yellow	64
			White on black	56
STOP	6	.3	Black on white	28
			Black on yellow	45
			White on black	33

In tables 5, 6, and 7, the component characteristics of shape, color, and legend, are separated. Table 5 gives the data for recognition by the shape of the sign.

TABLE 5.—*Correct recognition of shape at short time intervals; average for all distances*

Sign	Shape of plaque	Time interval	Color combination	Percentage of correct readings
		Seconds		
STOP	Octagon	0.5	Black on white	85
			Black on yellow	77
			White on black	59
SLOW	Diamond	.4	Black on white	61
			Black on yellow	66
			White on black	55
STOP	Octagon	.3	Black on white	32
			Black on yellow	49
			White on black	33

The advantage of the black on white at 0.5 second may possibly be attributed to the contrasting background aided by a bright afternoon sunlight falling directly on the sign. This advantage, however, did not obtain at the shorter intervals, at which black on yellow retains its superiority.

For recognition of color, a feature which is perhaps the most important of the three factors, in that the element of color contrast with surrounding backgrounds is paramount, the results were as shown in table 6.

These percentages clearly indicate the superiority of the Federal yellow for ground color. This superiority is most marked at the shortest interval. The high percentage of the black on white at 0.5 second seems to check the assumption previously made that bright sunlight materially assisted in accentuating the contrast with the surrounding background.

Table 7 gives the results for correct readings of the sign legend only.

TABLE 6.—*Correct recognition of color at short time intervals; average for all distances*

Sign	Time interval	Color combination	Percentage of correct readings
	Seconds		
STOP	0.5	Black on white	91
		Black on yellow	92
		White on black	75
SLOW	.4	Black on white	68
		Black on yellow	84
		White on black	68
STOP	.3	Black on white	31
		Black on yellow	54
		White on black	38

TABLE 7.—*Correct reading of legend at short-time intervals; average for all distances*

Sign	Size of letter	Time interval	Color combination	Percentage of correct readings
	Inches	*Seconds*		
STOP	6	0.5	Black on white	58
			Black on yellow	55
			White on black	47
SLOW	8	.4	Black on white	33
			Black on yellow	40
			White on black	44
STOP	6	.3	Black on white	18
			Black on yellow	27
			White on black	27

At these intervals no attempt was made to check the observer's accuracy by transposing or otherwise changing the letters and the data may not be conclusive because it was felt that at least some observers had subconsciously memorized previous indentifications. As the interval shortens the decreased accuracy is consistent with the decreases in the shape and color readings. The general averages for the three short-time intervals and at all the distances but for each of the elements of recognition, as shown in table 8, gives a very concrete idea of the weight the respective components bear to complete recognition.

TABLE 8.—*General averages of correct readings of shape, color, and legend at 0.5, 0.4, and 0.3 second for all distances*

Color combination	Shape	Color	Legend
	Percent	*Percent*	*Percent*
Black on white	59	63	36
Black on yellow	64	77	41
White on black	49	60	39

Here the fact that black on white is superior to white on black in the first and second cases is possibly due to the element of glare which did not affect recognition of either shape or color. For legibility of legend, however, white on black has 3 percent advantage over black on white, and black on yellow is more readily picked up than either of the other combinations.

Reading at the mid or critical distance of 350 feet before referred to and distinguishing between the factors shape, color, and legend, we have the following results at these short intervals. For recognition of shape, black on white gave 51 percent, black on yellow 55 percent, and white on black 42 percent. Here, as in the general average, the superiority of the white over the black background is again demonstrated, but the lead of the yellow is maintained. For recognition of color, black on white gave 55 percent; black on yellow 73 percent; and white on black 64 percent. This reverses the black and white order as shown by the previous percentages. For recognition of legend, black on white gave 37 percent; black on yellow 50 percent; and white on black 42 percent, again confirming the general averages.

At the minimum distance (200 feet) and for the same time intervals, that is, 0.5, 0.4, and 0.3 second, the following results were obtained. For recognition of shape, black on white registered 55 percent correct, black on yellow 81 percent, and white on black 85 percent. As to color, black on white registered 65 percent, black on yellow 89 percent, and white on black 85 percent. As to legend, black on white gave 58 percent, black on yellow 77 percent, and white on black 87 percent correct. At this short range, it is difficult to understand why the white on black sign should be so distinctly superior to the black on white. For color, however, the black on yellow is still superior to the other combinations.

At the maximum distance of 500 feet there is a reversal of the relative ratings of the black and white combinations, as compared with those obtained at the minimum distance of 200 feet, as the following will show. For shape, black on white registered 65 percent, black on yellow 65 percent, and white on black 23 percent correct. For color, black on white registered 65 percent, black on yellow 81 percent, and white on black 43 percent. For legend, black on white registered 17 percent, black on yellow 14 percent, and white on black 10 percent. For all three characteristics, black on white is superior to white on black, but black on yellow still leads. Especially significant is the high percentage of correct color readings, 81 percent for black on yellow as against 65 and 43 percent for the black and white combinations. With the varied background of foliage and artificial culture, it was not difficult to recognize the yellow even though the time interval was reduced to 0.3 second. The white sign contrasted distinctly with the natural background.

Analysis of the recognition of each of the three component elements by time interval at the critical station (350 feet) clearly presents the comparison sought and it is unnecessary to break the data down into the time factors obtained at the other stations. The consistency of the data obtained at the 350-foot station with the comparisons shown in the general averages for all distances is significant. The detailed data for this station are given in table 9.

REASONS FOR SUPERIORITY OF BLACK ON YELLOW DISCUSSED

The foregoing data are sufficiently exhaustive to indicate definitely that the black legend on the yellow background has a distinct advantage over either the white on black or black on white combinations and that the selection of this combination by the American Association of State Highway Officials is fundamentally correct.

In arriving at this conclusion two features which enhance its value as a signal, the rapidity with which a driver's attention is attracted to the yellow sign and the conspicuousness of its contrast with surrounding backgrounds, have been duly weighed. By signal value is meant the maximum distance at which a sign can be identified as a sign regardless of the distance at which its message becomes clearly readable. At distances of 350 feet or greater, with the 0.5 to 0.3 second

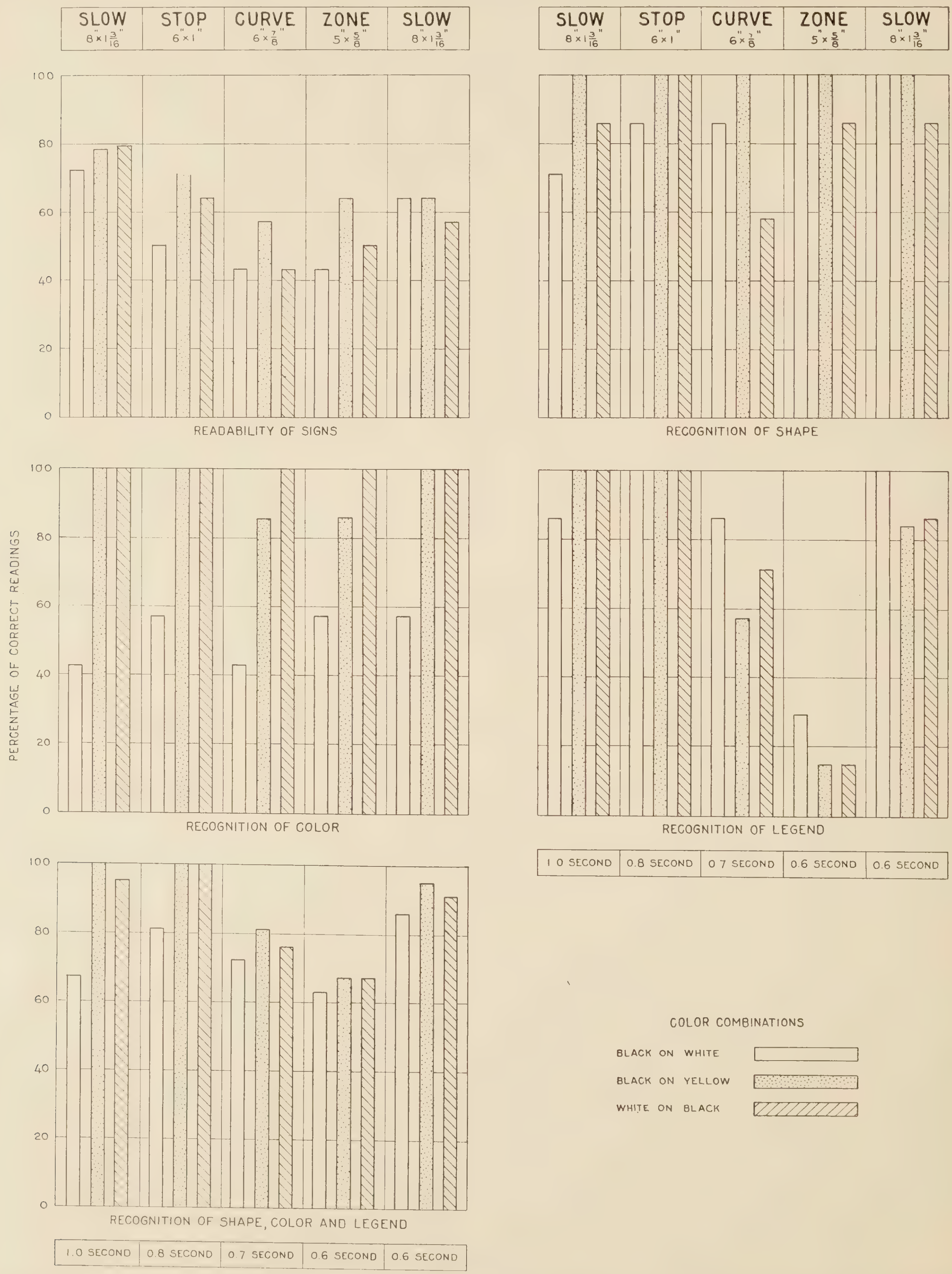

FIGURE 8.—NIGHT OBSERVATIONS ON NONLUMINOUS SIGNS: COMPARATIVE READABILITY AND RECOGNITION OF SHAPE, COLOR, AND LEGEND.

TABLE 9.—*Correct recognition of shape, color, and legend at 0.5, 0.4, and 0.3-second intervals at 350-foot station*

Time interval	Recognition of—	Color combination	Percentage of correct readings
Seconds			
0.5	Shape	Black on white	74
		Black on yellow	68
		White on black	58
.5	Color	Black on white	80
		Black on yellow	80
		White on black	71
.5	Legend	Black on white	55
		Black on yellow	61
		White on black	45
.4	Shape	Black on white	60
		Black on yellow	51
		White on black	39
.4	Color	Black on white	60
		Black on yellow	80
		White on black	80
.4	Legend	Black on white	41
		Black on yellow	51
		White on black	58
.3	Shape	Black on white	19
		Black on yellow	50
		White on black	29
.3	Color	Black on white	25
		Black on yellow	56
		White on black	35
.3	Legend	Black on white	13
		Black on yellow	38
		White on black	23

time intervals, particular advantage is seen for the yellow background and at 300 feet or less the wording becomes progressively more legible. At 40 miles per hour a car will cover 59 feet per second, so that if the driver's attention is attracted to the sign at 350 feet, he will have 3 seconds in which to arrive at a point approximately 180 feet in front of the sign, where legibility is reasonably assured.

NIGHT OBSERVATIONS ON DAYLIGHT SIGNS

As a proper supplement to the comparisons made in daylight, 260 observations of signs unequipped with reflecting units were made at night. The observing personnel consisted of 4 females and 6 males, a total of 10 observers. The general location was the same as that used in the daylight tests except that on account of side illumination from street lamps and adjacent buildings it was necessary to change the position of the test object. Automobile headlights of a type approved by the Eastern Conference of Motor Vehicle Administrators were mounted in front of the observer's screen previously described. The observing platform was set up in the right hand driving track of the highway and the signs were placed on the road shoulder approximately 2 feet to the right of the pavement edge. The headlight beams were directed straight ahead with the vertical angle such that the cut-off of the beam fell approximately on the upper third of the sign, thus simulating as far as possible actual driving conditions (fig. 3).

By experiment it was found useless at night to attempt to read the daylight signs at distances greater than 200 feet. For this reason the data presented are confined to that distance. At distances in excess of 200 feet, the black sign could not be distinguished from the surrounding background, except when piles of snow furnished a contrasting field. In a lesser degree this is also true of the yellow background. The white background seemed to merge into the illuminated pavement or snowbank; and if it was distinguished at all the observers invariably claimed to have seen a yellow sign. This may have been due to selective reflection or to the yellow hues of the light beam. Briefly, it was felt that the data obtained at distances greater than 200 feet would not be susceptible of any real differentiation and could not serve as a basis for comparison. At 200 feet the black sign was in distinct contrast with the snow background, resulting in 100 percent correct recognition of the color, as against 74 percent for legend and 83 percent for shape.

As in the daylight tests, four signs were used, i.e., SLOW, STOP, CURVE, and ZONE. The time intervals for reading the shape, color, and legend were 1.0, 0.8, 0.7, 0.6, and 0.5 second.

In order to determine the general readability of the signs under these conditions the device was employed of transposing letters and determining whether the transpositions could be picked up by the observer. The data on comparative readability are given in the first panel of figure 8. Average values for the different color combinations were as follows:

	Percent correct
Black on white	54
Black on yellow	67
White on black	59

The remaining panels of figure 8 give the data on recognition of shape, color, and legend, respectively, and of shape, color and legend combined. Average values are given in table 10.

TABLE 10.—*Night observations on daylight signs; average percentages of correct readings of shape, color, and legend for all time periods at the 200-foot station*

Recognition of—	Color combination	Percentage of correct readings
Shape	Black on white	88
	Black on yellow	100
	White on black	83
Color	Black on white	51
	Black on yellow	94
	White on black	100
Legend	Black on white	80
	Black on yellow	71
	White on black	74

Thus it seems that as a sign the yellow background contrasted more distinctly with its surroundings and was more easily recognized than either the black on white or white on black; but the legend was more legible on the latter two signs. It should be remembered, however, that the yellow tinge of the light beam threw a distinct yellowish hue on the white sign. The probability of this effect was called to the attention of the observers and it is possible that they were influenced thereby to a greater or less degree in their decision, calling the white sign yellow.

NIGHT OBSERVATIONS ON SIGNS EQUIPPED WITH REFLECTING UNITS

In carrying on the night tests for signs equipped with reflecting units (buttons) the same general procedure as for the daylight signs was followed but, inasmuch as a differentiation between reflectors of different diameters was sought, it was necessary to make up three sets of letters required for each sign. As the painted bristol board letters used on the daylight signs could not be perforated to receive the reflectors, letters punched to receive the reflectors were stamped out on aluminum sheets. These letter silhouettes were countersunk into wood blocks which in turn fitted into their respective places across the body of the sign proper. This permitted rapid change or transposition of letters equipped with different-sized buttons. The buttons used were white or colorless and of three diameters, viz, 0.95-inch, 0.76-inch, and 0.58-inch. These are the overall dimensions of the mounting flange. The optical diameters were 0.76, 0.58, and 0.41 inch, respectively. Figure 9 shows examples of the signs with reflector buttons and the manner in which they were fabricated.

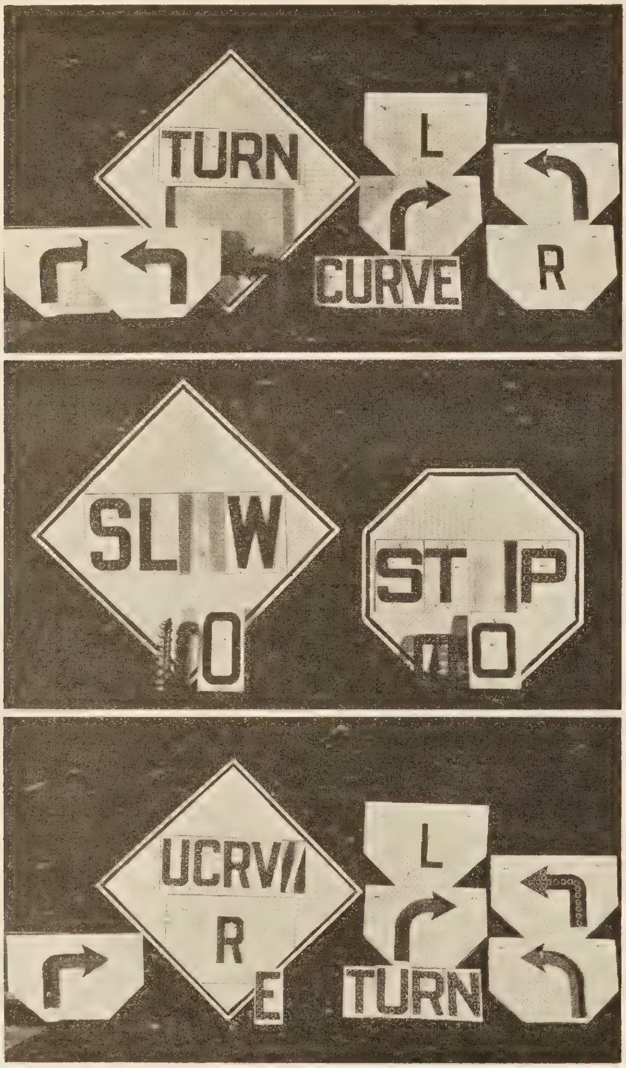

Figure 9.—Examples of Signs Equipped With Reflector Buttons, Showing Method of Fabrication.

Because of the different shapes and superficial areas of the various letters, spacing between reflecting elements could not be made constant except at the expense of proper definition. The letters L, T, and E, as shown in table 11, serve as a basis for the comparison of the spacing of the different-sized buttons and the relative areas occupied by them.

The SLOW and STOP signs, and CURVE and TURN signs with directional arrow symbols were used. The SCHOOL and HOSPITAL ZONE signs were not included. Signs of this character are not usually equipped with reflecting buttons; the width of the letter stroke would admit the 0.58-inch button only and even this would leave practically no margin.

There were 13 observers, 11 male and 2 female. The total number of observations was 652. Observing stations included the 200 and 300-foot stations for complete data and the 350-foot station for confirmatory data on the 0.95-inch button only.

Table 11.—*Proportions of areas of letters occupied by reflecting buttons of different sizes and spacing*

Letter	Size	Area	Diameter of button	Number of buttons	Spacing, center to center	Area occupied by buttons	Percentage of total area
		Sq. ins.	*Inches*		*Inches*	*Sq. ins.*	
L	8 by 1 3/16 inches	12.84	0.95	8	1 3/8	5.67	44
T	6 by 1 inches	9.31	.95	7	1 1/4	4.96	53
E	6 by 7/8 inches	10.06	.95	(1)	(1)	(1)	(1)
L	8 by 1 3/16 inches	12.84	.76	11	1	5.09	39
T	6 by 1 inches	9.31	.76	11	7/8	5.09	54
E	6 by 7/8 inches	10.06	.76	12	7/8	5.55	52
L	8 by 1 3/16 inches	12.84	.58	14	3/4	3.70	29
T	6 by 1 inches	9.31	.58	11	1 3/16	2.91	31
E	6 by 7/8 inches	10.06	.58	16	3/4	4.23	40

[1] The letter E in this series did not admit the large button.

In the night observations on signs equipped with buttons the ground color was not considered especially important, and was not used as a factor.

The general average percentages of correct readings for the four signs used in these observations are shown in figure 10. At 200 feet, the general averages of correct readings of the four signs and for all time periods, are: On the 0.95-inch button 74 percent correct; on the 0.76-inch button 88 percent correct; and on the 0.58-inch button 58 percent correct.

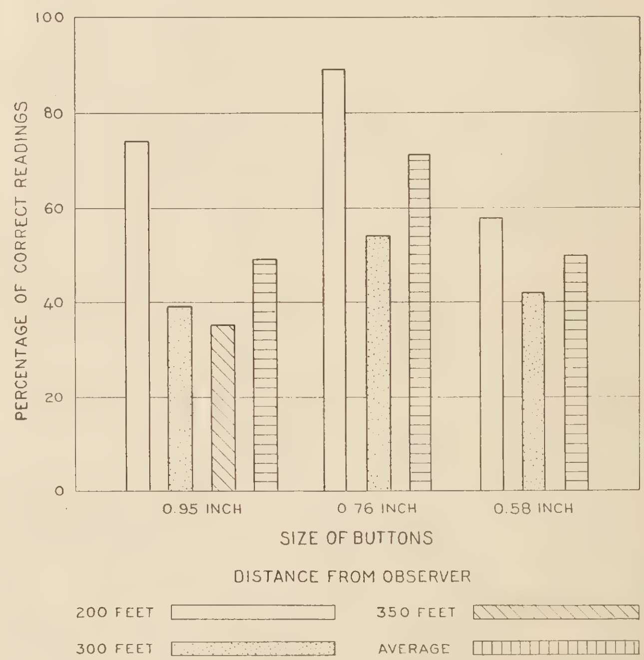

Figure 10.—Night Observations on Luminous Signs; Average Percentages of Correct Readings for Different Sizes of Button.

At 300 feet, the results are as follows: On the 0.95-inch button 39 percent correct; on the 0.76-inch button 54 percent correct; and on the 0.58-inch button 42 percent correct.

At these distances the 0.76-inch button is apparently the most efficient. Several observers intimated that the reflection from the 0.58-inch button dispersed in such a manner as to make the word illegible. On the other hand the small button was noted to be particularly brilliant, and thus a great measure of signal value or attention arresting attraction may attach to its use.

The large 0.95-inch button has an advantage over the smallest button at 200 feet but at 300 feet the condition is reversed and probably can be attributed to the fact that at the greater distance glare on the 0.58-inch button proportionately decreased. Observers also intimated that the 0.95-inch button lacked in brilliancy when compared with the other two.

Figure 11 gives the detailed data for each time period and size of letter. Table 12 gives the same material in tabular form for the 200- and 300-foot stations.

TABLE 12.—*Night observations on luminous signs; average percentage of correct readings by time period with different sizes of reflector button*

AT 200 FEET

Sign	Size of letter	Time interval	Percentage of correct readings		
			0.95-inch buttons	0.76-inch buttons	0.58-inch buttons
		Seconds			
SLOW	8 by 1 3/16 inches	1.0	81	94	69
STOP	6 by 1 inches	.8	81	94	50
TURN	6 by 1 inches	.7	81	88	62
CURVE	6 by 7/8 inches	.6	--------	88	44
STOP	6 by 1 inches	.6	69	81	62
SLOW	8 by 1 3/16 inches	.5	56	88	62
	AT 300 FEET				
SLOW	8 by 1 3/16 inches	1.0	60	85	75
STOP	6 by 1 inches	.8	30	60	60
TURN	6 by 1 inches	.7	35	55	15
CURVE	6 by 7/8 inches	.6	--------	45	20
STOP	6 by 1 inches	.6	35	45	40
SLOW	8 by 1 3/16 inches	.5	35	35	40

The two readings at the 0.6-second period were taken to check accuracy. The stroke of letters in CURVE is narrower than in STOP and the word itself has a more crowded appearance and is more difficult to read unless the meaning is suggested by using the direction arrow. As in the case of the TURN sign, the letters R or L were frequently substituted for the direction arrow as an additional check. The width of stroke of letters in the CURVE sign is too narrow to admit the large button.

These tabulations confirm deductions made from the general averages but it is especially interesting to note the apparent efficiency of the 0.76-inch button at 200 feet. With the 8-inch letter of the SLOW sign at 1.0 second, the readings were 94 percent accurate and at 0.5 second on the same sign this had decreased by 6 percent. In the case of the 0.95-inch button the decrease was 25 percent. With the 0.58-inch button there was an increase of 18 percent between the readings of the congested lettering in the CURVE sign at 0.6 second and the more open lettering on the STOP sign at the same interval. This wide difference also occurs at the 300-foot station and apparently justifies the assumption that legibility is greatly impaired by glare. The pattern on the word CURVE contributes largely to this feature.

At the 350-foot station the average of correct observations of the 0.95-inch button fell off to 35 percent and it was not considered worth while to increase the number of observations or to go to greater distances. Several signs, however, were carried back to 450, 500, and 600 feet to ascertain signal value, disregarding time period for readability of the legend. The distinct brightness of the 0.58-inch button was again noted to a degree not obtained with either of the larger-sized buttons.

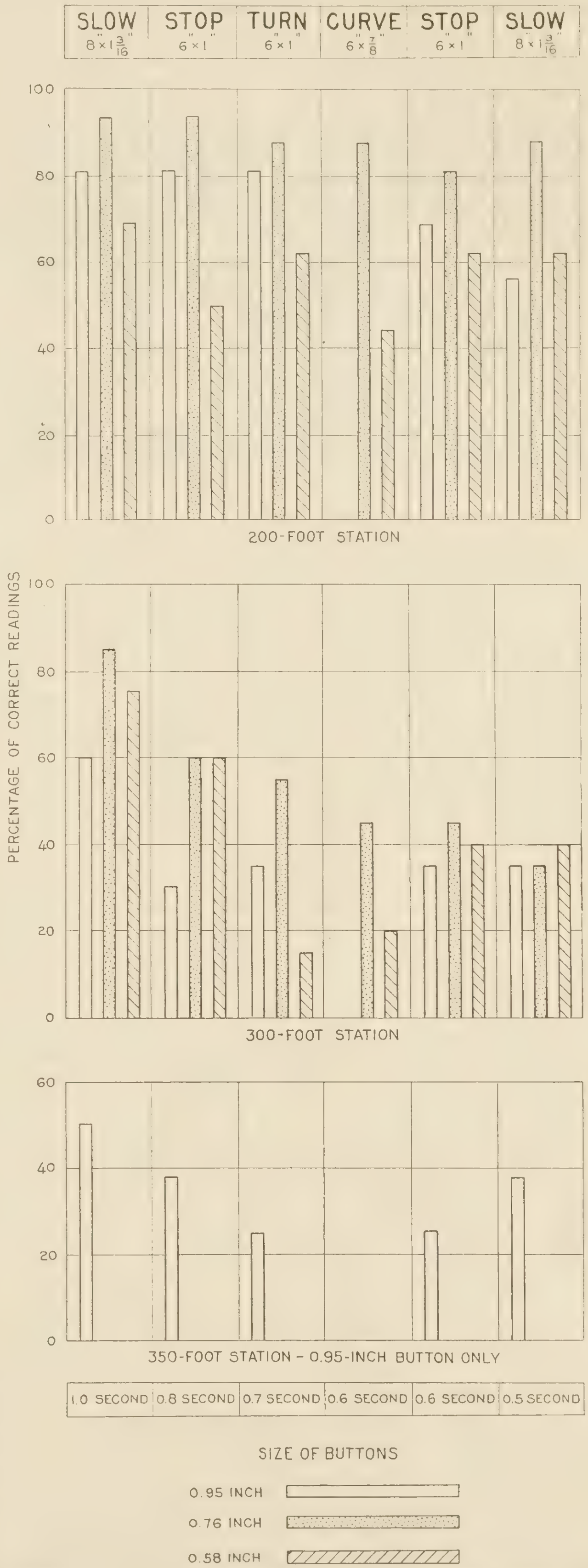

FIGURE 11.—NIGHT OBSERVATIONS ON LUMINOUS SIGNS: DETAILED PERCENTAGES OF CORRECT READINGS FOR DIFFERENT SIGNS, TIME INTERVALS, AND SIZES OF BUTTON.

LONG-RANGE IDENTIFICATION ASSISTED BY OUTLINING MARGIN OF SIGN WITH REFLECTOR BUTTONS

At these distances observations were also made of signs outlined by inserting 0.95-inch buttons in the margin as shown in figure 12. The shapes thus out-

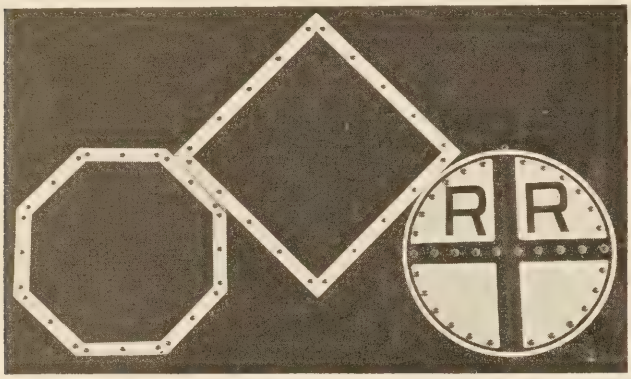

Figure 12.—Signs with Margins Outlined by Reflector Buttons.

lined were distinctly visible and could readily be described at all distances up to 600 feet or more. At extreme distances, however, some observers confused the octagon with the circular railroad sign. The characteristic difference in the illuminated outlines of these signs is the luminous cross bar carried on the railroad disc. Apparently this feature was noted by some observers and to that extent assisted in accurate differentiation. To other and presumably less acute observers the luminous outlines presented no material difference at distances greater than 500 feet. For long-range identification of a warning sign at night, the definition of shape by marginal installations of reflecting buttons has much to recommend it.

The idea of attributing special significance to the shape of the sign plaques was one of the first considerations in the design of standard highway signs adopted by the American Association of State Highway Officials. Obviously rapid and perhaps subconscious recognition of the sign warning by this method is largely a matter of education of the driving public. It is believed, however, that the indication of potential hazards existing on the highway as shown by a series of differently shaped signs will more readily appeal to the average road user than will a series of symbols such as has been recommended in some of the codes adopted by foreign governments and suggested for international usage. Outlining the shape of the sign by reflecting buttons for night use undoubtedly merits further investigation than the limited scope afforded by these tests.

RURAL AND CITY DRIVING CONDITIONS COMPARED

The night observations described up to this point were taken under full headlight illumination which at 200 feet was 0.2 foot-candle on the sign and at 300 feet was 0.1 foot-candle. Every effort was made to obtain actual rural road driving conditions. Surrounding street lights were extinguished and window lights from adjacent buildings were screened.

The investigation would not have been complete without an attempt to compare rural with city driving and to this end lights in adjacent buildings and street lights were turned on, and the headlights were dimmed. Observations, however, were restricted to the 300-foot station and four observers made 136 observations with the following results. Readings on the 0.95-inch button were 35 percent correct, on the 0.76-inch button 63 percent correct, and on the 0.58-inch button 81 percent correct. In figure 13 these results are compared with those obtained at the 300-foot station under rural driving conditions (full headlights).

Attention is particularly called to the increased efficiency of the small button under the city driving conditions. An appreciable increase is also found in the 0.76-inch button. This is probably due to the absence of glare under subdued lights or to the influence of the extraneous lighting combining with the headlight beam.

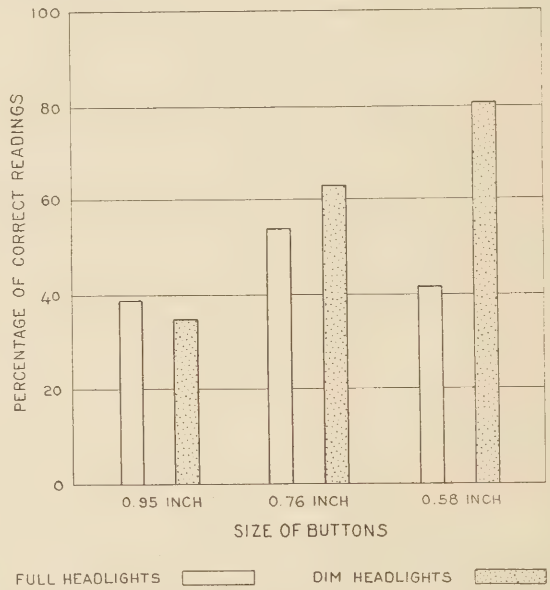

Figure 13.—Night Observations on Luminous Signs: Comparative Readability of Signs Under City and Rural Driving Conditions at 300-foot Station.

DAYLIGHT OBSERVATIONS OF SIGNS EQUIPPED WITH REFLECTING BUTTONS

Responsible manufacturers have laid great stress upon the reflecting values of their individual products and arguments in favor of this or that design have invariably emphasized advantages of brilliancy of the reflected beam, breadth of the angle of reflection, focal length, and other special characteristics of design, but have not considered their effect on the daylight legibility of the sign wording. It is recognized that many of the hazards inherent in a roadway, such as abrupt curvature, road intersections, railroad grade crossings, etc., readily seen in daylight, require adequate sign protection at night. This condition, however, should not operate to minimize the daylight values of the warning signs. The tests on signs equipped with buttons were, therefore, extended to cover daytime observations of the SLOW, STOP, TURN, and CURVE signs at distances from 200 to 400 feet. Black letters on yellow background and white letters on black background only were used.

Twenty-nine observers, of whom 9 were female and 20 male, made a total of 2,098 observations.

Figure 14 gives the percentages of correct readings in daylight, at distances from 200 to 400 feet, for signs equipped with the three sizes of button. For purposes of comparison, the average percentages obtained at these distances with daylight signs having the same backgrounds (black on yellow and white on black) are also plotted in this figure. Table 13 gives the comparative data in tabular form. Detailed data for the various distances are given in figure 15.

TABLE 13.—*Comparative readability of luminous and nonluminous signs under daylight conditions; average percentages of correct readings at each station for both black on yellow and white on black*

	Percentage of correct readings			
	At 200 feet	At 300 feet	At 350 feet	At 400 feet
Daylight signs	92	65	70	43
0.95-inch buttons	55	68	31	22
0.76-inch buttons	74	63	25	30
0.58-inch buttons	64	67	27	25

The percentages for the daylight signs were obtained from observations made in relatively bright sunlight during the summer months, whereas observations for the button-equipped signs were made in January with the sky overcast during a portion of the time. At the 350-foot station, observations were made during heavy snowfall, which probably accounts for the abrupt falling off in the percentages computed for that station. At the initial station (200 feet), however, atmospheric conditions affecting visibility were the same at both periods of observation and it is interesting to note that with approximately 49 percent of the area of the black letters occupied by the buttons, the legibility materially decreased. A tabulation of the detailed data for the 200-foot station is given in table 14.

TABLE 14.—*Comparative readability of luminous and nonluminous signs under daylight conditons at 200 feet*

Sign	Time interval	Percentage of correct readings			
		Without buttons	With buttons		
			0.95-inch	0.76-inch	0.58-inch
	Seconds				
SLOW	1.0	94	81	94	94
STOP	.8	98	38	87	81
TURN	.7	87	68	56	62
CURVE	.6	87	------	50	38
STOP	.6	92	44	75	56

Increase in legibility of the STOP sign at 0.6 second over the CURVE sign for the same period may be attributed to the wider stroke and more open distribution of the letters in the STOP sign.

Table 15 gives the comparative data for the 300-foot station.

TABLE 15.—*Comparative readability of luminous and nonluminous signs under daylight conditions at 300 feet*

Sign	Time interval	Percentage of correct readings			
		Without buttons	With buttons		
			0.95-inch	0.76-inch	0.58-inch
	Seconds				
SLOW	1.0	81	75	86	93
STOP	.8	76	75	67	82
TURN	.7	59	67	41	46
CURVE	.6	44	------	46	43
STOP	.6	66	57	71	71

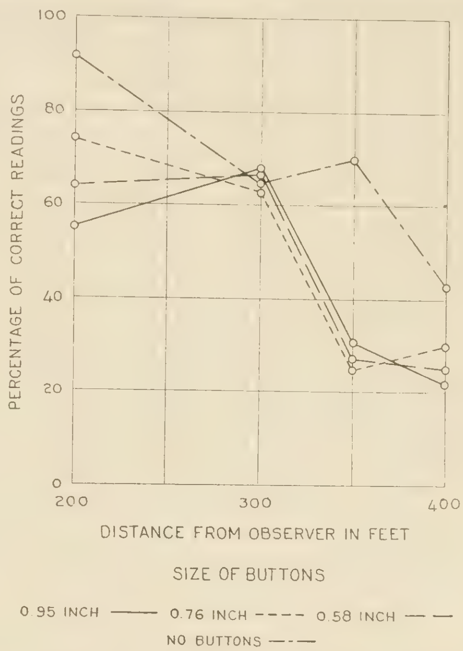

FIGURE 14.—COMPARATIVE READABILITY OF LUMINOUS AND NONLUMINOUS SIGNS UNDER DAYLIGHT CONDITIONS; AVERAGE PERCENTAGES OF CORRECT READINGS AT EACH STATION FOR BOTH BLACK ON YELLOW AND WHITE ON BLACK.

The visibility of the button-equipped signs at this station was considerably lessened by overcast or cloudy sky but the consistency of the results with the comparisons at 200 feet (table 14) should be noted.

The data for the 350- and 400-foot stations are given in table 16. At the 350-foot station observations of the button-equipped signs were made during a severe snow storm. Comparison, therefore, with the results obtained during bright sunlight from daylight signs will not form a basis for definite conclusions. The observations made under the differing atmospheric conditions, however, are decidedly interesting.

TABLE 16.—*Comparative readability of luminous and nonluminous signs under daylight conditions at 350 and 400 feet*

Distance from observer	Sign	Time interval	Percentage of correct readings			
			Without buttons	With buttons		
				0.95-inch	0.76-inch	0.58-inch
Feet		*Seconds*				
350	SLOW	1.0	77	59	63	58
	STOP	.8	77	34	28	33
	TURN	.7	65	21	11	11
	CURVE	.6	63	------	15	14
	STOP	.6	67	21	15	38
400	SLOW	1.0	59	53	64	64
	STOP	.8	39	16	25	27
	TURN	.7	42	8	3	3
	CURVE	.6	29	------	30	14
	STOP	.6	41	8	22	16

The conditions of visibility at the 400-foot station were similar during the observations on both the button equipped and the unequipped signs; and the decreased efficiency, particularly for the 0.7-second period, can be attributed directly to the lack of contrast between the letters and sign background due to the buttons.

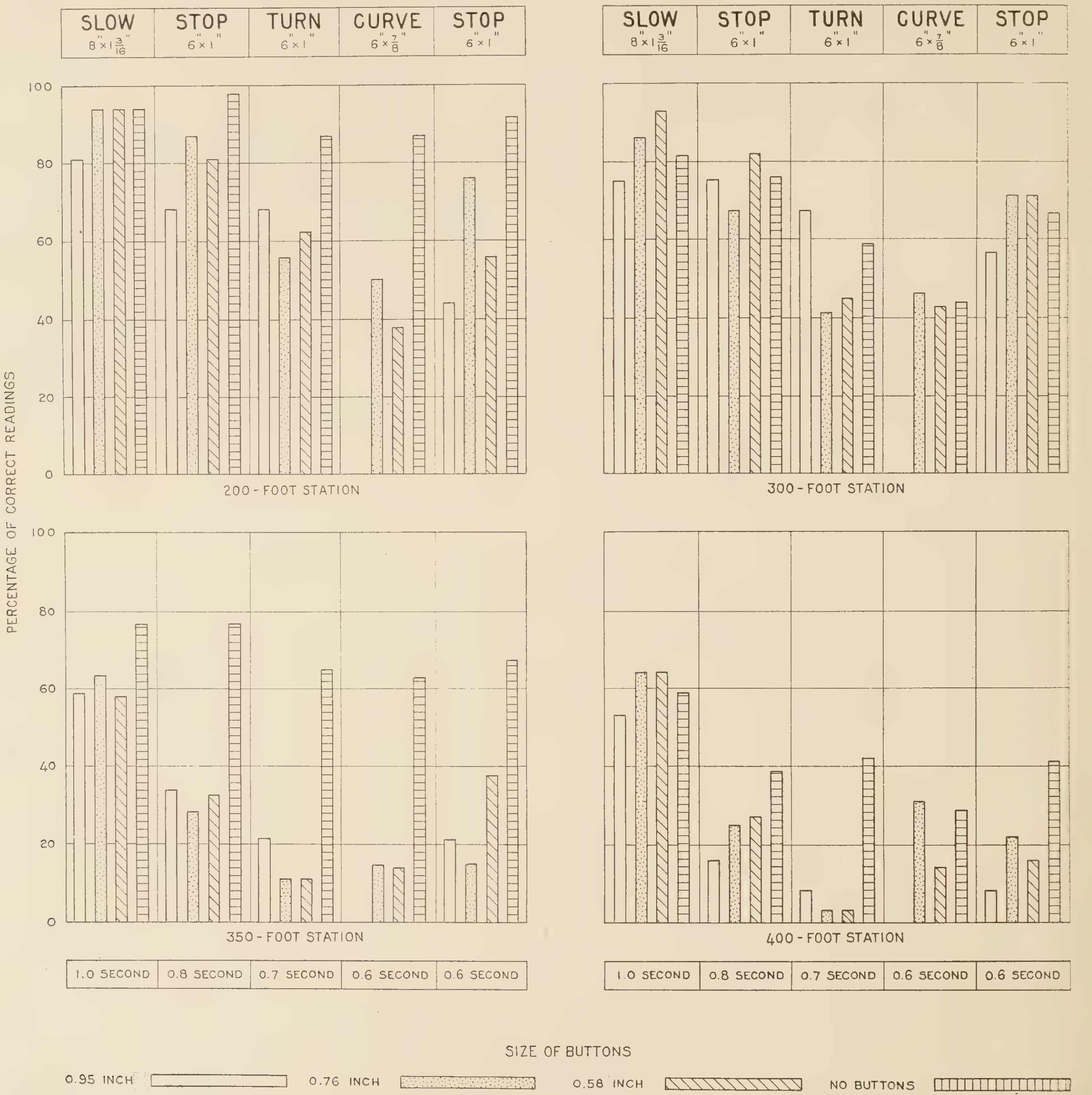

Figure 15.—Comparative Readability of Luminous and Nonluminous Signs under Daylight Conditions: Detailed Percentages of Correct Readings for Different Signs, Time Intervals, and Sizes of Button.

COMPARISON MADE OF RELATIVE LEGIBILITY OF BLACK AND WHITE LETTERS WHEN EQUIPPED WITH REFLECTING BUTTONS

Reference to table 11 in which are shown the percentages of the superficial areas of the letters L, T, and E occupied by buttons of different diameter, suggests the desirability of comparing the readability in daylight of black and white letters when equipped with reflector buttons. The figures and tables which follow give comparisons of percentages of correct readings, for legibility only, of signs with yellow background and black letters and those with black background and white letters. Figure 16 shows the variation of legibility with the distance from the observer. In the first panel of figure 17 the average values for each type of sign and each time interval used are given. The remaining panels of figure 17 give the detailed data for each station. Table 17 gives general averages for all distances, signs, and time periods.

Table 17.—*Comparative legibility of letters equipped with reflectors*

Size of button	Color combination	Percentage of correct readings
Inches		
0.95	Black on yellow	43
	White on black	45
.76	Black on yellow	49
	White on black	47
.58	Black on yellow	45
	White on black	46

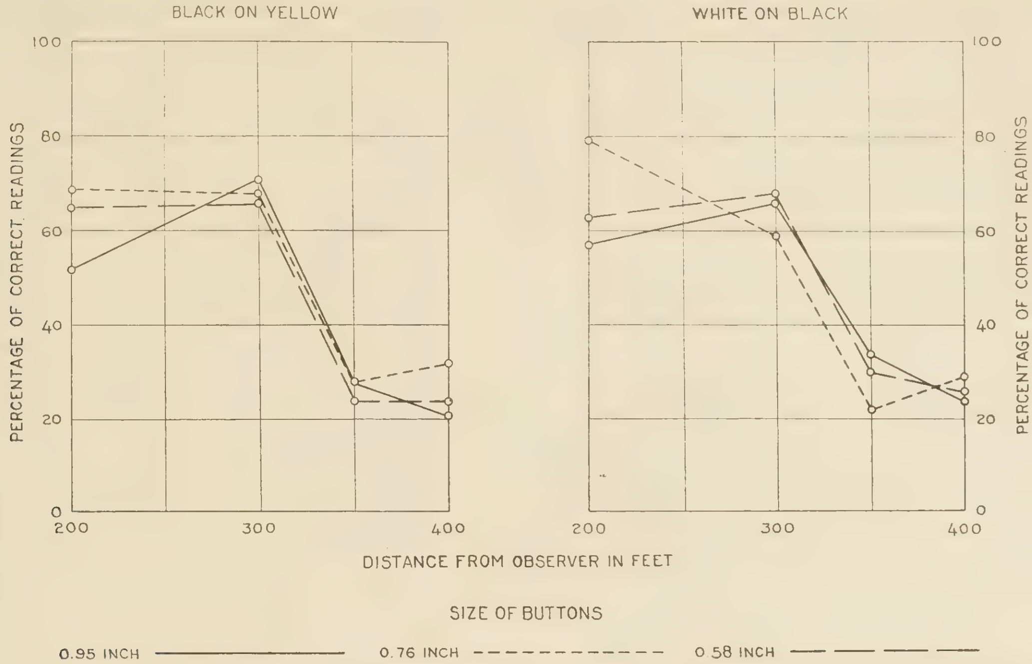

FIGURE 16.—COMPARATIVE READABILITY UNDER DAYLIGHT CONDITIONS OF BLACK AND WHITE LETTERS WHEN EQUIPPED WITH REFLECTOR BUTTONS OF VARYING DIAMETERS; VARIATION WITH DISTANCE FROM OBSERVER.

The differences in these averages are seen to be negligible and if we make the comparison station by station we obtain the extremely close check shown in table 18 and figure 16.

TABLE 18.—*Comparitive readability at various distances under daylight conditions of black and white letters equipped with reflecting buttons*

Distance from observer	Color combination	Percentage of correct readings		
		0.95-inch button	0.76-inch button	0.58-inch button
Feet				
200	Black letter	52	69	65
	White letter	57	79	63
300	Black letter	71	68	66
	White letter	66	59	68
350	Black letter	28	28	24
	White letter	34	22	30
400	Black letter	21	32	24
	White letter	24	29	26

Comparing this table also with the percentage readings for legibility of daylight signs given in figure 14, which indicated 92 percent correct at 200 feet, 66 percent at 300 feet, 70 percent at 350 feet, and 43 percent at 400 feet, we note that legibility has been greatly impaired by the introduction of the buttons if we disregard the unfavorable atmospheric conditions which obtained at the 350-foot station. At the 200-foot station the 0.95-inch button fell off from 92 percent to 52 percent; the 0.76-inch button to 69 percent, and the 0.58-inch button to 65 percent. These are for the black letters. At the 300-foot station there was a slight increase for the two larger buttons but no change for the 0.58-inch button is noted. At the 350-foot station, where snow fell during the observations of the button-equipped signs, the falling off for both the 0.95- and 0.76-inch button is from 70 to 28 percent, and from 70 to 24 percent for the 0.58-inch button. At the 400-foot station the decreases are from 43 to 21 percent for the 0.95-inch button; 43 to 32 percent for the 0.76-inch button, and 43 to 24 percent for the 0.58-inch button. The consistency of rise and fall or parallelism of the curves for the same button in the different colored letters is especially interesting.

The first panel of figure 17 is likewise interesting in this respect. It shows the average percentage of correct readings for legend only at all distances broken down into time periods for each of the three sizes of buttons in black and in white letters. Here the parallels are strongly emphasized. The CURVE sign was not used for the 0.95-inch button at the first 0.6-second period.

Finer analyses of these data at the 200-, 300-, 350-, and 400-foot stations are shown in the remaining panels of figure 17. In the case of the 0.76-inch buttons on black letters the STOP sign at 0.8 second shows a higher percentage than the SLOW sign at 1.0 second. This reversal may perhaps be attributed to the element of surprise in the initial reading in the case of two observers, the surprise having been overcome by the time the STOP sign was read. Between the CURVE sign at 0.6 second and the STOP sign at 0.6 second, the readings on this reflector were identical but with the large SLOW sign the white letter gave 100 percent while the black letter fell off to 63 percent. These results do not substantiate the hypothesis that a black letter is more impaired than a white letter by insertion of colorless buttons. There is some indication that such might be the fact at specific distances and for some of the time intervals but evidence that the white letter has a superior value when so equipped is not preponderant. It has been suggested that red buttons should be substituted for colorless buttons in the STOP sign on the ground that by so doing legibility of the word would suffer less impairment in daylight. Whatever the desirability of utilizing red buttons in this sign for emphasis may be, their use should not be based on the assumption of increased daylight visibility only, though red may have psychological potentialities as a mandate to stop.

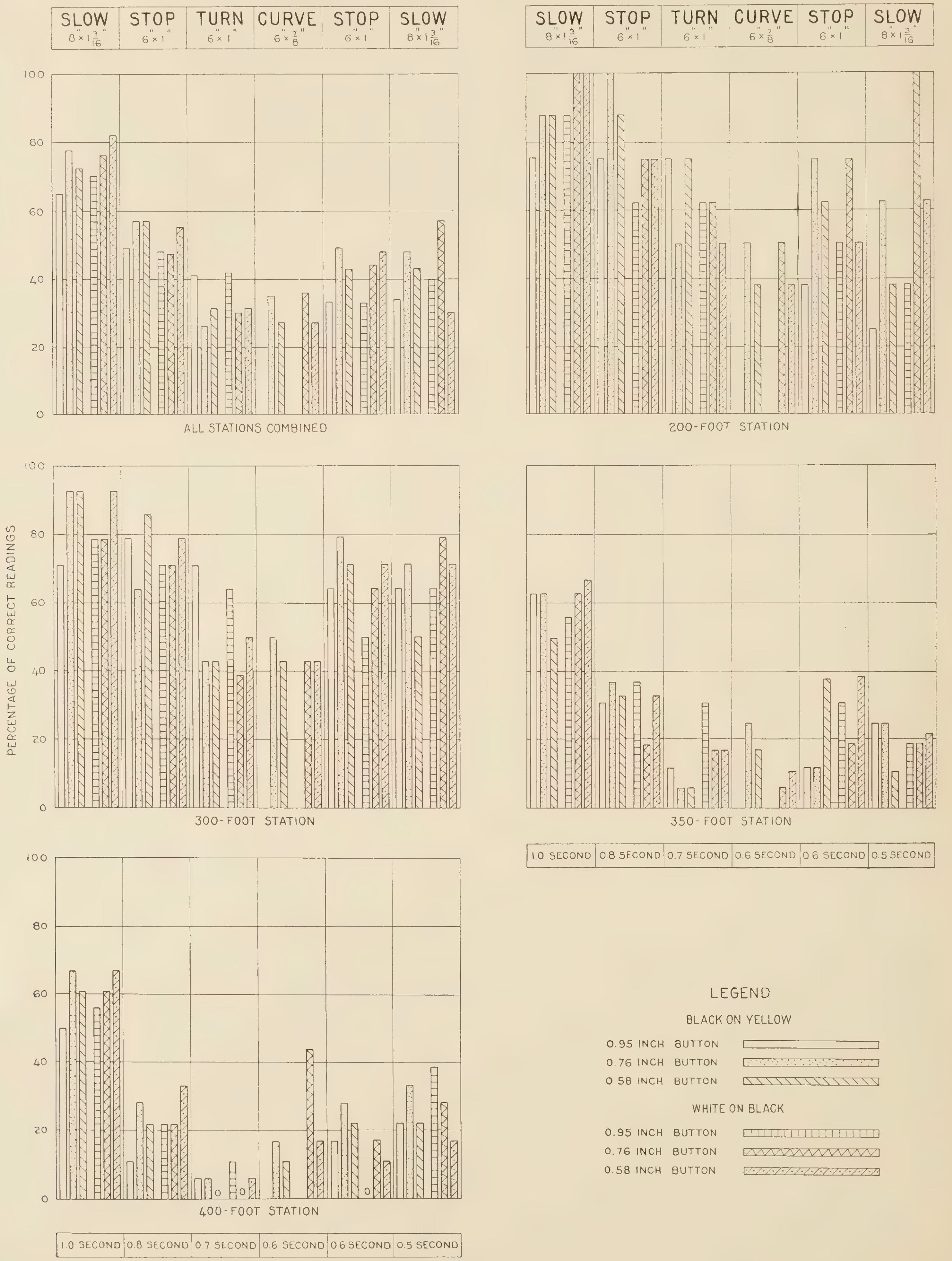

Figure 17.—Comparative Readability under Daylight Conditions of Black and White Letters When Equipped with Reflector Buttons of Varying Diameters; Detailed Data for Each Sign, Time Interval, and Station.

TABLE 19.—*Number and spacing of reflector buttons used for letters of various standard sizes*

Size of buttons	Size of letters	Letter	Spacing of buttons	Number of buttons
	SLOW			
Inches			*Inches*	
0.95	8 by 1 3/16 inches	S	1 1/4	14
		L	1 3/8	8
		O	1 5/16	14
		W	1 3/8	16
				52
.76	do	S	1 1/8	15
		L	1	11
		O	1	18
		W	1	24
				68
.58	do	S	13/16	21
		L	3/4	14
		O	13/16	22
		W	13/16	32
				89
	STOP			
.95	6 by 1 inch	S	1 1/16	16
		T	1 1/4	7
		O	1 3/16	14
		P	1 3/16	12
				49
.76	do	S	15/16	18
		T	7/8	11
		O	7/8	18
		P	15/16	15
				62
.58	do	S	13/16	20
		T	13/16	11
		O	13/16	20
		P	13/16	17
				68
	CURVE			
.76	6 by 7/8 inch	C	7/8	12
		U	7/8	14
		R	7/8	17
		V	7/8	12
		E	7/8	12
				67
.58	do	C	3/4	14
		U	3/4	17
		R	3/4	19
		V	3/4	15
		E	3/4	16
				81
	TURN			
.95	6 by 1 inch	T	1 3/16	7
		U	1 3/16	11
		R	1 3/16	13
		N	1 3/16	13
				44
.76	do	T	15/16	9
		U	1	13
		R	1	15
		N	1	16
				53
.58	do	T	3/4	12
		U	3/4	17
		R	3/4	21
		N	3/4	22
				72

STRUCTURAL CHARACTERISTICS OF BUTTONS NOT STUDIED

The resolution of the American Association of State Highway Officials covered investigation of focal lengths as well as the spacing and optical diameters of the reflecting units. It was, however, found impracticable at this time to consider the method of backing, mounting, or geometric shapes of the reflectors because such investigations would involve reconstructing all test letters with buttons from each of a dozen or more responsible manufacturers and repeating all tests for each of the different commercial products. A complete set of letters and symbols requires approximately 2,000 reflector buttons. As indicated in this report, the prime consideration was to test the personal acuity of the average road user and the effect of a reflecting unit on the legibility of the sign message. The product of but one manufacturer was selected as representative of the industry. Because of this fact tests can be duplicated and the results of this investigation checked without introducing any variables not now considered. Moreover, tests of the character and quality of the materials used for metallic backing and method of sealing the reflector in its housing would involve exposure to the weather over a long period of time and definite conclusions could not be arrived at unless such exposure could be made in rural as well as congested urban areas, and the effect of gaseous contamination ascertained.

SPACING OF BUTTONS DISCUSSED

In spacing the individual reflecting buttons in a letter the first consideration obviously is clear definition of the letter, and this in turn depends, apparently, not so much on the optical diameter and spacing of the unit as upon factors which may cause a merging of parallel lines in such a way as to render the pattern indistinct or increase the glare to a point where the word cannot be recognized, resulting in the sign having what has been termed an arresting or signal value only. This phase is apparent in the percentages tabulated and plotted and particularly so where the use of the bent arrows in the CURVE and TURN signs tended to suggest to the observer the meaning without his being able to read the wording correctly.

Table 19 shows the number of units required for each letter and their spacing center to center, and figure 18 shows the general arrangement of the units in the letters S, R, and O. Table 20 shows the number and spacing of the buttons for the bent arrows used in the TURN and CURVE signs. It is believed that in these the minimum number of units that will adequately outline the letter is not exceeded and any attempt to reduce the number of reflectors in the interest of economy should not be permitted, because of the liability of a driver confusing, for instance, an ill-defined N with H or an ill-defined S with the figures 8 and 2.

TABLE 20.—*Number and spacing of reflector buttons used in bent arrows for STOP and SLOW signs*

Size of buttons	Width of arrow	Spacing of buttons		Number of buttons		
		Stem	Head cluster	Stem	Head	Total
Inches	*Inches*	*Inches*				
0.95	2 1/8	1 1/8	1 and 1 1/8 inches	9	4	13
.76	2 1/8	7/8	7/8-inch	11	10	21
.58	2 1/8	3/4	7/8-inch	14	10	24

CONCLUSIONS SUMMARIZED

In summing up the foregoing the various phases of the investigation will be treated in the order in which the tests were made.

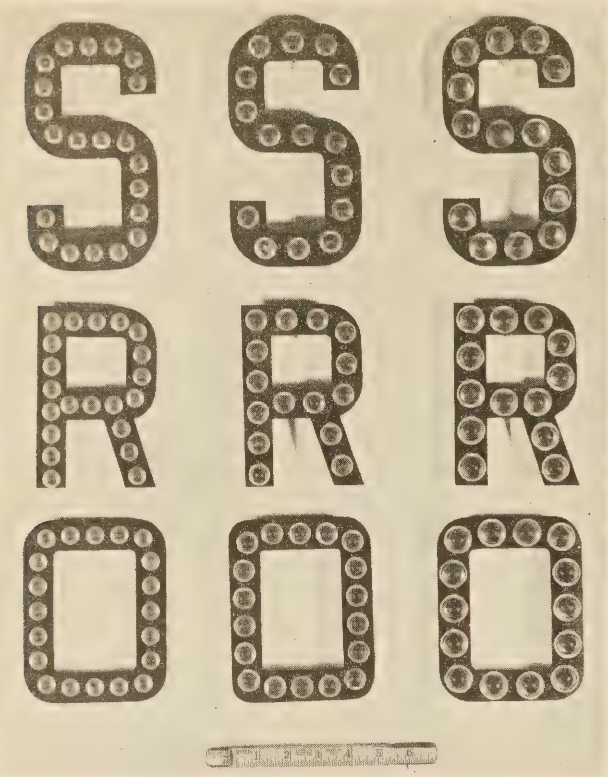

FIGURE 18.—ARRANGEMENT OF REFLECTOR BUTTONS IN LETTERS S, R, AND O.

The first phase involved determination of the relative values of the ground colors and the legibility of the respective legend colors and design. All evidence deduced and analyzed points to the definite conclusion that the standard yellow background with black design color, under all conditions which might reasonably be expected to obtain on either a city street or upon a rural highway, is much superior to black on white or white on black. Not only has this been demonstrated to be true as to readability of the legend but the yellow background is more arresting to the average observer, is more conspicuous by contrast with the average natural or artificial background, and, therefore, has a greater signal value than the other backgrounds or combinations. Moreover, by adopting a definite shade and hue, such as is covered by the specifications of the American Association of State Highway Officials in rule 53 of the sectional committee on colors for traffic signals of the American Standards Association, it may be possible by legislative act or otherwise to prohibit the use of this distinctive shade for advertising or for purposes other than official road signs upon the highways controlled by State or other properly constituted authorities. Obviously it would be difficult to obtain restrictive legislation for black or white backgrounds.

The investigation of the effect of headlights or local illumination such as street lights upon the signs not equipped with reflecting units was not in any way conclusive. When some of these observations were made the ground was covered with snow, of which there were several piles immediately adjacent to the line of sight, and conceivably this condition will obtain for several months in the year over a large area of the country. Such conditions emphasize the inadequacy of the daylight signs at night.

With respect to the use of reflecting units, there are two points to be considered which in a degree appear to conflict. In urban areas there is usually a great deal of illumination from street lights, electric signs, and other sources falling on the sign; and local regulations may require that headlights be dimmed or depressed. These conditions do not, as a rule, obtain on rural highways. In city driving speeds are relatively slower and clear perception of the sign message is more readily had than on rural highways. In view of these considerations, the conclusion is forced that the colorless button with a diameter of 0.76 inch with a minimum spacing of 1 inch, center to center, is the most efficient. This is notwithstanding the large increase in the efficiency of the 0.58-inch diameter button with dim headlights over the same button with full headlights. For rural use the small button apparently has a superior long-range signal value but is less readable than the unit of larger diameter.

The effect on distinctness in daylight of inserting reflecting buttons in the letters has been gone into exhaustively. As indicated by the tests, the effect of such insertions, even though approximately 50 percent of the superficial area of the letter is taken up by the use of colorless units, is not serious at 200 feet and the difference between black and white letters is negligible.

The recognition by the road user of the existence of a potential hazard by the shape or outline of the sign plaque alone has been briefly touched upon and the idea is susceptible of further development. Particularly is this true in view of the trend toward the use of symbols. The use of symbols, except for the arrows indicating curve or direction, is not considered as effective as outlining the sign with buttons. At night the road user can best be warned at long ranges against such hazards as may exist at narrow bridges, highway intersections, and other places in this category by clearly defining the shape of the plaque with reflecting units. Having been so warned he will be able to read the character of the hazard at 200 feet or well within braking distance for a car traveling at the maximum authorized speed.

These investigations had to do exclusively with the reactions of the average road user to the sign messages as measured by the tachistoscope. No account has been taken of the technical details of construction of the reflecting units, composition, refraction coefficients, or other optical properties of the glass; every effort, on the other hand, was made to simulate actual driving conditions. Maximum personal response to the warning is the ultimate consideration in sign design and it is not believed that optical analysis or other technical tests, however exhaustive, can measure this response. In the foregoing tests, 121 individuals were used as observers and these made a total of 7,710 separate observations involving about 12,000 items. These observers represent a fair cross section of the potential car-driving public. A number of them, however, had not received driving permits and were not car drivers. The gamut of education and personal intelligence was wide. A number of observers were furnished through the cooperation of the American Automobile Association, which in turn enlisted the aid of the local employment bureau. As indicated in the text, both males and females were used. Observations were made under the varied weather and seasonal conditions obtaining in the District of Columbia, and the results of the investigation may be taken as representative of the comparative visibility of the signs throughout the country as a whole.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

CURRENT STATUS OF FEDERAL-AID ROAD CONSTRUCTION

AS OF

AUGUST 31,1933

STATE	COMPLETED MILEAGE	UNDER CONSTRUCTION						APPROVED FOR CONSTRUCTION					BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS	STATE
		Estimated total cost	Federal aid allotted	Percentage completed	MILEAGE Initial	MILEAGE Stage[1]	MILEAGE Total	Estimated total cost	Federal aid allotted	MILEAGE Initial	MILEAGE Stage[1]	MILEAGE Total		
		$	$					$	$				$	
Alabama	2,385.7	4,215,785.67	2,107,892.74	89	97.0	103.1	200.1						3,157,514.70	Alabama
Arizona	1,426.7	913,963.20	352,587.93	78	26.9	29.5	56.4	74,368.32	51,819.92		8.7	8.7	106,364.30	Arizona
Arkansas	1,968.7	3,894,321.23	1,860,763.97	74	126.5	74.7	201.2	915,274.96	579,793.57	92.6	11.9	104.5	479,898.21	Arkansas
California	2,574.0	4,957,861.33	1,378,985.63	90	92.2	23.1	115.3						22,517.34	California
Colorado	1,890.6	2,691,086.13	1,165,919.30	62	90.5	46.5	137.0	173,962.64	78,283.16	2.2	21.5	23.7	47,698.17	Colorado
Connecticut	306.8	3,838,722.74	1,579,950.45	87	38.9		38.9						183,167.11	Connecticut
Delaware	413.5	138,879.50	25,512.72	64		7.3	7.3							Delaware
Florida	671.6	5,284,898.51	2,506,132.25	87	150.8	11.2	162.0		120,699.54				877,896.19	Florida
Georgia	3,332.9	3,010,067.23	1,239,254.11	93	89.6	104.3	193.9						100,636.93	Georgia
Idaho	1,607.7	2,241,411.93	834,741.56	84	73.4	116.8	190.2	113,905.40	51,929.06	4.0	24.0	28.0	12,987.00	Idaho
Illinois	3,177.2	18,141,194.46	6,697,500.54	81	561.0	56.6	617.6	486,007.26	231,323.05	17.5		17.5	119,376.28	Illinois
Indiana	2,173.5	7,763,205.12	2,589,042.73	88	239.5	24.9	264.4	13,439.70	2,167.84	.6		.6	19,336.79	Indiana
Iowa	3,721.6	1,842,467.88	324,092.99	89	109.4	1.1	110.5							Iowa
Kansas	4,083.4	3,155,204.24	900,986.34	77	186.8	46.3	233.1	400,368.33	109,578.66	72.4	68.0	140.4	20,489.02	Kansas
Kentucky	2,021.9	3,361,451.81	1,243,468.92	80	135.8	68.2	204.0	7,039.41	2,816.00		2.9	2.9	1.00	Kentucky
Louisiana	1,635.4	5,822,100.69	2,601,941.90	76	28.4	22.8	51.2						4,520.58	Louisiana
Maine	850.9	1,448,507.42	313,793.44	77	36.6	2.2	38.8						172.41	Maine
Maryland	881.9	749,787.77	95,954.66	88	27.2	1.5	28.7	112,967.80	12,639.48	2.4		2.4		Maryland
Massachusetts	876.4	4,115,901.96	972,218.48	88	57.2	4.9	62.1		229,375.00				169,445.05	Massachusetts
Michigan	2,486.9	4,633,278.33	1,819,467.45	79	227.1	37.0	264.1	202,500.00	95,835.00	3.6	5.5	9.1	16,266.12	Michigan
Minnesota	4,311.6	4,676,721.91	184,428.91	98	151.0	137.0	288.0						47,924.16	Minnesota
Mississippi	1,881.7	6,132,255.42	3,039,956.16	77	162.3	112.0	274.3	220,829.93	205,348.25	10.0	3.4	13.4	2,590,113.57	Mississippi
Missouri	3,261.9	3,841,847.52	672,265.63	71	135.7	33.7	169.4		50,048.60					Missouri
Montana	3,119.2	5,124,817.10	2,857,058.89	92	347.3	145.7	493.0	183,461.68	103,068.74	.5	53.3	53.8	146,648.28	Montana
Nebraska	4,478.1	1,815,058.75	842,092.22	94	57.7	31.7	89.4						163,468.22	Nebraska
Nevada	1,364.0	1,081,193.16	448,031.22	89	17.9	143.4	161.3	178,322.45	8,028.11	13.7	9.3	23.0	71,920.07	Nevada
New Hampshire	454.1	350,183.63	140,073.46	85	8.4	.5	8.9	175,656.85	77,387.63	1.8	2.3	4.1		New Hampshire
New Jersey	644.0	4,978,596.76	1,615,125.28	96	49.6		49.6						138,625.11	New Jersey
New Mexico	2,467.8	629,629.25	296,246.58	66	31.2	40.4	71.6	19,858.21	10,922.01		1.6	1.6	21,009.71	New Mexico
New York	3,551.4	17,103,830.05	5,042,650.00	73	444.3	32.0	476.3						355,781.37	New York
North Carolina	2,552.2	3,692,001.17	1,852,115.36	79	377.4	.5	377.9	129,408.73	407,098.37	11.9		11.9	641,264.98	North Carolina
North Dakota	5,619.9	2,700,986.74	1,348,048.63	61	174.5	329.3	503.8	244,282.00	114,051.47	11.5	57.4	68.9	205,902.91	North Dakota
Ohio	3,122.8	6,043,401.67	1,552,239.83	87	117.6	49.2	166.8	416,235.00	165,607.94	6.9	.3	7.2	13,739.73	Ohio
Oklahoma	2,547.1	3,417,500.89	1,103,939.12	90	162.1	62.0	224.1	1,093,216.00	434,320.36	69.7	5.6	75.3	98,134.21	Oklahoma
Oregon	1,655.5	3,535,967.28	1,483,611.28	88	94.8	59.3	154.1	17,877.20	7,329.65	.5		.5	53,738.69	Oregon
Pennsylvania	3,431.4	5,964,274.32	1,569,879.33	90	202.3	5.8	208.1						6,608.37	Pennsylvania
Rhode Island	287.8	435,012.32	120,817.09	91	6.6	4.3	10.9	18,249.80	9,124.90				61,709.13	Rhode Island
South Carolina	1,962.5	3,421,360.43	1,282,892.73	98	161.2	154.7	315.9		3,134.63				4,059.29	South Carolina
South Dakota	4,332.3	3,104,632.06	1,264,063.86	93	232.7	203.5	436.2	101,962.02	78,460.71		17.7	17.7	177,793.69	South Dakota
Tennessee	1,837.2	2,589,412.87	1,293,985.56	84	75.1	11.6	86.7		254,529.40				322,261.47	Tennessee
Texas	8,419.1	11,465,109.75	3,656,423.64	88	409.6	347.6	757.2	424,301.09	2,097.83		20.5	20.5	167,985.35	Texas
Utah	1,369.0	1,384,328.77	580,227.36	87	89.3	.2	89.5	118,531.26	49,939.43	17.1	11.8	28.9		Utah
Vermont	402.7	317,403.44	55,874.35	35	11.4	6.6	18.0	12,856.09	59.60	.1		.1	1,299.71	Vermont
Virginia	2,077.6	3,052,480.19	1,374,769.16	93	114.7	31.2	145.9	131,679.03	36,686.27	9.5		9.5	68,753.12	Virginia
Washington	1,340.0	2,774,263.82	781,920.63	88	92.9	16.9	109.8						3,356.82	Washington
West Virginia	937.5	2,574,911.01	1,057,657.50	94	95.2	14.7	109.9						20,322.07	West Virginia
Wisconsin	2,811.0	4,614,240.55	1,118,667.95	89	106.8	80.6	187.4		21,500.00					Wisconsin
Wyoming	2,360.6	1,578,401.84	604,430.49	96	111.3	59.8	171.1	134,390.27	67,100.00	6.2	12.8	19.0	73,262.89	Wyoming
Hawaii	139.3	420,141.08	420,141.08	36	7.3		7.3	87,664.50	29,902.55	.7		.7	485,864.71	Hawaii
TOTALS	111,226.6	191,040,060.90	68,269,841.41	83	6,443.0	2,896.2	9,339.2	6,208,615.93	3,702,006.73	355.4	338.5	693.9	11,299,834.83	TOTALS
Construction completed		159,354,000.00	57,005,000.00											
Balance uncompleted		31,686,000.00	11,265,000.00											

[1] The term stage construction refers to additional work done on projects previously improved with Federal aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.

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