AN INTERIM REPORT

ON

ROADSIDE SIGN VISIBILITY

by

Ned E. Walton

and

Neilon J. Rowan

Research Report 75-3

Supplementary Studies in Highway Illumination

Research Project Number 2-8-64-75

Sponsored by

The Texas Highway Department

In Cooperation With the

U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

June, 1967

TEXAS TRANSPORTATION INSTITUTE

Texas A&M University

College Station, Texas

TABLE OF CONTENTS

INTRODUCTION

More than any other sensory perception, vision is significant for the driver of a vehicle. In traffic the driver is constantly dependent upon his sense of sight. It is the visual aspect of the road ahead that starts the chain of events causing the road user to take some positive action in any traffic situation. Hence, the visual concept must be considered in all phases of highway design and traffic control.

All traffic control devices are basically visual communication techniques. The traffic engineer uses signing as the principal means of visual communication with the driver of a vehicle. This signing must be designed to provide adequate visibility distance to enable the driver to respond and take positive action. To avoid hazardous situations, careful consideration must be given to sign design and to its placement with respect to the roadway. Design of the signing must assure that such features as size, contrast, colors, shades, composition, and lighting or reflectorization where needed, are combined to draw attention to the device; that shape, size, colors, and simplicity of message combine to produce a clear meaning; that legibility and size combine with placement to permit adequate time for response; and that uniformity, reasonableness, size, and legibility combine to command respect. Placement of the signing must assure that it is within the zone of vision of the normal user so that it will command attention; that it is positioned with respect to the point, object, or situation to which it applies to aid in conveying the proper meaning; and that its location, combined with suitable legibility is such that a driver traveling at normal speed has adequate time to make the proper response. These criteria can be met easily for daytime conditions, but present a challenging problem to the designer for nighttime conditions.

Nighttime visibility is provided primarily by contrast. In the case of signing this contrast is attained by reflectivity or external illumination depending on whether the sign is a ground-mounted roadside sign or an externally illuminated overhead sign. For the ground-mounted sign reflectorization is achieved by using glass beads or other reflective elements that return part of the headlight beam back to the driver's eyes. Reflectivity enhances the color scheme of signs, but mainly visibility is achieved by contrast caused by the presence or absence of reflectorization. Because of the positioning of overhead mounted signs, reflectorized materials are not always effective and therefore external illumination is necessary to provide contrast for nighttime visibility.

Illumination is used on many traffic facilities to illuminate the physical features of the roadway and to aid in the driving task. In order to provide satisfactory illumination, light sources must be placed at precise intervals along the roadway. However, the location of these light sources relative to signs may tend to decrease the contrast of sign legend and thus decrease legibility of the sign message. Therefore, it is important that the effect of luminaire placement on sign visibility be investigated and necessary design criteria be established concerning the relative placement of signs and luminaires.

OBJECTIVES

For many years 30 feet has been accepted as a maximum mounting height for light sources in continuous illumination systems. As a result longitudinal spacings between light sources have been limited to approximately 160 feet. These limitations have been imposed principally in the interest of problems encountered in installing and maintaining light sources at higher mounting heights. However, these problems have been ameliorated considerably by recent advancements in maintenance and service equipment. Also, recent research has indicated that higher mounting heights provide a system of improved uniformity with comparatively lower source and system glare. This improvement makes for better visibility and thus greater safety.

Of importance also is the fact that the higher mounting heights result in increased spacings between luminaires. This indicates that for a safer and more efficient and economical installation, higher mounting heights should be used.

In 1964 the Texas Transportation Institute initiated a research project, "Supplementary Studies in Highway Illumination," under the sponsorship of the Texas Highway Department in cooperation with the U. S. Bureau of Public Roads. The ultimate goal in the research is to provide definite criteria for the design of economical and functional roadway lighting.

The research reported herein, which represents one phase of the overall project, was directed to determining the effects of mounting height and placement of luminaires on the visibility of highway signs.

The specific objectives of this research were as follows:

1. To evaluate the effects of luminaire mounting heights on roadside sign placement and visibility.
2. To investigate sign brightness, background brightness, and disability veiling brightness associated with luminaire mounting heights and to investigate their effects on sign visibility.
3. To correlate results obtained with previous research findings.

It is recognized that any change in the illumination geometry can alter vision. Therefore any results of this study can be applied only to illumination systems with similar parameters. However, an evaluation of the relationships between the varying conditions studied should provide valuable guides for the design of future illumination systems.

METHOD OF STUDY

Test Facilities

This investigation was conducted at the Highway Illumination Test Facility of the Texas A&M Research Annex. A 500- x 3000-foot paved test area provides for simulation of any roadway widths. A grid system of 10-foot longitudinal and 12.5-foot transverse spacings has been marked to provide reference points for various visibility and photometric studies.

The facility is equipped with ten portable illumination towers that can be arranged in any configuration to provide staggered, one-side or median lighting systems. Mounting heights of luminaires on the towers can be varied for any height up to 60 feet. Figure 1 shows a general view of the Highway Illumination Test Facility and a close up view of one of the illumination towers.

Experimental Plan

Four factors were considered in selecting the roadway conditions to be simulated in the experimental plan:

1. Type of sign used,

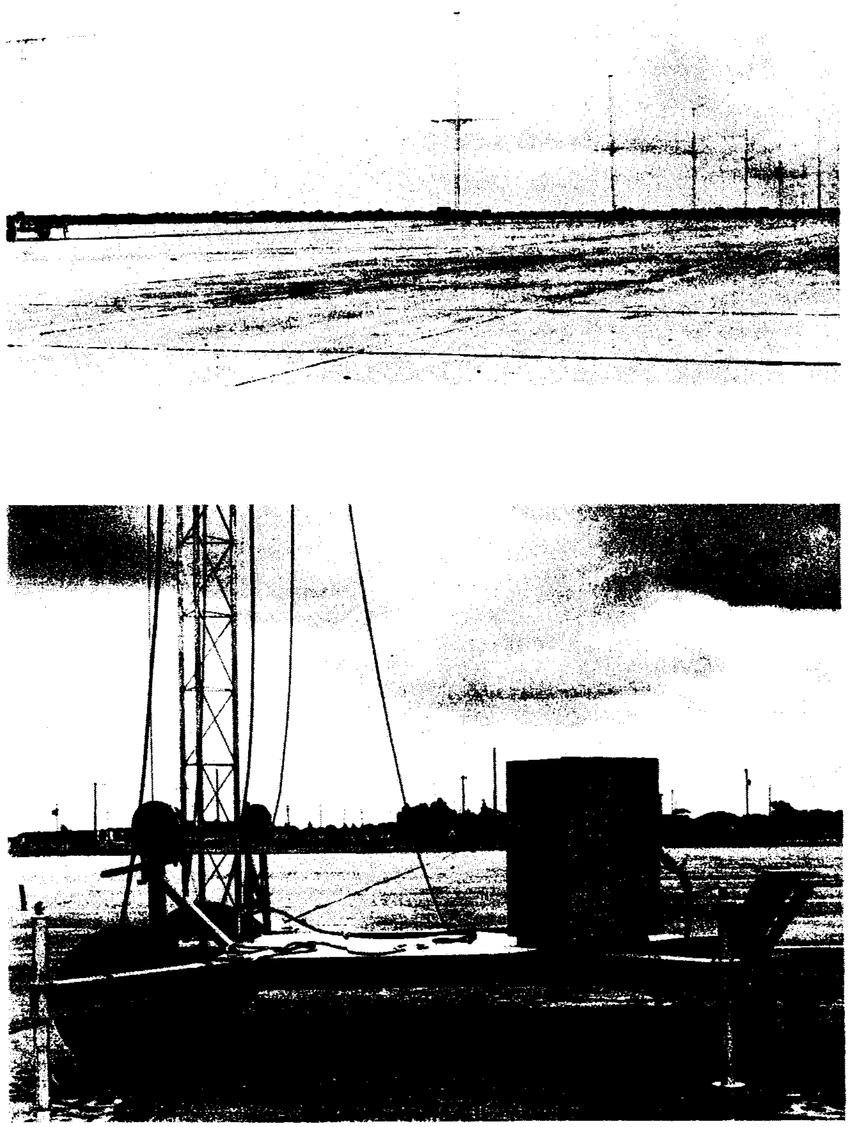
2. Probable locations for installation of this type sign,

3. Typical roadway dimensions at these locations,

4. Headlight conditions of vehicles within the system.

Earlier research by the Texas Transportation Institute [1,2] dictated the type of sign for study. This earlier research established that the relative placement of signs, consisting of unreflectorized letters on a reflectorized background, with respect to a light source influenced visibility of the sign. This research also established that there was no effect on visibility of signs using reflex reflector letters. Therefore, typical destination signs with black letters on a painted and reflectorized white background were selected for the study. These signs permitted correlation of results with the previous research findings.

A pilot study was conducted at the test facility to identify some of the factors involved in sign visibility. From this study it was possible to establish locations to be tested, mounting heights of luminaires, number of luminaires in the system, longitudinal placement of the luminaires, road-



HIGHWAY ILLUMINATION TEST
FACILITIES AT TEXAS A&M
UNIVERSITY RESEARCH ANNEX

Figure 1

way widths, headlight conditions, and test vehicle approach speed. The resulting factorial experimental design permitted the evaluation of the significance of and interrelationships among all major factors entering into the problem. This design consisted of two illumination systems, one 400-watt and one 1000-watt. For each system two mounting heights, two headlight conditions and thirty sign positions were studied using two observers per system. This design is illustrated in Figure 2.

Signs with real place names and similar letter characteristics were chosen to reduce bias. One of the signs is shown in Figure 3. Figure 4 is a nighttime view of the sign during testing. The observers sat in the right front passenger position of the test vehicle which was driven through the systems at 20 mph. As the observer read the sign, the legibility distance was recorded by the study supervisor. Sign placements, signs and corresponding headlight conditions were randomized to reduce bias. Only one observer was in the test vehicle at a time and different sets of observers were used for the 400-watt and 1000-watt studies.

Brightness and glare measurements were made during studies of the 400-watt systems. These measurements were limited to the studies under bright headlight conditions. A Spectra Pritchard Photometer, Figure 5, was used for making the brightness and glare measurements. The photometer is a precision instrument which has a telescopic viewing system reflected from two mirrors, and a straight through optical system for imaging what is to be measured on the cathode of a photomultiplier tube. The objective lens focuses the light from the area being measured through a mirror aperture onto the photomultiplier sensing element.

The light from the area surrounding that being measured is reflected by the aperture mirror onto the viewing mirror. The eye piece focuses on the image or area in the viewing mirror. In the eye piece of the photometer the operator sees an erect magnified image or area with a round black spot in the center. Since the spot is the hole in the aperture mirror, the photometer is measuring only the area covered by this black spot. The size of the spot and hence, the angular diameter of the field being measured by the photometer can be varied by inserting various mirror apertures into the photometer. Brightness measurements were made of the sign background, sign legend, and system background.

To make measurements of disability veiling brightness (glare), a glare integrator was used. This attachment fits tightly over the front end of the objective lens of the photometer. It consists of a light refracting and scattering

LEGEND

	400-WATT SYSTEMS 30' MH	400-WATT SYSTEMS 40' MH	1000-WATT SYSTEMS 50' MH	1000-WATT SYSTEMS 60' MH
S	200'	200'	300'	300'
S/10	20'	20'	30'	30'
W	12.5'	12.5'	12.5'	12.5'

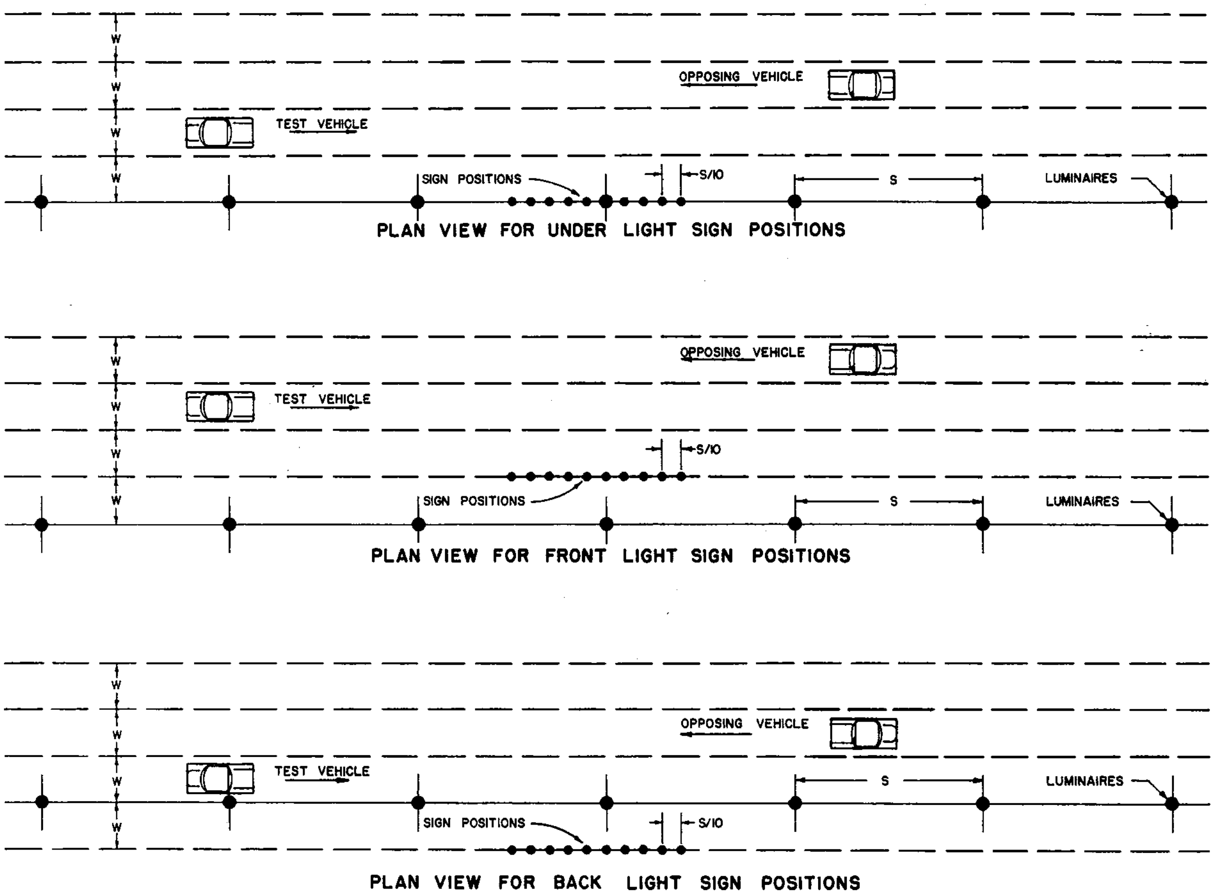
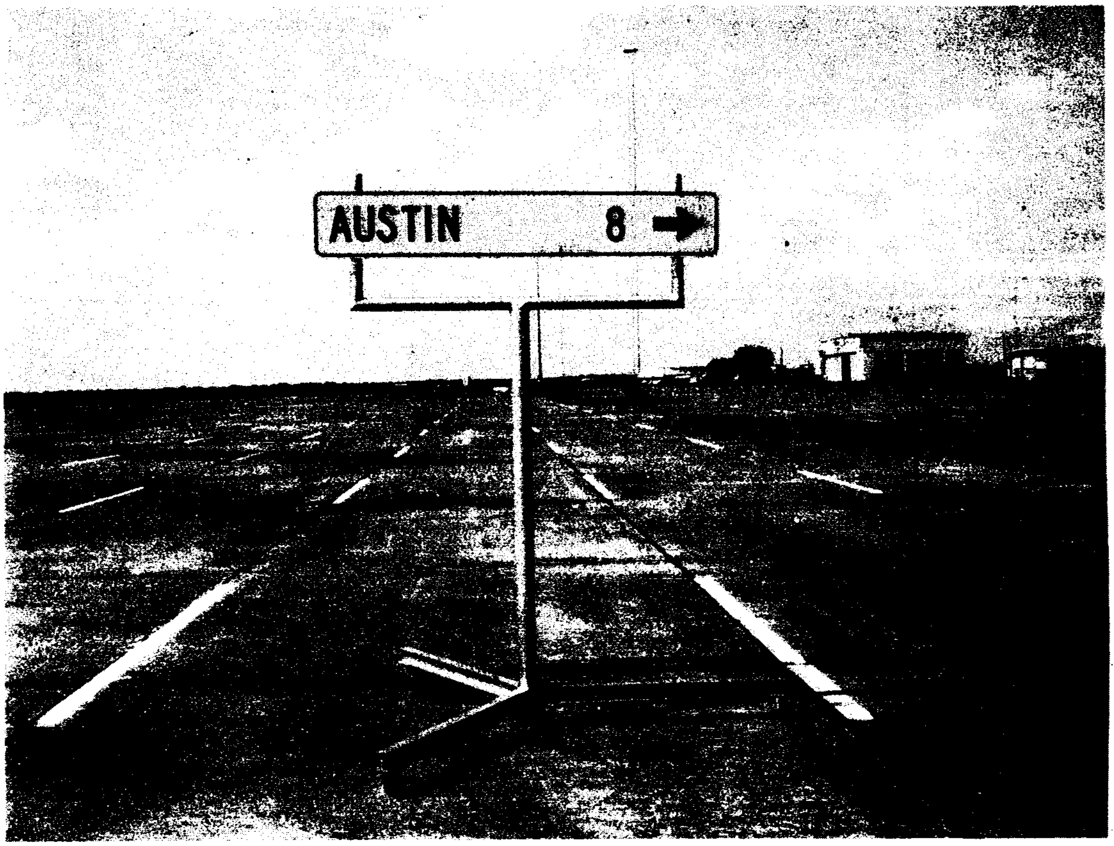
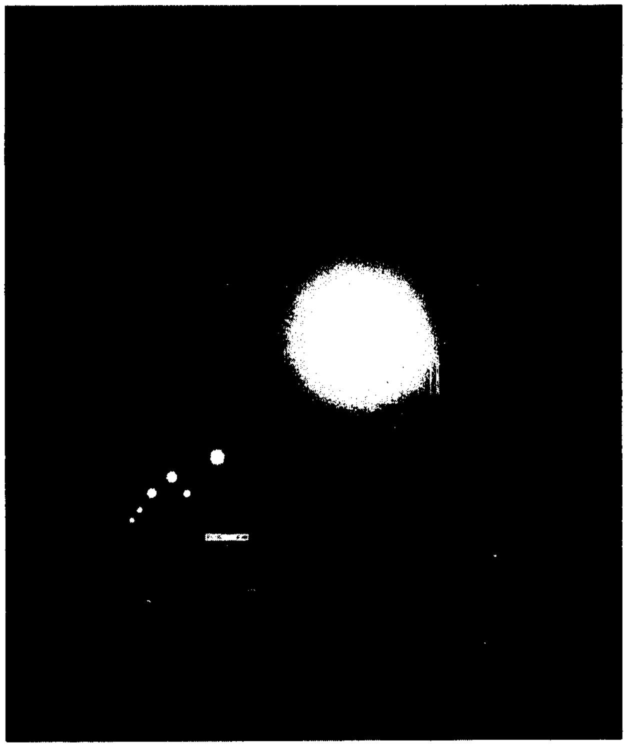


FIGURE 2

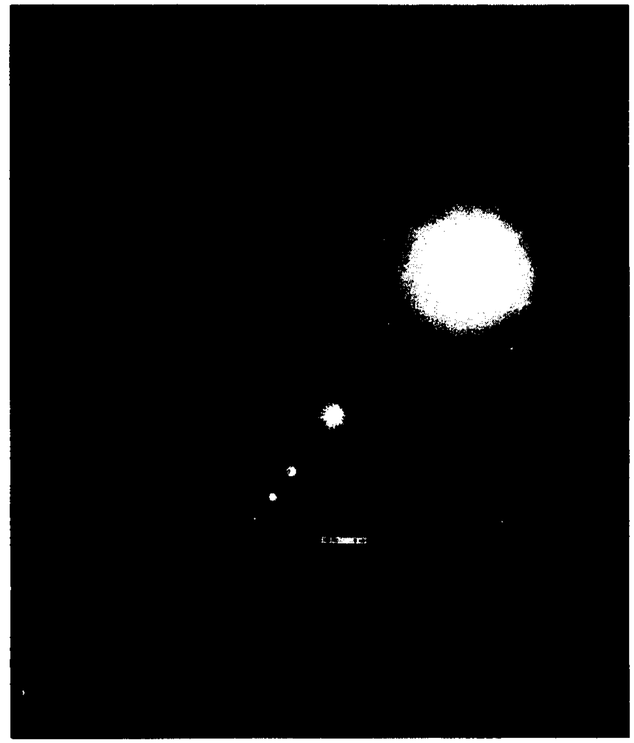


PORTABLE SIGN FRAME AND TEST SIGN

Figure 3



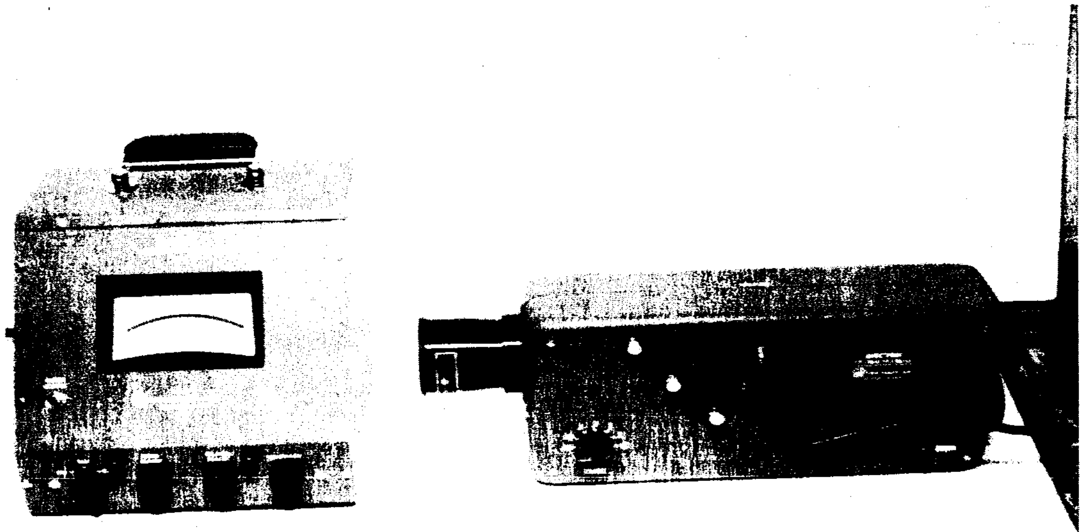
30-Foot Mounting Height



40-Foot Mounting Height

NIGHT-TIME VIEW OF TEST FACILITIES

Figure 4



SPECTRA PRITCHARD PHOTOMETER

Figure 5

surface which directs rays from the entire visual surrounding along the axis of the photometer so that they reach the photomultiplier with different effectiveness, representing the contribution of these rays to the total disability glare effect.

For the brightness and glare measurements, the photometer was mounted in the test vehicle in a position similar to that occupied by the observer so that realistic comparisons could be made between the visibility and photometric results.

ANALYSIS OF DATA

Analysis of Visibility Data

The first phase of this experiment was designed for an analysis of variance technique to be used in determining the statistical significance of the effects of the experimental variables and their interactions. The principles of the method of analysis of variance can be found in most statistical references.[3]

The experimental variables in this design were assumed to be fixed. They were predetermined instead of drawn at random from a population. Two observers, two mounting heights, two headlight conditions, three transverse sign placements, and ten longitudinal sign placements were selected to fullfill the objectives of the study.

Data, as recorded during the visibility test, were tabulated to facilitate the analysis of variance technique. Graphical means of representing the data and results were selected for explanation purposes. Detailed discussions of the analysis results will follow in a subsequent section.

Analysis of Photometric Data

The photometer data required transformation into sign brightness and DVB (Disability Veiling Brightness) values by application of correction coefficients for mirror-aperture, neutral filters, and glare lens. For each brightness reading on the photometer, values were recorded for the microammeter reading M, a mirror-aperture factor A, and a neutral factor N. To obtain the average brightness of the area imaged within the mirror-aperture the following expression was used:

$$B = M \times A \times N \qquad (1)$$

where B is the average brightness of the area within the aperture in foot-lamberts.

For each disability veiling brightness reading on the photometer, values were recorded for the same factors as for brightness. The resulting luminance value was multiplied by a correction factor to correct for change in the sensitivity of the instrument with the glare integrator attachment. Thus the following expression was used:

$$B_V = B_g \times G_C$$

where B_V = Equivalent veiling luminance produced by disability veiling brightness, in foot-lamberts.

B_g = The average luminance read with glare integrator in place as defined by equation (1).

G_C = Correction factor to correct for change in the sensitivity of the instrument with glare integrator attached.

Graphical methods of presentation of the brightness and DVB data were chosen to show the relationships of brightness and DVB to the variables for the visibility phase of the study.

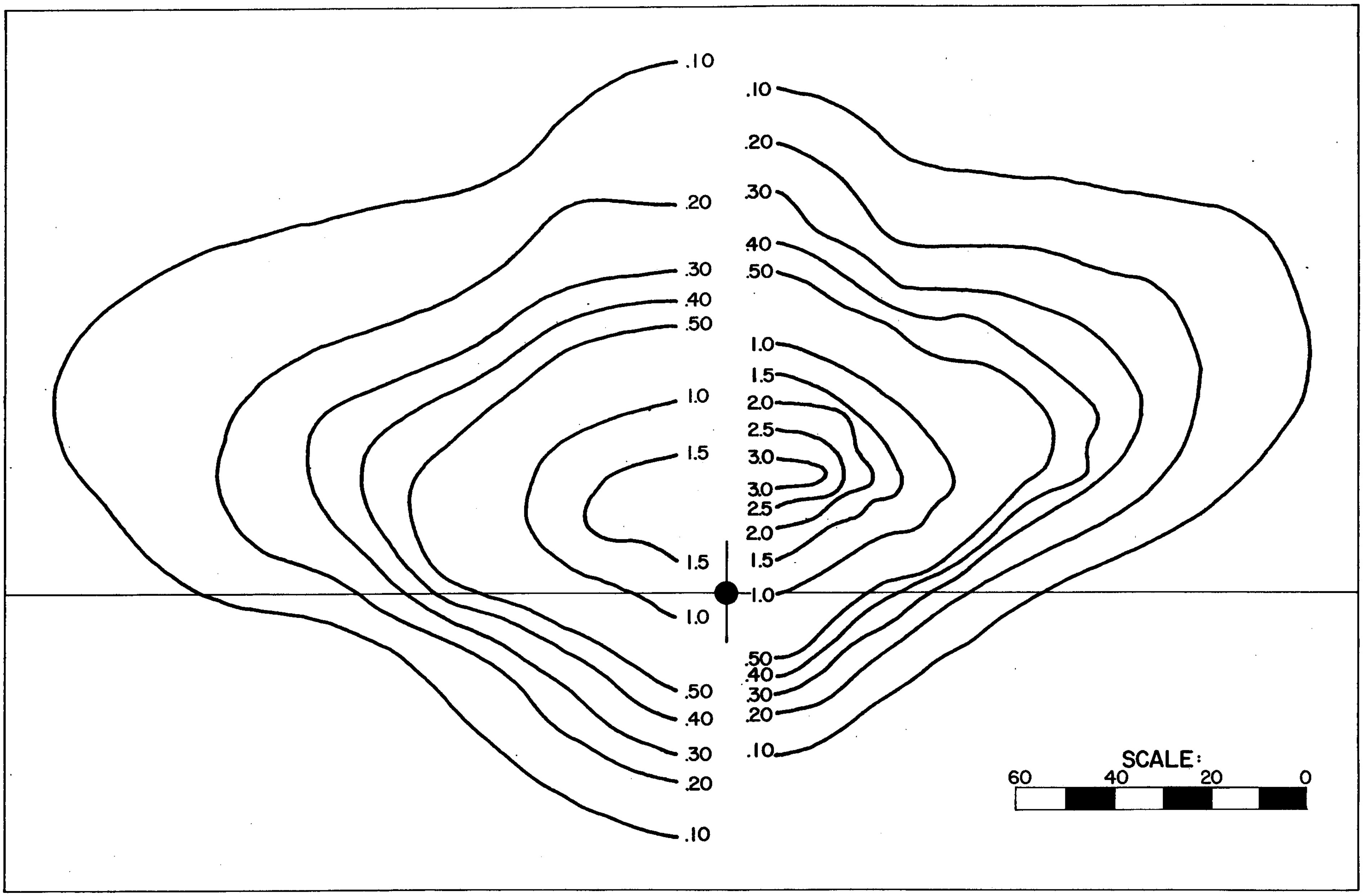
DISCUSSION OF RESULTS

Visibility Study--400-Watt Systems

Effects of Mounting Height of Luminaires

Lighting systems are often described in quantitative terms such as footcandles, foot-lamberts, light intensity, and ratios between maximum to minimum and average to minimum illumination. Standards are usually set for various types of highways and streets and a lighting system is often judged by the quantity of light on the pavement.

In designing a lighting system, a certain level of uniformity of illumination is dependent upon geometric control of light distribution, as demonstrated by a comparison of iso-footcandle curves for 30- and 40-foot mounting heights in Figure 6. By following a longitudinal section through the curves, it can be observed that better uniformity is achieved with the



40-FOOT MOUNTING HEIGHT 30-FOOT MOUNTING HEIGHT

ISO-FOOTCANDLE CURVE

40-foot mounting height. It has been demonstrated that maximum-to-minimum and average-to-minimum ratios can be improved by the use of higher luminaire mounting heights. This improvement is achieved because light is distributed over a much wider area than in cases of low mounting arrangements. For instance, at 30-foot mounting heights, an appreciable percent of the light output is confined to a relatively small area directly under the luminaire. This high concentration of light immediately under the luminaire creates an undesirable bright spot on the road. By mounting luminaires at higher levels, the light confined in the bright spot is distributed over a much larger area and this improves the uniformity. Briefly, the higher luminaire mounting arrangement creates a system with improved uniformity at low to average illumination levels.

What effect, then, does this improved system have on sign visibility? The effect is demonstrated in Figure 7 which presents a summary of sign legibility distance observed in this study. From observation it can be noted that the general trend is toward greater legibility distance for higher mounting height. Briefly stated, the 40-foot mounting height represents an increase of approximately 12 percent in legibility distance as illustrated in Figure 8. This is comparable to approximately two car lengths. At an operating speed of 60 mph an additional one-half second of reaction time is provided.

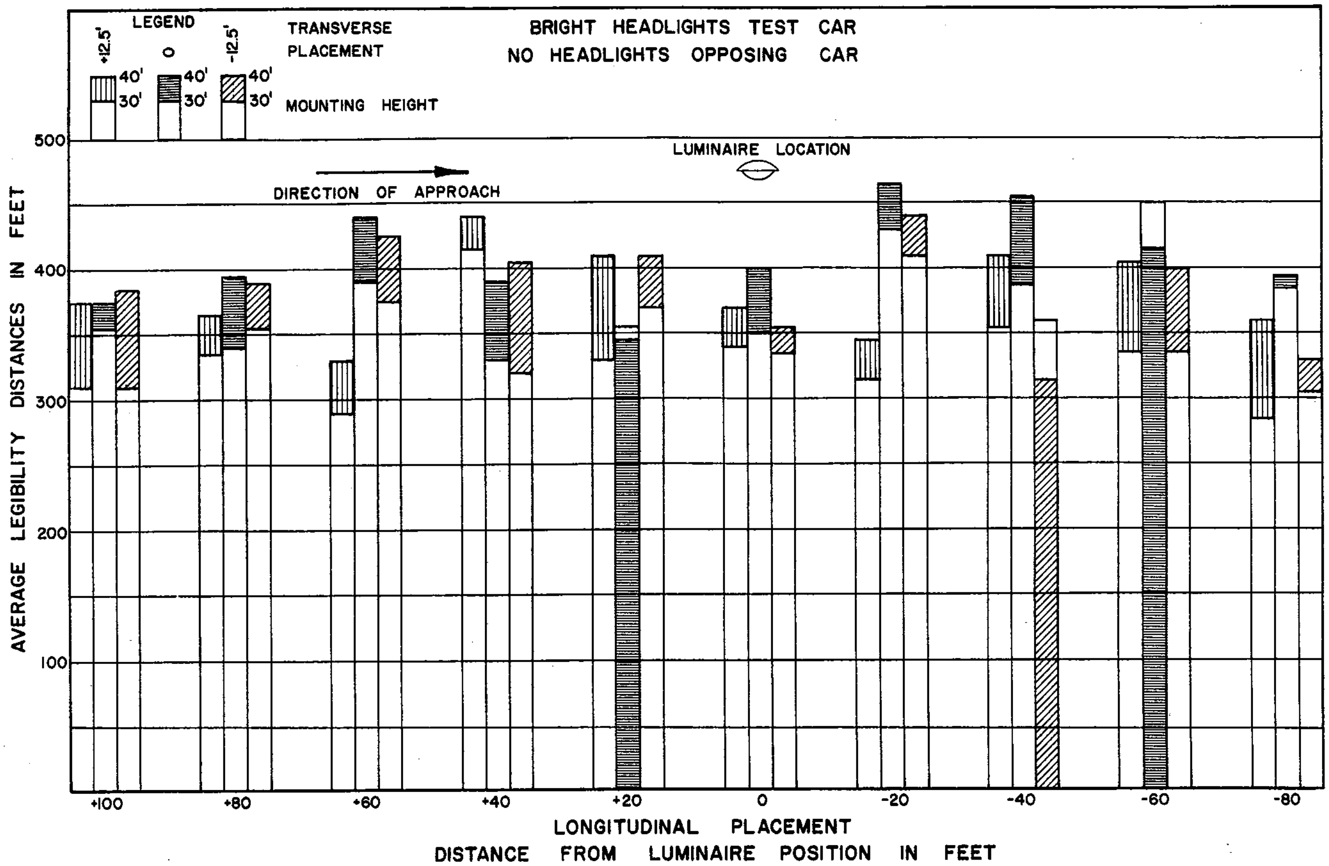
Table 1 gives the statistical significance of differences in sign legibility distance as related to mounting height. This analysis of variance and separation of means indicates that the increase in legibility distance for the 40-foot mounting height is significant.

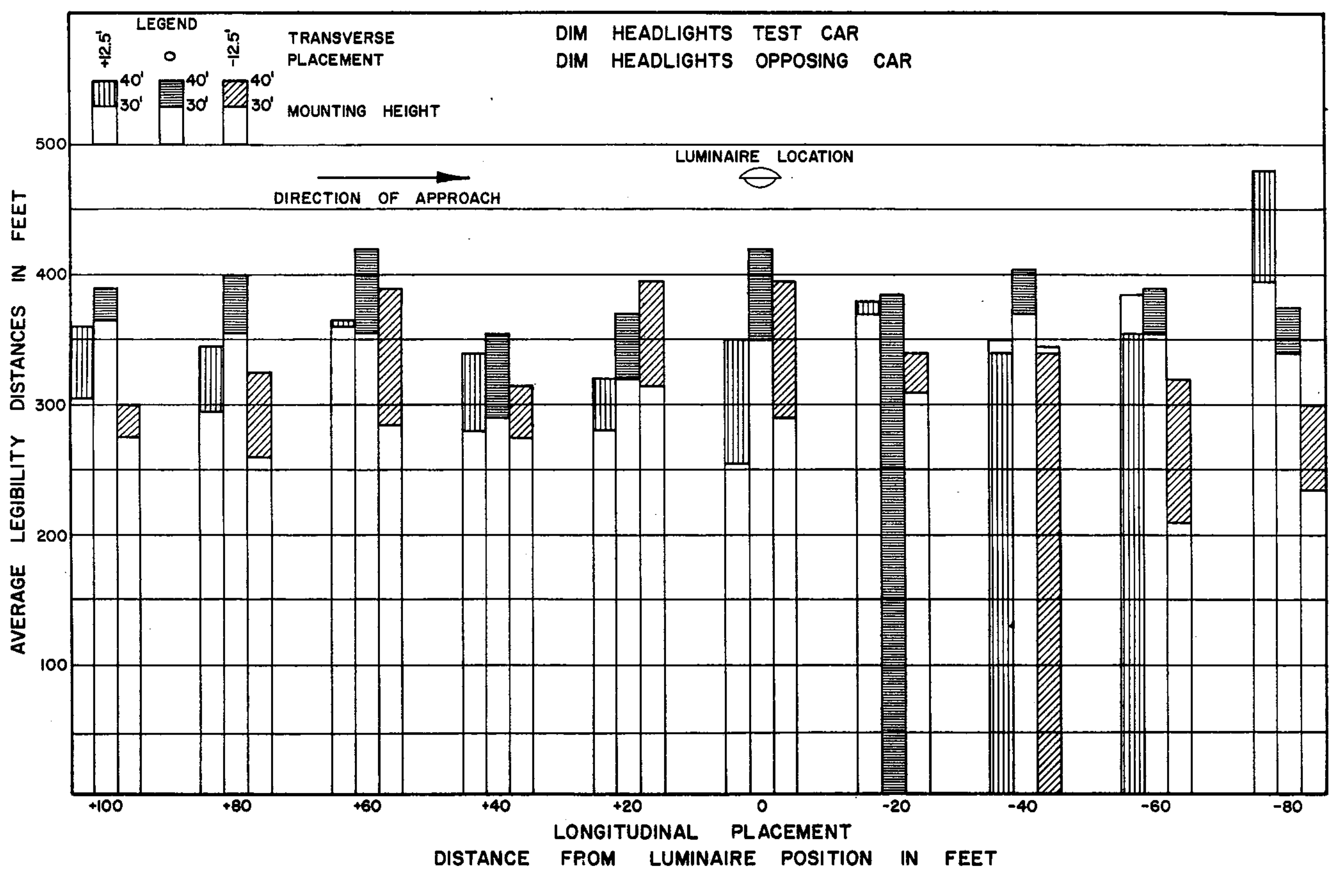
<u>Effects of Headlight Conditions</u>

As expected, the bright headlight condition on the test vehicle increased legibility distance. The bright headlight condition provided an average increase of 28 feet or approximately 8 percent. This increase is indicated in Figure 9. It is noted that the average increase in legibility distance due to bright headlight conditions is less for the 40-foot mounting height than for the 30-foot mounting height. This could very well be due to the improved uniformity of light distribution in the 40-foot mounting height system. In other words, the bright spot being spread over a larger area reduces the need for illumination from the headlights. For transverse positioning, it is also noted that the increase is less for the sign positions under the light source and in front of the light source than for the positions behind the light source. This, too, can be reasonably explained in that the positions behind the light source receive very little illumination from the luminaires.

The effects of headlight conditions for the various longitudinal sign positions tested show no definite pattern. However, the variation for the 30-foot mounting height is greater than that for the 40-foot mounting height and this too may be attributed to the poorer uniformity of the 30-foot arrangement. This variation is indicated in Figure 10.

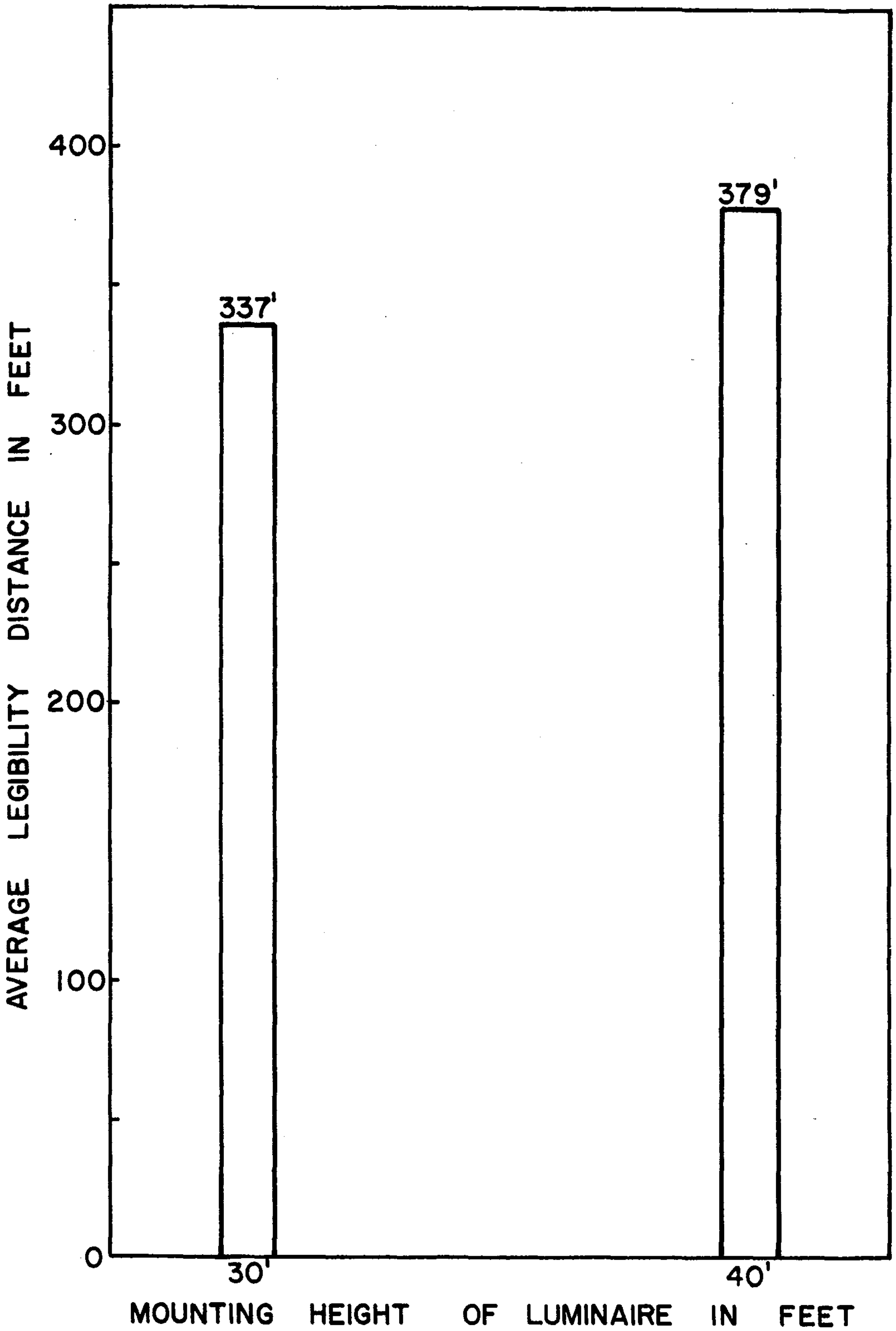
Statistically, the analysis of variance and separation of means indicate that the main effect of headlight conditions is significant. Likewise, the





EFFECTS ON LEGIBILITY DISTANCE FOR CONDITIONS SHOWN

FIGURE 7



MOUNTING HEIGHT EFFECTS ON LEGIBILITY

FIGURE 8

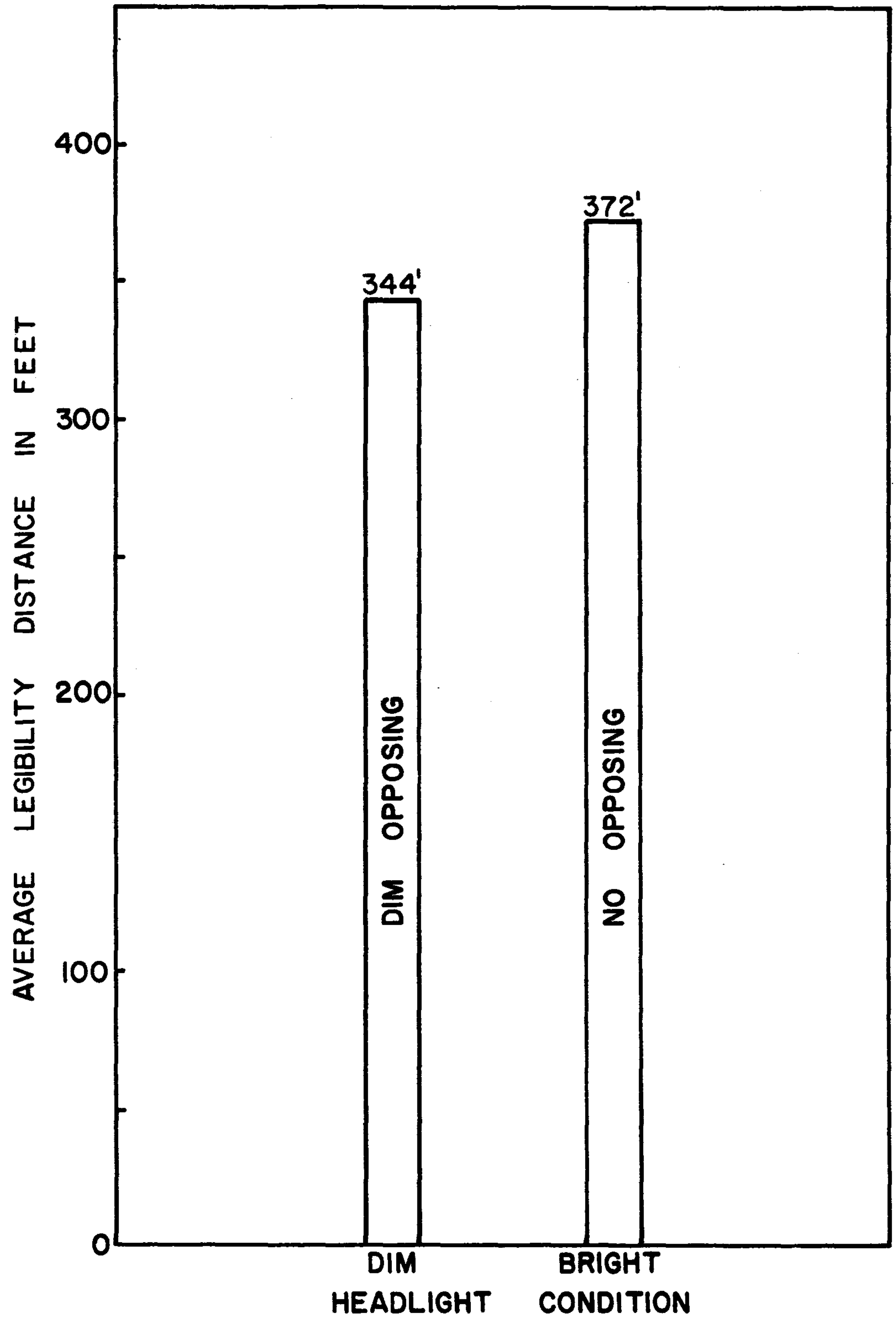
TABLE 1

ANALYSIS OF VARIANCE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square
Observers	1	2,042	
Treatments	119	564,100	
HT	1	105,002	105,002*
HL	1	47,602	47,602*
HT x HL	1	326	326N.S.
T	2	80,378	40,189*
T x HT	2	2,560	1,280N.S.
T x HL	2	24,206	12,103*
T x HT x HL	2	4,576	2,288*
L	9	34,792	3,866*
L x HT	9	11,489	1,276*
L x HL	9	30,223	3,358*
L x HT x HL	9	6,966	774N.S.
L x T	1	80,608	4,478*
L x T x HT	18	26,521	1,473*
L x T x HL	18	92,791	5,155*
L x T x HT x HL	18	16,060	892N.S.
Error	119	71,758	603

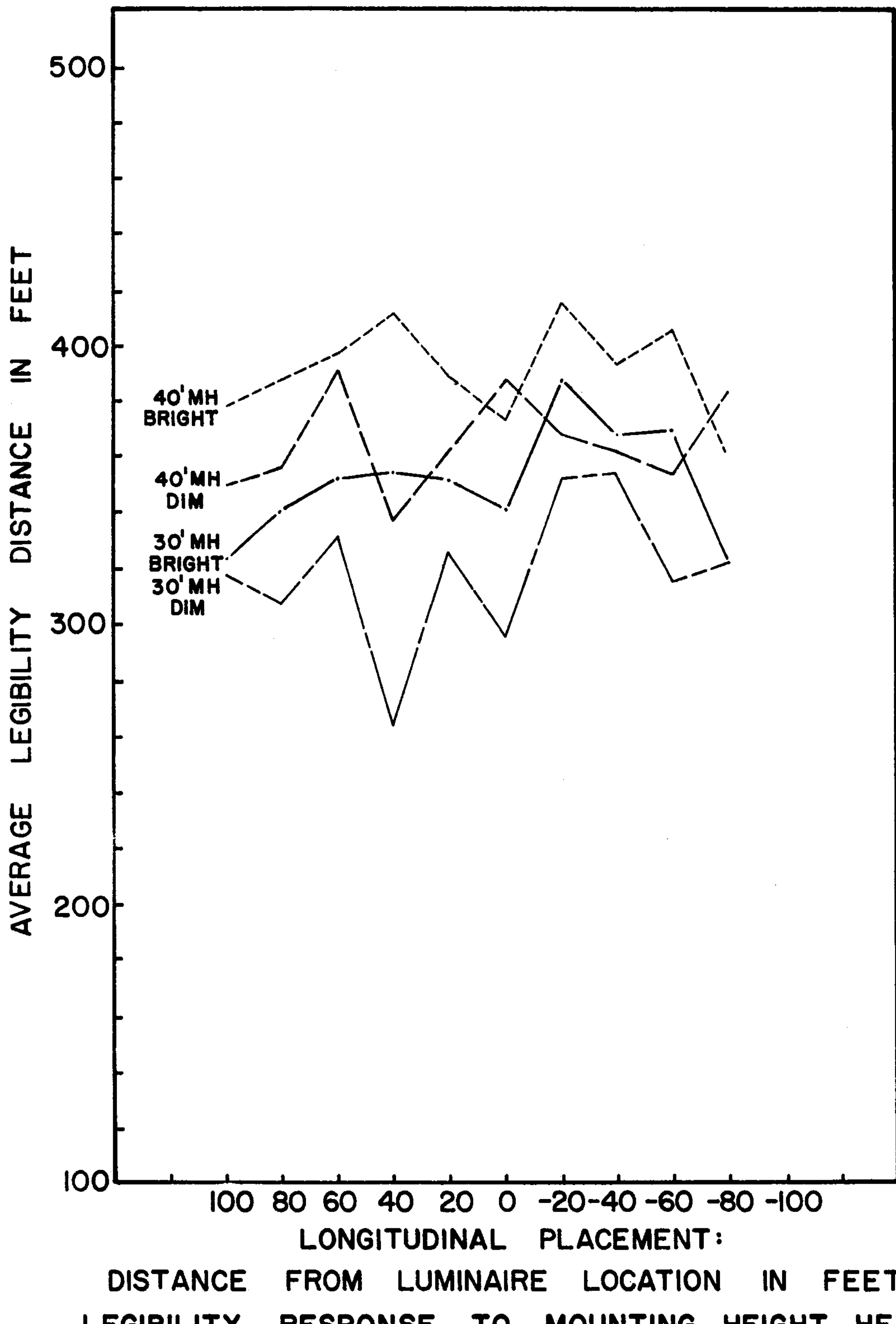
$F_{1,119}$ (.05) = 3.93;
$F_{2,119}$ (.05) = 3.08;
$F_{9,119}$ (.05) = 1.96;
$F_{18,119}$(.05) = 1.67;

HT = Height
HL = Headlight
T = Transverse
L = Longitudinal
* = Significant
N.S. = Not Significant



HEADLIGHT EFFECTS ON LEGIBILITY

FIGURE 9



LEGIBILITY RESPONSE TO MOUNTING HEIGHT, HEAD-LIGHTS AND LONGITUDINAL PLACEMENT

FIGURE 10

interactions between headlight conditions and transverse position, and headlight conditions and longitudinal position, are significant. The interaction between headlight conditons and mounting heights is not significant. (See Table 1).

Effects of Transverse Position

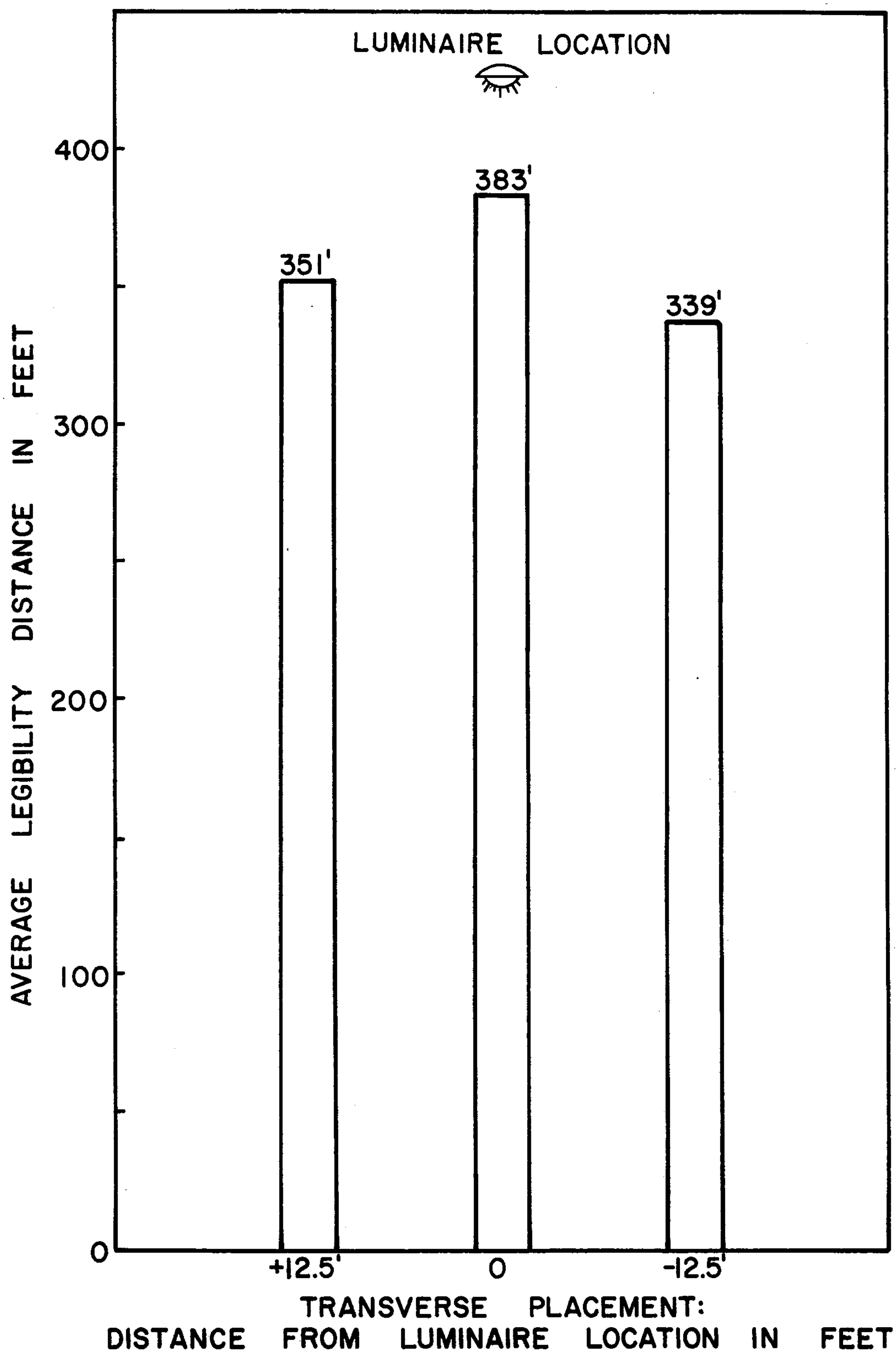
In all cases, the average legibility distance was greatest for the test signs mounted on line with the luminaires. Figure 11 indicates a mean increase of 13 percent for the under-light transverse positions over the back-light positions and 9 percent over the front-light positions. The effect of transverse position for the various mounting heights and headlight conditions can be seen in Figure 12. Figure 7 illustrates the interaction between transverse placement and longitudinal placement.

The analysis of variance and separation of means of Table 1 show that the main effects of transverse placement with respect to the light sources are significant. Similarly, the interactions between transverse placement and headlight conditions, and transverse placement and longitudinal placement are significant. The interaction between transverse placement and mounting height is not significant.

Effects of Longitudinal Position

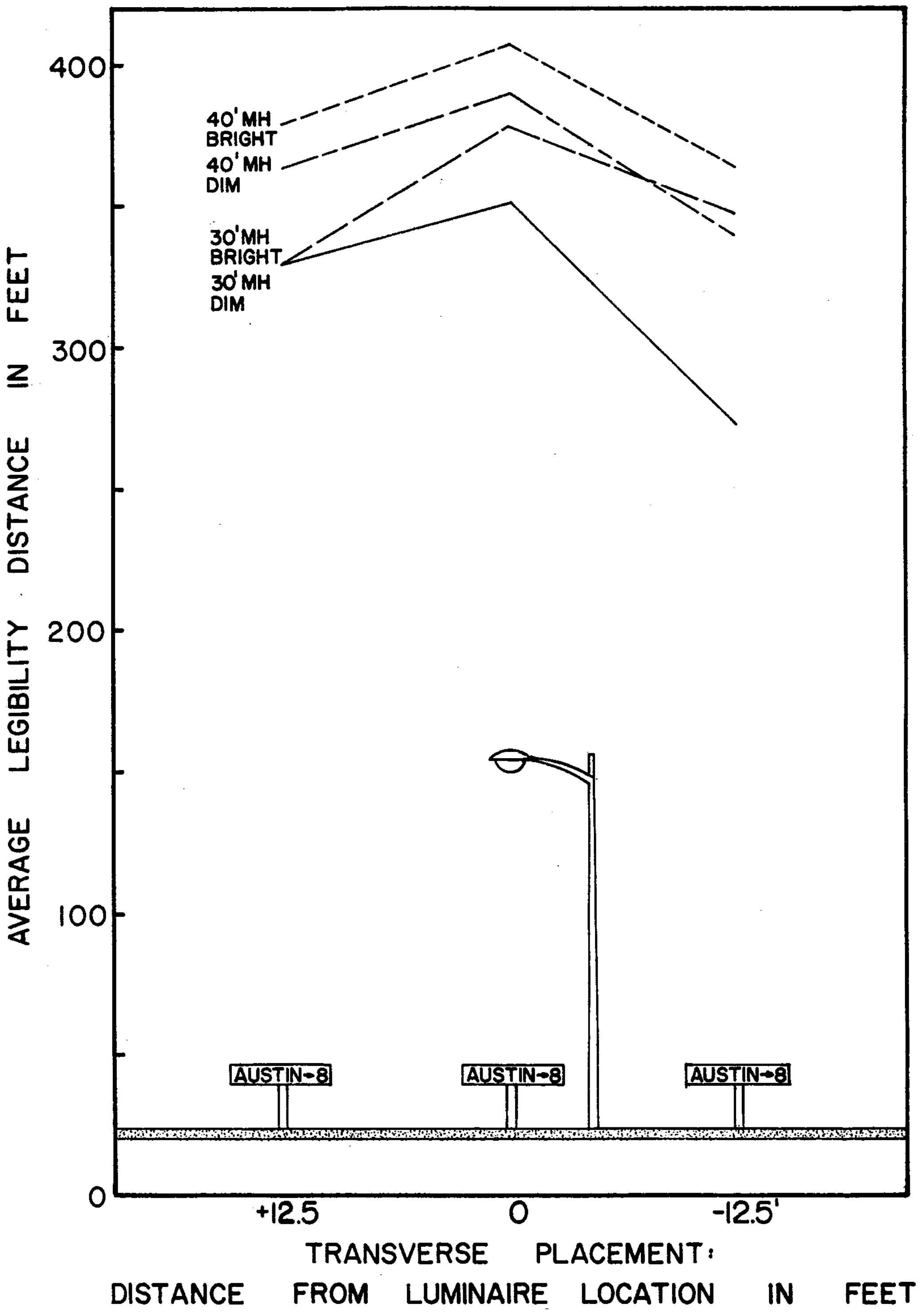
It was discussed previously that the increased mounting height arrangements produce a system of improved uniformity. With the 40-foot mounting height the objectionable bright pool of light directly under the luminaire has been spread over a much larger area. It might be expected that the longitudinal position of signs with respect to luminaire location could have considerable effect on legibility distances for the 30-foot mounting heights. Conversely less effect would be expected for the 40-foot mounting heights. Figure 13 represents the mean legibility distances for the ten longitudinal positions tested taken over the 30- and 40-foot mounting heights. The maximum mean legibility distance represents an increase of 11 percent over the minimum average legibility distance. From Figure 14 it can be noted that this increase is due primarily to the variations in the 30-foot mounting height arrangement. In the 30-foot mounting height arrangement the maximum mean legibility distance represents an increase of 16 percent over the minimum mean legibility distance while an increase of only 7 percent is noted for the 40-foot mounting height arrangement.

Statistically the main effect of longitudinal position is significant. Also, the interactions of longitudinal positions with mounting heights, headlight conditions, and transverse positions are significant.



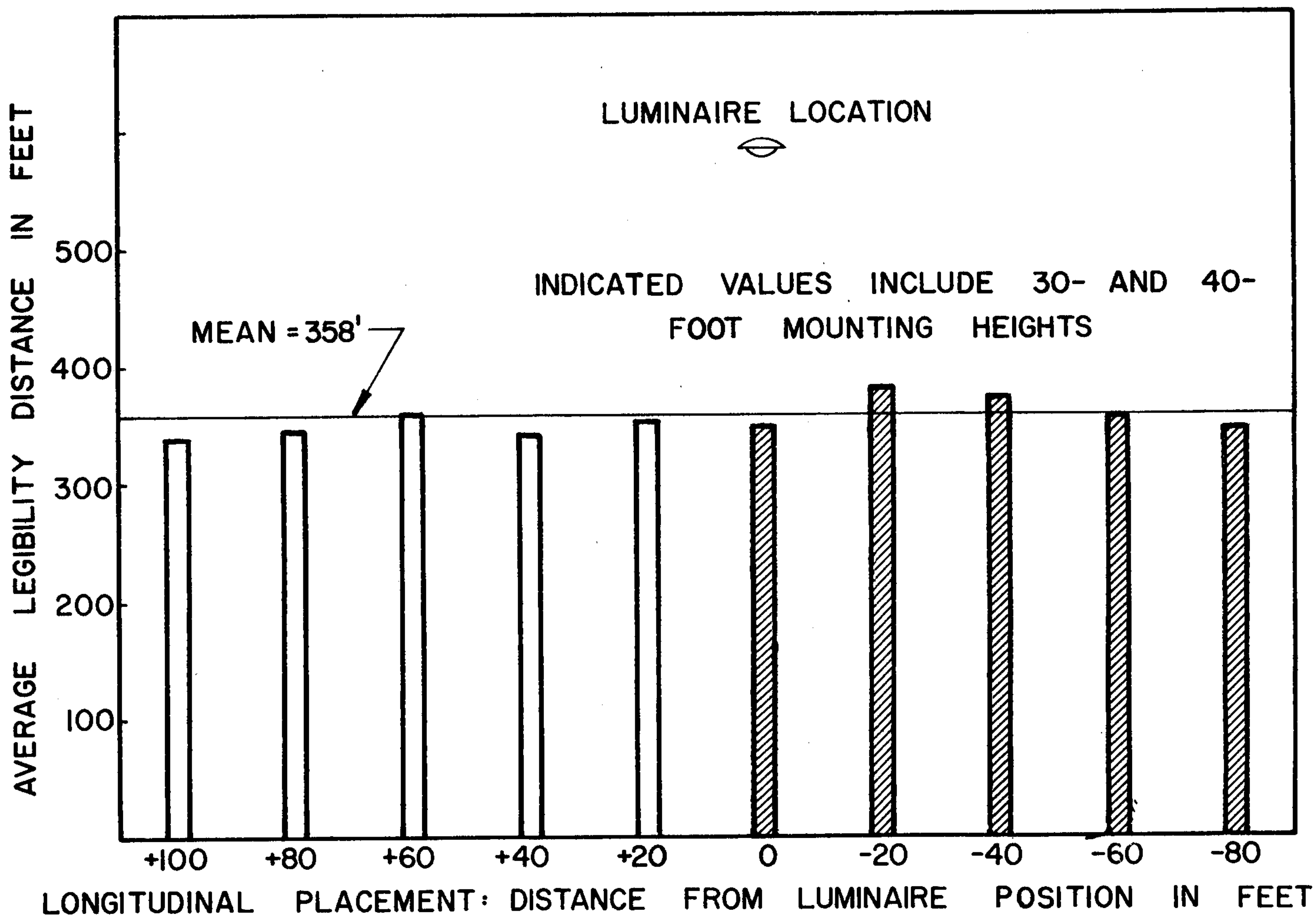
TRANSVERSE PLACEMENT EFFECTS ON LEGIBILITY

FIGURE 11



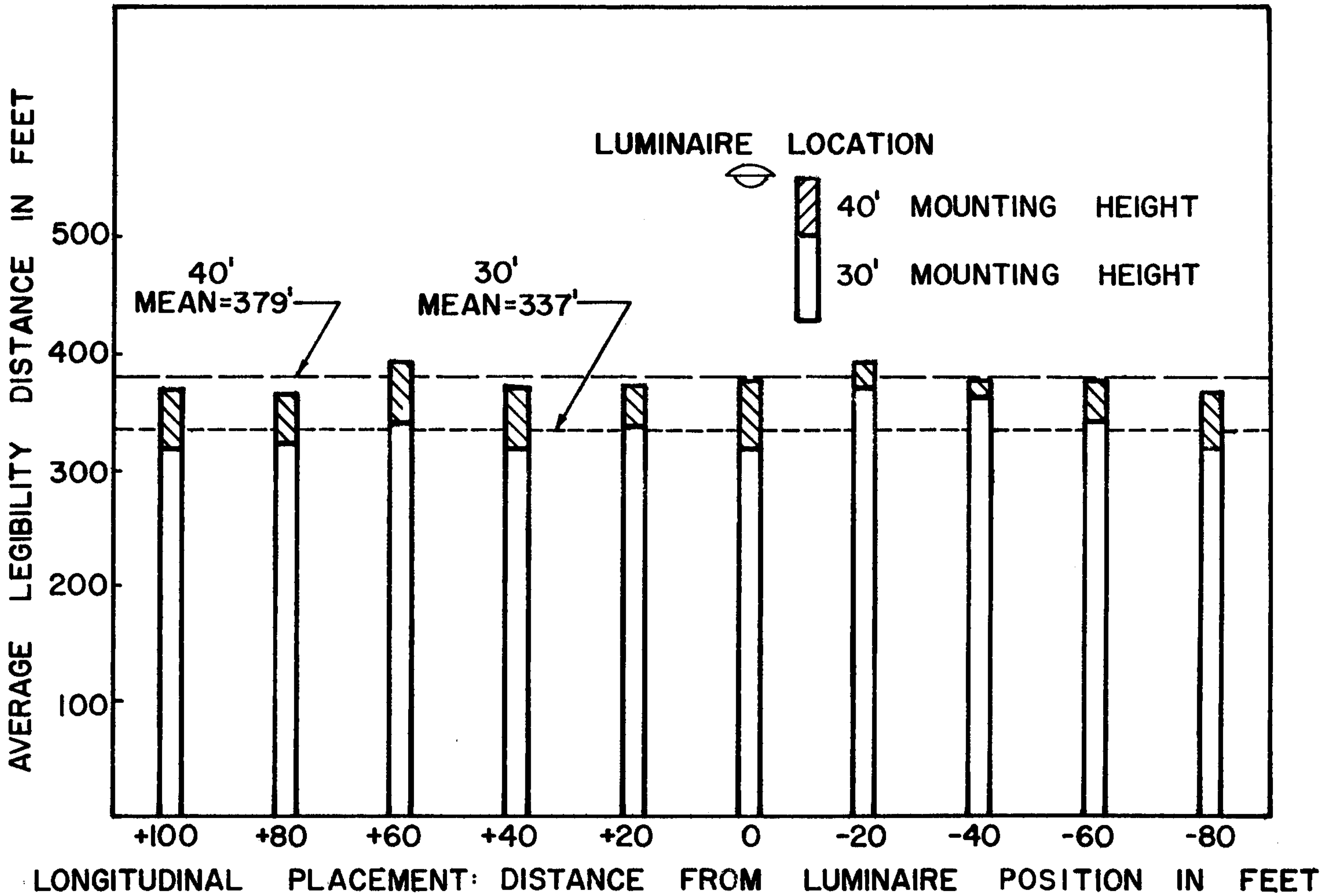
LEGIBILITY RESPONSE TO MOUNTING HEIGHT, HEADLIGHTS AND TRANSVERSE PLACEMENT

FIGURE 12



LEGIBILITY RESPONSE TO LONGITUDINAL PLACEMENT

FIGURE 13



LEGIBILITY RESPONSE TO LONGITUDINAL PLACEMENT

FIGURE 14

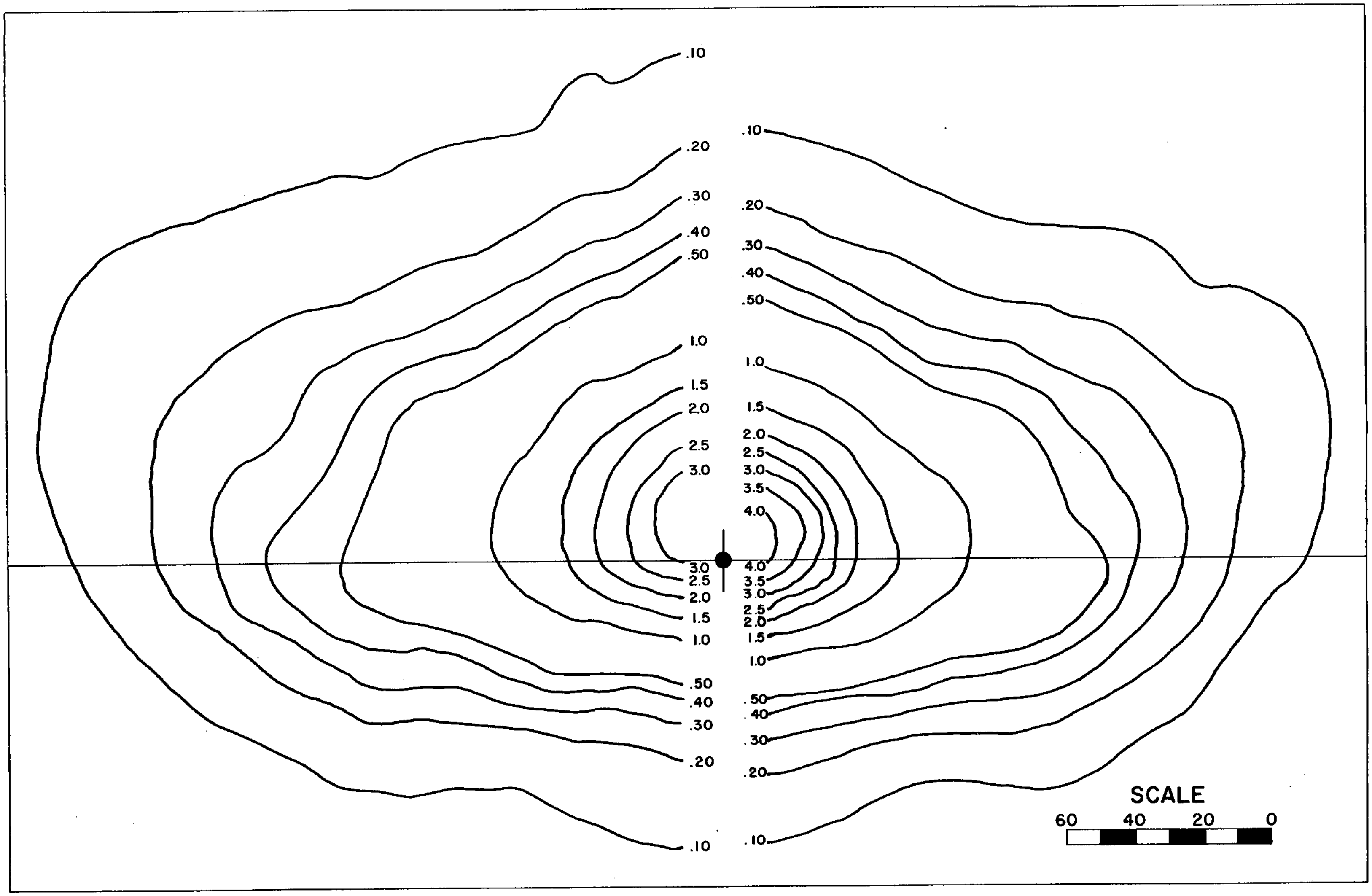
The real significance of these results is the fact that the engineer need not stress the importance of longitudinal position for the higher mounting heights. This flexibility can certainly be advantageous in situations where the location of both signs and luminaires is restricted. This flexibility is not provided by the lower mounting heights. With the 30-foot mounting arrangement the difference in legibility distance for various longitudinal positions is enough to warrant careful consideration.

Results indicate that a longitudinal position of 20 to 60 feet beyond the luminaire from the driver is desirable for the 400-watt units mounted at 30 feet. This can be explained in that the above mentioned sign positions are receiving illumination on the face of the sign, thus, increasing legibility distance. However, when the sign is in front of the light source the illumination is striking the back of the sign and in effect reduces contrast of the sign and thus legibility of the message. This is not so critical for the 40-foot arrangement because the uniformity of the entire system is so much improved.

Visibility Study--1000-watt Systems

Effects of Mounting Height of Luminaires

No appreciable difference in uniformity could be detected between the 50-foot and 60-foot mounting heights of 1000-watt units. At 50 feet the light distribution has been spread over a maximum area and by increasing the height to 60 feet results in approximately the same distribution with slightly lower levels of intensity. This is demonstrated in Figure 15 which shows a comparison of iso-footcandle curves for 50- and 60-foot mounting heights. By following a longitudinal section through these curves it can be expected that there would be little difference in legibility distance of roadside signs for the 50-foot and 60-foot mounting heights. Figure 16 presents a summary of sign legibility distances observed in this phase of the study. From observation it can be noted that there is little difference between the legibility distances for the two mounting heights. Briefly stated, there is only one percent difference in legibility distance for the two mounting heights with the 50-foot mounting height being slightly larger. For the 50-foot mounting height the mean legibility distance was 315 feet. For the 60-foot mounting height the mean legibility distance was 311 feet. Table 2 gives the statistical significance of difference in sign legibility distance as related to mounting height. This analysis of variance and separation of means indicates that the increase in legibility distance for the 50-foot mounting height is not significant.

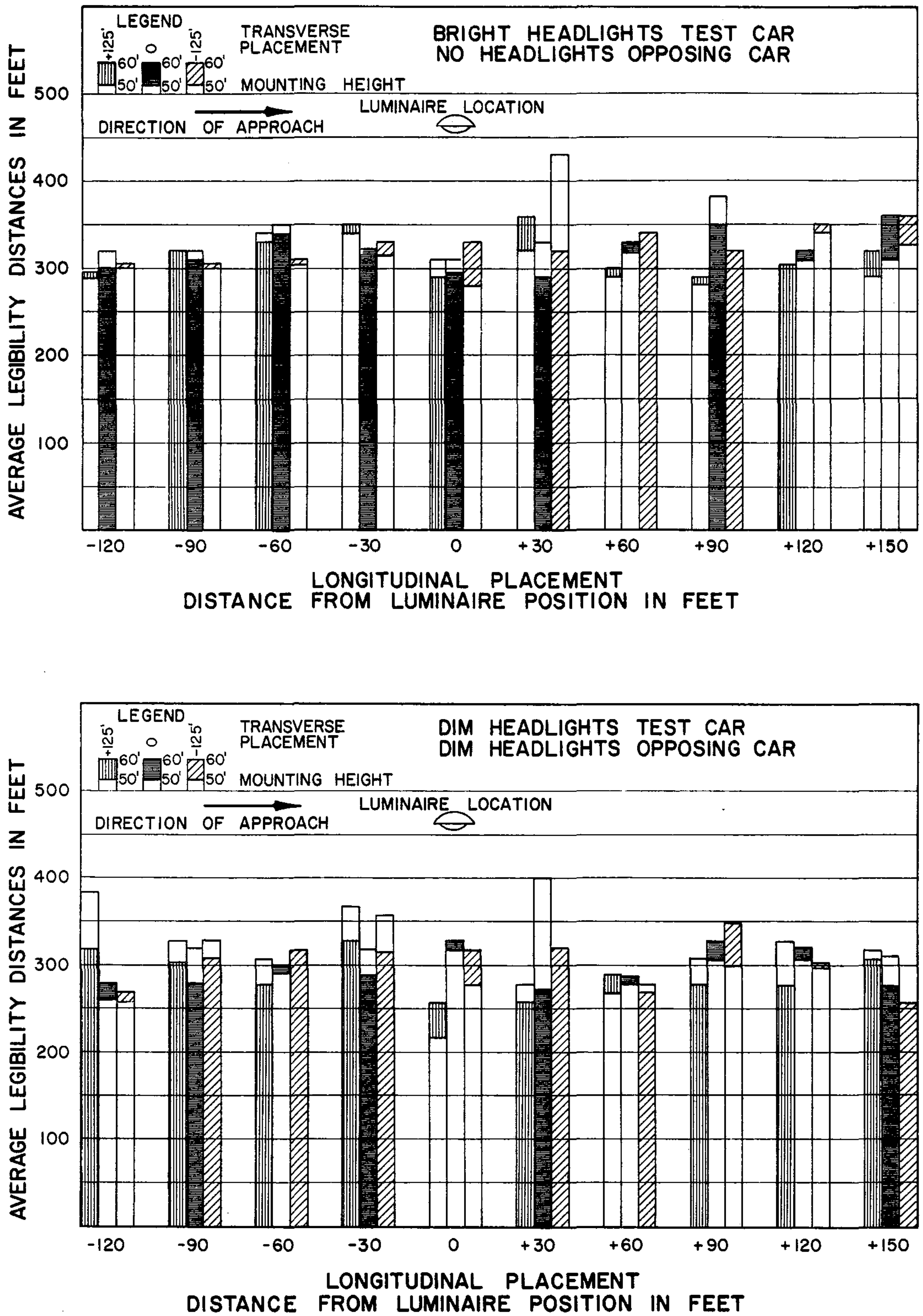


60-FOOT MOUNTING HEIGHT

50-FOOT MOUNTING HEIGHT

ISO-FOOTCANDLE CURVE

FIGURE 15



EFFECTS ON LEGIBILITY DISTANCE FOR CONDITIONS SHOWN

FIGURE 16

TABLE 2

ANALYSIS OF VARIANCE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square
Observers	1	188,160	188,160
Treatments	119	185,815	
HT	1	1,126	1,126 N.S.
HL	1	22,426	22,426 *
HT x HL	1	603	603 N.S.
T	2	1,627	814 N.S.
T x HT	2	2,142	1,071 N.S.
T x HL	2	2,272	1,126 N.S.
T x HT x HL	2	2,349	1,175 N.S.
L	9	31,023	3,447 *
L x HT	9	14,316	1,591 N.S.
L x HL	9	17,849	1,983 *
L x HT x HL	9	6,822	758 N.S.
L x T	18	32,202	1,789 *
L x T x HT	18	2,829	157 N.S.
L x T x HL	18	41,516	2,306 *
L x T x HT x HL	18	6,713	373 N.S.
Error	119	103,690	871

F_{1}, 119 (.05) = 3.93.
F_{2}, 119 (.05) = 3.08.
F_{9}, 119 (.05) = 1.96.
F_{18}, 119 (.05) = 1.67.

HT = Height.
HL = Headlight.
T = Transverse.
L = Longitudinal.
* = Significant.
N.S. = Not Significant.

Effects of Headlight Conditions

The bright headlight condition on the test vehicle in the 1000-watt system increased legibility distance approximately 6 percent. It is noted that the average increase in legibility distance due to bright headlight conditions is approximately the same for the 50-foot and the 60-foot mounting height. For transverse positioning, it is noted that the increase is less for the sign positions under the light source and in front of the light source than for the positions behind the light source. The positions behind the light source are more dependent upon headlights for illumination. The effect of headlight conditions for the various longitudinal sign positions tested showed no definite pattern. However, the variation for the 50-foot mounting height is greater than for the 60-foot mounting height.

Statistically, the analysis of variance and separation of means indicate that the main effect of headlight conditions is significant. Likewise, the interaction between headlight conditions and longitudinal positions is significant. The interaction between headlight conditions and mounting heights is not significant.

Effects of Transverse Position

For the front light, under light and back light transverse positions there was very little difference in average visibility distance. The values were 310 feet, 315 feet, and 316 feet for the respective positions. This represents approximately 1 percent difference for the three. The analysis of variance and separation of means of Table 2 show that the effects of transverse placement with respect to the light sources were not significant.

Effects of Longitudinal Position

For the ten longitudinal positions tested the maximum mean legibility distance represents an increase of 12.5 percent over the minimum legibility distance. It was noted that this increase is due more to the variations in the 50-foot mounting height arrangement than for the 60-foot arrangement. In the 50-foot mounting height arrangement the maximum mean legibility distance represents an increase of 15 percent over the minimum mean legibility distance while an increase of 10 percent is noted for the 60-foot mounting height arrangement.

Statistically, the main effect of longitudinal position is significant. Also, the interaction of longitudinal position with headlight condition and transverse position is significant. Results indicate that a longitudinal sign position of 30 feet beyond the luminaire from the driver provided maximum sign legibility for the 1000-watt units mounted at 60-feet. For the 50-foot mounting height the maximum legibility position was shown to be either 30 feet in front of the luminaire or 30 feet beyond the luminaire. Since there was very little difference in the longitudinal positions it is impossible to say that one position would be an optimum position. These results indicate that the engineer need not stress the importance of longitudinal position for either of the higher mounting heights.

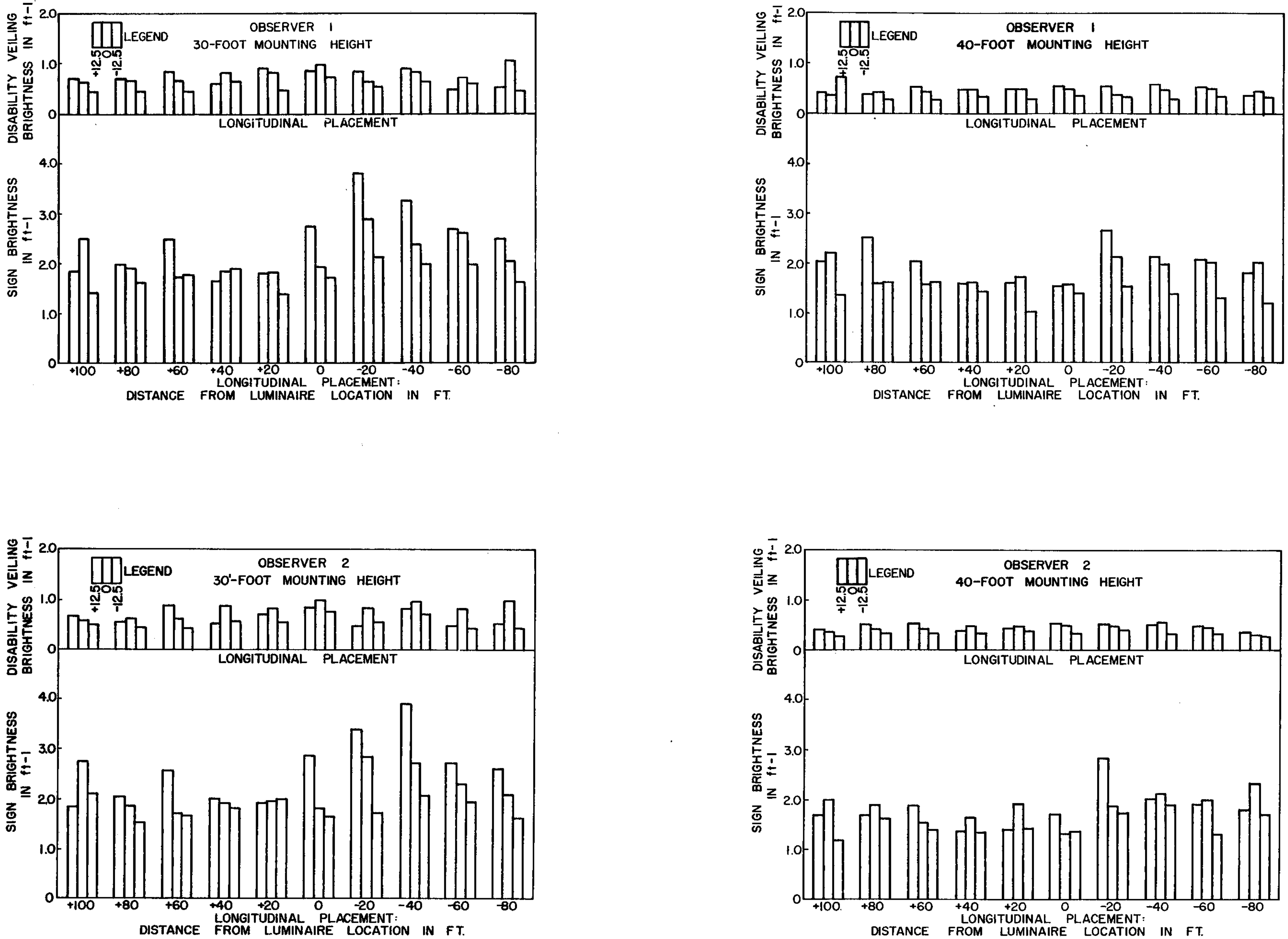
Brightness and Glare Study

Present practice in roadway lighting in the United States is to specify lighting in terms of illumination only. This practice implies that brightness patterns are sufficient if the average horizontal illumination is at a reasonable level. It should be considered that the amount of light reflected from the surface of the roadway, sign or any object in the direction of the observor is the only light that the driver has for evaluation. It is recognized that light must be applied to a surface in order to get light reflected from the surface. However, the directional characteristics of incident light, the directional reflectance characteristics of surfaces and the location of the observer determine whether or not the brightness is adequate for the specific purpose desired.

In this phase of the study the primary concern was surface detail. Silhouette alerts the driver that a sign is present and surface detail transfers the information of the sign legend.

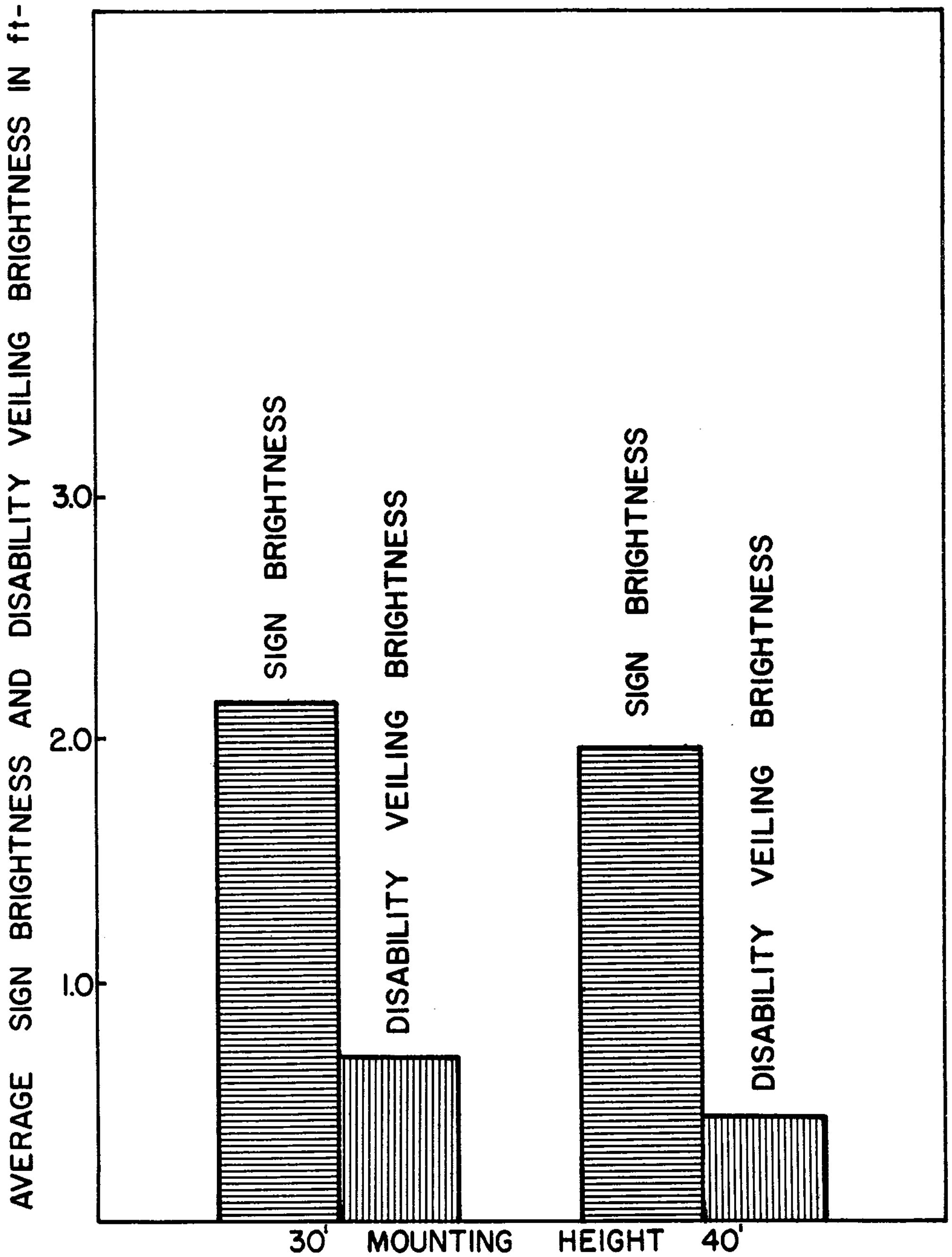
System background brightness, sign background brightness, and legend brightness were studied for the 400-watt systems. System background brightness remained fairly constant for all positions studied. Hence, increases and decreases in sign background brightness reflect direct changes in contrast due to silhouette and surface detail.

The over-all brightness and glare patterns are greater for the 30-foot mounting height than for the 40-foot mounting height. These increases are reflected in Figure 17. In an effort to relate brightness and DVB to the variables of the first phase of the study, Figures 18, 19, and 20 were prepared. Figure 18 represents the average sign brightness and disability veiling brightness for the two mounting height arrangements. Considerable difference is noted for the two mounting heights and can be explained in terms of the distance from the light sources to the signs. The 30-foot luminaires were closer to the signs thus throwing more incident light onto the surfaces resulting in the increased reflected light or brightness. The same is true for the disability veiling brightness in that the light sources are contributing more light into the line of sight.



SIGN BRIGHTNESS AND DISABILITY VEILING BRIGHTNESS FOR CONDITIONS SHOWN

Figure 17



SIGN BRIGHTNESS AND DISABILITY VEILING BRIGHTNESS FOR 30-AND 40-FOOT MOUNTING HEIGHTS

Figure 18

Transverse Position

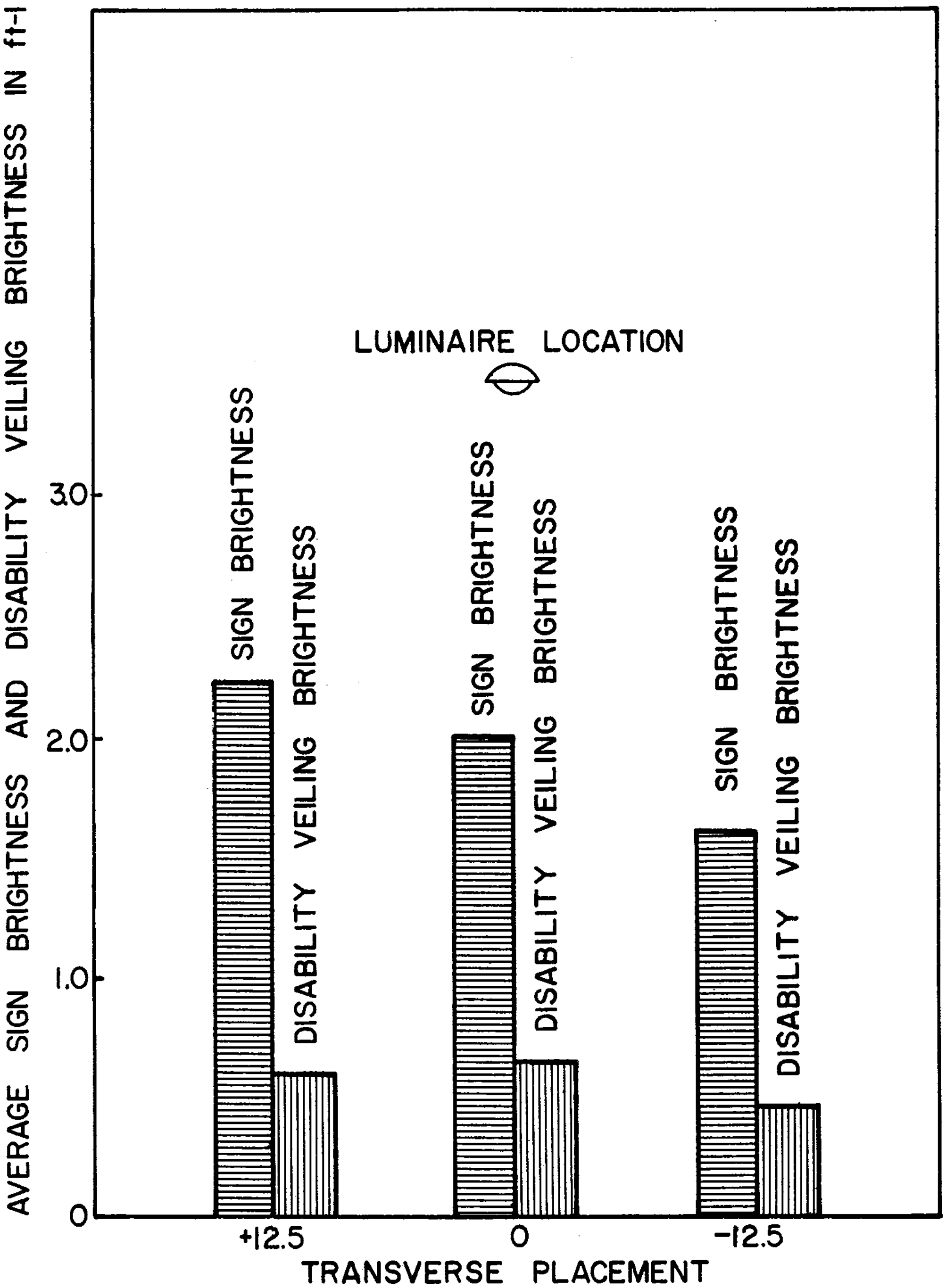
Figure 19 reflects the relative difference in brightness and DVB for the three transverse positions. The relative values for the three transverse positions indicate that signs in the front light receive more illumination than in the other two positions. The luminaires are constructed so as to focus the higher intensity light on the street side. Similarly brightness and DVB values are low for the back light position because, in that position, the signs are mainly dependent upon vehicle headlights for illumination. The under light transverse position indicates maximum disability veiling brightness although no large variation is noted.

Longitudinal Positions

The relationship of average sign brightness and DVB with longitudinal sign position can be observed in Figure 20. The maximum sign brightness occurs when the sign is located in such a position that it receives direct light on its face. Similarly the lower values were observed where less light was striking the face. Only small variations were observed in DVB measurements for the various longitudinal sign positions.

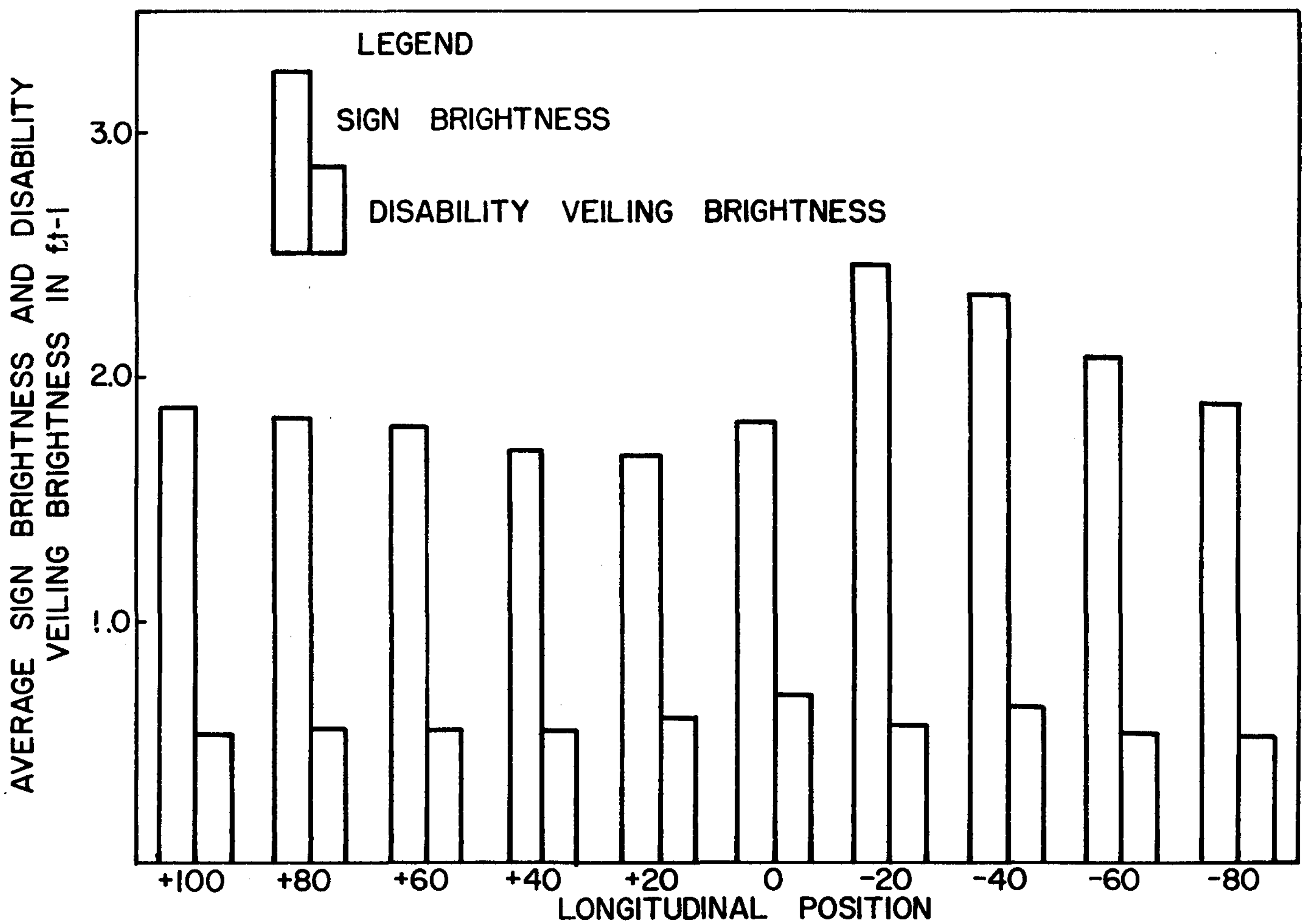
Effects on Visibility

By comparing Figure 20 and Figure 13 it can be seen that the general trend of the two histograms is similar. A particular note is drawn to the -20-, -40-, and -60-foot longitudinal positions. These positions represent both maximum average legibility distances and maximum average brightness values. The relationship between DVB and legibility as portrayed by the histogram seems insignificant; that is, there is no similar pattern between the two. The histogram of Figure 19 presents a different thought. The maximum average brightness occurs for the front light transverse position while maximum legibility distance occurs for the under light transverse position as illustrated in Figure 11. First, consider that reduced legibility may be an adaptation problem instead of a brightness problem. This could show considerable effects for the transverse and longitudinal position. When the eyes are adapted to low levels of brightness, the recovery from the light differences and the regaining of previous sensitivity are quite slow. They take place as the observer passes from dim to bright spots in the illumination system. If the observer is exposed to a bright sign while his eye adaption is for low levels of luminance the bright sign may appear to be washed out. The front light transverse position represents the areas of maximum brightness and this washing out was actually observed during the visibility test. This was particularly true for the 30-foot mounting height. For the under light transverse position the sign is not in the bright spots and the washing out is not present. Also, the observer's line of travel is not so much



SIGN BRIGHTNESS AND DISABILITY VEILING BRIGHTNESS FOR 12.5-, 0- AND -12.5-FOOT TRANSVERSE PLACEMENTS

Figure 19



SIGN BRIGHTNESS AND DISABILITY VEILING BRIGHTNESS FOR VARIOUS LONGITUDINAL PLACEMENTS

Figure 20

with similar parameters. From studying the selected systems and associated parameters the following observations are warranted.

1. Improved lighting uniformity can be achieved by increasing the mounting height of luminaires.

2. Significant increases in sign legibility are realized by increasing the mounting height of 400-watt luminaires from 30 to 40 feet. No significant difference is realized in changing the mounting heights of 1000-watt units from 50 to 60 feet.

3. Careful attention should be given to the placement of reflectorized roadside signs in an illumination system consisting of 400-watt units at 30-foot mounting heights while no particular problem is encountered in 40-foot mounting heights of 400-watt units or in 50- and 60-foot mounting heights of 1000-watt units.

4. The higher mounting height of 400-watt units resulted in a system of lower sign brightness and glare levels but increased legibility distance.

5. Effective contrast analysis did not define one system as being optimum with respect to the other. However, the values of effective contrast were nearly constant at .70 for all positions indicating that a minimum value of effective contrast is necessary for a particular visual task.

Correlation With Previous Findings

The results of the visibility phase of this study provide the following correlation with previous findings of the Texas Transportation Institute:

1. For this study the optimum longitudinal sign positions are from 20 to 60 feet beyond the light source from the driver as compared to a previous finding of 20 to 75 feet. This applies only to 400-watt units mounted at 30-foot height.

2. This study indicated an optimum transverse sign position of 0 feet from the luminaire for 400-watt units while previous research indicated a transverse position of 10 feet behind the light source from the roadway. This difference can be attributed to two possible causes. The design and vertical adjustment of the 400-watt luminaires used in this study were different from those in the previous study. Also the respective displacement of the observer from the sign remained constant in this study while in the previous study the displacement was varied.

REFERENCES

1. Cleveland, D. E., "Overhead Sign-Illumination Relationships," Research Report 5-8, Texas Transportation Institute, August, 1966.

2. Cleveland, D. E and Keese, C. J., "Intersection and Sign Illumination for Highway Safety and Efficiency," Research Report 5-9, Texas Transportation Institute, August, 1966.

3. Davies, O. L., Design and Analysis of Industrial Experiments, Hafner Publishing Company, New York, 1960.