

APPROACH-END TREATMENT OF CHANNELIZATION--
SIGNING AND DELINEATION

An Interim Report on
Project HPS-1-(27)-J

by

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This report results from a cooperative research project of the
Texas Highway Department, the Bureau of Public Roads,
and the Texas Transportation Institute

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SYNOPSIS

This report was developed from a research project conducted by the Texas Transportation Institute in cooperation with the Texas Highway Department. The general objectives of the research project were to evaluate the effects of design, signing, delineation, and illumination of channelization on the factors of safety, efficiency of operation, and capacity. The specific phases of research covered in this report dealt with the signing and delineation of channelization, and with the effect of channelization and approach-end treatment on certain characteristics of driver behavior.

PART I. DELINEATION

A study was conducted to evaluate comparatively the visibility characteristics of four materials commonly used to delineate channelizing island curbs. The materials were:

- (1) Yellow paint reflectorized with glass beads.
- (2) & (3) Highly reflective coating compound (yellow and white).
- (4) Prismatic reflectors.

The prismatic reflectors were visible at distances approximately four times as great as for any other materials tested.

PART II. SIGNING

A study was conducted to evaluate the visibility and legibility characteristics of a number of KEEP RIGHT signs used in the approach-end treatment of channelization. The signs, grouped according to visibility characteristics, are listed by material or type of construction as follows:

- | | |
|------------|--|
| Group I: | [Internally illuminated sign. |
| Group II: | [Prismatic reflector sign. |
| Group III: | [Beads-on-paint type with external illumination. |
| | [Reflective sheeting type with external illumination. |
| Group IV: | [Reflective sheeting legend on black background. |
| | [Reflective sheeting type. |
| Group V: | [Beads-on-paint type with hashmark panel delineator. |
| | [Beads-on-paint type. |

PART III. DRIVER BEHAVIOR

Studies were conducted to determine the effects of channelization and special approach-end treatment of channelization on driver behavior. These studies, conducted at different stages of the development of channelization, showed that the introduction of divisional island type of channelization caused a slight increase in the driver tension responses as measured by the Galvanic Skin Response (GSR) recorder. A further increase in tension response was observed after special approach-end treatment with prismatic reflector-type delineators and reflectorized lane markers.

A comparison of traffic speeds "before" and "after" channelization showed that traffic reduced speed at a greater distance from the intersection and did not resume normal speed until clear of the channelization.

ACKNOWLEDGMENT

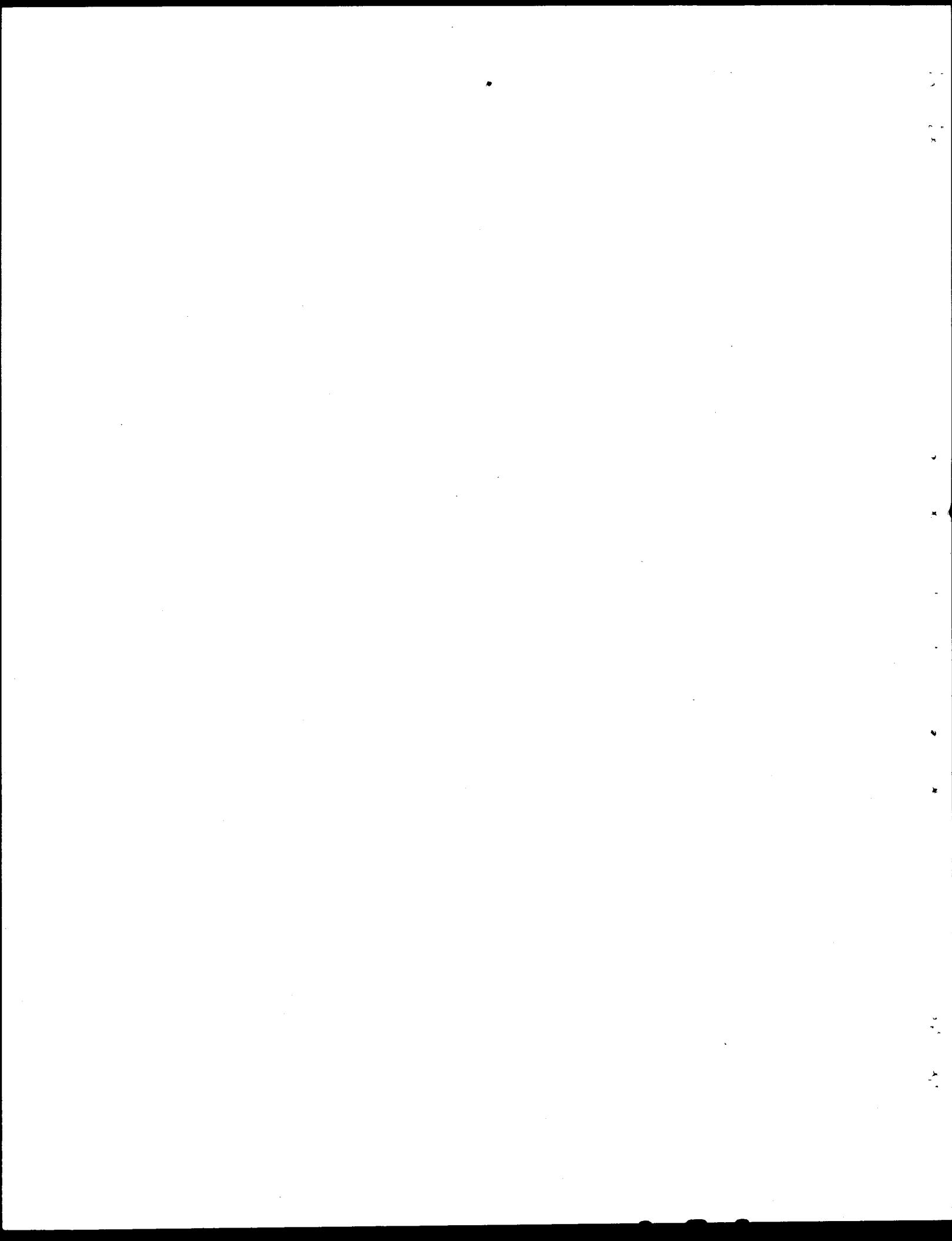
The author wishes to express appreciation to all who helped make this research possible; to the Texas Highway Department for their support during the first two years of the project when this research was conducted; and to the U. S. Bureau of Public Roads for their joint support during the final preparation of the report; and to both agencies for continued joint support of the research.

Special thanks are extended to the members of the Advisory Committee for their advice and assistance, and to Mr. Ronald D. Eubanks, Research Assistant, for his services in conducting the third phase of this research.

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INTRODUCTION



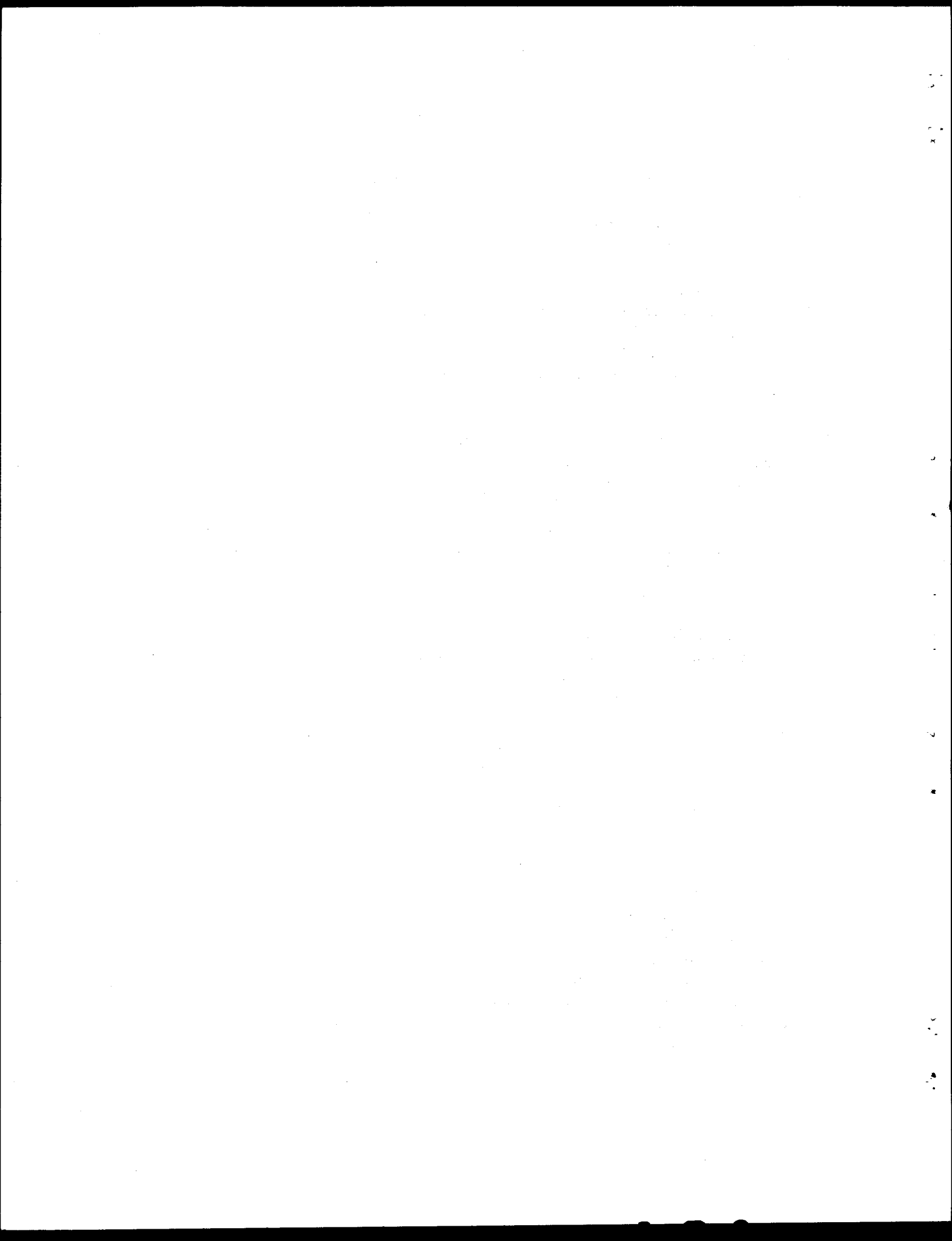
INTRODUCTION

In 1960, the research project, "Channelization" was initiated by the Texas Transportation Institute in cooperation with the Texas Highway Department. Its general objectives involved investigating the effect of design, signing, delineation, and illumination of channelization on the factors of safety, efficiency of operation, and capacity. The specific phases of the research covered in this report dealt with the signing and delineation of channelization, and with the effect of channelization and approach-end treatment on certain characteristics of driver behavior. Because of the discrete nature of the studies, each of the subjects is presented separately in the report.

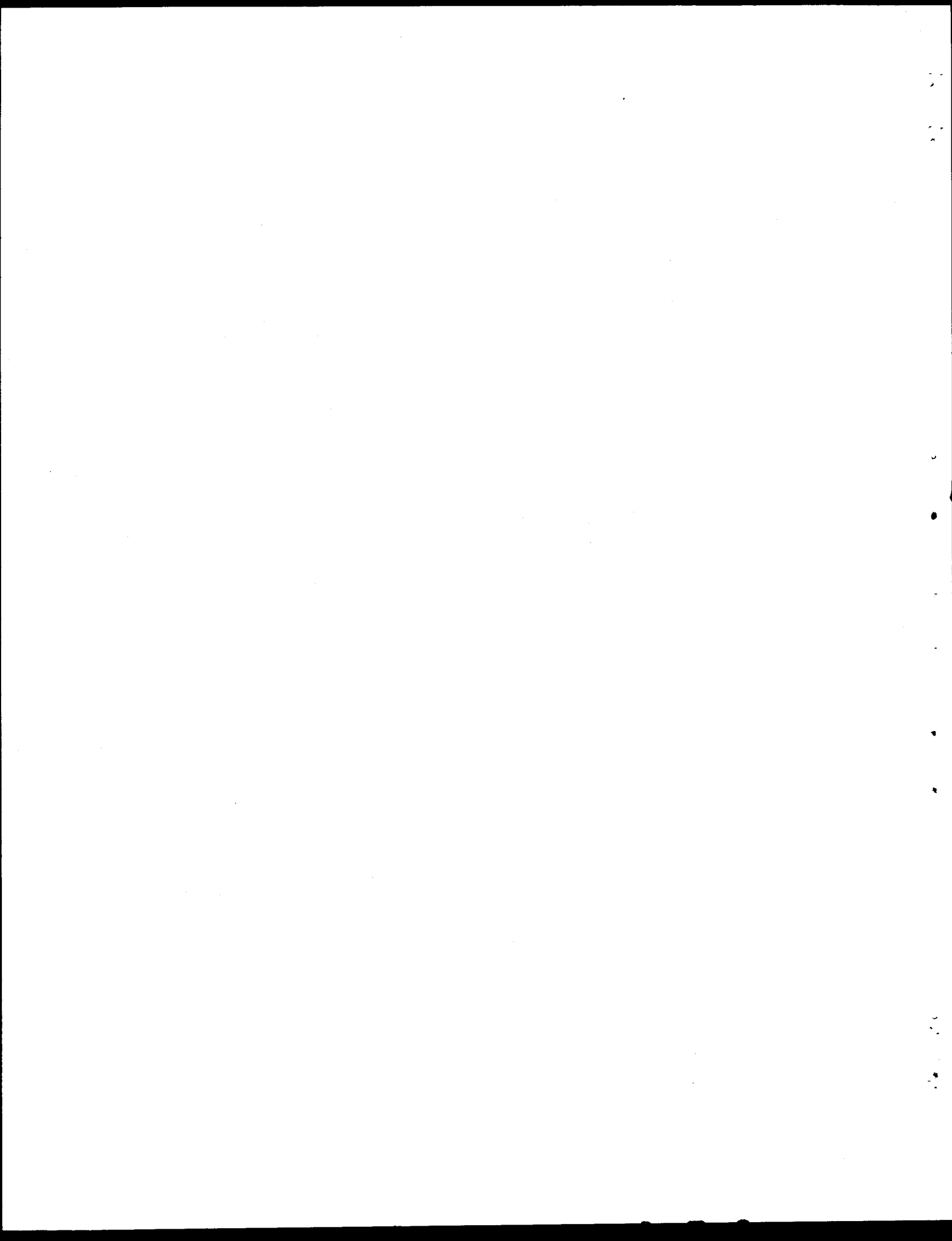
To avoid hazardous situations, careful consideration must be given to the approach-end treatment of channelization in regard to design, signing, and delineation. Signing used to (1) denote the beginning of the island and (2) locate it with respect to the roadway cross-section should have excellent visibility characteristics so as to provide adequate advance warning to the driver. In addition to signing of the approach-end, the island curb should be delineated from the remainder of the roadway to establish a proper perspective of the change in geometric conditions. The delineation should provide continuity over a considerable distance so that the driver will be aware of the overall configuration of the introduced channelization. And finally, the channelizing island and approach-end treatment must be designed geometrically to provide a natural maneuver for traffic to flow around the island.

In the first phase of this research, several materials were tested under controlled conditions to determine their relative effectiveness in delineating island curbs. The superior material, as indicated by the controlled tests, was then installed under actual traffic conditions to provide an evaluation of its practical performance characteristics.

In the second phase, several KEEP RIGHT signs used on channelization were tested to determine their relative visibility and legibility characteristics. In the third phase, studies were made at three stages of the development of channelization and approach-end treatment to determine the effect on driver behavior. In these studies a Galvanic Skin Response Recorder was used to measure driver tension responses, and traffic speeds were measured through several sections of the channelized area.



PART I
DELINEATION STUDIES



DELINEATION STUDIES

In these studies, several currently used delineation materials were tested to determine their comparative effectiveness. Then the most effective of the materials was used in studies of performance under actual traffic conditions.

COMPARISON OF DELINEATION MATERIALS

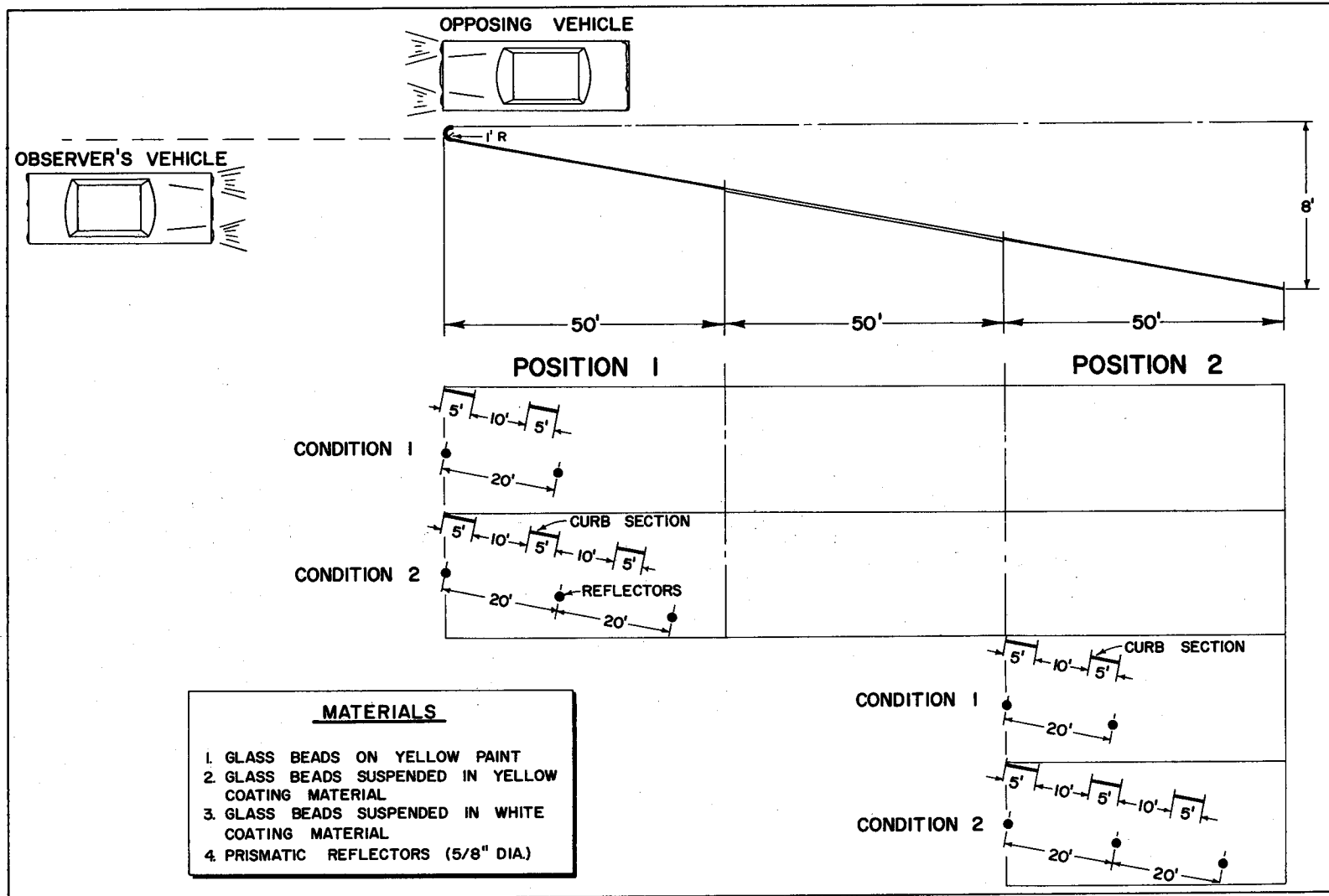
In this phase of the research, studies were conducted to evaluate comparatively the effectiveness of several materials currently used in delineating island curbs. These materials tested were:

- (1) Yellow paint reflectorized with glass beads.
- (2) and (3) Highly reflective coating material with glass beads in suspension (yellow and white).
- (4) Prismatic type reflectors (5/8 inches in diameter) mounted on top of the island curb.

DESCRIPTION OF STUDY

To facilitate a comparison of the materials, simulated conditions of channelization were devised and tested on runways at the A. & M. College Research and Development Annex, which was at one time the Bryan Air Force Base. Through such controlled conditions it was possible to eliminate a number of variables such as grade, alignment, outside light sources, and variable opposing headlights, that would normally be encountered in tests of the materials at actual installations of channelization.

To simulate a channelizing island, curb sections, 5 feet in length, were constructed of wood and shaped to resemble a barrier-type island curb. The curb sections were coated with the various materials to be tested. The prismatic reflectors were mounted in wooden blocks that could easily be aligned with the path of the test vehicle. To form the approach-end of the island, an island nose was shaped from sheet metal and reflectorized, and either the curb sections or the reflectors were placed along a line from the island nose tapered for a lateral transition of 8 feet in 150 feet of length. The details of the island layout and the test conditions are shown in Figure 1.



PLAN OF DELINEATION TEST SITE

FIGURE 1

The materials were tested at two positions along the taper to determine any effects of the relative position of the materials with respect to a vehicle with opposing headlights at the island nose. As indicated in Figure 1, Position 1 consisted of placing the curb sections and the reflectors in the 50-foot section of the taper immediately following the island nose. For Position 2, the curb sections and reflectors were placed in the third 50-foot section of the taper as shown.

To test the effect of length or continuity of the delineation provided by the materials, two test conditions were established. Condition 1 consisted of two curb sections placed ten feet apart, or two reflectors placed 20 feet apart. For the Condition 2, three curb sections or three reflectors were used at the same spacing. These conditions are illustrated in Figure 1.

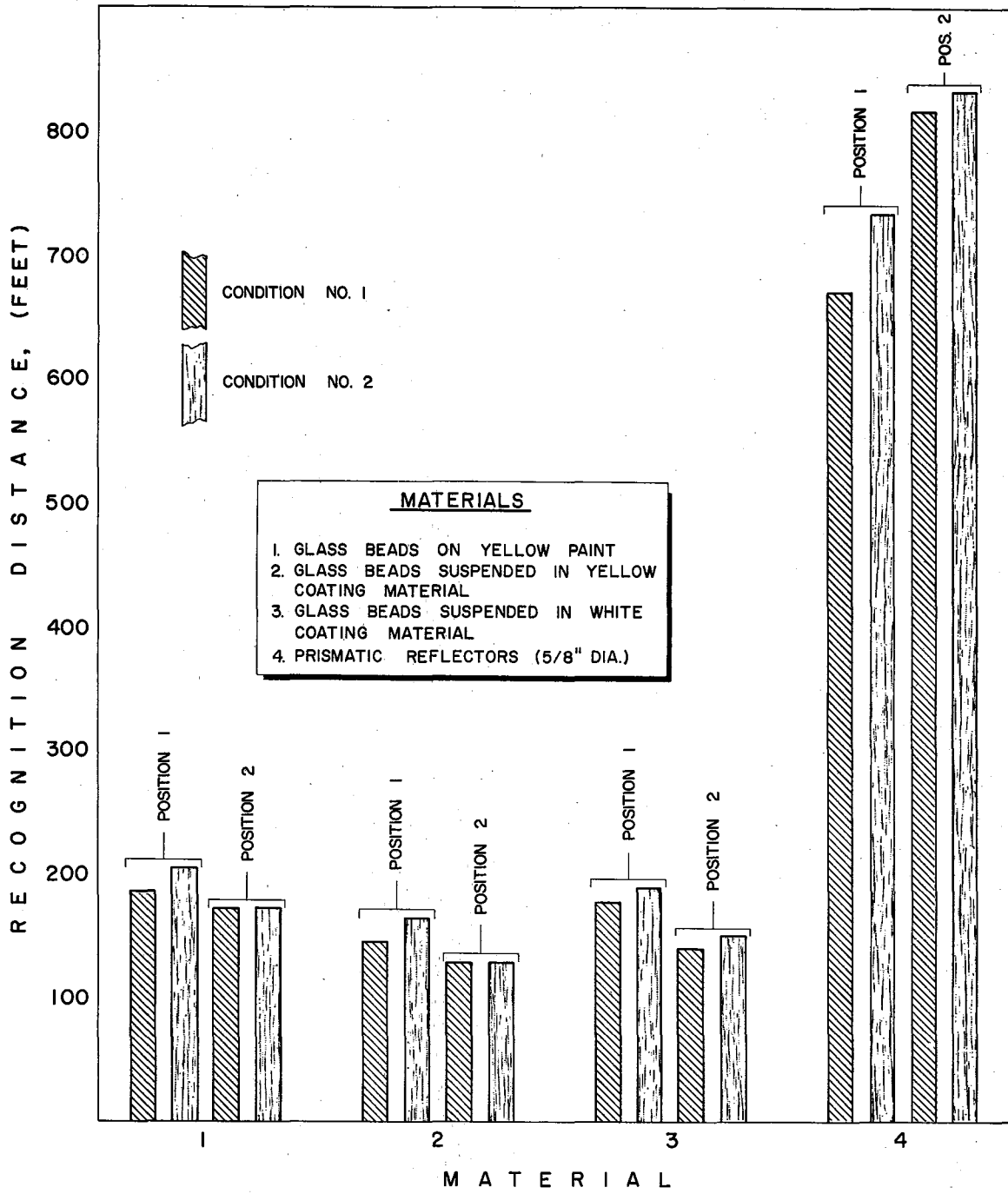
The visibility tests were conducted with an opposing vehicle and the observers' vehicle operating on low-beam headlights. The opposing vehicle was parked at the nose of the island to simulate the most critical condition of the chance meeting of two vehicles under actual conditions. The exact critical position of the opposing vehicle was verified by preliminary testing.

In the tests, four observers drove a pre-determined loop on the runways which included the simulated channelization. Prior to beginning the test, each observer was instructed to indicate the number of curb sections or reflectors he could see as he came into the range of visibility. The distance from the nose of the island at which the observer could distinguish the correct number of curb sections or reflectors was determined (to the nearest 20 feet) as the visibility distance. To avoid any anticipation on the part of the observer, the materials, positions, and conditions were completely randomized.

The experiment was designed to test the four materials under two conditions in each of two positions, making possible a total of 16 combinations. Also, two replications of the experiment were required of each observer to increase the reliability of the results.

FINDINGS

The results of the study shown graphically in Figure 2 indicate that the prismatic reflectors were visible at distances three to four times those of the other materials. These results show further that there was no appreciable difference in the visibility distances of any



**VISIBILITY DISTANCE OF CURB
DELINEATION MATERIAL**

FIGURE 2

of the coating-type materials. Actually, Material 1, beads-on-paint, was visible at a greater distance than the other two coating materials. However, the visibility distances of all three materials were below what could be considered acceptable for good delineation. Table A of the Appendix lists the results in detail to provide a more exacting comparison.

The superiority of the reflectors was attributable primarily to two characteristics:

- (1) The prismatic reflective surfaces in the reflector provide greater reflection efficiency.
- (2) The reflectors were mounted perpendicular to the stream of traffic, whereas, the coating-type materials were placed virtually parallel to the traffic stream.

Preliminary observations indicated that the coating-type materials provided good visibility when the test curb sections were placed perpendicular to the traffic stream. However, the visibility of the curb sections in the perpendicular position was not as great as for the prismatic reflectors. This is substantiated by the results of visibility tests on signs constructed of the same or similar materials reported in a later section of this paper.

Visibility vs. Position

A comparison of the visibility distances of the materials according to their position relative to the island nose and hence relative to the opposing vehicle (Positions 1 and 2, Figure 1) showed that the coating-type materials were less effective in Position 2 than in Position 1 (See Figure 2). On the other hand, the visibility distance of the reflectors was increased approximately 100 feet by moving them to Position 2, 100 feet behind the island nose. This increase in performance was attributed to the fact that moving the reflectors 100 feet along the taper also moved them 5 feet laterally and reduced the effect of the "halations" of the lights of the opposing vehicle. The other three materials showed a slight decrease because their reflective power was not great enough to compensate for the increased distance from the light source. The visibility distances were measured from the island nose, rather than from the actual position of the material.

Visibility vs. Condition

Increasing the number of curb units or reflectors from two to

TABLE 1

COMPARISON OF VISIBILITY DISTANCES OF MATERIALS FOR
 NORMAL WEATHER CONDITIONS VS. INCLEMENT
 WEATHER CONDITIONS

MATERIAL	VISIBILITY DISTANCE, FEET			
	<u>Position 1</u>		<u>Position 2</u>	
	Visibility Range, Feet	Average Visibility Distance, Feet	Visibility Range, Feet	Average Visibility Distance, Feet
Material 1	*100 - 160	*130	*0 - 120	* 60
Beads-on-Paint	140 - 240	195	120 - 220	167
Material 2	* 60 - 80	* 70	* 40 - 80	* 60
Yellow Reflective Coating	120 - 240	155	80 - 180	128
Material 3	* 60 - 80	* 70	* 60 - 80	* 70
White Reflective Coating	140 - 240	184	100 - 220	145
Material 4	*440 - 500	*470	*420 - 760	*590
5/8" Prismatic Reflectors	580 - 920	704	460 -1080	825

*Slow steady drizzle with wipers on.

three such as was the case in Conditions 1 and 2, increased the visibility only slightly in Position 1 and practically none in Position 2. This increased visibility indicated a dissipation of the effect of the "halations" of the opposing headlights when the materials were laterally removed. This also is an indication that continuous delineation offers greater advantages than a concentration of materials at the island nose.

These differences in visibility distances according to position and condition were not statistically significant. However, the differences were considered worthy of mention because of the consistency of the results.

It is logical that the delineation, when tested under controlled conditions, bore greater significance when all outside light sources were eliminated except for the opposing vehicle. This probably resulted in greater recognition distances than could be expected under actual conditions. However, the study was aimed at evaluating comparative visibility more than actual distances at which the materials were visible.

Visibility vs. Inclement Weather

On one particular occasion, a slow drizzle interrupted the normal testing of materials. Rather than cancel the night's work, limited tests were conducted to evaluate the visibility of the materials during inclement weather. The test data were obtained using two drivers in one replication of the study. The results, shown in Table 1 in comparison with normal weather tests, indicate a general reduction in visibility of about 50 percent due to inclement weather conditions. The reflectors were not affected as much as the coating-type materials. It is significant to note that the reflectors provided good visibility even in inclement weather.

PERFORMANCE STUDIES

The results of the tests of delineation materials showed definitely that the prismatic reflectors offered the greatest effectiveness under controlled conditions of testing. In order to evaluate the efficiency of the reflectors under actual traffic conditions, they were installed on several divisional islands in the Houston, Bryan, and Waco districts of the Texas Highway Department. In Houston and Bryan the reflectors were installed on divisional islands on arterials carrying high traffic

volumes through highly developed areas. Also, the locations were illuminated with mercury vapor-type luminaires.

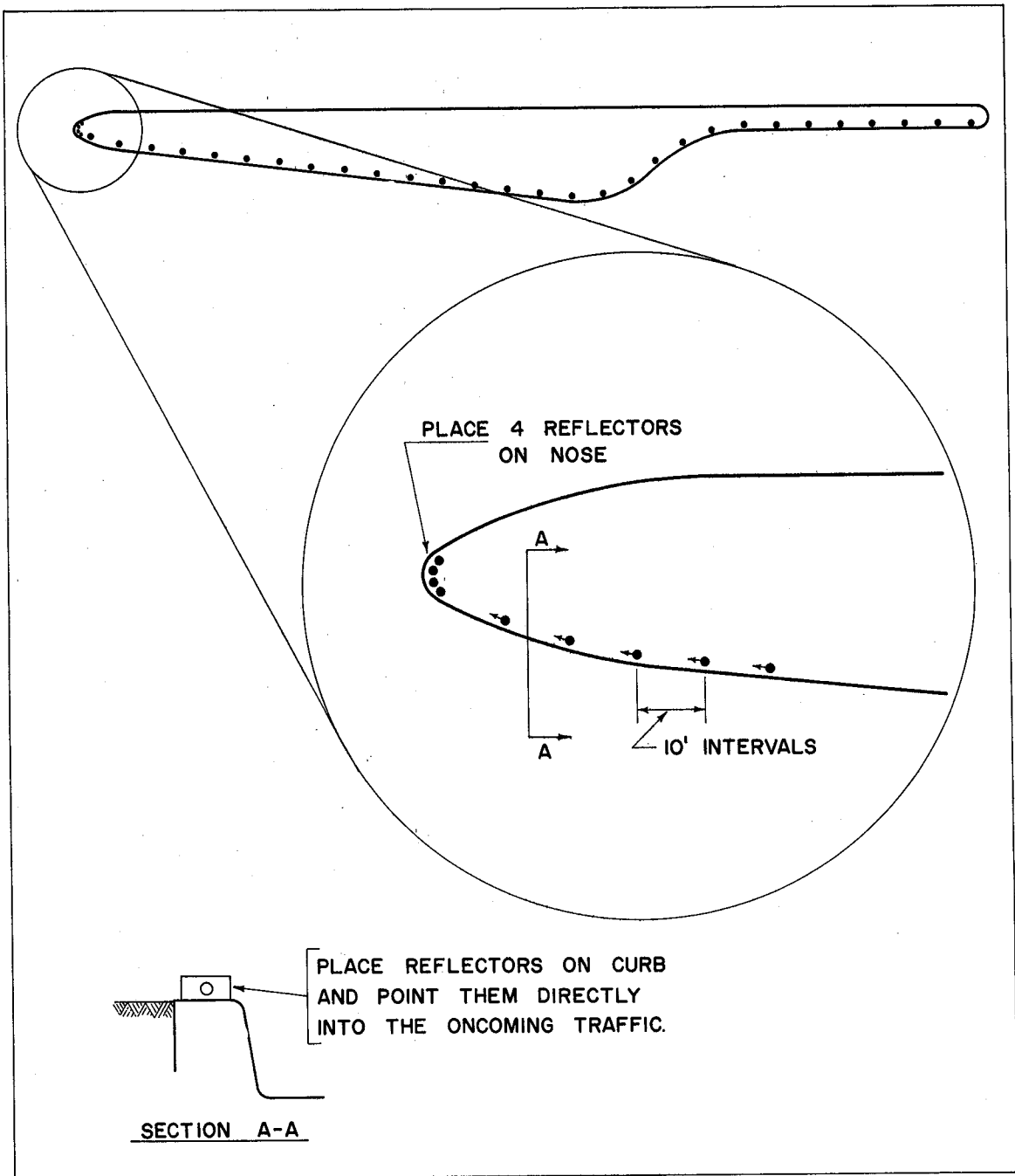
In the Waco district and at another location in the Bryan district, the reflectors were installed on islands in rural areas where traffic volumes were low and outside light sources were negligible. The reflectors were installed in wooden blocks with the face of the reflector mounted flush with the face of the block. These wooden blocks were then mounted on top of the curb at 10-foot intervals as shown in Figure 3. The wooden blocks were not considered as permanent mounting facilities, but merely an economical means of holding the reflectors in place for observation of their performance under actual traffic conditions.

No tests were conducted to evaluate the actual visibility distances of the reflectors under normal service because the variables that could influence their visibility were too great in number for the results of such a study to be of any great significance. However, observations indicated that the reflectors performed satisfactorily when first installed, even in the lighted areas.

The Bryan urban installation is shown in Figure 4. These pictures illustrate the real advantage of the prismatic reflectors. Due to their great range of visibility, the entire divisional island, including the added left-turn lane, is clearly outlined before the driver. As an indication of the range of visibility, the island was approximately 500 feet in length with an opening at 310 feet which can be detected in the photograph. This view is comparable to the driver's view of the island when approaching with high-beam headlights. For low-beam conditions, approximately the same view is seen with slightly less intensity.

The reflectors installed in the rural locations have given satisfactory service with little or no maintenance required. The installation in the Waco district has drawn numerous favorable comments from highway patrolmen, and officials of a nearby military base. Apparently, the delineators have improved the visibility of introduced divisional island channelization at a high speed rural intersection.

The performance studies in the urban areas have pointed up maintenance problems that must be resolved through further experimentation. During inclement weather, the visibility of the reflectors was reduced by road film coating the face of the reflectors. The Houston test installation was most seriously affected by weather conditions. However, it was anticipated that Houston would be the most critical test area, because of a great amount of rainfall combined with the existing soil type and poor drainage due to flat topography.



INSTALLATION LAYOUT FOR PERFORMANCE STUDIES

FIGURE 3

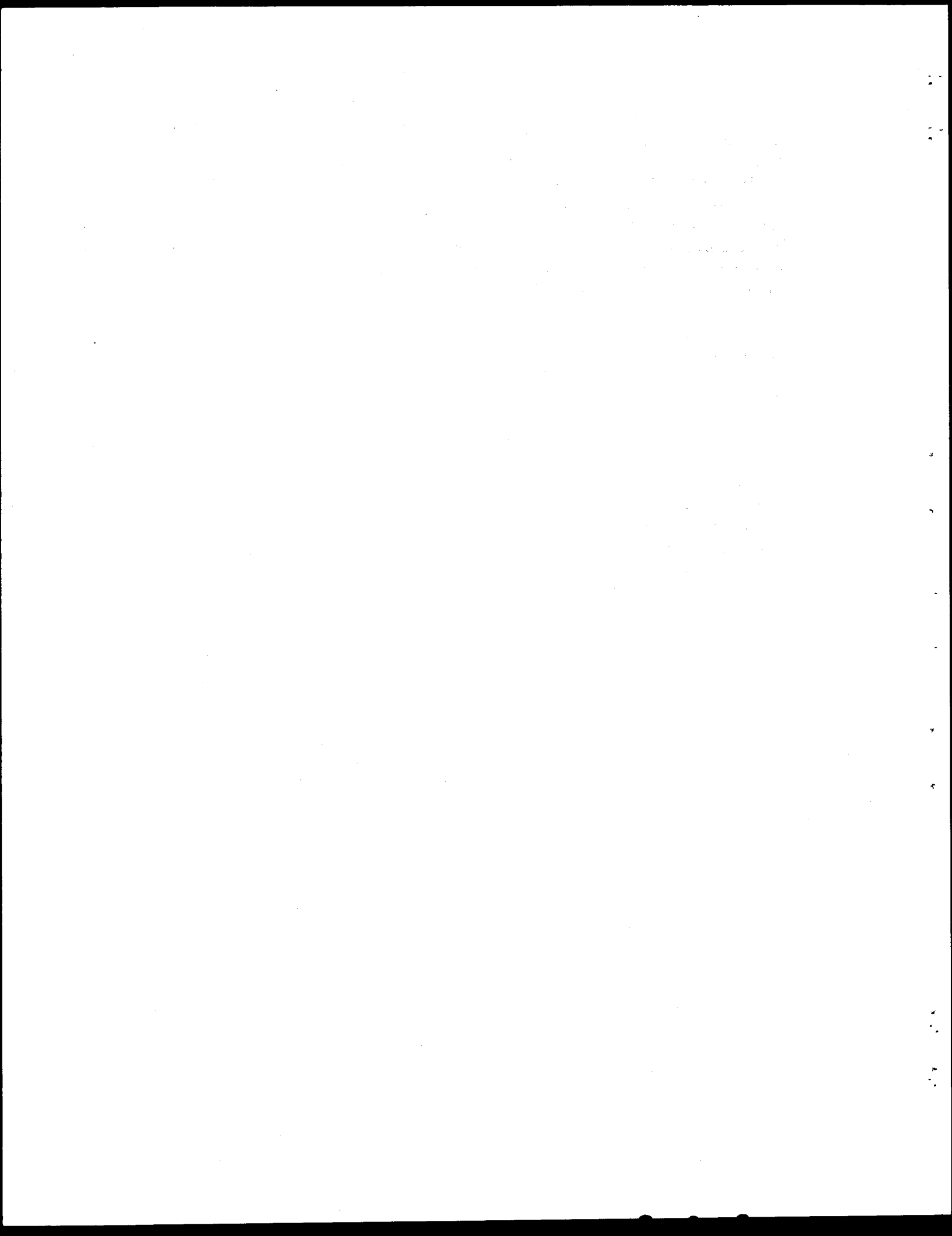


NIGHT VIEW OF DELINEATORS AT THE
BRYAN URBAN INSTALLATION

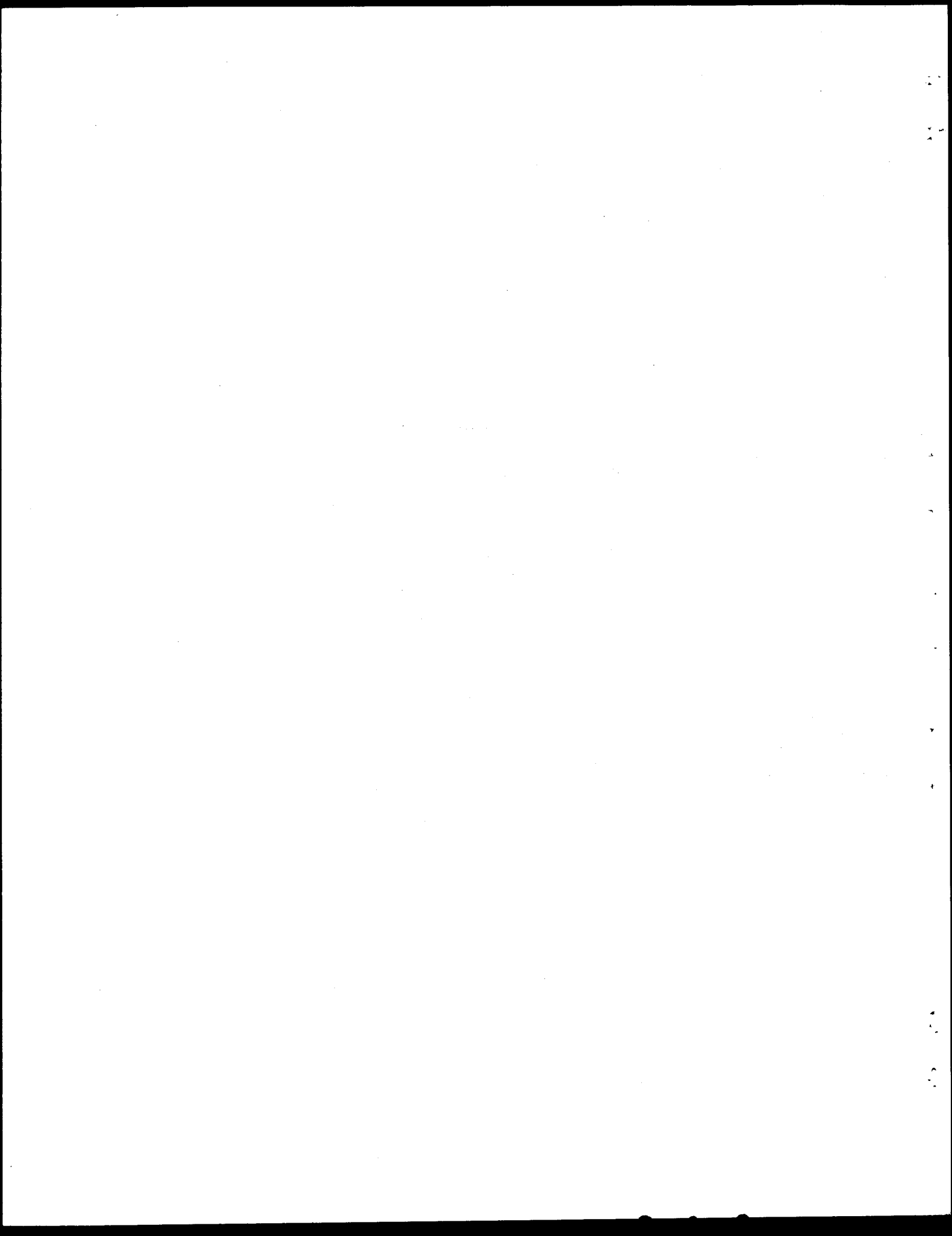
FIGURE 4

The reflectors installed in the Bryan area provided acceptable service for a period of three months (September to December) when there was not a great amount of rainfall. During that time, it was estimated that their reflectivity was reduced approximately 30 percent by road film coating the face of the reflector. Shortly afterward, they were subjected to an extended period of slow drizzle and rain, in which their reflectivity was reduced about 75 percent. However, it was observed that heavy rains removed some of the road film and thus restored an appreciable amount of their reflectivity. The fact remains that the reflectors, mounted as previously described, are in some cases subject to road film and are not effective during inclement weather, when most needed. This pointed out a definite need for the development of a mounting device for the reflectors which will serve as a shield from the "splash" or road film.

The amount of road film and the rate of its deposition on the face of the reflectors are considered to be functions of the amount of dirt and foreign matter on the roadway, the proximity of the traffic stream and the volume of traffic in the lane adjacent to the reflectors. From the performance studies, it appears that perhaps the proximity of the traffic stream may have the greatest effect. However, all of these factors will be considered in further research.



PART II
SIGN VISIBILITY STUDY



SIGN VISIBILITY STUDY

It is common practice to utilize the KEEP RIGHT sign in directing traffic around channelizing islands. Most frequently the sign is used in conjunction with painted and reflectorized curbs to delineate and define the island. However, signs are quite frequently used without additional delineation, especially in rural areas where channelizing islands normally are not curbed. Therefore, there is considerable dependency upon the proper function of the KEEP RIGHT sign, particularly in the case where it is used alone.

First, due consideration should be given to the true function of the sign. Since it is of generally standard form and so widely used, it probably can be considered more as a symbol than a printed message. For this reason, its recognition or knowledgable visibility is more important than its actual legibility.

The KEEP RIGHT sign is of generally standard form, as shown in Figure 5. However, there are several different innovations, dependent primarily upon the different types of materials and construction techniques.

DESCRIPTION OF STUDY

In this phase of the research, studies were conducted to compare the visibility and legibility characteristics of several types of signs and sign arrangements currently being used. The signs selected for study are shown in Figure 5 and described in Table 2. Most of these signs were selected because of their particular appeal in certain areas. The standard Texas Highway Department sign (Number 1) is used extensively throughout the state; however, some districts have recently gone to other types of signs or modifications of the standard type. In some districts, a hash mark panel (Number 5) has been placed immediately below the KEEP RIGHT sign as illustrated in Figure 5. Also, some districts have installed external illumination on the standard type signs. This modification is represented by sign Number 6 in Table 2.

There has been considerable interest in the internally illuminated sign, an innovation which is represented by sign Number 4.

The reflective sheeting type of sign construction is represented by sign Number 2 of the selection. Sign Number 7 is of the same type but was tested with external illumination.

SIGN NUMBER 1



SIGN NUMBER 2



SIGN NUMBER 3



SIGN NUMBER 4



SIGN NUMBER 5



SIGN NUMBER 6 & 7



SIGN NUMBER 8



TEST SIGNS

FIGURE 5

TABLE 2
DESCRIPTION OF SIGNS USED IN VISIBILITY
AND LEGIBILITY TESTS

Sign Number	Type of Sign by Material and Method of Illumination	Size of Sign	Size of Letters
1	Beads-on-Paint. Black letters on white background (Texas Highway Department Standard).	24" x 30"	5"
2	Reflective sheeting. Black letters on white background.	24" x 30"	5"
3	White letters and arrow inset with prismatic reflectors on black background.	24" x 30"	4"
4	Internally illuminated. Black letters on white opaque background (no arrow).	24" x 36"	7"
5	Same as Number 1 except black and white hashmark panel mounted below sign.	24" x 30" Panel 24" x 36"	5"
6	Same as Number 1 except externally illuminated.	24" x 30"	5"
7	Same as Number 2 except externally illuminated.	24" x 30"	5"
8	White reflective sheeting letters and arrow on black background.	24" x 30"	5"

The type of construction represented in sign Number 3, in which the message was composed of letters and arrow formed of prismatic reflectors, has been used favorably on high-type facilities. Also, it has seen some application as a KEEP RIGHT sign.

The final selection, sign Number 8 was selected to provide a materials comparison with sign Number 3. It was constructed using white reflective sheeting in place of the prismatic reflectors for letters and arrow on a black background.

Mounting Height

There are some differences in policy regarding the most effective mounting height for KEEP RIGHT signs. The "Texas Manual on Uniform Traffic Control Devices for Streets and Highways" specifies that KEEP RIGHT signs on channelizing islands should be mounted with the bottom edge not more than 7 feet nor less than 3.5 feet from the pavement surface. The "Manual on Uniform Traffic Control Devices for Streets and Highways" published by the Bureau of Public Roads, specifies that mounting height should be at least 7 feet in business and residence districts or in any case when there may be obstructions to view. It is logical that the greater mounting height will provide better visibility over the tops of vehicles ahead. Also, it is possible that mounting the sign at the maximum height will increase its visibility by removing it from the influence of opposing headlights. On the other hand, the higher mounting height may reduce the reflectivity of the sign. Since there is apparently no record of such a comparison, all signs were tested at mounted heights of 3.5 and 7 feet.

Test Site

Tests were conducted to compare the relative visibility and legibility characteristics of the signs. These tests were conducted on the runways at the A. & M. College Research and Development Annex to provide greater control over the variables influencing sign visibility and, thus, provide a more accurate evaluation. Testing in this remote location served to eliminate a number of variables, particularly the effects of external light sources and effects of variable geometrics and grades.

In designing the study, it was recognized that these idealized

conditions would not yield actual visibility and legibility distances that would apply directly to field applications. However, the selected testing procedure and conditions were expected to yield a relative comparison of the visibility and legibility characteristics of the signs.

Selection of Criteria

In the selection of criteria for measurement of the comparative performance of the signs, careful consideration was given to what is believed to be the two primary functional characteristics of the KEEP RIGHT sign. As mentioned earlier, the sign is universally used to mark the approach-end of channelization islands. Such widespread and repetitive application causes the sign to perform as a symbol rather than as a literal message. In other words, the sign has accomplished its purpose when its general shape and the shape of the arrow are visible to the driver. These characteristics are generally visible before it is possible for the driver to read the message. For this reason, the distance at which the driver could recognize the KEEP RIGHT sign in its general form was selected as the primary criterion for comparison. The distance at which all letters of the signs were legible was selected as a secondary measure of comparison.

Study Procedure

To facilitate the study, four observers were selected to drive a vehicle at uniform speed (15 mph) through the test area and indicate the point at which they could recognize the general form of the sign. The distance was also recorded when the driver was able to read the message.

Before beginning the study, the observers were briefed on their duties in the test. Also, trial runs of the tests were conducted to familiarize the observers with the signs being used. This was considered necessary to reduce the learning effect inherent in repeated tests involving the human mind. Also, the test runs were considered justifiable because drivers on the roadway frequently encounter the sign and thus, have gained familiarity in its use and purpose.

The test was designed to obtain two observations of each sign by each observer at both mounting heights, comprising a total of thirty-two observations for each driver. Because of the time consuming nature of the study, the two replications were conducted on separate nights to avoid undue fatigue.

In the test, the signs were drawn randomly within each mounting height to reduce any influences on the data resulting from anticipation by the observer. In other words, the signs were all randomly tested at the 3.5-foot mounting height. Then the sign mounting brackets were raised to the 7-foot height, and once again the signs were randomly tested. Testing heights were not randomized because of the difficulty involved in changing the mounting height, particularly in the case of the internally illuminated sign which was permanently attached to the sign support (Figure 5).

An effort was made to simulate the most critical visibility conditions that could normally be expected to occur at any sign installation, with exception to weather conditions. To simulate a realistic situation, the observers' vehicle was operated on low-beam lights and an opposing vehicle, also with low-beam lights was located adjacent to the sign. Preliminary observations were made to ascertain the most critical position of the opposing vehicle to be immediately adjacent to the sign. Apparently the greatest influence of the opposing vehicle is derived from the "halation" of the glare that surrounds the light. In these same observations, there was no indication that small changes in the angle of the opposing vehicle (0 to 15 degrees) had any appreciable effect on the visibility of the sign.

The external lighting used on sign Numbers 6 and 7 consisted of two 15-watt fluorescent tubes mounted in a white reflector. The reflector was mounted 18 inches from the sign and parallel with the top of the sign as shown in Figure 5. The intensity and distribution of light on the surface of the sign was as shown in Figure 6.

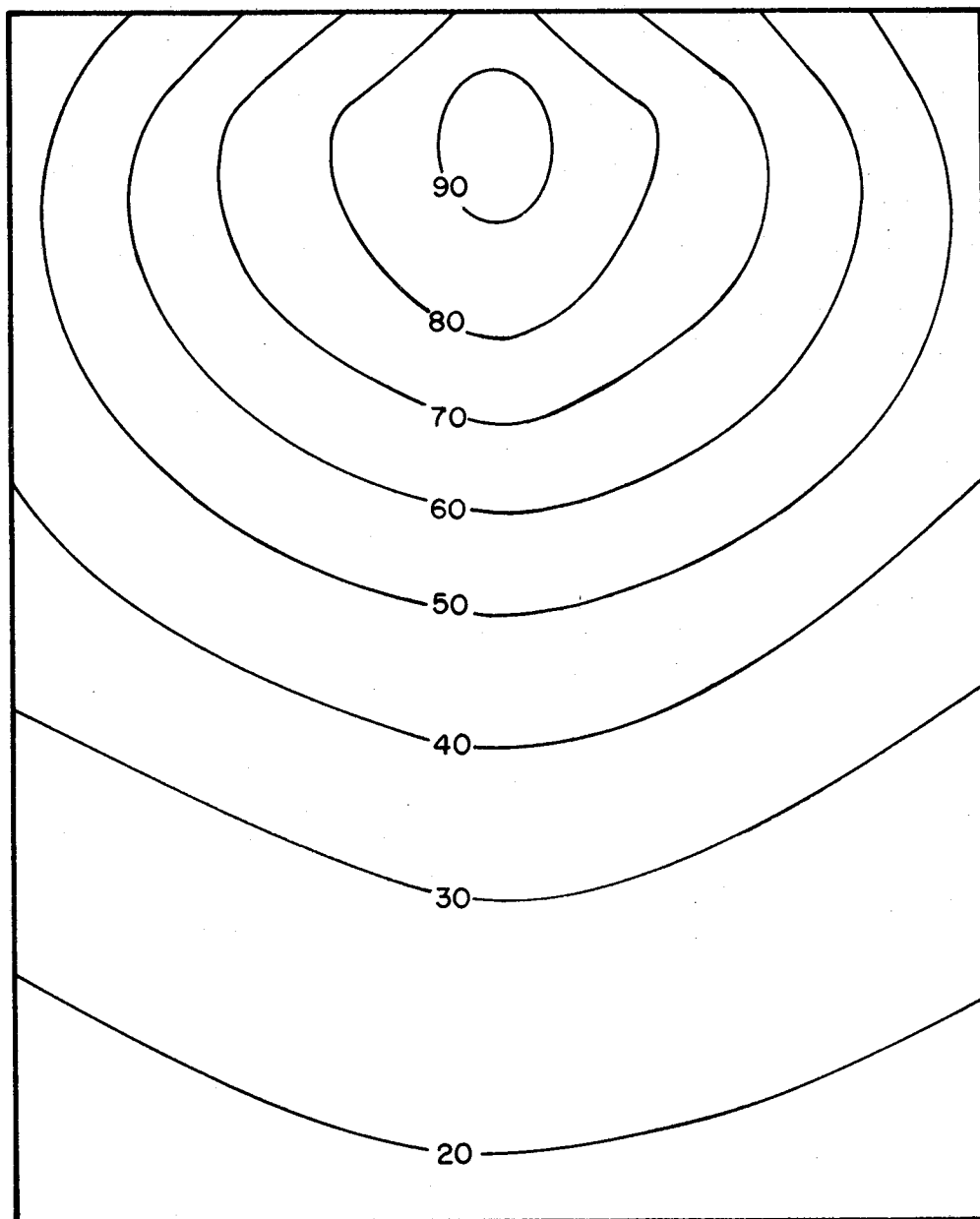
ANALYSIS OF DATA

The data collected in the study of visibility and legibility distances were treated by fixed-effects model of analysis of variance to evaluate any significant differences in the various signs tested. A multiple range test was applied to the average visibility and legibility distances to rank them according to their order of superiority and establish statistical reliability of any differences in the average values.

DISCUSSION OF RESULTS

Visibility Comparisons

The results of the visibility tests on the signs are shown in Figure 7.



LIGHT INTENSITY PATTERN FOR EXTERNALLY
ILLUMINATED SIGN
(SIGN NO. 6, FIGURE 5)
(MEASUREMENTS IN FOOT CANDLES)

FIGURE 6

This comparison shows the average visibility distance for each of the signs and the results of the multiple range test in arranging the various signs in groups of significantly different visibility distances. According to this comparison, the internally illuminated sign (Number 4) was superior to all others tested. In the order of relative performance, the second group included the prismatic reflector sign (Number 3) and the Texas Highway Department standard beads-on-paint sign with external illumination (Number 6).

The third group included both externally illuminated signs (Numbers 6 and 7) and the special white reflective sheeting legend on black background (number 8). The fourth group consisted of the standard reflective sheeting sign (Number 2) and the special sign with reflective sheeting legend. The lowest group in order of performance consisted of the Texas Highway Department standard beads-on-paint type (Number 1) and the same sign with the hash mark panel mounted below (Number 5).

The results of this test are not completely clear cut, because, as noted, there were overlaps in the ranges at sign Numbers 6 and 8. Actually, these signs can be considered in both of the groups but the groups cannot be combined.

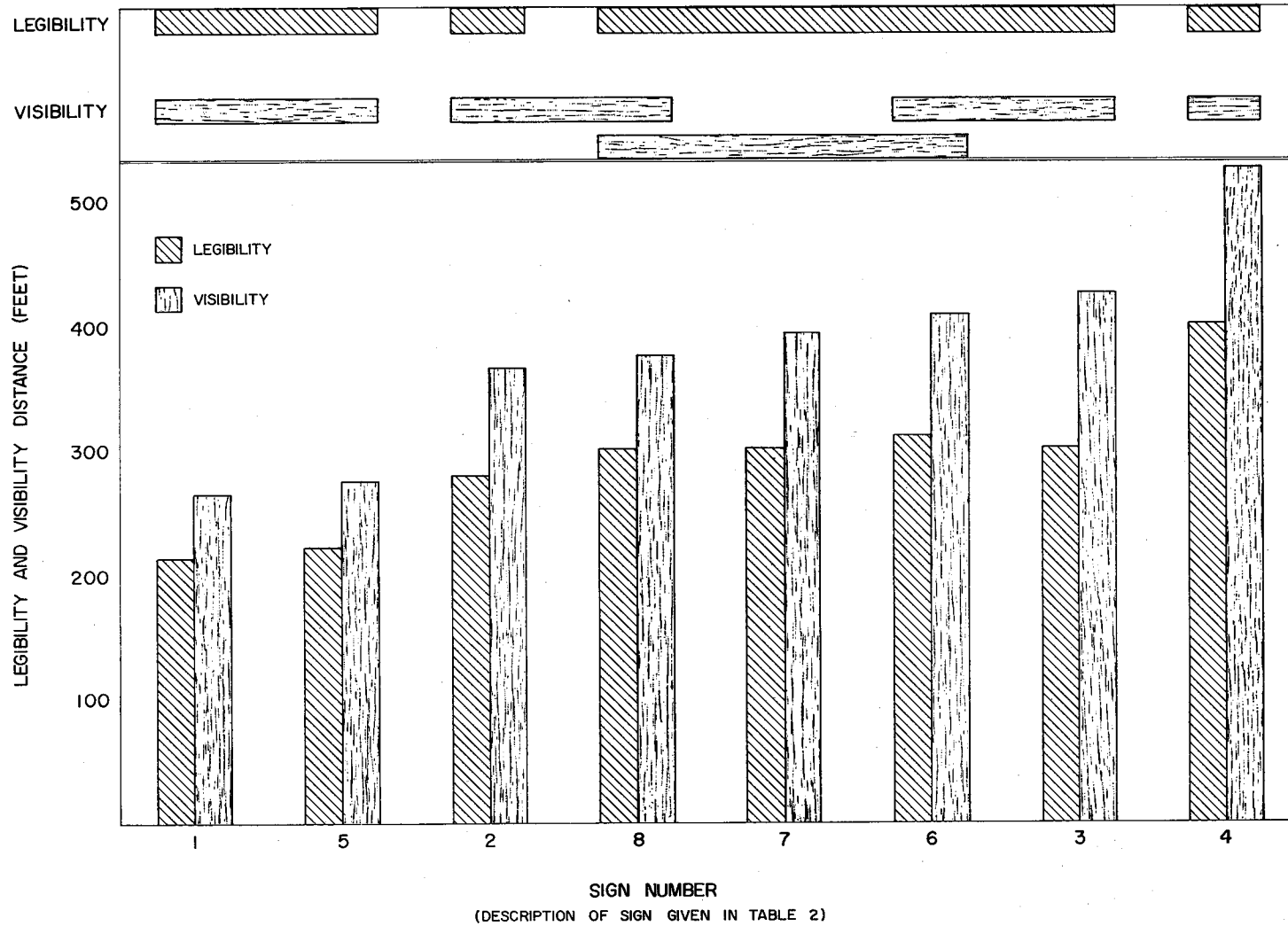
Legibility Comparison

Average values of the relative legibility distances of the signs are also shown in Figure 7. The results of the range test on the legibility distances were not greatly different from the results of the visibility tests, except that the groups were a little more clearly defined. The internally illuminated sign maintained its superiority. In this comparison the two externally illuminated signs (Numbers 6 and 7), the prismatic reflector sign (Number 3) and the special sign with reflective sheeting legend (Number 8) formed the second group. The standard reflective sheeting sign was alone in the third group, while the Texas Highway Department standard (Number 1), and the hashmark panel variation (Number 5) again comprised the lowest group.

Mounting Heights

The analysis showed no differences in either the visibility or legibility of the signs at the 3.5 - and 7-foot mounting heights under the conditions established in the study. Apparently, any advantages of either height cannot be measured in terms of night visibility or legibility.

MULTIPLE RANGE TEST (99% CONFIDENCE LEVEL)



LEGIBILITY AND VISIBILITY DISTANCE OF SIGNS TESTED

FIGURE 7

Reliability of Results

As anticipated, the analysis of data for visibility and legibility revealed a great amount of variation in drivers and replications as well as the previously described differences in signs. As indicated by the analysis summary in Tables B and C of the Appendix, the greatest variation was observed among the drivers. This variation can be explained by the normal differences in visual ability of individuals, and should not detract from the results because there was consistency among the relative visibility distances of each of the drivers for each of the signs. This consistency is illustrated in Figure 8. It should be noted that in only two instances (Driver Number 1 on sign Number 1 and Driver Number 3 on sign Number 6) did the general pattern change.

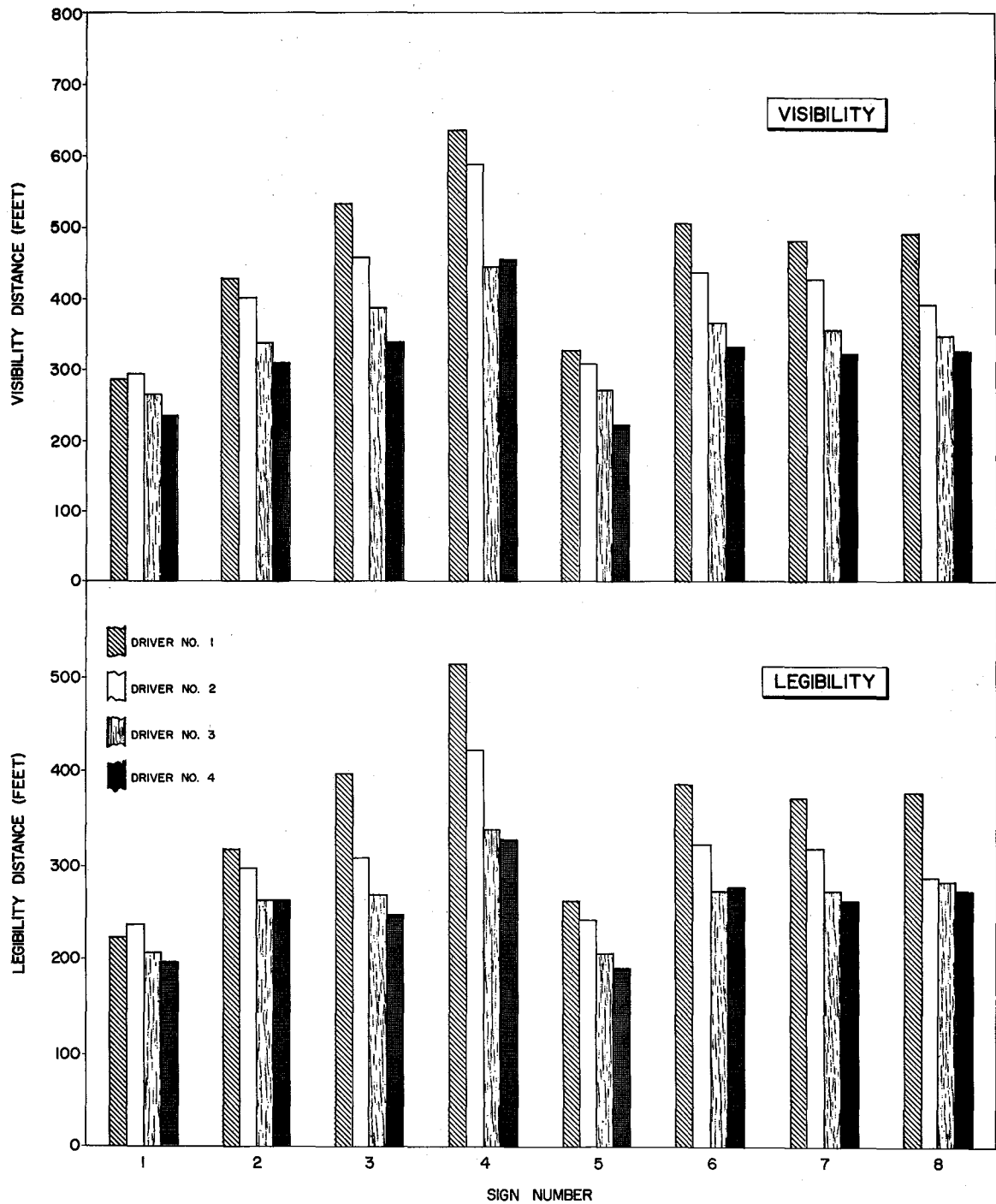
The analysis of variance indicated significant differences in legibility and visibility distances for each of the two replications. A comparison of the mean distances for each of the replications indicated a decrease between Replications 1 and 2, as shown in Table 3. The real causes of these differences are not readily evident. Aside from possible variations due to changes in climatic conditions and in the physical and mental conditions of the drivers, it is theorized that the drivers were more accustomed to the test conditions during the second replication, and therefore, exerted a lesser amount of effort in making the observations. At any rate, the differences in replications are quite small when viewed in light of differences in drivers and signs (see Tables B and C, Appendix).

Because the Analysis of Variance is based on the assumption that the data are normally distributed, tests were conducted to verify normality. The results of these tests were satisfactory.

Evaluation of Results

According to the results of this study, the internally illuminated sign provided greater visibility and legibility distances than any other sign tested. However, this indication of superiority must be considered in light of certain circumstances or conditions of the study. As previously pointed out, the only internally illuminated sign available for testing purposes was a 24" by 36" sign with a legend composed of 7-inch letters, which naturally afforded a greater legibility distance than the signs with 5-inch letters.

The second group of signs which included the prismatic reflector sign, the special reflective sheeting sign, and the externally illuminated word-signs.

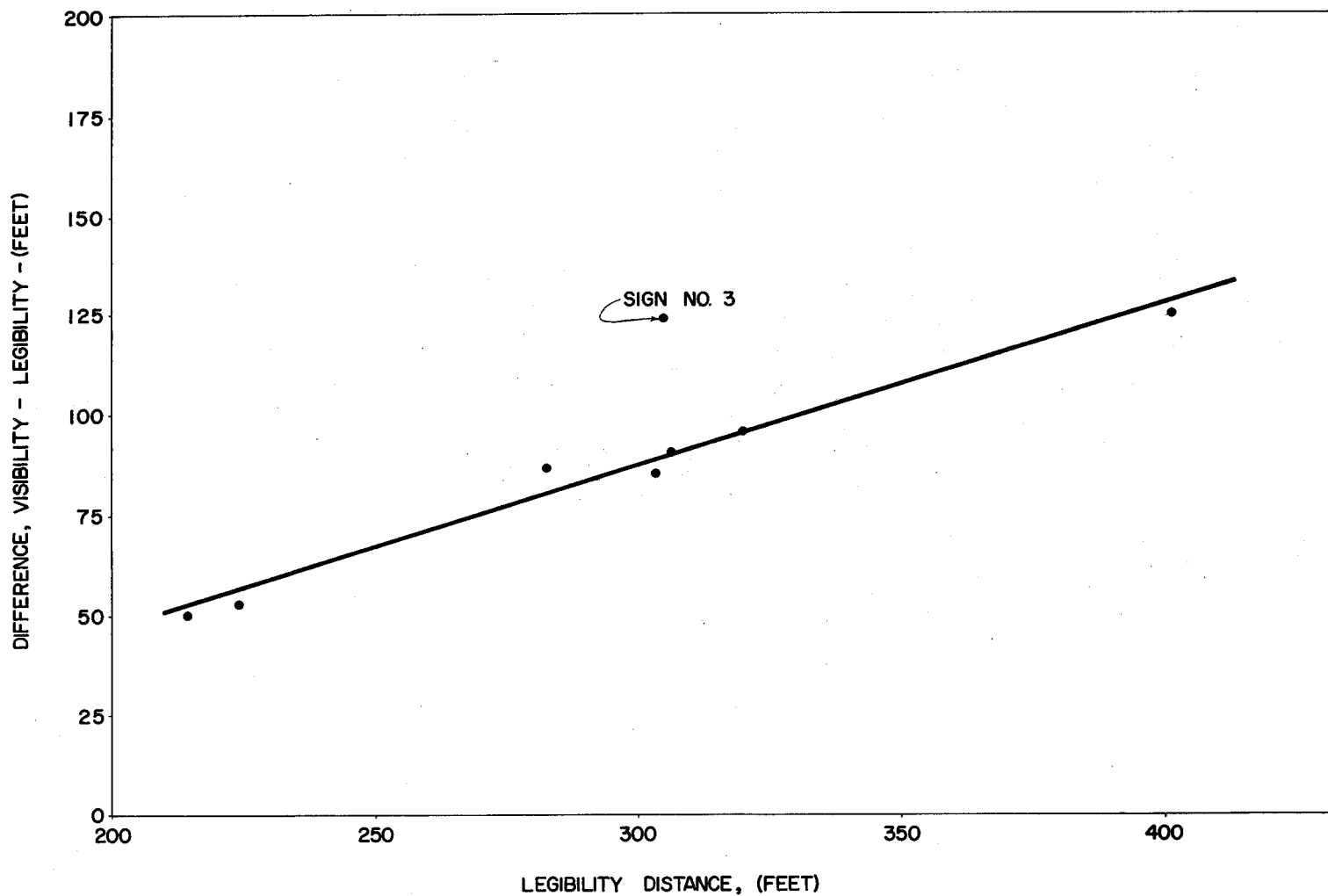


COMPARISON OF LEGIBILITY AND VISIBILITY DISTANCE OF EACH DRIVER FOR EACH OF THE SIGNS

FIGURE 8

TABLE 3
SIGN VISIBILITY TESTS
MEAN VISIBILITY DISTANCES

DRIVER	SIGN NUMBER								AVERAGE
	1	2	3	4	5	6	7	8	
1	280	425	530	635	325	505	480	490	459
2	290	400	455	585	305	435	425	390	411
3	260	345	385	440	270	365	355	345	346
4	230	305	335	450	220	330	320	325	314
AVERAGE	265	369	426	528	280	409	395	388	382
REPLICATION									
1	265	380	430	558	288	408	398	398	
2	265	358	422	498	272	410	392	378	



RELATIONSHIP BETWEEN VISIBILITY AND LEGIBILITY
DISTANCES OF THE SIGNS

FIGURE 9

provided good legibility and visibility characteristics. Of this group, the prismatic reflector sign is considered worthy of individual consideration on a practical level because of its relatively high performance characteristics and comparatively low cost of installation. The high performance characteristic takes on even greater importance when it is recalled that the legend on the sign was composed of 4-inch letters. The outstanding visibility characteristic of the sign is further demonstrated in Figure 9 which shows a linear visibility-legibility relationship for all other signs tested. However, the visibility of the prismatic reflector sign is proportionately greater than its legibility. This characteristic is attributable to the good visibility of the large arrow displayed on the sign.

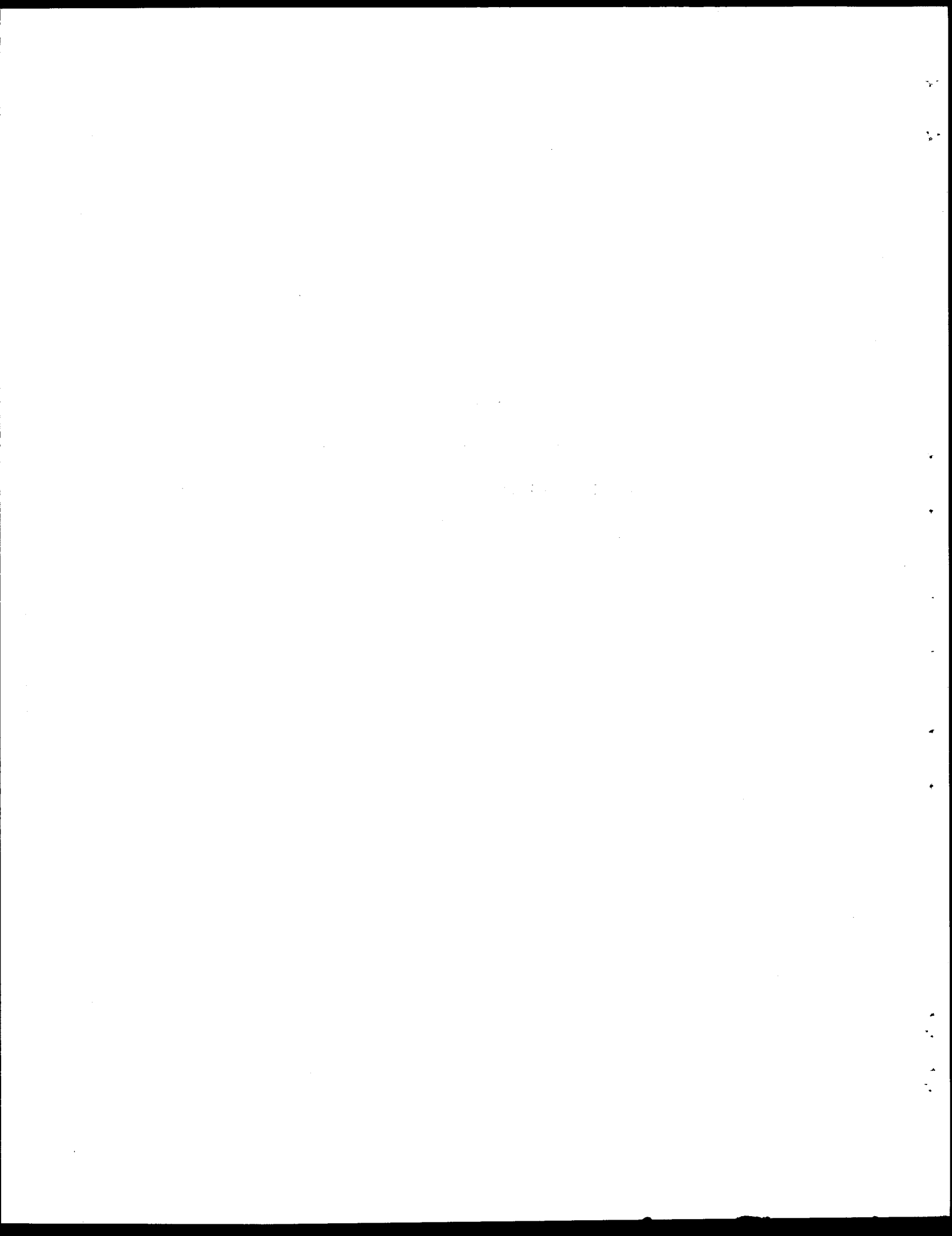
The visibility and legibility distances are apparently of great value in evaluating performance characteristics of signs. However, there are a number of other factors to be considered in making a practical selection of a type of sign for marking channelization. The first and primary consideration should be continuity of service. All of the illuminated signs, especially the internally illuminated sign, are dependent upon electrical power, and consequently, are subject to power failures and bulb or tube malfunctions. As an illustration of this effect, preliminary observations of the signs showed that the visibility distance of the internally illuminated sign was less than 100 feet when power was discontinued. This would indicate no serviceability in the event of power failure.

A second and important consideration in the selection of a sign is the contrast of the sign with other physical characteristics of the area in which it is to be installed. In urban or developed areas, there are numerous illuminated advertisement signs and street lights which reduce the target value of any sign. The internally illuminated sign could be greatly affected because it is quite similar to these foreign light sources.

A final consideration, but by no means least, is the comparative cost of installation, operation and maintenance of signs. In the selection of the proper sign for any particular installation, consideration should be given to the conditions surrounding the site, and to the resulting requirements for visibility and legibility. Consideration must also be given to the cost of installation, maintenance and replacement.

PART III

A STUDY OF THE EFFECT OF
CHANNELIZATION ON DRIVER BEHAVIOR



A STUDY OF THE EFFECT OF CHANNELIZATION ON DRIVER BEHAVIOR

DESCRIPTION OF STUDY

The primary reason for introducing channelization into a roadway is to segregate traffic into more orderly movement. If this is accomplished, then the capacity and the safety of the facility is increased. On the other hand, the introduction of channelization almost invariably places a physical barrier in the path of the traffic stream. Therefore, considerable dependence is placed on signing and delineation to alert the driver to the physical barrier and guide him comfortably and safely around the island.

In this third phase of the research on channelization, studies were conducted to determine the effect of introducing channelization with normal signing and delineation on driver behavior -- more specifically, his tension or emotion level and speed of operation. Additional studies were conducted to evaluate the effect of special techniques of approach-end treatment on driver behavior.

To facilitate the studies, a highway intersection which was scheduled for channelization was selected, and studies of traffic operation and driver behavior were conducted after each of three stages of installation of channelization was complete. The stages of development were:

1. No Channelization -- The section of roadway to be channelized was 28 feet wide. Eight-foot paved shoulders were provided.
2. Divisional Island Channelization -- A divisional island was installed to provide a protected left-turn lane as shown in Figure 10. The approach-end was tapered 8 feet in 150 feet and the island was 12 feet at the widest point. The approach-end treatment consisted of a standard KEEP RIGHT sign mounted near the nose of the island and barrier-type curbs coated with yellow paint and reflectorized with glass beads.
3. Divisional Island Channelization With Special Approach-end Treatment -- The geometrics of the island remained unchanged. The special approach-end treatment was based on the results of previous research on delineation, and other channelizing techniques.

- (a) A delineation line conforming to a one-degree curve was installed beginning approximately 400 feet in advance of the island nose and continuing to the widest point of the channelizing island (Figure 10). This line consisted of button-type lane markers 4 inches in diameter spaced at three-foot intervals. Two types of markers were used alternately. White reflectorized markers were used to provide night-time visibility and yellow non-reflectorized markers to provide daytime visibility. The purpose of this delineation line was to provide advance warning of the channelization island ahead and outline a smooth transition path around the island.
- (b) To supplement the visibility characteristics of the delineation line, a rumble strip was installed to provide an audible warning to the driver encroaching upon the area between the delineation line and the actual channelizing island. The rumble strip consisted of a surface treatment using 5/8 inch light-colored aggregate.
- (c) Prismatic reflectors, 7/8 inches in diameter, were installed on the island curb to delineate the physical barrier. The reflectors were spaced at 25-foot intervals and aimed in the direction of the oncoming traffic.

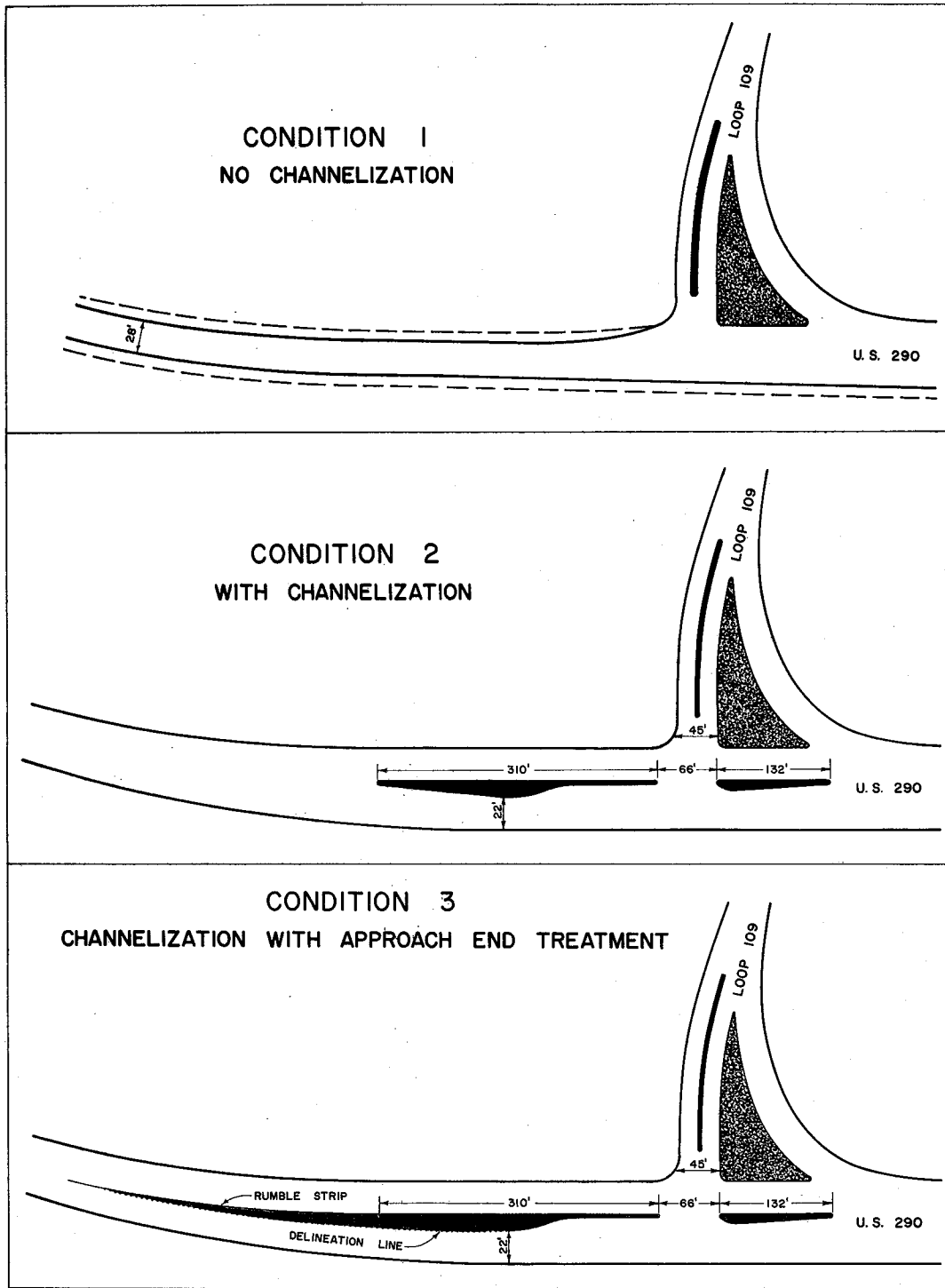
Study Methods

Two study techniques were used to obtain data on driver behavior and traffic operation. The study techniques were:

- (1) Test Car Method -- Measurement of driver tension responses and speeds of selected drivers operating a test car in a series of trips through the study area.
- (2) Individual Vehicle Speed Study Method -- Measurement of speeds of individual vehicles through several sections of roadway, including the channelized section.

Study Procedures

Test Car Method -- The test car was equipped with a Galvanic Skin Response (GSR) Dermograph to measure and record driver tension responses as the drivers traveled through the study area. Also, the



PLAN VIEW OF STUDY SITE SHOWING THREE STAGES OF CHANNELIZATION

FIGURE 10

test car was equipped with a recording speedometer to provide a continuous record of vehicle speed.

Four drivers were selected to drive the test car through the study section four times each as a "through" vehicle and four times each as a "left-turning" vehicle. These drivers, all male college students, were young, experienced drivers. None of the drivers was especially familiar with the study section, and they were not aware of the geometric conditions that existed at the study site before the tests were begun for each condition.

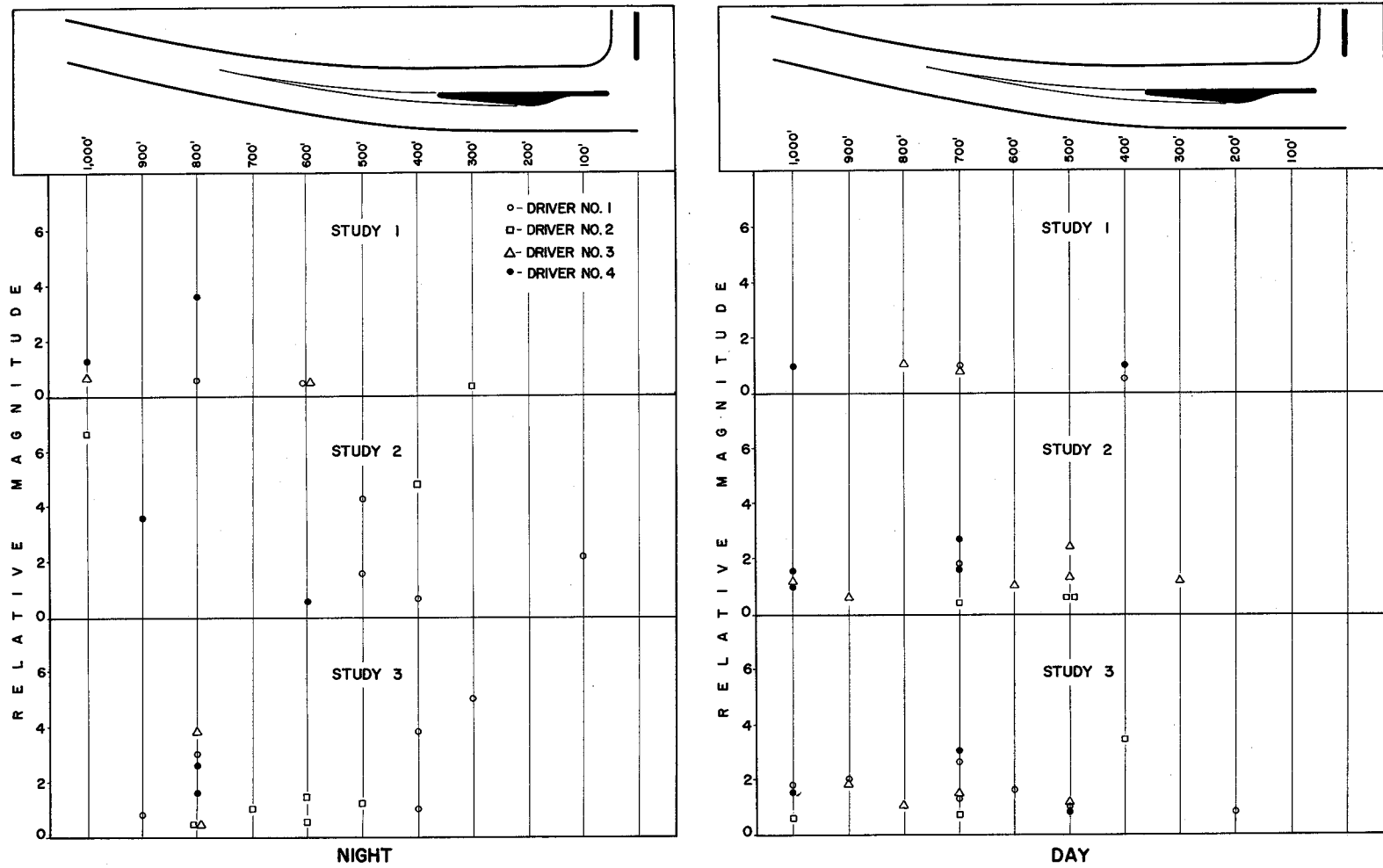
Individual Vehicle Speed Study Method² -- In addition to the controlled studies utilizing the test car method, studies were conducted to evaluate any differences in the speed characteristics of the vehicles in the normal traffic stream before and after the installation of channelization. To facilitate the measurement of speeds of the individual vehicles of the normal traffic stream, the study section was divided into four separate control sections, or sectors as shown in Figure 12. An event recorder actuated by road tubes was used to measure the time required for each vehicle to drive the length of each of the designated sectors. Then the average speeds for each sector were calculated from the time intervals.

DISCUSSION OF RESULTS

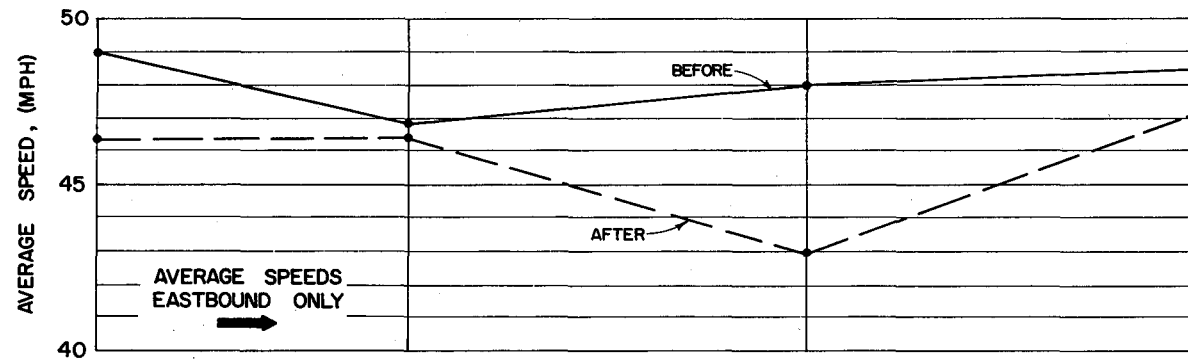
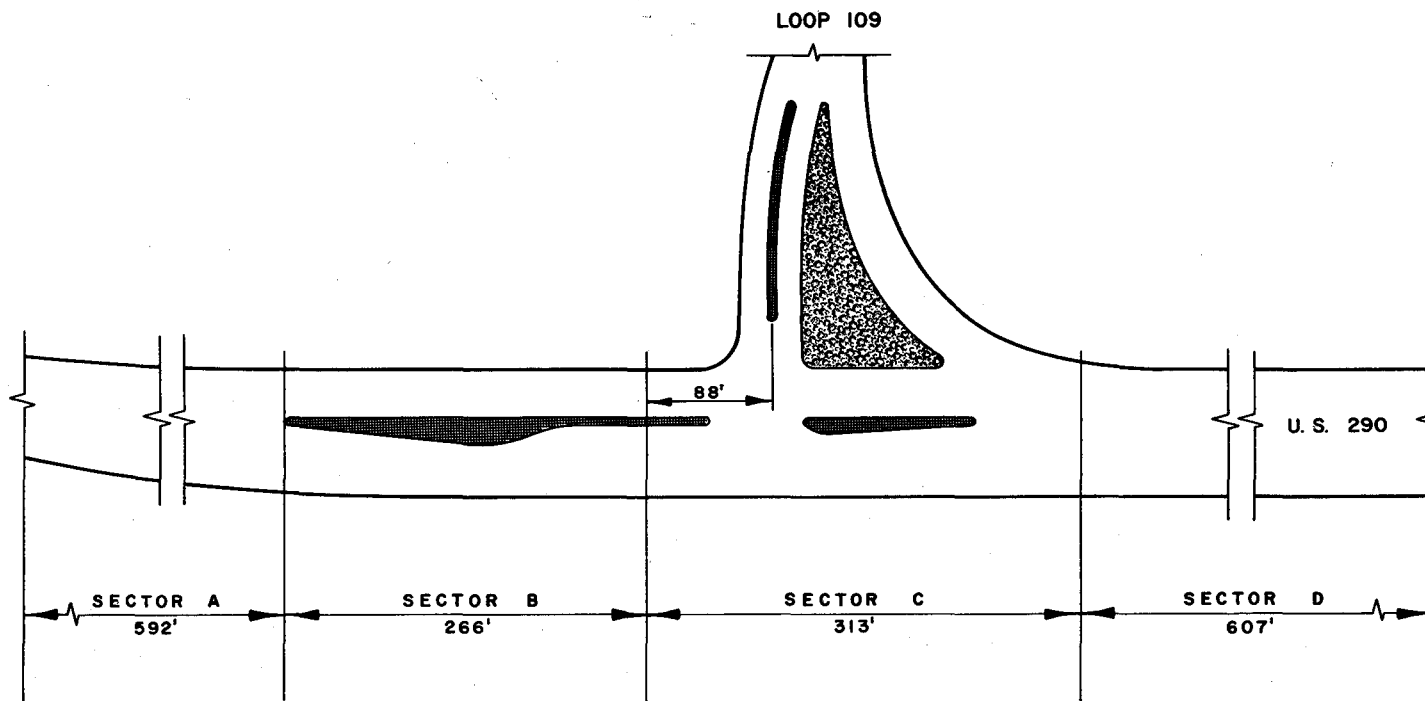
GSR Study

In an effort to evaluate differences in driver behavior for each of the three conditions of channelization, the GSR responses occurring in the section extending from the center of the intersection to a point 1000 feet in advance of the intersection were selected for a comparative analysis. The GSR responses of all drivers were examined on the basis of total frequency of responses and total magnitude of responses to determine any differences in driver behavior for each of the three conditions.

The results of the GSR studies shown in Figure 11 indicate a relatively small number of tension responses in all of the studies for both day and night. It was noted that the number of responses per study ranged from 6 for Study 1 (no channelization-day) up to 17 for Study 3 (channelization with special approach-end treatment). These responses were observed during four runs made by each of four drivers, or a total of 16 runs for each study. Also, two drivers were more responsive than the other two, contributing approximately 65 per cent of the responses. In view



GSR TENSION RESPONSES-THROUGH VEHICLE RUNS



INDIVIDUAL VEHICLE SPEED STUDY

FIGURE 12

of the relatively small number of responses the existent variability in drivers, it was felt that a comparison of the responses should not be interpreted as definite conclusions, but only as general indicators of driver behavior.

Referring to the results in Figure 11, it can be observed that a greater number of responses were recorded in Study 3 for both day and night runs. These responses were distributed along the general area of the delineation line but showed a greater concentration at a point 800 feet from the intersection. This point corresponded to the beginning of the delineation line. These patterns and the increased number of responses indicate that the special approach-end treatment did serve to forewarn the driver of the introduced channelization and the intersection ahead.

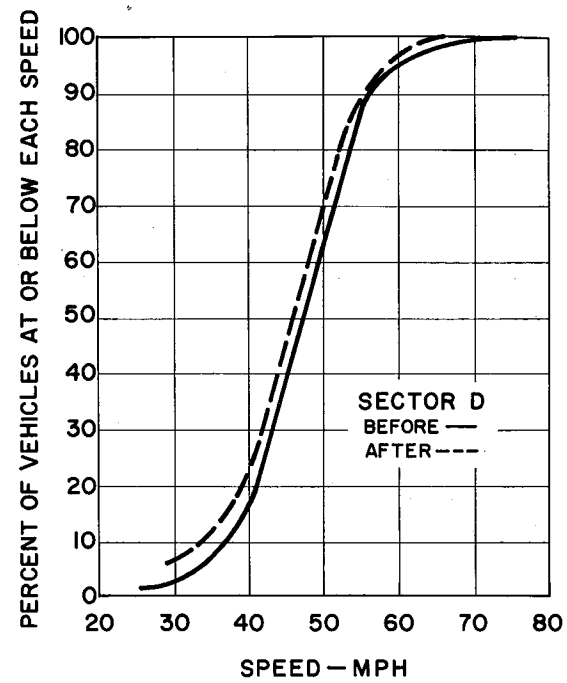
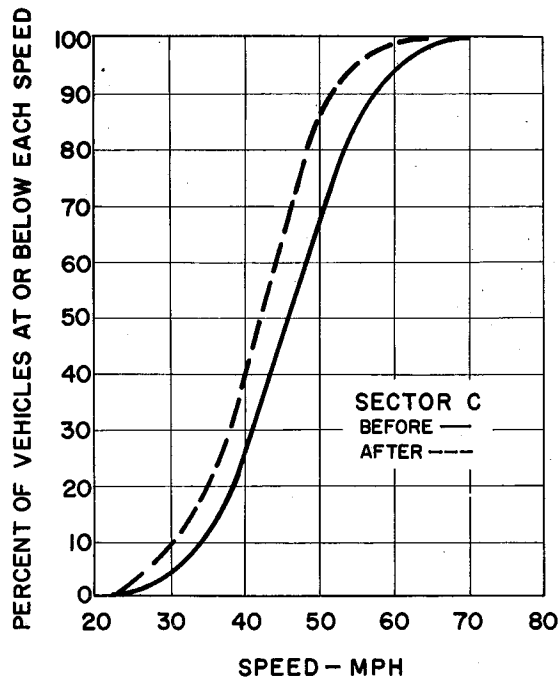
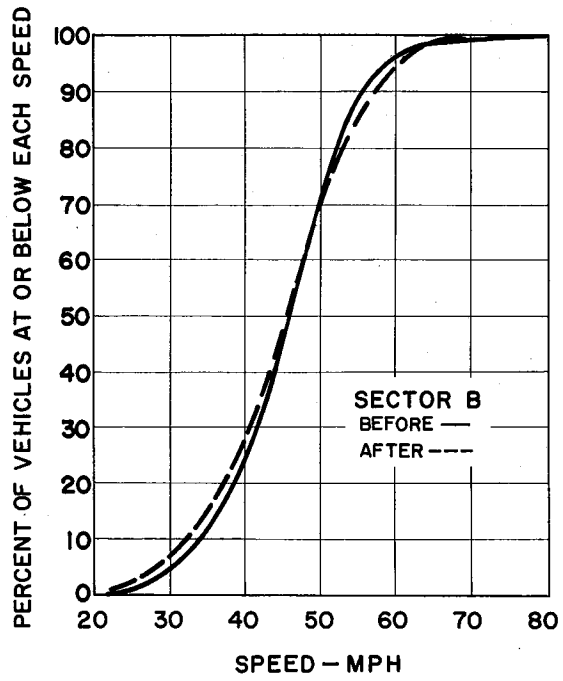
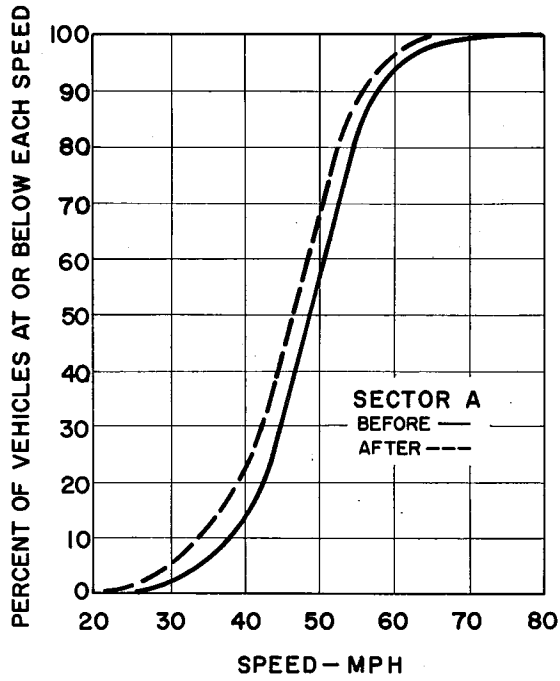
Test Car Speed Profiles

The speed profiles of the test car runs were not included in the report. Because of a great amount of variation, no meaningful comparison could be made.

Individual Vehicle Speed Study

As described earlier, the Individual Vehicle Speed Study method was used to measure traffic speeds through four sectors of the study section, as shown in Figure 12. The speeds observed for the "before" and "after" conditions of channelization are shown comparatively in Figure 13. It should be pointed out that this comparison was limited to speeds in the Eastbound direction only.

Statistical tests utilized in comparing the speed samples for the "before" and "after" conditions showed significant differences in the mean or average speeds in Sectors A and C but not in Sectors B and D. These differences are shown graphically in Figure 12. The difference observed in Sector A indicated that channelization and the special approach-end treatment caused traffic to reduce speed at a greater distance from the intersection. The reduction in speed in Sector C indicated that drivers were made more aware of the potential hazard at the intersection, and did not return to normal speed until they were clear of the channelized section. Before channelization was installed, the drivers returned to normal speed immediately after clearing the intersection. According to these results, channelization has, in effect, extended the "intersection area" to the limits of channelization, and



SPEED DISTRIBUTION CURVES FOR "BEFORE" AND
"AFTER" CONDITIONS OF CHANNELIZATION

FIGURE 13

increased the significance of the intersection.

EVALUATION OF THE APPROACH-END TREATMENT

Delineation Line

It was the intent in the design of the delineation line to provide a natural path around the channelizing island. To establish the effectiveness of the design of the delineation line in a smooth transition around the channelizing island, general observations were made of the placement of 382 vehicles and classified as follows:

- (1) Vehicles that encroached on the delineation line.
- (2) Vehicles that approached the delineation line but did not encroach upon the line.
- (3) Vehicles that remained approximately the same distance from the delineation line throughout its length.

The results showed that 28.5 percent of the observed vehicles changed their placement with respect to the delineation line and 8.1 percent of these actually encroached upon the line. However, only a few of those encroaching remained on the line any length of time due to the noise produced when the tires struck the buttons. None of the vehicles were in any danger of striking the island at any time.

Although the delineation line did accomplish its purpose of guiding traffic around the island, it apparently did not provide a completely natural path as indicated by the high percentage of vehicles changing their placement with respect to the line. It is possible that a smaller degree of curvature, a spiral curve, or a tangent section would have provided a more natural path.

Rumble Strip

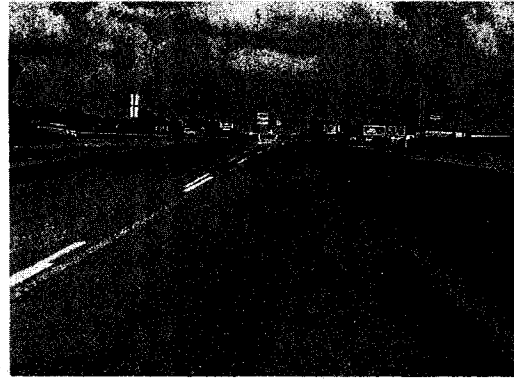
In evaluating the effectiveness of the rumble strip, it was found that the 5/8 inch aggregate did not produce the desired noise level, especially at lower speeds. Also, the color contrast provided by natural aggregate colors was not satisfactory.

Curb Delineation

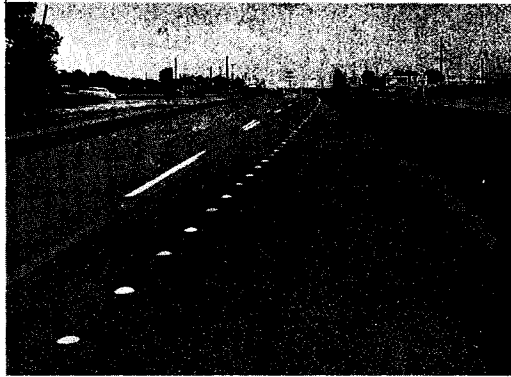
The island curb delineation provided by the prismatic reflectors



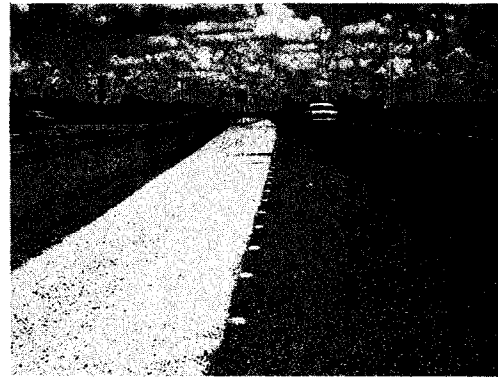
CONDITION 1 - NO CHANNELIZATION



CONDITION 2 - CHANNELIZATION



CONDITION 3 - DELINEATION LINE



CONDITION 3 - RUMBLE STRIP

CONDITION 3
NIGHT VIEW OF
DELINEATION LINE



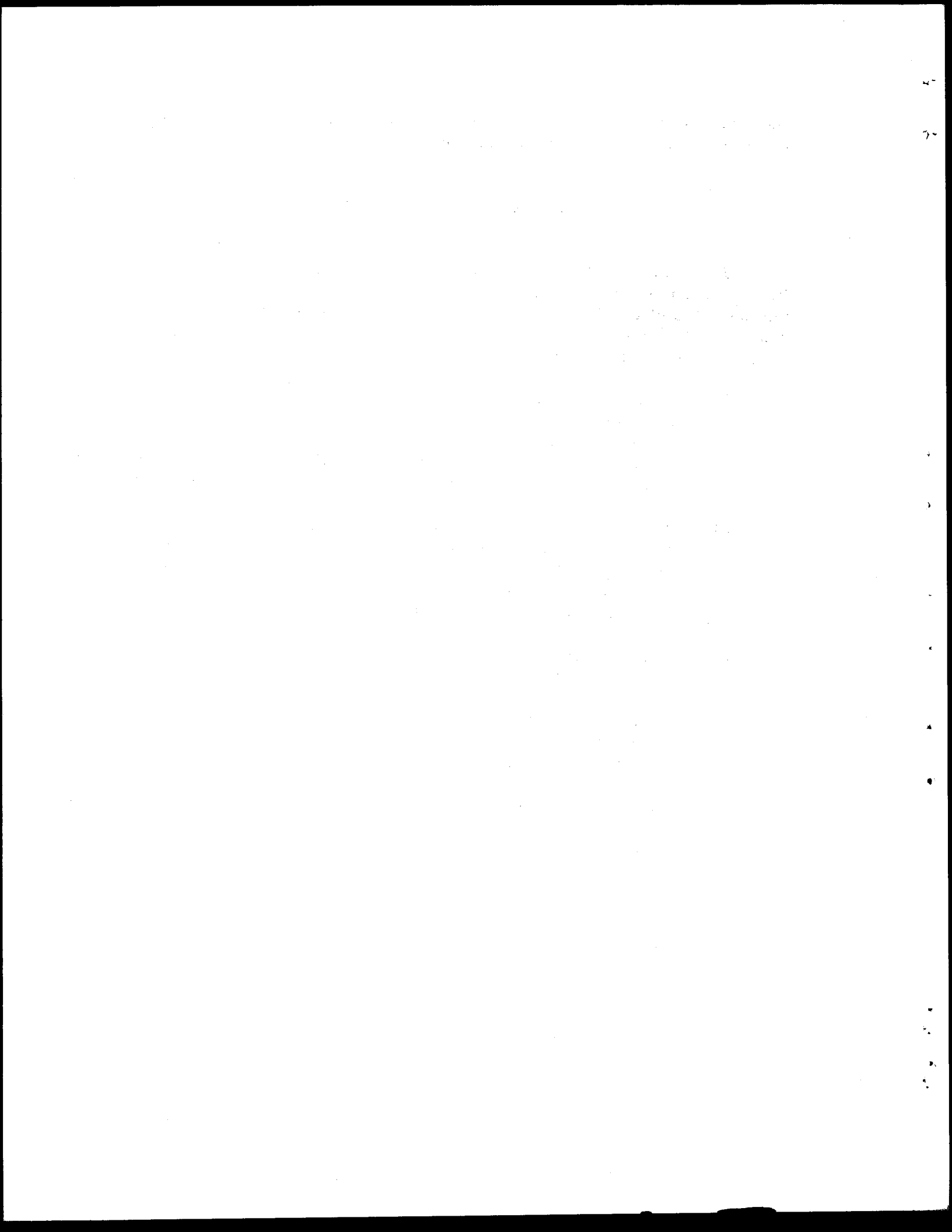
VIEWS OF ELGIN STUDY
FIGURE 14

was considered to be very effective. Figure 14 shows the relative brightness produced by the delineators.

SUMMARY OF FINDINGS

The results of the studies of driver behavior and traffic speeds in a channelized area are summarized as follows. Because the total number of GSR tension responses observed in the driver behavior study was low, the results of that portion of the research were interpreted as general indications rather than definite conclusions.

- (1) Both conditions of channelization (Conditions 2 and 3) indicated an influence on driver behavior by an increase in tension responses for the two conditions at night. These tension responses were considered as indications that the drivers were responsive to warning produced by the channelization.
- (2) The special approach-end treatment (Condition 3) produced greater tension responses than either of the other two conditions, particularly at a point 800 feet in advance of the intersection. This point was coincidental with the beginning of the special approach-end treatment.
- (3) The installation of channelization with an adequate approach-end treatment caused drivers of the normal traffic stream to reduce speed at a greater distance in advance of the intersection than where the channelization was not present. Also drivers did not begin to accelerate until they had cleared the channelized area whereas under unchannelized conditions they began to accelerate immediately upon passing the intersection.



CONCLUSIONS

CONCLUSIONS

The following conclusions were drawn from the results of this research.

(1) In the tests conducted under controlled conditions, the prismatic reflectors exhibited excellent visibility characteristics and were far superior to curb coating-type materials in delineating channelizing island curbs.

(2) The prismatic reflectors performed satisfactorily as curb delineators under actual traffic conditions in rural areas. However, in some urban areas the efficiency of the reflectors was substantially reduced by "splash" or road film. The reduction in efficiency occurred in the approach-end taper section where the roadway was not well drained and high traffic volumes passed very close to the reflectors.

(3) In the tests of KEEP RIGHT signs, the internally illuminated sign provided greater visibility and legibility distances than all other signs tested. However, much of this superiority must be attributed to the fact that the sign legend was composed of 7-inch letters while 4-inch letters were used on the prismatic reflector sign and 5-inch letters were used on all others.

(4) The prismatic reflector type, the externally illuminated, and the reflective sheeting type signs provided good visibility and legibility characteristics. When compared to the internally illuminated sign, they had relative visibilities of 80 percent to 70 percent in the order indicated above.

(5) The introduction of channelization with special approach-end treatment caused traffic to reduce speed at a greater distance from the intersection and continue at a reduced speed through the channelized section. A further reduction in speed in the immediate intersection area indicated that the channelization increased the significance or importance of the intersection.

REFERENCES

1. Cleveland, Donald E., "Driver Tension and Rural Intersection Illumination", Traffic Engineering, Vol. 32, No. 1, October, 1961.
2. Rowan, N. J. and Keese, C. J., "A Study of Factors Influencing Traffic Speeds," paper presented at Annual Meeting of the Highway Research Board, January, 1962.

TABLE A
RESULTS OF CURB DELINEATION
STUDY

Position	Driver Number	Replication Number	Material 1		Material 2		Material 3		Material 4	
			Beads-on Paint		Yellow Reflective Coating		White Reflective Coating		5/8" Prismatic Reflectors	
			Conditions		Conditions		Conditions		Conditions	
			1	2	1	2	1	2	1	2
Position 1	1	1	200	160	120	140	180	180	760	760
		2	200	220	140	180	180	160	840	920
	2	1	220	200	160	180	160	220	680	680
		2	200	220	140	240	140	180	580	740
	3	1	140	200	120	120	180	160	620	580
		2	160	200	180	140	180	180	660	820
	4	1	200	200	140	180	200	240	640	680
		2	160	240	160	140	200	200	600	700
Average Visibility Distances, Feet			185	205	145	165	178	190	672	735
			195		155		184		704	
Position 2	1	1	200	140	140	120	140	160	1040	1080
		2	140	160	160	140	140	140	820	880
	2	1	120	180	120	140	140	140	800	840
		2	140	160	100	120	100	100	600	660
	3	1	160	120	100	80	140	140	560	460
		2	180	160	100	100	160	140	720	660
	4	1	220	220	120	180	140	220	980	1060
		2	180	200	180	140	160	160	1000	1020
Average Visibility Distances, Feet			167	167	128	128	140	150	816	834
			167		128		145		825	

TABLE B
ANALYSIS OF VARIANCE SIGN VISIBILITY TEST

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Drivers	3	4033.8	1344.6	151.0**
Replications	1	81.3	81.3	9.1**
Signs	7	7729.8	1104.2	128.0**
Drivers/Replications	3	161.7	53.9	6.0**
Drivers/Signs	21	646.4	30.8	3.5**
Replications/Signs	7	111.4	15.9	1.8
Drivers/Replications/Signs	21	278.6	13.3	1.5
Residual	64	569.9	8.9	

** 1% level.

TABLE C
ANALYSIS OF VARIANCE SIGN LEGIBILITY TEST

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Drivers	3	538.2	179.4	138.0**
Replications	1	8.5	8.5	6.5*
Signs	7	954.1	136.7	105.0**
Drivers/Replications	3	92.3	30.8	23.7**
Drivers/Signs	21	160.1	7.6	5.8**
Replications/Signs	7	16.5	2.4	1.8
Drivers/Replications/Signs	21	27.0	1.3	1.0
Residual	64	82.5	1.3	

** 1% level.

* 5% level.

