# Delineation of Temporary Barriers in Work Zones

(DOT-FH-11-9688)

Research Report 4151-1

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16. Abstract

Temporary barriers may not be adequately distinguishable from the background, which may result in confusion on the part of the motorist with potentially catastrophic results. This problem may be solved by providing adequate warning of barrier presence and delineating the path created by temporary barriers. The objective of the present study was to evaluate the effectiveness of various delineation systems for use on construction sites while using a two-phased approach-a screening study performed to reduce the number of possible treatments to study and a proving grounds study to evaluate certain delineation systems in the field. After conducting the proving grounds study, it was determined that vertical panels and reflective cylinders were judged to be acceptable at least 85 percent of the time and that the spacing between these devices should be no greater than 200 feet. It was also noted that the reflective cylinders provide 360 degrees of reflectivity so that they are always at the optimum angle to the traffic, regardless of direction.

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# METRIC CONVERSION FACTORS

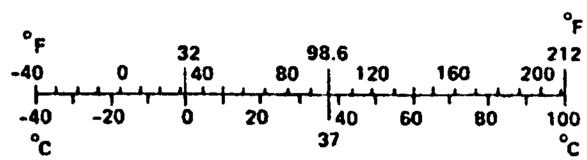
## Approximate Conversions to Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| in² | square inches | 6.5 | square centimeters | cm² |
| ft² | square feet | 0.09 | square meters | m² |
| yd² | square yards | 0.8 | square meters | m² |
| mi² | square miles | 2.6 | square kilometers | km² |
| | acres | 0.4 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| ft³ | cubic feet | 0.03 | cubic meters | m³ |
| yd³ | cubic yards | 0.76 | cubic meters | m³ |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.


## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| cm² | square centimeters | 0.16 | square inches | in² |
| m² | square meters | 1.2 | square yards | yd² |
| km² | square kilometers | 0.4 | square miles | mi² |
| ha | hectares (10,000 m²) | 2.5 | acres | |
| | | **MASS (weight)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| m³ | cubic meters | 35 | cubic feet | ft³ |
| m³ | cubic meters | 1.3 | cubic yards | yd³ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



FOREWORD

This report was prepared as part of Contract DOT-FH-11-9688 entitled "Use and Delineation of Traffic Barriers in Work Zones." The contract began September 1979 and is scheduled for completion the latter part of 1984.

The basic objectives of the contract were to develop guidelines for the use of positive traffic barriers in work zones and to examine the effectiveness of various delineation devices for work zone barriers. Five tasks were addressed: (A) review state of the art and current practice; (B) determine positive traffic barrier need; (C) examine delineation devices for work zone barriers; (D) develop guidelines; and (E) develop a User's Guide.

Results of the study are presented in the following reports:

1. "Delineation of Temporary Barriers in Work Zones," Brackett, R. Q., Jr., Stuart, M., Woods, D. L., and Ross, H. E., Jr., Research Report 4151-1, Texas A&M Research Foundation, Texas Transportation Institute, Texas A&M University, February 1984.
2. "Guidelines for Use of Temporary Barriers in Work Zones," Ross, H. E., Jr., and Sicking, D. L., Research Report 4151-2, Texas A&M Research Foundation, Texas Transportation Institute, Texas A&M University, June 1984.
3. "Temporary Barriers in Work Zones -- A User's Guide," Ross, H. E., Jr., and Sicking, D. L., Research Report 4151-3, Texas A&M Research Foundation, Texas Transportation Institute, Texas A&M University, September 1984. (Pending)

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# I. INTRODUCTION

Concrete and W-Beam temporary barriers are being used as a means of keeping traffic from entering a work area or from impacting an exposed object or excavation. If these barriers are properly used they have the potential of reducing the severity of accidents. They also provide positive protection for workers, separate two-way traffic and protect construction such as false work for bridges. However, it has been suggested that temporary barriers may not be adequately distinguishable from the background, which may result in confusion on the part of the motorist with potentially catastrophic results. In this respect temporary barriers may fail to satisfy the MUTCD requirement that motorists "...be guided in a clear and positive manner while approaching and traversing construction and maintenance work areas." This problem could be solved by providing adequate warning of barrier presence and delineating the path created by temporary barriers.

The informational needs that the driver has when negotiating a work zone with temporary barriers in place can be assessed using an information-decision-action (IDA) task analytic model. This sequentially backward analysis initially postulates what actions are to be taken for safety. Once these actions are defined, the decisions necessary to effect them are determined. The alternative decisions that the driver might make are also considered at this stage. Finally, the information that the driver needs leading to

TABLE 1. INFORMATION-DECISION-ACTION (IDA) SEQUENCE ANALYSIS FOR CONSTRUCTION AND MAINTENANCE SITES

| Geometric Situation | Actions to be Taken for Safety | Decisions to be Made | Information Required | Effect of Information Deficiency | Information Sources |
|---|---|---|---|---|---|
| TANGENT<br>CURVE<br>DETOUR OR CROSSOVER | 1. Maintain appropriate lane position<br>2. Maintain <u>Safe</u> Speed | 1. Determine if an anomalous condition exists.<br>2. Determine if speed adjustment is required.<br>3. Determine appropriate path. | 1. Advanced warning that anomalous condition exists.<br>2. Advise safe speed.<br>3. Indication of appropriate path. | 1. Confusion<br>2. Brake Application<br>3. Steering Changes<br>4. Lane Position Changes<br>5. Impact Barrier<br>6. Run Off Road<br>7. Lane Change<br>8. Ignore Other Devices | 1. Advance Warning Signs<br>2. Posted Speeds<br>3. Pavement Markings<br>4. Delineation of barrier<br>a. to identify presences<br>b. to indicate path<br>5. Other traffic<br>6. Road Geometry |

safe decisions can be specified (see Table 1). This cursory analysis supports the notion that advanced warning and barrier delineation would aid in supplying motorists with required information.

Unfortunately, surveys conducted as part of this study indicate that there is little or no standardization regarding the delineation of temporary barriers. The lack of standardization produces inadequate information in some cases and redundancy or "over-kill" in others. It also leads to the confusion of motorists who cannot anticipate the amount of information to be supplied from one work zone to the next.

Highway engineers need to have objective and standardized criteria for the delineation of these barriers. These criteria, if properly selected, should afford a well delineated temporary barrier which will reduce accident severity yet be easy to install and maintain; and the system should be relatively inexpensive.

I-1. Study Objective. The objective of this study was to evaluate the effectiveness of various barrier delineation systems and to suggest the optimum treatment considering both cost and relative efficiency in communicating with the motorist.

I-2. Study Approach. Assuming that some pattern of barrier delineation would assist the motorist in successfully negotiating a work zone where barriers are present, the task becomes a matter of selecting the most efficient. Efficiency in this case refers to selecting the least costly system that is still effective in accomplishing its designed function.

I-2-A. <u>Types of Temporary Barriers</u>. The most frequently used temporary barriers are those of concrete, commonly called portable concrete barriers (PCB). Also in use are barriers constructed of galvanized W-beam mounted on fifty-five gallon drums which are weighted with sand, dirt or gravel. Indiscriminant use of the W-beam barrier system is not recommended, however, since, in some instances, there are problems with their usage. Crash tests have proven that if the W-beam barrier does not have adequate beam stiffness and overall stability, there is a very strong possibility that the barrels will be overturned with impact. Additional information concerning the structural characteristics and impact performance of the PCB and W-Beam barriers is presented in Report 4151-2. These two barrier systems were selected for study; however, emphasis was placed on the PCB system.

I-2-B. <u>Temporary Barrier Configuration</u>. The geometric configuration in which a temporary barrier system is placed somewhat alters its visual characteristics. Consequently, it was necessary to evaluate the various treatments in configurations where they were likely to be used. This approach was taken to find out if a good system in one configuration was not adversely affected by a changed configuration.

The basic configurations selected for PCBs were the tangent, the curve, and the crossover. The crossover configuration consisted primarily of a series of taper and tangent segments so an individual taper configuration was not studied. The less frequently encountered W-beam barrier was evaluated in both tangent and curved configurations.

I-2-C. Environmental Conditions. Motorist information requirements remain constant across all environmental conditions, therefore systems designed to supply the needed information must function in all environments.

It should be noted that the information provided by the delineator systems is not as important in daylight conditions since many other informational cues are available. The six conditions selected for the study are included in Table 2.

I-2-D. Treatment Alternatives. There were ten delineation systems selected for evaluation for possible use on PCBs and eight for W-beam barriers. The treatments were selected from those systems in use by various jurisdictions, those recommended by The Federal Highway Administration (FHWA), and those recommended by The Texas Transportation Institute (TTI). A description of each system is given in Figures 1, 2, 3, and 4.

I-2-E. Evaluation Technique. Since the evaluation of each alternative treatment was to have considered the geometric conditions in which they are viewed as well as the visibility

TABLE 2. ENVIRONMENTAL CONDITIONS USED IN STUDY

| Illumination | Pavement Condition | Glare Condition |
|---|---|---|
| Daylight | Dry | None |
| Daylight | Wet | None |
| Night (Headlights)* | Dry | None |
| Night (Headlights) | Wet | None |
| Night (Headlights) | Dry | On-coming Headlights* |
| Night (Headlights) | Wet | On-coming Headlights |

*All headlights were on low beam.

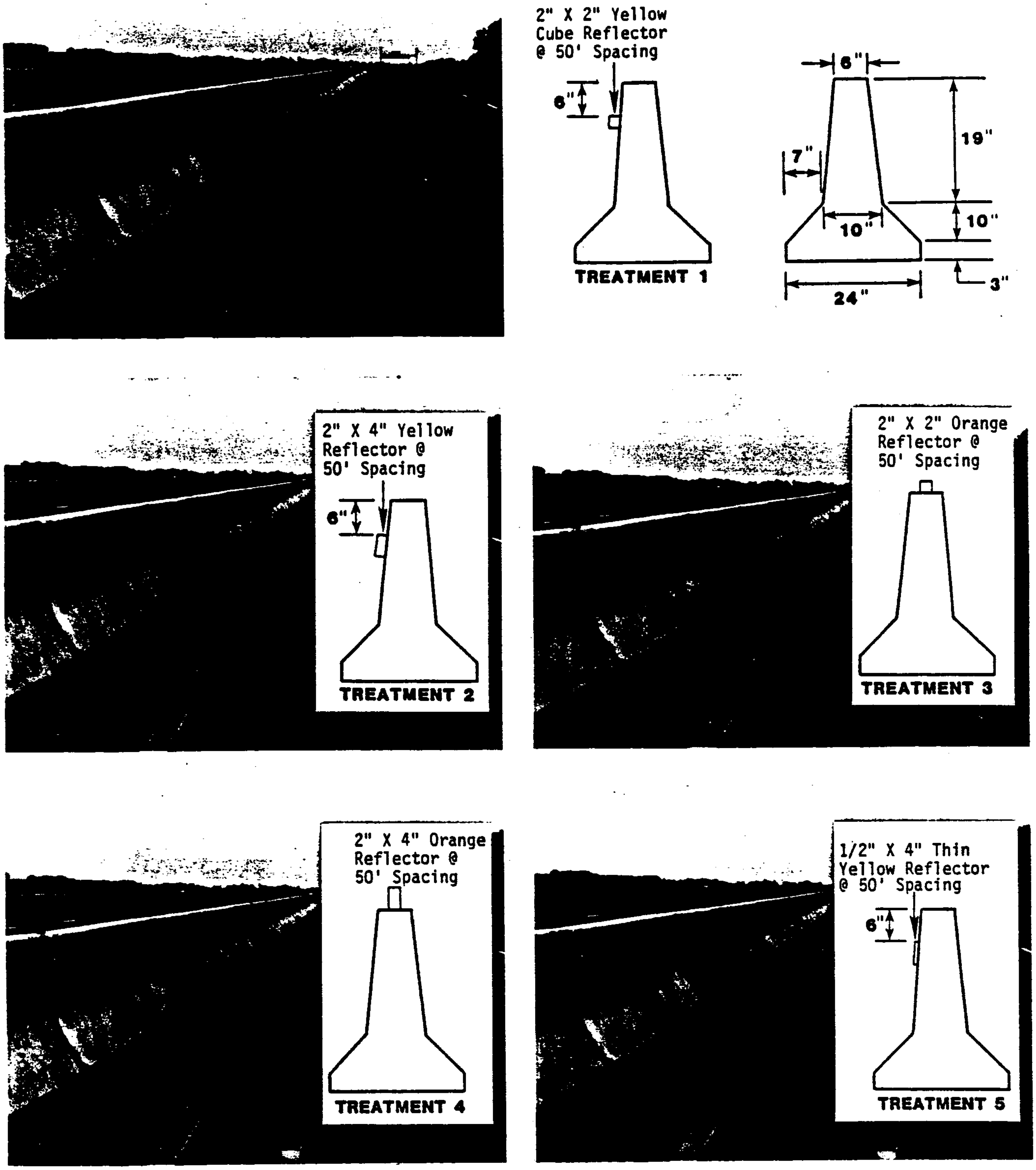


FIGURE 1. PCB Delineation Treatments 1 through 5.

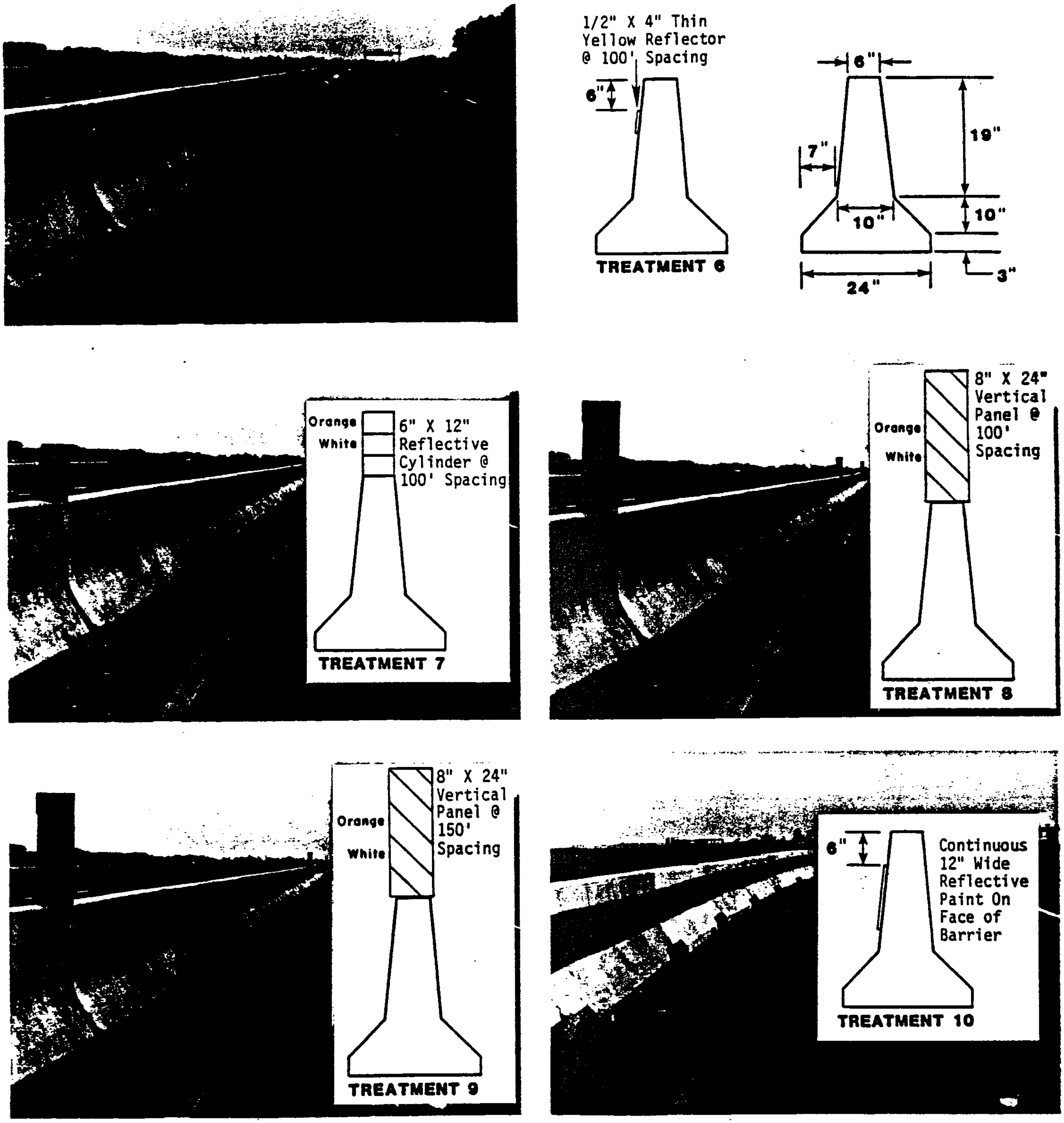


FIGURE 2. PCB Delineation Treatments 6 through 10.

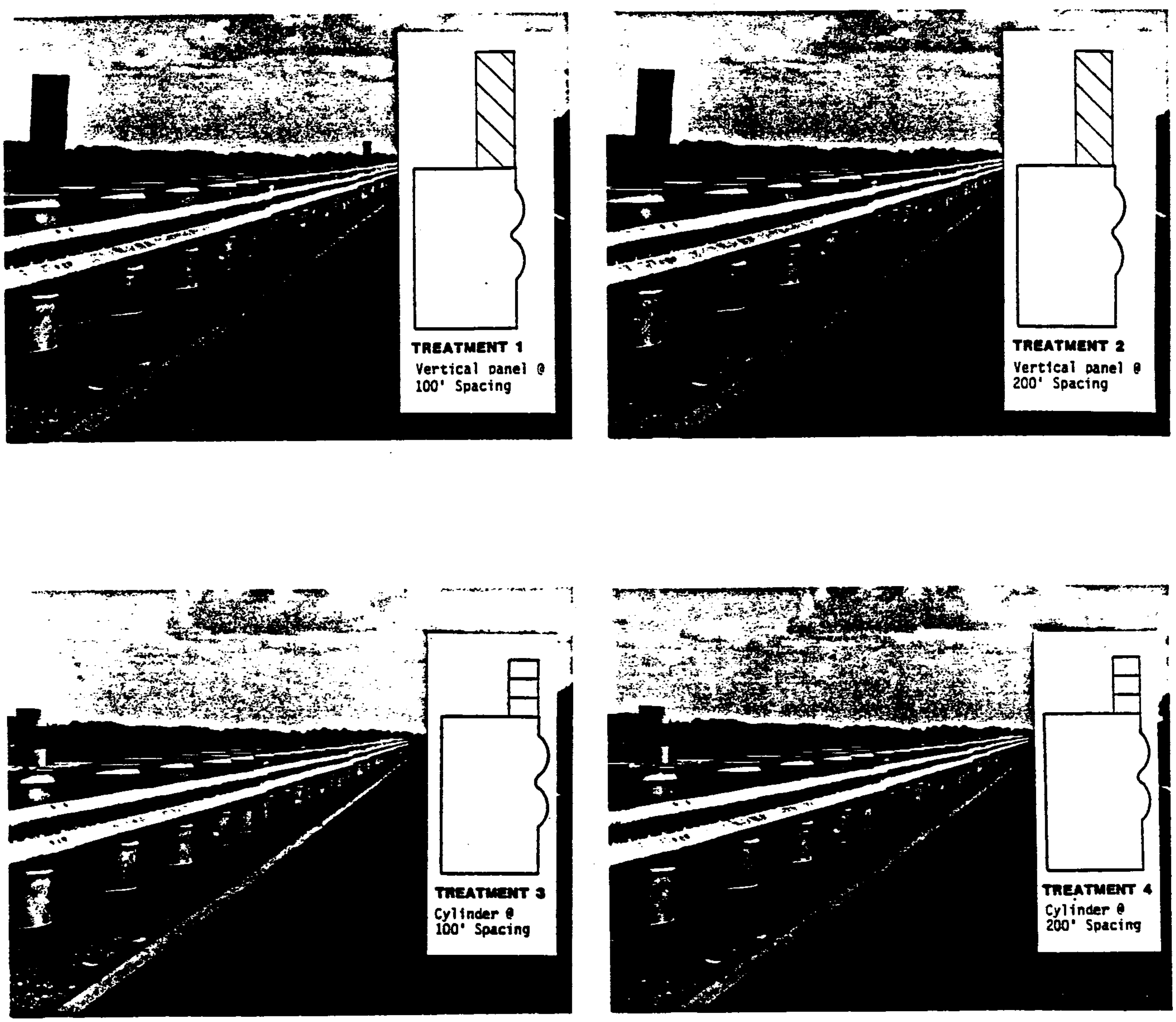


FIGURE 3. W-beam Delineation Treatments 1 through 4.

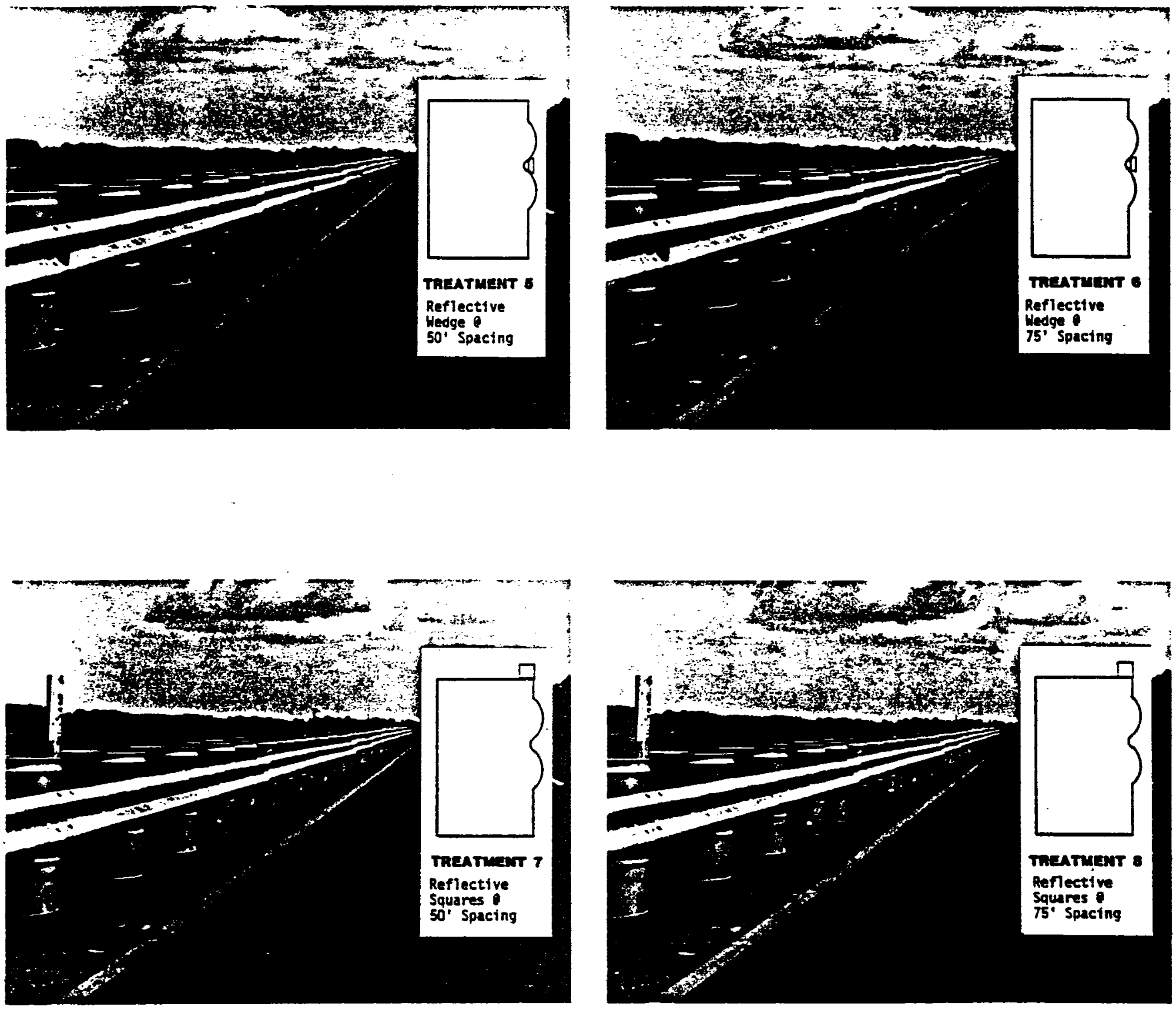


FIGURE 4. W-beam Delineation Treatments 5 through 8.

afforded by the ambient conditions, a comprehensive factorial design would have been desirable. However, such designs were deemed impractical from logistical and cost standpoints; consequently, other methods were considered.

The least costly approach would have been to use subjective opinion of the relative effectiveness of each treatment. However, this method could not produce results of high credibility. Thus, a hybrid approach, using subjective evaluation to reduce the number of alternative treatments examined experimentally followed by controlled experiments, seemed the only practical approach.

I-2-F. Methods. A two-phased approach was used for selecting the most efficient delineation systems for use on construction sites. First, a screening study was conducted to eliminate the insufficient systems; and second, the remaining systems were further studied in a in a simulated field environment at the Texas A&M Research Proving Grounds. The methods used for each phase are described in the following sections.

## II. SCREENING STUDY

Procedurally, the screening study involved a "Q-Sort" or subjective ranking of photographic depictions of the treatments taken in various geometric configurations taken under all environmental conditions.

The photographs used as stimulus materials in this screening study were taken from driver eye height at a location in the work zone area. All photographs for a particular configuration and environmental condition were taken from the same position with only the treatment system altered.

The accuracy of the photographic process was checked by having a team of five people view the actual treatment system then view the photograph of that treatment system and rate the photographic representation. This process indicated that the photographic process provided an "adequate-to-good" depiction of the actual treatment, barrier configuration and environmental condition as it was viewed with the naked eye.

The stimulus materials were taken to a large shopping mall where volunteer drivers were asked to rank order the photographs of treatments according to their ability to display the proper path for a motorist to follow. A minimum of fifty subjects ranked all treatment alternatives for each barrier configuration and environmental condition. In all, 1800 subjects were required for the entire screening study.

Concerned that the photographs might be ranked strictly on the basis the size of the delineation treatment, subjects were also asked to separate the acceptable treatments from those that were unacceptable. The instructions given to each subject are presented as Appendix A. For examples of a few of the many conditions in which the delineation treatments were studied, refer to Figures 1, 2, 3, and 4.

Results. Three types of analyses were performed on the data collection for each type of treatment (PCB delineators, W-beam delineators). These analyses included a Friedman Analysis of Variance for Ordinal Data; an Analysis of Variance of the proportion of unacceptability and a subsequent Newman-Keuls, a posteriori test to determine which treatments have significantly lower unacceptability proportions. The Friedman Analysis of Variance tests the basic probabilistic assumption that if there is no difference among the various delineation systems, then the rankings of the systems should be evenly distributed. The Analysis of Variance tests whether or not the proportion of unacceptability is greater across delineation systems than the variance within each delineation system. If the variance across the delineation systems is greater, then this suggests that there is a difference in the unacceptability due to the different delineations studied. The Newman-Keuls, a posteriori test is used to determine which delineation system was significantly more unacceptable than the others.

All Friedman analyses indicated that there were significant differences ($p<.01$) among the ranking of the various treatments for each barrier system. The average ranks for each system serve to illustrate the order of preference. However, this test does not allow an assessment of the interval between the ranks.

The Analysis of Variance performed on the proportion of unacceptability also indicated significant differences among treatments for each system. The subsequent Newman-Keuls tests showed that some treatments indeed had a lower proportion of unacceptability while others did not differ significantly from one another.

The ANOVA for the PCB delineation systems also indicated a significant interaction between the delineators and the configuration in which they were viewed. This interaction is a result of small differences in the unacceptability of middle range systems for different configurations.

The ANOVA for the W-beam delineation systems showed significant differences between the curve and tangent configurations, with the curve presentations receiving higher unacceptability selections. A summary of rankings is presented in Tables 3 and 4. Also presented in these tables is the average

TABLE 3. SUMMARY OF SCREENING STUDY RESULTS FOR PCB DELINEATION SYSTEMS

| Delineation | Vertical Panel | Vertical Panel | Cylinder (6"dia) | Paint Stripe | Yellow Reflector | Orange Reflector | Yellow Reflector | Yellow Reflector | Orange Reflector | Yellow Reflector | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dimension | 8"x24" | 8"x24" | 12" | 12" | 2"x4" | 2"x4" | ½"x4" | 2"x2" | 2"x2" | ½"x4" | |
| Spacing | 100' | 150' | Cont. | 100' | 50' | 50' | 50' | 50' | 50' | 100' | |
| Rank by Configuration | | | | | | | | | | | Subjects |
| Tangent | 1 | 2 | 3 | 4 | 5 | 6 | 9 | 7 | 8 | 10 | 306 |
| Curve | 1 | 2 | 4 | 3 | 5 | 8 | 7 | 6 | 9 | 10 | 305 |
| Crossover | 1 | 2 | 3 | 7 | 4 | 6 | 5 | 9 | 8 | 10 | 300 |
| Average | 1 | 2 | 3 | 4.5 | 4.5 | 6 | 7 | 8 | 9 | 10 | 911 |
| Percent Unacceptable | | | | | | | | | | | Subjects |
| Tangent | 4.0 | 5.3 | 19.0 | 36.5 | 49.3 | 54.5 | 68.8 | 63.2 | 71.5 | 83.7 | 306 |
| Curve | 12.6 | 16.6 | 25.3 | 27.5 | 41.3 | 61.7 | 75.8 | 56.8 | 75.8 | 79.3 | 305 |
| Crossover | 4.0 | 6.3 | 8.0 | 63.0 | 37.0 | 60.6 | 77.0 | 79.0 | 77.0 | 71.6 | 300 |
| Average | 7.6 | 9.4 | 14.2 | 42.3 | 42.5 | 59.9 | 74.7 | 66.3 | 74.7 | 78.2 | 911 |

TABLE 4. SUMMARY OF SCREENING STUDY FOR W-BEAM DELINEATION SYSTEMS

| Delineation | Vertical Panel | Vertical Panel | Cylinder (6"dia) | Yellow Wedge | Cylinder (6"dia) | Orange Reflector | Yellow Wedge | Orange Reflector | |
|---|---|---|---|---|---|---|---|---|---|
| Dimension | 8"x24" | 8"x24" | 12" | 4"x6"approx. | 12" | 4"x4" | 4"x6"approx. | 4"x4" | |
| Spacing | 100' | 200' | 100' | 50' | 200' | 50' | 75' | 75' | |
| **Rank of Configuration** | | | | | | | | | Subjects |
| Tangent | 1 | 2 | 3 | 4 | 6 | 5 | 7 | 8 | 337 |
| Curve | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 305 |
| Average | 1 | 2 | 3 | 4 | 5.5 | 5.5 | 7 | 8 | 642 |
| **Percent Unacceptable** | | | | | | | | | |
| Tangent | 1.5 | 13.5 | 12.0 | 26.7 | 41.1 | 30.0 | 47.3 | 52.7 | 337 |
| Curve | 2.1 | 17.3 | 13.5 | 45.7 | 40.5 | 55.5 | 69.0 | 66.2 | 305 |
| Average | 1.8 | 15.4 | 12.8 | 36.2 | 40.8 | 42.8 | 58.15 | 59.5 | 642 |

portion of times a particular system was determined to be unacceptable by the subject drivers viewing the photographs.

In general, the top three delineation or end treatment systems are readily distinguishable from the remaining devices. These systems were ranked higher and were selected as unacceptable fewer times than the rest. These selections were consistent across environmental conditions and configuration.

The most apparent aspect of the best treatments selected using the photographic technique is the amount of delineation present. It appears that the larger systems were preferred and within these systems, the most frequent. This conclusion was statistically verified with the use of a test of correlation. It was determined that for the PCB delineation systems the correlation between absolute area (surface area of a delineator x the frequency of use in a 300' section) and average rank was about -.86; for the W-beam systems it was even stronger (r=-.958). This indicates that the greater the amount of delineation available, the more favorable the ranking.

# III. PROVING GROUNDS STUDY

The results of the screening study allowed the delineation to be ordered in subjective terms. The intent of the Proving Grounds studies was to confirm that order using more objective measures and fewer treatments under nighttime conditions using a curved configuration. Since these studies were to be conducted in a simulated field environment using subjects that were well aware that they were participating in an experiment, there was a high degree of uncertainty that the selected objective measures could adequately discriminate among the various treatments. Consequently, subjective rankings of the systems were also obtained. At the very least, these rankings would be made by individuals that had seen the actual barriers rather than photographs.

The Proving Grounds studies were divided into two phases; the first to address delineation for PCB; the second, the W-beam.

III-1. PCB Phase. Since the objective of the Proving Grounds study was to confirm the ordering obtained during the screening study, one delineation system from each quartile was tested. So that a true comparison regarding the delineation systems' effectiveness could be made, a baseline or no delineation condition was also tested. For a list and description of each of the delineation systems studied, refer to Table 5.

TABLE 5. DELINEATION SYSTEMS STUDIED DURING THE PCB PROVING GROUND STUDY

| | |
|---|---|
| 1. Best | Vertical Panels spaced 100 ft. apart |
| 2. Upper Middle | Continuous Stripe |
| 3. Lower Middle | Yellow, 2"x2" reflectors spaced 50 ft. apart |
| 4. Worst | Yellow, 1/2"x4" reflectors spaced 50 ft. apart |
| 5. Baseline | No Delineation |

In the screening study, a 12-inch white reflective strip was used to delineate the PCB, however, it did not provide adequate contrast during daytime viewing. Consequently, a four-inch yellow reflective, temporary striping tape was used in the Proving Grounds study. The yellow tape was used to provide a color contrast with the white PCB.

These five systems represent points along the delineation continuum. It was anticipated that their evaluation would provide the information necessary to substantiate the findings of the screening study and recommend the most efficient system.

III-1-A. Procedure. The five delineation systems were displayed in counterbalanced order on a 300' section of PCB in a curved configuration. These delineation systems were viewed by 25 subjects in only the nighttime environmental conditions. The subject drivers drove an instrumented vehicle around the curve section of the PCB five times. The path that the drivers followed was denoted by lane lines on the pavement. The drivers were asked to maintain a speed close to 40 MPH. As drivers negotiated the curved barrier section, several performance measures were recorded. These measures were speed at various points, brake applications, and lane placement. Vehicle speeds and brake application measurements were taken at four points: (1) upstream (400 feet before the PCB), (2) entry of PCB curved barrier section, (3) midway though the curved barrier section, and (4) at the end (departure) of the curved barrier section. Lane position with respect to the right edge line was measured at the entrance of the curved barrier section, midway through the section, and at the end of the section. In addition, after the completion of all five runs, subjects were shown photographs of the five delineation systems and were asked to rank them and to indicate which they thought to be unacceptable.

III-1-B. Results. The rank orders made by the subject drivers were tabulated by, first, assigning one point to a delineation system if it was ranked the highest, two points if it was ranked second highest, and continuing in this manner until five points were assigned to the lowest ranked system. After summing up all points across all subjects it was determined that the vertical panels were ranked the best with 42 points, the continuous paint strips were ranked second best with 46 points, the 2"x2" yellow reflectors were ranked third with 69.5 points, the 1/2"x4" yellow reflectors were ranked fourth with 93.5 points, and the plain barrier was ranked the worst with 124 points.

A Friedman Analysis of Variance for Ordinal Data was performed on the rank order data. It was determined that there was a significant difference ($p<.05$) among the rank orders of the different delineation systems made by the subject drivers.

A repeated measures ANOVA was performed on the three different performance measures. It was determined that there were no significant results using this data. For a summarization of the speed and lane position data and tables depicting the statistical analyses performed, refer to Appendix B. Since no brake applications were recorded, no table is included for this variable.

In general, it appears that the same pattern that was exhibited during the screening study was present for this phase of the study. This trend is that the larger delineation systems are preferred and that within these systems, the most frequent are preferred.

III-2. W-Beam Phase. The objective of the W-Beam Proving Grounds study was the same as the PCB Proving Grounds study to confirm the ordering obtained during the screening study. The different delineation systems evaluated are listed and described in Table 6.

III-2-A. Procedure. The method was identical to that used during the PCB phase, except that, since only four delineation systems were evaluated, 16 subjects were used instead of 25.

III-2-B. Results. Point assignments based upon the subject rank orders were performed in the same manner as that of the PCB phase. After summing up all points across all subjects it was determined that the vertical panels were ranked the best with 24 points, the cylinders second best with 35 points, the 4"x4" orange reflectors third with 41 points, and the plain barrier last with 60 points.

TABLE 6. DELINEATION SYSTEMS STUDIED DURING THE W-BEAM PROVING GROUNDS STUDY

| | |
|---|---|
| 1. Best | Vertical Panels spaced 100 ft. apart |
| 2. Middle | Cylinders spaced 100 ft. apart |
| 3. Worst | Orange, 4"x4" reflectors spaced 75 ft. apart |
| 4. Baseline | No Delineation |

A Friedman Analysis of Variance for Ordinal Data was performed on the rank order data. It was determined that there was a significant difference among the rank orders of the different delineation systems When the performance data were analyzed using a repeated measures ANOVA, it was determined that there were no significant results. For a summarization of the speed and lane position data and tables depicting the statistical analyses performed, refer to Appendix B. Since no brake applications were recorded, no table is included for this variable.

The general trend exhibited from the W-beam study is similar to that of the screening study and the PCB study. This trend is that the subjects more favorably ranked the larger delineation systems.

## IV. COST CONSIDERATIONS

The total cost of a delineation system for a particular barrier is comprised of the cost of the delineator, the cost of installation, the frequency of use per length of barrier and the expected life of the system.

The cost of the delineator is related to surface area and the type of materials used. The majority of the systems studied were nothing more than high intensity, reflective sheeting (Type III-A) on sheet metal backing plates. Several types of plastic prismatic reflectors were used, but by far the most costly system was the temporary marking tape because so much was required. The cylinders were constructed using high intensity sheeting on a one foot section of PVC pipe, 6 inches in diameter.

The cost of installation includes an estimate of the cost of the device used to attach the delineator and the time required for labor. The estimated costs for the installation of each system were performed on the basis of what costs a state highway agency might expect. With the exception of the vertical panels and cylinders, all systems can be installed with adhesives. The panels and cylinders require nails or bolts.

The frequency of use was related to the size of the delineator; the smaller the size, the shorter the spacing.

There was no way to measure the expected life of a system, so this factor was treated as a constant. In actual practice some of these sytems will be more prone to loss due to traffic and movement damage.

The estimated cost per foot of delineation for PCB and W-beam barriers is presented in Table 7. These figures were developed for the range of delineators used in the Proving Grounds studies.

TABLE 7. APPROXIMATE COST PER FOOT OF SELECTED DELINEATION TREATMENTS

PCB

| | Vertical Panel | Paint Stripe | 2"X2" Yellow Reflector | 1/2"X4" Yellow Reflector |
|---|---|---|---|---|
| Cost/Unit | 6.88 | 0.91/Foot | 0.82 | 1.78 |
| Spacing | 1/100' | Cont. | 2/100' | 1/100' |
| Installation-Cost/Unit | 1.50 | 0.02/Foot | 0.75 | 0.75 |
| Cost of Systems/Foot of Temporary Barriers | 0.12 | 0.93 | 0.032 | 0.028 |

W-BEAM

| | Vertical Panel | Cylinder | 4"X4" Reflector |
|---|---|---|---|
| Cost/Unit | 6.88 | 4.00 | 1.54 |
| Spacing | 1/100' | 1/100' | 1/75' |
| Installation-Cost/Unit | 1.50 | 1.50 | 0.75 |
| Cost of System/Foot of Temporary Barriers | 0.12 | 0.09 | 0.04 |

# V. CONCLUSIONS

It was apparent in the screening studies that, with few exceptions, the subjects were evaluating the photographic depictions in terms of the absolute area (surface area X frequency) of delineation present. As was stated earlier in the case of the PCB, the correlation between absolute area and average rank was about -.86; for the W-beam it was even stronger (r=-.958). In addition, the objective measures taken in the Proving Grounds studies failed to discriminate any performance differences among the systems studied, while the subjective appraisals supported earlier findings of the screening study. Consequently, the matter of selection of an optimum treatment rests primarily on two factors, the percentage of unacceptable selection from the screening study and cost considerations.

The variable of unacceptability (those times that the subjects rated the delineator as unacceptable) can be used to select the three best systems for PCB, W-beam approach delineations. Since performance is apparently not a factor that can be dealt with at this time, cost per linear foot of these systems can be used as a basis for selection. This type of comparison is presented in Table 8.

As can be seen in this table, the vertical panels and reflective cylinders were determined to be acceptable to at least 85

TABLE 8. COMPARISON OF PERCENTAGE UNACCEPTABILITY AND COST

| | SYSTEM | SPACING | AVERAGE UNACCEPTABLE | ESTIMATED COST/FOOT |
|---|---|---|---|---|
| PCB | Vertical Panel | 100' | 7.6 | 0.12 |
| | Vertical Panel | 150' | 9.4 | 0.09 |
| | Cylinder | 100' | 14.2 | 0.09 |
| W-BEAM | Vertical Panel | 100' | 1.8 | 0.12 |
| | Cylinder | 100' | 12.8 | 0.09 |
| | Vertical Panel | 200' | 15.4 | 0.07 |

percent of the subjects viewing them. The spacing between these devices should be no greater than 200 feet. The cost of these sytems is estimated to be between $5.00 and $12.00, depending on spacing, for 100' of barrier.

Either of these devices, so spaced, are recommended for use on either PCB or W-beam, temporary barriers. It should be noted that the cylinders, although requiring new materials to be mounted, do have the advantage of always being properly oriented. Since it provides 360 degree reflectivity, it is always at the optimum angle to the traffic, regardless of direction.

APPENDIX A

Photograph Rank Order

Data Form

1. How many miles per year do you drive?

   ☐ Under 10,000   ☑ 10,000 - 20,000   ☐ Over 20,000

2. Age Range: ☑ 25 or Younger   ☐ 26-35   ☐ 36-50   ☐ 51 or Older

3. Male ☑   Female ☐

Condition NWG   Subject 18 CMB T

1. Please record the letter of the photographs from "BEST" to "WORST".

2. In your opinion, are all the reflector markings acceptable? If not, please draw a line separating those that are acceptable from those that are unacceptable.

BEST U
Y
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N
P
J
O
F
WORST C

THANK YOU!

APPENDIX B

TABLE 9. AVERAGE SPEEDS (IN M.P.H.) TAKEN AT VARIOUS POINTS FOR THE DIFFERENT DELINEATIONS USED DURING THE PCB PHASE

| | DELINEATION METHOD | | | | |
|---|---|---|---|---|---|
| LOCATION | NONE | VERTICAL PANELS | CONTINUOUS STRIPE | 2"x2"YELLOW REFLECTORS | 1/2"x4"YELLOW REFLECTORS |
| Upstream | 31.58 | 27.81 | 26.22 | 27.29 | 28.11 |
| Entry | 33.38 | 33.64 | 33.27 | 33.23 | 33.74 |
| Midpoint | 33.20 | 33.73 | 33.26 | 33.15 | 33.76 |
| Departure | 32.27 | 33.28 | 32.05 | 32.28 | 33.09 |

TABLE 10. AVERAGE POSITION WITH RESPECT TO THE RIGHT LANE LINE FOR THE DIFFERENT DELINEATIONS USED DURING THE PCB PHASE

| LOCATION | DELINEATION METHOD | | | | |
|---|---|---|---|---|---|
| | NONE | VERTICAL PANELS | CONTINUOUS STRIPE | 2"x2"YELLOW REFLECTORS | 1/2"x4"YELLOW REFLECTORS |
| Entry | 1.46 | 1.40 | 1.42 | 1.32 | 1.41 |
| Midpoint | 1.14 | 0.98 | 1.10 | 1.14 | 1.08 |
| Departure | 1.38 | 1.36 | 1.14 | 1.44 | 1.34 |

TABLE 11. ANALYSIS OF VARIANCE SOURCE TABLE FOR THE PCB SPEED DATA

| SOURCE | DEGREES OF FREEDOM | SUMS OF SQUARES | F VALUE | SIGNIFICANCE LEVEL |
|---|---|---|---|---|
| Delineation Method | 4 | 128.04 | 0.98 | .4220 |
| Point of Measurement | 3 | 2360.98 | 22.37 | .0001 |
| Subjects | 24 | 7102.81 | - | - |
| Delineation Method and Point of Measurement Interaction | 12 | 324.28 | 1.24 | .256 |
| Delineation Method Error Term | 96 | 3134.39 | - | - |
| Point of Measurement Error Term | 72 | 2532.64 | - | - |
| Interaction Error Term | 288 | 6284.32 | - | - |

TABLE 12. ANALYSIS OF VARIANCE SOURCE TABLE FOR THE PCB LANE POSITION DATA

| SOURCE | DEGREES OF FREEDOM | SUMS OF SQUARES | F VALUE | SIGNIFICANCE LEVEL |
|---|---|---|---|---|
| Delineation Method | 4 | 0.53 | 0.20 | 0.9351 |
| Point of Measurement | 2 | 6.65 | 5.75 | 0.0058 |
| Subjects | 24 | 90.08 | - | - |
| Delineation Method and Point of Measurement Interaction | 8 | 1.45 | 0.91 | 0.5126 |
| Delineation Method Error Term | 94 | 61.70 | - | - |
| Point of Measurement Error Term | 48 | 27.75 | - | - |
| Interaction Error Term | 1.88 | 37.64 | - | - |

TABLE 13. AVERAGE SPEED (IN M.P.H.) TAKEN AT VARIOUS POINTS FOR THE DIFFERENT DELINEATIONS USED DURING THE W-BEAM PHASE

| | | DELINEATION METHOD | | |
|---|---|---|---|---|
| LOCATION | NONE | VERTICAL PANELS | CYLINDERS | 4"X4" ORANGE REFLECTORS |
| Upstream | 28.72 | 29.11 | 27.66 | 27.59 |
| Entry | 35.99 | 35.79 | 35.14 | 36.36 |
| Midpoint | 35.90 | 35.90 | 34.82 | 36.33 |
| Departure | 34.98 | 35.75 | 34.21 | 36.11 |

TABLE 14. AVERAGE POSITION WITH RESPECT TO THE RIGHT LANE LINE FOR THE DIFFERENT DELINEATIONS USED DURING THE W-BEAM PHASE

| | DELINEATION METHOD | | | |
|---|---|---|---|---|
| LOCATION | NONE | VERTICAL PANELS | CYLINDERS | 4"X4" ORANGE REFLECTORS |
| Entry | 1.37 | 1.18 | 1.31 | 1.15 |
| Midpoint | 1.25 | 1.00 | 0.90 | 1.09 |
| Departure | 1.06 | 1.00 | 0.81 | 1.18 |

TABLE 15. ANALYSIS OF VARIANCE SOURCE TABLE FOR THE W-BEAM SPEED DATA

| SOURCE | DEGREES OF FREEDOM | SUMS OF SQUARES | F VALUE | SIGNIFICANCE LEVEL |
|---|---|---|---|---|
| Delineation Method | 3 | 58.45 | 1.05 | .3814 |
| Point of Measurement | 3 | 2594.72 | 157.37 | .0001 |
| Subjects | 15 | 2171.06 | - | - |
| Delineation Method and Point of Measurement Interaction | 9 | 35.70 | 1.14 | .3360 |
| Delineation Method Error Term | 45 | 838.05 | - | - |
| Point of Measurement Error Term | 45 | 247.32 | - | - |
| Interaction Error Term | 135 | 468.10 | - | - |

TABLE 16. ANALYSIS OF VARIANCE SOURCE TABLE FOR THE W-BEAM LANE POSITION DATA

| SOURCE | DEGREES OF FREEDOM | SUMS OF SQUARES | F VALUE | SIGNIFICANCE LEVEL |
|---|---|---|---|---|
| Delineation Method | 3 | 1.32 | 0.63 | 0.6023 |
| Point of Measurement | 2 | 2.11 | 3.85 | 0.0324 |
| Subjects | 15 | 56.69 | - | - |
| Delineation Method and Point of Measurement Interaction | 6 | 1.38 | 1.46 | 0.2017 |
| Delineation Method Error Term | 45 | 31.81 | - | - |
| Point of Measurement Error Term | 30 | 8.22 | - | - |
| Interaction Error Term | 90 | 14.27 | - | - |