FIELD EVALUATION OF UNLIGHTED OVERHEAD GUIDE SIGNS USING OLDER DRIVERS

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Russ College of Engineering and Technology

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16. Abstract

Twenty older drivers, aged 63 to 81 (average 72.1), with corrected visual acuity ranging from 20/20 to 20/29 (average 20/25), evaluated six sign material and lighting combinations under nighttime conditions on US Route 30 near Mansfield, Ohio. The tested material combinations, all unlighted unless noted otherwise, were (legend on background) beaded Type III on beaded Type III, lighted beaded Type III on beaded Type III, Type VIII on microprismatic Type III, Type IX on beaded Type III, Type IX on Type IX, and Type VII on beaded Type III. Evaluators sat in the passenger seat and middle center seat of a 2002 Dodge Caravan. Headlights were kept on low beam. The evaluation loop was driven twice, once approaching signs in the left lane, and once approaching in the right lane. The evaluators completed questionnaires regarding sign visibility, legibility, and appearance after driving under each sign group and also an exit interview on the same topics at the end of the evaluation.

Based on questionnaire responses, the highest rated sign groups in terms of legibility and visibility were Type IX on Type IX and Type VII on beaded Type III, which in the exit interview were deemed acceptable for nighttime use by 80% and 65% of evaluators, respectively. In contrast, the lighted beaded Type III on beaded Type III sign, representing existing signing practice in Ohio, was deemed acceptable by only 40-45% of evaluators. The Type VIII on microprismatic Type III sign performed about as well as the lighted sign group, receiving higher scores on the relevant questions on the Exit Interview (60% for legibility, 55% for visibility), but performing worse on the Sign Evaluation Forms. The Type IX on beaded Type III, a favored option in the previous study, performed noticeably still worse, and the unlighted beaded Type III on beaded Type III had the worst performance overall, as was the case in the previous study.

Given that the Type IX on Type IX and Type VII on beaded Type III was clearly favored by evaluators over the lighted sign group, it appears that switching from lighted signs to unlighted signs using Type VII on beaded Type III or Type IX on Type IX materials may represent an actual improvement for older drivers, in addition to having benefits in terms of saving on electricity, lighting maintenance costs, and worker/traffic hazards. With the greater needs of older drivers, the use at short distance of Type IX on Type IX signs instead of the previously suggested Type IX on beaded Type III is recommended.

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Helmut T. Zwahlen, Andrew Russ, and Sahika Vatan

Human Factors and Ergonomics Laboratory
Ohio Research Institute for Transportation and the Environment
Russ College of Engineering and Technology
Ohio University
Athens, Ohio 45701-2979

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Special thanks go to the 3M Company and Avery Dennison for supplying the sheeting material for the experimental signs.

Last but not least thanks go to all the older drivers who participated as evaluators in this study.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

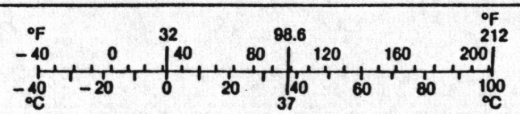
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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1 INTRODUCTION

Past and present practice in Ohio is to illuminate many overhead guide signs on freeways at night using external luminaires. This practice has enhanced the visibility and legibility of signs made with standard sheeting materials, such as engineer grade (ASTM Type I) and high intensity (Type III). To the authors' knowledge, high intensity sheeting comes in two types, a beaded Type III sheeting manufactured by 3M and other manufactures and a microprismatic Type III manufactured by Avery Dennison.

Newly developed microprismatic materials with higher retroreflectivity are now available and are known as ASTM Types VII, VIII, and IX sheeting materials [1]. Type VII is manufactured by 3M and is known as Diamond Grade LDP (Long Distance Performance) [2]. Type VIII is known as Series T-7000 MVP (Maximum Visual Performance) or Diamond Grade NAP (Narrow Angle Performance), depending on the manufacturer, which is Avery Dennison or 3M respectively [2]. Type IX, made by 3M is known as Diamond Grade VIP (Visual Impact Performance) [2]. These materials have the potential to allow the use of unlighted overhead guide signs in the future. Given the availability of these recently introduced materials, the continued lighting of highway signs becomes a questionable practice in terms of energy consumption, environmental impact, and cost to the public. Besides the electrical energy consumed, illuminated signs have costs for initial installation and maintenance of luminaires. These costs may be eliminated with the adoption of the practice of using unlighted overhead guide signs.

Throughout this report, the terms "lighted" (or "illuminated") indicate the external sign luminaires are on, and "unlighted" (or "not illuminated") indicate they are off and all sign illumination comes from the headlight beams of passing traffic.

Several states have already installed unlighted guide signs on some freeways, among them Minnesota, Kentucky, and Texas. Minnesota uses 3M Diamond Grade VIP (Type IX) for sign legends and backgrounds. Kentucky has been using High Intensity (beaded Type III for both legend and background) signs without illumination.

Paul J. Carlson of the Texas Transportation Institute has done a study evaluating Meeker and Associates' Clearview font with unlighted microprismatic retroreflective legend and background signs [3]. This study indicated that nighttime legibility distance of overhead signs increased by an average of 44 ft (13.4 m) or 7.5% if Type IX microprismatic sheeting is used instead of Type III. This can be increased further if a Meeker and Associates Clearview™ font is used instead of Series E(Modified), to an enhancement of 70 ft (21.3 m) or 11.9%. The Texas study only compared signs with uniform materials, i.e. Type III legend on Type III background versus Type IX legend on Type IX background, and did not consider mixed material signs such as Type IX legend on beaded Type III background, which are evaluated in this study.

Zwahlen, Russ, and Vatan conducted a previous study on unlighted overhead guide signs in Ohio [4]. Four different retroreflective overhead sign sheeting combinations, both illuminated by luminaires and automobile low beams ("lighted") and illuminated by

automobile low beams only ("unlighted") were evaluated during nighttime. A field evaluation was conducted on a section of US 30 near Mansfield, Ohio. Four overhead sign bridges with three overhead signs each of the same materials were evaluated when the sign luminaires were on and when they were off. Twelve ODOT evaluators rode in the test loops in groups of 3 in 2002 Dodge Caravans. The main results of the field evaluation indicate that the white Type IX legend on green beaded Type III background sheeting combination received the highest evaluation score (appearance, conspicuity, and legibility), which was slightly higher than that for the Type VII legend on beaded Type III background. The Type IX legend on Type IX background combination received slightly lower evaluation scores and the beaded Type III legend on beaded Type III background combination received significantly lower evaluation scores. In addition to the field evaluation the same four sheeting material combinations were photometrically (luminance and luminance contrast ratio) evaluated under low beam illumination at selected approach distances from 100 ft to 1000 ft using a 1984 Peterbilt Truck, a 2002 Chrysler Town and Country Minivan and a 2002 Toyota Camry. The photometric measurements were made with a ProMetric™ CCD Light and Color Measurement System. The luminance and luminance contrast ratio results indicated that under low beam illumination the Type VII legend on beaded Type III background sheeting material combination provided superior luminances and luminance contrast ratios for approach distances of 400 feet (122 m) or more while the Type IX legend on beaded Type III background sheeting material combination provided superior luminances and luminance contrast ratios for approach distances of less than 400 ft (122 m). The luminances for the signs illuminated with luminaires and the automobile low beam were considerably higher (for Type VII and Type IX legends on beaded Type III backgrounds: 1000 ft: 14cd/m^2 – 30cd/m^2; 600 ft: 17 cd/m^2 – 57cd/m^2; 200 ft: 37cd/m^2-68cd/m^2) when compared to the unlighted sign condition (1000 ft: 1cd/m^2-5cd/m^2; 600ft: 4cd/m^2-11cd/m^2; 200 ft: 2cd/m^2-13cd/m^2) but usually had lower luminance contrast ratios (1000 ft: 2.9-5.2; 600 ft: 4.2-9.4; 200 ft: 7.9-14) than when unlighted (1000 ft: 4-10.8; 600 ft: 4.3-12.2; 200 ft: 2.3-32.4) for Type VII and Type IX legends on beaded Type III backgrounds. Based on the results of the field and photometric evaluation the authors concluded that unlighted overhead signs with either white Type VII or Type IX legends on green beaded Type III backgrounds provided adequate appearance, conspicuity, and legibility without additional external lighting to be implemented without any appreciable detrimental information acquisition or safety effects on the driving public.

Because the age range of the expert panelists in reference [4] was relatively young: 27-48 years, average 38, it was considered necessary to study these same signs in the present study with a panel of older drivers, age 63 and over.

2 OBJECTIVE

The aim of this study is to compare selected signing materials in certain combinations to determine if there is adequate conspicuity, legibility, and appearance to allow ODOT to erect overhead guide signs on freeways without lighting at night, and to provide a recommendation to ODOT based on the results. The material combinations compared are beaded Type III (3M High Intensity) legend on beaded Type III background, , Type VIII (Avery-Dennison Series T-7000 MVP) legend on microprismatic Type III (Avery-Dennison High Intensity) background, Type IX (3M Diamond Grade VIP) legend on Type IX background, Type VII (3M Diamond Grade LDP) legend on beaded Type III background, Type IX legend on beaded Type III background, and lighted beaded Type III legend on beaded Type III background as a control. The evaluation is made using older drivers (age at least 63) riding at night in a van.

3 METHOD

The present study examines lighted and unlighted overhead guide signs made from beaded Type III materials for legend and background and from Type IX materials for legend and background. Three mixed material combinations were also evaluated: Type VII (Diamond Grade LDP) legend on beaded Type III (High Intensity) background, Type VIII (Series T-7000 MVP) on microprismatic Type III background, and Type IX (Diamond Grade VIP) legend on beaded Type III background. Finally, a lighted beaded Type III legend on beaded Type III background sign group was evaluated to compare results with existing lighting practice.

In this report, these material combinations may be abbreviated, such as "Type VII on beaded Type III", or even "VII on III", referring to Type VII legend on beaded Type III background.

For the field evaluation, signs were constructed at the ODOT sign shop using sheeting obtained from the manufacturers. All sign sheeting was manufactured by 3M with the exception of the Type VIII and microprismatic Type III, both manufactured by Avery-Dennison. Each material was used on a separate sign bridge (designated as sign groups A through F). Each sign bridge had three signs, one over the left lane, one over the right lane, and one over the exit lane. These signs were installed on US Route 30 in Mansfield for the panel evaluation. Table 1 lists the six sign groups, displays pictures showing the legends on the signs, and the material types used on the signs.

Table 1. Overhead guide signs and sheeting material combinations used in the older driver panel evaluation in Mansfield.

Sign Group		Signing Material Type	
		Legend	Background
A		III	III
B (lighted)		III	III
C		III (m)	VIII
D		IX	III
E		IX	IX
F		VII	III

Notes:
Legend color: White, Background color: Green
Beaded Type III: High Intensity (beaded)
Microprismatic Type III (m): High Intensity (microprismatic)
Type VII: Diamond Grade LDP
Type VIII: Series T-7000 Maximum Visual Performance
Type IX: Diamond Grade VIP
Technically, these are pictures of the old signs that were replaced with the experimental signs. The pictures do show the correct configuration, logos, and legends for each sign group.

3.1 Panel Evaluation

The six overhead sign groups were installed and evaluated on US Route 30 near Mansfield in central Ohio. The 27.4 mile long evaluation loop is depicted in Figure 1. In the figure, the sign groups are labeled A, B, C, D, E, F, corresponding to the labels used in Table 1, and the locations where the evaluators pulled off the road to safely fill out the forms after viewing a sign group are labeled 1, 2, 3, 4, 5. Location T is the Koogle Road exit that was used to turn around to head in the opposite direction (West) on US Route 30. In order to get a proper approach for all sign groups, it was necessary for the loop to include a subloop between the turn around and Laver Road, where groups A and D were located. Location 1 is where the form was filled out for Sign Groups A and C, Location 2 was where forms were filled out for Sign Group B, Location 3 is where forms were filled out for Sign Group D, Location 4 is where forms were filled out for Sign Group E, and Location 5, The Fairfield Inn parking lot, is where forms were filled out for sign group F. Location 5 was also the starting point of the loop, and also where the Exit Interview forms were completed at the end of the evaluation. The sign groups were located at the following exits: Group A, Laver Road eastbound; Group B, Reed Road westbound; Group C, Reed Road eastbound; Group D, Laver Road westbound; Group E, Springmill Road westbound; and Group F, Trimble Road westbound. These sites were chosen because they had relatively straight and flat approaches of at least 1000 ft (305 m).

Besides the experimental signs, there were five other sign bridges on each half of the loop; all of these were lighted, except one in the westbound direction where one sign of the two was not lighted. There were also two cantilever overhead guide signs in each direction, both lighted. And there were 17 ground-mounted green background guide signs on the shoulder heading East, and 16 heading West, not including "Exit" arrow signs mounted in gores. The order in which this signing appeared in the loop is shown in the schematic diagram of the loop in Figure 2, which is not to scale. A typical sign group (Group A) is depicted in Figure 3; all sign groups included three signs in approximately these positions, as shown previously in Table 1.

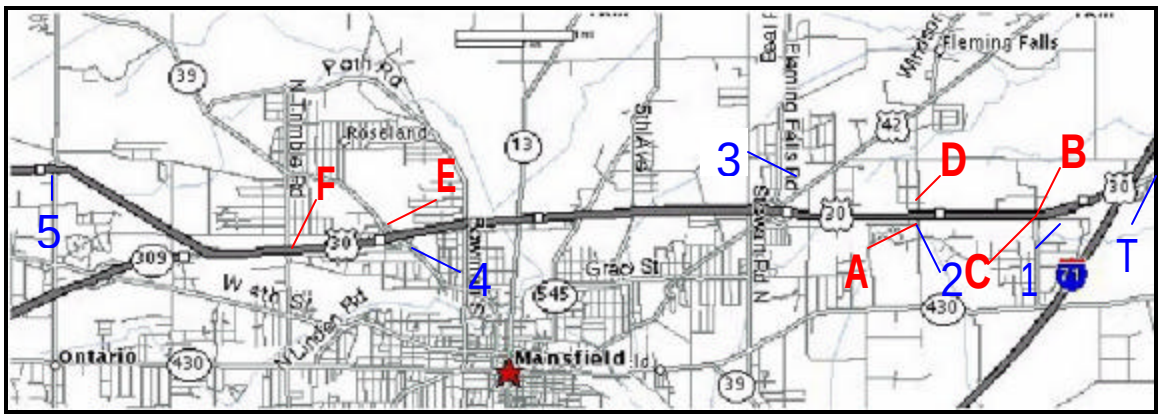

Figure 1. Map of Mansfield showing sign evaluation loop traveled on Route 30. Experimental sign bridges are labeled A, B, C, D, E, F in the order viewed by evaluators. The numerals 1, 2, 3, 4, 5 indicate the locations where the evaluators filled out the sign evaluation forms after viewing a sign group (location 1 was used twice per loop). The letter T indicates the Koogle Road exit used as a turn-around. The loop started and ended at the Fairfield Inn parking lot (position 5) on the West side; at this location the exit interview forms were filled out at the end of the run.

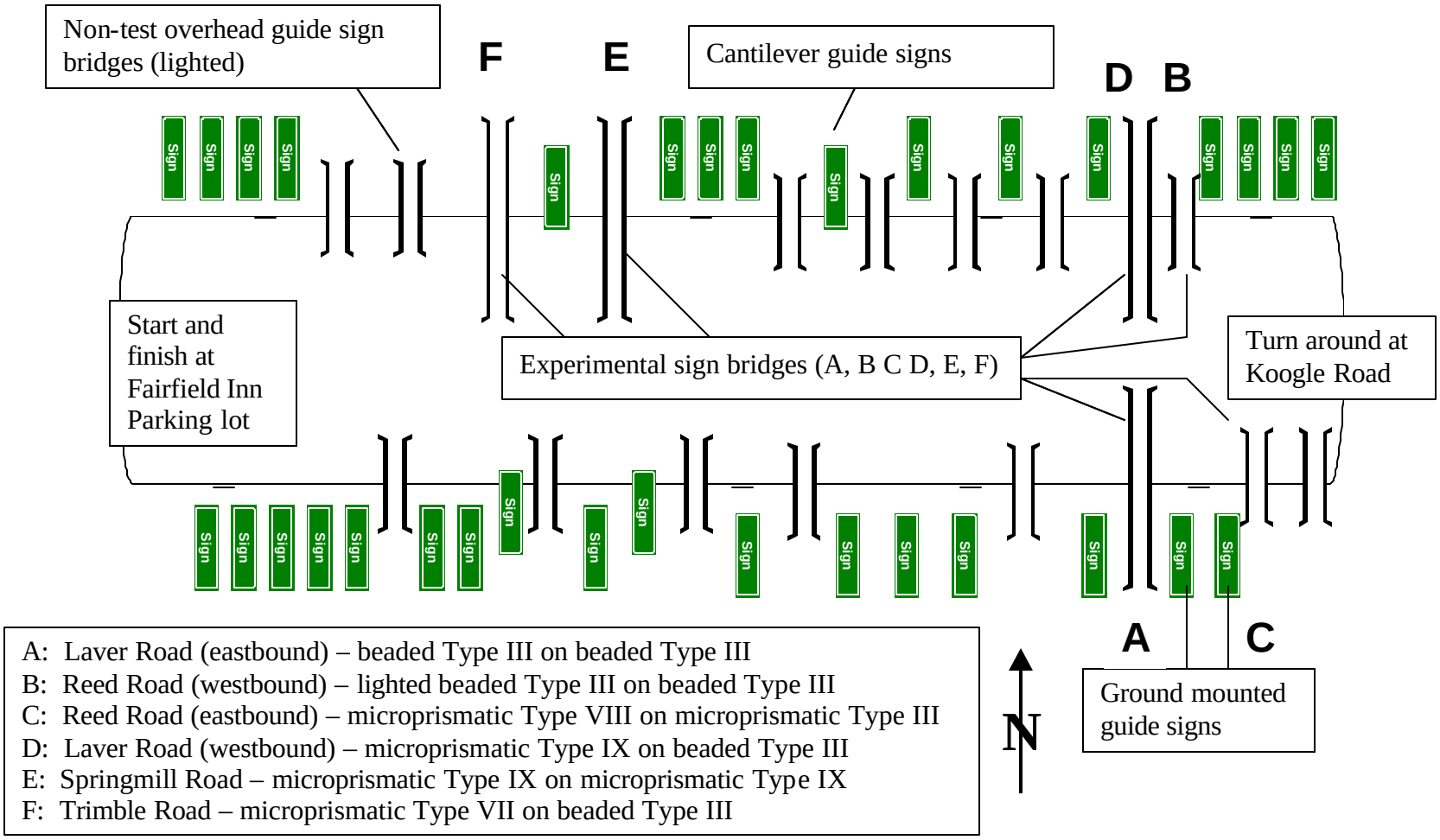

Figure 2. Schematic diagram of loop (not to scale) showing ordering of ground-mounted green background guide signs, isolated ground-mounted overhead guide signs, and existing overhead sign bridges in relation to experimental sign bridges A, B, C, D, E and F.

Figure 3. Sign Group A on Laver Road Westbound before replacement of test signs with identical legends.

Dimensions of the experimental signs installed in Mansfield are averaged in Table 2. These averages are used to determine dimensions of the average sign bridge as viewed on the evaluation loop, drawn in Figure 4 with dimensions.

Table 2. Experimental sign size dimensions, with averages for left, middle, and right signs on bridges.

US 30 Overall Sign Dimensions												
Sign Group	Left Sign				Middle Sign				Right Sign			
	Legend		Width	Height	Legend		Width	Height	Legend		Width	Height
A	30 East Wooster	(in)	144	84	Reed Rd EXIT 1 MILE	(in)	144	72	Laver Rd ↗	(in)	144	72
		(cm)	366	213		(cm)	366	183		(cm)	366	183
B	30 West Mansfield	(in)	156	84	Laver Rd EXIT 1 MILE	(in)	156	72	Reed Rd ↗	(in)	132	72
		(cm)	396	213		(cm)	396	183		(cm)	335.3	183
C	30 East Wooster	(in)	144	84	71 Cleveland Columbus EXIT 1 MILE	(in)	168	144	Reed Rd ↗	(in)	132	72
		(cm)	366	213		(cm)	427	366		(cm)	335.3	183
D	30 West Bucyrus	(in)	144	84	42 Mansfield Ashland EXIT 1¼ MILES	(in)	168	144	Laver Rd ↗	(in)	144	72
		(cm)	366	213		(cm)	427	366		(cm)	366	183
E	Trimble Rd EXIT 1 MILE	(in)	180	72	39 South Springmill St NEXT RIGHT	(in)	216	114	39 North Shelby ↗	(in)	100	84
		(cm)	457	183		(cm)	549	290		(cm)	254	213
F	30 West Crestline Bucyrus	(in)	156	114	309 West Ontario Galion EXIT ¾ MILE	(in)	156	144	Trimble Rd ↗	(in)	168	72
		(cm)	396	290		(cm)	396	366		(cm)	427	183
Average		(in)	154.0	87.0	Average	(in)	168.0	115	Average	(in)	136.7	74.0
		(ft)	12.8	7.3		(ft)	14.0	9.6		(ft)	11.4	6.2
		(cm)	391.2	220.8		(cm)	426.8	292.1		(cm)	341.7	188.0

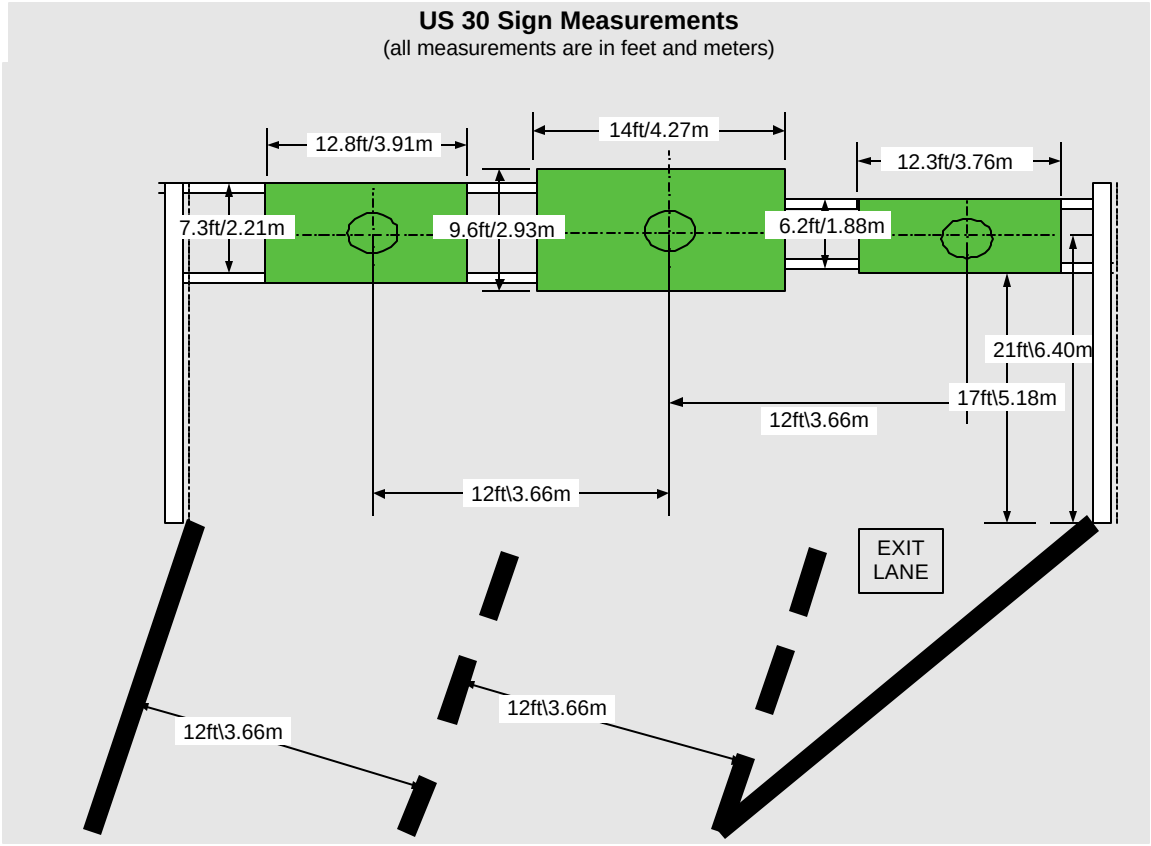

Figure 4. Dimensions for average experimental sign bridge evaluated in Mansfield, based on average sign dimension values in Table 2.

Table 3 summarizes the route taken by the drivers in the loop and the location of critical points expressed as distance around the 28-mile circuit. Critical events include the experimenter notifying evaluators of an approaching experimental sign group, passing the sign, parking to fill out forms, and turning around at Koogle Road. The complete circuit was driven twice, once with the vehicle approaching in the right lane, and once approaching in the left lane.

Table 3. Mileage points indicating locations of events in loop. Mileage is distance traveled from the beginning of the loop. Map Point refers to labels in Figure 1.

Location	Mileage	Dir	Map Point	Event
Fairfield Inn parking lot (off Lexington Springmill Road)	0.0		4	Head East towards sign group A.
Side mounted guide sign	7.4	E		Experimenter tells evaluators that Sign Group A will appear in a few seconds so they can focus attention.
Laver Rd. exit	7.8	E	A	Location of Sign Group A.
Rest Area	9.3	E	1	Evaluators fill out Sign Evaluation Form for Sign Group A.
Koogle Rd. exit	10.1	E	T	Turn around and head West.
				After crossing underpass after turnaround, experimenter tells evaluators sign Group B is approaching.
Reed Rd. exit		W	B	Sign Group B.
Off-track betting parlor parking lot	12.8	W	2	Laver Rd exit. Fill out sign evaluation form for Sign Group B.
		E		After returning to Route 30, now heading eastbound again, experimenter indicates Sign Group C is approaching.
Reed Rd exit		E	C	Sign Group C.
Rest Area	14.9	E	1	Evaluators fill out Sign Evaluation Form for Sign Group C.
Koogle Rd. exit	16.2	E	T	Turn around and head West.
Lodging guide sign	17.8	W		Experimenter tells evaluators that Sign Group D will appear in a few seconds so they can focus attention..
Laver Rd. exit	18.3	W	D	Sign Group D.
Sav-A-Lot food store parking lot off US Route 42	20	W	3	Experimenters take US Route 42 exit and turn north. Fill out Sign Evaluation Form for Sign Group D in parking lot.
Outback Steak House billboard and OSU Mansfield Campus side-mounted guide sign	23.1	W		Experimenter tells evaluators that Sign Group E will appear in a few seconds so they can focus attention.
Springmill Rd exit	23.5	W	E	Sign Group E.
Tammy B's Restaurant parking lot	24.1	W	4	Evaluators take Springmill Rd South exit after bridge. Evaluators fill out Sign Evaluation Form for Sign Group E in parking lot.

Back on Route 30 after Spring Mill Rd exit	24.6	W		Next sign group appears shortly after reentering US Route 30 West. Experimenter tells evaluators that Sign Group F will appear in a few seconds.
Trimble Rd. exit	25.2	W	F	Sign Group F
Lexington Springmill Rd. exit	27.3	W		Evaluators take second exit (Lexington Springmill Rd.) and go south to Fairfield Inn parking lot.
Fairfield Inn parking lot	28	W	5	Evaluators fill out Sign Evaluation form for Sign Group F. Then start next loop or fill out exit interview form.

Evaluations were conducted with all signs unlighted except Sign Group B, which was always lighted. During the first two of the five nights of the evaluation, one of the six luminaires on Sign Group B was dark, but the effect on the results was minimal as all signs had illumination, with the missing light compensated for by the neighboring lights. Results from later in the study were comparable to those at the beginning, further indicating the lighting problem was not a significant issue for the evaluators.

The two evaluators of each team were seated in the passenger seat and center of the middle seat in a 2002 Dodge Caravan provided by Ohio University. After the first loop, the two evaluators traded positions. The driver kept the headlights set to low beams for the sign approaches. The low beam light pattern from the van is shown in Figure 5 and Figure 6. Evaluators were also instructed to not discuss their opinions among themselves.

Figure 5. 2002 Dodge Caravan low beam headlamp pattern reflected on a garage door. Note the sharp vertical cutoff.

Figure 6. Close up view of Chrysler minivan headlamp pattern as seen in Figure 5, but with van closer to garage door.

An ORITE experimenter drove the van, and another experimenter rode on the driver's side of the middle seat. A third experimenter rode in the center of the rear seat. The experimenters would note weather conditions, notify the evaluators when a sign group was approaching so they could focus their attention on it, recorded traffic conditions on the road, handed out and collected the sign evaluation forms at each stop, and gave directions as needed or requested by the panelists.

The evaluations were performed over five nights, Monday through Thursday December 9 through 12, and Monday December 16, 2002, starting at full darkness (about 6:30 PM), and typically continued for about 2.5 hours for both loops. A second pair of evaluators would be taken out after the first pair had returned. The second group would finish shortly before midnight. Before embarking, the evaluators were given their instructions and were allowed to preview the questionnaires so that they would be familiar with the questions being asked and what characteristics of the signs were important. Eyesight examinations to determine the evaluators' visual acuity were also given at this time. The evaluator instructions are reproduced in Appendix A, and the evaluator questionnaires are reproduced in Appendix B and Appendix C. On each loop, the experimenter filled out a form on weather and traffic conditions, shown in Appendix D. Prior to the evaluation, each evaluator filled out a biographical information questionnaire, reproduced in Appendix E.

A Sign Evaluation Form (see Appendix B) was completed by each evaluator after viewing each of the experimental sign groups. Predetermined information including the date, evaluator group, loop number, approach lane and illumination condition were printed on each form to minimize the amount of writing the evaluators had to do. Black and white pictures of the sign groups were also printed on the forms to reinforce which signs were just viewed. Evaluators were asked whether the signs were visible at an adequate distance, whether traffic ahead on the road helped illuminate the signs, whether the signs were legible at an adequate distance, whether the legend had problems with glare or darkness both when first legible and at the last point where the sign was legible, whether the appearance of the sign legend and background were adequate, and whether any of the signs in the group appeared to be different from the others. Evaluators were also asked to list any problems (with traffic or otherwise) and were given a space to add additional comments. On each loop, the experimenter also filled out a report form (see Appendix D) assessing weather and traffic conditions.

An exit interview form (see Appendix C) asked the evaluators to compare the sign groups against each other. Evaluators were asked which sign groups (if any) were adequate in terms of visibility, legibility, and overall appearance. Evaluators were also asked to compare each sign group to side-mounted guide signs in terms of conspicuity, legibility, and appearance. Evaluators were also asked if any of the experimental signs appeared different in terms of conspicuity, legibility, or appearance quality between the two loops. Finally the last sheet was reserved for other comments the evaluators might have. Black and white pictures of the different sign groups (the same as those in Table 1) were reproduced throughout the questionnaire to remind the evaluators which sign group

was which. Evaluators were never told which signing materials were used on each sign group.

Weather conditions during the runs were generally clear. One night was cloudy with some light drizzle at the end of the second group, and another night had light snow and rain that did not appreciably affect visibility. There was some fog towards the end of the last loop on the day with snow. Also, frost affected signs on one of the clear days, but only towards on the second loop of the second group. On the approaches, traffic was generally light – only one vehicle or fewer between the test van and the signs, though occasionally traffic would rise to moderate levels, three or four vehicles between the van and the signs, and once rose to six vehicles between the van and the sign. All sign groups were approached at highway speed, approximately 55 mph (88 kph).

Twenty older driver volunteers were recruited by contacting local senior citizens' organizations and volunteer groups. The advertisement used, showing the toll-free number potential evaluators were to call, is included in Appendix F. Panelists were compensated for their time. All panelists reported that they still frequently drove after dark. Their gender, age, years of driving experience, and corrected visual acuity are chronicled in Table 4. They had an average age of 72.1 years (standard deviation 4.9, range 63-81) and an average of 54.3 years experience driving (standard deviation 8.3, range 35-65). Slightly over half (55%) of the evaluators were male. The average corrected visual acuity was 20/24.9, with the best being 20/20 and the worst being 20/29.

Table 4. Personal characteristics of evaluators. One evaluator did not provide the number of years driving experience.

Evaluator	Group	Gender	Age	Years driving	Corrected Visual acuity
A	1	F	75	59	20/29
B	1	F	74	56	20/25
C	2	M	81	65	20/22
D	2	M	76	60	20/25
E	3	M	70	54	20/25
F	3	M	73	65	20/25
G	4	F	69	60	20/20
H	4	M	71	56	20/25
I	5	F	73	53	20/25
J	5	F	68	50	20/29
K	6	M	75	61	20/22
L	6	F	63	47	20/20
M	7	F	79	35	20/29
N	7	M	79	59	20/29
O	8	F	71	36	20/29
P	8	M	73	57	20/29
Q	9	M	75	59	20/20
R	9	M	66	~50	20/25
S	10	F	65	49	20/20
T	10	M	66	50	20/25
Average			72.1	54.3	20/24.9
Standard Deviation			4.9	8.3	3.4
Minimum			63	35	20/20
Maximum			81	65	20/29

3.2 Observation Angles

Driver position, eye height, and headlamp position information were recorded for all vehicles used at both locations. Data for each evaluator from the second night at the previous study in Mansfield [4], also conducted in a 2002 Dodge Caravan, were measured for the driver's position and the center back seat position. The front passenger is assumed to sit at the same height and distance back from the headlamps, and with a similar offset to the right of the vehicle center instead of the left.
The dimensions for a driver are sketched in Figure 7, and corresponding measurements were made for other occupants or instruments in each vehicle, as appropriate. For a passenger who sits to the right of center, the offset is taken as negative. These and additional data were input into the Ergo2001 program [5] to compute observation angles. The data input to compute observation angles observed in the Mansfield evaluation are shown in Table 5.

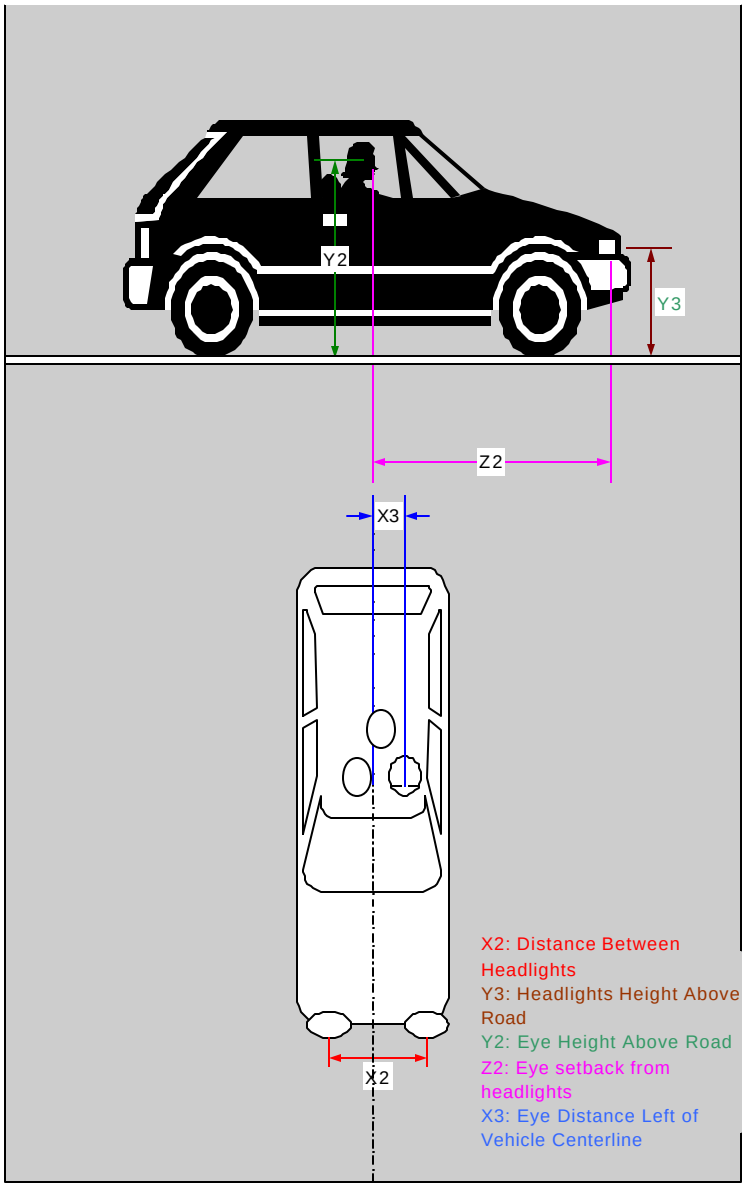

Figure 7. Diagram showing driver and headlamp position measurements made to determine observation angles.

Table 5. Data input to Ergo2001 to determine observation angles for sign evaluation in Mansfield.

Ergo2001 Input Data for US 30 Field Evaluation			
Lane Width			12 ft (3.66 m)
Number of Lanes	3 (Left, Right, Exit), Vehicle in Right Lane		
Road Geometry			Straight
Road Distance From Car to Sign			1000 ft (305 m)
			800 ft (244 m)
			600 ft (183 m)
			400 ft (122 m)
			200 ft (61 m)
			100 ft (30.5 m)
Sign Offset (RIGHT of RIGHT edge of driving lane)			-6 ft (-1.83 m)
Sign Height: Above the Road			21 ft (6.401 m)
Sheeting for the Sign			DG VIP-98
Headlight Type			umtri50e2000
Vehicle Type	2002 Dodge Caravan		
	Driver	Passenger	Back Passenger
Eye Height Above Road	4.78 ft (1.457 m)	4.78 ft (1.457 m)	4.72 ft (1.439 m)
Eye Setback From Headlights	6.1 ft (1.859 m)	6.1 ft (1.859 m)	7.52 ft (2.292 m)
Eye Distance Left of Vehicle Center	1.17 ft (0.357 m)	-1.17 ft (-0.357 m)	0
Distance Between Headlights	4 ft (1.219 m)		
Headlights Height Above Road	2.5 ft (0.762 m)		

3.3 Coefficient of Retroreflection Measurements

An Advanced Retro Technologies ART 920 Reflectometer was used to measure the signs made in the ODOT sign shop. This step was carried out to verify that signing materials met the ASTM standards. All retroreflectometer measurements were performed with an observation angle of 0.2° and an entrance angle of -4°.

The signs were measured in the ODOT sign shop in Columbus before they were assembled and erected in Mansfield. The coefficient of retroreflectivity was measured for each letter plus at least two locations on each arrow and shield to determine the coefficient of retroreflectivity of the legend material. The background material on each sign was measured at between 12 and 24 locations depending on the size of the sign. The same sign material combination was used for all three signs on each of the four sign bridges. Linear dimensions of each sign on each bridge were measured as shown in the example in Figure 8 in inches. Figure 9 shows a typical set of retroreflectometer measurements, with the numbers appearing at the approximate locations as indicated by their placement on the background, and by the lines drawn from the boxes with the numbers to the points measured on the legend. The coefficient of retroreflection was measured for each letter on each legend at least once, as well as at least twice on other legend features such as shields and arrows. Exact dimensions for all of these signs are in Appendix G. Retroreflectometer measurements and locations for all signs are in Appendix H.

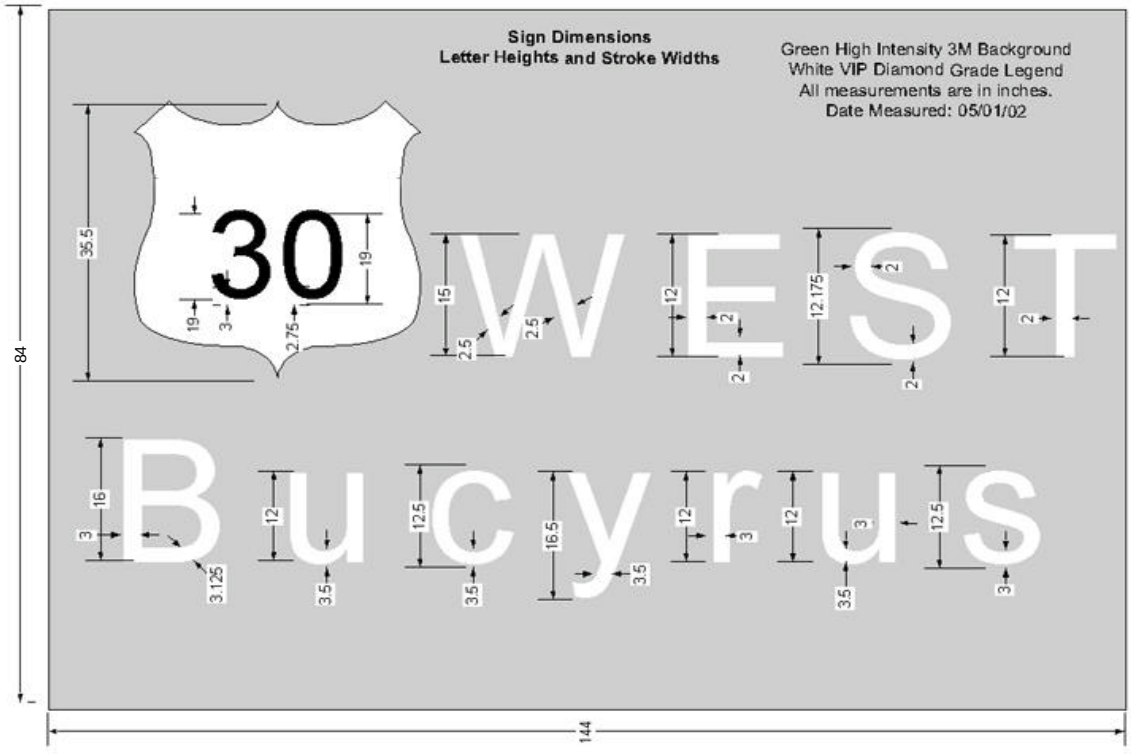

Figure 8. Dimensions in inches of a typical sign installed in Mansfield, showing linear dimensions measured in inches. 1 inch = 2.54 cm.

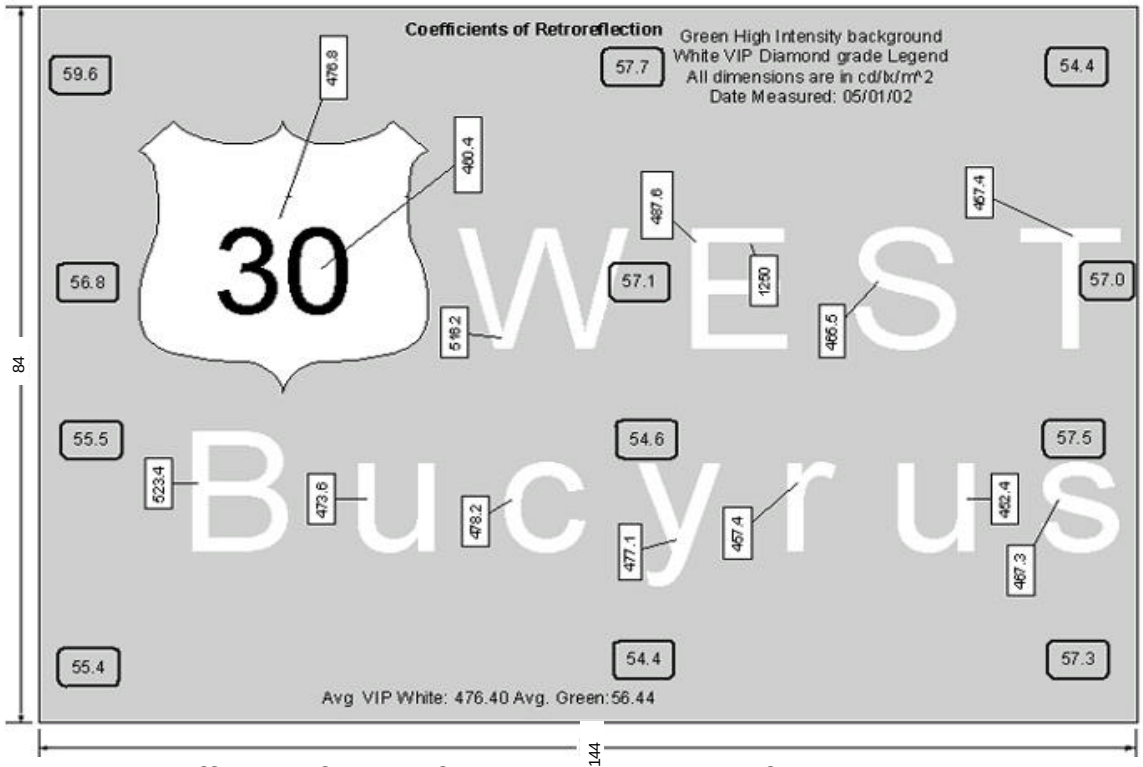

Figure 9. Coefficient of retroreflection measurements of the same sign as shown in Figure 8, indicating locations of retroreflectivity measurement points.

3.4 Photometric Luminance Measurements

Photometric luminance measurements of the signs constructed specifically for this study were taken at the ODOT Sign Shop Complex in Columbus the night of October 21, 2002. The signs were the Type VIII on microrpismatic Type III and beaded Type III on beaded Type III. The beaded Type III on beaded Type III sign was one of the groups that were evaluated with lighting by the older drivers, but here the luminance measurements were made without external sign illumination. A Spectra Pritchard photometer was set up between the front seats of an ODOT-supplied 2002 Dodge Caravan as shown in Figure 10. The vehicle was similar (same make and model) to that used in the evaluation and also similar to that used in the photometric study at 3M conducted as part of a previous research project [4]. The signs were held up by a crane at a typical overhead sign bridge height of 17 ft (5.1 m) as shown in Figure 11. A 24 in (61 cm) square patch made from the same sheet of white legend material used to fabricate the sign was temporarily attached to the sign to facilitate measuring the luminance with the photometer; it can be seen in the figure covering the word "Rd". Traffic cones were placed to mark locations exactly 200 ft (61 m), 400 ft (122 m), 600 ft (183 m), and 800 ft (244 m) along the flat approach directly in front of the sign, corresponding to distances analyzed in the previous study, as shown in Figure 12. Outdoor lighting at the sign shop complex was extinguished while the measurements were being taken. The sign was illuminated only by the Caravan's low beam headlights.

The luminance of the large square patch of white legend material and an open area of the green background was measured with an aperture of 2 minutes and 6 minutes at each distance, except that at 200 ft (61 m), a 20 minute aperture was used instead of the 2 minute one. Also, at 800 feet (244 m), the luminance was not measured with the 6 minute aperture for the beaded Type III on beaded Type III sign, as the aperture was too large to fit in the white square patch.

The legend and background luminance data are presented in Table 6 in foot-lamberts and in Table 7 in cd/m^2. The microprismatic Type III background material is consistently brighter than the beaded Type III material, as expected, but the difference is greatest close up – 3.82 at 200 ft (61 m) but only 1.34 at 800 ft (244 m). The Type VIII legend material is brighter than the beaded Type III legend material, by factors ranging from 3.58 at 200 ft (61 m) to 2.08 at 800 ft (244 m). All four sheeting materials were brightest at 400 ft (122 m). These data were used, along with the photometric data obtained in the previous study, with the program LEGI to determine the signs' legibility.

Figure 10. Pritchard photometer set up inside the 2002 Dodge Caravan. Measurements were actually made at night.

Figure 11. Experimental sign held at a height of 17 ft (5.1 m) by a crane in the ODOT sign shop parking lot. The sign was tethered to prevent movement.

Figure 12. Traffic cones placed at 200 ft, 400 ft, 600 ft and 800 ft to aid in positioning the minivan for measurements.

Table 6. Luminance measurements of unlighted signs in footlamberts for Type III beaded legend on Type III beaded background and Type VIII microprismatic legend on Type III microprismatic background.

Distance feet (m)	Dodge Caravan		
	Luminance (footlambert)	beaded III on beaded III	microprismatic VIII on microprismatic III
200 (61)	L (6 min)	0.372	1.332
	L (20 min)	0.375	1.345
	BG (6 min)	0.099	0.379
	BG (20 min)	0.098	0.374
400 (122)	L (6 min)	0.802	2.713
	L (2 min)	0.790	2.727
	BG (6 min)	0.159	0.471
	BG (2 min)	0.164	0.463
600 (183)	L (6 min)	1.206	2.465
	L (2 min)	1.212	2.556
	BG (6 min)	0.256	0.346
	BG (2 min)	0.260	0.379
800 (244)	L (6 min)		1.183
	L (2 min)	0.594	1.237
	BG (6 min)		0.180
	BG (2 min)	0.131	0.176

Table 7. Luminance measurements at night of unlighted signs in cd/m2 for Type III beaded legend on Type III beaded background and Type VIII microprismatic legend on Type III microprismatic background.

Distances feet (m)	Dodge Caravan		
	Luminance (cd/m^2)	beaded III on beaded III	microprismatic VIII on microprismatic III
200 (61)	L (6 min)	1.274	4.565
	L (20 min)	1.285	4.610
	BG (6 min)	0.341	1.297
	BG (20 min)	0.337	1.283
400 (122)	L (6 min)	2.746	9.296
	L (2 min)	2.707	9.342
	BG (6 min)	0.544	1.615
	BG (2 min)	0.563	1.588
600 (183)	L (6 min)	4.133	8.446
	L (2 min)	4.153	8.757
	BG (6 min)	0.879	1.184
	BG (2 min)	0.890	1.297
800 (244)	L (6 min)		4.054
	L (2 min)	2.035	4.238
	BG (6 min)		0.616
	BG (2 min)	0.450	0.603

4 RESULTS

4.1 Observation Angles

4.1.1 2002 Dodge Caravan used in Mansfield evaluation

Table 8 shows the complete set of observation angles of both evaluators and the driver in the 2002 Dodge Caravan used in the Mansfield sign evaluation as computed by Ergo2001. The following abbreviations are used for observation angles throughout this report: OALH for Observation Angle Left Headlamp, OARH for Observation Angle Right Headlamp, EALH for Entrance Angle Left Headlamp, EARH for Entrance Angle Right Headlamp. EALH and EARH are equal for all three passengers since they depend only on the positioning of the headlamps relative to the sign. EALH and EARH are the same for signs viewed straight on because of the symmetry about the centerline of the geometry. This symmetry is also reflected in the observation angles of the back seat passenger, who was positioned in the center of the vehicle. Because the position of the driver to the left of center is the same as that of the front seat passenger to the right of center, OALH for one equals OARH for the other.

The observation angles for the Dodge Caravan are plotted in Figure 13 for the left headlamp and in Figure 14 for the right. One can see that the highest observation angles from the left headlamp are seen by the front passenger and the lowest by the driver, while for the right headlamp this relationship is reversed. Figure 15 shows the entrance angles for both headlamps, which coincide because of the symmetry about the center of the vehicle.

Table 8. Observation angles for both evaluators and driver in the 2002 Dodge Caravan used in the sign evaluation in Mansfield based on viewing signs straight ahead. Driver data is included for informational purposes.

2002 Dodge Caravan Straight Ahead Analysis					
All angles in degrees					
Driver	Distance	OALH	OARH	EALH	EARH
	1000 ft (305 m)	0.14	0.23	1.07	1.07
	800 ft (244 m)	0.18	0.28	1.33	1.33
	600 ft (183 m)	0.25	0.38	1.78	1.78
	400 ft (122 m)	0.38	0.58	2.66	2.66
	200 ft (61 m)	0.82	1.19	5.32	5.32
	100 ft (30.5 m)	1.86	2.50	10.54	10.54
Passenger	Distance	OALH	OARH	EALH	EARH
	1000 ft (305 m)	0.23	0.14	1.07	1.07
	800 ft (244 m)	0.28	0.18	1.33	1.33
	600 ft (183 m)	0.38	0.25	1.78	1.78
	400 ft (122 m)	0.58	0.38	2.66	2.66
	200 ft (61 m)	1.19	0.82	5.32	5.32
	100 ft (30.5 m)	2.50	1.86	10.54	10.54
Middle Seat Passenger	Distance	OALH	OARH	EALH	EARH
	1000 ft (305 m)	0.18	0.18	1.07	1.07
	800 ft (244 m)	0.22	0.22	1.33	1.33
	600 ft (183 m)	0.30	0.30	1.78	1.78
	400 ft (122 m)	0.46	0.46	2.66	2.66
	200 ft (61 m)	0.98	0.98	5.32	5.32
	100 ft (30.5 m)	2.19	2.19	10.54	10.54

OALH: Observation Angle Left Headlamp
OARH: Observation Angle Right Headlamp
EALH: Entrance Angle Left Headlamp
EARH: Entrance Angle Right Headlamp

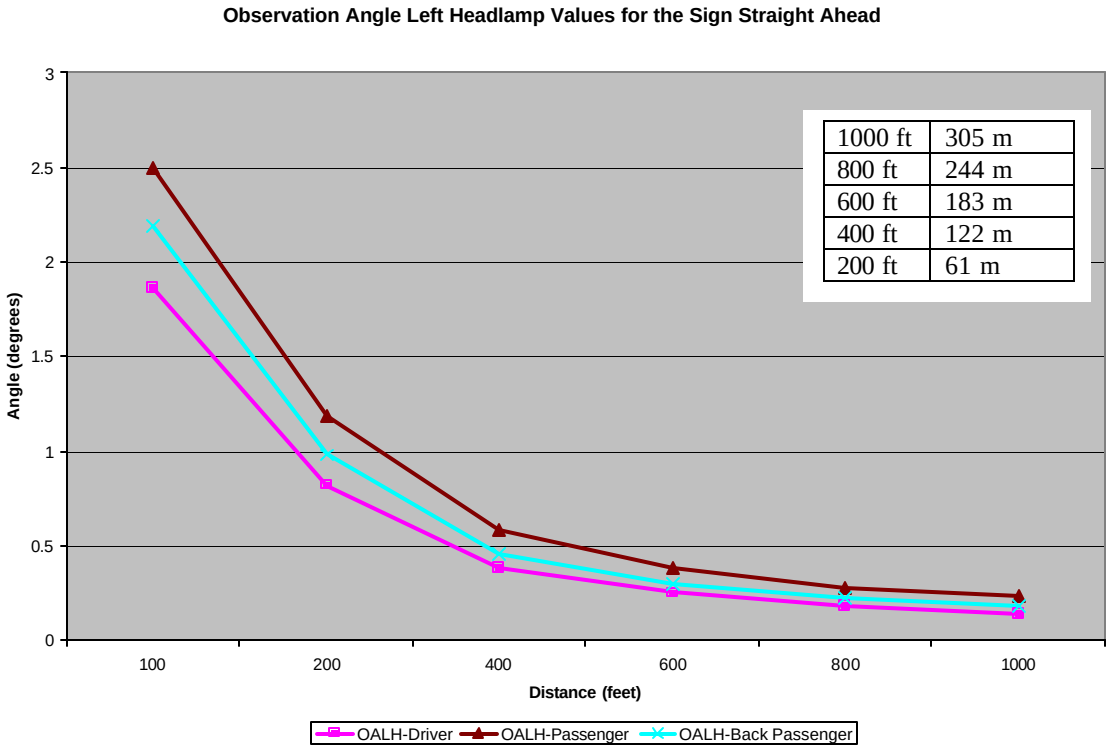

Figure 13. Observation angles for left headlamp (OALH) for evaluators in 2002 Dodge Caravan.

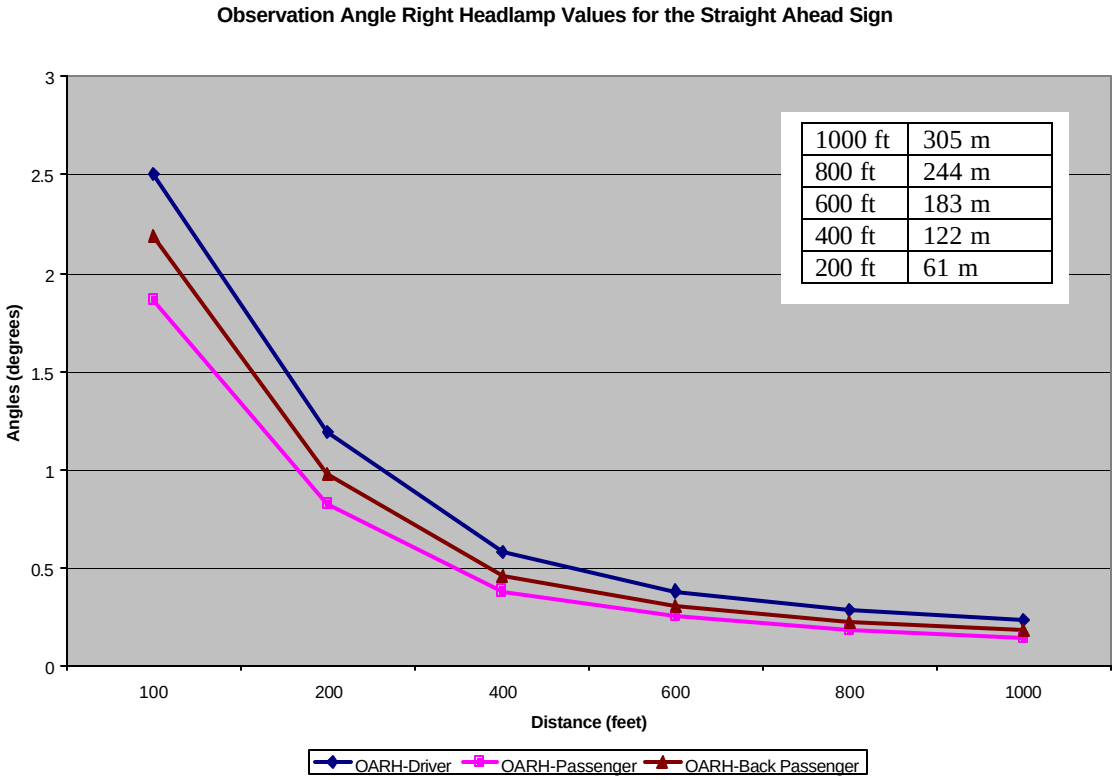

Figure 14. Observation angles for right headlamp (OARH) for evaluators in 2002 Dodge Caravan.

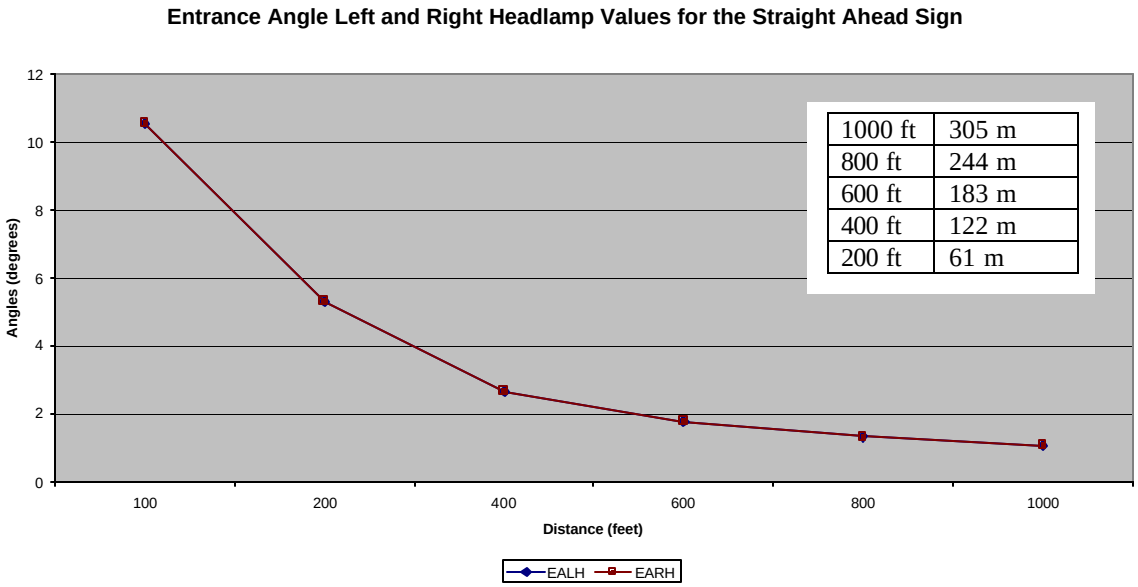

Figure 15. Entrance angles for both headlamps (EALH and EARH) for 2002 Dodge Caravan. These are the same because of the symmetry about the vehicle's center when directly facing the sign.

4.2 Retroreflectometer Measeurements of Signs

The retroreflectometer measurements for all signs are summarized and compared in Table 9. The specific values measured and the location on the sign of each measurement is given in Appendix H. All sign materials used are well above the minimum values for overhead guide signs shown in Table 10 from reference [6].

Table 9. Coefficients of retroreflection (RA) and their ratios for all signs grouped by material. All measurements are in cd/lx/m^2 and were made with an ART 920 retroreflectometer. Sign groups refer to the sign bridges installed in Mansfield as identified in the evaluator forms. Data for each sign in one group is provided, followed by a summary of all signs installed.

Beaded Type III legend on beaded Type III background (Sign Group A)								
Sign Legend Material Type	**Date Measured** **ASTM Type**	**N**	**Average R_A**	**St. Dev.**	**Min**	**Max**	**COV**	**Coefficient of Retroreflection Ratio**
30 East Wooster	05/09/02							
Green High Intensity Background	Type III	12	56.38	1.44	53.6	58.3	0.02554	
White High Intensity Legend	Type III	14	289.92	16.14	264	317.4	0.05567	5.142
Reed Rd Exit 1 Mile	05/09/02							
Green High Intensity Background	Type III	9	56.81	1.08	55.8	58.9	0.01901	
White High Intensity Legend	Type III	15	287.03	9.35	259.9	296.4	0.03257	5.052
Laver Rd with Arrow	05/09/02							
Green High Intensity Background	Type III	9	56.07	1.09	54.3	58.3	0.01944	
White High Intensity Legend	Type III	8	276.32	15.28	250.4	291.3	0.05529	4.928
Summary of beaded Type III on beaded Type III in Mansfield								
Green High Intensity Background	Type III	30	56.42	1.23	53.6	58.9	0.02180	
White High Intensity Legend	Type III	37	285.81	14.17	250.4	317.4	0.04950	5.065
All retroreflectivity measurements are in cd/lx/m^2, measured at 0.2° observation angle –4° entrance angle COV = coefficient of variation = St. Dev. / Average Coefficient of retroreflection ratio: Average R_A white/ Average R_A green								

Table 9 continued

Beaded Type III legend on beaded Type III background (Sign Group B)								
Sign Legend Material Type	**Date Measured** **ASTM Type**	**N**	**Average R_A**	**St. Dev.**	**Min**	**Max**	**COV**	**Coefficient of Retroreflection Ratio**
30 West Mansfield	10/21/02							
Green High Intensity Background	Type III	16	56.43	1.99	53.30	59.50	0.3523	5.56
White High Intensity Legend	Type III	30	313.54	4.93	305.6	323.60	0.01574	
Laver Rd Exit 1 Mile	10/21/02							
Green High Intensity Background	Type III	12	57.07	2.03	54	60.90	0.03559	5.53
White High Intensity Legend	Type III	27	315.73	3.54	308.6	322.40	0.01121	
Reed Rd with arrow	10/21/02							
Green High Intensity Background	Type III	9	56.38	1.35	54.40	58.80	0.02396	5.15
White High Intensity Legend	Type III	14	290.22	4.99	301.9	317.60	0.01718	
Summary for Type III on beaded Type III (lighted) in Mansfield								
Green High Intensity Background	Type III	37	56.62	1.85	53.30	60.90	0.03261	5.54
White High Intensity Legend	Type III	71	313.67	4.88	301.9	323.60	0.01554	
All retroreflectivity measurements are in cd/lx/m^2, measured at 0.2° observation angle –4° entrance angle COV = coefficient of variation = St. Dev. / Average Coefficient of retroreflection ratio: Average R_A white/ Average R_A green								

Table 9 continued.

Type VIII legend on microprismatic Type III background (Sign Group C)								
Sign Legend Material Type	**Date Measured** / **ASTM Type**	**N**	**Average R_A**	**St. Dev.**	**Min**	**Max**	**COV**	**Coefficient of Retroreflection Ratio**
30 East Wooster	10/21/02							
Green High Intensity Background	Type IIIm	12	118.99	10.06	99.5	133.9	0.08454	7.45
White Series T-7000 MVP Legend	Type VIII	27	885.92	41.06	818.0	964	0.04635	
71 Cleveland Columbus Exit 1 Mile	10/21/02							
Green High Intensity Background	Type IIIm	24	117.52	10.89	104.3	138.3	0.09271	7.57
White Series T-7000 MVP Legend	Type VIII	46	889.31	68.84	716.2	1031.5	0.07741	
Reed Rd with arrow	10/21/02							
Green High Intensity Background	Type IIIm	9	119.17	12.36	101.2	142.5	0.1037	7.63
White Series T-7000 MVP Legend	Type VIII	10	908.66	48.59	833.2	998.8	0.05348	
Summary for Type IX on beaded Type III in Mansfield								
Green High Intensity Background	Type IIIm	45	118.24	10.76	99.50	142.50	0.09098	7.53
White Series T-7000 MVP Legend	Type VIII	83	890.54	58.67	716.2	1031.5	0.06588	
All retroreflectivity measurements are in cd/lx/m^2, measured at 0.2° observation angle –4° entrance angle								
COV = coefficient of variation = St. Dev. / Average								
Coefficient of retroreflection ratio: Average R_A white/ Average R_A green								

Table 9 continued.

Type IX legend on beaded Type III background (Sign Group D)								
Sign Legend Material Type	**Date Measured** **ASTM Type**	**N**	**Average R_A**	**St. Dev.**	**Min**	**Max**	**COV**	**Coefficient of Retroreflection Ratio**
30 West Bucyrus	05/01/02							
Green High Intensity Background	Type III	12	56.44	1.59	54.4	59.6	0.02817	
White VIP Diamond Grade Legend	Type IX	13	476.4	21.76	452.4	523.4	0.04567	8.440
42 Mansfield Ashland Exit 1¼ Miles	05/09/02							
Green High Intensity Background	Type III	24	56.85	2.01	53	61.2	0.03535	
White VIP Diamond Grade Legend	Type IX	32	435.2	22.43	393.4	493.3	0.05150	7.655
Laver Rd with arrow	05/01/02							
Green High Intensity Background	Type III	9	57.88	1.319	56	59.9	0.02278	
White VIP Diamond Grade Legend	Type IX	11	469.36	40.43	383	515	0.08613	8.109
Summary for Type IX on beaded Type III in Mansfield								
Green High Intensity Background	Type III	45	56.95	1.82	53	61.2	0.03195	
White VIP Diamond Grade Legend	Type IX	56	451.47	32.39	383	523.4	0.07170	7.927
All retroreflectivity measurements are in cd/lx/m^2, measured at 0.2° observation angle –4° entrance angle COV = coefficient of variation = St. Dev. / Average Coefficient of retroreflection ratio: Average R_A white/ Average R_A green								

Table 9 continued

Type IX legend on Type IX background (Sign Group E)								
Sign Legend Material Type	**Date Measured** **ASTM Type**		**N**	**Average R_A**	**St. Dev.**	**Min**	**Max**	**COV**	**Coefficient of Retroreflection Ratio**
Trimble Road Exit 1 Mile		05/08/02							
Green VIP Diamond Grade Background		Type IX	12	93.49	3.48	86.4	97.8	0.03722	
White VIP Diamond Grade Legend		Type IX	16	421.76	42.12	313.6	465.8	0.09986	4.511
39 South Springmill St		05/08/02							
Green VIP Diamond Grade Background		Type IX	20	93.05	3.78	88.1	101.2	0.04062	
White VIP Diamond Grade Legend		Type IX	29	452.169	20.64	419.6	505.5	0.04564	4.859
39 North Shelby		05/08/02							
Green VIP Diamond Grade Background		Type IX	12	91.08	2.50	88	97.6	0.02744	
White VIP Diamond Grade Legend		Type IX	16	451.92	17.39	433.2	493.2	0.03840	4.961
Summary for Type IX on Type IX in Mansfield									
Green VIP Diamond Grade Background		Type IX	44	92.63	3.46	86.4	101.2	0.03730	
White VIP Diamond Grade Legend		Type IX	61	444.12	29.98	313.6	505.5	0.06750	4.79
All retroreflectivity measurements are in cd/lx/m^2, measured at 0.2° observation angle –4° entrance angle COV = coefficient of variation = St. Dev. / Average Coefficient of retroreflection ratio: Average R_A white/ Average R_A green									

Table 9 continued

Type VII legend on beaded Type III background (Sign Group F)								
Sign Legend Material Type	**Date Measured** **ASTM Type**	**N**	**Average R_A**	**St. Dev.**	**Min**	**Max**	**COV**	**Coefficient of Retroreflection Ratio**
30 West Crestline Bucyrus	05/01/02 05/08/02							
Green High Intensity 3M Background	Type III	12	57.21	1.29	55.4	59.6	0.02254	
White LDP Diamond Grade Legend	Type VII	27	1180.08	94.99	873.5	1293	0.08049	20.62
309 West Ontario Galion Exit 3/4 Mile	05/01/02 05/08/02							
Green High Intensity 3M Background	Type III	13	56.26	1.07	54.7	58.3	0.01901	
White LDP Diamond Grade Legend	Type VII	38	1121.61	100.37	827.9	1293.4	0.08948	19.93
Trimble Rd with Arrow	05/09/02							
Green High Intensity Background	Type III	16	56.40	1.69	53.2	59.1	0.02996	
White LDP Diamond Grade Legend	Type VII	11	1121.23	63.60	1015.9	1205	0.05672	19.87
Summary for Type VII on beaded Type III in Mansfield								
Green High Intensity Background	Type III	41	56.59	1.43	53.2	59.6	0.02520	
White LDP Diamond Grade Legend	Type VII	76	1142.33	97.13	827.9	1293.4	0.08500	20.18
All retroreflectivity measurements are in cd/lx/m^2, measured at 0.2° observation angle –4° entrance angle COV = coefficient of variation = St. Dev. / Average Coefficient of retroreflection ratio: Average R_A white/ Average R_A green								

Table 10. Minimum retroreflectivity recommendations for overhead guide sign materials from reference [6]. Values are for observation angle of 0.2° and entrance angle of -4°

Type of Sign	Speed (mph)	Lateral Position	Color	Minimum Retroreflectivity (cd/lux/m^2) for Specific ASTM Retroreflective Signing Material					
				I	II	III	VII	VIII	IX
Overhead Guide Signs	Not Applicable	Not Applicable	White	Do not use		120	130	100	85
			Green	15		20	20	15	15
Post-Mounted Street Name Signs	≥ 35	Right side	White	50			70	55	25
			Green	10			10	10	5
		Left side	White	Do not use		155	180	140	100
			Green	Do not use		25	25	20	20
	< 35	Right side	White	15			45	30	10
			Green	5			5	5	5
		Left side	White	30			65	50	15
			Green	5			10	10	5
Overhead Street Name Signs*	≥ 40	Not Applicable	White	50			65	45	40
			Green	10			10	10	10
	< 40		White	10			15	15	10
			Green	5			5	5	5

Note: * Includes street name signs mounted on a mast arm or span wire.

4.3 Legibility Analysis With Ohio University's LEGI Software Program

4.3.1 Description of the LEGI Program

The Ohio University Detection and Legibility Analysis Program LEGI [7] is based on Blackwell's 1946 [8] study. Blackwell's contrast threshold data are the most reliable available in legibility studies and consist of about 435,000 observations. Blackwell conducted his experiments using circular stimuli of various sizes ranging from 0.6 to 360 minutes in angular diameter. Since Blackwell's data is based on the detection of the presence of the circular targets, Guth and McNelis in the late 1960s [9, 10] conducted two consecutive studies in which the objective was to compare threshold data for circular targets with similar data for a variety of different objects. Based on their work, the stroke width is used instead of the character dimension to obtain legibility threshold of a symbol or a letter.

LEGI does not consider the glare effect that may be caused by high luminance values (greater than 100 cd/m^2). Since the highest luminance value obtained in this study was 78 cd/m^2 (at 200 ft or 61 m for lighted overhead signs), no practically significant legend glare effect would be expected.

For an alphanumerical legibility analysis, LEGI requires as input a subset of the observation conditions shown in Figure 16**,** which may include background luminance (cd/m^2), target luminance (cd/m^2), target distance (m), observation time (s), observer age (years), Z score, letter height (m), stroke width (m), stroke width to height ratio (SW/H), and a field factor to account for the change from ideal laboratory and observer conditions to real world conditions. The luminance data used included data collected specifically for this study for Type VIII on microprismatic Type III and beaded Type III on beaded Type III, and data collected from a previous study [4] for Type VII on beaded Type III and Type IX on beaded Type III. The LEGI outputs, as shown in Figure 17 include a summary of the input observation conditions, including those not specified in the input screen, plus visual angle (min), actual contrast, actual contrast ratio, actual modulation contrast, SW/H (included in the result area rather than under observation condition), field factor (again in results rather than observation condition), contrast threshold, and multiples of threshold contrast (MOT Contrast). Finally, LEGI determines whether the target analyzed is legible or illegible ("Conclusion"). An MOT contrast value of 1.00 represents the borderline between legible and illegible; a higher MOT contrast value would indicate a legible target. MOT contrast values greater than 10 indicate that the legend is highly legible and all visual details highly distinct.

4.3.2 Input Parameters for LEGI

Driver age is one of the most important factors in legibility calculations, for an older driver, a higher contrast or a larger sign legend or symbol size is required. The observer age was assumed to be 72 years for the LEGI calculations in this study, since this was the average age of the evaluators in this study. Exposure time is another factor that affects the contrast threshold. For shorter viewing or exposure time of the target, a higher threshold

contrast is required. In this study, exposure time (observation time) is assumed to be 2 seconds. The field factor was introduced and utilized by Blackwell in 1959 [11] to interpret the laboratory data for practical problems since the laboratory data were not directly applicable to field measurements. The target distances used in this study were 200 ft (61 m), 400 ft (121.9 m), 600 ft (182.9 m) and 1000 ft (305 m), which are the same as those used in the previous study by the same authors [4].

Other LEGI input for this analysis includes background and target luminance, target distance, 95% level Z score (1.645), lower case letter height (12 inches, 0.3048 m), stroke width (3 inches, 0.0762 m; SW/H 0.25; based on the average lower case letter height and stroke width of the letters in the legends of the overhead guide signs used in this study), and a field factor (4.5). For this analysis a 2 second exposure time was assumed and a field factor value of 4.5 was determined by a trial and error process with the criterion that the lower case letters in the legend "Dover" for the Type IX on Type IX sign was at the threshold of legibility at 600 ft (182.88 m). The same field factor is utilized in this study in order to make the results of this study comparable to the previous study.

4.3.3 Determination of Field Factor for Landolt Ring Target in LEGI

In the previous study [4], the field factor was determined as follows. Based on field observations at 3M's Chemolite test site, it was determined that an average 25 year old can read the "Dover" legend on the overhead guide signs at a distance of almost 600 ft (183 m) at night about 95% of the time. In order to find an appropriate field factor, all sign types were analyzed using the LEGI software program simulating the 2002 Toyota Camry Sedan used in the photometric evaluation. A trial and error method was used to find the field factor that for a 2 second exposure time would indicate the observer was at the threshold of legibility for reading the lowercase letters in the "Dover" legend of most signs at 600 ft (183 m), i.e. such that MOT contrast was at or close to 1. Results from the field factor determination with LEGI are shown in Table 11 below. A field factor of 4.5 with an exposure time of 2 seconds makes all the signs except the High Intensity (beaded Type III on beaded Type III) legible at 600 ft (183 m).

4.3.4 Legibility Determination using LEGI

For this study, a 2002 Dodge Caravan was utilized during the luminance measurements and only unlighted Type III beaded legend on Type III beaded background and unlighted Type VIII legend on Type III microprismatic background signs were measured. The measurements are presented in Table 12. The luminance values for unlighted Type IX legend on Type IX background signs and unlighted Type VII legend on Type III beaded background signs presented in Table 12 were measured in the previous study from a 2002 Chrysler Town and County Minivan. Due to the weather and time limitations in the previous study, we were not able to collect data for lighted Type III beaded legend on Type III beaded background sign and unlighted Type IX legend on Type III beaded background sign. Also, data were collected only at distances of 200 ft (61 m), 600 ft (183 m), and 1000 ft (305 m). Especially missing are any data for Type IX on Type IX, and

also for a lighted (beaded Type III on beaded Type III) sign group, which would have served as a useful benchmark to the unlighted signs.

The Multiple of Threshold (MOT) contrasts are plotted in Figure 18. Since some sign combinations and distances were not measured, it is impossible to make many conclusions based on LEGI results. However, it is clear that for a 72-year-old driver all the measured sign combinations are illegible at 600 ft. Measurements at 400 ft (122 m) would be very helpful to determine if the Type IX on beaded Type III and Type VII on beaded Type III combinations would perform as well or better than the two measured combinations; this was the case at 200 ft (61 m).

Contrast thresholds determined by LEGI for the signing material combinations (legend on background) are given in Figure 19.

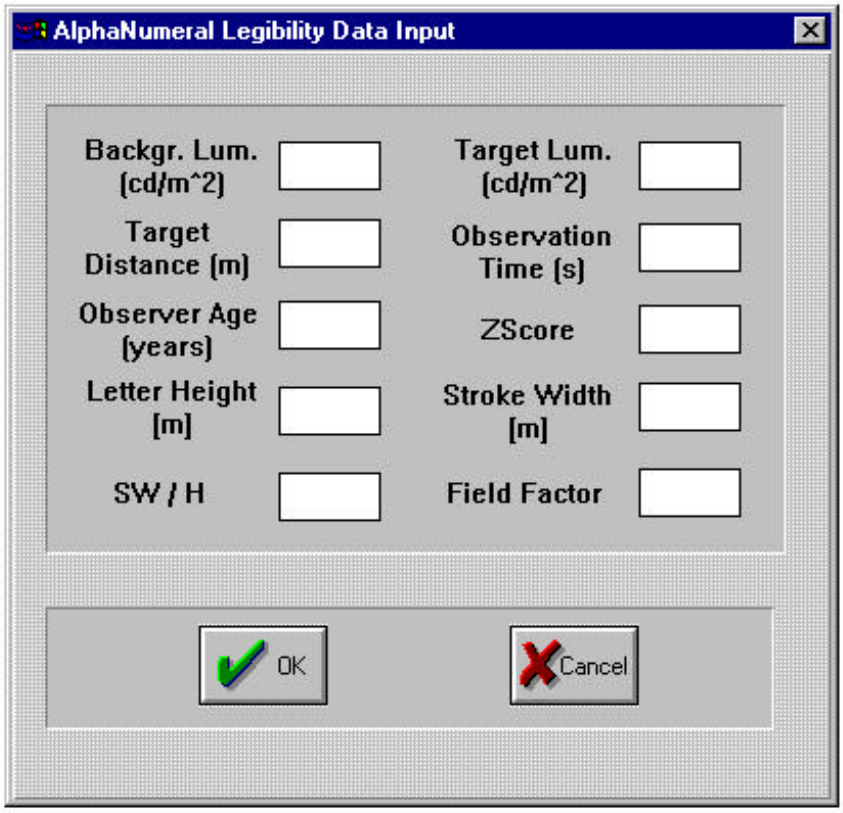

Figure 16. LEGI alphanumerical legibility analysis input window.

```
Observation Condition:

Target Luminance         :    19.530    [cd/m^2]
Background Luminance     :     1.440    [cd/m^2]
Age                           :     25  [years]
Exposure time       :     2.000    [sec]
ZScore              :     1.645
Polarity            :    Positive
Target Distance (m)      :    121.900   [m]
Font Height (m)          :    0.316667  [m]
Stroke Width (m)         :    0.076000  [m]


Result:

Visual Angle        :    2.143304  [min]
Actual Contrast          :    12.562500
Actual Contrast Ratio    :    13.562500
Actual Modulation Contrast    :    0.862661
Ratio of SW and H (SW / H)    :    0.240000

Blackwell 1946 partIII

Field Factor        :    4.500000
Contrast Threshold       :    1.767152
MOT (Contrast)                :    7.108897

Conclusion          :    Legible!
```

Figure 17. Typical LEGI output.

Table 11. Determination of field factor and exposure time in LEGI software program for legibility of test signs at night at a distance of 600 ft (182.9 m).

Distance 600 ft (182.9 m)	Luminaires Off				
	Exposure Time (s)	Field Factor	M.O.T. Contrast	Conclusion	
Type IX on beaded Type III	2	7	0.73	**Illegible**	
	2	6	0.85	**Illegible**	
	2	5.5	0.93	**Illegible**	
	2	5.25	0.97	**Illegible**	
	2	**5**	**1.02**	**Legible**	
	0.5	5	0.86	**Illegible**	
	0.5	4.5	0.96	**Illegible**	
	0.5	**4.25**	**1.02**	**Legible**	
	0.5	4	1.08	**Legible**	
Type VII on beaded Type III	**2**	**10**	**1**	**Legible**	
	2	9	1.11	**Legible**	
	2	8	1.25	**Legible**	
	0.5	10	0.85	**Illegible**	
	0.5	9	0.94	**Illegible**	
	0.5	**8.5**	**1**	**Legible**	
	0.5	8	1.06	**Legible**	
beaded Type III on beaded Type III	2	5	0.48	**Illegible**	
	2	3	0.81	**Illegible**	
	2	2.5	0.97	**Illegible**	
	2	**2.25**	**1.08**	**Legible**	
	2	2	1.21	**Legible**	
	0.5	5	0.41	**Illegible**	
	0.5	3	0.68	**Illegible**	
	0.5	2.25	0.91	**Illegible**	
	0.5	**2**	**1.03**	**Legible**	
Type IX on Type IX	2	5	0.91	**Illegible**	
	2	4.75	0.96	**Illegible**	
	2	**4.5**	**1.01**	**Legible**	**←selected values**
	0.5	5	0.77	**Illegible**	
	0.5	4	0.96	**Illegible**	
	0.5	**3.75**	**1.03**	**Legible**	
	0.5	3.5	1.1	**Legible**	

Observation Conditions	
Age	25
Z score	1.645 (95%)
Polarity	Positive
Font Height	12.5" (0.3175 m)
Stroke Width	3" (0.0762 m)
Ratio SW/H	0.24
Vehicle	2002 Toyota Camry

Abbreviations	
V. A. (min)	Visual Angle
A.C.R.	Actual Contrast Ratio
A.M.C.	Actual Modulation Contrast
C.T.	Contrast Threshold
Conc.	Conclusion
E. T.	Exposure Time (observation angle)

Table 12. LEGI results for 2002 Chrysler Town and County (used in the previous study) or 2002 Dodge Caravan with all signs tested at all distances tested. The computations are for a 72-year old driver, 2 s exposure time, positive polarity, 95% level Z 1.645, font height 12" (0.3048 m), stroke width 3" (0.0762 m), SW/H ratio 0.25, Field Factor 4.5.

Distance	Sign Type	Lum.	Legend	Background	V.A.	A.C.	A.C.R.	A.M.C.	C.T.	MOT	Conclusion
200 ft (61 m)	Type III (beaded) on Type III (beaded)	Off	1.274	0.341	4.29	2.73	3.73	0.57	2.22	1.23	Legible
	Type III (beaded) on Type III (beaded)	On									
	Type VIII on Type III (microprismatic)	Off	4.565	1.297	4.29	2.51	3.51	0.55	1.11	2.25	Legible
	Type IX on Type III (beaded)	Off	5.69	0.24	4.29	22.7	23.7	0.91	2.76	8.2	Legible
	Type IX on Type IX	Off									
	Type VII on Type III (beaded)	Off	2.28	0.21	4.29	9.9	10.9	0.83	3.01	3.27	Legible
400 ft (122 m)	Type III (beaded) on Type III (beaded)	Off	2.746	0.544	2.14	4.04	5.04	0.66	7.32	0.55	Illegible
	Type III (beaded) on Type III (beaded)	On									
	Type VIII on Type III (microprismatic)	Off	9.296	1.297	2.14	6.16	7.16	0.75	4.73	1.3	Legible
	Type IX on Type III (beaded)	Off									
	Type IX on Type IX	Off									
	Type VII on Type III (beaded)	Off									
600 ft (183 m)	Type III (beaded) on Type III (beaded)	Off	4.133	0.879	1.42	3.7	4.7	0.64	13.42	0.27	Illegible
	Type III (beaded) on Type III (beaded)	On									
	Type VIII on Type III (microprismatic)	Off	8.446	1.184	1.42	6.13	7.13	0.75	11.6	0.52	Illegible
	Type IX on Type III (beaded)	Off	4.19	0.95	1.42	3.41	4.41	0.63	12.91	0.26	Illegible
	Type IX on Type IX	Off									
	Type VII on Type III (beaded)	Off	5.7	0.77	1.42	6.4	7.4	0.76	14.35	0.44	Illegible
800 ft (244 m)	Type III (beaded) on Type III (beaded)	Off	2.035	0.45	1.07	3.52	4.52	0.63	33.96	0.1	Illegible
	Type III (beaded) on Type III (beaded)	On									
	Type VIII on Type III (microprismatic)	Off	4.054	0.616	1.07	5.58	6.58	0.73	28.57	0.19	Illegible
	Type IX on Type III (beaded)	Off									
	Type IX on Type IX	Off									
	Type VII on Type III (beaded)	Off									

Table 12 continued.

1000 ft (305 m)	Type III (beaded) on Type III (beaded)	Off									
	Type III (beaded) on Type III (beaded)	On									
	Type VIII on Type III (microprismatic)	Off									
	Type IX on Type III (beaded)	Off	1.98	0.69	0.85	1.86	2.86	0.48	40.55	0.04	Illegible
	Type IX on Type IX	Off									
	Type VII on Type III (beaded)	Off	3.52	0.59	0.85	4.96	5.96	0.71	44.06	0.11	Illegible
V.A.	Minimum Visual Angle	A.M.C.	Actual Modulation Contrast						No data Available		
A.C.	Actual Contrast	C.T.	Contrast Threshold								
A.C.R.	Actual Contrast Ratio	MOT	Multiples of Threshold Contrast (MOT Contrast)								

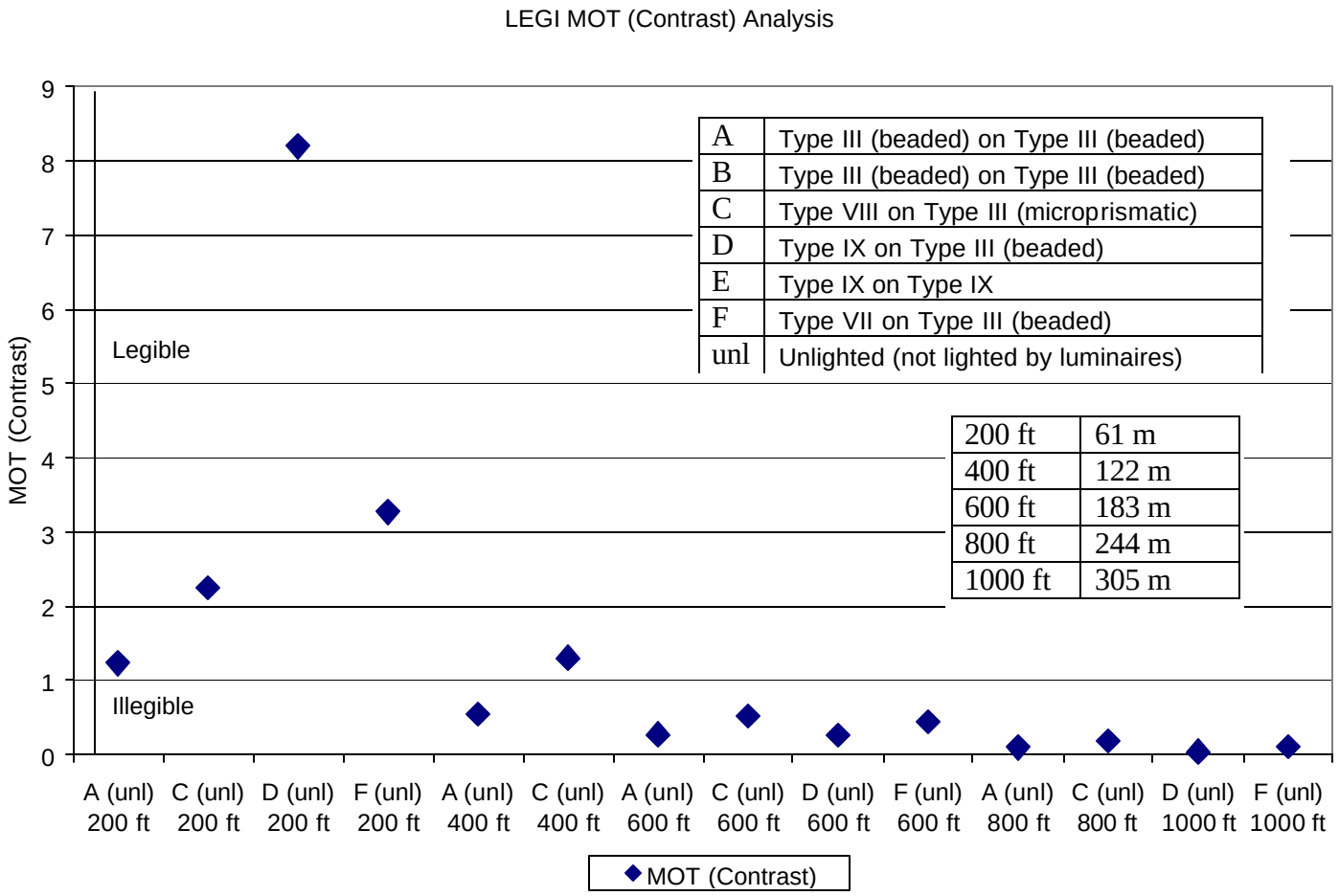

Figure 18. LEGI Multiple of Threshold (MOT) contrast results for 2002 Chrysler Town and County (used in the previous study) or 2002 Dodge Caravan with all signs tested at all distances tested. The computations are for a 72-year old driver, 2 s exposure time, positive polarity, 95% level Z 1.645, font height 12" (0.3048 m), stroke width 3" (0.0762 m), SW/H ratio 0.25, Field Factor 4.5. If the sign type is not listed in the x axis, this means that there are no data available.

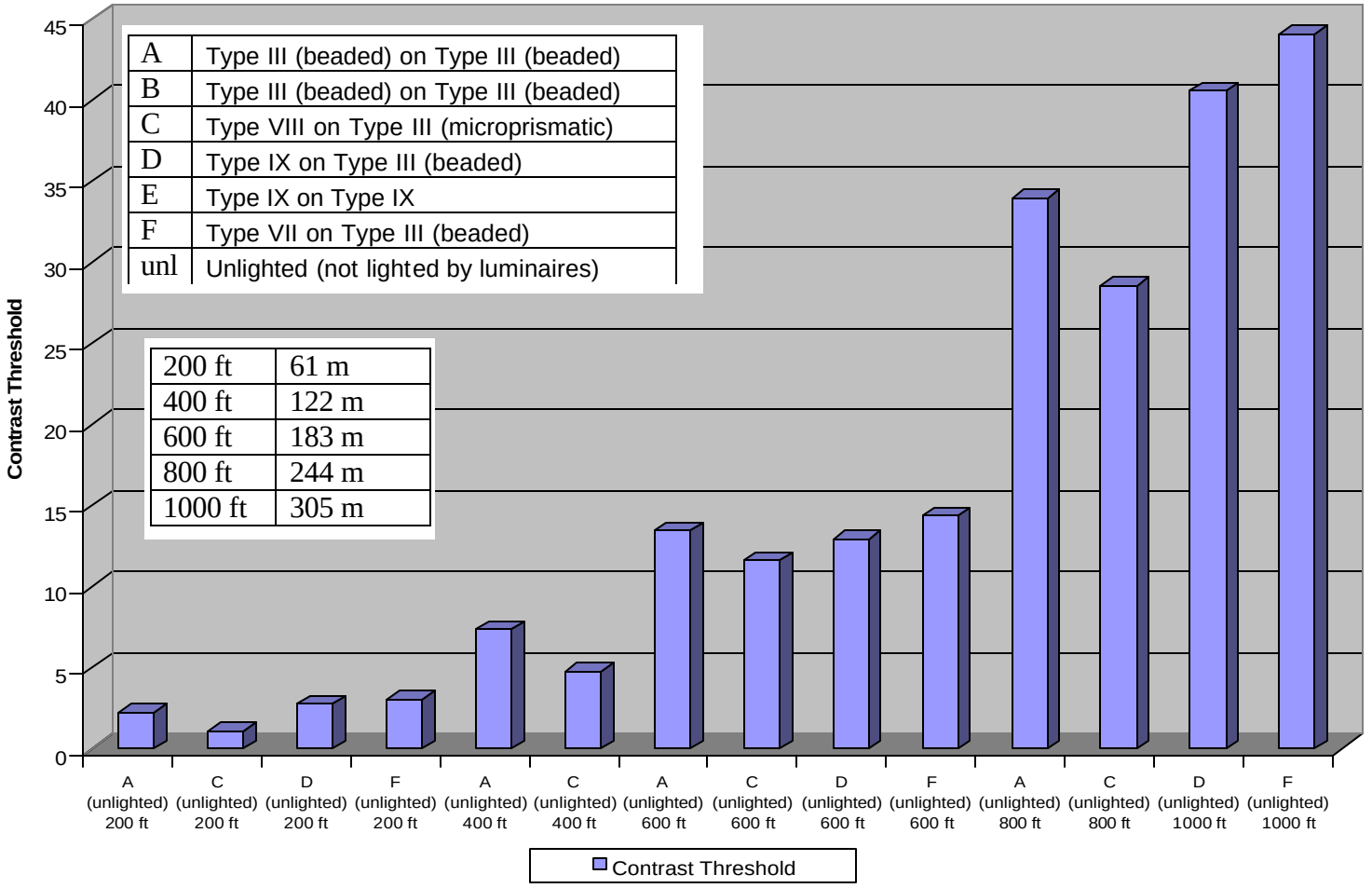

Figure 19. LEGI contrast threshold results for 2002 Chrysler Town and County (used in the previous study) or 2002 Dodge Caravan with all signs tested at all distances tested. The computations are for a 72-year old driver, 2 s exposure time, positive polarity, 95% level Z 1.645, font height 12" (0.3048 m), stroke width 3" (0.0762 m), SW/H ratio 0.25, Field Factor 4.5. If the sign type is not listed in the x axis, this means that there are no data available.

4.4 Panel Evaluation Results

4.4.1 Sign Evaluation Forms

Responses to the Sign Evaluation Form are given in this section. They are given for each question in a sequence of graphs. The responses for all 40 evaluations by the 20 panelists are shown in the first graph, followed by separate graphs for male and female evaluators, then for front seat and back seat positions of evaluators, and finally for right versus left lane approaches.

4.4.1.1 Visibility and Conspicuity (Question 1)

The first question pertained to conspicuity, and asked if the signs were visible during the approach. Responses allowed included whether the sign was visible at a more than adequate distance ahead, at an adequate distance ahead, or only at an inadequate distance ahead. Responses for all signs are shown in Figure 20. The responses "at an adequate distance ahead" and "at a more than adequate distance ahead" are combined. The overwhelming majority of evaluators, indicated that the unlighted signs were visible at an at least adequate distance ahead (Type VII on beaded Type III, 97.5%; Type IX on Type IX, 95%; Type VIII on microprismatic Type III, 92.5%; beaded Type III on beaded Type III lighted , 92.5%, Type IX on beaded Type III 85%, and beaded Type III on beaded Type III unlighted 77.5%). This was true even for the unlighted High Intensity sign group (beaded Type III legend and background), which 22.5% of evaluators found inadequately conspicuous. The Type IX on beaded Type III sign was rated inadequate by 15% of evaluators. Less than 10% of the evaluators found the other signs to be visible only at an inadequate distance.

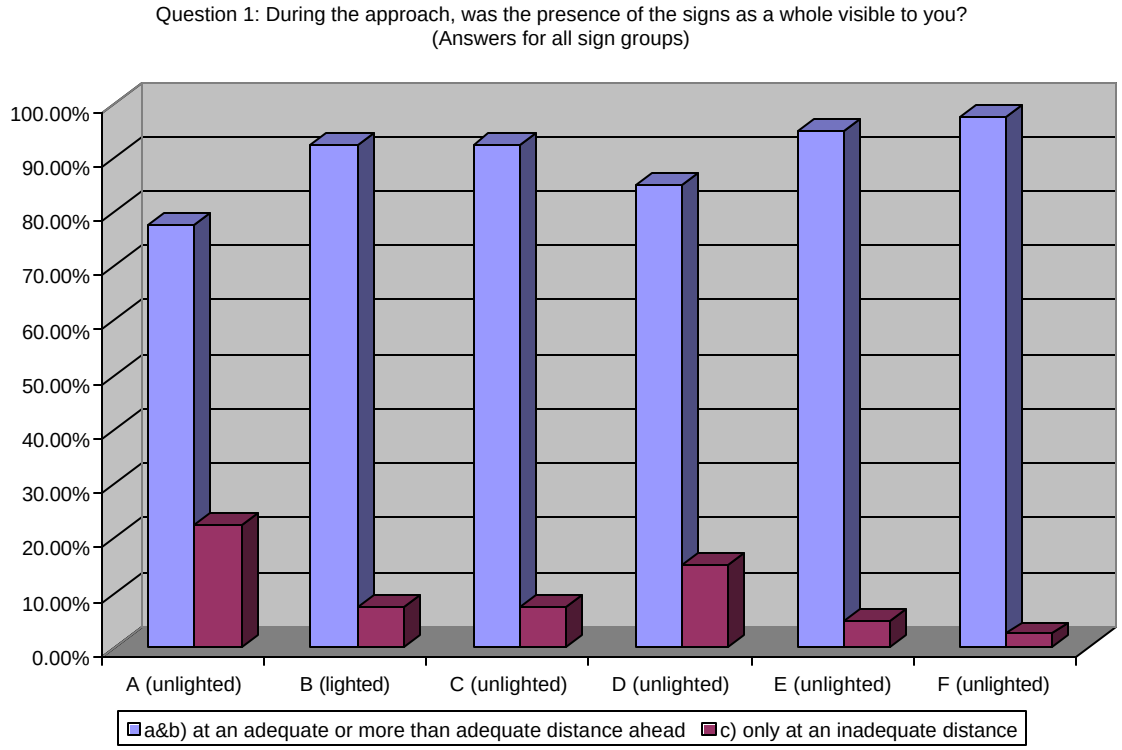

Figure 20. Responses to Question 1 of Sign Evaluation Form for unlighted signs with "at an adequate distance ahead" and "at a more than adequate distance ahead" responses combined for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

Figure 21 and Figure 22 compare the responses to Question 1 for male and female evaluators. In general the women tended to rate the signs as more conspicuous than did the men, the exception being Sign Group C (Type VIII on microprismatic Type III). All the female evaluators found Sign Groups E (Type IX on Type IX) and F (Type VII on beaded Type III) adequately conspicuous.

Responses to Question 1 are also considered as a function of seat position. Figure 23 has responses from passengers in the front seat, and Figure 24 has responses from passengers in the center of the middle seat of the Caravan. The differences between the two seat positions are quite minor, only by at most one evaluator out of 20 except for the Type IX on beaded Type III where the difference is two evaluators (from 90% to 80%), which is still a minor change.

Similarly the responses to Question 1 divided into groups based on lane of approach are given in the next two figures. Figure 25 has responses from the right lane approach, and Figure 26 has responses from the left lane approach. The differences again are very minor, by one evaluator at most, except for the beaded Type III on beaded Type III unlighted sign, where 35% of evaluators found the signs inadequately conspicuous from the right lane as opposed to only 10% finding the same from the left lane.

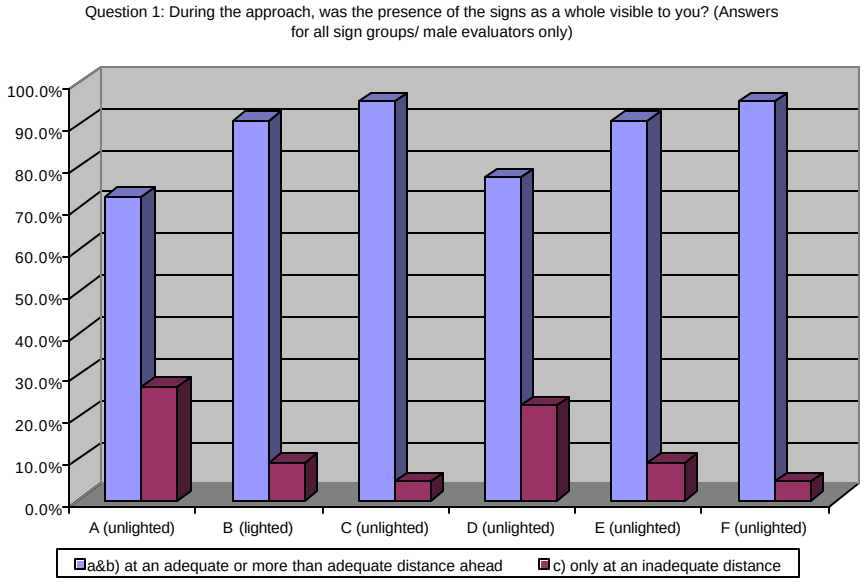

Figure 21. Responses from Male Evaluators only for Question 1 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

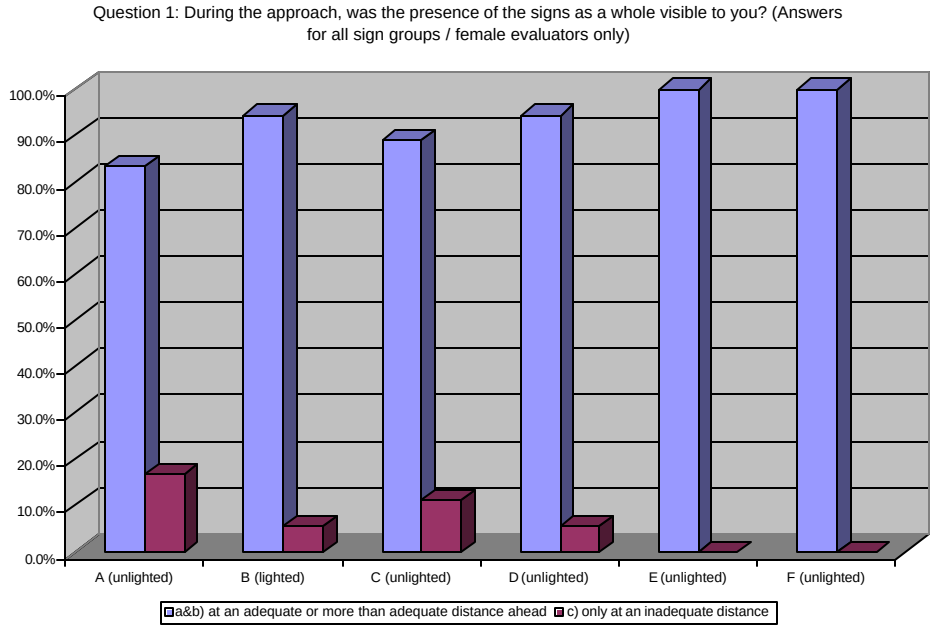

Figure 22: Responses from Female Evaluators only for Question 1 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

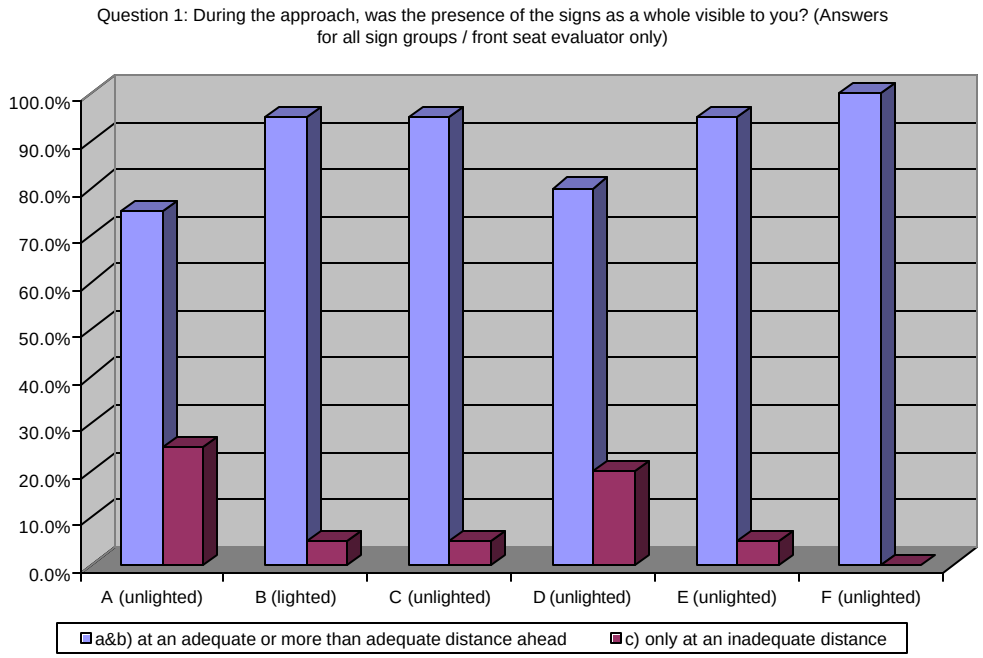

Figure 23. Responses from Front Seat Evaluators only for Question 1 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

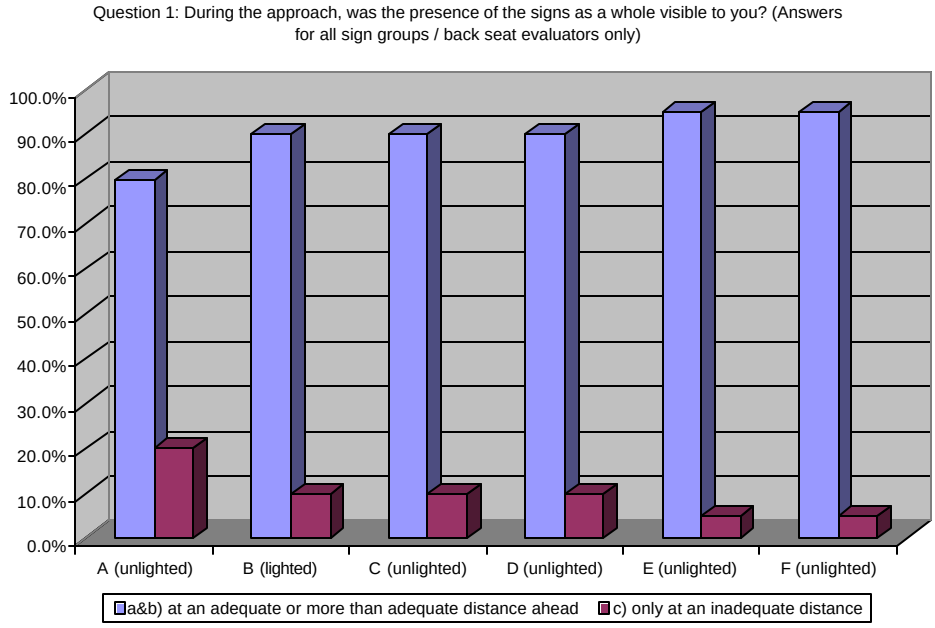

Figure 24. Responses from Back Seat Evaluators only for Question 1 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

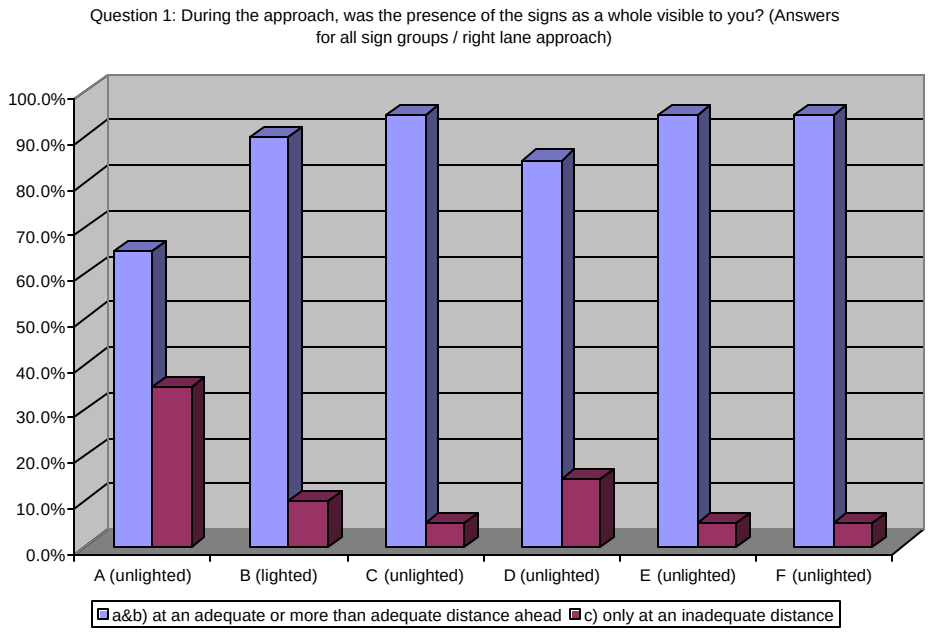

Figure 25: Responses for Right Lane Approach only for Question 1 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

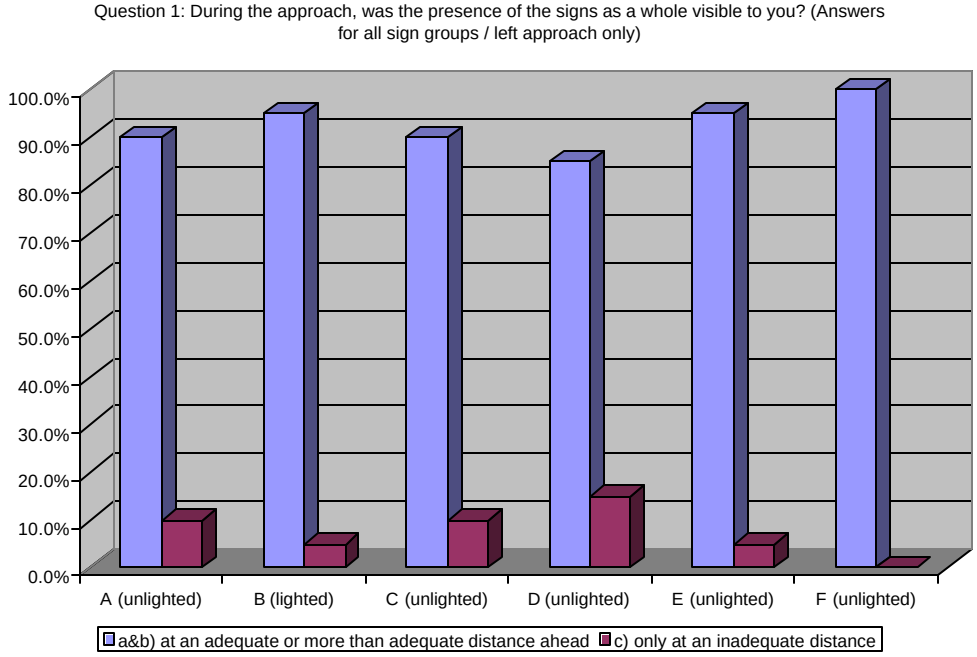

Figure 26: Responses for Left Lane Approach only for Question 1 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

Questions 2, Question 3, and Question 10 of the questionnaire asked if there was other traffic on the road, whether it helped illuminate the signs or obscured them. Responses to this question varied widely because of different traffic conditions on different groups on different loops, so they are not comparable.

4.4.1.2 Legibility (Question 4)

Question 4 inquired about the legibility of the signs, asking at what distance the legend could be read. Again, the response choices were "at a more than adequate distance ahead", "at an adequate distance ahead", and "only at an inadequate distance ahead". An additional choice, "could not read the information on the signs at all" was made available, but was never checked. The responses for all signs, as shown in Figure 27, show a strong preference for the "adequate distance" for legibility of all legends. Note again that the more than adequate and adequate responses have been combined. The beaded Type III on beaded Type III had the least positive response, only 77.5%, behind the next highest, Type IX on beaded Type III at 82.5%. The highest response was for Type VII on Type III at 95% then Type IX on Type IX and beaded Type III on beaded Type III lighted tied at 92.5%.

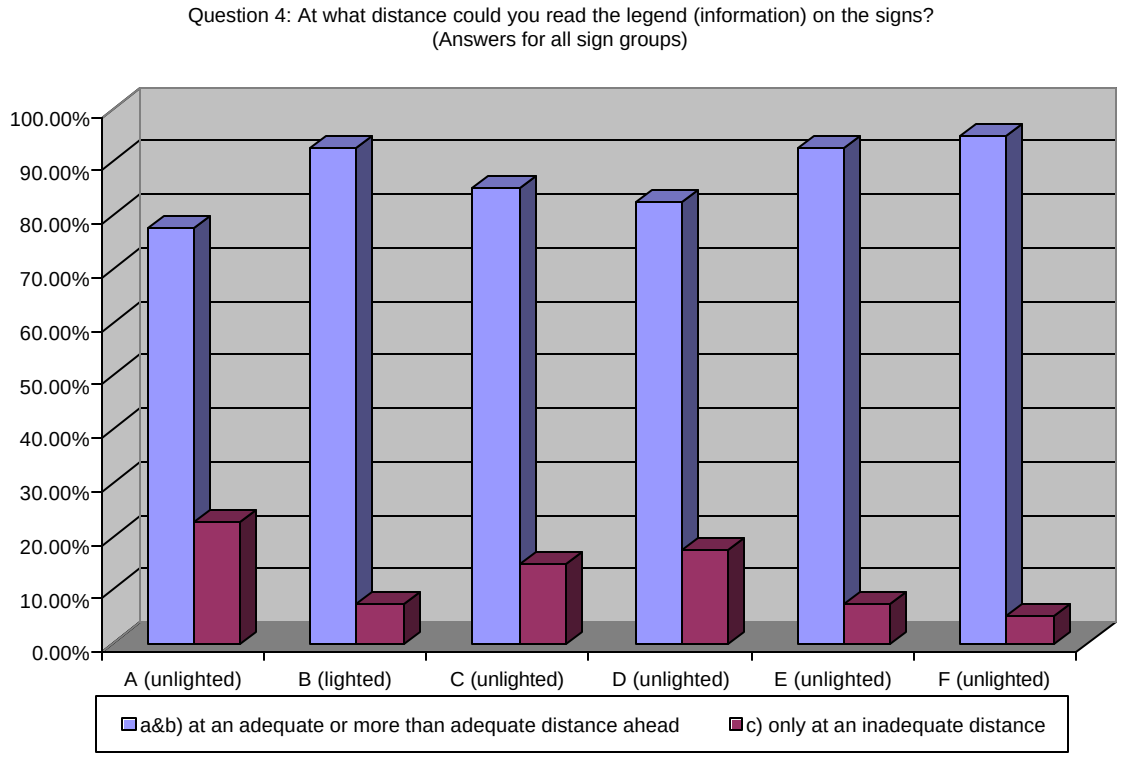

Figure 27. Responses to Question 4 of Sign Evaluation Form for all sign groups with "at an adequate distance ahead" and "at a more than adequate distance ahead" responses combined. For a key to sign group material combinations, see Table 1 on page 5.

Figure 28 and Figure 29 show responses from male and female evaluators respectively. Differences are insignificant, less than about 10% of evaluations in all cases. It is worth noting that all the female evaluators rated the Sign Group F (Type VII on beaded Type III) as at least adequately legible.

Differences between front seat evaluations, on Figure 30, and back seat evaluations, on Figure 31, are again negligible. The largest is 15% for Type IX on beaded Type III, which was found to be at least adequately legible 75% of the time from the front seat and 90% from the back seat. Type VII on beaded Type III was found to be at least adequately legible 100% of the time from the front seat.

The variations between the two approach lanes are considered in the next two figures, Figure 32 for right lane and Figure 33 for left lane. The beaded Type III on beaded Type III groups each had the largest discrepancies. The unlighted group was the largest, with only 65% of older drivers finding the signs at least adequately legible from the right lane, versus 90% from the left lane. For the lighted group the difference was smaller, 85% for the right lane versus 100% from the left lane. The Type VII on beaded Type III was also rated at least adequately legible by 100% of the evaluators from the left lane.

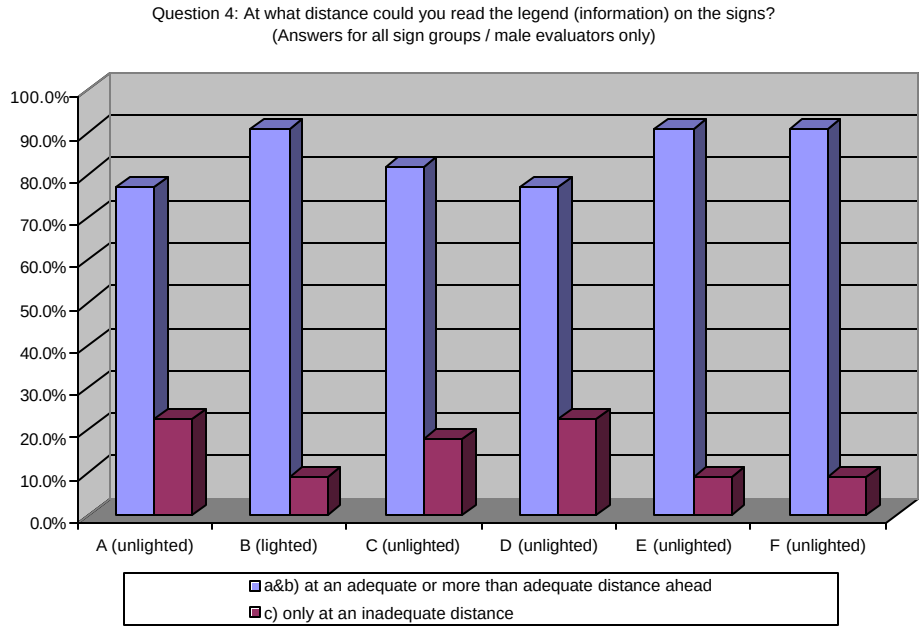

Figure 28. Responses from Male Evaluators only for Question 4 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

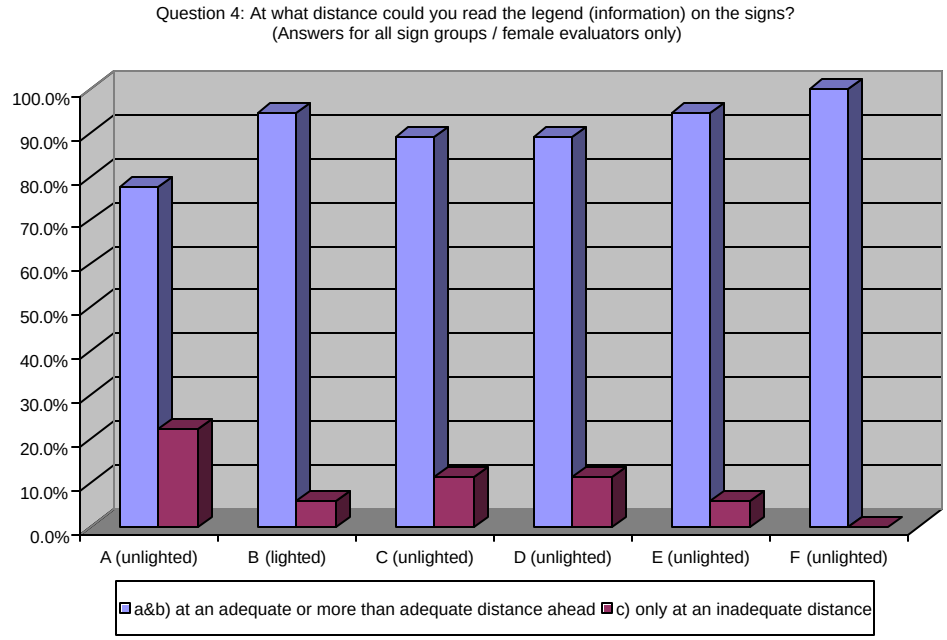

Figure 29. Responses from Female Evaluators only for Question 4 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

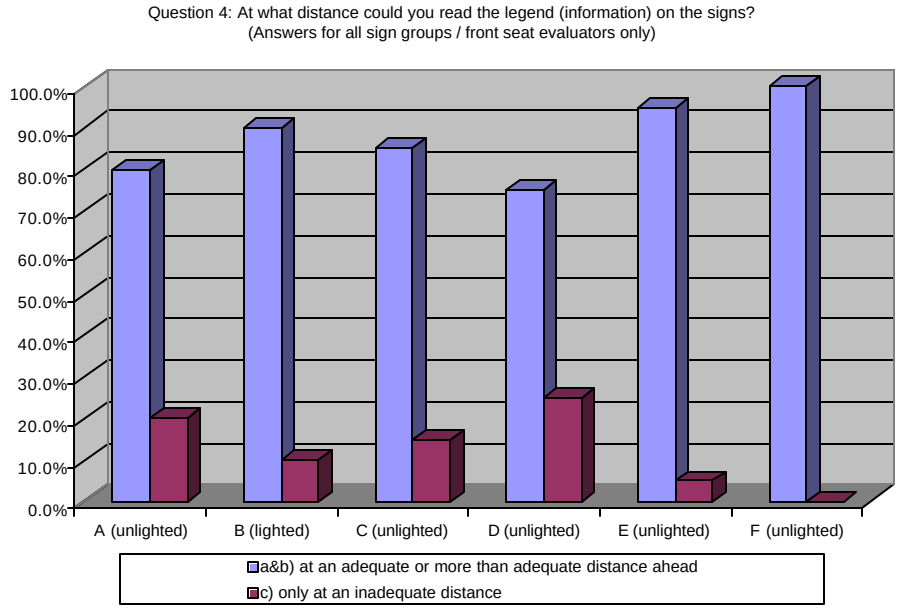

Figure 30. Responses from Front Seat Evaluators only for Question 4 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

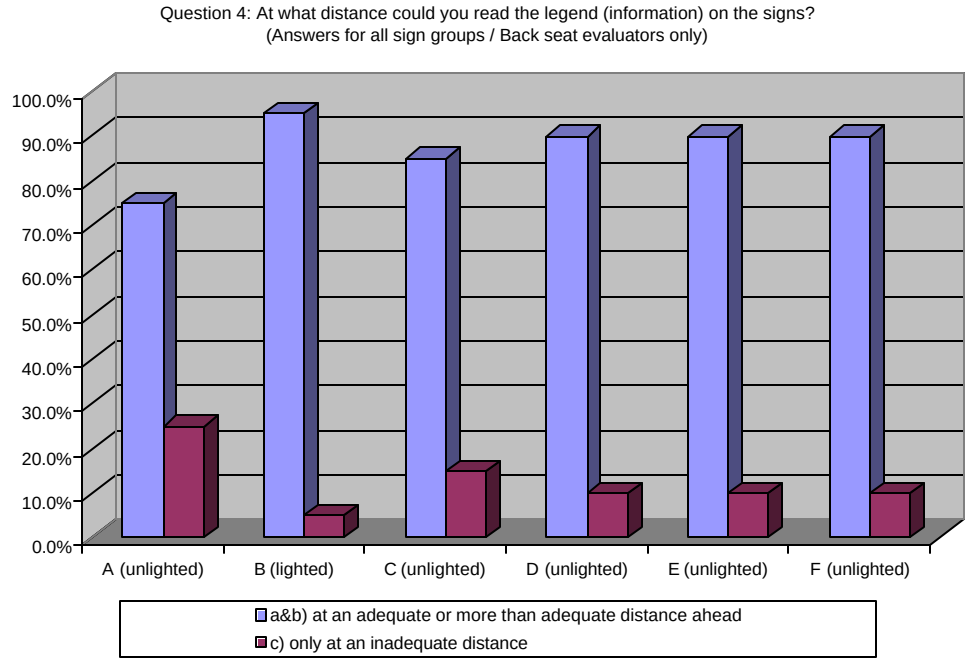

Figure 31: Responses from Back Seat Evaluators only for Question 4 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

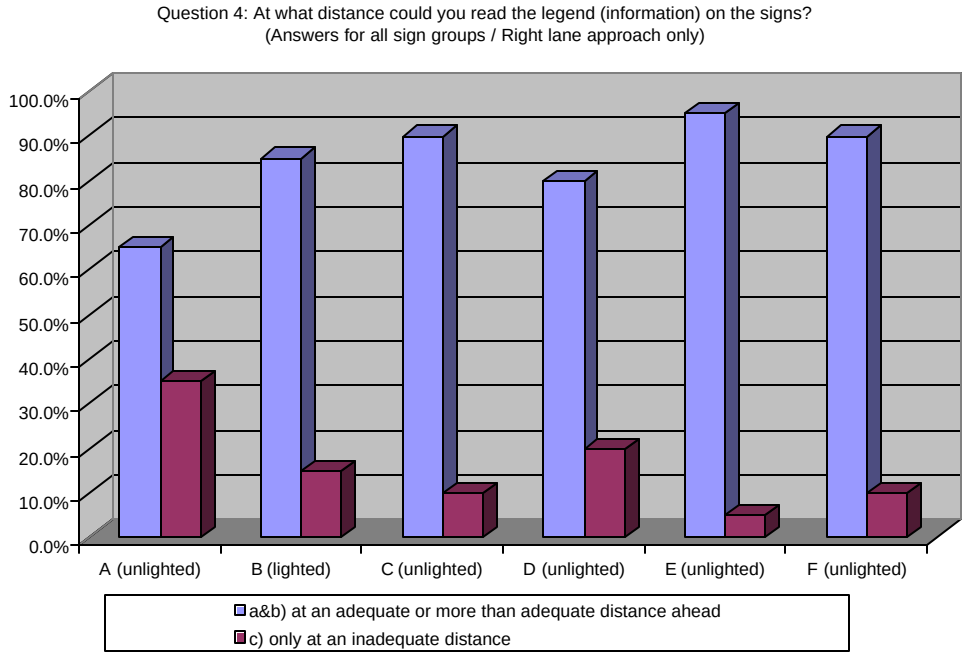

Figure 32. Responses for Right Lane Approach only for Question 4 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

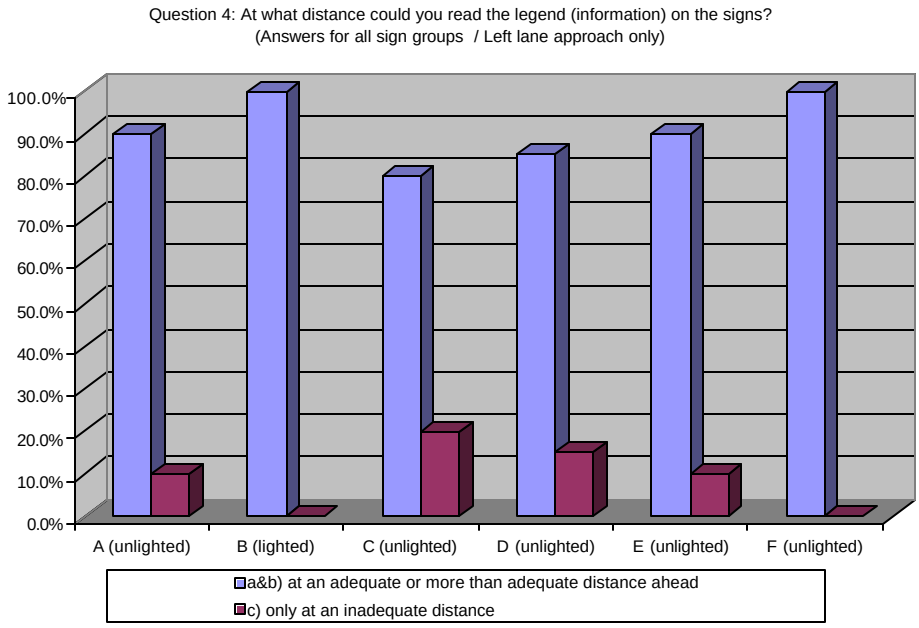

Figure 33: Responses for Left Lane Approach only for Question 4 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

4.4.1.3 Observations at the maximum legibility distance (Question 5)

Question 5 of the Sign Evaluation Form asks if the legend is too bright, too dark, or just about the right brightness at the earliest point where the sign became legible. Responses for all signs are shown in Figure 34, with the too bright and too dark responses combined. The overwhelming favorite choice of panelists was "The legend was at just about the right brightness and easy to read". The highest level of approval went to the lighted sign group, with 90% choosing "easy to read". This was followed by Type VII on beaded Type III with 87.5%, then Type IX on Type IX at 85% and Type VIII on microprismatic Type III at 82.5%. The lowest was Type IX on beaded Type III, at 72.5%, which is still a sizable majority.

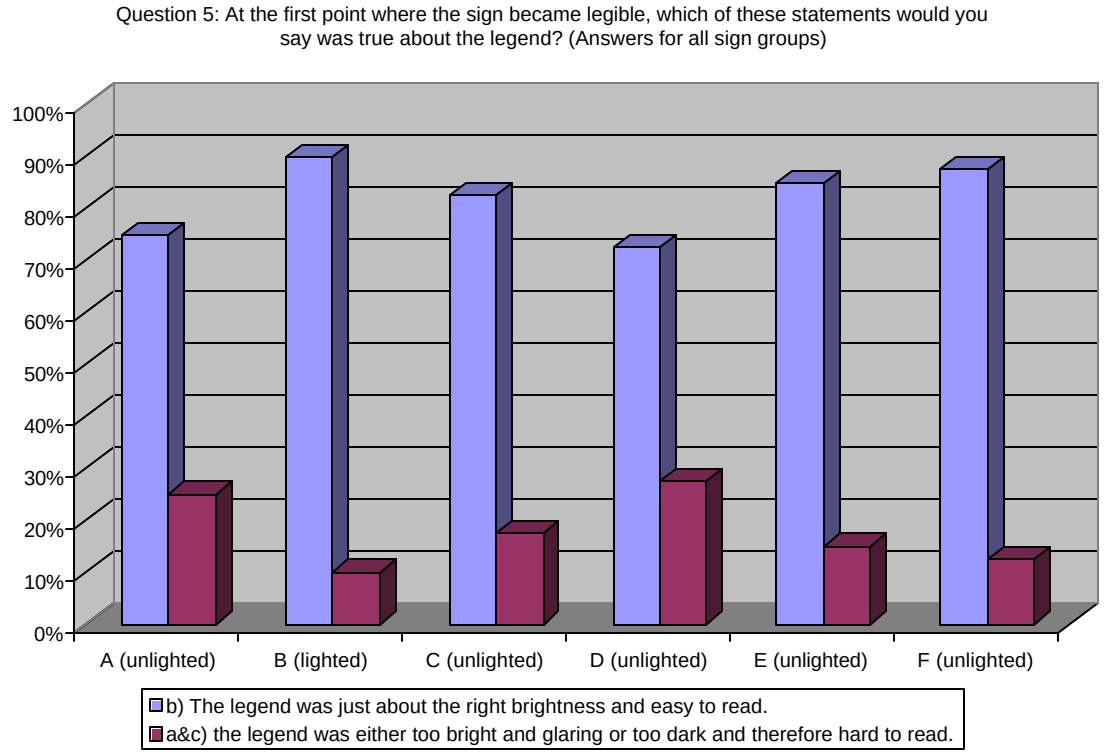

Figure 34. Evaluator responses to Question 5 of Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

Figure 35 has the responses for male evaluators, which can be compared to those for female evaluators in Figure 36. Differences are rather small, except for Sign Group C (Type VIII on microprismatic Type III), which 90.9% of men rated as easy to read while only 72.2% of women felt the same way. There was a smaller difference for Sign Group F (Type VII on beaded Type III), with 81.8% of men rating the sign group easy to read at the farthest point of legibility versus 94.4% of women.

Figure 37 and Figure 38 compare front and back seat responses, respectively. The only discrepancy of note is for Type IX on beaded Type III, where 75% of front seat

respondents chose “easy to read” versus 90% from the back seat. 100% of evaluators in the front seat chose Type VII on beaded Type III as “easy to read”.

The responses to Question 5 for unlighted signs are broken down by lane of approach in Figure 39 and Figure 40. In most cases, there is little difference between the left and right approach responses for the tested sign material combinations. However beaded Type III on beaded Type III unlighted is an exception, where only 65% of evaluators found the signs easy to read from the right lane, versus 85% from the left lane. For the Type IX on Type IX group there was a similar variation, with 95% finding the sings easy to read in the right lane, but only 75% saying the same from the left lane.

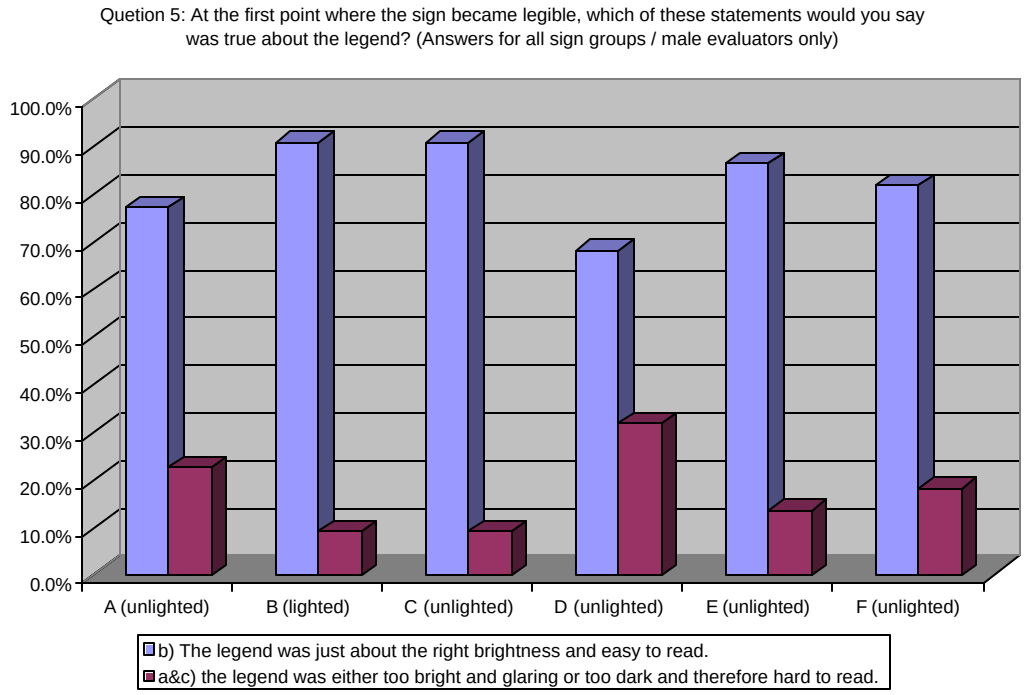

Figure 35. Responses from Male Evaluators only for Question 5 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

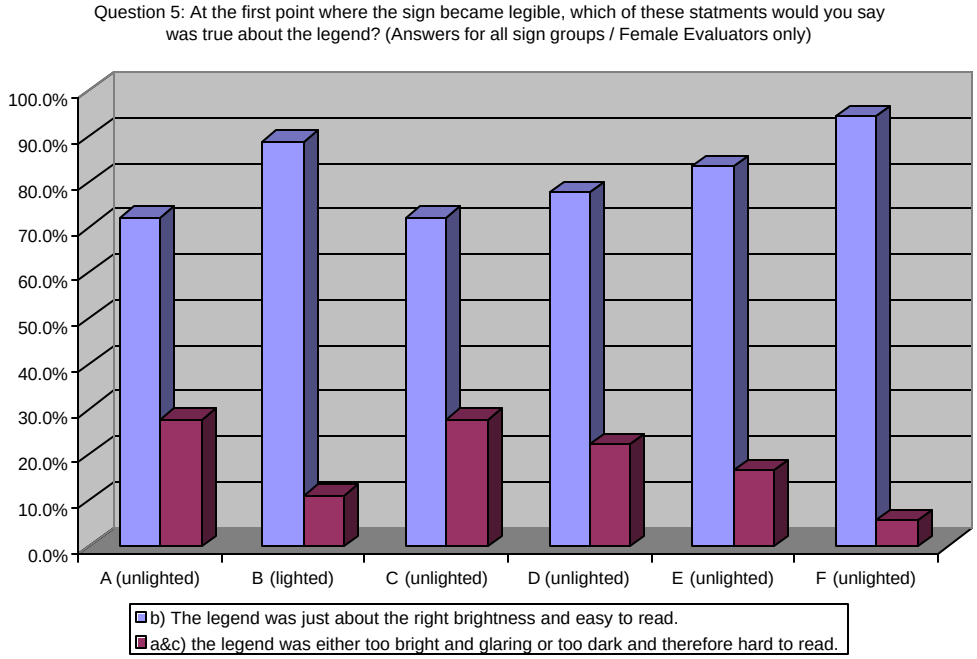

Figure 36. Responses from Female Evaluators only for Question 5 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

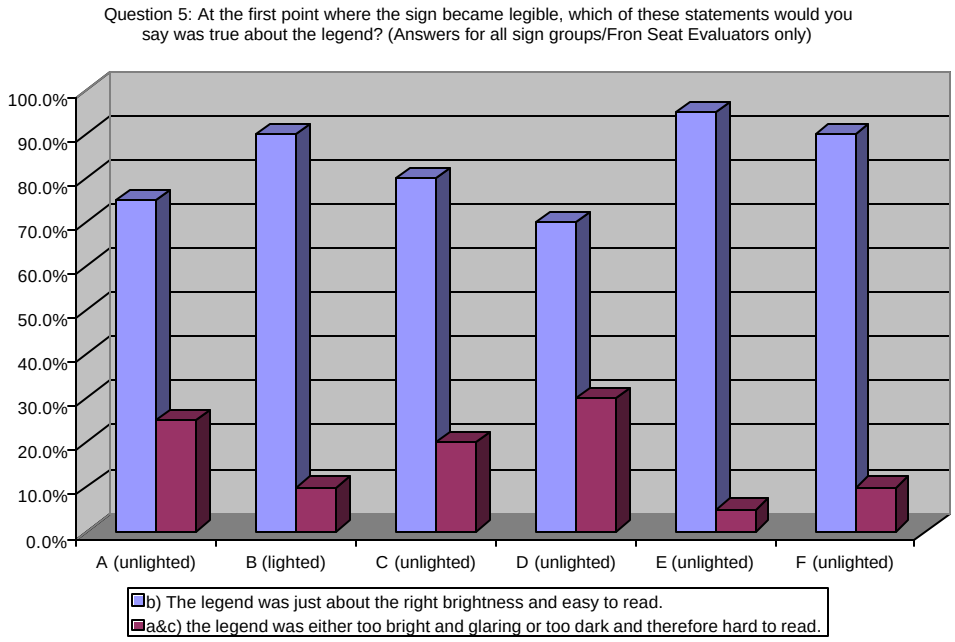

Figure 37. Responses from Front Seat Evaluators only for Question 5 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

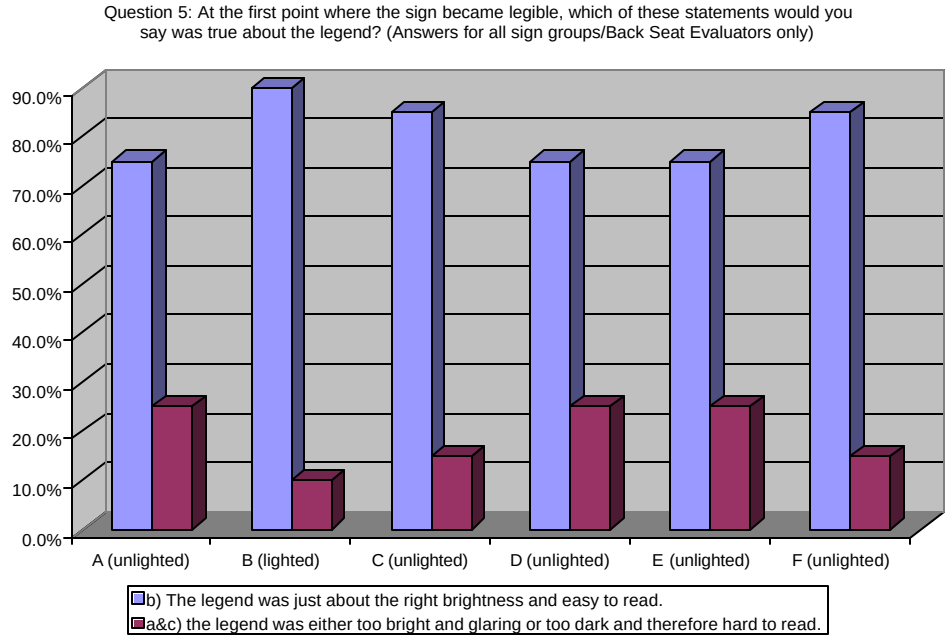

Figure 38. Responses from Back Seat Evaluators only for Question 5 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

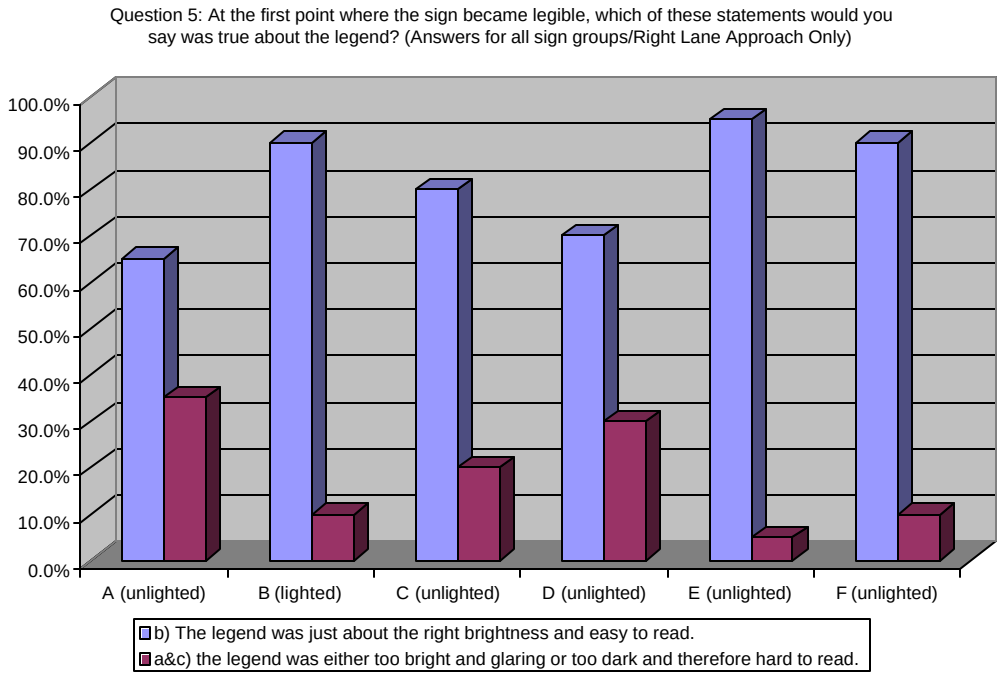

Figure 39. Responses for Right Lane Approach only for Question 5 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

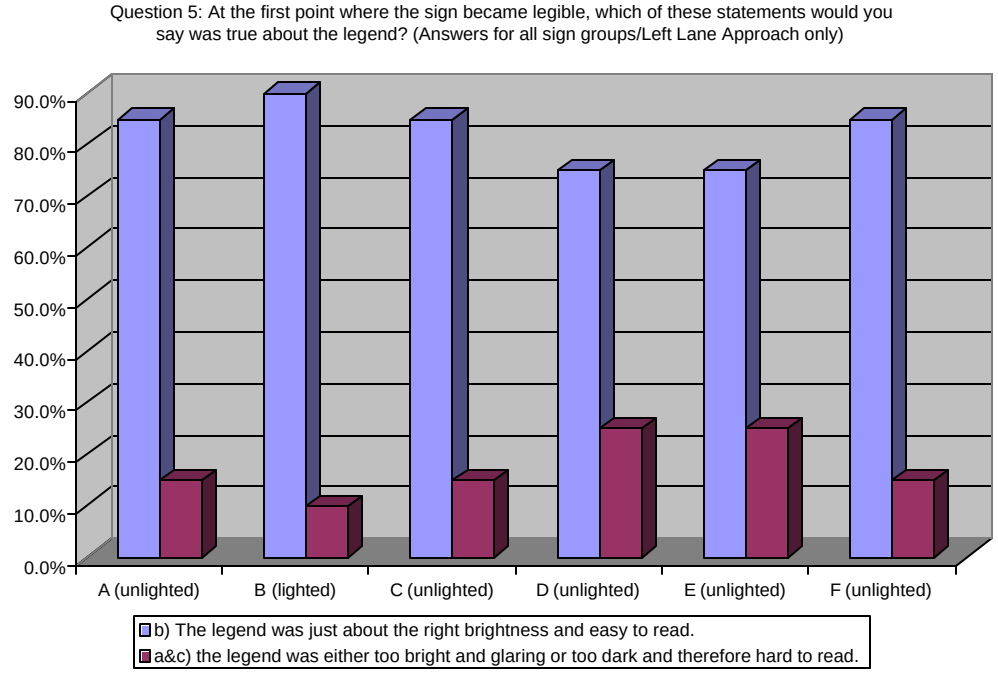

Figure 40. Responses for Left Lane Approach only for Question 5 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

Observations at the last point where the legend was still legible (Question 6)

Question 6 of the Sign Evaluation Form repeats Question 5, but for the last point where the sign was still legible. Responses for all signs are shown in Figure 41. The number of respondents selecting the "easy to read" option is uniformly lower than was the case for Question 5. But even the beaded Type III on beaded Type III unlighted sign rated 65%. The top two rated sign material combinations were Type VII on beaded Type III (82.5%) and Type IX on Type IX (80%). The differences between near and far legibility were greatest for lighted beaded Type III on beaded Type III (90% for Question 5, 75% for Question 6) and Type VIII on microprismatic Type III (82.5% for Question 5, 70% for Question 6); all other differences were 10% or less.

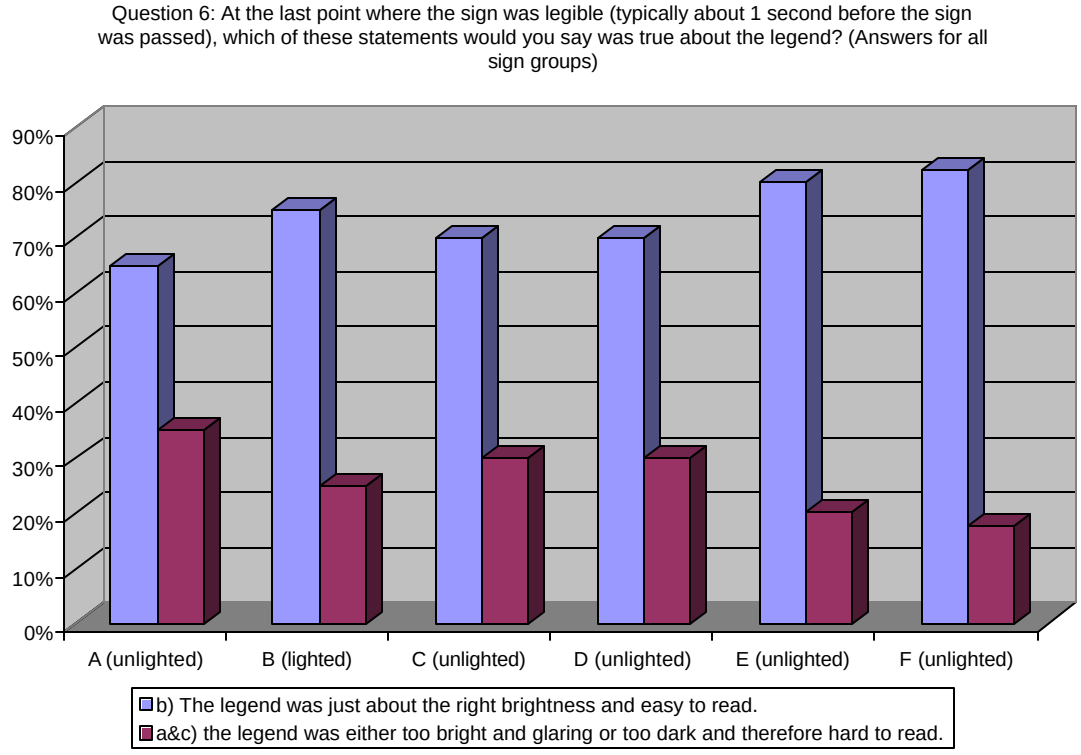

Figure 41. Evaluator responses to Question 6 of Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

Figure 42 and Figure 43 show the responses to Question 6 broken down by gender of evaluator. In all cases, more women rated the sign legends as "easy to read" than did men. These discrepancies were often larger than 20%. The smallest was 4%, for Type VIII on microprismatic Type III (72.2% for women, 68.2% for men), and the largest was 26.4%, for Type IX on Type IX (94.4% for women, 68.2% for men). Type VII on beaded Type III had a similarly large variation of 21.7% (94.4% for women, 72.7% for men), and Type IX on beaded Type III was also high, at 24.2% (83.3% for women, 59.1% for men). It seems that the men in this study have more problems reading signs close up than do the women.

Responses to Question 6 as a function of seat position are shown in Figure 44 for front seat passengers and in Figure 45 for rear seat passengers. There are no significant differences, the greatest being 10% for Type VIII on microprismatic Type III and Type IX on beaded Type III (65% chose "easy to read" from the front seat and 75% chose the same from the back seat, for both sign groups).

Finally, comparing right lane and left lane approaches in Figure 46 and Figure 47 respectively, we find only one difference of note, from 75% "easy to read" in the right lane to 90% in the left lane for the Type VII on beaded Type III group, the latter being the highest score for any sign group from either lane. All other responses were in the 70% to 80% range except unlighted beaded Type III on beaded Type III (60%) and Type IX on beaded Type III (65%).

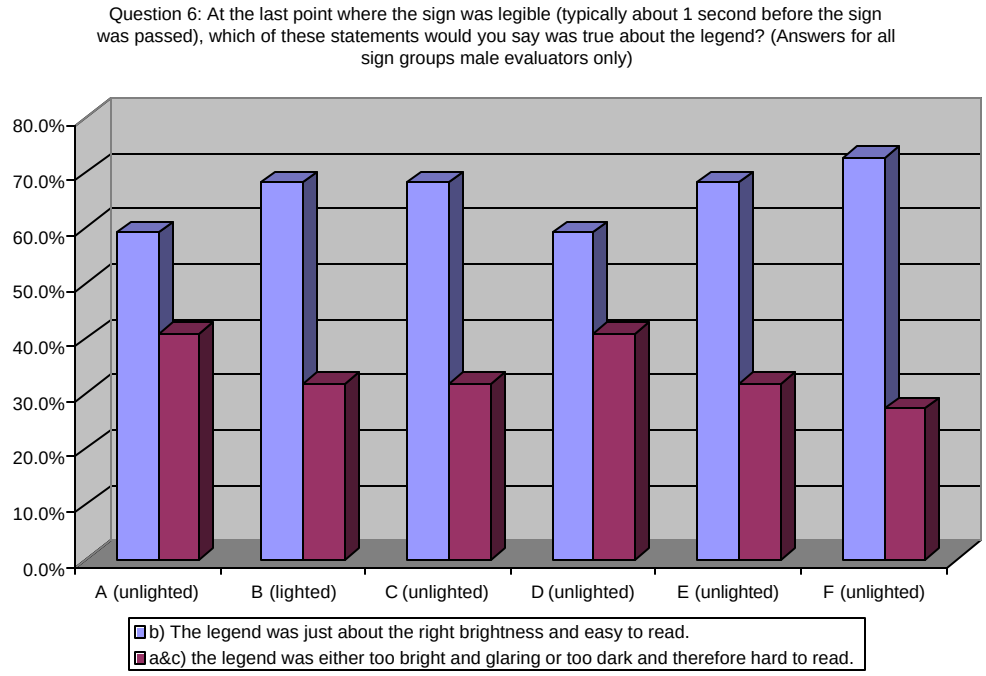

Figure 42. Responses from Male Evaluators only for Question 6 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

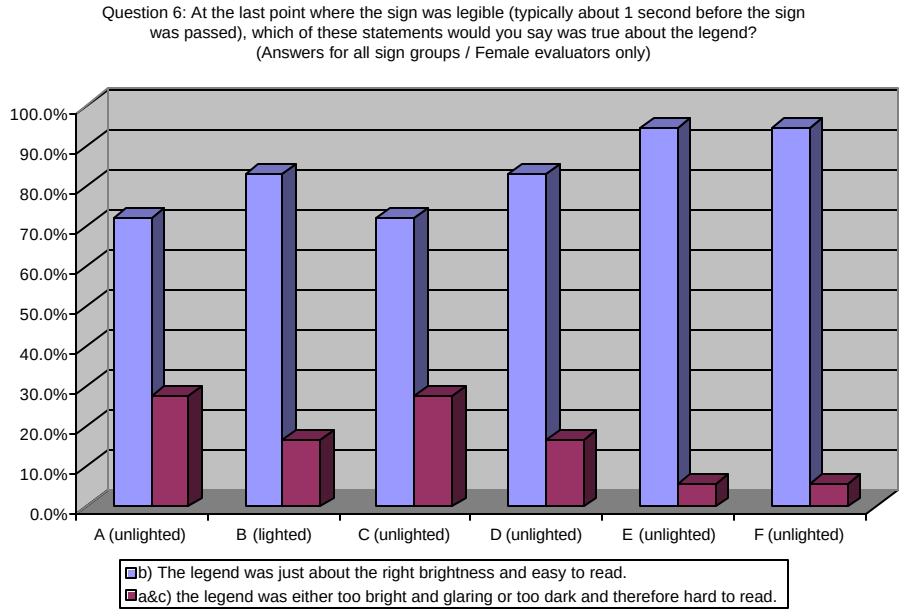

Figure 43. Responses from Female Evaluators only for Question 6 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

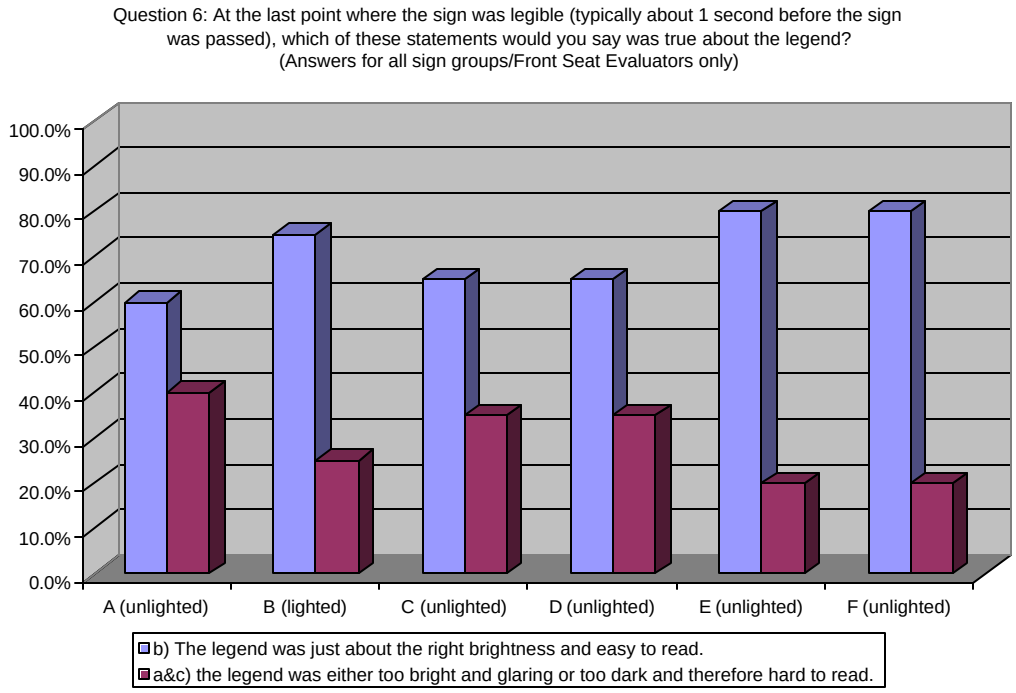

Figure 44. Responses from Front Seat Evaluators only for Question 6 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

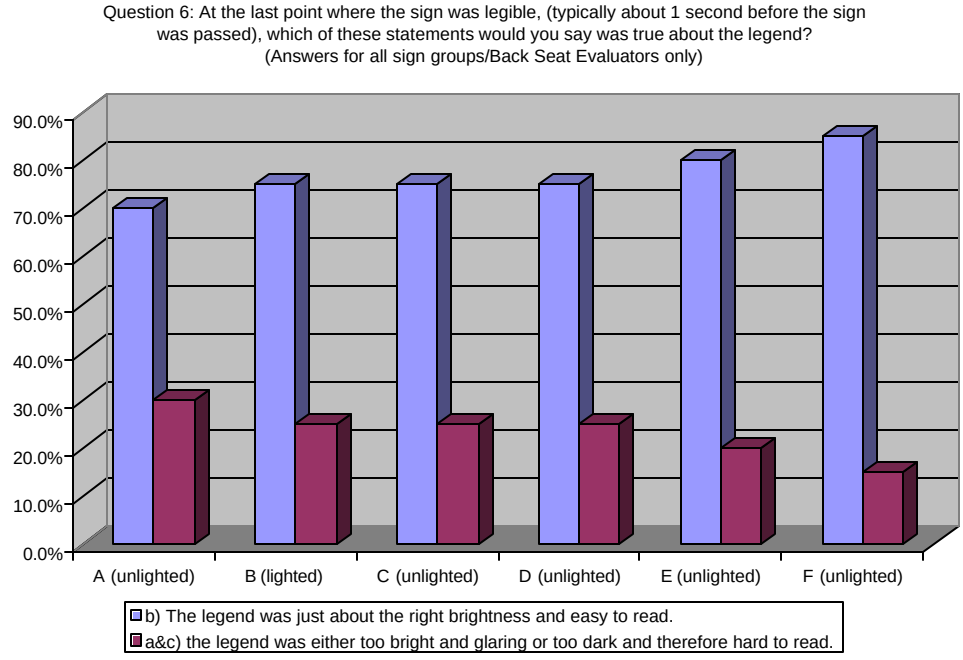

Figure 45. Responses from Back Seat Evaluators only for Question 6 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

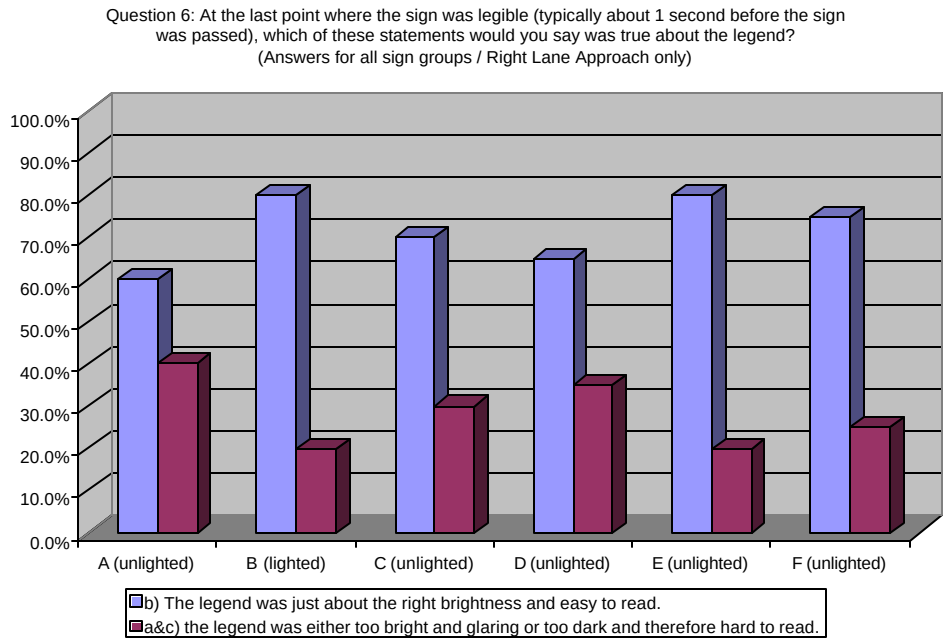

Figure 46. Responses for Right Lane Approach only for Question 6 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

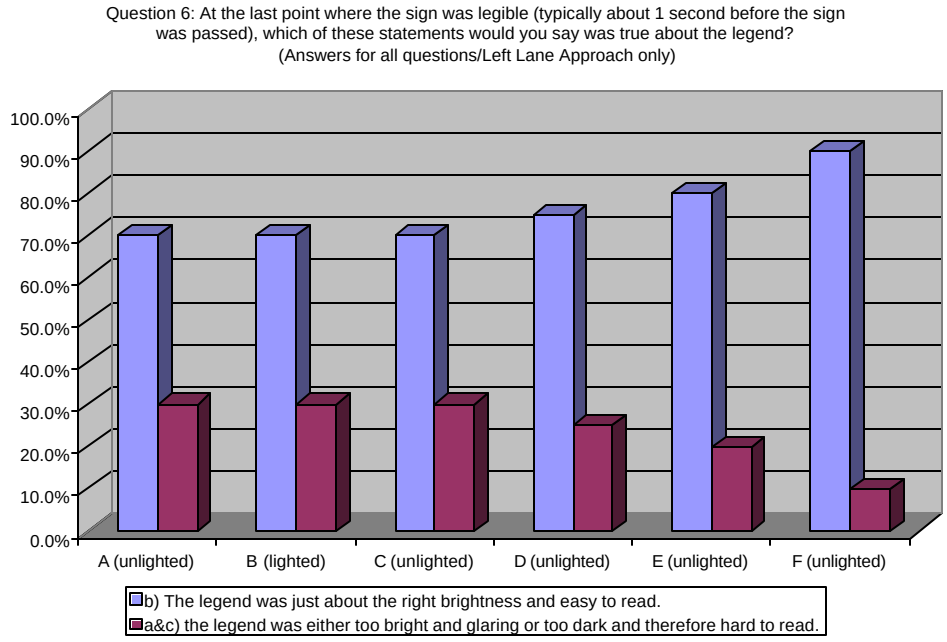

Figure 47. Responses for Left Lane Approach only for Question 6 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

4.4.1.4 Legend Sheeting Material Appearance (Question 7)

Question 7 asked evaluators to judge the appearance of the white legend, with the same response options as for Question 1 and Question 4. Responses for all signs are shown in Figure 48 with the "excellent" and "good" responses combined. The highest appearance ratings went to Type IX on Type IX and Type VIII on microprismatic Type III (95%) each, followed closely by the lighted beaded Type III on beaded Type III (92.5%) and Type VII on beaded Type III (90%). Further behind was the unlighted beaded Type III on beaded Type III (82.5%) and Type IX on beaded Type III (80%).

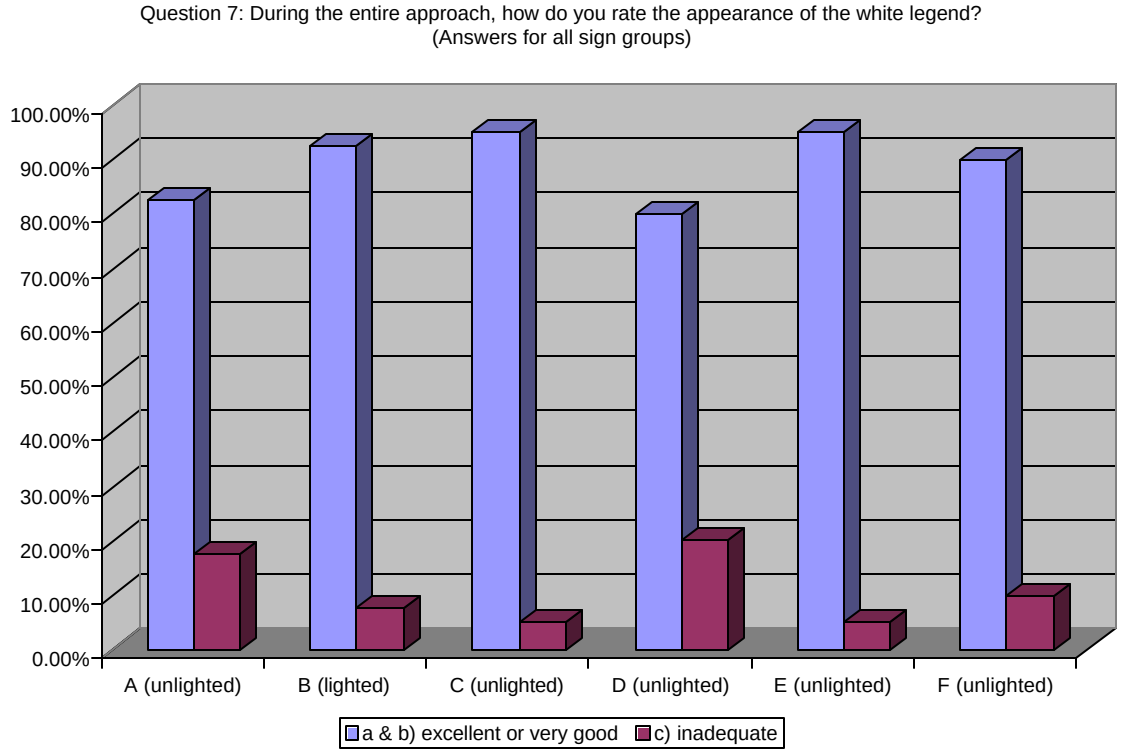

Figure 48. Evaluator responses to Question 7 of Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

Responses for male and female evaluators are given in Figure 49 and Figure 50 respectively. The women were more likely to approve a given sign group, as indicated by their choice of good or excellent. 100% rated Type IX on Type IX and Type VII on beaded Type III as at least "good or adequate", while 100% of the men said the same for the Type VIII on microprismatic Type III. The biggest discrepancy between the sexes was for the Type VII on beaded Type III, where only 81.8% of the men rated the signs as being at least adequate, compared to 100% of the women. For Type IX on beaded Type III, 88.9% of women rated the group at least good, while only 72.7% of the men did so. And 88.9% of the women rated the Type VII on microprismatic Type III signs at least good, compared to 100% of the men.

Comparing the front versus rear seat evaluations in Figure 51 and Figure 52, respectively, no significant differences are found, the largest being 75% of front seat evaluators rating the Type IX on beaded Type III sign group legend as at least good versus 85% of rear seat evaluators.

The responses for the right lane approach are shown in Figure 53, while those for the left lane approach are shown in Figure 54. Most groups have exactly the same percentage choosing at least good. The only significant difference is for unlighted beaded Type III on beaded Type III, where 75% of evaluators rated the legend as at least good from the right lane versus 90% said the same from the left lane.

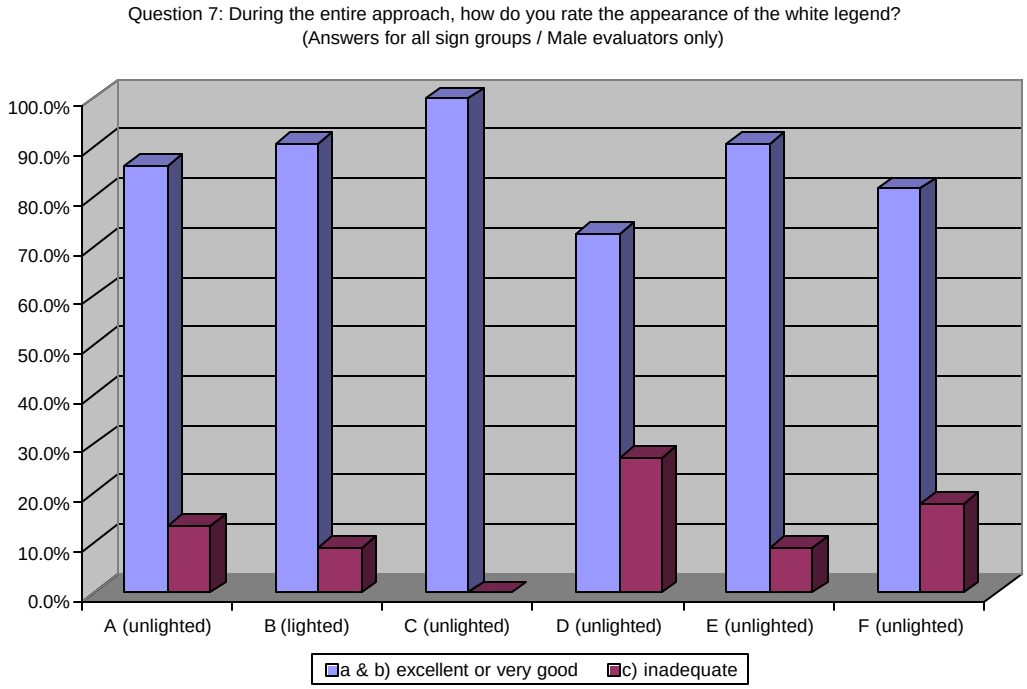

Figure 49. Responses from Male Evaluators only for Question 7 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

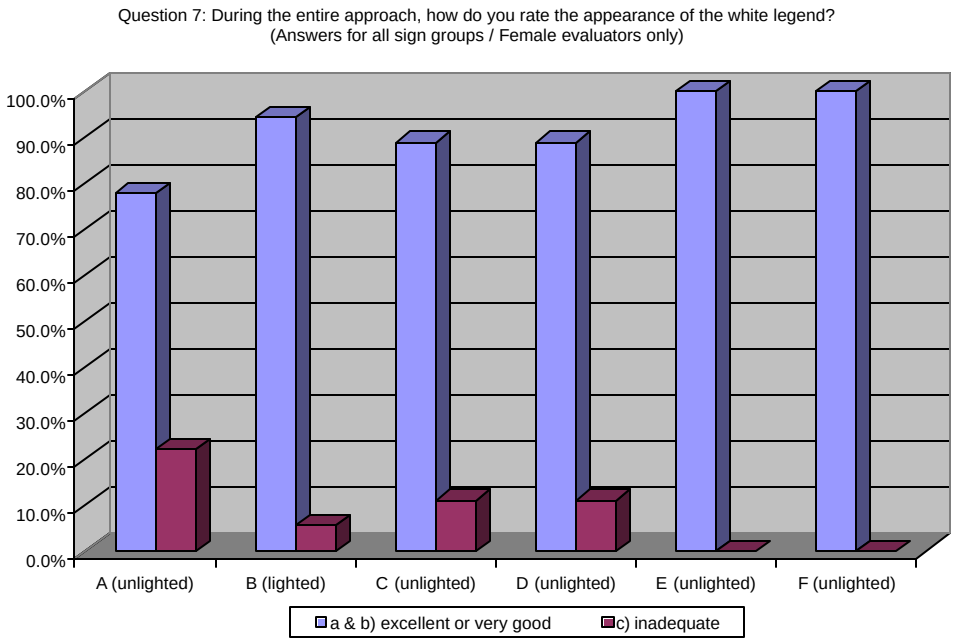

Figure 50. Responses from Female Evaluators only for Question 7 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

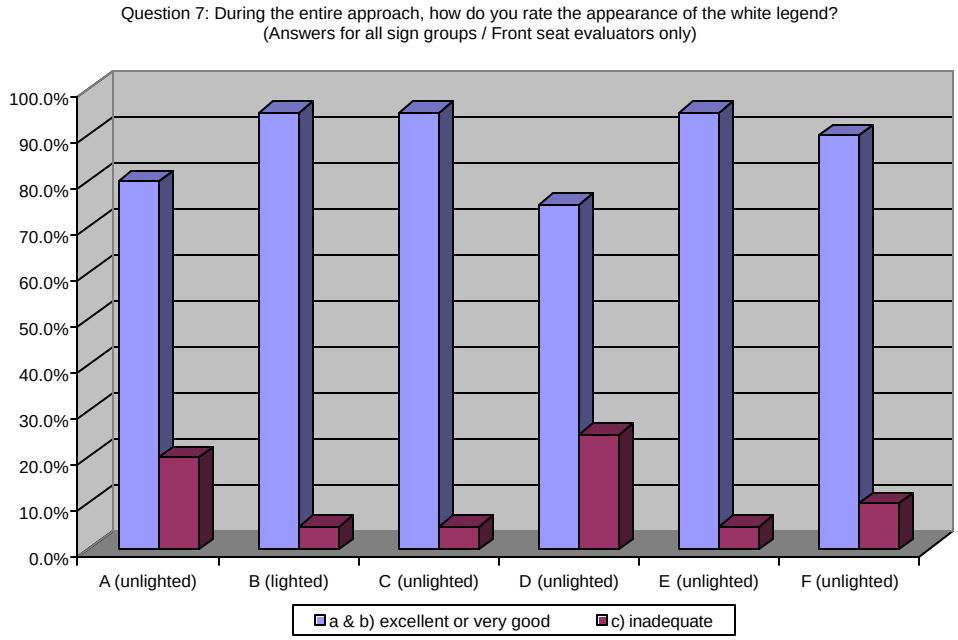

Figure 51. Responses from Front Seat Evaluators only for Question 7 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

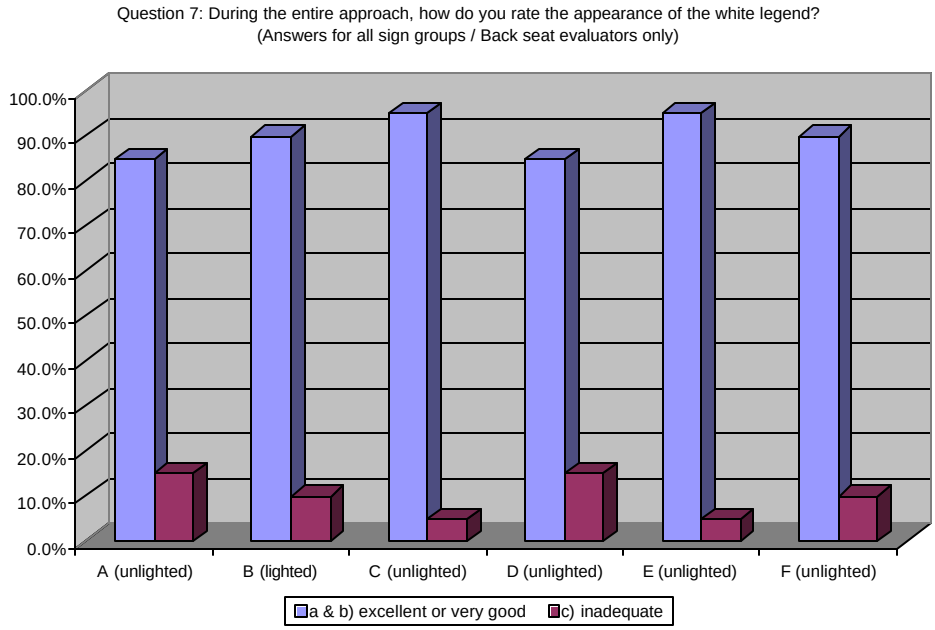

Figure 52. Responses from Back Seat Evaluators only for Question 7 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

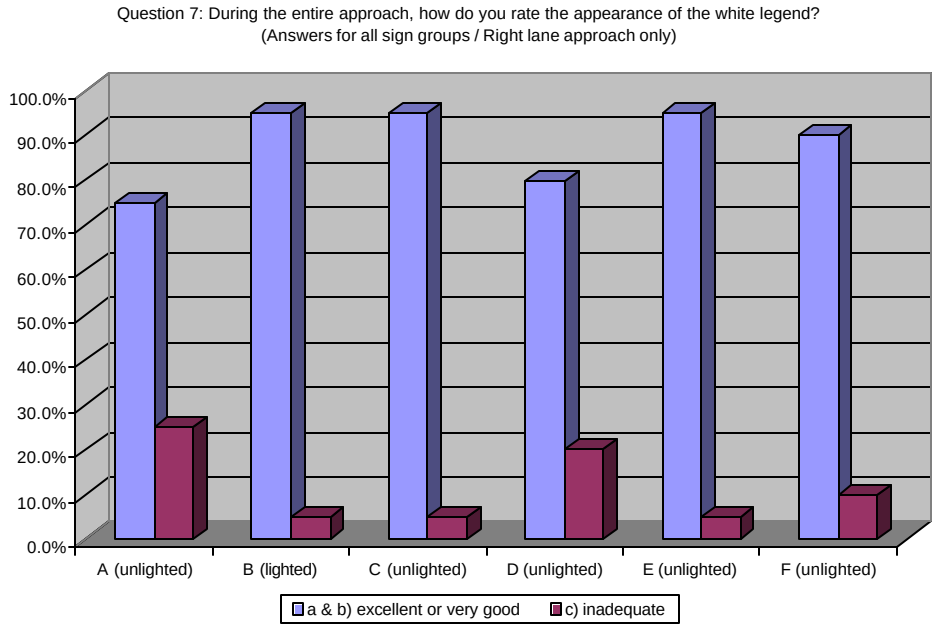

Figure 53. Responses for Right Lane Approach only for Question 7 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

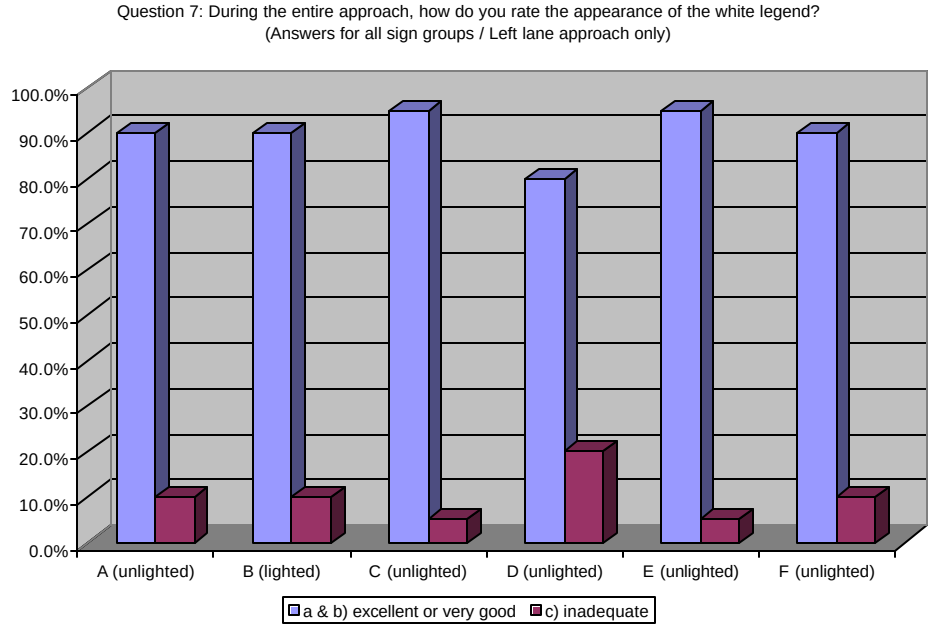

Figure 54. Responses for Left Lane Approach only for Question 7 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

4.4.1.5 Background Sheeting Material Appearance (Question 8)

Question 8 is similar to Question 7, except that it applied to the green background. Results for all signs are shown in Figure 55. Type VII on beaded Type III met with the most approval, 95% of evaluators selecting good or better, with the lighted beaded Type III on beaded Type III coming in just behind at 92.5%. The lowest rated background was also beaded Type III, this time with Type IX legend, at 82.5%. The microprismatic Type III and Type IX backgrounds each had 87.5% of evaluators rate it as good or better.

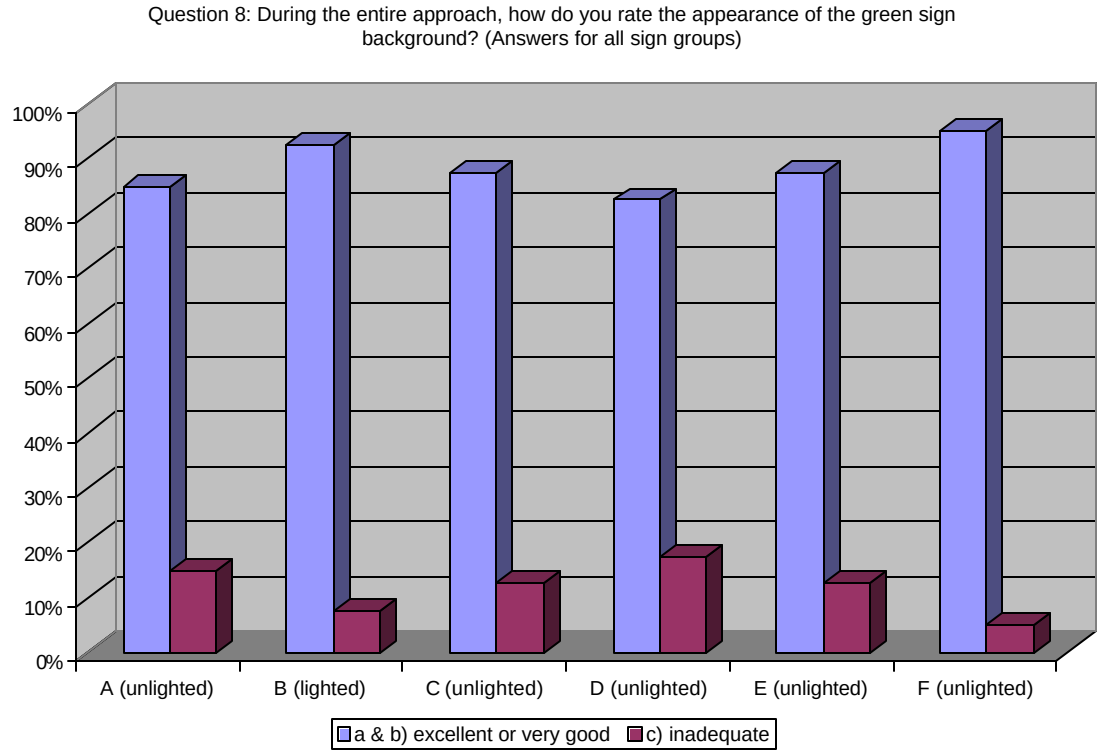

Figure 55. Evaluator responses to Question 8 of Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

Responses for male evaluators are shown in Figure 56 and those for female evaluators are shown in Figure 57. There was considerable variation among the different sign groups. For instance the lighted beaded Type III on beaded Type III sign group background was the highest rated among the women, with 100 % choosing good or better, but only 86.4% of men chose the same response. On the other hand, 95.5% of the men said the microprismatic Type III background was at least good, but only 77.8% of the women agreed. Also, more women rated the beaded Type III background in combination with the Type IX legend as at least good, 88.9% versus 77.3% of men. The same applies to the Type IX background, with 94.4% of women rating it at least good versus 81.8% of men.

Comparison between front and rear seat positions also turned up some interesting findings. Responses for front seat evaluators are given in Figure 58, while those for rear seat passengers are given in Figure 59. All backgrounds were rated at least as highly from the rear seat as from the front, with the minimum rear seat rating of 90% at least "good or adequate". The notable discrepancies are for unlighted beaded Type III with beaded Type III legend, where 75% of the front seat evaluators rated it at lest good, but 95% of rear seat evaluators made that same choice, and for beaded Type III with Type IX legend where the respective percentages were 75% and 90%. Note, however, that the unlighted beaded Type III background with Type VII legend was rated the highest, at 95% from both seats. Second highest was the lighted beaded Type III, with 90% from the front seat and 95% from the rear.

Finally, a comparison between approach lanes for Question 8 is provided. The right lane approach responses are graphed in Figure 60 and left lane responses are in Figure 61. The only significant difference is for the lighted beaded Type III on beaded Type III sign group, where 85% of evaluators rated the background at least good from the right lane, but 100% rated it the same way from the left lane. 100% of evaluators in the right lane rated the beaded Type III with Type VII legend as at least good.

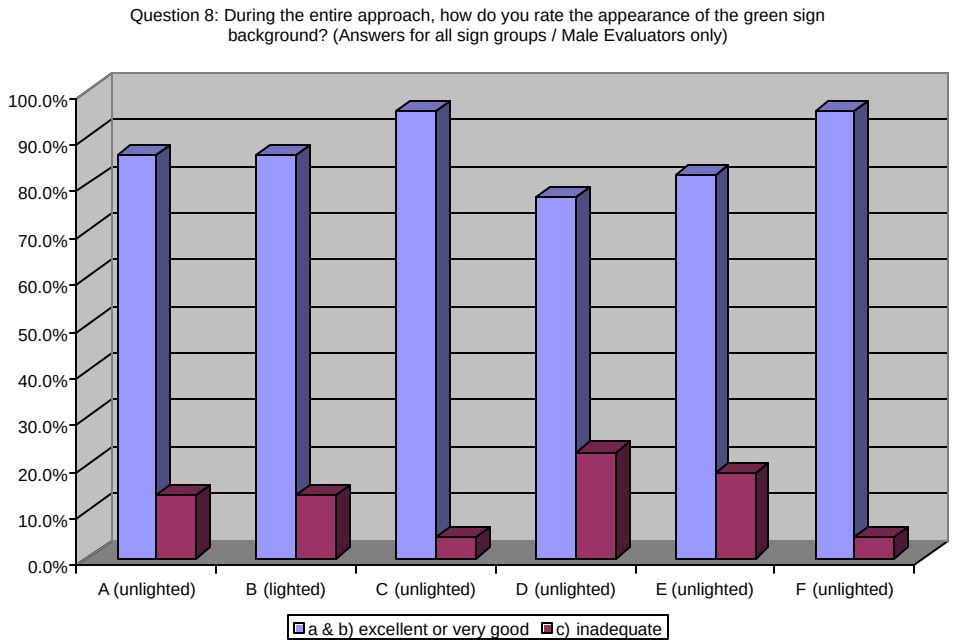

Figure 56. Responses for Male Evaluators only for Question 8 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

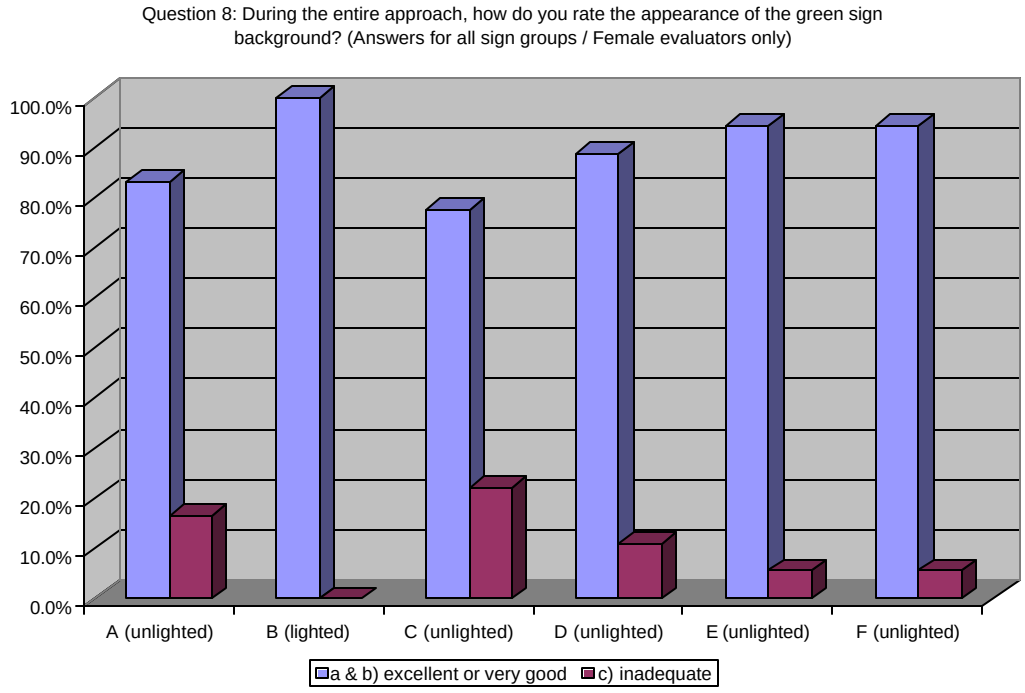

Figure 57. Responses for Female Evaluators only for Question 8 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

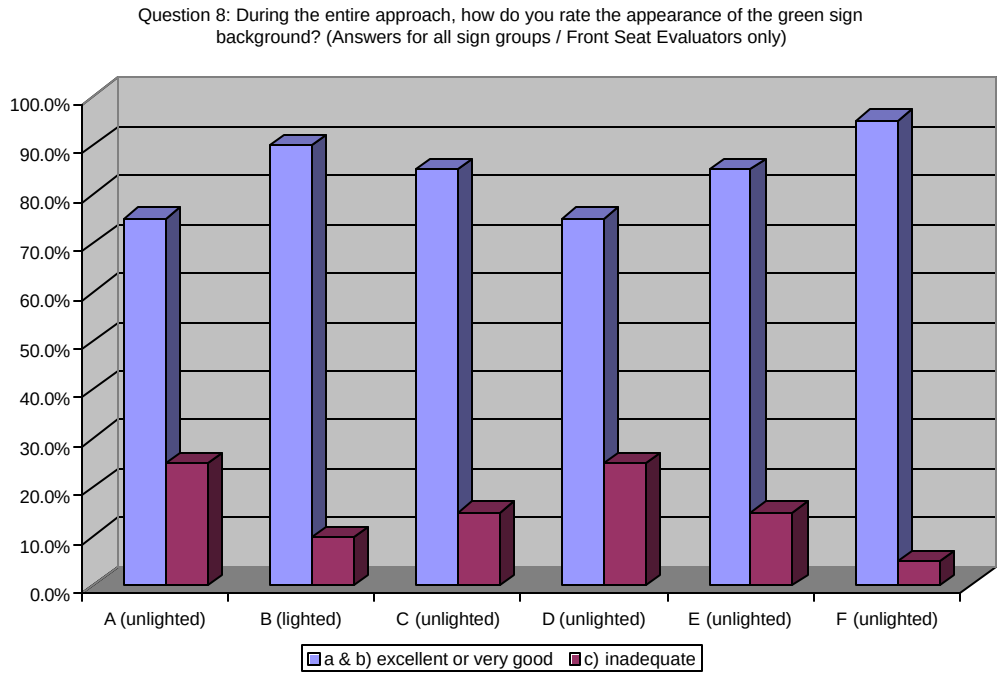

Figure 58. Responses for Front Seat Evaluators only for Question 8 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

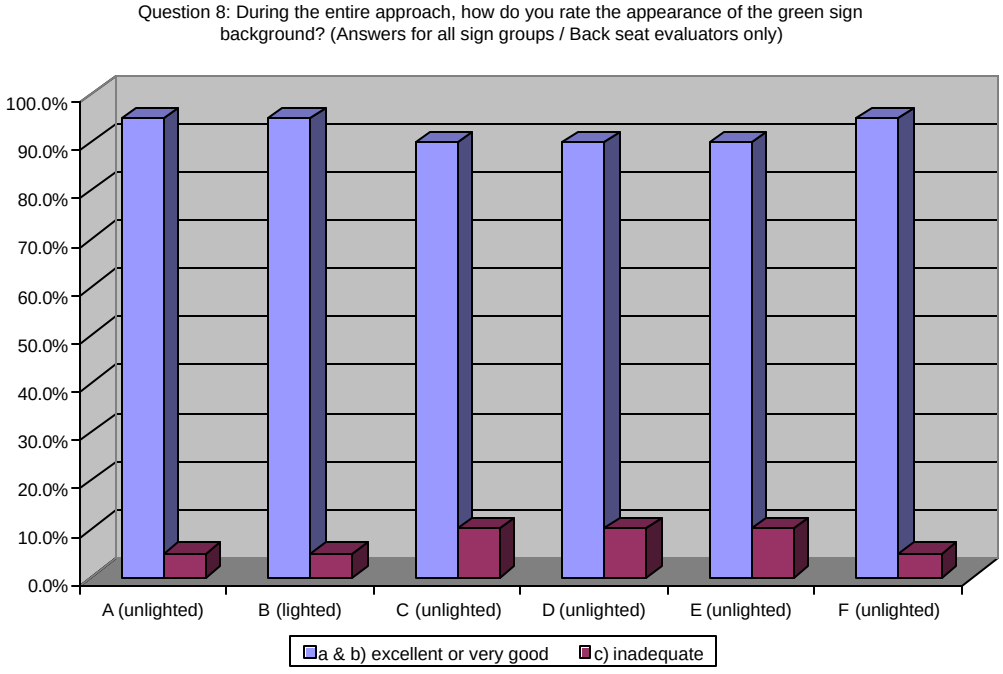

Figure 59. Responses for Back Seat Evaluators only for Question 8 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

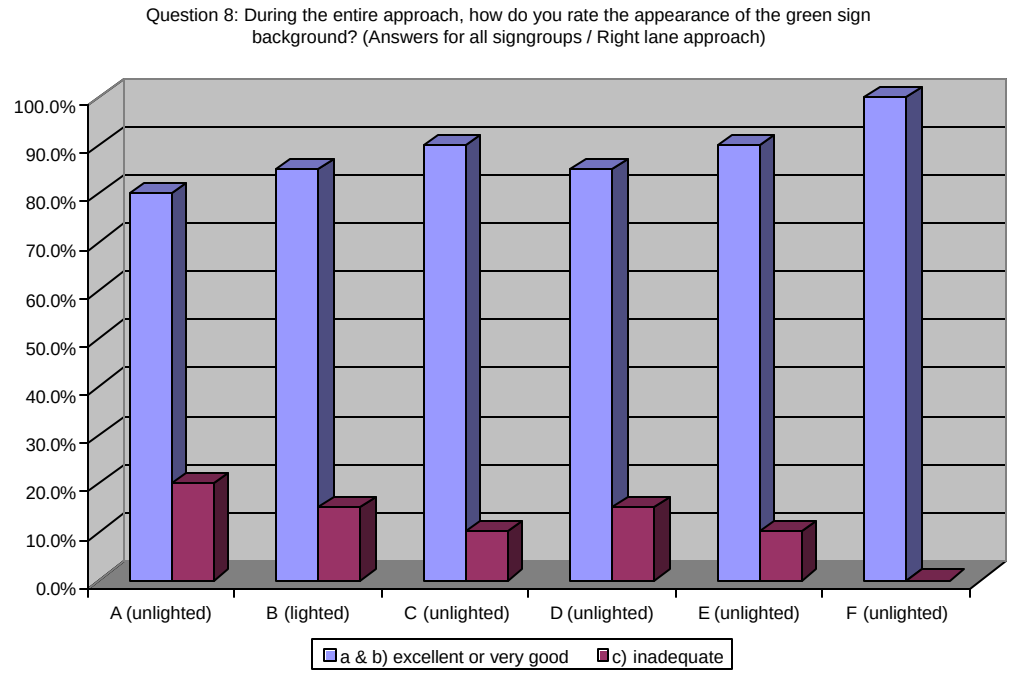

Figure 60. Responses for Right Lane Approach only for Question 8 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

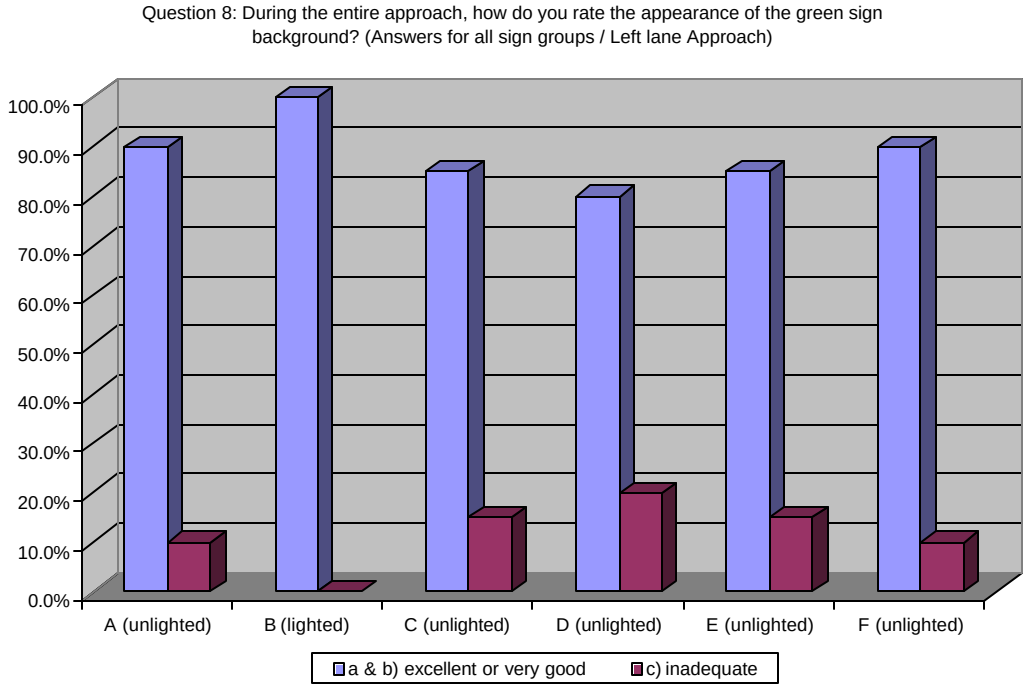

Figure 61. Responses for Left Lane Approach only for Question 8 on Sign Evaluation Form for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

4.4.2 Exit Interview and Overall Comparisons

The 20 older drivers who served on the panel were also asked to compare the signs in the Exit Interview and Overall Comparisons Form given at the end of the evaluation after the both circuits around the loop had been completed. The form itself is reproduced in Appendix C.

The questionnaire was organized as follows. The first question asked which sign groups were adequate in terms of conspicuity and visibility when not lighted. Question 2 asked the same thing except in terms of legibility, and Question 3 was the same except in terms of appearance. For each of these questions, evaluators chose as many sign groups as they deemed appropriate, or none, so the percentages of evaluators choosing various responses may total more than 100%. The fourth question asked if there were any noticeable differences between the two approaches (left and right lane) for the same group. The final question was reserved for general evaluator comments.

4.4.2.1 Conspicuity (Question 1)

The answers for Question 1 are given in Figure 62 and Table 13 below. The evaluators were asked which sign groups were adequate for nighttime use. Sign Group E, Type IX on Type IX, had the highest approval rating, with 80% of evaluators designating it as adequate. Sign Group F, Type VII on beaded Type III, ranked second, with 65%, and the other two microprismatic legend combinations further behind. Neither beaded Type III on beaded Type III group got even a majority approval, with 40% selecting the lighted group and 35% selecting the unlighted group as adequate.

Responses for male and female evaluators are shown in Figure 63 and Figure 64, respectively. The Type IX on Type IX was the preferred combination by both men and women, with the Type VII on beaded Type III second in both cases. Otherwise results were fairly close between the two sexes, except for the beaded Type III on beaded Type III groups, where the unlighted sign group was selected by only 22% of the female evaluators, versus 46% for men, while the lighted group was selected by only 27% of the male evaluators, versus 56% of women.

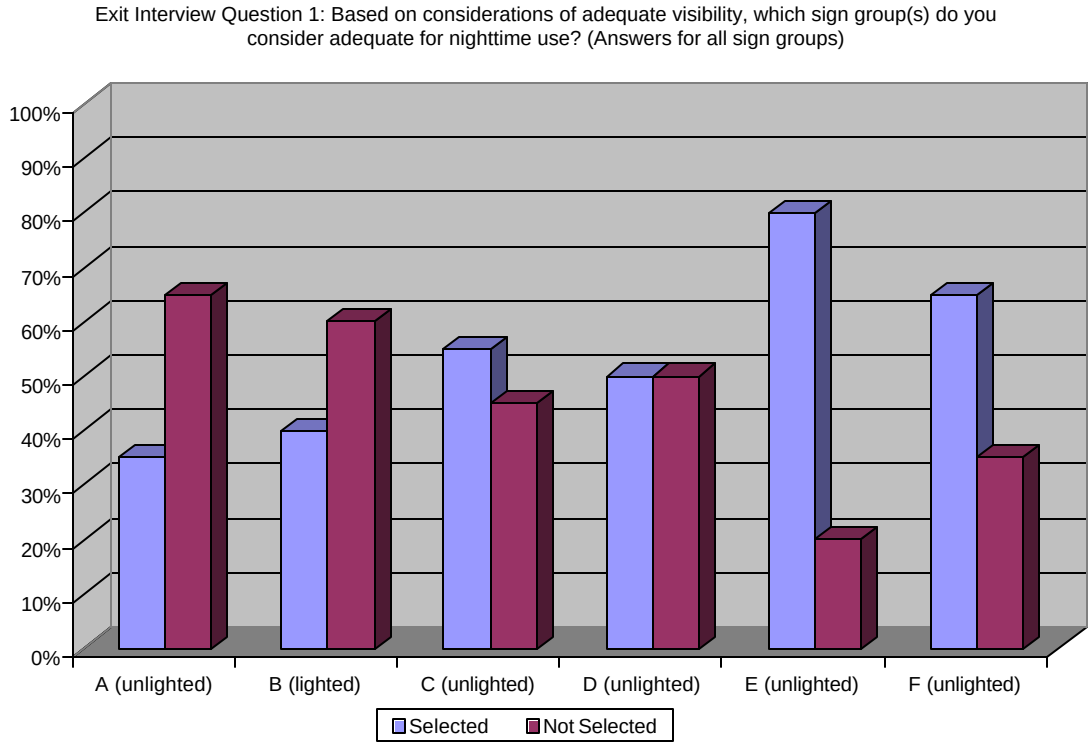

Figure 62. Responses for all sign groups for Exit Interview Question 1. For a key to sign group material combinations, see Table 1 on page 5.

Table 13. Responses to Question 1 of the Exit Interview Form, asking whether conspicuity of sign groups was adequate. For a key to sign group material combinations, see Table 1 on page 5.

Question 1			
Based on considerations of **adequate visibility**, which sign group(s) do you consider adequate for nighttime use? You may choose more than one.			
legend type/background type		% evaluators	# evaluators
A (unlighted)		35%	7
B (lighted)		40%	8
C (unlighted)		55%	11
D (unlighted)		50%	10
E (unlighted)		80%	16
F (unlighted)		65%	13

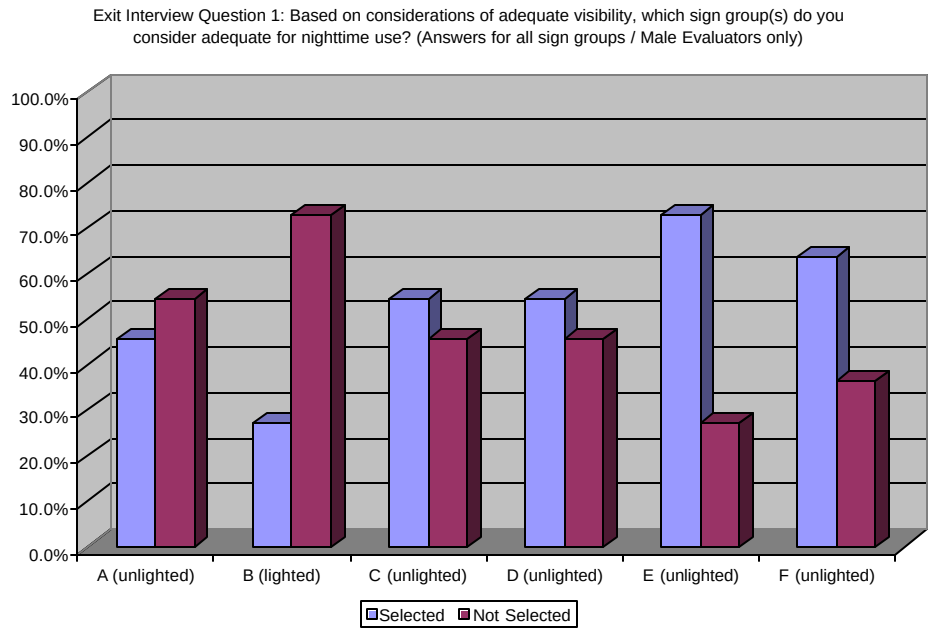

Figure 63. Responses for Exit Interview Question 1 from male evaluators only for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

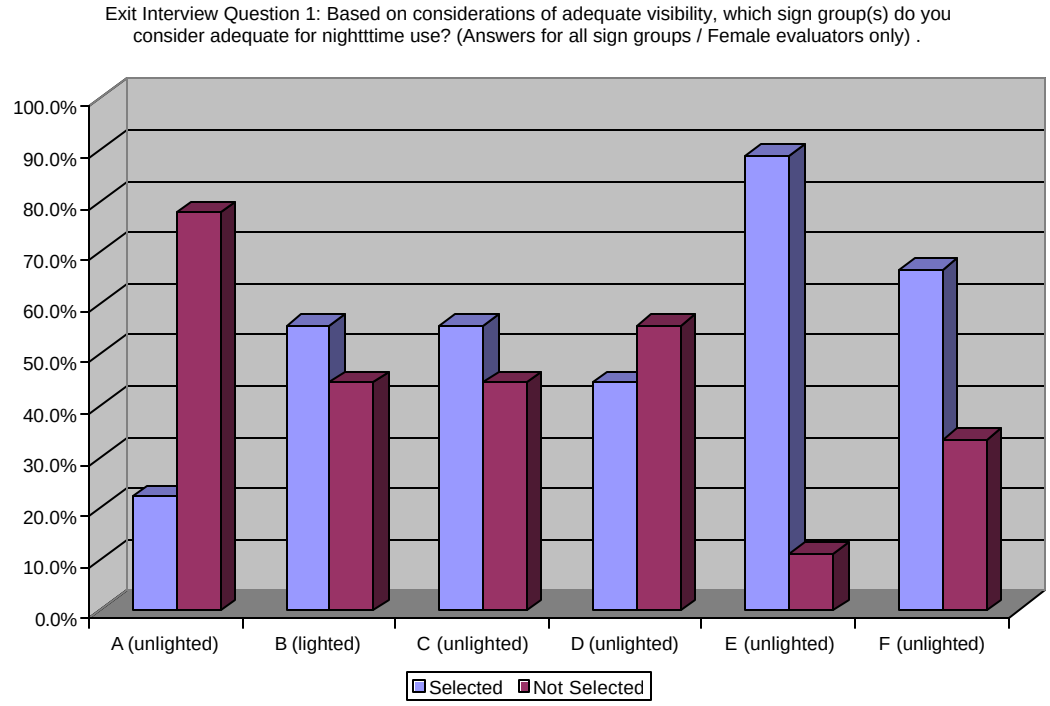

Figure 64. Responses for Exit Interview Question 1 from female evaluators only for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

4.4.2.2 Legibility (Question 2)

Responses to Question 2 are shown in Figure 65 and Table 14 below. This is the key question on legibility, which asked respondents to select which sign groups were adequately legible for nighttime driving. Responses for the various sign groups are similar to those on Question 1, differing by at most one evaluator. Thus Type IX on Type IX is the favorite, with 80% of evaluators approving, followed by Type VII on beaded Type III with 65%. Neither beaded Type III on beaded Type III combination, whether unlighted or lighted, was selected by a majority of evaluators, and neither was Type IX on beaded Type III.

Responses broken down by gender are shown in Figure 66 for men and Figure 67 for women. Again, the Type IX on Type IX group ranked highest for both sexes, followed by Type VII on beaded Type III. Two thirds (66.6%) of the female evaluators thought the Type VIII on microprismatic Type III was adequately legible, which was the same percentage as for Type VII on beaded Type III for women. However only 54.5% of men agreed, making it the third choice overall.

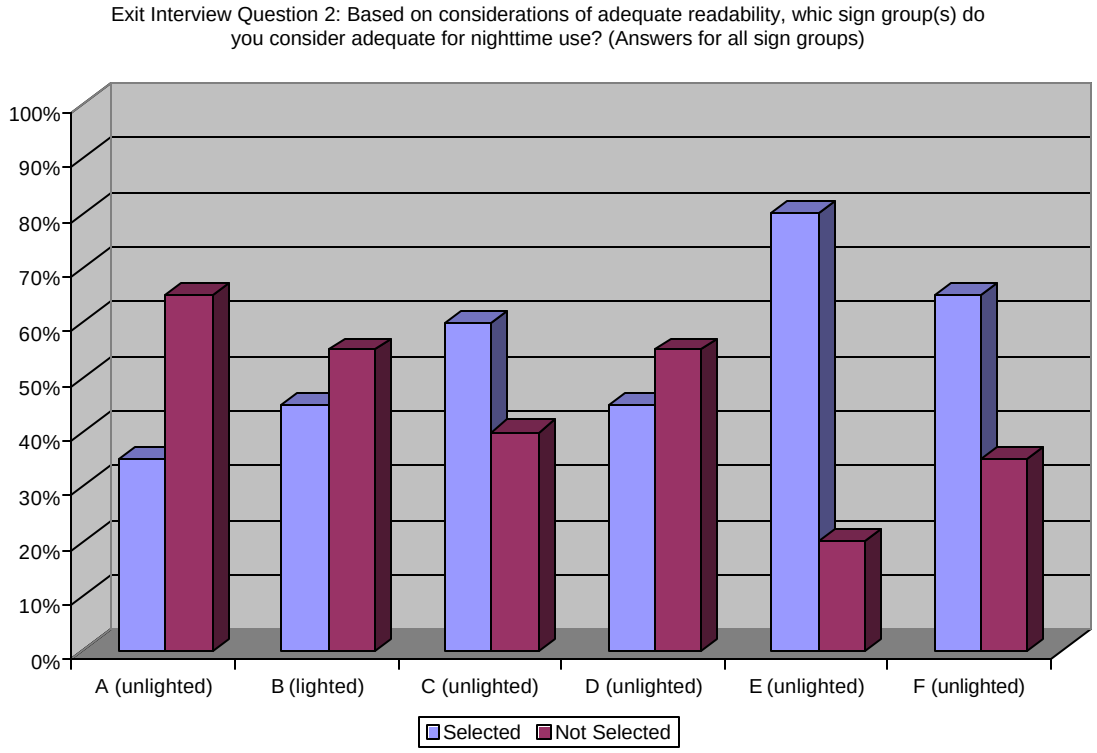

Figure 65. Responses for all sign groups for Exit Interview Question 2. For a key to sign group material combinations, see Table 1 on page 5.

Table 14. Responses to Question 2 of the Exit Interview Form, asking whether legibility of sign groups was adequate. For a key to sign group material combinations, see Table 1 on page 5.

Question 2			
Based on considerations of **adequate readability**, which sign group(s) do you consider adequate for nighttime use? You may choose more than one.			
legend type/background type		% evaluators	# evaluators
A (unlighted)		35%	7
B (lighted)		45%	9
C (unlighted)		60%	12
D (unlighted)		45%	9
E (unlighted)		80%	16
F (unlighted)		65%	13

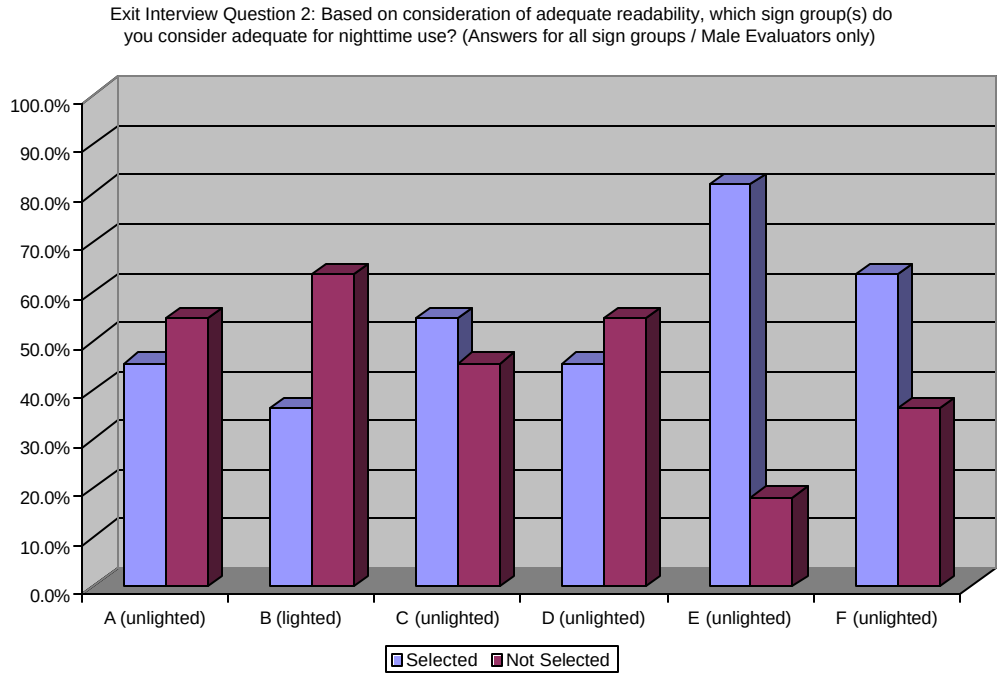

Figure 66. Responses for Exit Interview Question 2 from male evaluators only for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

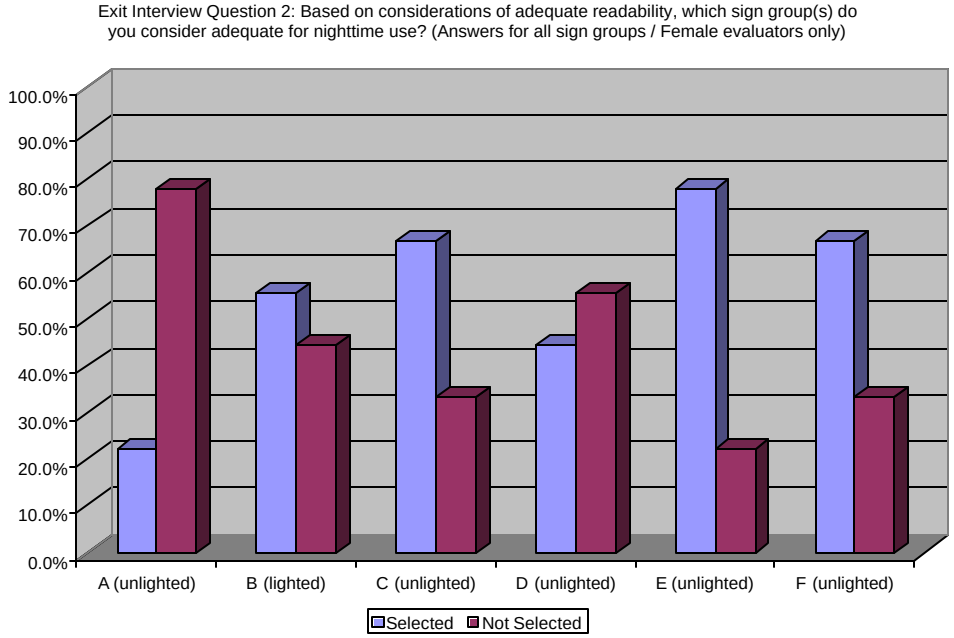

Figure 67. Responses for Exit Interview Question 2 from female evaluators only for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

4.4.2.3 Overall Appearance (Question 3)

Question 3 of the Exit Interview Form asked the evaluators to indicate which sign groups were adequate in terms of overall appearance. Responses are shown in Figure 68 and Table 15. Type IX on Type IX was rated exceptionally well, with all but one (95%) of the twenty evaluators indicating the sign group had adequate appearance. Three fourths (75%) said the same for Type VII on beaded Type III, and 65% for Type VIII on microprismatic Type III. Lighted beaded Type III on beaded Type III and Type IX on beaded Type III each got 50%, and the unlighted beaded Type III on beaded Type III got only 35%, indicating most evaluators found the appearance inadequate.

Responses for male evaluators to Question 3 are shown in Figure 69, and those for female evaluators are shown in Figure 70. Generally speaking, the appearance of the Type IX on Type IX was rated very highly by both sexes. The level of approval for the other sign groups was comparable between the sexes, except the beaded Type III on beaded Type III combinations, where the unlighted combination was rated acceptable by a larger percentage of men than women (45.5% versus 22.2%, respectively), and the lighted combination was rated adequate by more women than men (66.7% versus 36.4%, respectively).

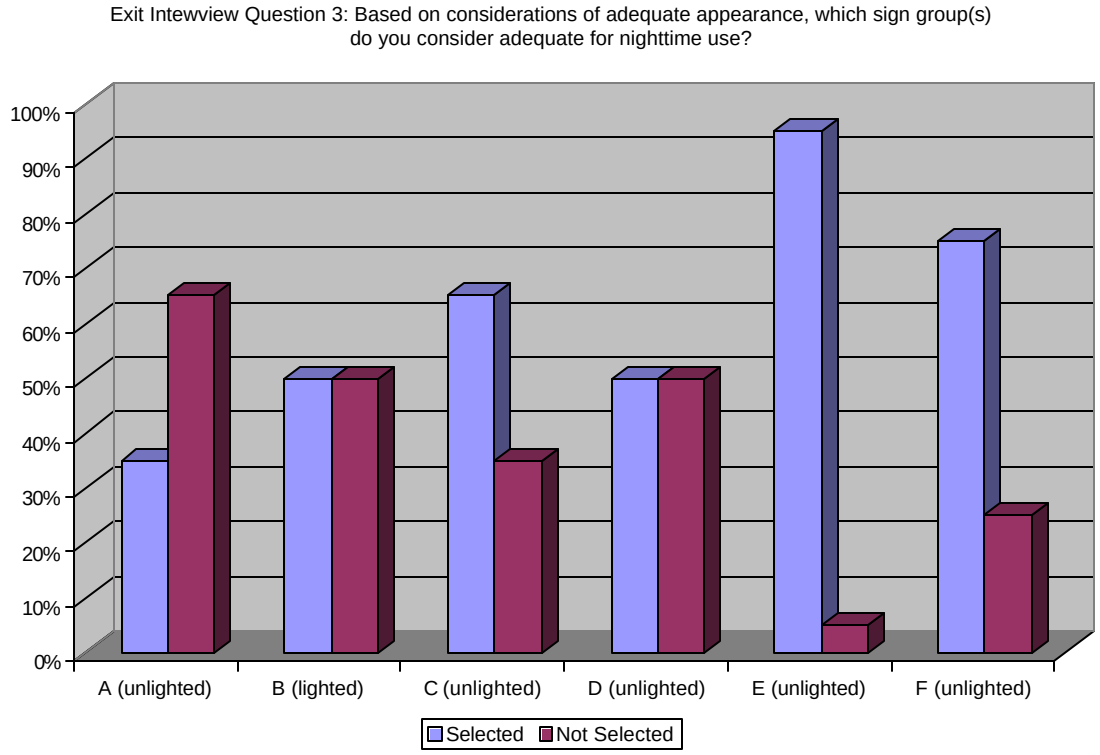

Figure 68. Responses for all sign groups for Exit Interview Question 3. For a key to sign group material combinations, see Table 1 on page 5.

Table 15. Responses to Question 3 of the Exit Interview Form, asking whether quality of appearance of sign groups was adequate. For a key to sign group material combinations, see Table 1 on page 5.

Question 3			
Based on considerations of **adequate appearance**, which sign group(s) do you consider adequate for nighttime use? You may choose more than one.			
legend type/background type		% evaluators	# evaluators
A (unlighted)		35%	7
B (lighted)		50%	10
C (unlighted)		65%	13
D (unlighted)		50%	10
E (unlighted)		95%	19
F (unlighted)		75%	15

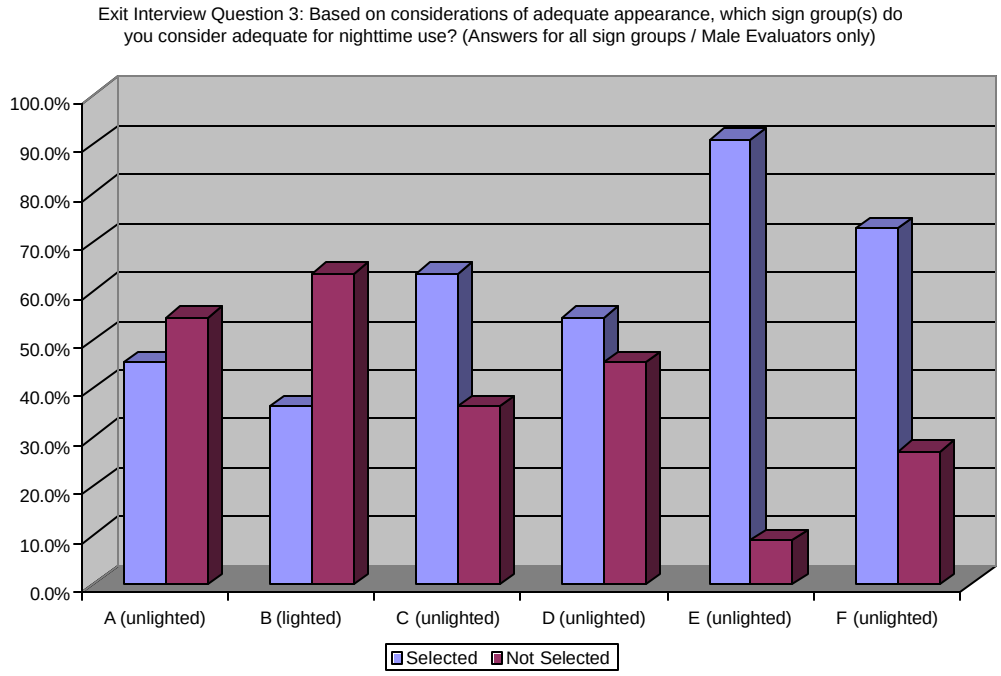

Figure 69. Responses for Exit Interview Question 3 from male evaluators only for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

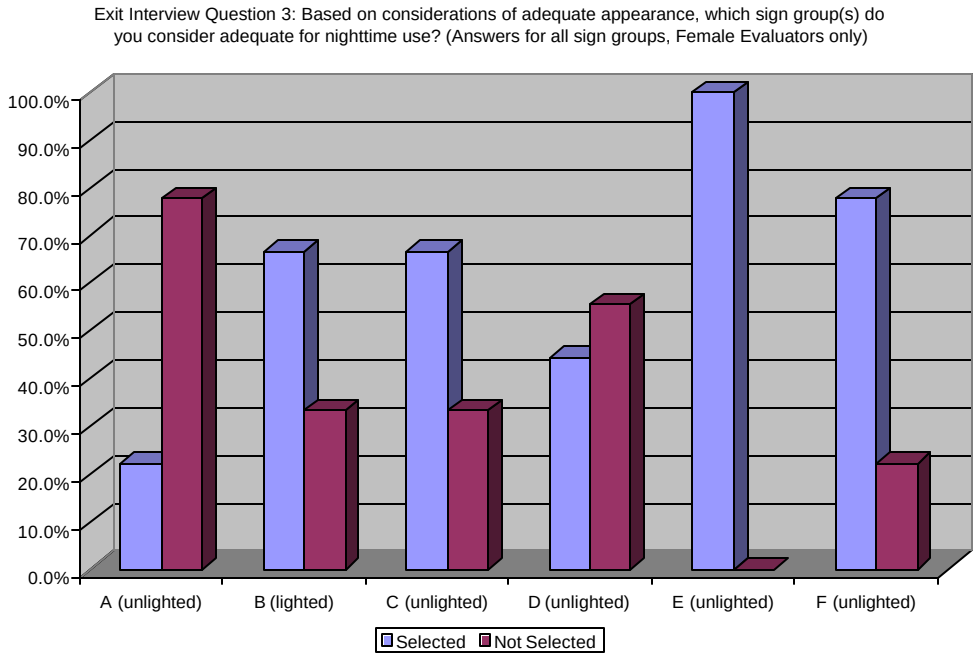

Figure 70. Responses for Exit Interview Question 3 from female evaluators only for all sign groups. For a key to sign group material combinations, see Table 1 on page 5.

5 SUMMARY DISCUSSION OF OLDER DRIVER PANEL EVALUATION RESULTS

The older driver panel evaluation is summarized in a series of four tables, one each for legibility, conspicuity, and overall appearance, and a fourth summarizing results from the first three. Each table has the following elements: Percentage of evaluators choosing "at least adequate", meaning the sum of "at an adequate distance (or "good or adequate") and "at a more than adequate distance" (or "very good or excellent") responses, for the relevant question on the Sign Evaluation Form for both lighted and unlighted signs, for easy comparison; Percentage of evaluators picking a sign group as adequate (Exit Interview Question 1, Question 2, and Question 3); Rankings of the sign groups based on the percentage of evaluators for each question; the sum of the rankings for each sign group; and the sum of the percentages responding "at least adequate" to the questions. All rankings for each question are such that the material combination that scores the best (highest percentage) is ranked first (1), and the one that ranks last is sixth (6). If two scores are tied for different materials, both are assigned the average of the two ranks – for scores of 100%, 92.5%, 92.5%, and 65%, the ranks are 1, 2.5, 2.5, 4 respectively. Thus for the sums of ranks, located on the next to rightmost column of the table, the lower the sum of ranks is, the better the material combination was perceived to perform overall for the attribute at the top of the table: legibility, conspicuity, or overall appearance. The higher the percentage or sum of percentages of a sign group, the better the performance on that attribute.

5.1 Legibility and Readability

Legibility results from the Sign Evaluation Form and the Exit Interview and Overall Comparisons form are combined in Table 16. Comparing the aggregate responses to the three Sign Evaluation Form questions completed after passing each sign bridge and the Exit Interview question, it can be seen that lowest sum of ranks belongs to Type VII on beaded Type III (Sign Group F), followed closely by Type IX on Type IX (Sign Group E). On the other hand, the sum of percentages is very slightly higher for Sign Group E, 337.5% versus 330%. It could be argued that either group is the best, however these two clearly performed better than the others. The next two highest performing sign groups were B (lighted beaded Type III on beaded Type III) and C (Type VIII on microprismatic Type III). The sum of ranks appears to be considerably better for the lighted signs, but the sum of percentages is only very slightly higher – five points out of about 300, which is somewhat unexpected. The Type IX on beaded Type III performed worse, and the unlighted beaded Type III on beaded Type III ranked at the bottom, as expected.

On the Sign Evaluation Form responses, Type VII on beaded Type III was in the top two. The lighted sign group had the highest number of evaluators rating it as easy to read at the farthest point that it was legible, but the Type IX on Type IX was rated as at least adequately legible on the Exit Interview Form. While the lighted group was in the top three for all the Sign Evaluation Form questions, it was tied for fourth on the Exit Interview, rated acceptable by only 45% of evaluators.

Table 16. Comparison of responses to legibility questions on Sign Evaluation Form and Exit Interview form with comparative rankings. A lower rank or higher percentage value indicates better performance.

Legibility												
			Sign Evaluation Form						Exit Interview Form			
			Question 4		Question 5		Question 6		Question 2			
			reading distance		at farthest point legible		at nearest point legible		legibility			
Sign	Sheeting Material		at least adequate		easy to read		easy to read		adequate for nighttime use		Sum of ranks	Sum of percentages
Group	Legend	Background	value	rank	value	rank	value	rank	value	rank		
A	III	III	77.5%	6	75.0%	5	65.0%	6	35.0%	6	23	252.5%
B*	III	III	92.5%	2.5	90.0%	1	75.0%	3	45.0%	4.5	11	302.5%
C	VIII	III** (m)	85.0%	4	82.5%	4	70.0%	4.5	60.0%	3	15.5	297.5%
D	IX	III	82.5%	5	72.5%	6	70.0%	4.5	45.0%	4.5	20	270.0%
E	IX	IX	92.5%	2.5	85.0%	3	80.0%	2	80.0%	1	8.5	337.5%
F	VII	III	95.0%	1	87.5%	2	82.5%	1	65.0%	2	6	330.0%

Notes:
*All sign groups were unlighted except Sign Group B, which was lighted
**All Type III materials were beaded except on Sign Group C. All other materials were microprismatic

5.2 Conspicuity and Visibility

Conspicuity results from the panel evaluation are summarized in Table 17. The Sign Evaluation Form question responses indicated that all the signs were adequately conspicuous, with the possible exception of the unlighted beaded Type III on beaded Type III sign group and maybe the Type IX on beaded Type III. Again the beaded Type III on beaded Type III ranked last all the way around. Type IX on Type IX was again the top performer, but only slightly over Type VII on beaded Type III. Type VIII on microprismatic Type III was third, and the next two places were taken by the lighted sign group and Type IX on beaded Type III.

Table 17. Comparison of responses to visibility questions on Sign Evaluation Form and Exit Interview form with comparative rankings. A lower rank or higher percentage value indicates better performance.

Visibility								
			Sign Evaluation Form		Exit Interview Form			
			Question 1		Question 1			
Sign	Sheeting Material		at least adequate		adequate for nighttime use		Sum of ranks	Sum of percentages
Group	Legend	Background	value	rank	value	rank		
A	III	III	77.5%	6	35.0%	6	12	112.5%
B*	III	III	92.5%	3.5	40.0%	5	8.5	132.5%
C	VIII	III** (m)	92.5%	3.5	55.0%	3	6.5	147.5%
D	IX	III	85.0%	5	50.0%	4	9	135.0%
E	IX	IX	95.0%	2	80.0%	1	3	175.0%
F	VII	III	97.5%	1	65.0%	2	3	162.5%
Notes: *All sign groups were unlighted except Sign Group B, which was lighted **All Type III materials were beaded except on Sign Group C. All other materials were microprismatic								

5.3 Legend and Background Sheeting Material Appearance

The panel evaluation results regarding the appearance of the legend, background, and signs overall are in Table 18. Overall, the favorite sign was the Type IX on Type IX, followed again by Type VII on beaded Type III. Somewhat further back were Type VIII on microprismatic Type III and the lighted beaded Type III on beaded Type III sign groups. At the bottom were Type IX on beaded Type III, and the unlighted beaded Type III on beaded Type III.

The individual question responses may be of some interest. The top ranked legends were the Type VIII and Type IX on Type IX, followed by lighted beaded Type III and Type VII, all of which were rated at least adequate by 90% of evaluators. The background was a somewhat different issue, the beaded Type III background with the Type VII legend had the highest percentage (95%) rating its appearance "at least adequate", and this was followed closely by the lighted sign (92.5%). The other three were in the 80s.

On the Exit Interview question, 80% rated the Type IX on Type IX sign as adequate, while the Type VII on beaded Type III received 65%, and the Type VIII on microprismatic Type III received 60%.

Table 18. Comparison of responses to questions on Sign Evaluation Form and Exit Interview form regarding appearance of signing materials with comparative rankings. A lower rank or higher percentage value indicates better performance.

Appearance										
			Sign Evaluation Form				Exit Interview Form			
			Question 7		Question 8		Question 3			
			Legend		Background		Overall			
Sign	Sheeting Material		at least adequate		at least adequate		adequate for nighttime use		Sum of	Sum of
Group	Legend	Background	value	rank	value	rank	value	rank	ranks	percentages
A	III	III	82.5%	5	85.0%	5	35.0%	6	16	202.5%
B*	III	III	92.5%	3	92.5%	2	50.0%	4.5	9.5	235.0%
C	VIII	III** (m)	95.0%	1.5	87.5%	3.5	65.0%	3	8	247.5%
D	IX	III	80.0%	6	82.5%	6	50.0%	4.5	16.5	212.5%
E	IX	IX	95.0%	1.5	87.5%	3.5	95.0%	1	6	277.5%
F	VII	III	90.0%	4	95.0%	1	75.0%	2	7	260.0%

Notes:
*All sign groups were unlighted except Sign Group B, which was lighted
**All Type III materials were beaded except on Sign Group C. All other materials were microprismatic

5.4 Older Driver Panel Evaluation results summary

Table 19 is a summary of the older driver panel rankings from Table 16, Table 17, and Table 18. The sums of ranks and percentages from each preceding table are in columns under the corresponding attribute: legibility, visibility, or appearance. To the right of that are two columns under the heading "Total". The left column has the sum of ranks from the other three sum of ranks columns added together; on the right is the sum of percentages from the corresponding preceding columns. On the right is an overall ranking based on the total sum of percentages.

The highest ranking sign group overall is Type IX on Type IX, followed by Type VII on beaded Type III. Following that is Type VIII on microprismatic Type III and the lighted beaded Type III on beaded Type III sign group. The Type IX on beaded Type III is next, and the unlighted beaded Type III on beaded Type III is last. If one considers sums of ranks, where the lower sum indicates better performance, then Type VII on beaded Type III is best, followed by Type IX on Type IX, a reversal of the positions under the sum of percentages ranking. Next are lighted beaded Type III on beaded Type III and Type VIII on microprismatic Type III, again switching order. Type IX on beaded Type III and unlighted beaded Type III on beaded Type III maintain their bottom two positions unchanged. The switching of orderings based on whether one follows sums of percentages or sums of ranks indicates that the two switched material combinations may be roughly equivalent. In the case of the top two combinations, the margin of preference for Type VII on beaded Type III on the Sign Evaluation Form questions was offset by a larger percentage of evaluators selecting the Type IX on Type IX as adequate for nighttime use on the Exit Interview Form.

There are nine questions summed to create the sum of percentages, so the maximum possible is 900. The highest sum actually obtained was 790 by Type IX on Type IX, which was helped considerably by its strong showing in the Exit Interview. That sign group clearly stuck favorably in the evaluators' minds. This was the third ranked of the four sign groups used in the previous expert panel evaluation [4]. While the Type VII on beaded Type III generally performed better on the Sign Evaluation Form questions, it was viewed considerably less favorably in the Exit Interview; the sign group's total sum of percentages is 752.5. This was one of the two top evaluated sign groups in the previous expert panel evaluation. The next sign group is the Type VIII on microprismatic Type III, with 692.5; this group was not evaluated previously. The lighted sign group had the fourth highest sum of percentages, 670, though some panelists indicated verbally that they preferred lighted signs. The Type IX on beaded Type III was the next highest, at 617.5, even though it had been the preferred sign group in the previous study. Not surprisingly, the unlighted beaded Type III on beaded Type III performed the worst, with a total score of 567.5, correlating well with its last place result in the previous evaluation.

Table 19. Total sums of ranks and percentages with overall evaluation ranks. A lower rank or higher percentage value indicates better performance.

Summary of Results from Older Driver Panel Evaluation											
			Legibility		Visibility		Appearance		Total		
Sign	Sheeting Material		Sum of		Sum of		Sum of		Sum of		Overall
Group	Legend	Background	Ranks	%	Ranks	%	Ranks	%	Ranks	%	Rank
A	III	III	23	252.5%	12	112.5%	16	202.5%	51	567.5%	6
B*	III	III	11	302.5%	8.5	132.5%	9.5	235.0%	29	670.0%	4
C	VIII	III** (m)	15.5	297.5%	6.5	147.5%	8	247.5%	30	692.5%	3
D	IX	III	20	270.0%	9	135.0%	16.5	212.5%	45.5	617.5%	5
E	IX	IX	8.5	337.5%	3	175.0%	6	277.5%	17.5	790.0%	1
F	VII	III	6	330.0%	3	162.5%	7	260.0%	16	752.5%	2
Notes: *All sign groups were unlighted except Sign Group B, which was lighted **All Type III materials were beaded except on Sign Group C. All other materials were microprismatic											

6 CONCLUSIONS AND RECOMMENDATIONS

In the previous study [4], it was concluded that the practice of lighted overhead signs can be discontinued if either white Type VII or Type IX legends are used on green beaded Type III backgrounds. With older drivers, it appears that the preferred options are Type IX on Type IX or Type VII on beaded Type III. It appears that the higher background luminance of the Type IX background material is preferred by older drivers, perhaps because it increases the amount of overall light reflected from the sign, even at some cost in contrast. Type IX materials are designed for better performance at closer distances. On the other hand, the Type VII legend may be preferred because it is designed to appear brighter at a longer distance. This may enhance the perceived legibility of the legend, which was highest for this sign group as measured by responses on the Sign Evaluation Form.

Both of these unlighted sign groups, Type IX on Type IX and Type VII on beaded Type III, were rated noticeably higher than the lighted beaded Type III on beaded Type III sign group. This suggests that implementing unlighted signs with appropriate materials may actually constitute a perceived improvement on Ohio's highways. The unlighted signs do have a more uniform appearance; sign lighting creates lighter and darker areas depending on where the light falls. However, it is not known how much of the results were affected by the presence of a burnt out bulb on the lighted beaded Type III beaded Type III sign group on two nights of the evaluation. In both cases the effect appeared to be minimal, as the burned out light was in between two other lights that helped compensate for its absence, and the results were similar after the light was fixed.

The top ranked sign group, based on the sums of percentages from the evaluation forms, Type IX on Type IX, was selected as acceptable on the basis of legibility and visibility by 80% of the evaluators, according to their responses on Questions 1 and 2 of the Exit Interview Form. The second highest rating in the Exit Interview for the same attributes was 65% for the Type VII on beaded Type III, which was the top ranked sign group based on sums of ranks. In contrast, the lighted sign group was fourth or fifth, with less than a majority considering them adequate for nighttime use (45% for legibility, 40% for visibility). This suggests that there is room for improvement of overhead guide signing from the point of view of older drivers, regardless of the presence of lighting.

In the previous study [4], it was concluded that using microprismatic Type IX or Type VII legends on beaded Type III backgrounds on unlighted overhead guide signs should not result in any detrimental information acquisition and safety effects to the majority of the driving public. For older drivers, it appears that there may actually be an improvement if Type IX on Type IX or Type VII on beaded Type III is used. These evaluator results are based upon a group of 20 older drivers ranging in age from 63 to 81 years (average 72) riding in a 2002 Dodge Caravan. Corrected visual acuity ranged from 20/20 to 20/29 with an average of 20/25.

Issues remaining to be investigated include the effect of unlighted guide signs on truck drivers with higher observation angles and the mitigation of the effects of dew and frost

on signs. It does appear that the effect of frost on overhead signs is slightly less than it is on ground mounted signs over vegetation. While we acknowledge that dew and frost could present a visibility and legibility problem, it should be recognized that dew or frost only form under certain atmospheric conditions and is not a nightly occurrence. In addition, traffic volumes are generally lower at night, during times when dew or frost are most likely to occur. We don't have a cure for this problem at the present time, but there are some products in development that promise to ameliorate the effects of dew and frost in the future.

As in the previous study [4], we recommend to ODOT to prepare a statewide implementation plan and schedule to discontinue the practice of providing and maintaining luminaires for overhead signs after replacing step by step all overhead signs in the State with microprismatic Type VII sheeting legends on beaded Type III background sheeting. Type IX on Type IX may be specified as an alternative combination, particularly for signs with relatively short approach distances of less than about 400 feet (122 m). To take into account older driver needs, which are greater than those of younger drivers, we recommend the use of Type IX on Type IX instead of the Type IX on beaded Type III previously recommended at short distances.

The change of practice from lighted to unlighted overhead signs with white microprismatic Type VII legends on green beaded Type III backgrounds, or Type IX legends on Type IX backgrounds, will have a number of benefits including the elimination of the luminaire installation costs, the electricity requirements at overhead signs, the electricity costs, the maintenance and associated traffic control costs, and the wasted illumination towards the night sky ("light pollution").

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Appendix A. Instructions given to evaluators

Overhead Sign Evaluation on US 30 near Mansfield OH

Welcome

We welcome you as an evaluator of the visibility, readability, appearance, and adequacy of overhead signs under night time driving conditions.

Explanation of Evaluation Procedure

Before starting the evaluation, your vision will be tested. Based on the results, you might be excluded from the rest of the study. After the vision test, you need to complete a subject biographical questionnaire and fill the human subject consent form.
You are part of an evaluator group of two evaluators. There will be ten groups of two evaluators each in this experiment. We will complete two loops, each time evaluating six sign groups. Your position in the van will be rotated after the first loop so that you will be the front seat passenger on one loop, and center rear seat passenger on the other loop. You are required to wear a seatbelt at all times. In the first loop the van will be driven in the left hand lane and in the second loop the van will be driven in the right hand lane. There will be two experimenters in the van with you at all times who will give you directions and the appropriate evaluation forms.

One of the experimenters will be driving the car. The headlights will be on low beams and will be kept there for the duration of the experimental loops.

In each loop there will be the same six sign bridges, each displaying three overhead guide signs which you will need to evaluate. The experimenter will always tell you in advance when you approach a group of overhead signs that you will need to evaluate. We expect you to be especially alert during these approaches and observe the overhead signs and memorize as well as possible your impressions about the visibility of the signs, the

readability of the information presented on the signs, the appearance of the legends and the sign backgrounds, potential glare and other problems, as well as whether or not these signs are inadequate, adequate, or more than adequate at night in your opinion. Please note we expect you to keep your conversations to a minimum during the loops and not discuss your evaluator opinions with the other member of your group.

After passing each experimental sign bridge, we will take the next exit. The experimenter will give each of you a sign evaluation sheet to fill out. After the evaluation sheet is filled out, you will reenter US 30 and proceed to the next sign bridge and repeat the evaluation procedure.

During the loops, besides evaluating the overhead guide signs, you need to view also the ground mounted guide signs on the right. You will be asked to compare the ground mounted signs against overhead guide signs.

Each loop will take about 90 minutes. After all two loops have been completed and 12 (2 loops x 6 sign groups) evaluation sheets have been filled out, you will be asked to fill out an overall comparison, comments, and suggestions form. The total duration of the evaluation is expected to be about four and half hours. The total duration is also dependent on how much time will be spent during the evaluation at the rest areas. When the paperwork is completed, you will be paid and free to leave.

These procedures and evaluation forms will also be explained to you orally by the experimenters.

Thank You!

We appreciate your participation and help with this evaluation. We hope that you have a safe trip home after the evaluation and we thank you again!

Appendix B. Sign Evaluation Form filled out by evaluators after passing each experimental sign bridge

Note: Some of the initial fields known in advance, such as date, loop number, or illumination condition, were automatically filled out in advance of the evaluation using a mail merge. These fields appear like **«Date»** .

Sign Group A used as an example. Forms for other groups were identical except for the group letter and picture.

Sign Evaluation Form
Evaluator
Name:_____
Time:_____ Date: **«Date»**
Evaluator Group (1-10): **«Group»**
Loop Number (1-2): **«Loop»** Evaluation Number (1-20): **«Evalnum»**
Approach Lane: **«lane»**

Sign Group A	

1. During the approach, was the **presence of the signs as a whole visible** to you?
_____ a. at a more than adequate distance ahead
_____ b. at an adequate distance ahead
_____ c. only at an inadequate distance ahead
2. Was there **other traffic** on the road ahead of you as you approached the sign group?
_____ a. Lots of traffic
_____ b. Some traffic
_____ c. No traffic.
3. If there was other traffic on the road ahead of you on the approach, did the headlights from the **other traffic on the road help make the signs more visible**?
_____ a. Yes, the traffic ahead helped make the signs more visible.
_____ b. No, there was traffic, but the traffic did not appear to make the signs more visible

4. At what distance could you **read the legend** (information) on the signs?

_____ a. At a more than adequate distance
_____ b. At an adequate distance
_____ c. Only at an inadequate distance
_____ d. Could not read the information on the signs at all.

5. At the **first point where the sign became legible**, which of these statements would you say was true about the legend?

____ a. The legend (white destination words) was too bright and glaring, making it hard to read.
_____ b. The legend (white destination words) was at just about the right brightness and easy to read.
_____ c. The legend (white destination words) was too dark and therefore hard to read.

6. At the **last point where the sign was legible** (typically about 1 second before the sign was passed), which of these statements would you say was true about the legend?

_____ a. The legend (white destination words) was too bright and glaring, making it hard to read.
_____ b. The legend (white destination words) was at just about the right brightness and easy to read.
_____ c. The legend (white destination words) was too dark and therefore hard to read.

7. During the entire approach, how do you rate the **appearance of the white legend**?

_____ a. excellent or very good
_____ b. good or adequate
_____ c. inadequate

8. During the entire approach, how do you rate the **appearance of the green sign background**?

_____ a. excellent or very good
_____ b. good or adequate
_____ c. inadequate, rather dark

8. Did you experience **any traffic-related problems** during the approach which prevented you from having a fair chance to evaluate the visibility, legibility, or other factors of the signs?

_____ a. no traffic problems
_____ b. yes, traffic obscured view of signs
_____ c. yes, traffic distracted attention from signs
____ d. other traffic related problems. Specify: _____

9. Did you notice **any difference between the three signs** in terms of visibility, readability, or appearance?

_____ a. No significant differences
_____ b. Yes. Explain: _____
_____

10. Compared to unlighted green background guide signs mounted on the ground on the right hand side of the highway, the visibility, readability, and appearance of the overhead sign group is

visibility: _____Better _____Same _____Worse
readability: _____Better _____Same _____Worse
overall appearance: _____Better _____Same _____Worse

12. Did you experience **any other** (non-traffic-related) **problems** during the approach which prevented you from having a fair chance to evaluate the visibility, readability, or other factors of the three signs? If yes, please explain:

_____
_____
_____
_____
_____
_____

13. Do you have any **other comments** regarding this sign group's visibility, readability, appearance, or other factors? Or other comments for this approach?

_____
_____
_____
_____
_____
_____
_____
_____
_____

Appendix C. Exit Interview and Overall Comparisons form filled out by evaluators at end of experiment

Exit Interview and Overall Comparisons

Evaluator Name:_____

Date: 12 / / 2002

Time: _____

Evaluator Group:

Evaluator Number:

1. Based on considerations of **adequate visibility**, which sign group(s) do you consider adequate for nighttime use?
You may choose more than one.

____ Sign Group A	
____ Sign Group B	
____ Sign Group C	
____ Sign Group D	
____ Sign Group E	
____ Sign Group F	

____ No sign group is adequate.

2. Based on considerations of **adequate readability**, which sign group(s) do you consider adequate for nighttime use?
You may choose more than one.

_____ Sign Group A	
_____ Sign Group B	
_____ Sign Group C	
_____ Sign Group D	
_____ Sign Group E	
_____ Sign Group F	

_____ No sign group is adequate.

3. Based on considerations of **adequate appearance**, which sign group(s) do you consider adequate for nighttime use?
You may choose more than one.

_____ Sign Group A	
_____ Sign Group B	
_____ Sign Group C	
_____ Sign Group D	
_____ Sign Group E	
_____ Sign Group F	

_____ No sign group is adequate.

4. Did you notice any differences with regard to the visibility, readability, and appearance of the overhead signs when you approached in the left hand lane versus when you approached in the right hand lane?

Sign Group A	

_____ No differences
_____Yes, different.
Explain: _____

Sign Group B	

_____ No differences
_____Yes, different.
Explain: _____

Sign Group C	

_____ No differences
_____Yes, different.
Explain: _____

Sign Group D	

_____ No differences
_____Yes, different.
Explain: _____

Sign Group E	

_____ No differences
_____Yes, different.
Explain: _____

Sign Group F	

_____ No differences
_____Yes, different.
Explain: _____

5. Please add any other comments you wish to make about this evaluation. You may comment on overhead signs, which lane you approached in, any difficulties making your evaluation judgments, distractions, recommendations regarding signs, comments on procedures used, or whatever is relevant to you.

Thank You!

We appreciate your participation and help with this evaluation.

Appendix D. Experimenter Report Form filled out by experimenter for each loop of panel evaluation

Note: This is the part of the form for the first loop, the second part is identical to the first except the loop number is 2 and the approach lane is Right.

Experimenter report form
for Unlighted Overhead Guide Sign Evaluation for Older Drivers

Experimenter Name:

Time loop began: _____ Date: 12 / / 02

Evaluator Group (1-10): Loop Number (1-2): 1

Approach Lane: **Left**

Weather conditions:
_____ Clear
_____ Cloudy, no precipitation
_____ Drizzle
_____ Light rain
_____ Heavy rain
_____ Fog
_____ Frost or dew on signs
_____ Other: _____

Weather comments: _____

_____

Sign Group A (Laver Rd exit on US 30 Eastbound):

Traffic when signs become visible: _____ No vehicles observed

close to test vehicle _____ cars _____ trucks
(within halfway to sign)
farther away from test vehicle_____ cars _____ trucks
(more than halfway to sign but still before sign)

Did trucks or other traffic probably obscure sign? _____

Other comments: _____

Time sign was passed: _____

Sign Group B (Reed Rd exit on US 30 Westbound):

Traffic when signs become visible: _____ No vehicles observed

close to test vehicle _____ cars _____ trucks
(within halfway to sign)
farther away from test vehicle_____ cars _____ trucks
(more than halfway to sign but still before sign)

Did trucks or other traffic probably obscure sign? _____

Other comments: _____

Time sign was passed: _____

Sign Group C (Reed Rd exit on US 30 Eastbound):

Traffic when signs become visible: _____ No vehicles observed

close to test vehicle _____ cars _____ trucks
(within halfway to sign)
farther away from test vehicle_____ cars _____ trucks
(more than halfway to sign but still before sign)

Did trucks or other traffic probably obscure sign? _____

Other comments: _____

Time sign was passed: _____

Sign Group D (Laver Rd exit on US 30 Westbound):

Traffic when signs become visible: _____ No vehicles observed

close to test vehicle _____ cars _____ trucks
(within halfway to sign)
farther away from test vehicle_____ cars _____ trucks
(more than halfway to sign but still before sign)

Did trucks or other traffic probably obscure sign? _____

Other comments: _____
Time sign was passed: _____

Sign Group E (SR29 N to Shelby on US 30 Westbound):

Traffic when signs become visible: _____ No vehicles observed

close to test vehicle _____ cars _____ trucks
(within halfway to sign)
farther away from test vehicle_____ cars _____ trucks
(more than halfway to sign but still before sign)

Did trucks or other traffic probably obscure sign? _____

Other comments: _____

Time sign was passed: _____

Sign Group F (Trimble Rd exit on US 30 Westbound):

Traffic when signs become visible: _____ No vehicles observed

close to test vehicle _____ cars _____ trucks
(within halfway to sign)
farther away from test vehicle_____ cars _____ trucks
(more than halfway to sign but still before sign)

Did trucks or other traffic probably obscure sign? _____

Other comments: _____

Time sign was passed: _____

Appendix E. Subject biographical questionnaire.

Ohio University

Ohio Research Institute for Transportation and the Environment

Evaluator First Name: _____Last Name:_____

Evaluator Number: _____Today's Date:_____

Subject Biographical and Driving Questionnaire

What is your date of birth? _____
Mo Day Year

Specify your gender: Male Female

Do you currently have a valid U.S. Drivers License? Which State?

Yes No State: _____

Expiration Date _____ Restrictions:_____

How many years have you been driving an automobile? _____

Have you ever held a professional driver's license? Yes No

If Yes, How many years? _____

Do you have any experience in traffic engineering? Yes No

Do you use any of the following visual aids? Check all that apply.

	Glasses	Contacts	None
During daytime			
During nighttime			

Estimate your present visual capabilities related to driving

	Excellent	9 HU\ JRRG	Good	Average	$ GHIXDOW
During the day					
During the night					

During the last 4 years approximate the total miles you have been driven in

Year	Miles	% Daytime	% Nighttime
1999			
2000			
2001			
2002			

Did you ever had trouble with reading signs?

	Specify what kind of signs you had problems. (overhead, ground mounted, warning, etc.)
During daytime	
During nighttime	

Name and address of person(s) to be contacted in case of an emergency.

Name: _____

Address: _____

_____

_____

Telephone No: _____

_____

Name: _____

Address: _____

_____

_____

Telephone No: _____

_____

Appendix F. Advertisement used to recruit evaluators.

65 year old and up drivers needed to evaluate traffic signs at night
pay: $100

We are working with the Ohio Department of Transportation to evaluate overhead traffic signs on US Route 30 near Mansfield.
The study runs December 9-20, 2002.

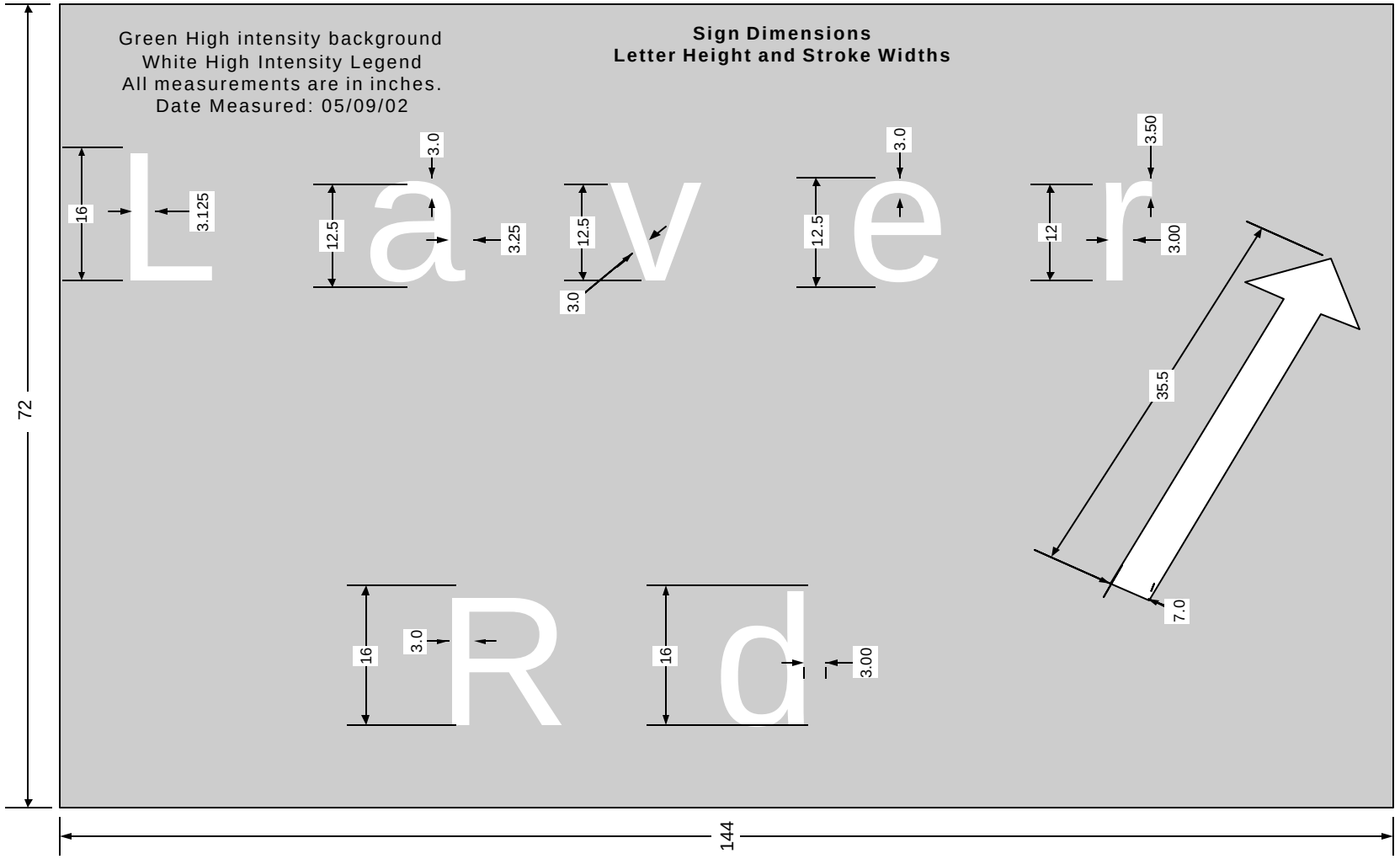
We will pay $100 upon successful completion of the evaluation, which will last one night (6 PM to around 10 PM or 8:30 PM to around 1 AM). You will ride as a passenger in a van and evaluate the signs on the basis of visibility, readability, and overall appearance.

We need 10 males and 10 females, ages 65 and up.
To qualify, you must possess a valid Ohio driver's license, still drive regularly after dark, be in good health, and pass a vision test.

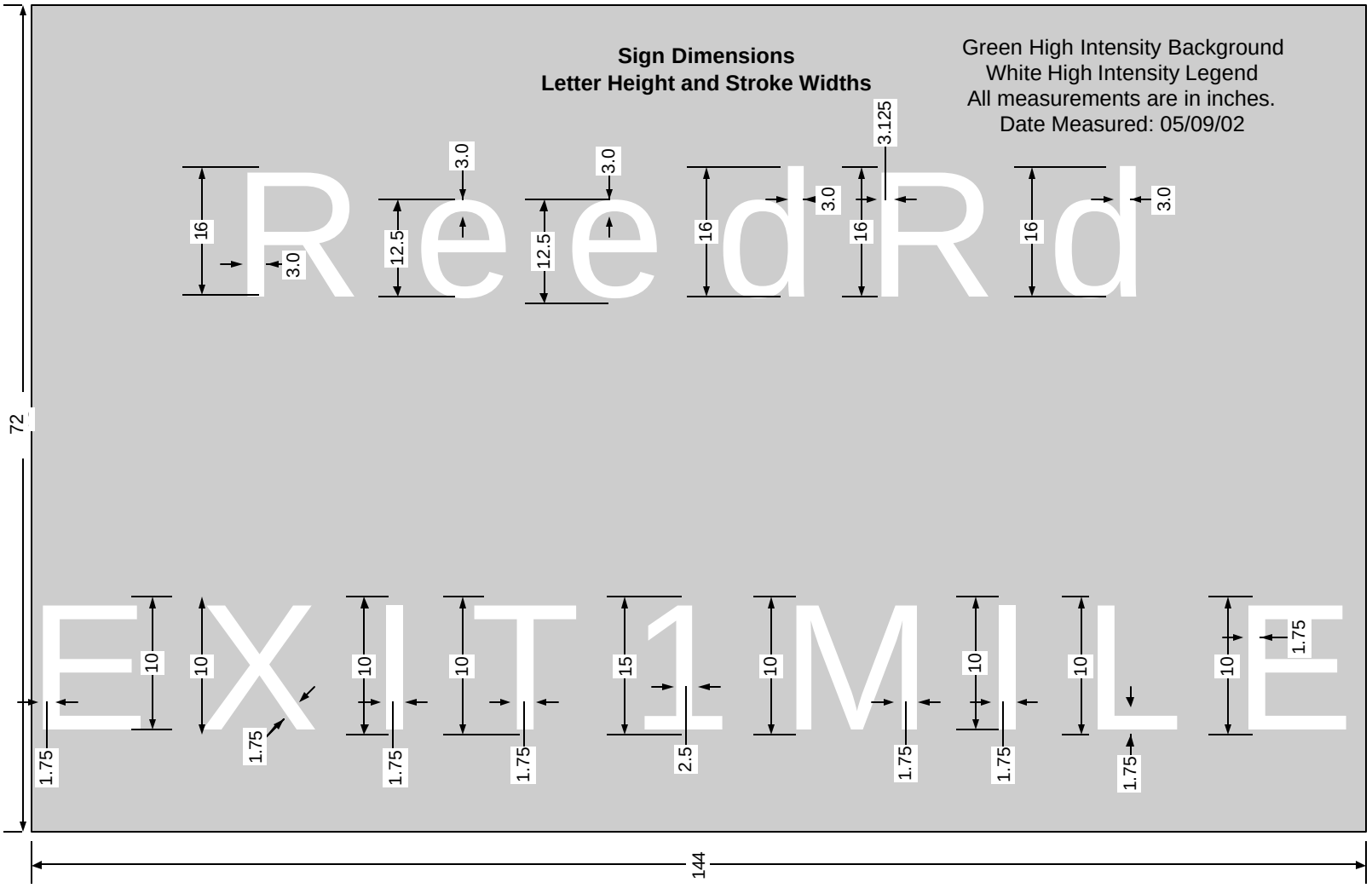
If you are interested, call toll-free 1-877-897-0210 and leave your name and telephone number. We will contact you.

Ohio Research Institute for Transportation and the Environment, 114 Stocker Center, Ohio University, Athens OH 45701

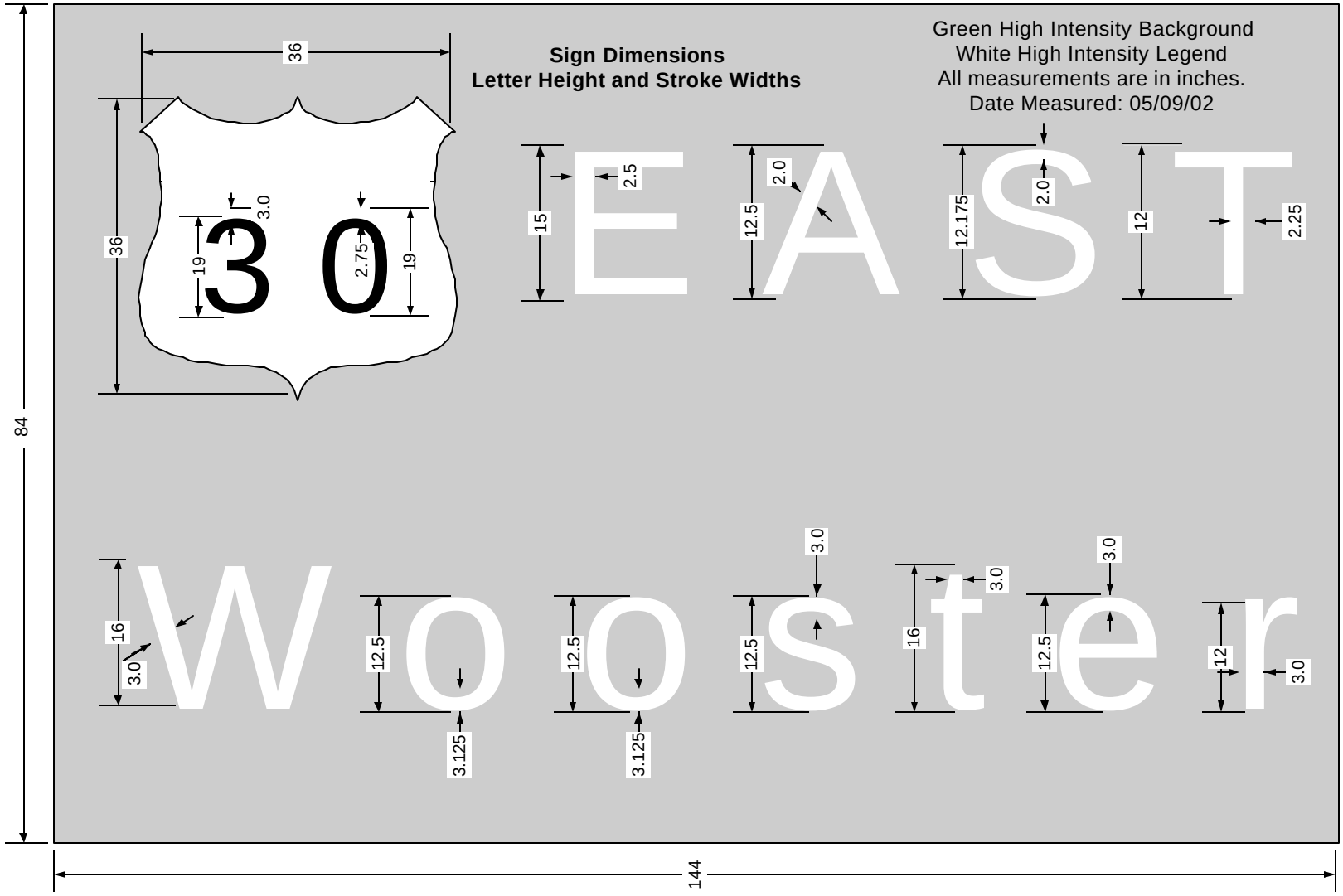
Appendix G. Exact dimensions of experimental signs erected for field evaluation in Mansfield



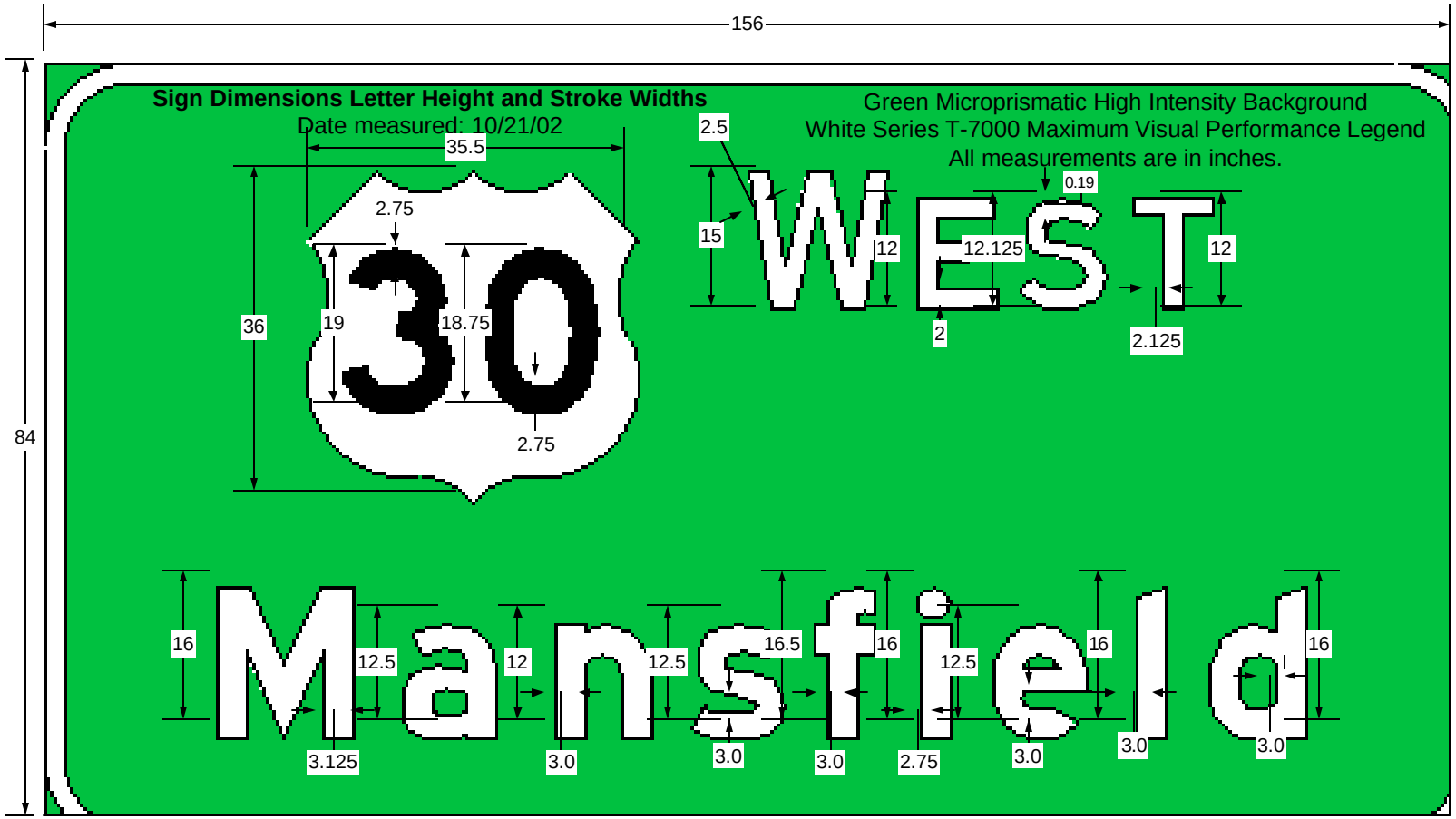
Sign Group A: beaded Type III legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.



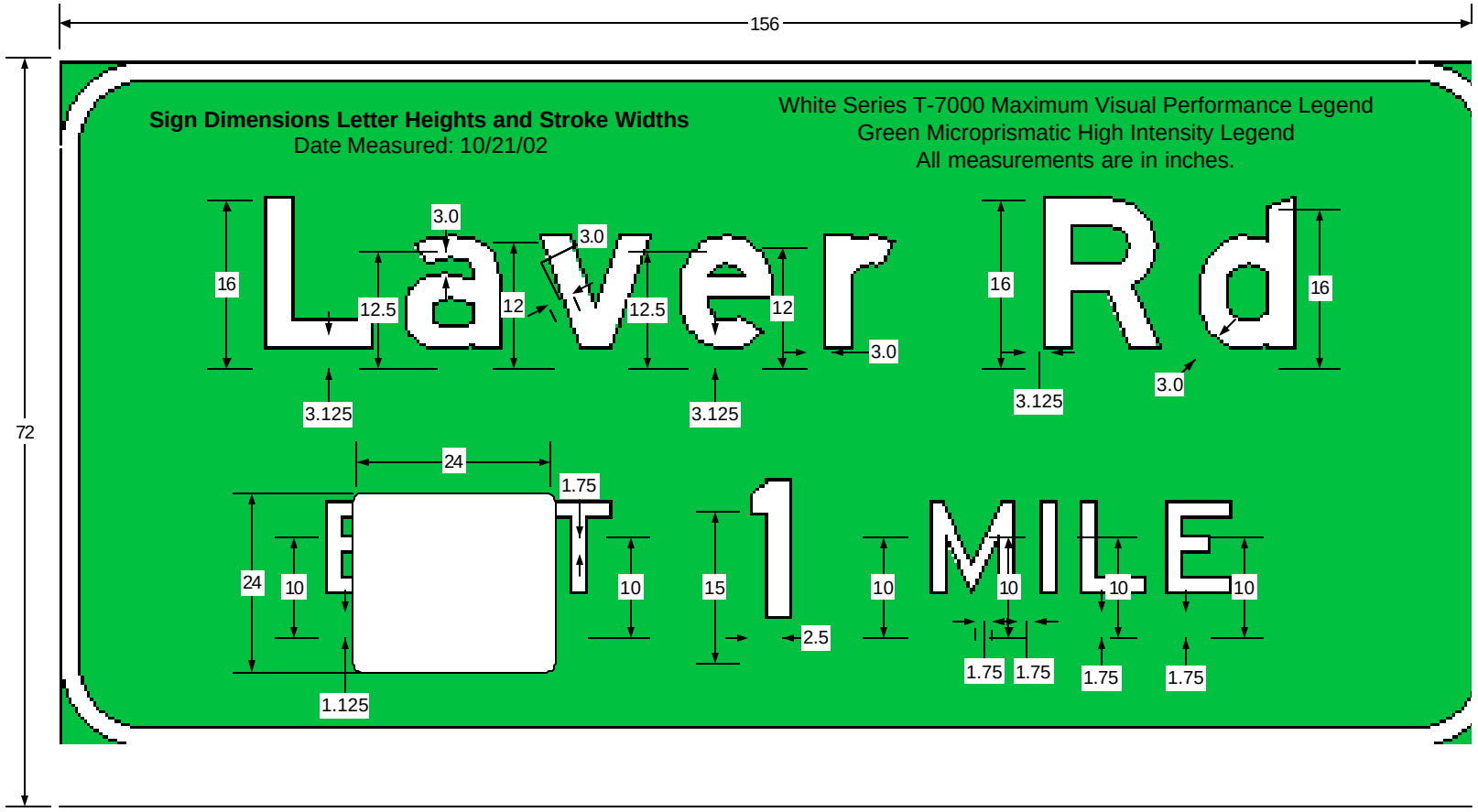
Sign Group A: beaded Type III legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.



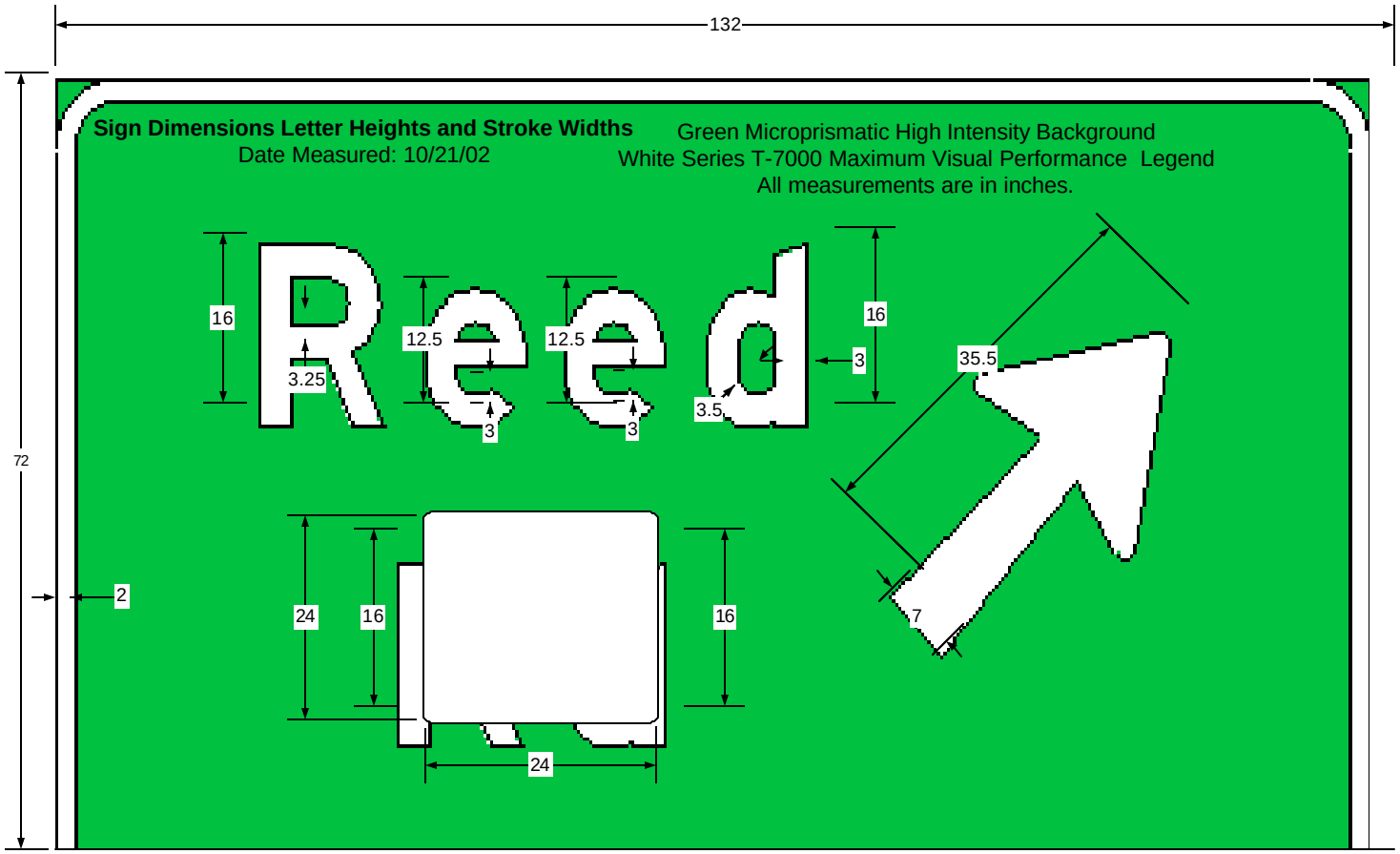
Sign Group A: beaded Type III legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.



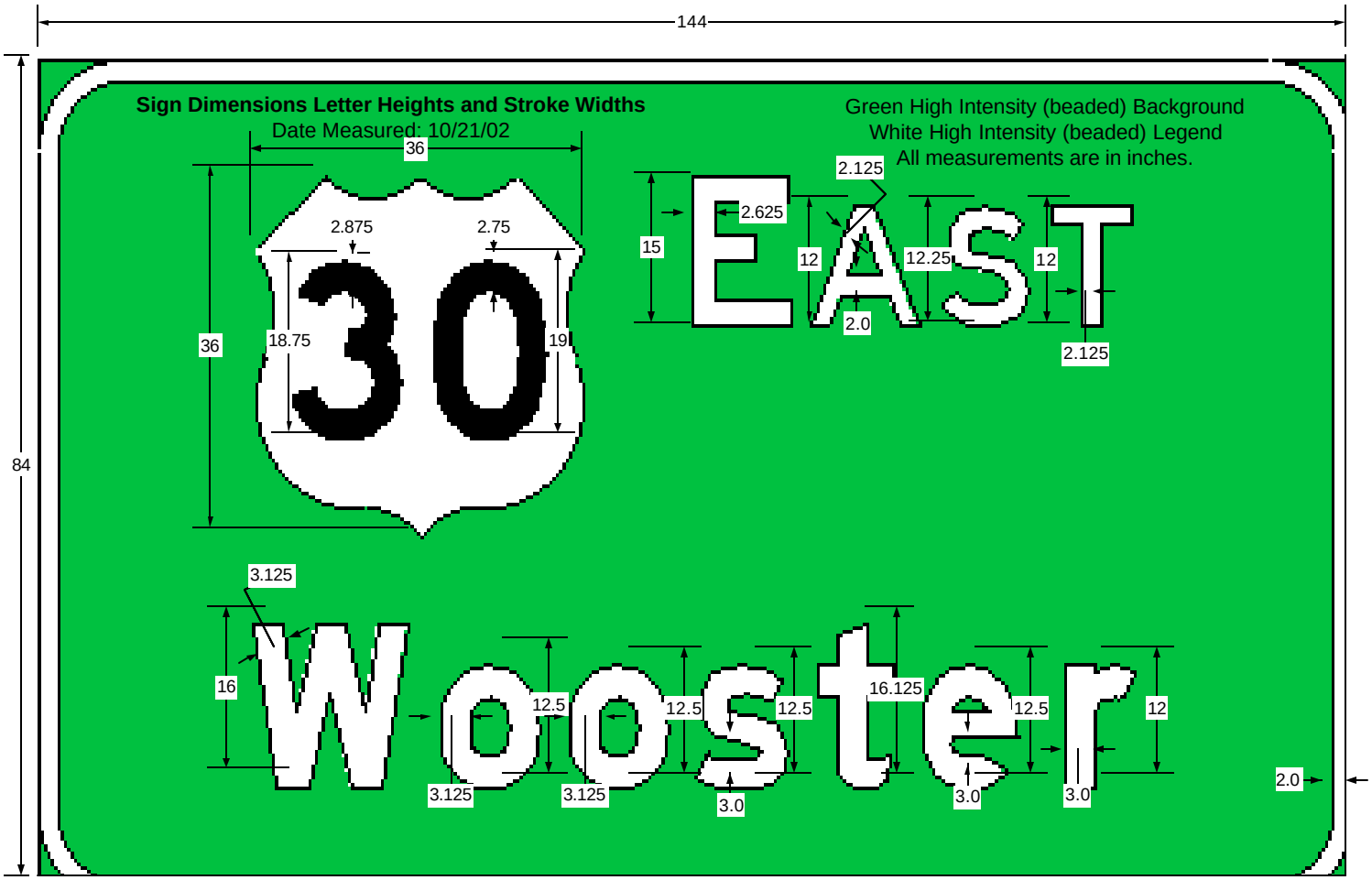
Sign Group B: lighted beaded Type III Legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.



Sign Group B: lighted beaded Type III Legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm. The white square represents an area of beaded Type III material temporarily applied to the sign for making photometric luminance measurements.



Sign Group B: lighted beaded Type III Legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm. The white square represents an area of beaded Type III material temporarily applied to the sign for making photometric luminance measurements.



Sign Group C: Type VIII legend on microprismatic Type III background dimensions in inches. 1 inch = 2.54 cm.

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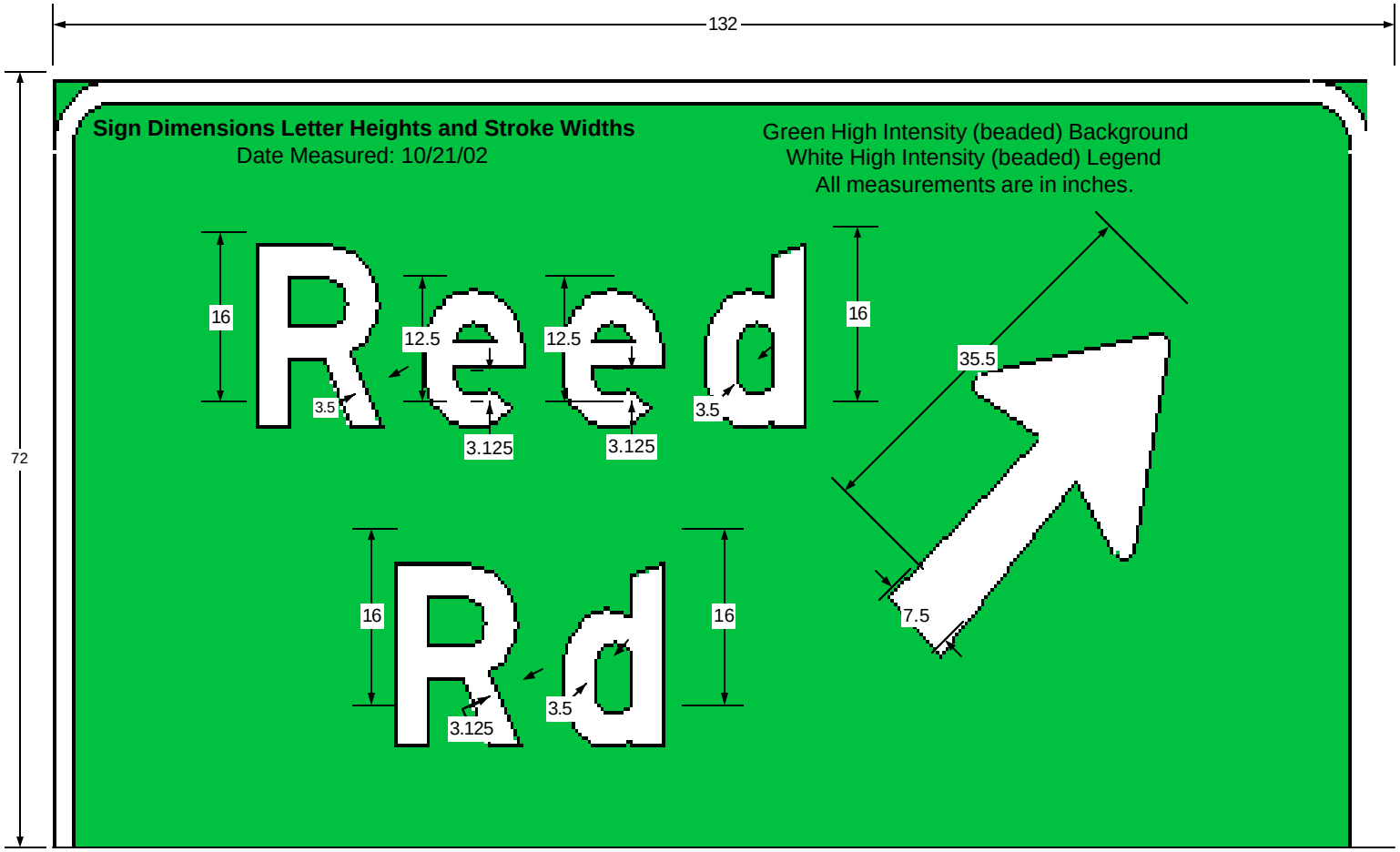
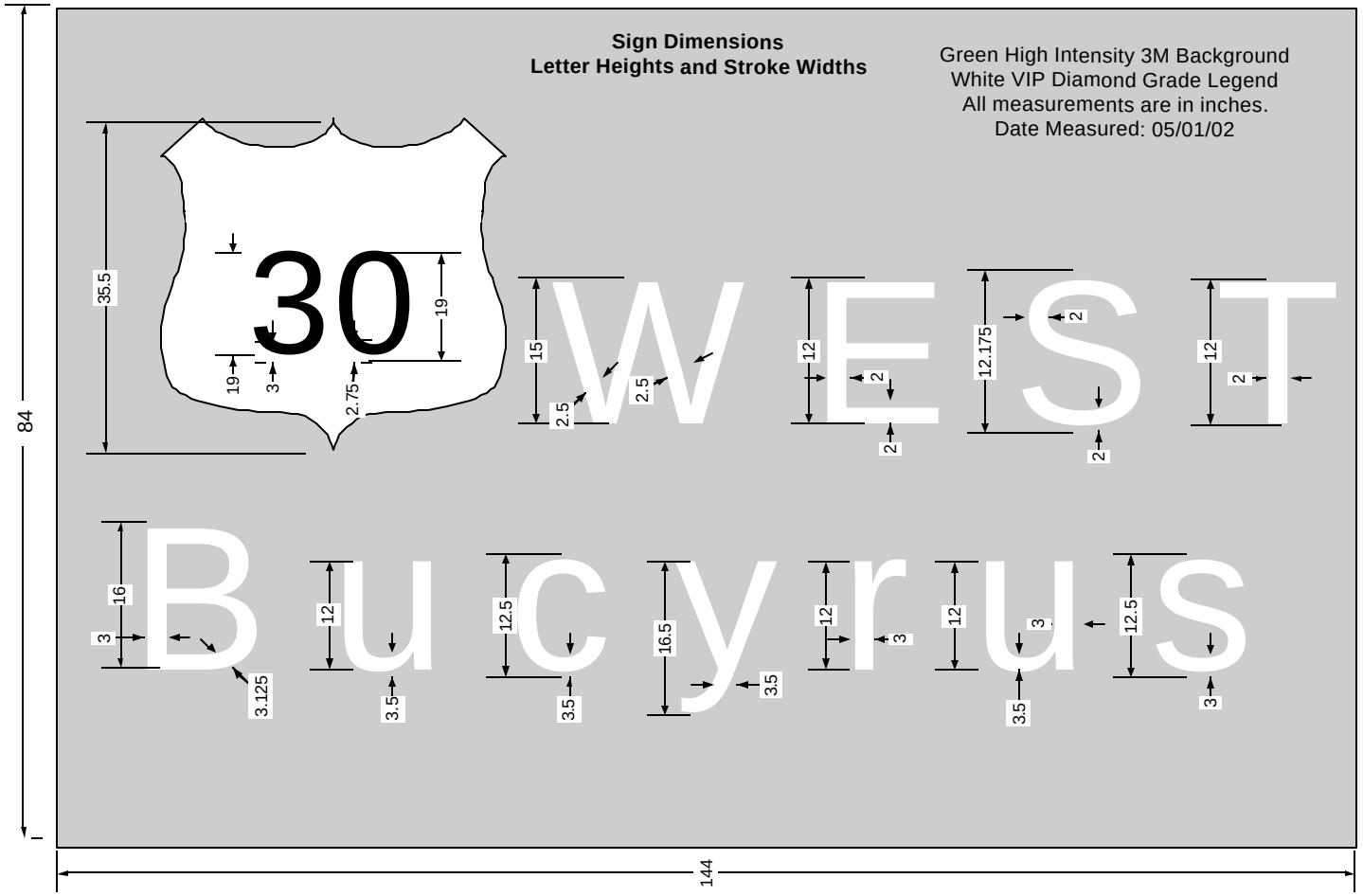
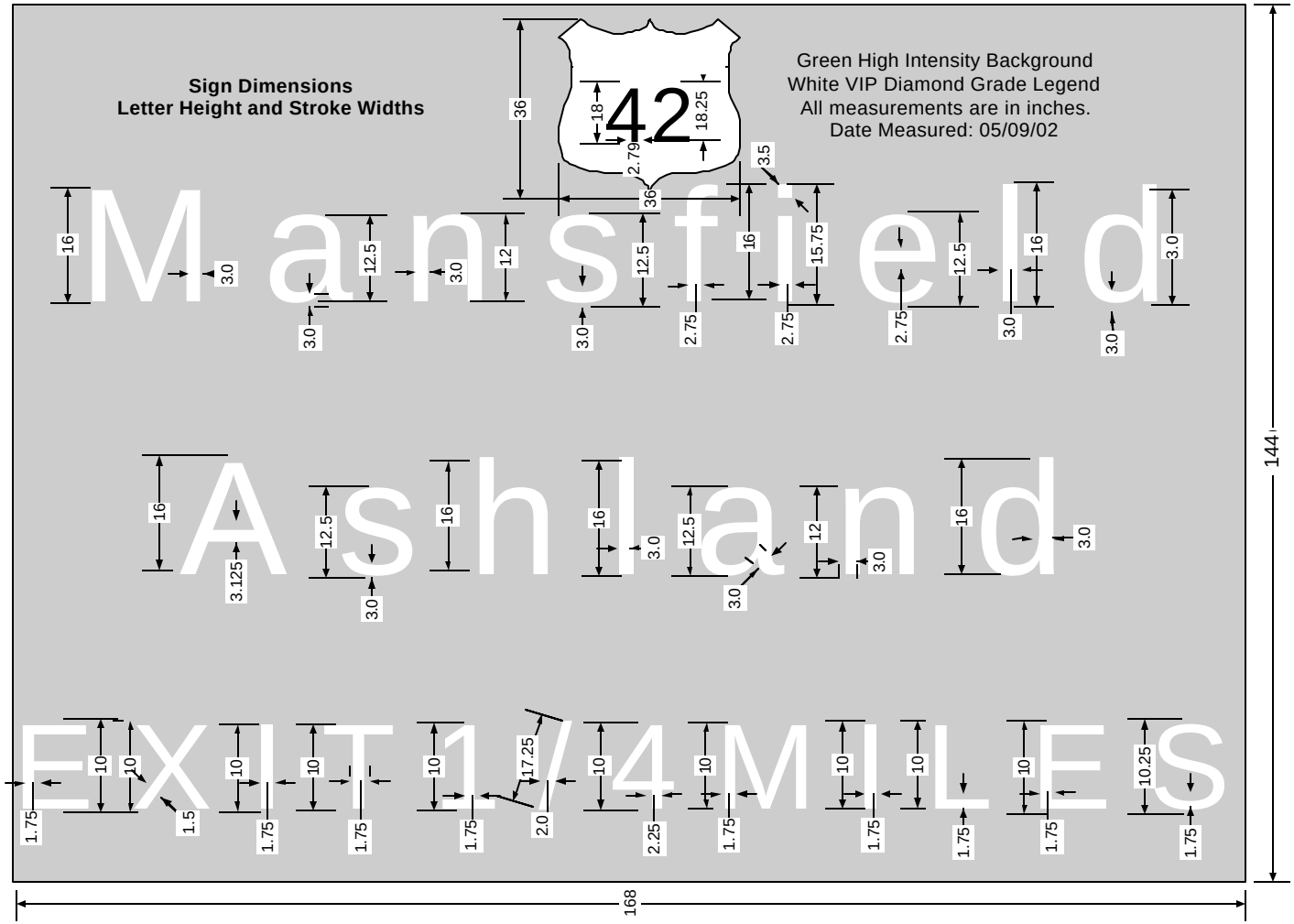


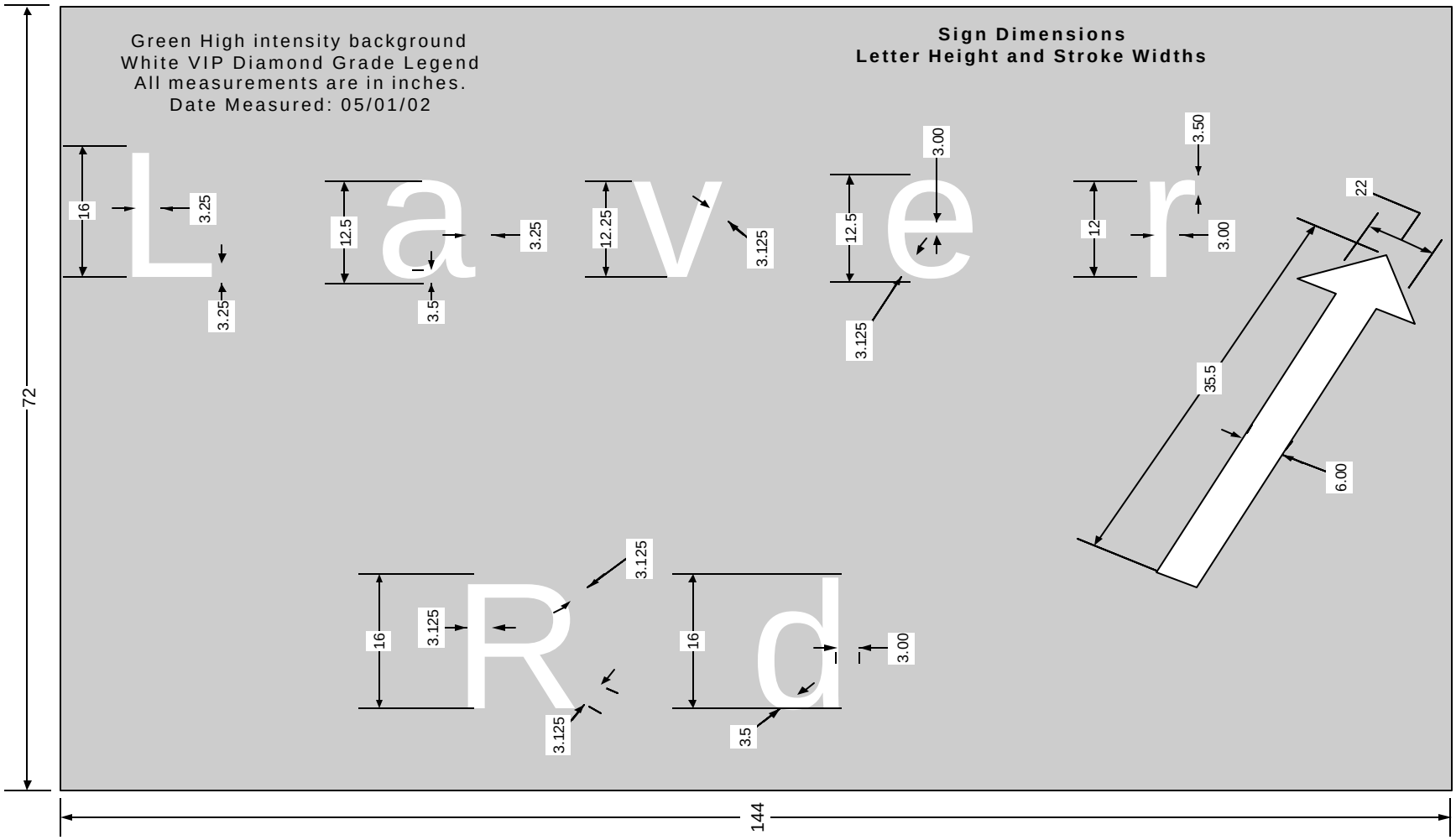
Sign Group C: Type VIII legend on microprismatic Type III background dimensions in inches. 1 inch = 2.54 cm.



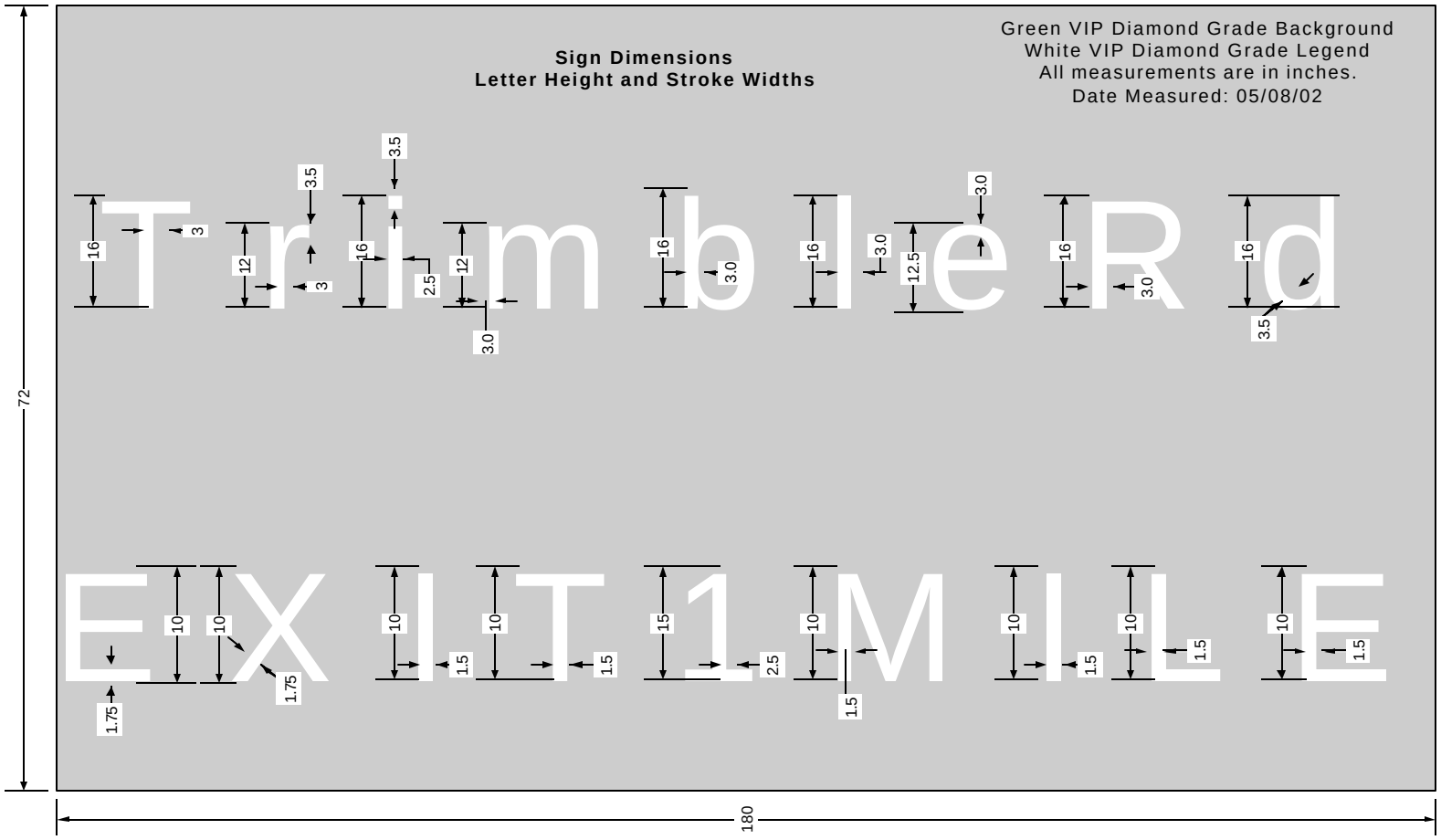
Sign Group D: Type IX legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.



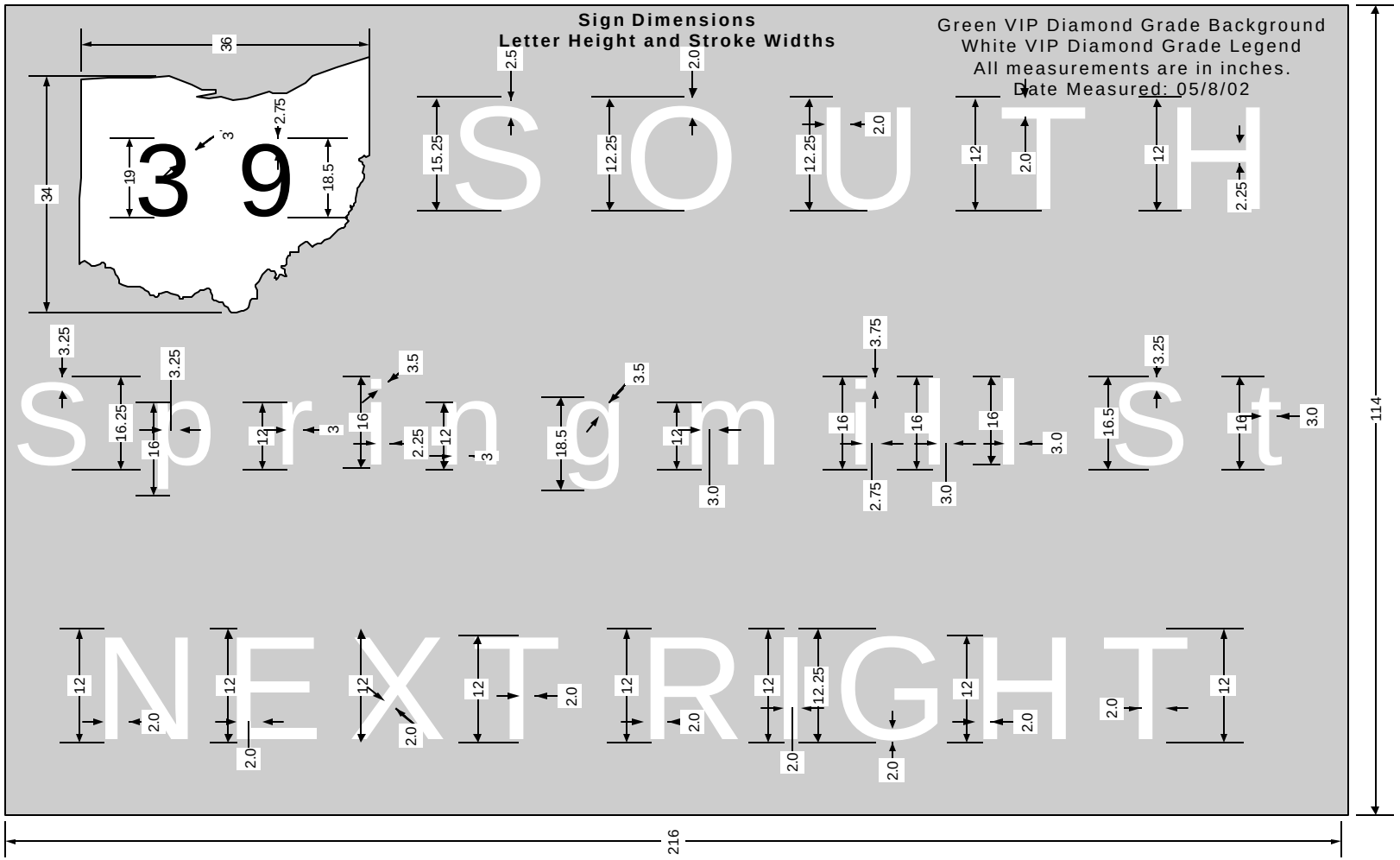
Sign Group D: Type IX legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.



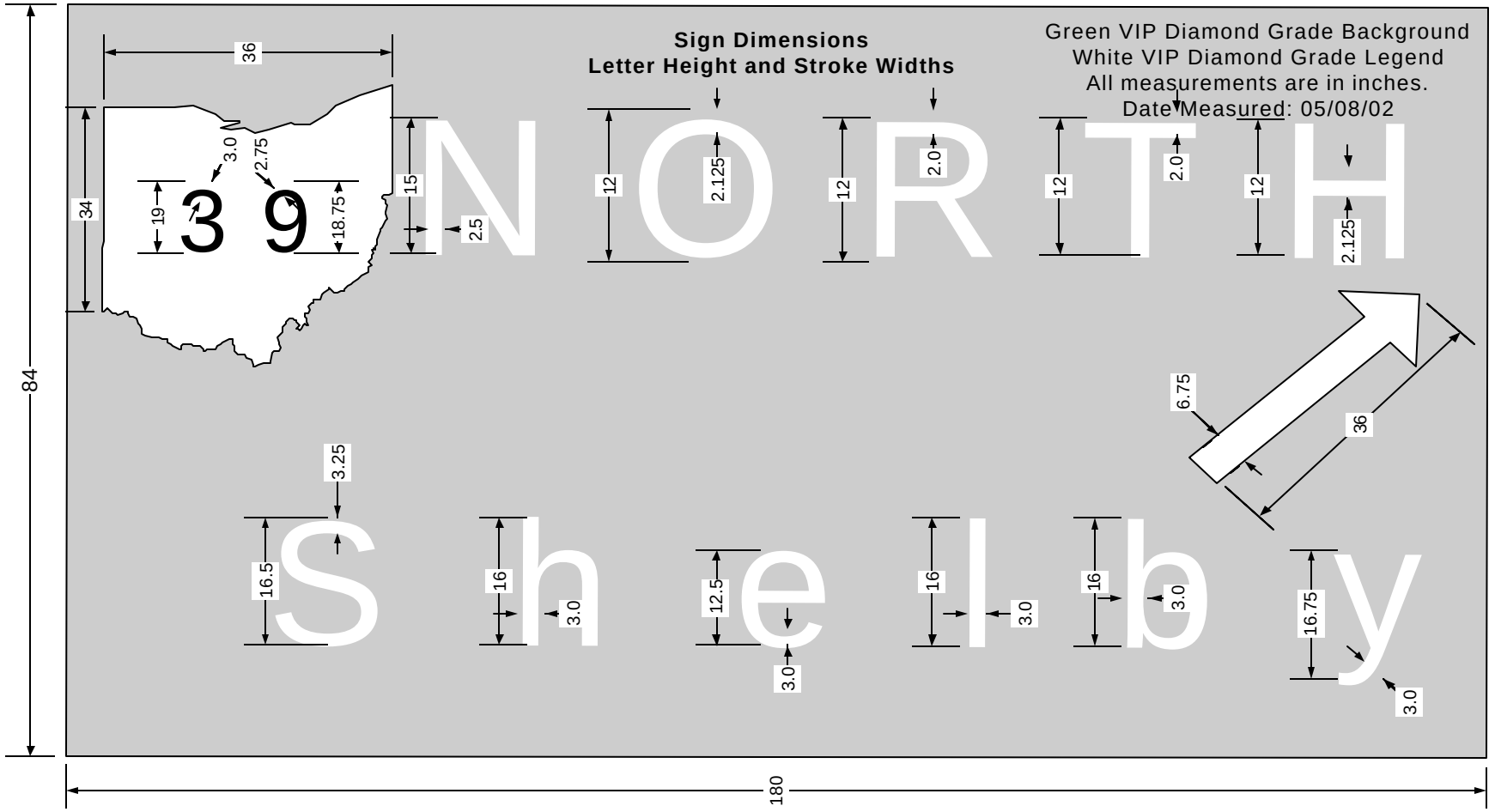
Sign Group D: Type IX legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.



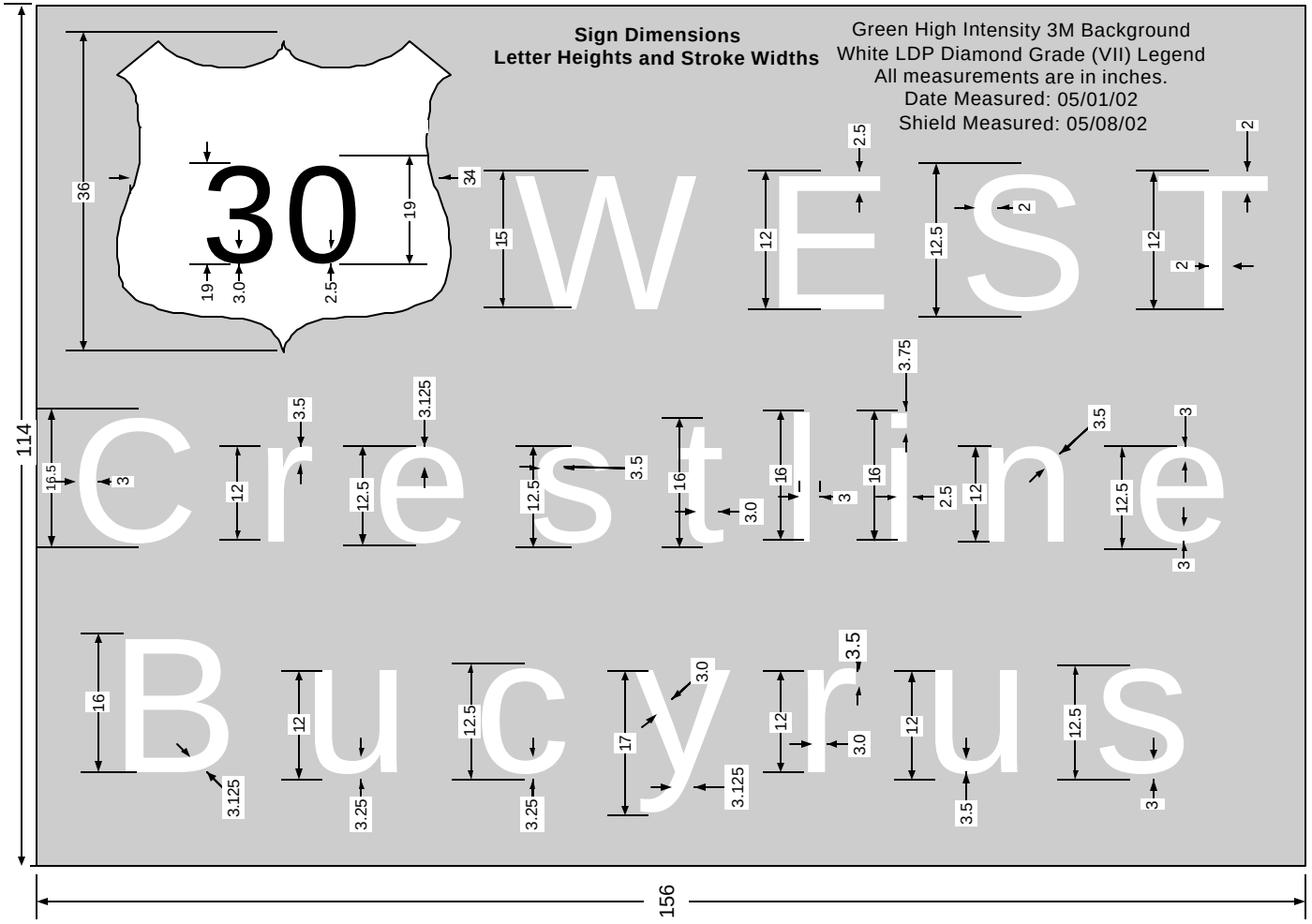
Sign Group E: Type IX legend on Type IX background dimensions in inches. 1 inch = 2.54 cm.



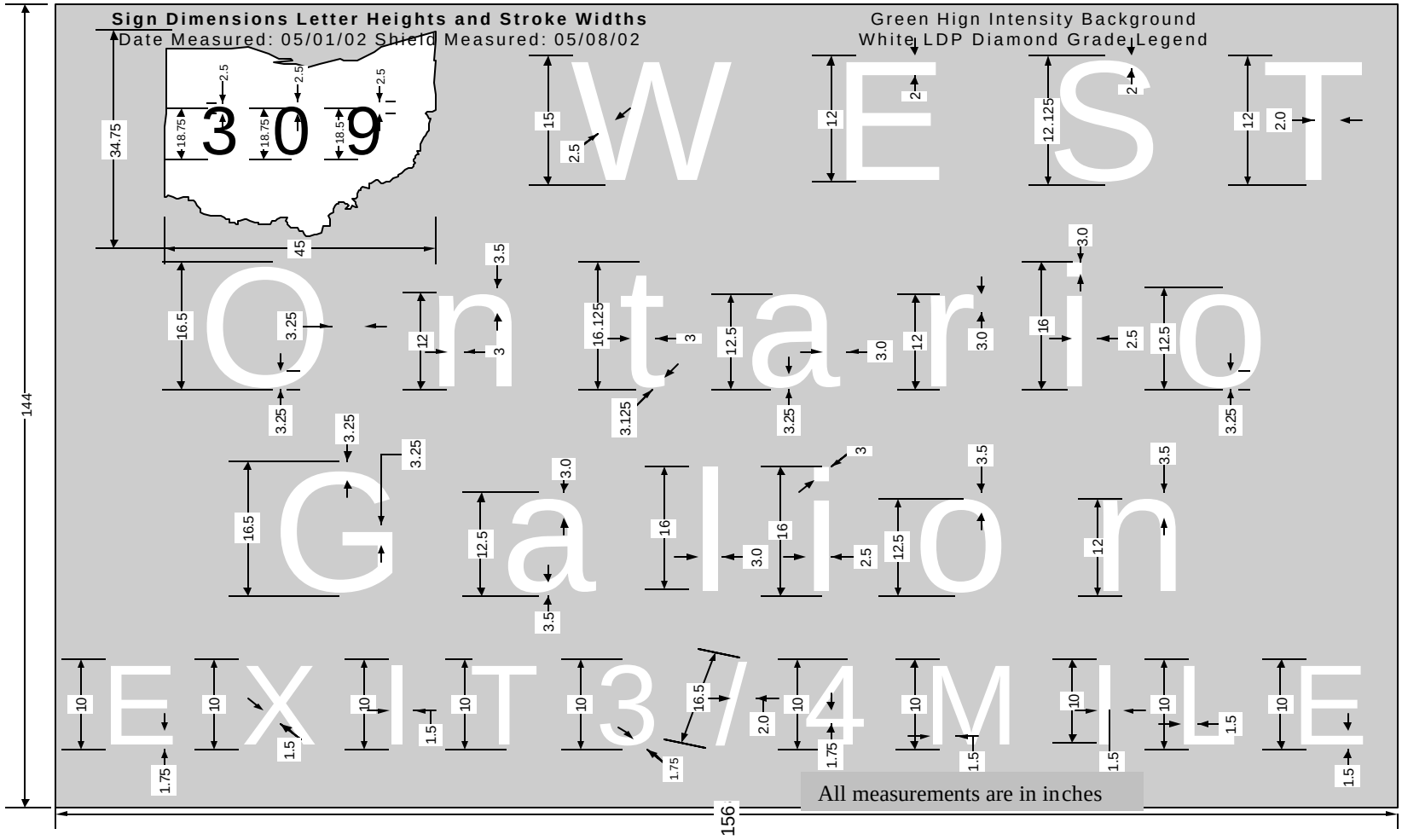
Sign Group E: Type IX legend on Type IX background dimensions in inches. 1 inch = 2.54 cm.



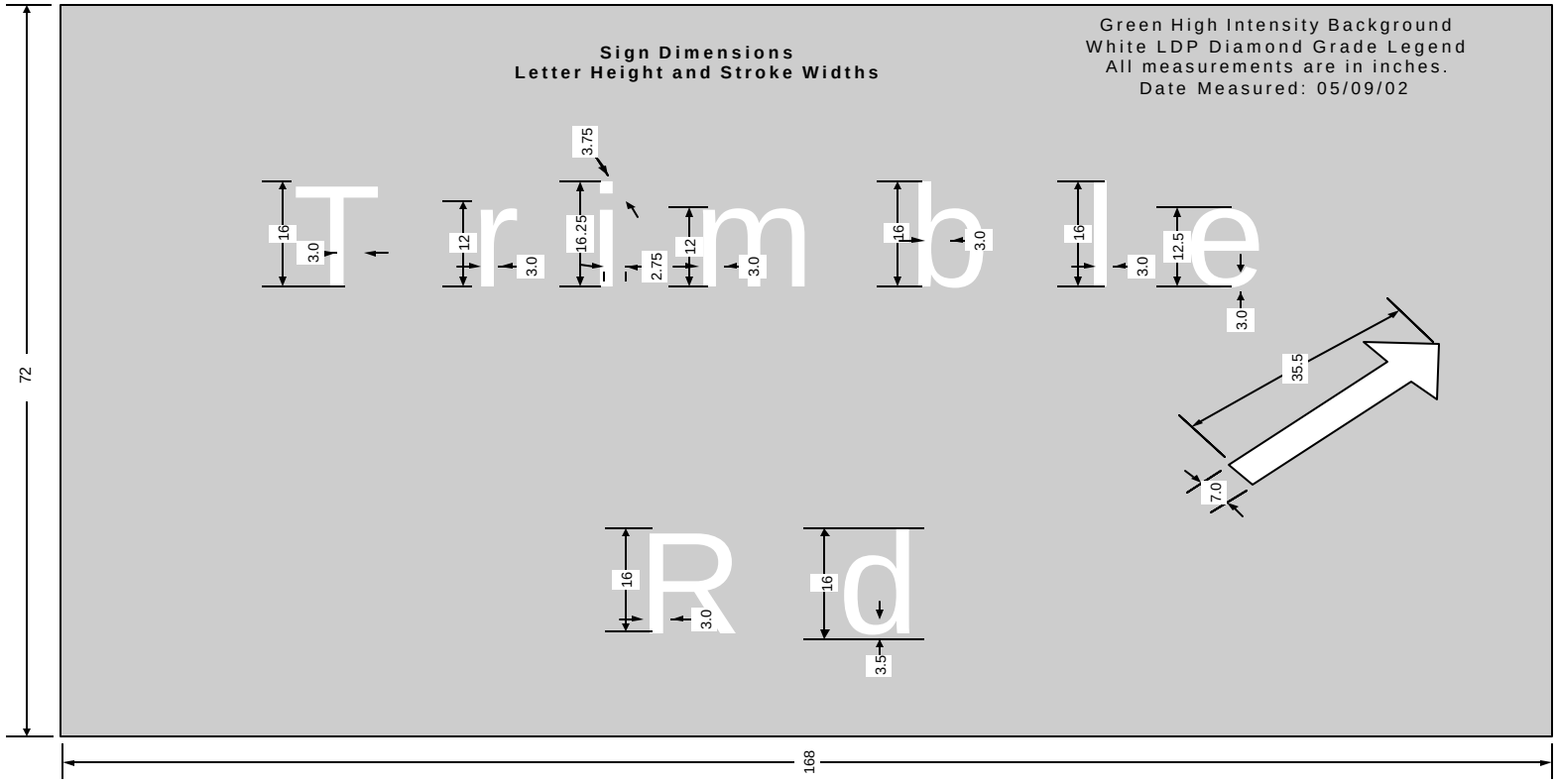
Sign Group E: Type IX legend on Type IX background dimensions in inches. 1 inch = 2.54 cm.



Sign Group F: Type VII legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.

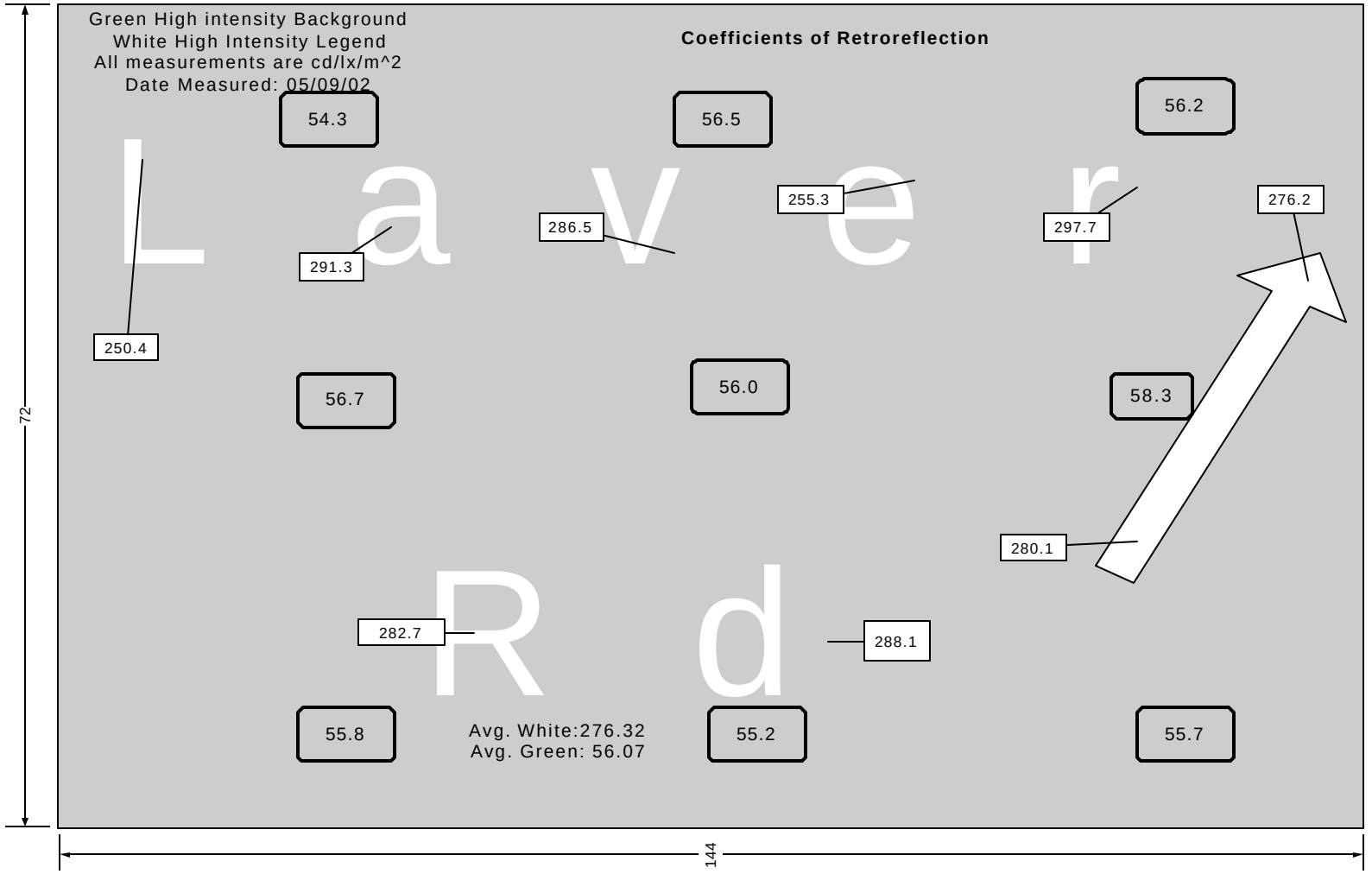


Sign Group F: Type VII legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.

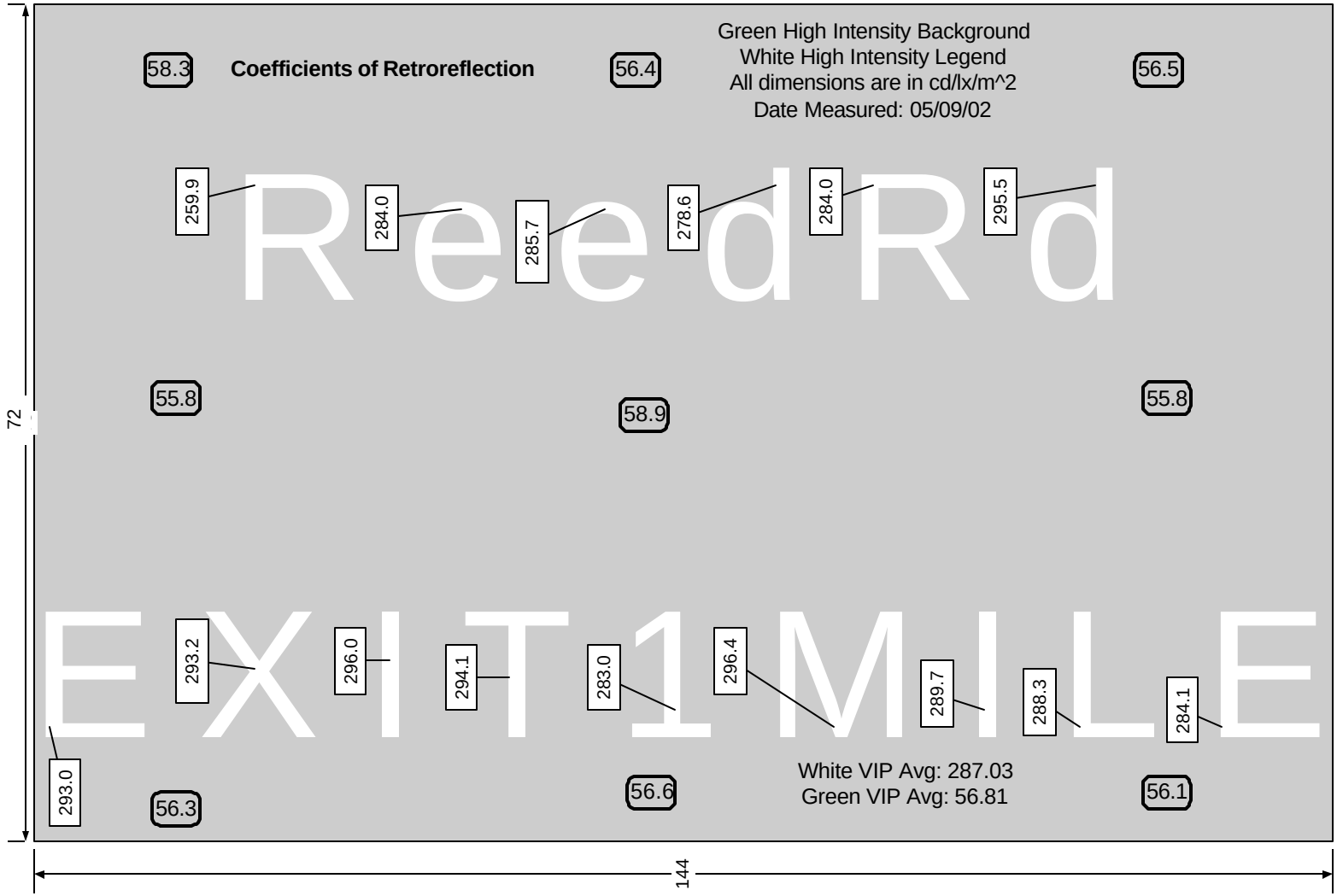


Sign Group F: Type VII legend on beaded Type III background dimensions in inches. 1 inch = 2.54 cm.

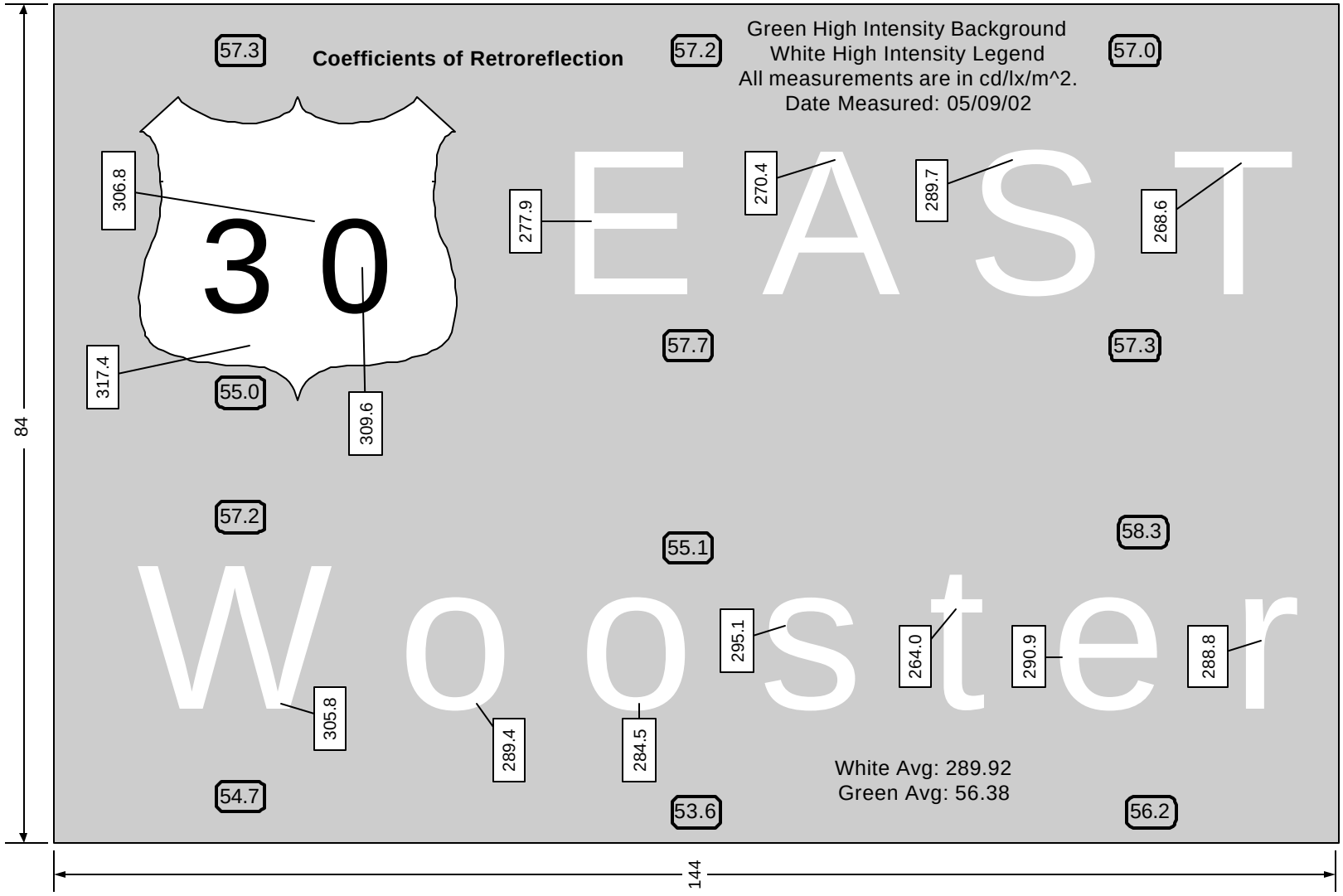
Appendix H. ART 920 Retroreflectometer measurements of each sign erected for field evaluation in Mansfield



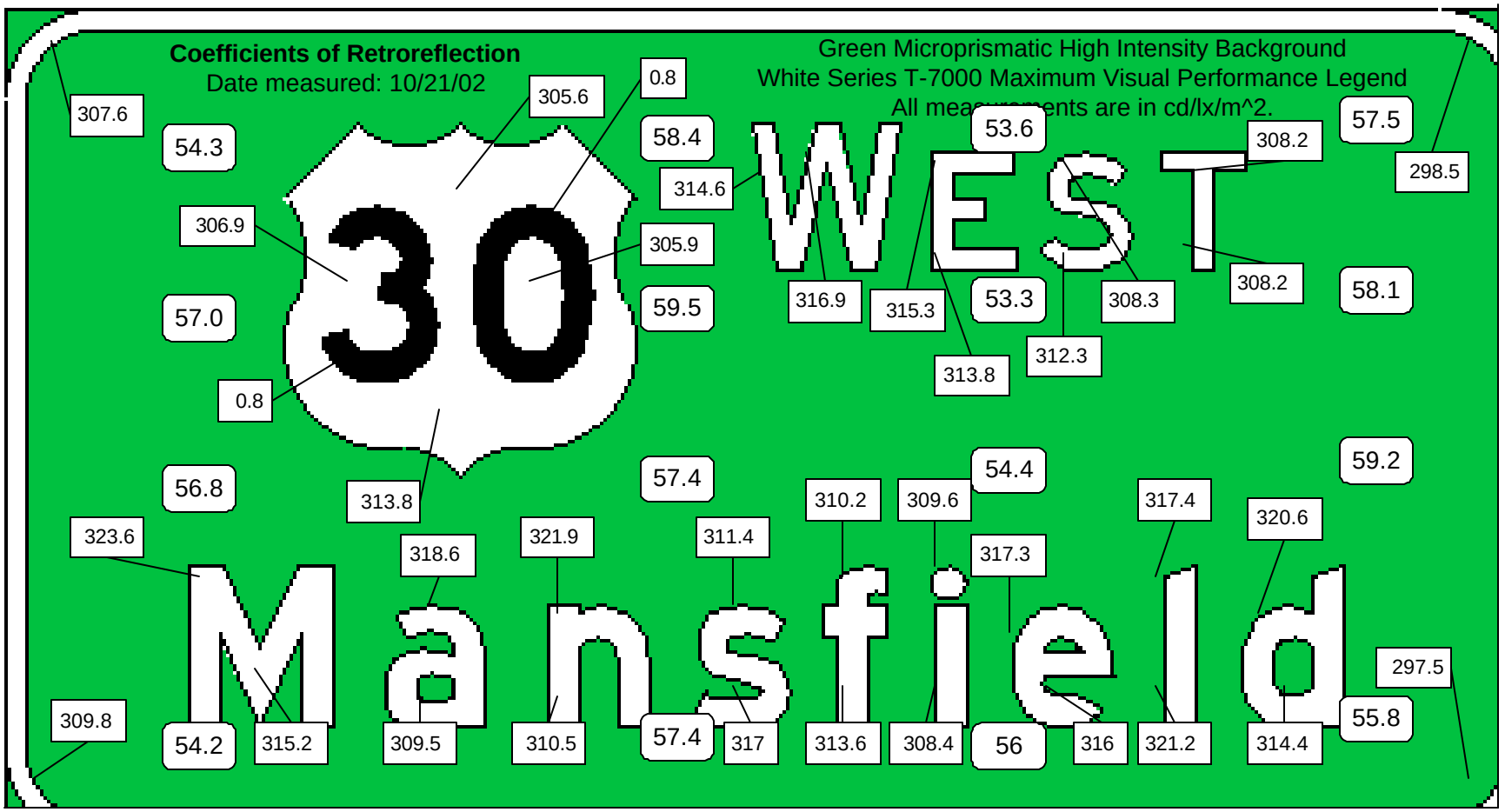
Sign Group A: beaded Type III legend on beaded Type III background.



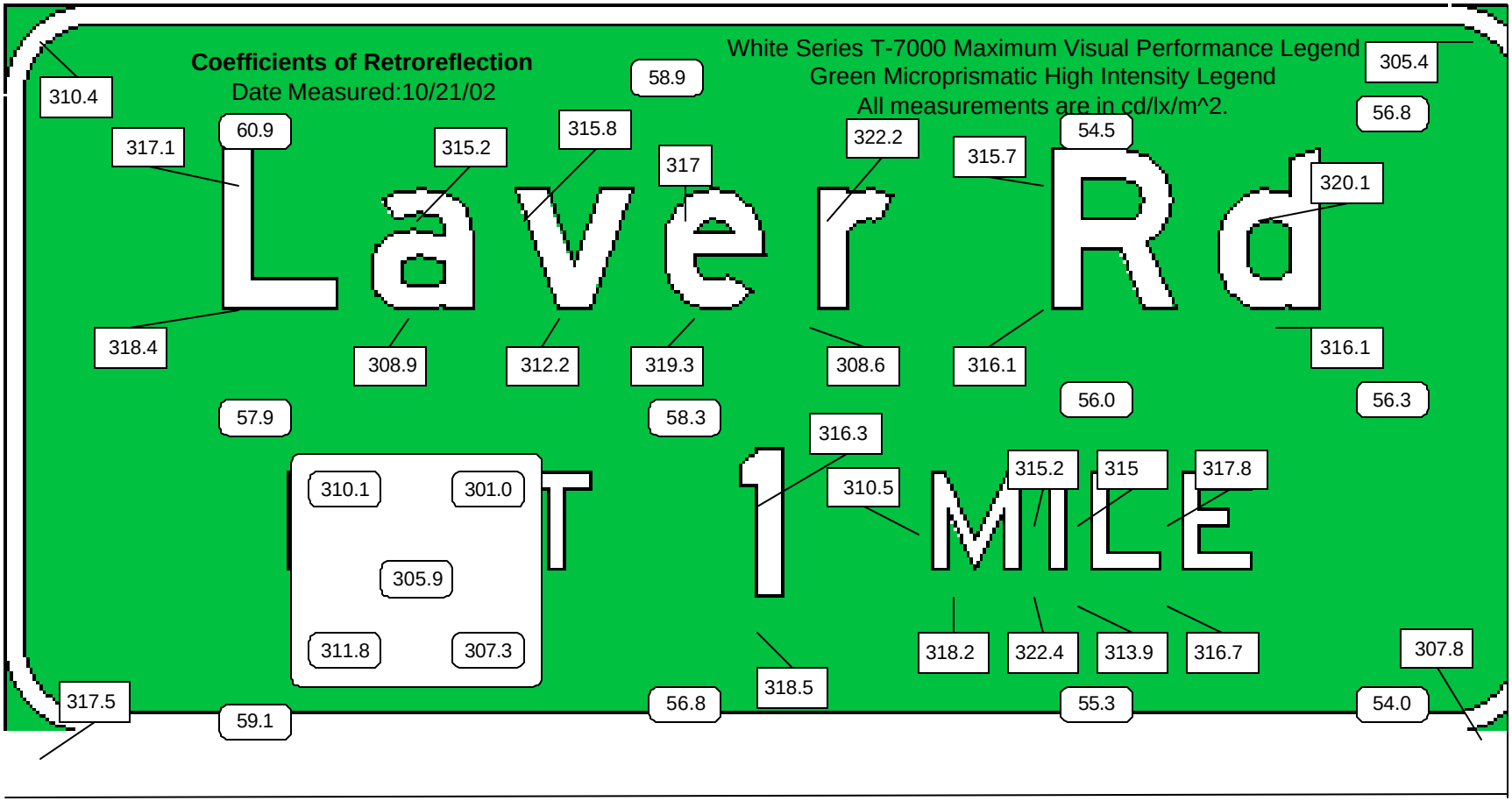
Sign Group A: beaded Type III legend on beaded Type III background.



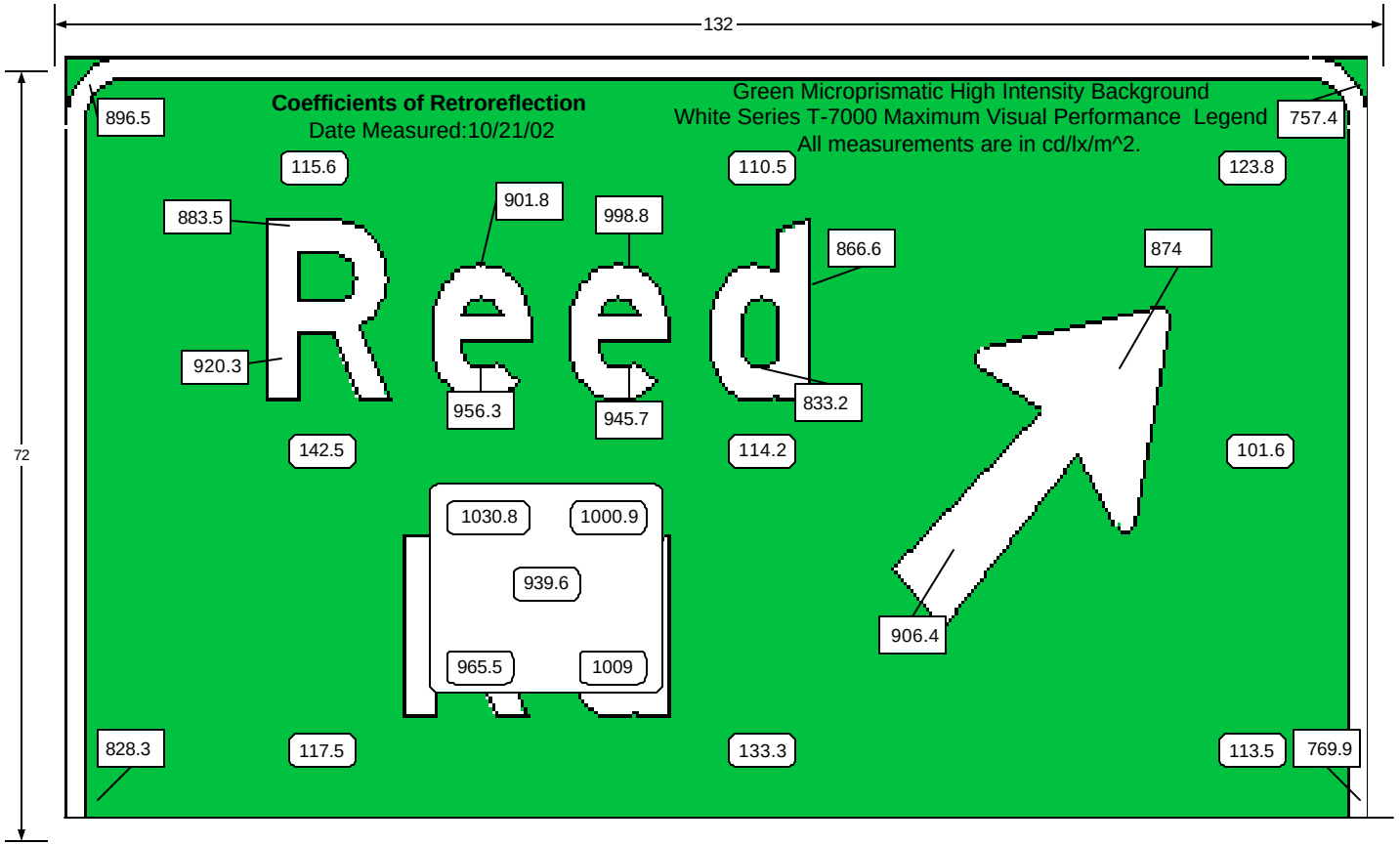
Sign Group A: beaded Type III legend on beaded Type III background.



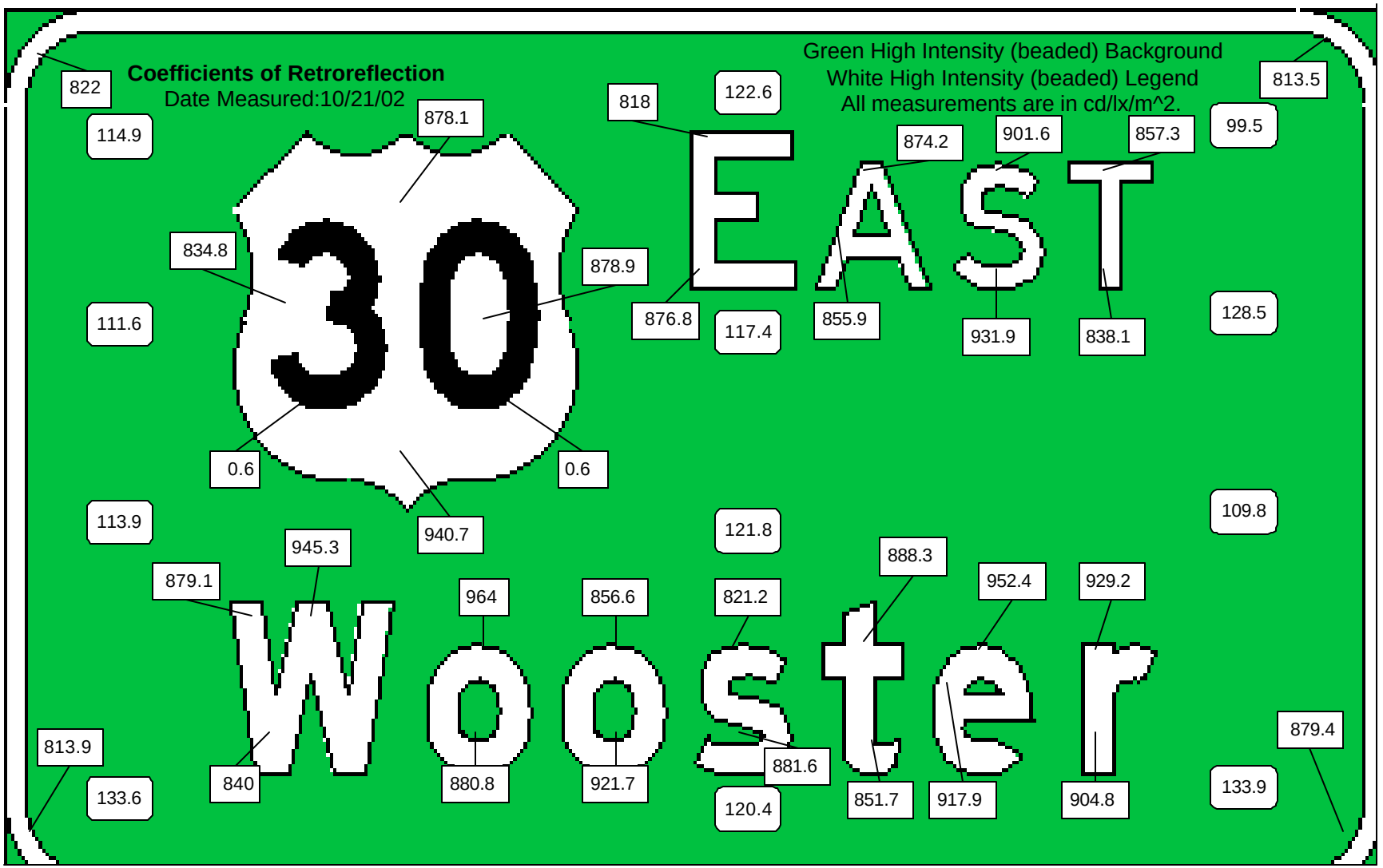
Sign Group B: lighted beaded Type III legend on beaded Type III background.



Sign Group B: lighted beaded Type III legend on beaded Type III background. The white square represents an area of beaded Type III material temporarily applied to the sign for making photometric luminance measurements.

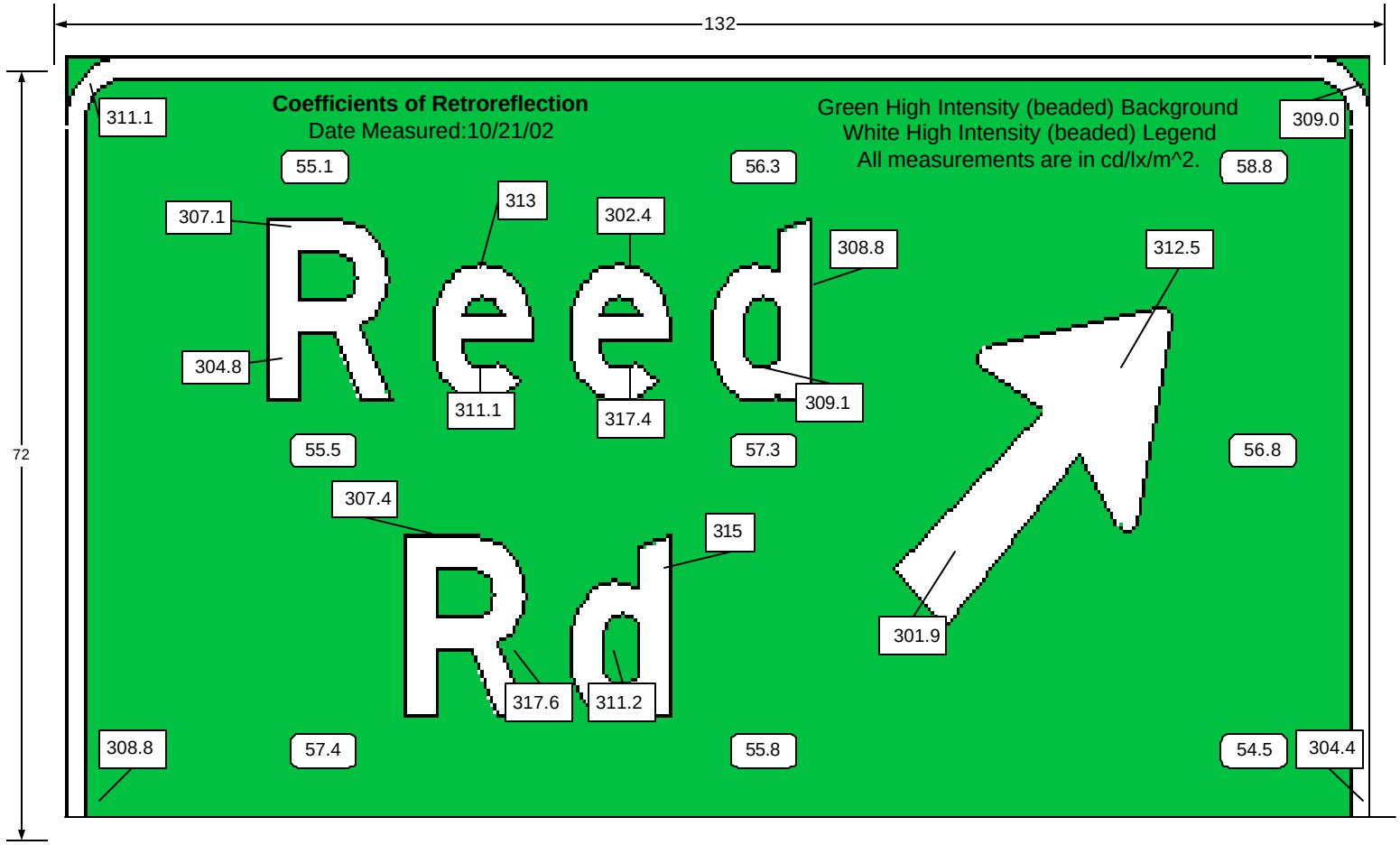


Sign Group B: lighted beaded Type III legend on beaded Type III background. The white square represents an area of beaded Type III material temporarily applied to the sign for making photometric luminance measurements.

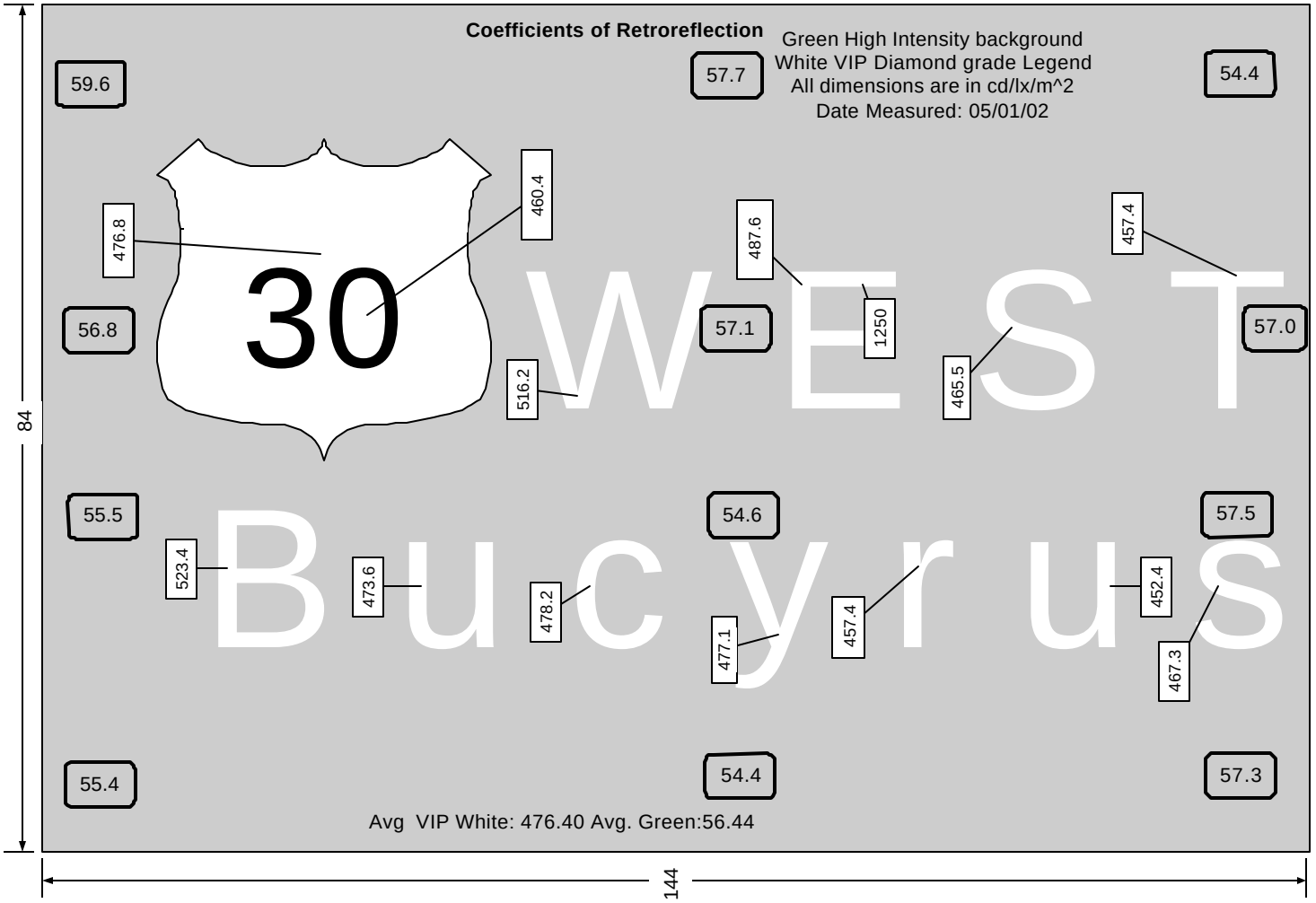


Sign Group C: Type VIII legend on microprismatic Type III background.

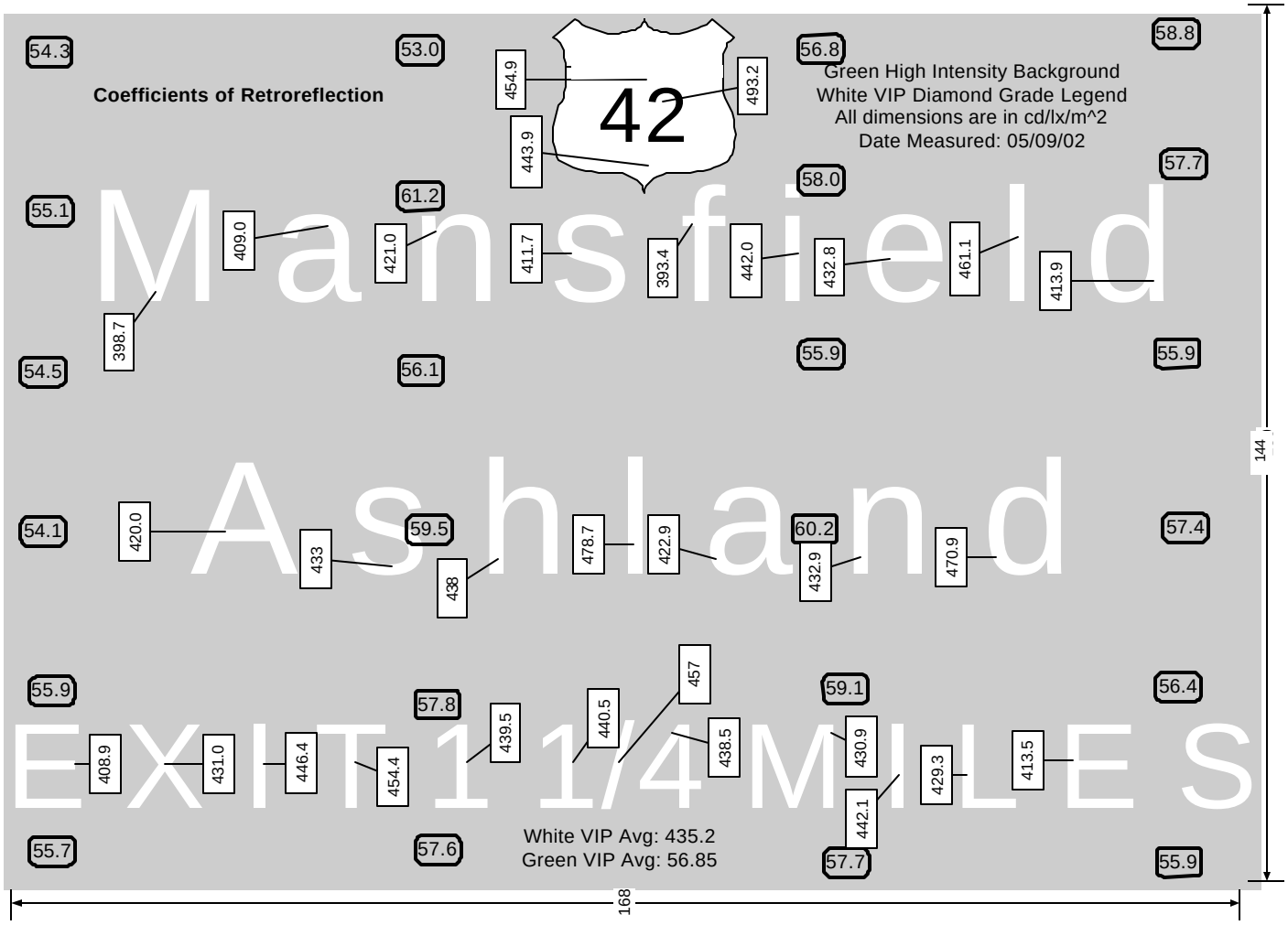
Sign Group C: Type VIII legend on microprismatic Type III background.



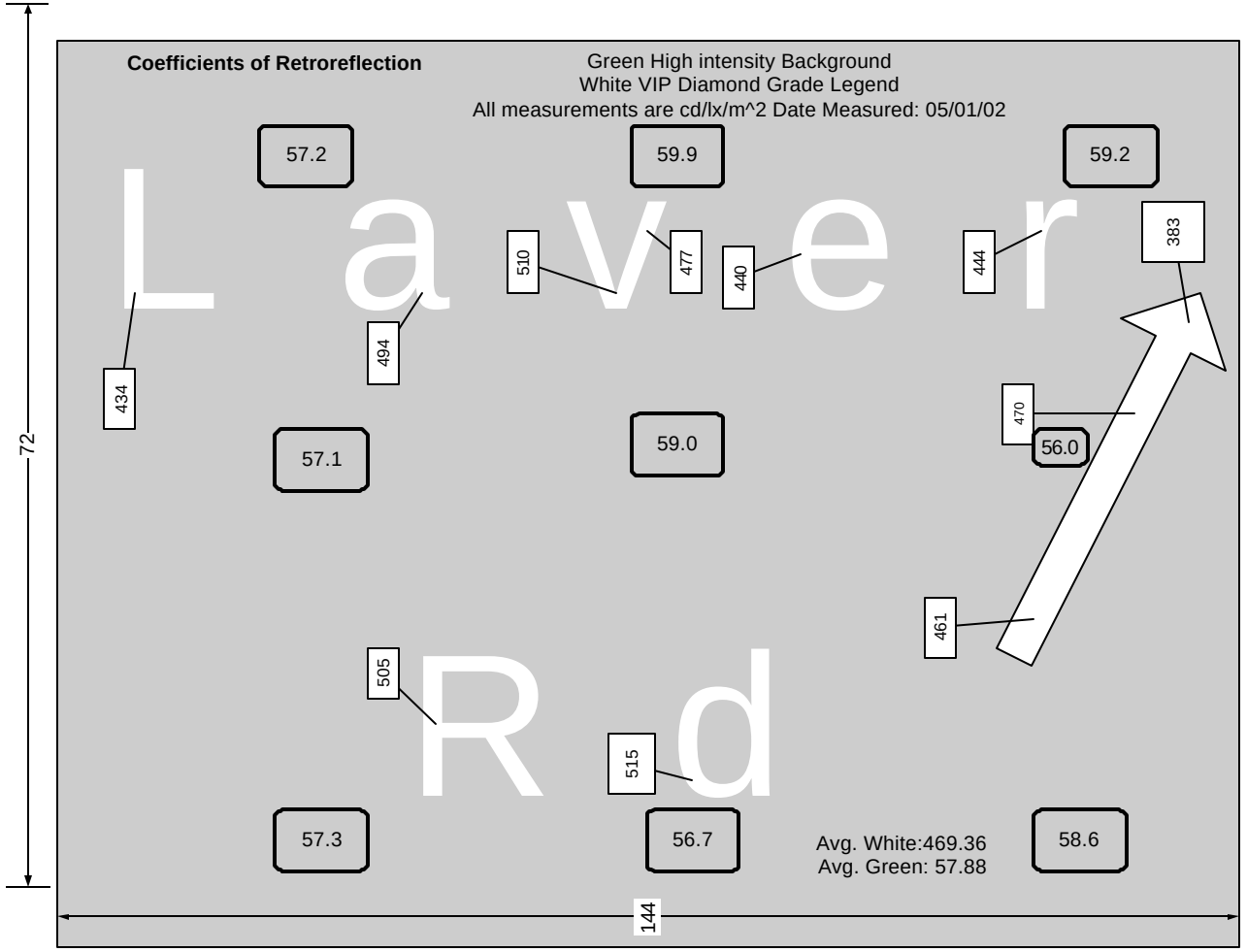
Sign Group C: Type VIII legend on microprismatic Type III background.



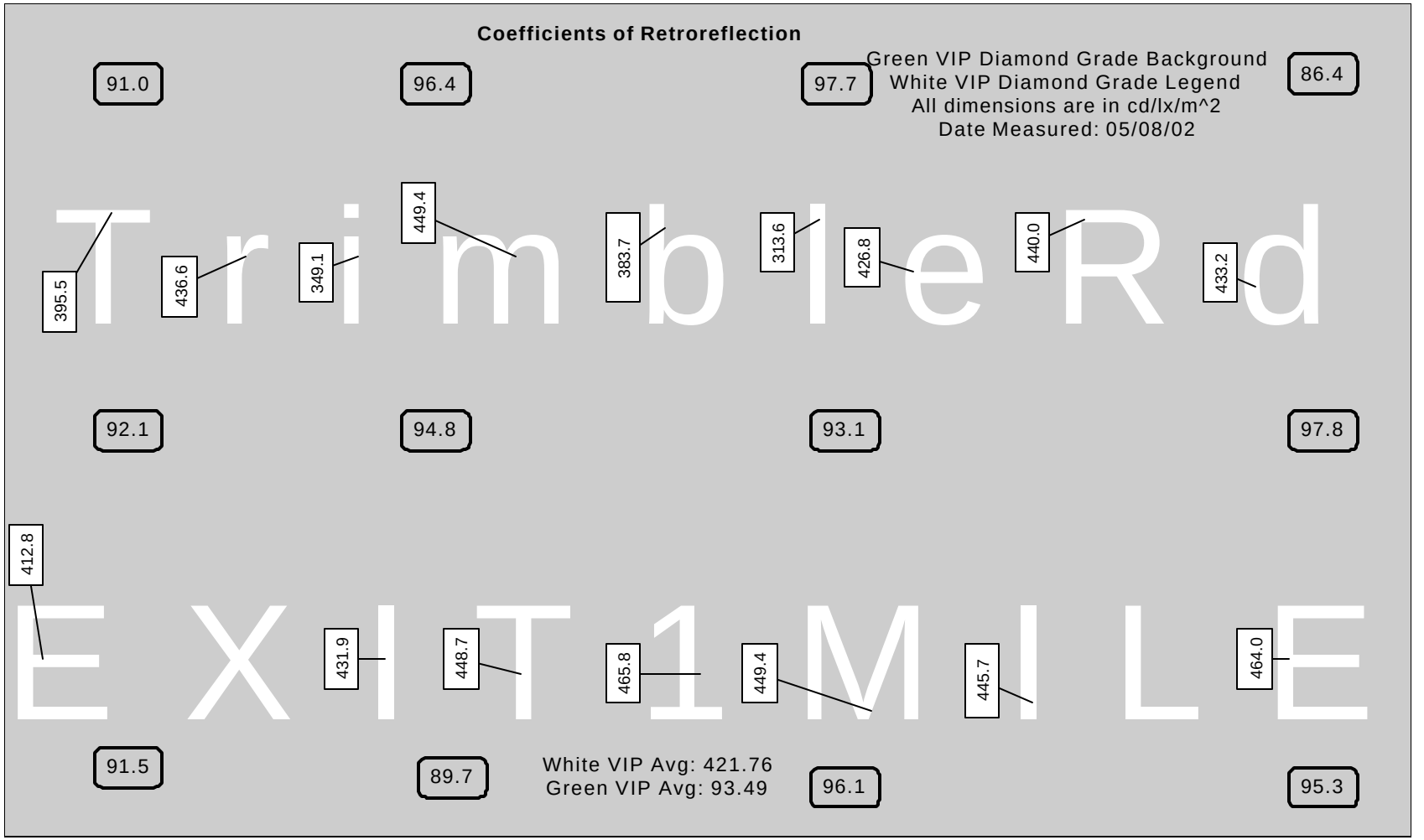
Sign Group D: Type IX legend on beaded Type III background.



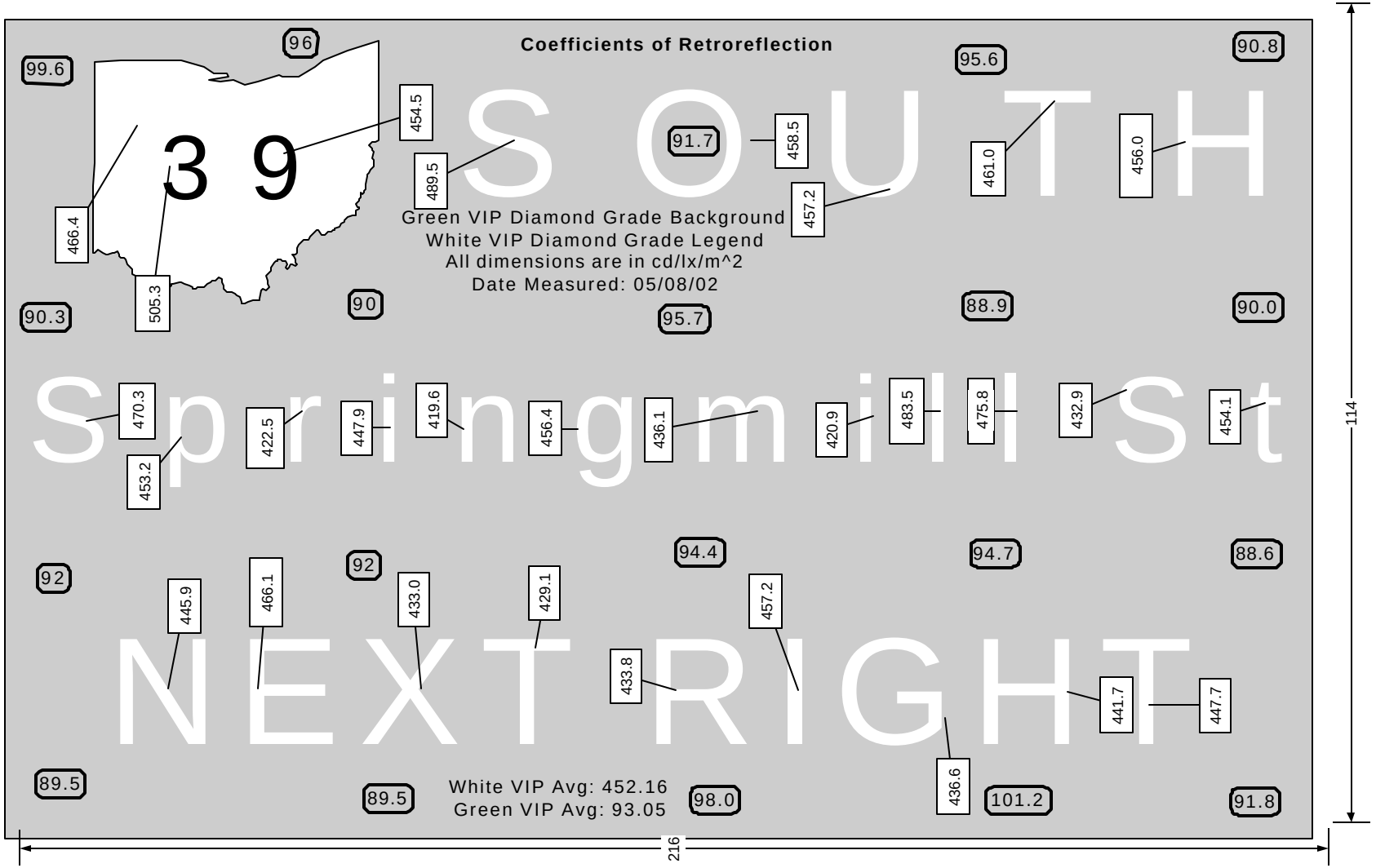
Sign Group D: Type IX legend on beaded Type III background.



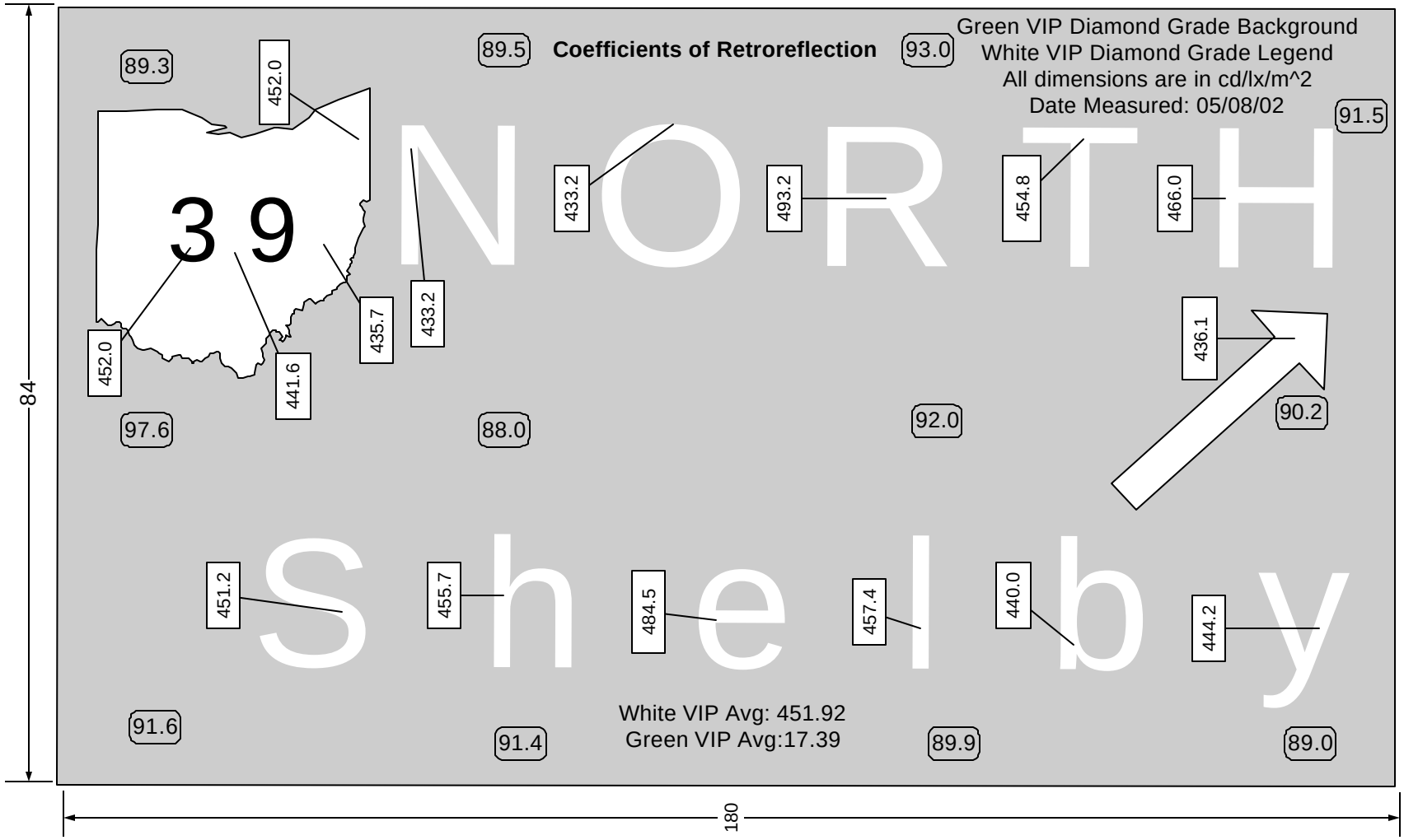
Sign Group D: Type IX legend on beaded Type III background.



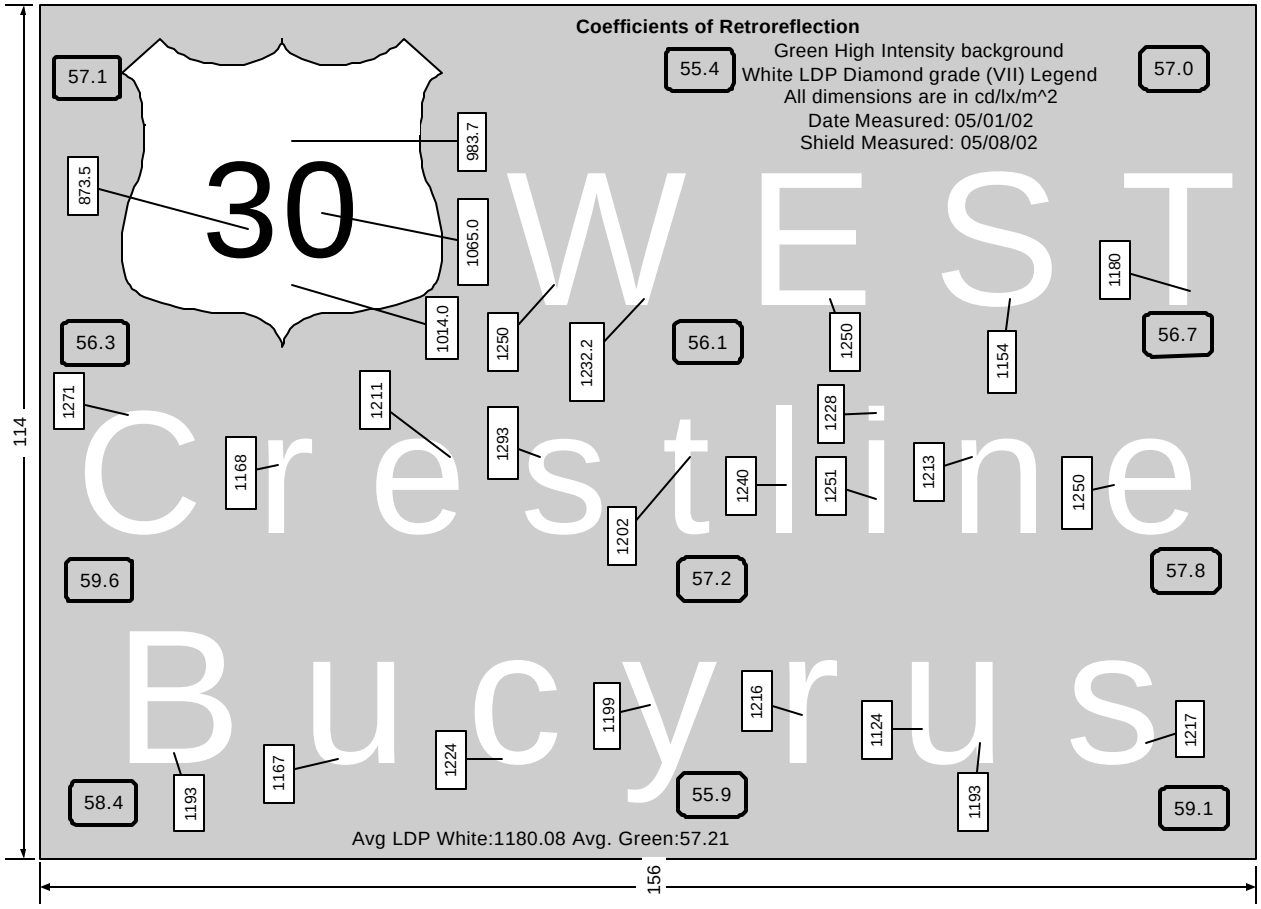
Sign Group E: Type IX legend on Type IX background.



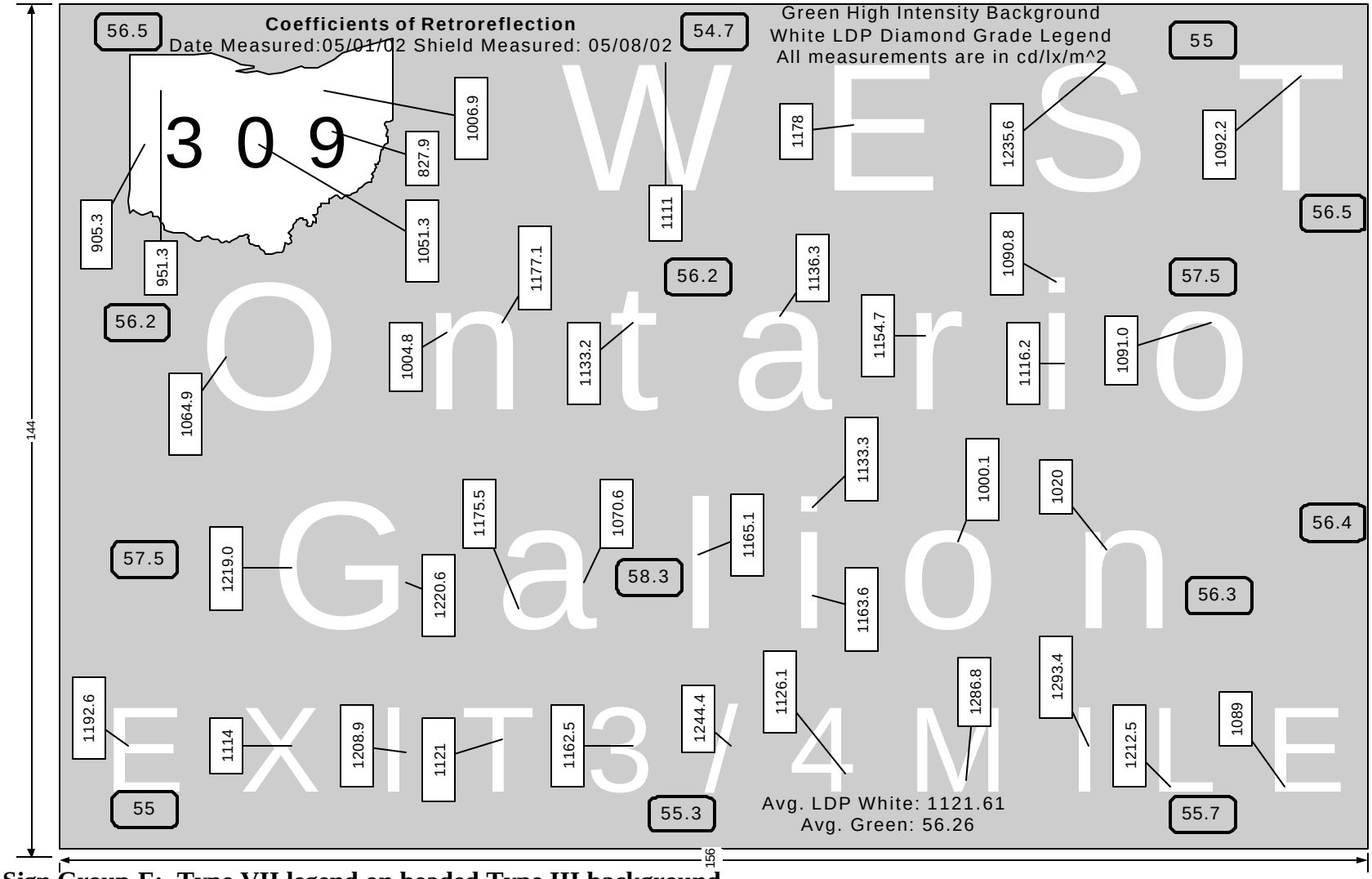
Sign Group E: Type IX legend on Type IX background.



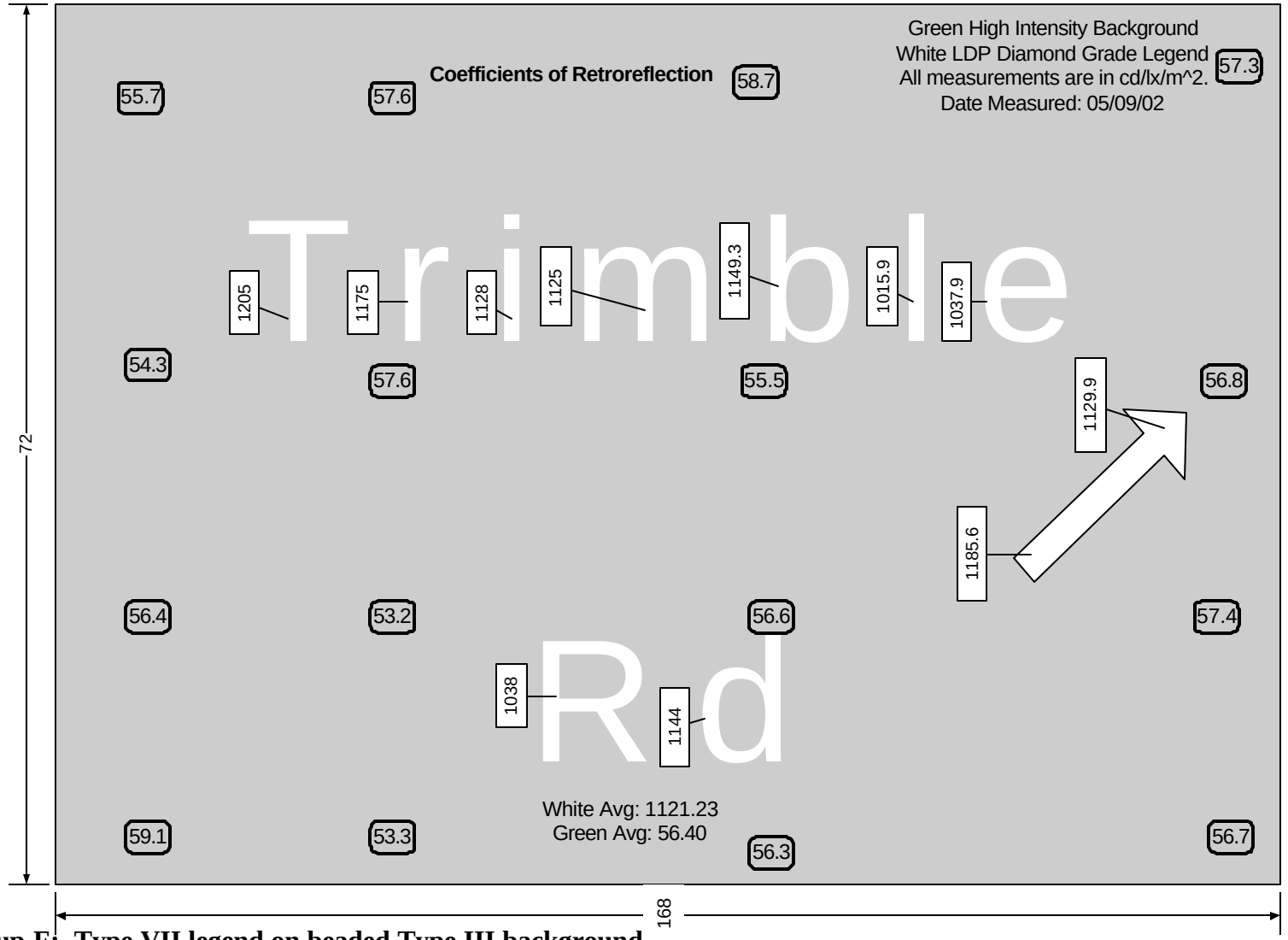
Sign Group E: Type IX legend on Type IX background.



Sign Group F: Type VII legend on beaded Type III background.



Sign Group F: Type VII legend on beaded Type III background.



Sign Group F: Type VII legend on beaded Type III background.