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IMPROVED MOTORCYCLE AND MOPED HEADLAMPS

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16. Abstract

The purpose of this study was to examine current motorcycle headlighting, available research, and the visual needs of motorcyclists to determine what modifications to the headlighting standards would be desirable.

A survey was conducted of motorcyclists to find out what their opinions were concerning current lighting systems and where improvements were most needed. These data, together with other background information, were used to recommend lamps for evaluation.

The evaluation stage consisted of a subjective appraisal by a number of riders under a variety of riding conditions, objective measures of seeing distance to various types of objects under conditions designed to be as realistic as possible, and a computer analysis of visibility distances on hills, curves, and in glare meeting situations.

The results of this study suggest that both automotive and specialized motorcycle lamps function well in general. There is no "best" design. It is desirable to upgrade the headlamp specifications, and recommendations to do so are included in the report.

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This project had several purposes:

a. To define the minimum photometric requirements necessary to satisfy the needs of motorcycle and moped operators.

b. To recommend ways in which the differences between various motorcycle and moped headlamps could be reduced, to improve availability and perhaps reduce cost.

c. To recommend a standard method of headlamp mounting.

d. To investigate means by which aiming could be made simpler and more accurate.

The first step in the study was to assemble information about current motorcycles and mopeds and the headlamps available for each. It is apparent that there have been significant improvements in motorcycle headlighting in recent years, but smaller bikes especially still use lamps which are relatively weak.

In an effort to identify the needs of motorcyclists as concerns night visibility and document their experience with headlighting, a survey was conducted on a sample of Motorcycle Safety Foundation Senior Instructors. The results indicate a need for more illumination in the foreground area and to the sides of the lane. There was evidence that the respondents liked the new generation of halogen lamps, but still regarded much motorcycle headlighting as inadequate.

Three motorcycle headlamps were selected for detailed evaluation. These were:

a. A relatively new motorcycle lamp having a halogen source and a symmetrical low beam.

b. A standard automotive sealed beam.

c. A motorcycle headlamp which had been tested in a earlier study.

(Continue on additional pages)

HS Form 321
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Three moped lamps were also selected for detailed evaluation:

a. A relatively powerful two-beam unit.

b. A relatively powerful two-beam unit, the low beam of which had a sharp horizontal cut-off. This unit had been tested in an earlier study.

c. A relatively weak single-beam unit.

Two field studies were carried out using these lamps. The first study was entirely subjective. Subjects rode the bikes over a prescribed course and filled in a rating form at the end. The results showed little difference among the motorcycle lamps. The weakest of the three moped lamps was strongly downrated.

In the second study measurements were made of target identification distances. This was done on public roads, using realistic targets (e.g., pedestrian, roadway debris), and subjects who did not know what the targets would be or where they were located. The results showed little difference among the motorcycle lamps. Lamp C of the moped lamps yielded significantly shorter identification distances compared to the other two.

As a final step, a computer model was used to evaluate the motorcycle lamps in glare meeting situations and on hills and curves. These data indicate that the symmetrical beam (Lamp A) is better on curves in terms of revealing objects near the lane edges. It is poorer than the other lamps at revealing objects near the lane center and is more glaring to oncoming drivers.

Recommendations are offered for reducing the number of motorcycle-moped headlamps by standardizing on certain sizes. Modification to the photometric standards are proposed as well, which will result in improved lighting, especially for smaller motorcycles. A strategy is described which will, it is believed, significantly improve the aiming problem.

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INTRODUCTION

Headlamps are the primary and often sole source of illumination for much of the world through which motorists move at night. Since vision is crucial to safe and effective operation of a motor vehicle, headlamps are very important safety items. However, it is generally recognized that low-beam headlamps do not provide adequate seeing distances, especially at higher operating speeds. Further, based on a great deal of research over a period of many years, it is apparent that there is no simple solution to this problem (e.g., Olson, 1977).

The situation just described indicates a problem for all persons who operate a motor vehicle at night. But, for motorcyclists it is worse. Many motorcycle headlamps do not have the output of an automotive headlamp, and most motorcycles have but one headlamp.

The reasons for the reduced lighting on motorcycles are logical enough. Many bikes, the smaller ones especially, have limited electrical generating capacity, and finding space for paired headlamps is a problem even if the power was available.

But, however logical the reasons might be, there is a potentially serious problem. Almost all motorcycles, even relatively small ones, are fully capable of traveling at the 55 mph national speed limit. Thus, it would appear that, in terms of visibility distance at least, the needs of the motorcyclist are no different than those of the driver of an automobile.

Given this situation, it might seem logical for motorcycle headlighting to have been the subject of a great deal of research. Such has not been the case. There have been several studies which have examined the problem to some extent, but by far the most comprehensive work is that of Sturgis (1975). Sturgis did the following:

1. Collected motorcycle headlamp samples from a number of manufacturers, cataloging information such as size, mounting arrangements, electrical connections, wattage, and beam pattern characteristics.

2. Measured the aim of the headlamps of 90 motorcycles in service.

3. Studied the eye fixations of two experienced motorcyclists while operating both a motorcycle and a car on various roads.

4. Collected subjective ratings of various headlamps under a variety of riding conditions.

5. Measured desired aim based on a sample of 20 riders who were provided with an adjustable headlamp.

6. Evaluated seeing distances for several headlamps under glare and no-glare conditions.

Based on this work, Sturgis recommended changes in the motorcycle headlighting standards. He also suggested steps toward standardization of lamp parameters such as size and electrical connections, better voltage control, and improvements in aimability.

There are two studies which dealt with motorcycle headlamps to a very limited extent (Bartol, Livers and Hirsch, 1973, and Bartol, Livers and Miennert, 1975). However, the main focus of each was motorcycle safety in general.

In the years since the Sturgis report was prepared there have been significant changes in motorcycle headlamps (primarily through the introduction of halogen lamps), appreciable activity on the part of appropriate SAE committees, and reports of measures on the part of motorcycle manufacturers to upgrade their electrical systems. Thus, it seems appropriate to examine the area once again.

The study which will be described had as its purpose the collection of up-to-date information about motorcycle headlamps and the visibility needs of motorcyclists. Beam patterns were to be prepared and tested, both subjectively and objectively. Finally, recommendations were to be made for changes to Federal Motor Vehicle Safety Standard (FMVSS) 108.

This report is divided into three main sections. The first describes the present situation concerning motorcycle headlighting. In the second section several studies are described which were carried out in an effort to define an improved headlighting system for motorcycles and mopeds. The third section is concerned with recommendations for changes in the standards which control motorcycle and moped headlighting.

CURRENT STATUS OF MOTORCYCLE/MOPED HEADLAMPS IN THE UNITED STATES

When the sealed beam headlamp was adopted for use on automobiles in this country in the late 1930's, the specifications covered not only beam distribution but dimensions of the lamp. That practice has continued to the present day. As a result, sealed beam headlamps have been readily available and relatively inexpensive. However, the standards for motorcycle headlamps do not cover lamp dimensions. A consequence of this lack of control is that motorcycle headlamps are available in a number of types of construction, sizes, and electrical connections. In addition, the photometric specifications for motorcycle headlamps are less stringent than for automobile headlamps. Hence, motorcycle headlamps come in a variety of beam patterns, intensities, and wattages.

This lack of standardization has long been a source of difficulty for motorcyclists. Many bikes use lamps which are available only through the parts department of a dealer handling that make of motorcycle. Thus, they are not readily available and have usually been much more expensive than automotive headlamps.

This section of the report is intended to document motorcycle headlamps and their use in the U.S. Based on a comparison with the data reported by Sturgis (1975), it is apparent that there have been very significant changes in the last several years. Changes are still occurring at a fairly rapid pace. Hence, it should be noted that the data to be reported are based on the 1980 model year, and may be outdated rather quickly. Further, the data will refer only to four makes of Japanese and one U.S. made motorcycle (i.e., Honda, Kawasaki, Yamaha, Suzuki, and Harley-Davidson), which together accounted for 98% of all motorcycles sold in 1980, according to the 1981 Motorcycle Statistical Annual.

Types of Construction

Three types of construction were found on the headlamps surveyed:

1. All-glass sealed beam. These are identical in construction to the sealed beam headlamps used in cars in the United States.

Their primary advantage is that there will be no loss in lamp output due to reflector-lens degradation for the life of the vehicle. The entire unit must be replaced when a filament burns out, and its bulk makes it difficult for the motorcyclist to carry a replacement. American-made motorcycles use all-glass sealed beams exclusively. They are much less common on Japanese bikes.

Recently halogen all-glass sealed beams have been introduced for automotive use. They have not yet appeared on motorcycles.

2. Composite sealed beam. For these units a bulb is sealed into a metal reflector, which in turn is sealed to the lens. The lens and reflector are protected from contamination, as in the case of the all-glass sealed beam. Because of the inner bulb, the unit could survive the lens being perforated, which the all-glass type could not. However, the inner bulb can be expected to darken with age, with consequent loss of output. Like all sealed beams, the entire unit must be replaced when a filament burns out.

   Composite sealed beams have been much the most common type used on Japanese bikes.

3. Replaceable-bulb units. These use a metal reflector which is sealed to the lens. The bulb is removable. It is held in place by a spring clip and covered by a rubber "boot." This is the technology which the Europeans have employed for many years on automotive lamps. The obvious advantage is in the convenience and economy of having to replace only the bulb when a filament burns out.

   All of the replaceable-bulb units surveyed use the quartz-halogen H-4 bulb. The H-4 is used universally in two-beam European automotive lamps. This bulb is much more readily available and generally less expensive than comparable motorcycle headlamps. As a side benefit, the bulbs are small enough that the motorcyclist can easily carry a spare.

Unsealed headlamps have been prohibited in the U.S. for automotive use in part because of a concern that dirt and moisture can enter the envelope and contaminate the lens and reflector. There is no doubt that this happens, and it can significantly degrade the performance of headlamps as a vehicle ages. There is some debate about how serious the problem is with newer headlamps, and whether it applies at all to motorcycles, which are less likely to be operated under unfavorable weather conditions.

Lamp Sizes

Motorcycle headlamps come in round and rectangular shapes. The rectangular units are all replaceable-bulb type and standard 142 x 200 mm automotive size. The round units are of all three constructions and come in a variety of sizes.

The largest round headlamps correspond to the PAR 56 (7 inch, 178 mm) sealed beam units used in the U.S. In all cases examined, standard automotive lamps of either U.S. or European type could be substituted with relatively little difficulty.

Six other smaller lamp diameters were noted. One was a standard PAR 46 (5.75 inch, 146 mm) size, used in an American-made bike. The other five ranged from 167 mm to 135 mm in diameter. There is often more than one lamp of a given diameter. However, in most cases these units are not interchangeable, due to differences in mounting hardware and/or power consumption.

Moped headlamps are generally round, and range from 128 mm to 113 mm in diameter. Most are composite, some are all-glass sealed beams. One all-plastic "semi-rectangular" unit was noted, which used a flashlight-type bulb.

Electrical Connections

Almost all of the motorcycle headlamps surveyed use a three-blade, push-on connector identical to that used in automobiles. A few use individual spade-type connectors. Most mopeds use spade-type connectors. Some use screw terminal connectors.

Beam Patterns, Intensity, Power Consumption

The FMVSS 108 standards for motorcycle headlamps are reproduced in Tables 1 and 2. Table 3 defines the various classes of motorcycles mentioned in the first two tables. For reference purposes, the standards for automobile headlamps are also included.

Comparisons between automobile and motorcycle headlamp specifications are made difficult by the fact that only rarely do test points correspond. However, an examination of Tables 1 and 2 will show that the specifications for motorcycle headlamps permit a wider range of patterns, and lower intensities than do the specifications for automotive lamps.

Sturgis (1975) noted three broad classes of motorcycle beam patterns. Two of these classes referred to the relationship of the areas of maximum intensity for the high and low beams. He pointed out that all American and some Japanese lamps have an asymmetrical relationship, similar to U.S. automotive lamps. That is, the area of maximum intensity of the low beam is below and to the right of that of the high beam. Most Japanese lamps are symmetrical, in that the maximum intensity area of the low beam is directly below that of the high beam.

The last class of beam patterns noted by Sturgis referred to the differences between the sharp horizontal cut-off characteristic of European low beams and the more diffuse pattern characteristic of American or Japanese low beams. Few original-equipment European lamps enter this country because European-made bikes have such a small fraction of the market. However, comments from motorcyclists collected by Sturgis, and in the present study, indicate that owners of larger bikes will sometimes replace their stock headlamp with a European automotive lamp. Persons who had done this often reported they liked the broad coverage of the low beam and the improved visibility provided by the more powerful high beam.

Sturgis also noted a variety of magnitudes of displacement between low and high beams of different lamps. Some were great enough that if the lamp was aimed properly for one beam the other beam would be too high or low for optimum performance.

TABLE 1

PHOTOMETRIC SPECIFICATIONS FOR LOW BEAMS FOR AUTOMOBILES AND MOTORCYCLES

Position, Degrees	Automobile Type 2	Motorcycle	
		Class A & B	Class C & D
10U-90U	125 max		
1 1/2U-1R to R	1,400 max	1,000 max	1,000 max
1U-1 1/2 L	700 max		
1U-1L to L		500 max	500 max
1/2U-1R to 3R	2,700 max	2,000 max	2,000 max
1/2U-1L to L		800 max	800 max
1/2U-1 1/2L to L	1,000 max		
1/2D-1R to R		15,000 max	15,000 max
1/2D-1L to L		2,000 max	2,000 max
1/2D-1 1/2 R	20,000 max 8,000 min		
1/2 D-1 1/2 L to L	2,500 max		
1D-6L	750 min		
1 1/2D-2R	15,000 min		
1 1/2D-9R and 9L	750 min		
2D-3R		3,000 min	2,000 min
2D-3L		2,000 min	1,500 min
2D-6R and 6L		750 min	500 min
2D-15R and 15L	700 min		
4D-4R	12,500 max	12,500 max	12,500 max

TABLE 2

PHOTOMETRIC SPECIFICATIONS FOR HIGH BEAMS
FOR AUTOMOBILES AND MOTORCYCLES

Position, Degrees	Automobile			Motorcycle	
	Large Round or Rectangular	Small Round or Rectangular			
	Type 2	Type 1 or 1A	Type 2 or 2A	Class A & B	Class C & D
2U-V	1,000 min	750 min	750 min		
1U-3R and 3L	2,000 min	3,000 min	2,000 min		
H-V	20,000 min	60,000 max 18,000 min	15,000 max 7,000 min	10,000 min	2,000 min
H-3R and 3L	10,000 min	12,000 min	3,000 min		
H-6R and 6L	3,250 min	3,000 min	2,000 min		
H-9R and 9L	1,500 min	2,000 min	1,000 min		
H-12R and 12L	750 min	750 min	750 min		
1/2D-V				20,000 min	5,000 min
1/2D-3R and 3L				4,000 min	3,000 min

TABLE 2 (continued)

PHOTOMETRIC SPECIFICATIONS FOR HIGH BEAMS FOR
AUTOMOBILES AND MOTORCYCLES

Position, Degrees	Automobile			Motorcycle	
	Large Round or Rectangular	Small Round or Rectangular			
	Type 2	Type 1 or 1A	Type 2 or 2A	Class A & B	Class C & D
1/2D-6R and 6L				1,000 min	750 min
1D-V				15,000 min	5,000 min
1 1/2D-V	5,000 min	3,000 min	2,000 min		
1 1/2D-9R and 9L	1,500 min	1,250 min	750 min		
2D-V				5,000 min	3,000 min
2 1/2D-V	2,500 min	1,500 min	1,000 min		
2 1/2D-12R and 12 L	750 min	600 min	400 min		
3D-V				2,500 min	1,000 min
3D-6R and 6L				750 min	500 min
4D-V	5,000 max	5,000 max	2,500 max	5,000 max	5,000 max

TABLE 3

DEFINITION OF CLASSES OF MOTORCYCLES AS REFERENCED IN SAE HEADLIGHTING STANDARD J584b

Class	Description
A	2 wheels - 170cc and larger
B	(motor driven cycle) 50cc and larger but less than 170cc
C	less than 50cc and not meeting the definition of class E
D	three wheels - 170cc and larger
E	(commonly referred to as a mini-bike) any bike having one or more of the following characteristics:
	a) less than 10" (254 mm) nominal wheel rim size
	b) less than 40" (1016 mm) wheelbase
	c) less than 25" (635 mm) at seat height measured at the lowest point on the top of seat cushion w/o rider

The basic types of beam patterns and high-low beam distributions reported by Sturgis still exist. The major difference in motorcycle headlamps since 1975 is in the introduction of halogen sources by the Japanese manufacturers. As noted earlier, all of those units use the H-4 bulb. This source produces a sharp horizontal cut-off due to the shielded-filament design. However, the Japanese motorcycle lamps have a symmetrical low beam, with a slight dip at the V axis. The typical European automotive low beam is asymmetrical, i.e., flat on the left side, with a 15° upslope on the right, starting at the V axis. (Iso-candela diagrams of examples of both types are shown in Figures 5 and 11 later in the report.)

Many moped lamps have a single beam. All of the Japanese moped lamps surveyed were two-beam units, with the high intensity zones of the beams displaced vertically.

Power requirements for the 12 volt motorcycle lamps surveyed ranged from 25 to 55 watts on low beam, and from 35 to 65 watts on high beam. Six volt lamps were about 35 watts on either beam. Moped lamps ranged from 6 to 20 watts on low beams. High beams, where present, were either 15 or 20 watts.

As might be expected from the wattage figures just presented, beam intensities varied a great deal. The higher wattage units produced illumination levels comparable to an automotive headlamp. (Comparing a motorcycle headlamp to an automotive headlamp is merely to provide a frame of reference with which all readers are familiar. It is not intended to imply that the automotive lamp constitutes a standard of excellence.) The lower wattage units produced patterns which were more compact and at significantly lower intensities. These characteristics were well documented by Sturgis, and the data are still applicable.

Current Lighting Practices

Table 4 is a breakdown of all motorcycles registered in the U.S. in 1980 by displacement and type, taken from the Motorcycle Statistical Annual. This will be helpful in interpreting headlighting information to follow. About half the motorcycles in the U.S. at present are designed to run on hard surfaces, the remainder are either off-road, competition, or dual purpose machines. The largest single category, about one-sixth of the total, are the big bikes (750 cc and larger), all of which are designed for on-highway use.

Table 5 is a compilation of original-equipment headlamps by make and displacement of motorcycle and is intended to provide some indication of the wide range of lamps in common use and the types of bikes on which they are found. The data are from 1980. Only the five makes of motorcycle which currently dominate the American market are shown. Each cell of the matrix lists the manufacturer(s) and model numbers of lamps for that brand and size of bike.

Table 6 provides a listing of various specifications for each of the lamps listed in Table 5.

TABLE 4

DISTRIBUTION OF MOTORCYCLES BY DISPLACEMENT AND MODEL TYPE (1980)

Engine Displacement	On Highway		Off Highway & Competition		Dual Purpose	
	Number	%	Number	%	Number	%
750cc and larger	1,290,900	17.4	--	--	--	--
450cc to 749cc	930,000	12.6	18,800	0.3	19,000	0.3
350cc to 449cc	918,800	12.4	117,400	1.6	239,000	3.2
125cc to 349cc	427,800	5.8	640,100	8.7	1,008,900	13.6
Under 125cc	152,500	2.1	788,700	10.7	848,100	11.5
TOTALS	3,720,000	50.3	1,565,000	21.1	2,115,000	28.6

Data from the Motorcycle Statistical Annual, 1981.

TABLE 5

LISTING OF POPULAR MOTORCYCLES SOLD IN THE UNITED STATES AND FACTORY-EQUIPMENT HEADLAMPS

Engine Displacement	Honda	Yamaha	Suzuki	Kawasaki	Harley-Davidson
750cc and larger	Stanley 001-1970 001-2103	Koito 997-16121 Stanley 001-1843	Stanley 001-1970 001-2309 001-2385	Stanley 001-1970 001-2309 030-9016	G.E. 4420 4467 T.S. 4458
450cc to 749cc	Stanley 001-2103 HM-29M-S	Koito 4438 4020	Koito 997-16121 997-15303 4420 x 2 4020 x Stanley 001-2385	Stanley 001-1014 001-1269	
350cc to 449cc	Stanley HM-231M-S	Koito 997-15303	Koito 4438	Stanley 001-1269	
125cc to 349cc	Stanley HM-29M-S	Koito 4020 x Stanley 001-2233	Koito 4020 x 4420 x2	Stanley 001-1047 Koito 4020 x	
Under 125cc	Stanley HM-29M-S	Koito 4020 x	Koito 4020 x	Koito 4020 x	

TABLE 6

MOTORCYCLE HEADLAMP SPECIFICATIONS

Manufacturer	Model Number	Construction	Shape	Size (mm)	Source	Wattage		Volts
						Low	High	
Stanley	001-1970	Replaceable Bulb	Round	178	Halogen	55	60	12
	001-2385	Replaceable Bulb	Round	167	Halogen	55	60	12
	001-2309	Replaceable Bulb	Rectangular	142 x 200	Halogen	55	60	12
	001-2103	Composite Sealed Beam	Round	178	Tungsten	50	65	12
	001-1843	Replaceable Bulb	Rectangular	142 x 200	Halogen	55	60	12
	030-9016	All Glass Sealed Beam	Round	178	Tungsten	50	60	12
	001-1014	Composite Sealed Beam	Round	178	Tungsten	35	50	12
	011-2233	Composite Sealed Beam	Round	167	Tungsten	35	50	12

TABLE 6 (continued)

MOTORCYCLE HEADLAMP SPECIFICATIONS

Manufacturer	Model Number	Construction	Shape	Size (mm)	Source	Wattage		Volts
						Low	High	
Stanley	HM-23M-S	Composite Sealed Beam	Round	167	Tungsten	35	50	12
	001-1269	Composite Sealed Beam	Round	157	Tungsten	35	50	12
	001-1047	Composite Sealed Beam	Round	157	Tungsten	25	35	12
	HM-29M-S	Composite Sealed Beam	Round	135	Tungsten	36.5	35	6
Koito	997-16121	Replaceable Bulb	Round	178	Halogen	55	60	12
	4438	All-Glass Sealed Beam	Round	178	Tungston	40	50	12
	997-15303	Composite Sealed Beam	Round	160	Tungsten	35	50	12
	4420 x 2	All-Glass Sealed Beam	Round	140	Tungsten	40	45	12

TABLE 6 (continued)

MOTORCYCLE HEADLAMP SPECIFICATIONS

Manufacturer	Model Number	Construction	Shape	Size (mm)	Source	Wattage		Volts
						Low	High	
Koito	4020x	All-Glass Sealed Beam	Round	140	Tungsten	35	35	6
General Electric	4467	All-Glass Sealed Beam	Round	178	Tungsten	35	50	12
	4420	All-Glass Sealed Beam	Round	146	Tungsten	30	30	12
Tung-Sol	4458	All-Glass Sealed Beam	Round	178	Tungsten	50	60	12

Using Tables 5 and 6, it is apparent that most 1980 motorcycles 750cc and larger incorporate headlamps which are approximately equal to an automotive headlamp. A great many of these are using halogen headlamps such as the Stanley 001-1970 and Koito 997-16121. The manufacturers have told us that the beam pattern provided by these units is based on the recommendations of Sturgis (1975).

For bikes smaller than 750cc, the situation is more variable. All bikes of less than 350cc are equipped with headlamps having considerably less output than an automotive headlamp, although the on-highway vehicles among them are supposed to be able to go anyplace a car can go, and at the same (legal) speeds.

In sum, there have been significant improvements in motorcycle headlighting in recent years. Indications are that there will be more improvements in the future. Clearly, there is room for significant improvement, especially in the lighting provided smaller motorcycles.

INVESTIGATIONS CONDUCTED AS PART OF CURRENT PROGRAM

This section of the report will describe four studies which were carried out to develop information necessary to answer the main concern of the contract, i.e., to recommend minimum headlighting needs for various classes of two-wheeled vehicles.

The first step was a survey, that sought information to aid in defining the visual needs of motorcyclists. Based on these data, a limited number of headlamps were recommended for detailed evaluation. The evaluation was carried out in three steps: a subjective study, an objective assessment of visibility distances, and a computer analysis of visibility distance under a variety of riding conditions not included in the objective study.

A Survey of Motorcyclists' Experience with Motorcycle Headlamps

One of the assumptions on which the motorcycle headlighting project is predicated is that the visual needs of motorcyclists are significantly different from those of car drivers. If true, this means the standard automotive headlamp pattern may be unsatisfactory for use on motorcycles.

A knowledge of the visual needs of motorcyclists is important to the design of a satisfactory lighting system. Unfortunately, there is little information to go on. Sturgis (1975), faced with a similar problem, asked 90 participants in an in-service headlamp aim survey to rank order the most important areas or objects in the driving environment to be able to see while operating a motorcycle at night. The three areas most frequently mentioned were:

Center of lane, at distance.
Center of lane, close in.
Periphery, other than in lane.

One possible interpretation of these data is that motorcyclists need more illumination everywhere. Due to the relatively unstructured procedure, it is not clear whether the responses reflect different needs or are a reaction to the fact that most motorcycle headlamps of that era had appreciably less output than automotive headlamps.

In an effort to develop better information about the visual needs of motorcyclists as they might relate to headlamps, a survey was designed and conducted by the Motorcycle Safety Foundation (MSF). HSRI provided some assistance in the formulation of the questions and analysis of the results.

Method: The survey addressed the issue of needs in two ways: by asking the respondents to compare driving a car with riding a motorcycle, and by asking them to list problems they had noted with headlamps in their own riding experience. The survey also asked the respondents to note headlamps that they had found to be good. A complete copy of the survey form, including the cover letter, is in Appendix A of this report.

The questionnaire was mailed/provided to MSF staff and to chief instructors for the MSF riders course around the U.S. A total of 152 forms were distributed.

No claims are made that the survey respondents are "representative" of the motorcycle rider population. The people were chosen primarily because they were easily accessible through listings maintained by the MSF. However, they had other characteristics that made them good choices for this survey. In particular, it was thought likely that the chief instructors would have substantial riding experience in terms of time, miles, and types of bikes. In addition, they should be persons with a sincere concern for safety issues, who had probably given some thought to the matters with which the survey was concerned.

It should also be noted that past experience with subjective assessment of headlighting systems (Mortimer and Olson, 1974) has shown that subjects' preferences do not necessarily correlate with objective measures of visibility performance. Hence, these data, while interesting and useful as a starting point in the evaluation process, are no substitute for a thorough objective evaluation.

Results:

Description of the population: Usable data were received from 68 persons, a response rate of 45%. All but two of the respondents were male.

The average age was 36 years. The age distribution was as follows:

29 years and younger -	14
30-39 years -	31
40-49 years -	17
50 years and older -	3

(Three respondents provided no age data.)

Riding experience averaged 10 years, distributed as follows:

4 years and less -	8
5-9 years -	29
10-19 years -	23
20 or more years -	8

The respondents rode an average of 7700 miles in 1980. The distribution was as follows:

Fewer than 10,000 miles -	46
10,000-19,999 miles -	14
20,000 miles and more -	6

(Two respondents provided no mileage estimates.)

Miles ridden at night averaged 20%. The distribution was as follows:

Less than 10% -	7
10-19% -	19
20-29% -	22
30-39% -	14
40% or more -	5

(One respondent provided no estimate.)

Three "classes" of motorcycle were mentioned on the first page of the survey form, defined in terms of engine displacement. These were: less than 300 cc, 300 cc to 699 cc, and 700 cc or more. Most respondents had significant experience with more than one class. (Only three claimed to have had any experience with mopeds, however.)

The distribution was as follows:

All three classes of motorcycle -	21
Two of the three classes -	27
One of the three -	20

The number of respondents claiming experience with each class of motorcycle was as follows:

Less than 300 cc -	41	(60%)
300 cc to 699 cc -	52	(76%)
700 cc or more -	42	(62%)

<u>Questions 1 and 2</u>: Question 1 asked whether the visual needs were different for the operator of a car and a motorcycle. For those respondents answering "yes," question 2 asked them to explain in what way the needs differed.

Fifty of the respondents (74%) answered "yes" to question 1. They provided a wide variety of responses to question 2. The points mentioned most frequently were:

Need more illumination to the sides.	(21)
Need more foreground illumination.	(17)
Need more down-the-road illumination.	(13)
Need better illumination to the right.	(5)
Need better side lighting for sharp turns.	(4)

The numbers in parentheses indicate the frequency with which each point was mentioned.

Two major needs are noted, illumination to the sides, and foreground illumination. The comment about more down-the-road illumination possibly reflects a general concern about motorcycle headlighting. Thus it is not necessarily appropriate to interpret the comment to mean "more illumination than a car's headlamps."

<u>Questions 3 and 4</u>: Question 3 asked whether the respondents had ever encountered motorcycle headlamps they considered very good or very poor. If they answered "yes," they were asked to describe the lamps in question 4.

Of the 64 persons who responded to question 3, 42 (66%) marked "yes." They provided very interesting responses to question 4. Forty-seven indications of "very good" headlamps were provided. In 39 of these cases it was clear the respondent was referring to a halogen lamp of some kind. The most frequent response (18 times) was "halogen lamp" (or quartz-halogen, or quartz, or quartz-iodine, or iodine, all of which are equivalent terms). Often the response was in the form of: "the halogen lamp on such-and-such bike." Sometimes the make of lamp was identified, less frequently the model number was provided.

It was apparent that many respondents had replaced stock headlamps with something they considered more adequate (generally a halogen lamp but, in one case, an aircraft landing light).

The identification of the lamps was such that the investigators often could not be certain whether the halogen lamp referred to was one designed for automotive or motorcycle use. However, in eight cases it was possible to verify that the units being described were one of the relatively new motorcycle halogen lamps described earlier. The respondents seemed quite enthusiastic about these lamps. In seven cases the lamps were clearly automotive, both U.S. and European.

There were fewer responses in the "very poor" category. The most frequent was "most stock non-halogen," which occurred four times. Most other responses referred to mid-size and smaller motorcycles.

The frequency with which the respondents mentioned halogen lamps raised a question as to whether there were differences between those who had such lamps on the bike(s) they were presently riding (based on the response to the last question on the first page of the survey form), and those who did not.

The forms were sorted into three categories as follows:

Have halogen headlamps (10 respondents)
Do not have halogen headlamps (42 respondents)
Could not determine type of headlamp (16 respondents)

Those which fell in the third category were discarded for purposes of this analysis.

The most obvious difference between those who had halogen lamps and those who did not was that the former all had large (700 cc or more) bikes of recent vintage. Most of the latter group were riding medium and smaller bikes.

In most other respects the groups were very similar, as indicated by the following averages:

	Halogen	Non-Halogen
Age	35	35
Years riding experience	9.4	9.4
1980 miles	10,000	8,900
Percent at night	20	20

In responding to question 1, 80% of those with and 76% of those without halogen units answered "yes."

However, in response to question 3, 80% of those with and only 62% of those without halogen units answered "yes." This difference may reflect a lack of exposure to halogen lamps by those in the latter group.

While those with halogen lamps typically responded to question 4 with a statement like "the halogen lamp on my present bike is very good," those who did not have halogen lamps on their own bikes typically responded with something like "I understand the new halogen lamps are very good," or made reference to a friend's bike which they had ridden. Thus, while the number of references to halogen lamps is impressive, the actual exposure may be much less than the numbers suggest.

Question 5: Question 5 asked the respondents to describe the main shortcomings of the motorcycle headlamps with which they were familiar.

There were a number of responses to this question, but two dominated. These were: inadequate range (mentioned 41 times), and poor vision to the sides (mentioned 28 times). Other points were:

Poor foreground illumination	5
Aim problems	5
Beam vibrates at higher speeds	3
Inadequate electrical system	2
Patterns wrong for turns	2
High cost	2
Poor performance in bad weather	2

Discussion: The results of this investigation confirm the data reported by Sturgis (1975). It is apparent that motorcyclists feel a need for better illumination in general. In addition, there appear to be two features desired by motorcyclists which are not necessarily provided by automotive lamps. These are:

1) Foreground illumination (i.e., immediately in front of the bike).

2) Illumination to the sides (i.e., to the right and left of the lane being used).

Lamps having these characteristics will provide the near-field illumination necessary to avoid roadway objects which are no more than a nuisance to a car driver, but which can cause serious problems to a motorcyclist (e.g., potholes, road debris). It also reduces the beam distortion and loss of illumination associated with cornering. (One respondent described cornering as "driving into a black hole.")

The frequent reference to halogen lamps, especially the units such as the Stanley 001-1970 and Koito 997-16121 led to a recommendation that a pattern such as they provide be included in the evaluations to follow.

Subjective Evaluation of Motorcycle/Moped Headlighting

Introduction: The purpose of this test was to provide a broad-based subjective evaluation of several possible lighting systems for both motorcycles and mopeds.

There are obvious advantages to subjective studies, including simplicity and the opportunity to uncover factors that might otherwise have been overlooked. In the case of headlighting, it is also about the only way that a number of features of the lighting system can be evaluated (e.g., uniformity, distortion on curves).

On the other hand, there are problems that make total reliance on subjective data inadvisable. For example, Mortimer and Olson (1974) noted a discrepancy between objective and subjective measures of visibility distance, which suggested that their subjects were unduly influenced by glare levels. There is also a concern that people will react in an unrealistic way to conditions which differ from what they are used to, or which they feel are new or experimental.

On balance, the subjective study seemed a good way to start the evaluation process, providing a great deal of data with relatively little effort and offering some guidance in the design of the objective study to follow.

Method:

Vehicles: One of each type of bike was used. The motorcycle was a 1980 Honda 650cc "Custom," on loan from Honda Corporation. The moped was a Motobecane "Moby." Both bikes were modified by removing the stock headlamp and replacing it with a flat panel as shown in Figure 1. The headlamps were then mounted in hardware which permitted them to be adjusted vertically and horizontally for aiming purposes. They were then attached to flat plates (see Figure 2), which could be bolted to the panel on the bike as shown in Figure 3.

Both bikes were equipped with control devices which maintained the voltage to the lamp filament at a precise level (12.8 and 6.4 volts for the motorcycle and moped, respectively). The moped had a 12-volt system that was found to be inadequate to power the two larger lamps scheduled for test. A 12-volt, 18-ampere hour battery was used instead. This was secured on the saddle behind the rider as shown in Figure 4. The voltage was stepped down to 6.4 volts by the control device and the battery was recharged regularly.

The lamps were aimed prior to the start of the test. The front and rear wheels of each bike were aligned relative to the V axis by placing them in a metal channel. The height of the lamp was measured to determine the H axis. Each lamp was aimed on low beam to conform to the distributions indicated in Figures 5 through 17. Aiming was by visual means, and was carried out with a 175 pound person in riding position.

Test headlamps: Four headlamps were evaluated on the motorcycle. Two of these were designed for motorcycle use and two were automotive lamps that are sometimes used to replace stock lamps on larger motorcycles. All were 12-volt units. These can be described as follows:

Lamp 1 (Figures 5 and 6). Round unit, 178 mm in diameter, replaceable-bulb type, using an H-4 (halogen) source. Wattages are 55 and 60 for the low and high beams, respectively. This is a Stanley

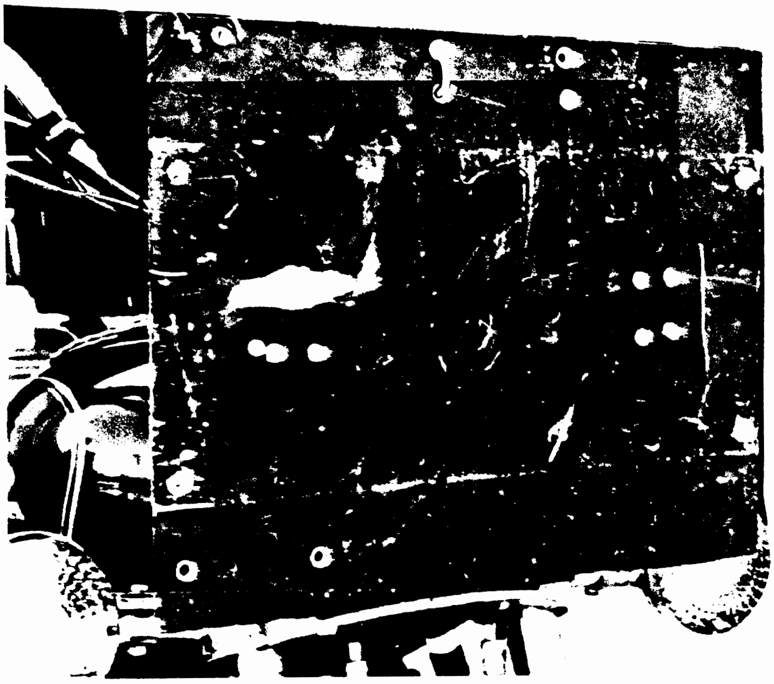

Figure 1. Headlamp mounting plate on motorcycle.

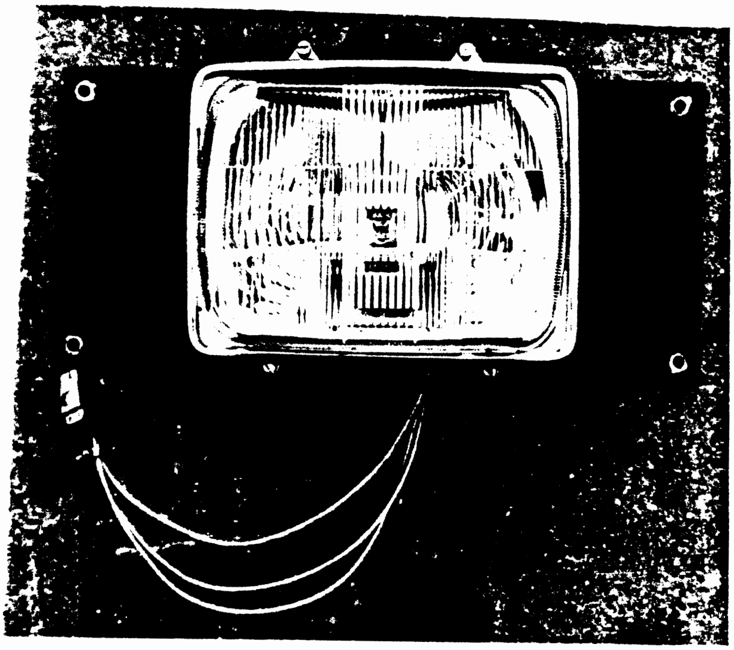

Figure 2. Headlamp attached to aiming plate.

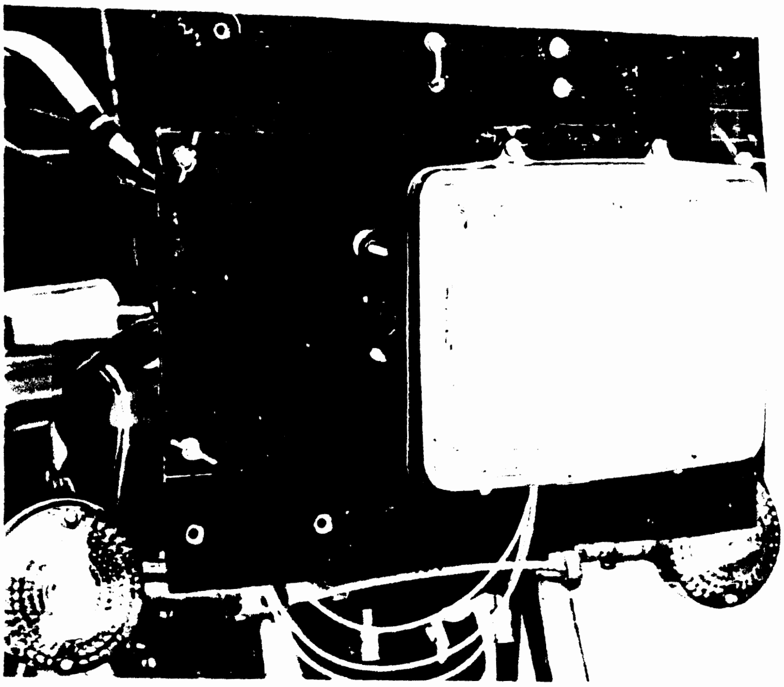

Figure 3. Headlamp mounted on motorcycle, ready for test.

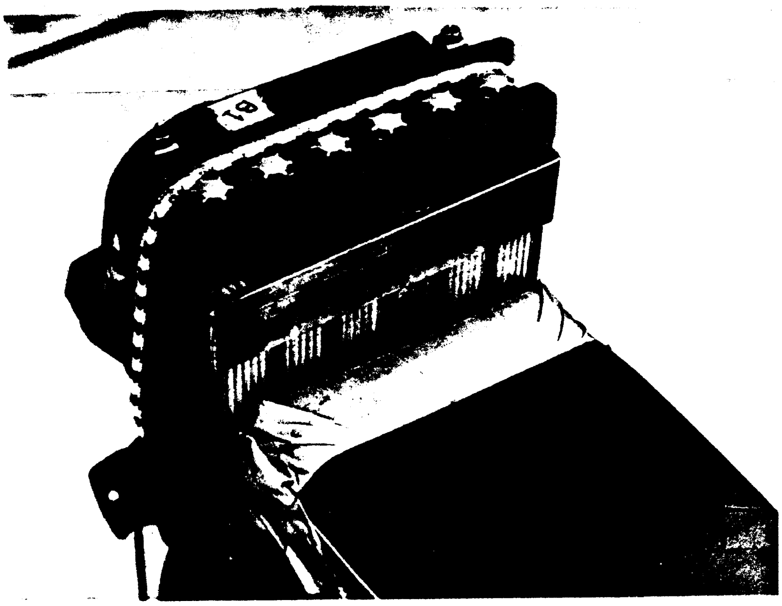

Figure 4. Twelve-volt battery mounted on moped saddle.

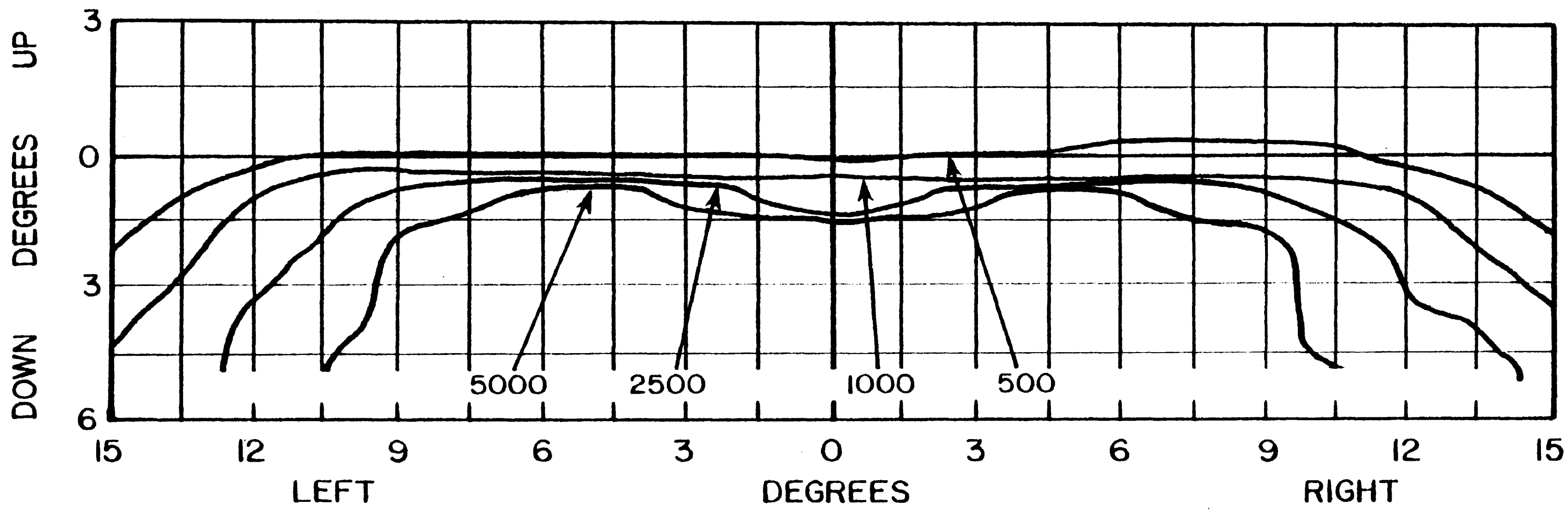

Figure 5. Isocandela diagram of low beam of Lamp 1. Figures shown are candelas (cd).

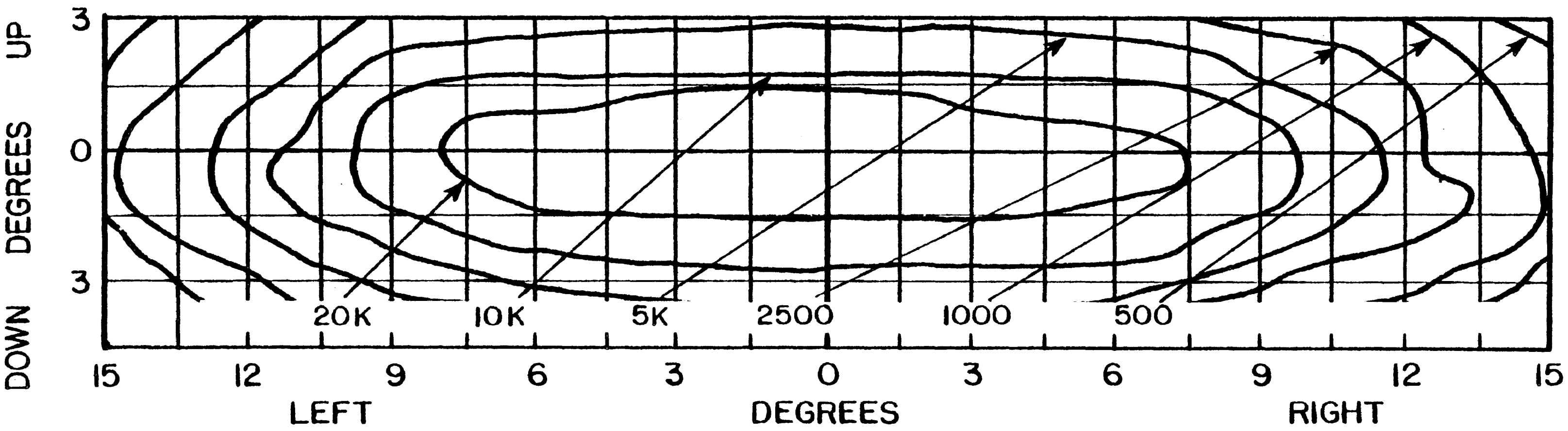

Figure 6. Isocandela diagram of high beam of Lamp 1. Figures shown are candelas (cd).

001-1970, selected because it received a number of specific favorable mentions in the user survey.

Lamp 2 (Figures 7 and 8). Round, all-glass sealed beam, 178 mm in diameter, with tungsten source. Wattages are 40 and 50 for the low and high beams respectively. Based on the data reported by Sturgis (1975), this was one of the better stock motorcycle lamps he tested.

Lamp 3 (Figures 9 and 10). Round, all-glass sealed beam, 178 mm in diameter (type 6014), with tungsten source. Wattages are 50 and 60 for low and high beams respectively. This is a standard automotive lamp, designed to meet FMVSS 108 (U.S.) standards.

Lamp 4 (Figures 11 and 12). A 142 x 200 mm rectangular unit, replaceable-bulb type, using an H-4 (halogen) source. Wattages are 55 and 60 for the low and high beams respectively. This is an automotive lamp, built to meet ECE (European) standards.

Three moped lamps were tested. All were 6-volt units.

Lamp 5 (Figures 13 and 14). Round, composite sealed beam, 128 mm in diameter. Tungsten source. It has both high and low beams, 20 watts each. Selected as a representative "good" moped lamp.

Lamp 6 (Figures 15 and 16). Same size, construction and wattage as Lamp 5. Selected because it was the best moped lamp tested by Sturgis (1975).

Lamp 7 (Figure 17). Rectangular plastic unit. Replaceable tungsten bulb. One beam, 6 watts. Selected as a relatively weak unit, based on results reported by Sturgis (1975).

Test courses: The bulk of the moped course wound through University housing areas. The road is good-quality asphalt, two lanes wide, with many hills and curves. Both vehicle and pedestrian traffic were light in the hours during which data were taken. The total course length was about 11 km. It typically took about 25 minutes to complete.

The motorcycle course was laid out on roads on the east side of the city of Ann Arbor. It included freeway, dark two-lane, and lighted city streets. Speed limits ranged from 30 to 55 mph (48 to 88 km/hr). Vehicular traffic ranged from medium to light during the test; there was

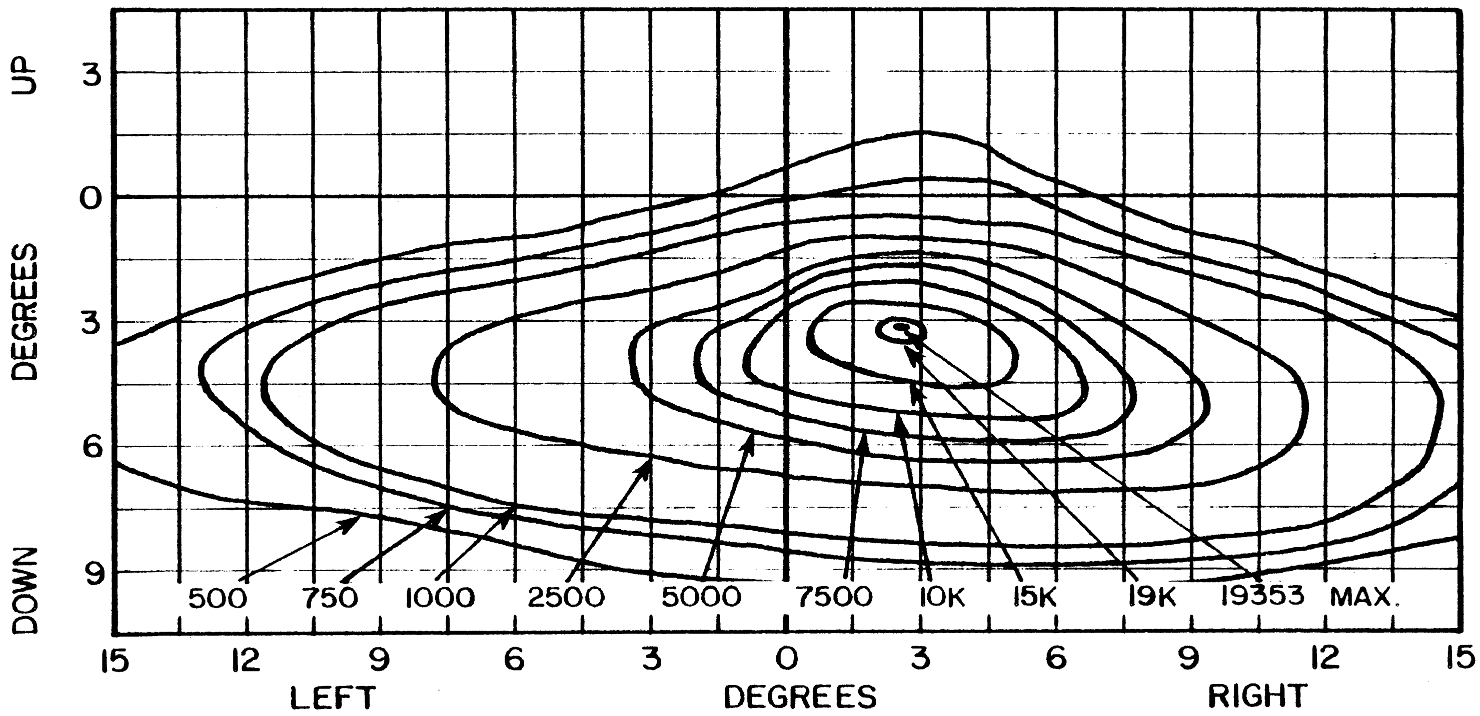

Figure 7. Isocandela diagram of low beam of Lamp 2. Figures shown are candelas (cd).

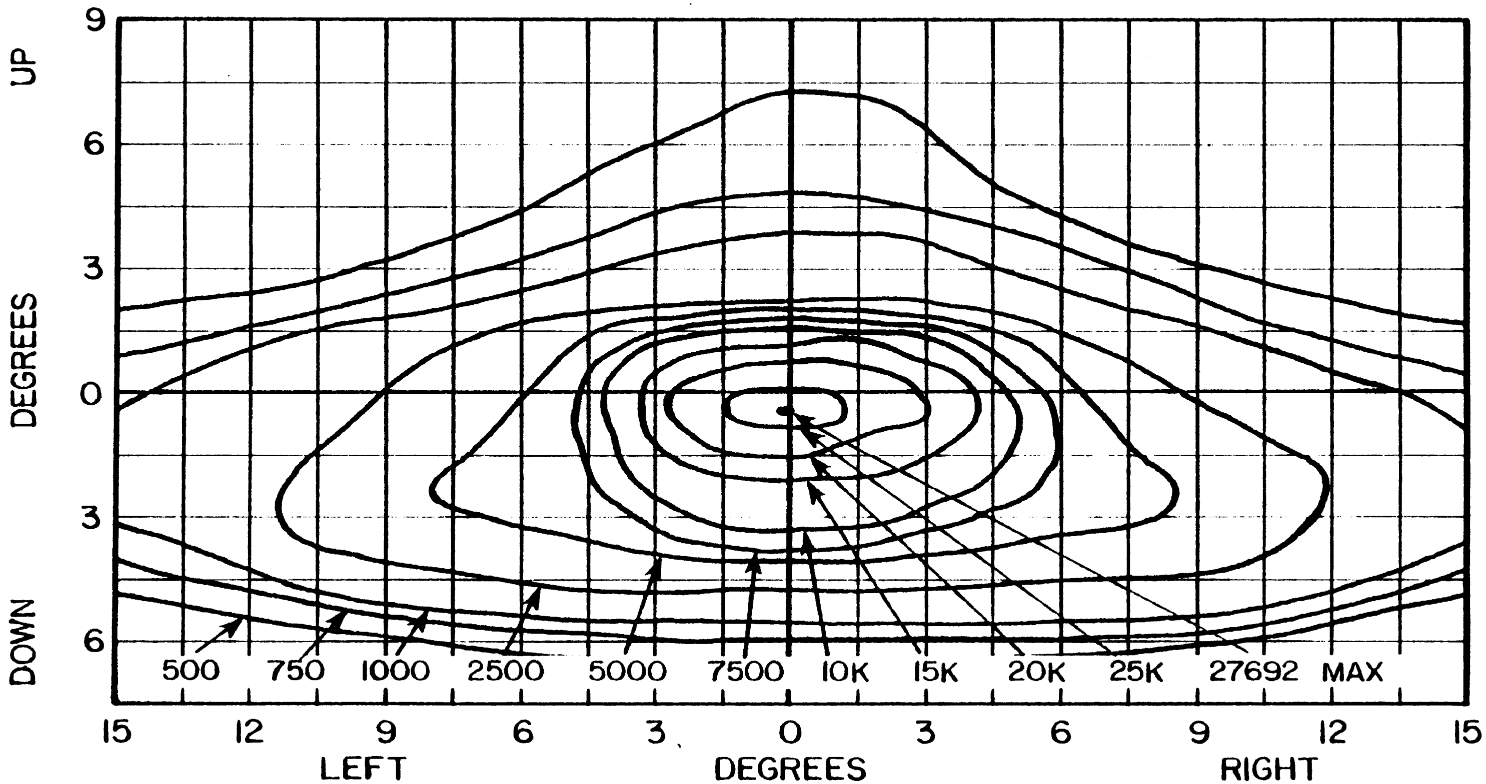

Figure 8. Isocandela diagram of high beam of Lamp 2. Figures shown are candelas (cd).

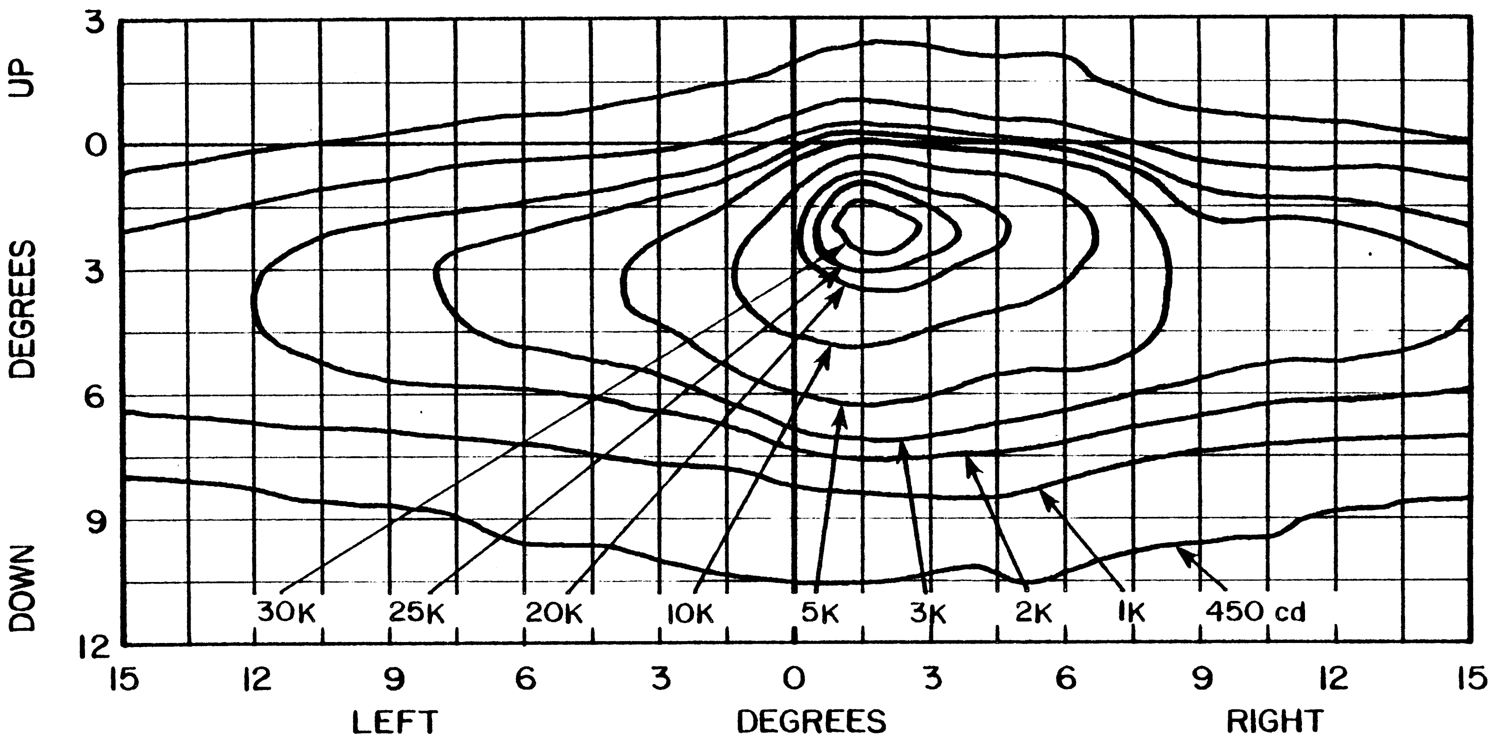

Figure 9. Isocandela diagram of low beam of Lamp 3. Figures shown are candelas (cd).

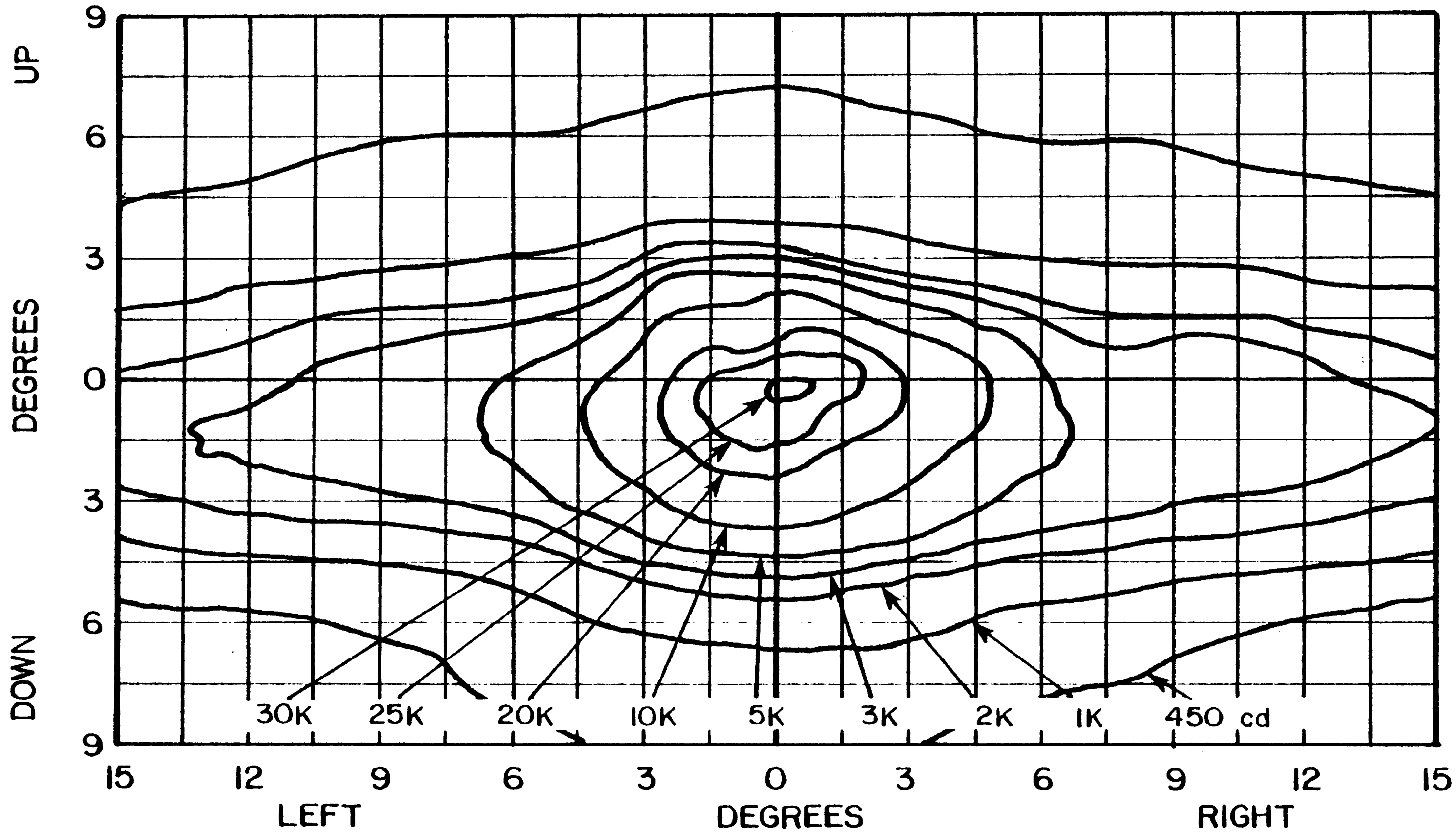

Figure 10. Isocandela diagram of high beam of Lamp 3. Figures shown are candelas (cd).

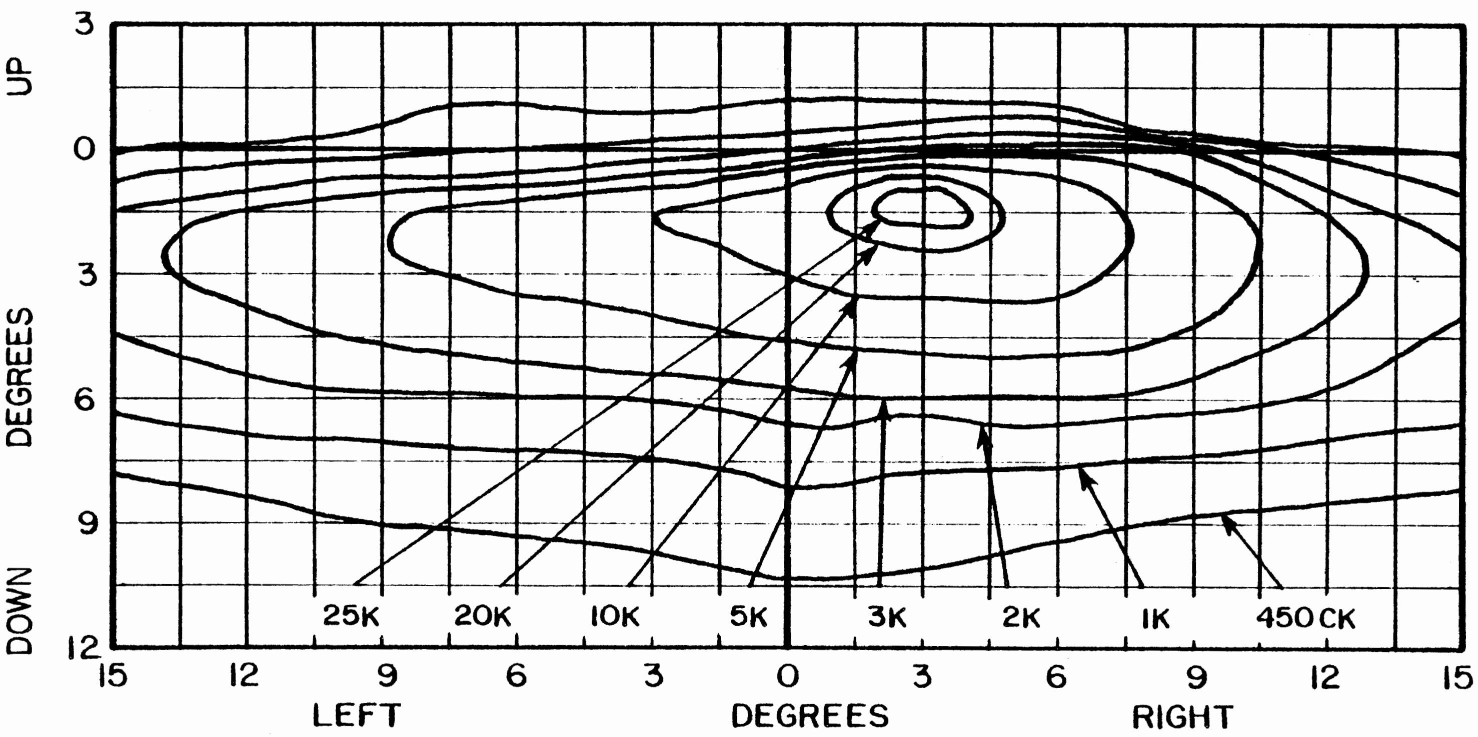

Figure 11. Isocandela diagram of low beam of Lamp 4. Figures shown are candelas (cd).

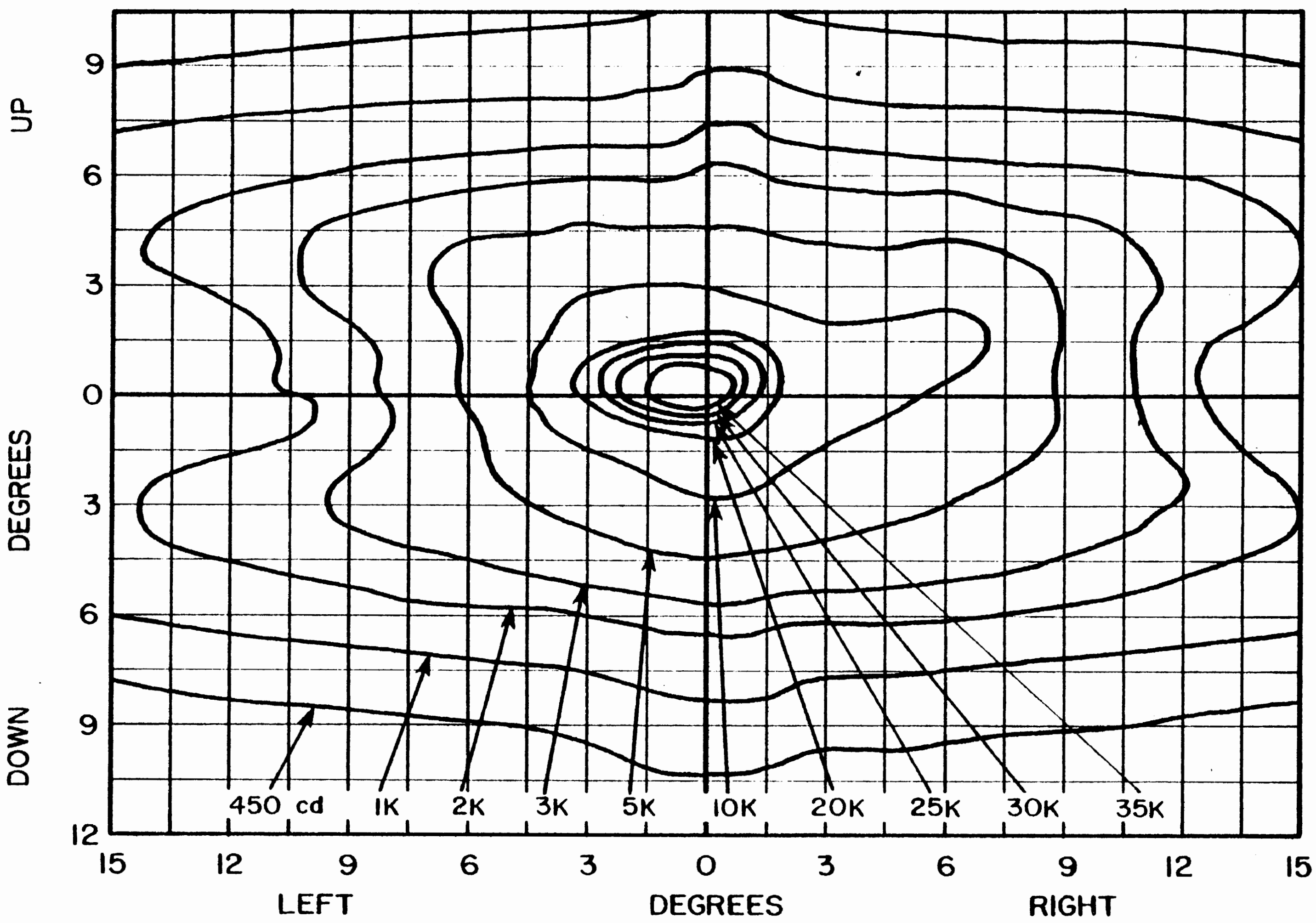

Figure 12. Isocandela diagram of high beam of Lamp 4. Figures shown are candelas (cd).

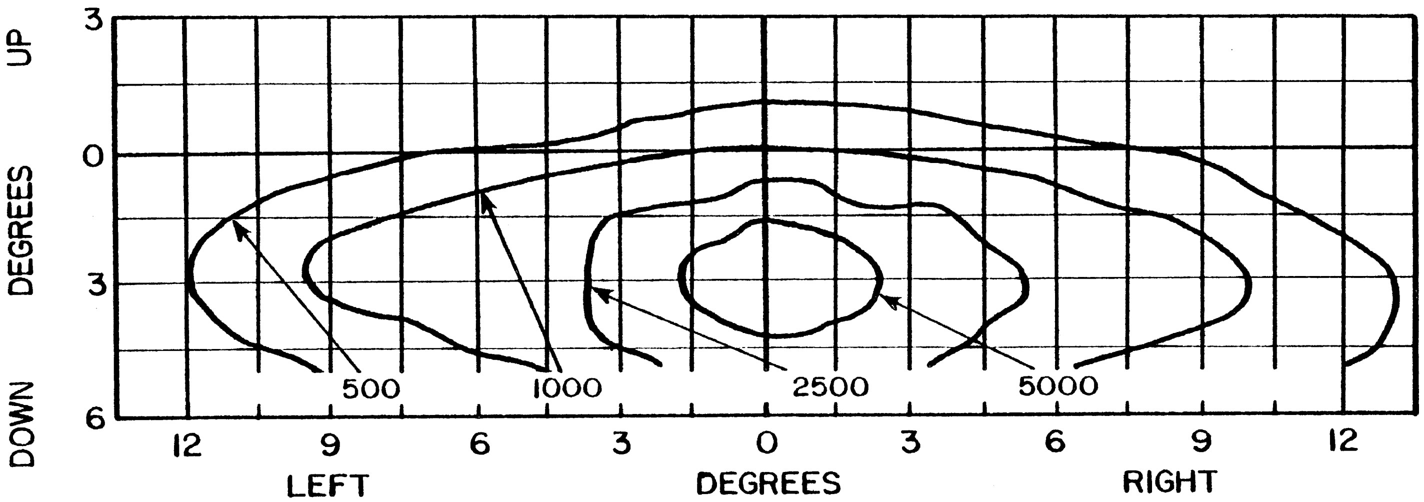

Figure 13. Isocandela diagram of low beam of Lamp 5. Figures shown are candelas (cd).

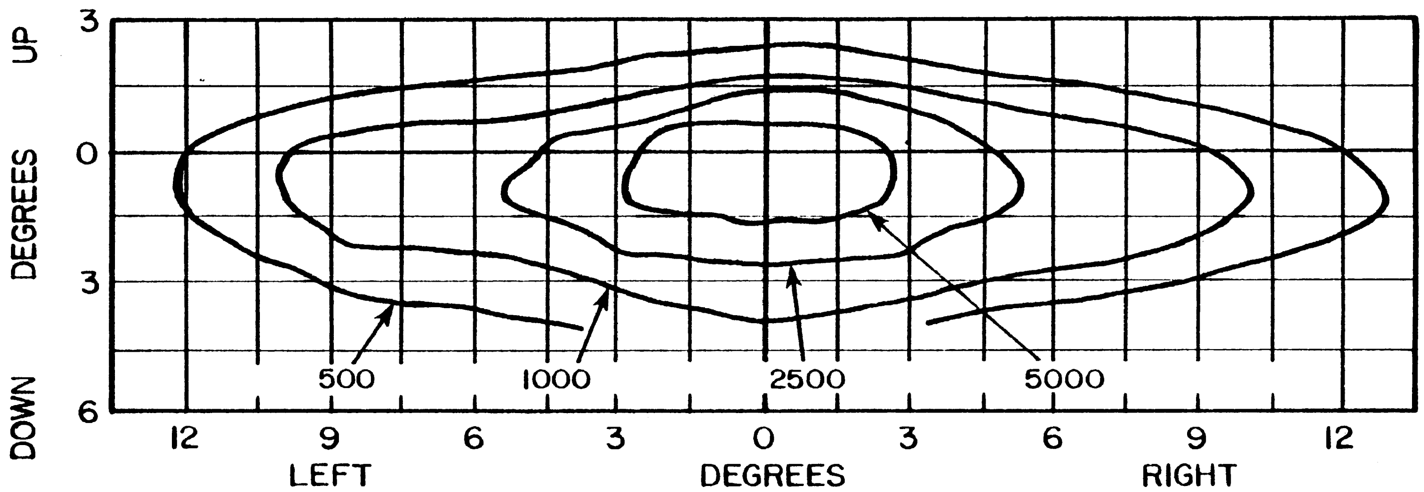

Figure 14. Isocandela diagram of high beam of Lamp 5. Figures shown are candelas (cd).

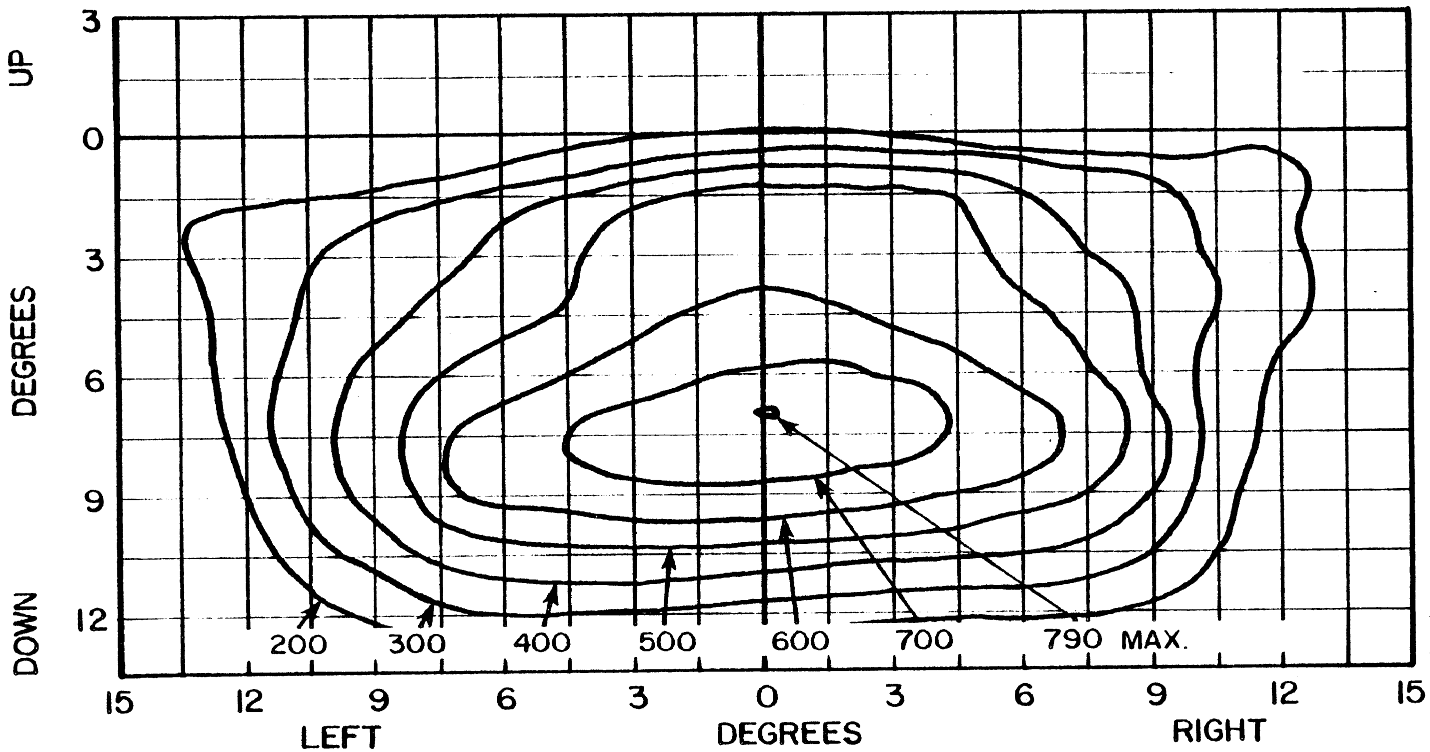

Figure 15. Isocandela diagram of low beam of Lamp 6. Figures shown are candelas (cd).

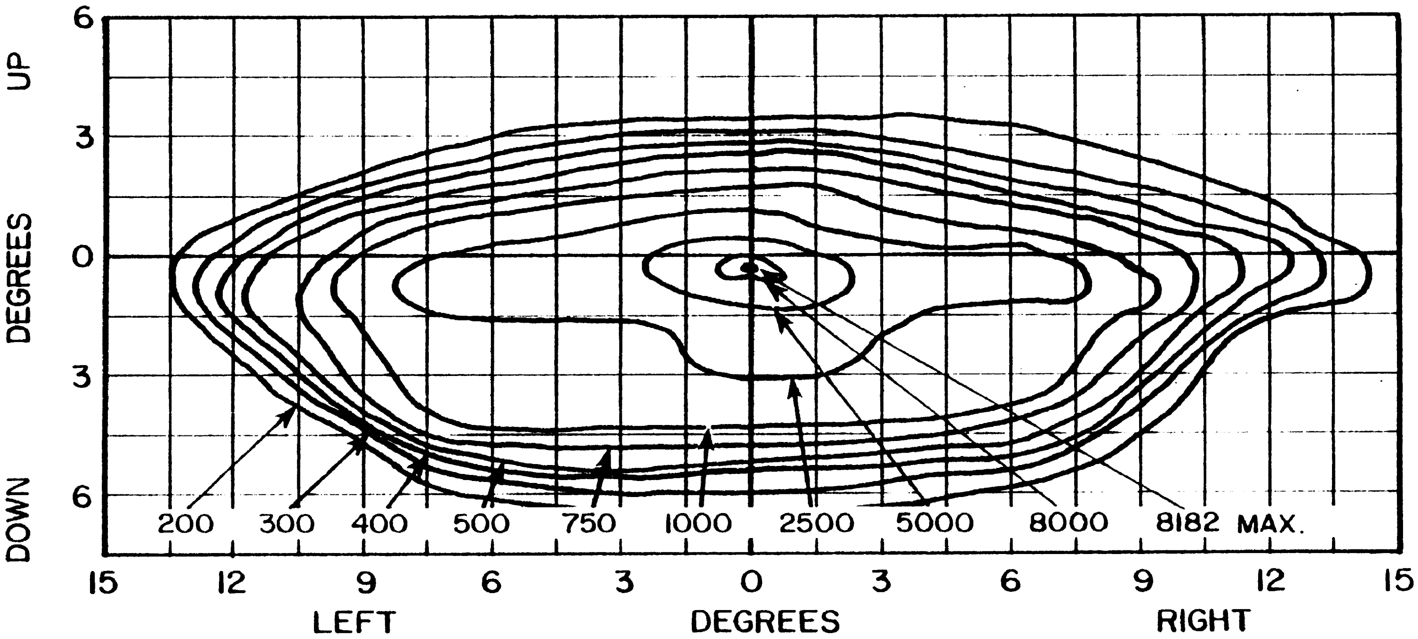

Figure 16. Isocandela diagram of high beam of Lamp 6. Figures shown are candelas (cd).

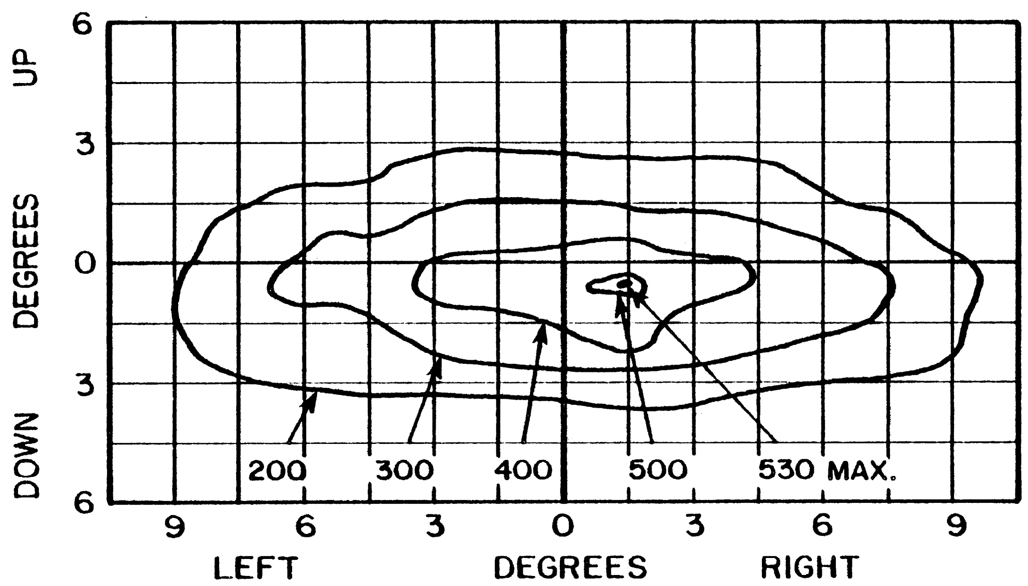

Figure 17. Isocandela diagram of Lamp 7. Figures shown are candelas (cd).

little pedestrian traffic. The course was about 25 km long. It typically took about 30 minutes to complete.

Subjects: Twelve subjects participated in the motorcycle evaluation, nine in the moped. All were young (i.e., under 30 years of age). They were recruited in a variety of ways, e.g., advertisements in newspapers, fliers in motorcycle shops and on campus bulletin boards, and by participants telling their friends about it. All of the motorcycle subjects had a valid Michigan motorcycle endorsement and recent experience on a bike at least as large as the one used in the test. Most of the moped subjects had at least some recent experience on a moped. A few had never ridden a moped, but had substantial experience on small motorcycles.

Rating forms: Ratings were made on a number of factors, using a 7-point scale. Scale end- and mid-points were identified as:

1 = very poor
4 = just acceptable
7 = excellent

Copies of the rating forms are provided in Appendix B.

Procedure: One subject was run on each bike each night. The subjects reported to the Institute just as it was starting to get dark. They were provided with a map of the course and asked to review a copy of the rating form so they would know what to look for. When all questions had been answered they left to run the course. When they returned they filled out the rating form while the experimenter changed to the next headlamp. This process was repeated until all lamps had been tested.

The order in which the lamps were rated was changed systematically, based on a Latin Square. Three complete sequences were used for each bike.

Results:

Moped: Tables 7 and 8 summarize the results of this phase of the study for low and high beams respectively. Tests to determine the significance levels for differences in the ratings given each lamp for each statement in the questionnaire were made using the Friedman ANOVA

TABLE 7

MEAN RATINGS* FOR MOPED HEADLAMPS ON LOW BEAM:
NINE YOUNG SUBJECTS

QUESTIONS	LAMPS			
	5	6	7	Sig
1. Overall - unlighted areas	5.4	5.0	2.4	.01
2. Overall - lighted areas	5.7	5.7	4.1	--
3. Visibility down the road	5.4	4.2	2.7	.05
4. Visibility to the right	5.2	4.2	3.7	--
5. Visibility to the left	5.1	4.4	3.6	--
6. Visibility of signs	4.9	3.4	2.7	--
7. Visibility on right curves	5.7	4.8	3.3	.05
8. Visibility on left curves	5.7	5.3	3.2	.01
9. Visibility on hills	5.7	4.8	2.8	.01
10. Foreground illumination	6.2	5.3	3.9	.05
11. Beam distortion on sharp curves	5.1	5.1	3.7	--

*Rating Scale:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

TABLE 8

MEAN RATINGS* FOR MOPED HEADLAMPS ON HIGH BEAM:
NINE YOUNG SUBJECTS

QUESTIONS	LAMPS		
	5	6	7**
1. Overall - unlighted areas	5.4	5.8	--
2. Overall - lighted areas	5.2	5.4	--
3. Visibility down the road	5.8	6.1	--
4. Visibility to the right	5.2	5.3	--
5. Visibility to the left	4.9	5.4	--
6. Visibility of signs	5.3	5.8	--
7. Visibility on right curves	5.6	4.7	--
8. Visibility on left curves	5.3	5.3	--
9. Visibility on hills	5.2	5.3	--
10. Foreground illumination	5.0	4.7	--
11. Beam distortion on sharp curves	4.8	4.7	--

*Rating Scale:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

**Lamp 7 did not have a high beam.

on low beams and the Wilcoxon test on high beams (see Siegel, 1956). The Wilcoxon was also used to make individual comparisons on significant Friedman tests.

An inspection of Table 7 shows that the 6-watt Lamp 7 was always rated poorer than the other two, and Lamp 5 was generally rated better than Lamp 6. In six categories there are differences which are significant at least at the 0.05 level. In each case the differences between Lamps 5 and 7 are significant, and on questions 1, 8, and 9 the differences between Lamps 6 and 7 are as well. In no cases were the differences between Lamps 5 and 6 significant.

The moped high beam ratings reproduced in Table 8 indicate the beams were judged very similar on virtually every item. None of the differences shown are statistically significant ($p > 0.05$).

Few comments were received concerning the moped lamps. There were two negative remarks about Lamp 7 ("inadequate"). One person indicated they thought Lamp 6 was best. Another thought Lamp 6 would be O.K. on a slower bike. One person thought Lamp 5 was best of the three.

<u>Motorcycle</u>: Tables 9, 10, and 11 summarize the ratings obtained for the low beams under various route conditions. In general, Lamp 3 was rated best, Lamp 2 poorest. However, none of the differences noted are statistically significant ($p > 0.05$). To a large extent, the relatively poor mean ratings given to Lamp 1 are attributable to being severely downrated in several categories by one subject and virtually all categories by another. As a result, the means are about 10-15% lower than they would have been otherwise.

Tables 12, 13, and 14 summarize the ratings obtained for the high beams under various route conditions. These ratings are generally closer and much higher than for the low beams. As might be expected, the two most powerful units (Lamps 1 and 4) were generally rated best, and the least powerful (Lamp 2) rated poorest. However, none of the differences shown are statistically significant ($p > 0.05$).

There were a number of comments offered. In general these did not add significantly to the basic ratings. However, several persons complained about the sharp cut-off characteristics of Lamp 4, especially

TABLE 9

MEAN RATINGS* FOR MOTORCYCLE HEADLAMPS ON LOW BEAM ON A FREEWAY: TWELVE YOUNG SUBJECTS

QUESTIONS	LAMP			
	1	2	3	4
1. Overall	4.4	4.4	5.1	4.6
2. Visibility down the road	4.3	4.2	4.9	4.7
3. Visibility to the right	4.6	4.9	5.8	5.1
4. Visibility to the left	4.6	4.6	4.7	5.0
5. Visibility of overhead signs	4.2	4.0	4.7	4.0
6. Visibility of roadside signs	4.8	4.5	5.6	4.5
7. Visibility on right curves	4.8	4.7	5.6	4.8
8. Visibility on left curves	4.9	4.2	4.8	4.6
9. Foreground illumination	5.4	4.6	5.4	5.1

*Rating Scale:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

TABLE 10

MEAN RATINGS* FOR MOTORCYCLE HEADLAMPS ON LOW BEAM ON A DARK RURAL ROAD: TWELVE YOUNG SUBJECTS

QUESTIONS	LAMP			
	1	2	3	4
1. Overall	5.0	4.3	5.4	4.6
2. Visibility down the road	4.6	4.2	5.3	4.8
3. Visibility to the right	4.7	5.0	5.9	5.7
4. Visibility to the left	4.8	4.7	5.2	5.5
5. Visibility of signs	4.8	4.5	5.2	4.6
6. Visibility on right curves	5.2	4.8	5.4	5.2
7. Visibility on left curves	6.0	4.3	4.8	5.1
8. Visibility on hills	4.8	4.3	5.3	4.3
9. Beam distortion on sharp turns	5.7	4.5	4.6	4.5
10. Foreground illumination	5.0	4.3	5.8	5.4

*Rating Scale:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

TABLE 11

MEAN RATINGS* FOR MOTORCYCLE HEADLAMPS ON LOW BEAM ON A LIGHTED URBAN STREET: TWELVE YOUNG SUBJECTS

QUESTIONS	LAMP			
	1	2	3	4
1. Overall - lighted areas	5.2	5.2	5.4	5.6
2. Overall - unlighted areas	5.3	4.8	5.5	5.1
3. Visibility to the right	5.0	5.3	5.9	5.4
4. Visibility to the left	5.0	4.8	5.3	5.3
5. Visibility of signs	5.4	4.8	5.2	4.6
6. Visibility on right curves	5.4	4.8	5.5	5.3
7. Visibility on left curves	5.3	4.6	5.0	5.2
8. Visibility on hills	4.9	4.9	5.5	5.2
9. Beam distortion on sharp turns	5.8	4.7	5.0	4.3
10. Foreground illumination	4.9	4.4	5.4	5.3

*Rating Scale:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

TABLE 12

MEAN RATINGS* FOR MOTORCYCLE HEADLAMPS ON HIGH BEAM ON FREEWAY:
TWELVE YOUNG SUBJECTS

QUESTIONS	LAMP			
	1	2	3	4
1. Overall	6.0	5.5	5.5	5.9
2. Visibility down the road	5.8	5.9	5.8	6.3
3. Visibility to the right	5.8	5.8	6.2	6.5
4. Visibility to the left	5.9	5.3	5.7	6.2
5. Visibility of overhead signs	6.6	5.9	6.2	6.5
6. Visibility of roadside signs	6.5	5.8	6.3	6.5
7. Visibility on right curves	5.9	5.9	5.9	6.0
8. Visibility on left curves	5.8	5.3	5.3	5.9
9. Foreground illumination	5.8	5.0	5.7	6.1

*Rating Scale:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

TABLE 13

MEAN RATINGS* FOR MOTORCYCLE HEADLAMPS ON HIGH BEAM ON A DARK RURAL ROAD: TWELVE YOUNG SUBJECTS

QUESTIONS	LAMP			
	1	2	3	4
1. Overall	6.3	5.8	5.8	6.3
2. Visibility down the road	6.0	5.9	5.9	6.2
3. Visibility to the right	6.0	6.1	6.0	6.3
4. Visibility to the left	6.0	5.7	5.5	6.1
5. Visibility of signs	6.6	6.2	6.1	6.3
6. Visibility on right curves	6.3	6.1	6.0	5.9
7. Visibility on left curves	6.2	5.4	5.5	5.9
8. Visibility on hills	6.0	5.4	6.0	5.6
9. Beam distortion on sharp turns	5.8	5.3	5.1	5.1
10. Foreground illumination	5.9	5.2	5.6	6.1

*Rating Scale:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

TABLE 14

MEAN RATINGS* FOR MOTORCYCLE HEADLAMPS ON HIGH BEAM ON A LIGHTED URBAN STREET: TWELVE YOUNG SUBJECTS

QUESTIONS	LAMP			
	1	2	3	4
1. Overall - lighted areas	6.0	5.3	5.7	5.8
2. Overall - unlighted areas	6.5	5.8	6.0	6.2
3. Visibility to the right	5.8	5.8	5.8	6.2
4. Visibility to the left	5.8	5.5	5.3	6.1
5. Visibility of signs	6.3	6.1	5.8	6.4
6. Visibility on right curves	6.3	5.8	5.5	6.2
7. Visibility on left curves	6.2	5.4	5.4	6.1
8. Visibility on hills	6.0	5.8	5.8	5.8
9. Beam distortion on sharp turns	6.0	5.4	5.0	5.1
10. Foreground illumination	5.8	5.1	5.7	6.0

*Rating Scale:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

when negotiating hills and trying to read signs. A number of riders noted that the two asymmetrical units (Lamps 2 and 3) were relatively weak to the left side on low beam. Four subjects noted Lamp 2 had a dark area a short distance in front of the bike. Two persons noted the center depression on Lamp 1, which they described as a "dark spot" in the middle of the lane.

Discussion: The results of this phase of the evaluation provided few statistically significant differences. Indeed, the only significant differences involved lamps on the moped, where there were relatively large discrepancies in intensity.

The motorcyclists appeared to like the more powerful high beam units (Lamps 1 and 4), which is to be expected. Some of them objected to the European-type low-beam configuration on Lamps 1 and 4. One of the surprises of this test was the fact that Lamp 1, which was selected because of the number of favorable mentions it received in the MSF survey, did not receive especially high ratings on low beam. As noted earlier, this was partly due to two subjects who gave the unit very low ratings. But, even discounting this bias, the ratings given Lamp 1 were about the same as those for Lamps 3 and 4 and only slightly better than Lamp 2. (The differences are still not statistically significant.) This may have come about because all four lamps are relatively powerful, compared to the population of motorcycle headlamps in general, and compared to what many of the subjects were used to.

Lamp 1 on low beam seemed to generate strong opinions, being bottom-rated by some subjects and top-rated by others. The beam pattern provided by this lamp is a fairly radical departure from other lamps, whether motorcycle or automotive. It most closely resembles the old-style symmetrical European pattern. Because it is so different, it may take some getting used to. This possibility is supported by the fact that the two persons who gave Lamp 1 the lowest ratings had no previous experience with European sharp-cutoff type lamps.

Objective Evaluation of Motorcycle and Moped Headlamps

Introduction: In this phase of the investigation, candidate low-beam headlighting systems were evaluated objectively, i.e, by measuring the visibility distance they provided.

The intent was to measure visibility distances under conditions which were as realistic as possible, consistent with the need to maintain adequate controls so that a meaningful analysis could be conducted. To do this, the test was carried out on public roads, the "targets" were objects which would appear normal to that environment, and the subjects were operating under instructions which alerted them to look for certain conditions but kept them uncertain as to what would occur and when.

Objective headlighting evaluations have typically been carried out under rather artificial conditions (e.g., private roads, specific targets, subjects with full knowledge of the test). There are many advantages to collecting data that way, and although the resultant "visibility distances" would be long, relative to what could be expected under normal operating conditions, it seems reasonable to assume that lamps which perform better under these conditions would also perform better in the real world.

This assumption was called into question by the results of a recent study (Graf and Krebs, 1976), that used an eye-fixation criterion and unalerted drivers. Graf and Krebs' results suggested that detection distance in the real world is unrelated to beam intensity. No attempt has been made to replicate this study, but the results have been partially responsible for procedural and criterion modifications in at least two recent headlighting studies (i.e., Helander et al., 1979, who used vehicle control measures, and Halstead-Nussloch et al., 1979, who used realistic targets on public roads and "semi alerted" subjects).

For the evaluation planned in this study, measures related to forward visibility seemed most appropriate, other concerns having been addressed in the subjective study. The procedure elected was based on that used by Halstead-Nussloch et al., with some modifications.

The reason for using such a non-traditional procedure is to reduce, if not eliminate the possibility of a beam-by-task interaction, and to obtain more realistic estimates of real-world visibility distances. There are a number of problems with the method which combine to increase error variance, necessitating an increase in the number of subjects required to establish a given level of confidence. The time required for each data point collected is also considerably greater than for more traditional methods. Because of these considerations, this study was limited to straight, flat road, no-glare conditions. Hills and curves, as well as meeting situations involving disability glare were covered in the computer evaluations to be described later.

Motorcycle Headlamps:

Independent Variables:

Headlamps: Because of the difficulties involved in data collection in this study, it was felt necessary to test no more than three lamps. These were:

Lamp 1 was the same as Lamp 1 in the subjective study. It was selected because it represents a new and promising approach to headlamp design, and because such lamps are being widely used on newer motorcycles. Its photometrics are described in Figure 5.

Lamp 2 was the same as Lamp 2 in the subjective study. It was selected because it is a popular type of motorcycle headlamp, and the fact that it was tested by Sturgis (1975) provides a link between the two studies. Its photometrics are described in Figure 7.

Lamp 3 was a 178 mm (7-inch) round all-glass sealed beam unit having a halogen source and designed to meet FMVSS 108 (U.S.) standards. Its photometric characteristics are described in Figure 18. It will be noted that it is similar to lamp 3 in the subjective study (Figure 9), although somewhat lower in intensity, in the lower right quadrant, and higher in intensity in the upper left (glare) quadrant.

Halogen automotive lamps of this type may prove popular with motorcyclists because they provide relatively high intensity with low power consumption (35 watts on both high and low beams).

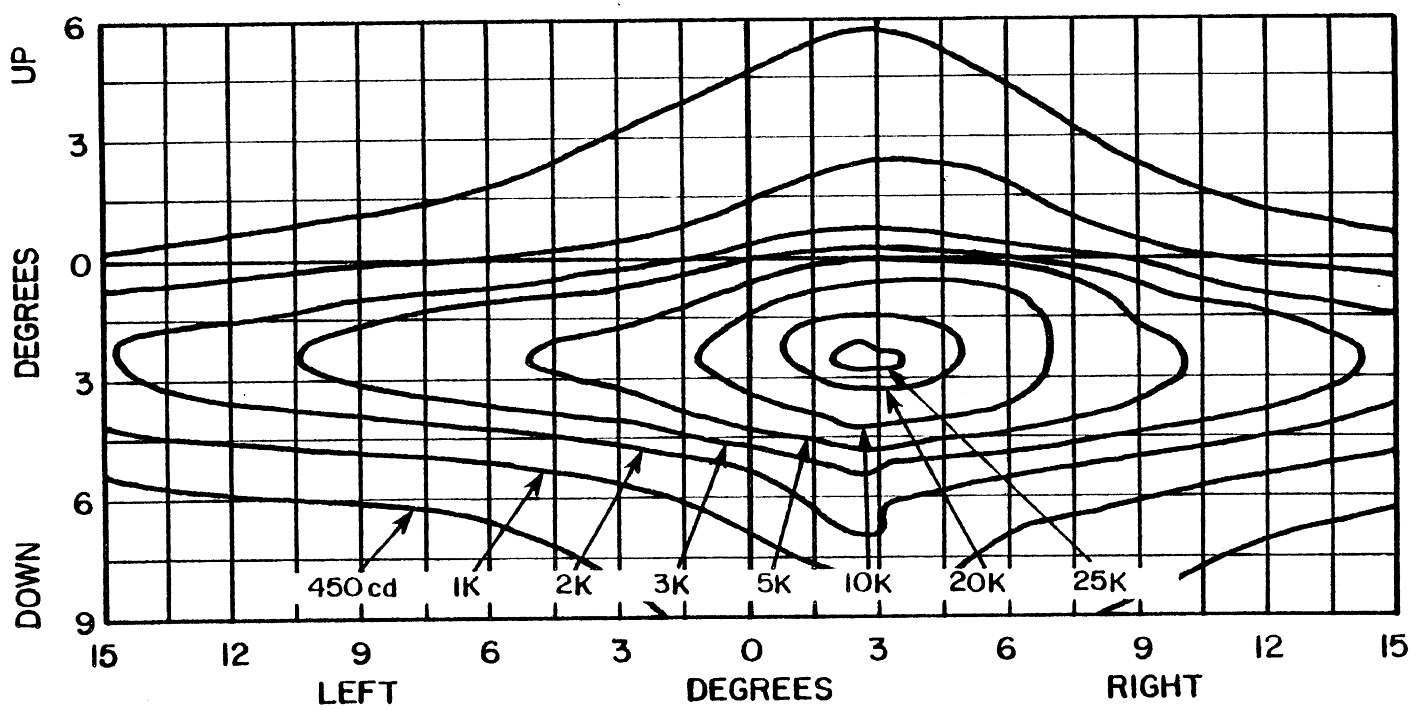

Figure 18. Isocandela diagram of Lamp 3 in objective study. Figures shown are candelas (cd).

The order in which the headlamps were used was varied systematically to balance order effects.

Targets: Three clases of targets were used. These were:

1. Parked car. The parked car was always the same vehicle, a 1969 Plymouth station wagon. It was parked on the shoulder of the road as shown in Figure 19. All lights were extinguished while the car was visible to the subject, and the driver ducked down so the vehicle appeared unoccupied.

The car was detected by the subject based on the reflectors built into the rear lamp lenses on each side, and the reflectorized treatment (beads-on-paint) used on the license plate numerals and border. It was much the easiest of the targets for the subjects to detect.

2. Roadway debris. The debris consisted of slabs of foam rubber, measuring about 15 cm (6 inches) thick, 20 cm (8 inches) wide and 90 cm (36 inches) long, laid on the road as shown in Figure 20. From subject 10 on (total of 12 subjects) debris was also introduced on the left side of the bike, as shown in Figure 21. The material was yellow in color.

Originally it was intended to use actual items of junk that might typically be found on or near a road. To this end, an old muffler, tire tread, and tree branch were collected. All were dark in color and about the same size. However, during the pilot phase these proved so hard to detect that the experimenters became concerned that the subject might impact one or be startled and make an evasive maneuver which could result in loss of control. The foam rubber debris targets looked solid from a distance, but were much more visible and thus less likely to provoke a severe evasive maneuver. Further, they would cause no problems for the subject if they were contacted.

3. Pedestrians. Research assistants served as the "pedestrian" targets. They were attired entirely in blue denim or other dark clothing, along with dark shoes and socks. They stood stationary next to the edge of the road, as shown in Figure 22, left shoulder toward the approaching bike, as though waiting to cross the road.

Figure 19. Parked car target.

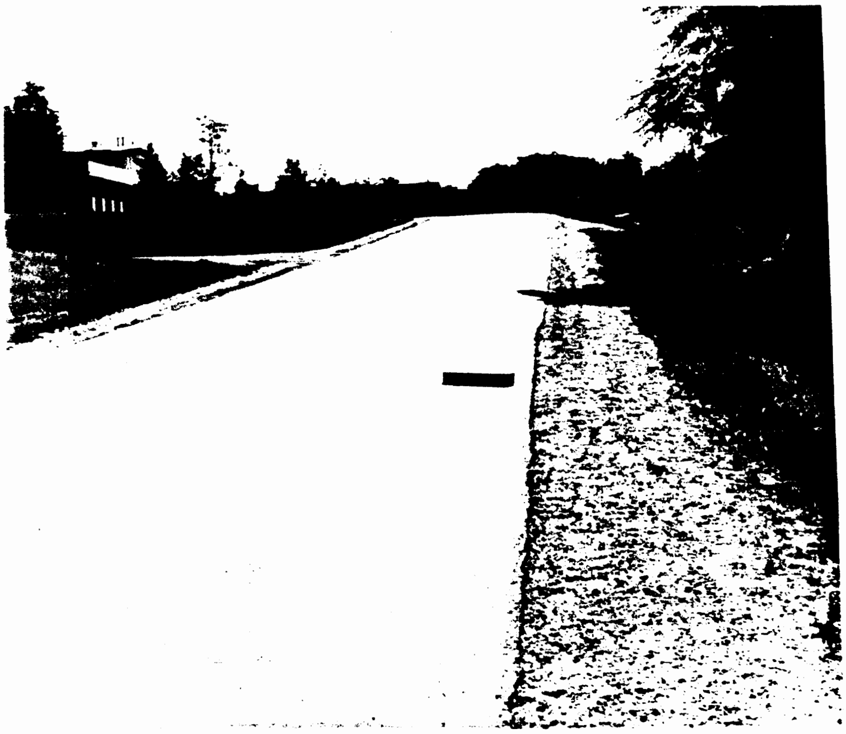

Figure 20. Roadway debris on right.

Figure 21. Roadway debris on left.

Figure 22. Dark pedestrian target.

Two reflectivity levels were employed. The "dark" pedestrian was as described above and shown in Figure 22. A "light" pedestrian was created by wearing a hip-length gray lab coat, as shown in Figure 23.

Initially, the intent was to use dark pedestrians only, and have them stand about one meter away from the edge of the road. However, these were responded to only about half the time by the pilot subjects. To improve the response rate, the pedestrians were asked to move to the road edge. Since the response distances were still very short, the "light" pedestrian was introduced as a second level.

After nine subjects, a further modification was made. The "dark" pedestrian was dropped entirely in favor of introducing additional road debris to the left of the motorcycle.

To summarize, the first nine subjects encountered, twice with each headlamp, the following targets:

Parked car

Roadway debris on right

Dark pedestrian

Light pedestrian

Subjects 10 through 21 encountered the same array, except roadway debris on the left was substituted for the dark pedestrian.

The following is a summary of the targets used and the number of subjects exposed to each:

Parked car	21
Roadway debris on right	21
Roadway debris on left	12
Dark pedestrian	9
Light pedestrian	21

Test Vehicle and Instrumentation: The same motorcycle, headlamp mounting and voltage regulating equipment that was used in the subjective study was used here as well.

Figure 23. Light pedestrian target.

To obtain the required data, three items of information were necessary:

1. Distance traveled by the bike.

2. An indication of the subject's identification point.

3. A means of determining when the subject passed the target.

Distance was measured with the aid of a magnetic sensor attached to the bike frame. This was triggered by two metal plates attached 180° apart on the wheel. A close-up picture of this arrangement is shown in Figure 24. Figure 25 is a photograph of the motorcycle with all equipment in place.

The output of the wheel sensor was transmitted to a pursuit vehicle and recorded on a digital counter. The recording system was calibrated to read out the appropriate distance units directly. This calibration was checked each evening.

The subjects were instructed to press a button located near the left handgrip when they detected a "potential hazard." This marked the identification point and started the counter in the pursuit vehicle. The counter was put in a "hold" mode by an experimenter in the pursuit vehicle when the motorcycle passed the target. After writing down the total, the experimenter reset the counter.

Subjects: The subjects were experienced, licensed motorcyclists who claimed to have had experience with bikes at least as large as the test motorcycle. They were recruited by means of advertisements in newspapers, fliers distributed in various places around campus, and by past subjects telling their friends about the study.

Dependent Variable: The dependent variable was the distance measured from the subject's button press until he/she passed the target.

It is common to refer to results of headlighting studies such as this one as "detection distances." This is not quite right, since the nature of the subjects' task is such that they have gone through a process of detection-identification-decision-response to produce the data. In the most typical type of study, with simple, uniform targets

Figure 24. Wheel rotation sensor.

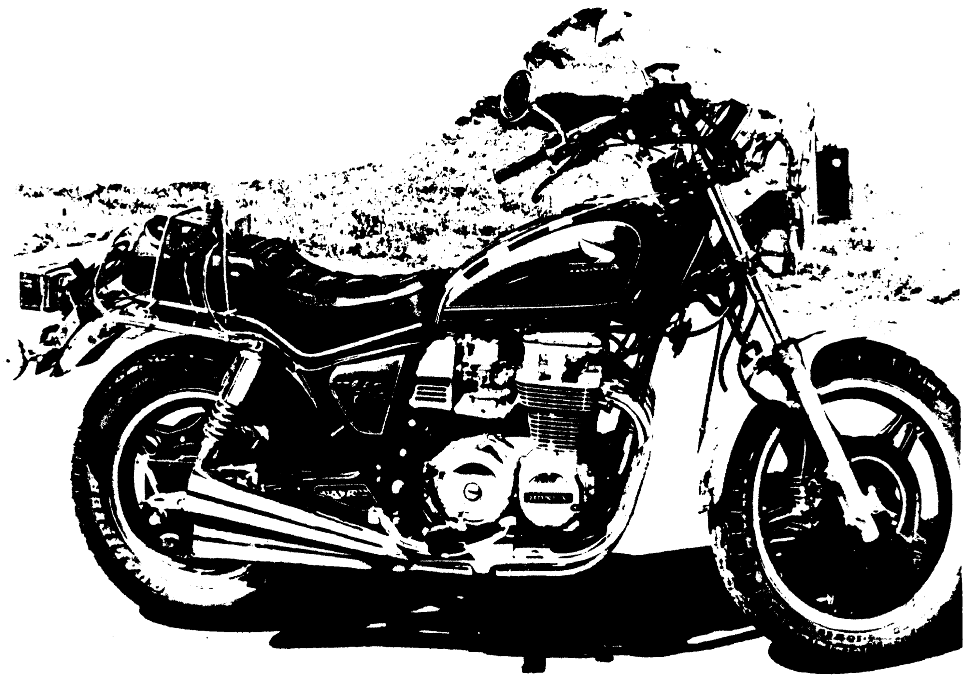

Figure 25. Photograph of motorcycle equipped for test.

and a straightforward button-pressing response, the identification and decision steps are minimized. Some studies have required the subject to tell something about the target (e.g., whether it is oriented right or left), which introduces a fairly simple identification-decision process.

In the present study the decision-response steps were elementary. However, the detection-identification process was quite complex and, except for the alertness of the subject, approximated real-world conditions, at least initially. During each subjects' participation he/she probably came to realize that the targets of interest were drawn from a limited population and deliberately placed in the roadway environment by the experimenter. A considerable uncertainty as to what target was next and where it would occur was always present.

The data resulting from this study will be referred to as "response distances." It is expected that these measures would be much shorter than commonly reported for similar targets and test conditions, but still longer than would be expected in the real world.

Procedure: The study was run on secondary roads north of the city of Ann Arbor. All were good quality, two-lane asphalt, selected because they were dark and lightly traveled.

Figure 26 is a map of the route, showing target positions. The subject started at the point labeled "start" and followed the path indicated by arrows to the point labeled "end." He/she then turned around and retraced the route back to the start point. Total distance was about 64 km (40 miles). The test was run in six sections, three out and three in. The headlamp was changed after every second section. At the start of each section, the subject was provided a verbal description of the next portion of the route.

Besides the test motorcycle and subject, three cars and six persons were required to run the test. Two persons were in the pursuit car referred to earlier. One drove, trying to maintain a spacing of about 30 meters (100 feet) behind the motorcycle. The other person was responsible for data collection, subject instruction, and general operation of the study.

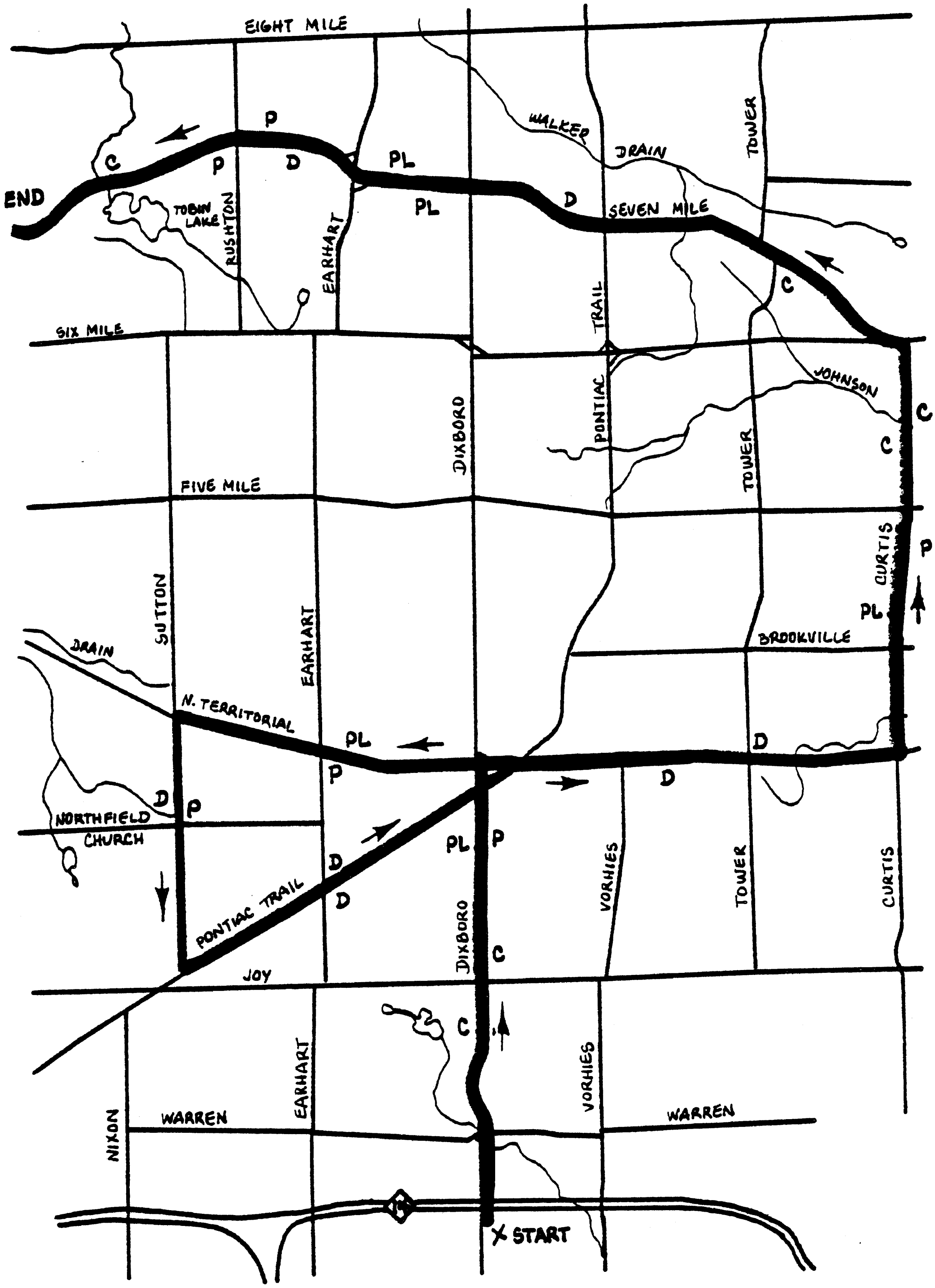

Figure 26. Map of motorcycle test route.
Target code: P = dark pedestrian, PL = light pedestrian,
C = car, D = debris

The pursuit car was equipped with European-type low-beam headlamps, which were deliberately aimed about two degrees down. Thus, its headlamps provided neither assistance in seeing nor significant glare for the subject.

One person was assigned to operate each of the other two cars in the study. The Plymouth station wagon served as a parked car target once in each section. In addition it was used to drop off and retrieve pedestrian and debris targets.

The other car's primary function was to drop off and retrieve pedestrian and debris targets. In addition, its driver served as a pedestrian target or placed a debris target once each section. At these times the car was parked out of the subject's sight.

The other two persons in the test served as pedestrian targets or placed debris. In the latter case they waited until the motorcycle was the next vehicle to pass, placed the debris and moved out of sight, and then retrieved the debris as soon as the pursuit vehicle passed.

The course was arranged so that the first and last target positions in each section contained a car. The car might appear as a target or be hidden from the subject's view. As soon as the motorcycle and pursuit car passed, the first car would move off, collect the two pedestrian/debris targets and transport them to the proper positions in the next section. The motorcyclist stopped at the end of each section for instructions on the next section. This pause allowed the next targets to be placed.

The subjects were scheduled for a practice ride on the day of the test. They reported to the Institute, signed the consent form, and were shown the location and operation of the basic controls on the bike. They then took a short (about one-half hour) familiarization ride. They reported to the Institute again at the assigned time that evening for the data run. At that time they were met by the experimenter with the motorcycle and pursuit car. The other two cars and four persons were located out of the subject's sight. The subject then proceeded to the start point, and the instructions were read while the first targets were set.

The instructions (see Appendix C) were intended to create an impression that the concern of the study was with common roadway hazards such as potholes, debris, animals, parked cars, and pedestrians. When the rider saw something of this type he/she was told to press a button located near the left handgrip.

When all questions had been answered the experimenter described the first section of the route and the test began.

Two-way radios were used to maintain contact between the experimenter and all others involved in the study. Thus, the experimenter was advised when targets were in position and he, in turn, broadcast an announcement each time a target was passed or a key landmark was reached.

At the end of the first section the motorcycle and pursuit car stopped. The next section of the route was described by the experimenter and any problems were discussed. At the same time the lamp and the subject's face shield were cleaned. In the meantime the driver of the pursuit car monitored the radio to check for target readiness.

Most subjects produced relatively few false alarms (i.e., responding to conditions other than those associated with the test). However, some subjects interpreted the instructions rather broadly, and responded to things such as bumps in the road and oncoming traffic. When this happened, the problem was discussed with the subject at the end of the first section. The usual solution was to tell the subject that, for purposes of this test, "potential hazards" did not include certain conditions to which he/she was responding.

A great effort was made to establish target positions which were as uniform as possible. That is, all were straight-flat road sections and the targets and their backgrounds were judged uniform by the experimenter in the pre-test phase.

However, working on public roads presented problems in relative target visibility. For example, where straight and flat sections were fairly short (i.e., 300 to 600 meters), as they tended to be in one section of the route, there would typically be retroreflective road signs in the target background, which would not be the case in other sections. This "visual noise" could have had an effect on target detection-identification. One section of road had virtually no shoulder area, which made it difficult to position the parked car target.

A tabulation was made of response distances at each target position throughout the course. These are summarized in Table 15. Clearly, there are differences in the response distances for the same target at different positions throughout the course. In general, the first time a target appeared yielded relatively short response distances. This was expected. However, this "adaptation" phenomenon aside, there are still position differences that are quite large in some cases. In the case of the number 3 car position, it is felt the problem is associated with shrubbery that partially obscured the right-side reflex reflector. In other cases the causes are less clear.

TABLE 15

RESPONSE DISTANCES FOR THE SAME TARGET AT DIFFERENT POSITIONS IN THE TEST COURSE: MOTORCYCLE TEST

Target Type	Mean Response Distances in Meters (feet)					
	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Car	124 (408)	199 (654)	62 (205)	140 (458)	179 (588)	197 (647)
Debris on Right	44 (145)	46 (152)	62 (213)	68 (233)	48 (156)	44 (143)
Debris on Left	34 (8110)	57 (188)	73 (239)	58 (189)	34 (111)	44 (143)
Dark Pedestrian	20 (66)	29 (94)	24 (80)	31 (102)	9 (28)	27 (87)
Light Pedestrian	35 (115)	47 (155)	62 (203)	57 (186)	74 (243)	60 (196)

Moped Headlamps:

Independent Variables:

Headlamps: Three headlamps were tested in this study. They will be identified as Lamp 4, 5, and 6. They were the same as lamps 5, 6, and 7 in the subjective study, and their low beam photometrics are described in Figures 13, 15, and 17. The order in which these lamps were presented to the subjects was varied systematically to balance sequence effects.

Targets: The original intent was to use the same targets as the motorcycle study. However, it was not possible to use the parked car, because about three-quarters of the route was curbed, and on-street parking was prohibited. Finally, two classes of targets were used, with two levels of each.

1. Roadway debris. The debris was the same as in the motorcycle study in terms of composition and placement (to the rider's right and left, as shown in Figures 20 and 21).

2. Pedestrians. A "dark" and "light" pedestrian was used. The dark pedestrian was the same as that described in the motorcycle study and shown in Figure 22. The light pedestrian wore a white, knee-length lab coat as shown in Figure 27, rather then the hip-length gray coat used in the motorcycle study. The pedestrians stood at the edge of the pavement, next to the curb.

Test vehicle and instrumentation: The same moped that was used in the subjective study was used here as well. The instrumentation package described in the motorcycle section was adapted to the moped. Figure 28 shows the moped with instrumentation in place.

The pursuit vehicle and general operating procedures were the same as those used in the motorcycle study.

Subjects: It proved difficult to recruit experienced moped riders for this study. The same techniques described earlier for securing motorcycle subjects were used here, but yielded only two persons who rode mopeds regularly, and three others who claimed to have had some experience. The rest of the 18 subjects were experienced with

Figure 27. Light pedestrian target as used in Moped study.

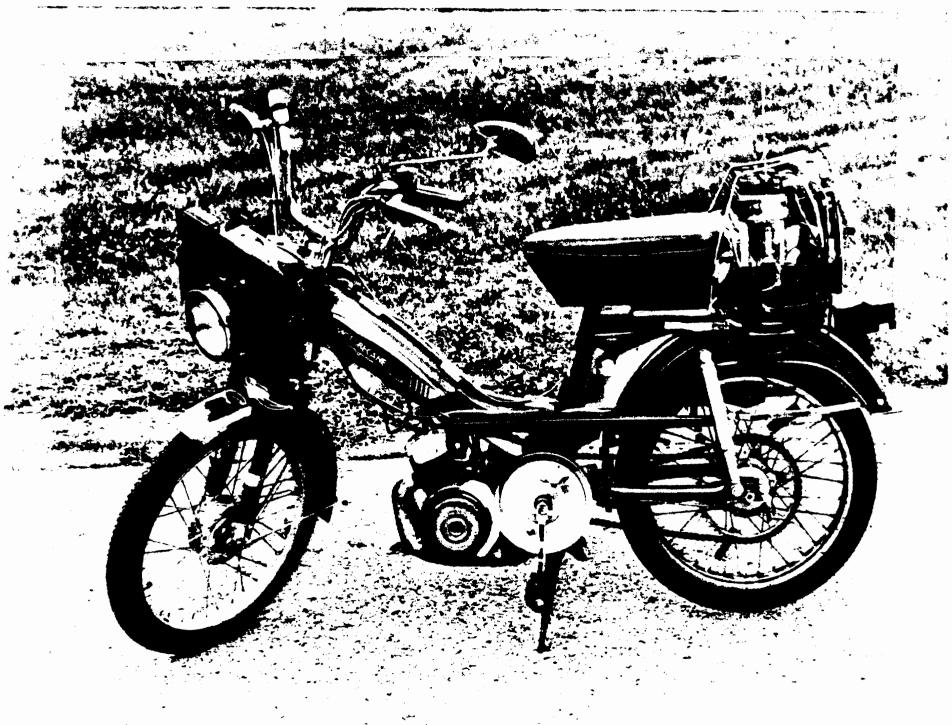

Figure 28. Photograph of moped equipped for test.

either bicycles or small motorcycles. All were given a familiarization ride of 15-30 minutes.

Dependent Variable: As in the motorcycle study, the dependent variable was the distance measured from the subject's button press until he/she passed the target.

Procedure: The route for this test covered sections of four streets on the east side of the city of Ann Arbor. Except for one section about one-half mile in length, the route lacked fixed illumination. (No targets were placed in the area with fixed illumination.) It was paved in asphalt, was about half two- and half four-lanes wide, had a 56 km/hr (35 mph) speed limit and was relatively lightly traveled. The route was about 10 km (six miles) long and was traversed three times by each subject, once with each lamp. A map, showing various target positions, is provided in Figure 29.

Besides the test moped and subject, one car and six persons were required to run the test. As in the motorcycle test, two persons were in the pursuit car. Their roles were the same as described earlier for the motorcycle test, except the driver tried to maintain a spacing of about 15 meters (50 feet) behind the moped.

The course was divided into four sections, A through D. One experimental assistant was assigned to care for targets in each section. Course sections A, B, and D each had four target positions, and section C had five. These are indicated in Figure 29 as A1, A2, etc. On the outbound leg of the course the subject passed four targets, one in each section. He/she passed another four, again one in each section, on the return leg of the course. This made a total of eight targets, two of each of the types described earlier, for each lamp and each subject. On each subsequent run the same general strategy was followed, except the target positions and targets used at each position were changed. No one target position was used more then twice, with each subject, and never with the same target.

The general procedure, problems, etc. in this study were virtually identical to those in the motorcycle study, except it was not necessary

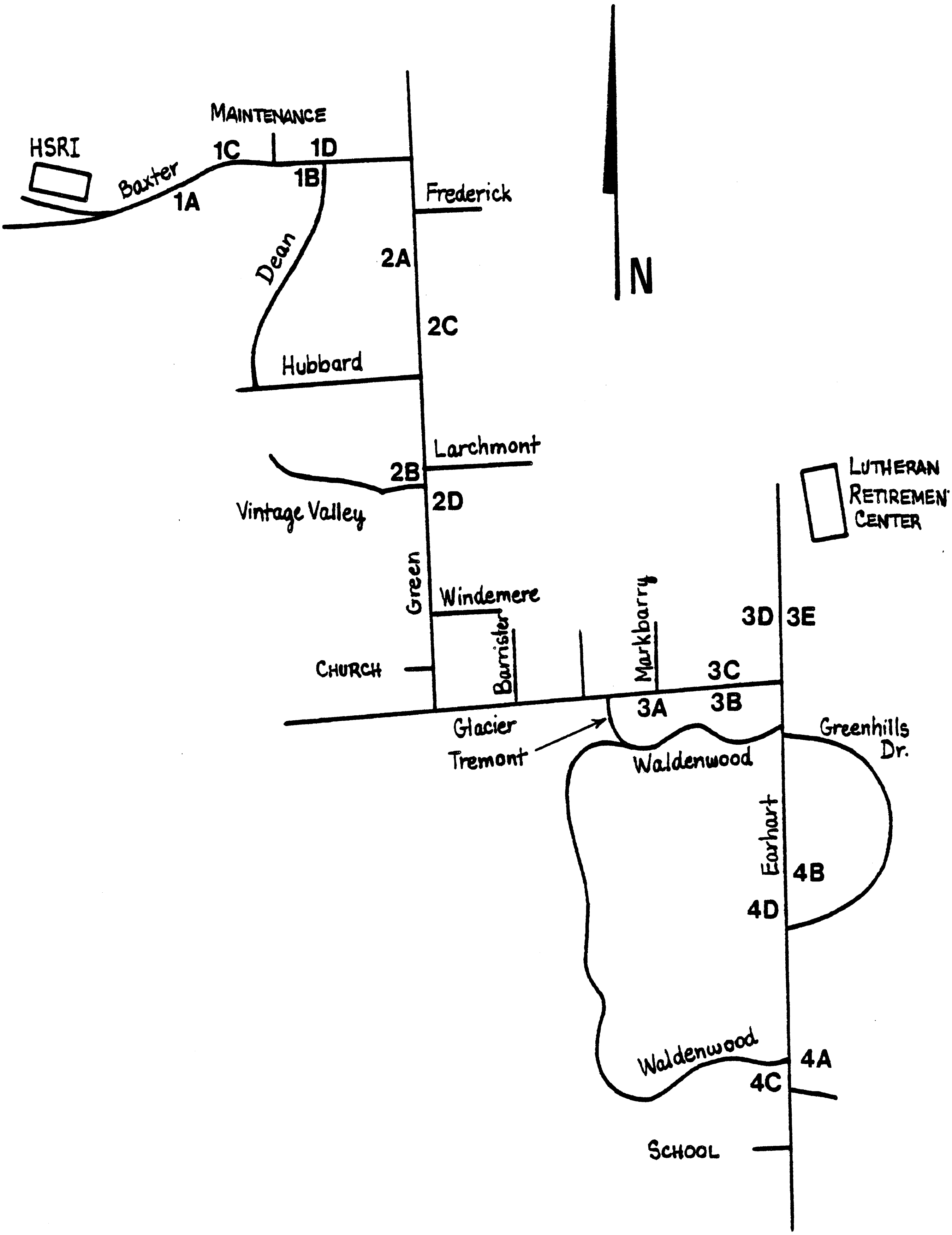

Figure 29. Map of moped course, showing target positions.

to transport the test personnel and targets from site to site because the distances were so much shorter. They simply walked.

The instructions to the moped subjects are reproduced in Appendix C.

Initial target positions were selected with care, and many were subsequently modified during pilot testing to achieve the greatest uniformity possible. Table 16 shows the mean response distances for each individual target used in the study. In general, the variability appears less than in the case of the motorcycle study (see Table 15). However, for each of the four categories, the mean response distance for the most visible condition was about double that of the least visible. As noted earlier, the reasons for these differences are many and are not always obvious.

TABLE 16

RESPONSE DISTANCES FOR THE SAME TARGET AT DIFFERENT POSITIONS IN THE TEST COURSE: MOPED TEST

Target Type	Mean Response Distances in Meters (feet)					
	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Dark Pedestrian	24 (78)	27 (90)	19 (62)	33 (108)	34 (110)	28 (93)
Light Pedestrian	45 (149)	40 (131)	52 (171)	45 (147)	30 (99)	42 (138)
Debris on Right	25 (81)	30 (99)	34 (113)	23 (75)	42 (138)	34 (112)
Debris on Left	23 (74)	22 (72)	41 (134)	35 (116)	46 (150)	27 (90)

Results - Motorcycle: Table 17 lists the mean response distances associated with the three lamps and five types of targets used in the test. The differences between lamps for any particular type of target are typically small. None of the between-lamp differences are significant ($p > 0.05$), as determined by the Friedman test (Siegel, 1956).

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TABLE 17

RESPONSE DISTANCES FOR VARIOUS HEADLAMPS AND TARGETS IN MOTORCYCLE TEST

Target Type	Mean Response Distance in Meters (feet)		
	Lamp 1	Lamp 2	Lamp 3
Car	153 (502)	144 (472)	150 (493)
Dark Pedestrian	21 (68)	25 (82)	23 (74)
Light Pedestrian	55 (181)	55 (179)	59 (192)
Debris on Right	49 (162)	54 (176)	54 (178)
Debris on Left	55 (182)	41 (135)	56 (185)

<u>Results - Moped</u>: Table 18 lists the mean response distances associated with the three lamps and four types of target used in the test. The differences between lamps tend to be much larger than in the case of the motorcycle. Indeed, the differences are significant $p < 0.01$) for all targets, based on the Friedman test. Differences between lamps 5 and 6 are significant ($p < 0.02$) for the light pedestrian and debris-on-right targets. Differences between lamps 4 and 5 are significant ($p < 0.02$) only for the debris-on-left target. (In all cases the Friedman test was used, which is an ANOVA by ranks. This accounts for the apparent inconsistency in which the smaller response distance differences between lamps 4 and 5 was significant [debris-on-left target], and the larger difference [debris-on-right target] was not.)

TABLE 18

RESPONSE DISTANCES FOR VARIOUS HEADLAMPS
AND TARGETS IN MOPED STUDY

Target Type	Mean Response Distances in Meters (feet)		
	Lamp 4	Lamp 5	Lamp 6
Dark Pedestrian	31 (101)	30 (100)	22 (72)
Light Pedestrian	55 (181)	45 (149)	29 (96)
Debris on Right	42 (139)	30 (98)	20 (66)
Debris on Left	42 (138)	33 (107)	22 (72)

A comparison of Tables 17 and 18 seems to indicate that the pedestrian targets were seen as well or better with the moped headlamps than with the motorcycle headlamps. It will be recalled that the pedestrian target in the moped study stood in the road, while in the motorcycle study he/she stood on the shoulder, next to the road. This difference in position, combined with the fact that the streets on which the moped was operated were generally narrower than those on which the motorcycle was operated, resulted in the pedestrian being much closer to the path of the moped, hence easier to see.

Discussion:

Motorcycle headlamps: The results of this study failed to find significant differences between the three lamps tested. Given that all three lamps were relatively powerful, this is not surprising. As will be noted in the next section, differences between the lamps for these targets are predicted to be fairly small, based on the computer analysis.

The mean response distances to all targets except the dark pedestrian are adequate to permit safe stopping/maneuvering distance at almost all legal speeds. However, there was a great deal of variability, and response distances of less than 30 meters were occasionally noted for both debris and the light pedestrian targets. At higher speeds these distances are short enough to cause problems.

The difficulties the subjects had with the dark pedestrian were a sobering indication of just how hard it is to detect and identify low-contrast objects with headlamps. Although the pedestrian stood only about 1.5-2 meters off the path of the motorcycle (two to three steps) the subjects failed to respond prior to passing about ten percent of the time. Even the mean response distances were about one-second of travel at 55 mph.

Moped headlamps: The results of this study indicate that successful moped headlamps are possible at about 20 watts. Both of the more powerful lamps tested (Lamps 4 and 5) provided mean response distances to all targets which were more than adequate for a vehicle whose top operating speed is 25 to 30 mph. Some short distances (i.e., 10 meters or less) were recorded to all targets, but these occurred less than ten percent of the time for the two better lamps, even with the dark pedestrian target.

In short, it appears as though reasonable moped headlamps can be achieved with minor modifications to existing standards.

Computer Seeing Distance Analysis

The objective study described in the preceding section was designed to provide estimates of response distances to various targets under realistic riding conditions.

Because of the difficulties involved in collecting such data, the range of conditions considered was very limited. Of particular concern is the lack of data on glare and different road geometrics. Performance on curves is especially important because of the beam distortion associated with bank angle.

Estimates of beam performance under these conditions was obtained using a computer seeing-distance model (Mortimer and Becker, 1973). The model allows the following parameters to be set:

Headlamps

- Beam characteristics
- Intensity
- Number
- Position (height, lateral spacing)
- Aim (horizontal, vertical, rotation)

Road

- Flat-straight
- Hills and curves

Target characteristics

- Position (vertical and horizontal)
- Reflectivity

Driver eye position

An "approaching" vehicle is included in the simulation. The headlamps on this vehicle can be specified as fully as on the primary vehicle, and they need not be the same. The lateral spacing between the tracks of the two vehicles can be varied, as can the longitudinal separation at the start and end of the simulated run.

The model outputs a variety of data, the most important of which for purposes of this study are:

(1) Target detection distances at various points during and after the meet.

(2) Maximum and minimum detection distances.

The model was developed and validated based on closed-course seeing distance tests (see Mortimer and Olson, 1974a, 1974b). Thus, the predictions which it yields would be expected to be substantially greater than would be measured under the conditions of the field test described earlier.

As a first step, the model was run to allow comparisons between actual and predicted distances for three targets (dark pedestrian, left and right debris) for each of the three motorcycle lamps (lamps 1, 2, and 3, as described in Figures 5, 7, and 18, respectively). Car simulations are also included, to provide a frame of reference. The car was assumed to be equipped with two 6014 units as described in Figure 9. These data are summarized in Table 19.

TABLE 19

COMPARISON OF PREDICTED AND MEASURED RESPONSE DISTANCES (in feet) FOR MOTORCYCLE HEADLAMPS

Target	Condition	Lamps			Car
		1	2	3	
Dark Pedestrian	Predicted	158	142	161	166
	Measured	68	82	74	
	P/M*	2.3	1.7	2.2	
Right Debris	Predicted	328	328	348	365
	Measured	162	176	178	
	P/M*	2.0	1.9	2.0	
Left Debris	Predicted	324	322	339	309
	Measured	182	135	185	
	P/M*	1.8	2.4	1.8	

* Ratio of predicted to measured.

Three significant points should be noted from Table 19. First, the predicted response distances are much longer (about double, on the average) than the measured response distances. Second, the car provides greater visibility for the two right-side targets, and slightly less for the left-side target. Third, and most important, the model seems to be doing an acceptable job of simulating the various lamps and targets, as indicated by the fact that the ratio of predicted to measured response distances (P/M) vary only from 1.7 to 2.4. This suggests that the results of the rest of the simulation can be interpreted with some confidence.

Table 19 suggests that the difference between car and motorcycle headlighting is small, considering that the car has two relatively powerful units. One advantage the motorcycle does have is greater mounting height. The road-surface to headlamp-center distance for the test motorcycle was 39 inches, and that value was used in the simulations as well. The car headlamp mounting height was assumed to be 24 inches. Had the car headlamps been mounted at 39 inches it would have improved response distances by about 10%, to 180, 401, and 340 feet for the pedestrian, right and left debris targets respectively.

Federal Motor Vehicle Safety Standard 108 permits headlamp mounting heights between 24 and 54 inches, measured from the road surface to the lamp center. Most cars have tended toward the minimum, and, as cars grow smaller in the future this trend will continue. Thus the 24 inch height selected for this study seemed reasonable.

<u>Straight-Flat</u>: Figures 30 through 33 show the predicted response distances to each target for each lamp through a meet with a car equipped with the same lamps as the car in Table 19 on a straight-flat two-lane road. The minimum (maximum disability glare) and maximum (no-glare) response distances are shown in the upper right-hand corner of each plot. The maximum value corresponds to the "predicted" values in Table 19.

An inspection of Figures 30 through 32 reveals that Lamp 1 provides better performance under maximum glare conditions for all targets, despite the fact that the no-glare response distances associated with it are never more than second best. These data are summarized in Table 20. The ratio of no-glare to maximum-glare response distance for Lamp 1 is lowest of the three lamps for all types of target.

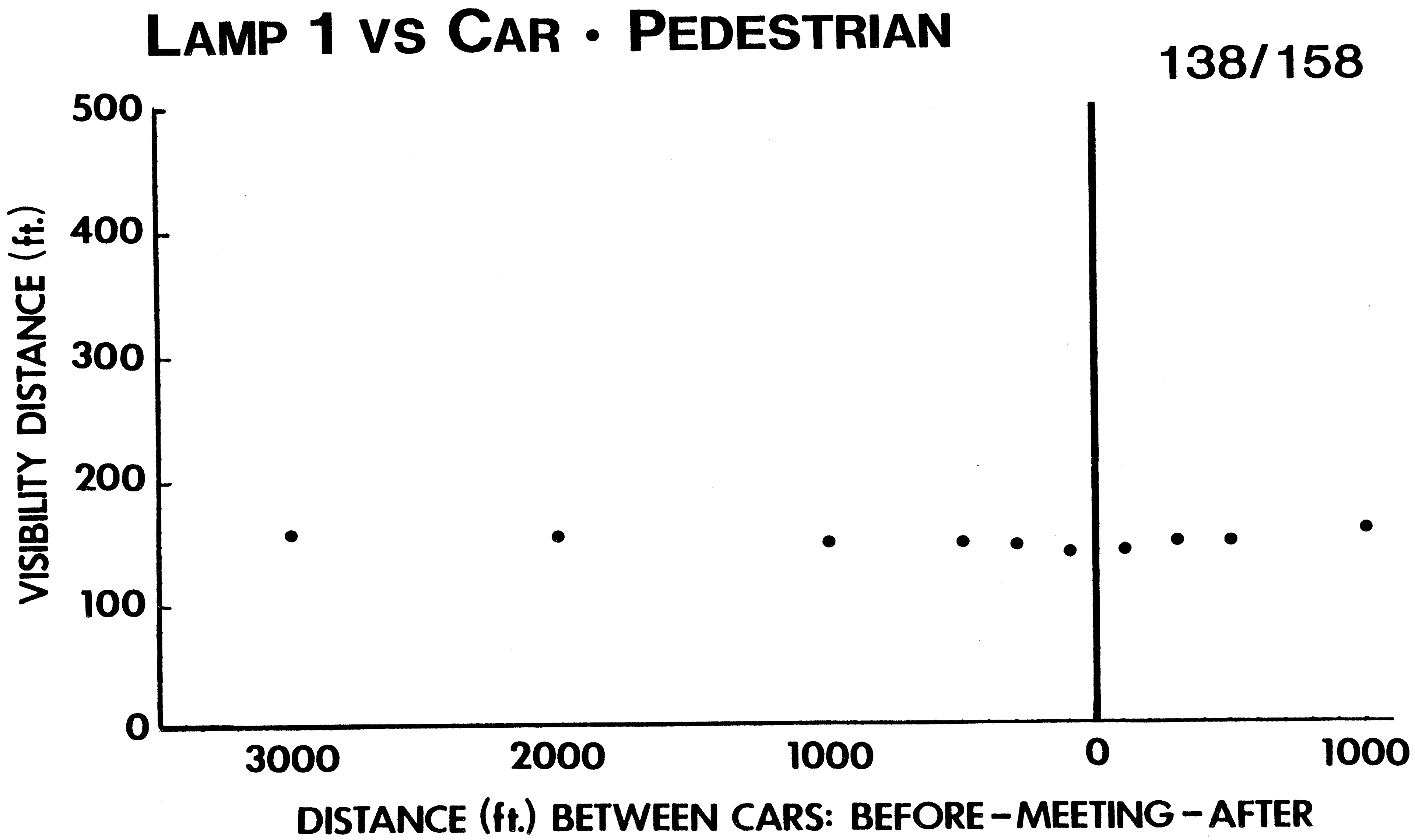

Figure 30. Predicted response distances provided by Lamp 1 meeting a car on a two-lane, flat-straight road. Both vehicles on low beam.

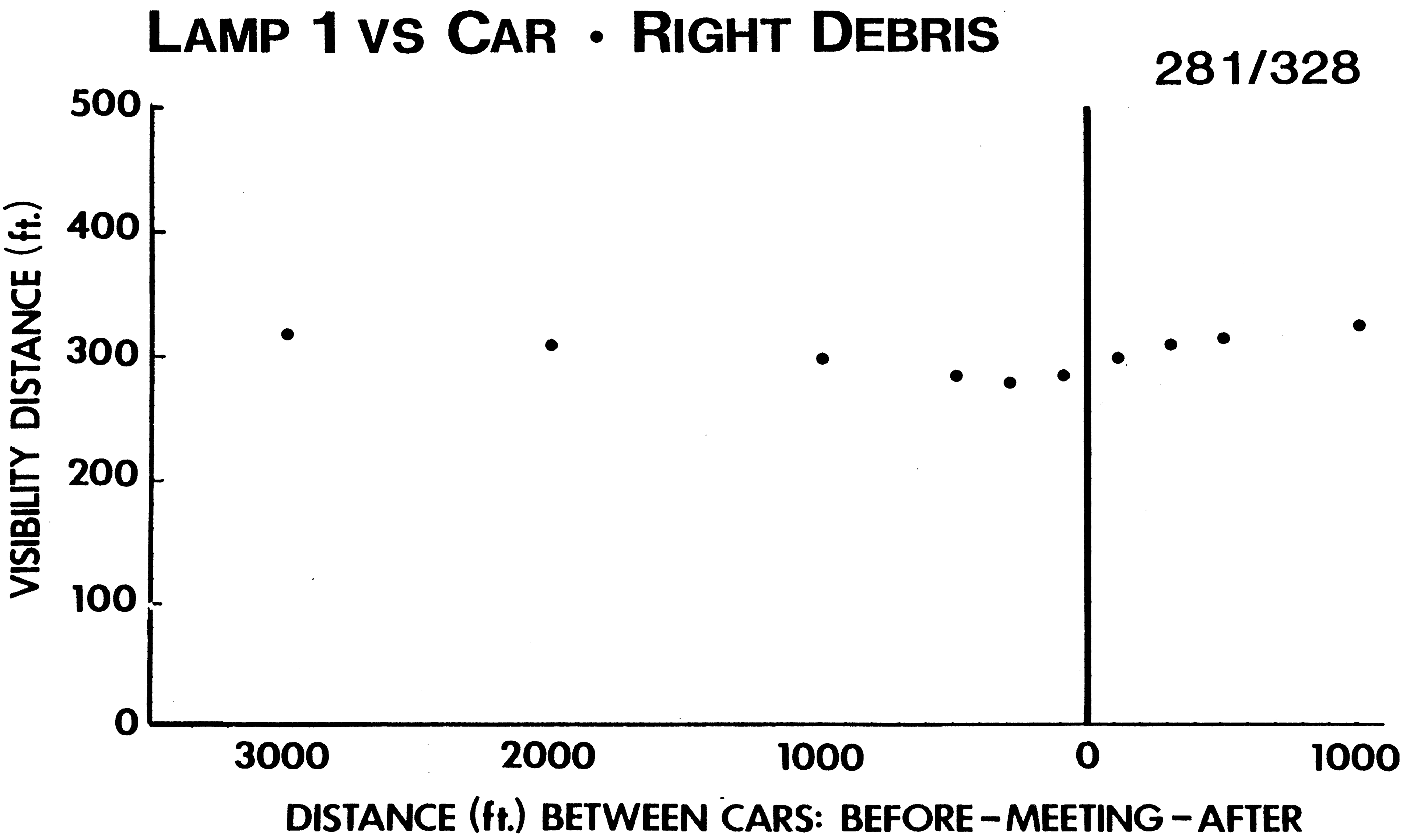

Figure 30. (continued) Predicted response distances provided by Lamp 1 meeting a car on a two-lane, flat-straight road. Both vehicles on low beam.

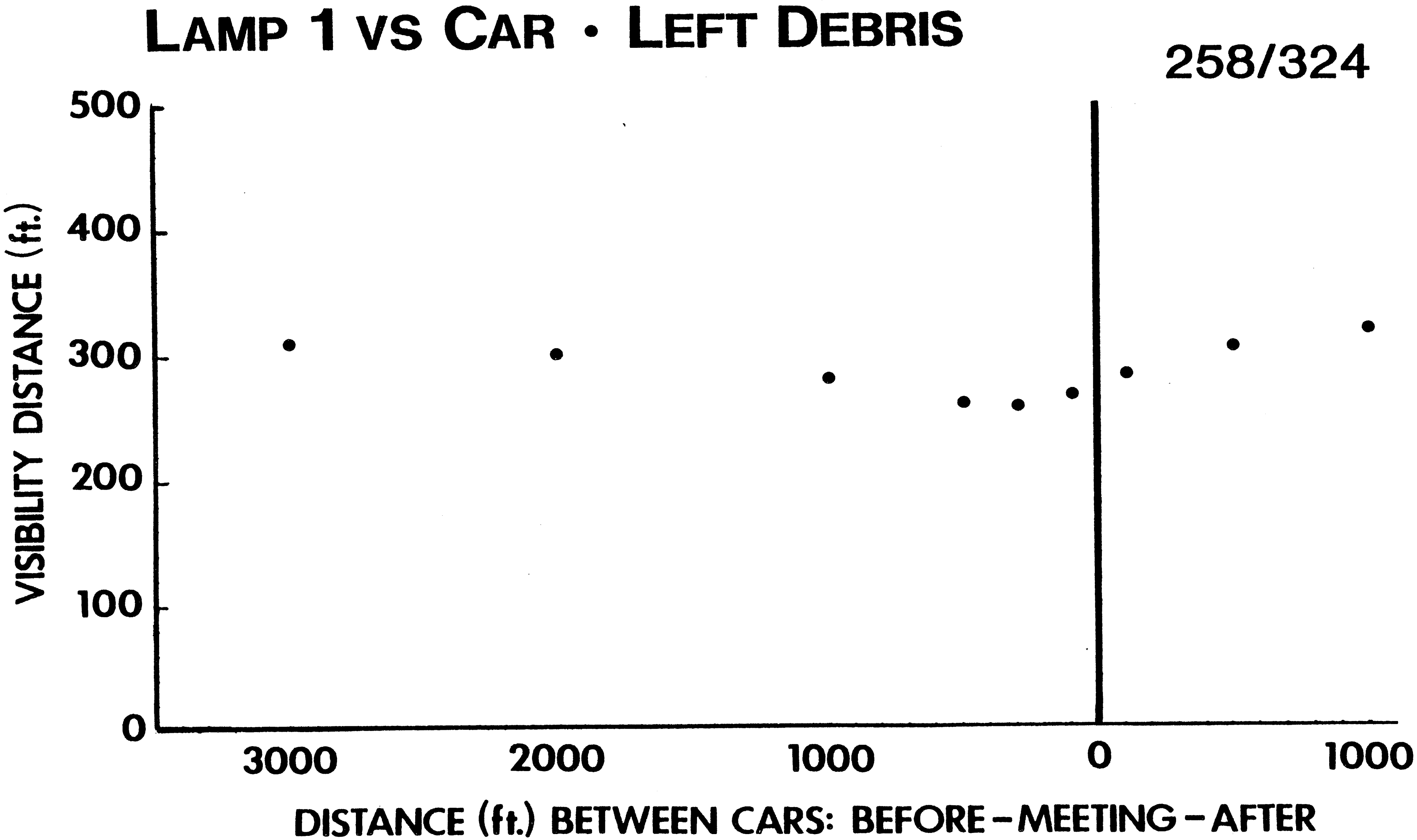

Figure 30. (continued) Predicted response distances prvided by Lamp 1 meeting a car on a two-lane flat-straight road. Both vehicles on low beam.

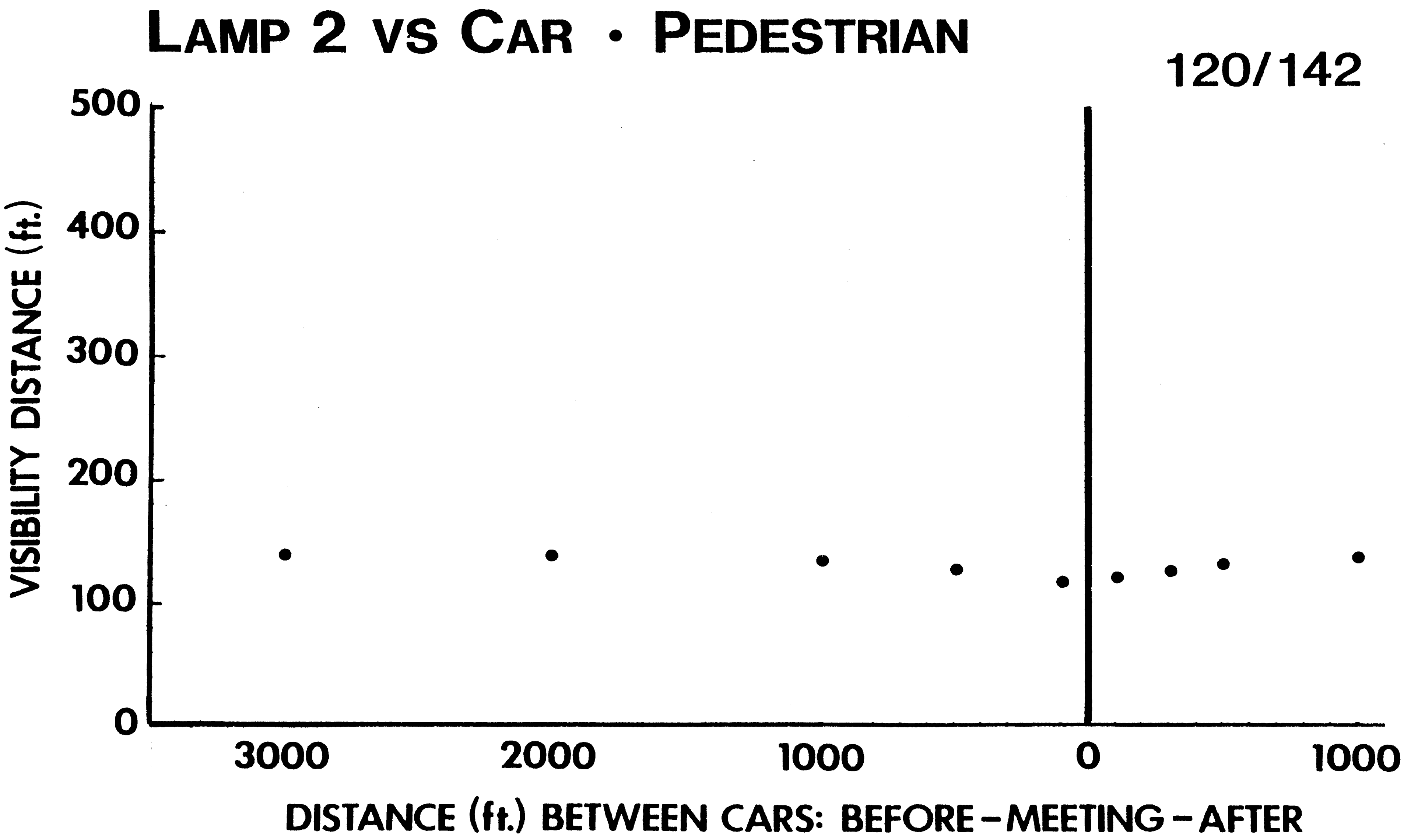

Figure 31. Predicted response distances provided by Lamp 2 meeting a car on a two-lane, flat-straight road. Both vehicles on low beam.

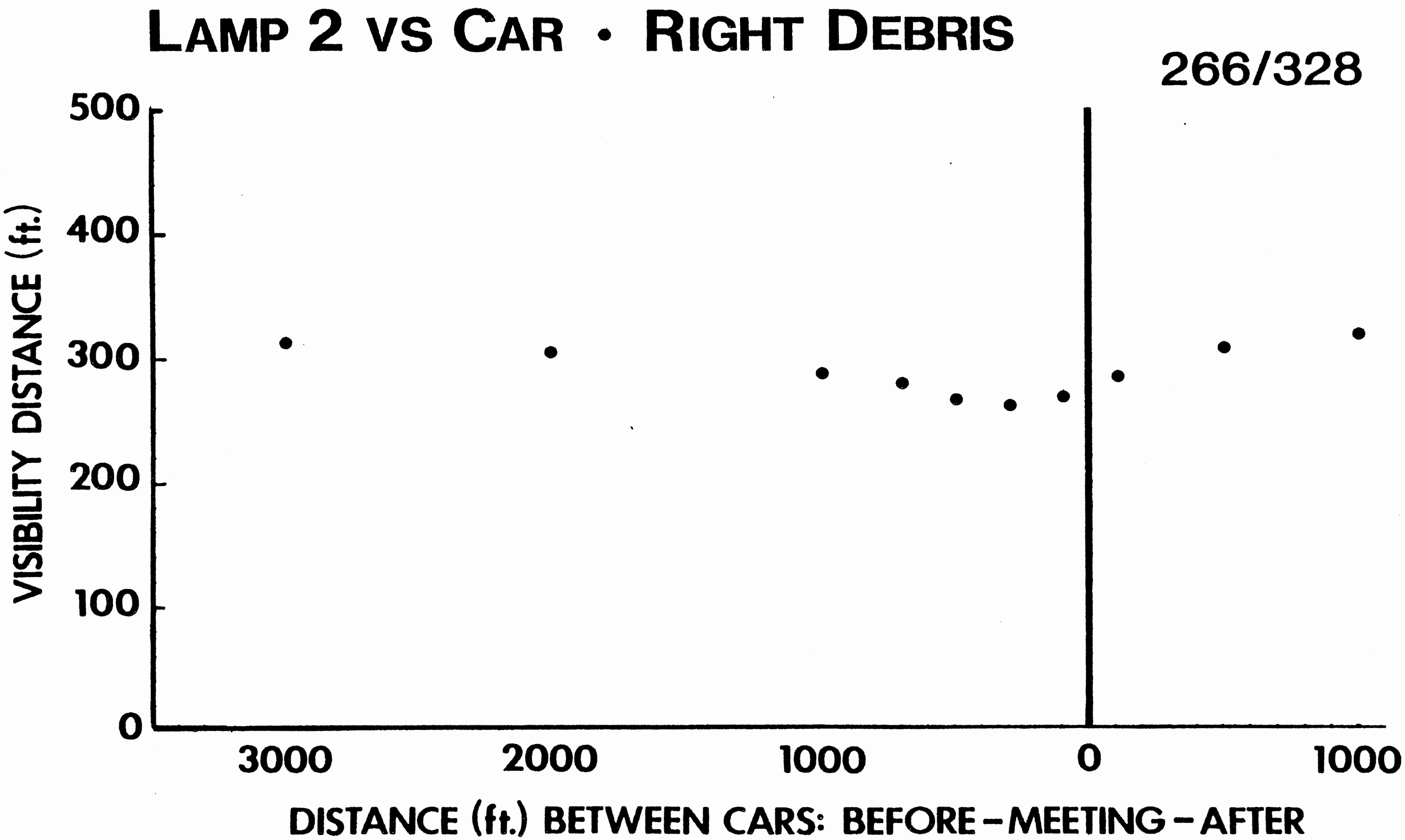

Figure 31. (continued) Predicted response distances provided by Lamp 2 meeting a car on a two-lane, flat-straight road. Both vehicles on low beam.

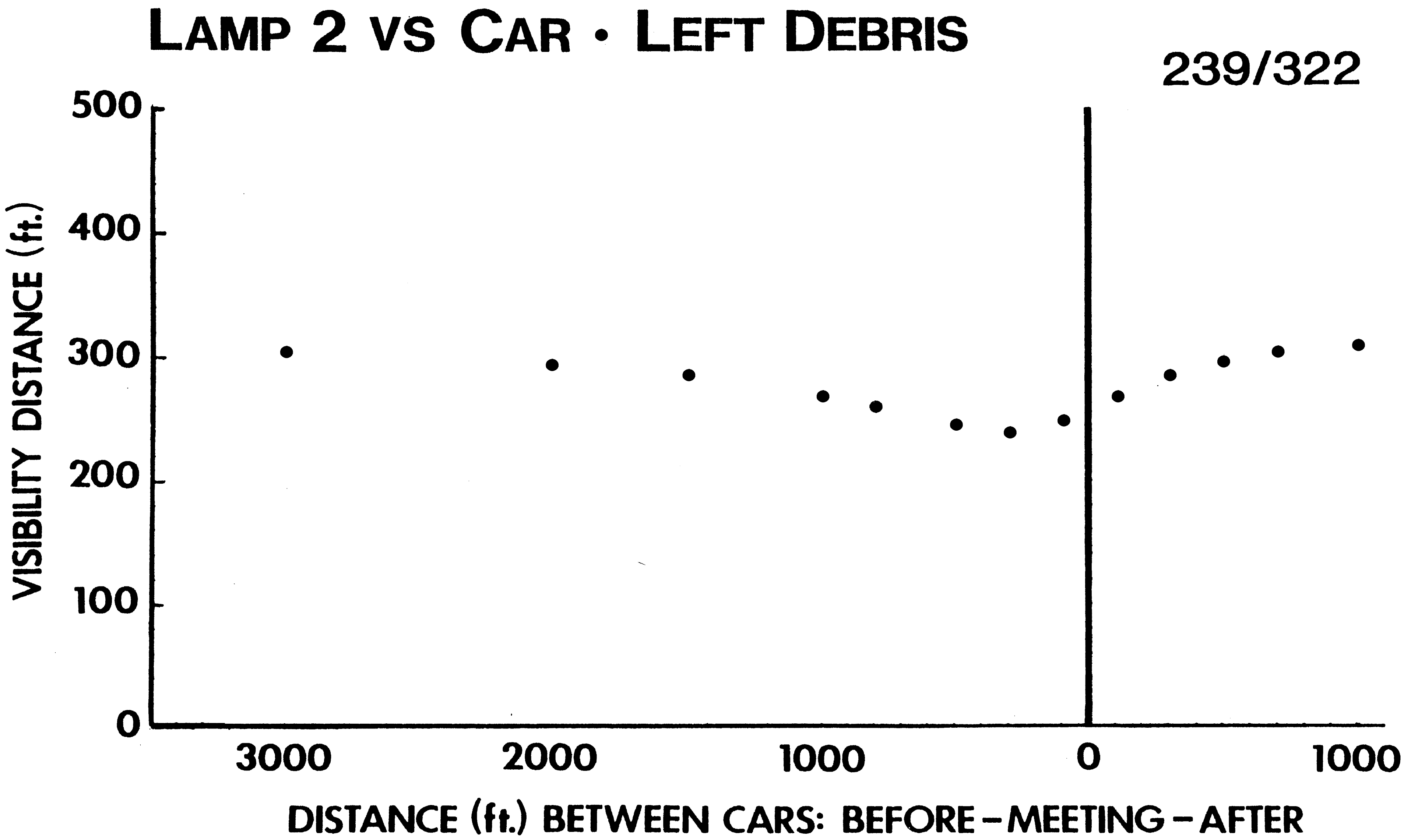

Figure 31. (continued) Predicted response distances provided by Lamp 2 meeting a car on a two-lane, flat-straight road. Both vehicles on low beam.

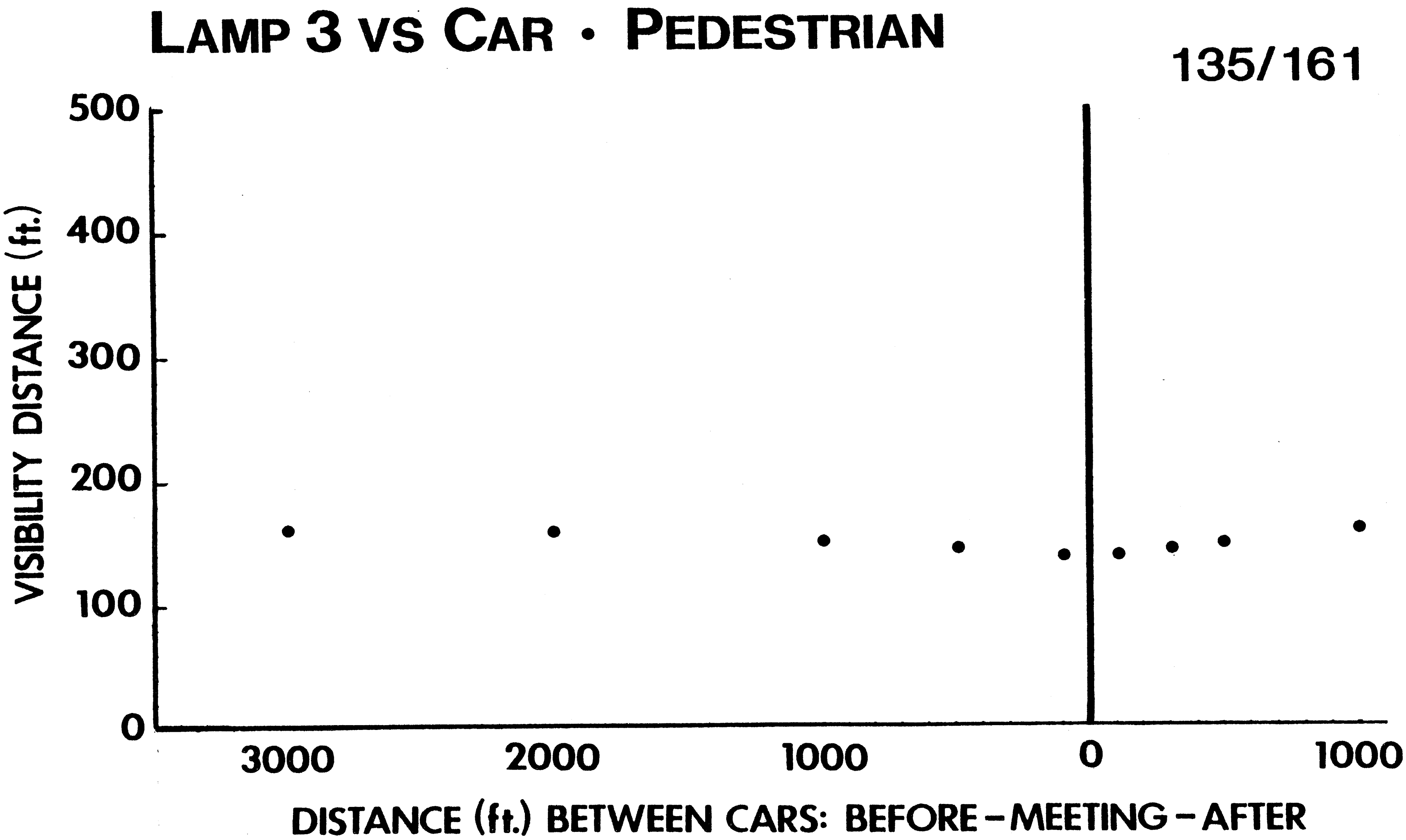

Figure 32. Predicted response distances provided by Lamp 3 meeting a car on a two-lane, flat-straight road. Both vehicles on low beam.

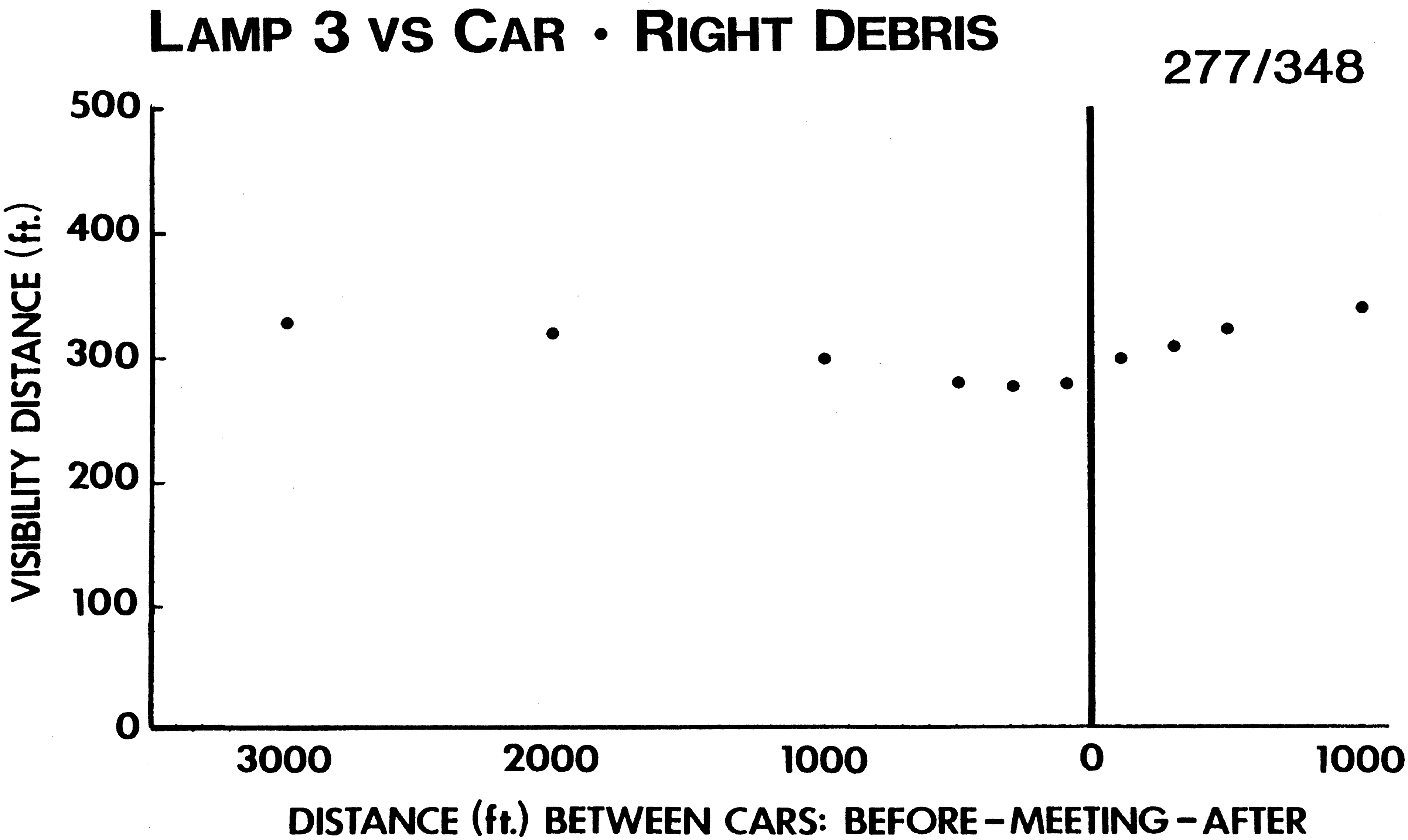

Figure 32. (continued) Predicted response distances provided by Lamp 3 meeting a car on a two-lane, flat-straight road. Both vehicles on low beam.

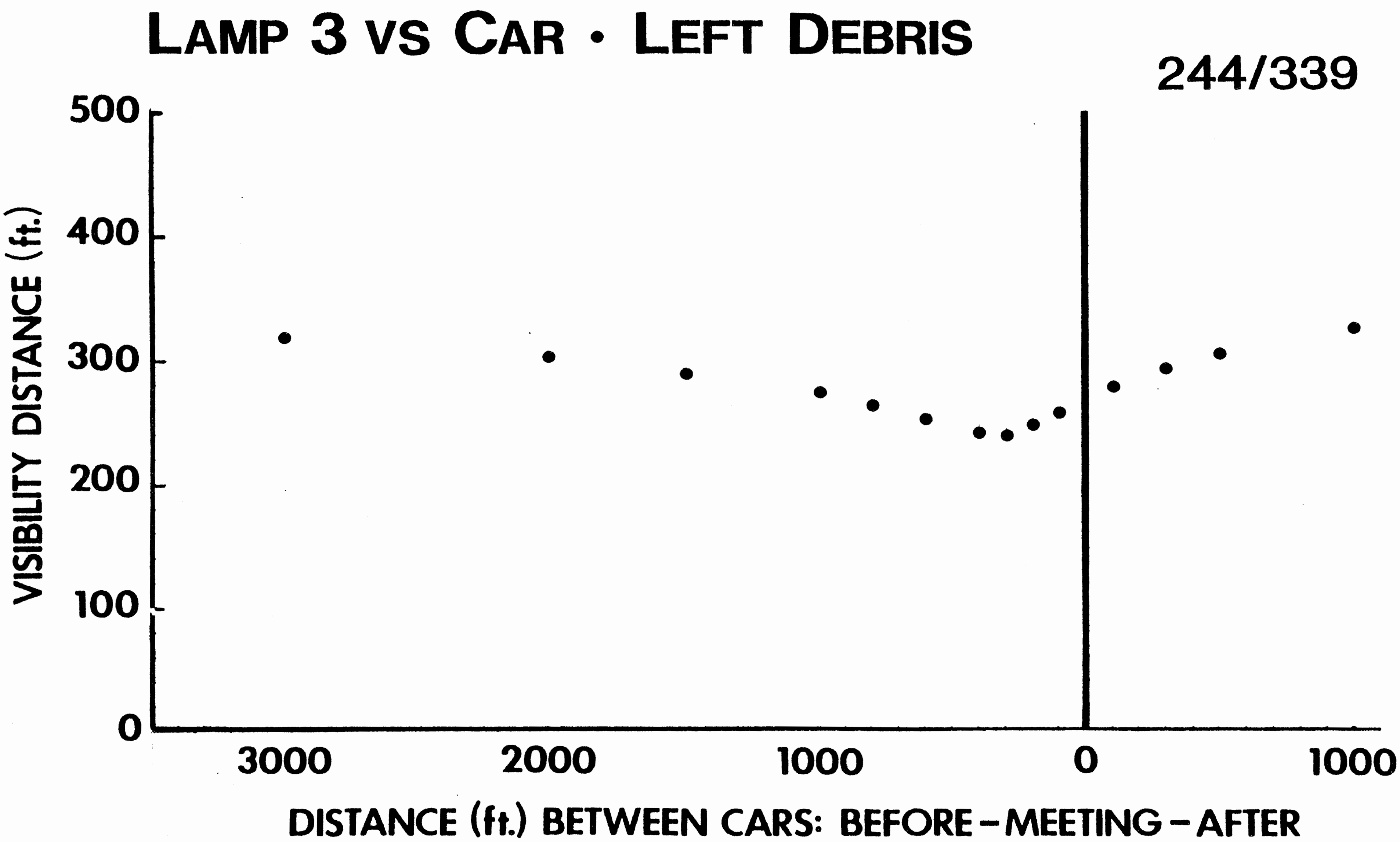

Figure 32. (continued) Predicted response distances provided by Lamp 3 meeting a car on a two-lane, flat-straight road. Both vehicles on low beam.

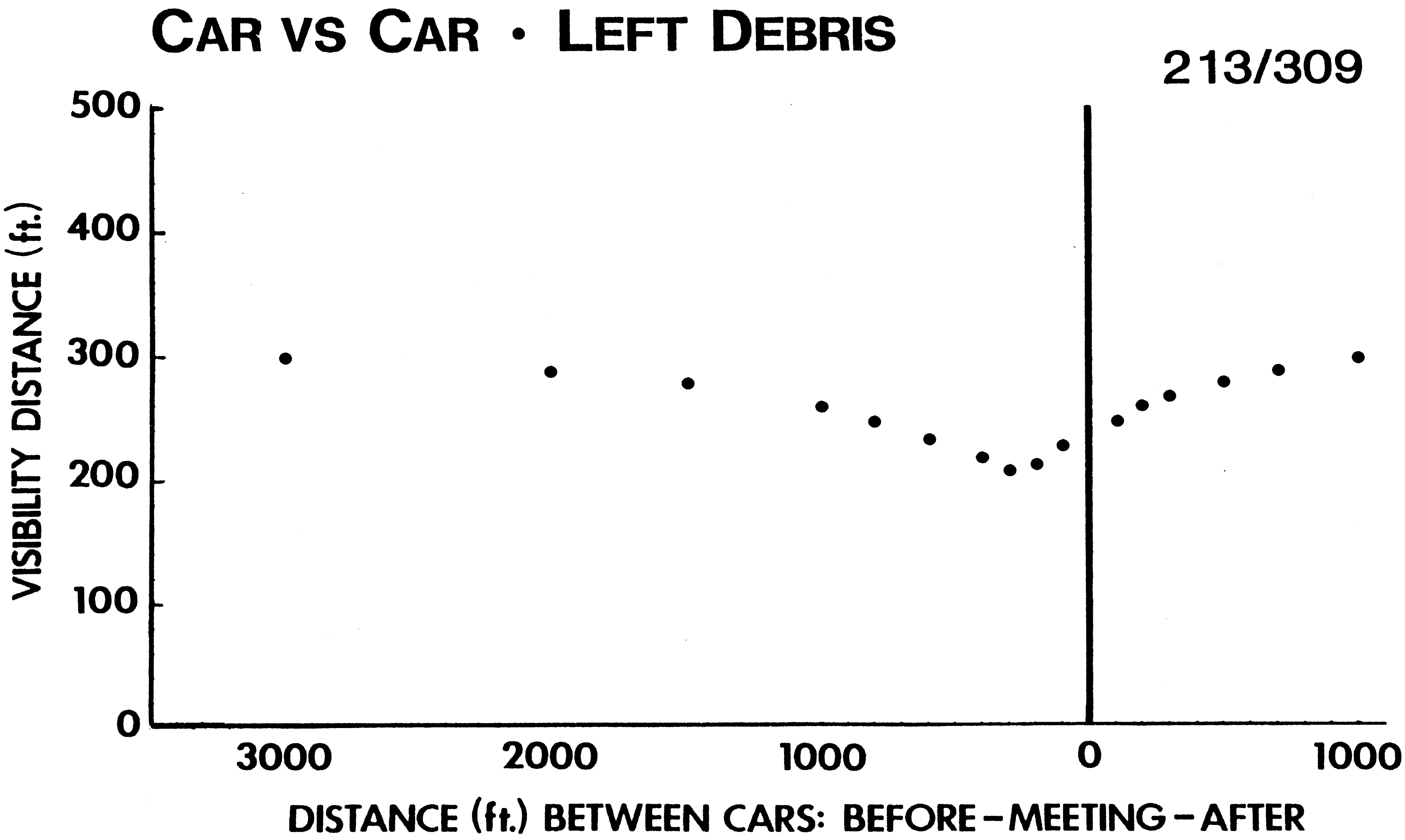

Figure 33. Predicted response distances resulting from two identically equipped cars meeting on a two-lane, flat-straight road. Both vehicles on low beam.

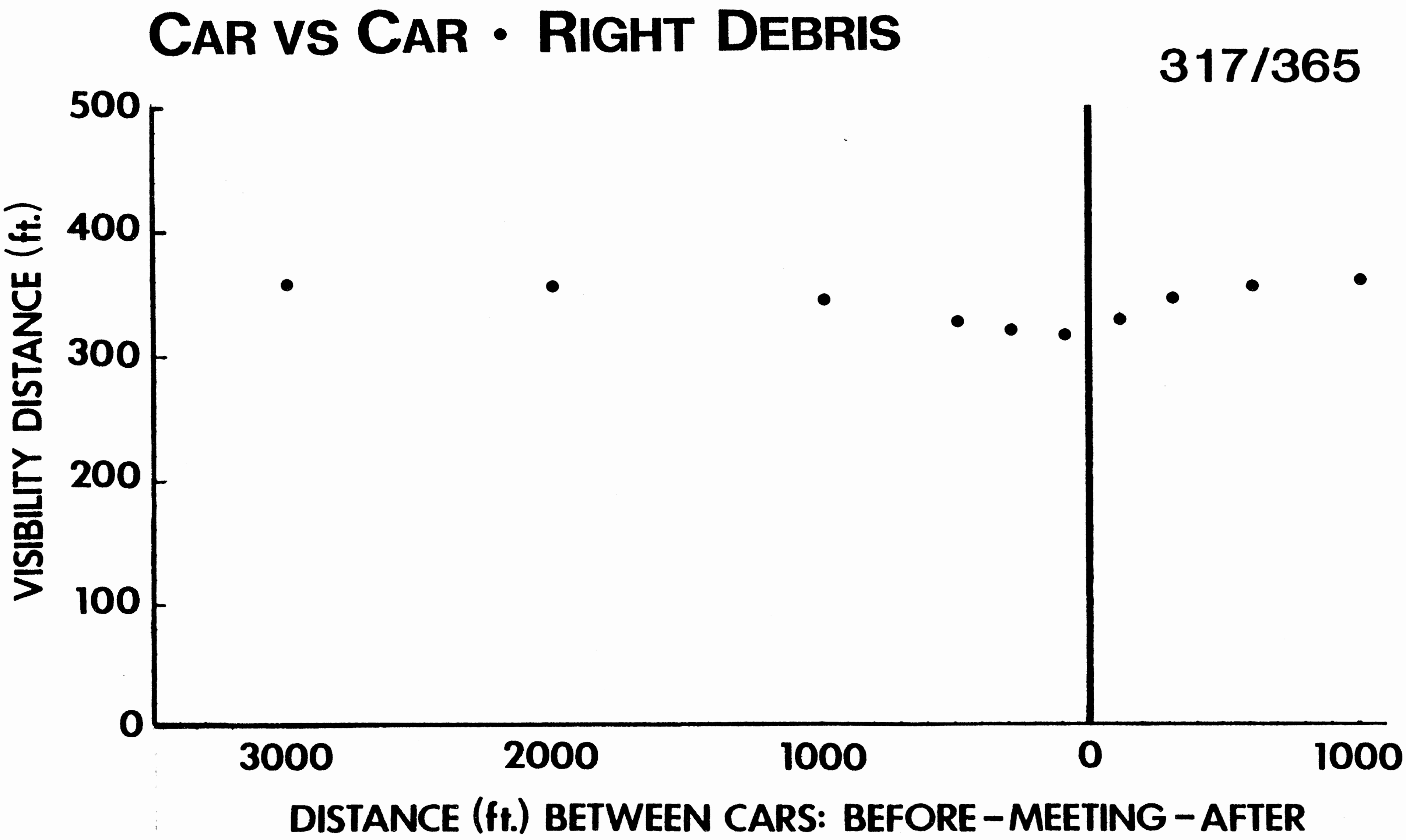

Figure 33. (continued) Predicted distances resulting from two identically equipped cars meeting on a two-lane, flat-straight road. Both vehicles on low beam.

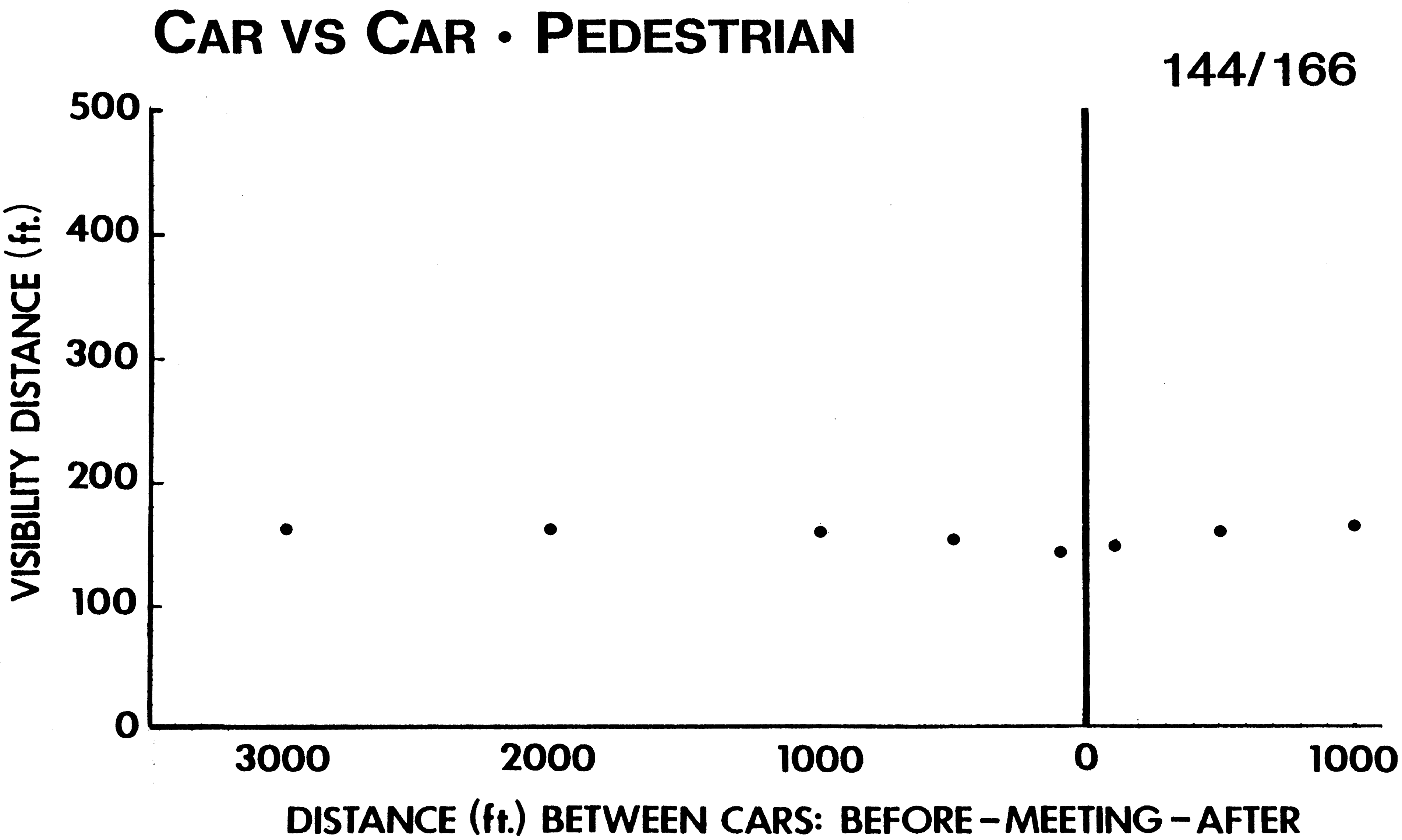

Figure 33. (continued) Predicted distances resulting from two identically equipped cars meeting on a two-lane, flat-straight road. Both vehicles on low beam.

TABLE 20

COMPARISON OF SIMULATED RESPONSE DISTANCES IN FEET
FOR ALL THREE MOTORCYCLE HEADLAMPS UNDER CONDITIONS
OF MAXIMUM GLARE AND NO GLARE

Target	Condition	Lamps		
		1	2	3
Dark Pedestrian	No Glare	158	142	161
	Max Glare	138	120	135
	No/Max	1.14	1.18	1.19
Right Debris	No Glare	3.28	328	348
	Max Glare	281	266	277
	No/Max	1.17	1.23	1.26
Left Debris	No Glare	324	322	339
	Max Glare	258	239	244
	No/Max	1.26	1.35	1.39

Note: Glare provided by car on low beam using 6014 lamps, two-lane, flat-straight road.

Curves: Motorcycle headlamp beams are distorted on curves due to a combination of roll and steer angle. It was thought important to evaluate the relative performance of the three lamps under curve conditions.

The headlamp model used in this study makes it possible to simulate motorcycle cornering characteristics because it permits independent control of horizontal aim (equivalent to steer angle) and rotation of the lamp (equivalent to roll angle).

As a first step, calculations were made of roll and steer angles for curve radii from 100 to 900 feet, and speeds from 25 to 55 mph. Six representative conditions were selected for computer analysis. These are listed in Table 21. The major criterion in the selection of conditions was to be able to separately assess the effects of roll and steer angle. Additional analyses were made at 0° steer angle to evaluate the effect of a frame mounted headlamp.

TABLE 21

LISTING OF CURVE CONDITIONS EVALUATED

Curve Radius (feet)	Speed (mph)	Motorcycle Parameters	
		Roll Angle	Steer Angle
300	25	8°	1°
300	35	15°	1°
300	45	23°	1°
500	55	23°	0.6°
700	55	15°	0.4°
900	45	8°	0.3°
300	45	23°	0° contribution to simulate frame-mounted headlamp
300	35	15°	
300	25	8°	

Note: Roll angles shown are approximate. Small adjustments have been made to allow exact comparisons in the modeling phase.

The nine conditions listed were evaluated for right and left curves, all three targets and all three lamps, a total of 162 runs.

These data are summarized in Tables 22, 23, and 24. Each table is for a different target and shows the maximum and minimum visibility distances achieved by each lamp in a meet with a car equipped with two 6014 low beams (as described in Figure 9). The following comments are based on these data.

The pedestrian target (Table 22) is hard to see under the best of conditions, but especially so when it is on the inside of the curve (e.g., on the right side of a right-hand curve, as in this case).

TABLE 22

PERFORMANCE ON CURVES: VISIBILITY DISTANCE (in feet) TO PEDESTRIAN TARGET

Curve Radius (ft)	Speed (mph)	Direction (Right or Left)	Roll Angle	Steer Angle	Pedestrian					
					Lamp 1		Lamp 2		Lamp 3	
					Max	Min	Max	Min	Max	Min
300	25	R	8°	1°	65	22	30	0	67	0
		L			112	103	88	79	96	82
300	35	R	15°	1°	23	0	5	0	31	0
		L			102	94	85	77	90	79
300	45	R	23°	1°	0	0	0	0	0	0
		L			92	85	81	77	87	78
500	55	R	23°	0.6°	7	0	5	0	0	0
		L			111	99	99	92	106	94
700	55	R	15°	0.4°	76	0	37	0	49	0
		L			118	108	116	113	120	105
900	45	R	8°	0.3°	131	68	66	0	107	0
		L			134	116	127	108	133	112
300	45	R	23°	0°	0	0	0	0	0	0
		L			88	84	78	71	82	74
300	34	R	15°	0°	27	0	5	0	7	0
		L			99	94	79	74	86	76
300	25	R	8°	0°	67	0	21	0	60	0
		L			111	102	84	76	93	78

Differences between lamps in revealing the pedestrian target were small in most cases. In general, Lamps 1 and 3 were better than Lamp 2, sometimes a great deal better, especially in marginal situations. On balance, Lamp 1 performed better than Lamp 3. This is attributable to the former's symmetrical design, which is intended to reduce roll angle effects.

TABLE 23

PERFORMANCE ON CURVES: VISIBILITY DISTANCE (in feet) TO RIGHT DEBRIS TARGET

Curve Radius (ft)	Speed (mph)	Direction (Right or Left)	Roll Angle	Steer Angle	Right Debris Lamp 1 Max	Lamp 1 Min	Lamp 2 Max	Lamp 2 Min	Lamp 3 Max	Lamp 3 Min
300	25	R	8°	1°	170	142	161	121	199	139
		L			166	158	162	137	195	158
300	35	R	15°	1°	140	121	149	105	162	124
		L			153	140	151	119	180	150
300	45	R	23°	1°	124	100	149	98	192	148
		L			176	163	153	115	184	172
500	55	R	23°	0.6°	147	123	216	110	248	146
		L			164	148	159	140	269	170
700	55	R	15°	0.4°	220	166	188	141	235	161
		L			201	190	203	166	227	180
900	45	R	8°	0.3°	278	217	232	171	264	191
		L			278	251	231	187	254	204
300	45	R	23°	0°	123	92	151	95	163	136
		L			184	171	154	108	185	174
300	35	R	15°	0°	145	115	148	101	184	123
		L			157	139	153	116	181	152
300	25	R	8°	0°	185	138	157	117	195	135
		L			163	153	155	130	190	154

In examining Table 23 and 24, a different pattern is seen. First, it should be noted that on all but the 900-foot radius curve, the visibility distances are much shorter than was the case on straight-flat sections (Table 20). If the calculated visibility distances shown are reduced by half, as suggested by Table 19, the debris targets could pose a significant hazard for operation at higher speeds.

TABLE 24

PERFORMANCE ON CURVES: VISIBILITY DISTANCE (in feet) TO LEFT DEBRIS TARGET

Curve Radius (ft)	Speed (mph)	Direction (Right or Left)	Roll Angle	Steer Angle	Left Debris					
					Lamp 1		Lamp 2		Lamp 3	
					Max	Min	Max	Min	Max	Min
300	25	R	8°	1°	171	149	165	130	199	145
		L			158	147	157	128	192	154
300	35	R	15°	1°	144	132	149	117	196	135
		L			147	133	154	108	161	148
300	45	R	23°	1°	133	114	163	106	183	151
		L			159	141	156	100	189	179
500	55	R	23°	0.6°	159	138	181	130	244	154
		L			156	136	169	103	276	179
700	55	R	15°	0.4°	227	178	201	157	239	173
		L			192	177	191	157	223	172
900	45	R	8°	0.3°	285	226	244	184	272	201
		L			271	243	226	180	251	196
300	45	R	23°	0°	123	109	162	100	192	142
		L			166	153	157	94	165	157
300	35	R	15°	0°	144	125	145	111	190	130
		L			153	128	156	101	162	148
300	25	R	8°	0°	188	144	161	123	195	141
		L			153	142	157	119	192	150

In most cases for the debris targets, Lamps 2 and 3 outperform Lamp 1. These differences are relatively large for some cases, especially at greater roll angles. What happened was the center dip in the Lamp 1 pattern interacted with the roll and steer angle effects so that the position of the debris often fell near the center of the dip. Thus Lamp 1 appears to be better for objects near the road edge and poorer for objects near the road center.

This analysis suggests that visibility distance is strongly affected by roll angle, but the relatively small steer angles characteristic of motorcycle operation have little effect.

Vertical Curves: Table 25 is a comparison of the performance of the three test lamps on crest and sag vertical curves. It was found that, even with a 3,000 foot radius curve, the visibility distance to a debris target on a crest vertical curve was limited by the roadway surface. Thus, these analyses are shown only for sag curves.

TABLE 25

VISIBILITY DISTANCE IN FEET (Max/Min) TO VARIOUS TARGETS DURING MEET WITH CAR WHILE NEGOTIATING CREST AND SAG VERTICAL CURVES*

Target	Crest or Sag	Lamp 1	Lamp 2	Lamp 3
Pedestrian	crest	210/105	218/113	236/129
	sag	115/113	94/85	108/89
Right Debris	sag	198/195	223/207	252/206
Left Debris	sag	198/192	219/202	245/199

* Radius = 3,000 feet. Car equipped with 6014 low beams as described in Figure 9.

The differences between the lamps are small in all cases, but Lamp 1, with the exception of the pedestrian target on the sag curve, yielded the shortest visibility distances.

Glare to Opposing Drivers: A matter of concern in lamp design must be glare to opposing drivers. Accordingly, a series of analyses were run comparing the disability glare associated with the three lamps. In the tables which follow the observer is assumed to be operating a car equipped with two 6014 low beam units (Figure 9). The targets are the same as those considered earlier. However, the right and left debris targets have been moved laterally to a point two feet outboard of the right and left headlamps respectively.

Table 26 illustrates max/min visibility distances for a straight-flat meet. Lamps 2 and 3 provide less glare than would be expected in meeting a car on low beam, but Lamp 1 provides considerably more.

TABLE 26

VISIBILITY DISTANCES IN FEET (Max/Min) FROM A CAR TO VARIOUS TARGETS WHILE MEETING A MOTORCYCLE ON A FLAT-STRAIGHT ROAD

Target	Lamp 1	Lamp 2	Lamp 3	Car vs. Car
Pedestrian	166/114	166/153	166/147	166/144
Right Debris	365/264	365/336	365/326	365/317
Left Debris	310/175	310/255	310/241	310/213

Tables 27, 28, and 29 show performance on curves for the pedestrian, right and left debris targets respectively. For right curve meets, the differences between the lamps are minor. However, for left curve meets, Lamp 1 provides considerably more disability glare.

Finally, Table 30 provides a comparison of disability glare from the motorcycle headlamps on vertical curves. The same pattern is seen as before, with Lamp 1 being the most glaring.

TABLE 27

VISIBILITY DISTANCES IN FEET FROM A CAR TO A PEDESTRIAN TARGET WHILE MEETING VARIOUS MOTORCYCLE HEADLAMPS ON CURVES

Curve Radius (ft)	Speed (mph)	Direction (Right or Left)	Roll Angle	Steer Angle	Pedestrian					
					Lamp 1		Lamp 2		Lamp 3	
					Max	Min	Max	Min	Max	Min
100	25	R	23°	3°	43	0	43	0	43	0
		L			75	35	75	55	75	53
300	25	R	8°	1°	83	44	83	46	83	37
		L			93	53	93	85	93	93
300	35	R	15°	1°	83	48	83	46	83	35
		L			93	49	93	78	93	74

TABLE 28

VISIBILITY DISTANCES IN FEET FROM A CAR TO A RIGHT DEBRIS TARGET WHILE MEETING VARIOUS MOTORCYCLE HEADLAMPS ON CURVES

Curve Radius (ft)	Speed (mph)	Direction (Right or Left)	Roll Angle	Steer Angle	Pedestrian					
					Lamp 1		Lamp 2		Lamp 3	
					Max	Min	Max	Min	Max	Min
300	25	R	8°	1°	206	180	206	187	206	170
		L			230	121	230	203	230	191
300	35	R	25°	1°	206	176	206	187	206	193
		L			230	115	230	168	230	146

TABLE 29

VISIBILITY DISTANCES IN FEET FROM A CAR TO A LEFT DEBRIS TARGET WHILE MEETING VARIOUS MOTORCYCLE HEADLAMPS ON CURVES

Curve Radius (ft)	Speed (mph)	Direction (Right or Left)	Roll Angle	Steer Angle	Pedestrian					
					Lamp 1		Lamp 2		Lamp 3	
					Max	Min	Max	Min	Max	Min
300	25	R	8°	1°	236	113	236	204	236	195
		L			210	184	210	191	210	176
300	35	R	15°	1°	236	104	236	168	236	142
		L			210	180	210	191	210	195

TABLE 30

VISIBILITY DISTANCES IN FEET (Max/Min) FROM A CAR TO VARIOUS TARGETS WHILE MEETING A MOTORCYCLE ON CREST AND SAG VERTICAL CURVES*

Target	Crest or Sag	Lamp 1	Lamp 2	Lamp 3
Pedestrian	Crest	210/141	210/160	210/162
	Sag	89/65	89/79	89/73
Right Debris	Sag	226/195	226/213	226/207
Left Debris	Sag	213/180	213/200	213/194

* Radius = 3,000 feet.

Discussion: The results of the various investigations summarized in this section of the report indicate that there are headlamps available for motorcycles which provide seeing distances roughly equivalent to car lighting systems. This is due to a combination of greater mounting height on motorcycles (which has always been the case, but the difference is growing as cars shrink) and more powerful motorcycle headlamps.

This is not to suggest that motorcycle low beams are adequate to reveal all relevant objects at a safe distance. As should be clear from the field study, they are not. But, this is a problem common to vehicle headlighting in general. At least the motorcyclist need not necessarily be at a disadvantage relative to the drivers of four-wheel vehicles.

The most adequate headlamps are still used on the larger bikes. The main difference in recent years has been in the wider use of halogen sources and extending their use down to mid-size bikes (i.e., 600-650 cc). Smaller motorcycles still use less adequate headlamps.

It seems unnecessary that any motorcycle capable of 55 mph should have headlighting less adequate than the largest bikes. Automotive sealed beams using halogen sources (such as Lamp 3 in this study) require no more power than the headlamp with which most small bikes are equipped. The extension of this technology to motorcycle use seems an obvious and desirable thing to do.

Lamp 1 in this study represents a fairly radical departure from traditional motorcycle headlighting. It was designed to address certain concerns and needs of motorcyclists as described by Sturgis (1975). Based on the data reported here, it is at least partially successful.

One of the purposes of the design represented by Lamp 1 is to reduce the effects of beam distortion while cornering. For objects and conditions located near the lane edge and beyond it seems effective. Such a lamp would aid in seeing lane markers and detecting potentially troublesome conditions in the lane periphery while rounding curves either to the right or left. It seems less effective than conventional lamps for detecting lane-center conditions (e.g., chuck-holes), however. And, it is a good deal more glaring to oncoming drivers.

The additional glare associated with Lamp 1 is a troublesome issue. The weighting such a factor should be given is something about which considerable disagreement can be expected. The authors of this report are inclined to feel that, given the relative infrequency of meetings with motorcycles, the glare problem is minor so long as it results from something which produces a benefit.

The general thinking in the design of Lamp 1 appears sound. The center depression in the unit utilized in these studies may be excessive. Reducing this characteristic, and providing more illumination near the H axis and the center of the beam should aid in reducing the deficiencies noted.

RECOMMENDATIONS

As was noted earlier, there are a great number of motorcycle headlamps. It has been common practice for each manufacturer of motorcycles to use several different headlamps in the line, these lamps differing in size, power requirements, photometrics, and electrical connections.

The problem this state of affairs causes motorcyclists in terms of expense and inconvenience, have already been mentioned. This is compounded by the fact that most motorcycle headlamps operate continuously, due to local laws or design of the electrical system, contributing to a relatively short life.

The fact that motorcycle headlamps burn out more often than automobile headlamps, are expensive, and are relatively difficult to secure has safety implications. By day, headlamps are a proven conspicuity aid, reducing collisions significantly. By night, having both beams functioning properly is an obviously desirable condition. Reformulating the lighting standards to improve availability may reduce the number of motorcycles with defective headlamps and improve operator safety. The suggestions that follow are offered with this idea in mind.

Motorcycles

Size: The present variety of options serves no useful function. It is strongly recommended that the necessary steps be taken to reduce the variability in motorcycle headlamps to an absolute minimum.

There is some justification for allowing two sizes of motorcycle headlamp. Bikes designed for easy maneuverability (especially off-road use) will benefit from the reduced mass associated with a relatively small headlamp. Small motorcycles, regardless of their intended use, would probably look better with a small headlamp. However, in general, better photometrics can be achieved with a relatively large lamp. Thus, where it is dynamically and aesthetically permissible, a large lamp should be fitted.

There are sound arguments for making the large lamp to conform to the PAR 56 (7 inch, 178mm) round or 142 x 200 mm rectangular sizes described in the automotive specifications. The reasons are:

1. A substantial fraction of motorcycles in current manufacture and on the road are equipped with lamps in one of these two sizes. Lacking some compelling reason to do otherwise, there are clear advantages in continuing their use.

2. Since the same reflector can be used for both motorcycle and automotive applications, manufacturing economies should be possible.

3. An automotive lamp can be substituted. The results of this investigation suggest that automotive lamps will perform satisfactorily for most motorcycling conditions. Since there is no clearly superior option, there is no justification for prohibiting their use on motorcycles. As a further consideration, automotive lamps are widely available and can often be purchased from outlets that keep late hours. In addition, automotive lamps are available in both tungsten (typically at 50 watts on low and 60 watts on high beam) and halogen (typically 35 to 40 watts for each beam), so power consumption of the unit being replaced can be matched.

Arguments concerning the smaller size lamp are not as clear cut. On balance, it seems desirable that they not conform to the PAR 46 (5.75 inch, 146 mm) round or the 100 x 165 mm rectangular automotive specifications. The primary concern is that the Type 2 (two-filament) lamps designed for four-headlamp systems on automobiles do not produce a satisfactory high beam. The so-called high beam on such lamps is primarily designed to provide fill light and prevent the unit from icing over in winter weather, rather than providing maximum seeing distance.

As this is being written there is a petition before NHTSA to allow 100 x 165 mm size lamps to be designed for and used in two-lamp systems. If granted, this would result in a small rectangular lamp which is the photometric equivalent of the large round and rectangular lamps on both high and low beams. Such a lamp would be a useful emergency replacement for a motorcycle headlamp. Although there are no small rectangular lamps in use on motorcycles currently, it would be desirable that their use be permited, if the small rectangular two-lamp system is legalized.

Barring the above-mentioned eventuality, it is recommended that the small motorcycle headlamp be a size close to, but different from small automotive lamps. There are a few lamps being made now which are possibly an appropriate size (e.g., Stanley HM-29M-S at 135 mm, and the Koito 4420X2 and 4020X at 140 mm). However, there are no compelling arguments to favor a particular size.

Construction: The major problem in types of construction concerns the composite sealed beam. There are two principal issues:

(a) Lamps incorporating metal reflectors have been troubled with corrosion problems in automotive applications. However, motorcycle headlamps, as noted earlier, are not typically subjected to nearly as harsh an environment as are automotive headlamps. Hence, the corrosion problem should not be significant.

(b) The main problem with tungsten composite sealed beams may be loss of output attributable to blackening of the interior bulb. There are no data on motorcycle lamps specifically, but the problem is well known in other types of lighting equipment.

Given headlamps which are often inferior to that provided automobiles, it seems undesirable to permit a technology which will cause the output to decline significantly as the bulb ages.

One obvious solution is the use of halogen lamps. Indeed, if the upgraded photometrics recommended later in this report are adopted, halogen lamps are the only means by which they can be met in many cases without increasing power requirements significantly.

It is recommended, however, that NHTSA include in their motorcycle headlighting standard a requirement that lamp output not change more than 20% over the life of the unit.

Replaceable-bulb headlamps are coming into more common use on motorcycles. As noted earlier, they enjoy three major advantages compared to most motorcycle headlamps (relatively low replacement cost, ready availability, and the ease with which they can be carried as a spare). The principle disadvantage to such lamps in automotive use, degradation of the lens and reflector, should not be nearly as significant in motorcycle use. Thus, the replaceable-bulb concept seems ideally suited to motorcycles.

The principle disadvantage to replaceable-bulb headlamps for motorcycles is that the H-4 bulb has relatively high power consumption (55 and 60 watts on low and high beam respectively). This makes it impractical for use on smaller bikes, unless their electrical generating capabilities are upgraded appropriately.

An obvious solution to providing more adequate photometrics on smaller motorcycles is the halogen sealed beam. The availability of a proven technology, which can provide the desired illumination at wattage levels within the capabilities of even small motorcycles makes it unnecessary to differentiate between motorcycles based on engine size in setting headlighting standards.

A drawback to halogen sealed beams is cost. Compared to tungsten sealed-beams for cars, halogen versions cost up to ten times more. However, since motorcycle headlamps are relatively expensive anyway, the cost difference would not be as great, and the performance difference would be substantial.

<u>Mounting and Electrical Connections</u>: Mounting and electrical connection recommendations are governed by the desirability of being compatible with automotive lamps, at least in the larger size lamp. There seems no reason to employ other techniques in the smaller lamp, since interchangeability will be ruled out by size standardization.

The push-on automotive-type connector is very widely used in motorcycles today and is recommended as a standard.

<u>Aiming</u>: Current FMVSS 108 standards call for aiming motorcycle lamps on high beam. The reason is that the high beam provides a relatively well-defined hot spot, and the instructions (same height as the lamp and slightly down) are easily understood. Given the characteristics of the vehicle, it is probably easier for a motorcyclist to properly aim the high beam than it is the low beam, whether moving or stationary. Hence, it is recommended that aiming on high beam remain the standard.

Means for improving the aimability and maintenance of correct aim of motorcycle headlamps was one of this project's concerns.

The problem is not simple. For example, to produce accurate horizontal aim the bike must be vertical, its longitudinal axis aligned with the vertical aim reference, and its front wheel straight (for fork-mounted lamps). Minor errors in any of these, especially the second two, can produce major errors in horizontal aim. Vertical aim is affected by rider weight and can be drastically altered if a passenger is carried.

The authors of this report have not been able to devise a simple jig that would make accurate aiming a do-it-yourself job. Certainly, on a dealer basis, a jig can be devised and accurate aim offered as a service. However, this would not solve the problem of motorcycle headlamp aim on a systematic, national basis and it does not really address the problem of vertical aim variance resulting from operator and passenger load.

In the opinion of the authors, the following strategy would be an effective means of minimizing aim variance:

1. Factory aim the headlamps. Using production jigs, the lamps could be aimed with a precision not otherwise possible. Horizontal aim would be referenced to the bike; vertical aim to gravity with a bubble-reference visible to the operator. A lever would be provided so the operator could center the bubble easily (and by so doing appropriately alter vertical aim).

2. Remove the user-adjustable horizontal aim control.

This system would ensure good aim for new motorcycles, and provide a simple means for properly compensating for the major source of vertical aim variance. Possible problems are:

a. Relying on the motorcyclist to set the vertical aim opens the system to abuse and the consequences of carelessness.

This is a valid criticism. However, it is difficult to see how it could be worse than the present situation. Sturgis noted that many bikers in his survey deliberately kept the bolts on the headlamp loose so they could adjust it for load. Such an adjustment would not be very accurate, but it is probably better than ignoring load changes.

Abuse tends to be self-policing. A rider who deliberately aims his/her lamp high will find oncoming vehicles flashing with annoying frequency. The biker who drops off a passenger and then forgets to reset the lamp will suffer a substantial loss of visibility which only he/she can detect. However, we feel that, in time, motorcyclists will adapt to this feature and use it properly as a real safety aid.

b. The aim will change when new lamps or bulbs are installed.

Recent work on the effect of bulb replacement on unit aim (Olson, 1982) suggests that this need not be a problem for either H-4 or sealed beam units, so long as the same type of bulb is used as a replacement. Assuredly there would be an increase in aim variance as headlamps are replaced, but it would be small compared to the present situation.

c. Wear or modification to the bike suspension will change aim.

Not true. If the reference is to the headlamp can itself it is actually possible for the cyclist to compensate for such changes to the bike.

d. Damage from accidents will alter aim and the cyclist will be unable to reaim.

This is a problem which can be overcome if dealers maintain a capability of restoring reference aim. It is unlikely they could do as good a job as the factory, but they should be able to come reasonably close.

e. The system will add cost and complexity to motorcycles.

True. The system cost is not known at the present time, but estimates could be obtained easily, if NHTSA is sufficiently interested. However, it must be admitted that benefits (i.e., cost savings due to fewer accidents) cannot be estimated with any confidence.

Should a system such as that proposed be adopted, it is recommended that the standards be altered to aim on low beam. The aim of the low beam is clearly more critical than that of the high beam and it is preferable to use it so long as it can be done accurately.

Photometrics:

Low Beam: Current specifications for motorcycle headlamps (see Table 1) distinguish between two classes of vehicle based on engine displacement, number of wheels, etc. In the opinion of the authors the primary factor which should govern headlamp output is speed capability. Thus, it is recommended that two classes be maintained, but their descriptions be altered, i.e., Class A for any bike having a design speed capability of 35 mph (56 km/hr) or more, and Class B for any bike having a design speed capability less than 35 mph.

Based on the results of this study the standards should be modified to achieve the following goals:

(a) An increase in output to rule out less adequate headlamps.

(b) A symmetrical beam pattern (i.e., equal illumination to both right and left).

(c) Assured minimally adequate forward and peripheral illumination.

It is also desirable that the standards allow use of automotive lamps in the 7 inch (178 mm) round or 142 x 200 mm sizes, and of either SAE or ECE beam pattern.

A proposal to modify the motorcycle headlighting standards is currently before the Headlighting Task Force of the SAE. Its recommendations meet very well the goals outlined above. They are presented in Table 31 and are recommended to NHTSA as the basis for a revised FMVSS 108.

High Beam: While the high beam is somewhat less of a problem, modification to the photometric specifications are seen as desirable to assure more adequate visibility down the road and to the periphery.

A proposal to modify the high beam standards is also before the SAE Headlighting Task Force. This document has been reviewed by us and is felt to generally meet the desired goals. It is presented in Table 32 with only two modifications. The H-V point has been increased from 12,500 cd to 15,000 cd min, and the 1/2D-V point has been increased from 20,000 cd to 25,000 cd min. These changes will cause no problems for

TABLE 31

CURRENT AND RECOMMENDED LOW BEAM PHOTOMETRICS
FOR CLASS A MOTORCYCLE*

Position, Degrees	Current cd	Recommended cd
1 1/2U-1R to R	1,000 max	1,400 max
1U-1L to L	500 max	
1U-1 1/2L to L		700 max
1/2U-1 1/2L to L		1,000 max
1/2U-1L to L	800 max	
1/2U-1R to 3R	2,000 max	
1/2U-1R to 3R		2,700 max
1/2D-1R to R	15,000 max	
1/2D-1L to L	2,000 max	
1 1/2D-9R and 9L		700 min
2D-V		7,000 min
2D-3R	3,000 min	
2D-3L	2,000 min	
2D-3R and 3L		4,000 min
2D-6R and 6L	750 min	1,500 min
2D-12R and 12L		700 min
3D-6R and 6L		800 min
4D-V		2,000 min
4D-4R	12,500 max	12,500 max

* A motorcycle capable of speeds of 35 mph or more.

TABLE 32

CURRENT AND RECOMMENDED HIGH BEAM PHOTOMETRICS
FOR CLASS A MOTORCYCLES*

Position, Degrees	Current cd	Recommended cd
2U-V		1,000 min
1U-3L and 3R		2,000 min
H-V	10,000 min	15,000 min
1/2D-V	20,000 min	25,000 min
1/2D-3R and 3L	4,000 min	10,000 min
1/2D-6R and 6L	1,000 min	3,300 min
1/2D-9R and 9L		1,500 min
1/2D-12R and 12L		800 min
1D-V	15,000 min	17,500 min
2D-V	5,000 min	5,000 min
3D-V	2,500 min	2,500 min
3D-6R and 6L	750 min	
3D-9R and 9L		1,500 min
3D-12R and 12L		300 min
4D-V	5,000 max	1,500 min 5,000 max
Anywhere		75,000 max

* A motorcycle capable of speeds of 35 mph or more.

any of the more adequate lamps on the market today and will aid in assuring minimally adequate performance levels.

With the changes noted, the test points and associated candela values recommended in Table 32 are seen as desirable changes to FMVSS 108.

Mopeds

It is clear that the situation with respect to mopeds is not nearly as critical as with motorcycles. Available evidence suggests that they are ridden infrequently at night (Anonymous-1980). Their owners are mostly young, they are used mainly on city streets (which are often lighted), and their headlamps are probably more important as a conspicuity aid than to reveal objects in the forward field.

However, there is no assurance that what is presently true will always remain so. So long as it is legal and possible to operate the vehicles at night and on unlighted roads some persons will do so. In addition, the moped, which enjoys great popularity in other parts of the world, may develop to a similar level in the U.S., and become a very significant element in the traffic mix. Thus, there seems to be no way to argue that the lighting system should be other than adequate for the most demanding conditions in which the vehicle may be used.

The difference is in the urgency associated with the following recommendations. In general it is felt that moped headlamps should provide reasonable levels of illumination, be readily available and inexpensive. This can only be achieved by working toward standardization. However, the future status of mopeds in the U.S. is somewhat uncertain. Thus, the Government may wish to attach lower priority to rule making in this area unless or until moped popularity improves.

Size: A single moped lamp configuration is desirable. This should be different from other standard motorcycle, automotive or special purpose lamps (e.g., the PAR 36, 4.5 inch, 114 mm) which might be inappropriately substituted. The two most effective lamps tested as part of this project were 128 mm in diameter, suggesting that adequate photometrics can be obtained with that size reflector.

Construction. The more adequate moped headlamps are either all-glass or composite sealed beams. The same comments apply here as in the case of motorcycle lamps, in that the composite units have a potential problem of loss of output due to blackening of the interior bulb. It is therefore recommended that the standards include a provision that the unit output not change more than 20% over its life.

Mounting and Electrical Connections: Mounting is an optional matter, except that true interchangeability is facilitated if no mounting hardware is permanently affixed to the lamp itself. Mounting can and should be accomplished by clamping to the rim, as is presently done in most motorcycle and all automotive lamps.

No strong case can be made for any particular connector scheme. Screw-on or spade-type connectors would work equally well for single-beam lamps. Two-beam lamps allow the possibility of making the wrong connections. This should be guarded against either by using color-coded spade-type or, preferably, an auto-type push-on connector.

Photometrics

Low Beam: It is clear from the results of this study that moped lamps which exceed the current FMVSS 108 standards for class C and D motorcycles are practical (i.e., within the electrical generating capabilities of current models) and desirable (i.e., they provide reasonable seeing distances).

Further, it is the opinion of the authors that moped lamps, like motorcycle lamps, should be symmetrical. While the problem of high-g cornering is not so serious with mopeds, neither is the glare their lamps provide oncoming vehicles. On balance, a symmetrical pattern seems the best choice.

The SAE Headlighting Task Force is also considering possible modifications to headlamps for mopeds. Their proposal has been reviewed by us and is felt to be satisfactory. It is reproduced in Table 33, and is recommended as a modification to FMVSS 108.

TABLE 33

CURRENT AND RECOMMENDED LOW BEAM PHOTOMETRICS FOR CLASS B MOTORCYCLE*

Position, Degrees	Current cd	Recommended cd
1 1/2U-1R to R	1,000 max	1,400 max
1U-1L to L	500 max	
1U-1 1/2L to L		700 max
1/2U-1 1/2L to L		1,000 max
1/2U-1L to L	800 max	
1/2U-1R to 3R	2,000 max	
1/2U-1R to 3R		2,700 max
1/2D-1R to R	15,000 max	
1/2D-1L to L	2,000 max	
2D-V		4,000 min
2D-3R	2,000 min	
2D-3L	1,500 min	
2D-3R and 3L		3,000 min
2D-6R and 6L	500 min	1,500 min
3D-6R and 6L		800 min
4D-V		2,000 min
4D-4R	12,500 max	12,500 max

* Redefined for purposes of this proposed standard as a motorcycle having a designed top speed of less than 35 mph (56 km/hr).

High Beam: Based on an analysis of available lamps, it seems entirely feasible to upgrade the high beam specifications considerably. This aspect of the standard has also been addressed by the SAE. Their recommendations are summarized in Table 34, and are suggested as revisions to FMVSS 108.

TABLE 34

CURRENT AND RECOMMENDED HIGH BEAM PHOTOMETRICS FOR CLASS B MOTORCYCLE*

Position, Degrees	Current cd	Recommended cd
1U-3R and 3L		1,000 min
H-V	2,000 min	5,000 min
1/2D-V	5,000 min	7,500 min
1/2D-3R and 3L	3,000 min	3,000 min
1/2D-6R and 6L	750 min	800 min
1D-V	5,000 min	5,000 min
2D-V	3,000 min	3,000 min
3D-V	1,000 min	1,000 min
3D-6R and 6L	500 min	500 min
4D-V	5,000 max	7,500 max
Anywhere		75,000 max

* Redefined for purposes of this proposed standard as a motorcycle having a designed top speed of less than 35 mph (56 km/hr).

A basic question is whether mopeds should be required to have high beams. On balance, we believe the answer should be "no," at the present time. The results of the field evaluation suggest that good moped headlamps provide visibility on low beam which is adequate for most riding conditions, given the speed capability of the machine. When considered with the apparent infrequent use of the vehicles at night and on unlighted roads, the added cost of high beams is difficult to justify. If the use patterns of mopeds change greatly in the future, this opinion should be reviewed.

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APPENDIX A

MOTORCYCLE HEADLIGHTING SURVEY QUESTIONNAIRE

COVER LETTER

There is growing interest now in improving motorcycle headlighting. It is hoped that future lamps will provide better illumination, be more readily obtained, easier to aim, etc.

By and large, the persons who design headlamps are not motorcyclists. Thus, they require information about the special problems of motorcycle operation from experienced riders to guide them in making design decisions.

The Motorcycle Safety Foundation is assisting in this information-gathering effort by sending the attached questionnaire to selected persons having substantial experience and a demonstrated interest in safety. You are such a person.

We believe the questionnaire will require no more then a half hour of your time to complete. It will be greatly appreciated by us if you would fill it out and return it to us in the enclosed envelope as soon as possible.

Thank you very much.

This questionnaire contains five questions designed to provide background information for the design of motorcycle headlamps. Note that questions 1 and 3 require a simple "yes" or "no" response, by checking the appropriate box. If your answer to either or both is "yes," please write out your answer to questions 2 and/or 4, as appropriate. Question 5 also requires a written response. Feel free to use extra sheets or the back of these sheets if more space is required.

It would be helpful if you would provide the personal data requested below. The questionnaire is anonymous. Any product information you provide will be treated as confidential.

Thank you very much.

Age: _______ Sex: M F

Years of motorcycle street riding experience: _______

Approximate number of street miles ridden in 1980: _______

About what percent of these miles were ridden at night? _______

Have you ever owned or had substantial street riding experience (more than a thousand miles) on any of the following?

	Yes	No
Moped	☐	☐
Motorcycles:		
Less then 300 cc?	☐	☐
300 cc to 699 cc?	☐	☐
700 cc or more?	☐	☐

What make and model of motorcycle do you now ride most of the time? (If you divide your riding among two or more motorcycles, please list all that you have ridden at least 500 miles during 1980.)

Please go on to the questions on the following pages.

1. Compare riding a motorcycle with driving a car at night. Do you feel that your visual needs are different in the two cases? In other words, do you need illumination in different places for best motorcycle operation than for best car operation?

Yes ☐ No ☐

2. If you answered "yes" to question 1, please describe briefly in the space below the place or places you think a good motorcycle headlighting system should illuminate which may not be adequately covered by automotive headlights.

3. In your own experience, have you encountered any motorcycle headlamps that you thought were either very good or very poor?

Yes ☐ No ☐

4. If you answered "yes" to question 3, please describe in the space below first, whether the headlamp or headlamps you are referring to were very good or very poor, and then what made them that way. If possible, describe the headlamp by manufacturer and model number.

5. Finally, please describe in the space below what you have found to be the main shortcomings (in terms of illumination) of motorcycle headlamps with which you are familiar.

APPENDIX B

SUBJECTIVE EVALUATION OF MOTORCYCLE HEADLAMPS FORMS

SUBJECT #: ____________________

HEADLAMP: ____________________

ORDER #: ____________________

DATE: ______________________

Attached to this form is a rating sheet which you will use to evaluate the headlamps you will be using tonight. Ratings will be made using a 7-point scale as follows:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

For each statement on the following sheet enter the number which best indicates your rating of both high and low beams from this headlamp.

Before starting out, check the items on the form to find out what kind of things you should be looking for while riding. If you have any questions, ask the experimenter before you start out.

Rating form for mopeds.

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

	Low Beam	High Beam
1. Overall - unlighted areas	☐	☐
2. Overall - lighted areas	☐	☐
3. Visibility down the road	☐	☐
4. Visibility to the right	☐	☐
5. Visibility to the left	☐	☐
6. Visibility of signs	☐	☐
7. Visibility on right curves	☐	☐
8. Visibility on left curves	☐	☐
9. Visibility on hills	☐	☐
10. Foreground illumination	☐	☐
11. Beam distortion on sharp curves	☐	☐

SUBJECT #: ______________________

HEADLAMP: ______________________

ORDER #: ______________________

DATE: __________________________

Attached to this form are three sheets, one each for the freeway, dark rural, and urban portions of the route you will be using. Ratings of each headlamp will be made for each portion of the route using a 7-point scale like the following:

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

For each statement on the following sheets enter the number which best indicates your rating of both high and low beams from this headlamp.

Before starting out, page through this form to find out what kind of things you should be looking for while riding. If you have any questions, ask the experimenter before you start out.

Rating form for motorcycles.

FREEWAY

1 Very Poor	2	3	4 Just Acceptable	5	6	7 Excellent

	Low Beam	High Beam
1. Overall	☐	☐
2. Visibility down the road	☐	☐
3. Visibility to the right	☐	☐
4. Visibility to the left	☐	☐
5. Visibility of overhead signs	☐	☐
6. Visibility of roadside signs	☐	☐
7. Visibility on right curves	☐	☐
8. Visibility of left curves	☐	☐
9. Foreground illumination	☐	☐

Comments: ____

____

____

____

DARK RURAL

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

	Low Beam	High Beam
1. Overall	☐	☐
2. Visibility down the road	☐	☐
3. Visibility to the right	☐	☐
4. Visibility to the left	☐	☐
5. Visibility of signs	☐	☐
6. Visibility on right curves	☐	☐
7. Visibility on left curves	☐	☐
8. Visibility on hills	☐	☐
9. Beam distortion on sharp turns	☐	☐
10. Foreground illumination	☐	☐

Comments: ____

____

____

____

URBAN

1	2	3	4	5	6	7
Very Poor			Just Acceptable			Excellent

	Low Beam	High Beam
1. Overall - lighted areas	☐	☐
2. Overall - unlighted areas	☐	☐
3. Visibility to the right	☐	☐
4. Visibility to the left	☐	☐
5. Visibility of signs	☐	☐
6. Visibility on right curves	☐	☐
7. Visibility on left curves	☐	☐
8. Visibility on hills	☐	☐
9. Beam distortion on sharp turns	☐	☐
10. Foreground illumination	☐	☐

Comments: ______________________________

____

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____

APPENDIX C

FIELD EVALUATION OF MOTORCYCLE AND MOPED HEADLAMPS

SUBJECT INSTRUCTIONS

INSTRUCTIONS - MOTORCYCLE FIELD STUDY

This is a study of certain problems motorcyclists have in seeing and responding to potential hazards while riding at night. By "potential hazards" I mean objects or conditions which are sufficiently near the road so that some drifting from your normal track on your part or some movement on their part could cause serious trouble. Examples are pot holes, junk in the road, animals, pedestrians, and parked or crossing cars which may pull out in front of you.

In this exploratory study we are trying to find out how readily motorcyclists can see potential hazards under normal riding conditions.
All you have to do is ride this motorcycle over a series of roads which I will describe to you shortly. Try to maintain a speed around 43 miles per hour. Each time you see an object or condition such as I have described press the button located under the left handgrip. Just press it once, firmly, and release. That's all you have to do until some other potential hazard appears.

The route we are using is about 40 miles long, and we will run it in several segments. At the start of each segment I will describe the route to you. When you come to the end, stop and we will talk about the next section. Throughout the test I will be following about 100 feet behind you in that green station wagon.

Several cautions:

First, you can accelerate much faster than we can, so when you start off take it easy, so we can keep up.

Second, we would like to stay as isolated from other traffic as possible. So, when you turn onto another road, make sure there are no vehicles in sight who will be going in the same direction as we are. If there are, allow them to get well ahead of us before continuing.

Third, if it becomes necessary for us to stop at any point along the route,we will try to get your attention by flashing our headlamps. If this occurs, you should pull over to the shoulder and stop as soon as it is safe to do so. If there is any question as to whether a turn is required at a particular intersection, you should check our turn signals.

Finally, you should use the low beam at all times. Please do not switch to the high beam.

Once again, when you see a "potential hazard"; pot holes, junk on the road, animals, pedestrians, and parked or crossing cars, quickly press the button located under the left handgrip.

Any questions?

INSTRUCTIONS - MOPED FIELD STUDY

This is a study of certain problems riders of mopeds have in seeing and responding to potential hazards while riding at night. By "potential hazards" I mean objects or conditions which are sufficiently near the road so that some drifting from your normal track on your part or some movement on their part could cause serious trouble. Examples are pot holes, junk in the road, animals, pedestrians, and parked or crossing cars which may pull out in front of you.

In this exploratory study we are trying to find out how readily riders of mopeds can see potential hazards under normal riding conditions. All you have to do is ride this moped over a series of roads which I will describe to you shortly. Try to run at or near maximum speed (20 or 25 mph). Each time you see an object or condition such as I have described press the button located above the left handgrip. Just press it once, firmly, and release. That's all you have to do until some other potential hazard appears.

The route we are using is about six miles long. It is split into two segments and we will travel through the entire course several times. At the start of each segment I will describe the route to you. When you come to the end, stop and we will talk about the next section. Throughout the test I will be following about 100 feet behind you in that green station wagon.

<u>Some cautions</u>:

First, we would like to stay as isolated from other traffic as possible. So, when you turn onto another road, try to make sure there are no vehicles in sight who will be going in the same direction as we are. If there are, allow them to get well ahead of us before continuing.

Second, if it becomes necessary for us to stop at any point along the route, we will try to get your attention by flashing our headlamps. If this occurs, you should pull over to the shoulder and stop as soon as it is safe to do so. If there is any question as to whether a turn is required at a particular intersection, you should check our turn signals.

Third, above all, be careful. We will be running on public streets and almost all cars you see will <u>not</u> be part of our test. Treat them as you would any cars, that is with caution.

Any questions?