SEEING ON THE HIGHWAY

RECENT RESEARCHES ON LIGHTING REQUIREMENTS

By Kirk M Reid, *Illuminating Engineer*
Nela Park Engineering Department, General Electric Company

SYNOPSIS

Since 1930 there has been a 32 per cent increase in night traffic fatalities, whereas deaths during the daytime have decreased 4 per cent A substantial majority of night accidents on rural highways occurs on a very small percentage of the total highway mileage

Poor visibility has proved to be one of the most important single factors in the abnormal hazard at night Experience indicates that on urban streets and on the more dangerous portions of highways, improved illumination has reduced night accidents one-third to one-half, at a cost less than one-third of the losses from the accidents prevented by the lighting The available data suggest the desirability of obtaining larger scale experience for the more complete analysis of the effect of lighting upon night accidents and traffic volume on heavily traveled and hazardous highways

Extensive researches have for the first time given us the instruments and technique for measuring the end-product, visibility, as affected by color of light, glare, light distribution, pavement brightness, and obstacle brightness Startling advances have come about in light sources and their control to provide the maximum seeing and safety per dollar of total cost

On a very high percentage of the highway mileage the lower traffic density and accident experience indicate that fixed lighting would be uneconomic On these roads more adequate motor car headlights and their proper use will have to be depended upon for better visibility at night New data have recently been added to the available knowledge of the relation between visibility distance and headlamp beam candlepower under typical driving conditions Measurements have been made of the effect upon visibility distance of variations in speed, glare, and reflection factor of obstacles Of particular significance are data obtained with observers unaware of the fact that they were engaged in a test, providing for the first time quantitative information on the effect of the driver-attention factor

The alarming growth in traffic fatalities is an after-dark increment Analysis recently made by the National Safety Council reveals that since 1930 night fatalities throughout the United States have increased 32 per cent as compared with a 4 per cent decrease in day fatalities At night, with only about one-quarter of the total 24-hour traffic on the road, 60 per cent of the traffic fatalities take place This means that the average fatality rate per vehicle mile at night is well over four times that by day On the more hazardous stretches of highway the differential is much greater The urgent problem, then, is to reduce the abnormal and rapidly increasing night hazard

Information on the causes of traffic accidents is becoming more specific Poor visibility has proved to be one of the most important single factors in the abnormal proportion of night accidents Other factors, such as fatigue, drinking, carelessness, all play an appreciable part in the greater hazard at night, but darkness—lack of adequate visibility—is the major difference in the night condition Good visibility mitigates even the effects of the other factors named

This conclusion is based upon extensive experience on urban streets and main highways where variations in illumination—and visibility—have permitted studies of the effect of this factor On these streets and highways, analyses of accidents in relation to the visibility provided have been made by insurance companies, by safety organizations, and by city and state officials

Many of these analyses have been presented at your annual meetings or have been published in your "Highway Research Abstracts" For example, Schrenk (1)* reported a doubling of the ratio of night to day fatalities when the Detroit thoroughfare lighting was cut one-third, followed later by a proportionate decrease in night accidents when the lighting was again improved Schrenk has just issued his latest findings (2) on 31 miles of Detroit thoroughfares where through modernized illumination the night fatalities over an eight-month interval have been reduced to one-fifth of the former rate Specifically, this means that there are now some 28 people who are alive and going about their daily pursuits who, by all reasonable computation, would be dead if the visibility had not been improved on those Detroit streets This striking reduction in fatalities—at the rate of some 40 lives a year on only a limited mileage of Detroit's thoroughfares—is something to give pause to anyone who may doubt the primary effectiveness of good seeing in safeguarding traffic

Vey has reported experience (3) on main New Jersey highways where the night accident rate on lighted sections was only one-third that on adjacent unlighted sections Other analyses have been published by such organizations as the Travelers Insurance Company (4) and the National Bureau of Casualty and Surety Underwriters (5, 6)

These studies have shown that one-third, one-half, and often more of the night accidents are prevented where reasonably good visibility is provided On urban streets and on those portions of highways with high night-accident experience, the cost of providing good visibility by means of modern street and highway lighting has been found to be less than one-third of the losses from the accidents prevented by the lighting (4, 5, 6)

Mr T H. MacDonald, Chief of the Bureau of Public Roads, has pointed out the importance of developing the revenues derived from the "earning roads" If good illumination—through greater safety and comfort—increases the traffic on a main highway only a small percentage, the taxes on the increased use of gasoline will pay a substantial part or all of the lighting cost Where the increased revenue exceeds the lighting cost —a reasonable expectation on many highways—there is a net cash profit, in addition to the above-mentioned dividends accruing through conservation of life, limb, and property. These considerations suggest the desirability of obtaining larger scale experience for the more complete analysis of the effect of fixed lighting upon night accidents and traffic flow on heavily traveled and hazardous highways

The problem of providing safe seeing on streets and highways is being attacked on two fronts—fixed street and highway lighting, and automobile headlighting The latter will, of course, always have to be depended upon for by far the greater part of the road mileage On city streets, due weight should be given to the requirements of pedestrians not only from the point of view of safety but also from the point of view of convenience and comfort in the use of the public ways

FACTORS OF SAFETY IN SEEING

In the development of both methods of lighting, knowledge is first of all needed of the illumination required for safe seeing And then we need to know something about requisite factors of safety to insure quick, certain seeing while driving Factors of safety are incorporated in the design of all other parts

* Figures in parentheses refer to list of references at end

of the car and highway. Unfortunately, few people have had a sufficient knowledge of the science of seeing to appreciate the elements that make factors of safety in visibility imperative under actual conditions of driving at night.

A factor of safety of 1 in visibility might be defined as the illumination which, under favorable conditions of road and weather, enables an observer—stationary, with normal eyesight, and at fixed attention—barely to see, at a safe distance away, an obstacle which he knows is there. Contrast these ideal conditions with those actually obtaining in seeing on a highway. In the first place

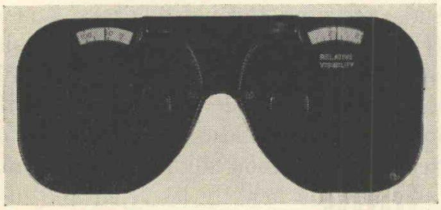

Figure 1. The Luckiesh-Moss Visibility Meter permits for the first time quantitative measurements of the end-product sought-visibility.

it takes time to see. Therefore with the car in motion one first sees an obstacle at a shorter distance than when standing still. Driving a car, it has been found, is not an automatic operation; it uses up part of the driver's sense capacity and thereby reduces his ability to see. As the speed increases, more sense capacity is used up in driving and the less he can see—and also the time element in seeing becomes more important. External factors—engine noise, radio, conversation, scenery—reduce the distance at which hazards are recognized. So do internal factors, such as preoccupation, inattention, and fatigue. The driver's eyesight may not be normal. Weather and road conditions may not be favorable. Nearly always an obstacle on the highway is not expected; it takes one by surprise.

Because seeing is such a complex physiological and psychological function, any considerable body of quantitative information directly applicable to the problem of safe driving has only recently become available. There had been a lack of instruments and techniques adequate for such quantitative measurements. Fortunately we now have them and are getting really significant data. Reference will be made later to some of these studies.

RESEARCHES IN HIGHWAY LIGHTING

Of the night accidents on rural highways, samplings show that a substantial majority occurs on a very small percentage of the total highway mileage. On these main highways, as on city thoroughfares, the traffic conditions are such that fixed highway lighting offers the most practical and effective means of providing safe seeing.

The possibilities of this approach to traffic safety have until recently had little attention from highway and safety organizations. This is not surprising because it is only within the last few years that there has been an adequate scientific and technical basis for a rational development of lighting for main highways.

The new instruments and techniques for measuring the end-product, visibility—as affected by color of light, glare, light distribution, pavement brightness, and obstacle brightness are themselves products of extensive researches. For example, the Luckiesh-Moss Visibility Meter (Fig. 1) now makes possible quantitative measurement of visibility. The Luckiesh-Taylor brightness meter (Fig. 2)—a telescopic photometer with highly restricted field—permits, for the first time, measurement of the brightness of limited areas of pavement at the grazing angles at which a roadway is viewed by a motorist. We are also using the Holst-Bouma meter, recently developed by the

Philips Laboratories in Holland, for measuring minimum perceptible brightness contrasts.

Recent years have made available new light sources, and marked improvements in former sources. Developments on streets and highways so as to achieve greatest value to the public—that is, maximum seeing per dollar of cost.

So several years ago we undertook to attack this whole problem of highway seeing really fundamentally. Our first

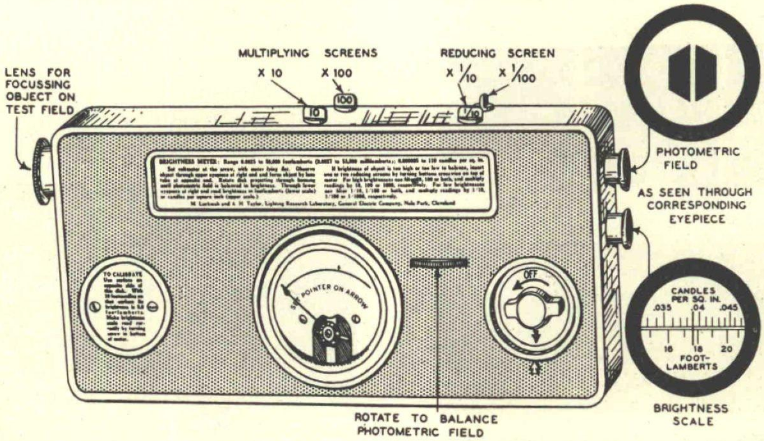

Figure 2. The Luckiesh-Taylor Brightness Meter has a magnified and restricted field ideal for measurement of the brightness of small pavement areas at grazing angles of viewing

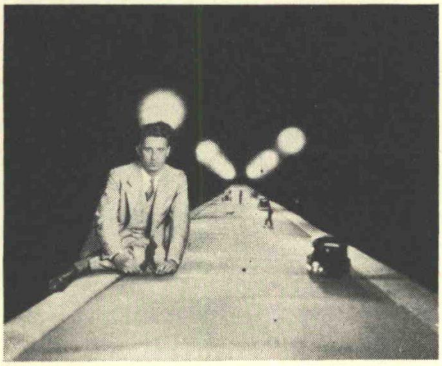

Figure 3. This realistic and flexible Laboratory Test Model Highway was employed in studies of fundamentals of street and highway illumination.

of new materials and new processes of fabrication have extended former limitations in light control and luminaire design. It was important to find out the relative merits of the new sources from the standpoint of safe seeing. It was important to find out how to utilize light

studies (Fig. 3) were conducted on an elaborate one-eighth scale test-model highway whose actual length was 250 ft. Through the flexibility and accuracy of this large scale model, researches (7) were completed in one year which would have required over ten years if conducted on actual streets.

Measurements were made of visibility (Fig. 4) with lighting systems employing sodium-vapor, mercury-vapor, and incandescent lamps. It was found that for equal amounts of light, equally distributed, one cannot see obstacles any sooner or any farther away with one color of light as compared with others.

An exploration of methods of discernment (Fig. 5) revealed that at four out of five locations on a lighted highway obstacles are seen chiefly as silhouettes—that is, darker rather than lighter than the pavement background. Therefore, it is important to have substantial uniformity of pavement brightness, because one cannot silhouette a dark object against a dark area of pavement.

We found that glare from representative lighting systems may waste as much as half of the illumination provided, insofar as its seeing value is concerned. That is certainly not good engineering.

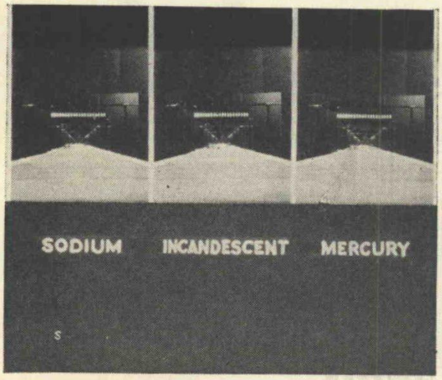

Figure 4. For equal amounts of light, equally distributed, these spectral qualities of light were found not to affect safe visibility.

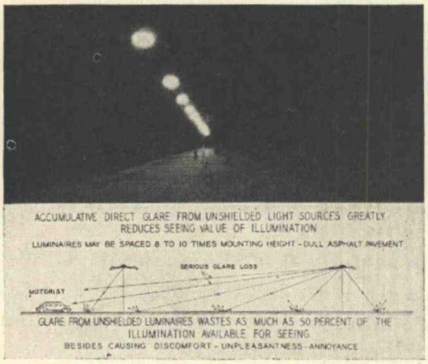

Figure 5. Glare from representative former lighting systems may waste half the illumination insofar as its seeing value is concerned.

"Spotty" lighting effects (Fig. 6) have been all too common. Contrary to popular impression, uniform illumination does not eliminate spottiness. This is what a uniformly lighted road looks like—to the driver of a car, not to an aviator. The model highway offered an opportunity (Fig. 7) for experiments in light distribution to produce the desired results of uniform pavement brightness.

Our researches have not been confined to the laboratory (Fig. 8). Measurements of visibility and related factors (8) have been made on streets and highways having various lighting systems.

Further studies, of a particularly comprehensive nature, are now nearing completion. Measurements are being made of the candlepower from luminaires vari-

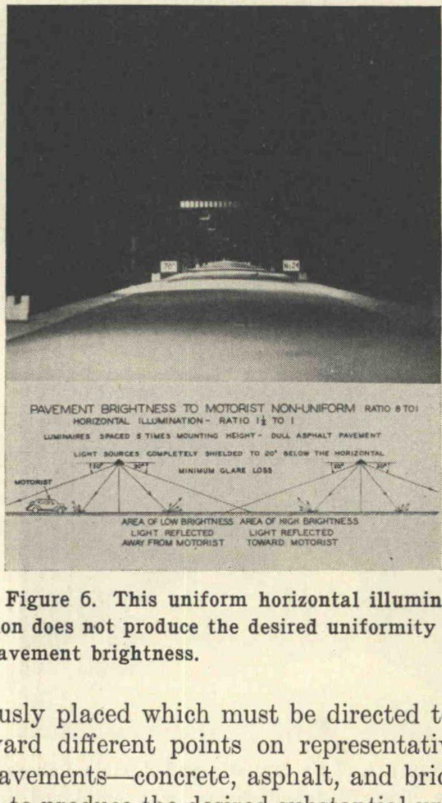

Figure 6. This uniform horizontal illumination does not produce the desired uniformity of pavement brightness.

ously placed which must be directed toward different points on representative pavements—concrete, asphalt, and brick—to produce the desired substantial uniformity of pavement brightness. Measurements are also being made of visibility of obstacle and pavement as affected by variations in pavement brightness, in obstacle brightness, and in glare.

These studies have influenced the design of modern luminaires for streets and highways. One by-product has been the development of the new High-Visibility luminaire (Fig. 9) for two and three-lane highways. It employs a new type of incandescent lamp, admirably

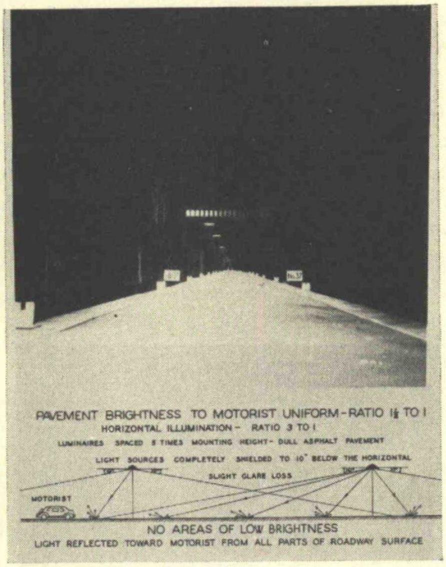

Figure 7. Obstacles are seen as silhouettes at 80 per cent of the locations on a lighted roadway; uniformity of pavement brightness is therefore of first importance.

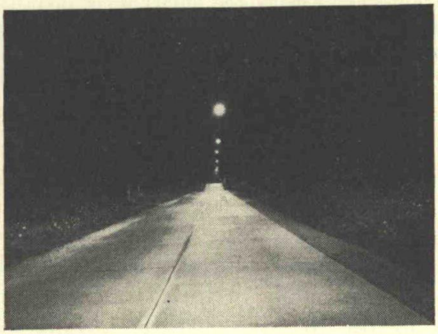

Figure 8. Measurements of visibility and related factors have been made on lighted streets and highways, as well as in the laboratory.

suited both mechanically and optically for road illumination. This lighting system (Fig. 10) has three outstanding features:

1. The proportion of light reaching the pavement is two to three times as great as that with former equipments.
2. Glare is suppressed by shielding the light source to approximately 10 degrees below the horizontal.
3. The road surface presents an altogether higher order of uniformity of brightness.

Through these gains in effectiveness, the seeing and safety obtained on the nar-

Figure 9. A direct result of researches in highway seeing is the new High-Visibility luminaire and improved incandescent lamp employed with it.

rower highways could have been equalled under past systems only by providing four or five times as much generated light.

The features of the sodium lamp (Fig. 11) were reported by Loewe (9) at the 1933 meeting. Because of its high efficiency of light production and the necessarily broad distribution of light from the large source, this lamp is particularly effective on the wider highways. It might be of interest that there are now over 5,000 of these in service in this country, for the most part on main highways and bridges. Two of the largest recent installations are on the Golden Gate Bridge and the San Francisco-Oakland Bay Bridge (Fig. 12).

Figure 10. High-Visibility incandescent lighting system near Albany. The seeing and safety provided by this type of lighting on 2- and 3-lane roads is greater than that from any other light source or lighting system now employed.

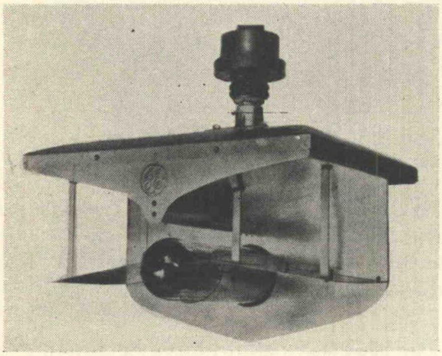

Figure 11. The new sodium-vapor lamp and luminaire. This lamp, because of its high luminous efficiency and its inherently broad distribution of light, is particularly effective on wide highways.

RESEARCHES IN AUTOMOBILE HEAD-LIGHTING

On a very high percentage of the highway mileage the lower traffic density and accident experience indicate that fixed highway lighting would be uneconomic. On these roads, as well as on many urban streets, more adequate motor car headlights and their proper use will have to be depended upon for better visibility at night.

New data have recently been added to the available knowledge of the relation between visibility distance and headlamp beam candlepower under typical driving conditions. Measurements have been made by Roper and Howard (10) of the effect upon visibility distance of variations in speed, glare, and reflection factor of obstacles.

Of particular significance are data (Fig. 13) obtained with observers un-

Figure 12. Among the outstanding installations of sodium lighting are the two new bridges at San Francisco.

aware of the fact that they were engaged in a test, providing for the first time quantitative information on the effect of the driver-attention factor. The data indicate that the average driver perceives the unexpected obstacle only half as far away as he sees the expected one. All of the drivers saw the unexpected obstacle at least 20 per cent as far as the expected obstacle, whereas none saw it at more than 80 per cent of the distance. Over two-thirds of the observers were grouped within a range of 40 to 60 per cent, and the over-all average is 51 per cent. The lower values indicate less than average attention, while the higher ratios indicate unusual attention or a chance fixing of the eye on the location of the obstacle at the critical time These data reveal that a seeing factor of safety of at least 2, and more logically 5, is required through variations in driver-attention alone Here is a guide to the practical adaptation of data obtained in the usual manner—that is, by observers who know they are taking part in a test of visibility distance

Figure 14 shows the relation, for several driving speeds, of beam candlepower to visibility distance for a dark obstacle Perception distance increases very rapidly for the first few thousand candlepower, but more slowly at the higher values The variation of visibility with candlepower as found in these tests is a straight-line relation between the logarithms of the two variables This conforms to the well established fact that the visual sensation—seeing—increases proportionately to the logarithm of the stimulus—illumination

These tests show a definite decrease in perception distance with increasing car speeds As would be expected, the spread among observers and among the determinations of a given observer was rather large But higher speeds always resulted in decreased visibility distance—for it does take time to see The over-all average shows a 20-ft loss in visibility distance for each increment of 10 miles per hour in speed, for observer-drivers not expecting the obstacle This loss, so far as these tests go, applies irrespective of beam candlepower and reflection values

Of course, in the case of light-colored objects, seeing distances increase materially Figure 15 shows the variation of visibility distance for obstacles of several reflection factors It is to be noted that visibility distance does not increase directly with reflectivity of the object, but more rapidly in the lower range than in the higher Changes in contrast or background and the angular size factor come in to affect the result

The type of road surface seems to have relatively little effect upon perception distance for an obstacle projecting above the road, though the road surface itself is visible for a greater distance ahead for the more diffuse, highly reflective surfaces such as concrete or crushed stone Under normal driving conditions, and with no light from behind the obstacle,

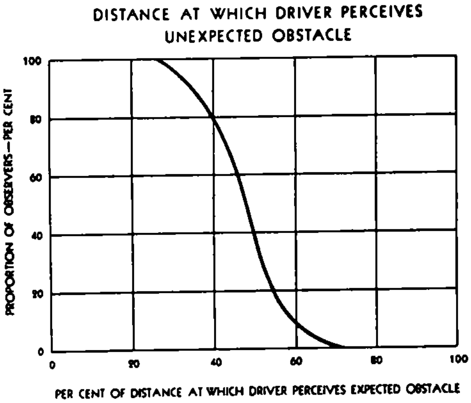

Figure 13 On the average, a driver perceives an unexpected obstacle only half as far away as he sees the expected one

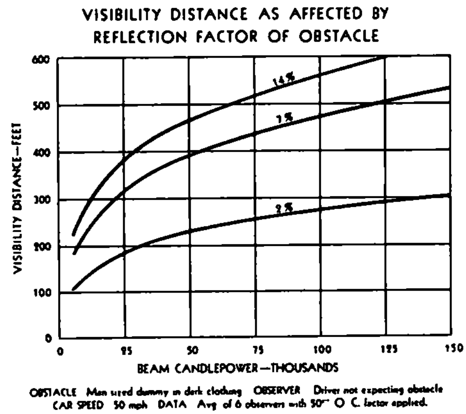

Figure 14 The distance at which a driver perceives an unexpected obstacle decreases about 20 feet for each increment of 10 miles per hour in speed

the driver sees the unexpected obstacle in almost every instance by reflected light and contrasted with a darker background, even when the obstacle has a very low reflection factor and the road surface is light It was observed that when the driver knows that he will encounter an obstacle, he will frequently "pick up" the dark obstacle while it still appears darker than the background This change in the method of discernment accounts for greater spread in test results with dark obstacles, since the

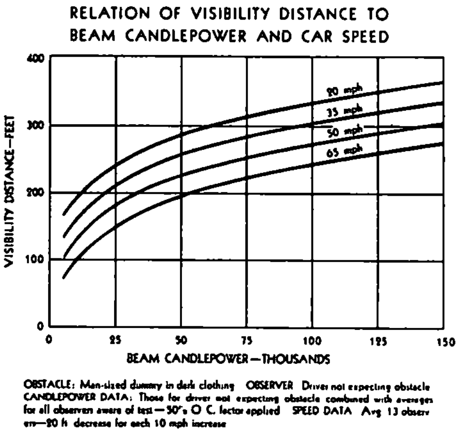

Figure 15 For a given beam candlepower, dark-colored obstacles are seen only about half as far away as light-colored obstacles

range of distance through which low contrast obtains is a considerable one

The tests confirm the conclusions of careful observers that, contrary to popular assumption, perception distances for obstacles projecting above the road are not reduced when the road surface becomes wet, even though the visibility of the road is radically reduced This is logical in the light of the test results reported in the above paragraph Furthermore, while wetting may in some instances reduce the reflectivity of the obstacle, the more specular wet road surface will reflect more light to the obstacle

Figure 16 presents the relation of perception distance to that required for stopping a car travelling at 50 mph Results are given for four values of beam candlepower The value of 20,000 beam candlepower is equal to or more than the average for headlamps found in service, 50,000 beam candlepower is the initial value for which most headlights have been designed in recent years, 75,000 beam candlepower is the maximum specified in the Uniform Code The stopping distance used in the chart is that published by the National Safety Council and applies to average driver reaction

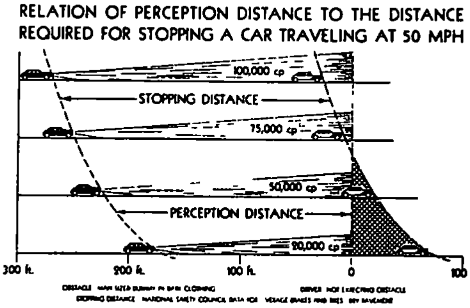

Figure 16 Under average conditions, about 75,000 candlepower in the driving beam is needed for bare seeing at a distance to insure safety This includes no factor of safety for unfavorable conditions of road, car, or driver

time, average brakes and tires, and to smooth dry pavements

This chart shows that about 75,000 candlepower is needed, on the average, for bare seeing at a distance to insure safety It must be kept in mind that the data apply to average people, cars and road conditions There is no factor of safety whatsoever for impaired vision, older eyes, unfavorable atmosphere, abnormal distractions or inattention, fatigue, slippery roads, subnormal voltage, or brakes below par

It is well known that glare from approaching headlamps materially reduces visibility, and should be compensated for in the design of the meeting beam When an object is between the driver and approaching headlamps, it is usually fairly well revealed in silhouette against either the bright road surface or the headlamps themselves The most critical condition is that of an obstacle which moves onto the road after the approaching car has passed that location, in which case it must be discerned by reflected light In the Roper-Howard study, data applying to that condition are consistent with those reported by Moon and Warring (11) The average results of a series of tests with eight observers are shown in Figure 17 The candlepower of the headlamps illuminating the obstacle appears to have little effect upon the percentage by which glare reduces the visibility distance Roper and Howard expect to extend their testing in this aspect of the problem

It is apparent that visibility is reduced very rapidly for the first few hundred candlepower toward the eye, but walls off less rapidly as candlepower is further increased One thousand candlepower directed toward the driver is about the value from the well-adjusted lower or meeting beam of modern head-lamps It is seen to reduce the perception distance roughly one-third Seven thousand candlepower reduces the distance by about two-thirds

These glare data were obtained with a dark dummy placed behind the approaching car and at a lateral distance of 10 feet to the right of its headlamps If the obstacle is nearer the glare source, perception distances are still further reduced The location selected is, however, the most typical

You will have observed that the foregoing seeing data reveal the inadequacy of present headlighting for drivers observing moderate and legal speeds It is clear that under existing headlamp regulations motorists cannot always see with safety on unlighted streets or highways This fact accounts for the recent recommendation of the Eastern Conference of Motor Vehicle Administrators—already in effect in some states—that legal speed limits be lower at night than by day It is disturbing to consider what influence this might have (if enforced) in reducing the night traffic and therefore the revenue derived from the "earning roads", and also what effect it might have in diverting traffic from night to day, thereby adding to the present daytime congestion It is heartening, however, to

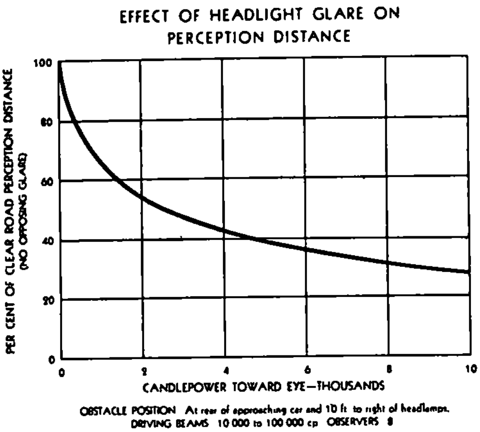

Figure 17. The decrease in perception distance due to glare from oncoming headlamps emphasizes the importance of using the depressed or meeting beams when meeting other cars

find the data indicating unmistakably that an adjustment in the terms of the headlamp regulations now imposed on the car manufacturers, undertaken in the light of the more complete knowledge, would permit them to make a very important contribution to the safety of night motoring

The car and headlamp manufacturers are now cooperating as a unit in the development of a superior system of headlighting They are coordinating their researches, and are taking other measures necessary to eliminate obstacles which might interfere with the broad program of providing safe lighting While still in its earlier stages, this program gives promise of an important contribution to traffic safety

In order to make a definite gain in safety there must be a radical forward step in headlighting The objectives of headlamp performance are clearly shown by the new knowledge of the requirements Driving beam candlepowers must be materially greater than at present, and the high-intensity portion of the beam must cover a wider spread The passing beam must direct very much more light at the right edge of the road, as Dickinson (12) and others have urged, it will then afford such obviously superior seeing when meeting other cars that the driver will choose to turn to it for his own protection as well as that of the approaching driver Means are being developed for more exact light control, which should be utilized in any new headlighting system instead of accepting compromises in beam patterns as in the past With the cooperation of all concerned it is possible to take the major step of providing headlighting which furnishes safe seeing initially and with maintained effectiveness

REFERENCES

1 L J Schrenk "Relation of Lighting to Traffic Safety," *Highway Research Abstracts* No 35, November, 1936, p 4

2 L J Schrenk "Saving Lives With Light" Convention of the Illuminating Engineering Society, October, 1937

3 Arnold Vey "Highway Lighting and Accidents" *Proceedings*, Highway Research Board Vol 14 p 429 (1934)

4 "The Life-Preserving Role of Good Street Lighting" *The Travelers Standard*, September 1933

5 R E Simpson "Public Safety as Affected by Street Lighting," National Bureau of Casualty and Surety Underwriters December, 1934

6 R E Simpson, "Highway Lighting and Public Safety" National Bureau of Casualty and Surety Underwriters, September, 1936

7 Kirk M Reid and H J Chanon, "Studies in Street and Highway Illumination," *General Electric Review*, November and December 1935 and March, 1936

8 Kirk M Reid and H J Chanon "Determination of Visibility on Lighted Highways," *Transactions*, Illuminating Engineering Society, February, 1937, p 187

9 A F Loewe, "Highway Lighting Research," *Proceedings*, Highway Research Board Vol 13, p 244 (1933)

10 V J Roper and E A Howard "Seeing With Motor Car Headlamps" Convention of the Illuminating Engineering Society, October, 1937

11 Parry Moon and R C Waring, "Some Visibility Tests on Lighted and Unlighted Highways," *The Journal of the Franklin Institute*, March, 1935, p 285

12 H C Dickinson, "Report on Vehicle and Headlight Mechanics as Related to Traffic," *Proceedings*, Highway Research Board, Vol 11, p 388 (1931)

DISCUSSION ON HIGHWAY LIGHTING

Dr H C Dickinson, *National Bureau of Standards* There is one point that I would emphasize—that is the need of more roadside illumination when one is using the medium or depressed beam We do not want bright roadside illumination when using the driving beam because that will detract from the visibility On the other hand, we do need roadside illumination when meeting other cars or making sharp turns

Such roadside illumination is incompatible with the means now used for going from one beam to another It can not be secured with two headlights which are alike—using two filaments in the same bulb and shifting from one filament to the other by a switch, that will require some other device We have not done anything experimentally By using two headlights which are not alike it is possible to get that kind of light beam However, that is not a very good solution

I hope in this program of research going on, that the companies will succeed in developing lights which will give adequate roadside illumination—that is, a spread of at least 100° when using the depressed beam and of at least 20 or 25° when using the driving beam.

CHAIRMAN MORRISON: I wonder if Mr. Reid will say something about street lighting. All the talks I have heard refer to rural highways. The streets of most cities are inefficiently and inadequately lighted. Is there any suggestion you can make about that?

MR. REID: The research findings reported in my paper have been embodied in modern lighting equipments for urban streets. These equipments are capable of providing adequate visibility for safety at moderate cost. The authoritative guide to proper installation practice is the Illuminating Engineering Society's Code of Street Lighting.

The Detroit experience is striking evidence of what can be accomplished with modern lighting equipments, properly applied. On many of the Detroit streets where the lighting was improved, there was no increase in the number or wattage of the lamps employed. The only change was replacement of obsolete by modern equipments, at adequate mounting heights and transverse positions. Yet the amount of light on the street was more than tripled by this change in equipment.

In many cases, of course, it is not possible to correct inadequate illumination so simply. Where the lamp size is too small or the mounting height is too low or the lamp spacing is too great, these basic deficiencies must be corrected in order to obtain safe visibility for night traffic.

The major street lighting problem, in my opinion, is no longer one of engineering. Efficient luminaires are available, and the requirements of proper installation are known. The problem is to arouse the public to a realization that adequate street illumination is an essential factor in night traffic safety, and that poor street lighting (with its preventable accidents and crime) really costs at least three times as much as good lighting.

Most municipal officials understand the value of good lighting and would like to provide it. But they are reluctant to spend the necessary money without assurance of the public approval.

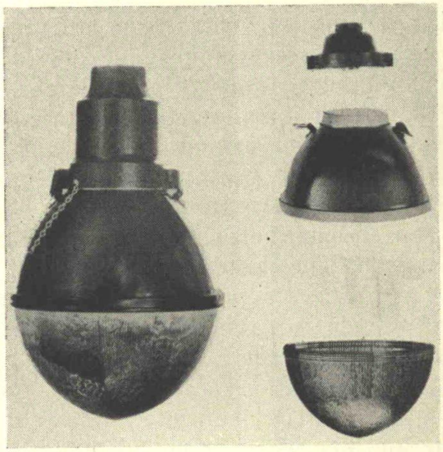

Figure 18. Research findings are embodied in this new and radically improved luminaire for street lighting.

Progressive officials—in Detroit, Syracuse, Akron, Troy, Hornell, Lynn, and other municipalities—have found an effective solution. They have selected those streets or portions of streets having the worst night-accident record and have lighted them adequately as "safety demonstrations". The first-hand observation and the invariable reduction in night hazard have crystallized public support of further lighting improvements needed.

CHAIRMAN MORRISON: I am thinking of an intersection where there have been a number of pedestrian fatalities and injuries. There were four light standards, one on each corner, and each had five lights A hundred feet away in every direction there was another one They were like so many Christmas trees—all kinds of illumination—but not on the pavement Is not a boulevard system of lighting inefficient so far as safety is concerned? It is all right to make a pretty picture, but what about safety?

MR REID Professor Morrison asks about the five-lamp clusters This is an ineffective and inefficient type of lighting equipment introduced during the early years of the century, when the 100-watt vacuum type was the largest practical incandescent lamp The development of the gas-filled type of lamp, in 1913, permitted manufacture of lamps of greater light output and of much higher efficiency Improved luminaire designs followed, with the result that the ball cluster became obsolete some twenty years ago The cluster served to give the street a festive appearance, but it cannot provide safe visibility for modern conditions of traffic

The illumination of intersections for pedestrian safety is an interesting problem, and one which is not as simple as it appears at first thought It is logical, of course, to provide more light at intersections than between intersections, and the Code of Street Lighting so recommends But if the street areas between intersections are poorly illuminated, even though the intersections themselves are quite well lighted, the pedestrian hazard at the intersections is usually found to be abnormally high

The reason for this situation is that obstacles on a roadway are seen predominantly as silhouettes—that is, as darker than the pavement beyond If the mid-block pavement areas are dark, this important silhouette method of discernment of obstacles at the intersections is largely lost The conclusion is that for pedestrian protection the entire street length should be lighted adequately, with somewhat increased illumination at the intersections It might be noted that the visibility requirements for vehicular safety are the same

The sodium-vapor lamp has two features which suggest that it may prove particularly valuable for use at such points as railroad grade crossings and dangerous intersections, both rural and urban First, the sodium lamp can be made successfully only in the larger sizes, which means that wherever it is used there will be a substantial amount of light Second, the light from the sodium lamp has a characteristic yellow-orange color which one associates instinctively with caution Installations now in service in several states—on railroad crossings and dangerous intersections—will probably permit evaluation of the practical effectiveness of these features

DR. A R LAUER, *of Iowa State College* I would like to ask several questions about highway lighting

(1) How much light, measured in footcandles, is needed?

(2) How much does it cost to light a mile of highway?

(3) After driving under sodium lighting for an hour, would not the adaption of the eyes to the yellow-orange color destroy the value of the caution feature?

(4) Is not the monochromatic color of sodium light fatiguing to the eyes?

(5) Does not the greater cost of the sodium lamps fully offset the saving due to their lower wattage?

MR REID· I shall try to answer Dr Lauer's questions in the order asked

(1) For pavements light in color, the Illuminating Engineering Society's Code of Highway Lighting calls for 0 2 to 0 5 lumens per square foot delivered on the pavement These values correspond to 0 2 to 0 5 footcandles, measured on a horizontal plane at the street surface For the darker pavements, the Code

recommends an increased amount of light

(2) The cost of lighting a highway varies rather widely with the conditions to be met Under average conditions, installation costs for a utilitarian system are usually in the range of $2,500 to $3,000 per mile; and operating costs, exclusive of investment charges, are usually in the range of $600 to $1,000 per mile per year

These costs are high enough to make it apparent that the place for lighting is on the heavily traveled and hazardous highways As stated in the paper, samplings have shown that a substantial majority of the rural night accidents occurs on a very small percentage of the total highway mileage On this limited mileage, studies by insurance organizations and highway departments indicate that the cost of good lighting is only about one-third the cost of the accidents prevented by the lighting

(3) After driving under sodium lighting continuously for an hour one's eyes would undoubtedly become so adapted that the light would appear to have lost its characteristic yellow-orange color to an appreciable extent This condition would not lessen the "caution" value of sodium for the lighting and marking of danger points along streets and highways where the great majority of the illumination is supplied by incandescent lamps

(4) Several tests have shown that monochromatic light has no disadvantage as regards eye-fatigue In one study, conducted by the Port of New York Authority, critical office work was performed for several weeks under sodium light, with no measurable effects upon the workers' eyes

(5) It is correct that the greater cost of the sodium lamps just about offsets the saving due to their lower wattage, for the average energy rates As production on the sodium lamp increases its cost will undoubtedly come down

For lighting highways the choice between illuminants depends largely upon the pavement width On wide roads the inherently broad distribution of light from the sodium lamp is particularly effective On the narrower roads the accurate control of light possible with the concentrated incandescent-lamp sources results in greater seeing per dollar of total cost On urban streets the color of the light from vapor sources is generally considered to limit their use to special conditions—such as dangerous intersections for sodium, and business areas for mercury in combination with incandescent lamps to modify the color.

PROF GREENSHIELDS: On city streets, the brightness and moving patterns of electric signs are often a handicap rather than a help to visibility for traffic safety In New York City, where the traffic signals are sometimes three blocks apart, confusion between traffic signals and colored signs is particularly serious What do you think is the best solution to this traffic signal problem?

MR REID Where a traffic signal is so located as to be viewed against an unfavorable background, its visibility can be improved by using a larger lamp or by putting an opaque shield a foot or more in width around the signal Good practice calls for signalization of each intersection where traffic control by signals is warranted

MR MAURICE HOLLAND, *Director of Engineering and Industrial Research, National Research Council* I would like to identify the major groups, social, economic or public, which are throwing hurdles in the way of what the highway engineer and the technician would like to do For example, where is the centre of economic interests in this whole job? Whether they like it or not, that would be the automobile industry itself At their last show the emphasis was on the technical subject of safety—having to do with the safety of steel body, safety glass, and things like that That is for the automobile population

Now about the poor old pedestrian The automobile industry, the Automobile Manufacturers Association, the Sloan Foundation, the insurance companies or some group who have a real interest in Mr and Mrs America walking around the streets, should give some encouragement and support, morally, politically or by pressure groups in municipalities, to put in force some of the recommendations which you have made

MR REID It is true that inadequate illumination takes its major toll, not among motorists, but among pedestrians on city streets and along main highways If the public will demonstrate a sincere desire for traffic safety, as you suggest, we can have it The requirements of safety are well known—proper judgment in driving and walking, rigid enforcement where needed, and provision of effective safety facilities (of which good lighting is one) The amount of expense involved is not great—undoubtedly less than the present accident cost But the public must show a real interest in safety

As to the lighting of heavily traveled and hazardous highways, there has been some opposition For the most part I believe the objections have come from groups which feared wholesale and unwarranted lighting of highways, or which have questioned whether the lighting of selected main highways is effective as a safety measure and economically sound Reliable data are limited, although more is known about the average cost of preventing an accident by lighting than by most of the other safety features of highways Larger scale experience is needed to settle any doubts of the value of properly applied highway lighting in reducing accidents and increasing traffic at night

MR V J BROWN, *Publishing Director, Roads and Streets* I have a lot of night driving to do and I notice one thing with respect to lighting that I think we are overlooking as highway engineers, and that is the wasted headlight value of our own cars on curves and on certain intersections As I drive around I have noticed that reflected light from certain types of roadside signs gives me as much value as the light of a street lamp, sometimes better, because the light so strikes the surface as to silhouette without the interference of the light source This reflected light can be gotten from our own headlights by the proper application of some kind of reflectors along the roadsides—take our own headlight beams and throw them back on to the road several hundred feet ahead of us

MR REID I am inclined to think the additional amount of light obtained on the pavement from such reflectors would be small Except where used in conjunction with guard rails, reflectors might interfere with shoulder development and maintenance Trial is being made in Michigan of a row of reflector buttons along a highway to mark the shoulder edge