USE OF POLARIZED HEADLIGHTS

Lewis W. Chubb, Jr., Research Engineer
Polaroid Corporation

If we can agree that night driving under present conditions is an uncomfortable and hazardous experience and can show that discomfort and hazard can be eliminated through the use of a technically perfected device which is not expensive in relation to the results achieved, there would then seem to be no reason why such a device should not come into immediate general use at least on all new cars.

Statistics on the percentage of night highway fatalities due to headlight glare are lacking. But statistics are available which show that more than half of the fatalities occur at night when less than half of the cars are on the road. Indeed, it appears that for the same mileage driven, one is 5 to 10 times as likely to be killed in a night accident as in a daylight accident. Admittedly, some of this can be attributed to drunken driving, fatigue, etc., but we are certainly justified in assuming that the major factor stems from the basic difference between day and night; namely, the presence or absence of overall illumination. Only insofar as the artificial lighting provided by one's headlamps can materially overcome the effect of nightfall—and do so uninterruptedly and particularly when other cars are being met—can one hope to reduce the night-time accident toll due to glare and restricted visibility.

Before discussing how a polarized headlight system may be used effectively, one should have a clear understanding of the shortcomings of the present system of automotive headlighting and of what modifications and additions to the present equipment are inherent in the new system.

Modern headlight installations, employing the Sealed Beam lamp, are highly standardized and their operation is quite uniformly specified throughout the country, although the enforcement of correct practice is lacking in many states. This refers principally to misuse of the headlights in situations where cars are meeting and passing on country highways. Misuse may result

from lack of knowledge of correct practice or from unwillingness on the part of the driver to respect the comfort of drivers he is meeting. Whatever the cause, both comfort and safety are compromised by misuse. Most state administrators, even those whose departments are not charged with execution of regulations, recognize that enforcement of proper practice in headlight use is among the factors which might arrest the alarmingly high toll of night accidents which, moreover, is taken during hours when people are disinclined to drive largely on account of the discomfort due to headlight misuse.

However, an examination of the ultimate capabilities of the present headlighting system reveals that, even with education and enforcement carried to a point where misuse would be exceptional rather than common, there would still be room for considerable improvement from the standpoints of both safety and comfort. For example, when two drivers meet at night they are expected to switch to their lower beams before they attain a specified minimum distance from one another. Their lower beams are so designed that on a level road, with proper headlamp aim and car loading, no more than 1000 glare candlepower reaches their eyes from the opposing lamps, whereas continuing on their upper beams would subject each to a glare candlepower many times as great. Actually the 1000 candlepower limit, which is often enough to reduce perception distance by 30%, is frequently exceeded due to road contour. But usually, through a simple operation (conventionally by foot-switch) each driver can substantially reduce the discomfort which he would otherwise cause the opposing driver. Neither driver however, can offer this relief from glare without penalty to himself, because in switching to his lower beam he redirects the light by which he sees to an area close at hand and leaves in nearly complete darkness that portion of his right of way extending beside and beyond the opposing car. At such times, unless the drivers slow down to less than 40 mph, they will be over-driving the perception distance and creating a hazard. It is well known that this precaution is seldom observed and that, beyond showing a slight increase in attentiveness, a driver only feels his way through the meeting situation by watching the edge of the road and the position of the opposing car, and by remembering what he saw of the roadway before he depressed his beam. Thus we see that the beam control principle

in modern headlighting merely effects a compromise by balancing barely tolerable glare against barely adequate seeing. It divides the hazard of blinding glare into these two other hazards. Beam control alone does not promise further improvement under conditions where each driver *needs* to put a powerful beam right where it will blind another.

Note that we have referred to glare in the above situation as something to be avoided by depressing our beams. Depressing reduces glare under some road conditions, to a point where it is not the major factor when cars are meeting at night. But something else becomes of great importance when we depress—a reduction in our ability to see as far ahead as we could if glare did not make it necessary to depress. This is a factor which may contribute to a far greater percentage of night accidents than does glare alone. Partly responsible for this is the fact that we do not realize that depressing makes it necessary to slow down to avoid overdriving our lights. As drivers, we are much less conscious of *this subtle effect* of depressing *our* beams than we are of the *obvious reduction in glare* of the oncoming lights when *they* are depressed for us.

Let us try to imagine an ideal situation for me as a night driver. Suppose that I were somehow privileged to drive on any highway at night, using my upper, country driving beam at all times—even when meeting other cars. Suppose, furthermore, that all cars I met were equipped to operate with very dim lights, only a fraction as bright as the conventional *lower* beam. I think you will all agree that I would be in an enviable position. No one could make me uncomfortable by glaring me, and my seeing would not be compromised by my having to depress my beam. My position would be one of unaccustomed comfort and safety. There *is* a system of headlighting which accomplishes just this result for everyone who drives at night—not just for me as the privileged driver. The basis of the system is light polarization.

I have here two pieces of light polarizing material. They are thin sheets of film like slightly darkened Cellophane. If I put one over the other with their grain running parallel, you can see right through them. But if I turn one like a wheel over the other, you can't see through them. They black out.

While polarized light can be a complicated subject, its ap-

plication to automotive headlighting is not complicated in principle, and, now that a complete operating installation has been developed, we find that the use of the system is simple to the point of being practically automatic. Its performance rests on the fundamental fact in physics that two polarizers with their axes parallel pass a substantial part of the light, whereas two polarizers with crossed axes block it out. The system utilizes polarizer material in two places on each equipped car: On the front of the headlights and before the eyes of the driver in the form of a viewer. All cars are equipped exactly alike with the axes of the material arranged so that in any one installation the driver's viewer is optically parallel to his headlight polarizers whereas between any two opposing installations, the drivers' viewers are optically crossed with the opposing headlight polarizers. The result of this arrangement is that each driver sees his roadway brightly illuminated but receives no glare from the opposing lamps, which appear as faintly blue disks. This offers the only known practical system which will eventually put an end to the use of lower beams when cars meet on the country highway. It permits any driver to maintain the same level of illumination far down the roadway beside and beyond an approaching car as is maintained today only when the road ahead is clear. It accomplishes this without any blinding of the opposing driver.

Before referring to a pair of photographic slides which illustrate the effectiveness of the proposed system in operation, a discussion of the elements of the installation will be helpful. A pair of 125 watt, single filament polarized lamps is used for the upper or country-driving beam. These lamps are of the same physical size and shape as today's Sealed Beam units except for having a flat face against which the polarizer is laminated. An additional pair of lamps, unpolarized and of fog-light size, is used to provide the lower or traffic beam. These are operated through the conventional footswitch. They will be used only for city driving and for meeting non-equipped cars until such time as all cars on the road carry the complete system. Because these "traffic lamps" also carry only one filament, they make possible a better control of light distribution in the lower beam than is afforded by today's Sealed Beam lower beam.

The polarizing viewer may take any of a number of forms. Although we have standardized, for purposes of uniformity of

demonstration, on a readily adjustable hinged visor supported from the body of the car, some persons prefer the viewer in the form of spectacles, clip-over glasses, polarizing windshields, etc. The basic requirements of the viewer are that it be correctly positioned before the eyes and be of such size as to allow wide-angle vision through it. It is preferable to have it removable from the line of sight for city driving and for long periods of unopposed country driving.

You may at once recognize that, due to the two-way nature of this system, all cars on the road must be equipped before the *ultimate* benefits are achieved. The polarizing viewer does not perform as described against ordinary headlamps. This is important in considering how the system might be introduced. Also, because the material used on the front of the polarized lamp absorbs more than half of the light produced at the lamp filament, and because the viewer adds a further absorption, it is necessary approximately to double the capacity of the electrical system if open road visibility *through the viewer* is to equal that afforded by the upper beam from today's Sealed Beam headlamps. This means a larger generator, heavier wiring and relays, but no change in battery. These items are primarily important as cost considerations.

Since it is not possible to arrange a road demonstration for a group as large as this, let me describe for you the sensations you will have while driving with this polarized system after it has come into general use. In the first place, you will appreciate that the viewer, the only new piece of equipment of which you are conscious from your position within the car, is the device which protects you from glare. It therefore need not be used for clear-road driving when opposing traffic is not likely to be met or is likely to be met only occasionally. With the viewer raised from the line of sight, you are at once conscious of much better visibility than with the present upper beam. The beam is brighter and is aimed horizontally so that it reaches far down the road. You can see dark objects as far away as 500 feet.

I have a photographic slide (Illustration 1) illustrating this point. The three negatives of the slide were made with identical exposures on the same film and were developed and printed under identical conditions. Two dark-coated pedestrians were

stationed at distances of 200 feet and 400 feet from the camera in each of the three exposures. The only variable was the headlight beam which provided the illumination. The captions make the comparison self-explanatory. In this slide, as in the following one, the representation of distance has been somewhat foreshortened by enlargement.

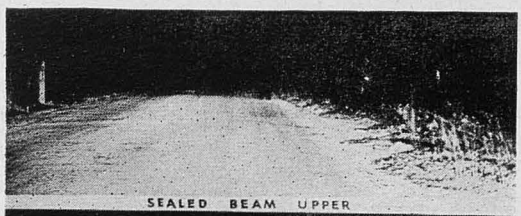
Continuing your drive, you suddenly see a car approaching about one-half mile away. You lower your viewer and find that it extinguishes the approaching lights except for a faint blue color which is a characteristic of the system. This informs you that the opposing car is also equipped with the system, so you do not depress your beam. As you approach closer, you can see the outline of the other car and a little later, the details of its front end—even the people inside.

Meanwhile, I call your attention to something else you have never seen before at night; the roadway beside and beyond that opposing car. Indeed you can see *by* it almost as though it were not there.

To illustrate this point, I will now show you a second photographic slide (Illustration 2) made by the same careful technique as the first one. This shows an approaching car at 200 feet, beyond which a dark-coated pedestrian stood at 250 feet in both sections of the slide. He is visible, however, only in the lower section, with the polarized system. This slide accurately represents what the eye could see under the two conditions chosen.

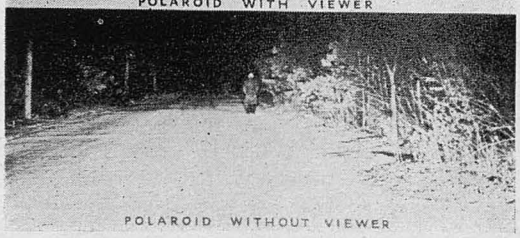
As you pass the opposing car, you are at once surprised and relieved to realize that you do not have to go through the usual short period of glare-recovery or to kick your foot switch to go back to your upper beam. The whole experience has been one of relaxation, and after you have had a few more of them, you no longer watch those approaching lights; you concentrate on your right of way, which you must be sure is clear if you are to maintain your even speed and run no chance of accident.

Soon you meet a car whose lights do not appear to be extinguished by your viewer, nor do they appear blue. You at once recognize this as a car not equipped with the polarized system. So you step on your foot switch and thereby change to your unpolarized pair of lamps, which are designed to give you fair visibility (even through the viewer) and to afford the opposing

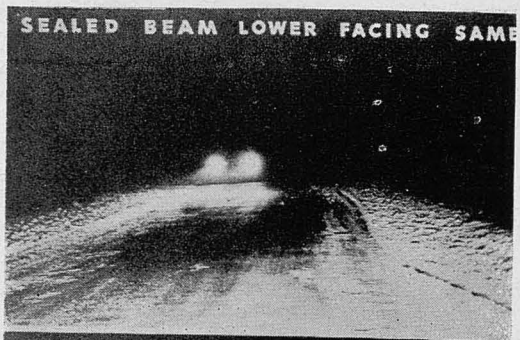


SEALED BEAM UPPER

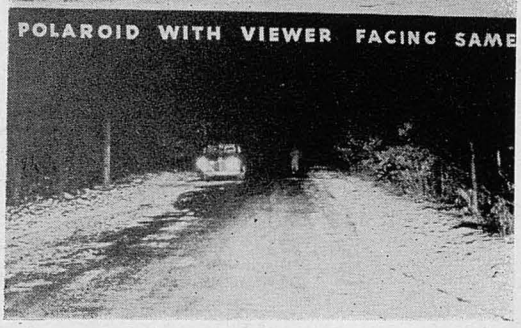
POLAROID WITH VIEWER



POLAROID WITHOUT VIEWER



SEALED BEAM LOWER FACING SAME



POLAROID WITH VIEWER FACING SAME

driver reasonable comfort. In fact, they provide a beam which is essentially like today's lower beam. The opposing driver, of course, dims too, and the passing is effected just as though neither car had polarization. You soon become impressed with the simplicity of the new rule of the road for headlighting:

"DIM FOR WHITE LIGHTS"

Groups of cars present no problem. If any lights ahead appear white through your viewer, depress your beam. If all appear blue, do nothing.

In the long development of the proposed system, most attention was given to perfection of the polarizing headlight. Now, with the time for adoption at hand, we find also that it is the requirements and characteristics of this special light source which raise the chief questions of how the system is to be adopted. It would be relatively simple to specify that, as of a certain date, all night-time drivers must use some form of polarizing viewer if this were all that were needed, because these devices can be made in a variety of attractive forms, can be very inexpensive and can be installed with a minimum of trouble. On the other hand it would not be simple, and might be impractical, to insist that polarized headlights as well as viewers be installed on all cars operating at night at some early date. This is due solely to the fact that present automobile electrical systems will not handle the higher wattage of the polarized lamps, even though these lamps are capable of being substituted physically for the present-day type. Thus the adoption of the system presupposes that there will be some introductory period during which polarized and unpolarized headlighting will be in simultaneous use on the highway. This would mean that for a time the practice of depressing one's beam for an oncoming car would continue in situations where any car involved carried the older, unpolarized type of lighting. For meetings in which all cars carried the new system (relatively infrequent in the early stages of the interim period but more frequent as the period lengthens) drivers would not have to depress.

The idea of an introductory period is not new. Ever since the early days of motoring there has been gradual, step-by-step improvement in headlight design and at no time have all of the

cars on the road carried identical lighting equipment. In 1940, all new cars were equipped with headlamps of the highly standardized design known as Sealed Beam. We are now going through an interim period between the universal use of Sealed Beam and the universal use of the old, unsealed lamps. This transition is in its ninth year and would be very nearly complete except that, on account of the war, an abnormal number of old cars are still on the road.

One way to introduce the polarized system would be to make it standard on all new cars as of a certain year of manufacture and to depend upon the badly needed increase in new car production plus the equally badly needed scrapping of old cars to hasten the time when all cars on the road carry polarized lighting. There are other ways by which such an interim period might be shortened artificially, one of which will be mentioned later.

Having described for you what this new headlighting system does and what is required in the way of equipment to accomplish the result, I should now like to tell you what has been done to get the system adopted.

About ten years ago, the Automobile Manufacturers Association (AMA), at the request of the motor vehicle administrators, undertook a study of the possibilities of polarization for improving headlighting. Except for the war years, this study was continuous until November, 1947. The AMA evolved specifications for the technically adequate installation now ready for adoption and arranged for mass demonstrations. 40 equipped cars have actually been used simultaneously. The General Electric Company solved problems of lamp design, and Polaroid Corporation, those of polarizer development and application. General Electric also undertook, on two seperate occasions, an appraisal of the polarizing system on the basis of quantitative measurements which showed the comparative visibility distances obtainable with the proposed system as against the present Sealed Beam system for a number of different combinations of headlighting when cars are meeting. I will refer to results of these tests in a few moments.

The AMA has made a formal presentation to the national organization of state administrators, the AAMVA. These are the officials whose responsibility it would be to request the state

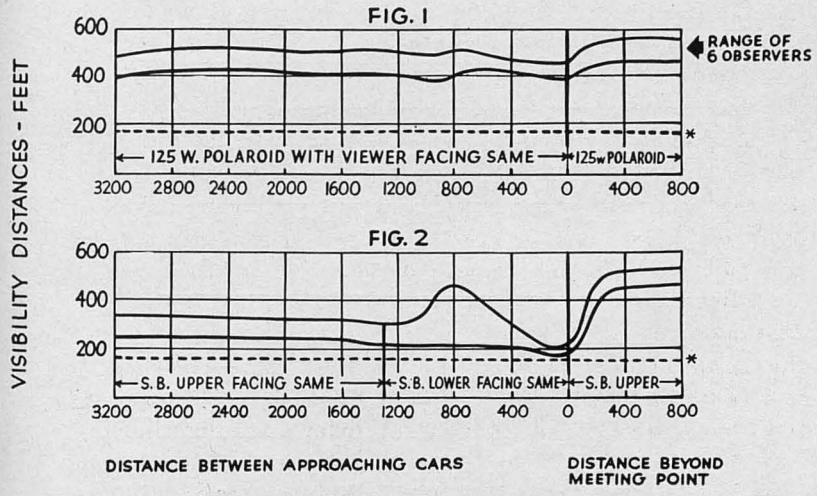
legislatures to permit the system on all cars. In its presentation, the AMA recommended "against the adoption of polarized headlighting at this time." In giving its reasons for this recommendation, the AMA did not in any way claim that the fundamental advantages were lacking. In fact, their statement included the following points: "All cars can have identical polarized lamps and viewers, and have the viewers on any car prevent glare from any opposing car's polarized lamps. With his viewer in use, any driver can see the illumination from his own headlamps practically without interference from opposing polarized headlamps. When the opposing car is close he can see the roadway beyond the opposing car's polarized headlamps" . . . "Road vision during the operation of meeting an opposing car is much better than obtainable with Sealed Beam" . . . "When using the polarized lamps without a viewer on the open road, the driver has a more satisfactory beam than Sealed Beam upper."

And if further support is required, we have the direct comparison afforded by the General Electric test results as reproduced in this slide (See Chart I). The curves in the figures plot the visibility distance for a dark obstacle as two cars approach and pass each other, from the standpoint of the observer-driver travelling from left to right and whose lighting equipment is first-described in the area under the curve. Note that in Fig. 1, the six observers all maintained a visibility distance of about 400 feet from the time the two cars were 3200 feet apart until after they had passed. On the other hand, today's headlighting properly used, as shown in Fig. 2, gave wide variation in visibility distance as a function of the relationship of the meeting cars and considerable spread between observers as the cars approached close. The peak in the upper curve in this figure is due to the unreliable phenomenon of silhouette seeing, which all observers do not experience. Finally, notice the margin of safety provided by the polarizing system (Fig. 1) by maintaining visibility distance well in excess of the safe stopping distance denoted by the dotted line at 165 feet. This margin is not maintained with Sealed Beam lighting (Fig. 2) and, in fact, decreases to a margin of only a few feet, even at the fairly reasonable speed of 40 mph.

What, then, were the automobile industry's reasons for the recommendation against adoption at this time? The following three appear to be weighted most heavily by them:

DRIVER-VISIBILITY DISTANCES
PROPER HEADLAMP USAGE

OBSTACLE - MAN-SIZED DUMMY IN DARK CLOTHING
SPEED - 40 MILES PER HOUR

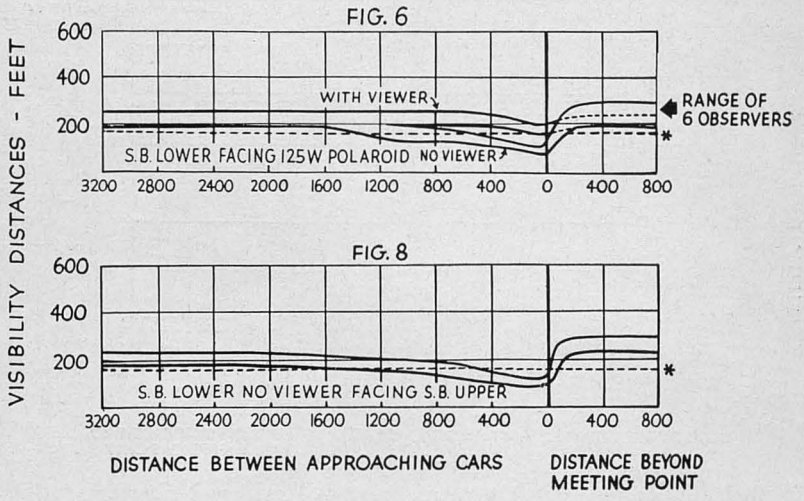


* STOPPING DISTANCE - 165 FEET
DECELERATION - 14.5 FT./SEC.^{2}
PLUS 3/4 SEC. REACTION TIME

CHART I

VISIBILITY DISTANCES FOR A SEALED BEAM DRIVER ~ IMPROPER USAGE

OBSTACLE - MAN-SIZED DUMMY IN DARK CLOTHING
SPEED - 40 MILES PER HOUR



STOPPING DISTANCE - 165 FEET
DECELERATION - 14.5 FT./SEC.^{2}
PLUS 3/4 SEC. REACTION TIME

CHART II

1. Since the ultimate benefits of polarization would result only when all cars are equipped, and since there appears no practical way quickly to convert all cars now on the highway, a lengthy period of mixed meetings when the new and present types of headlighting would be in simultaneous use would result from introduction of the system on new cars only. Buyers of the cars carrying the new equipment would be disappointed in the delay in getting through this introductory period, during which they would not always get the use of their polarized equipment in meeting other cars.
2. During such an introductory period, glare would continue to be a problem because carelessness or discourteous drivers of one type of headlighting could, by failure to follow correct practice, glare drivers of the other type, and this might well build up public resentment which would result in repeal of permissive legislation in some states. Contributing to this factor would be the increased brightness of the polarized beam, which would give rise to more complaint on the part of drivers of unequipped cars and of rural pedestrians than would equivalent misuse of the present upper beam.
3. New hazards will develop in the use of polarized headlighting at hilltops and curves, and in the overtaking and passing of other cars unless all drivers follow different practices than those used by some drivers today.

We at Polaroid, and others who have studied polarized headlighting, recognize that the foregoing factors embody certain unknowns which must be considered in any far-reaching recommendation, and we can understand that the AMA feels the need of guidance from organizations representing legislative and consumer groups at this point. But we disagree that the reasons given for the postponement are sufficient to outweigh the agreed advantages of the system in view of the following facts:

1. Granted that it would be impractical to obtain compulsory legislation requiring conversion of cars now on the road, it is nevertheless possible to supply to the present car owner an inexpensive conversion kit, consisting of a single polarized lamp and a viewer, to be **added** to his present system. This would secure for him part of the benefits of the full system without the cost of an increase in generator size. Such an auxiliary system would not be "substandard" because it would be used only when meeting other polarized cars—not for any clear-road driving—and, under such conditions, would be a decided improvement over present headlighting. The General Electric tests have established this fact. With an active campaign of the type which has resulted in the sale of from 6 to 10 million conversion kits for pre-Sealed Beam cars, the introductory period of polarized headlighting could be materially shortened, giving the new car buyer an earlier realization of the full benefits of universal use.

   On the subject of the cost of building the complete system into new cars, we point out that estimates of the

resulting increase in **selling price** of a new car vary widely, but that no estimate has exceeded the retail cost of an average car radio. It seems likely that the system could be built into new cars for less than the cost of a car heater. We do not believe that, in such a case, a new car owner will be greatly concerned about the length of the period of mixed use, especially since the benefits of superb open-road seeing will be realized from the first time he drives his new car at night.

2. Granted that the polarized lights are brighter than today's upper beam, and that likelihood of their misuse in the introductory period could be as great as today's misuse of the upper beam, the General Electric data show that this increased brightness does not mean increased hazard, even though the annoyance may be greater than today. A comparison of Figs. 6 and 8 on Chart II shows clearly that a Sealed Beam driver operates for the same period with safe stopping distance in excess of visibility distance whether he is facing, unprotected by a viewer, the polarized beam or the Sealed Beam upper beam. Other data from the General Electric tests give us every reason to believe that the transition from Sealed Beam to polarized headlighting will be far safer from the standpoint of the user of the older type of equipment than is the transition from pre-Sealed Beam to Sealed Beam, which we have been going through since 1940.

   As for annoyance to rural pedestrians, they are usually observing the roadway where they are walking, rather than looking into approaching lights. The brighter beam will serve to light their roadway better and—more important—will make them more visible to the drivers. And let me point out what may already have occurred to some of you: the driver or pedestrian who today is subjected to glare from approaching headlights can do little to gain relief. Against the polarized system, he can obtain complete relief through the use of a readily available, inexpensive viewer. The effect of this application is illustrated by the upper set of curves of Fig. 6 on Chart II, which shows no period of operation with safe stopping distance in excess of visibility distance.

   In regard to public resentment resulting in repeal of permissive legislation, we propose a thorough educational program, so that an informed, and therefore not overexpectant public can handle the system with minimum abuse during the introductory period with the assurance that when this period is over, glare and the need for depressing to avoid it will be gone forever. In this connection, it is important to realize that drivers of unequipped cars need in no way change their night driving habits with regard to depressing for others. Only the users of the new system need observe the new, simple rule of the road: "Dim for White Lights." These new car buyers are the very ones who can be most easily reached with information on proper usage during interim-period driving.

3. It happens that the polarizing viewer, if it covers the entire field of view, will eliminate the atmospheric haze sometimes seen at tops of hills or on curves (if produced

by opposing polarized headlamps) and will, therefore, remove the warning that a car is approaching. The AMA believes that this may lead to increased hazard for those who habitually use the absence of this warning haze as a signal that they may overtake and pass other cars at hilltops or on curves. If this is considered an important point, we have designs of viewers which will pass more warning haze than is seen today. We believe that this is normally a matter for self-education for each driver of the new system; after brief experience, as in daytime, he will regulate his driving habits to reduce, rather than increase, hazard at such places.

When one pulls out of line to overtake and pass a car going in one's own direction, the determining factor in making the maneuver is the distance and speed of the approaching traffic. The AMA believes that the appearance of extinguished, oncoming polarized lights is deceptive as to their distance and speed of approach. However, what tests they have run have shown that, while some persons have difficulty using the polarized system under such conditions, others find it easier to judge distance and speed of oncoming traffic than when using Sealed Beam lighting. Polaroid Corporation has investigated this matter and concludes that there is no essential difference. In any event, this appears at most to be another case for driver self-education. After a few experiences in overtaking maneuvers using polarized headlighting, a driver will become thoroughly at ease—if, indeed, he found himself otherwise at the outset.

In closing, I should like to emphasize that polarized headlighting is no longer a subject for laboratory demonstration; it has been developed into a system ready for adoption and use on all new cars at an early date. Full realization of its advantages awaits only enough demand upon those who can make the system available through legislation *by* those who will use it and benefit from it. A spokesman for the auto industry has said, "The public is going to have to want this thing enough to demand it."

Our experience is that the public does want relief from glare, and safer night driving visibility. Groups such as yours can assist by advising others that such benefits are available. Within the past few months, several influential organizations and public-spirited citizens have proposed legislation permitting or requiring the use of polarized headlighting. The Lighting Engineer of the State of Minnesota has recommended to the state motor vehicle department, the immediate adoption of the system as a result of demonstrations he has seen and the study that has been made. At present, the Automobile Club of New York, Inc., is sponsoring a bill in the New York legislature to make polarized equipment mandatory on new cars after a cer-

tain future date. It appears that a similar effort is about to be made in at least one other state. This goes beyond the permissive legislation we have had in mind, but could be most effective in speeding adoption of the system. It would be gratifying to find your state ready to undertake the same type of action at some early date.

The writer acknowledges his indebtedness to Mr. Val J. Roper of General Electric Company for collecting the data and preparing the charts which have been reproduced herein.