HIGHWAY RESEARCH BOARD

Bulletin No. 11

SEALED BEAM LOWER

POLARIZED

The Polarized Headlight System

1948

PRESENTED AT THE
TWENTY-SEVENTH ANNUAL MEETING

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HIGHWAY RESEARCH BOARD

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THE POLARIZED HEADLIGHT SYSTEM

by

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PRESENTED AT THE TWENTY-SEVENTH ANNUAL MEETING

1947

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

Washington 25, D. C. June 1948

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Cover Pictures:

The picture on the left shows the effect of present lower beam lights facing lower beam where the opposing car is 200 ft. away. There is a dark coated pedestrian 50 ft. beyond the opposing car.

The picture on the right shows the visibility afforded by polarized headlights opposing polarized headlights, under exactly the same conditions as shown on the left.

THE POLARIZED HEADLIGHT SYSTEM

DR. EDWIN H. LAND

President and Director of Research, Polaroid Corporation

SYNOPSIS

The technical evolution of a polarized headlight system consisting of polarizing filters on two 125-watt headlamps and a viewer-filter before the driver's eyes has been completed. The polarizing direction of the viewer is parallel to his own headlights and crosses automatically with that of oncoming cars, thereby reducing the brightness of approaching headlights on the average to one-seventh of the down beam of the current Sealed Beam headlamps The higher wattage overcomes the light loss at the polarizing filters sufficiently to make open road visibility of critical hazards seen through the viewer at least as good as present open road seeing with the upper beam.

This system has been referred by the Automobile Manufacturers Association to the American Association of Motor Vehicle Administrators for consideration

The limitations of beam control in dealing with the glare problem and the particular properties of polarizing light are cited. The period of transition to the polarized system need introduce no new hazards not found in the current transition from pre-Sealed Beam to Sealed Beam lamps. Research data from General Electric Company is presented which indicates that even misuse of the new headlamps would be no more hazardous than misuse of Sealed Beams now.

The cost of such a system would not be out of line with the benefits obtained.

The importance of public education and support of glare elimination by consumer organizations is stressed. The technical acceptability of the system has been established. The only problematical areas remaining are related to methods and results of introduction

It is a pleasure to report the present status of glare elimination to a group representing the driving public of this country. For a decade we have been engaged in engineering activities with the automotive industry which have resulted in a system that is ready technically for immediate adoption. There is general agreement that it eliminates glare and at the same time provides visibility by and beyond oncoming cars.

The industry has found itself unable to go further at this time because of the nationwide problems of introduction, and has asked the American Association of Motor Vehicle Administrators for help in solving them, indicating their readiness to consider proceeding if the public shows sufficient interest in glare elimination.

Not Polaroid, not the automotive industry, not the vehicle administrators, not even your group alone should presume to arrange this program; but all of us working together can arouse the public to an awareness of the remarkable fact that a practical means for eliminating glare is now available. How much do they want it? Until November 18, 1947, they had scarcely heard of it. Neither the public nor consumers associations were re-

presented during the development stage.

We believe the most feasible method of introduction is to build the equipment into all new cars on a certain date, and make universally available viewers for removing the glare from the new headlights.

The Polaroid headlight system rests on the fundamental fact in physics that two polarizers with their axes parallel, such as your own Polaroid viewer and your own Polaroid headlights, pass a substantial part of the light; whereas two polarizers with crossed axes, such as your viewer and oncoming Polaroid headlights, block it out.

THE CLASSIC PROBLEM OF HEADLIGHTING

When you meet a car on the highway at night, you play two parts. Because you have to see where you are going, you have to point a beam of light down the road with your headlights. The approaching driver has to do likewise. You are necessarily on the receiving end of his light beam, and he is on the receiving end of your light beam. If you use ordinary natural light, there is only one thing you can do: you must compromise between your need to illuminate the road and your need not to illuminate, and blind, the driver who forms a part of the scene ahead. You can direct the beam a little away from the other car, deliberately avoid lighting up a part of the road that you would like to light up, to reduce somewhat the glare in the other driver's eyes. That compromise has been made in many ways, with great ingenuity. It has never been a comfortable compromise, or a safe one. You always come down to this: for safe night driving, each driver needs to put a powerful beam right where it will blind the other.

Beam Control Cannot Be Final Solution Using ordinary, unpolarized light under any circumstances, you find that it is impossible to keep the glare out of the approaching driver's eyes by controlling the direction of the beam alone. To drive safely at a reasonable speed, you have to direct a shaft of light of many thousands of beam candle power several hundred feet down the road. To avoid blinding an approaching driver, you must not allow that beam to extend more than three feet above the road. That proves to be impossible, even with the finest headlighting equipment available today. To give relief from glare, the present Sealed Beam system provides a foot button which allows drivers to switch from an upper to a lower beam, but here again beam control is not satisfactory even under ideal conditions, and in practice leaves a great deal to be desired.

Depressing the beam only reduces the glare reaching your eyes. It by no means eliminates it. With cars 400 ft. apart, even with a properly aimed lower beam, and with the car loaded evenly and not too heavily, and with the road perfectly level, you receive the glare of 900 beam candle power (Fig. 1). But perfectly level roads are few and far between. With an angular elevation of 3 deg. and a curve in the road, you may be confronted with the glare of 20,000 beam candle power from the lower beam of the Sealed Beam system. With the upper beam under ideal aiming and loading circumstances and on a straight level road, you receive the glare of about 20,000 beam candle power. With an angular elevation of only 1 deg. in the road, the upper beam throws the glare of 40,000 beam candle power into your eyes.

Many accessory devices have been offered for sale through the years to protect you against headlight glare. These have usually taken the form of colored viewers. Some

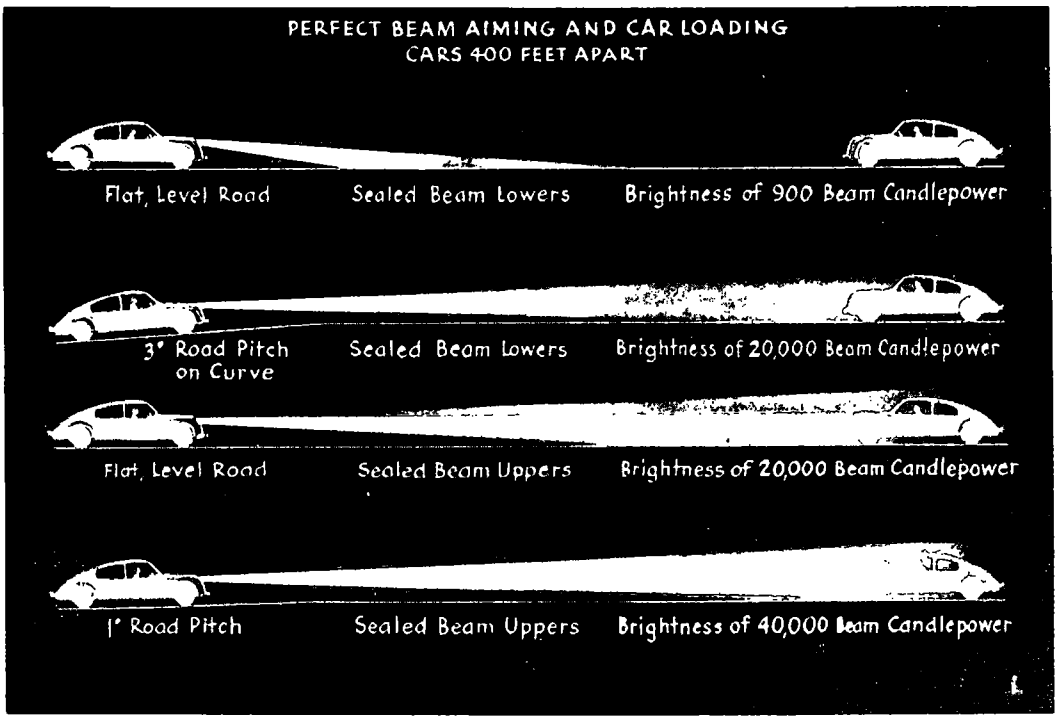

Figure 1. The Glare of Ordinary Headlights

are designed for installation directly in the line of sight, while others are intended to be used as shields in back of which a driver may "hide" oncoming lights while he views the roadway around the edge of the shield. I venture to say that no one considers any one of these to be an acceptable answer to the problem of glaring headlights.

The only known final solution to the problem of glaring headlights is a system that uses polarized light.

THE POLAROID VIEWER-HEADLIGHT SYSTEM

We believe that there are two main questions that the public wants to have answered about Polaroid headlights:

Does the Polaroid headlight system really put an end to headlight glare?

Does it also give enough light for really safe driving?

Perhaps the simplest way to answer is by summing up the performance of the Polaroid system in this way: with the Polaroid system, it is as if you were always driving with a light at least comparable to the upper beam of your present Sealed Beam lamps, and as if the approaching car were getting along with the lower beams of his Sealed Beam lamps cut, furthermore, to about one-seventh of their present brightness.

The Polaroid system, as evolved under the ground rules laid down by the industry, is composed of a pair of 125-watt Polaroid headlamps for country driving, and a pair of special non-polarizing passing lamps that are used for city driving and for passing old cars during the transition period when both Polaroid and Sealed Beam headlights are

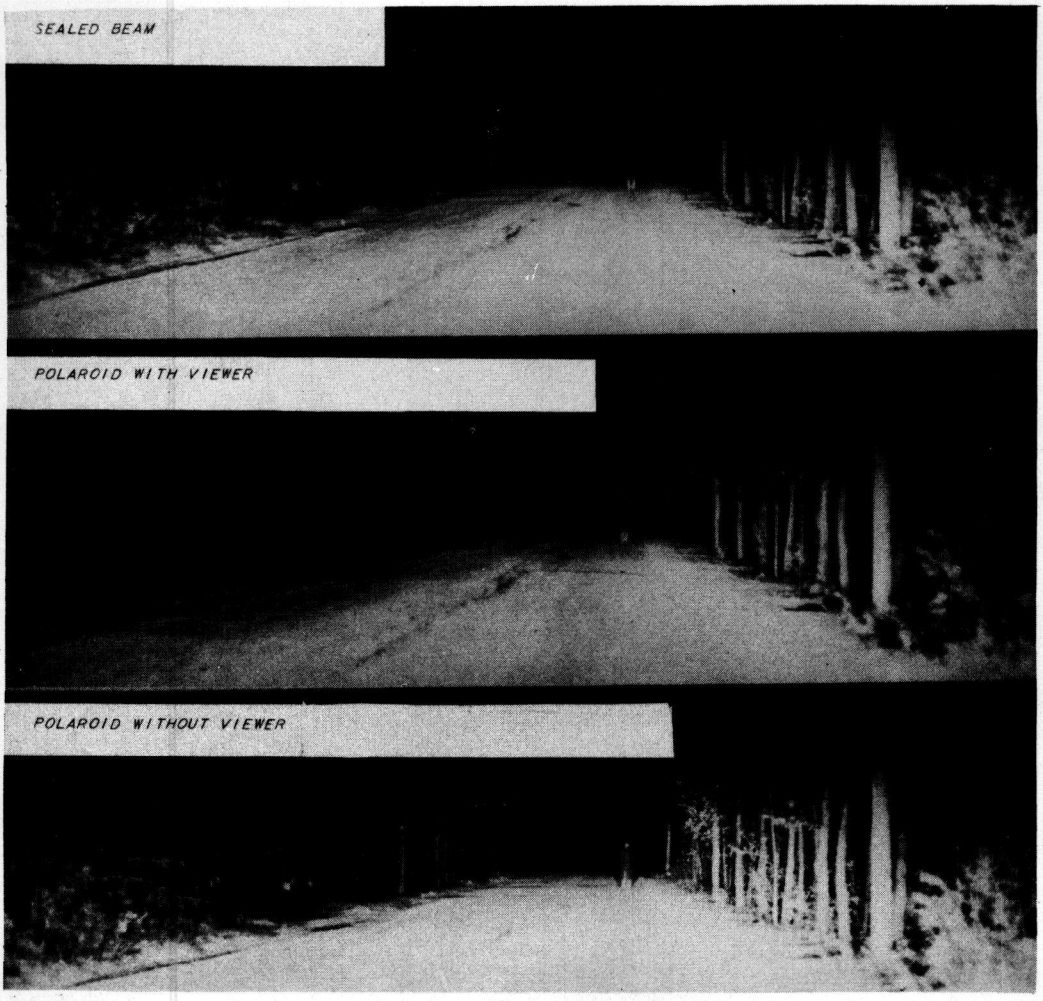

Figure 2. Comparative Illumination Down the Road

on the road together. A Polaroid viewer completes the system. It eliminates the glare. Through it, the approaching Polaroid lamps have an unmistakable, characteristic blue color.

While several types of viewers are suitable, including windshields, visors, and various types of spectacles, for the purposes of simplicity and uniformity of impression, we are standardizing on an available visor.

COMPARISONS OF POLAROID SYSTEM WITH PRESENT SYSTEM

Let us now examine the Polaroid system and the present Sealed Beam system side by side and see what the Polaroid system offers in safety and comfort as compared with the Sealed Beam system that you are now using.

Polaroid System Provides Excellent Illumination Figure 2 presents a comparison of the old and the new systems simultaneously and under

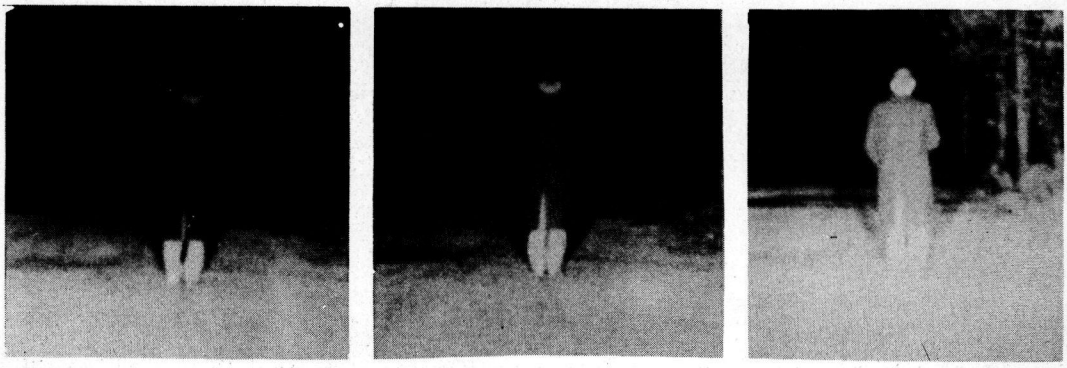

Figure 3. Comparative Contrast of Pedestrian in Figure 2

identical road conditions, by means of photographs made with careful photogrametric control.

We have a road with a dark-coated pedestrian about 200 ft. ahead; at the top - as seen with the Sealed Beam upper beam; in the middle - Polaroid headlights with viewer in position; and at the bottom - Polaroid headlights without the viewer. The figure shows several interesting points.

First is the greater sense of distant illumination with the Polaroid headlamps. The light from the horizontally-aimed Polaroid headlamps, viewed through the visor, is a safer light to drive by because it is directed to intercept obstacles in the roadway at a considerable distance. The foreground illumination from Sealed Beam upper beams appears brighter than from the Polaroid lamps with the viewer, partly in consequence of the Sealed Beam lamps being aimed below the horizontal.

Secondly you see, in the lower section, Polaroid lighting without the viewer. It is clear that you can see farther down the road, a result of the greater candle power and the higher aiming of the Polaroid beam.

We have made a number of measurements of the actual illumination down the road. At one typical, critical point just short of the pedestrian, though not at all points, the road has a measured brightness with the Polaroid lamps seen through the viewer which is actually 30 percent brighter than the brightness provided by the Sealed Beam lamps.

Figure 3 shows the relative visibilities of the pedestrian. Note especially his dark coat.

Polaroid System Has No Blind Drivin Zone A comparison of the amount of illumination provided by the two systems, favorable as it may be to the Polaroid system, does not take into account what is probably your most important concern as a night driver: How far can you see ahead when another car is approaching?

I should like to mention here that the numerical data in many of our subsequent illustrations are based on visibility distance measurements made by Mr. Val Roper of General Electric Company, but the interpretations are our own. We feel that the conditions under which the data were taken, mainly on a flat, straight road, are more favorable for glare reduction by the Sealed Beam system than ordinary driving conditions would be.

When present day Sealed Beam headlights come toward you, you

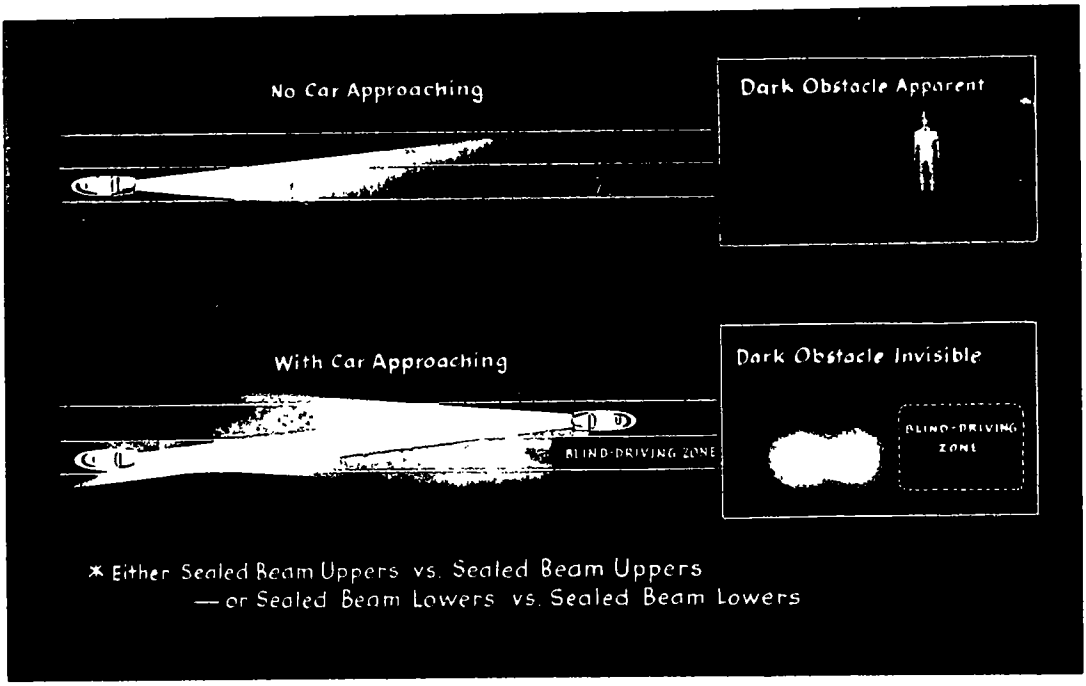

Figure 4. The Blind Driving Zone of Ordinary Headlighting

cannot see past them. You have the situation which we have diagrammed in Figure 4. The area to the right of the approaching headlights is, for you, a blind driving zone. In speaking of it, many drivers refer to it as the blind spot. All of us, as we drive at night, habitually drive into this zone on faith, hoping there is no obstacle in the road, but with a sense of hazard and insecurity. This sense is correct. If a man with a dark coat is standing in this zone, you cannot see him with your present headlights, even with the upper beams (used against upper beams) because you are blinded. There is frequently a similar blind driving zone for drivers who use their lower beams (against lower beams) because of inadequate illumination. This blind driving zone is a real thing. You are driving at 40 mph. into a zone on the road in which you cannot see a dark obstacle at sufficient distance to permit you to make an emergency stop.

You cannot see the pedestrian or any other dark object in this blind driving zone because your eye simply cannot record a very faint image when that image is close to the enormously brighter oncoming headlights.

With the Polaroid headlight system in use, there is no blind driving zone (Fig. 5). The pedestrian to the right of oncoming Polaroid headlights can be seen clearly. From the day Polaroid headlights are first introduced, there will be no blind driving zone for any meetings in which all cars are equipped with Polaroid headlight systems.

The Pedestrian Is Safer With Polaroid System Many a pedestrian confronted with glaring Sealed Beam headlamps feels instinctively that the driver behind the headlamps can see him clearly. In effect, the pedestrian relies on the driver for his security. Actually, the driver

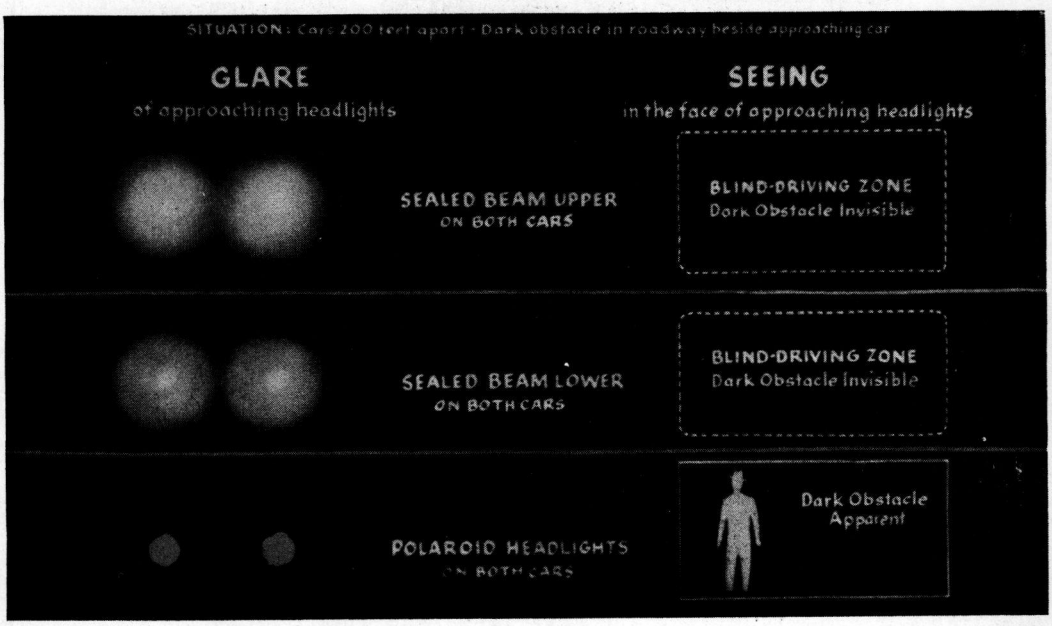

Figure 5. Polaroid System Eliminates Blind Driving Zone

cannot see at all the pedestrian walking in the blind driving zone. With the blind driving zone eliminated by the Polaroid system, the pedestrian will be sufficiently illuminated for the driver to see him in time to stop if necessary.

It is true that the pedestrian will be glared somewhat more by the Polaroid headlights than by Sealed Beams if he looks into them, but this increased brightness and the absence of glare in the eyes of the driver are the factors which operate to make him safer. What's more, the pedestrian frequently watches the roadway just in front of him as he walks. Thus the brighter Polaroid headlamps might even serve to improve visibility for him.

For the pedestrian who habitually walks on highways at night and who is inclined to look well down the road ahead of him, the Polaroid system provides an opportunity for glare relief in the form of a simple, inexpensive viewer, whereas today, he has no means of relief from the glare of Sealed Beam headlights.

Polaroid System Provides Greater Visibility Under conditions of proper use, the maximum apparent brightness of Polaroid headlights is about 1/250 of the maximum apparent brightness of the upper beam of the present-day Sealed Beam system. The extinguished Polaroid headlights, as I have said, are on the average one-seventh the brightness of the lower beam of present day Sealed Beam headlights.

The Polaroid system provides 400-ft. visibility distance with two approaching cars 200 ft. apart, while at the same distance, present day Sealed Beam uppers provide a visibility distance of 175 ft. and the Sealed Beam lowers provide a visibility distance of only a little more than 200 ft. (Fig. 6). Note that there is no blind driving zone in this situation with the Polaroid system, while the blind driving zone is present with the Sealed

Figure 6. The Polarized Headlight System Provides Greater Visibility

Beam system for both Sealed Beam uppers and Sealed Beam lowers.

Approaching Polaroid headlights seen through a viewer are completely free from glare (Fig. 7). When you drive a car with Polaroid headlights, and approach another car with Polaroid headlights, you do not glare the oncoming driver, yet, when the cars are 200 ft. apart, you are able to see about twice as far down the road.

Polaroid System Is Practicable Your next concern, I believe, will be the proper method of introducing the system. Granted that the Polaroid system closely approaches the ideal in safe headlighting, your immediate question should properly be: How do we get from where we are now, to the time when all cars on the road are Polaroid-equipped?

Since the invention of the automobile, there has been a series of transition periods during which cars with different types of headlights have been on the road at the same time; the transition period from oil to acetylene, acetylene to the early incandescent lamps and then a period when a number of different types of electric lamps were in use all at the same time and, finally, the transition period from those bulb-and-reflector type lamps to the Sealed Beam. During each of these transition periods the driver of the old car has been placed at somewhat of a disadvantage facing the lights of a new car.

We are still in the transition stage between the old bulb-and-reflector type headlights and the Sealed Beam.

Figure 8 shows the successive increases in beam candle power which have occurred at each of these transition periods. You will note that in the current transition period, Sealed Beam lights with a maximum of 60,000 beam candle power and the old bulb-and-reflector type lights with a maximum of between 5,000 and 40,000 beam candle power are on the road at the same time. You will recall that the maximum beam candle power of the pre-Sealed Beam lamps

Figure 7. The Polaroid Headlight System: No Glare - Greater Visibility

dropped off very rapidly due to deterioration of reflector and bulb. The introduction of the Polaroid system will bring about approximately the same relative step-up in maximum beam candle power that we have experienced since 1940 when the Sealed Beam was introduced. The Polaroid headlights, when you are not looking through a viewer, are bright - about 100,000 beam candle power compared with the 60,000 of the upper beam of the Sealed Beam lights. Moreover, as a matter of policy, the Polaroid lights are not aimed below the horizontal as are the Sealed Beams, so that you are likely to get the full brightness of the Polaroid beam more often than you would get the full brightness of the Sealed Beams. For this reason, those who have been involved in the Polaroid headlight development program have given attention to the possible effects of this increase in brightness.

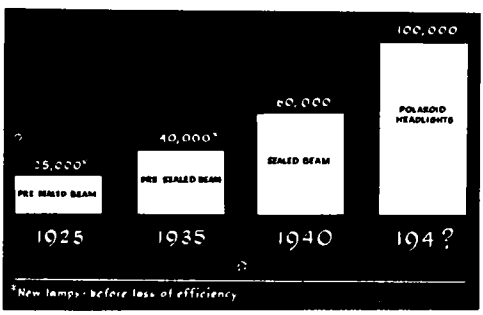

Figure 8. The Trend in Beam-Candle-Power

An increase in beam candle power of the upper, country driving beam has gone hand in hand with every major improvement in headlighting over the past twenty years. The reason is an obvious one: The need for more and better illumination for better clearer road seeing as finer highways and better cars have been provided. The adoption of the Polaroid headlighting suggests a further step in the trend toward better open road seeing, but with important differences.

It appears from careful studies that the transition from Sealed Beam to Polaroid headlights will be far safer than the transition between pre-Sealed Beam and Sealed Beam. (This assumes that pre-Sealed Beam cars will be off the roads at night by the time the Polaroid sys-

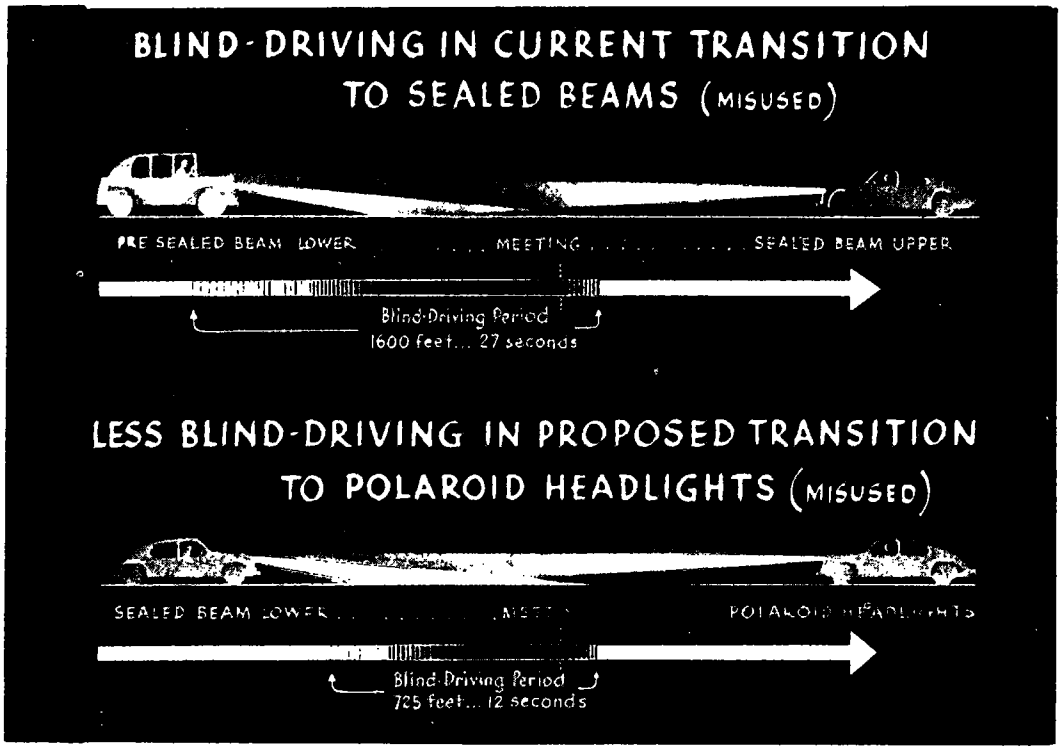

Figure 9

tem is introduced.)

Figure 9 shows the comparison under conditions of misuse of the blind-driving period for the pre-Sealed Beam driver facing a Sealed Beam car and for a Sealed Beam car facing a Polaroid-equipped car. You will see that the blind-driving period is over twice as long in the current transition to Sealed Beams, as it will be in the transition to come.

Proper Use of Polaroid System in Transition Period Is Easy to Learn With the introduction of the Polaroid headlight system, the rule of the road for headlights will be easy for all drivers to learn (Fig. 10). There need be only a single rule, "Depress for white light." You can have a rule as simple as this because Polaroid headlights have a characteristic blue color when you see them through a viewer. The rule is the same for all drivers.

If you are driving a present-day Sealed Beam car, all the lights approaching will be white, so you depress as usual. If you are driving a Polaroid-equipped car, the lights from Sealed Beam cars will be white and for these you depress too; the lights from Polaroid-equipped cars will be blue and for these you do nothing at all.

Groups of cars present no cause for confusion. An old car driver proceeds as at present; a new car driver does nothing at all if all cars ahead have blue lights, depresses if any have white lights.

During Transition Misuse of Polaroid Headlights No More Hazardous Than Misuse of Sealed Beams Now If the rule of the road is not observed,

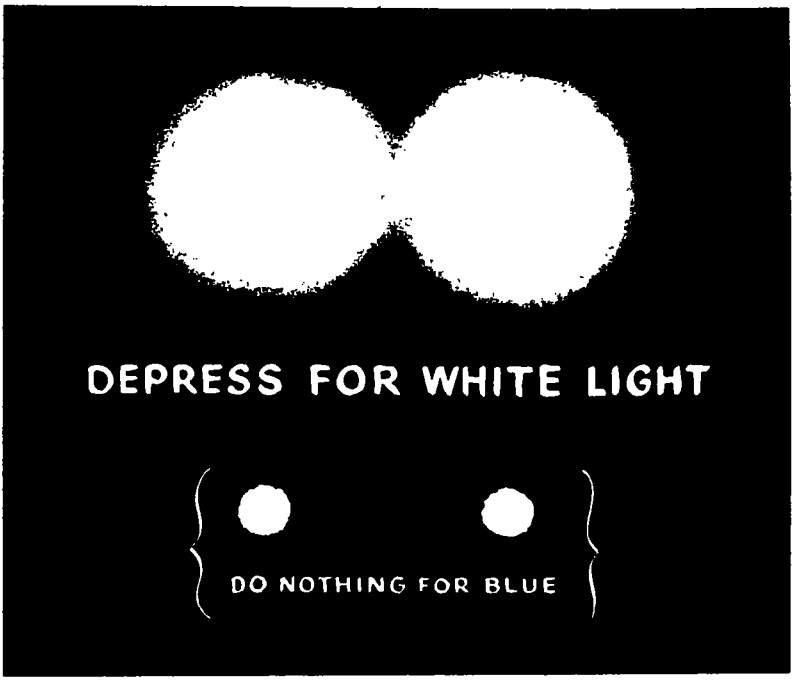

Figure 10. During the Transition Period the Single Rule of the Road

if the driver does not depress for white light, the blind driving period is no longer than it is now when drivers fail to depress their upper Sealed Beams and thus misuse the Sealed Beam system. Even under conditions of misuse, all possible meetings, once the Polaroid headlight system is introduced, will be at least as safe as (although sometimes less comfortable than) they are at the present time under conditions of misuse of the Sealed Beam system. The worst that can happen today with Sealed Beam headlights is the situation that arises when your car with Sealed Beam lowers approaches a car with Sealed Beam uppers. You are then temporarily in jeopardy: your own headlights fail to illuminate enough of the road for you, and the glare from the oncoming upper beams blinds you (Fig. 11). The result is that at 40 mph., for example, you go through a blind driving period of 725 ft. or 12 sec. This, of course, is a highly undesirable situation. Yet it occurs frequently, as we all know. People are inclined to overdrive their lights.

Now the worst that can happen, once the Polaroid system is introduced, is the situation I have just described as the worst for Sealed Beams. If you do not use a viewer and approach Polaroid headlights, you naturally experience a blind-driving period. Research data indicate that this blind-driving period with misuse of the Polaroid system, is no longer than the one resulting from misuse of the Sealed Beam system. However, let me point out what must be obvious. There is no remedy in sight for the misuse of the Sealed Beam system. There is no protection for you as a Sealed Beam driver who is confronted by a discourteous or thoughtless Sealed Beam driver who fails to depress. But there is a remedy for you if

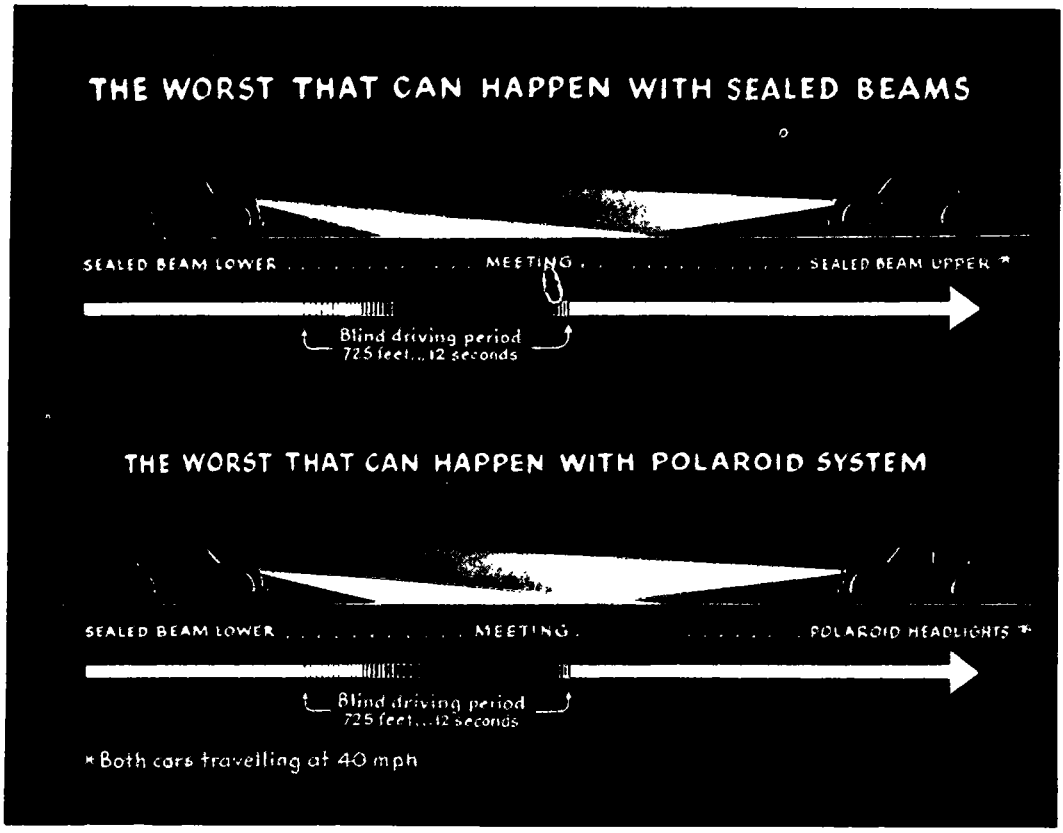

Figure 11

you are confronted during the transition period by a discourteous or thoughtless Polaroid driver (Fig. 12). You not only can reduce the glare of the oncoming Polaroid headlights, you can eliminate it completely, simply by using a viewer. All other situations involving misuse of Polaroid headlights appear to be more favorable than situations of misuse involving present-day Sealed Beam headlights.

Length of Transition Stage Statistitions point out that the length of the transition stage depends upon numerous variables and upon the numerous interpretations that can be made of these variables. For example: At what rate can we expect new cars to be built? At what rate can we expect old cars to become obsolete? How many car meetings at night are simple - that is, involve only two cars? What is the ratio of newer cars used for night driving against older ones? (See Appendix B). Since, as we have already seen, drivers of cars equipped with ordinary headlights are not affected adversely, should the data be interpreted from the point of view of the driver who has purchased Polaroid equipment? How much weight should be given to the possibility of providing conversion equipment for old cars?

Against the background of these and other unknowns, one known fact stands out. When all cars are finally equipped with the Polaroid system, headlight glare will be a thing of the past.

And even during the transition

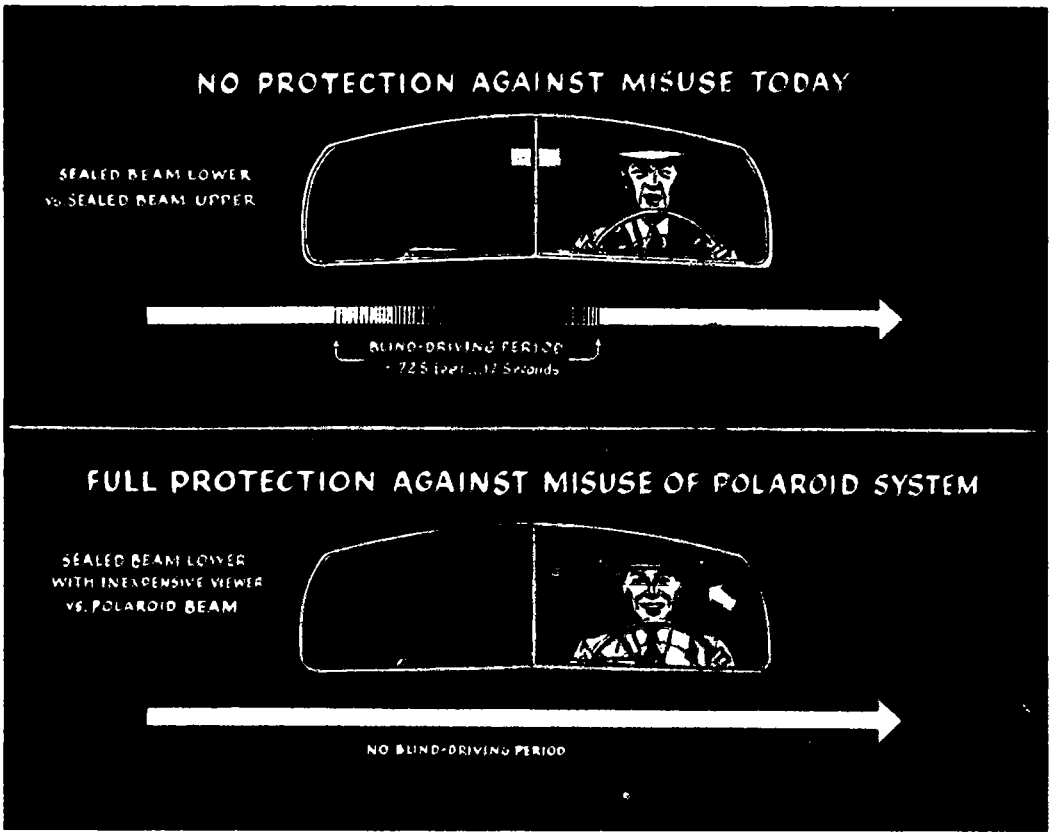

Figure 12

stage, the system will eliminate the blind driving zone for drivers of any two Polaroid-equipped cars involved in simple meetings. Since a certain number of accidents is attributable to the blind driving zone, it is to be expected that the number of such accidents will be reduced as soon as Polaroid-equipped cars start simple meetings, and that the reduction will accelerate as additional simple meetings of Polaroid-equipped cars take place.

In situations covered by proper usage where they meet Sealed Beam cars, Polaroid-equipped drivers will be able to see somewhat better with their new equipment than they would if they were using Sealed Beam equipment.

And on the open road, Polaroid-equipped drivers will have better light than ever before.

COST NOT OUT OF LINE

One further consideration is the cost of the system and its effect on the price of cars. On the largest item, the more powerful generator, I should like to point out that, since 1934, the industry has increased the capacity of generators substantially on two occasions; once, I am told, by about 50 percent in 1934, and again by about 25 percent in 1940. The increase to take care of Polaroid headlights is not much greater than these two which have already been made.

The polarizers are relatively cheap. It is estimated that a pair of polarizing filters for the headlamps, together with a Polaroid

visor for the driver, will have a cost to the manufacturer of less than $2.00. With a simpler viewer, the price would be less. Moreover, we have entered into an agreement with the Automobile Manufacturers Association under which Polaroid materials can be made available to the industry from several sources of supply at competitive prices.

In general, we believe the cost of the Polaroid system in new cars, even assuming that it turns out to correspond with the present estimates, will not be a cause for surprise, one way or another. It seems to be about what one would expect to pay for an improvement of this magnitude, a cost completely justifiable as compared with the costs of such improvements as safety glass and four-wheel brakes.

Certainly the cost of the Polaroid system does not appear to be out of line if you compare it with the cost of a number of popular automobile accessories (Fig. 13), such as an outside sun visor, a heater, or a radio.

Furthermore, we at Polaroid believe that the industry can be counted upon to reduce the cost of the system to a point well below the current estimates through the economies resulting from mass production.

SUMMARY OF SOME OF THE ADVANTAGES OF THE POLAROID SYSTEM

Let me attempt to sum up for you some of the justifications for the prompt introduction of the Polaroid system.

1. It is the only system which makes it possible to increase the down-the-road illumination and at the same time decrease the risk involved when cars meet and pass each other.

2. It is the only system which provides an opportunity for complete protection against glare, even for the driver who does not have Polaroid headlights on his own car.

3. Short of illuminating all the roads of the nation with overhead lights, or making all streets one-way, at an astronomical cost, the Polaroid system is the only system which can bring an end to the regulation and enforcement problems of beam depression - and it can do so at a cost which is not considered an insuperable obstacle.

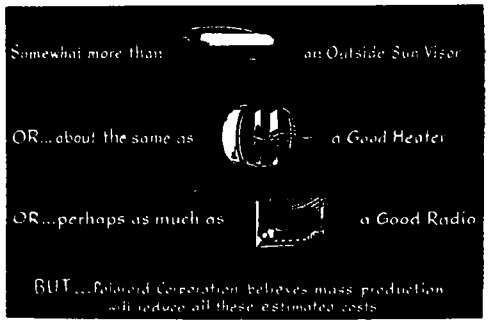

Figure 13. How Much Is the Polaroid System Likely to Cost?

If you will look back over the history of important new improvements that we now take for granted in our day-to-day life, you will find, I believe, that each was introduced for obvious and overwhelming reasons, but that at the same time each of these improvements presented a number of minor disadvantages which may have seemed significant at the time the change was proposed but which we have now come to disregard. You will also find that the minor disadvantages have been balanced by a number of minor advantages to which little attention was given when the improvement was introduced. If pressed, I am sure we could all point out a number of minor disadvantages of such overwhelming improvements as the telephone, the electric light, or even the automobile. All of us could at the same time point out a great many minor advantages of these improve-

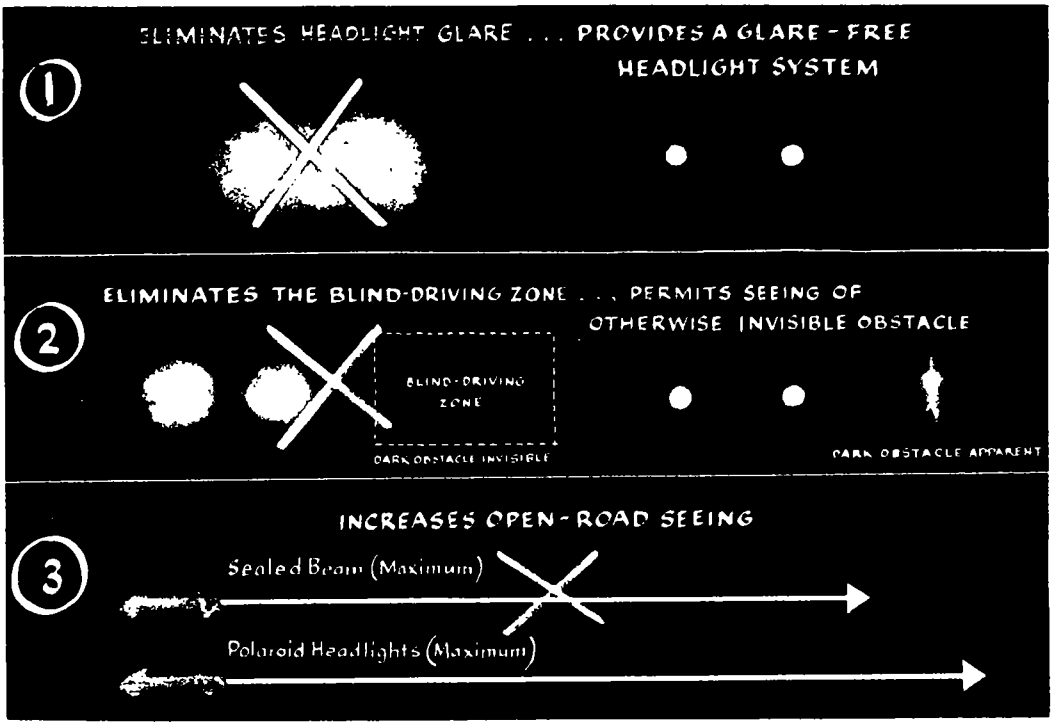

Figure 14. Chief Benefits of Polaroid Headlight System

ments beyond the obvious ones. This, I believe, will prove true of the Polaroid headlight system.

For example, through the Polaroid viewer you cannot see the haze which ordinarily warns of the approach of a car over a hill. On the other hand, if you now depend on this hilltop haze and would like to continue to use it, you will find that by looking around the edge of the viewer, you will get the warning haze at least twice as bright, and more reliably, because of the above-the-horizontal aiming of the Polaroid lights. And there are engineering methods for retaining the haze by affixing plastic pieces to the viewer.

What effect, if any, does the Polaroid system have upon your judgment of the distance of approaching cars? For some people the dim lights of Polaroid-equipped cars appear to be somewhat farther away than the hotter lights of Sealed Beam cars, which are actually at the same distance. These subjective impressions are difficult to measure, and neither our own tests nor those of the industry provide any scientific basis for anticipating additional hazards from this source. Yet you may predict that distance judgments will prove to be more precise when the Polaroid system is in universal use; because all approaching cars will be using the same driving beam, you will be able to use the apparent brightness of the approaching lights as a reliable indication of distance - something you cannot do now because you often do not know whether the approaching car is close at hand on his lower beam or at a greater distance on his upper beam.

That leaves us with the essential reasons for introducing the system which we all have had in our minds.

Figure 14 sums them up: The system eliminates headlight glare, it removes the blind driving zone, and it improves open road seeing.

Again, you may feel that the Polaroid lights are uncomfortably bright when you accidentally see them without a viewer. But against this disadvantage you may very well balance the greatly improved visibility on the open road, when traffic is light and you choose to raise the viewer.

It is possible to continue at some length reciting minor disadvantages of the Polaroid system and setting them off against minor advantages. It may be worth mentioning, for example, that the viewer appears to clear up a dirty windshield. When it rains, the viewer removes the scintillation from the drops on the windshield. On wet pavements, the system eliminates most of the glaring reflections from the oncoming car's lights - reflection which is today a source of considerable glare even from the depressed beam. There is a real possibility that the Polaroid system can reduce over-congestion of highways. Drivers hate highway congestion by day, and they fear blinding headlights by night. Of the two evils, they choose congested highways and leave the highways relatively empty at night. With Polaroid headlights, motorists may be encouraged to drive much more at night and may so relieve the increasingly widespread daytime highway congestion.

We believe that the minor advantages and disadvantages of the system will balance out more or less evenly. In any event, the study of these advantages and disadvantages has proceeded to a point where we believe it can be stated that there are no unacceptable disadvantages of a fundamental nature in the Polaroid headlight system.

As you have seen, all of the research and engineering data support the immediate adoption of the system. The technical evolution of the Polaroid headlight system is essentially complete. We have now entered what might be called "the phase of political evolution" - a phase in which the Highway Research Board may, I believe, take an important part.

The ordinary normal course for a development in the automotive field would be for the company which has invented and developed a new improvement (safety glass, for example, or an automatic transmission) to sell the improvement to one of the automobile companies. This company would go to the trouble and expense of building the improvement into its cars. One of the basic and most reliable motives of our free enterprise economy would have been at work - a desire for profit on the part of the company inventing and developing the improvement, and a desire for competitive advantage and profit on the part of the company adopting it. This has been the history of most of the great improvements which have occurred in the American automobile. The competitive profit-making motive has been the driving force which has brought them from the laboratory, through the troubles and expenses of introduction, to final use by the public.

As you have seen, there is an obstacle which prevents the Polaroid headlight system from following this well-worn path. If the system is introduced on only one make of automobile, it will be fully effective only in meetings between cars of that particular make. Introduced on one make of car, after obtaining the necessary permissive legislation, it cannot offer a strikingly effective competitive advantage. To be fully effective, it should be built into new cars of all makes at the same time. But if this is done the competitive advantage is again removed.

Who, then, does have a driving incentive to bring about the adoption of this system? The public is clearly interested.

Polaroid has an obvious incentive in addition to its belief in this system as a major safety contribution.

The Motor Vehicle Administrators function as regulatory or enforcement officers. Their efforts in proposing and studying the system, undertaken as representatives of the public, are an extra burden which they have voluntarily added to their already heavy administrative and legislative load. They have an important role in the program, covering regulations and permissive legislation, and I am sure we can count on their cooperation. Individually they all have a fundamental interest in safety measures, but many lack facilities for implementing such a program.

I have already touched on the lack of competitive incentive to the automobile manufacturers. I feel that under the circumstances they have spent a surprising amount of time and energy on the program and it is understandable, if regrettable, that they should feel that they have now gone as far as they can on the system until they know the public wants it badly enough to insist on its installation. The introduction of Polaroid headlighting is a major program requiring responsible handling. We have the industry's assurance that they will cooperate under what they consider appropriate conditions.

Where then can an effective driving force be found? We believe that the public must supply the force and that your organization, the Highway Research Board, is the type of organization which could help to work out means for introducing the system. Dedicated to the improvement of public welfare through the products of research, your only bias is the bias of public interest. You can find facilities for making an accurate estimate of the value of polarized headlights in improving highway safety and comfort. You have the organization and the channels of communication necessary for bringing the facts to the attention of the public and for finding the response of the public to these facts. You are in close association with other organizations, private and governmental, who share your interest in public safety. It appears to me that you are one of the key organizations, in a position not simply to cooperate, but also to help organize and lead the cooperative effort the public must make to obtain adoption of the system.

APPENDIX A

EARLY HISTORY OF THE POLAROID HEADLIGHT SYSTEM[1]

Early in the twenties, polarized light was recognized, particularly by Dr. Lewis Chubb, as the best escape from the headlight glare dilemma. In 1925, the present engineering secretary of the AMA told a meeting of the Illuminating Engineering Society that a "proper and universally satisfactory solution of the headlighting problem is one of the most important needs of the automobile industry," that "it would seem that the headlighting problem should be solved with the proper polarizing materials." He had to go on to say, however, that "the schemes which have been mentioned will undoubtedly seem very wild to the average engineer" since, as he had already explained, "no substance of the properties for a windshield plate is yet known, while analyzing prisms for goggles is quite out of the question commercially."

He had in mind the polarizing prisms used in physics laboratories at that time, cut from natural calcite and the fragile plates of herapathite, the only synthetic polarizing device then known. That was the situation up to 1932.

In that year, I brought to Detroit a polarizer in sheet form. Some time earlier, I had set down the requirements of a polarizer suitable for automobile use, conceived of it as a plastic film of some kind, and, after some effort, succeeded in synthesizing what we came to call Polaroid J Film. This material promised to be quite satisfactory for the headlights then in use, and we proceeded at once with the developments necessary for putting it to work - the building of a production machine capable of turning out some thousands of square feet of material per day, the designing of the special adhesives for bonding the material between glass, etc.

Meanwhile, however, the industry had become dissatisfied with even the best headlights of that time and had started on the program that ended with the adoption of the Sealed Beam. This introduced an entirely new concept; that of a complete, self-contained polarizing light source. That, in turn, called for an entirely new polarizer; one that would be capable of withstanding the 400-degree temperatures of the face of a Sealed Beam lamp in still air, the destructive exposure in sunlight, and the wear and tear of continuous use for the entire life of the lamp.

We set to work all over again, against the assurance of our friends in the plastics industry that there were no plastics capable of standing that range of temperature, and against our own certainty that there were no polarizing crystals that would stand that abuse, even if we found a plastic to embed them in. It took many months to arrive at a solution; a polarizer containing no crystals, made up of a plastic of a new kind.

With this new polarizer perfected we proceeded with the materials and devices for using it; the development of an adhesive for bonding it to the front of the lamp, the de-

[1] Excerpts from "Progress Report on the Polaroid Headlight System" read July 16, 1947 by Edwin H. Land, President, Polaroid Corporation, at the meeting of the Engineering Committee of the AAMVA and the Engineering Liaison Committee of the AMA at the General Motors Proving Grounds in Detroit.

velopment of a coverglass that would project the film without depolarizing the light; the design and testing of dozens of different viewers; and the combining of these developments into a matched system, adjusted for the slope of windshields and the use of safety glass. We had a great number of inventions to make and a new mass production process to perfect.

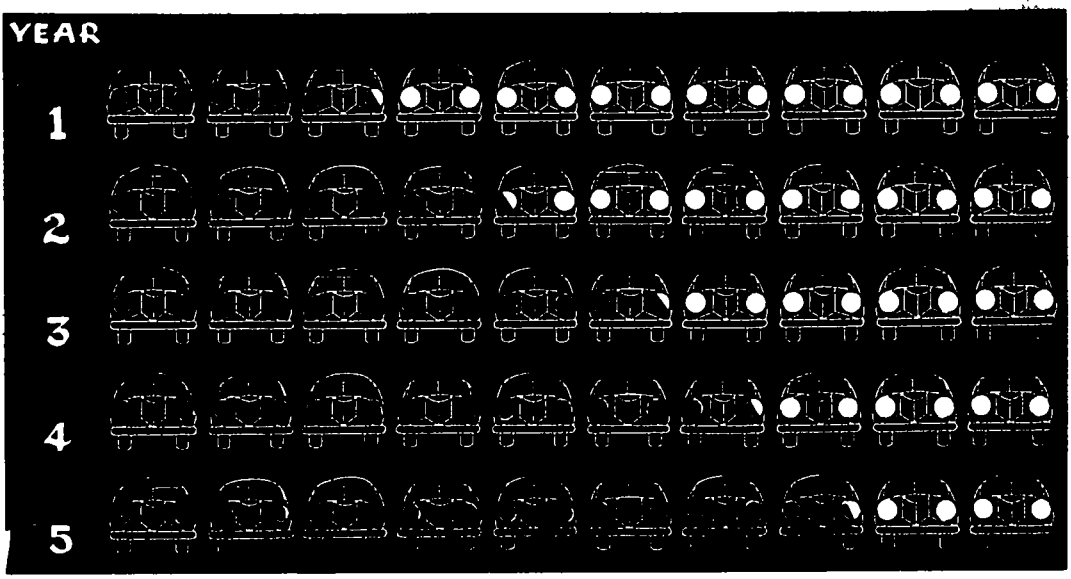

Figure A. Transition Period Without Conversion

APPENDIX B

TRANSITION CAN BE SHORT

How long will the transition stage last?

We have done some counting on the intercity highways, 10 to 30 miles out of town, in six different parts of the country - near Seattle, Los Angeles, Detroit, Dallas, Savannah and Boston - only about 3,500 cars, but probably an indicative sample. We find that the ratio of post-war cars to pre-war cars met at night is over three times as great as the number of post-war cars to pre-war cars registered. One might predict a result something like this on the common-sense grounds that a large proportion of night driving is done by those who are driving for pleasure, and who want to have a new car, and by salesmen and others who run up a high yearly mileage and who, therefore, have to have new cars. The ratio may not hold after the age-distribution of cars is restored more nearly to normal. Assuming this ratio, however, for want of any better, and assuming also a continuation of the normal 10 percent retirement of old cars each year, we can make a rough calculation of how long the transition period is likely to last. We have the situation shown in Figure A. In the

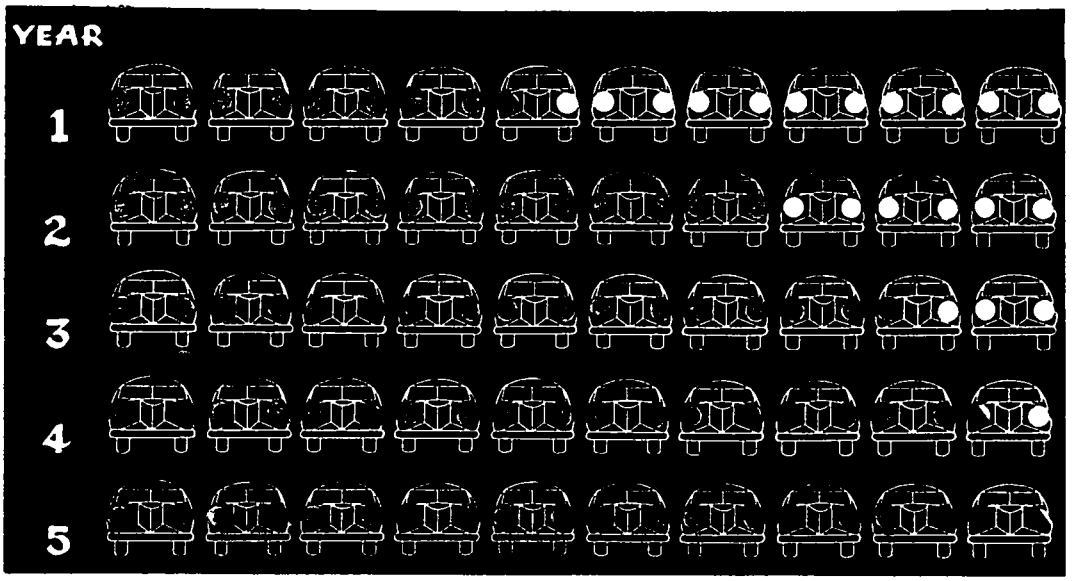

Figure B. Transition Period With Conversion

fifth year, if all passings were single passings, over three out of four of the cars you would meet on the road at night would be glareless. By the eighth year, over 95 percent of them would be glareless, and the transition period would be substantially ended.

If we assume a really attractive conversion system can be offered to the old-car drivers, and assume a very successful sale of this system accounting for the conversion of 25 percent of the old cars the first year, 20 percent the second, 20 percent the third, 10 percent the fourth, and 5 percent the fifth, we would have the situation shown in Figure B. After the second year, 70 percent of all cars on the road at night would be equipped; after five years, 95 percent. I present this as perhaps the most optimistic view, to be weighed against the very conservative view set forth in Figure A which assumed no conversion system at all.

In short, the Polaroid system can be working at a high degree of effectiveness in meetings in possibly five, certainly in less than eight years after it is introduced. Its immediate contribution to open-road seeing and occasional meetings has already been pointed out.

THE AUTOMOBILE INDUSTRY SURVEY OF POLARIZED HEADLIGHTING

J. H. HUNT
Secretary, Engineering Liaison Committee
Automobile Manufacturers Association

The Engineering Liaison Committee of the AMA has been carrying on an extensive investigation of the possibilities of polarized headlighting. This work was undertaken because polarized headlighting can practically eliminate glare when cars meet at night if all the cars involved are properly equipped. The Committee believes that any device which gives promise of contributing to highway safety should be thoroughly studied. Another compelling reason for the work was a request for an investigation from members of the AAMVA with whom the Committee cooperated in the development of the Sealed Beam headlamp.

The present statement is a summary based on a more complete report of the Engineering Liaison Committee presented to the AAMVA in November 1947. Members of the Highway Research Board may obtain copies by applying to the AMA office in Detroit.

The program followed was to cooperate with the Polaroid Corporation and the General Electric Company in the development of a system agreed to be adequate to demonstrate the advantages of polarized headlighting, and then study this system on the road. The resulting system as it now exists is believed to provide a proper basis for production designs. Final opinion on this point is not possible because the necessary endurance tests have not been run on the system installed in road vehicles. Unfortunately, the nature of the equipment makes it impossible to operate the system as it would eventually be used, when the test cars are driven in traffic on the public roads. The polarized lamps on experimental cars cause protest from meeting drivers of ordinary equipment at distances of 1200 to 1500 ft. Experience in using the lamps when meeting under ordinary traffic conditions is unobtainable because lamps on the road are not polarized, and the demand on the electrical supply is less than it would be in universal use.

THE EQUIPMENT

The essential components of the polarized light system are the viewer and the polarized headlamps.

The viewer is used to stop the polarized light from the meeting cars. It must of course transmit enough of the reflected light from the roadway, which originated in the car's own lamps, so that adequate vision is obtained. A preferred form for driver use is shown installed in Figure 1. This form is very well adapted to the use of the front seat passenger. Passenger protection may not be necessary for safety, but would undoubtedly be demanded for comfort by all passengers. A very thin sheet of Polaroid, protected by highly transparent plastic is supported in a

light metal frame. This frame is supported by linkage from the windshield frame in such a way that the plane of polarization can be adjusted to be perpendicular to the plane of polarization of the meeting headlamps. The viewer can be moved into and out of the line of vision by rotation about its upper edge without disturbing the adjustment of height or of the plane of polarization.

Figure 1. Polaroid Viewer in Position for Use

Adequate provision for motion in and out of the line of sight is needed because of light losses in transmission through the viewer. Approximately 63 percent of unpolarized light is absorbed, which means an equal loss of illumination in city driving when the illumination available will be from street lighting and the car's unpolarized city beam lamps. Under conditions of universal use, the viewer must be moved into and out of the line of sight every time a municipal limit is passed. The viewer absorbs about 25 percent of the light from the car's own lamps which has been reflected from dark objects without depolarization, and 63 percent of any light depolarized in the process of reflection, which occurs to a very high degree in reflection from light colored objects. Therefore when no cars are near the roadway appears much brighter when no viewer is used.

The polarized headlamps are 125 watt all glass units with a polarizing sheet protected by glass mounted on the front of the flat lens. The watts supplied have been increased from the 45 watts of the Sealed Beam upper to make up for the 60 percent loss in polarizing the beam and the additional losses in the viewer. Even then, with the viewer in use it is only possible to see dark objects as well as with ordinary Sealed Beam installations. Dark colored objects do not depolarize much of the light in the process of reflection. Lighter colored objects, which do depolarize most of the reflected light are not as visible as with Sealed Beams. Fortunately these lighter colored objects are not the controlling hazards since they are always visible farther than are the dark ones. These polarized lamps require the adjustments of the present aiming mechanism to insure good illumination, although faulty aim does not increase glare to a driver protected by a viewer.

A separate pair of 60 watt city beam lamps are required which must have the same adjustments as Sealed Beam. These lamps are not polarized since glare must be avoided by beam design and by lamp aim to protect pedestrians. The increase of the watts from 35 to 60 does not secure as good seeing with the viewer in use as is now obtained with Sealed Beam lower since the light at the so-called glare points, at and above the horizontal, cannot be greater than at present, and the viewer absorbs about 63 percent of illumination provided by this horizontal light. These city lamps must be used as country passing lamps when meeting cars with present lighting.

Figure 2 shows a car with both polarized and city lamps mounted on the sheet metal.

Windshields must be so manufactured and inspected as to eliminate faults not apparent in ordinary

light. A considerable percentage of windshields in service would so affect polarized light passing through that the viewers will permit more leakage than desirable and a small percentage would permit so much leakage that opposing polarized lamps would seem brighter than the Sealed Beam lowers now appear. Plural images caused by lack of parallelism of the outer glass surfaces and which are a present source of difficulty in the production of laminated glass become much more serious with polarized light than with ordinary light. The ghost image is relatively very much brighter with respect to the main image than when ordinary light is used.

The increase in lamp watts requires an electrical generator of about twice the present capacity and a complete revision of the wiring. Relays are used to reduce the distance the current must be carried in the wiring. The total increase in weight for one of the smaller cars was 26 lb. Figure 3 shows at the right side of the vertical line the Sealed Beam equipment removed, and on the left the equipment added in changing one of the smaller cars from Sealed Beam to the Polarized system. Parts of one of the polarized lighting units are shown before assembly. The car manufacturers have estimated that the selling price of the complete vehicle must be increased from $30 to $80 on the basis of 1947 costs if the change in headlighting is made. In a normal production year the increased cost to the car buying public would be over $100,000,000.

THE SYSTEM IN USE

Meeting at night when all cars use the system permits the driver

Figure 2. Polaroid and City Headlamps Installed

to see almost as well during the whole time of passing as he can see with the viewer in place with no opposing traffic. Conditions during rain relative to use of Sealed Beam, are better than in dry weather.

The increased light above the horizontal will compel depressing to lower beam or to adverse weather

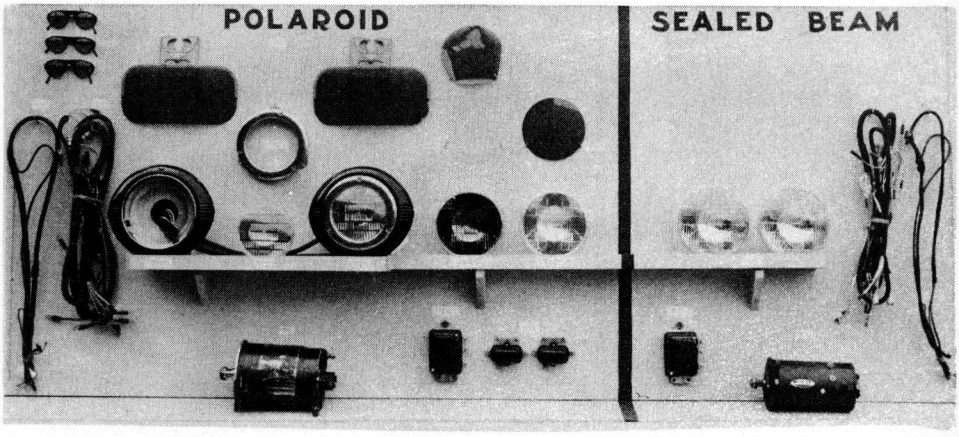

Figure 3. Comparison of Polaroid and Sealed Beam Equipment

lamps slightly more than with Sealed Beam.

The polarized lamps can be used only on rural roads. They can provide relief from glare and good vision during meeting only when all of the cars involved are equipped. A part of the public might mistakenly attempt to use viewers alone for glare relief. If 60,000 candlepower from Sealed Beam uppers should be aimed into a driver's eyes, inserting the viewer would reduce the effective glare candlepower to approximately 22,000, which would cause nearly the same loss of vision as the full 60,000.

Seeing with the polarized lamp when the viewer is in use is as safe as with the Sealed Beam upper, but since light colored objects are not as bright as with Sealed Beam at present, many observers will consider the illumination less adequate. The 100,000 cp. polarized beam, which has a larger hot spot than Sealed Beam, and relatively more light above the horizontal, will undoubtedly be accepted as a considerable improvement when no viewer is used. The polarized beam during an introductory period could be used about as the Sealed Beam upper is now used, but at each meeting a longer distance must be driven on the lower beam than is required on Sealed Beam, since the meeting drivers demand depression at least as far as 1000 ft. and usually considerably farther on a straight road. The average driver of Sealed Beam lamps shows he considers the lamps more glaring than Sealed Beam.

The viewer completely suppresses the atmospheric glow from polarized lamps, therefore, a driver behind a viewer cannot usually detect the approach of polarized lamps as long as the lamps are over a hill top, around a curve, in a road depression, or even behind another vehicle. More careful driving will be required with polarized lamps under certain conditions than is the practice of some, and possibly new design features are required, to prevent possible new driving hazards. There has not yet been enough driving with complete systems under all possible road conditions to make certain whether other hazards, presumably minor, may not require attention.

Polarized headlamps, seen through a viewer, and the surroundings of the approaching car are quite different in appearance from Sealed Beam lowers. Some observers believe that new hazards may exist in overtaking and passing cars on two lane roads in the face of opposing traffic. Other observers believe that glare elimination overbalances any handicaps. More study would be required to eliminate uncertainty regarding this question.

The city lamps when properly aimed should give a better city driving result than Sealed Beam lowers. The higher candlepower near the top of the beam increases the glare resulting from bad aim, whether this aim comes from road conditions, faulty adjustment, or overloading. This beam is non-symetrical with more light on the right than on the left. Experience has shown that it is more difficult to aim such lamps properly than is the case with Sealed Beam. When these lamps are used to supply a country passing beam and are used without a viewer, the seeing distance of obstructions is not better than with Sealed Beam lower beam candlepower limits to the so-called glare point.

Drivers having ordinary lamps can, of course, protect themselves against careless use of opposing lamps by using viewers. The viewer will cut down the effective illumination of their own lamps by 63 percent. However, the Sealed Beam driver who uses his upper beam and a viewer when driving against polarized lamps would have a seeing advantage over the driver of the lat-

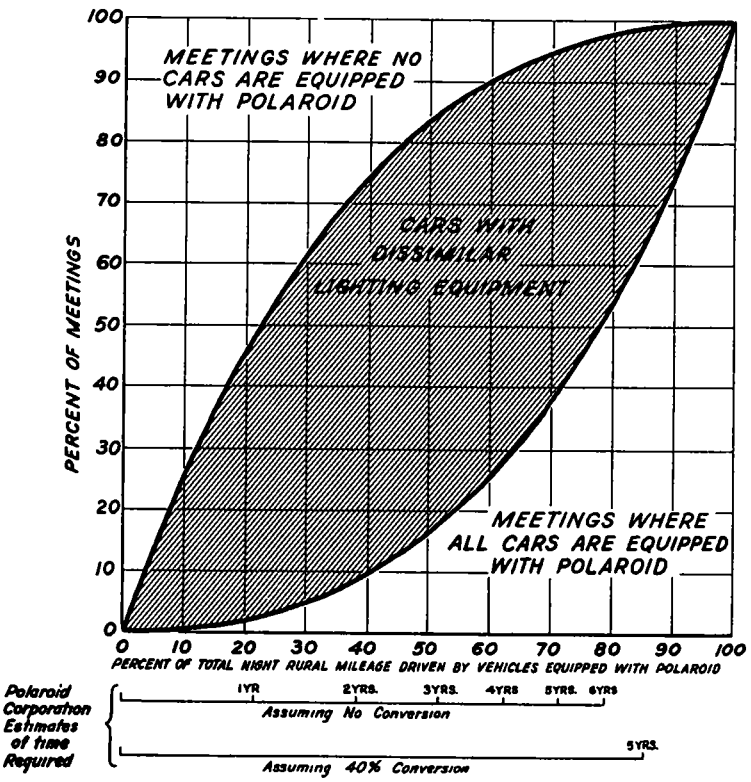

Figure 4. Estimated Proportions of Possible Types of Meetings of Cars at Night

ter when the cars are approaching each other at short distances, and the driver of the polarized lamps could do nothing to protect himself. Such driving would be a direct source of hazard, and might have an indirect injurious effect by irritating other drivers into an unfortunate attitude toward the regulations. Drivers of ordinary lamps would also be losing 63 percent of the illumination when using viewers.

Drivers would require considerable education if they are to use the polarized lamps properly. This is particularly true during any introductory period when present day and polarized systems would be in use at the same time.

CONDITIONS OF INTRODUCTION

Installation of polarized lighting on all new cars at some future date is the most rapid method of introduction that now appears possible. The cost of complete conversion of the equipment on cars in service would be much greater than for assembly line installation on new cars. Many drivers of older cars will doubt that their percentage of rural driving will justify any such cost, or even a cost considerably less than that expected. Compulsory conversion of equipment on cars on the road is not believed possible. At the end of the first year after adoption on new cars only 10 to 12 percent of the registered vehicles would have polarized lamps, and years would elapse before the last Sealed Beam car would leave the road.

The Public Roads Administration

made a traffic survey on a rural trunk road in Ohio in 1939. Mr.A.T. Court has taken the traffic distribution from this survey and constructed the curves shown in Figure 4 showing the percentage of car meetings involving different headlighting combinations for different percentages of night mileage with polarized lamps. When 50 percent of the mileage is with polarized lights, about 17 percent of the meetings involve Sealed Beam lamps only, or the same conditions as at present. Another 17 percent involve only polarized lights which should provide greatly improved conditions from the safety standpoint. The remaining 66 percent involve meetings with two kinds of equipment. There is uncertainty as to safety conditions in mixed meetings. It is difficult to see how mixed meetings could be better than Sealed Beam meetings. If mixed meetings should be actually worse, or should be believed to be worse, accidents alleged to be due in some degree to glare would be increased during the early introductory period.

New Laws Required The polarized light system cannot be used in any state until the present legal requirements for headlamps have been changed. If normal interstate traffic is to continue, the new legislation must be secured in all states before introducing polarized light and must be maintained in all states thereafter. This new legislation must provide for continued use of present lighting, and for the special problems resulting from the simultaneous use of two systems, as well as permit the use of the new polarized lighting.

CONDITIONS INFLUENCING ENGINEERING LIAISON COMMITTEE DECISION

The members of the group which had been cooperating in the polarized headlighting development were agreed early in 1947 that the system was then adequate to demonstrate the advantages of polarized headlighting. The next step for the Engineering Liaison Committee was to report to the AAMVA. Influential members of this organization had requested the study. Also the Engineering Liaison Committee desired the advice of this association, whose membership included the men best qualified to predict how the public would use polarized headlighting if given an opportunity.

Two questions might very properly be raised about the system as it stands. Will the public use it in such a way as to introduce any new night driving hazards which could be avoided by design modifications? Will the overall result in the public use be an improvement in safety for the system as it exists, or after such improvement as may be found necessary? Neither of these questions can be answered with confidence until after a tryout in the hands of the public, in a large enough area, and over a time sufficiently long so that conditions in all kinds of traffic and weather can be studied. The Engineering Liaison Committee is unfortunately not in a position to carry out any such tests. In the past new features have been tried out by offering them as optional equipment, or some aggressive manufacturer had standardized them on one or more models, and taken an advantage or a loss relative to more conservative competitors. In the case of polarized headlighting, the purchasers of new equipment which appears on a small percentage of cars would get no real benefit as far as meeting conditions in rural night driving are concerned.

Since a large scale public tryout does not appear possible, and such tryout is the only certain way to settle whether additional design modifications are needed, it seems desirable to take the system

as it stands, and make the best estimate possible whether any method of introduction available would be likely to be acceptable to the public. If the introductory conditions seem tolerable, additional work to deal with remaining uncertainties would be justified.

The automobile manufacturers have not themselves developed the electrical components in the headlighting improvements which have followed the standardization of electrical lighting nearly 40 years ago. The car manufacturers had to select from the possibilities the new devices believed desirable, develop the necessary auxiliary equipment, and then deal with the reactions of public officials and of the public. Special engineering personnel had to be assigned to the problems and this personnel supported by more expenditures relative to cost of product than has been usual for any other feature of the vehicle. A lot has been learned about what the industry can and cannot do to influence the public operation of lighting equipment. Many of the problems of the motor vehicle administrators in this area have become apparent to automobile people. The committee has used the above background in estimating the effect of various conditions, of which the following seem most important.

The complete system will provide glare-free-meetings only on rural roads, and then only when all cars involved are equipped.

The benefits during meetings in the early introductory period will be apparent at first for only a small and slowly increasing percentage of night meetings on rural roads. During this early introductory period enthusiastic endorsement cannot be expected from all owners. Some owners may easily have an unfavorable reaction if occasionally exposed to glare by Sealed Beam drivers who can use viewers and their upper beams when meeting polarized lights.

Accident records showing the percentage in any way due to glare are incomplete and apparently inaccurate. Better records are urgently needed. What evidence there is indicates that glare-caused accidents are a much smaller percentage of the total than frequently assumed. During the early introductory period mixed meetings involving polarized and present headlighting equipment increase more rapidly than do meetings involving only polarized equipment. Any increase in accidents in meetings involving mixed equipment which may be assigned to glare, could conceal any benefits due to glare prevention in the small percentage of meetings in which glare is eliminated.

The owner of a polarized light system must give it more attention than required for a Sealed Beam system if maintenance and operation are to be satisfactory. More adjustments are required. Until the last Sealed Beam equipment has been retired, the driver must be ready and willing to treat any car being met differently from the car last passed. After three years a large percentage of the cars will be in the hands of new owners, who will not be influenced by whatever instruction was given the original purchasers. Today owners of old cars in areas where there is no official periodic inspection permit their lighting equipment to get into and remain in defective condition. The use of defective polarized light systems would seem likely to involve rather more hazards than defective Sealed Beam systems.

Careless use of polarized lights seems certain to cause more complaint against glare than is caused by the same degree of carelessness in handling Sealed Beam. There is continual complaint at present that a percentage of the public fails to use the depressing switch properly.

The increased skill required to handle polarized light during the introductory period will make conditions worse. There is no reason to expect any immediate improvement in effectiveness in enforcing headlamp use regulations.

Some Sealed Beam drivers may attempt to use viewers to protect themselves against glare from polarized light drivers who fail to depress properly. They will be tempted to retaliate against such drivers by using their upper beams. Viewers will reduce the seeing of drivers of ordinary lighting. If polarized lighting is in use, it will undoubtedly be impossible to prevent any driver from purchasing viewers and attempting to use them. This condition seems to provide possibility of trouble.

A part of the public is almost certain to believe at the time of any initial announcement of introduction that polarized lighting is a complete cure for the glare problem. This seems likely regardless of efforts to prevent misunderstanding. This part of the public would be likely to be seriously disappointed sometime during the introductory period after everyone has had some experience in meeting faulty use of the equipment, and before any real benefits have been accomplished. If any important group in any state became actively opposed to continuing the use of polarized light, active support from some organization believed to be without bias or self interest might be required to prevent legislative changes restricting the later use of polarized lamps. Such adverse legislation could seriously handicap the normal interstate traffic and sale of automobiles.

After consideration of the facts available, the Committee arrived at the decision stated in its report to the AAMVA, from which the following is quoted:

"RECOMMENDATIONS"

"The automobile industry, with the cooperation of the Polaroid Corporation and the General Electric Company, has developed a complete polarized headlighting system in order to investigate its possibilities as an answer to the glare problem. The system has been subjected to extensive testing and study not only by the industry's lighting engineers but also by the same engineering executives who were responsible for the development of the Sealed Beam headlamps.

"On the basis of this development work, the Engineering Liaison Committee of the Automobile Manufacturers Association, which has been responsible for the investigation, has recommended against the adoption of polarized headlighting at this time. This recommendation has been approved by the Board of Directors of the Association and is concurred in by the Ford Motor Company, which has cooperated in the program. The recommendation is based on the following considerations, among others:

1. The full benefits of such improved seeing and relief from glare as may be afforded by polarized headlighting when driving on rural roads would be obtained only when used on all cars.

2. Such universal rural use cannot be secured quickly since there appears to be no practical way to quickly convert the more than 30 million cars on the highways to polarized headlighting.

3. Introduction of polarized headlighting on new cars only would be followed by a lengthy period of mixed use of new and present headlighting.

4. During the period of mixed use among the probabilities foreseen are the following:

A. Drivers who have paid the higher prices for new cars made necessary by polarized lighting

would be disappointed at the long delay in getting the advantages of the new lighting in any large percentage of meetings with other cars at night.

B. Careless or discourteous drivers of cars with present lighting could use their upper beams to glare the drivers of polarized lighting, and at the same time protect themselves against the glare of the polarized beam simply by equipping their cars with polarized viewers.

C. The percentage of drivers of polarized lights who would be careless or discourteous in the use of the polarized beam when meeting cars with present lighting may be expected to be as large as it is with drivers of Sealed Beam cars, and just as hard to control through police power as at present.

D. Thus glare would continue to be a problem, and particularly during the first part of a period of mixed driving might well produce a build-up of public resentment against polarized lights that would result in the repeal of permissive legislation in some states. This would interfere seriously with interstate motoring and incidentally produce serious problems in the distribution of mass produced automobiles.

5. New hazards will develop in the use of polarized headlighting at hill tops, curves, and when overtaking and passing unless all drivers follow different practices from those used by some drivers today. It has been difficult in the past to persuade many drivers to change their habits by educational methods.

"Based on experience to date, the Committee is not convinced that the benefits during a considerable period after complete conversion to polarized lighting will overbalance the troubles which it feels certain will develop in the long transition period. Therefore, the Committee believes that it is not in the public interest to introduce polarized lighting at the present time.

"The Committee would be very glad to study, in cooperation with the administrators if they so desire, any new developments which may promise to make the introduction of polarized headlighting at some later date, a worthwhile venture in the interest of public safety."

The Committee on Engineering and Vehicle Inspection of the AAMVA reported to its association that it was "in accord with the belief that polarized headlighting should not be introduced at this time." This committee also recommended in its report which was accepted by the association that a study should be made of the legal problems which would be involved in the introduction of polarized headlighting.

The situation at present is that the Engineering Liaison Committee is awaiting advice from the administrators as to what additional studies may be desirable. Any organization interested in the possibilities of polarized lighting is urged to give careful consideration to any report from the AAMVA, and to the November 1947 report of the Engineering Liaison Committee to the AAMVA.

THE GENERAL ELECTRIC CO. TESTS ON POLARIZED HEADLIGHTING

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GENERAL DISCUSSION

In his paper, Dr. Land mentions comparative visibility data based upon tests with observer-drivers conducted by the General Electric Company. Since the prime requisite of motor vehicle headlighting is seeing distance in excess of stopping distance we have, over a period of years, made a large number of seeing distance measurements with observer-drivers to determine the relation between beam candle power and visibility distance both on the clear road and when meeting other vehicles.

The headlighting problem would be relatively simple if we could ignore the condition of meeting other vehicles. That is, it is easy to design headlamps with a single beam which would provide adequate seeing distances on the clear road. The upper beam of Sealed Beam headlamps comes fairly close to meeting this clear road requirement. As a matter of fact, with a moderate increase in the high-intensity zone, and a considerable increase in beam candlepower 1 deg. above the horizontal, the Sealed Beam upper beam would fulfill practically all requirements for safe driving at reasonable speeds, when no other cars are approaching.

The present Sealed Beam lower beam is a compromise between the requirements of providing seeing for the driver behind it and the need to avoid blinding glare for the approaching driver. It is a relatively poor clear-road beam because the light at and near the horizontal is limited to values that will not give undue glare annoyance.

When drivers use Sealed Beam headlamps properly - the upper beam when no cars are approaching within 1000 ft., and the lower beam when signalled, and always within 1000 ft. of an approaching car - seeing distances generally are enough greater than minimum stopping distances from reasonable night speeds to provide a factor of safety. But they do vary from values which provide a reasonable factor of safety to those which provide little or no factor of safety. And under the conditions of improper usage - failure to shift to the lower beam when meeting other cars, and failure to shift back to the upper beam when the road is clear - the seeing distance is often less than the stopping distance.

The most critical hazard from the standpoint of seeing is a pedestrian dressed in dark clothing. An observer-driver, knowingly engaged in a test and using the Sealed Beam upper beam can see the pedestrian in dark clothing at 500 ft. when driving 40 mph. Tests upon a large number of observer-drivers show an attention factor of 0.5. That is, we have found that the unexpected obstacle is seen only half as far away as the expected obstacle on the clear road. Applying this attention factor of one-half to the 500-ft. measurement we obtain a seeing distance of 250 ft. for a pedestrian in dark clothing with the Sealed Beam upper beam on the clear road. Applying the legally

accepted deceleration rate of 14.5 ft. per sec. per sec. plus 3/4-sec. reaction time for stops from 20- to 40-mph speed, we arrive at a stopping distance of 165 ft. Therefore with a Sealed Beam upper beam on the clear road the 250-ft. seeing distance provides a margin of 85 ft. beyond the stopping distance at 40 mph.

When meeting other vehicles, the seeing distance is reduced by the glare from the approaching lamps. Considering the condition of a Sealed Beam upper beam facing another Sealed Beam upper beam, when the two cars are 3200 ft. apart, the clear road seeing distance, according to our measurements is reduced 40 percent. That is, the 500 ft. figure mentioned previously is reduced to 300 ft.

We have never been able to establish a numerical value for the attention factor under the condition of meeting approaching vehicles, but it seems logical to assume that this is higher than the 0.5 value obtained under clear road driving conditions. The driver should and no doubt does, concentrate his attention upon his immediate path of travel when meeting other vehicles - certainly more so than when driving on the clear road. I believe that a fair estimate of the attention factor for the condition of meeting other vehicles is 0.7. Therefore, considering the condition of two cars with Sealed Beam upper beams, 3200 ft. apart, if we apply a factor of 0.7 to the 300-ft. seeing distance value for the observer-driver knowingly engaged in a test, we arrive at a seeing distance of 210 ft., which still gives a margin of 45 ft. above the stopping distance value, at 40 mph.

As the two cars continue to approach, the seeing distance drops because the effect of glare becomes worse. Our tests show that when they are 1200 ft. apart on a straight road, the seeing distance has dropped to a value which is equal to that for the lower beams of Sealed Beam headlamps. This therefore is the optimum distance for depressing the beams. Many drivers experience excellent silhouette seeing with the lower beams. That is, they see objects on the road between the two cars silhouetted against the road lighted by the approaching lamps. This silhouette seeing distance sometimes exceeds the clear road seeing distance for the upper beams. However, many drivers do not always experience this silhouette seeing, and the direct seeing distance with the lower beam, facing another lower beam continues to drop and reaches its lowest value when the two cars are approximately 100 ft. apart. For the observer knowingly engaged in a test, the seeing distance drops to approximately 200 ft. And if we apply my estimated attention factor of 0.7 this becomes 140 ft. for the normal driver. This 140-ft. value is 25 ft. less than the stopping distance I mentioned previously, and applies to the last 100 ft. of meeting.

Therefore, even with proper usage of Sealed Beam lamps when meeting other vehicles, there are short periods when the seeing distance with Sealed Beam headlamps is somewhat less than the stopping distance, at 40 mph., considering the critical hazard of a pedestrian dressed in dark clothing. Of course when drivers do not depress their beams, the situation is worse because of the added glare from the upper beams.

As Dr. Land has indicated, if all cars have polarized headlighting of the type developed cooperatively by the automotive industry, the Polaroid Corporation, and the General Electric Company, the clear road seeing distance looking through the analyzer, and considering the observer-driver knowingly engaged in a test, is the same as that for the Sealed Beam upper beam:

500 ft. When meeting another polarized car on a straight, level road, our tests show that the seeing distance drops only about 50 ft. below the clear road values - to 450 ft. If we apply the estimated attention factor of 0.7, this becomes 315 ft. and therefore provides a margin of 150 ft. beyond the stopping distance value. And this 150 ft. margin or the 350 ft. seeing distance continues to apply until the two cars meet and pass.

During transition period from a Sealed Beam headlighting to polarized headlighting, we can certainly expect some misuse of the headlamps. That is, just as many drivers now do not depress their beams, we can expect this condition to continue, assuming present degrees of enforcement and education.

To determine the seeing conditions during a transition period of driving, we made a comprehensive series of tests with Sealed Beam headlamps facing polarized headlamps and polarized headlamps facing Sealed Beam headlamps under conditions of proper and improper usage. These test results lead to a general conclusion to the effect that the range of seeing distances encountered during the period of transition to polarized headlighting would be no greater than the range of seeing distances encountered during the present period of transition from pre-Sealed Beam to Sealed Beam headlighting. And the driver of the polarized car would enjoy somewhat higher seeing distance (without the analyzer) even during the early stages of the transition period. However, the annoyance when facing the polarized upper beam without an analyzer would be greater than that when facing the present Sealed Beam upper beam. This leads to a justified fear on the part of the automotive industry that the greater annoyance to drivers without polarized headlamps when facing drivers with polarized headlamps who don't depress, may cause a public reaction against polarized headlighting which could lead to restrictive legislation. A possible answer might be compulsory legislation similar to that requiring safety glass. Such compulsory legislation would serve to protect the industry's, and the public's investment in polarized headlighting and would minimize the opportunity for subsequent restrictive legislation. In addition to compulsory legislation, we would also need a concerted educational effort directed toward obtaining better usage of headlighting than we have been able to enjoy up to this time.

DESCRIPTION OF TESTS

For the comprehensive series of tests here reported, the General Motors Corporation made available to us the facilities of its proving grounds. The test roadway was a 1.3-mi. stretch of straight, level concrete. A test car was started at each end, one mile apart. They travelled in adjacent lanes at a uniform speed of 40 mph. Man-sized dummies in dark clothing were placed about 2 ft. inside the edge of the lane on the right-hand side. Determination of distance at which the driver first became aware of the presence of the obstacle was made from both cars and of two dummy positions for each run. The determinations were repeated with dummies placed at successive intervals ahead and behind the passing point to permit plotting a continuous seeing-distance curve. Six observers were used and a minimum of two observations were made by each observer for each dummy position. The accompanying charts show in each case the range of results for the six observers.

I should emphasize the fact that these data were obtained with observer-drivers who were expecting to see an obstacle, who knew that

the road ahead was straight and how the oncoming car would be driven, and who were therefore undoubtedly paying somewhat more attention to the seeing task than drivers proceeding normally in traffic. Therefore the seeing distances shown on

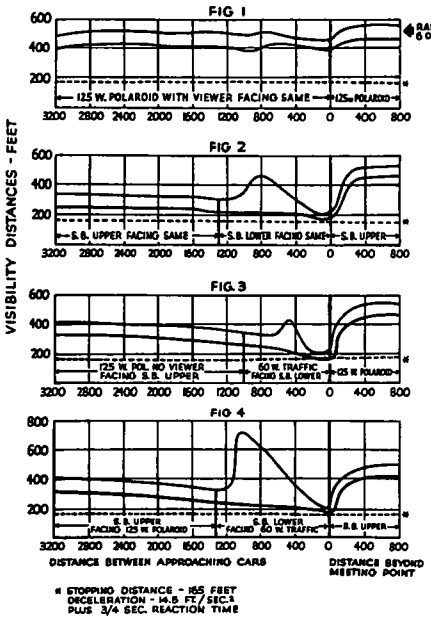

Chart I. Driver-Visibility Distances - Proper Headlamp Usage

the accompanying charts are higher than would be encountered under more normal driving conditions, which points to the desirability of maintaining values of seeing distance well above the legally accepted stopping distances. No attention factor was applied to these data.

To obtain a comparison of seeing distances with polarized headlamps and with Sealed Beam headlamps during the transition period following an introduction of polarized headlighting, we investigated a number of different combinations which would be encountered. The respective resulting visibility distances are charted in Figures 1 through 11. They cover both proper and improper usage of each of the conditions. The upper beams, polarized and Sealed Beam, were aimed with the center of the high-intensity zone directed straight ahead and at the level of the lamp centers from the ground.

Polarized Headlamps Facing Same Figure 1 on Chart I shows the seeing condition when a polarized car meets another polarized car. The band of seeing distance represents the spread between six observers, all of whom had 20/20 visual acuity or correction to 20/20. Seeing distances are relatively uniform and provide a good factor of safety above the stopping distance.

Sealed Beam Headlamps Facing Same Figure 2 illustrates the situation with Sealed Beam lamps on both cars, and properly used. Because of glare interference, the visibility distance when the two cars are 3000 ft. apart is 40 percent less than the clear road value. This continues to drop as the cars approach and when it reaches the value for lower beams, this is the optimum time for depressing the beams. At the moment of passing, the two drivers shift to their upper beams and the seeing distance rises to the clear road value. Most of the seeing distance curve is well above the stopping distance line. But part drops close - even under this condition of proper usage, and with drivers knowingly engaged in a test.

The large spread between observers for that part of the curve represented by use of the lower beams, is due to the fact of silhouette seeing - the outlining of the obstacle as a dark silhouette against the road lighted by the approaching headlamps. However, this is not as certain as direct seeing, hence the greater spread between observers for this section of the curve.

Polarized Headlamps Facing Sealed Beam Headlamps Figure 3 shows the

condition for a polarized car facing a Sealed Beam car, both using their headlamps properly. Figure 4 shows the reverse of the situation in Figure 3 - a Sealed Beam car facing a polarized car. You will note that these curves are similar to that of Figure 2.

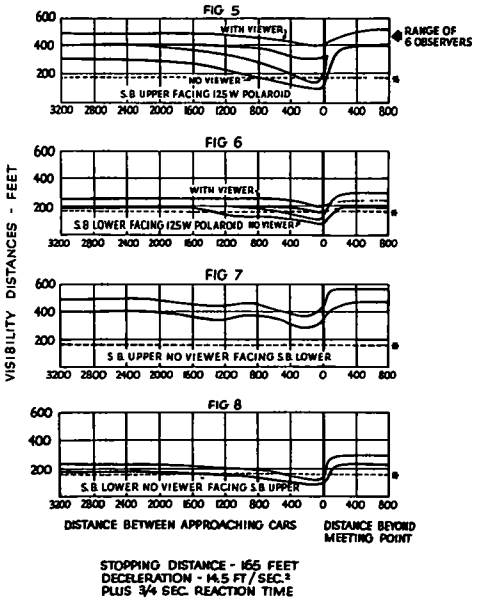

Chart II. Visibility Distances for a Sealed Beam Driver Improper Usage

From these data it appears that with proper usage, the driver of a polarized car on the average will be able to see somewhat farther during the transition period - as compared with present conditions, and the driver of the Sealed Beam car on the average, will be about as well off as at present. Of course these data do not indicate relative annoyance due to glare. Undoubtedly many drivers of Sealed Beam will be annoyed more by the polarized upper beams and will probably signal for depressing at a greater distance. In fact, this has been illustrated by actual driving experience with test cars fitted with polarized lamps.

Charts II and III, Figures 5 to 11, illustrate the seeing distances under improper usage of both Sealed Beam and polarized lamps. Chart II covers the Sealed Beam car facing the polarized car; Chart III covers the polarized car facing the Sealed Beam car. These data should of course be compared with improper usage of Sealed Beam units under present conditions. Chart II includes such data. Considering improper usage the driver of the polarized car (under this test situation) had somewhat better average seeing distance as compared with

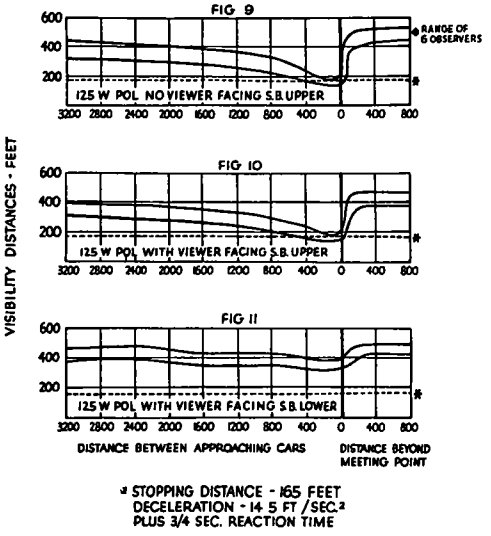

Chart III. Visibility Distances for a Polaroid Driver Improper Usage

present situations of improper usage; whereas the driver of the Sealed Beam car faced a situation that gave seeing distances varying from somewhat better to slightly worse than the present situation.

However, there is still another comparison that should be made. We are now in a transition period - from pre-Sealed Beam headlights to Sealed Beam headlights. Because of the serious depreciation common to pre-1940 headlamps, these drivers, still numbering approximately 1/3

of the total, have much shorter seeing distances than those indicated by the data discussed so far.

Pre-Sealed Beam Headlamps Facing Sealed Beam Figures 12, 13, and 14 illustrate the situation for a pre-Sealed Beam car facing the Sealed Beam car, considering both proper and improper usage. The headlamps on this car are assumed to be depreciated to a point where the maximum output has been reduced to 5000 beam candlepower from the pair. Many on the road are this poor, especially after considering the factor of misaim. This driver has less seeing distance than the driver of a Sealed Beam car facing polarized headlamps, considering either proper or improper usage. Assuming that there will be few, if any, pre-Sealed Beam cars on the road at the time of introduction of polarized lighting, a general conclusion may be made that the range of seeing distances encountered during the period of transition to polarized headlighting would be no greater than the range of seeing distances encountered during the transition to Sealed Beam headlighting. And the driver of the polarized car would enjoy somewhat higher seeing distance, even during the early stages of the transition period.

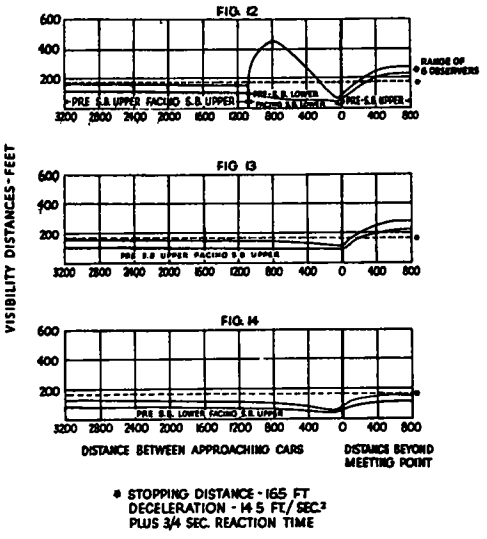

Chart IV. Visibility Distances for a Pre-Sealed Beam Driver 5000 Beam Candlepower

Auxiliary Polarized System If it were found feasible to provide a suitable auxiliary polarized system for old cars, the conditions in the transition period should be alleviated. Figures 15 and 16, Chart V, illustrate the situation with a system suggested by the Polaroid Corporation consisting of one 70-watt polarized unit added to the Sealed Beam system. The suggested use is Sealed Beam upper for clear road driving, Sealed Beam lower for driving in the city and when signalled on the open road, and one lower beam unit plus the polarized auxiliary when meeting polarized headlamps. The switching could be effected in combination with raising and lowering the polarized visor.

The polarized part of the system is supplementary to the regular Sealed Beam headlighting, and is intended for use only when meeting other polarized cars. This makes it feasible to sacrifice spread to the sides from the polarized unit,

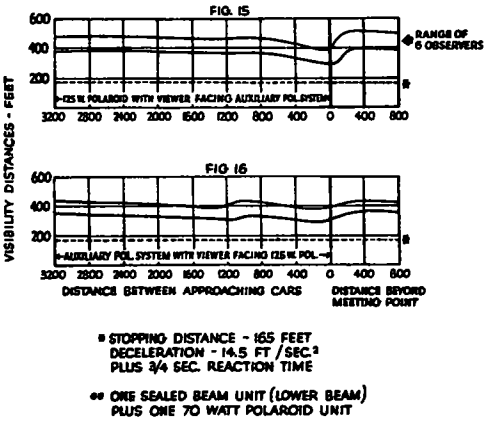

Chart V. Visibility Distances for Drivers with Full Polaroid and Auxiliary Polaroid Systems

hence gain sufficiently high beam candlepower for seeing distances that are superior to the present situation. This system could be handled with present generator capacity.

I believe we all agree that the most serious problem in connection with a decision of the use of polarized headlighting is that of the 34,000,000 vehicles now on the roads. If the legal authorities wish to permit the use of a standard, low cost auxiliary system for voluntary installation by present owners, some percentage of present cars, trucks, and busses would be equipped, thus increasing the incidence of polarized meetings.

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