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

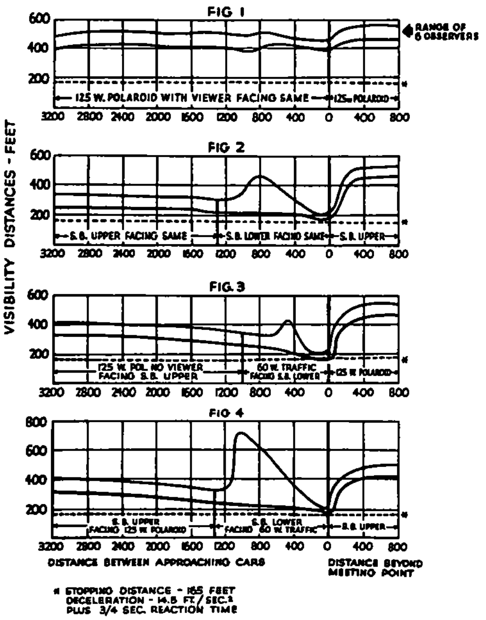

Chart I. Driver-Visibility Distances - Proper Headlamp Usage

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.

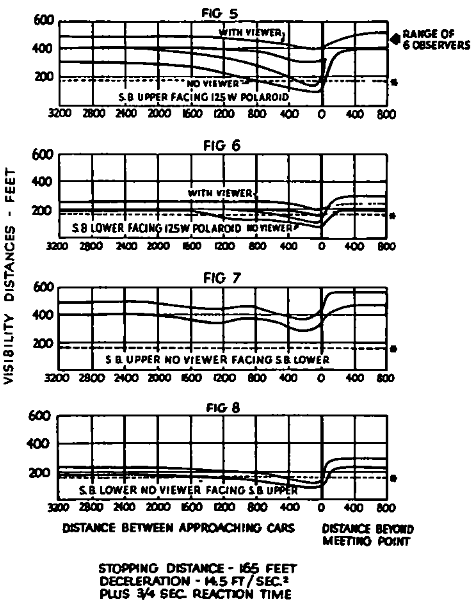

Chart II. Visibility Distances for a Sealed Beam Driver Improper Usage

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

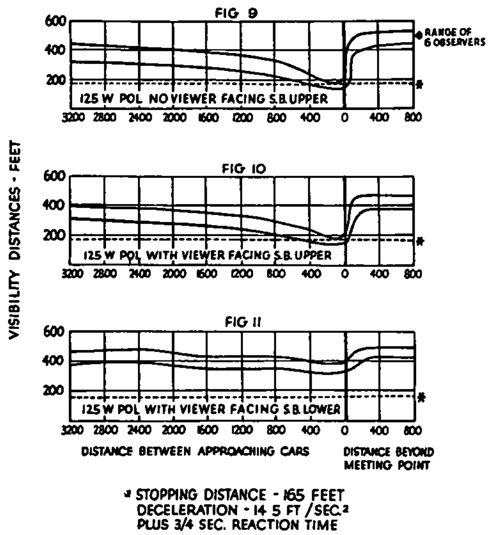

Chart III. Visibility Distances for a Polaroid Driver Improper Usage

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 fac-

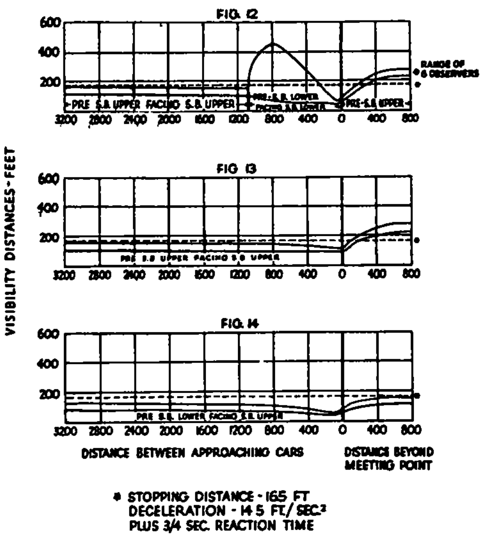

Chart IV. Visibility Distances for a Pre-Sealed Beam Driver 5000 Beam Candlepower

tor 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.

Auxiliary Polarized System If it were found feasible to provide a

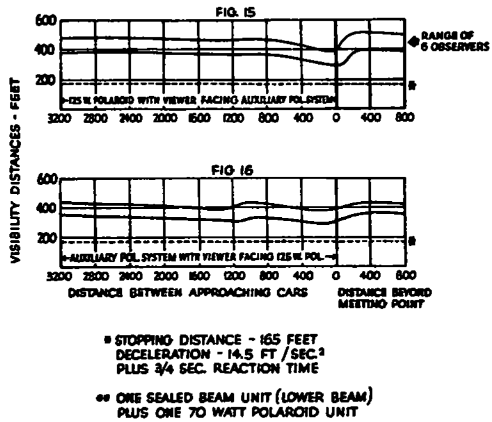

Chart V. Visibility Distances for Drivers with Full Polaroid and Auxiliary Polaroid Systems

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, 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.