CONTROLLING HEAD-LAMP AIM

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The results of passenger vehicle inspections in California and examination of a 20-vehicle test sample indicate that perhaps one-third to one-half of the head lamps in all vehicles are misaimed. Results obtained for the sample of 70 sealed-beam head lamps of the various types in common use show that, when correctly aimed existing lamps were simply replaced by other units, nearly half of the newly installed head lamps failed to meet the SAE aim requirements. After 90 days of normal service on the test vehicles, involving an average mileage per vehicle of 12,762 miles, about half of the lamps—all of which began the test period in correct adjustment—no longer met the specified aim requirements. A general survey of head-lamp housings revealed a number of design and construction features that appear to be endowed with an inherent instability and thus probably contribute materially to the problems of controlling head-lamp aim. Photometric tests were performed in accordance with SAE specifications for each of 165 sealed-beam head-lamp units purchased on the open market in northern California. Of the entire test sample, 64 percent failed to meet the photometric requirements specified. Of those that failed, however, about two-thirds could meet the photometric requirements if the aiming plane were shifted to some position other than that specified for the test. This indicates that the aiming plane, as determined by the aiming pads on the sealed-beam unit, is in many cases not being established with sufficient accuracy in production, and as a consequence even a correctly aimed head lamp on a vehicle may not produce an acceptable beam pattern on the roadway.

•A GREAT deal of progress has been made over the years in the optical design of automotive head lamps so that today's sealed-beam units are capable of providing vastly better roadway illumination than those that were first introduced on cars. In one respect, however, the present situation is like a castle built on sand. A head lamp will perform well only as long as it remains correctly aimed, and this, unfortunately, is what constitutes the unstable foundation for the entire headlighting system. As in the past, it is still too difficult to maintain proper head-lamp aim on vehicles, and as a consequence the quality of headlighting on the roadway remains substantially degraded.

The problem of controlling head-lamp aim became quite apparent as early as 1918 when the first joint IES-SAE specifications for the optical performance of head lamps on the road were adopted. Although the purpose of these specifications was to help provide adequate roadway illumination with a minimum of glare to oncoming drivers, it was found that variations in the aim of head lamps designed to meet these standards contributed substantially in practice to glare discomfort as well as inadequate road visibility (1). This factor was thus capable of almost completely offsetting the beneficial effects of the specification.

Although various devices for preventing or reducing head-lamp glare were introduced, the problem of misaim continued to mount in subsequent years, particularly as head-lamp beam intensities were being increased. The control of head-lamp aim was

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not seriously dealt with until the first SAE specification for adjustable head-lamp mountings (SAE J566) was adopted in 1936, and a recommended visual aiming procedure (SAE J599) was established shortly thereafter.

Although these practices constituted a step in the right direction, the situation remained far short of what must be considered desirable. Specification J566 suffered from being somewhat ambiguous because it used such vague or ill-defined terms as "practical operating conditions" and "ordinary conditions of service." The visual aiming procedure, because it relies heavily on subjective factors as well as on suitable uniformity among head-lamp beam patterns, produces results too inconsistent to be satisfactory. This is particularly true in the case of the low beams, which in this procedure must be aimed by judging something as indefinite as the "top edge" or "left edge" of a nonsymmetrical high-intensity zone.

In 1956 a great stride forward was made with the introduction of new sealed-beam units incorporating aiming pads around the periphery of the outer lens surface. These aiming pads made it possible to aim the lamps by means of relatively simple mechanical aiming devices, thus greatly simplifying the aiming procedure and doing away with the need to rely on visual judgment. Along with this development, the industry launched a widespread educational program designed to promote proper head-lamp aiming practices among the motoring public as well as among automotive service facilities and law-enforcement agencies (2).

Under this double-pronged attack, the problem of head-lamp misaim should have dwindled to negligible proportions. But, as anyone who does much night driving can testify, this has not proved to be the case; at times, the situation seems to be as bad as ever.

HEAD-LAMP AIM STUDIES

To assess the situation and examine some of the problems of controlling head-lamp aim, particularly in relation to manufacturing considerations, our laboratory studied the subject for the California Highway Patrol.

TABLE 1

HEAD-LAMP AIM TEST SAMPLE

Vehicle Type	Number of Vehicles	Number of Head Lamps		
		Type 1 (5¾ in.)	Type 2 (5¾ in.)	Type 2 (7 in.)
1968/69 Dodge Polara[a]	9	18	18	–
1962 Mercury Monterey	1	2	2	–
1963 Chevrolet BelAir station wagon	1	2	2	–
1961 Chevrolet Impala	1	2	2	–
1966 GMC ½-ton pickup	1	2	2	–
Peterbilt truck tractor	1	2	2	–
Kenworth tractor	1	2	2	–
1967 Chevy II sedan	1	–	–	2
1965 International Travelall	1	–	–	2
1966 Ford Ranchero	1	–	–	2
White truck tractor	1	–	–	2
Mack truck tractor	1	–	–	2
Total	20	30	30	10

[a]California Highway Patrol cars.

Effects of Driving and Lamp Replacement

In one of these studies (3) we worked with a small sample of 20 vehicles, including a total of 70 head lamps of various types (Table 1), to see how lamp aim would be affected by 90 days of field service and the degree of misaim arising solely from lamp replacement.

First we checked the aim of the head lamps of all 20 vehicles in the sample as they were brought in for test. Our purpose in this step was to get a rough idea of the extent of head-lamp misaim among the existing vehicle population as represented by our sample. In performing these tests, we used a set of mechanical aimers similar to those used by California Highway Patrol-Passenger Vehicle Inspection (CHP-PVI) teams in their on-the-road inspection program. The aim of the lamps was checked with respect to both the California Official Lamp Adjusting Station tolerances (based on SAE specifications) and the CHP-PVI tolerances (Table 2). The latter are much broader than the former to allow for the considerable variations in aim due to the different vehicle loads that might be encountered by the inspection teams. The results of our examination are shown in Figure 1.

Although based on an admittedly tiny sampling, our results nevertheless proved to be quite indicative of the situation—at least as it exists in California—as revealed by the following figures from the CHP-PVI program. Of a total of 158,000 domestic 1968- through 1970- model cars inspected, approximately 19 percent were in violation insofar as head-lamp aim was concerned (4). It should be noted that, in the CHP data, only one violation per vehicle is counted regardless of how many lamps on the vehicle may have been outside the specified tolerances. Because the CHP sample included cars with both two- and four-lamp systems, it is quite probable that on the average as many as two head lamps per vehicle in violation were misaimed.

TABLE 2

HEAD-LAMP AIM TOLERANCES[a]

Lamp Type	Official Lamp Adjusting Station Tolerance		CHP-PVI Tolerance	
	Horizontal	Vertical	Horizontal	Vertical
Type 2	1.0 left to 4.0 right	0.5 down to 3.5 down	4.0 left to 8.0 right	4.0 up to 8.0 down
Type 1	4.0 left to 4.0 right	0.5 down to 3.5 down	8.0 left to 8.0 right	4.0 up to 8.0 down

[a] Figures represent displacement in in. from H and V axes at 25 ft in front of lamp.

After the head lamps of our 20-vehicle test sample were checked for their "as-is" aim condition, they were carefully adjusted for correct aim in accordance with SAE specifications (J599a). All of the sealed-beam units were then replaced with new ones purchased at various retail outlets and, without disturbing the previously made aim settings, the aim was checked once again. (The same lamp-replacement procedure was also followed after the 90-day field service period to increase the size of our sample.) In this way, we obtained an indication of the extent to which lamp replacement alone can affect the aim in a vehicle population; the results are shown in Figure 2.

All head lamps were once more adjusted for correct aim, and the vehicles were returned to normal use for a period of 90 days. At the end of that time, a check of the lamp aim on all test vehicles yielded the results shown in Figure 3. The mile-age registered by the test vehicles ranged from 1,000 to 25,000 miles, with a mean value of 12,762 miles for the 20 vehicles. No record was kept of the type or severity of service in the test period. However, at the conclusion of the test, none of the vehicles showed any signs of physical damage that could have affected the head-lamp aim settings.

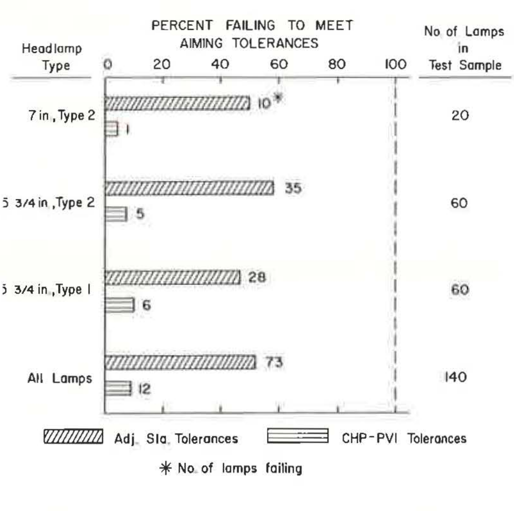


Figure 2. Aim of head lamps on test vehicles immediately after replacement of sealed-beam units.

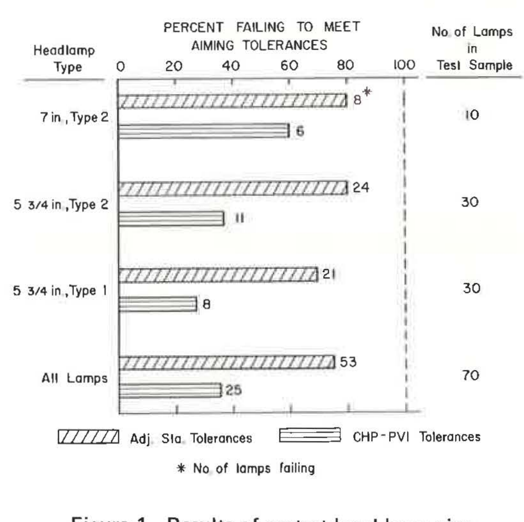


Figure 1. Results of pretest head-lamp aim inspection of test vehicles.

Construction of Head-Lamp Housings

The question of what could cause roughly half of the head lamps, which were properly installed and aimed, to go out of adjustment within 3 months of normal service led, in a subsequent study for the California Highway Patrol, to an investigation of the design and construction of head-lamp housings (5). Examination of a variety of housings of both domestic and foreign manufacture revealed a number of what we consider to be design weaknesses.

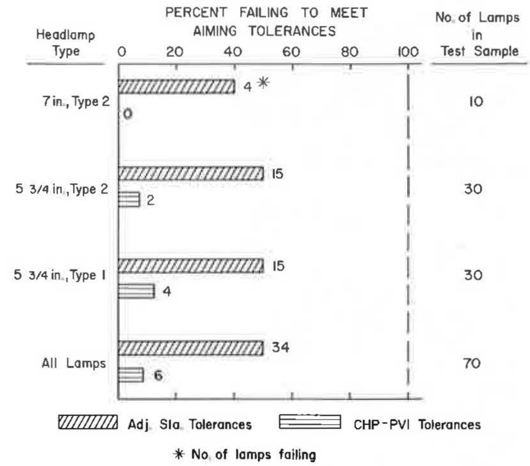


Figure 3. Aim of head lamps on test vehicles after 90 days of normal service.

All automobile head-lamp housings apparently use the same basic aim-adjustment mechanism, in which the back of the mounting ring that holds the sealed-beam unit bears against three raised points on the housing frame and slides against these points as the adjustment screws are turned. Although these contact points are greased on many new vehicles to reduce friction, continued use will result in the accumulation of corrosion products and dirt in the contact areas. As a result, the sliding surfaces may bind when an aim adjustment is being made so that the lamp assembly remains in a metastable state until subsequent vibration or jarring moves it into a more stable condition but out of aim tolerances.

Many head-lamp housing frames are made of inadequately reinforced sheet metal. These are particularly prone to deformation by the force or impact from minor collisions such as might be encountered in parking or at traffic stops. It is even possible, in some cases, that the force due to the weight of a mechanical aiming device attached to the head lamp may cause enough temporary deformation of the housing to result in an incorrect aim adjustment. It should be noted in this regard that, although SAE specifications (J580a) require that sealed-beam head-lamp assemblies withstand a force of 50 lb against the outer lens surface without the lamp unit receding into the housing, this does not preclude the bending of the entire housing frame.

Another example of poor design encountered among head-lamp assemblies involves the arrangement for fastening the lamp retaining ring to the mounting ring. The retaining ring, sometimes called the trim ring, is the part that holds the sealed-beam unit firmly in place within the mounting ring so that the entire lamp assembly pivots in unison as the aim-adjustment screws are turned. In one type of design, the sheet metal screws holding the trim ring in place must be completely removed and reinserted each time the head-lamp unit is replaced. This makes the few threads in the holes of the sheet-metal mounting ring highly susceptible to stripping, particularly when improperly started screws produce cross-threading. If the mounting hole threads strip, the trim ring can pop out enough to throw the lamp badly out of aim (Fig. 4). A much more preferable design uses slotted ears on the retaining ring or figure-eight clearance holes (Fig. 5) so that the sheet-metal mounting screws do not have to be taken out entirely to remove or replace the ring.

Establishment of Mechanical Aiming Plane

Even if all the foregoing deficiencies were to be corrected, however, one additional difficulty would still remain insofar as controlling head-lamp aim is concerned. This problem involves the establishment of the mechanical aiming plane in the manufacture of the sealed-beam units. There is strong evidence to suggest that current manufacturing controls are inadequate in many cases to maintain the proper dimensional relationship between the optical system of the lamp unit and the aiming plane as determined

Figure 4. This fastening arrangement for the head-lamp retaining ring can lead to the stripping of threads in the mounting hole and consequent loosening of the assembly as shown.

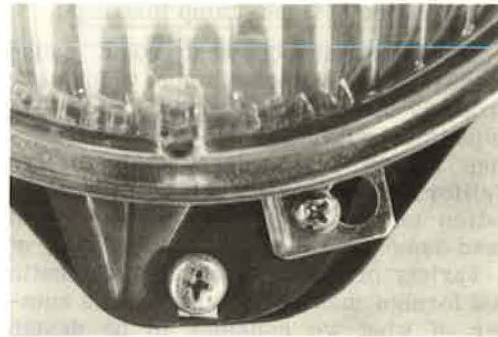


Figure 5. This preferred type of fastening arrangement for the head-lamp retaining ring permits replacement of the sealed-beam unit without complete removal of the mounting screws.

by the aiming pads. As a result, such a lamp may be correctly set within mechanical aiming tolerances and still not produce the required beam pattern on the roadway.

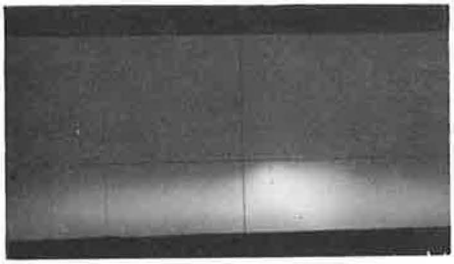
We investigated a sample of 165 sealed-beam head lamps of various types and makes that had previously received type approval for use on new vehicles sold in California (4). Although these lamps were bought at retail outlets as replacement units, they are presumably identical to the corresponding OEM units because manufacturers are not known to maintain separate production facilities for the two categories.

All of the lamps in our sample were tested in accordance with SAE Standard J579a, which forms a part of the current Federal Motor Vehicle Safety Standards and sets forth the photometric and visual-aim requirements for sealed-beam head-lamp units. The test results showed that 106 units, or 64 percent of the sample, failed to meet the photometric requirements, and 90 units, or 55 percent, failed to meet the visual-aim requirements. It was found, furthermore, that, of the 106 units failing the photometric test, perhaps 67 percent (based on a sampling of 79 units out of the 106) would meet the photometric requirements if their aiming planes were shifted to some position other than that specified for the test and not necessarily to one producing a correct visual-aim setting. Figure 6 shows the beam pattern produced by one of our test lamps on an aiming screen at three different settings, each meeting only one of the specified requirements—mechanical aim, visual aim, or photometric distribution.

These results indicate that, although some 78 percent of the sealed-beam head lamps in use are optically capable of producing an acceptable photometric distribution, roughly half of these will not produce the proper beam pattern on the roadway throughout the entire allowable range of mechanical-aim settings because the aiming planes are not established with sufficient accuracy in the course of manufacture.

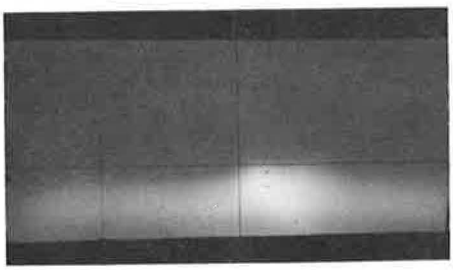
DISSUSSION OF FINDINGS

There is abundant evidence to show that, despite the many years of effort that have gone into improving motor vehicle headlighting, the control of head-lamp aim remains the weakest element in the system and still presents a serious problem insofar as proper roadway illumination is concerned. Indeed, it has been shown that a sealed-beam unit



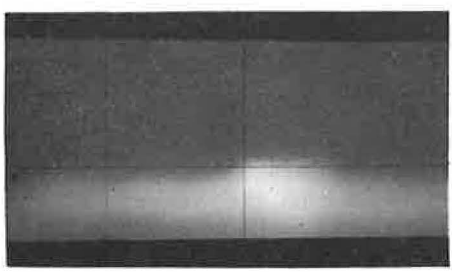
a.

Lamp set for correct mechanical aim; fails to meet SAE photometric and visual-aim requirements under these conditions.



b.

Aiming plane of lamp shifted for correct visual aim; lamp still fails to meet photometric requirements.



c.

Aiming plane shifted to point at which beam meets photometric requirements; lamp fails to meet visual-aim requirements at this setting.

Figure 6. Low-beam patterns produced by head lamp (type 4002) on aiming 25 ft away (lines represent horizontal and vertical aiming axes, crosses indicate SAE photometric test points): (a) lamp set for correct mechanical aim fails to meet SAE photometric and visual-aim requirements under these conditions; (b) with aiming plane of lamp shifted for correct visual aim, lamp still fails to meet photometric requirements; (c) with aiming plane shifted to point at which beam meets photometric requirements, lamp fails to meet visual aim requirements.

such as used in present dual head-lamp systems, if misaimed 1 deg low, can reduce the seeing distance to well below that provided by a correctly aimed unit of the type in use in 1940, thus virtually nullifying almost 20 years of progress in head-lamp beam design (6). By the same token, if the lamps are misaimed high or to the left, the glare for an oncoming driver is increased, and his seeing distance may be significantly reduced (7, 8).

Among the factors contributing to misaim, the process of lamp replacement appears to play an important role. Our tests have shown that when a correctly aimed sealed-beam unit is replaced by a new one, without adjustment, there is only about a 50 percent probability that the new unit will also be within correct aim requirement. Although it is true that the motor vehicle industry and law enforcement agencies have stressed in their extensive educational efforts the importance of checking and readjusting aim after head-lamp replacement, actual practice still falls far short of the desired goals. Thus, for example, many motorists tend to replace malfunctioning head-lamp units at night, when the problem is most obvious, at a conveniently located service station that more than likely is not equipped to perform a proper aim adjustment. Such a motorist is also likely to forget to have the new units checked and adjusted at a subsequent opportunity.

Our tests have shown, also, that there is only about a 50 percent probability that a correctly aimed head lamp will, after 90 days of service, still be in correct aim. This situation appears to be the result largely of inadequately constructed mounting assemblies and housings stemming, possibly, from a desire on the part of the manufacturers to keep down production costs. We believe that the importance and desirability of providing much more stable designs make such economies false ones. Head-lamp housings can and should be made less vulnerable to vibration and shock and more resistant to damage from light impact.

Along these lines, another problem that should be mentioned has to do with the long delays frequently involved in settling accident damage claims. Because motorists in such situations tend to avoid making the necessary repairs to their vehicles until their claims are settled, vehicles with badly out-of-aim head lamps due to accident damage will often continue to appear on the road at night over protracted periods of time.

The effect of vehicle loading on head-lamp aim also poses a problem, which has been investigated to some extent both in this country and in Europe (5, 9). This problem seems rather difficult to deal with although a number of technical solutions have been proposed, including load-leveling devices for the vehicle and/or self-leveling mechanisms for the lamps themselves.

One interesting scheme for improving control of head-lamp aim involves a simple aiming gage and adjustment mechanism incorporated as an integral part of the head-lamp mounting assembly (10). This device, it is claimed, not only would do away with the need to use external tools or instruments in adjusting aim but also would permit replacement of sealed-beam units without the necessity of re-aiming. The mechanism could be further refined to allow the driver to adjust the head-lamp aim from his seat and thus correct for the effects of various vehicle loads, or any other factors, before starting out.

Establishing the mechanical aiming plane accurately and precisely enough in the manufacture of sealed-beam head lamps is admittedly a difficult problem. Nevertheless, as indicated by the results of our investigation, the problem will have to be dealt with more adequately than at present if we are to continue to rely on the present mechanical aiming techniques for satisfactory results.

CONCLUSIONS

If the current head-lamp aim situation is to be materially improved, everyone involved in the design and manufacture of head lamps and head-lamp housings will have to devote more attention and effort to the underlying problems and to finding more effective solutions. Although there may be some who consider this to be strictly an enforcement problem, experience has shown that under present circumstances not much can be gained by making the motorist entirely responsible for maintaining correct head-lamp aim at all times. The fact is that substantial improvements in the design of head-lamp assemblies are possible and would, in the long run, be more economical and satisfactory for almost everyone.

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