

## DEVELOPMENT of the GUIDE "AUTRONIC EYE"

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### SYNOPSIS

Headlamp glare has been a problem since headlamps have been used on automobiles. Over the years, headlamps have been standardized and improved until now the glare problem is largely a matter of improper usage. Many drivers use their headlamp beams improperly; some do not depress to the lower beam when meeting another car; and others drive continuously on their lower beam. It has not been possible to get drivers to use their beams properly.

An automatic headlamp-control device offered possibilities for solving the glare problem. However, the variations in the brightness of headlamps between upper and lower beams made the outlook very discouraging, but the promise of real improvement in the glare situation forced the development in spite of difficulties. Early in the development, the problem was to make something sensitive enough to dim for lower beams at a safe distance. As sensitivity was increased, other problems in the fields of electricity and optics had to be solved. Gradually, the desirable characteristics of an automatic headlamp-control device became apparent.

The device should: (1) switch to the lower beam promptly when subjected to sufficient light and should switch back to the upper beam promptly when light is removed; (2) retain the lower beam when the approaching driver dims; (3) dim for cars on curves and should not dim excessively for extraneous light at the roadside; (4) not be affected by variations in the reflectivity of road surfaces; (5) function under conditions of adverse weather, such as rain, snow, and fog; (6) provide the driver with a means of obtaining a lower beam for use in the city and when following another car, when there is insufficient light to retain the lower beam automatically; (7) provide the driver with a means of obtaining an upper beam for signaling and at dusk, when there is too much light for the device to switch to the upper beam automatically; (8) function with normal variations of car loading; (9) provide the lower beam during warm-up; (10) not be impaired when operated in the daytime; (11) be insensitive to changes in battery voltage; (12) use a minimum of current to avoid exceeding the generator capacity; (13) withstand the abuses of automotive service which includes heat, cold, vibration, and moisture; and (14) be easily adjustable in the field.

The Guide "Autronic Eye" complies with all of these requirements and experience during the first year of production demonstrates that it offers real possibilities for solving the glare problem.

HEADLAMP glare has been a continuing problem ever since electric headlamps have been used on automobiles. A beam which illuminates the road far ahead for safe driving is too bright for the approaching driver. At first we had only one beam, and a resistance was switched in and out of an electric circuit to make the beam dim for approaching cars. Later we had headlamps with two beams: an upper beam designed for clear road driving and a lower beam designed to reduce glare when passing. As the years passed, headlamps were standardized and improved in accuracy, and inspection and service facilities were developed until now the glare problem is largely a matter of improper headlamp usage. However, conditions change so rapidly during open road driving that the correct choice of beam calls for rather careful attention on the part of the driver. All drivers are not willing to devote that much attention to the job. A few drivers do not dim until they are signaled, and many drive constantly on their lower beams to avoid using the foot switch. Both habits are dangerous. Experience indicates that it is hopeless to get drivers to pay more attention to their driving, either through education or law enforcement.

Even 15 or 20 years ago it was obvious that automatic headlamp-control devices offered possibilities for solving the glare problem -- if they could be made to function properly. The outlook was far from encouraging when we consider that the brightness of an oncoming upper beam would, of course, be many times that of an oncoming lower beam, not to mention the added variation due to deterioration in pre-sealed-beam lamps. Even so, the promise of real improvement in glare was so obvious that the idea of automatic headlamp-control could not be ignored, no matter how hopeless it might look.

At the start, the problem was to develop something that was sensitive enough -- something that would dim for lower beams at a safe distance. Satisfactory sensitivity was achieved by using a multiplier phototube, which is capable of about a million times the sensitivity of standard vacuum phototubes. As sensitivity was increased it was found that extreme variations in brightness of oncoming headlamps was not nearly as serious as anticipated, because very few roads are straight and level for any great distance. However, as sensitivity was increased, other problems in the fields of electricity and optics had to be solved. Gradually the desirable characteristics of an automatic headlamp-control device became apparent and were incorporated.

Figure 1 shows the circuit diagram of the "Autronic Eye" ("Autronic Eye" is Guide's trademark for an automatic headlamp-control device). Energy is provided by the car electrical system through the standard light switch. This voltage is applied through the fuse and the ballast tube to the primary winding of the transformer and then through a vibrator to the ground. The transformer has two secondary windings, one producing approximately 1,150 volts AC and the other approximately 150 volts AC. The higher voltage is rectified to produce approximately 1,000 volts DC across a load-resistor network. A high-voltage control is adjusted to supply the necessary voltage for the phototube unit. A sensitivity control in the phototube unit adjusts the high voltage to compensate for variations in phototubes. The voltage is applied to the various dynodes in the phototube through a voltage divider network.

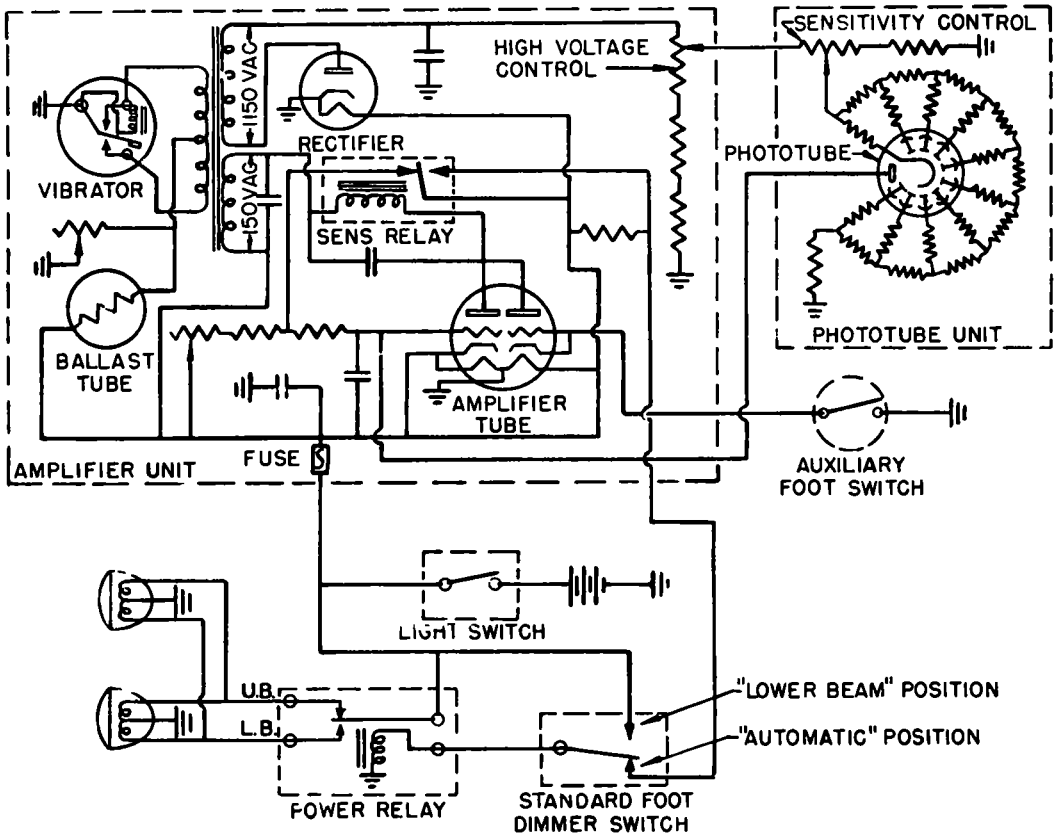


Figure 1. Circuit diagram of Autronic Eye.

The 150-volt secondary winding of the transformer supplies power for the amplifier tube and the sensitive relay. In the absence of light on the phototube, the amplifier tube passes enough current through the sensitive relay to close it. Light causes the phototube to pass a current through a load resistance which develops a negative bias voltage on the amplifier-tube control grid. This causes the amplifier tube to reduce the current through the sensitive relay. When the current is reduced sufficiently, the sensitive relay opens. When the sensitive relay opens it switches a much larger load resistance into the phototube circuit and, in this way, causes the device to be about 10 times as sensitive in the lower-beam position as it is in the upper-beam position.

When the standard dimmer foot switch is in the "Automatic" position, the sensitive relay opens and closes the power relay which switches the headlamps between the upper and lower beams.

When the push-button-type auxiliary foot switch is depressed, it closes the sensitive relay through an added section in the amplifier tube, and overrides the automatic control to provide the upper beam, even when bright light is on the phototube.

When the standard dimmer switch is depressed and released, as in

changing from upper to lower beam, the power relay is closed directly from the light switch and holds the headlamps on the lower beam regardless of the position of the sensitive relay.

Figure 2 shows the optical design of the phototube unit. A condensing lens focuses light through an amber filter and through an opening in a mask to a multiplier phototube. The condensing lens is corrected for spherical aberration and focuses the light from approaching headlamps to a point in the plane of the mask. The vertical and horizontal angles through which the device responds to light are limited by the size of the opening in the mask, and the sensitivity cuts off abruptly when the point of focused light passes the edge of the mask opening.

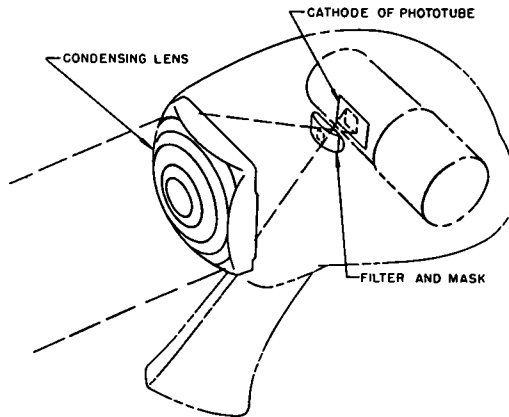


Figure 2. Optical design of phototube unit.

The multiplier phototube is manufactured with an S4 (blue-sensitive) cathode surface, because red-sensitive surfaces are not compatible with the materials used in the amplifying sections. However, the high sensitivity of the multiplier phototube permits the use of an amber filter, which absorbs blue light and moves the effective response toward the red end of the spectrum. Figure 3 shows a series of color-sensitivity and emission curves of the S4 cathode surface, the amber filter, an incandescent bulb, skylight, and the S4 surface through the amber filter.

The curves show that the relative emission of skylight is much better than from an incandescent bulb near the violet end of the spectrum while the incandescent bulb is better near the red end. The curves also show that the amber filter blocks off the light near the violet end and, thus, reduces skylight much more than incandescent light. The amber filter permits the device to function sooner at dusk by reducing the effect of skylight.

The "Autronic Eye" automatic headlamp-control device embodies a number of characteristics which are the result of years of development and testing. A discussion of these characteristics which are desirable in any automatic headlamp-control is as follows:

1. The device should switch to the lower beam promptly when subjected

to sufficient light, and should switch back to the upper beam promptly when light is removed.

There are occasions when the approaching car comes suddenly into view, as, for example, over the crest of a hill. At such times rapid dimming is important. Then, after passing a car when the road ahead is dark it is important to regain the upper beam promptly.

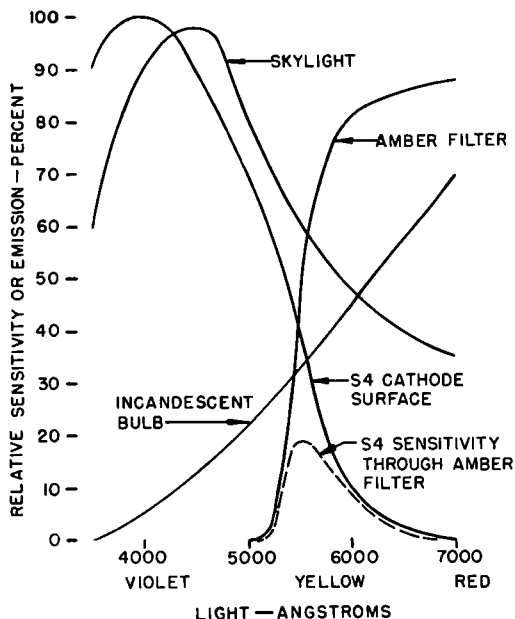


Figure 3. Color-sensitivity and emission curves.

2. The device should retain the lower beam when the approaching driver dims.

When the approaching driver switches to his lower beam the light on the phototube is greatly reduced. The device must not switch back to its upper beam in such a situation. The "Autronic Eye" was designed to dim for one sensitivity and then retain the lower beam with about 10 times as much sensitivity. The multiplier phototube provided the sensitivity for this technique and at the same time permitted rapid operation in both the dimming and upper beam recovery cycles.

3. The device should dim for cars on curves but should not dim excessively for extraneous light at the roadside.

The desire for dimming on curves conflicts with the desire to restrain the device from dimming for extraneous light at the roadside. The first desire would be satisfied by making the device responsive to light at wide angles to the sides while the second desire would demand that the device must not be sensitive to side light. Guide's automatic headlamp-control represents a compromise between these two conditions, designed to provide the narrowest possible sideways response angle consistent with proper operation on curves.

4. The device should not be affected by variations in the reflectivity of road surfaces and the device must function with normal variations of car loading.

Headlamps illuminate the road ahead and the road brightness reflecting back to the driver varies from almost nothing from wet asphalt to a considerable amount from dry gravel or fresh snow. A device which is sensitive enough to retain the lower beam after the approaching driver dims would necessarily be sensitive enough to be greatly affected from road reflection, unless the downward response angle was carefully controlled. If too much light from the road is permitted to reach the phototube, the device will stay on the lower beam. At the same time, the sensitivity response angle must extend enough below horizontal so that the device will function properly under conditions of normal car loading. Guide's unit has a lens and mask system which provides a sharp, lower cut-off. The cut-off is aimed as low as possible without incurring interference from road reflection. This aim is low enough to stand the upward tilting caused by normal car loading without undue loss in sensitivity.

5. The device should function under conditions of adverse weather such as rain, snow, and fog.

The light from approaching cars is somewhat diffused by rain on the windshield, but fortunately the device is not affected appreciably in sensitivity. There seems to be an increase in light from the approaching car, probably due to reflections from wet pavement adding to the normal direct light coming from the lamps and this may offset any loss from light diffusion. Drivers are particularly appreciative of the device in bad weather, because their attention can be concentrated on driving without having to pay attention to their headlights. Very little sensitivity is lost in moderate snow and fog. If the snow or fog is severe, the back reflection of the vehicle headlamps from the snow or fog particles is sufficient to retain the vehicle headlamps on the lower beam.

6. The driver should be provided with a means of obtaining a lower beam for use in the city and when following another car, when there is insufficient light to retain the lower beam automatically.

Occasionally, it is desirable to obtain a lower beam when there is not sufficient light ahead to retain the lower beam automatically. The amber filter previously referred to corrects, as much as possible, the relatively poor red sensitivity of the multiplier phototube. With this combination, the device will retain the lower beam satisfactorily when following a modern car with relatively bright tail lights, but it will not retain the lower beam at a sufficient distance for many older tail lights, and it will not dim for any of them. The "Autronic Eye" is connected to the standard dimmer foot switch so that it functions automatically in one position only. The other position of the dimmer switch provides a fixed lower beam. When necessary, the driver may use the foot switch to lock the device on the lower beam. One of the times when a continuous lower beam is desirable is when following another vehicle.

7. The driver should be provided with a means of obtaining an upper

beam for signaling and at dusk, when there is too much light for the device to switch to the upper beam automatically.

After the automatic headlamp control has dimmed, very little light is required to retain the lower beam. There are occasions, particularly from skylight at dusk, when there is sufficient light to retain the lower beam but not enough to cause the device to dim. On such occasions, the driver may prefer the upper beam. Guide's automatic headlamp control includes a push-button auxiliary foot switch to override the automatic control and provide the upper beam regardless of light conditions. This switch resets the sensitive relay to the upper beam position and the device will remain on the upper beam when the foot switch is released unless there is sufficient light ahead for dimming. Also, the overriding switch may be used to signal approaching drivers if they forget to dim.

8. The device should provide the lower beam during warmup.

Most electronic devices require a moderate warmup time, and during this period, they do not provide automatic control. This period of no control should be considered in design, because vehicles will usually be operated in areas of opposing traffic during the warmup period and it is desirable to have a fixed lower beam until the automatic control is functioning. Guide's device requires 10 to 15 sec. warmup time for the rectifier and amplifier tubes. The rectifier tube controls the high voltage to the phototube, and the amplifier tube provides the current to the sensitive relay. The sensitive relay is in the lower beam position when the amplifier tube current is "off." The rectifier tube was adjusted to warm up ahead of the amplifier tube so that the phototube is in control before the amplifier tube can operate the sensitive relay to the upper beam position.

9. The device should not be impaired when operated in the daytime.

Most phototubes, particularly multiplier phototubes, must be protected from damage from bright light. A multiplier phototube can easily destroy itself if it is permitted to pass too much current. We must assume that a driver will occasionally operate his automatic headlamp control during the daytime. There are places, for example, through the tunnels on the Pennsylvania Turnpike, where a driver is requested to turn on his headlamps in the daytime. It is common to see cars travel a considerable distance beyond the tunnel before their lights are turned off. The device is connected to be turned on with the headlamps so the phototube is functioning during this period. The dynodes of the multiplier phototube are connected through individual protective resistors so that the current through each dynode is limited to a safe value. These protective resistors do not affect the multiplier phototube function at night because the current values are too small to cause detrimental voltage changes to the dynodes.

10. The device should be insensitive to changes in battery voltage.

Car battery voltages vary from 5.5 to 7.5 volts, which is  $\pm 15$  percent from the midpoint. Multiplier phototubes are very sensitive to voltage changes; in fact, a 10 percent increase in voltage will double the output. In order to obtain satisfactory performance on a car, the "Autronic Eye" had to be designed with voltage regulation. Regulation was obtained by

using a current regulator (ballast tube) in the primary of the transformer. Table 1 shows the sensitivity with variations in battery voltage. The dimming distance varies from about minus 7 percent to plus 2 percent.

TABLE 1  
VARIATIONS IN SENSITIVITY WITH  
CHANGES IN BATTERY VOLTAGE

<u>Voltage</u>	<u>Percent Sensitivity (Dimming Distance)</u>
5.5	93
6.0	100
6.5	100
7.0	102
7.5	102

11. The device should use a minimum of current to avoid exceeding the generator capacity.

Car generators are designed to keep the batteries charged under given load conditions; and ordinarily they will not accommodate much extra load. For this reason, the device should be designed to use a minimum of current. Guide's automatic headlamp-control device uses 2.1 amperes in the upper-beam position and 2.5 amperes in the lower-beam position.

12. The device should withstand the abuses of automotive service which includes heat, cold, vibration, moisture, and dust.

Extensive field testing and tests on the Belgium Block road at the General Motors Proving Ground indicated that special precautions were required to make the automatic headlamp control rugged enough for automotive service. The chassis was reinforced and condensers were anchored to avoid wire breakage. A special lead construction was used in the vibrators to avoid internal wire breakage. High-temperature condensers were used because of high engine heat on hot days. The amplifier was enclosed to protect it from moisture and dust. Special alloy points were used on the sensitive relay to avoid tarnish. Special alloy points were used on the power relay to handle the headlamp load. Special materials were used in the phototube base to avoid electrical leakage due to moisture. Experiences with the "Autronic Eye" indicate that extensive tests on cars are required to locate and correct weaknesses in devices of this nature.

13. Service facilities should be available to adjust the device in the field.

An automatic headlamp control is basically a light-measuring device. It dims with a particular amount of light and switches back to the upper beam with a much smaller amount of light. The value of light at each operating point is important and must be obtainable in the field for service adjustments. Also, the phototube unit should be aimed. The lower edge of the response angle is particularly important. Two pieces of test equipment were developed for servicing Guide's automatic headlamp control: a test lamp for sensitivity adjustments and an aiming device for aiming the phototube unit. The test lamp projects light against the phototube in about the same manner as headlamps under operating conditions. The brightness of the test lamp is adjusted to specific values by means of a meter - one brightness is used to adjust "dim" sensitivity and a different brightness is used in making "hold" sensitivity adjustments (this is the point where the device switches back to the upper beam.) The aiming device is a mechanical



fixture which aims by means of a level. The fixture sets on top of the phototube unit and it has an aiming dial which is adjusted to a code number stamped on a nameplate underneath the phototube unit. The code number adjusts the position of the level to compensate for variations between the top surface of the phototube unit and the lower edge of the response angle. The code number is stamped at the factory. The bottom edge of the response angle is located in an optical fixture by means of test lights and then a master level is placed on the phototube unit to find the code number. In this manner, an optical aim of the response angle is converted at the factory into a mechanical aim, and then the mechanical aim is used for field service. Due to the high sensitivities required in automatic headlamp-control devices, satisfactory operation is largely a matter of proper adjustment so the importance of adequate field service facilities cannot be overemphasized.

### CONCLUSION

The Guide "Autronic Eye" complies with all of these requirements, and experience during the first year of production demonstrates that it offers real possibilities for improving the glare problem. Public acceptance has been unusually good, particularly since an owner's first thought is that he is spending money for a device which only benefits the other fellow. However, he quickly learns that the device does even more for him than for the approaching driver. He finds that the device gives him an upper beam more often than ever before in spite of the fact that it always dims for approaching cars. By relieving the driver of the burden of operating his headlamps, the "Autronic Eye" makes night driving more pleasant and safe.