of the driver is increasing and is expected to continue at an accelerated rate. Thus, the hazards associated with glare may be expected to increase. Inasmuch as the payoff potential of reducing glare through the use of polarized headlighting is great, its proponents maintain that a concerted research program is justified.

Because of the absorption of light by polarizing filters, the lumen output of the light source must be considerably greater than a nonpolarized light to maintain parity in headway illumination. This increase can, in part, be achieved by using more efficient light sources and reflectors. However, the primary increase will be achieved by more wattage. The increase in wattage will result in greater energy drain on the automobile engine and thus increase fuel consumption. The rough calculations given in Table 1 provide an estimate of what the annual increment in fuel consumption in the United States would be if all vehicles were eventually converted to polarized lighting.

Table 1.

| Item | Value |
|---|---|
| Vehicle miles per year (U.S.) | $1.5 \times 10^{12}$ |
| Driving hours per year[a] | $3.7 \times 10^{10}$ |
| Night driving hours per year ($\frac{1}{3}$ of total) | $1.2 \times 10^{10}$ |
| Kilowatt-hours[b] | $2.4 \times 10^{9}$ |
| Horsepower-hours | $3.2 \times 10^{9}$ |
| Pounds of fuel (0.6 hp-hour) | $1.9 \times 10^{9}$ |
| Gallons of fuel per year | $3.1 \times 10^{8}$ |
| Gallons per vehicle per year | 2.0 |

[a]40 mph avg. [b]At 200-W increments per vehicle.

Based on these rough computations and assumptions, the annual domestic increment in fuel consumption for polarized lighting would be 300 million gallons. This amount represents about $\frac{1}{4}$ of 1 percent of our road use consumption of fuels. For this typical vehicle, this represents about 2 gallons of fuel per year.

In addition to these fuel penalties, the original polarized lighting equipment will have an incremental cost over conventional headlights. The estimated costs vary with configuration, but range from $15 to $35 per vehicle. The vehicle and fuel consumption costs might well be compensated for by significantly improved driving safety at night. However, comprehensive research programs will be necessary to develop precise safety and public comfort benefits and cost penalty estimates so that a rational decision can be made on whether polarized lighting systems should be implemented and, if so, how they should be configured.

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In view of my background, I would be presumptuous indeed if I attempted to comment in depth on the fixed lighting studies. My remarks, therefore, will use as a springboard the studies on automotive lighting.

## IMPLEMENTATION RECOMMENDATIONS

The papers by Mortimer and Farber and Bhise cover methodology and might profitably be referred to the Test Methods Subcommittee of the SAE Lighting Committee. Following this route would carry the advantage of further shaking down the techniques proposed and provide the additional benefit of having the work more widely publicized through printing and distribution by SAE after acceptance.

Burg's paper, I suggest, would receive increased consideration if called to the attention of the American Association of Motor Vehicle Administrators' Committee on Driver Licensing.

All this is not to ignore the thought-provoking work done by Rockwell and his associates. Further interpretation, however, may indicate a more accurate direction to implement this research.

## IMPLEMENTATION THROUGH STANDARDIZATION

The main thrust of my remarks is to explore the benefits of further performance standardization on channeling and implementation of research. Behind this thinking are three steps: Basic research identifies matters of principle; applied principle shows up in the form of hardware; and hardware normally produces an output designed or manufactured to conform to certain standards. Thus, there is a direct line between research and the number of different standards that bear on application of research results.

A variety of claims have been made for the relative importance of fixed lighting versus automotive lighting. These contentions are commonly dealt with by weighing capital outlay and speed of implementation, leaving many of the claims essentially unresolved.

Two examples may serve to illustrate opportunities for standardization, at least between Europe and the United States; these have been selected from the fields of headlighting and rear lighting.

## HEADLIGHTING STANDARDIZATION

For a number of years, controversy has existed on the relative merits of the Anglo-American headlight beam distribution and that obtained from European head lamps. Because these performance differences are rooted in philosophy, there has been more despair than optimism over the prospect of obtaining standardization in any significant sense of the word. Adoption of three-beam headlighting in this country and abroad would resolve a seeming impasse.

It is well grounded in cliché that "all engineering is a compromise." Compromise of the following makeup of a three-beam system, therefore, may be in order.

### Upper Beam

Revision of the 75,000-cd maximum output restriction that currently prevails in this country and adoption of 200,000 cd, more or less, as the new maximum would essentially eliminate differences in permissible intensities. When this new level was suggested by NHTSA in a past Notice of Proposed Rule Making, no significant adverse comment resulted. Because the upper beam is a symmetrical one, fixing the details of light distribution should not be a major hurdle. Since a tungsten-halogen light source could optionally be used, that preference (or lack of it) should also occasion no difficulty.

### Middle Beam

A middle-beam configuration would habitually be used for driving outside urban areas and would be produced by adding the output of a special unit to that of the lower beam. If careful attention were given to aiming of the special unit, the middle beam could be used even on two-lane roads without objectionable glare to oncoming drivers.

In the case of cars equipped with two-unit headlighting, a third unit could be added to produce a functional benefit and offer various designers the chance to produce a new look.

Based on the specifics of the test setups, this intermediate beam has shown a vision improvement from 85 to 125 ft as compared to a regular low beam. The beam upper cutoff could have a treatment someplace in between the feathered approach used in this country and the sharp black line characteristic of European lower beams.

### Lower Beam

In the new system, the lower beam would be used for city driving only; its intensity could be less than the present low beams and greater than that of parking lamps. This should be quite satisfactory in this country, give better results than the European practice of driving with parking lights on in cities, and meet objections concerning too high intensities that dazzle pedestrians and cyclists. Even if this were designed with something approaching the sharp European cutoff, the dancing shadow, which has been one of the major objections here, would be minimized as a result of the contrast reduction due to fixed urban area lighting.

### Switching

A must in three-beam lighting is a simple, readily understandable switch arrangement. A three-position, linear motion, column-mounted switch is one configuration that would meet the above-mentioned criteria; this matter also should not be an insurmountable obstacle.

### General

Recent experiences in obtaining approvals in Europe on three varieties of head lamps to be manufactured in this country demonstrated friendliness and cooperation from quite a few people. The time and money involved, however, might have been saved had we more resolutely pursued a standardization path in our past interactions.

Perhaps SAE in the United States and such organizations as GTB in Europe can spearhead meaningful efforts to get us all on the track.

## REAR LIGHTING

The differences between U.S. and continental approaches to rear lighting and signaling include mandatory amber rear turn signals, stop light intensity requirements, physical location of lighting devices, and use of rear fog lamps. A little give and take on each side could be the basis for zeroing in on research for better rear lighting rather than investigation for better American rear lighting and still more for better European rear lighting.

## FIXED LIGHTING

There are substantial differences in thinking and practice regarding intensity of light on a road (produced by fixed lighting) in this country and in Europe. Surely the actual requirements cannot be all that much different. Would not development of improved fixed lighting be aided by having standards that are closer together?

## CONCLUSIONS

When automotive lighting research is finally implemented—the production of hardware designed to conform to certain standards—we must evaluate factors over and above those identified by conventional laboratory-proving ground-public road activity. We must additionally consider cost-benefit, contribution to safety, lead time, and operational environment. It is quite possible for a lighting device to appear to have merit within itself; when taken in concert with what we already have, however, it may only add to visual clutter or actually dilute the effectiveness of existing devices.

An effective method of determining net worth—including the public interest—of a device in the past has been to offer it as optional equipment. Some items, as a result, have dropped by the wayside, whereas others have become standard equipment.

It is certainly hoped that future laws and regulations will not be structured to preclude use of this valuable tool. The relationship of industry and government could also be moved from a seemingly adversary position to one of more cooperation by having more effective dialogue prior to issuance of notices of proposed rule making.

More effective research and use of research funds through more carefully coordinated standards—it seems worth a better try than we've been giving it.

Richard E. Stark,
Illinois Department of Transportation

My concern with a symposium on night driving visual needs is to extract from the information presented those concepts and ideas that will help in more effectively serving the public in my capacity as a district lighting engineer in Illinois.

As I review the papers presented, my concern falls into four basic needs:

1. There is need for additional justification of roadway lighting installations,
2. Visibility criteria for fixed roadway lighting must be improved or refined,
3. More sophisticated design techniques for roadway lighting are needed, and
4. New hardware to more effectively implement these techniques and to improve or correct existing deficiencies is required.

## ADDITIONAL JUSTIFICATION OF ROADWAY LIGHTING

A solid base for providing roadway lighting is required. Lighting just like other highway projects must be justified. I was encouraged by Irving and Yerrell's report of a 30 percent reduction in nighttime accidents and a parallel reduction in severity when lighting is installed. We have relied heavily on the report by the Illuminating Engineering Research Institute for freeway lighting justification and our own experience of a 40 percent reduction in freeway accidents after lighting. We certainly need more information, better measurements, and controlled studies on the relationship between accident rates and illumination. It will be of great interest to know the outcome of the study being conducted by the British Transport and Road Research Laboratory.

Accident rates related to night illumination are important, but research should explain why these problems occur. Henderson and Burg's paper brings the area to the front: "At this point we know that visual performance is seriously degraded under conditions typically encountered in night driving, i.e., low levels of illumination, glare, and low-contrast targets... Further, we know that some individuals are much more severely affected by these factors than others, and as a result the total variability in visual performance of the driving population increases significantly as the level of illumination decreases, glare increases, or contrast decreases."

Another problem that relates closely to fixed lighting is that of headlight adequacy. I refer now to urban freeways with speeds up to 55 mph where traffic densities are sufficient to warrant fixed lighting. It appears that there are a number of problems with headlights such as misaim, dirt depreciation, changes due to different loadings, and glare production. Thus, whereas the only solution in rural areas is head lamps, in urban areas fixed lighting may be the total solution. Irving and Yerrell's and Mortimer's comments on their problems with head lamp adjustment are of great interest.

Walton expressed the idea that "fixed roadway lighting probably offers the most comprehensive means of correcting poor night visual environments." He also cataloged the night visual requirements of the driver from the standpoint of the three performance levels involved in the driving task. This information will be extremely helpful to the designer in providing the proper illumination to meet driver visual needs. Still there is much work to be done to illuminate those objects that need to be seen.

Rockwell and Rackoff's findings with the eye camera tend to lead to the conclusion that fixed lighting improved driver performance.