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COVER: Currently available railroad-highway grade crossing signals have been shown to exceed specifications for visibility by motorists when properly maintained. Proper signal aiming, proper lamp and reflector positioning, and other maintenance functions can ensure continued good service from the signals.

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The Secretary of Transportation has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department.

Improving the Visibility of Railroad-Highway Grade Crossing Signals[1]

by
William H. Andrews, Jr.

Introduction

Studies have shown that many signals at public railroad-highway crossings do not meet industry visibility specifications; further a large percentage of drivers involved in accidents at protected crossings report not having noticed the warning signals. (*1*, *2*)[2] These facts indicate that signal visibility must—for safety's sake—be improved.

In recognition of this need, the Federal Highway Administration (FHWA) recently sponsored two studies. The first of these, prepared by Allard, Inc., explored the history, human factors, and state of the art of signal hardware design. (*1*)

This article discusses the second of these studies, which examined available signal hardware and sought ways to improve the brightness and uniformity of crossing signals without changing their familiar appearance, increasing their cost, or complicating their maintenance.

During the investigation, seven design alterations and three maintenance aids were developed and evaluated—several of which have significant commercial value. This article describes the new hardware and the motivation behind its development.

Background

Early in the study, it became apparent that, when properly maintained, crossing signals perform much better than minimum visibility specifications require. However, since this visibility is based on extremely precise adjustment of several signal parameters, special-purpose tools are needed in signal maintenance.

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[1]Research sponsored by the Federal Highway Administration and performed at Oak Ridge National Laboratory, operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy (Contract No. DE-AC05-840R21400).

[2]Italic numbers in parentheses identify references on page 35.

The importance of proper adjustment can be seen by considering the optical components in a standard crossing signal (fig. 1). The roundel filters light passing through it and spreads the remaining light in a prism pattern (which is molded into the roundel) to produce the desired output pattern. This occurs when the light reaching the roundel is perfectly collimated; uncollimated light is dispersed in an uncontrolled manner. Since the light flux from a crossing signal lamp is low (typically 530 lm for a 10 V, 25 W unit compared to 1900 lm for a 120 V, 150 W traffic signal lamp), its visibility will be insufficient unless it is carefully distributed.

Beam collimation depends on the position of the source relative to the reflector, the reflector's shape and surface quality, and how well the source approximates an ideal point source. For instance, a perfect paraboloidal reflector will take light rays from an ideal point source at its focal point and direct them outward in a uniform beam parallel to its axis of symmetry. Because real lamps have filaments of finite size, only one point on the filament can be at the focal point. Compact filament geometries that concentrate light output in a small volume around the focal point produce the most tightly collimated beams. Mispositioning the filament in a crossing signal by as little as 1.0 mm (0.04 in) can cause enough spread in the beam to reduce its on-axis intensity by one-half.

For maximum effectiveness, the signal should be aimed carefully to the point at which the motorist first needs to see the signal in time to stop safely before reaching the crossing. The importance of precise alignment varies with the beam pattern of the roundel used, but in the most extreme case—a long-range roundel designed for straight approaches—a misalignment of as little as 3 degrees can reduce beam intensity at the target location by one-half.

Such precision is extremely difficult both to achieve and maintain. Much of the lamp-mounting hardware in available signals is not rigid enough to keep the lamp position fixed when the light unit is subjected to repeated shocks or lamp replacement. Because the focusing problem is so severe, it was a primary target for half of the new hardware designs produced in the course of this study.

Study Components

The study addressed the focusing difficulties identified by:

- Designing and fabricating two permanently focused signal units.
- Evaluating two hardware configurations employing commercial (120 V, 60 Hz) power.
- Developing an instrument for use in optimizing adjustable-focus signals.

The following hardware developments also were evaluated in this project:

- An alignment scope to aid in proper signal alignment.
- Quartz-iodide lamps to improve efficiency.
- Antireflective roundel coatings to increase transmittance.
- A special-purpose photometer for measuring crossing signal and traffic signal flux.
- A small clip to preventing rotation of loosened roundels.
- The application of a low lamp current between flashes to extend lamp life.

All of these hardware developments were laboratory-tested and the signal hardware prototypes subjected to environmental and field tests.

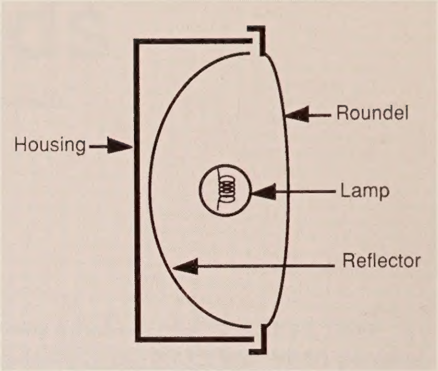

Figure 1.—Components of a standard crossing signal.

Signal Hardware

Two prototype units were developed of each new signal design selected for evaluation. Each of these was subjected to shock, vibration, elevated temperature, and temperature cycling tests. Two of each prototype also were mounted on an outdoor test stand along with two standard units. These 10 signals were flashed continuously for a period of 1 year to ensure that none of the design changes adversely affected lamp life or signal reliability. The prototypes developed and evaluated are detailed below.

Lamp mounts. Two permanently focused lamp mounts were selected for development: A variation on a tripod mounting bracket (suggested by the Allard, Inc., study), and an integral reflector/socket assembly. Because the tripod bracket fixes lamp position relative to the signal housing, its use presumes proper reflector positioning. Further, since neither of these fixtures is adjustable, the filament must be properly positioned relative to the lamp base.

The tripod lamp mounting bracket (fig. 2) is secured to the signal housing by nylon screws. Insulating tabs under the tripod feet hold the reflector in place and allow one of the legs of the aluminum fixture to serve as an electrical conductor for lamp power. The base-out orientation of the lamp fully illuminates the reflector.

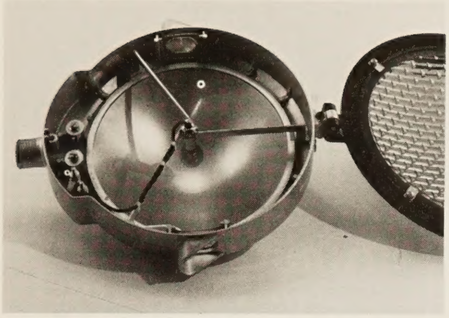

Figure 2.—Tripod lamp mounting bracket (reflector dulled for photograph).

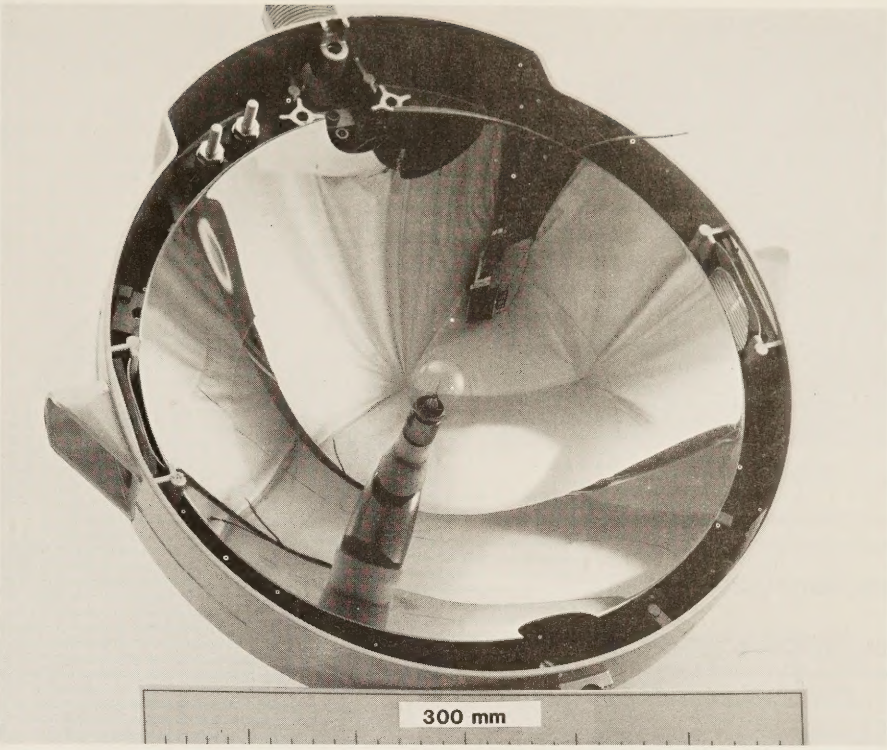

Figure 3.—Integral lamp/reflector assembly.

In the integral lamp reflector/socket assembly (fig. 3), the lamp mount penetrates the apex of the reflector, fixing the lamp in an orientation similar to that found in a traffic signal. The lamp socket threads into a plastic spacer that provides the crucial positioning of the lamp relative to the metal reflector. The metal reflector is part of a retrofit kit purchased from a signal vendor. The base-in orientation facilitates changing lamps.

120 V power configurations. Two hardware configurations employing 120 V lamps were evaluated. In one of these, the optical components—lamp, reflector, and roundel were replaced by their counterparts from a traffic signal. (This configuration also was tested with a crossing signal roundel.) In the second 120 V prototype, standard crossing signal hardware was used with one exception: The lamp was replaced by a compatible 120 V, 25 W unit.

Both 120 V lamps have long [nearly 50 mm (2 in)] filaments surrounding the focal point. These present a distributed light source to the reflector, which should make the beam profile less sensitive to lamp position.

Other design changes. Three other design changes expected to improve signal visibility were evaluated. The first, which employs antireflective (subwavelength) coatings on both roundel surfaces, could theoretically increase light transmittance by 10 percent (e.g., increase it from 20 to 22 percent). Vapor-deposited, 130 nm (0.005 microinches) layers of magnesium fluoride (MgF_2) were used for the coatings. The second modification involves the substitution of a clip (fig. 4) for one of the four clamps securing the roundel to the signal housing cover. This clip will prevent roundel rotation should the clamps become loosened. The third change evaluated was the use of quartz-iodide lamps, which offer higher efficiency (more visible light per watt) and longer continuous-operation lifetimes than incandescent lamps. Both a 10 V, 16 W unit and a 10 V, 36 W unit were tested.

Signal operation. To extend lamp life, a variation in normal signal operation also was tested. Light flashing is ordinarily accomplished by applying and removing the rated voltage. However, reducing the applied voltage by 70 percent between flashes—rather than removing it entirely—keeps the filament heated to a temperature at which it glows only faintly. This reduction in temperature cycling extends lamp life by an average of 50 percent. This method is often used for blinking lights on radio antenna towers and other structures where lamp changing is particularly difficult.

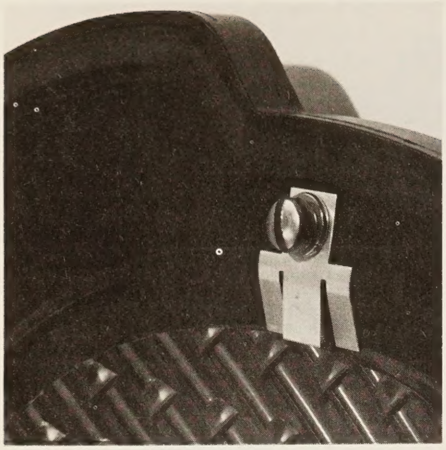

Figure 4.—Roundel retainer clip.

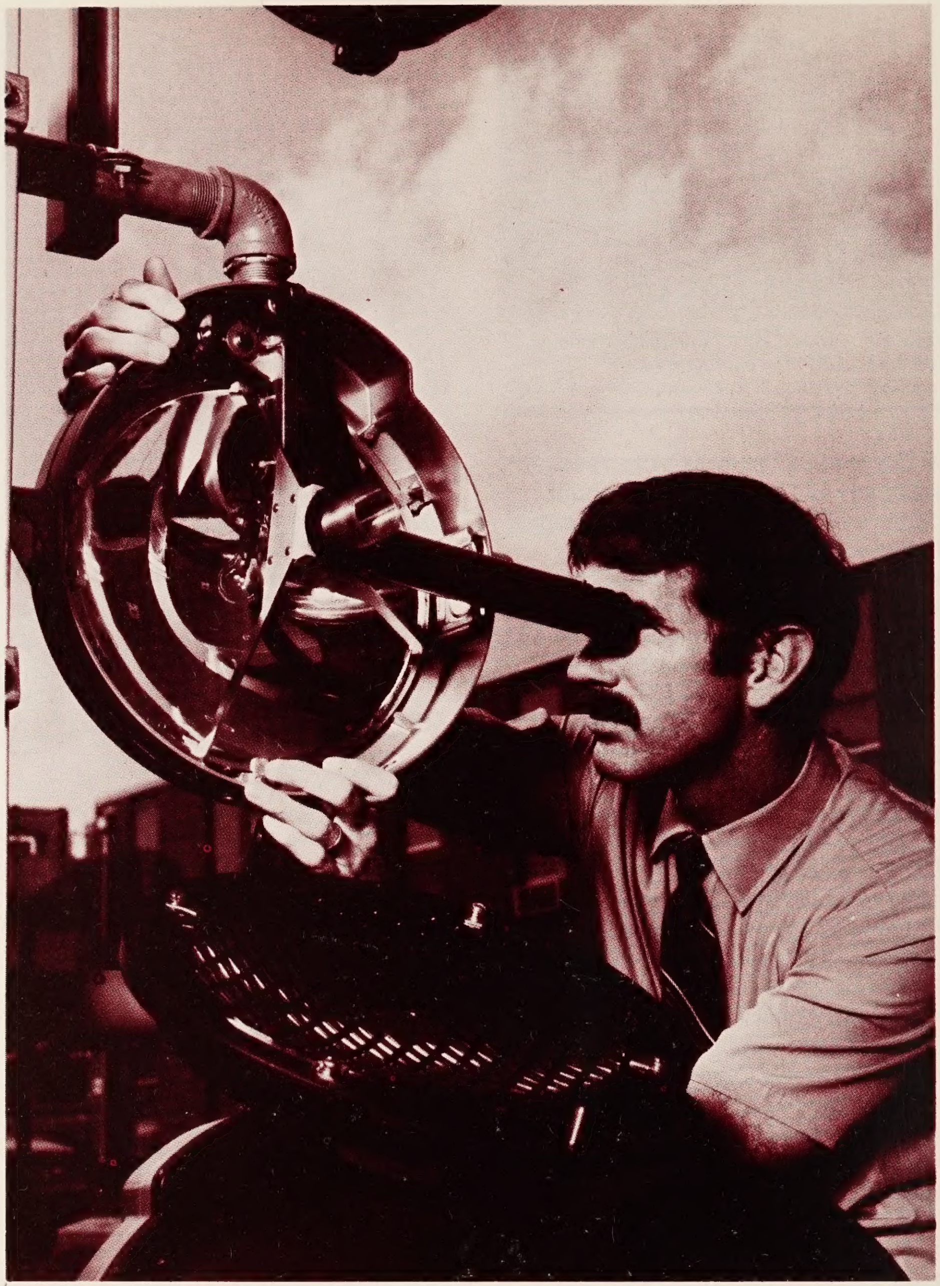

Figure 5.—Signal alignment tool.

Maintenance Instrumentation

Three maintenance instruments were designed and developed under the study. Two of these—a signal alignment scope and a signal focusing tool—were developed to facilitate adjustment of a crossing signal for optimum visibility. The third tool, a special-purpose photometer for measuring light flux from crossing or traffic signals, alerts the maintainer to problems that decrease light output.

Alignment scope. The signal alignment instrument (fig. 5) adapts the rifle scope principle to a crossing signal. A telescope is mounted on three legs that seat against the rim of the reflector. A right-angle prism enables the user to look into the telescope from the signal's side and see down the road along the signal beam axis to the point where the signal is aimed. Cross hairs give an accurate indication of beam center. This tool is intended for use when the signal housing is open; it would probably be used only when other maintenance (e.g., relamping) is being performed or when the signal is obviously in need of alignment.

Focusing tool. The focusing tool (fig. 6) indirectly measures the lamp's position relative to the reflector by showing how well reflected light is collimated. The tool's operating principle is simple and is shown in figure 7.

The focal point of a simple convex lens is—by definition—that point where incident rays of light parallel to the lens axis on one side converge on the other. The focal point of a paraboloidal reflector is that point where light rays parallel to the reflector's axis converge after being reflected. Conversely, the reflector, capturing light from a point source

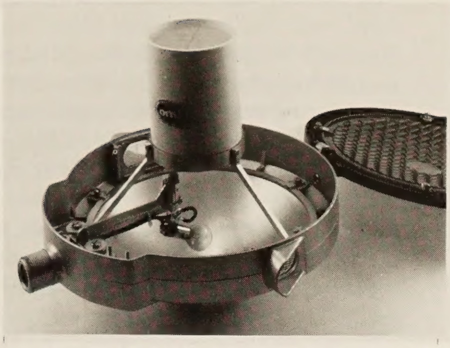

Figure 6.—Signal focusing tool (reflector dulled for photograph).

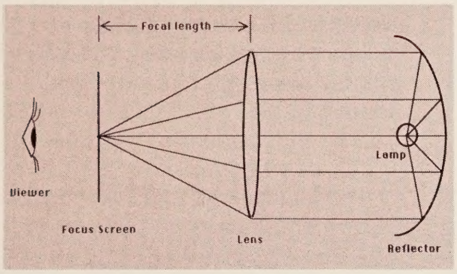

Figure 7.—Operating principle of focusing tool.

located at its focal point, will collimate the light into a beam parallel to its axis of symmetry. The axis of the lens in the focusing tool is aligned with the beam axis; a focusing screen, similar in function to the ground-glass screen in a view camera, is oriented perpendicularly to the lens axis and centered around the len's focal point. An opaque mask allows light to pass only through three small areas around the perimeter of the lens. (A large-diameter lens is required for high sensitivity.)

The user sees three images of the lamp filament on the focusing screen. When the images converge at the center of the screen, the filament is at its optimum position. If, for instance, the images converge at a point above and to the left of center, the lamp is too low and too far to the right. If the images are separated, the lamp needs to be moved along the axis until they overlap.

Flux meter. A photometer for quantifying the total light flux from traffic or crossing signals also was developed. The flux meter (fig. 8) samples light output from 42 small areas on the roundel's face and provides an output indication proportional to the amount of light collected. Instead of using 42 separate light sensors, fiber-optic cables gather the light samples and deliver them to an optical integrating sphere that scrambles the light from all 42 fibers and presents it to a single photodetector. This innovation permits use of a high-quality sensor (in this case, a sensitive, stable photoresistor) without a major impact on the instrument's cost; this in turn avoids those problems inherent to low-cost sensors: High temperature-sensitivity, drift, and dark-currents.

A simple electronic resistance-measuring circuit is used to drive an analog meter, which will be used most often to indicate that the signal either is functioning satisfactorily or needs servicing.

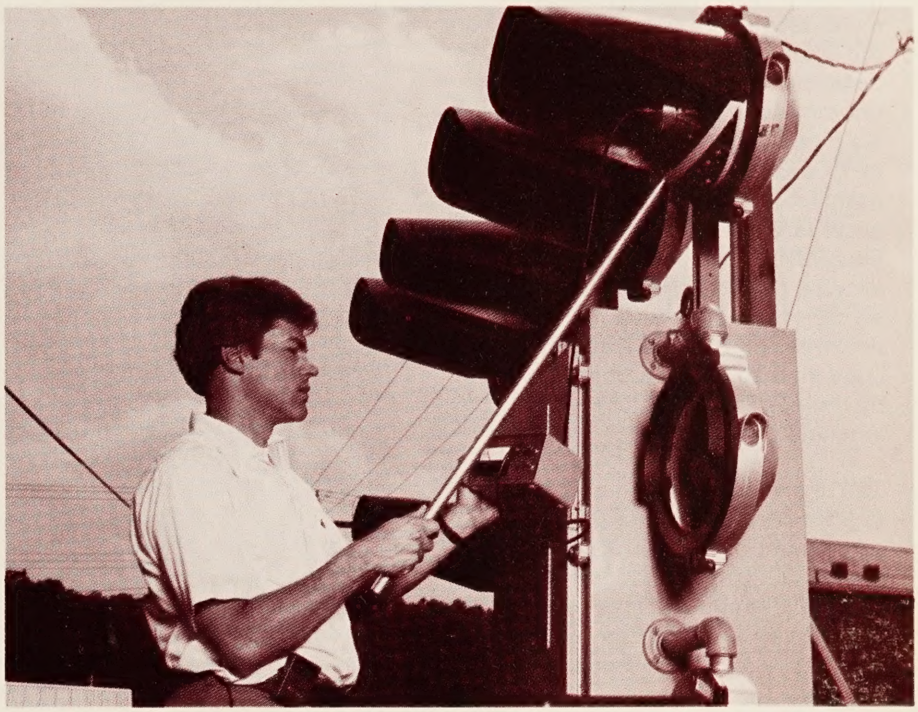

Figure 8.—Signal flux meter in use.

To accurately quantify the perceived brightness of a signal, a photometer requires a spectral response closely matching that of the human eye. If this is not the case, the photometer could unfairly compare signal outputs. For instance, if the photometer is sensitive to infrared energy and compares the output of a signal illuminated by an incandescent lamp with one using a quartz-iodide lamp, the comparison will be biased in favor of the former since more than 90 percent of an incandescent lamp's output is in the infrared region. In the flux meter, however, color correction and infrared filtering are accomplished using a single glass filter.

Measurements

Signal light measurements were performed with a laboratory-quality narrow-angle (1 degree) luminance meter located 14.5 m (47 ft 7 in) from the signal being evaluated. At this distance, the signal lens filled the photometer's active aperture when the signal was rotated by angles up to 15 degrees. The photometer's usable range was extended, when necessary, by using neutral-density filters over the lens of the probe; this allowed direct measurement of a signal's luminance with its roundel removed. Luminance readings were converted to intensity measurements by multiplying the readings by the illuminated surface area.

The signal being tested was installed in a fixture allowing for precise adjustment of angular displacement around horizontal and vertical axes passing through the focal point of the signal's reflector. Lamps were operated at their rated voltage (±1 percent).

The terms "beam" and "beam profile" here refer to the variation of signal output intensity with angular displacement (usually in the horizontal plane) with no roundel in place. "Output pattern" or "output distribution" refer to light distribution with a roundel installed.

Standard signal units

Over a 5-month period, 25 signals (from three different procurements) were received directly from the same manufacturer. Each bore a sticker inside the housing advising that the signals had been factory-focused and that the user should be careful not to disturb the focusing adjustments. The units were each fitted with a 10 V, 18 W incandescent lamp; on-axis intensity measurements (as received) ranged from a high of 3.77 kcd (thousand candela) to a low of 2.24 kcd, with an average value of 3.28 kcd.

The output distribution of a typical new, well-focused signal fitted with a 10 V, 25 W lamp exceeds—at some points by a factor of 25—the minimum intensity criteria developed earlier in this study (fig. 9). This, however, is not to suggest that hardware design standards should be relaxed to permit lower near-axis outputs. Rather, the criteria referenced represent *minimum* requirements for driver recognition; designs should provide ample margins for visibility reduction resulting from component aging, dirt accumulation, fog, and haze.

The beam for this signal (as measured between half-intensity points) was slightly more than 1 degree.

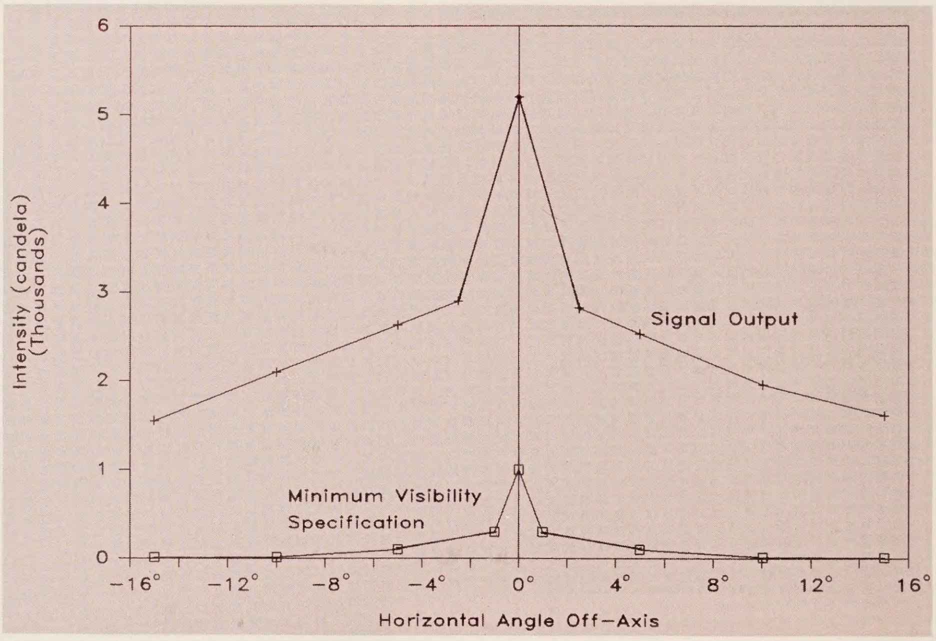

Figure 9.—Output distribution for a standard signal fitted with a 10 V, 25 W lamp and a 30°/15° roundel compared to minimum visibility criteria for this configuration.

Quartz-halogen lamps

The 10 V, 16 W quartz-iodide lamp available for crossing signals has a flux rating of 502 lm, nearly equal to the 528 lm rating of the standard 10 V, 25 W incandescent lamp. The on-axis beam intensity obtained using the 25 W lamp was about 25 percent higher than that obtained with the 16 W quartz-iodide. With a roundel in place, however, the difference was only 10 percent. The on-axis intensity obtained with a typical 10 V, 16 W halogen lamp was about 40 percent higher than the maximum obtained with any 10 V, 18 W incandescent lamp, demonstrating the higher efficiency of the halogen units.

Because of its smaller filament, a 16 W halogen lamp should produce a beam profile more sensitive to misfocus than that of an incandescent lamp. This postulate was verified by the narrower peak in the data plotted in figure 10, which show a sensitivity approximately 50 percent higher.

The 36 W quartz-iodide lamp available for use in crossing signals has a flux rating more than twice that of the 25 W incandescent lamp or the 16 W quartz-iodide lamp. Its filament is much larger and is oriented along the lamp axis. As expected, beam profile measurements showed that most of this additional light flux was uncollimated (i.e., outside of the half-intensity beam width). In fact, on-axis intensities for the 36 W halogen lamps were usually about 15 percent lower than for the 16 W units.

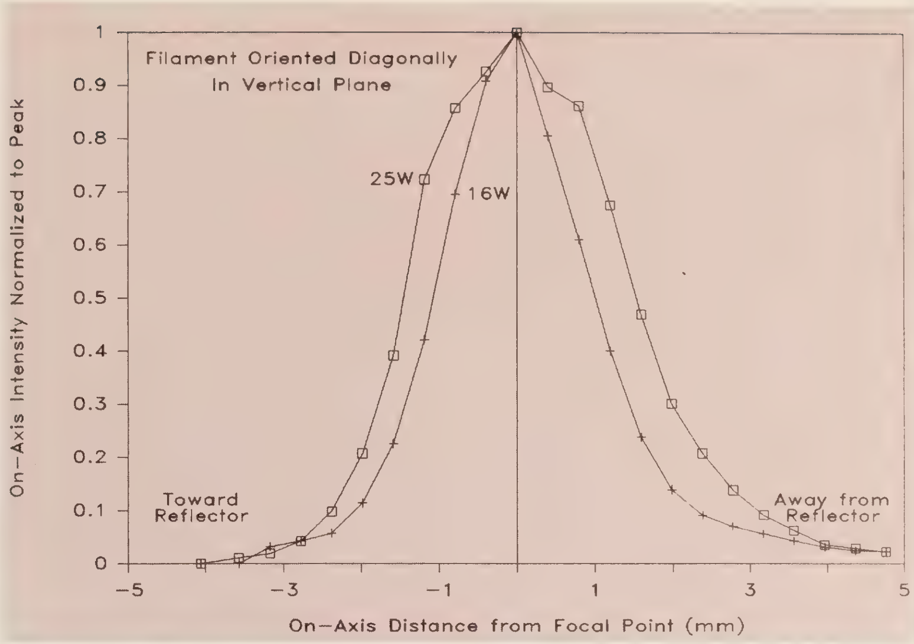

Figure 10.—Comparison of the focusing sensitivity of a standard signal fitted with a 10 V, 16 W quartz-iodide lamp and with a 10 V, 25 W incandescent lamp. (1 in = 25.4 mm)

The lamp-center length (i.e., the distance along the lamp axis from the locator pins on the lamp base to the filament's center) for the 36 W halogen units tested seemed to be poorly controlled. When these lamps were used, drastic refocusing was necessary to achieve optimum beam pattern. Figure 11 shows the beam profile resulting when a 36 W halogen lamp was installed in a factory-focused signal (which was demonstrated to be very close to the optimum adjustment) for an 18 W incandescent lamp, and the profile after focus has been optimized for the 36 W halogen lamp using the focusing tool. This adjustment required moving the lamp socket approximately 7 mm (0.28 in). The focusing problem alone is a sufficient argument against using currently available 36 W halogen lamps in most circumstances.

120 V configurations

Two approaches to using commercial 120 V ac power were evaluated: (1) using a 120 V lamp compatible with standard crossing signal hardware, and (2) using a crossing signal modified to accept the reflector, lens, and 150 W lamp from a traffic signal.

The first evaluation of these two signals compared their output patterns to those of a standard crossing signal (fig. 12). The 120 V outputs are compared with the minimum intensity requirements in figure 13. The reduced near-axis intensity resulting from the use of the traffic signal lens, with its darker color and wider dispersion, also is shown in these two figures.

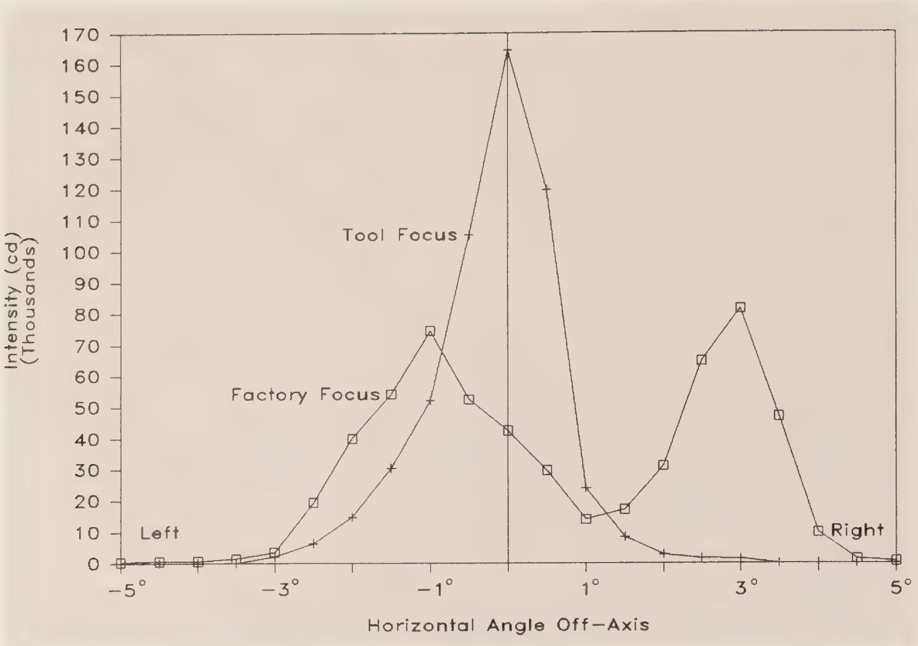

Figure 11.—Beam profiles of a signal fitted with a 36 W quartz-iodide lamp that had first been focused for a standard crossing signal lamp and then refocused using the focusing tool.

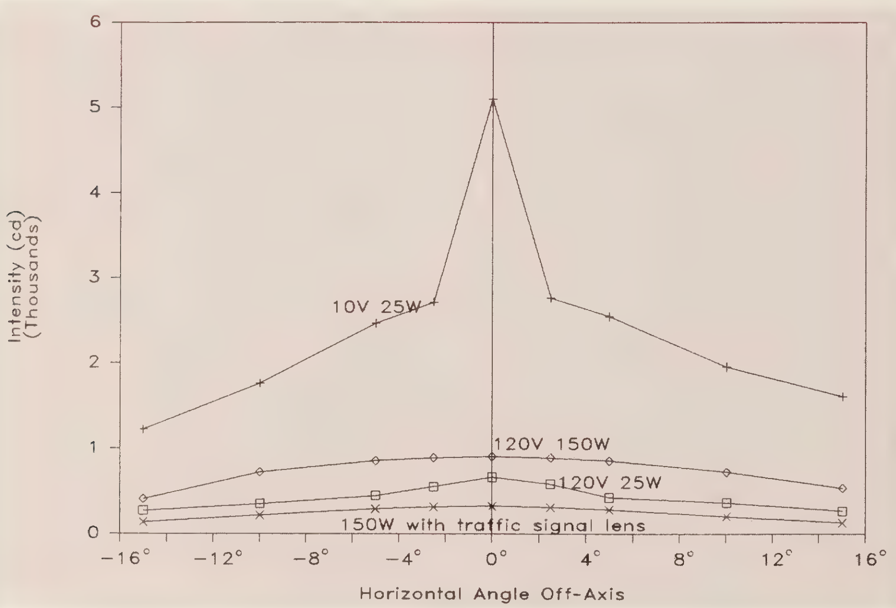

Figure 12.—Output distribution for a standard signal fitted with a 10 V, 25 W lamp and with a 120 V, 25 W lamp, and for a modified signal fitted with the reflector and 120 V, 150 W lamp from a traffic signal. A 30°/15° long-range roundel was used except where noted.

A severely defocused beam resulting from the large filaments in these lamps is the primary cause of the poor showing of the 120 V units (beam width measurements for these signals ranged to 20 degrees and higher). Another factor is the lower luminous efficiency of the relatively cool 120 V filaments.

When used with 30 degrees/15 degrees or 70 degrees/0 degrees (not long-range) roundels, signals with traffic signal lamps and reflectors may meet minimum intensity specifications. (Roundel chromaticity and output pattern were not variables in the hardware evaluations.) Still, visibility would be much lower than if standard hardware and lamps were used. The advantage of the 120 V lamps lies in reduced focusing concerns; this is not, however, worth the corresponding loss of visibility and the added cost of providing and maintaining backup power. The cost of batteries capable of providing power for the same length of time would be about 50 percent higher than with 10 V power. Additionally, there would be 12 times as many battery cells requiring water-level monitoring—and 12 times the chance that a bad cell or cell interconnection would totally disable backup power.

Conventional traffic signal hardware does not exhibit the same attention to those details affecting light output as does crossing signal hardware. Even if the former hardware were thoroughly redesigned for use in crossing signals and their output boosted sufficiently to meet the minimum requirements when new, it is doubtful that there would be much margin to allow for degradation

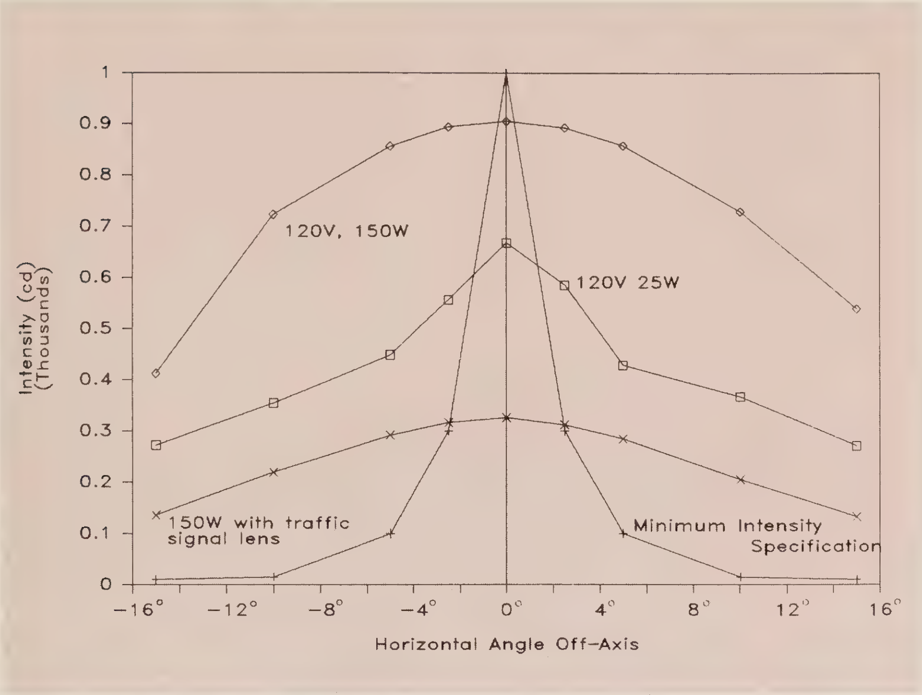

Figure 13.—Comparison of output distributions for 120 V signal prototypes and minimum intensity criteria for a 30°/15° long-range roundel. The signals tested were fitted with 30°/15° long-range roundels except where noted.

caused by lamp aging and dirt accumulation. Barring an unanticipated breakthrough in lamp or signal design, the use of 120 V signal power cannot be recommended at public crossings where better-than-marginal visibility is required—that is, where approach speeds are greater than 72 km/h (45 mi/h) or where bright or distracting backgrounds are present.

Permanently focused prototypes

Output for signals fitted with permanently focused assemblies compared favorably to well-focused standard signals having the same lamp type. Although they could not consistently outperform precisely focused conventional signals, this and other studies have shown that adjustable signals are seldom precisely focused, even when new. Furthermore, permanently focused units would provide demonstrably better output after only a short time in the field.

Antireflective coatings

The antireflective coatings on both surfaces of each of four new roundels increased on-axis intensity by an average of 2.9 percent. This increase could be at least doubled—and perhaps tripled—by careful optimization of coating material and thickness. The cost of a coated roundel is estimated at an additional 30 percent—a cost that signal engineers might not be willing to pay.

Focusing tool

The ideal measure of the focusing tool's accuracy would be the distance between the reflector's true focal point and the lamp filament center after applying the tool. Locating the true focal point however, would be tedious and, given the manufacturing tolerances in reflector shape, might be impossible. The instrument was instead evaluated by using it to refocus several factory-focused signals and measuring the resulting improvement in on-axis beam intensity. The results (fig. 14) show that focus was improved in each case.

Alignment scope

The prototype alignment tools are accurate to better than 10 minutes of arc, far better than necessary for their intended purpose. The limiting factor on their performance probably will be the degree to which the reflector's rim (against which the alignment tool rests) is perpendicular to its own axis of symmetry. The peepsights in the signal housings used in this study were about as effective as this tool (in laboratory testing) for distances up to 15 m (49.2 ft)—distance over which the narrow-angle luminance meter was usable. Given its nine-power magnification, the alignment scope would probably prove more effective at long distances. In addition, field installations often render the peepsights unusable because there is usually not enough clearance between signals to permit convenient access to the rear of the units.

Flux meter

Flux meter readings varied linearly with signal flux as lamp output was modulated by adjusting the applied voltage. Signal-to-signal consistency is harder to demonstrate because of variations in lamp filaments, reflector shapes and finishes, and roundel transmittances. The lowest reading obtained for any 10 V signal—40 percent—corresponded to an on-axis intensity of 4.6 kcd, or more than 4 times the minimum intensity criteria for that roundel. Any signal in the field that produces a reading of 20 percent requires attention and should be serviced as soon as possible—although it would meet minimum specifications if properly focused.

Lamp life

Lamp life data were obtained for each fixture type on the signal cycling test stand (fig. 15). Even with the limited number of lamps tested, two conclusions can be drawn:

- Applying of a low "warming voltage" during the off-portion of the flash cycle can significantly extend filament life.
- The longer lifetime promised by the halogen lamp's continuous-duty ratings (in this case, 2500 h) cannot be realized in flashing service.

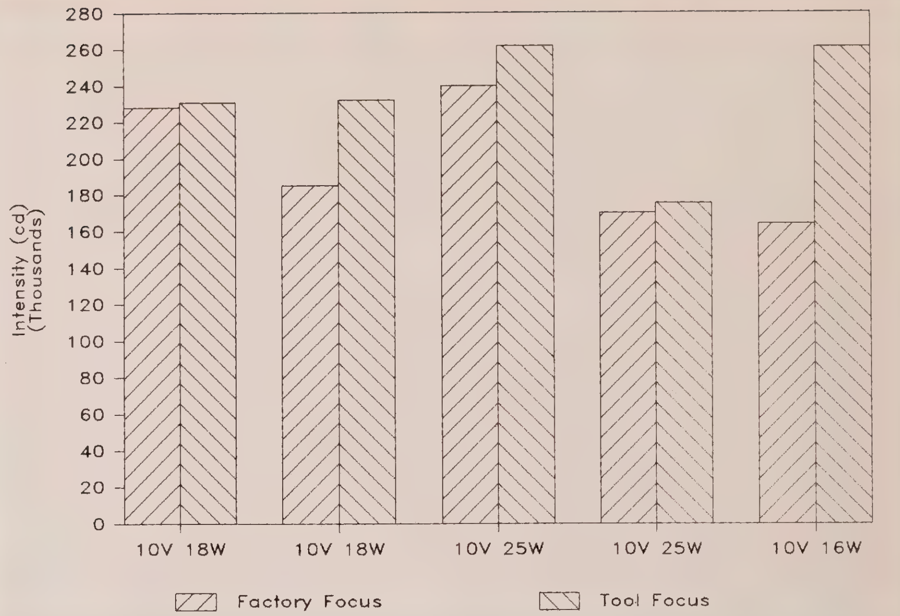

Figure 14.—Improvement obtained by refocusing factory-focused signals using the focusing tool.

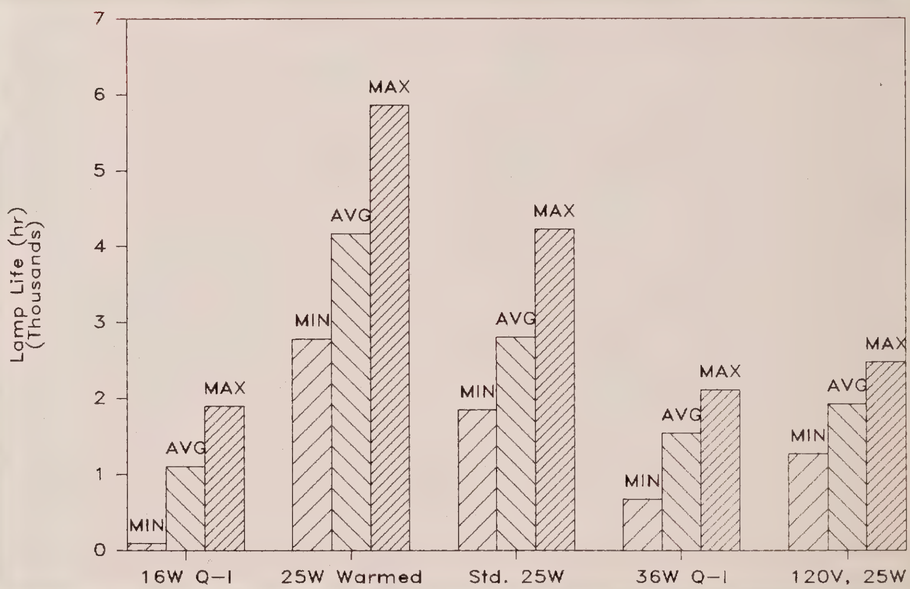

Figure 15.—Lifetime statistics for the different lamp types tested in the signal cycling test stand. A total of 56 lamps were tested.

Conclusions

Assuming that the rest of the signal hardware is in good condition, both the integral reflector/socket assembly and the tripod lamp mount will provide reliable visibility far exceeding any government or industry minimum criteria. While either of these concepts could be incorporated into a new signal design without a major impact on its cost, the integral reflector/socket assembly may be the more desirable of the two as it:

- Is more readily adaptable to signals from different manufacturers.
- It allows easier access to the lamp than any available crossing signal.
- Can survive malicious mischief (especially gunshot damage) that would disable signals of other designs. The 120 V prototypes could not meet specifications for crossings where vehicle traffic approaches at speeds greater than 72 km/h (45 mi/h). Their adequacy for other crossings is marginal.

The alignment scope gives an accurate indication of the direction of the signal axis. It could be valuable to a signal crew for ensuring proper alignment, and is intended for use when the signal housing is open for other maintenance. Units of acceptable quality could be manufactured (in quantity) for sale at an estimated $75 to $100.

The flux meter provides meaningful information about a signal's total light output. There is now no commercially available instrument practical for field use that serves this function. A low meter reading may alert the user to a developing problem before it is noticeable to the unaided eye. This instrument's cost is estimated at $300 to $400 when produced in quantity.

The focusing tool is the most promising of the three systems for commercial development. It could be made in quantity for less than $50 and would pay for itself in its first few hours of use. Its simple design, ease of use, and informative display are significant features.

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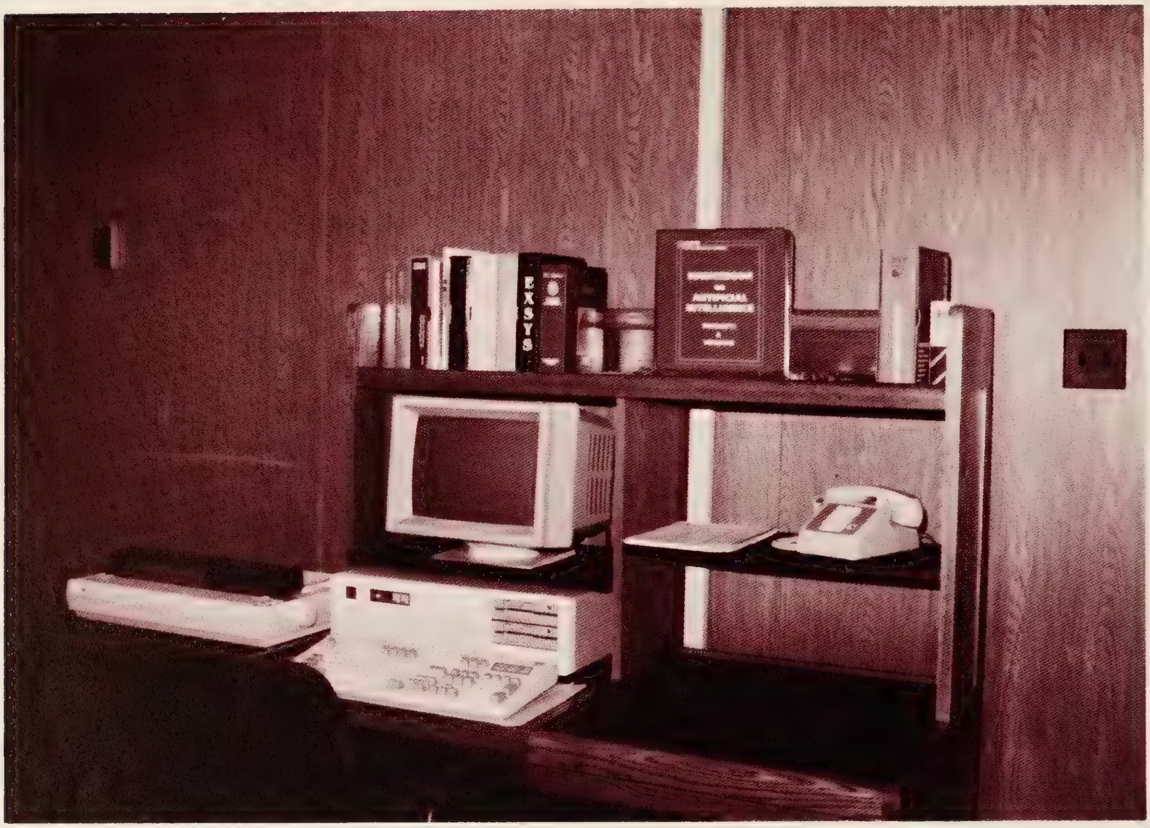
William H. Andrews, Jr., the principal investigator for this study, has been an electrical engineer with the Instrumentation and Controls Division at Oak Ridge National Laboratory since 1977. A specialist in instrument development, he also works in the related areas of data acquisition, process control, electro-optics, analog and digital circuit design, and, most recently, computer security.



Advisory (Expert) Systems— An Assessment of Opportunities in the Federal Highway Administration

by
James A. Wentworth

Introduction

Advisory systems represent a technology that is expanding rapidly in many industries but has not reached widespread use in the highway engineering field. The Federal Highway Administration (FHWA) and others in the highway community are beginning to consider this technology for its potential application to highway engineering. In considering this technology, there are a number of questions that are being asked. These questions include:

- What are advisory systems?
- When should advisory systems be used?
- What is being done related to highway technology?
- What are the barriers to the acceptance of advisory systems?
- What areas should FHWA consider for possible development?

What are Advisory Systems?

The label "expert system" is applied to computer programs that attempt to mimic the reasoning and problem solving processes of human experts (clone the expert). In other words, a computer program that incorporates the knowledge, rules of thumb, and reasoning process of experts in a field, interacts with users to evaluate a situation, and aids in the decision-making process. However, since the expert system label is often misused, "advisory system" will be used to describe the applications of these programs.

Advisory systems are different from conventional or algorithimic programs in the architecture of the program and the way information is stored and used, i.e., the use of knowledge. A conventional (algorithimic) program contains precisely defined logical formulas and data. The operations never vary because the problem solving sequence and procedures must be predetermined by the programmer. If any element is missing the program cannot run. By contrast the advisory system may contain nonnumeric knowledge and can function with incomplete information (like the human expert).

The major characters involved with the development and use of an advisory system are the user, the domain expert, and the knowledge engineer. The user is the one with the problem or goal that the advisory system addresses. The domain expert is the human source of knowledge and experience for the rules in the knowledge base. Finally, the knowledge engineer translates the knowledge and experience of the expert into the rules of the advisory system's knowledge base. With the advent of user friendly shells (development programs), it is possible for the domain expert to be the knowledge engineer also for some applications.

Major components of an advisory system are the knowledge base, inference engine, and user interface. (*1*)[1] The knowledge base contains the facts and rules that capture the expert's knowledge and enables the advisory system to do useful work, i.e., solving problems and advising or guiding the user. The inference engine combines information supplied by the user with the facts and rules in the knowledge base to advise the user on how to solve a problem or reach a goal, i.e., what conclusions can be reached or what additional information is needed. The user interface translates the results from the knowledge base and advisory system operation into a form that the user can understand. Advisory systems programs may be applied to several situations:

- Diagnosis and Correction (e.g., what is wrong and what should be done about it—failure analysis).
- Situation Analysis and Understanding (e.g., what is happening and what do the signals mean—construction inspection, bridge painting strategies, or pavement management).
- Industrial Operations and Management (e.g., scheduling, accounting, etc.).
- Engineering Design (how to do it best—from traffic engineering to pavement design).

In each of these situations, the advisory system can be used as a teacher as well as an aid in decision making. This is possible because the system is interactive with the user. The system can ask questions to obtain information needed to reach a conclusion, explain its questions to the user, give the reasons for those questions, and explain and justify any conclusions reached. (*2*) This enables the user to assess the basis and logic of the systems advice, and reason like the expert.

[1] Italic numbers in parentheses identify references on page 41.

Advisory systems do not represent a new technology. They are applied artificial intelligence and have been evolving for three decades. During much of this time expert systems were limited to the university environment with little use in industry. During the 1980's, this situation has changed, and there are dozens of operational expert systems being used in industry with many new advisory systems under development.

When Should Advisory Systems Be Used?

There are a number of criteria that should be considered in deciding whether or not to develop an advisory system. These criteria are not rules but considerations:

- Both the problem to be addressed and the expected output from the advisory system can be clearly defined.
- There are recognized experts in the field, and there is general agreement among these experts on the knowledge required to solve the problem.
- Experts need private knowledge (experience, heuristics, etc.) in addition to technical tools (such as handbooks and computers) to identify the problem, make inferences about it, and analyze it.

In addition to the technical considerations, there are management and human conditions that must be met if an application is to be successful.

- The end users must be identified and their needs and skills considered. The transfer to and application by the end users of the completed system must be major factors in the system planning and design.
- Someone in the organization must be an advocate of the advisory system. Ideally this includes both a developer and a user.

In addition to the above considerations for development, an advisory system also must have the characteristics of usefulness, performance, and transparency identified by Hendrickson. (*3*)

- Usefulness—The advisory system must perform a useful function. This depends on the need the system was designed to address.
- Performance—The advisory system must perform as well as needed over the range of conditions or applications addressed by the user. This requires that the system have specialized knowledge that separates human experts from novices.
- Transparency—The system must be transparent to the user. It must be able to be understood by the user and must be able to explain its logic, actions, and reasoning to the user.

What Is Being Done Related to Highway Technology?

There are a number of highway-related advisory systems either developed or under development. These vary from partially deployed and partially operational systems developed in conjunction with State highway agencies to student projects conducted as part of a course requirement or as an advanced degree thesis. The following list of highway related systems is organized under the categories of the Nationally Coordinated Program of Highway Research, Development, and Technology:[2]

A. Highway Safety

There are no systems in this category.

B. Traffic Operations

D. Bryson and J. Stone, *The Intersection Advisor: An Expert System for Intersection Design,* Department of Civil Engineering, North Carolina State University, Raleigh, NC, 1986.

E. Chang, *Select Traffic Analysis Software Using Expert Systems,* Texas Transportation Institute, College Station, TX, 1986.

Application of Artificial Intelligence to Urban Congestion Problems. This application is being developed under the sponsorship of the FHWA (HSR-10).

S. Tung, *Designing Optimal Networks: A Knowledge-Based Computer Aided Multicriteria Approach (EXPERT-UFOS)* Department of Civil Engineering, University of Washington, Seattle, WA, 1986.

C. Zozaya-Gorostiza and C. Hendrickson, *TRALI: A Traffic Signal Setting Expert System Assistant,* Technical Report, Carnegie-Mellon University, Pittsburgh, PA, 1985.

C. Pavements

K. Hall, M. Darter, S. Carpenter, and J. Connor, *EXPEAR: A Computer System to Assist the Design Engineer in Concrete Pavement Evaluation and Rehabilitation.* This system was developed under an FHWA contract with the University of Illinois, Urbana, IL, 1986.

An Expert System for Asphalt Concrete Construction. Under development by the FHWA and the Army Corps of Engineers' Construction Research Laboratory, Champaign, IL.

C. Haas, *Preserver: A Pavement Management Consultant,* Student Project, Carnegie-Mellon University, Pittsburgh, PA, 1986.

C. Haas, B. Ritchie, and J. Shelley, *An Expert System for Pavement Distress Data Analysis,* Department of Systems Design Engineering, University of Waterloo, Waterloo, Ontario, Canada, 1984.

C. Haas, H. Shen, W. Phang, and R. Haas, *An Expert System for Automation of Pavement Condition Inventory Data.* Prepared for presentation to the North American Pavement Conference, Toronto, Canada, 1985.

M. McGartland, *Application of Knowledge-Based Expert Systems to Construction Project Monitoring,* Masters Thesis, Carnegie-Mellon University, Pittsburgh, PA, 1983.

S. Ritchie, C. Yeh, J. Mahoney, and N. Jackson, *SCEPTER: A Surface Condition Expert System for Pavement Rehabilitation,* University of California, Irvine, CA, 1986.

D. Structures

J. Chahin, *Retaining Wall Diagnostic,* Student Project, Carnegie-Mellon University, Pittsburgh, PA, 1986.

C. Kostem, *AASHTO Bridge Rating System,* Lehigh University, Bethlehem, PA, 1986.

T. Maples, *A Knowledge Based System for Plate Girder Design,* Masters Thesis, Massachusetts Insitute of Technology, Cambridge, MA, 1985.

K. Maser, *Automated Interpretation of Sensor Data for Evaluating In-Situ Conditions,* Massachusetts Institute of Technology, Cambridge, MA, 1986.

S. McNeil, *Identification of Feasible Bridge Painting Systems Using an Expert System,* Massachusetts Institute of Technology, Cambridge, MA, 1986.

W. Seymour, *Preliminary Development of a Bridge Management System with Rule Based Expert System Decision Support Enhancements,* Masters Thesis, Massachusetts Institute of Technology, Cambridge, MA, 1985.

J. Welch, *BDES: Bridge Design System,* Duke University, Durham, NC, 1986.

E. Materials and Operations

D. Ashley and M. Wharry, *SOILCON: Soil Exploration Consultant,* Department of Civil Engineering, University of Texas, Austin, TX, 1985.

L. Cohn, A. Harris, and W. Bowlby, *CHINA: An Expert System for Highway Noise Decision Making,* Technical Report, Vanderbilt University, Nashville, TN, 1984.

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[2] See *Public Roads,* Volume 51, Number 1 (June 1987), for a discussion of the Nationally Coordinated Program of Highway Research, Development, and Technology, page 1.

M. Joro, *Knowledge Based Planning Schedules for Public Works Projects,* Masters Thesis, Massachusetts Institute of Technology, Cambridge, MA, 1986.

P. Mullarkey, *CONE: An Expert System for Interpretation of Geotechnical Characteristics Data from Dutch Cone Penetrometers,* Carnegie-Mellon University, Pittsburgh, PA, 1985.

I. Tommelein, R. Levitt, and B. Hayes-Roth, *SITEPLAN: Layout of Temporary Construction Facilities,* Stanford University, Civil Engineering and Computer Science Departments, Palo Alto, CA, 1986.

F. Planning and Policy

D. Fayegh and S. Russell, ''An Expert System for Flood Estimation,'' *Expert Systems in Civil Engineering,* ASCE, 1986.

J. Fricker, *Forest Road Design,* Department of Civil Engineering, Purdue University, Lafayette, IN, 1986.

C. Yeh, *HERCULES,* Department of Civil Engineering, University of Washington, Seattle, WA, 1985.

G. Motor Carrier Transportation

G.A. Sparks, F.P. Nix, and G.L. Campbell, *HEVCO: Heavy Vehicle Configuration Optimization Project,* Roads and Transportation Association of Canada, 1986.

H. R&D Management and Coordination

There are no systems in this category.

Barriers to the Acceptance of Advisory Systems

As appealing as advisory systems may appear to many, there are a number of barriers to their acceptance. These barriers are generally based on either mistrust or misunderstanding of the technology. The discrepancies between promises and actual performance of the modeling and simulation programs of the 1970's have left many with a mistrust of unproven computer-based systems. The artificial intelligence (AI) community has been very cavalier in repeating grandiose old success stories and not discussing current accomplishments, giving rise to the suspicion that there are no new accomplishments.

There is also an arrogant attitude in some of the AI (knowledge engineering) promotions that is offensive to many experts. This is characterized by the ''expert as a cow'' attitude where the expert is milked of knowledge and the knowledge engineer translates this knowledge into something useful and lasting. This is dehumanizing and insulting to significant numbers of potential contributors and users.

Many demonstrations have been too weak and poorly explained. The simple examples used have left the audience thinking that advisory systems have little use and asking ''Why do I need an advisory system to tell me that? I'll just ask anyone for the answer.'' Other demonstrations have led to confusion by introducing, and then not explaining, unfamiliar terms such as ''inference engine.'' (The inference engine is the part of the program that combines the users responses to questions with rules in the knowledge base.)

The training aspects of advisory systems are neglected in many demonstrations. In the near future in the highway community, the use of advisory systems as interactive training systems is important. This area must be addressed if advisory systems are to be properly used by the highway community.

Most promotions and demonstrations also fail to address the updating problem. Most experts and management officials are well aware that any expert becomes obsolete in a very short time if the education process is not continuing. The problem of keeping advisory systems up to date is even more severe than it is for human experts because computer programs do not take training courses, learn from reading technical journals, or learn from daily experience as human experts do. The advisory system must be regularly maintained by experts if it is to stay current.

Areas for Development

In spite of the barriers to the acceptance of advisory systems, there are potential areas for useful advisory systems in virtually every aspect of highway engineering and management. The following list is a limited sample of promising applications:

A. Highway Safety

Design, Selection, and Location of Roadside Safety Appurtenances—An advisory system to support the updated *Roadside Design Guide* (when it becomes available) which is a guide for the selection of the proper roadside safety hardware for a particular situation.

Work Zone Advisor—A system to assist the highway engineer in planning the best work zone delineation and warning systems for various types of work zones and for different terrains and highway conditions.

B. Traffic Operations

MUTCD Advisor—A training module for the novice traffic engineer on the application of the *Manual on Uniform Traffic Control Devices*.

Disaster Response—An advisory system for route selection and emergency response during natural disasters.

C. Pavements

Construction Management—Various systems for project planning, scheduling, control, bid evaluation, and contract management.

Construction Inspection—Different advisory systems to assist in construction inspection for various construction sites.

Materials Design—Various systems for concrete and asphalt mix designs and for steel selection and coatings.

D. Structures

Design Aids—Systems for the design and selection of bridge elements, drainage systems, foundations, etc.

Storm Water Runoff—A system to assist in designing for storm water runoff.

E. Materials and Operations

Snow and Ice Control—An advisory system to assist the maintenance engineer in the planning and scheduling of adverse weather maintenance operations.

Vegetation Management—A tutor for equipment selection and operation (regional).

Construction Contamination Control—An advisory system to assist in designing measures to ensure that construction runoff is not a problem.

Construction Site Materials Storage Advisor—An advisory system for materials storage planning and operation.

F. Planning and Policy

Planning Model Selection Guide—A system to assist the planner in selecting the most appropriate planning tool to fit a particular set of conditions.

G. Motor Carrier Transportation

Route Advisor—A system to advise in the selection of routes for the transportation of hazardous materials or a system to select a route for a given cargo based on local regulations, etc.

H. R&D Management and Coordination

Technology Transfer Advisor—A system to advise in the proper technology transfer media for specific products and target audiences.

HTIMS Helper—A system to simplify use of the FHWA Office of Research, Development, and Technology *Highway Technology Information Management System* (HTIMS), to provide help screens, and to assist FHWA staff and managers in generating special reports.

Regulations Advisor—A system to locate the proper regulations and interpret them based on what the user needs to do.

FHWA's Technology Transfer (T^2) Laboratory

The Technology Transfer (T^2) Laboratory in the FHWA's Office of Implementation is coordinating advisory systems development for the Headquarters offices of the FHWA.[3] This involves chairing an advisory systems working group, serving as a clearinghouse for information, advising and assisting in the development and distribution of advisory systems, and developing guidelines for the development of advisory systems. In conjunction with the National Highway Institute, the T^2 Laboratory also has sponsored training on advisory systems development.

In providing assistance, the T^2 Laboratory is focusing on the evaluation of the potential of proposed systems and on the development of rapid prototypes for candidate advisory systems. This assistance is available to all FHWA Headquarters offices. The development of major advisory systems is expected to be performed under contract after the concept has been demonstrated to be viable by the prototype.

[3]See *Public Roads*, Volume 50, Number 3 (December 1986), page 97 for a discussion of the Technology Transfer Laboratory.

What is the Future?

In the longer term, advisory systems will have a major impact on the way highway administrators, engineers, planners, designers, inspectors, and others perform their duties. They will add a valuable new tool to a transportation specialist's tool kit. (The National Aeronautics and Space Administration is working on a system for satellite maintenance and repair that will be operational before the end of this decade.) The highway construction inspector of the future may use an inspection aid no larger than a walkie-talkie that can analyze a situation from voice inputs and the device's internal knowledge, show the inspector a detailed picture of what a particular construction detail should look like (on a small display screen), suggest corrective action if needed (using its voice synthesizer), and file the inspection report.

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(*3*) C. Hendrickson, D. Rehak, and S. Fenves, *Ps Expert Systems in Transportation Systems Engineering*, Technical Report, Carnegie-Mellon University, Pittsburgh, PA, 1985.

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The Potential Impact of Automobile Headlamp Changes on the Visibility of Reflectorized Overhead Highway Guide Signs[1]

by
John B. Arens

Introduction and Background

For almost 20 years, there has been no radical change in U.S. automotive headlamp design. In the late 1930's the two-lamp round sealed beam headlight system became the U.S. standard. Later, the four-lamp round system and the two- and four-lamp rectangular systems were added. Other changes included the use of a halogen light source, and increasing headlight high-beam maximum intensity from 75,000 to 150,000 candelas for the system. However, the basic photometric configuration as well as the sealed-beam concept remained unchanged.

At the same time, considerable changes took place in European headlamp design, including aerodynamic styling and photometric changes to enhance low-beam foreground illumination and reduced glare toward oncoming traffic.

In the United States, the concept of the sealed-beam headlight was altered in 1983 when the National Highway Traffic Safety Administration (NHTSA) approved the use of the separate halogen light source with an aerodynamic lens. Since then, an increasing number of cars sold in this country are delivered with individually styled headlamps and replaceable lamp capsules. Although all of these headlamps meet the test criteria of the Society of Automotive Engineers (SAE) Standard J579c, there are some differences in photometric performance among individual makes of headlamps. (*1*)[2] Because headlamps are a major source of roadway glare, especially on two-lane roadways, future U.S. headlamp designs may incorporate European concepts to reduce glare.

[1]A paper similar to this article was originally presented by Mr. Arens at the International Congress and Exposition of the Society of Automotive Engineers in Detroit, Michigan, in February 1987.

[2]Italic numbers in parentheses identify references on page 47.

In reviewing the possible influence of such headlamp design changes on the conspicuity and visibility of the approximately 10,000 unlit overhead roadway signs in the United States, it was noted that SAE Standard J579c contains no minimum intensity values above the horizontal and to the right of a vertical plane parallel to the longitudinal road axis. Theoretically, therefore, a headlamp could be designed and manufactured to meet all currently applicable national standards, but the headlamp might not adequately illuminate highway signs.

This article examines the effects of low-beam headlamp design changes on the conspicuity and visibility of overhead guide signs on U.S. roads and highways as well as the safety impact of such design changes. The headlamp design changes discussed are permissible under present national standards and will meet all photometric requirements of Standard J579c. The article also develops lighting intensity values required for minimum overhead sign visibility, reviews the performance of current U.S. sealed-beam and European headlamps, and suggests some changes to SAE Standard J579c to assure the continued usefulness of unlit overhead guide signs.

Overhead Guide Sign Luminance Needs

To ensure safe, orderly, and predictable movement of traffic, overhead guide signs must be visible, conspicuous, and legible, both during the day and the night. The best, but not necessarily the most cost-effective way to meet these requirements at night is to furnish the signs with an external (or internal) lighting system. In rural areas of relatively low ambient luminance and minimal visual clutter, non-illuminated signs usually are sufficiently visible under low-beam headlight illumination if they are constructed with the proper reflective materials and installed on straight sections of roadways. (*2*)

Earlier studies indicate that legend luminance levels between 10 and 30 fL (34 and 103 cd/m²) provide optimum sign legibility. (*3*, *4*) In relatively dark, rural areas without headlamp glare from opposing traffic, luminance levels can decrease to as low as 1 fL (3.4 cd/m²) without a serious reduction in legibility distance. When legend luminance levels are reduced below 1 fL (3.4 cd/m²), however, legibility deteriorates rapidly. In a survey of sign materials, it was found that sign legend luminances greater than 1 fL (3.4 cd/m²) are possible with low beams for Type III sign sheeting (high-intensity, encapsulated) and button reflective signing materials. (*5*)

Three major parameters determine the luminance of any reflectorized roadway sign that does not have its own lighting system:

- The geometry of the roadway and the position of a vehicle relative to the sign.
- The reflective materials used to construct the sign.
- A vehicle's headlamps (low beam, high beam, aim, and beam pattern).

Many other factors influence sign conspicuity, legibility, and luminance, such as, dirt accumulation on the sign surface, on the headlamps, and on the windshield; weather conditions (e.g., rain, fog, snow, and dew in the atmosphere and on the sign); and the condition of the retroreflective materials used on the sign.

Because sign construction and placement are prescribed by specific guidelines (*6*) and the performance of properly aimed sealed-beam lamps is fairly predictable, overhead guide sign conspicuity and legibility often were accomplished strictly by the retroreflective characteristics of the signs and some headlamp illumination.[3]

[3] "Encapsulated Lens (High Intensity) Reflective Sheeting Sign Material," FHWA Notice N 5040.17, *U.S. Department of Transportation, Federal Highway Administration*, Washington, DC, 1976.

The *Manual on Uniform Traffic Control Devices* (MUTCD) cites that the amount of low-beam headlight illumination incident to an overhead sign is relatively small, and the use of non-illuminated reflectorized signs should be limited to areas without serious interference from extraneous light sources. (*7*) Sign visibility study results, recommendations, and rulings are based on U.S. low-beam headlamp patterns used over the past 20 years. If the luminous intensities of the upper right-hand quadrant of low-beam headlamps are decreased to reduce glare, the usefulness of many overhead guide signs may be seriously diminished at night.

Headlamp luminous intensity requirements

A detection distance of between 1,100 and 1,200 ft (335 to 366 m) and a legibility distance of 800 to 900 ft (244 to 274 m) on limited access roads generally are considered desirable for proper traffic maneuvers. Assuming a 1-fL (3.4-cd/m²) legend luminance as the minimum acceptable sign brightness, headlamp intensity requirements can be developed for typical sign/distance condition such as that illustrated in figure 1.

To find the specific intensity per unit area (SIA), the observation angle α and the entrance angle β first must be computed by equation. Table 1 shows α and β for distances between 300 and 1,200 ft (91 m and 366 m). The next step is to compute the required illuminance E on the sign surface for the various entrance angles β to produce the desired luminance of 1 fL (3.4 cd/m²) on the sign legend. Finally, through a series of equations, the total and per headlamp luminous intensity requirements can be developed for a 1-fL (3.4 cd/m²) sign legend brightness. Table 2 shows the intensity requirements for vertical entrance angles between 1° and 4° up (representing distance from 1,200 to 300 ft [366 m and 91 m]) over a relatively narrow lateral spread (from the longitudinal road axis to about 3° to the right), provided new Type III white sheeting is used as legend material.

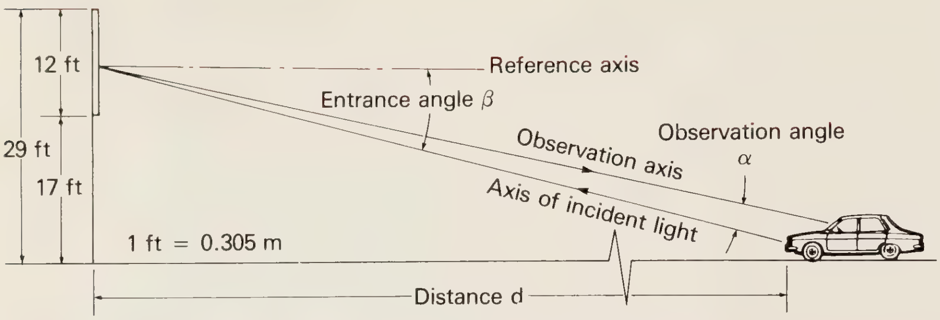


Figure 1.—Geometry to determine headlamp luminous intensity requirements.

Table 1.—Observation angles, entrance angles, and specific intensities per unit areas

Distance d	Observation angle α	Entrance angle β	SIA
Feet	*Degrees*	*Degrees*	*cd/fc/ft²*
1,200	0.07	1.00	250
800	0.10	1.50	250
600	0.14	2.00	250
400	0.21	3.00	250
300	0.28	4.00	200

1 ft = 0.305 m
1 cd/fc/ft² = 1 cd/lux/m²

Table 2.—Headlamp luminous intensity requirements

Distance d	Entrance angle β	Required illuminance I	Luminous intensity I	Luminous Intensity I headlamp
Feet	*Degrees*	*Footcandles*	*Candelas*	*Candelas*
1,200	1.0	.00127	1832	916
800	1.5	.00127	814	407
600	2.0	.00127	458	229
400	3.0	.00127	204	102
300	4.0	.00159	144	72

1 ft = 0.305 m
1 cd/fc/ft² = 1 cd/lux/m²

Headlamp luminous intensities characteristics

Photometric data of currently available U.S. sealed-beam headlamps and European headlamps were reviewed to determine how well these lamps meet the luminous intensity requirements shown in table 2. The areas of interest are the upper right-hand quadrant of the low-beam configuration, an area where an overhead guide sign normally would be found, that is, in line with and to the right of the longitudinal road axis and vertically between 1° and 4° up. Because complete photometric data (candela tables) were available for all but three lamps (and these data were furnished with Isocandela charts), it was easy to pick candela values at locations of interest. Values were recorded at 1° up, 1.5° up, 2° up, 3° up, and 4° up, each at lateral locations 0°V (vertical), 1°R (right), 2°R, and 3°R. Although SAE Standard J579c restricts the luminous intensities in this general area, no minimum candela values are required in the upper right-hand quadrant of headlamps.

Table 3 shows the average candela values found for the various types of lamps. All sealed-beam headlamps as well as the Bosch elliptical lamps (average values) meet the minimum intensity requirements shown in table 2 for distances of 800 ft (244 m) or less (1.5° up to 4° up). At the sign detection distance of 1,200 ft (366 m), 1° up, all sealed-beam and Bosch headlamps meet the requirements between 1° and 3° R. However, the intensity values of the VW and Marchal lamps are consistently and considerably below the requirements. It is important to note that these VW and Marchal lamps were either prototype or production lamps currently not permitted for the use on highways in the United States and used only to investigate the impact a sharp cutoff headlamp might have on overhead sign visibility.

Field experiment

A 1-mi (1.6 km) section of a straight, asphalt-paved, four-lane divided highway with some vertical curvature was used in a limited field evaluation using three sets of headlamps. Highway grades vary from −1.4° to +2.1°, with an approximately 1,000-ft (305 m) long, flat section of −0.1°.

Three overhead sign structures alert motorists of an upcoming modified cloverleaf interchange. The first two structures carry three signs each; the third structure carries one sign. The individual signs range in height from 9 to 10 ft (2.7 to 3.0 m) and in width from 7 to 12 ft (2.1 to 3.7 m). The lower edges of the signs are approximately 19 ft (5.8 m) above the pavement.

The signing material used for all legends, borders, and backgrounds is Type III reflective sheeting (high-intensity, encapsulated). The signs have been in service for about 3 years and appear to be in excellent condition. Figure 2 shows the road profile, the observation points, and the sign locations.

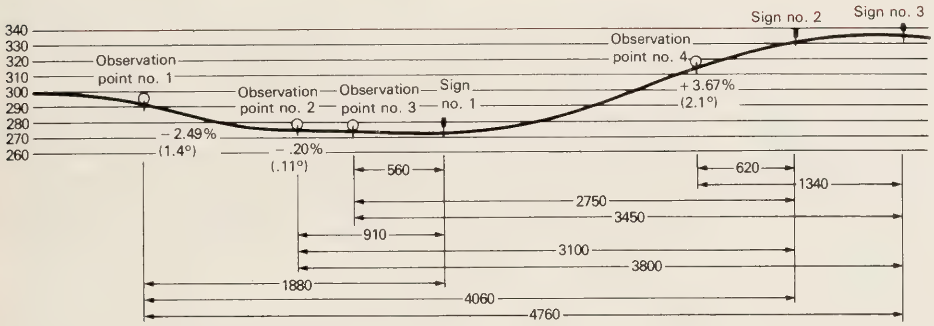
Table 3.—Average luminous intensity values (in candelas) by lamp type

Distance (ft) and intensity requirements/ headlamps (cd)	Intensity points, degrees	Lamp Type							
		SAE 2A1	SAE 2B1	SAE 2D1	SAE 2E1	SAE VW(1)	SAE VW(2)	Bosch	Marchal
	1° up 0°V*	717	820	907	1170	220	340	775	195
	1°R†	929	1108	1097	1375	240	400	1090	210
1,200 ft	2°R	1106	1276	1230	1615	300	450	1225	225
916 cd	3°R	1057	1204	1233	1735	330	430	1160	235
	1.5° up 0°V	596	584	610	865	160	220	660	160
	1°R	741	713	685	975	170	240	825	175
800 ft	2°R	855	799	772	1105	100	150	855	185
407 cd	3°R	804	814	752	1180	220	250	790	185
	2° up 0°V	505	433	467	675	140	160	495	145
	1°R	602	531	510	755	150	180	150	150
600 ft	2°R	666	585	567	820	160	200	640	150
229 cd	3°R	636	598	543	845	160	190	605	160
	3° up 0°V	292	283	307	460	100	120	320	120
	1°R	344	325	337	500	110	130	375	120
400 ft	2°R	383	363	375	520	120	130	390	120
102 cd	3°R	391	369	372	525	120	130	375	120
	4° up 0°V	210	205	227	350	<100	<100	235	95
	1°R	230	236	248	385	<100	<100	255	95
300 ft	2°R	259	256	262	385	<100	<100	265	100
72 cd	3°R	254	269	263	400	<100	<100	250	100

1 ft = 0.305 m
1 cd/fc/ft² = 1 cd/lux/m²

* V = Vertical plane parallel to longitudinal road axis.
† R = Vertical planes to the right of "V."
//// = Candela values below those required.

NOTE: Although the Hella VW and the Bosch elliptical headlamps meet J579c, neither of these lamps is currently in use in the United States.



1 ft = 0.305 m

All dimensions are in feet. The vertical scale has been expanded by a factor of 10 relative to the longitudinal scale.

Figure 2.—Road profile, grades, sign and observation locations of Route 7 in Virginia used for field experiment.

The entire 1-mi (1.6 km) section of roadway was filmed with a 16 mm movie camera to show the effects of the various headlamp configurations on overhead sign visibility and legibility. In addition, 35 mm color transparencies were taken from the four observation points shown in figure 2 with a 180 mm zoom lens to optimize sign image. The slides and the motion pictures show the signs when illuminated by a pair of sealed-beam lamps, by two Bosch lamps, by one Bosch lamp, and by a pair of Marchal lamps.

All headlamps were mounted 26 in (660 mm) above the pavement; lamp power was regulated with a specially provided voltage regulator. The sealed-beam lamps were aimed mechanically; the European lamps were aimed visually according to the manufacturers' instructions.

The most meaningful transparencies were taken of sign number 1 from observation points number 2 and number 3. The section of roadway between observation point number 2 and sign number 1 is practically flat (constant grade of −0.1°) and yielded observation distances of 920 ft (280 m) and 560 ft (171 m). Although the photographs taken from observation points number 1 and number 4 are of interest, the vertical curvature of the road re-emphasizes or de-emphasizes the impact of the sharp headlamp cutoff. It was felt that the slides could be used to judge the effects of the various lighting configurations on the signs.

Table 4 summarizes an objective evaluation of the performance of the various headlamp configurations.

Discussion

In this experiment, many conditions were controlled that could not necessarily be controlled in the real world. First, the signing material of the unlit overhead guide signs was relatively new Type III high-intensity sheeting. Also, the headlamps were properly aimed, operated at the design voltage, and were in relatively good repair. The road section used in the experiment was straight and flat, and the atmosphere free of fog, rain, or snow. Under these ideal conditions, the currently produced and available sealed-beam headlamps provided sufficient luminous intensity in the upper right-hand quadrant to make non-illuminated overhead guide signs sufficently visible to be detected and read by motorists in time to execute any necessary maneuvers safely.

Although the light emitted by sealed-beam headlamps also contributes significantly to the glare experienced by oncoming motorists and decreases forward visibility during heavy rain, snow, and fog, optical design changes to improve headlight cutoff characteristics to reduce glare could jeopardize the usefulness of non-illuminated overhead guide signs during the night. Figures 3 through 6 show the low-beam luminous intensity distributions of a sealed-beam headlamp, the Hella VW headlamp, the Bosch elliptical headlamp, and the Marchal headlamps. As can be seen, the upper right-hand intensities (as well as the upper left-hand intensities) are severely reduced in the European lamps.

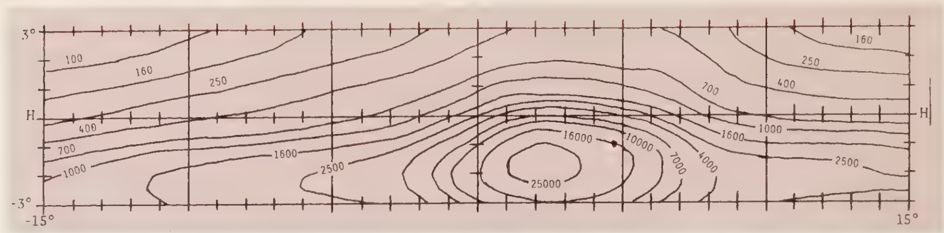


Figure 3.—Isocandela-diagram of SAE type 2B1 sealed-beam headlamp (low beam).

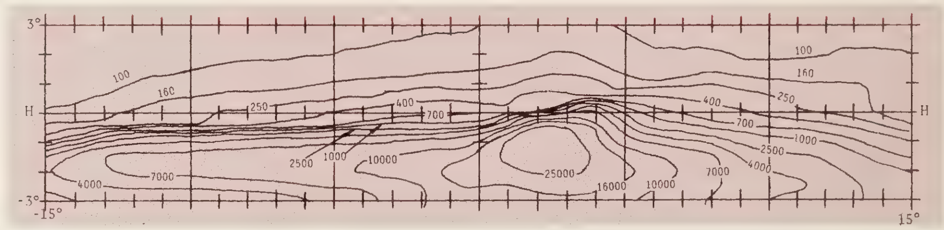


Figure 4.—Isocandela-diagram of VW/Hella headlamp (low beam).

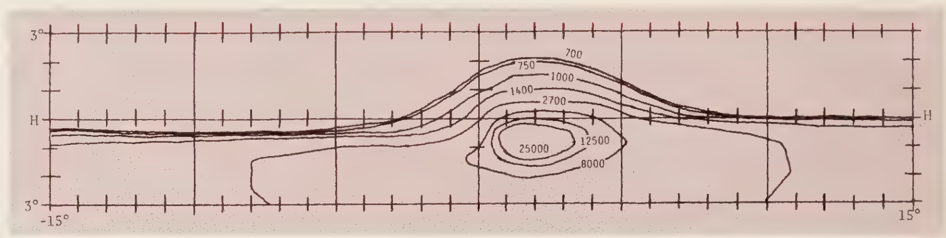


Figure 5.—Isocandela-diagram of Bosch elliptical headlamp (low beam).

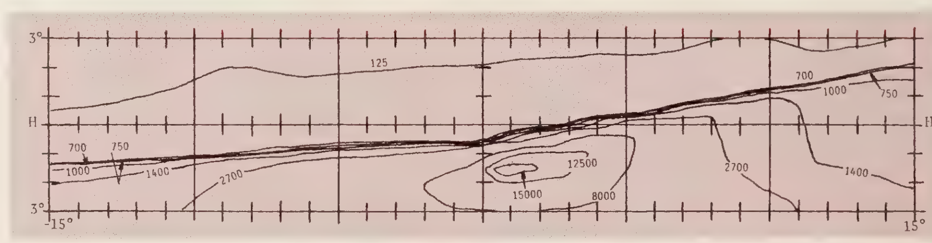


Figure 6.—Isocandela-diagram of Marchal headlamp (low beam).

Summary and Conclusions

Although there have been no major optical design changes in U.S. headlamps yet, now is the time to consider the options available to preserve the usefulness of unlit overhead guide signs if headlamp designs are changed. One option which would ensure that minimal illumination is always available, is to revise SAE Standard J579c to include minimum requirements in the upper right-hand quadrant of headlamps for low beams. Another option, although expensive, is to install lighting on all non-illuminated signs. A conservative estimate to furnish lighting for all signs presently not illuminated would be about $50 million to $60 million, plus $4 million to $5 million per year to operate and maintain this equipment. The social and economic trade-offs between the potential safety benefits resulting from reduced glare

Table 4.—Visual assessment of sign visibility using different types of headlamps

Distance	Headlamps			
	Sealed beam	Bosch—2 lamps	Bosch—1 lamp	Marchal
1,880 ft to sign No. 1	Quite good	Marginal	Not conspicuous	Invisible
910 ft to sign No. 1	Very good	Good	Marginal	Invisible
560 ft to sign No. 1	Very good	Good	Marginal	Almost invisible
620 and 1,340 ft to signs Nos. 2 and 3	Very good/ Very good		Good/ Very good	Marginal/ Almost invisible

1 ft = 0.305 m

headlamps versus the cost of illuminating most of the currently unlit overhead guide signs should be investigated. A third option is to develop and to use new retroreflective materials having much higher specific reflectance characteristics than materials presently available.

A review of low-beam photometric data of 26 currently available headlamps showed sufficient candela values at 0.5° up between 1°R and 3°R, and 1.5° up between 1°R and 5°R to justify a suggestion to add minimum values of 1,000 cd and 450 cd, respectively, to Standard J579c at these locations. These suggested values are about one-third of the maximum values specified at these points in Standard J579c. Holding manufacturing tolerances within a 3 to 1 maximum to minimum ratio should not present an overly difficult production task to manufacturers who exercise prudent quality control. Although these suggested luminous intensity values are somewhat lower than the minimum values shown in table 2, by setting 1,000 cd and 450 cd as minimums, actual candela values of production runs will be somewhat higher once these changes are adopted into Standard J579c.

To observe how such a low-beam configuration actually would perform, just one of the two Bosch elliptical low-beam headlamps was operated at one point in the field evaluation. These headlamps produce about 2,000 cd at 0.5° up between 1°R and 3°R and about 850 cd at 1.5° up from 1°R to R. These values are very close to two lamps if designed and manufacturered to produce the minimum candela values suggested. This one-lamp configuration provided marginal visibility at 910 ft (277 m) and 560 ft (171 m). Actual production units probably would provide somewhat higher values, improving sign visibility slightly. It also should be recognized that illumination on the sign surface will be improved with stream traffic and by light being reflected off of the pavement, especially wet pavement. But by setting 1,000 and 450 cd as minimum values for these specific points, retroreflective overhead guide signs will not become obsolete.

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(*7*) "Manual on Uniform Traffic Control Devices," *U.S. Department of Transportation*, *Federal Highway Administration*, Washington, DC, 1978.

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Luminance Requirements For Signs With Complex Backgrounds

by
Richard N. Schwab and Douglas J. Mace

Introduction

Lack of adequate visual guidance information has generally been recognized as a major reason there are higher accident and fatality rates observed at night. This is because during day, landmarks and other visual cues provide information to help guide the unfamiliar motorist. At night, however, the driver is much more reliant on formal traffic control devices, such as signs, to warn of conditions ahead and provide other needed visual guidance. These devices must not only be seen but they must be seen at a point in space where there is sufficient time to detect, read, understand, and react.

Whether or not a given traffic control device is visible to the driver at the appropriate distance is a function of many factors. Various laboratory studies conducted over the past century have indicated that visual performance is mainly dependent upon:

- Luminance adaptation level to which the eye is previously exposed.
- Size and shape of the object to be seen.
- Time available for seeing.
- Contrast between the object and the background. (*1*)[1]

Of the factors mentioned above, contrast and, to some extent, size are the ones most conveniently employed by the traffic engineer to enhance the sign visibility. By properly selecting the retroreflective material to be used and sign size, the traffic engineer can produce a traffic control device which will be visible to the approaching motorist at the distance required to process the information. (The grade of retroreflective material determines the apparent luminance and, therefore, determines the contrast the device has to its surroundings.)

[1] Italic numbers in parentheses identify references on page 55.

Another set of concerns remains to be addressed, however, the complexity of the visual environment can have a profound effect on target detection. (*2*) Since highway environments are often complex—especially in and around urban areas where most travel takes place—there is a need for a method to classify the complexity of the visual background and to quantify the impact of this complexity on sign detection requirements.

This article describes a research study establishing luminance requirements to ensure that a yellow diamond warning sign is conspicuous at night. The study developed a procedure for rating sign locations to identify those locations requiring higher luminance level signs. The article presents this procedure, the study's major conclusions, and recommendations on the maximum allowable sign luminance deterioration that can still provide the driver with adequate detection distances. The significance of this study is that it attempts to provide standards for signing luminance by developing criteria based on the complexity of the surrounding visual environment.

Background

In the United States, the "*Manual on Uniform Traffic Control Devices*" (MUTCD) contains standards for what signing is required or recommended for use on all streets and highways open to the traveling public. (*3*) These basic requirements specify standard color, shape, location, position, and legend or symbol size for each application where a traffic control device is either required or desirable. The basic requirement for all traffic control devices is that they be applied in such a manner as to be visible and easily understood at all times to permit proper response by all drivers. The MUTCD requires that these signs, which are applicable at night, be either illuminated or made from retroreflective materials. The MUTCD, however, does not define the level of retroreflectivity or illumination required. Because of this lack of guidance and standardization it is feared that many traffic signs have been allowed to deteriorate to the point where they are no longer readily seen and understood.

Several factors affect sign detection:

Drivers' needs for sign luminance are of two types, luminance requirements for conspicuity and luminance requirements for legibility. These requirements are separate and distinct parts of the visual task. A sign must first get the driver's attention and then have sufficient contrast for legibility to effectively provide its information. Conspicuity is of primary concern for warning and regulatory signs where the driver is not expecting the traffic control device. Such signs must have the capacity to attract the driver's attention without any overt searching required on his or her part. The signs must be seen with a high degree of certainty.

Visual Background Complexity

The detection of simple targets, such as traffic signs, seen against a uniform and fairly dark background of known luminance can be predicted with reasonable confidence. This is the case on most rural highways. As the motorist approaches urban areas, however, there is considerably greater uncertainty in attempting to make such predictions. In such areas, signs are often seen against visually complex parts of the urban environment, e.g., a row of brightly lit shops or an array of advertising signs. This complexity of the visual environment profoundly affects target detection necessitating a method for identifying those locations where background complexity is high enough that warning signs would benefit from the use of high retroreflectivity materials.

Driver Expectancy

Jenkins and Cole distinguish two classes of conspicuity situations. (*4*) In the first of these situations, called "search conspicuity," the driver is actively searching for information, such as a guide or street name sign. In this case, the sign needs a relatively low level of conspicuity to be quickly and readily located. Usually it is the legibility variable of contrast between the sign legend and its background which is crucial in the design of such signs. In the second case, "attention conspicuity," sign occurrence is not expected by the driver; this is the case for most warning, construction, and regulatory signing. Attention conspicuity is thus of primary importance in designing such signs, since it is the capacity of the traffic control device to attract attention when its occurrence is not expected by the driver.

In an attempt to operationally define visual complexity as it relates to nighttime conspicuity of traffic signs, an extensive laboratory study was conducted with 80 different highway scenes and four types of traffic signs. (*2*) Approximately 40 different visual and photometric measures were made of scene, target, and surrounding variables. The performance criterion was the proportion of correct sign recognitions obtained when the scene was quickly viewed by 40 subjects. A correct response required identifying the specific type of sign (i.e., color and shape) present in the scene.

The Mace study demonstrated that when the visual information in the scene was high, complexity was more important in determining whether a sign would be seen than was the physical contrast between the sign and its immediate surroundings. In other words, the brightness difference between the sign and its surroundings was a poor predictor of whether or not a sign would be seen. In the case of low visual complexity, conspicuity was not an issue. Therefore, in simple, largely uniform scenes typical of most rural highway situations, sign contrast and size largely determined the probability of detection.

The Mace research also showed that interference from complex visual background could be partly overcome by employing a sign made from more highly retroreflective and costly materials. (*2*) While the study suggested that luminance requirements for conspicuity were related to a scene's visual complexity, Mace's regression equations were not practical for use in determining the complexity of specific sign locations or the definitive levels of sign luminance required. On the other hand, the results did hold out the promise that a practical, systematic procedure might be developed to differentiate a low complexity environment where standard signing materials would be adequate from a high complexity area requiring special high reflectivity signs.

Development of Complexity Scales

As a first step in reaching this system, a practical field technique was developed for rating the complexity of a specific highway location. Such a rating system could then be employed in further field studies to determine quantitative levels for which signing material should be used there. The rating system could then be employed by traffic engineers in determining what grade of sign material to specify for a given sign location.

One approach to developing appropriate scales for rating complexity was to base them on general principles derived from the scientific literature on target detection. Another approach was to apply factor-analysis procedures to the group of 40 visual variables describing the highway scenes used earlier. (*2*)

Both of these approaches were used to develop 11 five-point scales with both theoretical and practical meaning for the initial evaluation. In one such scale, observers were asked to rate each scene on the "presence of distracting visual objects." (It was reasoned the driver would be less likely to see a sign when other "distracting" objects were in the visual scene.) The scenes were to be rated on this five-point scale ranging from scenes with very high levels of visual distraction to scenes with little or no distracting elements. (*5*)

The 11 scales were first evaluated using photographic projection of the 80 scenes from the earlier study for which sign detection probability data were already available. (*2*) Thirty-two professional employees of New Jersey Department of Transportation (NJDOT) viewed and subjectively rated each scene employing the 11 rating scales. Multiple correlations were computed and the regression equations examined. Based on this analysis, the 11 scales were reduced to the 8 scales shown in figure 1.

Site No. ________

COMPLEXITY EVALUATION FORM

1. How distracting is the scene?

very distracting	distracting	average	not very distracting	not distracting

2. How many traffic signs are in the cone?

five or more	four	three	two	one or more

3. How much detail is visible in the scene?

a great deal of detail	a lot of detail	average	little detail	very little detail

4. How many bright sources are in the scene?

very many	many	average	few	very few

5. How much detail is visible in the cone?

a great deal of detail	a lot of detail	average	little detail	very little detail

6. How bright is the cone?

very bright	bright	mixed	almost dark	uniform (dark)

7. How demanding would driving be at this location?

very demanding	demanding	average	not demanding	easy

8. To be easily spotted, how bright would a new traffic sign have to be?

very bright	bright	average	not bright	dim

Figure 1.—Complexity evaluation form.

These eight scales were then used to rate the complexity of 24 potential sign locations along a 24-mile (38.6 km) loop of roadway near Trenton, New Jersey. One group of 12 NJDOT employees rated the locations in the field, viewing each site from a point 500 ft (152 m) prior to the potential sign location. A second group of 15 NJDOT employees rated the sites based on a photographic slide presentation. The onsite rating procedure provided for more reliable ratings.

Sign Recognition and Legibility Distances

A second step in developing a procedure was to determine drivers' luminance requirements for sign recognition and legibility. For this, 19 of the same sites were used for which complexity ratings had been obtained. Three brightness levels of yellow diamond warning signs were installed alternately at each site. Each experimental subject saw only one level of sign brightness at a given site, but experienced all three levels along the route. Each test site was observed by all 15 test subjects. The subjects were divided into three groups which saw the various test sites at each of the three levels of sign brightness.

The signs were all constructed of new, enclosed lens retroreflective sheeting material. To create the lower brightness conditions, the material was artificially degraded with a silkscreened black dot pattern. The mean Specific Intensity value of the 3 sets of signs measured 65, 36, and 18 cd/fc/ft² (65, 36, and 18 cd/lx/m²) at a 0.2 degree observation angle and −4 degree entrance angle. All signs were viewed along tangent highway sections.

Employing the field-measured detection distances as the dependent variable, a forward stepwise multiple-regression analysis was run using the ratings scores for each site on the eight complexity scales. The analysis resulted in the following regression equation employing four of the eight scales:

$$Y = 2030 + 409\,x_3 + 341\,x_4 + (-543\,x_5) + (-615\,x_7) \qquad (1)$$

where: x_i is the observed value for the *ith* scale in figure 1.

This equation ($R^2 = 0.62$) could then be used to predict detection distance; this predicted score in turn would serve as a surrogate for complexity. (It was determined that the increase in validity with more than four scales was not worth the additional effort needed to collect the data.)

As shown in figures 2 and 3, both recognition and legibility distances were improved with greater sign retroreflectivity over the range tested. The visual complexity defined by the predicted complexity scores, however, had a significant effect only on recognition distance, not on legibility. This result was not unexpected since legibility depends almost entirely on the internal contrast between the sign legend and its background while recognition of an object, such as a sign, is highly dependent on the amount and type of visual information surrounding it.

To evaluate how well the measured recognition and legibility distances serve the driver's need for information, estimates of the minimum required sign recognition and legibility distances were calculated using the decision sight distance model of McGee et al., as tailored for traffic signs by Perchonok and Pollack. (*6*) and (*7*). The model includes components for detection, reading, decision making, driver response, and vehicle maneuvers. The results of the calculations are shown in table 1.

Recognition distance is defined here as the distance at which the sign must be detectable by the driver. It includes components for detection, reading, decision making, driver response and, if required, vehicular maneuvers. Legibility distance is the distance at which the driver is required to start to read the sign; it does not include any component for detection.

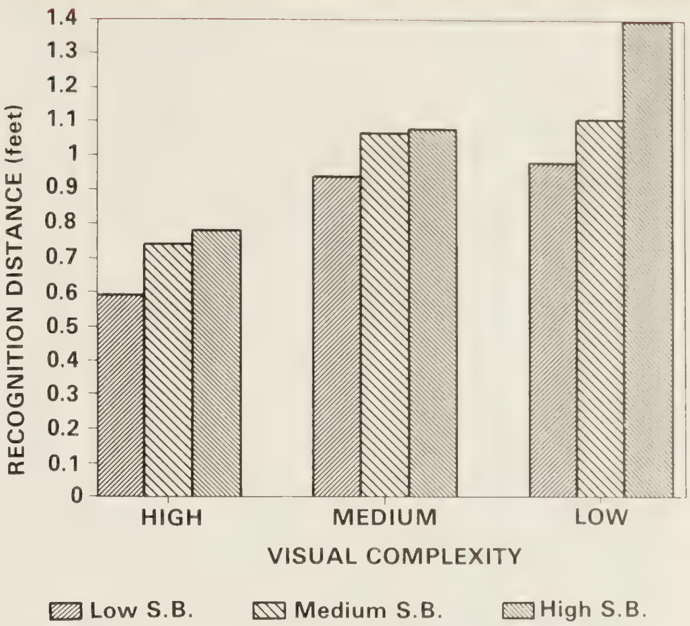

Figure 2.—Observed recognition distance by visual complexity and sign brightness.

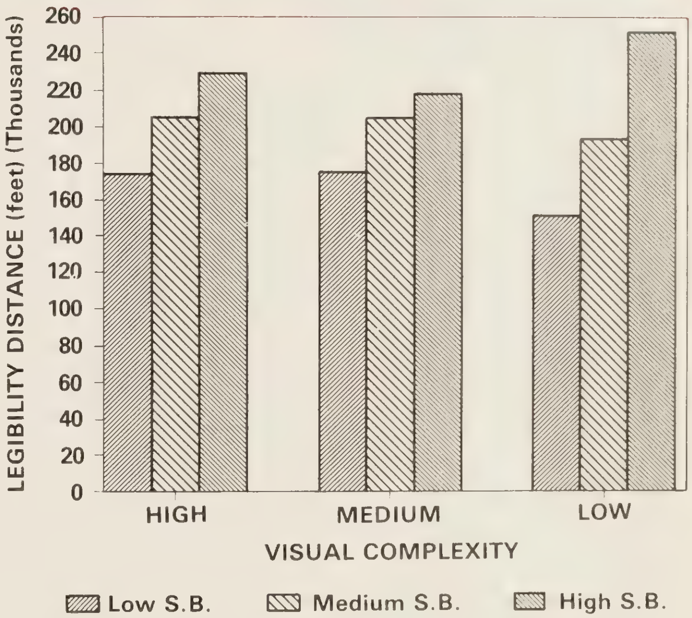

Figure 3.—Observed legibility distance by visual complexity and sign brightness.

Table 1.—Required Recognition and Legibility Distances (ft)

	Recognition Distance		Legibility Distance	
Speed (mi/h)	No Maneuver Before Sign	Maneuver Before Sign	No Maneuver Before Sign	Maneuver Before Sign
35	325	489	179	343
45	419	691	231	503
55	520	927	290	697

1 mi/h = 1.609 km/h

No maneuver cases

Yellow warning signs generally do not require the driver to have made a maneuver prior to reaching the sign itself. For example, a curve warning sign is placed before the curve's beginning, before the driver must start his or her steering manuever. The distances shown in the "no maneuver" columns are relevant for most warning signs since only detection, reading, decision, and driver response times need to be considered.

Comparing the required distances for the more typical "no manuever" case shown in table 1 with the recognition and legibility distances measured in the field reveals some areas of concern. The 520-ft (158.5 m) recognition distance required at 55 mi/h (88 km/h) can easily be met by the most degraded sign tested in low complexity situations. (table 1) However, in the higher complexity situations, the mean performance for the low brightness sign (figure 2) was barely above the required distance. Mean performance is really not adequate for safe design, since it will allow for the visual capabilities of only half the drivers; thus, the low brightness sign did not provide a sufficient safety margin for warning signs in high complexity locations. On the other hand, the medium brightness signs with a luminance level of approximately 0.25 cd/ft² (2.69 cd/m²) were adequate for all subjects.

Legibility presents even more of a problem. As with recognition, the low brightness sign failed to provide adequate legibility distance regardless of travel speed. The mean of observed legibility distance was 167 ft (50.9 m) while the minimum required legibility distance was 179 ft (54.6 m). Again, more than half of the driving population would not be satisfied. Medium and high brightness signs were adequate at 35 mi/h (56 km/h) and high brightness signs at 45 mi/h (72 km/h). None of the signs used appeared to be adequate for a 55 mi/h (88 km/h) condition. Legibility may not be quite as bad as this comparison would imply. With the 5-in (12.7 mm) letters employed on the signs in this study, the low brightness signs provided approximately 30 ft/in of letter height or 360:1 Legibility Ratio (LR), while the medium and high brightness signs provided about 40 ft/in 480:1 LR.[2] Jacobs et al., found symbolic signs typically have twice the legibility of alphabetic signs of the same size. (*8*) Because most warning signs are either symbolic or are recognized as a symbol without reading the actual words on them, a sign with 30 ft/in or 360:1 LR with alphabetic information may provide very adequate legibility distance for a symbol sign.

These data may also imply a poorer situation than exists for the case where the sign is an advance warning of a "hazardous condition" and the driver has time to react to the sign after passing it. Both of these situations may explain why traffic authorities receive fewer complaints about inadequate sign legibility than might be expected for these data.

Maneuver cases

In a few special cases, a warning sign may require the driver to complete a maneuver before reaching the sign. An example of this is a "lane ends" sign, which requires a driver to change lanes. The "maneuver" columns in table 1 would apply in these cases. Once more, there are some areas of concern. While recognition distances for most signs appear to be adequate except for the high speed conditions, legibility distances do not appear adequate if a maneuver is required. For these cases, advance warning or larger signs may be needed, especially for higher speed roads. On the other hand, the data given here is for a 30-in (762 mm) sign; typically a larger sign would be used on high speed roads.

Decision Rules for Luminance Requirements

Next, a decision rule was sought for determining the type of reflective sheeting that should be used at a particular location, and when a sign should be removed from service. The sites studied were classified by the empirically obtained recognition distances to find an effective cutoff score for determining from the predicted score whether a site was of high or low complexity. One hundred percentile recognition distances were used to provide a conservative estimate of driver's needs. At eight sites, the 100 percentile recognition distance was roughly equal to or greater than 520 ft (158.5 m) for the low brightness condition. This is the required recognition distance (table 1) when no vehicular maneuver is required prior to reaching the sign. It is also sufficient if a maneuver is required for speeds barely exceeding 35 mi/h (56 km/h), such as would be encountered on many lower level rural roads. On this basis, these eight sites were initially classified as "low complexity."

With medium and high brightness signs, four sites had 100 percentile recognition distances below 325 ft (99.1 m), the minimum required distance for the "no maneuver" situation at 35 mi/h (56 km/h). (table 1) Four additional sites failed to provide a 100 percentile recognition distance greater than that required with approach speeds to 55 mi/h (88 km/h). These eight sites were initially classified as "high complexity."

With 16 sites thus classified, a cut-off score was selected to minimize errors classifying sites based upon score predicted by equation 1 and the four rating scales it employs. Cut-off scores were conservatively selected since it is better to classify a site as high complexity, which is not truly high complexity, than to fail to classify a true high complexity site as high. Similarily, it is better to fail to classify a low complexity site than to wrongly classify one as low.

[2] 360:1 Legibility Ratio (LR) is the distance in front of a sign that the letters can be read by a driver having 20/20 visual acuity.

Field Procedure

To classify sites on visual complexity, one or two people would visit a potential sign location after dark under normal traffic conditions. From approximately 500 ft (150 m) upstream of the sign location, they would view and rate the site using each of the four scales (from equation 1) shown in figure 4 with appropriate weighting factors. To compute the predicted complexity value, the numerical values representing the appropriate site description for each scale are added if positive, and subtracted if negative. Sites with complexity values greater than 11 are low complexity; sites with complexity values less than 9.5 are high complexity.

For low complexity sites, enclosed lens material is adequate and can undergo considerable deterioration without losing its effectiveness. The data given above indicate a Specific Intensity value of 18 cd/fc/ft² (18 cd/lx/m²) provided the minimum required recognition distance of approximately 500 ft (150 m) at straightaway locations. The luminance of these signs was approximately 0.14 cd/ft² (1.51 cd/m²).

1. How much detail is visible in the scene?

Detail is anything you can see against the darkness. It includes lights and objects that the lights illuminate. Consider the entire field of view including the road, the horizon, and the area on both sides of the road. Can many objects be picked out?

Answer this question by circling the appropriate scale value:

Scale Value	Subjective Description	Scale Definition
25	A great deal of detail	80% or more of the scene has visible detail
21	A lot of detail	60 to 80% of the scene has visible detail
17	Average	40 to 60% of the scene has visible detail
13	Little detail	20 to 40% of the scene has visible detail
9	Very little detail	20% or less of the scene has visible detail (dark country road)

2. How many bright sources are in the scene?

Are there many bright spots, street lights, internally lighted signs, bright billboards, car lights, parking lot lights, lighted store windows, and bright reflections from glass and metal?

Answer this question by circling the appropriate scale value:

Scale Value	Subjective Description	Scale Definition
22.5	Very many	The scene is saturated with bright sources (many strong lights and reflectors, bright signs, bright store fronts, and car lights)
19	Many	Above average
15.5	Average	Moderate
12	Few	Some distant lights
8.5	Very few	Virtually no bright sources

3. How much detail is visible in the cone?

Are many lights and objects visible?

NOTE: Much detail may be visible in the scene, but very little in the cone. For example, a bridge approach may be lighted to the degree where you can see pavement seams. The horizon may be cluttered with lights. The cone, however, can include just a barely discernible bridge railing. Conversely, a dark country road with a lighted service station in the cone may exhibit little scene detail, but above average cone detail.

Answer this question by circling the appropriate scale value:

Scale Value	Subjective Description	Scale Definition
−22.5	A great deal of detail	80% or more of the cone has visible detail (city area with many lights and objects in the cone)
−17	A lot of detail	60 to 80% of the cone has visible detail
−11.5	Average	40 to 60% of the cone has visible detail
− 6	Little detail	20 to 40% of the cone has visible detail
− 0.5	Very little detail	20% or less of the cone has visible detail (dark country road with virtually no illumination in the cone)

4. How demanding would driving be at this location?

Drivers' ability to detect and recognize traffic signs deteriorates as the demands of driving increase. The demands increase with the number of lanes and the number of vehicles traveling in the same direction. Many pinpoint lights to the left and right of the cone also increase the demands. Pedestrians and intersections controlled by traffic signals or signs add to the difficulty.

Answer this question by circling the appropriate scale value:

Scale Value	Subjective Description	Scale Definition
−25	Very demanding	80% or more of driver's time spent looking for driving information—would not try to light cigarette in this location
−19	Demanding	70 to 80% of driver's time spent looking for driving information
−13	Average	60 to 70% of driver's time spent looking for driving information
−7	Not demanding	50 to 60% of driver's time spent looking for driving information
−1	Easy	50% or less of driver's time spent looking for driving information—no problem lighting cigarette in this location

NOTE: Cone—The "cone" is the portion of the right side of the road where one would normally look for traffic signs. It can extend from a few feet in front of the vehicle to the horizon, but when driving, most people monitor an area in the cone from 200 ft (60 m) to 600 ft (180 m) down the road. The cone may include traffic signs, advertising signs, traffic lights, street lights, and even store fronts if they are near the road.

Scene—The "scene" is everything one sees when looking at a site through the windshield of a vehicle. It includes the road, the sky, and everything within sight on both sides of the road.

Figure 4.—Visual complexity rating form.

At high complexity locations, signs with new enclosed lens material had recognition distances that in many cases were less than the drivers' needed recognition distances. The results of this study suggest that materials with high levels of retroreflectivity (i.e., encapsulated or prismatic), larger signs, or advanced warning signs may be needed at these locations—particularly where speeds are high or where extensive maneuvers, such as, lane changes or large speed reductions, are needed.

Locations where the complexity score has a value between 9.5 and 11 should be examined closely. If the prevailing speed is low or the sign does not require a maneuver, then enclosed lens material is adequate, but it should not be allowed to degrade to the same level as a low complexity site. If the speeds are high or a major maneuver is required of the driver, the site should be treated as a high complexity site.

Successful site evaluation is simply a matter of asking the question associated with each of the four scales in figure 4, and answering them systematically based on observations. Each scale should be considered independently and a preceding question should not influence the response on the next scale. After a rating is made on each scale, the value to the left of the appropriate description should be circled and the values added together to reach the overall complexity rating. Figure 5 shows an example of two scenes with their corresponding scale values.

Scene 21

	Scale 1	Scale 2	Scale 3	Scale 4	Complexity Value
Value	21	19	– 17	– 13	10

Scene 15

	Scale 1	Scale 2	Scale 3	Scale 4	Complexity Value
Value	17	19	– 11.5	– 13	11.5

Figure 5.—Example of complexity scaling.

Conclusions

The method described above allows for simple field determination of a potential location's complexity for installing a warning sign. Most sign locations will be easily classified and will usually fall into the low complexity group. At low complexity sites, enclosed lens retroreflective sheeting gives adequate recognition performance well in excess of the predicted driver requirements of the decision sight distance model. The study has further demonstrated that at low complexity sites, signs can undergo considerable deterioriation without losing their effectiveness.

At high complexity locations, however, signs with new enclosed lens material often were not adequate to meet the predicted needs of the driver for recognition distance. This suggests that materials with higher specific intensities, larger than normal size signs, or advance warning signs be employed at these locations.

The above conclusions apply to yellow warning signs and are based on a small sample of observations. The observers used in the study probably do not represent the full range of visual capabilities in the driving population. Full research will determine how these cut-off scores would need to be adjusted to account for all drivers' needs. Despite these caveats, however, these preliminary guidelines should provide a reasonable method for selecting alternative materials.

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(*2*) D.J. Mace, K. Perchonok, and L. Pollack, "Traffic Signs in Complex Visual Environments," Report No. FHWA/RD-82/102 *Federal Highway Administration*, *U.S. Department of Transportation*, Washington, DC, November 1982, (NTIS PB No. 83 248914).

(*3*) *"Manual on Uniform Traffic Control Devices for Streets and Highways," U.S. Government Printing Office*, Washington, DC, 1978.

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(*6*) H.W. McGee, W. Moore, B.G. Knapp, and J.H. Sanders, "Decision Sight Distance for Highway Design and Traffic Control Requirements," Report No. FHWA-RD-78-78, *Federal Highway Administration*, *U.S. Department of Transportation,* Washington, DC, February 1978, (NTIS, PB No. 288748/AS).

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(*8*) R.J. Jacobs, A.W. Johnston, and B.L. Cole, "The Visibility of Alphabetic and Symbolic Traffic Signs," *Australian Road Research*, Vol. 5, No. 7, 1975, pp. 68-86.

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Douglas J. Mace is a senior research scientist with the Environmental Research Institute of Michigan (ERIM). He began his career in highway research in 1967 directing a study of driver information requirements at freeway interchanges. Before joining ERIM, he was a senior research scientist at IFR Applications, Inc., in State College, Pennsylvania, where he served as principal investigator of the study from which the material for this article is drawn. Mr. Mace has served as principal investigator on a series of FHWA-sponsored studies related to sign luminance, conspicuity, and visual complexity of highway scenes.

Recent Research Reports You Should Know About

The following are brief descriptions of selected reports recently published by the Federal Highway Administration, Offices of Research, Development, and Technology (RD&T). The Office of Engineering and Highway Operations Research and Development (R&D) includes the Structures Division, Pavements Division, and Materials Division. The Office of Safety and Traffic Operations R&D includes the Traffic Systems Division, Safety Design Division, and Traffic Safety Research Division. All reports are available from the National Technical Information Service (NTIS). In some cases limited copies of reports are available from the RD&T Report Center.

When ordering from the National Technical Information Service, use PB number and/or the report number with the report title, and address requests to:

National Technical Information Service
5285 Port Royal Road
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Requests for items available from the RD&T Report Center should be addressed to:

Federal Highway Administration
RD&T Report Center, HNR-11
6300 Georgetown Pike
McLean, Virginia 22101-2296
Telephone: (703) 285-2144

Bridge Rail Retrofit for Curved Structures, Report No. FHWA/RD-85/040

by Safety Design Division

This report presents the results of research conducted to evaluate the performance of barrier configurations mounted on a curved, superelevated structure with a downgrade alignment. Overall performance of the barriers was evaluated in relation to their vertical and perpendicular placement on the curved alignment.

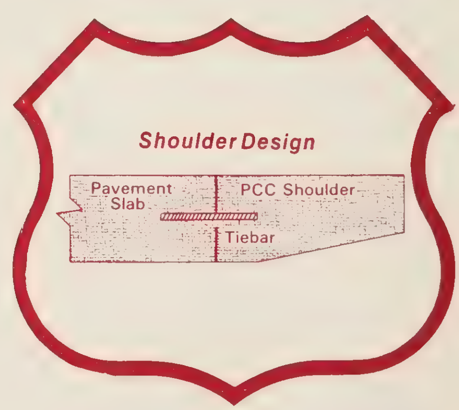
Three bridge rail systems using three vehicle types for comparison were evaluated by crash test. Concrete safety shape barriers were installed at vertical and perpendicular positions to the superelevation, and a tubular thrie-beam system was evaluated. Test vehicles included an 1800-lb (820 kg) class mini-compact car, a 2250-lb (1020 kg) class subcompact car, and a 20,000-lb (9070 kg) school bus. Impact conditions for all tests were 40 mi/h (64 km/h) at a 15-degree angle (as measured at the curve tangent). All barrier systems performed successfully for the full range of vehicles. Vehicle mass properties and geometries were measured for a 40,000-lb (18,140 kg) intercity bus, two 20,000-lb (9070 kg) school buses, and a 2250-lb (1020 kg) subcompact car. This report also includes the evaluation of front corner vehicle crush properties for a school bus and a subcompact car.

Limited copies of the report are available from the RD&T Report Center.

Structural design of Roadway Shoulders, Executive Summary, Report No. FHWA/RD-86/088, and Final Report, No. FHWA/RD-86/089.

by Pavements Division

These reports discuss a method to design the thickness of roadway shoulders, based on mechanical principles of stress/strain analysis. Both flexible and rigid shoulders can be designed by this method. All combinations are posssible, including the use of a widened rigid mainline lane with a flexible shoulder. The inner and outer edges are designed using fatigue distress functions and stress/strains resulting from encroached and parked vehicles.



The design method includes an interactive microcomputer program to evaluate the expected life of trial design sections. A mainframe version of this program also is provied for batch processing. The reports also cover methods for drainage design as well as methods to evaluate the adequacy of the proposed design.

The reports may be purchased from NTIS (PB Nos. 86 206638/AS, Price code: A02, and 86 206646/AS, Price code: A10).

Assessment of Existing Data Bases for Highway Safety Analysis, Report No. FHWA/RD-85/117

by Traffic Safety Research Division

This report assesses the utility of existing data bases for highway safety analysis. The Fatal Accident Reporting System (FARS), Highway Performance Monitoring System (HPMS), National Accident Sampling System (NASS), State accident data bases, and three special purpose data bases were reviewed in this effort.

The study recommended a National Safety Information System be created from four or five individual States already possessing the ability to merge accident, highway inventory, and traffic data regularly collected by the States.

This report may be purchased from NTIS (PB No. 86 187226/AS, Price code: A04).

Development of a Methodology for Estimating Embankment Damage Due to Flood Overtopping, Report No. FHWA/RD-86/126

by Structures Division

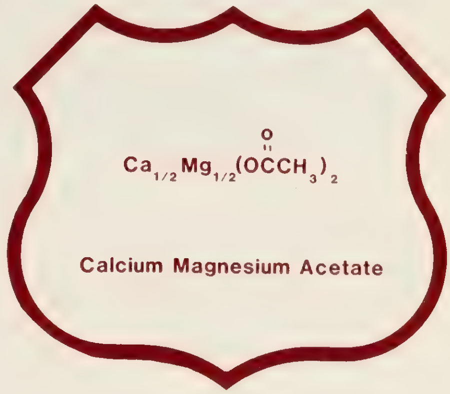
This report describes a series of large-scale hydraulic model experiments to simulate floods overtopping highway embankments. Laboratory tests were conducted to develop a methodology for quantitatively determining embankment damage and assessing protective measures.

The embankments used in this study are 6 ft (1.8 m) high, 10 to 22 ft (3.0 to 6.7 m) in crest width, and 3 ft (0.9 m) in length, with slope varying from 2:1 to 3:1. The embankment surfaces are constructed both with and without protective measures such as pavement, grass, mattresses, Geoweb, soil cement, Enkamat, and other methods. The flood overtopping depths ranged from 0.5 to 4 ft (0.15 to 1.22 m), discharges ranging from 1 to 25 cfs/ft (0.1 to 2.32 cms/m), and tailwater conditions ranging from 10 percent water-surface drop to free fall. A computer model was developed to determine hydraulics of overtopping flow and associated erosion damage. This model was verified using field data and laboratory test results, and was utilized to generate charts for estimating embankment damage.

The research conducted during this study was co-sponsored by the U.S. Department of Agriculture Forest Service.

Limited copies of the report are available from the RD&T Report Center.

Ice-Melting Characteristics of Calcium Magnesium Acetate, Executive Summary, Report No. FHWA/RD-86/180, and Final Report, Report No. FHWA/RD-86/005



by Materials Division

This study was conducted to determine the pertinent properties of Calcium Magnesium Acetate (CMA) and to determine the pH and ratio of calcium to magnesium that provide optimum road deicing characteristics.

Tests conducted include solubility at three temperatures, deicing rate, heat of solution, effects on portland cement concrete (PCC), eutectic temperature, and stability of the CMA material. The optimal CMA product determined had a calcium/magnesium ratio of 3:7 and did not damage PCC. This product in solution had the lowest eutectic point and the fastest deicing rate of all CMA solutions tested. Using these results the compositions and properties of the optimum CMA deicer were obtained.

Limited copies of the Executive Summary are available from the RD&T Report Center. It may also be purchased from NTIS (PB No. 87 122123, Price code: A02). The Final Report may be purchased from NTIS (PB No. 86 142742/AS, Price code: A04).

New Directions for Learning About Safety Effectiveness, Report No. FHWA/RD-86/015

by Traffic Safety Research Division

This study raised some basic issues concerning the evaluation of highway safety measures. An empirical Bayesian statistical technique is proposed for avoiding many of the pitfalls of before/after evaluations, which potentially yield inflated estimates of safety measure effectiveness. The technique is demonstrated by several examples. Also, a formal means is proposed for preserving and combining information from various individual studies, which taken separately may have little statistical significance, but which yield significant information when combined. In addition, new ideas are explored using several case studies to determine the value of proposed research.

The report may be purchased from NTIS (PB No. 86 180759/AS, Price code: A04).

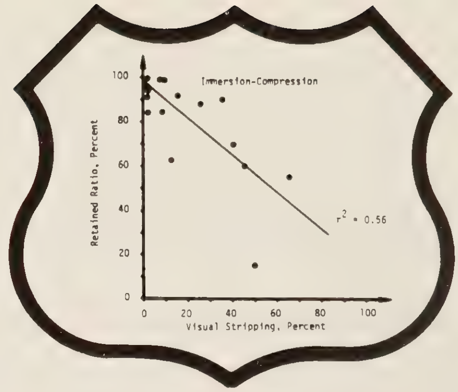
Driver Response to Active Advance Warning Signs at High-Speed Signalized Intersections, Report No. FHWA/RD-86/130

by Traffic Safety Research Division

A variety of active advance warning signal devices were compared and evaluated by 60 test subjects. Flashing beacons with six different advance warning times were used. Some displayed words while others used symbols of warning. Location of mounting also was tested. Drivers gave their preferences in interviews following the tests.

During the tests, subjects were measured for reaction time to the devices, distance of identification, vehicle speed, and vehicle lateral placement measured on the FHWA highway driving simulator (HYSIM). The test results showed that the symbolic flashing beacon was preferred by most drivers and had the greatest identification distance of all signals tested. No difference was found between ground-mounted vs overhead signs. All of the active warning signs were found to be superior to passive warning signs.

The report may be purchased from NTIS (PB No. 86 209103/AS, Price code: A05).



Evaluation of Procedures Used to Predict Moisture Damage in Asphalt Mixtures, Executive Summary, Report No. FHWA/RD-86/090 and Final Report, Report No. FHWA/RD-86/091

by Pavements Division

A comparison of procedures used to evaluate the moisture susceptibility of asphalt mixtures was performed and the most effective methods were selected. The various tests were done on mixtures having a known history of susceptibility. The data included the retained ratios, visual stripping, mechanical values (tensile strength, stability, etc.), saturation, and swell.

The most promising procedures appeared to be the NCHRP 246 and NCHRP 247. Several tests proved to be ineffective in predicting moisture susceptibility. A freezing period, or higher air void levels, proved to be beneficial in this evaluation. The degree of saturation, while an important factor, was found to be secondary, affecting moisture damage.

Limited copies of the Executive Summary are available from the RD&T Report Center, NTIS (PB No. 87 165312/AS, Price code: A03). The Final Report may be purchased from NTIS (PB No. 87 154514/AS, Price code: A06).

Implementation/User Items "how-to-do-it"

The following are brief descriptions of selected items that have been completed recently by State and Federal highway units in cooperation with the Office of Implementation, Offices of Research, Development, and Technology (RD&T), Federal Highway Administration. Some items by others are included when the items are of special interest to highway agencies. All reports are available from the National Technical Information Service (NTIS).

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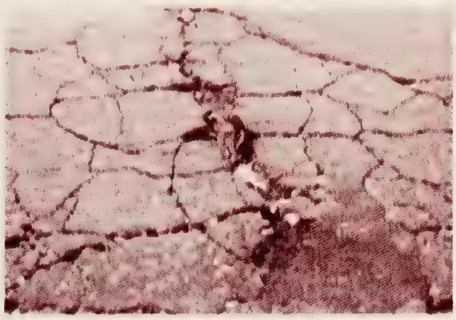


Guidelines for Spring Highway Use Restrictions, Report No. FHWA-TS-87-209

by Office of Implementation

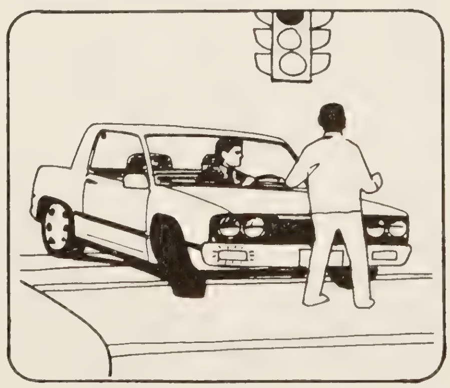
This report is a supplement to the video presentation "Guidelines for Spring Highway Use Restrictions." Air temperature based criteria (thawing index) were developed which can be used to estimate when to apply and remove load restrictions. This supplement provides guidelines for where to apply load restrictions, and the amount of the load restrictions to apply. Example calculations and a blank data collection sheet also are included.

Limited copies of the report are available from the RD&T Report Center. Copies of the videotape are available on loan from the RD&T Report Center.

Methods of Increasing Pedestrian Safety at Right-Turn-On-Red Intersections Users Manual, Report No. FHWA-IP-86-10

by Office of implementation

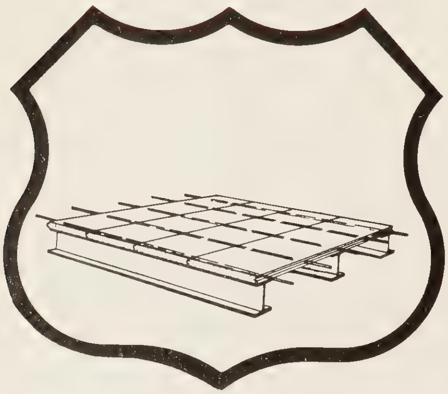
This report gives the results of a study to determine current motorist compliance to Right-Turn-On-Red (RTOR) regulations, develop and field test countermeasures for RTOR pedestrian accidents, and develop improved warrants and guidelines for prohibition of RTOR. Based on conflict and violation data from several cities, 30 countermeasures were developed as possible remedies for RTOR pedestrian accidents. Seven of these were field tested including pavement markers and electronic signs. Several promising applications of the devices were recommended. A critique was made of current MUTCD guidelines for RTOR prohibitions and improvements to them were recommended based on analysis of intersection conflicts.



This users manual provides guidance to highway agency officials on techniques to improve pedestrian and motorist safety with respect to RTOR.

The manual may be purchased from NTIS (PB No. 86 180767/AS, Price code: A05).

Precast Concrete Modular Bridge Deck Case Studies, Report No. FHWA-TS-85-232



by Office of Implementation

Among the most acute problems in highway construction today is the rehabilitation of deteriorated bridge decks. Deck deterioration has been attributed to poor construction quality control and the use of deicing salts during the winter months. Conventional cast-in-place bridge deck rehabilitation often results in severe disruption of traffic due to extensive forming and curing time. Full-depth precast concrete modular bridge deck panels have recently been given considerable attention as an alternative method of deck rehabilitation and replacement. Modular deck panels significantly improve the quality control of concrete, reduce total construction time, and allow minimal disruption of traffic.

The report contains an in-depth review and literature search of past and current practices on the use of full-depth precast concrete modular bridge deck panels at six representative bridge sites. The report also contains information of the design, construction, performance, and cost of precast panels.

The report may be purchased from NTIS (PB No. 86 182102/AS, Price code: A08).

The Development and Application of Priority Accessible Networks for Elderly and Handicapped Pedestrians, Report No. FHWA-TS-86-210

by Office of Implementation

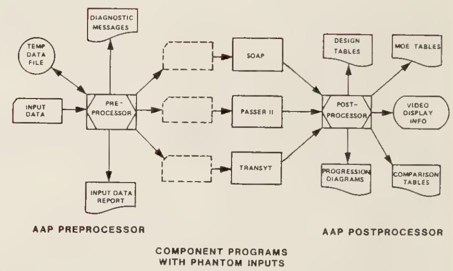
The need for improvements in accessibility for the elderly and handicapped pedestrian is a problem that has been addressed in many cities and communities throughout the United States.

This report describes the process for developing a "Priority Accessible Network" (PAN) to serve elderly and handicapped pedestrians. The PAN concept involves developing a fully accessible pedestrian environment by connecting a series of accessible routes into one continuous system in a programmed manner according to priorities identified in a plan. It provides the results and findings from field tests in the cities of Baltimore, New Orleans, and Seattle.

The report will be of interest to city planners, traffic engineers, pedestrian safety program managers, and others concerned over the mobility of handicapped persons.

The report may be purchased from NTIS (PB No. 86 195898/AS, Price code: A03).

Arterial Analysis Package Users Manual, Report No. FHWA-IP-86-1



by Office of Implementation

The Arterial Analysis Package (AAP) is a tool for timing traffic signals in arterial street systems. Proper timing of traffic signals can significantly affect traffic flow, fuel consumption, vehicle emissions, and user and vehicle operating costs. The AAP provides easy access to three of the most popular and trusted signal timing programs using one simple data input scheme.

The users manual deals primarily with the mainframe version of AAP, which accommodates all intersection approaches for up to 48 contiguous time periods. A more limited microcomputer version is discussed in the appended material.

Copies of the manual and the accompanying microcomputer software may be purchased from the McTrans Center, University of Florida, 512 Weil Hall, Gainesville, Florida 32611. Telephone: (904) 392-0378

Bored Piles (English Translation of French Publication, LES PIEUX FORES), Report No. FHWA-TS-86-206

by Office of Implementation

This report was prepared in conjunction with a National Highway Institute training course "Drilled Shaft Foundations," currently being developed by the Office of Implementation. The report is an English translation of a French publication, "Les Pieux Fores," in which the construction, inspection, and testing of bored piles (drilled shafts, drilled piers, caissons) as practiced by government agencies in France are discussed in detail. Topics included in this report are contracting, methods of making the excavation, casings and liners, rebar cages, tests for completed shafts, and methods of repair of defective shafts. It will be used as a reference for the drilled foundation courses.

This report will be of interest to geotechnical, structural, and construction engineers involved in design and construction of drilled shaft foundations.

The report may be purchased from NTIS (PB No. 87 164794, Price code: A17).

Railroad-Highway Crossing Resource Allocation Procedure—Users Guide, Second Edition, Report No. FHWA-IP-86-11

by Office of Implementation

The Highway Safety Acts of 1973 and 1976 and the Surface Transportation Acts of 1978 and 1982 provide funding authorizations for individual States to improve safety at public rail-highway crossings. Safety improvements frequently consist of the installation of active motorist warning devices such as flashing lights or flashing lights with gates. To assist States and railroads in determining effective allocation of Federal funds for rail-highway crossing improvements, the U.S. Department of Transportation has developed the DOT Rail-Highway Crossing Resource Allocation Procedure. The procedure consists of the DOT accident and casualty prediction formula, which predicts the number of casualties and accidents at crossings, and the resource allocation mode, which nominates crossings for improvement on a cost-effective basis and recommends the type of warning device to be installed. This guide, jointly sponsored by the Federal Highway Administration and the Federal Railroad Administration, provides interested users with complete information for application of the DOT Rail-Highway Crossing Allocation Procedure.

The second edition of the guide incorporates results of recent research including a casualty prediction formula, extended data on warning device effectiveness, and consideration of standard highway stop signs as a warning device option under certain conditions.

The guide may be purchased from NTIS (PB No. 87 137535/AS, Price code: A08).

New Research in Progress

The following new research studies reported by FHWA's Office of Research, Development, and Technology are sponsored in whole or in part with Federal highway funds. For further details on a particular study, please note the kind of study at the end of each description and contact the following: Staff and administrative contract research—*Public Roads* magazine; Highway Planning and Research (HP&R)—performing State highway or transportation department; National Cooperative Highway Research Program (NCHRP)—Program Director, National Cooperative Highway Research Program, Transporation Research Board, 2101 Constitution Avenue, NW., Washington, DC 20418.

NCP Category A—Highway Safety

NCP Program A.4: Special Highway Users

Title: Designated Highway System Truck Operations Study—Phase II. (NCP No. 4A4A3112)
Objective: Design and/or redesign the criteria for a typical intersection on the designated truck network. Recommend any appropriate changes in standards to the Federal Highway Administration (FHWA), Transportation Research Board (TRB), and the American Association of State Highway and Transportation Officials (AASHTO). Develop software, nomographs, etc. for intersection design.
Performing Organization: University of Wisconsin, Madison, WI 53707
Funding Agency: Wisconsin Department of Transportation
Expected Completion Date: September 1988
Estimated Cost: $69,000 (HP&R)

NCP Program A.9: Technology Transfer for Highway Safety

Title: Planning and Scheduling Work Zone Traffic Control. (NCP No. 3A9A0083)
Objective: Increase effectiveness of traffic control measures to reduce accidents in temporary construction or maintenance zones. Prevent accidents and reduce congestion on highways that are under construction.
Performing Organization: Applied Resources, Inc., Vienna, VA 22180
Expected Completion Date: April 1991
Estimated Cost: $216,000 (FHWA Administrative Contract)

NCP Category B—Traffic Operations

NCP Program B.2: Traffic Analysis and Operational Design Aids

Title: Progression Through a Series of Intersections With Traffic Actuated Controllers. (NCP No. 3B2A1012)
Objective: Develop methods of timing coordinated signal systems which include vehicle-actuated controllers. Develop and evaluate new techniques to accommodate vehicle progression while allowing for allocation of green time at individual intersections based on local measured vehicle demand. Using NETSIM, evaluate performance of existing control strategies in networks consisting of coordinated, vehicle-actuated signals over a range of volume conditions. Propose new methods and control strategies based on evaluations of same networks and volume conditions.

Performing Organization: Deakin, Harvey, Skabardonis; Berkeley, CA 94708
Expected Completion Date: September 1988
Estimated Cost: $107,000 (FHWA Administrative Contract)

Title: Traffic Assignment Analysis of Arterial Intersections—St. Charles Case Study. (NCP No. 4B2B1092)
Objective: The objective of this study is to develop improved travel time functions for use in equilibrium assignment models and apply the results to a study of the St. Charles Route 64 bypass arterial.
Performing Organization: University of Illinois, Urbana, IL 61801
Funding Agency: Illinois Department of Transportation
Expected Completion Date: March 1988
Estimated Cost: $59,000 (HP&R)

Title: Levels of Service in Shared/Permissive Lanes. (NCP No. 3B2C1013)
Objective: Determine delay for vehicles approaching intersection in lanes from which both left turns and through movements are permitted. Examine how vehicles distribute themselves among lanes when one of the lanes is shared with permissive left turns, and examine the exact ways in which through vehicles are delayed in such situations. Examine functions of volume in lane, opposing volume, intersection geometrics, and geographical location.
Performing Organization: Polytechnic Institute of New York, Brooklyn, NY 11201
Expected Completion Date: September 1989
Estimated Cost: $265,000 (FHWA Administrative Contract)

NCP Program B.9: Technology Transfer for Traffic Operations

Title: Self-Powered Vehicle Detector—Test and Evaluation. (NCP No. 3B9A0043)
Objective: Design, test, and develop a self-powered vehicle detector (SPVD) system using commercially available hardware and materials.
Performing Organization: Joslyn Defense Systems, Inc., Shelburne, VT 05482
Expected Completion Date: May 1990
Estimated Cost: $298,000 (FHWA Administrative Contract)

NCP Category D—Structures

NCP Program D.1: Design

Title: Use of Adhesives to Replace Welded Connections in Bridges—Phase II. (NCP No. 3D1C3022)
Objective: Conduct laboratory studies to further characterize the properties of existing structural adhesives. Test adhesives on steel-to-steel bonds similar to actual bridge connections after the joint has equilibrated with the environment. Determine the essential properties of a structural adhesive for bridges and develop test methods and specifications. Solicit industry support to develop adhesive chemistries having the required properties.
Performing Organization: Materials Research Laboratory, Inc., Glenwood, IL 60425
Expected Completion Date: May 1990
Estimated Cost: $300,000 (FHWA Administrative Contract)

Title: The Design and Construction of Small Bridges and Culverts Using Controlled Low Strength Materials (CLSM). (NCP No. 4D1D1082)
Objective: Evaluate the use of controlled low strength materials (CLSM) for backfill and bedding materials and develop a load-factor curve. Reduce the minimum cover required. Reduce foundation requirements on metal pipe arches.
Performing Organization: Ohio Northern University, Ada, OH 45810
Funding Agency: Ohio Department of Transportation
Expected Completion Date: September 1988
Estimated Cost: $86,000 (HP&R)

Title: Field Testing of a Steel Bridge and a Prestressed Concrete Bridge. (NCP No. 4D1A3152)
Objective: Conduct parallel experimental and analytical studies of the structural response of a seven-span continuous steel stringer bridge and a nine-span prestressed concrete I-beam stringer bridge. Measure stresses and strains for these bridges in Phase I, and analytically calculate stresses in Phase II. Use five finite-element method computer programs. Determine load distribution, bridge response and the relative precision of "Bridge System," "Strudl-2," "Descus," "Curvbrg," and "Stress."
Performing Organization: Lehigh University, Bethlehem, PA 18015 and Modjeski and Masters; Harrisburg, PA 17105
Funding Agency: Pennsylvania Department of Transportation
Expected Completion Date: February 1990
Estimated Cost: $300,000 (HP&R)

Title: Cross Frame Analysis and Design. (NCP No. 4D1A3122)
Objective: Determine the effects of cross frame stiffness and spacing, bridge skew, and radius of curvature, upon forces in cross frames, beam displacements, load distribution, stress at connections, and distribution of support reactions, using a finite-element analysis. Analyze four existing bridges (one straight, one curved, two kinked). Fit two bridges with strain gauges on the cross frames to confirm analysis. Change the cross frame stiffness, spacing, and bridge skews and reanalyze. Formulate cross-frame design guidelines.
Performing Organization: Bishara Engineering, Columbus, OH 43220
Funding Agency: Ohio Department of Transportation
Expected Completion Date: April 1989
Estimated Cost: $90,000 (HP&R)

NCP Program D.9: Technology Transfer for Structures

Title: Guidelines for Developing Inspection Manuals for Segmental Concrete Bridges. (NCP No. 3D9B0063)
Objective: Prepare a comprehensive guide for developing inspection manuals for segmental concrete bridges to be used by the States in formulating their own inspection manuals. Provide uniformity in inspection procedures and allow flexibility in addressing unique features of each bridge.
Performing Organization: Tony Gee and Quandrel, Pottsville, PA 17901
Expected Completion Date: July 1988
Estimated Cost: $75,000 (FHWA Administrative Contract)

NCP Category E—Materials and Operations

NCP Program E.3: Geotechnology

Title: Design Aids for Pile Foundations. (NCP No. 3E3A0162)
Objective: Review existing data bases and available load test data to compile subsets of load tests which include load transfer measurements, and sufficient site data for detailed static and dynamic analyses. Develop correlations among pile type and geometry, soils properties, pile installation, and pile behavior. Design and conduct load tests addressing specific needs as arise. Store all data for easy access by State personnel. Develop design aids (e.g., charts, nomographs, etc.) based on materials properties, geometry and structure performance.
Performing Organization: GEO/Resource Consultants, Inc., San Francisco, CA 94107; and Earth Engineering Sciences, Baltimore, MD 21225
Expected Completion Date: March 1990
Estimated Cost: $500,000 (FHWA Administrative Contract)

NCP Program E.8: Construction Control and Management

Title: Establishing Contract Duration Based on Production Rates (NCP No. 4E8C2082)
Objective: Prepare an updated, improved production rate list for engineers to use for accurately establishing contract time estimates for projects.
Performing Organization: University of Florida, Gainesville, FL 32611
Funding Agency: Florida Department of Transportation
Expected Completion Date: May 1988
Estimated Cost: $66,000 (HP&R)

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RD&T Outstanding Accomplishment Award Presented

Mr. John C. Fegan received the 1986 award for the annual outstanding technical accomplishment competition held among the employees of Office of Research, Development, and Technology, Federal Highway Administration (FHWA). The award covers the documentation of any technical accomplishment, which may be a publication, technical paper, report, film, or package; an innovative engineering concept; an instrumentation system; test procedure; new specifications; mathematical model; or unique computer program. Each eligible candidate is judged on excellence, creativity, and contribution to the highway community, general public, and the FHWA.

Mr. Fegan, a research psychologist in the Safety Design Division of the Office of Safety and Traffic Operations Research and Development, received the award for his slide-tape program "Safety Steps for Pedestrians." The program was designed to increase awareness of pedestrian safety among older adults in the United States. It consists of a 15-minute audiotape, eighty slides, and a program guide. The program is available on loan from the American Association of Retired Persons, Program Scheduling Office, 1909 K Street, NW., Washington, DC 20049.

Mr. D.K. Phillips presents Mr. K.D. Stuart a letter noting his honorable mention in the award competition, as Mr. T.J. Pasko, Jr., Acting Director of the Office of Engineering and Highway Operations R&D, looks on.

Mr. D.K. Phillips, Associate Administrator for Research, Development and Technology, presents Mr. J.C. Fegan with the 1986 RD&T Outstanding Technical Achievement Award as Mr. S.R. Byington, Director of the Office of Safety and Traffic Operations R&D, looks on.

Mr. Kevin D. Stuart, a research highway engineer in the Pavements Division of the Office of Engineering and Highway Operations Research and Development, received honorable mention for his research report "Evaluation of Procedures Used to Predict Moisture Damage in Asphalt Mixtures." The reports, which consist of an executive summary (FHWA/RD-86/090) and a final report (FHWA/RD-86/091), discuss the tests that were used to measure the susceptibility of asphalt mixtures to moisture damage, and how the results of each test compared with each other and to field performance. The report may be purchased from the National Technical Information Service (PB No. 87 165312/AS and PB No. 87 154514/AS).

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