Unified Reflective Sign, Pavement And Delineation Treatments for Night Traffic Guidance

JOSEPH T. FITZPATRICK, Manager, Technical Service, Reflective Products Division, Minnesota Mining & Manufacturing Company, St. Paul

Consideration of the perception factor in night visibility has led to the joint evaluation of a recognized guidance concept and new reflective materials recently installed at a typical interchange. The retro-reflective treatment was specifically designed to distinguish by color, brightness, and position the location and design of exit and merging ramps.

High intensity delineation was used for distant identification. For close approach, paved ramp surfaces were reflectorized for 200-300 ft. Yellow delineation and road surfaces for merging zones formed an integrated system denoting the required caution. For maximum contrast with its complement, and based on airfield practice for off-ramp guidance, a similar system in blue was used for exit areas and pertinent destination signs. Silver through lane delineation was retained with standard green guide signs.

To provide adequate differential between green and blue signs, a distinctive blue sheeting was employed. Color and brightness requirements also established criteria for delineation and reflective road treatments. With upper beams, the reflective blue roadway initially provides 6 foot-lamberts luminance at 200 ft, the yellow, 40 ft-l compared to the untreated pavement returning 0.08 ft-l.

The substantial increase in road surface luminance offers markedly improved contrast over the surround in both color and brightness. Integrated, color-keyed reflective systems thus afforded, suggest a method for effectively providing the motorist's visual cue and guidance needs night and day.

● CONSIDERABLE PROGRESS has been realized in those fields of night visibility related to the visual function and to effective design and use of vehicle lighting, roadway illumination and reflectorization. Substantial improvements in roadway visibility have resulted, in many cases with corresponding and demonstrable improvement in night driving characteristics and safety. However, the ultimate objective of increased perception and safety proportional to the visibility improvement encourages continued research, both for further improvement of visibility aids and their effectiveness.

The 1957 Symposium sponsored by the Armed Forces-NRC Committee on Vision directed attention to many of the pertinent visual problems. Among these was the suggestion that a substantial difference exists between what the driver should see and what he does see. Seeing while driving was defined by Brody as "selective directional seeing in a multivisual environment." Others suggested improvement in presentation of essential information to the motorist. Additional visual problems ascribed to night driving conditions included limited perceptual performance at mesopic levels of luminance, and visual disability or discomfort.

As an aid to selective and effective seeing, reflective materials have long been used on signs, delineators and road markings. Research in this field has increasingly concentrated on brightness, design and application possibilities. The consideration of additional color and shape coding in signs and markings — recommended by the Armed Forces-NRC Committee — has encouraged more research as have a number of related military and industrial applications. As a result, recent technological developments have led to more versatile reflective materials including pavement markings exhibiting notably increased brightness and color utility, a correlate inasmuch as adequate color discrimination at mesopic levels and highway viewing distances requires either substantial luminance or areas.

To test these materials under typical field conditions, a cloverleaf interchange at the intersection of US 61 and Minnesota 36 was selected with the assistance and cooperation of the Minnesota Highway Department for an experimental installation and study. The complexity of the driving task at such locations has been reported by Forbes and Katz together with the need for increased warning distance, visibility, attention value and, particularly, choice limitation. Simple 2-choice channels afford least difficulty, provided sufficient conspicuity to insure early perception particularly after nightfall.

Accordingly, the reflective treatment at the test interchange was designed to clearly distinguish significant features of interchange design; namely, signs and markings, destination, precise location and design of ramps, speed change and through lanes. In view of the common purpose of related signs, speed change lanes and ramps, and to exclude possible confusion from invariable use of similar colored delineation and marking systems, the significant characteristics were further distinguished by color.

Consistent with the established use of yellow to denote caution, yellow reflective materials were employed at on-ramp and merging zones. The traveled surface of on-ramp terminal ends and adjoining speed change lanes were coated with a yellow reflective treatment consisting principally of minute reflective particles and associated binder applied by conventional pavement marking equipment and techniques. For maximum contrast with silver delineators customarily employed on through lanes and tangents, 50 cp/ft-c triple, yellow-amber delineators (dominant wave length 595m μ) were used on both sides of ramp and alongside the acceleration lane. Delineation and color treated surface of the acceleration lane was visible to through as well as on-ramp traffic.

Deceleration lanes and exit ramps together with relevant signs were similarly identified, using color to establish a relationship between signs, delineation, and roadway, thus simplifying the perceptual task. Search for a distinctive color not presently assigned other traffic control functions led to use of blue which has the additional advantage of providing maximum contrast with the complementary yellow of entrance locations. Required use of blue lighting and reflectorization for airfield taxiway and off-ramp guidance offers an analogous experience which, with similar experimental highway guidance applications elsewhere, suggests the use of blue in bifurcation treatment.

Application of the various reflective components incorporated into the cloverleaf interchange system is shown in Figure 1. Blue pavement areas represent reflectorized sections of exit roadway, paralleled by triple, blue delineators along ramps and deceleration lanes with blue guide signs pertaining to the adjacent exit. Yellow pavement areas represent reflectorized sections of entrance or merging roadways, paralleled by yellow delineation along ramps, acceleration lanes, and the right edge of the through highway preceding merging zones. Adjacent yellow signs are customary standard warning series. The remainder of through lane delineation was accomplished with conventional silver materials and traffic guidance, with standard green signs.

Interchange guidance information therefore is first presented to the approaching, north-bound motorist on conventional, green, 2-mi and 1-mi advance guide signs. Confirmation is subsequently provided by the color treatment as blue signs and delineation corresponding to the east-bound deceleration lane first appear, followed closely by the blue pavement treatment on approach areas, ramp surface and continuing with ramp delineation. Indication of merging lanes and identification of exit ramps to the north is similarly achieved by the distinction apparent between conventional through route markings, yellow at entrance points, and blue at exits. In the experimental Minnesota application, this treatment was installed on US 61 and the four appendant ramps at intersection with Minnesota 36 for the north-bound direction of travel. Abbreviated speed change lanes at this older interchange were sufficiently long to permit up to 150 ft of taper for test purposes. Roadway reflectorization covered these lanes and extended 200 ft up leg ramps from the nose, 150 ft for loop ramps. Conventinal 200-ft delineator spacing was used for the approach but decreased within the interchange to emphasize

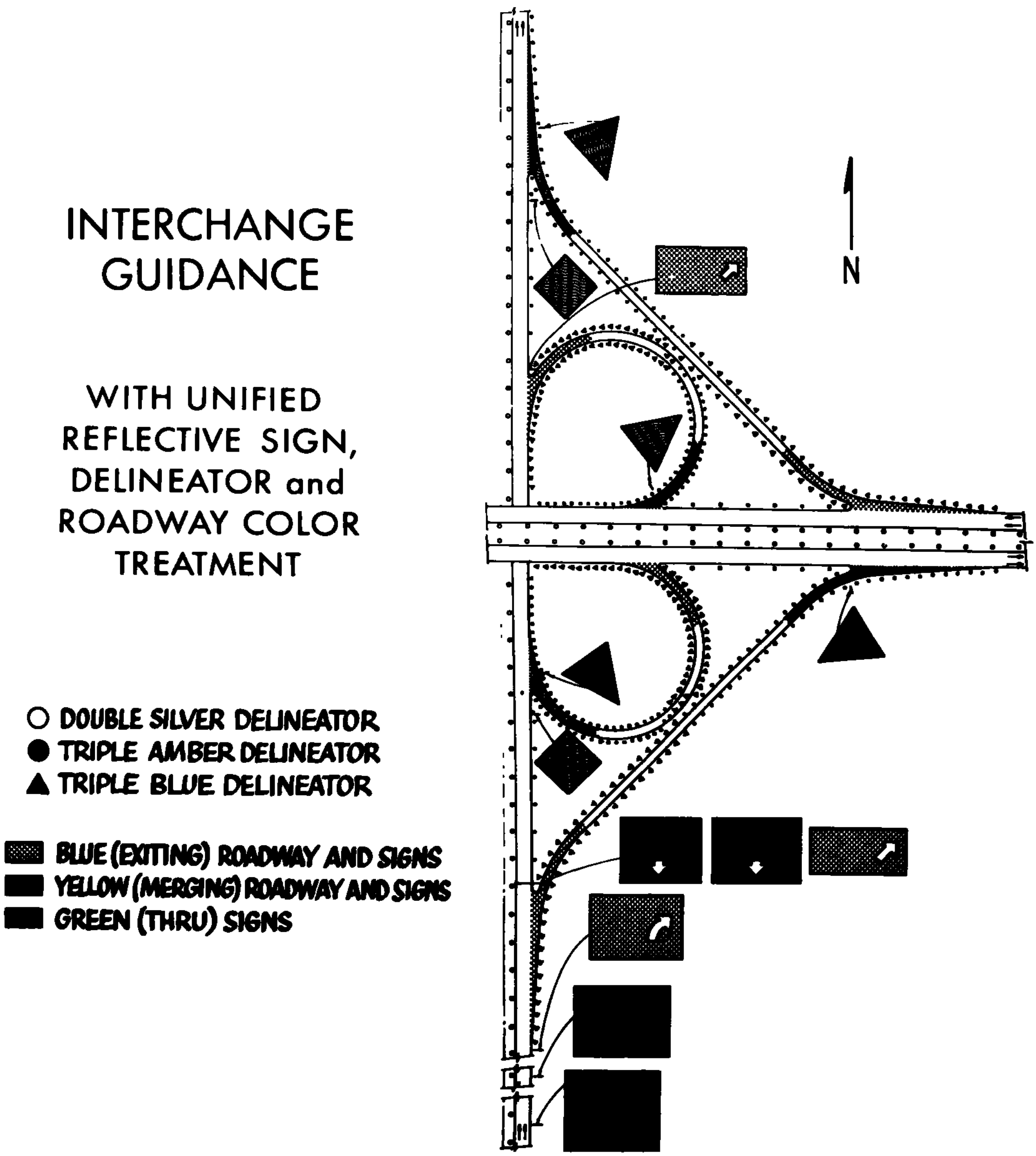

Figure 1. A unified reflective sign, delineator and roadway color treatment showing order of presentation for northbound traffic through a typical interchange. Similar systems may be employed in a number of related traffic guidance applications.

significant design features for effective distant perception. Within the interchange, 50-ft spacing was employed for through lanes, 25 ft for leg ramps and 15 ft for loop ramps, including connecting speed change lanes. Sign legend materials and sizes followed interstate standards with some legend modification in the absence of fully limited access or overhead sign structures (Fig. 2).

Previous use of reflectorized blue background signs in juxtaposition with green signs has led to some question of color discrimination. The dominant wave length of conventional blue reflective sheeting is approximately 495 mμ and peak reflectance 498 mμ compared to approximately 520 mμ for both in the case of the standard green. The similarity of hue (blue-green, green-blue) and possibility of confusion at night led to the development of an attractive blue reflective sheeting with a peak reflectance deep in the blue end of the spectrum (475 $m\mu$) and relatively high saturation in the red (620-700 $m\mu$), resulting in a distinctive indigo-blue and subjective brightness similar to that of standard green.

Purity and reflectance of blue roadway treatment and delineators were similarly adjusted to provide dominant wave lengths of comparable value and sufficiently blue to be unmistakable (Fig. 3). Role and limited size of delineators together with reduced visual sensitivity to blue necessitated blue delineation of relatively high brightness. A construction of standard size resulted, with a characteristic value of 489 $m\mu$ and luminance of 6 cp/ft-c — a signal adequate to meet minimum long-range visibility requirements. Directional reflectance values for these retro-reflective components at representative

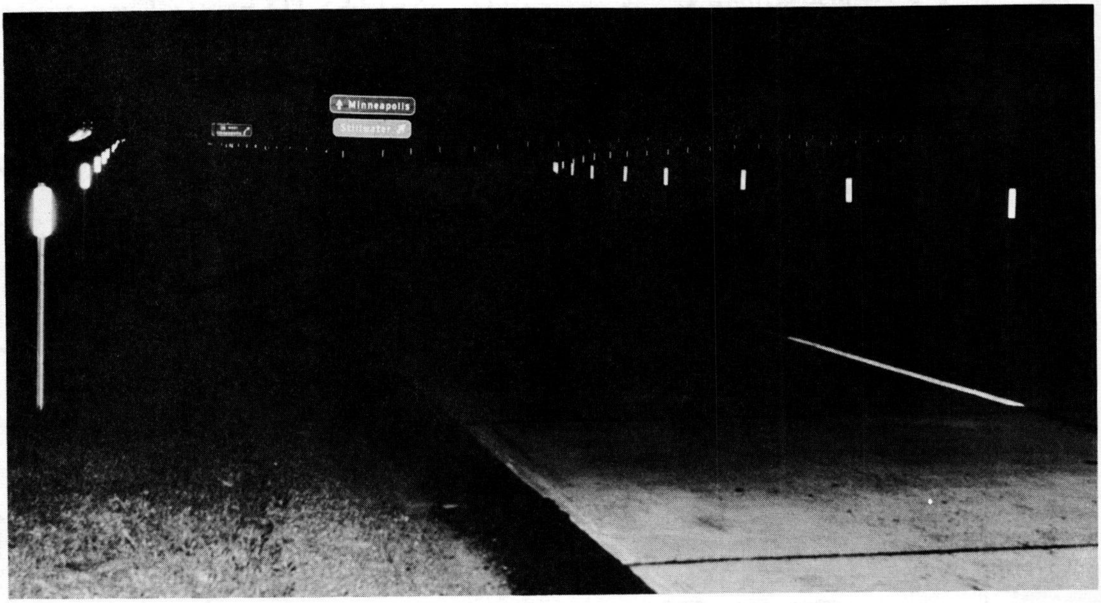

Figure 2. Night view of bifurcation treatment at exit ramp.

observation and incidence angles were established with a modified spectrophotometer. These are shown together with a 90 percent reflectance, diffuse white surface, relative to perfectly diffusing white.

Colored reflective roadway treatments are shown in terms of specific luminance (ft-l/ft-c) at divergence angles corresponding to viewing distances ranging from 1,000-80 ft (Fig. 4). Values are based on retro-reflective performance at representative entrance angles (88 deg) and exhibit initial efficiencies comparable to like-colored reflective sign materials and 20-500 X greater at applicable divergence angles than a hypothetical, 18 percent reflectance roadway surface. Relative to a perfectly diffusing, standard white surface, the brighter, yellow treatment increases luminance in the order of 65 X at 0.5 deg divergence, the blue 4 X.

Initial luminance of the treated road surface at 80 to 1,000 ft is shown relative to available headlamp illumination (Fig. 5). Upper and lower beam performance was derived from iso-candle curves based on representative output of the Dual Headlamp System (GE-4001 and 4002) and current headlamp-driver relationships, with vehicle centered in a straight, 12-ft lane. Luminance of right and left edges viewed with upper beams are identical for those distances considered. In view of lamp design features, lower beams understandably provide increased luminance at the right relative to the left edge.

Luminance of a conjectural 18 percent reflectance surface is illustrated as a standard of comparison with the treated roadway in establishing relative performance at all distances with upper and lower beams. Field measurements and limited published data

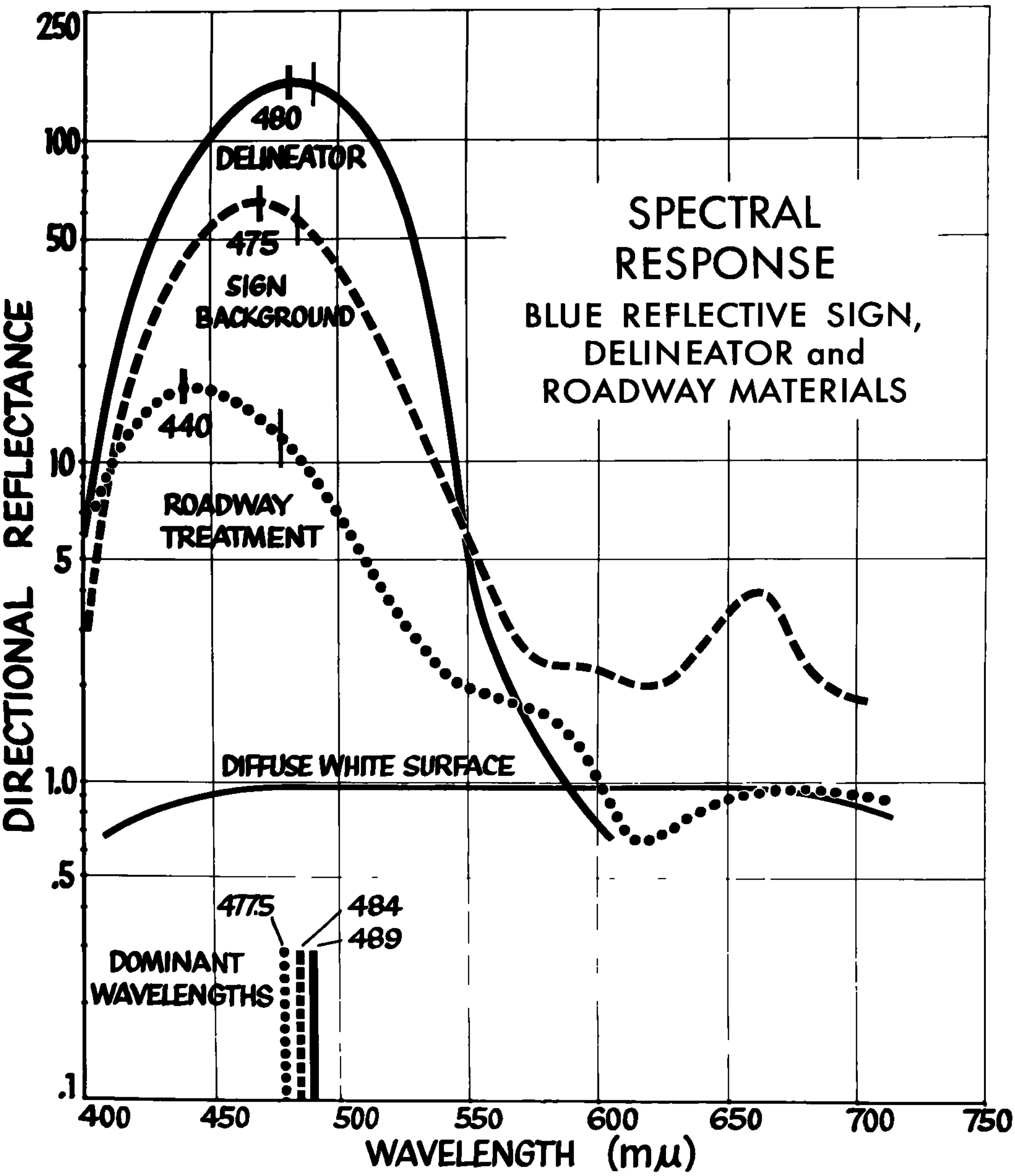

Figure 3. Spectral distribution of blue reflective signs, delineators and roadway marking materials shown relative to a diffuse white surface. Figures for spectral response at peak reflectance and dominant wavelength are given in millimicrons.

reveal typical pavement brightness illuminated with upper beams on the order of 0.08 foot-lamberts at 200 ft. At this distance with high beams, the reflective blue surface initially is shown to provide 6 foot-lamberts luminance, the yellow 40 ft-1, suggesting a 500-fold increase over a conventional pavement surface exhibiting 0.08 ft-1 luminance. This relationship applies equally to wet surfaces in the case of those portions of the experimental application designed to perform wet or dry throughout their useful life, and appears independent of pavement texture.

Although the luminance of reflective pavement treatments is relatively independent of pavement surface type, brightness is quite naturally a function of the projected pavement area. Horizontal ramp or speed change lane surfaces subtend a vanishingly small angle at distances greater than 1,000 ft. In addition, intersection surfaces may be temporarily covered with snow or ice or partially obscured by preceding vehicles, strongly establishing the warrant for supplementary delineation. The several reflective components may therefore contribute in varying proportion to the total perceptual purpose.

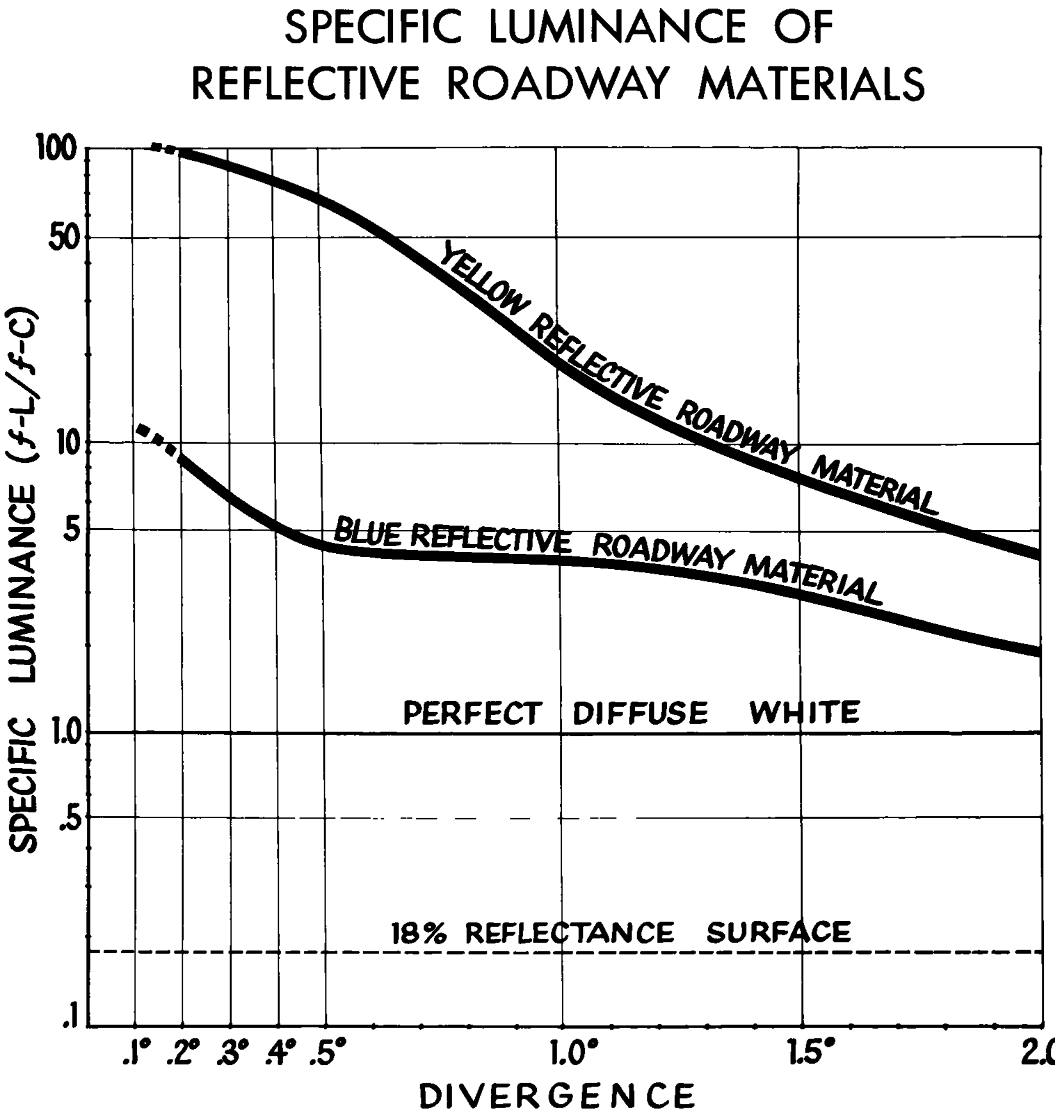

Figure 4. Specific luminance (foot-lamberts per foot-candle) of reflective roadway materials at divergence angles of 0.2 to 2.0 deg (approximately 1,000 to 80 ft). A diffuse surface exhibiting 18 percent reflectance and a perfectly diffusing white surface are shown for comparison.

Significant reduction of the perceptual impact through aberrant color deficiency is unlikely at the wave lengths in question. Frequency of tritans (blue-yellow deficient) has been found to be less than 0.008 percent in contrast with the more prevalent red-green

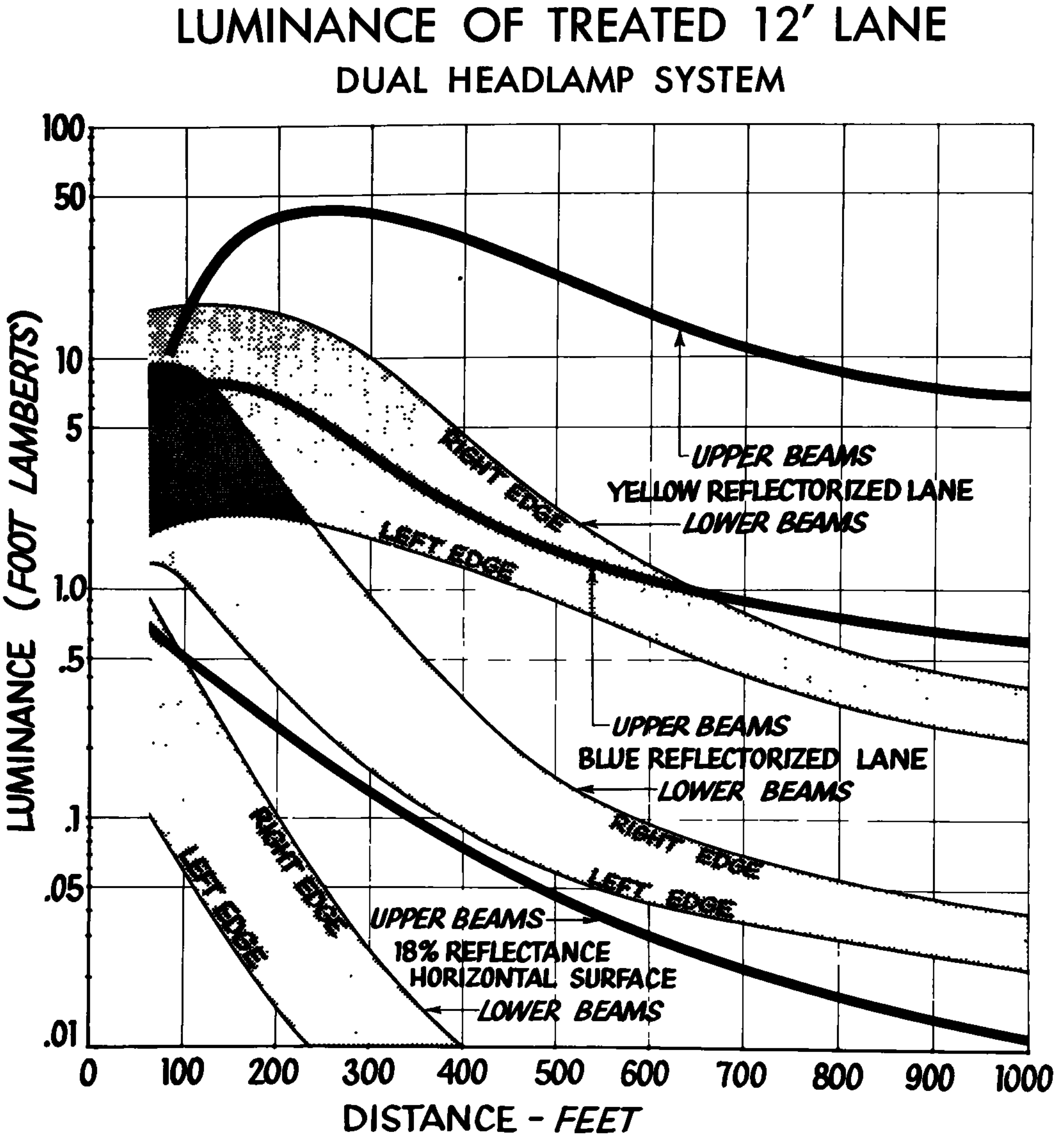

Figure 5. Luminance of treated roadway surface seen from 100 to 1,000 ft with Dual Headlamp System (G.E. 4001 and 4002) shown relative to an 18 percent reflectance roadway surface. Luminance of a straight 12-ft lane is shown from left to right for each color and upper and lower headlamp beams.

defectives. Their incidence has generally been found to be at least 2 percent of the adult population and the vast majority of this group are acutely perceptive of blue. Individuals deficient in ability to perceive yellow comprise the greatest rarities, suggesting that the complementary use of blue and yellow in this application offers the least likelihood of confusion, and provoking far less serious question than the color of traffic signal ware.

Choice of the particular location was largely dictated by the desirability of analyzing relative benefits of such treatment where established expressway traffic patterns and representative pavement surfaces, ambient illumination and lighting existed. Studies of driver attitudes, traffic characteristics and performance were undertaken in cooperation with the Traffic and Planning Division of the Minnesota Highway Department. These studies were conducted over a seven-week, midsummer period before and after installation of the reflective color treatment and included, in turn, conventional delineation, modified interstate standard delineation and supplementary illumination.

It is not in the scope of this paper to report the results of these studies, however, the substance of completed work and expressions of other investigators suggest that valuable insight has been gained into the night visibility problem and effective techniques disclosed both for assessment and improvement of the perceptual element. Because all seeing depends on light, perception on contrast levels, and guidance on perception, effective guidance is dependent on both luminance and contrast. Intense retroreflective brightness, with contrast afforded by color as well as generally low background luminance, presages extensive new perceptual and guidance opportunities.

Color-keyed, reflective guidance systems should be restricted to readily distinguished hues and applications for maximum effectiveness. Indiscriminant color use may serve to defeat rather than enhance the effort to reduce driving complexity. Inasmuch as distinctive colors are limited, their application should be well considered, though not overlooked. Well conceived, unified reflective systems suggest a method that may effectively provide for the motorist's visual cue and guidance needs as well at night as by day.

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