Nov. 1, 1966 D. M. HUBER ETAL 3,283,138

LIGHTING APPARATUS AND SYSTEM

Filed May 8, 1964

FIG.1A. (PRIOR ART)

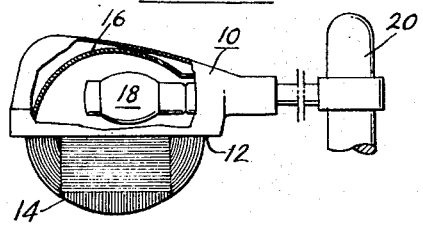


FIG.3.

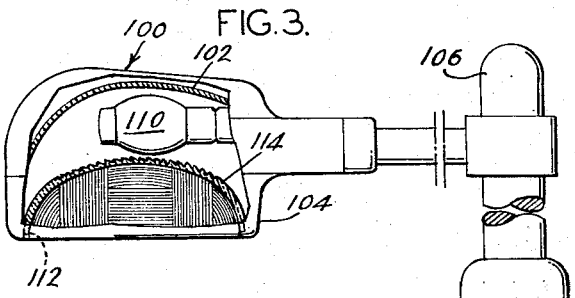


FIG.1B. (PRIOR ART)

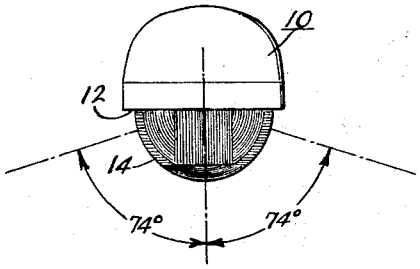


FIG.4.

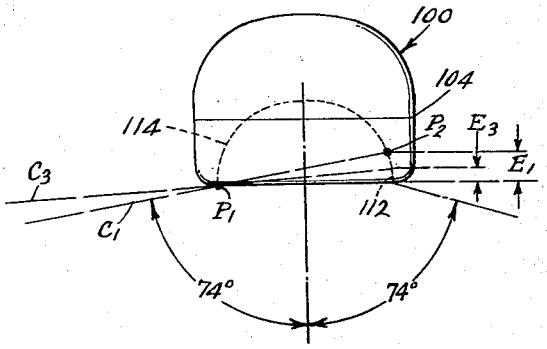


FIG.5.

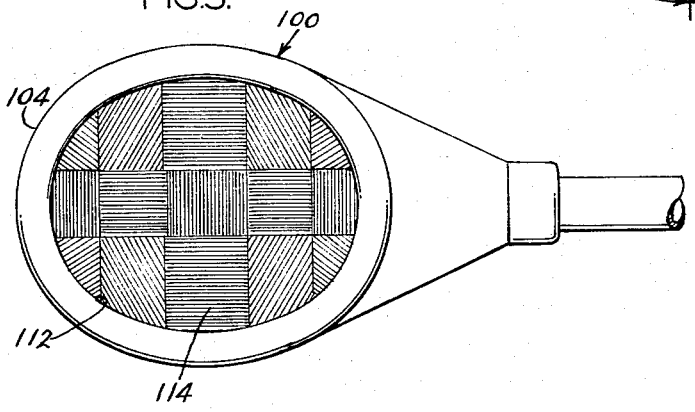
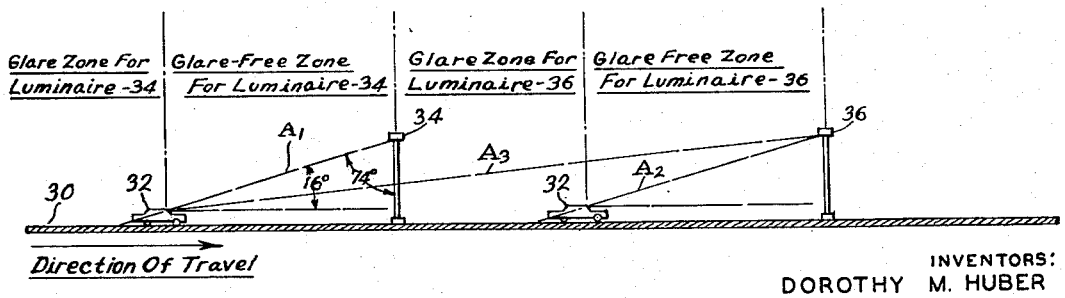


FIG.2.



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LIGHTING APPARATUS AND SYSTEM

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The present invention relates to apparatus and systems for lighting travel surfaces, and particularly to street and highway lighting apparatus and systems for illuminating roadways traversed by passenger-containing vehicles.

In street and highway lighting systems it is common to employ luminaires mounted on supporting structures fixed to the earth and positioned and arranged so as to direct light downward upon the roadway surface. One common type of such luminaire now in use comprises a housing having a bottom opening, a reflector in the housing, a light source beneath the reflector so that reflected light is directed through the bottom opening of the housing toward the roadway, and a generally bowl-shaped, downwardly-protruding refractor having a top opening which fits the bottom opening of the housing and provides an enclosure for the light source and reflector. The primary purpose of the bowl-shaped refractor is to disperse light from the source and reflector into a predetermined desired type of pattern for projection downward onto the roadway.

A major disadvantage of such a lighting arrangement is that while it may provide adequate lighting of the travel surface of the highway it often produces very objectionable glare in the eyes of the traveler traversing the roadway. The glare referred to here is not only the glare which one naturally encounters by looking upward into the luminaire, but also that glare which is objectionably intense even when the traveler confines his gaze forwardly and substantially horizontally along the highway. In addition to the luminaire immediately forward of the vehicle, other more remote luminaires can also contribute to glare. In addition, particularly near overpasses and underpasses, glare can occur at nearly any azimuth angle from a luminaire and not only parallel to the roadway. Not only is such glare uncomfortable, but it also can interfere with proper visual perception.

It is recognized that for the usual front-seat passenger in the ordinary motor vehicle moving along a highway the objectionable glare from an overhead luminaire is generally eliminated when the vehicle reaches a position sufficiently near a point directly under the luminaire that the opaque top structure of the automobile intervenes between the eyes of the passenger and the luminaire. For the average passenger and average automobile the angle then subtended, at the passenger's eyes, between the horizontal and the upper side of his windshield, is approximately 15° to 20°; the latter angle is referred to herein as the passenger's maximum upward viewing angle and is often given as 16°. For any given height of a luminaire above the highway there exists a corresponding glare-free zone along the highway in front of each luminaire. However, when the passenger is just in front of this glare-free zone a zone of relatively intense glare is passed through as each luminaire is approached.

While efforts have been made in the past to design the optical nature of the downwardly-protruding refractor in each luminaire so that the illumination provided thereby is strong in the glare-free region and very weak in the glare zone, appreciable glare remains even when such an arrangement is in optimum adjustment; furthermore, it has been found in practice that such an arrangement can be so critical that ordinary minor discrepancies in the installation or maintenance of the luminaire can cause undesired intense glare in the glare zone.

While it is possible to place opaque masks or reflectors around the conventional luminaire to obviate the possibility of intense glare in the glare zone, this produces a hybrid design which is generally not entirely satisfactory, from both mechanical and optical standpoints.

In accordance with the invention many of the disadvantages of previously-known lighting structures and systems are overcome and other advantages achieved by the provision of a novel luminaire construction and system of the following type.

The luminaire of the invention differs from previously-known types primarily in that the usual protruding, downwardly-extending refractor is replaced with a refractor which has a concave lower surface and is recessed within the opaque housing of the luminaire, preferably so that its lowest surface is approximately flush with the bottom of the adjacent opaque housing. The arrangement is such that when a passenger-containing vehicle is approaching the luminaire and is in the glare zone just ahead of the glare-free zone, the only portion of the refractor to which the eyes of the traveler are exposed is a small part near the remote lower edge of the refractor. The total amount of light directed toward the observer from this small portion of the refractor is so small that objectionable glare in the glare zone is eliminated. In the preferred form, a similar important reduction in glare is also provided in all other directions from the luminaire, as is particularly important at overpasses, underpasses and intersections.

Other objects and features of the invention will be more readily understood from a consideration of the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1A is an elevational view and FIGURE 1B is an end view of a typical prior-art luminaire;

FIGURE 2 is a schematic elevational view of a roadway and lighting system therefor to which the luminaire of the invention is applicable, and to which reference will be made in explaining the advantages of the invention;

FIGURE 3 is an elevational side view, with parts broken away, of a luminaire constructed in accordance with the invention;

FIGURE 4 is an elevational end view of the luminaire of FIGURE 3; and

FIGURE 5 is a bottom view of the luminaire of FIGURE 3.

Referring now to the prior-art luminaire shown in FIGURES 1A and 1B, a typical highway lighting luminaire comprises an opaque metal housing **10** having therein a bottom opening **12** which is closed by a mating downwardly-protruding glass refractor **14**. A concave-downward specular reflector **16** is mounted in the housing **10**, and a light source such as a mercury-vapor tube **18** is mounted between the reflector **16** and the refractor **14** so that light from source **18** illuminates all of the refractor **14** either directly or after reflection from the reflector **16**. The housing **10** is normally mounted in any convenient manner on a supporting structure **20**, such as a pole, affixed to the ground.

Light from refractor **14** is transmitted in substantially all directions below the horizontal, to varying extents depending upon the particular optical interrelationship of the light source, reflector and refractor, including the specific prismatic form of the surface of the refractor as well as its over-all general shape. Such a refractor may often produce highly objectionable glare in the eyes of an approaching traveler over the road beneath the luminaire.

More particularly, referring to FIGURE 2, there are represented therein a travel surface **30**, such as a paved

highway, along which a passenger vehicle **32** is moving to the right in the figure. The luminaires **34** and **36** are mounted in spaced relationship along the highway so as to overhang, and direct light downwardly upon, the highway travel surface. The dashed lines A_1 and A_2 extend from the roadway to the luminaires **34** and **36** respectively at an angle of approximately 16° above the horizontal, and thus form angles from the vertical of about 74°. When vehicle **32** of the usual passenger-automobile type is approaching the region under the next luminaire such as **34** and is within the triangle formed by that luminaire, the corresponding dashed line such as A_1 and the driver's eye level line, the roof structure of the automobile will shield the eyes of a front-seat passenger from the direct rays of the nearest luminaire, and accordingly the roadway region within each such triangle is designated as a glare-free zone for that luminaire. However, when the vehicle **32** is in a position just in front of the position shown in FIGURE 2, it is in the normal glare zone, the eyes of a front-seat passenger are in direct line of view with the luminaire immediately before it, and quite often objectionable glare occurs with the conventional luminaire. Furthermore, as indicated by the line A_3, the next subsequent luminaire **36** and others beyond it are visible to the passenger, and near overpasses, underpasses and intersections other luminaires will also be visible at a variety of angles, e.g. even from their ends or transverse to the highway they are intended to illuminate. Thus when any one of the luminaires **34**, **36** is constructed in accordance with the prior-art arrangement shown in FIGURES 1A and 1B, the large, brightly-illuminated surface of the downwardly-protruding refractor **14** is often capable of producing highly-objectionable glare in the eyes of the passenger. Using a luminaire in accordance with the present invention however, the amount of light reaching the eyes of the front-seat passenger while in the glare zone is so greatly reduced as no longer to be objectionable, as is the glare due to other more remote luminaires.

FIGURES 3, 4 and 5 illustrate one typical embodiment of a luminaire in accordance with the present invention. This embodiment employs a reflecting chamber **100** made up of a specular reflector **102** which has a concave bottom surface, and an opaque metal housing **104** which supports the reflector **102** and is in turn supported from the usual supporting structure **106** which may be a light pole affixed to the ground. A plurality of such supporting structures and luminaires are spaced along the highway as shown in FIGURE 2 to provide overlapping light patterns on the roadway. The light source **110**, such as a mercury-vapor lamp, is mounted directly beneath the reflector **102**, and a lower opening **112** in housing **104** is closed by a translucent refractor **114**. Light from source **110** therefore illuminates refractor **114** either directly or by reflection from reflector **102** and passes from the refractor downward upon the roadway surface in a pattern which can be varied and controlled in detail by choice of the particular optical arrangement including the exact position and size of the light source, and the size, shape and detailed prismatic surface form of the refractor **114**, according to general principles known in the art. While not optimum for all purposes, if desired the refractor **114** may have the same form as the conventional refractor **14** shown in the prior-art arrangement of FIGURES 1A and 1B, but reversed in position so as to have a concave lower surface rather than a convex lower surface.

Referring particularly to FIGURE 4, it can be seen that a line C_1 at an angle of about 74° from the vertical and passing through a point such as P_1 at the lowest edge of refractor **114** and housing **104** strikes the opposite interior surface of the refractor **114** at a point P_2 only slightly above the lower edge of the opposite interior

surface of the refractor. Now if the luminaire of the inventive form shown in FIGURES 3, 4 and 5 is used for each of the luminaires **34** and **36** in FIGURE 2, it will be apparent that when the passenger vehicle **32** is in a glare zone the only portion of the nearest luminaire in direct line of sight with the eyes of the passenger is the sector corresponding to the height E_1 in FIGURE 4, which not only represents a small fraction of the total illuminated surface of refractor **114** but, in general, is also a portion of the refractor from which the intensity of light per unit area refracted toward the passenger is small. More remote luminaires have even less illuminated area visible to the passenger, as indicated by the height E_3 intercepted by line C_3 in FIGURE 4. The net result is that the intensity of light reaching the eyes of a front-seat passenger in the glare zone is very greatly reduced, and in general is so greatly reduced as to become unobjectionable. In the preferred form shown, this same reduction in glare occurs at all azimuth angles from a given luminaire, for example transverse to the highway, so that no special arrangement need be added when the luminaire is used in locations where glare transverse to the highway is important. At the same time, by any of a large variety of appropriate optical designs of the light source and reflector, and of the refractor over-all shape and detailed prismatic form, any of a large variety of illumination patterns can be provided on the roadway within the glare-free zone as desired.

Because the luminaire of the invention assures an abrupt decrease in illumination in passing the dividing line between the glare-free zone and the glare zone, the luminaires will in many cases be spaced along the highway sufficiently closely that the glare-free zones overlap to a small extent, as indicated in FIGURE 2 for example. Where the elimination of glare is considered to be especially important and particularly where intense illumination is also desired for the roadway as around underpasses, overpasses and interchanges for example, the corresponding relatively-close spacing of the luminaires is no disadvantage.

As indicated above, the refractor utilized in accordance with the invention may have any of a large variety of forms. It may for example, and typically will, have prismatic projections along its surfaces which constitute irregularities small compared to the complete transverse dimension of the luminaire in the direction of travel of the vehicle, and these irregularities may be on one or both of the bottom or top surfaces of the refractor and may be variously directed and configured. As indicated in FIGURE 4, typically the refractor will be generally arcuate in section parallel to the direction of travel on the roadway and will have a single direction of curvature for its over-all shape in that direction. The shape of the refractor and other constructional details of the luminaire transversely of the direction of travel along the highway will depend upon what type of light pattern is desired in that direction, and may take any of a large variety of forms in different applications. While the nature of the transverse pattern is not the primary concern of the present invention, it is highly advantageous to employ a similar construction along other azimuthal directions to eliminate glare in directions non-parallel to the roadway, for reasons indicated hereinbefore.

Preferably, as shown, the luminaire is symmetrical with respect to a plane through its center transverse to the roadway so that it operates in the same manner described above for opposite directions of vehicle travel along the highway.

While the invention has been described with particular reference to specific embodiments thereof in the interests of complete definiteness, it will be understood that it may be embodied in any of a large variety of forms diverse from those specifically shown without de-

parting from the scope and spirit of the invention as defined by the appended claims.

We claim:

1. Highway-lighting apparatus, comprising:

a highway-lighting luminaire for providing downwardly-directed overhead lighting along a highway;

a supporting structure for said luminaire, mountable adjacent said highway to support said luminaire above the path of passenger-containing vehicles on said highway;

said luminaire comprising an open-bottomed substantially opaque enclosure, a light source entirely within said enclosure, a light reflector within said enclosure and extending above said light source, and a prismatic refractor extending across said open bottom of said enclosure for distributing light from said source along said subjacent highway;

said refractor having a lower surface which, in a vertical plane along the direction of said highway, is concave with a single direction of curvature and symmetrical about a vertical axis, said refractor including the edges thereof being substantially entirely within said enclosure.

2. The apparatus of claim 1, in which said refractor is concave in all vertical planes and circularly symmetrical about said vertical axis.

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