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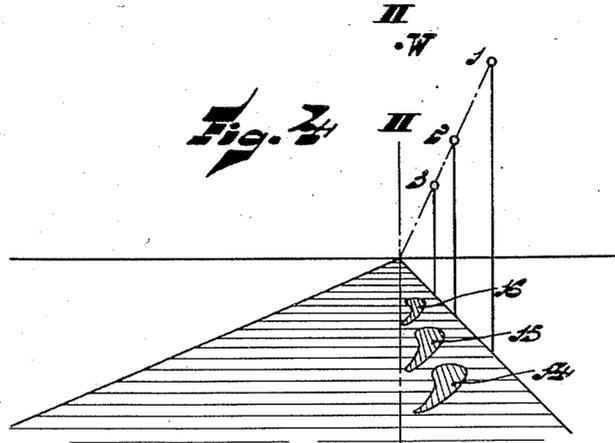
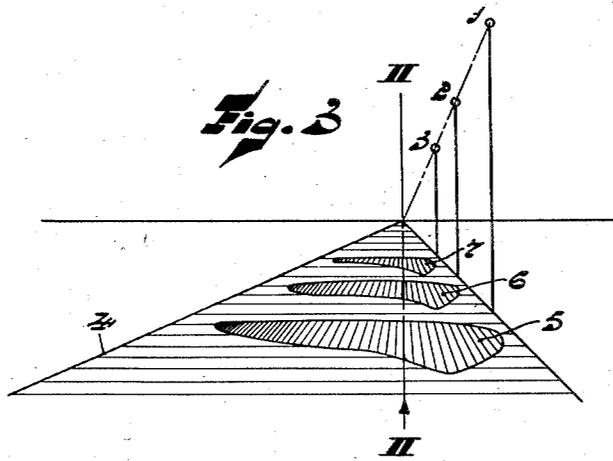
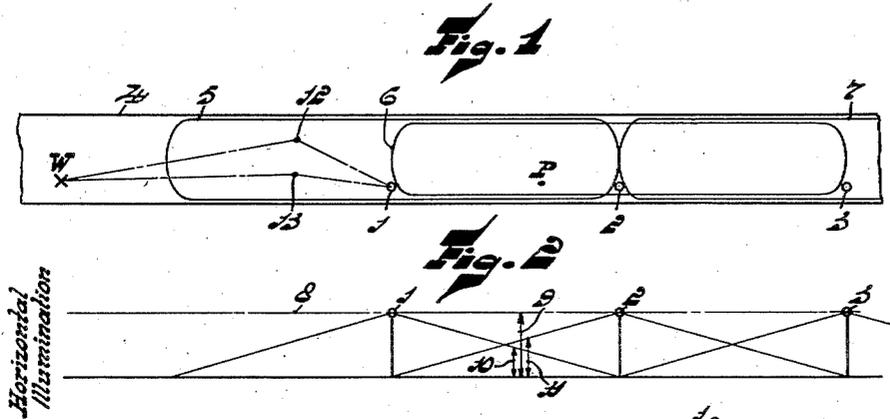
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2,229,034

HIGHWAY ILLUMINATION

Filed Feb. 10, 1938

5 Sheets-Sheet 1



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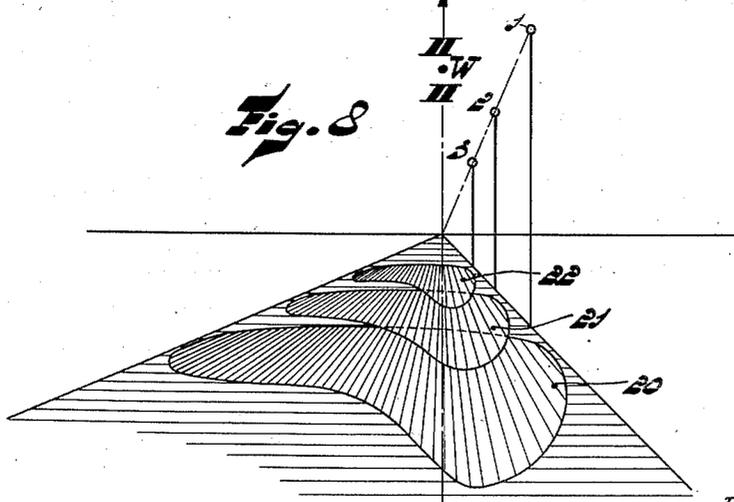
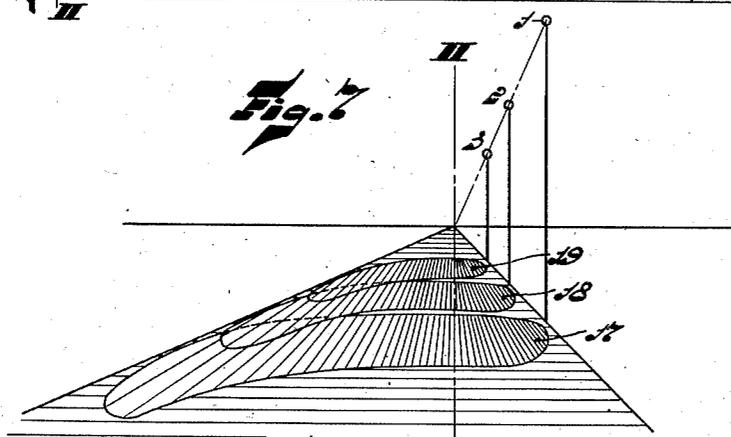
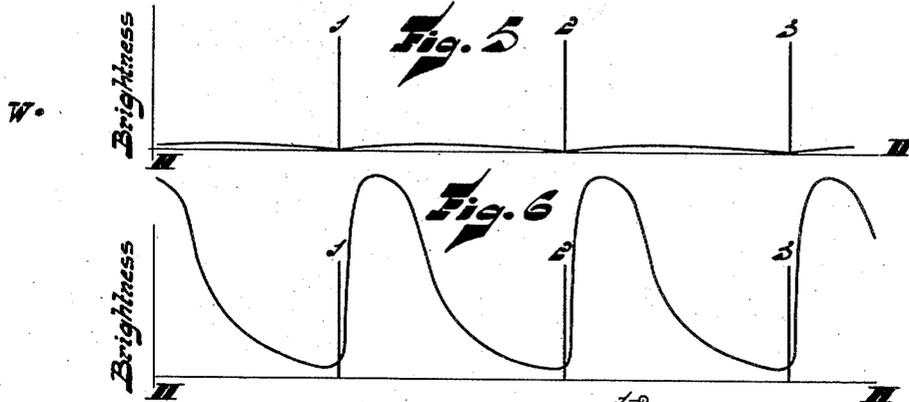
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HIGHWAY ILLUMINATION

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5 Sheets-Sheet 2



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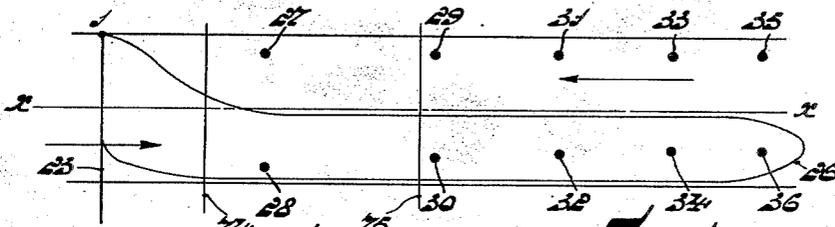
HIGHWAY ILLUMINATION

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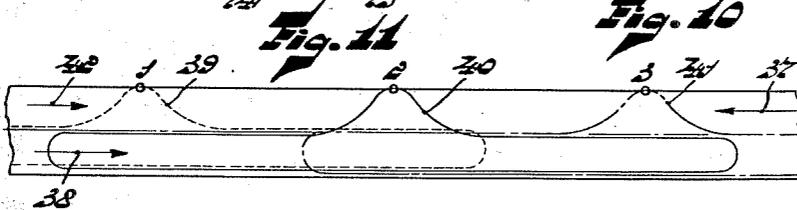
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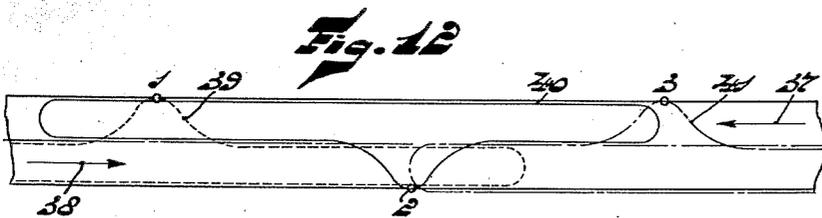
**Fig. 9**



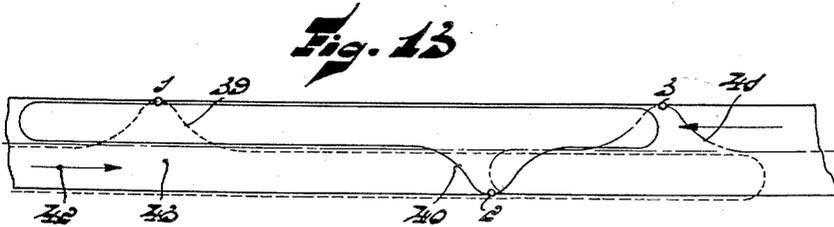
**Fig. 10**



**Fig. 11**



**Fig. 12**



**Fig. 13**

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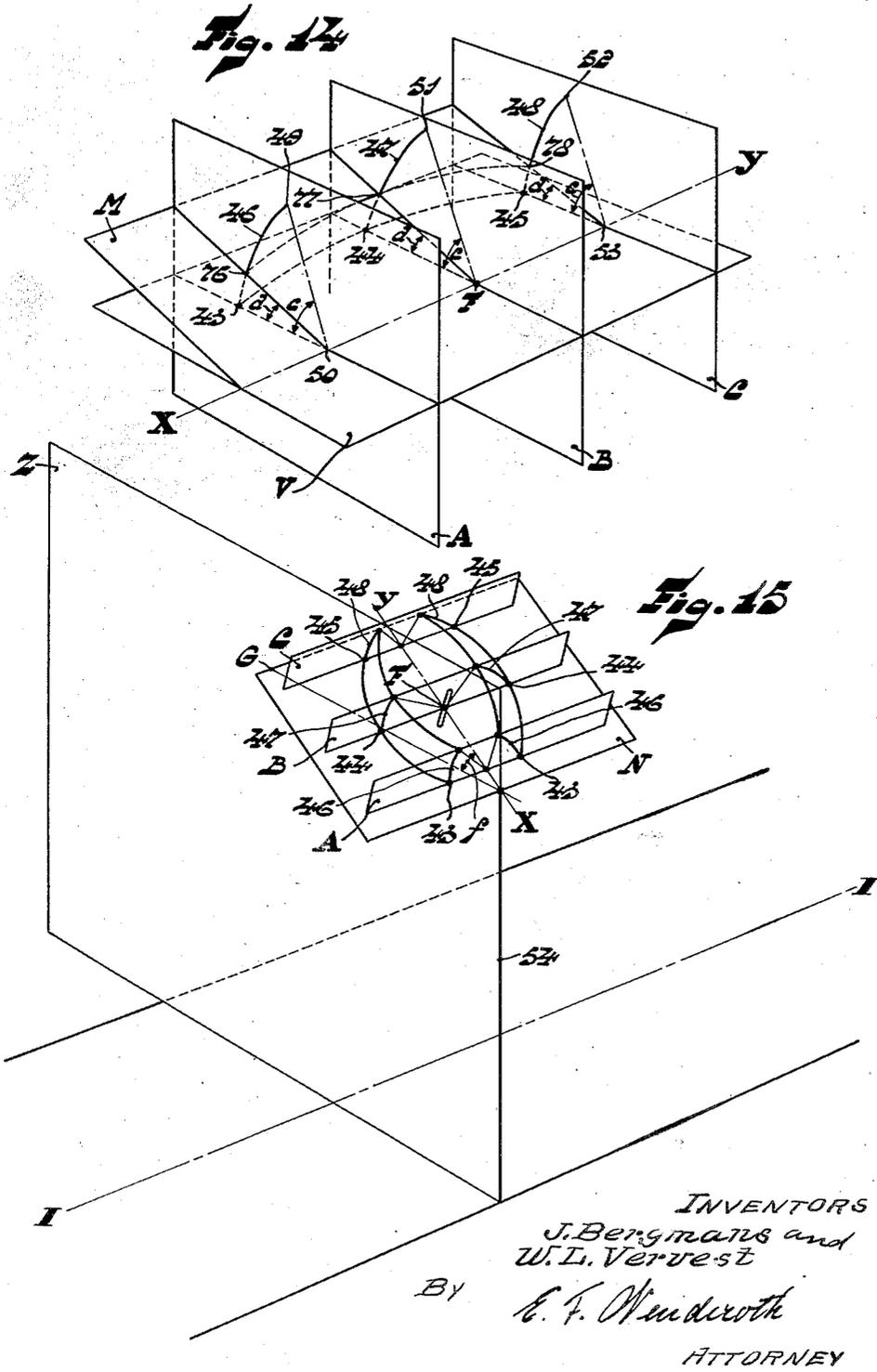
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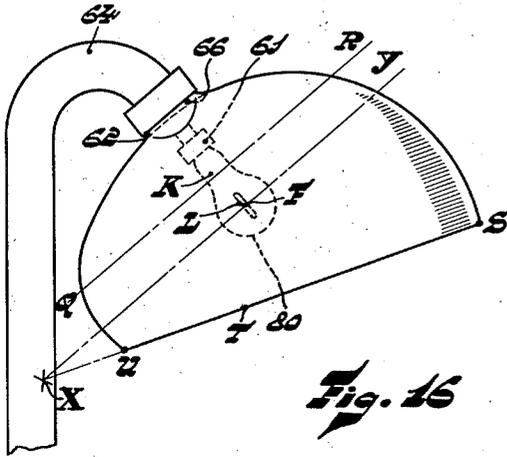
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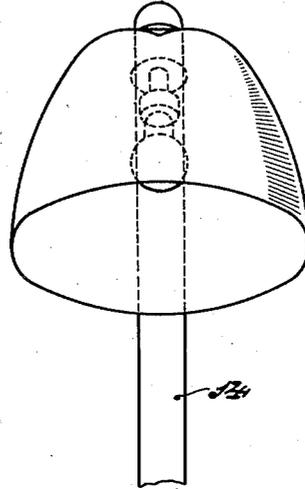
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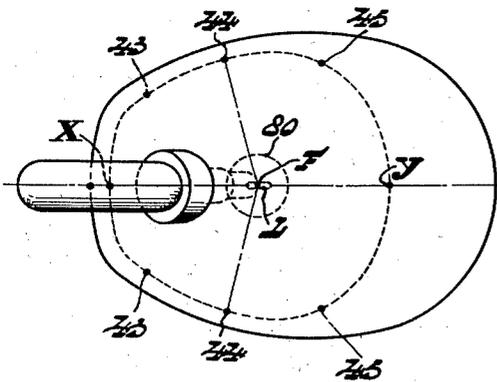
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**Fig. 16**



**Fig. 18**



**Fig. 17**

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# UNITED STATES PATENT OFFICE

2,229,034

## HIGHWAY ILLUMINATION

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Application February 10, 1938, Serial No. 189,871  
In the Netherlands February 18, 1937

12 Claims. (Cl. 240—25)

Our invention relates to the illumination of highways, particularly highways with a high-speed traffic in the country.

Because of the increase in high-speed traffic on such highways, it has become desirable, if not necessary, to illuminate the same so that motorists will not be dependent solely upon the illumination afforded by their headlights, but can obtain an idea of the direction of the highway and perceive obstacles thereon beyond the range of their headlight beams. Systems using widely-spaced light sources without additional means are not satisfactory for this purpose because the light sources act merely as beacons to the motorist, and the illumination obtained makes it practically impossible for the motorist to distinguish obstacles on the highway. Furthermore, such systems have the great drawback that bright and dark light patches are formed upon the highway surface, with the result that the brightness is not at all uniform. On the other hand, if the light sources are placed very close together, it makes the system too expensive for use on highways in the country.

To overcome the above drawbacks, it has been proposed to provide the light sources with reflectors so that the light emitted by a certain light source is distributed over the highway surface in such a manner that the lux-values, i. e. the light intensity as viewed from above the surface, are fairly constant over the entire surface. Such systems, however, do not take into consideration the very important point that in practice the illumination qualities of a given portion of a highway surface is not judged from a point at or above that portion. On the contrary, a user of the highway, such as a motorist, sees a given highway surface portion at a distance of about 250 feet, and hence does not obtain an idea of the horizontal illumination, but of the brightness of this portion.

In this connection it should be noted that the brightness of a given surface portion when viewed in a definite direction depends entirely upon the direction of incidence of the light striking this surface portion. For every combination of the projection on the highway surface of the direction of incidence of the light and of the corresponding projection on the highway surface of the direction of observation, there is—for a given surface portion—a certain ratio between the brightness in the direction of observation and the illumination of this portion. Hereinafter and in the claims we will refer to this ratio as the "coefficient of brightness."

However, merely studying the "coefficient of brightness" of a highway surface and utilizing these results in the design of the system does not completely solve the problem, because the coefficient of brightness of a given surface portion are quite different when the surface is dry or wet. The term "wet" surface as used hereinafter and in the claims, is to be understood to mean a surface which is entirely or partly covered with a thin layer of water which follows all unevennesses of the surface. This does not include complete inundation of the surface, because in such cases the layer of water fills all the cavities in the surface so that surface unevennesses are no longer perceivable and a watery mirror is formed at the surface.

The object of our invention is to overcome the above difficulties and to provide an illumination system especially adapted for highways in the country which illuminates the surface in such a manner that the illumination appears substantially uniform to a motorist.

A further object of our invention is to provide an illuminating system which produces good results when the surface is either wet or dry.

Further objects of the invention will appear as the description progresses.

In accordance with the invention, we illuminate the highway surface in a particular manner, at least on one side of the line of intersection with the surface of a "normal" plane i. e. a plane perpendicular to the longitudinal axis of the surface and passing through the light source. More particularly we so illuminate at least in the surface portion lying between the intersecting lines with the surface of two planes passing through the light source and making angles of about at least 30° and 60° respectively with the normal plane, that the ratio between the illumination of the "remote" half and the illumination of the "adjacent" half is at least 2:1.

By "remote" half is meant the half of the surface located on the side opposite the light source, whereas the "adjacent" half is the half near the light source.

In the surface portion in the intermediate vicinity of the light source, i. e. the portion between the intersecting lines of the normal plane and the 30° plane, the illumination may be greater on the adjacent half than on the remote half.

Such illumination can be effective on either or both sides of the normal plane, depending upon the location of the light source, and upon whether the highway surface must be illuminated throughout its width. Furthermore, the light sources

may be arranged on one or both sides of the highway.

Although the illumination according to the invention is not uniform over the entire surface, the motorist receives the impression of a substantially uniform brightness in a substantially lateral direction, which is very important. In fact, it is much more important that a given portion of the surface have at least a substantially uniform brightness when observed in the above manner, than when observed in a longitudinal direction. More particularly, a motorist will see the surface ahead of him in perspective, and will be able to readily distinguish several strips in a lateral direction, which strips in prior lighting systems practically always exhibited very great brightness differences. On the other hand, he will perceive practically no brightness differences in a longitudinal direction of the highway, because the strips, which have a mutually-different brightness to him and are about 85 feet long, will appear in perspective as very narrow indistinguishable strips. However, it is also advantageous that these strips have a uniform brightness, although this is of secondary importance.

The reflectors used in the illuminating systems according to the invention have various shapes, which depend on their position and desired form of light beams. In many cases it is necessary that there be a symmetrical distribution of light on both sides of the normal plane and in such cases the reflectors are provided with two similarly-shaped reflecting portions which are located symmetrically with respect to this plane.

We prefer to arrange the reflectors with their major axis at right angles to the longitudinal axis, and preferably inclined with respect to the lateral axis, of the highway surface. The angle which this major axis makes with the lateral axis depends on various factors, and in determining this angle the height at which the reflector and light source are arranged above the highway surface, as well as the width of this surface, play a prominent part.

Each reflector is provided with at least one reflecting portion formed by a generatrix which is moved along directrices lying in planes which extend perpendicularly to the major axis of the reflector. These directrices or frame lines are preferably parabolas whose foci lie in the major axis, and the position and form of the generatrix is such that the light reflected by the reflecting portions produces on the highway surface the light distribution according to the invention. When each reflector emits two mutually-similar beams extending symmetrically with respect to the normal plane, each of the reflectors are provided with two similarly-shaped reflecting portions of the above type which lie symmetrically with respect to the major axis.

As a generatrix we prefer to use a second-degree curve, such as parabola whose focus lies in the major axis, and, when the reflector has two symmetrically-arranged reflecting portions, we prefer to provide an intermediate reflecting surface which has a dent in the plane of symmetry of the reflector passing through the major axis.

With the symmetrical reflector according to the invention the axis of the parabolic directrices preferably make an angle of about  $20^\circ$  to  $40^\circ$  with the major plane. Furthermore, the transition curves between the elongated reflecting portions and the intermediary portion extend in one form of construction in two planes, each of which makes

an angle of the order of magnitude of  $10^\circ$  with the major plane.

When symmetrical reflectors according to the invention are positioned at the side of the highway, the elongated reflecting edge portions serve to light the remote half by means of two equal beams; this effect being substantially determined by the shape and the position of the generatrix. We have found that when the axes of two parabolic generatrices form a maximum angle of about  $10^\circ$  with a line perpendicular to the major axis, the two beams will extend in the desired direction.

To prevent the portions of the emitted light beams intended for lighting the adjacent half from extending in a direction which deviates too much from the desired direction, the extreme limiting plane of the reflector preferably makes an angle of from  $15^\circ$  to  $35^\circ$  with the major axis.

With regard to the positioning the light source within the reflector, it is desirable that a least the main direction of the light source intersects the main plane of the reflector in the major axis. This main direction is standing at least practical perpendicular on the main plane of the reflector when the reflector construction is asymmetrical and has only one elongated reflecting portion, the main plane is to be understood to mean the plane which passes through the major axis and on which also the main direction of the light source is standing at least practically perpendicular. If, in a symmetrical reflector, the two generatrices have the form of parabolas whose foci lie at the same point on the major axis, the main direction of the light source intersects the main plane at right angles at this point.

In order that our invention may be clearly understood and readily carried into effect, we shall describe the same in more detail by comparison with the prior art systems and with reference to the accompanying drawings, in which:

Figure 1 is a plan view of a highway illuminated in accordance with the prior art,

Fig. 2 is a graph showing the illumination of the highway of Fig. 1,

Fig. 3 is a perspective view of the highway of Fig. 1 when dry,

Fig. 4 is a perspective view of the highway of Fig. 1 when wet,

Fig. 5 is a graph showing the brightness of the surface of the highway of Fig. 3,

Fig. 6 is a graph showing the brightness of the surface of the highway of Fig. 4.

Fig. 7 is a perspective view of a dry highway illuminated according to the invention,

Fig. 8 is a perspective view of a wet highway illuminated according to the invention,

Fig. 9 is a graph illustrating the distribution of light of a highway illuminated according to the invention,

Fig. 10 is a plan view of the highway of Fig. 9,

Fig. 11 is a plan view of a highway with the light sources located on one side.

Figs. 12 and 13 are plan views of a highway with light source arranged on both sides.

Fig. 14 is a perspective diagram illustrating the generation of a reflector according to the invention,

Fig. 15 is a perspective diagram illustrating the positioning of the reflector of Fig. 14 with respect to a highway,

Fig. 16 is a front view of a reflector according to the invention,

Fig. 17 is a plan view of Fig. 16, and Fig. 18 is a side view of Fig. 16.

As shown in Fig. 1, a highway 4 is illuminated by three light sources 1, 2, and 3, located at one side of the highway. In accordance with the prior art each of the light sources are provided with reflectors (not shown) of such shape that a substantially constant horizontal illumination is obtained over the entire surface of the highway. More particularly, light sources 1, 2 and 3 produce light patches indicated by reference numerals, 5, 6 and 7, which overlap to produce a substantially constant illumination. This is shown more clearly in the graph of Fig. 2, in which, the ordinates represent horizontal illumination, and the position of the light sources are indicated as abscissae. From this graph it appears that the total illumination as indicated by line 8, is equal to the sum of the illuminations of two adjacent light sources. More particularly, at a point 9 the total illumination equals the sum of the ordinates 10 and 11 of the light curves of light sources 1 and 2 respectively.

From Fig. 2 it appears that the total horizontal illumination, as indicated by line 8, is uniform over the entire surface of the highway, and thus when observing this surface from above it will appear as a substantially uniformly illuminated surface. However it should be noted that to a user of the highway, for instance a motorist, the surface will always appear as a triangle due to the perspective effect, and when observing the surface in this manner, the situation is quite different. This is illustrated in Figs. 3 and 4 in which the direction of observation of an observer W is indicated by line II—II. When the observer W views the highway surface of Fig. 1 in perspective, he receives an impression of this surface, when in its dry state, as shown in Fig. 3, in which light patches 5, 6 and 7 produced by light sources 1, 2 and 3 respectively can be distinguished, but will not have a uniform brightness. This difference in brightness is indicated in the figures by using widely-spaced sectioning for the portions of greatest brightness, and using more closely-spaced sectioning for the portions of lower brilliance; and surface portions that appear dark being horizontally sectioned.

The fact that not all surface portions will appear equally bright to a motorist although the horizontal illumination intensity is equal throughout will be explained with reference to Fig. 1, in which the observer W views a point 12 within the light patch 5 produced by the light source 1. The projection of the direction of observation W—12 on the road surface makes a comparatively large angle W—12—1 with the projection of the direction of incidence of the light 1—12 at this point. As the coefficient of brightness has high values in direction making a comparatively small angle with the direction of incidence, it follows that when the observer views a point 13, he will obtain a much brighter impression from this point than from point 12. As a result, with the positioning of the light sources and with the distribution of light as shown in Fig. 1, the observer W will always receive a brighter impression of those parts of the highway surface where the projection of the direction of observation on the surface makes a comparatively large angle with the corresponding projection of the direction of incidence of the light i. e. on the remote parts. Although in the luminous patch produced by one of the light sources, lines of uniform brightness might be shown, to avoid undue complications, it may be said that on the whole the portions of the light patches lying to one side of the observer W will appear

brighter to him than do the opposite portions of these light patches.

Irrespective of the fact that dark portions still remain between patches 5, 6 and 7 in Fig. 3, it appears that the uniform brightness in a horizontal direction is far from satisfactory. Furthermore, it should be noted that to the observer those parts of the light patches which lie on the sides of the light sources opposite him will appear darker than the parts in front of the light sources because of the theory regarding the coefficient of brightness, which will be referred to later.

The above difficulties become much worse when the road surface is wet, and this is illustrated in Fig. 4 in which the observer W views the highway surface when it is wet. When a highway surface is wet, the brightness coefficient in the projection of a direction on the road surface—which at least substantially coincide with the corresponding projection of the angle of incidence of the light—is much higher than the reflection coefficients in other directions which reach a very small value in this case. As a result the observer W receives an impression of the road surface as if each light source radiated only a bright band of light directed toward him, whereas the remainder of the road surface is entirely dark.

In Fig. 4 these bright light patches are indicated by reference numerals 14, 15 and 16, and are wide in the vicinity of the light source. As the highway is entirely dark except for the bright light patches 14, 15 and 16, it will be appreciable that the illumination of the surface is very poor.

With the prior art illumination of the type illustrated by Figs 1 to 4 there is no question of uniform brightness in a lateral direction and obstacles on the dark portions of the highway can be perceived only by means of the light radiated by the headlights of the motor car. This will be more clearly explained with reference to Figs. 5 and 6, in which line II—II of Figs. 3 and 4, represents the abscissa axis, the ordinates represents the brightness, and the light sources are indicated by reference numerals 1, 2 and 3. Fig. 5 shows the brightnesses of a dry road surface such as that of Fig. 3 and Fig. 6 those of a wet one such as that of Fig. 4, the brightnesses being derived from experiments made on an asphalt-concrete road. From these figures, which are drawn to the same scale, it appears that brightness differences of about 1:30 occur between the dry and wet surfaces. From Fig. 5 it appears that the brightness in a longitudinal direction i. e. in the line II—II, is comparatively constant, and Fig. 6 shows that very great brightness differences occur when the surface is wet.

In regard to the coefficient of brightness, it should be noted that when a motorist is at a comparatively great distance from a given portion of a dry highway surface, the coefficient of brightness of the surface on the side remote from him will differ only comparatively slightly from the portion of the road surface on his own side because of so-called diffuse reflection. However, when the road is wet, the situation is quite different because in such cases the coefficients of brightness vary to a larger degree. More particularly for the projections on the surface of the direction of incidence of the light and the direction of observation, which form together an angle of the order or magnitude of 180°, the coefficients of brightness increase very strongly relative to those combinations of the projections of the directions of incidence and observation forming a smaller angle. With combinations of

these two directions, which form a small angle, the coefficient of brightness decreases very strongly. Thus, it will be seen that those surface portions which lie on his side of the highway and between him and a light source located on the same side (when no special measures are taken) will appear much brighter to the motorist than a surface portion lying at the same distance from him but on the other side of the highway.

To ensure sufficiently uniform brightness in the dry and wet state, we provide suitable reflectors to throw the light to the remote side of the road. We have found that when correctly positioning the reflectors and the cooperating light source with regard to the highway surface, the remote side of the highway, when dry, is about four times as bright as on the motorist's side, whereas when wet, the motorist's side is about four times as bright as the opposite side of the road appears to be. Our experiments have shown that with existing road-lighting and with the highway surface in a wet state, brightness differences between the motorist's side of the highway and the opposite side may be of the order of magnitude of 100 or more, whereas in the dry state these differences are smaller, but materially greater than those obtained with the systems of the present invention. The values stated for the system according to the invention may not be considered as normal because the coefficients of brightness naturally are dependent to a large degree upon the type of road surface. Nevertheless, when using the illumination according to the invention, the brightness differences with every type of road surface are materially smaller than with present day lighting systems.

By suitably selecting and positioning the reflector and the light source, the ratio between the illumination on the opposite side and on the own side can be controlled. More particularly, if the light source is arranged above the surface, at a distance of order of the width of the highway, the remote side of the highway is preferably illuminated with an illumination ten times stronger than the illumination on the adjacent side. If, on the contrary, a narrow road is illuminated by means of a light source located at a great height, or a broad highway by means of the light sources located only a short distance above the surface, this proportion becomes smaller and larger respectively. A ratio of about 2 to 1 has been found to give good results.

In the system according to the invention, generally speaking and within a definite region, those parts of the highway surface lying on the "remote" half are illuminated with an illumination which is at least twice as strong as that of the "adjacent" half. Such a system, which overcomes to a very large extent the difficulties set forth above in connection with Figs. 1 to 6, is illustrated by Figs. 7 and 8, which are perspective views of a highway surface as viewed by an observer located at W, and in which positioning of the light sources is indicated. In Fig. 7 the light sources 1, 2 and 3 illuminate the highway surface, when in its dry state, with light patches 17, 18 and 19 respectively. The parts of the light patches which appear brightest to the observer W are widely hatched, whereas the darker portions of the highway surface are hatched horizontally. Because of the higher illumination intensity of the remote half of the surface, the parts of the light patches 17, 18 and 19 on this side are more brightly illuminated

than on the adjacent half. Comparison of the figure with Figure 3 clearly shows this difference. With the illumination according to the invention as shown in Fig. 7, the brightness differences are smaller in a lateral direction than with the illumination shown in Fig. 3, so that a material advantage is obtained already in this respect.

The term "light source" as used herein is to be understood to mean one or more light-emitting members supported from one post. This may be one or more incandescent lamps and/or one or more discharge tubes, such as the super-high-pressure mercury-vapor discharge tubes described in the U. S. Patent No. 2,094,694 to Bol et al. These lamps, which will hereinafter be mentioned as light-radiating members, may each be located in a separate reflector or together in one reflector. In practice it is, of course, simpler and cheaper to use only one reflector to each post, and in such cases the reflector may have a very special shape.

As shown in Fig. 8 the advantages of the invention are more pronounced when the highway surface is wet. As the surface gradually becomes wet, to the observer W it appears, as if the brightest parts of the light patches slowly shift towards the light sources from which they originate, although sufficient brightness remains on the remote half of the highway. This phenomenon is caused by the fact that when the surface becomes wetter, the brightness coefficients greatly increase at those points at which the projection of the direction of observation on the surface has substantially the same direction as the corresponding projection of the direction of incidence of the light, whereas the brightness coefficients pertaining to combinations of projection of directions of incidence and observation, which are at different angles with each other, decrease comparatively strongly. Due to the fact that, according to the invention, each light source illuminates the "remote" half of the road with a much greater illumination intensity than the "adjacent" half, these brightness differences are eliminated for a very large part. As shown in Fig. 8, the light patches 20, 21 and 22 are formed, and the brightness distribution in a lateral direction of the wet highway is appreciably better than that shown in Fig. 4.

The above is illustrated more clearly in Figs. 9 and 10, of which Fig. 9 is a side view of a highway on which one light source 1 is located, and Fig. 10 is a plan view of the highway. As shown in Fig. 9, light source 1 illuminates the highway surface at least on one side of a "normal" plane indicated by reference numeral 23. Let us now consider the conditions prevailing on one side of this plane, namely, the right-hand side. Planes indicated by reference numerals 24 and 25 pass through the light source 1 and make angles of about 30° and 60° respectively with the normal plane 23, and, as shown in Fig. 10, intersect the surface of the highway in lines 74 and 75 which are normal to the longitudinal axis X—X. In accordance with the invention the illumination of the surface is such that at least in the strip of the highway surface between lines 74 and 75 the illumination of the "remote" half i. e. the portion below axis X—X is at least twice the illumination of the "adjacent" half, i. e. the portion above axis X—X.

As shown in Fig. 10, the light source 1 throws a light patch 26 (seen from above) on the highway surface. In the conditions illustrated, the illumination substantially throughout the length

of patch 26 are at least two times as high as those at points located symmetrically with respect to the road axis X—X on the adjacent half of the surface. For example the illumination at the points indicated has the following relation:

Illum. intensity at 28: ill. intensity at 27= 2:1  
 Illum. intensity at 30: ill. intensity at 29= 5:1  
 Illum. intensity at 32: ill. intensity at 31= 9:1  
 Illum. intensity at 34: ill. intensity at 33=10:1  
 Illum. intensity at 36: ill. intensity at 35=10:1

From these values it appears that the ratios are frequently much larger than 2:1. However, values of illumination of 2:1 with a fairly diffused road surface yield satisfactory results. The choice of the illumination and of the mutual relation depends greatly on the nature of the surface of the highway.

From Figure 10 it also appears that the light patch 26 extends a considerable distance to the right of the intersecting line 75. In this case, the selection of the length of the light patch is substantially determined by the distance between the light sources.

It is also possible to produce on the left side of plane 23, a light patch (not shown) which has the same shape as the light patch 26 but is reversed. However, in this case it is possible to use a quite different light distribution which greatly depends on the positioning of the light sources, on the ruling direction or directions of traffic, etc. This will be more clearly explained by reference to the Figures 11 to 13.

Fig. 11 shows the conditions for a highway having two right-hand traffic directions indicated by arrows 37 and 38, and with the light sources 1, 2 and 3 located on the same side of the highway and producing light patches 39, 40 and 41 respectively. These light patches overlap each other and each patch consists substantially of two adjacent patches each similar to patch 26 of Fig. 10.

When the highway is intended for unidirectional traffic, the light sources are positioned in the manner illustrated in Fig. 11; in countries keeping to the right normal traffic is designated by the arrow 37, and for countries keeping to the left by 42. In this case, the conditions are about ideal.

Fig. 12 shows a highway with the light sources 1, 2 and 3 spaced apart at equal distances but with successive light sources located on opposite sides. The light patches are indicated with the same reference numerals as in Fig. 11, and each consists of two portions which extend to different length to each side of the corresponding light source. Also in this case it clearly appears that the light patches partly overlap each other. The traffic directions for right-hand traffic are indicated by arrows 37 and 38. Due to the fact that the light-patch halves are asymmetrical dazzling is practically completely eliminated as the length of the lightpatches in the direction opposite to the direction of traffic is smaller than the length of these patches in the direction of traffic.

When the light sources are positioned in the manner illustrated in Fig. 13, i. e. similar to Fig. 12 but spaced apart unequal distances, the light patches are asymmetrical and dazzling is entirely avoided. For instance, a motorist at a point 42 and traveling in the direction of the arrow, is practically not troubled by the light from the beam portion produced by light source 1 and directed towards him, whereas when he has arrived at a point 43, the light source 1 radiates over him in his traffic direction. The great advan-

tage is, however, that the light source 2 throws a strong beam on the opposite half of the highway surface which enables him to see the surface evenly brightly illuminated in a lateral direction (due to the difference in brightness coefficients). This impression always subsists; also in the systems shown in Figs. 11 and 12.

The above will be clarified by a numerical example. Assuming the ideal case which, however, never occurs in practice, i. e. that a highway surface in the dry state is of uniform brightness throughout its length, it is found that the brightness of such a surface when wet show differences in brightness of 16:1; assuming that the brightnesses on the side of the highway at which both the observer and the light source are located are 16 times as great as those on the opposite side. We have found that a very great improvement is obtained when the remote surface portion i. e. the portion opposite a light source (and the observer) in its dry state shows a brightness which is four times as great as on the side adjacent the light source. As a result the brightness of this surface on adjacent side wet state is four times as great as the brightness on the opposite side. From this it follows that the relation 1:16 has been reduced to 1:4.

The construction and positioning of a reflector which distributes light in the manner shown in Fig. 11, will be explained with reference to the Figures 14 and 15. In Fig. 14 the major axis of such a reflector is denoted by the line XY. In a plane V passing through line XY is a curved line 43—44—45, which acts as the generatrix of the side portions of the reflector. As regards its position and form, this line determines to a large degree the direction of the light beam reflected by the reflector surface portion generated thereby. It will be appreciated that for every special case line 43—44—45 must be given a different form, and it is preferably formed by a second degree curve, such as a parabola, whose focus F lies in line XY. In this case line 44—F is the axis of the parabola 43—44—45 and by varying the angle 44—F—X it is possible to vary, in accordance with the width of the highway surface to be illuminated, the position of the reflected beam formed by the reflector portion generated. We have found that the deviation from the perpendicular position of line 44—F relative to XY may have a maximum value of 10°, i. e. the angle 44—F—X may be from 80° to 100°.

When the reflector has to throw two equal and opposite light beams on the highway surface, such as is the case, for instance, in Fig. 11, a generatrix similar to generatrix 43—44—45 is provided on the opposite side of the line XY, so that a plane perpendicular to plane V and passing through line XY can be considered as the "symmetry" plane of the reflector. When, however, the reflector emits only one strong beam, for instance the left half of the beam 40 in Fig. 11, only one of the elongated reflector portions is formed in the manner shown in Fig. 14.

In forming the reflecting surface portion, the generatrix 43—44—45 is moved so that the surface formed intercepts planes A, B and C, which extend normally to axis XY, in parabolic directrices 46, 47 and 48 whose foci lie in the points of intersection of planes A, B and C with the major axis XY. Consequently the major axis XY forms the geometrical position or locus of the foci of parabolas 46, 47 and 48. The above may be more clearly explained by using expressions employed in ship-building, in which planes A, B and

C would be the frame planes and lines 46, 47, and 48 would be frame lines.

The axes of the parabolas lying in the frame planes, i. e. lines 49—50, 51—F, and 52—53, preferably make an angle C of about 20° to 40° with the plane determined by lines 44—F and XY, which plane will hereinafter be called the "major" plane.

As has been stated, at least one of the extreme elongated reflector portions is formed in the manner shown in Fig. 14. It will be appreciated that the intermediate portion which intersects the elongated reflecting position shown in Fig. 14 along line 76—77—78 and which part is noted in Fig. 16 above line QR may be constructed in various ways in accordance with the nature and the direction of the light beams to be obtained. This is of less importance than the form of the elongated reflector portions, but the intermediate portion is preferably so constructed that it shows a dent in a plane extending perpendicularly to the line 44—F and XY i. e. in the symmetry plane. The transition curve of each of the elongated edges with the intermediate portion preferably lies in a plane M which extends through the major axis XY and makes an angle  $d$  of the order of magnitude of 10°, with the major plane. In Fig. 14 this transition curve is indicated by reference numerals 76, 77 and 78.

Fig. 15 shows schematically how the reflector is positioned on the side of a road surface and the relative position of the main direction. This figure shows a highway surface in oblique projection having a center line I—I. The reflector is supported from a post 54, and the plane perpendicular to center line I—I and passing through the center line of post 54 is indicated by reference letter Z, being the normal plane out of Figures 9 and 10. The major axis XY shown in Fig. 14 is denoted with the same reference numerals in this figure, and lies in the plane Z, but as the opposite side of the highway is at a comparatively large distance from post 54 the axis XY is inclined at an angle  $f$  of about 45° to a line XG lying in plane Z and extending parallel to the surface of the highway. A so-called major plane N, which includes the generatrices, extends perpendicularly to plane Z and passes through the axis XY.

If the reflector is to provide for the distribution of light illustrated in Fig. 11, plane N includes two generatrices 43—44—45, which lie symmetrically with respect to line XY, and as shown in Fig. 14 these directrices are formed as parabolas and have a common focus at F. The axis of these parabolas are denoted by 44—F and both of the angles 44—F—X equal 88°; however, as stated they may also have different values. The generatrices 43—44—45 are moved along the directrices 46, 47 and 48, to generate two reflecting portions.

From Fig. 15 it appears that the two parabolas 46 lie in the plane A, and their foci lie at the point of intersection of plane A and axis XY, whereas parabolas 44 and 45 lie in the planes B and C respectively. As will be set out hereinafter, the light-radiating member L is so positioned with respect to the said reflector surfaces that at least its main direction intersects the major planes at least substantially perpendicularly in the common focus of the generatrices.

The position of the above-mentioned reflecting edge portions, the intermediate reflecting portion, and the position of the light source will be more clearly set forth with regard to Figs. 16, 17, and

18. In these figures the light source L is constituted by a super-high-pressure mercury vapor discharge tube located in a bulb; such light sources being described in the above-mentioned patent to Bol et al.

The major axis of the reflector mentioned in connection with Figures 14 and 15, is indicated by XY in Figs. 16 and 17, and Figure 17 shows the position of the generatrices 43—44—45; the projections of the generatrices lying in a plane with line XY in Fig. 16. In the form of construction illustrated, generatrices 43—44—45 are parabolas whose common focus lies at F, and whose axes indicated lines 44—F—F in Fig. 17 make in this case angles 44—F—X, of the order of magnitude of 80°, with the axis XY. The frame planes extend perpendicularly to line XY i. e. perpendicular to the plane of the drawing in Fig. 16. Furthermore, Fig. 16 shows the position of one of the elongated reflector portions generated by one of the generatrices moving along the frame lines, this portion being denoted by QKRSTU. In Fig. 16 the extreme limiting edge of the reflector lies in a plane indicated by line STU, which plane preferably makes an angle YXS of the order of magnitude of 15° to 35° with the major axis XY.

The reflector is provided with an aperture 66 for introducing the bulb 80 which is mounted in a suitable fitting 61. The position of aperture 66 and the supporting edge 62 of the reflector may be different from that shown, as will be explained hereinafter. The reflector is secured by means of the supporting edge 62 to a post 64 which is located perpendicularly to and at the side of the highway surface. (Not shown.)

In Figures 16 to 18 the light source L is a high-pressure mercury-vapor discharge tube having a contracted discharge path, and is so positioned that the axis of the discharge path perpendicularly intersects a plane passing through the axis XY and perpendicular to the plane of the drawing in Fig. 16 in the common focus F of the two generatrices. Although such a light source is particularly adapted for this purpose because of its high surface brilliance, and incandescent lamp provided with a filament, preferably of semicircular shape, may also be used successfully. When using an incandescent lamp the main direction extending through the center of gravity of the filament is located at the same place as the axis of the discharge path in Fig. 16. In order to use a lamp having a standard filament, it is desirable in this form of construction that the neck axis should coincide with the major axis XY, and for this purpose the center of the aperture 66 in the reflector is located in a plane perpendicular to the main axis XY, as shown in Fig. 16.

In regard to Figs. 16, 17, and 18, it should be noted that when such a reflector is used for highway lighting in which only one very strong beam is directed to the opposite side of the highway, such as illustrated in Fig. 13, only one of the extreme elongated reflecting surfaces is constructed as shown in the drawings. More particularly, only one side would be provided with the portion QXRSTUZ shown in Fig. 16, whereas the opposite reflecting side of the reflector would be shaped to the form and the direction of the weaker beam of light to be reflected thereby.

While we have described our invention with reference to specific examples and applications, we do not wish to be limited thereto, but desire the appended claims to be construed as broadly as permissible in view of the prior art.

What we claim is:

1. In combination, a highway having a surface, a light source at one side of the highway and at least three meters above the surface thereof, and reflecting means cooperating with said light source to illuminate the "remote" half of the highway surface portion lying between the intersecting lines with the surface of planes making angles of at least 30° and 60° with the "normal" plane, with an intensity of at least twice the intensity on the "adjacent" half.

2. A highway lighting system comprising a light source at one side of the highway and at a height of at least three meters, and reflecting means cooperating with said light source to illuminate the "remote" half of the highway surface portion lying between the intersecting lines with the highway surface of planes making angles of at least 30° and 60° with the "normal" plane, with an intensity of at least twice the intensity on the "adjacent" half, said means comprising a reflector whose major axis is perpendicular to the longitudinal axis of the highway and having a surface portion having a generatrix, and parabolic directrices lying in planes perpendicular to the major axis with their foci lying in said axis.

3. A highway lighting system comprising a light source at one side of the highway and at a height of at least three meters, and reflecting means cooperating with said light source to illuminate the "remote" half of the highway surface portion lying between the intersecting lines with the highway surface of planes making angles of at least 30° and 60° with the "normal" plane, with an intensity of at least twice the intensity on the "adjacent" half, said means comprising a reflector whose major axis is perpendicular to the longitudinal axis of the highway, and having two reflecting portions arranged symmetrically with respect to the major axis, each of said portions having a generatrix, and parabolic directrices lying in planes perpendicular to the major axis with their foci in said axis.

4. A highway lighting system comprising a light source at one side of the highway and at a height of at least three meters, and reflecting means cooperating with said light source to illuminate the "remote" half of the highway surface portion lying between the intersecting lines with the highway surface of planes making angles of at least 30° and 60° with the "normal" plane, with an intensity of at least twice the intensity on the "adjacent" half, said means comprising a reflector whose major axis is perpendicular to the longitudinal axis of the highway and having two portions arranged symmetrically with respect to the major axis and having generatrices in the form of second degree curves whose foci lie in the major axis and forming edges of the portions lying in a common plane, and parabolic directrices lying in planes perpendicular to the major axis with their foci in the major axis, and an intermediate reflecting portion having a dent in the plane of symmetry of the reflector.

5. A highway lighting system comprising a light source at one side of the highway and at a height of at least three meters, and reflecting means cooperating with said light source to illuminate the "remote" half of the highway surface portion lying between the intersecting lines with the surface of planes making angles of at least 30° and 60° with the "normal" plane, with an intensity of at least twice the intensity on the "adjacent" half, said means comprising a reflector whose major axis is perpendicular to the longitudinal

axis of the highway and having two portions arranged symmetrically with respect to said axis and having generatrices in the form of second degree curves whose foci lie in said axis, and parabolic directrices lying in planes perpendicular to said axis with their foci in the axis, the axis of said directrices making angles of between 20° and 40° with the major plane of the reflector.

6. A highway lighting system comprising a light source at one side of the highway and at a height of at least three meters, and a reflector whose major axis is perpendicular to the longitudinal axis of the highway and having two reflecting portions arranged symmetrically with respect to the major axis and having generatrices whose foci lie in the major axis, and parabolic directrices lying in planes perpendicular to the major axis with foci in the major axis, and an intermediate reflecting portion intersecting said first two portions in lines lying in planes making an angle of the order of 10° with the major plane of the reflector.

7. A highway lighting system comprising a light source at one side of the highway and at a height of at least three meters, and a reflector whose major axis is perpendicular to the longitudinal axis of the highway and having two portions arranged symmetrically with respect to the major axis and having generatrices whose foci lie in the major axis and whose axis make an angle of between 80° and 100° with the major axis, and parabolic directrices lying in planes perpendicular to the major axis with foci in the major axis.

8. A highway lighting system comprising a light source at one side of the highway and at a height of at least three meters, and a reflector whose major axis is perpendicular to the longitudinal axis of the highway and having two portions arranged symmetrically with respect to the major axis and having generatrices whose foci lie in the major axis, and parabolic directrices lying in planes perpendicular to the major axis with foci in the major axis, the edges of said reflector lying in a plane making an angle of from 15° to 35° with the major axis.

9. A highway lighting system comprising a light source at one side of the highway and at a height of at least three meters, and a reflector whose major axis is perpendicular to the longitudinal axis of the highway and having two portions arranged symmetrically with respect to the major axis and having generatrices whose foci lie at a common point in the major axis, and parabolic directrices lying in planes perpendicular to the major axis with foci in the major axis, the main direction of the light source being substantially perpendicular to the major plane of the reflector and intersecting the same at the common focal point of the generatrices.

10. A highway lighting system comprising an incandescible lamp disposed at one side of the highway and having a neck portion, said lamp being at least three meters above the surface of the highway, and a reflector whose major axis is perpendicular to the longitudinal axis of the highway and having two portions arranged symmetrically with respect to the major axis and having generatrices whose foci lie in the major axis, and parabolic directrices lying in planes perpendicular to the major axis with their foci in the major axis, the axis of the neck portion of the lamp passing through the common focal point of the generatrices and forming an angle of from 30° to 40° with a plane passing through the generatrices at the edges of said portions.

11. In a highway lighting system a high-pressure metal-vapor discharge tube having a contracted discharge path and located at one side of the highway and at a height of at least three meters, and a reflector whose major axis is substantially perpendicular to the longitudinal axis of the highway and having two reflecting portions arranged symmetrically with respect to the major axes and having generatrices whose foci lie at a common point in the major axis, and parabolic directrices lying in planes perpendicular to the major axis with their foci in the major axis, the discharge path of the tube lying in a line passing through the common foci of said generatrices.
12. In a highway lighting system an incandesible lamp having a filament and located at one side of the highway and at a height of at least three meters, and a reflector for said lamp having a major axis substantially perpendicular to the longitudinal axis of the highway, said reflector having two reflecting portions each having a generatrix whose focus lies in a common point on the major axis, and parabolic directrices lying in planes perpendicular to the major axis, said lamp having a "main" direction passing through the common focus and substantially perpendicular to a plane passing through the edge generatrix of each of said portions.

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