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# AUTOMATIC STEERING APPARATUS

Filed March 24, 1944

2 Sheets-Sheet 1

*Fig. 1*

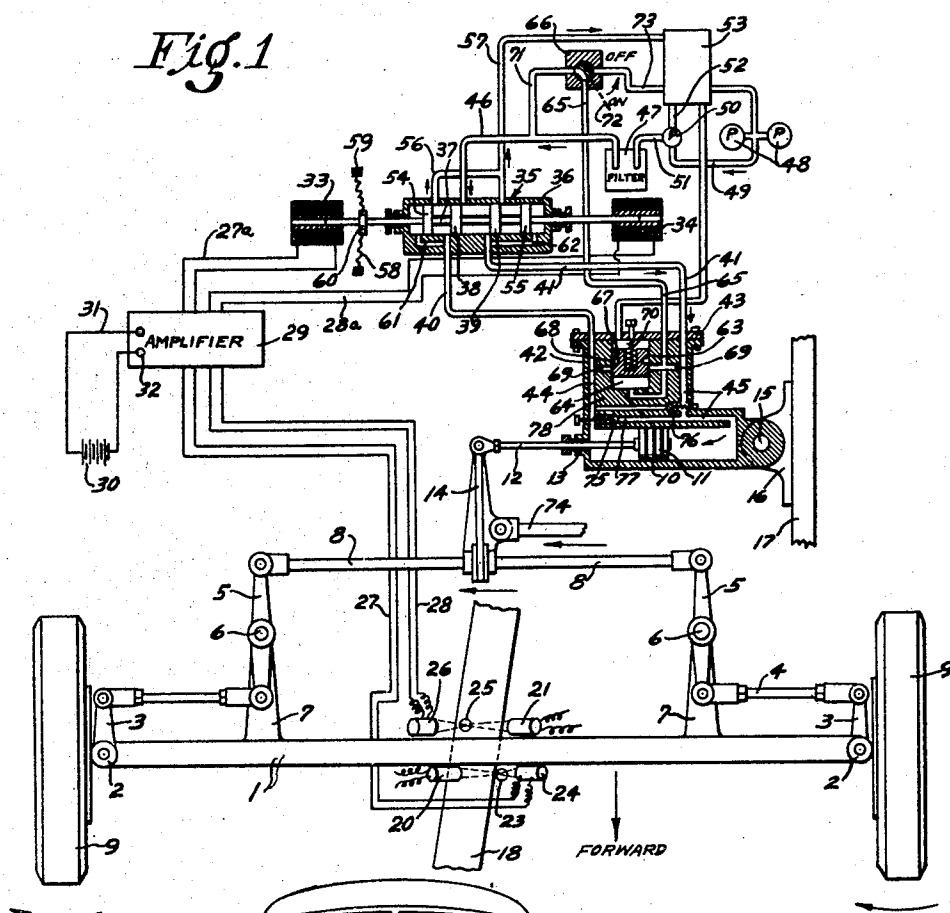
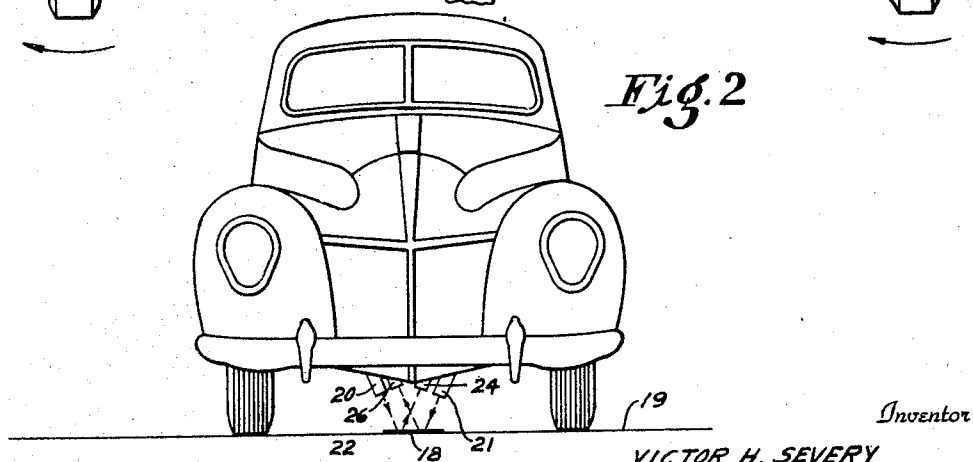


*Fig. 2*



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2 Sheets-Sheet 2

*Fig. 3*

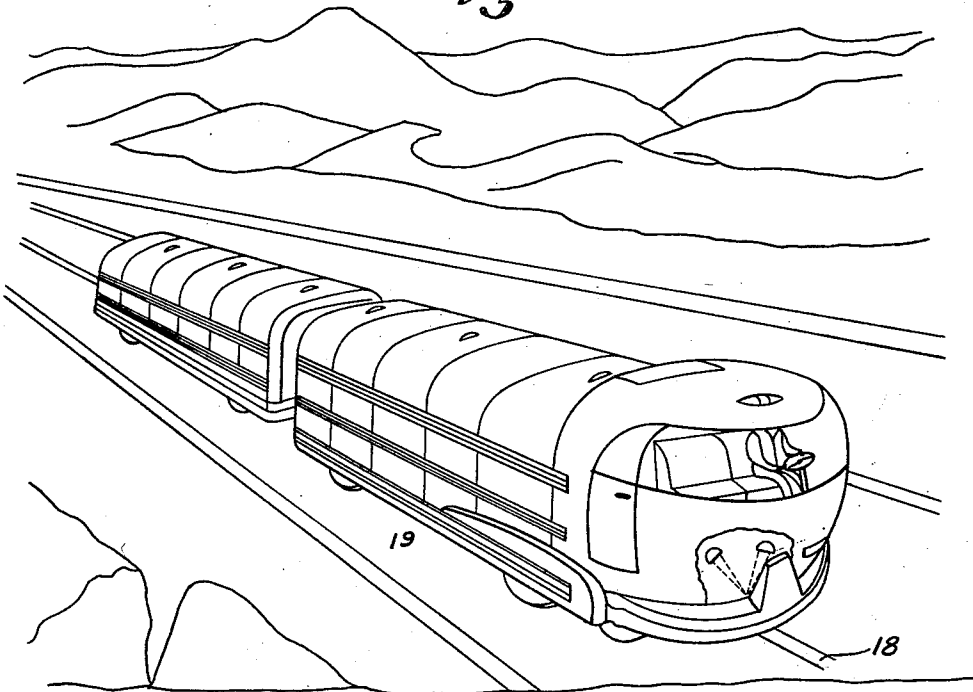
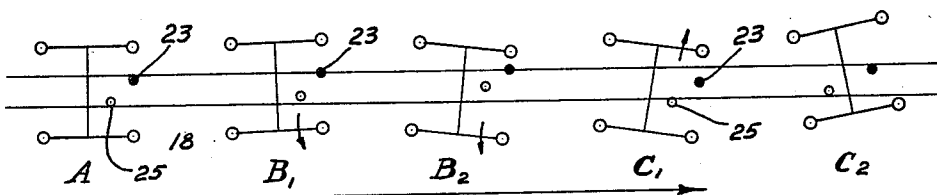


*Fig. 4*



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## UNITED STATES PATENT OFFICE

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## AUTOMATIC STEERING APPARATUS

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8 Claims. (Cl. 180—79.2)

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This invention relates to a method and apparatus for effecting the automatic steering of a vehicle running along a roadway, to maintain the vehicle in the middle of the roadway or in the middle of the lane on which the vehicle should run.

An object of the invention is to provide a simple method and apparatus for utilizing a guide-strip extending along the middle of the lane, to control the steering apparatus of the vehicle, such as an automobile or truck, in such a way as to maintain the vehicle in line directly over the guide-strip.

In practicing the invention I provide a guide strip extending along the roadway; and on the vehicle I provide electro-mechanical apparatus including means cooperating with the strip, and particularly its edge portions, in such a way that as long as the vehicle is running normally over the strip the steering gear will be unaffected, but when it deviates from the line the electro-mechanical apparatus is immediately affected, and proceeds to move the steering mechanism in the proper direction to bring the vehicle back into line over the strip.

Another object of the invention is to provide a simple method and apparatus for utilizing rays reflected from a strip or band, for effecting the automatic steering of a vehicle such as an automobile, and maintaining the same in line over such a band extending along a roadway.

In accomplishing the above objects, a further object is to provide means for projecting rays onto a reflecting guide-strip so that the points of impingement of the instant rays onto the guide-strip are so related that if a portion of the rays projected onto the guide-strip should fail to impinge upon the guide-strip, the steering mechanism of the vehicle will automatically be affected to steer the vehicle and bring it back into a substantially central and aligned position over the guide-strip.

In practicing the invention, I prefer to employ two distinct light rays or beams, one of which is projected onto the guide-strip near an edge of the guide-strip, and the other of which is projected onto another edge of the guide-strip at a point located in a forwardly disposed position with respect to the first-named ray or beam; and one of the objects of my invention is to provide means whereby the reflected rays, through the agency of electric circuits, are utilized to maintain a control member or valve normally in a mid position, which of course would correspond to a proper central position of the vehicle directly

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over the guide-strip, and with its longitudinal axis substantially coinciding with the vertical plane extending through the central axis of the guide-strip; and to maintain normally a condition of balance between devices in branch electric circuits corresponding to each of the rays, operating in such a way that if the vehicle becomes out of line over the guide-strip, one of the points of impingement of one of the rays will pass off of the reflecting area of the guide-strip, thereby developing an unbalance which I utilize to affect the steering mechanism to bring the vehicle back into proper alignment over the guide strip.

In the preferred embodiment of the invention, I employ a steering device or fluid-operated cylinder for controlling steering gear, and this steering device, in the operation of the apparatus, is controlled through the agency of the two branch circuits controlled by the two reflected rays; and one of the objects of the invention is to provide means associated with this actuating device or steering cylinder, that will enable its automatic operation through the agency of the rays to be inhibited to prevent the same from interfering with regular hand-steering of the vehicle whenever it may be necessary or advisable to steer the vehicle by hand.

Another object of the invention is to provide improved relief means associated with the steering cylinder and inhibiting device, which will prevent any possibility of pressure being built up in the steering cylinder above a predetermined limit with which the cylinder is intended to operate, the general purpose being to prevent too sudden actuation of the steering means, which of course might cause an accident. In this way I attain the purpose of having the apparatus operate generally by making very slight corrections in the position of the steering wheels or mechanism, rather than to operate by making relatively large movements of the steering gear; in other words, the apparatus and method operate to make slight and continual corrections in the position of the steering gear to maintain the vehicle running in line over the guide-strip whenever the vehicle has made any deviation from its course, sufficient to bring the impinging point of a portion of the rays off of the reflecting surface of the strip.

Further objects of the invention will appear hereinafter.

The invention consists in the novel parts and combination of parts, and also in the novel combination of steps, all of which contribute to produce an efficient apparatus and method for ef-

fecting the automatic steering of a vehicle on a roadway.

A preferred embodiment of the invention is described in the following specification, while the broad scope of the invention is pointed out in the appended claims.

In the drawing:

Fig. 1 is a diagrammatic plan of the apparatus, a portion of which is shown in plan, while much of it is shown in horizontal cross-section. This view illustrates the forward wheels and steering gear of a vehicle such as an automobile, to which the apparatus as illustrated, is applied. Fig. 1 also indicates the position and relation of the guide strip on the roadway, to the vehicle when it is running in line with the strip.

Fig. 2 is a front elevation of an automobile, and illustrating the means for projecting and reflecting the light rays from the car and back to the car, for effecting the control of the steering of the car.

Fig. 3 is a perspective showing a view of a truck and trailer, the forward portion of the truck being broken away to indicate the point at which the light-ray devices would be installed so as to maintain the truck in line with the guide-band in the lane on which the truck and trailer are running.

Fig. 4 is a view of a diagrammatic nature, graphically illustrating a way in which the position of the point of impingement of the light rays on the roadway controls the steering of the vehicle.

Before describing the invention more in detail, it should be understood that broadly it consists of a control apparatus involving the use of an elongated guide cooperating with means for projecting two rays or beams of light onto the guide means, one of the points of impingement of the light being adjacent one edge of the guide means and the other adjacent the other edge of the guide means. If, in the operation of the control part one of the points of impingement or light spots is caused to pass partially or completely off of the guide means, the apparatus will then be affected to effect the control. In order to accomplish this I employ two branch circuits in each of which there is a light sensitive resistance which cooperates with its corresponding ray or beam referred to above. By balancing the force of the electric current in these two branch circuits against each other, I am enabled to provide a control apparatus capable of use for any desired specific purpose that depends for its action and operation upon whether either or both of the light spots are impinging on the elongated guide-means. Although this invention can be used in many situations, I have described it in the present specification as applied to the steering of a vehicle along a roadway.

Referring particularly to Figs. 1 and 2, I indicate an axle of the vehicle, preferably the front axle, the ends of which are provided with steering knuckles 2 having steering arms 3. Each of these arms is connected up by an adjustable link 4 to a lever 5, the fulcrum pin 6 of which is on the end of a fixed bracket 7 that may be attached to the rear side of the axle. The rear arms of the levers 5 are connected by a link 8. In applying my invention to such a vehicle steering apparatus, I provide means for shifting the link 8 to move the wheels 9 on the axes of their steering knuckles 2, and in order to accomplish this, I provide a fluid-operated power device which, in the present instance, consists of a fluid-operated cylinder 10

having a piston 11 within it, which is normally located at an intermediate point in the cylinder. This point is normally the middle point in the length of the cylinder, and the piston 11 carries a piston rod 12 that extends through a stuffing-box 13 at the inner end of the cylinder so as to be attached to a rigid arm 14 that projects laterally from the link 8. The outer end of the cylinder 10 may be supported on a vertical pivot pin 15 to permit the inboard end of the cylinder to swing slightly in a fore-and-aft direction when the link 8 is shifted. This is necessary on account of the fact that the ends of the link 8 rotate about the pivot points 6. The pivot pin 15 for the cylinder may be attached to a bracket 16 that is secured to the side of the frame member 17 of the vehicle frame.

In accordance with my invention, I provide means for admitting fluid under pressure to either end of the cylinder 10, depending upon the direction of the necessary steering movement that must be given to the wheels 9 to correct their position and maintain the body of the vehicle running in line with the guideband 18 that extends longitudinally along the roadway 19, and in the middle of the lane along which the vehicle travels.

For this purpose at a suitable point on the vehicle, for example, at the front axle 1, I provide means for projecting light rays onto the guide-strip 18. This guide-strip must have a surface capable of reflecting the rays projected upon it. For this purpose an ordinary white band such as now used on roadways for marking lanes, is found to be satisfactory. The means for projecting the rays preferably comprises two electric illuminating devices or lamps 20 and 21. As illustrated in Fig. 1, the lamp 20 is located on the forward side of the axle 1, and is in the form of a tubular lens box carrying condensing lenses for focusing a ray or beam 22 down onto the guide-strip 18 in an inclined direction as illustrated in Fig. 2, and this ray is reflected up from its point of impingement indicated by the circle or spot 23. From this reflecting point 23 the ray is reflected up onto a light-sensitive element such as a selenium cell or photoelectric cell 24 of any desired type. The lamp 21 back of the axle is mounted in the same way as the lamp 20, and throws a condensed light ray or beam down onto the strip 18 at the spot 25 from which this ray is reflected up onto a selenium cell or photoelectric cell 26. In this connection it should be understood that any type of light-sensitive device may be employed, capable of causing a change in the resistance to a current flowing in two branch circuits 27 and 28 that connect up to the light-sensitive devices 24 and 26. The lamps and light-sensitive devices are positioned so that the light spots 23 and 25 are located respectively near to different edges of the guide-band, and also so that one of these spots is in advance of the other with respect to the direction of travel of the vehicle on the roadway.

With this arrangement it will be evident that if the vehicle in its course, tends to deviate toward the left as it travels along the roadway in the direction of the arrow indicated in Fig. 1, the light spot 23 will pass off of the reflecting surfaces or area of the strip 18, and this will increase the resistance to the current passing in the branch circuit 27 as compared with the current passing in the branch circuit 28.

In practicing the invention, I balance these two currents against each other in suitable apparatus, and I utilize any unbalance existing in these two

branch circuits as compared with each other, to effect the proper movement in the steering apparatus for the wheels 9 to guide the vehicle back into line with the strip 18. In accomplishing this it is necessary to employ an amplifier 29 which may be energized by any suitable source of E. M. F. such as a battery 30 connected into a circuit 31 that connects up to the terminals 32.

The branch circuit 27 includes a section 27a on the output side of the amplifier, which is connected to a solenoid 33, and similarly the branch circuit 28 includes a section 28a that is connected up to the coil of a solenoid 34. These solenoids control means for admitting fluid under pressure to the cylinder 10, and in the present instance, this means consists of a valve device 35 having an elongated casing or barrel 36 in which a balanced piston valve is mounted to slide, said piston valve having a piston rod 37 the ends of which project into the coils of the solenoids 33 and 34, and part way through the same. The piston valve includes two piston heads 38 and 39 rigidly secured on the piston rod 37, and in the normal and neutral position of this valve, these two piston heads 38 and 39 cover outlet ports through the valve casing 36, that are connected up to inlet ducts or hose 40 and 41 that lead over to the block or casing 42 of which the cylinder 10 forms a part.

The hose 40 and 41 connect through the cover plate 43 on the casing 42, to inlet ports 44 and 45 that lead into the interior of the cylinder 10. The central chamber of the piston valve casing 36 is supplied with fluid under pressure through a supply pipe or hose 46 that leads to the same from a filter 47, said filter being supplied with fluid under pressure from a pump 48 through a delivery pipe 49 that delivers the fluid through a pressure-controlled device 50 that delivers the fluid under pressure through a delivery pipe 51 into the filter, said pressure device being provided with a lateral by-pass pipe 52 not under pressure, that leads excess fluid such as operating oil or similar fluid over to a sump or reservoir 53.

In addition to the heads 38 and 39 on the piston rod 37, two remote heads 54 and 55 are provided that are similar to the heads 38 and 39, and the space between the head 38 and 54 is connected to a branch outlet pipe 56 that connects to a return pipe 57, which return pipe is also connected through the casing 36 of this valve so that these two outlets 56 and 57 lead off from the interior of the casing 36 beyond the piston heads or valve heads 38 and 39.

In order to hold the piston rod 37 with its heads 38 and 39 normally in a neutral position, I provide yielding means connected with the piston rod for this purpose. In the present instance, this yielding means is in the form of a convoluted disc 58, the outer edge of which is held in a fixed frame 59 and the center of which is attached to a collar 60 rigidly secured on the piston rod 37. In Fig. 1 this disc is shown pulled slightly toward the right as though the current through the solenoid 34 has become substantially de-energized by reason of the fact that the light spot 23 has passed off of the area of the strip 18, as illustrated in Fig. 1.

The casing 36 is provided with vent ports 61 and 62, the former of which connects up to the inlet port or hose 40 and leads from the adjacent end of the casing 36 beyond the piston head 54. The port 62 is similarly located but leads from the opposite end of this casing 36. These vent ports 61 and 62 prevent accumulation of fluid

in the ends of the casing, in such a way as to interfere with the free movement of the piston rod 37 under the action of the solenoids.

The operation of my method, and the apparatus as described above, is illustrated in Fig. 1, which shows the piston valve moved from its neutral position toward the right. This movement would be occasioned by the light spot 23 passing off of the strip 18, as indicated in Fig. 1. When the piston valve moves over to the right to a position such as that indicated in Fig. 1, the outlet hose 41 will be immediately supplied with liquid under pressure, which will pass to the inlet port 45 for the cylinder 10, developing pressure in the right end of the cylinder 10, and this will move the piston 11 toward the left by shifting the link 8 toward the left as indicated by the arrow in Fig. 1. This will tend to swing the wheels 9 in the direction indicated by the arrows near them, and this will guide the vehicle back into alignment with the strip 18. If the vehicle deviates from its proper course, toward the right of the roadway, the light spot 25 would pass off from the strip 18, and an opposite effect would be occasioned in the solenoids 33 and 34, causing shifting of the piston valve heads 38 and 39 toward the left, which would admit the operating fluid to the inlet hose 40 instead of the hose 41. This would admit the operating fluid through the port 44 into the left end of the cylinder 10 instead of the right end, thereby developing an opposite steering effect that would swing the wheels 9 in a direction opposite to that indicated by their arrows, to bring the vehicle back into line with the strip 18.

In either case, when the piston valve is shifted to the right or to the left as described above, this valve will open communication to the return pipe 57 so that any liquid in the end of the cylinder toward which the piston 11 is moved, will find outlet through the valve casing 36 back to the sump 53.

This apparatus is preferably provided with means operable at will, to inhibit the operation of the cylinder 10 if it is desired to steer the vehicle by hand. In order to accomplish this, it is merely necessary to provide a by-pass for the fluid in the ends of the cylinder 10, so that when the fluid is forced out of one end of the cylinder by movement of the piston 11, it can pass around into the other end. If, in the design of an automobile provided with this apparatus, it is possible to locate the cylinder 10 in a convenient position so that a valved by-pass port between the ends of the cylinder 10, could be opened from the driver's position, this could be done in practicing this invention; but as the cylinder 10 in practice, would probably be located in an inaccessible position, I have illustrated means for utilizing the pressure existing in the pipe system to control the establishment of such a by-pass. In other words, I provide for a remote control through the agency of the pressure existing in the pipe system or hose system. For this purpose, in the casing 42 I provide an inhibitor device which includes a bore 63, the inner end of which forms a pressure chamber 64 to which fluid under pressure is normally admitted through a pipe connection or hose connection 65, the operating end of this hose connection 65 being connected to a three-way valve 66. The fluid pressure in the chamber 64 exerts its force against a movable member or piston 67 in the bore 63, and this piston has a circumferential port 68 which is normally held by the

pressure in the chamber 64 out of line with a cross port 69 that connects the two inlet ports 44 and 45 that communicate with the ends of the cylinder 10.

At the other side of this piston 67, resilient means in the form of a coil spring 70 is provided, which is a compression spring and normally held in a state of compression. However, if the pressure in the chamber 64 becomes relieved, then the spring 70 will move the piston 67 toward the forward end of the chamber 64 as illustrated in Fig. 1, and this will bring the circumferential groove 68 into line with the cross-port 69. This will of course open communication between the ends of the cylinder 10.

The valve 66 to which the pipe or hose 65 connects, has a port connected up to a pipe connection or hose 71 that leads over to it from the fluid supply pipe 46 leading from the filter 47; and the port and the plug of this valve 66 in its normal position, connects this pipe 71 to the pipe 65, thereby supplying liquid under pressure to the chamber 64.

However, if the lever of this valve, indicated by the dotted line 72, is swung back as indicated by its arrow, to the "off" position, then the port in this valve plug will open up communication between the pipe or hose 65 and return pipe 73 that leads back to the sump 53. This will isolate the cylinder 10 from the pressure system, and permit free movement of the piston 11 in the cylinder 10.

Any suitable means can be employed for connecting up a hand-steering gear to the wheels 9 for steering them. If desired, such a hand-steering mechanism can include a link 74, one end of which is pivotally connected to the arm 14.

The cylinder 10 and its piston 11 will not prevent the use of hand-steering at any time, to override the automatic steering, by reason of the presence of two spring pressed ball type valves 75 and 76, located respectively in by-pass passages 77 and 78 that connect the ducts 44 and 45. One of these check-valves is a relief for flow in one direction while the other relieves for flow in the other direction.

In Fig. 4 I illustrate graphically the manner in which the position of the reflected light spots on the strip 18, control the steering gear of the car. This Fig. 4 includes separate diagrams A, B<sub>1</sub>, B<sub>2</sub>, C<sub>1</sub>, C<sub>2</sub>. In the diagram A, both spots 23 and 25 are on the strip 18. In B<sub>1</sub>, the spot 23 is partly over the edge of the strip 18, which would seriously reduce the strength of the current passing through the coil of the solenoid 33, which would enable the solenoid 34 to pull the piston valve heads 38 and 39 over toward the position in which they are illustrated in Fig. 1. This would swing the wheels 9 toward the right as indicated by their arrows in Fig. 1, and bring the car back into line over the strip. This pulling action is indicated by the arrows in the small diagrams B<sub>1</sub> and B<sub>2</sub>. The diagram B<sub>2</sub> indicates the position of the wheels after the automatic steering apparatus has commenced to operate. The diagram C<sub>1</sub> illustrates the light spot 25 as having moved off of the right-hand edge of the strip, while the spot 23 is still on the strip. This would cause the solenoid controls to exert a steering movement on the wheels as indicated by the small arrow in Fig. 4, thereby turning the wheels toward the position shown in the diagram C<sub>2</sub>, which would bring the body of the car back into alignment with the strip.

In the operation of these light spots, it should

be understood that they would have the power and area to enable them to substantially affect the solenoids even if the light spots were only partially off of the reflecting area of the strip.

Special attention is called to the direction in which the downwardly directed ray impinges upon the guide strip. By reason of the fact that the direction of this ray is inclined to the vertical line, substantially all the ray is reflected onto the photoelectric cell that is cooperating with that particular ray projecting means. The efficiency of reflection is increased due to this inclined direction in which the ray impinges upon the guide strip.

Although I have described and illustrated a simple narrow strip 18 as a control or guide-strip for the apparatus, it should be understood that this strip may be made as wide or as narrow as may be desired, and variations in the character of this strip could be made while still practicing the invention.

Many other embodiments of the invention may be resorted to without departing from the spirit of the invention.

What I claim is:

1. In vehicle guiding apparatus for guiding a vehicle passing along a roadway, the combination of a reflecting guide-strip of substantially uniform width extending along the roadway, means for projecting a ray of light onto the guide-strip adjacent one edge thereof so that the ray is reflected from the same, a second means for projecting a ray of light onto the guide-strip adjacent another edge thereof so as to be reflected from the same, located forward, or aft, behind, the first-named means, a light-sensitive element upon which the first named light ray normally impinges to form a lighted spot on the guide strip when the vehicle is running normally in line with the said strip, a second light-sensitive element upon which the other ray impinges to form a lighted spot on the guide strip when the vehicle is running normally in line with said strip, electric circuit means including a branch-circuit corresponding to each of said light-sensitive elements, and connected to the same, and means controlled by said electric means through the agency of said branch-circuits for maintaining the vehicle in line with said guide-strip the said fore and aft relative positions of said light projecting means operating to displace one or the other of the said light spots from the guide strip when the vehicle becomes out of the line with the guide strip.

2. In vehicle guiding apparatus for guiding a vehicle having a pair of steering wheels, in passing along a roadway, the combination of a reflecting guide-strip of substantially uniform width extending along the roadway, means carried on the vehicle for projecting a ray of light onto the guide-strip adjacent an edge thereof so that the ray is reflected from the strip back toward the vehicle, a second means for projecting a ray of light onto the guide-strip adjacent another edge of the strip, at a spot forward or aft with relation to the spot of impingement of the first-named ray and so as to be reflected from the strip, a light-sensitive element upon which the first named light ray normally impinges when the vehicle is running normally in line with said strip, a second light-sensitive element upon which the other ray impinges when the vehicle is running normally in line with said strip, electric-circuit means including a branch-circuit corresponding to each of said light-sensi-

tive elements and connected to the same, and means controlled by said electric means connected to the steering wheels for moving the same to steer the vehicle into line over the strip when the longitudinal axis of the vehicle gets out of substantial parallelism with the axis of the strip so that either of said light rays impinges upon the roadway off of the area of said guide-strip.

3. In a vehicle control apparatus for guiding a vehicle passing along a roadway, the combination of a reflecting guide-strip extending along the roadway, means for projecting rays of light onto the guide-strip so that they are reflected from the same, an electric-circuit including light-sensitive means mounted in the path of the reflected rays, a pipe system including fluid-operated means connected into the pipe system for controlling the steering of the vehicle, a valve for controlling the flow of fluid to the fluid-operated means, means connected with the electric-circuit for normally maintaining the valve in a neutral position and controlled through the agency of the said light-sensitive means, all of said parts cooperating when a portion of the rays of light fails to impinge on the guide-strip, to move the valve in a direction that will steer the vehicle back into line with the guide-strip; a valve in the pipe system movable at will, and means controlled by said valve for inhibiting the operation of said fluid-operated means so as to prevent the fluid-operated means from interfering with steering the vehicle by hand.

4. A vehicle automatic control apparatus according to claim 3, in which the fluid-operated means consists of a cylinder with a piston normally located at an intermediate point in the length of the cylinder when the vehicle is running normally in line with the guide-strip, and in which the means controlled by the hand-operated valve for inhibiting the automatic steering includes a pressure-controlled part to which the fluid under pressure is admitted, and by-pass ports controlled by the said pressure-controlled part for opening communication between the ends of the cylinder when the steering is to be accomplished by hand.

5. In a vehicle control apparatus for guiding a vehicle passing along a roadway, the combination of a reflecting guide-strip extending along the roadway, means for projecting rays of light onto the guide-strip so that they are reflected from the same, an electric-circuit including light-sensitive means mounted in the path of the reflected rays, a pipe system including a fluid-operated cylinder with a piston therein, with means to connect the same to steering means of the vehicle to control the same, means for controlling the flow of the operating fluid to the said cylinder, means connected into the said electric-circuit for normally maintaining said last named means in a neutral position and controlled through the agency of said light-sensitive means, all of said parts cooperating when a portion of the rays of light fails to impinge on the guide-strip, to move the fluid-controlled means in a

direction that will admit fluid to the said cylinder to enable the said piston to effect the steering of the vehicle back into line with the guide-strip, a manually-controlled valve connected into the pipe system, movable at will, and an inhibitor-device associated with the cylinder, having ports for the fluid and including means controlled by the pressure in the pipe system for normally holding the inhibitor-device in a condition to permit operation and control of the said cylinder through the agency of said light-sensitive means, and a spring associated therewith for actuating the inhibitor-device when the fluid pressure within the same is relieved, to control said ports to open communication between the ends of said cylinder, and thereby permit free movement of the piston, so as to prevent the fluid-operated cylinder from interfering with steering the vehicle by hand.

6. In an automatic control apparatus for steering a vehicle having a steered wheel or wheels, the combination of a pipe-system for conducting fluid under pressure, a steering cylinder connected to the pipe-system, having a piston normally disposed in an intermediate position in the cylinder, and having means connecting the same with the steered wheel or wheels, for steering the vehicle, a valve for controlling the admission of the fluid under pressure to either end of said cylinder, an inhibitor device associated with said cylinder, including a pressure chamber and a pressure-controlled member therein, said inhibitor device and cylinder having by-pass ports capable of opening communication between the ends of the cylinder; and means for controlling the flow of fluid pressure to said chamber to control the position of the said movable member therein.

7. An automatic steering apparatus according to claim 6, including resilient means associated with the movable member of said inhibiting device for opposing the fluid pressure acting upon the same, and operating when the pressure fluid is cut off, to move the said movable member in the said chamber and thereby effect communication between the ends of the steering cylinder.

8. An automatic steering apparatus according to claim 6, including an admission port corresponding to each end of the cylinder for admitting the operating fluid into the same, and having a pressure relief port including a spring-pressed relief-valve leading from each admission port over to the opposite admission port.

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