

United States Patent

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[72] Inventor **Bruce H. Bettcher**
Bellevue, Wash.
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[73] Assignee **Energy Control Corporation**
Bellevue, Wash.

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Primary Examiner—Benjamin Dobeck
Attorney—Christensen, Sanborn & Matthews

[54] **MARINE AUTOPILOT SYSTEM**
12 Claims, 8 Drawing Figs.

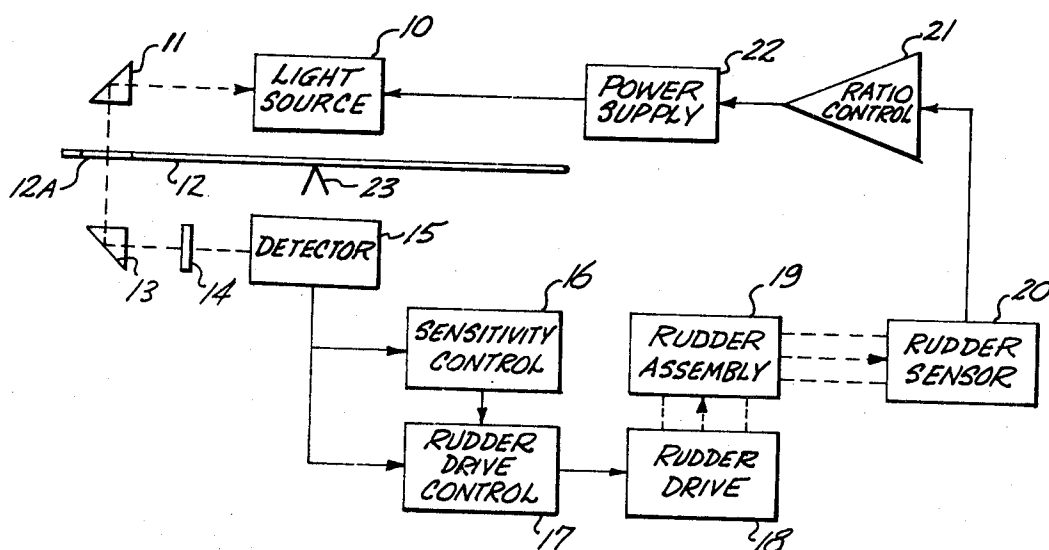
[52] U.S. Cl. **318/588,**
318/640
[51] Int. Cl. **G05d 1/00,**
B64c 13/18
[50] Field of Search 318/488,
588, 589

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ABSTRACT: This application discloses a novel low-cost autopilot assembly for ships. The system includes a simplified control loop between the rudder and the course-determining apparatus with the signal paths between the course-determining apparatus and the rudder used for course corrections being maintained separate from the signal path used for conveying rudder position information to the course-determining apparatus. Radiant energy passing through a set of arcuate prisms and a slit in a compass card to a light detector provides error signals when the ship is not on course. Corrective action then takes place in response to such signals. A rudder position-sensing device controls the energization of the light source so that as the ship is brought to an on-course condition the intensity of the light source is adjusted. Details of the electrical system as well as mechanical details of one preferred embodiment are provided.



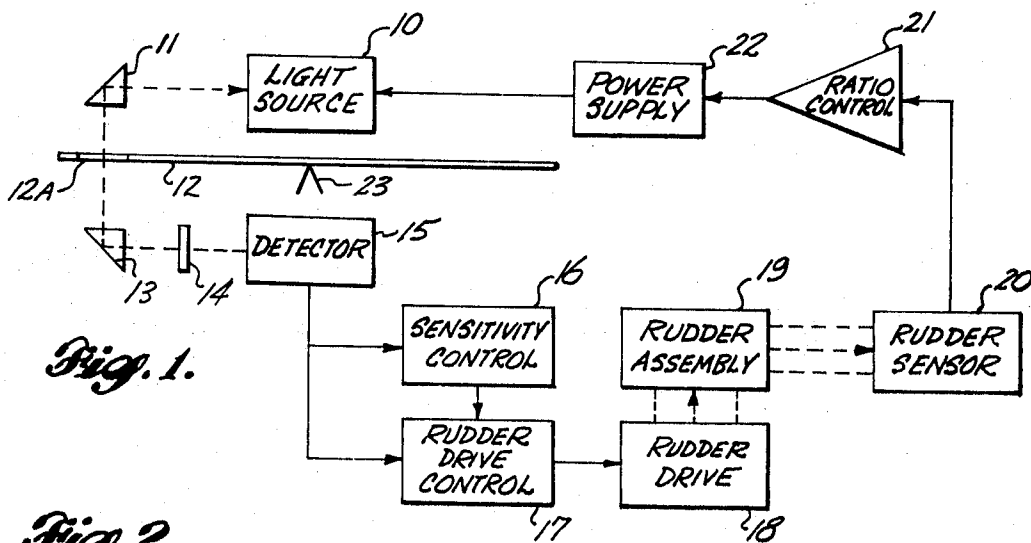


Fig. 2.

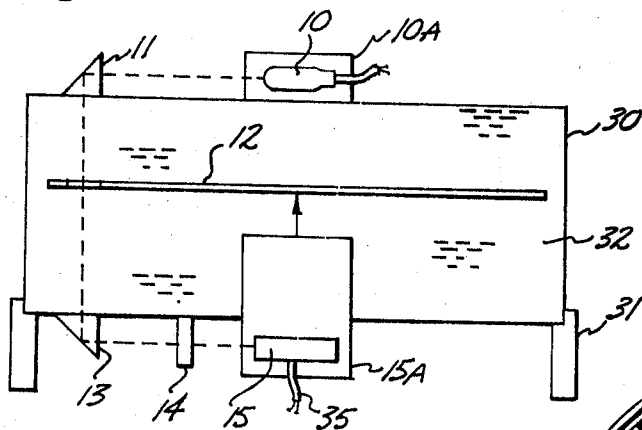


Fig. 7.

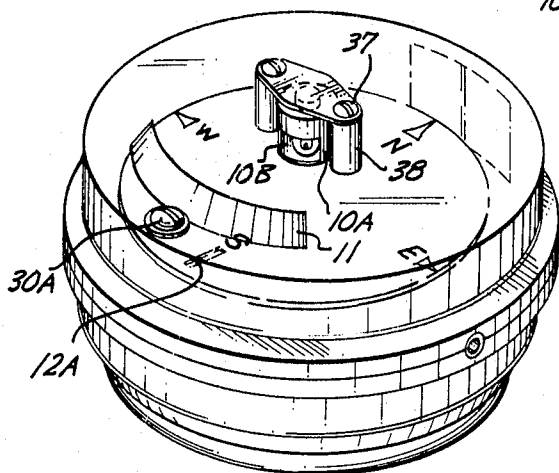
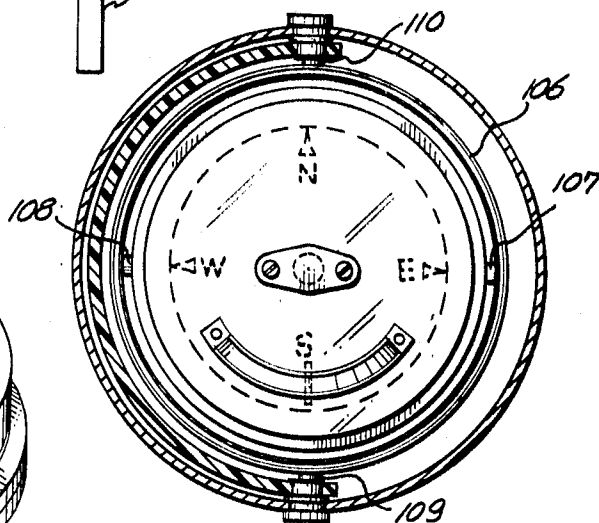


Fig. 3.

INVENTOR.
BRUCE H. BETTCHER
 BY *Christensen Sanborn & Matthews*

ATTORNEYS

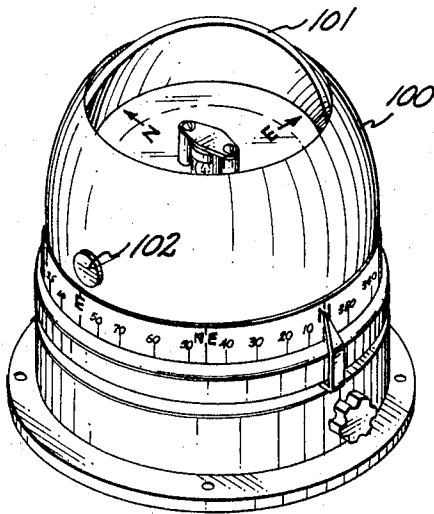


Fig. 4.

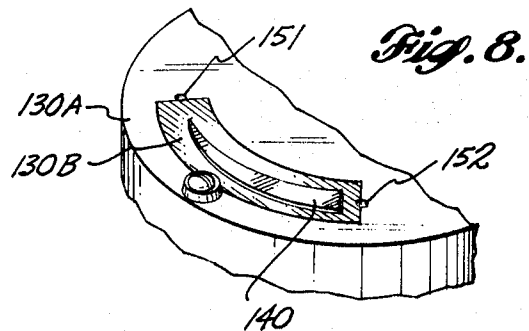


Fig. 8.

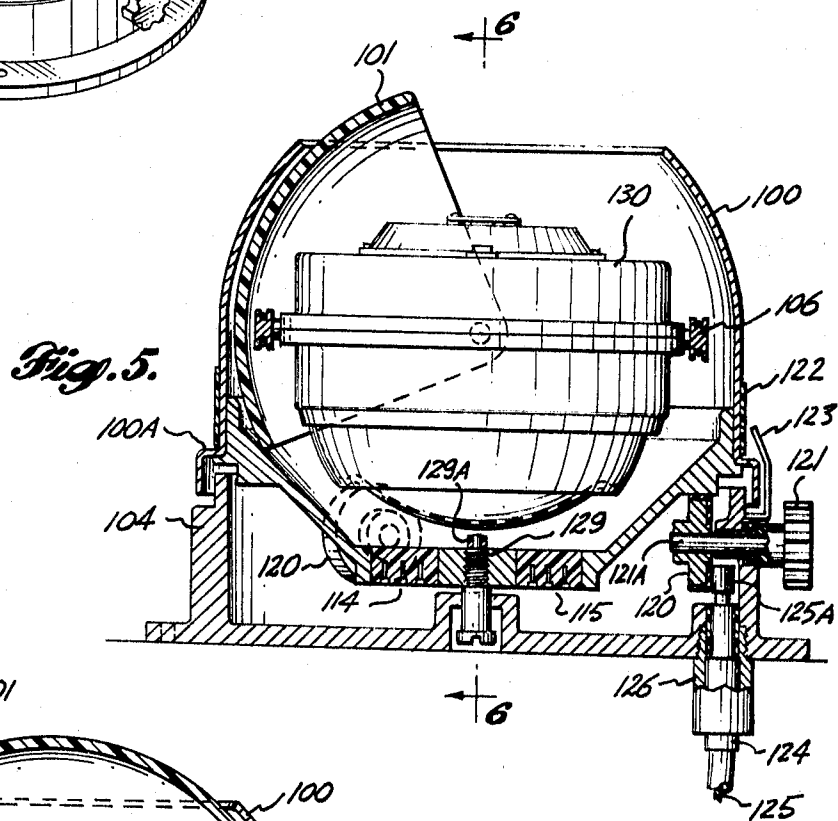


Fig. 5.

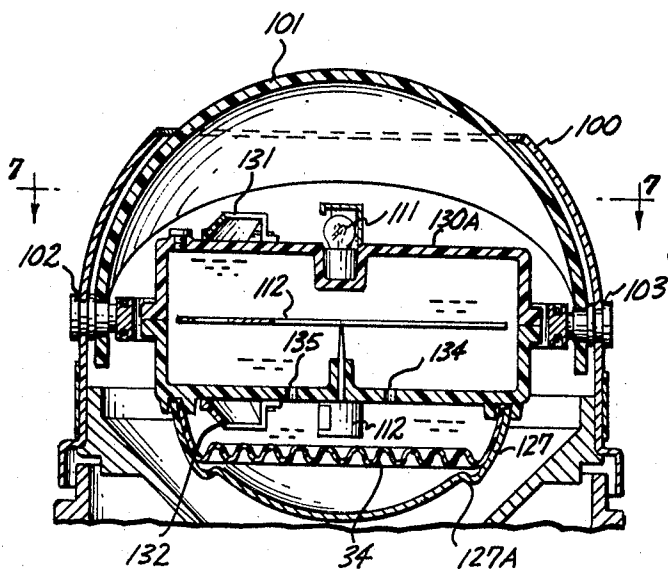


Fig. 6.

INVENTOR.
BRUCE H. BETTCHER
BY
Christensen Sanborn &
Matthews
ATTORNEYS.

MARINE AUTOPILOT SYSTEM

The present invention relates to autopilot systems in general and more particularly to a low-cost yet highly accurate autoassembly for ships. While automatic pilot assemblies for use on ships are old in the art, it is found that the sensitivity of most systems does not remain constant. It is also found that the cost of such systems is often so high that the equipment is not economically feasible except on relatively large and expensive boats. Even in those systems which are available at a relatively high cost it is found that system sensitivity varies due to the basic nature of the control arrangement.

It is therefore an object of the present invention to provide a low-cost automatic pilot system for ships. Another object of the present invention is to provide a novel feedback signal arrangement between the rudder assembly and a course-determining assembly for a ship.

An additional object of the present invention is to provide a ship control system utilizing a radiant energy error-detecting apparatus wherein course error signals are substantially linearly related to course error. Another object is to provide an autopilot system wherein the off-course and on-course system sensitivity remains substantially constant.

The above as well as additional advantages and objects are achieved through the use of a system wherein an arcuate prism located above a compass card having a slit therein is illuminated by a light source in a manner such that light is directed downwardly onto the surface of the compass card. A second arcuate prism located beneath the compass card directs any light passing through the slit onto a light detector such as a photocell. A mask assembly which is conveniently secured to one surface of one of the prisms is mated to the characteristics of the photodetector so that the position of the slit in the compass card relative to the mask bears a predetermined relationship to the amplitude of output signals from the radiant energy detector. This relationship in one system was selected to be linear with the impedance of the photodetector varying between 1,000 ohms and 3,000 ohms, and being 2,000 ohms when the compass card slit is centrally oriented relative to the radiant energy mask. The radiant energy mask is selectively positionable and therefore can be used to determine a desired course for the ship with the output signal from the detector being proportional to the divergence between an actual course and a desired course. Due to the relationship between output signals and the course error a sensitivity control in the output circuit of the detector is readily adjusted so that a selected dead zone is achieved with system sensitivity remaining essentially constant for off-course and on-course conditions.

The control loop is completed through the use of a rudder drive and rudder position-sensing system including conventional potentiometers connected in circuit between the rudder and the power supply for the radiant energy source. Thus as the ship comes to an on-course condition the intensity of the radiant energy is decreased or increased depending upon the direction of correction being undertaken so that a smooth transition from an off-course condition to an on-course condition results. It is found in practice that overshoot and associated oscillation of the ship about the desired course is avoided.

The above as well as additional advantages and objects will be more clearly understood from the following description when read with reference to the accompanying drawings.

FIG. 1 is a schematic block diagram illustrating the general principles of the system.

FIG. 2 is a cross-sectional diagrammatic view of one preferred embodiment of the novel error signal-generating apparatus.

FIG. 3 is a perspective view of one preferred embodiment of the compass and position-determining assembly corresponding to the diagrammatic illustration of FIG. 2.

FIG. 4 is a perspective view of a completely assembled position-determining apparatus including the housing therefor.

FIG. 5 is a partially sectional view of the apparatus of FIG. 4 showing the details of the housing and mounting assembly.

FIG. 6 is a cross-sectional view along lines 6-6 of FIG. 5.

FIG. 7 is a view along lines 7-7 of FIG. 6 showing the details of the support assembly as seen from above.

FIG. 8 is a perspective view of a portion of the compass housing showing a small mask in position for production of a radiant energy gradation pattern.

Turning now to the drawings and in particular to FIG. 1, the system will be seen to include a radiant energy source indicated as the light source 10 adapted to direct light against the arcuate prism 11 which is mounted above the compass card 12. The compass card 12 is provided with a single slit 12A (FIG. 3) so that light can pass from prism 11 to prism 13 which in turn directs the radiant energy onto a detector 15. A radiant energy mask 14 is illustrated as being positioned between the prism 13 and detector 15 although in practice the mask can also be conveniently formed on the surface of one of the prism members 11 or 13 as shown in FIG. 6. The transmission characteristic of the mask is such that output signals from the detector 15 bear a predetermined relationship to the angular position of the slit in the compass card 12 relative to the mask 14. In one preferred embodiment this was a linear relationship. As is well known in the art, most radiant energy detectors have an exponential sensitivity characteristic and thus the transmissivity of the mask 14 is matched to the detector 15 so that the desired linear signal relationship is obtained.

Signals from the detector 15 are applied to the sensitivity control circuit 16 and to the rudder drive control 17. In practice the sensitivity control 16 is a threshold circuit which disables the rudder drive control 17 until the level of signals from the detector 15 reaches a predetermined amplitude. In the marine autopilot art the sensitivity control is sometimes referred to as a "weather adjustment." The well-known Bendix Automatic Pilot Model 14 and the Sperry Magnetic Compass Pilot system, which has been on the market for approximately 20 years, are examples of well-known systems which utilize conventional sensitivity and rudder drive control circuits. The rudder drive control 17 is any suitable on-off device such as a relay and serves to control the application of signals to the rudder drive assembly 18. The drive assembly 18 can be any of a number conventionally used in the art, such as a servomotor system or a hydraulic drive arrangement for adjusting the position of the rudder assembly 19. A rudder-sensing assembly 20 which includes a set of potentiometers senses the position of the rudder assembly 19 and provides control signals to the ratio control circuit 21. The ratio control circuit 21 in turn is coupled with the power supply 22 and serves to adjust the energization of the light source 10 via the control exercised on the power supply 22. The compass card 12 is shown diagrammatically as pivoted on support 23 and of course includes a magnetic assembly so that the card has a portion which always points north. Details of the gimbal supports are not shown since they are conventional.

In operation the mask 14 is oriented in accordance with the desired direction of ship travel relative to a compass heading and thus there may initially be a divergence between the position of the slit in the compass card 12 relative to the center of the mask 14. Under such conditions the impedance of the detector 15 would be either increased or decreased depending upon the relative position of the slit and the center of the mask 14. The sensitivity control 16 in one system was adjusted so that the rudder drive control 17 was disabled when the impedance of the detector 15 was approximately 2,000 ohms but served to energize the rudder drive control when the impedance of the detector either increased above or decreased below the nominal value of 2,000 ohms. The system is so adjusted that the lamp provides less than its maximum output light when the slit on the compass card is centered relative to the mask 14.

Assume the position of the slit in the card 12 relative to the mask 14 is changed from a centered position to one such that the quantity of light reaching the detector 15 is increased.

This causes the detector impedance to decrease below 2,000 ohms and the sensitivity control 16 to close the rudder drive control circuit 17. The rudder drive control 17 therefore causes a signal to be applied to the rudder drive assembly 18. In response thereto the ship's rudder is moved in a direction to bring the ship to an on-course condition. The course correction position of the rudder causes the rudder sensor 20 to apply a signal via the ratio control 21 to the power supply 22, which signal causes the output radiant energy from the light source 10 to be decreased. This decrease in light intensity thus causes the impedance of the detector 15 to be increased back to and in fact be maintained close to the center value of 2,000 ohms. The rudder however is now in the proper position to cause course correction.

As the ship comes about in response to the corrective rudder position the slit in the compass card and the mask 14 undergo relative movement such that the intensity of the light reaching the detector is decreased. As a result the impedance of the detector is increased, the sensitivity and drive controls 16 and 17 operate, and the rudder is repositioned so that the amount of correction is decreased. This in turn causes the intensity of the light from source 10 to be increased to thus reduce the error signal from detector 15. It will be seen that the closed loop arrangement results in the impedance of the detector actually undergoing little change as the ship is brought to an on-course condition. The ratio control 21 permits adjustment of the amount of change in energization of the light source 10 which results from a given signal from the rudder sensor 21 (the ratio control per se being analogous to the "rudder adjust" in systems such as the Sperry Magnetic Compass Pilot referred to above). Thus the autopilot is easily adapted to the response characteristics of a given ship. It is also of importance to note that with the indicated arrangement the detector impedance actually undergoes only a momentary major change when a new course is set by positioning of the mask 14. That is, as soon as the system reacts to the error signal the light intensity is changed by adjustment of the power supply 22. Therefore the system operates primarily on the basis of error signals of a small magnitude once the corrective action has started and hence the system remains in adjustment once the threshold and ratio controls have been set. It is of importance to note that the on-course and off-course sensitivity are the same since the positioning of the rudder for course correction causes an adjustment in the intensity of the light source output.

In FIG. 2 there is illustrated in diagrammatic form a specific preferred embodiment of the invention corresponding in general to the apparatus shown in perspective view in FIG. 3. The assembly of FIG. 2 is to be housed in a lighttight container and thus the housing 30 is made of clear plastic. This permits the use of the unit as the ship's compass when the control unit is not being used as an autopilot. The lower frame 31 is adapted to fit in a conventional gimbal assembly for maintaining the guidance device in a horizontal position irrespective of pitch and roll of the ship. The interior of the housing member 30 is filled with fluid 32 via the oil fill hole 30A as is conventional in the compass art. The light source is shown as including the bulb 10 and light housing 10A, the housing 10A having the opening 10B therein (FIG. 3) for directing light from the bulb onto the arcuate prism 11. In the embodiment illustrated in FIG. 3 the prism 11 as well as the lower prism 13 is formed as an integral part of the housing 30 in order to simplify construction of the final unit. A flexible plastic diaphragm member 34 (FIG. 6) is included in the lower portion of the unit to accommodate expansion of the fluid resulting from temperature changes. In one embodiment of the invention the entire bottom portion of the fluid-filled chamber was made from flexible polypropylene which acted as a flexible diaphragm. In the arrangement illustrated in FIG. 2 the housing 15A for the photodetector 15 is secured to the bottom of the main housing 30 with electric leads 35 extending from the detector to the sensitivity control and rudder drive control in the manner illustrated in FIG. 1. Bolt and spacer members 37

and 38 are illustrated as holding the light housing 10A in position on the top of the main housing 30. As seen in FIG. 3 the compass card 12 is provided with the usual compass marking so that the unit can be used as a compass when the lighttight binnacle housing the guidance unit is opened and the system is disabled.

In FIG. 4 the exterior of an assembled control unit is illustrated with FIG. 5 and 6 being sectional views showing construction details of the assembly of FIG. 4. The assembly includes a binnacle housing 100 made of an opaque material, such as for example an aluminum spinning. A black Plexiglas shutter 101 is pivoted at 102 and 103 to the housing 100 so that the shutter 101 can be swung from its position of FIG. 5 to a closed position to prevent the entrance of light to the interior of the binnacle assembly. As seen in FIG. 5, the lower portion of the spinning 100 is enlarged at 100A and is disposed about the upper portion of the mounting base 104. The arrangement is such that the control unit 130 is positioned inside of the binnacle and is thereby shielded against external light when the control apparatus is being used for controlling ship movements. However by moving the shutter 101 to its lowered position as seen in FIG. 5 the control unit can be used as a conventional compass when not being used as part of the autopilot system.

The control unit 130 is supported on the gimbal ring 106 by means of the pins 107 and 108 (FIG. 7) and is adapted for pivotal movement with respect to the gimbal ring 106 in a manner well known in the art. The gimbal ring 106 is in turn supported by the rivnuts or pins 109 and 110 which pass through the spinning 100. The shutter is supported for rotation on the pins 109 and 110.

As seen in FIG. 5, the gimbal ring 106 is of a substantially H cross-sectional configuration so that the electrical leads for the light source 111 and for the photocell unit 112 can be placed in the depressed portions thereof. The leads are then run along the pivot pins for connection to the detector and light source. The leads also go to the slip rings 114 and 115 (FIG. 5) for connection to the system as shown in FIG. 1.

The spinning portion 100 of the binnacle assembly rides on three rubber wheels carried by suitable support members such as the shaft 121A carried by the base 104. One of the wheels has a control knob 121 associated therewith so that when the knob 121 is rotated the spinning 100 and hence the control unit 130 will be rotated to a selected position. Thus the slit in the compass card is moved relative to the gradation pattern to achieve the results described above. A direction-indicating ring 122 is carried by the spinning 100 with the markings thereon being as shown in FIG. 4. The arrangement is such that rotation of the knob 121 causes the control unit 130 to be rotated to the necessary position for displacement of the gradation pattern relative to the card slit to cause the control system to bring the ship to an on-course condition as indicated on the indicator ring 122 under the pointer 123.

A remote control cable 125 passes through the fitting 126 in the bottom of the base support member 104 and is provided with a rubber portion 124A on the inner end thereof. The rubber portion 125A engages the wheel 120 associated with control knob 121 so that the control unit can be selectively positioned from a remote location via the cable 125. As is conventional in the cable art, a protective sheath 124 is disposed about the cable 125. In one embodiment of the invention the control knob 121 was provided with a small coil spring for urging the control knob 121 outwardly with the operator then pressing the knob inward and away from engagement with the rubber end 125A on the control cable. The resistance of the remote control cable 125 to adjustment via the knob 121 is thus avoided.

In the embodiment of the invention illustrated in FIGS. 4, 5 and 6, the flexible diaphragm 34 is disposed inside the diaphragm cover 127 which is made of opaque plastic material and is secured to the bottom of the control unit housing 130A (which is also opaque except for the clear top as described above for viewing the compass card). The diaphragm cover

not only shields the photodetector 112 but also serves to protect the assembly during shipment to a customer since the interior of the binnacle assembly can then be filled with particulate material to avoid damage due to shock which might be encountered during shipping. The diaphragm cover is provided with a circumferential lip 127A which cooperates with the stop pin 129 having a rubber end 129A. Engagement of end 129A with the lip 127A thus serves to limit the degree of pivoting of the control unit relative to the binnacle assembly.

As seen in FIG. 6, the embodiment of the invention illustrated therein makes use of a cast thin-walled arcuate reflector 131 having the polished surface thereof facing the light source 111. A similar arcuate reflective member 132 is disposed beneath the compass card 112 for directing the light onto the photodetector 112. In this embodiment (as seen in FIG. 7) the radiant energy gradation pattern is formed integrally with the reflective member 131. Fluid holes 134 and 135 are provided in the lower part of the housing 130A to permit the flow of fluid into the chamber defined by the diaphragm 34.

I have found in practice that it is convenient to form the desired radiant energy gradation pattern directly on the surface of the housing 130A. A preferred method of forming the pattern will be understood from FIG. 8 wherein a small brass template 140 is positioned on the upper surface 130A of the housing. The area of the surface 130A disposed beneath the reflective member 131 of FIG. 6 is illustrated as the area 130B and is painted black to prevent the transmission of light through the blackened area. By having the template 140 in position during the painting operation, it will be seen that the desired light transmission pattern is provided on the surface 130A when the template is removed. After the painting step the template 140 is removed and the reflective member 131 is screwed to the upper surface 130A by means of screws entering the threaded openings 151 and 152. Thus the production of the assembly is enhanced since an operator simply places the template 140 in the proper position on the surface 130A, sprays the area 130B with black paint, and removes the template.

In another embodiment of the invention the compass card is replaced by a substantially flat wire having a widened paddle near the outer end thereof for interrupting the energy being directed onto the photodetector. As relative movement between the widened paddle and the gradation pattern takes place, the total energy received by the photodetector is thus increased or decreased depending upon the direction of relative movement between the paddle and the gradation pattern. This arrangement reduces the frictional forces associated with movement of a compass member in a stabilizing fluid. Other similar arrangements could be utilized to provide a system wherein the intensity of the radiant energy received by the detector is dependent upon the relative position between a compass member and the source of energy.

There has thus been disclosed an improved autopilot system having a novel control unit which makes use of relatively low cost components.

What I claim is:

1. An automatic vehicle direction control system comprising in combination: an adjustable radiant energy source; radiant energy detection means; means directing radiant energy from said source to said detection means along a first path; a directional member disposed in said path and adapted to control the radiant energy reaching said detection means in accordance with the relative orientation between said member and said first path; vehicle direction control means coupled with said detection means and including a positionable course control member movable to a position determined by the signal from said detection means; and radiant energy control means connected to said radiant energy source and to said

positionable member and operative to adjust a characteristic of the radiant energy output by said source in accordance with the position of said positionable member.

2. A system as defined in claim 1 wherein said directional member is a compass member.

3. A system as defined in claim 1 including radiant energy gradation means disposed in said path and selectively positionable relative to said directional member to establish a desired course.

4. A system as defined in claim 3 wherein said directional member is a compass card having a light slit therein.

5. A system as defined in claim 1 wherein said vehicle direction control means includes sensitivity means preventing operation of said positionable member until the signal from said detection means reaches a selected value.

6. A system as defined in claim 1 wherein said radiant energy control means is operative to change the output energy from said source in a manner to maintain the output signals from said detection means substantially constant.

7. A system as defined in claim 6 wherein said directional member comprises a compass member disposed in said path, said compass member operating to increase or decrease the radiant energy reaching said detector means when said first path is displaced in a first or a second direction, respectively, relative to said compass member, and wherein said radiant energy control means operates to decrease or increase the radiant energy output of said source when said path is displaced in said first or said second direction, respectively.

8. A system as defined in claim 7 and including a compass housing disposed about said compass member with said compass member being freely movable therewithin to point in a substantially constant direction; first and second arcuate light-directing members carried by said housing and disposed on opposite sides of said compass member for directing light from said source to said detection means via a path which includes at least a portion of said compass member.

9. A system as defined in claim 8 wherein said radiant energy source is supported on one surface of said housing and is aligned with said first directing member, said detection means is supported in alignment with said second directing means, and radiant energy gradation means disposed in the light path extending from said source to said detection means via said directing means.

10. The system of claim 9 wherein said compass member is a compass card having direction indication means thereon; said housing has a viewing surface aligned with said card to permit visual observation of said indication means; and lighttight means disposed about said housing and having a movable portion for selective viewing of said indication means.

11. A control unit for an autopilot system comprising in combination: a compass having an arcuate compass card and a cylindrical housing pivotally supporting said card therewithin, said card being of light opaque material and having a light-transmitting opening therein; first and second arcuate radiant energy directing members supported by said housing on opposite sides of said card and aligned with said opening; a radiant energy source secured to said housing and aligned with said first directing member; a radiant energy detector secured to said housing and aligned with said other directing member; and means defining a radiant energy gradation pattern in the energy transmission path between said source and said detector via said direction members.

12. A unit as defined in claim 11 wherein said last named means is carried by said housing, and including a binnacle having a gimbal assembly supporting said housing, and control means coupled with said housing for positioning said housing from a location on the exterior of said binnacle.