Dec. 31, 1929. E. L. HOLMES 1,741,713

AUTOMATIC DEVIATION AND DISTANCE INTEGRATING APPARATUS

Filed April 13, 1927 7 Sheets-Sheet 1

Fig. 1.

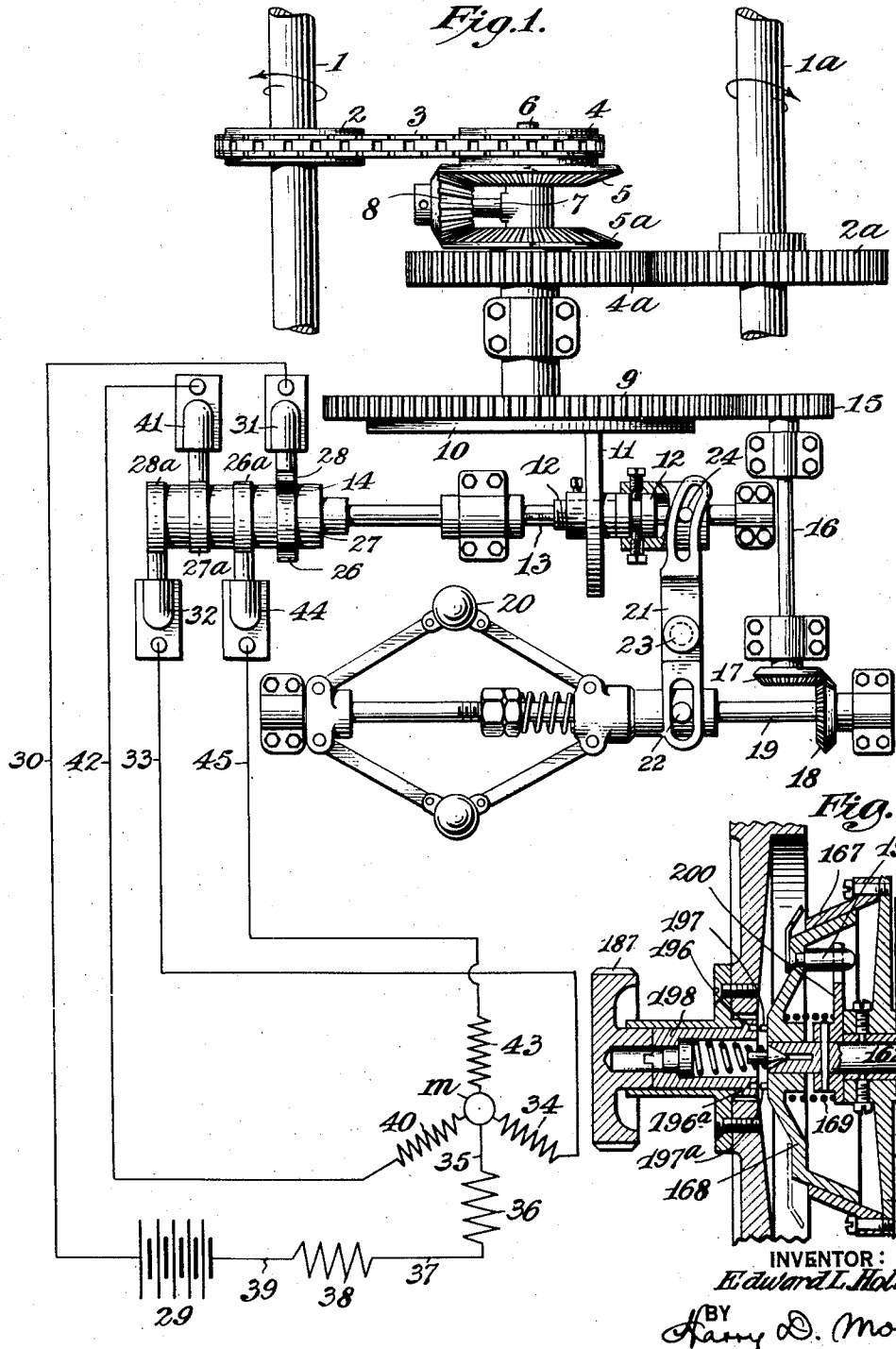


Fig. 9.

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AUTOMATIC DEVIATION AND DISTANCE INTEGRATING APPARATUS

Filed April 13, 1927 7 Sheets-Sheet 2

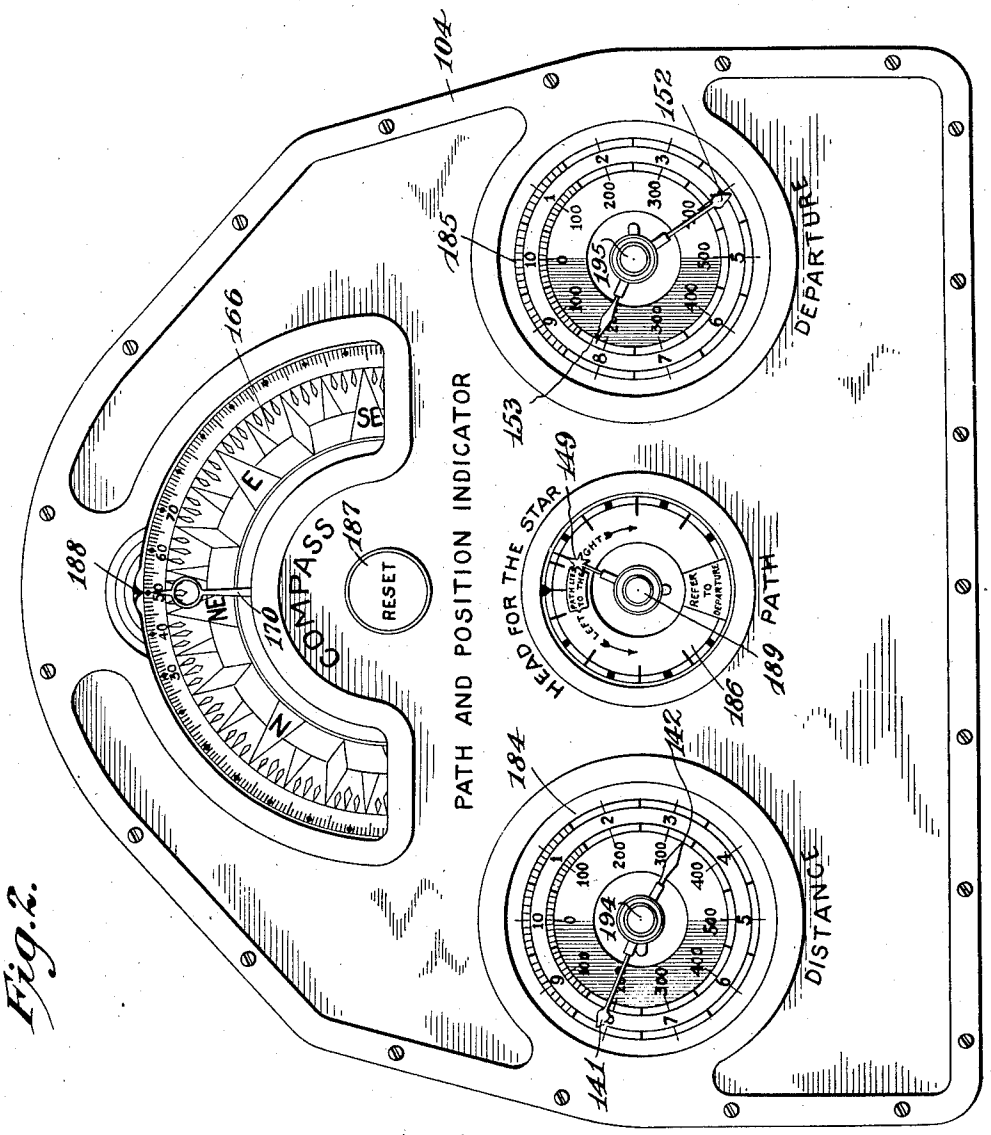


Fig. 2.

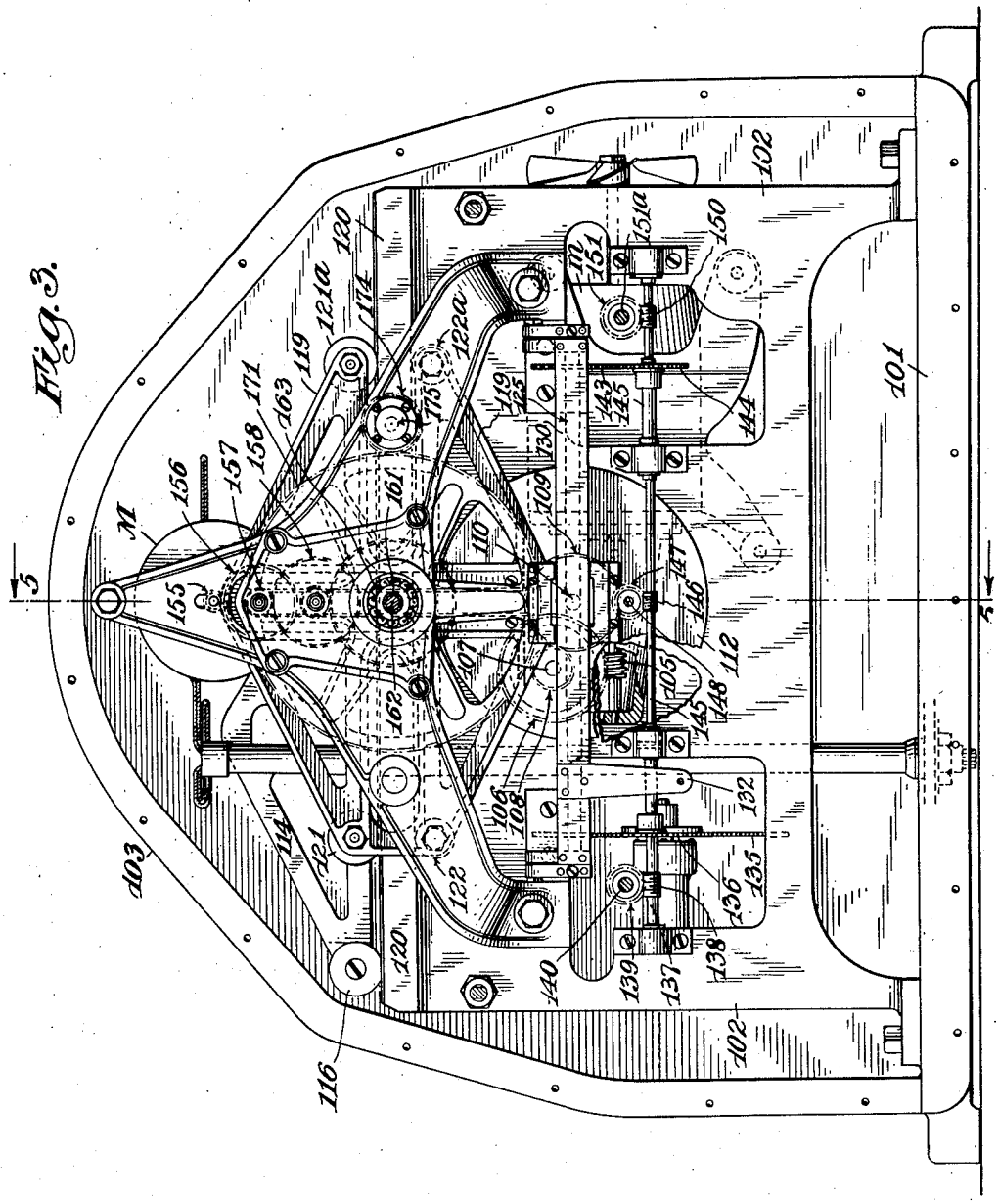
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AUTOMATIC DEVIATION AND DISTANCE INTEGRATING APPARATUS

Filed April 13, 1927 7 Sheets-Sheet 3

Fig. 3.



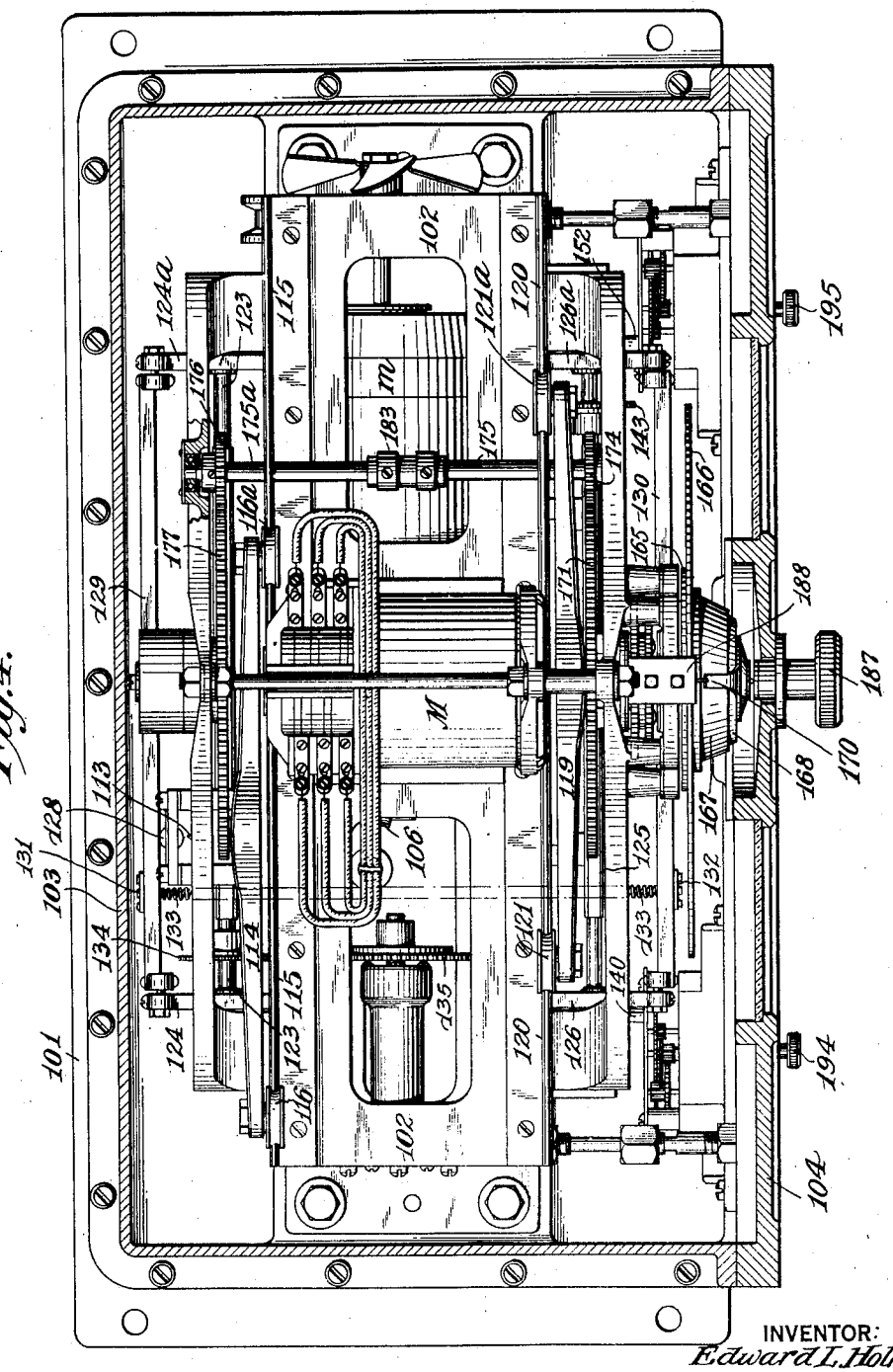
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AUTOMATIC DEVIATION AND DISTANCE INTEGRATING APPARATUS

Filed April 13, 1927 7 Sheets-Sheet 4

Fig. 4.



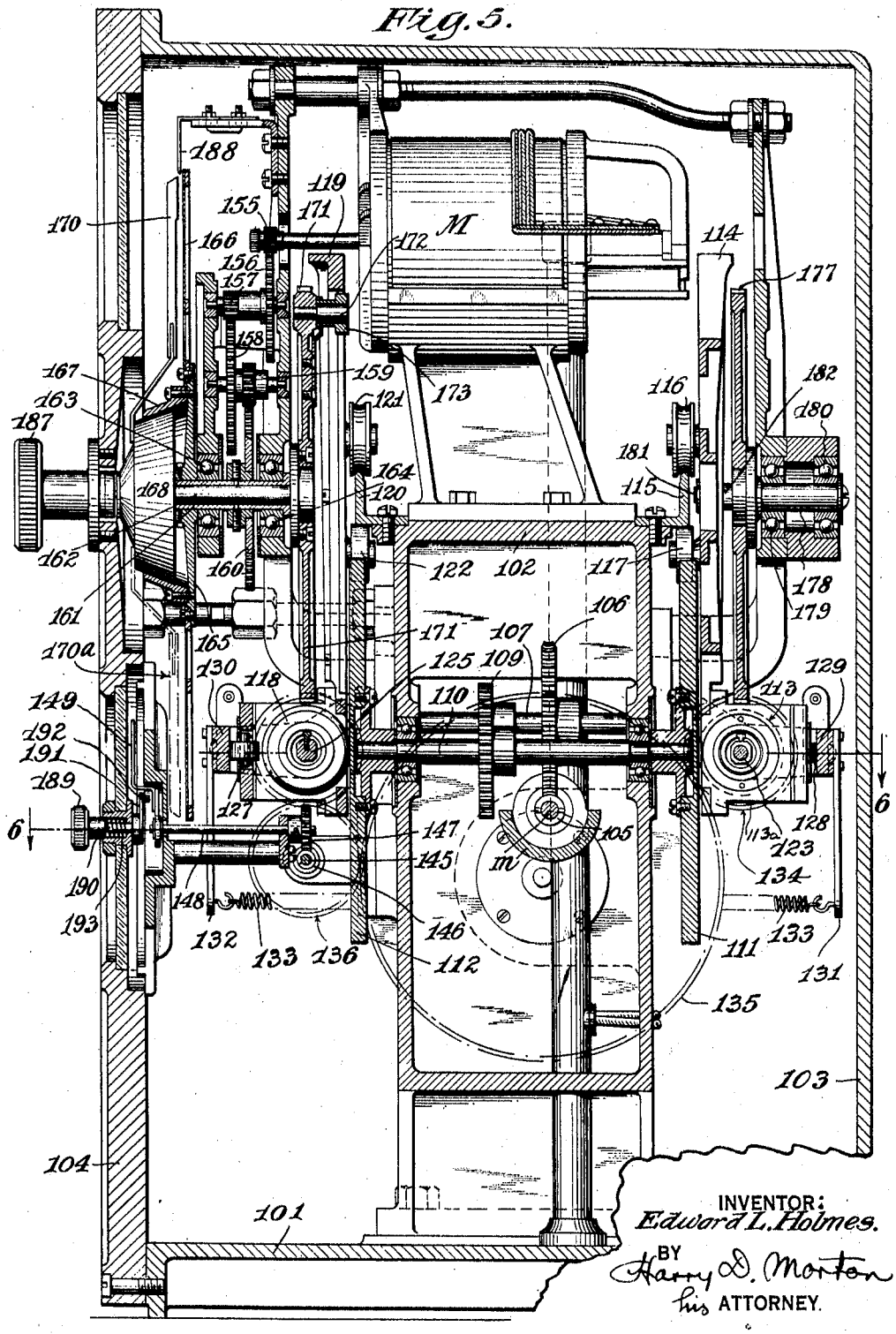
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AUTOMATIC DEVIATION AND DISTANCE INTEGRATING APPARATUS

Filed April 13, 1927 7 Sheets-Sheet 5

Fig. 5.



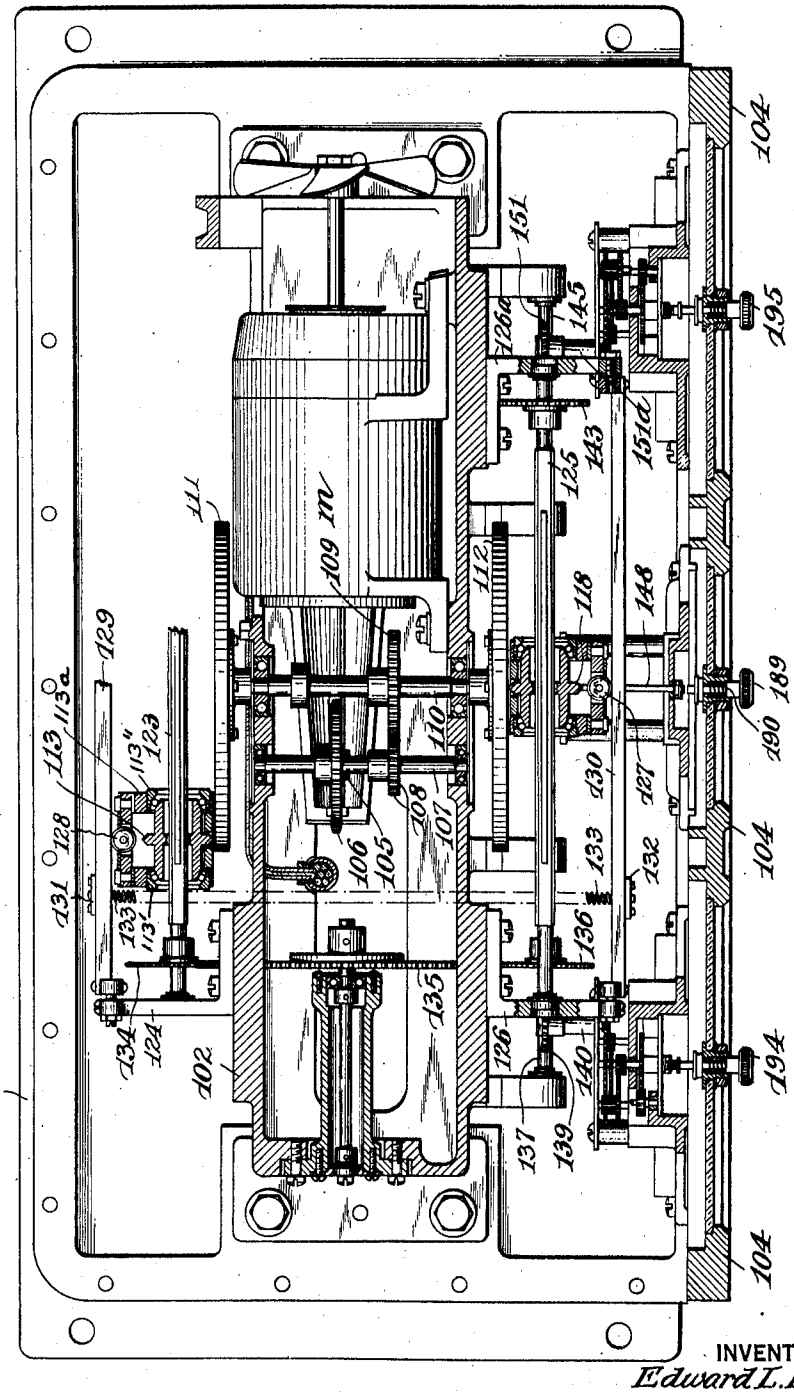
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AUTOMATIC DEVIATION AND DISTANCE INTEGRATING APPARATUS

Filed April 13, 1927 7 Sheets-Sheet 6

Fig. 6.



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Dec. 31, 1929. E. L. HOLMES 1,741,713

AUTOMATIC DEVIATION AND DISTANCE INTEGRATING APPARATUS

Filed April 13, 1927 7 Sheets-Sheet 7

Fig. 8.

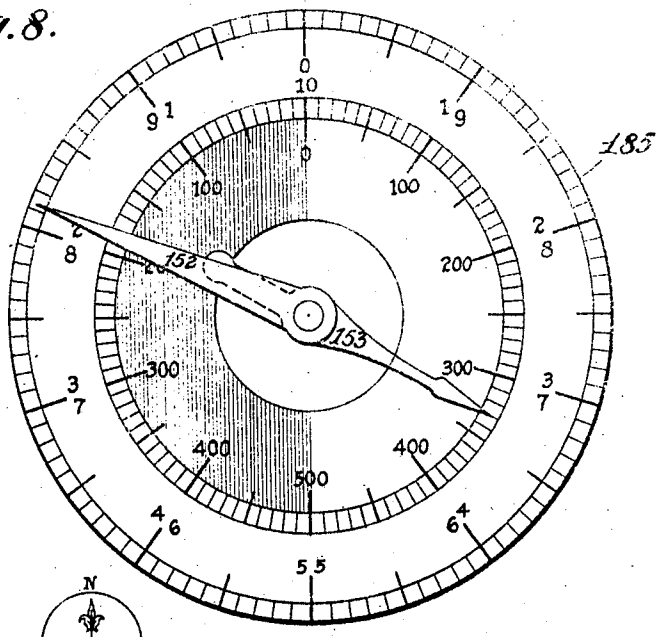
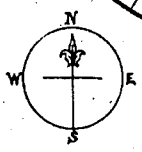
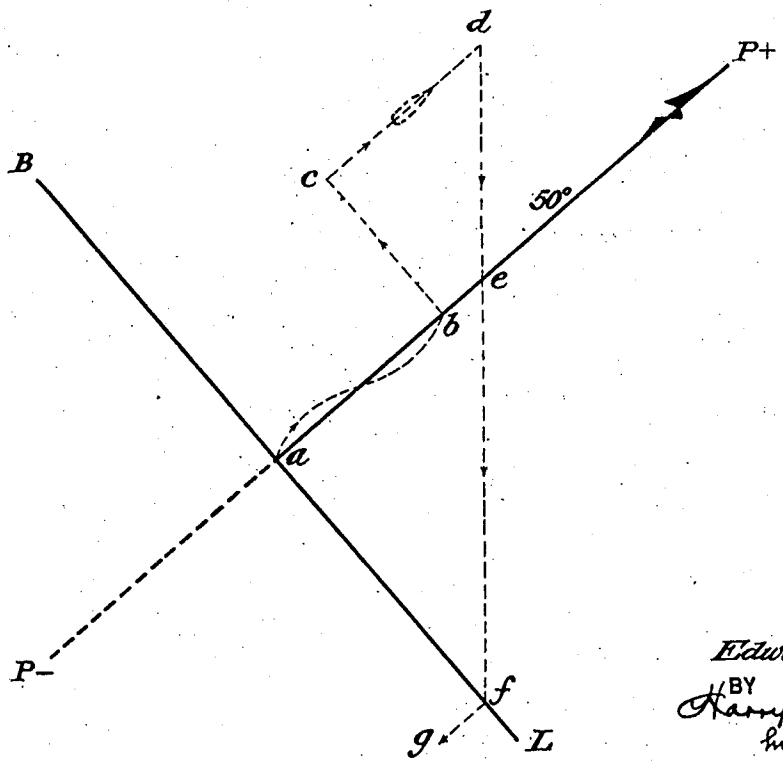


Fig. 7.





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UNITED STATES PATENT OFFICE

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AUTOMATIC DEVIATION AND DISTANCE INTEGRATING APPARATUS

Application filed April 13, 1927. Serial No. 183,442.

The following is a description of one embodiment of the invention in a form at present preferred; but it will be understood that various modifications and changes may be made therein without departing from the spirit of the invention and without exceeding the scope of the claims.

This invention relates to apparatus for insuring that a mobile object, such as a ship, is steered upon its set path, and for determining, at any time, its position in terms of latitude and longitude. These results are accomplished by integrating, with movements automatically correlated to distances of travel, two functions of angles of operation corresponding to the angles of direction involved in such travel, whereby there is shown the distance that a ship or other mobile object carrying the apparatus angularly deviates from its set path, and the distance it travels with reference to its known point of departure.

The apparatus will be described as being installed upon a ship, and as having its angle-reproducing devices governed by a master compass, and its distance-factor devices driven by the propelling means of said ship. It will be understood that the apparatus will function in like manner when installed on other types of self-propelled objects.

In my application Serial No. 4620, filed January 24, 1925, I disclosed apparatus adapted to integrate, with time of operation, two functions of angles of operation. The angle-reproducing devices of said apparatus, as in the case of the present invention, were described and illustrated as being governed by a master compass; but the time-factor devices were shown as being actuated by an electric motor, rotating at a substantially uniform speed. With apparatus wherein functions of angles of operation are integrated with time of operation alone, it is necessary, in determining the actual distance of a ship from its set path and its actual distance from a base-line passing through its known point of departure and at right angles to its set path (for the purpose of determining the position of such object in terms of latitude and longitude), that the integrations of the angle and time factors be correlated to the travel of the ship. This involves a calculation in which there is introduced with the time factor in the integration the speed at which the ship has traveled during the time of operation of the apparatus—said speed being assumed to have been at a uniform rate and being determined by means independent of the integrating apparatus, such, for example, as the taffrail log of the ship. Thus, if it be found desirable, during the voyage of a ship, to change its rate of speed, it is necessary, with the apparatus of my said prior application, to first locate the ship's position in terms of latitude and longitude, establish the line of direction of a new path, and re-set the integrating apparatus to operate with reference to said new path. Under such conditions, the determined position is treated as a new point of departure.

In the present invention, however, two functions of reproduced angles of operation relative to the set path are integrated with a factor automatically correlated to the actual travel of the ship, rather than merely with the factor of time of operation of the integrating apparatus. The inconveniences are thereby obviated of making the calculations involved in introducing speed of travel with the time factor, and of re-setting the apparatus when the speed of the ship is required to be changed. The likelihood of error incident to such steps is of course eliminated; and other advantageous results are obtained.

In the apparatus of my prior application, the results of the integrations of sines and cosines of angles of operation with time of operation were shown on counters. The present invention also embodies the feature of novel indicating means which are in several respects preferable to such counters.

The invention will best be understood by reference to the accompanying drawings, in which are illustrated the preferred forms and arrangements of the devices comprising the apparatus, and wherein Fig. 1 shows schematicaly apparatus actuated by the twin propellers of a ship, by which apparatus there is transmitted to the integrating instrument a factor correlated to the travel of the ship.

Fig. 2 is a front elevation of an integrating

and indicating instrument comprising a portion of the apparatus.

Fig. 3 is a front elevation of said integrating and indicating instrument with the cover and certain other parts removed to show the mechanism thereof.

Fig. 4 is a top plan view of said integrating and indicating instrument with the housing and cover thereof shown in section.

Fig. 5 is a vertical section of the integrating and indicating instrument on the line 5—5 of Fig. 3.

Fig. 6 is a plan section of the integrating and indicating instrument on the line 6—6 of Fig. 5, with the housing removed.

Fig. 7 is a diagram showing a point of departure, a set path, a base-line passing through the point of departure and at right angles to the set path, and various courses traveled by a ship in the progress of maneuvering.

Fig. 8 is a detail diagram of a novel type of dial, with associated hands, for indicating the direction and distance to the set path.

Fig. 9 is a detail on a somewhat larger scale of a clutch mechanism forming part of the integrating and indicating instrument.

Like reference characters indicate like parts throughout the drawings.

Referring to the drawings (Fig. 1), 1 and 1^a are twin propeller shafts, of which shaft 1 carries sprocket 2 and shaft 1^a carries spur gear 2^a. Through chain 3, sprocket 2 drives sprocket 4; and spur gear 2^a drives spur gear 4^a. Sprocket 4 and spur gear 4^a are rotatably mounted on shaft 6. Integral with said sprocket 4 is bevel gear 5, and integral with spur gear 4^a is bevel gear 5^a, driven by which bevel gears is differential bevel gear 8, rotatably mounted on one end of shaft 7. The opposite end of shaft 7 is attached to shaft 6, and rotates said latter shaft at a speed proportional to the mean of the speeds of said propeller shafts. Attached to the outer end of shaft 6 and rotating therewith are governor-driving gear 9 and friction disk 10, which disk frictionally rotates transmitter-shaft wheel 11, mounted on a collar 12 splined to transmitter-shaft 13, whereby said wheel 11 may move along said shaft to vary the speed of rotation of transmitter 14. Governor-driving shaft gear 9 drives gear 15, attached to intermediate shaft 16, carrying bevel gear 17, which drives bevel gear 18, attached to governor-shaft 19, carrying centrifugal governor 20.

The diameters of the driving friction disk 10 and of the driven friction wheel 11 are so proportioned, and said wheel 11 is initially so positioned with reference to the face of driving disk 10 that, for a given speed of travel of the particular ship upon which the apparatus is installed, the rates of rotation of transmitter 14 and of the integrating elements actuated thereby are proportional to the mean speeds of the propeller rotational speeds as corrected for slippage and to the predetermined rate of travel of the ship at such resultant propeller speed. However, the coefficient of propeller slippage is not constant for all propeller speeds, but increases with such speeds; and the extent of this increase varies in different ships and with different sizes and types of propellers. Provision is made for correcting for this variable factor as follows: slotted lever 21 is actuated through pin 22, carried by the governor sleeve, and through fulcrum post 23 and a pair of pins 24, and operates, upon a change in governor speed produced by a variation in the resultant speed of the propeller shafts 1—1^a, to shift the position of contact between transmitter-shaft wheel 11 and its driving disk 10; and thereby correlates the speed of rotation of transmitter 14 to the actual rate of travel of the ship under varying conditions of propeller speed. By predetermining, as a result of actual tests, the propeller slippage coefficient curve of a particular ship and propeller under normal conditions, the slotted portion of lever 21 may be conformed to such curve. In order to be able to correct for variations in the normal relation between propeller speed and actual rate of ship's travel, such as result from the fouling of the ship's bottom, the wheel 11 may be adjusted lengthwise of collar 12, thereby insuring an accurate relationship between the rate of travel under such abnormal conditions and the distance factor in the integrations.

While, for purposes of illustration, the distance-factor elements of the apparatus are shown as actuated by twin propellers, it is to be understood that these elements are equally operative when the ship is driven by a single propeller. In the latter case, the differential gearing 5, 5^a and 8, together with shaft 6, is omitted—disk 10 being driven directly from the single propeller shaft.

Transmitter 14 is provided with an interrupted ring comprising three segmental contacts 26, 27 and 28, electrically connected respectively to transmitter rings 26^a, 27^a and 28^a. In the course of rotation of said transmitter, current from one terminal of a source 29 flows through line 30, brush 31, segmental contact 28, ring 28^a, brush 32, line 33, armature winding 34 of step-by-step motor *m*, line 35, field coil 36 of said motor, line 37, field coil 38 of said motor, and line 39 to the opposite terminal of said source—thereby energizing said field coils and said armature winding 34. Armature winding 40 and field coils 36 and 38 will be thereafter similarly energized by current flowing from said first terminal of source 29, through line 30, brush 31, segmental contact 27, ring 27^a, brush 41, line 42, armature winding 40, line 35, field coil 36, line 37, field coil 38, and line 39 to the opposite terminal of source 29; and there-

after armature winding 43 and field coils 36 and 38 of said motor will be similarly energized by current flowing from said first terminal through line 30, brush 31, segmental contact 26, ring 26ª, brush 44, line 45, armature winding 43, line 35, field coil 36, line 37, field coil 38, and line 39 to the opposite terminal of said source 29. Brush 31 conveying current to the segments 26, 27 and 28 is constructed in a well-known manner to alternately effect, during the revolution of transmitter 14, successive contacts with such segments singly and in pairs, thereby producing a step-by-step rotation of the armature of motor *m*.

Referring to Figs. 2, 3, 4, 5 and 6, the integrating and indicating instrument comprises a bedplate 101, mounted upon which is a stanchion 102 and a housing 103. Attached to the housing is a front plate 104. Supported on stanchion 102 is motor *m* (Figs. 3, 4 and 6), controlled by transmitter 14 (Fig. 1), in the manner hereinbefore described. The armature shaft of motor *m* carries a worm 105 (Figs. 3, 5 and 6), driving worm wheel 106, attached to shaft 107, rotatably mounted in suitable bearings in stanchion 102. Also attached to shaft 107 is pinion 108, driving gear 109, attached to integrating-disk shaft 110, mounted in suitable bearings in stanchion 102. Referring to Fig. 5, mounted on the right-hand end of integrating-disk shaft 110 is cosine-integrating-disk 111; and similarly mounted on the left-hand end of said shaft is sine-integrating-disk 112.

Driven by cosine-integrating-disk 111 (Fig. 6) is cosine-integrating-wheel 113, rotatably mounted in suitable bearings 113′ and 113″, supported in a housing, 113ª, attached to the lower end of integrating yoke 114 (Fig. 5), which yoke is movable along track 115 and supported thereon by grooved rolls 116 and 116ª. Coacting with grooved roll 116 is retaining roll 117 (Fig. 5); and coacting with grooved roll 116ª is a similar retaining roll (not shown).

Driven by sine-integrating disk 112 is sine-integrating wheel 118, rotatably mounted in suitable bearings supported in integrating yoke 119, which yoke is movable along track 120 and supported thereon by grooved rolls 121 and 121ª. Coacting with grooved roll 121 is retaining roll 122 (Figs. 3 and 5); and coacting with grooved roll 121ª is a similar retaining roll 122ª.

Cosine-integrating wheel 113 is splined to and movable along cosine-integrating shaft 123, which shaft is rotated by said cosine-integrating wheel. Said cosine-integrating shaft is supported in suitable bearings in brackets 124 and 124ª. Sine-integrating wheel 118 is similarly splined to and movable along sine-integrating shaft 125, which shaft is rotated by said sine-integrating wheel. Said sine-integrating shaft is supported in suitable bearings in brackets 126 and 126ª.

Rotatably mounted in the supporting structure of sine-integrating wheel 118 (Fig. 6) is roll 127; and similarly mounted in the supporting structure of cosine-integrating wheel 113 is roll 128. Supported in hinged mountings between brackets 124 and 124ª is bar 129; and similarly supported between brackets 126 and 126ª is a like bar 130. Attached to bar 129 is spring-supporting member 131, and attached to bar 130 is a similar spring-supporting member 132 (Figs. 3, 5 and 6). A tension spring 133 (Figs. 5 and 6) connects spring-supporting members 131 and 132, thereby maintaining pressure on rolls 127 and 128 and insuring frictional driving contact between cosine-integrating disk 111 and its cosine-integrating wheel, 113, as well as between sine-integrating disk 112 and its sine-integrating wheel 118.

Mounted on cosine-integrating shaft 123 (Figs. 5 and 6) is pinion 134, which drives gear 135. Gear 135 in turn drives gear 136, attached to shaft 137. Shaft 137 also carries worm 138, which drives worm wheel 139, attached to shaft 140, driving, through a gear train and with shaft and sleeve construction of the type usually employed in clocks, hands 141 and 142 (Fig. 2).

Mounted on sine-integrating shaft 125 is pinion 143 (Fig. 3), which drives gear 144, attached to shaft 145, carrying worm 146, which drives worm wheel 147 (Fig. 3), attached to shaft 148 (Fig. 6), carrying steering hand 149 (Fig. 2).

Shaft 145 also carries worm 150, which drives worm wheel 151, attached to shaft 151ª, driving, through a gear train and with shaft and sleeve construction of the type usually employed in clocks, hands 152 and 153 (Fig. 2).

There will now be described the portions of the integrating instrument which operate to introduce into the integration cosines and sines of angles of travel relative to its set path of a ship equipped with the apparatus

The position of contact of cosine-integrating wheel 113 with cosine-integrating disk 111, and the position of contact of sine-integrating wheel 118 with sine-integrating disk 112, and, consequently, the rates of rotation of said integrating wheels and the values of their respective integrations, are governed by the angle-reproducing devices of the apparatus in the following manner: a step-by-step motor M (Figs. 3, 4 and 5) is mounted on stanchion 102. This motor is controlled by a transmitter (not shown) similar to transmitter 14 of Fig. 1. The transmitter is rotated, in turn, by what is known as a follow-up motor, which is constructed and arranged to turn in one direction or the other in response to movements of the ship relative to the directional element of its mas-

ter compass. Apparatus for so controlling such a motor is shown in my application Serial No. 4151, filed January 23, 1925; and generally-similar devices are commonly employed in connection with gyro compasses for actuating repeater compasses, chart-recording devices, automatic steering mechanisms, etc. The mode of operation of instrumentalities of this class is such that they reproduce, in external apparatus, angular movements of a ship relative to the directional element of its master compass. Thus, when a ship carrying the apparatus of the present invention angularly deviates from the set path for which the integrating instrument has been initially adjusted, the resulting rotation of the follow-up and its transmitter actuates step-by-step motor M in the same manner as that in which transmitter 14 has been described as actuating step-by-step motor *m*.

Referring to Fig. 5, the armature shaft of motor M carries a pinion 155, driving a gear 156, integral with which gear is a pinion 157, driving a gear 158, integral with which gear is a pinion 159, driving a gear 160, attached to sleeve 161, which is rotatable with reference to shaft 162. Sleeve 161 is rotatably mounted in bearings 163 and 164. Attached to sleeve 161 and rotatable therewith is a spider, 165, carrying a repeater-compass card 166 and a female clutch member 167. Coacting with female clutch member 167 is a male clutch member 168 (Figs. 5 and 9). The female and male clutch members are normally held in frictional engagement by a spring 169. Male clutch member 168 carries compass pointers 170 and 170ª. Attached to the inner end of shaft 162 is a gear 171, carrying integrating-yoke shifting-pin 172, rotatably mounted upon which pin is integrating-yoke block 173, movable in a vertical slot formed in sine-integrating yoke 119, whereby, upon the rotation of gear 171, said sine-integrating yoke is caused to move, in one direction or the other, along its track 120. Referring to Fig. 4, gear 171 drives gear 174, attached to shaft 175. Shaft 175ª carries gear 176, driving gear 177, which latter gear is attached to shaft 178 (Fig. 5), rotatably mounted in bearings 179 and 180. Gear 177 is provided with an integrating-yoke shifting-pin 181, carrying an integrating-yoke block 182, movable in a vertical slot formed in cosine-integrating yoke 114.

The locations of cosine-integrating yoke 114 and sine-integrating yoke 119, upon their respective tracks 115 and 120, control the positions of contact, respectively, of cosine-integrating wheel 113 with cosine-integrating disk 111, and of sine-integrating wheel 118 with sine-integrating disk 112, whereby there are governed the rate of rotation of said integrating wheels and the values of the integrated results which are indicated by their respective dials and hands. In order that the apparatus may operate to integrate the cosine and sine functions of reproduced angles of travel, a fixed relationship must be established and maintained between the cosine-integrating and the sine-integrating elements of the instrument. This relationship is initially effected by bringing (by movement of its integrating yoke along its track) one of the integrating-wheels into its central or non-rotating position of contact with its integrating disk, while the other integrating wheel is brought (by movement of its integrating yoke along its track) into its extreme outward position of contact with its integrating disk. Shafts 175 and 175ª are then fastened together by means of the set-screws carried by coupling 183. With this relationship established between the positions of the cosine- and sine-integrating yokes and the cosine- and sine-integrating wheels, sine-integrating yoke shifting-pin 172 is in a position separated by 90° of the circle from cosine-integrating yoke shifting-pin 181. This 90° relationship is thereafter maintained by reason of the fact that the sine-integrating and the cosine-integrating elements of the instrument are operatively connected together, through the medium of gear 171, gear 174, shaft 175, coupling 183, shaft 175ª, gear 176 and gear 177. Hence, any rotation of shaft 162, either by motor M in the course of operation of the instrument or manually for the purpose of setting the instrument, will shift the two integrating yokes 119 and 114 along their respective tracks, thereby varying the positions of driving contact of the integrating wheels 118 and 113 with their respective integrating disks, and, consequently, varying the rate of rotation of the said integrating wheels. The 90° relationship in the positions of the integrating yokes and integrating wheels being always maintained, it follows that whenever either the sine- or the cosine-integrating wheel is in the central or non-rotating position of contact with its integrating disk, the other such integrating wheel will be in its extreme outward position of contact with its integrating disk; and it also follows that, as one of the integrating wheels moves away from the center of its integrating disk, the other such integrating wheel will move toward the center of its disk.

Inasmuch as motor M, in its rotation, reproduces angular movements of the ship relative to the directional element of its master compass, the position of cosine-integrating yoke 114 upon its track 115 at all times corresponds to the cosine of the angle at which the ship has traveled with reference to the set path to which the integrating instrument was initially adjusted; and that the position of sine-integrating yoke 119 upon its track 120 similarly corresponds to the sine of such angle of travel.

The speed of rotation of the integrating

disks 111 and 112 being a function of the travel of the mobile object; and the rotation of cosine-integrating wheel 113 and of sine-integrating wheel 118 being correlated to the speed of said integrating disks, and to the position of driving contact between said disks and wheels, respectively, as controlled by the movements of the repeater-compass motor M, there results, on the cosine-integrating side of the instrument, an integration of the cosines of the angles of travel of the ship relative to its set path, with the distance which said ship has traveled from a base-line passing through its known point of departure and at right angles to its set path; and, on the sine-integrating side of the instrument, an integration of the sines of the angles of travel of the ship relative to its set path, with distances of angular travel relative thereto. The result of the integration of the cosines of angles of travel with the distance traveled from the base-line are indicated in terms of nautical miles and decimals thereof by the traverse the base-line indicating hands 141 and 142 over the "Distance" dial, 184 (Fig. 2). The results of the integration of the sines of the angles of travel relative to the set path with distances of angular travel relative thereto are indicated in terms of nautical miles and decimals thereof by the traverse of path-indicating hands 152 and 153 over the "Departure" dial, 185; and also in terms of nautical miles and decimals thereof by the traverse of the more rapidly moving steering hand 149 over the "Path" dial, 186. The set path being assumed to have been plotted upon a chart, it is possible at any time, by referring to the dial indications, to readily and accurately determine the position of the ship in terms of latitude and longitude.

There is preferably employed such a driving speed for the sine-integrating wheel 118 and such gear ratios in the indicating units that, when the ship is traveling at ten knots in a direction at right angles to its set path, steering hand 149 will traverse 180° of dial 186 in eighteen seconds; path-indicating hand 152 will traverse a like portion of dial 185 in thirty minutes; and path-indicating hand 153 will traverse a like portion of said dial 185 in twenty-five hours, the rate of movement of hand 149 thus being one hundred times that of hand 152; and the rate of movement of hand 152 being fifty times that of hand 153. All five of the indicator hands rotate either clockwise or counter-clockwise, depending upon the direction in which the ship angularly deviates from its set path.

The apparatus is adjustable in the following manner to integrate, with distances of travel, sines and cosines of all angles of operation with reference to any two right-angle lines: when no current flows through step-by-step motor M, clutch shaft 162 (Figs. 5 and 9), as well as the gear train between said motor and the clutch, and the said clutch, are freely rotatable. This movement is effected in the following manner: slight pressure upon hand-wheel 187 causes pins 197 and 197ª (mounted in the hub of male clutch member 168) to enter recesses 196 and 196ª, in slidable member 198, effecting a driving connection between hand-wheel 187 and said male clutch member 168. Through the clutch mechanism, clutch shaft 162 is now manually rotated by hand-wheel 187 until the desired point (say 50) on the compass-card registers with a fixed point, such as lubber's line 188. When a signal is received that the ship is headed on the 50° course, as indicated by the master compass, the circuit which includes motor M and its controlling transmitter is closed; and thereafter the repeater compass will synchronize in its movements with movements relative to the directional element of the master compass. The integrating apparatus is then adjusted to operate with reference to this set path and its base-line in the following manner: further pressure upon hand-wheel 187 causes male clutch member 168 to be forced inwardly and to thereby become disconnected from female clutch member 167, thus permitting, through pin 199 (in engagement with a yoke portion of arm 200, attached to shaft 162) of rotation of pointers 170 and 170ª (which are attached to said male clutch member), and of clutch shaft 162, without, however, disturbing the position of repeater-compass card 166. The male clutch member is then rotated until one of the pointers, 170—170ª, registers with the figure 50 on the repeater-compass card 166. Through the action of integrating-yoke shifting-pin 172, this rotation will have simultaneously moved sine-integrating yoke 119 along its track 120 to a point where sine-integrating wheel 118 is in operative relationship with reference to the compass course 50. Coincidently, cosine-integrating yoke 114 will have been moved into operative relationship with said compass course 50. The male clutch member is then released, and clutch spring 169 returns said male member to its position of frictional engagement with female clutch member 167. The angle-reproducing devices being under control of the master compass, sine-integrating yoke 119 and cosine-integrating yoke 114 will thereafter be shifted along their respective tracks in accordance with angular movements of the ship relative to the directional element of its master compass.

Provision is made for quickly and easily re-setting the hands of the indicating units by frictionally mounting such hands upon their shafts and sleeves. It will be understood that in connection with the initial adjustment of the integrating units in relation to the set path to be followed, the indicating hands are turned to their zero positions. This

may be accomplished in the following manner (Fig. 5): hand-wheel 189 (associated with "Path" dial 186) is attached to shaft 190, carrying at its inner end arm 191, mounted in which arm is pin 192, normally held out of engagement with the indicator hand by spring 193. By pushing hand-wheel 189 inwardly, pin 192 is brought into a position where it will contact with the edge of steering-hand 149, and subsequent rotation of the hand-wheel carries the hand to the desired position. Referring to Figs. 2 and 6, the "Distance" dial 184 is provided with a similar hand-wheel 194 and with other elements similar to those just described as being associated with the "Path" dial, 186, for setting base-line indicating hands 141 and 142; and "Departure" dial 185 is provided with a similar hand-wheel 195 and with other elements similar to those just described, for setting path-indicating hands 152 and 153.

Referring to Fig. 7, *a* represents a point of departure of known latitude and longitude. The line defined by characters P− and P+ indicates the direction (assumed to be 50°) of a set path from *a* to P+. The characters B—L indicate a base-line passing through the known point of departure *a* and at right angles to the set path. When, in the progress of its travel over the course *a*—*b*, the ship, by reason of yawing or from other causes, angularly deviates toward the left and from the set path, sine-integrating wheel 118 will be in contact with the face of sine-integrating disk 112 at the right of the vertical center line of said disk; and steering-hand 149 and path-indicating hands 152 and 153 will rotate clockwise from the vertical center lines of their respective dials.

The direction of rotation of the elements comprising the indicating unit of the sine-integrating portion of the apparatus is such that, upon the occurrence of an angular deviation of the ship from its set path, the hands 149, 152 and 153 show the direction in which the set path lies, this indication by hand 149 being for at least 18 seconds, by hand 152 for at least 30 minutes, and by hand 153 for at least 25 hours. The extent of movement of these hands shows in nautical miles and decimals thereof the distance from the ship to the set path. The invention thus possesses the dual advantages of sensitively indicating, by the relation of steering-hand 149 to the zero point of its dial, even very slight deviations from set path; and of simultaneously indicating, by the relation of path-indicating hands 152 and 153 to the zero point of their dial, and for long periods, the direction in which the set path lies. For steering purposes, the zero point of the steering dial corresponds to the lubber's line of a mariner's compass. When the ship angularly deviates to the right of the set path, the path-indicating hands rotate counter-clockwise and similarly show the direction and the distance to the set path.

"Path" dial 186 is preferably graduated into thousandths of a nautical mile, so that, upon a very slight angular deviation of the ship from its set path, the helmsman may quickly steer it back to such path.

So long as the ship, in the progress of its travel, continues upon a course angularly deviating to the left from its set path, sine-integrating wheel 118 will continue to be in contact with the face of inegrating disk 112 at the right of the vertical center line of said disk. Under these conditions, the indications of distance to said set path, as shown by steering-hand 149 in its traverse over its dial 186, and by path-indicating hands 152 and 153 in their traverse over their dial 185, will continue to increase. If the ship be swung to travel parallel to its set path, sine-integrating wheel 118 will, under the action of the master compass and its associated devices, be brought to its central or non-rotating position of contact with sine-integrating disk 112, so that, so long as the ship continues on such parallel course, the indication of distance to set path will remain constant. If the ship be then steered in a direction to travel toward its set path, sine-integrating wheel 118 will thereupon, under the action of the master compass and its associated devices, be shifted to the left side of the face of sine-integrating disk 112—thus reversing the direction of rotation of said sine-integrating wheel and of the mechanism of the path-indicating unit, and causing the indication of distance to set path to progressively decrease; and, when the set path is again reached, sine-integrating wheel 118 will once more be in its central position with reference to the face of sine-integrating disk 112; and the hands 149, 152 and 153 will once more be in their zero positions relative to their dials.

It will be understood by those skilled in this art that the mode of operation of the cosine-integrating and the base-line-indicating features of the apparatus, with reference to the base-line B—L, is the same as the mode of operation of the sine-integrating and path-indicating features of the apparatus with reference to the set path—the registration shown by hands 141 and 142 of the base-line-indicating unit representing at all times the direction and the distance from the ship to said base-line B—L. In the progress of the travel of the ship away from the base-line B—L and in the direction of the set path, the cosine-integrating wheel 113 operates in a zone near the outer edge of the right-hand face of its integrating disk 111, and the base-line-indicating hands 141 and 142 rotate clockwise.

Course *b*—*c* is assumed to be at right angles

to the set path; and under this condition of travel of the ship, the steering-hand 149 and the path-indicating hands 152 and 153 will be rotating clockwise; the sine-integrating wheel 118 will be at its extreme outward position of contact with the face of its sine-integrating disk 112, and will therefore be rotating at maximum speed; and the hands 149, 152 and 153 will be registering progressively-increasing indications of the distance to the set path. Course *b*—*c* being parallel to base-line B—L, the base-line-indicating hands 141 and 142 do not move, and their registration does not change—cosine-integrating wheel 113 being in its central or non-rotating position with reference to the face of cosine-integrating disk 111.

Course *c*—*d* is assumed to be parallel to the set path; and under this condition of travel of the ship, sine-integrating wheel 118 is in its central or non-rotating position with reference to sine-integrating disk 112, and hands 149, 152 and 153 remain in the positions of registration which they occupied when the ship was at point *c*. As the ship is traveling in a straight line directly away from base-line B—L, cosine-integrating wheel 113 will operate at its extreme outward position with reference to the right side of the face of integrating disk 111; and, when the ship has reached the point *d*, the base-line-indicating portion of the apparatus will have added to the indicated distance between base-line B—L and point *b*, which it theretofore showed, the actual distance between the points *c* and *d*. When, in its progress along course *c*—*d*, the ship reaches the point shown by the outline sketch thereof, the positions of the compass card and of the various hands with respect to their dials will be as follows: because the course *c*—*d* is parallel to the set path, figure 50 on the repeater-compass card will register with the lubber's line. For the same reason, steering-hand 149 will be stationary, as will also path-indicating hands 152 and 153; and the figures registered by these three hands will represent the actual distance from line *c*—*d* to the set path *a*—P+; and hand 153 will indicate the direction in which said set path lies. Base-line-indicating hands 141 and 142 will register figures representing the actual distance from the ship to the base-line B—L.

When the ship is traveling along the course *d*—*e*, i. e. in a direction toward the set path, sine-integrating wheel 118 will be in contact with the left-hand side of the face of sine-integrating disk 112; hands 149, 152 and 153 will be rotating counter-clockwise; and the registration of distance shown by such hands with reference to their respective dials will progressively decrease until the ship reaches the point *e*, when such registration will be zero—the hands 149, 152 and 153 being at that instant in vertical alignment with the centers of their respective dials. As the ship is traveling in a direction toward the base-line B—L, cosine-integrating wheel 113 will be in contact with the left-hand side of the face of cosine-integrating disk 111; base-line-indicating hands 141 and 142 will be rotating counter-clockwise; and the registration of distance shown by the relation of such hands to their dial will be progressively decreasing, and will represent, when point *e* is reached, the actual distance between said point and the point of departure *a*.

While the ship is traveling along course *e*—*f*, i. e. in a direction away from and to the right of the set path, path-indicating hands 149, 152 and 153 rotate in a counter-clockwise direction, and the registration of distance shown by such hands, in their relation to their respective dials, progressively increases. As the ship is traveling in a direction toward the base-line B—L, base-line-indicating hands 141 and 142 will still be rotating counter-clockwise, and the registration of distance shown by such hands, in their relation to their dial, will progressively decrease until the ship has reached the point *f*, when such registration will have become zero—the hands 141 and 142 being at that instant in vertical alignment with the center of their dial.

When the ship is traveling along the course *f*—*g* (which course is assumed to be parallel to the set path), the sine-integrating wheel 118 is in its central or non-rotating position of contact with sine-integrating disk 112; path-indicating hands 149, 152 and 153 remain in the positions of registration which they occupied at the point *f*, and they continue to show the direction and the distance to the set path. As the ship has now crossed base-line B—L and is traveling directly away from said line, cosine-integrating wheel 113 will operate at its extreme outward position of contact with the left-hand side of the face of its cosine-integrating disk 111. Base-line-indicating hands 141 and 142 will therefore be rotating counter-clockwise, and will at all times show the direction and the distance to the base-line B—L.

Referring to Fig. 8: a novel type of dial, with associated hands, is provided for continuously indicating the direction and distance to the set path. A generally-similar dial is provided for indicating the direction and the distance to the base-line. The dial is provided with an outer circle, preferably graduated into tenths of a nautical mile; and with a concentric inner circle preferably graduated into ten nautical miles. The outer circle is to be read with reference to hand 152, and the inner circle with reference to hand 153. The outer circle is provided with two sets of figures of different colors, those beginning at the right of the zero point being black, and increasing in a clockwise direction around the circle; and those beginning at the

left of the zero point being red and increasing in a counter-clockwise direction. The dial area inside the inner circle is vertically divided into semi-circular segments, the right-hand segment being provided with black figures and the left-hand segment with red figures. The purpose of this color design is to distinguish between the zones over which hand 153 may be traversing in order that the position of said hand may at all times indicate the direction in which the set path lies and the distance to the set path. This color design also serves as a key to the reading with reference to hand 153. Thus, when hand 153 is found in the left-hand or red zone, it indicates that the ship has departed to the right from its set path; and it also indicates that hand 152 is to be read with reference to the red figures on the outer circle of the dial. As is well known to those skilled in the art of navigation, in considering direction to the right or left from a ship to its set path, the ship is always visualized as being headed in the same direction as the direction of its set path; and by following this practice, the position of hand 153 in relation to the vertical line of its dial is always indicative of the direction to the set path—regardless of the actual heading of the ship. It will be understood that the corresponding cosine-dial and hands function in a like manner with reference to the base-line passing through the known point of departure. The indications of the two hands of the path-indicating and the base-line-indicating dials are, of course, to be read together, for the purpose of determining the position of the ship in terms of latitude and longitude.

I claim:

1. In navigating apparatus, the combination of means for integrating with functions of angles of travel of a self-propelled object relative to a set path a factor of distances of travel of said object relative to said path, means for adjusting said apparatus to integrate with reference to any set path, and continuously-operative automatic means for correcting the distance factor to compensate for variations in the coefficient of slippage of the propeller of said object.

2. In navigating apparatus, the combination of means for integrating with functions of angles of travel of a self-propelled object a factor of distances of travel of said object relative to any set path, and reversible, continuously-operative automatic means for correcting the distance factor to compensate for variations in the coefficient of slippage of the propeller of said object.

3. In navigating apparatus, the combination of means for reproducing angles of travel of a self-propelled object relative to any set path, means rotatable at a speed correlated to that of the propelling means of said object, means driven by said last-named means, continuously-operative reversible means for automatically altering the speed of said driven means to correct for variations in the relation between the speed of the propelling means and the rate of travel of said object, devices actuated by said driven means to register a factor of the rate of travel of said object and devices for integrating with said travel factor two functions of said angles of travel.

4. In navigating apparatus, the combination of means for reproducing angles of travel of a self-propelled object relative to any set path, and coacting devices driven by the propelling means of said object and automatically and continuously correlated in speed to the speed of travel of said object under varying conditions of propeller slippage for integrating with a factor of distances of travel of said object two functions of said angles of travel.

5. In navigating apparatus, the combination of means for reproducing angles of travel of a self-propelled object relative to any set path, and coacting reversible devices driven by the propelling means of said object and automatically and continuously correlated in speed to the speed of travel of said object under varying conditions of propeller slippage for integrating with a factor of distance of travel of said object two functions of said angles of travel.

6. In apparatus for integrating functions of angles of travel with a factor of distance of travel of a self-propelled object relative to any set path, means rotating at speeds proportional to the mean of the speeds of a plurality of propelling means for said object, means driven by said last-named means, and automatically-acting means for correctively altering the speed of said driven means in order to compensate in the operation of said integrating apparatus for variations in the coefficient of slippage of said propelling means.

7. In apparatus for integrating functions of angles of travel with a factor of distance of travel of a self-propelled object relative to any set path, means for adjusting said apparatus to operate with reference to the direction of any base-line and continuously-operative, automatically-acting means for compensating in said apparatus for variations in the relation between the speed of the propelling means of said object and its rate of travel.

8. In apparatus for integrating functions of angles of travel with a factor of distance of travel of a self-propelled object relative to any set path, means for adjusting said apparatus to operate with reference to the direction of any base-line and continuously-operative, automatically-acting reversible means for compensating in said apparatus for variations in the relation between the speed of the propelling means of said object and its rate of travel.

9. In navigating apparatus, the combination of means for reproducing angles of travel of a self-propelled object relative to any set path, coacting devices driven by the propelling means of said object and automatically and continuously correlated in speed to the speed of travel of said object under varying conditions of propeller slippage for integrating with a factor of distance of travel of said object a function of said angles of travel and dials and hands rotatable with reference to said dials for displaying the results of such integrations.

10. In navigating apparatus wherein a function of angles of travel of a mobile object with reference to a set path is integrated with a factor of distance of travel of said object, a plurality of hands rotating at different speeds with reference to a dial for indicating the results of such integrations.

11. In navigating apparatus wherein functions of angles of travel of a mobile object with reference to a set path are integrated with a factor of distances of such travel, a plurality of dials and a plurality of hands rotatable with reference to said dials for indicating the results of such integrations.

12. In navigating apparatus, means for integrating functions of angles of travel of a mobile object relative to a set path with a factor of distance of such travel, hands for indicating the results of such integrations and dials coacting with said hands and constructed and arranged to indicate the direction of the set path from the mobile object.

13. In navigating apparatus, means for integrating functions of angles of travel with a factor of distance of travel of a mobile object, hands for indicating the results of such integrations and a dial coacting with said hands and constructed and arranged to indicate the position of said mobile object relative to any base-line.

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