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E. L. HOLMES

INTEGRATING APPARATUS

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Fig. 1.

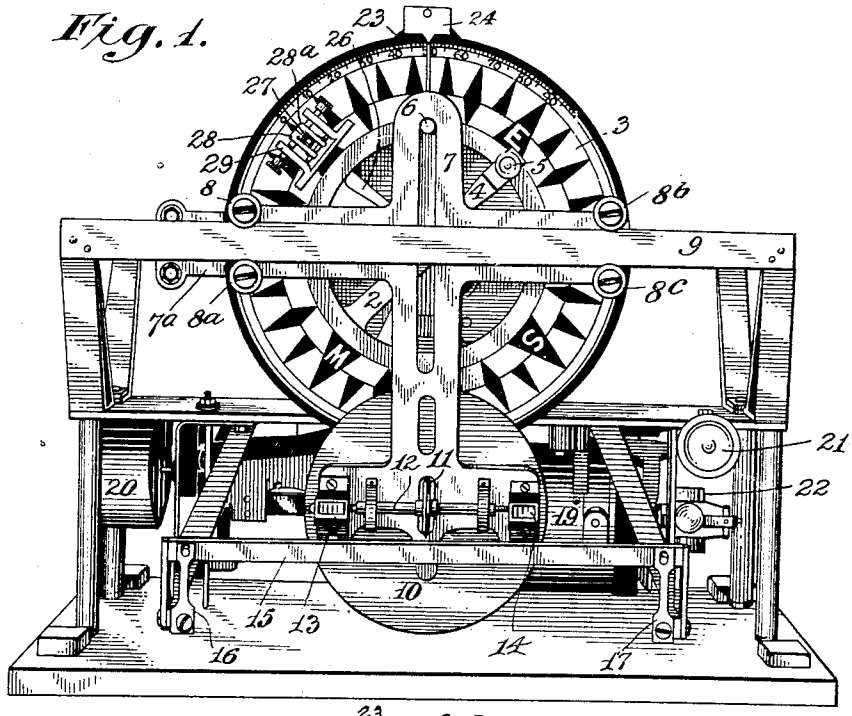


Fig. 2.

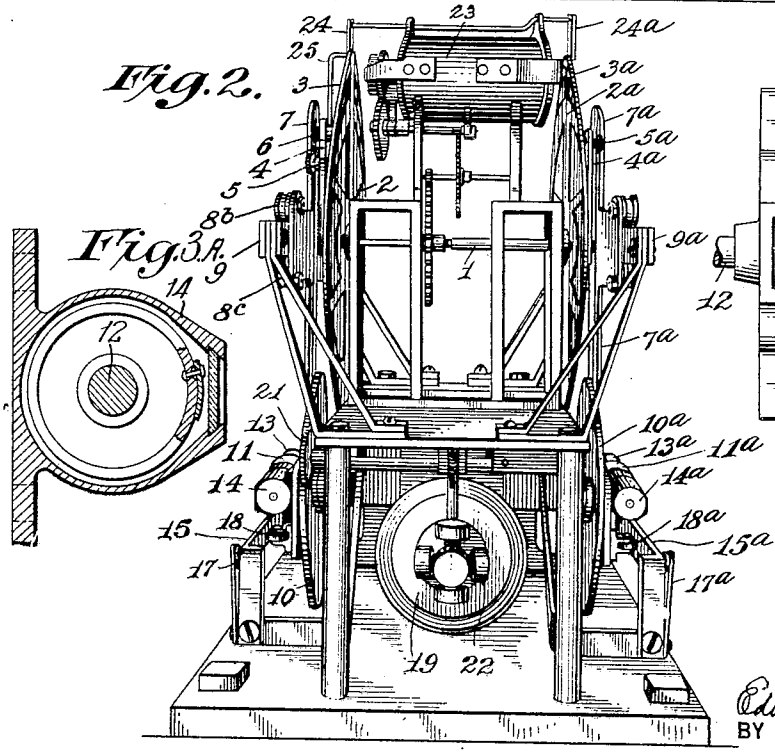
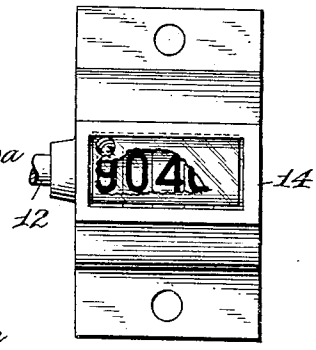


Fig. 3A.

Fig. 3.



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INTEGRATING APPARATUS.

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The following is a description of integrating apparatus embodying my invention in the form and manner at present preferred by me; but it will be understood that various modifications and changes may be made without departing from the spirit of my invention and without exceeding the scope of my claims.

My invention will best be understood by reference to the accompanying drawings, in which I have illustrated the preferred form of devices for carrying out my invention and in which Fig. 1 is a front perspective view of the apparatus; Fig. 2 is an end perspective view thereof; Fig. 3 is a perspective view of a counter having attached to one dial thereof a shutter for concealing the numbers of said counter, such shutter being partially broken away; Fig. 3^{A} is a sectional view of the counter shown in Fig. 3, showing the left-hand dial of said Fig. 3 partly in elevation and partly in section, to illustrate the manner of attaching said shutter to said dial. Like reference characters indicate like parts throughout the drawings.

The apparatus integrates and registers two functions of all angles of operation with time of operation. For purposes of illustration it will be described as installed upon a ship or other mobile object, travelling at a uniform speed, and as being controlled by a master-compass to integrate, with time of operation, the sines and cosines of all angular movements of said ship or mobile object relative to a set path. It is thus possible by means of the invention to determine the distance which the mobile object has traveled from said set path and from its known point of departure. It will, however, be understood that my invention is useful in other connections than as an aid to navigation, it being applicable generally to the integration of functions of angles of operation with time of operation.

Referring to the drawings: At the left-hand side of Fig. 2 is shown a mechanism for integrating and registering in numbers sines of angles of operation with time of operation; and at the right-hand side a mechanism for integrating and registering in numbers cosines of angles of operation with time of operation. Attached to rotatable shaft 1 at the left-hand end thereof is spoked wheel 2, and attached to said rotatable shaft at the right-hand end thereof is spoked wheel 2^{a}. Mounted upon spoked wheels 2 and 2^{a} respectively are compass cards 3 and 3^{a}. Rotatably mounted upon the left-hand end of shaft 1 is yoke 4, carrying at the outer end of one arm set-screw 5; and similarly mounted upon the right-hand end of said shaft 1 is yoke 4^{a}, carrying at the outer end of one arm set-screw 5^{a}. These set-screws are for the purpose of clamping the yokes to the annular portions of spoked wheels 2 and 2^{a}, respectively. The other arm of yoke 4 carries at its outer end a pin 6, engaging a vertical slot in cruciform yoke 7, whereby said pin actuates said cruciform yoke. The cruciform yoke is supported by grooved rollers 8, 8^{a}, 8^{b} and 8^{c} on yoke-track 9. Attached to the arm which carries pin 6 is a pointer 25, which is mounted in radial alignment with reference to the centers of shaft 1 and said pin 6. Mounted on the lower portion of cruciform yoke 7 is a sine-integrating unit driven by integrating disk 10, and comprising integrating wheel 11, counter-driving shaft 12 (rotating in suitable bearings), and counters 13 and 14, carried by said shaft 12. Integrating wheel 11 is maintained in driving contact with sine-integrating disk 10 by bar 15, pressed by springs 16 and 17 against roller 18, mounted on the lower end of said cruciform yoke 7. Yoke 4^{a}, at the right-hand side of the device, has a yoke-pin engaging a corresponding cruciform yoke 7^{a}, supported in like manner on a yoke-track 9^{a}, and carrying a cosine-integrating unit comprising an integrating wheel, a counter-driving shaft and counters 13^{a} and 14^{a}, carried by said shaft. The operative relationship between the cosine-integrating cruciform yoke 7^{a} and its yoke pin is not the same as the operative relationship between the corresponding sine-integrating elements, being such that, as appears from Fig. 1, when the sine-integrating cruciform yoke 7 is central with reference to sine-integrating disk 10, cosine-integrating cruciform yoke 7^{a} is at its extreme outward position with reference to cosine-integrating disk 10^{a}. Thus, while sine-integrating wheel 11 is in its central or non-rotating position of contact with sine-integrating disk 10, cosine-integrating wheel 11^{a} is in its extreme outward position

of contact with cosine-integrating disk 10^a, and therefore is rotating at maximum speed. A corresponding integrating disk 10^a drives cosine-integrating wheel 11^a. Integrating disks 10 and 10^a are driven, through speed-reduction gearing (not shown) by a motor rotatable at substantially constant speed and here illustrated as an electric motor 19, which receives its current from any suitable source of electrical energy (not illustrated). This motor 19 also preferably drives a clock 20. The speed of motor 19 is regulated in a well-known manner by a cam (not shown), operated by hand-wheel 21, and acting upon friction-brake governor 22. The clock is so designed that it keeps correct time when the motor is operating at normal speed. By comparison of this clock 20 with a standard timepiece, the correctness or incorrectness of the motor speed may at any time be determined.

Compass card 3^a on the cosine-integrating side is a duplicate of compass-card 3 on the sine-integrating side, except for the reversal of the figures thereon.

It is well known that when a rotary member is provided with a pin engaging in a slot of a linearly-moving member, the movement of the latter member may be correlated to the sine or to the cosine of the angle of movement of the rotary member.

The position of contact of integrating wheel 11 and its corresponding wheel on the cosine-integrating side with the integrating disks, and, consequently, the rate of rotation of said wheels and the value of the numbers registered by their counters, is governed through rotating shaft 1 by the operation of a motor and preferably by a step-by-step electric motor 23. Thus, angular movements relative to the directional element of a primary compass may be caused, through a master-compass and suitable transmitting devices, to so energize some of the field magnets of step-by-step motor 23 as to rotate shaft 1 and thereby bring integrating wheel 11 to such a position of contact with integrating disk 10 as to inpart to it a speed resulting in the registration by one of the sine-indicating counters of a number which represents an integration of the sine of the angle of movement with reference to the directional element of the primary compass, with time of operation. Simultaneously, one of the cosine-indicating counters registers in numbers an integration of the cosine of such angle with time of operation. Thus, through the intermediary of step-by-step motor 23 the integrating units become operatively electro-magnetically locked to the master-compass or other controlling device, and therefore reproduce all angular movements thereof and integrate all such angular movements with time of operation.

The apparatus is adjustable to integrate with time of operation sines and cosines of all angles of operation with reference to indicated direction of any base-line—such adjustment being effected in the following manner: When no current flows through step-by-step motor 23, shaft 1, together with spoked wheels 2 and 2^a and attached compass cards 3 and 3^a, is freely rotatable. Shaft 1 is manually rotated until the desired points (say 50) on the two compass cards register with fixed points, such as lubber's lines. Set-screws 5 and 5^a are then released, and cruciform yokes 7 and 7^a are moved upon their respective tracts until the cruciform yoke-pin pointers are also in alignment with the figures, such as 50, on the respective compass cards and with the respective lubber's lines—yokes 4 and 4^a being then clamped by their set-screws to the annular portions of spoked wheels 2 and 2^a, respectively. Thereafter rotative movement of shaft 1 will cause a shifting of cruciform yokes 7 and 7^a upon their tracks to positions correlated to the sine and the cosine, respectively, of such angle of rotation. The four counters are then set at zero, the clock is set, and the motor 19 (which actuates the two integrating disks 10 and 10^a and said clock) is started. The initial adjustment of cruciform yoke 7 has brought sine-integrating wheel 11 to the center of sine-integrating disk 10, and the initial adjustment of cruciform yoke 7^a has brought the cosine-integrating wheel to its maximum outward position from the center of cosine-integrating disk 10^a. Therefore motor 19 will produce no rotation of sine-integrating wheel 11, and will cause cosine-integrating wheel 11^a to rotate at maximum speed. These conditions will obtain so long as there is no variation relative to the directional element of the primary compass from the assumed 50° position.

Assuming now that there occurs an angular movement of 1° relative to the directional element of the primary compass, as for example, by reason of veering of the ship which carries the device and its controlling compass: Through the action of a master-compass controlled by the primary compass, and a suitable transmitting device, step-by-step motor 23 will be actuated to rotate shaft 1 and spoked wheels 2 and 2^a by 1°. Through yoke 4 and yoke-pin 6, cruciform yoke 7 will be moved along its track, thereby shifting sine-integrating wheel 11 away from its non-driven position at the center of sine-integrating disk 10 to a position wherein its speed will be correlated to the sine of the angle of 1°. Simultaneously, and through yoke 4^a and its yoke-pin, cruciform yoke 7^a will have been moved along its track, thereby shifting the cosine-integrating wheel from its extreme outward position whereby its speed will be correlated

to the cosine of the angle of 1°. I preferably so fix the speed of motor 19 that at the end of one hour of operation the figure registered by one of the sine-integrating counters will represent the actual sine of the angle at which the device has been operating; and the number registered by one of the cosine-integrating counters will represent the actual cosine of said angle. For example, at the end of one hour of operation under the condition of the assumed 1° change from the initial 50° setting, one of the sine-indicating counters will register 0.0174, which is the sine of the angle of 1°; and one of the cosine-indicating counters will register 0.9998, which is the cosine of the angle of 1°. As the counters register numbers in which time of operation is a factor, such numbers will progressively increase so long as the device continues to operate at 1° deviation from the original 50° setting. If the ship has traveled at a uniform speed one nautical mile in said hour, its distance from its set path, at the end of such hour, will be .0174 of a nautical mile. If it has traveled at a uniform speed 15 miles in said hour (as determined by any of the methods well known in navigation), it is only necessary to multiply such registered number 0.0174 by 15 to learn the distance (.261 of a nautical mile) from the ship to its set path. Under the assumed conditions, the number 0.9998 on the cosine-integrating side of the device will indicate the distance in nautical miles between the known point of departure and the ship, as projected upon the set path, provided the ship has traveled at a uniform speed one nautical mile in one hour. If it has traveled at a uniform speed 15 miles in that hour, the distance between the known point of departure and the ship as projected upon the set path will be $15 \times .9998$, or 14.997 nautical miles.

It will be understood that if the device is required to operate for long periods of time, counters may be employed having a larger number of dials than that shown in the drawings. It will also be understood that the gear ratios may, if desired, be such that the dials will rotate more slowly than above indicated. For example, these gear ratios may be such that, at the end of one hour of operation, the indications of the counter dials will register a figure representing but one-tenth the actual sine or cosine.

If the ship be swung to head parallel to the set path of 50°, the consequent 1° movement relative to the directional element of the primary compass will result in shifting the sine-integrating wheel 11 back to the center of the sine-integrating disk 10, where it will stop rotating—leaving registered upon one of its counters a number representing the sine of the angle of 1° multiplied by the time in hours during which the device was operating at a 1° angle from the initial setting. If the ship be now headed toward its 50° set path, the sine-indicating counter number will begin to decrease—the rate of such decrease being proportional to the new angle of direction of the ship relative to said set path. Thus, if the ship be headed directly toward its set path, i. e. at an angle of 90° thereto, sine-integrating wheel 11 will be shifted to its maximum outward position from the center of sine-integrating disk 10, and will therefore rotate in a reverse direction at its maximum speed. Regardless of the angle of direction at which the ship traveling at a uniform speed, approaches its set path, the sine-integrating counters will again register zero when said set path is reached. Thus the sine-integrating counters show at all times the integration of the sines of all the various angles at which the device has operated, with all the various periods of time involved in such operation. Similarly, the cosine-integrating counters will show at all times the integration of the cosines of all the various angles at which the device has operated, with all the various periods of time involved in such operation.

With the distance and direction of the ship from its set path indicated, and with the distance indicated between a point of departure of known latitude and longitude and the ship as projected upon the set path, the position of the ship in terms of latitude and longitude may at any time be readily ascertained.

I employ counters of the reversible type, one of each pair being right-hand drive and the other left-hand drive. With both counters of the path-indicator set at zero when the ship is heading on its set path, a veering to the right causes the number showing on the left-hand counter (Fig. 1) to increase. Simultaneously, a shutter automatically covers the negative, or decreasing, number on the right-hand counter. I believe this expedient of exposing one counter and covering the opposite counter is novel in this art; and it possesses the advantage of instantly indicating the direction in which the set path lies. It is further desirable in that the confusion which might result from the necessity of considering the values of two sets of exposed figures is thereby obviated. Moreover, when the ship, traveling at a uniform speed, crosses the set path, one shutter will automatically close, while the opposite shutter will automatically open; and this alternate closing and opening constitutes a practical and readily-observable guide to the set path, which permits of more accurate steering than is possible with any other apparatus or by any other method with which I am familiar. The shutters are caused to

operate in the described manner by attaching them over the highest digit of the highest dial of each counter, as illustrated in Fig. 3. In this position they respond immediately to the reversal of the counterdriving shaft which produces a negative reading.

My integrating apparatus may be used in conjunction with a gyro-compass of the type in which an electric circuit is controlled by a rolling conductor attached to the sensitive element of said compass and contacts with conductors adjacent said sensitive element, and wherein the latter conductors are rapidly oscillated to overcome static friction. Such oscillations, which are at the rate of about two per second, are transmitted throughout the entire repeater-system—even the repeater-compass card having an oscillatory movement, which interferes with accurate reading thereof. If these oscillations (which are of the order of ¾ of one degree in extent) were communicated to spoked wheels 2 and 2^a, to yokes 4 and 4^a, and to cruciform yokes 7 and 7^a, they would cause the integrating wheels to constantly shift backward and forward over the faces of the integrating disks, and the counters would be rapidly actuated in alternate directions. This would produce undue wear throughout the mechanism, and would also render difficult the reading of the counters. Where it is desired to employ my integrating apparatus with such a gyro-compass, I provide means for preventing the communication of the oscillations to these parts and to the compass cards in the following manner: I mount spoked wheels 2 and 2^a rotatably, instead of fixedly, on shaft 1; and attach to said shaft an arm 26, the outer end of which arm is bent at a right angle and oscillates about the center of slot 27, between adjustable members 28 and 28^a, carried by member 29, mounted upon spoked wheel 2—without, however, contacting with said adjustable members. The oscillations are therefore not communicated to the spoked wheel or to any of the devices actuated thereby. When, however, step-by-step motor 23 moves in response to deviations of the ship, rather than merely in response to oscillations of the electrical terminals of the gyro-compass, arm 26 will take up a new position, carrying with it spoked wheel 2 and the parts controlled thereby, and will thereafter oscillate about a new center. The cosine side of the device will, under these circumstances, carry similar elements for preventing the communication of oscillations to its compass card and parts associated therewith.

Various chart-recording devices, under control of both gyro-compasses and magnetic-compasses, are shown in the prior art. While such devices, when properly designed and constructed, will record the integration of sines and cosines of angles of movements with distances of such movements, and with reference to a set path and a known point of departure, they are open to the objection that in order that the movements of the stylus used in connection therewith shall be of any advantage as a steering guide in relation to set path, the chart must be impracticably large. If large-scale charts be employed, they must be frequently changed. Moreover, the integrations on such charts are not shown in numbers, and distances must therefore be measured and computed. My apparatus is operatively independent of charts and their size limitations. Its rate of operation is preferably such that the counter registrations are in terms of one ten-thousandth of a nautical mile, at a uniform speed of one nautical mile per hour—thus constituting it a very sensitive and legible indication, for steering purposes, of departures from set path. In order that a chart might be equally legible, it would require to be on a scale of about 175 lineal feet per hour. If such a chart were intended to be used in connection with maneuvering, it would require to be proportionately wide. Therefore, as a path-and-position indicator, my invention has the distinct advantage over chart-recording devices of registering clearly-observable numbers which require but a simple multiplication to convert them into the desired terms of distance from set path and distance made good on set path from known point of departure; and of operating upon a scale very much larger than is feasible in a chart recorder.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, rotatable means for indicating the direction of any base line, and means responsive to angular movement of said rotatable means away from said base line for integrating with time of operation and registering in numbers a function of the angle through which said rotatable means has moved.

2. In combination, rotatable means for producing an indication of the direction of any base line, a motor and means actuated by said motor to integrate with time of operation a function of angles of movement of said rotatable means relative to the indication of direction of said base line.

3. In combination, rotatable means for producing an indication of the direction of any base line, a second rotatable means correlated in speed to angles of movement of said first rotatable means relative to said base line in order to produce an integration of a function of said angles of movement with time of operation, and means for registering in numbers the result of such integration.

4. In combination, a motor rotatable at a

substantially constant speed, means for producing an indication of the direction of any base line, said means being movable relative to said indicated base line, means actuated by said motor and co-operative with said direction-indicating means to integrate with time of operation a function of angles of movement of said direction-indicating means relative to said indicated base line, and a counter for registering in numbers the result of such integration.

5. In combination, a motor, a disk driven by said motor, a wheel driven by said disk and movable across the face thereof, and means for moving said wheel relative to said disk and adjustable to indicate the direction of any base line, said disk and wheel co-operating with said wheel-moving and direction-indicating means to integrate with time of operation functions of angles of movement of said direction-indicating means relative to said indicated base line.

6. In a self-contained integrating apparatus, a rotatable member adjustable to produce an indication of the direction of any base line, and means controlled by said member for registering in numbers the integration, with time of operation, of a function of an angle of movement of said member relative to said indication of direction, said means comprising a motor rotatable at a constant speed, a disk driven by said motor, a wheel driven by said disk, and a device for moving said wheel across the face of said disk.

7. In combination, means for indicating the direction of any base line and angularly movable with reference thereto, means co-operative with said direction-indicating means to integrate with time of operation a function of angles of movement of said direction-indicating means relative to said indicated base line, a pair of counters for registering in numbers the results of such integrations, and means operatively related to said counters for distinguishing between the same.

8. In combination, angularly-movable means for indicating the direction of any base line, means co-operative with said last-named means to integrate with time of operation two functions of angles of movement of said direction-indicating means to the right or left of said indicated base line, and two pairs of counters controlled by said integrating means for registering the results of such integrations.

9. In combination, rotatable means for indicating the direction of any base line, means co-operative with said rotatable means to integrate with time of operation two functions of angles of movement of said rotatable means relative to said indicated base line, and two pairs of counters for registering the results of such integrations, said counters being controlled by said integrating means and being supported on yokes movable along tracks.

10. In combination, rotatable means for indicating any base line and means responsive to angular movement of said rotatable means away from said base line for integrating with time of operation and registering in numbers two functions of the angle through which said rotatable means has moved.

11. In combination, a self-contained device including a motor rotatable at a substantially constant speed, means actuated by said motor to produce an indication of the direction of any base line, said means being movable relative to said indicated base line, and means whereby said last-named means integrates and registers in numbers two functions of such angles of movement with time of operation.

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