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COMPLETE SPECIFICATION

Navigational Computer of the Slide Rule Type

I, OSCAR EUGENE BATORI, a citizen of the United States of America, of Hotel Shelton, 527, Lexington Avenue, City of New York, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to navigational computers of the slide rule type.

One important object of this invention is to simplify the basic computation in air and sea navigation involving speed, time and distance.

Another important object of the invention is to determine correct air speed in air navigation with allowance for compressibility and compressibility heating of air.

Another object of the present invention is to provide a computer of simple structure which is inexpensive to produce.

To these ends, the present invention broadly consists in providing a computer comprising a fixed circular base member having thereon a logarithmic scale in terms of distance, a rotatable member in front of and smaller than said base member and rotatable relative thereto, said rotatable member having an outer logarithmic scale in terms of time and an inner logarithmic scale in terms of speed, said inner scale being inverted and angularly displaced by logarithmic 60 with respect to said outer scale, and an indicator fixed to said base member, overlying said rotatable member and of a diameter to conceal the inner scale and expose the outer scale on said rotatable member, said indicator having an opening therethrough over said inner scale so as to reveal parts thereof.

Prior computers of the slide rule type, to perform a simple computation, such as multiplication or division, use two coacting scales. One is the base scale on the base member, generally fixed in position, the other the slide scale, on the slide member, relatively movable with respect to the base scale. These two scales are used for the three arguments of a computation. In case of multiplication these arguments are the multiplicand, multiplier and result. In case of division they are the dividend, divisor and quotient. Accordingly one scale has to be used for the two arguments and the other for the third. Consequently certain rules have to be known and followed in the procedure. The scale on which each of the arguments must be set must first be determined, and the scale on which the result is to be read must be known. For users without mathematical background the procedure is complicated and difficult. Furthermore in the case of circular slide rules the results are given around a circular scale at varying locations, inconvenient for reading, necessitating turning the computer around in order to read the result. This invention utilizes three scales, one for each argument, thus avoiding any difficulty or misunderstanding as to which is to be used for a given argument. Furthermore it has a fixed indicator. This fixed indicator gives all results at a permanent location, with the numbers in upright position in all cases, thus minimizing the need to turn the computer around for reading in many computations.

In navigation the most frequent computations are for speed, distance and time. Prior navigational computers apply two scales for these three arguments. One scale, marked "Miles" is used for speed and also for distance. The other scale, marked "Minutes," is for the time element. To perform a computation with these three arguments and the two scales, one must first learn how to use the miles scale for the speed and the distance too, which is difficult for a beginner or for the user without mathematical background. In addition, when circular computers are involved all three arguments extend around the circular scale. First the eye must find the number involved and then make the reading inconveniently or else the computers must be turned for a better reading. This invention uses three separate scales, one scale being for distance, marked "Miles," one for the time element, marked "Minutes," and a third one for "Speed" and appropriately marked. There is nothing to learn; all the user has to do is simply to set the arguments on their respective designated scales. The speed is indicated in a fixed indicator window with the numbers in upright position for convenience in reading.

In speed, distance and time computations, to obtain speed in terms of distance per minute, the distance in miles must be divided by the time in minutes. To obtain speed in miles per hour, as is generally required, the speed per minute has to be multiplied by the constant factor of 60, since there are 60 minutes in one hour. The multiplication by 60 is done inherently in the computer of this invention by angularly translating the speed scale by logarithmic distance of 60 with respect to the minutes scale, thus greatly facilitating use of the computer.

Air speed is an important factor in air navigation and is measured generally by air speed indicators or meters. Air speed indicators are pressure measuring instruments and their reading will depend on the density of the air. The denser the air, the greater the pressure and the higher the reading. Therefore the air speed indicator can only be made to give the correct speed at one air density. An average density of air at sea level is chosen, the actual pressure being 1013.2 millibars or 29.92 inches of mercury and the temperature being arbitrarily chosen as 15 degrees centigrade or 59 degrees Fahrenheit. As the aircraft climbs, the air becomes less dense. Therefore the pressure built up by the forward speed of the aircraft is less and the air speed indicator consequently reads low. The density of the air can be recorded by the altimeter, provided that it has first been set to the standard pressure of 1013.2 millibars or 29.92 inches. The reading it gives with this setting is called "pressure altitude," and this reading can be used to correct the air speed indicator for air density. Air density is also affected by temperature and therefore allowance has to be made for temperature as well as for the pressure altitude.

At high speeds another factor becomes important. This is "compressibility," which results from the fact that at high speeds the air at the pitot head cannot move out of the way of the aircraft fast enough and therefore the pressure builds up more than it should. This tends to make the air speed indicator read high. Also, at the thermometer bulb the compressibility effect heats up the air and hence the thermometer reads higher than the actual air temperature.

To find true air speed corrections must therefore be made: (a) for density, measured by pressure altitude and temperature; (b) compressibility and (c) compressibility heating. Prior computers of the conventional type correct air speed for density only, neglecting compressibility altogether, and consequently are in error in determining speed. The computer of this invention, on the other hand, corrects air speed not only for density, but for the two other factors as well. These latter corrections are made by new scales, created in connection with and used first in this invention. The scales are: The pressure altitude and temperature scales which correct for density and compressibility, and a separate scale which corrects for compressibility heating. These scales co-operate with one another and with the time and distance scales so as to facilitate use of the computer for all computations, simple and complex.

Special navigational computers exist which correct air speed for compressibility and compressibility heating by using special scales instead of the standard logarithmic scales for distance and time. These computers, however, are of a limited use only and cannot be used for other computations as well, thus necessitating an additional computer for regular time, speed and distance computations.

For economical engine performance, the flier may wish to know the density of the air which is being fed into his engine. This can be expressed as a height, after allowing for the actual air temperature, and is then known as density altitude. The computer of this invention facilitates the determination of density altitude.

In order that the invention may be more clearly understood and readily carried into effect, the same will now be described more fully with reference to the accompanying drawings.

Figure 1 is a plan view of the front face of the computer; and

Figure 2 is a cross-section through the computer with the parts shown separated.

Referring to the drawings, the computer includes a fixed member 1 of largest diameter having a logarithmic scale A on its one face. Immediately on the front of the fixed member 1 is a ring member 6 of smaller outer diameter than member 1 and having an inner diameter of a size to accommodate an inner disk member 8. Ring member 6 has scales B and A, while disk member 8 is not provided with any scales and acts as a bearing for the rotation of ring member 6.

Outer disk member 7 is fixed with fixed member 1, while ring member 6 is relatively rotatable. Disk member 7 is placed in front of and is of smaller diameter than ring member 6 but of larger diameter than disk member 8. In disk member 7 there is provided a window 10 to expose to view a part of scale B inscribed on ring member 6 and it is also provided with logarithmic scales.

The members so far described are held in cooperative relationship by screw and nut 9 and 5 upon which they are mounted concentrically. The inside diameter of disk member 8 is slightly larger than the outside diameter of nut 5 as can be observed at 12 so that it is possible to adjust concentrically the disk member 8 and therewith the ring member 6 before tightening together the nut 5 and the screw 9. Accordingly, there is a certain amount of adjustment possible between the various disks in order to remove defects in their concentricity.

A certain amount of frictional drag between the bearing surfaces of ring member 6 and its cooperating disk member 8 may be provided by means of chordal slots 13 cut in the periphery of disk member 8 thereby to provide spring arms 14 exerting a certain amount of radial spring pressure against the inner surface of ring member 6. This feature eliminates a certain amount of play between the cooperating bearing surfaces and will also serve to retain movable ring member 6 and its adjusted positions against accidental displacement.

The front faces of members 1 and 6 are provided with a scale A consisting of identical standard logarithmic scales of one logarithmic unit wherein log 10 is equal to 360 degrees of rotation. These scales go from 10 to 100. The outermost scale A on member 1 is marked in miles representing the distance and the cooperating identical scale on the periphery of ring member 6 is marked in minutes for the time of flight. The indicia of these scales are actually the logarithmic values of the respective numbers, but for simplicity they will be referred to hereinafter as the actual numbers or corresponding values, as is usual with slide rules.

On the front face of ring member 6 there is also a scale B which represents speed values in units of miles per hour or knots or nautical miles per hour or kilometers per hour, according to the specific use of the computer for navigational purposes. This scale B is arranged in increasing values from 100 to 1000 and it is concealed from view by disk member 7 except where it is exposed through window 10. This scale B, furthermore, is shifted relatively to scale A by logarithmic value 60. This arrangement is generally referred to as a folded scale. The scale B is marked with speeds and may be set or read at the pointer SP which is located at the center of the window 10 provided in disk member 7.

For the sake of simplicity the scales are shown in the drawing with only their main indicia but without sub-divisions.

When using the computer so far described, a given speed may be set on scale B opposite the pointer SP and the distance covered in a given time will be readily available on the miles scale A opposite to the time on the minutes scale A. Normally such a computation implies a multiplication by 60 which is eliminated by displacing the scale B by log 60.

As mentioned before, known computers of the conventional type in determining correct air speed, take into consideration only the density of the air so that an appreciable error is unavoidably introduced into the computation. The scale of these computers for airspeed correction are based upon the following formula:

$$Vt = Vi\sqrt{\frac{Po}{P}} \times \sqrt{\frac{T}{To}}$$

wherein V_t is the true airspeed, V_i the indicated airspeed as shown by the speed indicator, P the pressure at that altitude as shown on the altimeter set to standard atmospheric conditions, P_o the pressure at sea level under normal conditions 29.92 inches, T the actual temperature absolute at the operational altitude, and T_o the absolute temperature at sea level. This formula, which is widely used, in fact assumes that air is not compressible and introduces an error of as much as 8.1 knots at a speed of 300 knots, while at 500 knots the error is 36.5 knots in true speed.

This invention, as mentioned before, in determining correct air speed, takes into account not only the density but the compressibility of the air too, as expressed in the following formula:

$$Vt = Vi \times \frac{1}{B}\sqrt{\frac{Po}{P}} \times \sqrt{\frac{T}{To}}$$

$$B = 1 + \frac{Vt^2}{4\gamma RT}\left(1 - \frac{P}{Po}\right)$$

In the above formula B is the compressibility term as a function of the true airspeed V_t, V_i is the indicated air speed, R is a gaseous constant, T is the temperature absolute at the operational altitude, P is the pressure at the operational altitude, P_o the pressure at sea level, and δ the ratio of the specific heats for the ambient atmosphere.

For a selected airspeed V_t and a known pressure P, the compressibility term B becomes constant and the first part of the formula can be incorporated in logarithmic scale D. The last part of the formula, namely the square root of the quotient of the temperature absolute at operational level and at sea level $\left(\frac{\sqrt{T}}{T_o}\right)$ is incorporated in scale C. In this manner a correct airspeed can be computed by designing scale D for any required speed. In order to find the true airspeed, the temperature at the operational level shown on scale C is set opposite to the pressure altitude on scale D. It is then possible to read the true airspeed on the fixed scale A opposite to the indicated airspeed on the movable scale A.

Scale C is graduated from plus 50° to minus 80° Centigrade, while scale D is graduated from 0 to 40,000 feet altitude.

Due to the compression of the air at the outside thermometer bulb, the thermometer indicates higher temperature than the actual temperature of the surrounding atmosphere. In order to correct this difference and to incorporate such correction in the speed computation, a short scale E is provided on the same member as movable scale A, namely on ring member 6. This scale E is indicated as being placed between the numerals 13 and 14 of movable scale A starting with the arrow or pointer at 14. The graduations are marked 2, 3, 4, 5 and 6, which stand for 200, 300, 400, 500 and 600 knots. The operation is as follows: Set arrow at 14 to true air speed on fixed scale A. (True air speed had been previously obtained and includes correction for density and compressibility of air). Then, opposite the same true air speed mark on scale E, read true air speed corrected for compressibility heating on fixed scale A. For example, if true air speed is 400 knots, set arrow at 14 opposite 400 (40) on fixed scale A. Opposite 4 (400) on scale E, read true air speed 388 knots on fixed scale A.

The scale E is based on the formula

$$\sqrt{1+\frac{V^2}{337}}$$

wherein V is the true airspeed. Although this formula is based on standard atmospheric temperature, deviation therefrom will cause only a negligible error.

The computer is also provided with a temperature scale G on ring member 6 graduated in temperatures from plus 50 to minus 60 degrees cooperating with a scale H on fixed member 7 incorporating temperatures and graduated in terms of altitude from 0 to 30,000 feet. These two scales G and H which are known *per se* cooperate with the two scales A to correct the altimeter indications to obtain true altitude.

A scale F is located on fixed member 7 between scales D and H incorporating the density of the air under standard atmospheric conditions. It is calibrated in terms of altitude from 0 to 40,000 feet and it cooperates with a pointer DN provided on ring member 6. In order to find the density altitude, use is made of scales C and D. When the pressure altitude on scale D is set opposite temperature on scale C, the density altitude is readily available on scale F opposite to the pointer DN.

The rear face of the fixed member 1 is provided with a computer assembly similar in constructional details to the computer just described but which is provided with different scales permitting other computations. The computer assembly on the reverse face of the fixed member 1 forms no part of the present invention and has been divided out of this application and forms the subject matter of my divisional Application No. 17601, filed July 11, 1952 (Serial No. 708,893).

What I claim is:—

1. A computer comprising a fixed circular base member having thereon a logarithmic scale in terms of distance, a rotatable member in front of and smaller than said base member and rotatable relative thereto, said rotatable member having an outer logarithmic scale in terms of time and an inner logarithmic scale in terms of speed, said inner scale being inverted and angularly displaced by logarithmic 60 with respect to said outer scale, and an indicator fixed to said base member, overlying said rotatable member and of a diameter to conceal the inner scale and expose the outer scale on said rotatable member, said indicator having an opening therethrough over said inner scale so as to reveal parts thereof.

2. The computer according to claim 1, wherein the rotatable member has an open central portion, and a circular spacer member is provided in front of and fixed to the base member and snugly fitted within the open central portion of the rotatable member.

3. The computer according to claim 2, wherein the circular spacer member is provided with chordal slots at the periphery thereof defining segmental spring arms which engage and exert radially outward pressure on the inner surface of the rotatable member.

4. The computer according to claim 2, wherein the base member, the indicator, and the spacer member are all centrally axially apertured, and a fastening member is passed through the apertures so as to secure said members together, the axial aperture of said spacer member is larger than the fastening member so that the spacer member and said rotatable member may be adjusted concentrically in relation to said fixed members.

5. The computer according to any one of claims 1 to 4 for use in an aircraft, wherein the rotatable member and one of said fixed members carry cooperative logarithmic scales, one graduated in terms of temperature and incorporating the square root of the ratio of observed air temperature to air temperature at sea level, and the other graduated in terms of altitude and incorporating functional values of the density and compressibility of air in accordance with altitude and speed, whereby indicated air speeds can be corrected for density and compressibility.

6. The computer according to claim 5, wherein one of said scales is on the rotatable member and the other of the scales is on the indicator.

7. The computer according to claim 6, for use in air navigation, wherein the rotatable member carries a logarithmic scale graduated in terms of speed and incorporating values of the compressibility heating of air with regard to speed, said scale being inverted with respect to the outer scale on the rotatable member, whereby true air speed can be corrected for compressibility heating.

8. The computer according to any one of claims 1 to 4 for use in air navigation, wherein one of said fixed and rotatable members carries a logarithmic scale graduated in terms of speed and incorporating values of the compressibility heating of air with regard to speed, said scale being inverted with respect to the outer scale on the rotatable member, whereby true air speed can be corrected for compressibility heating.

9. The computer according to any one of claims 1 to 4 for use in air navigation, wherein the rotatable member and one of said fixed members carry cooperating logarithmic scales, one graduated in terms of temperature and the other graduated in terms of altitude and incorporating values of air temperature in terms of altitude, whereby indicated altitude can be corrected for temperature.

10. The computer according to claim 9, wherein the scale graduated in terms of temperature is on said rotatable member and the other scale is on said indicator.

11. The computer according to claim 5 for use in air navigation, wherein one of said members carries an indicating mark, another member movable relative thereto carrying a logarithmic scale graduated in terms of altitude and incorporating values of the density of air in terms of altitude, whereby the density of the air expressed in altitude can be obtained.

12. The computer according to claim 11, wherein the indicating mark is on the rotatable member and the scale is on the indicator.

13. The computer having its parts constructed, arranged and adapted to operate substantially as hereinbefore described with reference to the accompanying drawings.

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708,811 COMPLETE SPECIFICATION
1 SHEET

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