March 14, 1944. H. B. HUNTLEY ET AL 2,344,146

COMPUTER

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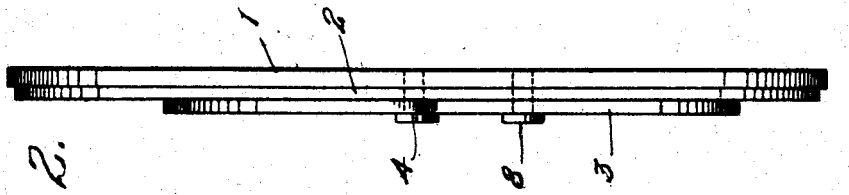

Fig. 2.

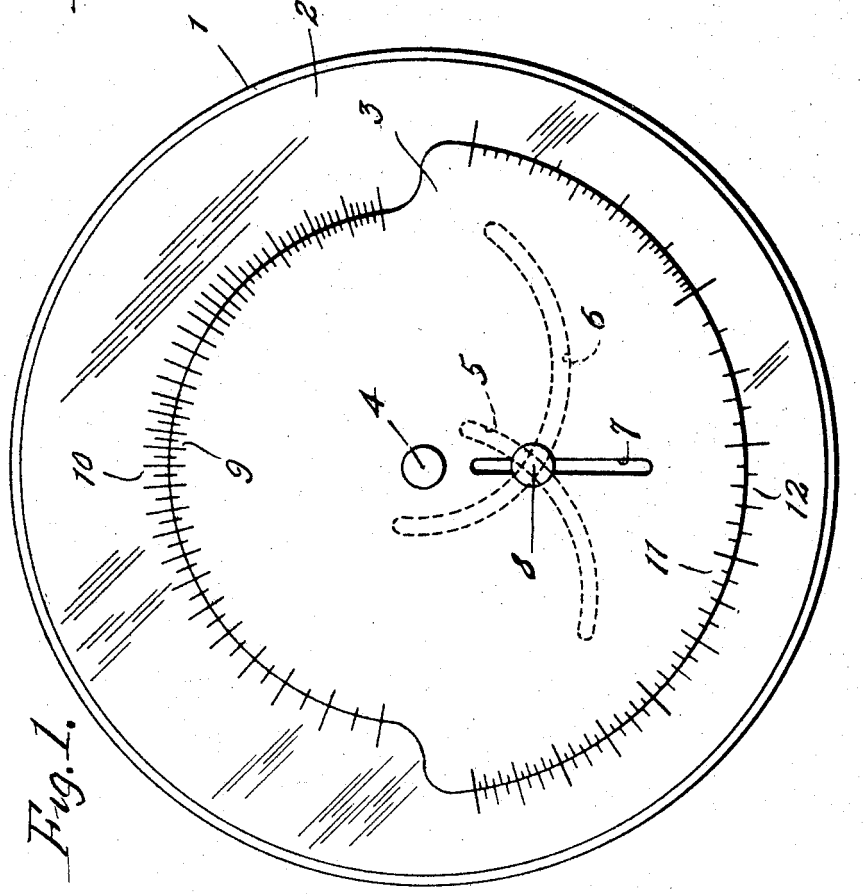

Fig. 1.

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COMPUTER

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9 Claims. (Cl. 235—61)

Our invention relates to calculating devices and more particularly to calculating devices or computers of the slide rule type adapted to solve directly equations which are incapable of direct solution with known types of such devices.

The known examples of the slide rule type of calculating device, whether rectilinear, circular or cylindrical, all operate on the principle of addition and subtraction of 1-argument functions. Hence such devices or computers can solve directly only those equations which are in or convertible to a form involving the addition and subtraction of such functions. For example, the most commonly known type of slide rule is that designed to solve equations of the type

$$x=\frac{a}{b}\cdot c$$

which can be converted to the form

$$\log x=\log a-\log b+\log c$$

Such computers, however, are incapable of solving directly equations of the form

$$x=\frac{a}{b}+c$$

While the value of

$$\frac{a}{b}$$

may be determined with the known type of slide rule, the relative displacement of the scales furnishes a measure of

$$\log \frac{a}{b}$$

to which c cannot properly be added. It is necessary, therefore, to read the value of

$$\frac{a}{b}$$

and set it up on another slide rule having uniform rather than logarithmic scales for proper addition to c or to make the addition mentally or on paper.

The principal object of our invention is to provide a calculating device or computer capable of solving directly a wide variety of equations not susceptible of solution with computers of known types because of the presence in the equations of mixed rational operations and/or certain kinds of 2-argument functions. The above cited equation

$$x=\frac{a}{b}+c$$

is a simple example of the first case and the "time to turn" equation hereinafter discussed is an example of the second. The direct solution embodied in this invention not only simplifies the process or method, but it also wholly eliminates the chances of error heretofore present where an intermediate reading and transfer of values is required.

While the invention as herein disclosed was developed for the solution of the so-called "time to turn" equation encountered in aircraft radius of action problems, it is to be understood that the principles involved may be used in devising slide rules for solving an infinite variety of equations. These more or less basic principles, as well as further objects of the invention, will be apparent from the following description when considered in connection with the accompanying drawing, wherein:

Fig. 1 is a top plan view of the calculator showing the relative arrangement and construction of the various calculator parts and the preferred arrangement of the cooperating juxtaposed scales, and

Fig. 2 is an edge view of the calculator.

In the embodiment of the invention selected for illustration the base member of the calculator is designated as 1, the intermediate or actuating member as 2, and the top or follower member as 3. Said members are preferably directly superimposed and rotatably connected by means of a suitable center rivet or eyelet 4. The intermediate or actuating member 2, so that the scale therebeneath may be visible at all times, is preferably constructed of transparent material.

The base member 1 has formed therein a slot 5; the intermediate member 2, a slot 6; and the top member 3, a slot 7. Slots 5 and 6 are essentially spiral in shape, although reversed as to direction, whereas slot 7 is radial. All three slots are of the same width.

Projecting through the three members and fitting snugly but freely within the three slots is a floating pin 8 in the form of a suitable rivet or eyelet. This pin 8 controls the relative movement of the top or follower member 3 with respect to the intermediate or actuating member 2 as the latter is moved relatively to the base member 1. In operation, the adjustment of the members 2 and 3 is effected by movement of the intermediate member 2 through finger pressure.

A scale 9 is inscribed along a portion of the edge of the top or follower member 3 and a cooperating scale 10 (visible through the transparent intermediate member 2) is inscribed on the base member 1. Along another portion of the edge of the follower member 3 there is in-

scribed another scale 11. For cooperation with this latter scale, a scale 12 is inscribed on the intermediate member 2.

On the equation which the calculator is designed to solve will depend the shapes of the slots 5 and 6 and the markings of the several scales. For example, for solution of the equation

$$x=\frac{a}{b}+c$$

the scales 9 and 10 are ordinary clockwise logarithmic scales on which values of a and b, respectively, are indicated, whereas the scales 11 and 12 are clockwise uniform scales on which the values of c and x, respectively, are indicated. The range of these scales is such as to encompass the extreme values of the several variables which may be encountered.

The slot 5 in the base member is a logarithmic spiral defined by the general polar equation

$$\log \frac{r}{m}=n\theta$$

in which r and θ are the radial distance and the angular displacement respectively, and m and n are constants selected to give the desired scale proportions. The slot 6 in the intermediate member is an Archimedes spiral, the general polar equation of which is

$$r=k\theta$$

in which k is a constant likewise selected to obtain suitable proportions.

From the foregoing it will be apparent that if the actuating member or disc 2 is rotated to bring the value of a on scale 9 opposite the value of b on scale 10, the angular position of the follower member or disc 3 with respect to the base member 1 will correspond to

$$\log \frac{a}{b}$$

This may be mathematically expressed as

$$n\theta_1=\log \frac{a}{b}$$

The floating pin 8 moving in both spiral slot 5 and radial slot 7 will be moved to a radial distance r from the center such that

$$\log \frac{r}{m}=n\theta_1$$

This distance r then equals

$$q.\frac{a}{b}$$

where q represents the scale modulus reflecting the effect of the other scales involved. At the same time, the floating pin 8 must move also in the spiral slot 6 in the intermediate member 2, thereby causing the member 2 to rotate with respect to the follower member 3 through an angle

$$\theta_2=\frac{r}{k}=\frac{q}{k}.\frac{a}{b}$$

that is to say—the angular displacement represents the value of

$$\frac{a}{b}$$

In other words, the logarithmic angular motion of the follower disc 3 with respect to the base member 1 has been converted through the medium of the pin 8 and the slots 5, 6 and 7 into uniform angular motion of the follower disc 3 with respect to the intermediate or actuating disc 2. In this connection, it should be noted that the scales 11 and 12 are so laid out that the zero mark on scale 11 is opposed to the unit mark on scale 12 when $r=m$, so that the value of x is read on scale 12 opposite the value of c on scale 11.

If the equation to be solved is one such as the so-called "time to turn" equation previously referred to as used in aircraft radius of action problems, the arrangement of the scales and slots is somewhat different. In this equation

$$t=\frac{T}{\frac{s_1}{s_2}+1}$$

wherein

t =time to turn
T=total hours of usable fuel capacity
s_1=rate of departure, and
s_2=rate of return

which expression may be reduced to

$$\log t=\log T-\log\left(\frac{s_1}{s_2}+1\right)$$

Moreover, the scales 9 and 10 are clockwise logarithmic scales of s_1 and s_2, respectively, so that the angular displacement of the follower disc 3 with respect to the base member 1 represents the

$$\log \frac{s_1}{s_2}$$

whereas spiral slot 6 in the actuating member 2 is a spiral, the equation of which is

$$\log \frac{r-1}{m}=n\theta_1$$

and the spiral slot 5 in the base member 1 is a logarithmic spiral having the equation

$$\log \frac{r}{m+1}=q.\theta_2$$

It is obvious from the foregoing that when the value s_1 on scale 9 is brought opposite the value of s_2 on scale 10, the follower member or disc 3 will be displaced with respect to the intermediate member 2 through an angle representing

$$\log\left(\frac{s_1}{s_2}+1\right)$$

And since the scales 11 and 12 are clockwise logarithmic scales of "time to turn" and "total hours of usable fuel capacity" respectively, it is further obvious that if the scales are so located that their indices coincide when $r=m+1$, the "time to turn" may be read on the scale 11 opposite the pertinent value of total hours on scale 12.

While the configuration of the arcuate or spiral slots 5 and 6 has been described above by reference to the mathematical expressions defining them, probably the easiest procedure for laying them out is the simple mechanical one. For example, in the case of the calculator for solving the equation

$$t=\frac{T}{\frac{s_1}{s_2}+1}$$

a construction disc is pivotally mounted on the member. This disc has inscribed thereon a scale corresponding to scale 9 on follower disc 3 and is cut away to provide a radial edge corresponding to the center line of the radial slot 7. Along

this edge is marked a uniform scale covering the range of probable values of

$$\frac{s_1}{s_2}+1$$

These values are then computed for various combinations of s_1 and s_2, and the construction disc is then rotated to bring these combinations successively opposite each other on the respective scales. A series of marks is then made on the base member 1 opposite the corresponding values of

$$\frac{s_1}{s_2}+1$$

on the radial edge scale, and the line joining these points is the center line of the slot in the base member. Similar procedure is then followed in carrying out the spiral or arcuate slot in the intermediate or actuating member 2. The above mechanical procedure can also be used to advantage in laying out computers according to the present invention for solving problems working directly from empirical data in cases where it is not possible to set up a mathematical equation showing the relationship between the variables.

In conclusion, it may also be pointed out that there are an infinite number of pairs of spirals which will produce a particular angular movement of the follower disc 3 with respect to the intermediate member 2 in response to a given angular movement of the follower disc 3 with respect to the base member 1. The combination selected should, in every case, be such that the two spiral slots meet at an angle as near 90° as possible in order to minimize side play binding of the floating pin 8.

While we have described our invention in detail in its present preferred embodiment, it will be obvious to those skilled in the art, after understanding our invention, that various changes and modifications may be made therein without departing from the spirit or scope thereof. We aim in the appended claims to cover all such modifications and changes.

We claim as our invention:

1. A calculating device comprising three relatively movable members having cooperating juxtaposed scales thereon and guideways formed therein; and means engaging in said guideways adapted to produce a prescribed relative motion between two of said members in response to relative movement of one of said two members with respect to the third thereof.

2. A calculating device comprising three relatively movable axially aligned members having cooperating juxtaposed scales thereon and guideways formed therein; said guideways being adapted to intersect, and means engaging in said guideways adapted to produce a prescribed relative motion between two of said members in response to relative movement of one of said two members with respect to the third thereof.

3. A calculating device comprising three relatively movable members having cooperating juxtaposed scales thereon and slots formed therein, and means engaging in and movable lengthwise said slots adapted to produce a prescribed relative motion between two of said members in response to relative movement of one of said two members with respect to the third thereof.

4. A calculating device comprising three relatively movable members having cooperating juxtaposed scales thereon and slots formed therein, at least one of said slots being a radial slot, and means engaging in and movable lengthwise said slots adapted to produce a prescribed relative motion between two of said members in response to relative movement of one of said two members with respect to the third thereof.

5. A calculating device comprising three relatively movable members having cooperating juxtaposed scales thereon and slots formed therein, at least two of said slots being arcuate slots arranged to intersect, and means engaging in and movable lengthwise said slots adapted to produce a prescribed relative motion between two of said members in response to relative movement of one of said two members with respect to the third thereof.

6. A calculating device comprising three relatively movable members having cooperating juxtaposed scales thereon and slots formed therein; one of said slots being a radial slot and the remaining two being arcuate slots arranged to intersect each other and said radial slot, and means engaging in and movable lengthwise the slots at the point of intersection thereof adapted to produce a prescribed relative motion between two of said members in response to relative movement of one of said two members with respect to the third thereof.

7. A calculating device comprising a base member having a scale thereon and a slot formed therein, an actuating member mounted on and rotatable with respect to said base member, said actuating member having a scale thereon and a slot formed therein, a follower member mounted on said actuating member and rotatable both with respect to said actuating member and to said base member, said follower member having scales thereon adapted for cooperation respectively with the scale on the base member and the scale on the actuating member and having a slot formed therein, and a floating pin engaging in and movable lengthwise said slots adapted by its engagement with the slot walls to produce a predetermined movement of the actuating member relatively to the follower member in response to movement of either the actuating member or the follower member relatively to the base member.

8. A calculating device comprising a base member having a scale thereon and an arcuate slot formed therein, a first movable member having a scale thereon and an arcuate slot formed therein, said slots being arranged to intersect and the arcuity thereof being reversed, a second movable member having scales thereon adapted for cooperation respectively with the scale on the base member and the scale on the first movable member, and having a substantially radial slot formed therein arranged to intersect the two arcuate slots at the point where the two arcuate slots intersect, said movable members being movable relatively to each other as well as with respect to said base member, means joining the three members and providing for the two movable members a common axis of rotation, and a floating pin engaging in and movable lengthwise the total number of slots adapted by its engagement with the walls thereof at said point of intersection to produce a predetermined movement of the first movable member relatively to the second movable member in response to movement of either movable member relatively to said base member.

9. A calculating device comprising three relatively movable members having cooperating juxtaposed scales thereon, each said member having formed therein a slot, two thereof being arcuate

slots and the third a radial slot, said slots being arranged to provide a common point of intersection and the two arcuate slots having their arcuity reversed, a pin engaging in all three slots at said common point of intersection adapted by its movement lengthwise the slots to produce a predetermined movement between two of said members in respect to relative movement of one of said members with respect to the third thereof, and means connecting all three members and providing therefor a common axis of rotation.

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