

Oct. 18, 1949.

L. W. IMM

2,485,200

SQUARING MECHANISM

Filed Oct. 29, 1943

2 Sheets-Sheet 1

Fig. 1.

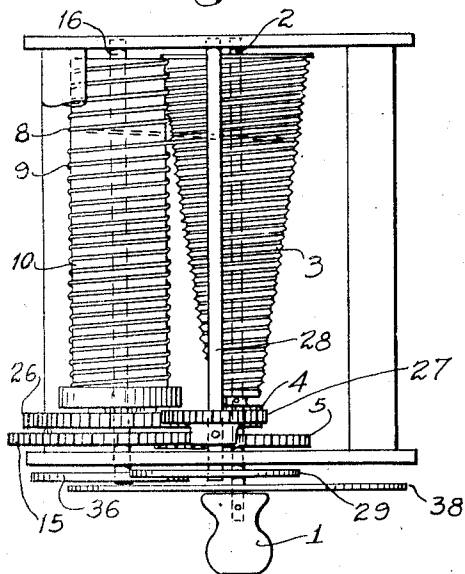


Fig. 3.

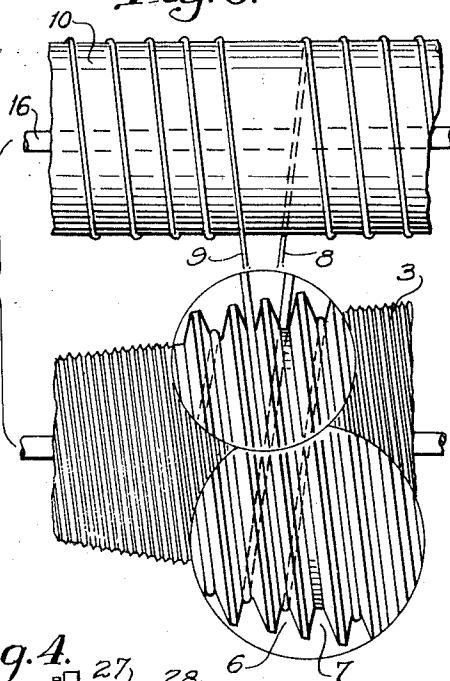


Fig. 2.

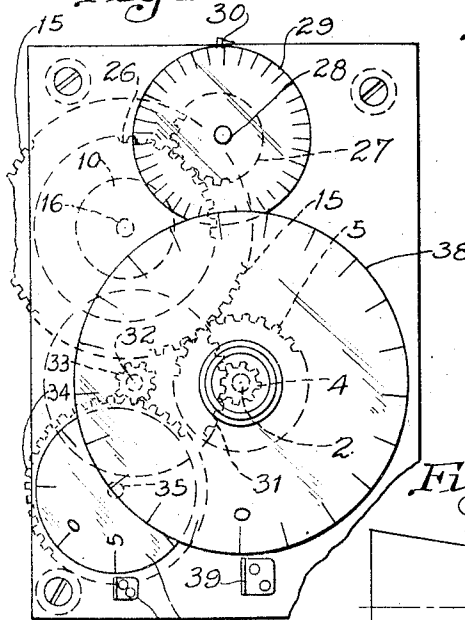


Fig. 4.

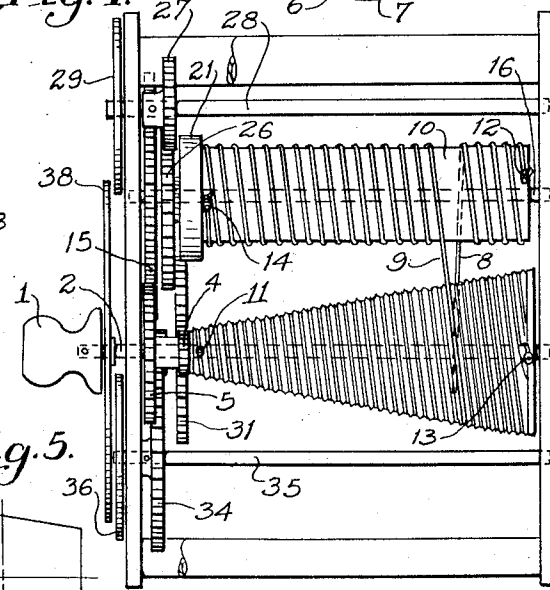


Fig. 5.

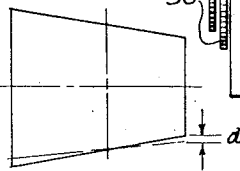
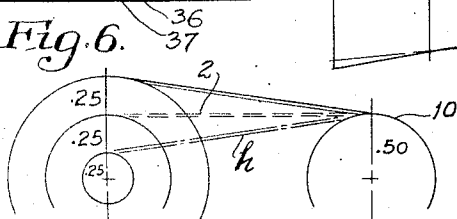


Fig. 6.



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2 Sheets-Sheet 2

Fig. 7.

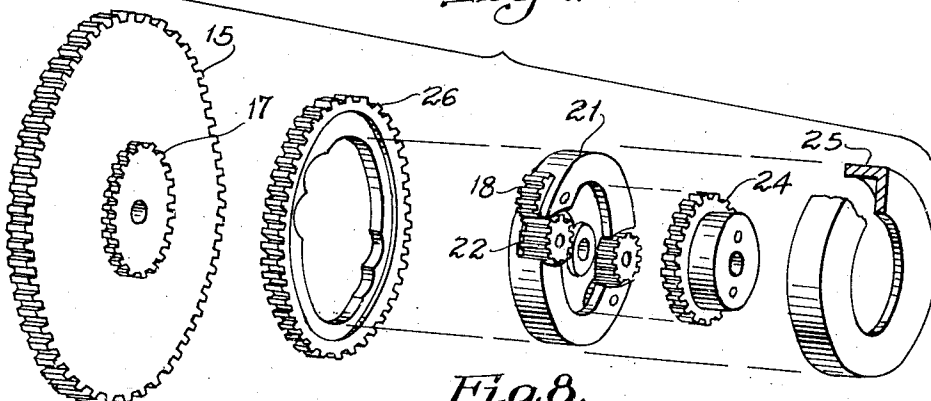


Fig. 8.

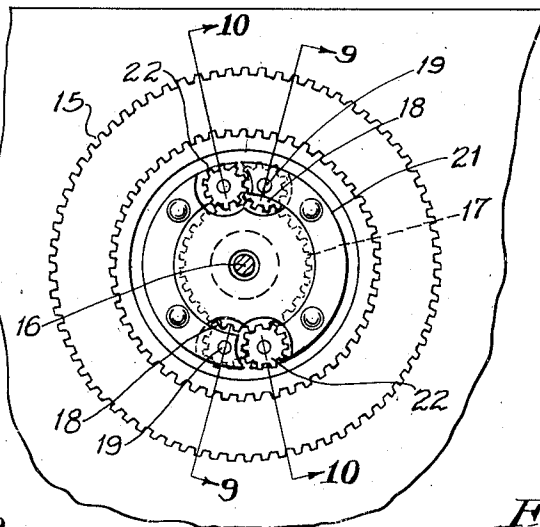


Fig. 9.

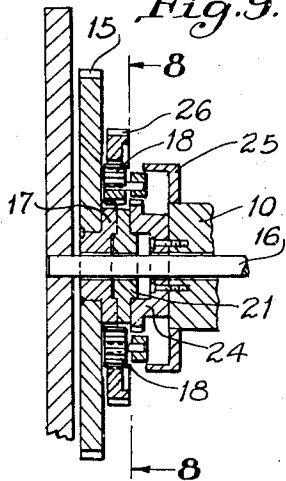


Fig. 10.

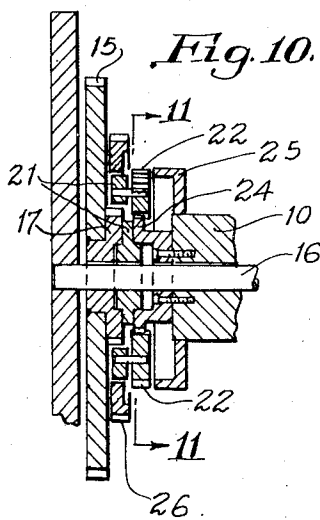


Fig. 11.

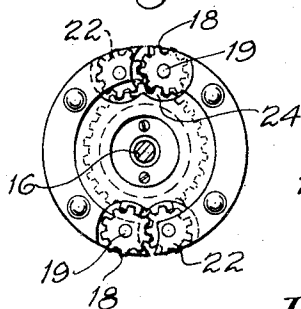


Fig. 13.

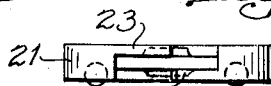
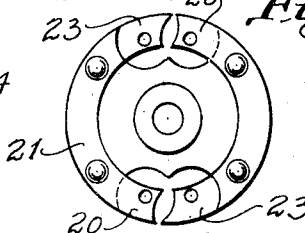


Fig. 12.



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UNITED STATES PATENT OFFICE

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SQUARING MECHANISM

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corporation of California

Application October 29, 1943, Serial No. 508,231

13 Claims. (Cl. 235—61)

1

The object of this invention is to provide a squaring mechanism of high accuracy, by which a number may be directly squared or conversely the square root of a number may be obtained.

Another object of the invention is to provide a squaring mechanism of extreme simplicity in design and which may be cheaply manufactured.

Another object of the invention is to provide a squaring mechanism of a design which is extremely rugged in character, and which may be easily manufactured in quantities.

One of the essential features of the invention is a squaring mechanism incorporating a cone and cylinder with a cable attached, to be unwound from either the cone or cylinder and wound on the other. The term "cone" as used herein is not confined to a mathematical cone or a solid generated by the rotation of a right triangle about one of its legs as an axis but is used in its broader sense to include cone shaped structures such as a frustrum of a cone and irrespective of whether it is solid or hollow.

Another object of the invention is to provide two cables interconnecting the cone and cylinder so that one of the cables is wound on the cylinder or cone, while the other cable is being unwound from the same, thereby eliminating the necessity of springs to actuate either the cone or the cylinder.

Obviously it is impractical for the cone to taper down to an absolute zero value. In practice the diameter of the small end of the cone must be some fixed value above zero such as, for instance, $\frac{1}{2}$ ", while the diameter of the large end of the cone would have a greater diameter such as, for instance, $1\frac{1}{2}$ ". The average diameter therefore of the cone would be, in the instance given, 1", and preferably the diameter of the cylinder would be the same value as the mean diameter of the cone. It would at first appear that it would be impossible to square a number so small as to fall within the range of that part of the theoretical cone between a zero value and the value of the small part of the actual cone. One of the objects of this invention is to provide means whereby these small numbers may be squared by utilizing the actual cone and cylinder and in effect transferring the zero part of the theoretical cone to a part of the actual cone such as its small end or even its mid portion. This can be

2

accomplished by a differential mechanism interposed between the cylinder and the cone and actuated by both of them, which differential mechanism would not be necessary in case the cone could be constructed as a theoretical cone, tapering down to an actual zero value.

Let it be assumed that we desire to square the number x , which may be a variable number, and let us assume that the radius of the cone at its smallest end is c . The square of $x+c=x^2+2xc+c^2$. The object of the differential mechanism is to eliminate the $2xc$, and the scale employed in conjunction with the output can have its zero value at the point c^2 . This leaves only x^2 , which is the square of the number sought to be squared.

The invention may be better understood by referring to the attached drawings in which

Fig. 1 is a plan view of my improved squaring mechanism.

Fig. 2 is a front elevational view thereof.

Fig. 3 is a side elevational view of fragments of the cylinder and cone, with the interconnecting cables and with certain of the threads on the cone being viewed through magnifying glasses.

Fig. 4 is a side elevational view of the mechanism shown in Fig. 1.

Figs. 5 and 6 are diagrammatic views to illustrate the differential tapers to compensate for slack in the cables.

Fig. 7 is an exploded view of the differential mechanism.

Fig. 8 is a side elevational view of the differential mechanism taken on the line 8—8 of Fig. 9.

Fig. 9 is a cross sectional view taken on the line 9—9 of Fig. 8.

Fig. 10 is a cross sectional view taken on the line 10—10 of Fig. 8.

Fig. 11 is a side elevational view of a portion of the differential mechanism taken on the line 11—11 of Fig. 10.

Fig. 12 is a side elevational view of the spider, and

Fig. 13 is a plan view thereof.

An input knob 1 is secured to a shaft 2 to which is secured a cone 3, a pinion 4 and a gear 5. The cone is provided with two sets of spiral threads 6 and 7 which receive wires or ribbons 8 and 9 respectively, which are wound on to or from a cylinder 10. As shown in Fig. 3 the ribbon 8

passes from one side of the cone to the corresponding side of the cylinder while the wire or ribbon 9 passes from the opposite side of the cone. When, therefore, the ribbon 8 is being unwound from the cone and is being wound on the cylinder, the ribbon 9 is being wound on the cone and is being unwound from the cylinder, and if these ribbons are always maintained in a taut condition, the actuation of either the cone or the cylinder will actuate the other member.

In the above mechanism it is apparent that the most important component is the cone, in the surface of which is cut the double helical groove or thread. One of the cables is fastened to the small end of the cone at the point 11 and is wound in the thread 6 toward the large end of the cone. This ribbon or cable 8 passes from the cone to the cylinder 10 at a point depending upon the amount the cone has been rotated by the input knob 1 and is now wound on the cylinder 10. The cable or ribbon 8 is attached to the cylinder at the point 12. The other cable 9 is attached to the large end of the cone at the point 13 and as the cable 8 is wound on the cylinder 10 as above described, the ribbon 9 will be unwound from the cylinder onto the cone. The cable 9 is secured to the cylinder 10 at the point 14. If the cone should be rotated in a reverse direction, these motions would be reversed. When the cone is rotated with the cable 8 passing therefrom near the small end of the cone, the cylinder will be rotated slowly for each rotation of the cone and will be rotated more rapidly when the cable passes from the cone near the larger end thereof. The rate at which the cables move will increase uniformly from the small end of the cone to the large end.

Obviously if an indicator were directly actuated by the cylinder 10 and if the cone tapered down to an absolute zero value, the indicator would indicate the square of a number by means of the mechanism heretofore described. However, it is not possible, or at least not practicable, for the cone to extend to a mere point. It is, therefore, necessary to provide a differential mechanism actuated both by the cylinder and the cone shaft. The gear 5 of the cone shaft 2 meshes with and drives the gear 15 loosely mounted on the cylinder shaft 16. The gear 15 has secured thereto a pinion 17 which may be considered as a sun gear, which meshes with and drives planet pinions 18 mounted on arbors 19 carried by arms 20 of a spider 21. The planet pinions 18 mesh with and drive pinions 22 likewise carried by the spider on arms 23. The side faces of the pinions 18 and 22 are out of alignment with each other so that the pinions 18 mesh with the pinion 17 but the pinions 22 are offset so as not to mesh with pinion 17, the pinion 17 driving the pinions 18 and the pinions 18 driving the pinions 22. The pinion 24 is secured to cylinder 10 and meshes with pinions 22. A cover 25 is secured to the cylinder 10 so as to protect a portion of the gearing. Gear 26 is secured to spider 21 by any suitable means. The gear 26 drives a gear 27 mounted on a shaft 28 to which is affixed an output dial 29 having suitable calibrations thereon starting from a zero point and which may be read relative to a reference point 30.

The small pinion 4 on the cone shaft drives a gear 31 secured to a shaft 32 to which is secured a pinion 33, which drives a gear 34 secured to a shaft 35, to which is secured dial 36 to indicate the number of revolutions of the cone shaft and cone.

The reading index indicator 37 is provided adjacent the said dial.

A large dial 38 is secured to the cone shaft 2 and is provided with unit calibrations to be read relative to an index point 39. The dial 38 would therefore make one revolution for each revolution of the cone, whereas the dial 36 would make one revolution for a large number of revolutions of the cone. This is beneficial when we wish to be exact as to the number of rotations to be given to the input and output in the same manner as the minute hand on a clock in conjunction with the hour hand gives a much closer reading of the time than if we simply had an hour hand. When the ribbons 8 and 9 are passing from the cone at the extreme small end thereof or the end adjacent the point 11, the indicating dials 36 and 38 would be at zero. However, the zero point of the cone could be its midpoint or any other selected point, provided the gear ratio of the differential mechanism were accordingly modified.

The differential mechanism may be of any standard construction having two spur gears such as 17 and 24 coupled by two pairs of interconnecting pinions 18 and 22 carried by spider 21. Holding either spur gear and rotating the spider rotates the other spur gear in the same direction. Holding the spider and rotating either spur gear rotates the other spur gear in the opposite direction. This enables the differential mechanism to be used as an addition or subtraction mechanism in a computer.

The cone possesses the properties of an Archimedean spiral, each revolution of the spiral increasing the differential length of cable per revolution by a constant increment. Practically, a ribbon wound on itself could be utilized so that it increases the coil diameter by twice the ribbon thickness for each revolution. Mechanically, it is more satisfactory to wind the ribbon in a spiral groove cut on the surface of a cone.

If x represents a variable such as any number which it may be desired to square, and if c represents a constant, such as the radius of a cone at its selected zero point, the value of x^2 could be obtained from the equation

$$(x+c)^2 = x^2 + 2xc + c^2$$

provided the $2xc$ and the c^2 could be eliminated. This would mean that we are transferring the absolute zero point of a theoretical cone tapering down to a point from the point to a part of the cone, such as the small part thereof, which we will for illustration consider as the radius of $\frac{1}{4}$ ". The differential mechanism above described, which is actuated both by the cone shaft and the cylinder shaft, eliminates the value of $2cx$ provided the gearing between the gear 5 and the gear 15 has the same ratio as the ratio between the radius of the diameter of the zero portion of the cone is to the diameter of the cylinder. The constant value c^2 can be eliminated by making the zero point of the output dial equal to the value of c^2 . This leaves only x^2 which is the number which it is desired to square.

The actual operation may be better illustrated assuming that the diameter of the small portion of the cone is .5" and the diameter of the large portion is $1\frac{1}{2}$ ", giving a mean diameter of 1". and that the cylinder also has a diameter of 1". The gear ratio between the gear 5 and gear 15 would be 1:2. Let us assume that the indicators 36 and 38 are at zero. Suppose further that it would have required 25 revolutions of the cone

to have unwound the ribbons from an actual zero point to the .5" diameter of the cone. We will also assume that 50 threads are cut on the cone, therefore requiring 50 revolutions to completely wind the cable onto the cone. The mean diameter of each groove on the cone progressing from the minimum to the maximum will be .02 greater than the preceding groove mean diameter. If we presume that we wish to square a quantity over a range from 0 to 10, each revolution of the cone will represent $\frac{1}{50}$ of a unit. The following table gives the rotations of the cone, cylinder and differential output over the first 10 turns of the cone, and will illustrate how the output is directly proportional to the square of the number. As above mentioned, if the cone had gone down to a diameter of 0, it would have required 25 revolutions of the cone to unwind the ribbon up to the smallest portion of the actual cone.

Number of Turns Cone	Mean Diameter Cone Groove	Number of Revolutions 1" Cylinder	Number of Revolutions Subtracted by Differential .5 rev./ rev. Cone	Twice the Number of Revolutions Differential Output	Input Value (1/rev.) Squared
1	.51	.51	.5	.01	1
2	.53	1.04	1.00	.04	4
3	.55	1.59	1.5	.09	9
4	.57	2.16	2.00	.16	16
5	.59	2.75	2.5	.25	25
6	.61	3.36	3.00	.36	36
7	.63	3.99	3.5	.49	49
8	.65	4.64	4.00	.64	64
9	.67	5.31	4.5	.81	81
10	.69	6.00	5.00	1.00	100

With a cone of uniform taper the angularity of the cables leading to the cylinder causes them to be under greater tension when they leave the extremities of the cone than when they leave the central part of the cone. By cutting one of the threads on a slightly different taper, this angularity can be compensated for, and a uniform tension of the cables maintained at all positions.

The method of calculating the exact difference of taper of the two threads may be explained as follows in connection with Figs. 5 and 6. Let it be assumed that the radius of cylinder 10 is .5" and that the radii of the small, mid and large portions of the cone are .25, .5 and .75 inch respectively, that the center line distances between the cone and cylinder are 2", that threads 6 and 7 each have 50 turns with 14 threads to an inch, and that the length of the cone is 3.5714". If one of the threads increases uniformly from the .5" diameter to the 1½" diameter, the increase in radius per turn of the cone would be .01". The other thread should have an increased diameter at the small end of the cone and a smaller diameter at the larger end of the cone.

In Fig. 6 if h represents the tangential distance between the small end of the cone and the cylinder, and 2 represents the tangential distance between the mid portion of the cone and cylinder, the value of h equals

$$\sqrt{2^2 + .25^2} = 2.015565$$

The taper must therefore be provided to take up a length of .015565. The theoretical length of the cable on the lower half of the cone would be

$$\pi \frac{(.5^2 - .25^2)}{.01} = 58.90486$$

In the above formula the .5 will be the radius at the midpoint of the cone, .25 will be the radius at the small end of the cone, and the .01 represents the increase in radius per turn of the

cone. The actual length of the cable would therefore be

$$58.90486 + 2(.015565) = 58.93599$$

Both of the cables are this length.

To calculate the radial difference d between the threads 6 and 7 at either end of the cone we may employ the above formula

$$\pi \frac{(.5^2 - .25^2)}{.01}$$

but modified so as to include this radial difference d . The formula then becomes

$$\pi \frac{[.5^2 - (.25 + d)^2]}{.5 - 2d}$$

The reason that $-2d$ was employed is because

We have this differential d in each end of the cone. From the above

$$\pi d^2 - .7866437d + .0003113 = 0$$

Therefore $d = .00039634$. One of the threads should therefore have a radius at the small end of the cone equal to .25, while the other thread should have a radius at the small end of the cone equal to .25039634. At the large end of the cone the first thread would have a radius of .75, and the second thread would have a radius of .74960366.

By the above described mechanism I have therefore provided a direct squaring mechanism. While I have shown an input knob 1 connected to the cone and an output dial 29, I recognize the fact that my squaring mechanism may be principally utilized as a part of a machine in which one of the functions thereof is to perform a squaring operation. I therefore do not wish to limit myself to a manual input or an indicator, but would prefer to consider that there is any form of an input and any form of an output.

It is of course apparent that the square root of a number could be obtained by setting the output dial 29 to represent the said number and reading its square root on dials 36 and 38. By squaring mechanism I therefore mean means whereby the square of a number or the square root of a number may be obtained.

I realize that many changes may be made in the form of the invention as shown by way of illustration herein, and I therefore desire to claim the same broadly, except as I may limit myself in the following claims.

Having now described my invention, I claim:

1. In a squaring mechanism, a rotatable conical member having a spiral groove thereon, a rotatable cylinder, an input means for driving the conical member and cylinder, a cable wound around the cylinder and conical member in the

groove thereof, a differential mechanism having a part actuated proportionally to the rotations of the conical member, and a part actuated proportionally to the rotations of the cylinder, and an output means actuated by said differential mechanism.

2. In a squaring mechanism, an input, a conical member of uniform taper driven thereby, a cylinder, cable means interconnecting the conical member and cylinder and partly wound on each, a gear train and differential mechanism interconnecting said conical member and cylinder, said differential mechanism including two gears driven in opposite directions by rotation of the conical member and cylinder, and also including a spider and an output connected to the spider.

3. In a squaring mechanism, an input, conical member of uniform taper, provided with two threads extending over the effective length of the conical member, said conical member and cylinder being rotatable on substantially parallel axes, a cylinder, two cables connecting said conical member and cylinder and wound in said threads so that as one cable is wound on the cylinder from the conical member, the other cable is wound on the conical member from the cylinder, said threads having slightly different tapers to prevent slack in the cable, a differential gear mechanism interconnecting the conical member and the cylinder, and an output connected to the differential mechanism.

4. A function computing device comprising two rotatable members, one being cylindrical and having a uniform surface and the other being tapered and having helical grooves proportioned in accordance with a function to be computed, and a pair of flexible cables wound in said grooves and around said cylindrical member respectively but reversely with respect to each other, said cables having their opposite ends connected to the two rotatable members so that they constitute a positive driving connection therebetween.

5. A function computing device comprising two rotatable members, one being cylindrical and having a uniform surface and the other being tapered and having helical grooves proportioned in accordance with a function to be computed; the radius of one of said grooves progressively changing from a radius smaller than that of the other groove at the larger portion of said tapering member to a radius larger than that of said other groove at the smaller portion of the tapering member, and a pair of flexible cables wound in said grooves and around said cylindrical member, respectively, but reversely with respect to each other, said cables having their opposite ends connected to the two rotatable members so that they constitute a positive driving connection therebetween.

6. A function computing device comprising two rotatable members, one being cylindrical and having a uniform surface and the other being tapered and having helical grooves proportioned in accordance with a function to be computed, a pair of flexible cables wound in said grooves and around said cylindrical member, respectively, but reversely with respect to each other, said cables having their opposite ends connected to the two rotatable members so that they constitute a positive driving connection therebetween, an output member, and an actuating mechanism for said output member comprising differential mechanism actuated by the rotation of said rotatable members.

7. In a computing device having input means

and output means, means for driving the output from the input in a desired mathematical relationship comprising a rotatable cylindrical member, a rotatable tapering member with at least one helical groove having the characteristics of an Archimedean spiral formed thereon, at least one cable attached to the cylindrical member and to the tapering member, said cable being wound around the cylindrical member and the tapering member in the groove thereof, means for maintaining said cable taut whereby the rotation of one of said members is at all times controlled by the rotation of the other, a differential gear mechanism operable by both the cylindrical member and the tapering member and connecting them between the input means and the output means to permit the use as a zero point of a place on the tapering member located between the theoretical apex thereof and its base, said differential gear having a gear ratio equal to the ratio between the radius of the tapering member at the zero point and the diameter of the cylinder.

8. A computing device according to claim 7 in which the means for maintaining the cable taut is a second cable reversely wound with respect to the other cable and in which a second helical groove is formed on the tapering member for operation therein of the second cable.

9. A computing device according to claim 7 which includes a differential mechanism having planet pinion gears carried by a spider, other pinion gears carried by the spider and meshing with the planet pinion gears, a spur gear connecting with the tapering member and meshing with the planet pinion gears, another spur gear secured to the cylinder and meshing with the other pinion gears, whereby holding either spur gear and rotating the spider rotates the other spur gear in the same direction.

10. A computing device according to claim 9 in which the output means is connected to the spider.

11. A computing device according to claim 7 which comprises two rotatable members mounted to rotate on substantially parallel axes.

12. In a function computing device having two rotatable members at least one of which is tapered and is proportioned in conjunction with the other of said rotatable members in accordance with a function to be computed, a pair of flexible cables reversely wound around said members and constituting a positive driving connection between them, means for preventing slack in said cables which consists of separate grooves in said tapering member each to receive one of said cables, the radius of one of said grooves progressively changing from a radius smaller than that of the other groove at the larger portion of said tapering member to a radius larger than that of said other groove at the smaller portion of the tapering member.

13. In a function computing device having an input means and an output means, two rotatable members at least one of which is tapered and is proportioned in conjunction with the other of said rotatable members in accordance with a function to be computed and means for fixing the position of one of said rotatable members with respect to the other including a cable wound around both of said members, and means for securing at a position of finite radius on said tapering member the effective operation which would be given by a position of zero radius which consists of a differential gear system interposed between said input means and output means and

having driving connection to said rotatable members.

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