May 8, 1923. **1,454,104**

F. W. CALDWELL

CALCULATOR

Filed Aug. 11, 1921

Fig. 1.

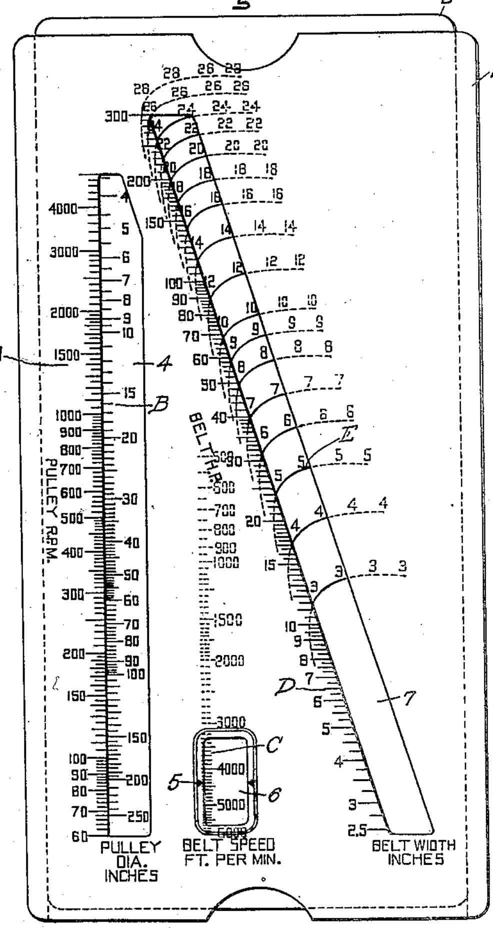
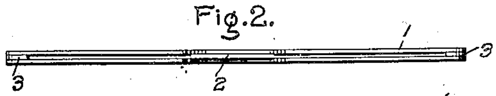



Fig. 2.



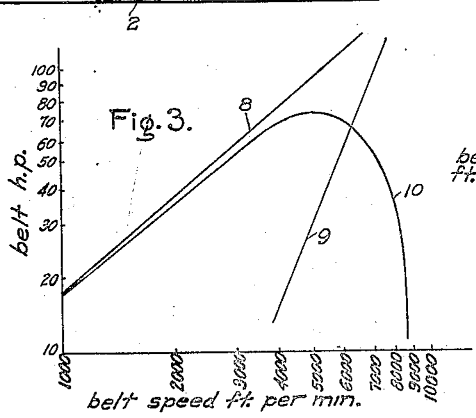



Fig. 3.

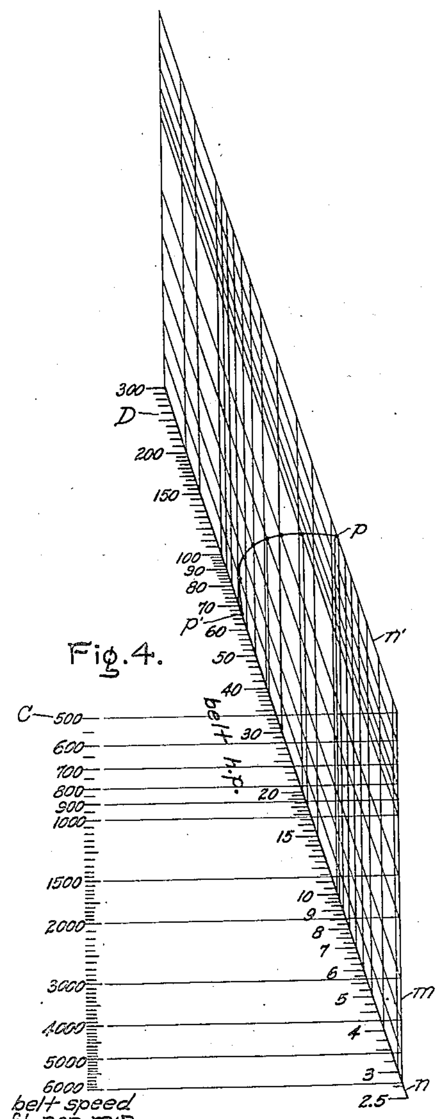



Fig. 4.

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by Chas. W. Fuller
His Attorney.

**Patented May 8, 1923.** **1,454,104**

# UNITED STATES PATENT OFFICE.

FREDERICK W. CALDWELL, OF SCHENECTADY, NEW YORK.

## CALCULATOR.

Application filed August 11, 1921. Serial No. 491,612.

*To all whom it may concern:*

Be it known that I, FREDERICK W. CALDWELL, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Calculators, of which the following is a specification.

My invention relates to calculators and more particularly to a calculator for use in determining the size of belt which should be used to transmit a predetermined amount of power when either the belt speed or the speed and diameter of one of the power transmitting pulleys is given.

An object of my invention is to provide a simple compact calculator which shall enable certain equations to be solved with a single operation of the calculator which equations are of considerable complexity and may involve operations of multiplication, division, involution or evolution and addition or substraction.

A further object of my invention is to provide a belt calculator which shall take into account the effect of centrifugal force and which shall at the same time require but a single operation of the calculator to determine the belt horse power for any given condition.

A further object of my invention is to provide an accurate belt calculator which shall comprise a minimum number of scales easily read, thereby reducing to a minimum the liability of error and making it possible for persons without technical education or training to use the calculator with speed and precision.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing Fig. 1 is a face view of my calculator, showing in dotted lines the parts of the scales and curves on the slide which are covered in the position of the slide illustrated; Fig. 2 is an end view showing one manner of securing the slide in the case or cover portion of the calculator; Fig. 3 is a diagram showing the relationship between speed and belt horse power and the effect of centrifugal force upon belt horse power, and Fig. 4 is a diagram showing a method of laying out the curves on the calculator.

The theory of belts has been carefully developed by a number of investigators. Nagle's formula for belt horse power (Trans. A. S. M. E. Vol. 2, 1881, p. 91) is as follows:

$$(1)\quad \text{H. P.} = \frac{Cvwt(S - .012v^2)}{550}$$

In this formula—

$v$=velocity ft. per sec.
$w$=belt width.
$t$=belt thickness.
S=stress upon belt per sq. in.
C=a constant.

The value of the constant C is given by the following equation:

$$(2)\quad C = 1 - 10^{-.00758fa}$$

In this equation—

$a$=degrees of belt contact.
$f$=coefficient of friction.

The arc of belt contact will, of course, vary with the sizes of pulleys used and the coefficient of friction will have a value dependent upon the character of the pulley surface and the character of the belt. That is to say, $f$ will have one value for iron pulleys with leather belts, and a different value for paper pulleys with leather belts, and it will have still different values where rubber belts are used.

My invention is not limited to any particular kind of pulley or any particular kind of belt or to any particular arc of contact, but in order to disclose clearly how to make and use my calculator, I will describe how it may be laid out for leather belts, using an arc of contact of 165° and a co-efficient of friction equal to .4.

With the values for $f$ and $a$ given in the preceding paragraph substituted in equation (2), the constant C will be found to be approximately equal to .684. This constant may also be found from the table given in Kent's Mechanical Engineers Pocket Book, page 879, edition of 1900.

It will be noticed that formula (1) involves the term $wt$ which is the product of the width and thickness of the belt. As belts increase in width they customarily increase in thickness. I have made a large number of measurements on leather and rubber belts and have found that there is a relation between width and thickness, which relation in leather belting, for example, follows closely the following equation:

$$(3)\quad t^2 = .011w$$

From equation (3) it at once appears that—

$$wt = \sqrt{.011}\, w^{\frac{3}{2}}$$

This fact enables me greatly to simplify my calculator since by substitution it eliminates the variable $t$ from formula (1) and renders it unnecessary to make more than a single operation of the slide to solve the equation.

Substituting the value of C from equation (2), the value of $wt$ from equation (3), and using V=velocity in ft. per min., formula (1) becomes:

$$(4)\quad \text{H.P.} = \frac{.684V\sqrt{.011}\, w^{\frac{3}{2}}}{60\times 550}\left(275 - \frac{.012V^2}{3600}\right)$$

Simplifying equation (4) gives

$$(5)\quad \text{H.P.} = 572w^{\frac{3}{2}}V10^{-6}(1-1211V^2 10^{-11})$$

The negative quantity in equation (5) represents the effect of centrifugal force in diminishing the horse-power that may be transmitted. It will be observed that this quantity varies as the square of the belt speed.

In the equations thus far considered the belt speed has been considered as given. In the ordinary case, however, merely the diameter and speed of the pulley are given, the diameter being given in inches and the speed in revolutions per minute, whence

$$(6)\quad V = \frac{\text{R.P.M.}\times\pi D}{12}$$

Referring now to the drawing, the calculator comprises a case or cover 1 and a movable slide 2. The case and slide may be made of any suitable material, for example, celluloid, but I prefer to make the parts of thin metal since the calculator may then be made so durable and the parts fitted so nicely that they will last indefinitely and give accurate results. In the construction illustrated, as will be seen from Fig. 2, the side edges of the front and back faces of the case are secured in any suitable manner, as for example by soldering, brazing, or welding to spacing strips 3 which provide the channel for the slide 2.

A logarithmic scale A on the case is laid out to include the range of pulley speeds, and a cooperating scale B on the slide is laid out to include the sizes of pulleys, which will be utilized in practical belting problems. An opening 4 is provided in the case to enable the scale B to be read. By laying off the scales A and B in opposite directions, the position of the slide may be made to indicate the product of the quantities placed in registry on scales A and B as is well known in the slide rule art. A logarithmic scale C is placed on the slide laid out according to belt speed in feet per minute and a marker 5 on the case is placed in cooperative relationship with scale C so that the belt speed corresponding to the setting of scales A and B may be read on the scale C through the window 6 in the case. The scales A, B and C solve equation (6). Since the constants of equation (6) are the same for every speed and diameter of pulley, the scale C and window 6 may be arranged in any desired location on the calculator.

The case of the calculator is provided with an opening 7 cut at an angle to the direction of motion of the slide 2, and to one edge of this opening a logarithmic scale D is applied which cooperates with a plurality of curves E on the slide. The curves E correspond to different widths of belts, curves being shown for belts varying from 3 to 26 inches in width. The point where any belt curve E crosses the scale D gives the horsepower that such belt will transmit when running at the speed indicated on the scale C. The method of drawing one of the curves E will be hereinafter set forth, but assuming for the moment that one of these curves is properly laid out, the other belt curves are spaced therefrom according to $\frac{3}{2}$ times the logarithms representing the various belt widths. It will, therefore, been seen that in the going from one belt curve to the belt curve of the next wider belt, $\frac{3}{2}$ the logarithm of the belt width is added to the logarithm of the speed V as determined by the setting of the slide. This operation obtains the product $w^{\frac{3}{2}}V$ of equation (5). It will be observed that the set of belt curves E and scale D may be located in any desired position on the calculator since the constants outside the brackets of equation (6) are constant for every speed and belt width. If there were no centrifugal force effect tending to reduce the horsepower with increase in speed, the belt curves E would be parallel straight lines. This condition would be represented by formula (5) if the negative quantity in the brackets were zero.

Before proceeding to point out how the curves E are laid out it will make for clearness to refer to Fig. 3 which shows for a 10 inch belt the relationship between belt speed and belt horse-power plotted with logarithmic coordinates. The straight line 8 shows the relationship which would obtain if there were no centrifugal force effect. The ordinate of this line at any speed V is equal to

$$\log (572 \times 10^{\frac{3}{2}} V 10^{-6})$$

The straight line 9 shows the relationship between belt speed and horse-power lost due to centrifugal force. The ordinate of this curve at any speed V is equal to

$$\log \{572 \times 10^{\frac{3}{2}} V 10^{-6} (1211 V^2 10^{-11})\}$$

The curve 10 shows the relationship between belt speed and the horse-power that may be actually transmitted. While the points of curve 10 might be found directly by means of equation (5), they may also be found by subtracting the ordinates of curve 9, as measured in the logarithmic scale of belt horse-power, from the ordinates of curve 8. It will be observed that curves 8 and 9 will cross at a belt speed of about 9000 ft. per min. at which speed no power could be transmitted by the belt.

The curves E on the slide of Fig. 1 correspond in a general way to the curve 10 of Fig. 3. It will be observed that when the slide is withdrawn so that a low belt speed is indicated on scale C by the marker 5, then the edge of the slot 7 to which the scale D is applied will intersect curves E near their right hand ends, and that with increasing belt speeds the side of the slot 7 travels across the curves E from right to left. The curves are so laid out that the motion of the slide from minimum to maximum belt speed moves the scale D over the whole of each curve. If the centrifugal force effect were absent and the curves E parallel straight lines, then the horse-power indicated on the scale D by any curve E would vary directly with the speed. Since, however, the curves turn downwardly so as to become tangent to the side of the slot 7 at the maximum belt speed, the horse-power indicated on the scale D falls off with increase of belt speed just as the ordinates of curve 10 of Fig. 3 fall off with increasing belt speed. The slot 7 may be placed at any desired angle to the direction of motion of the slide but too small an angle will make the curves E too short for accurate reading and too great an angle will add unnecessarily to the width of the calculator.

Fig. 4 shows a convenient method of laying out the curves E. The scale C is laid out and parallel lines drawn horizontally from a suitable number of speeds to intersect a line *m* drawn parallel to the scale C. The line *m* is therefore divided logarithmically according to the scale C. A line *n* is then drawn intersecting the line *m* at the desired angle of the side of the slot 7. From each of the points of intersection between the line *m* and the lines drawn from scale C, lines are drawn parallel to the line *n* and on these lines the belt horse-power corresponding to the various speeds is laid out according to the logarithmic scale D, the spacing of which is $\frac{3}{2}$ as great as the spacing of scale A, B and C.

For example, the point *p* of the curve E corresponding to the 10″ belt running at a speed of 500 ft. per min. may be found by laying off on line *n′* from the point of intersection between *n′* and *m* a distance equal to the log of the horse-power as found from equation (5). Similarly the point *p′* corresponding to a speed of 6000 ft. per min. may be found by laying off on line *n* from the point of intersection between *m* and *n* a distance equal to the log of the horse-power as found from the same equation. Having laid out one curve E, the others may be spaced therefrom as heretofore described or, if desired, the points of each curve may be laid out as just described.

The method of operating my calculator is as follows: Move the slide until the pulley diameter to be used is opposite the R. P. M. at which it is to be run. The rim or belt speed will be read in the opening 6 opposite the marker 5. Knowing the horse-power to be transmitted, the width of belt necessary can be determined from where the curve on the slide intersects the inclined belt scale D.

While I have described my invention as embodied in a structure in which the parts move linearly which structure I prefer by reason of its simple and compact character, it is apparent that, in its broader aspects, my invention is not limited to such arrangement of parts. It is also apparent that where transparent material is used, the curves E and scales B and C may be applied to the casing member and the scales A and D to the slide. It is further apparent that different sets of curves E may be laid out for different conditions. For example, one set of curves may be drawn for iron pulleys and another set for paper pulleys, the curves being made distinctive in any desired manner, and if desired, a set or sets of curves E and cooperating scales D may be laid out on the back as well as the front of the calculator. Moreover, while I have described my calculator particularly as laid out for belting problems, it is apparent that it is not limited to this relation of utility. For example, if the term involving $V^2$ in equation (5) were preceded by the positive instead of the negative sign, the curves E would turn up instead of down. Likewise if the term referred to involved a power of V which was a proper fraction, the calculator would perform the operation of involution instead of evolution.

I have explained my invention by illustrating and particularly describing a certain specific embodiment thereof, but it will be readily understood by those skilled in the art that the invention may be embodied in many other forms than that shown and described. I, accordingly, do not wish to be restricted to the particular form or construction disclosed herein by way of example for the purpose of setting forth my invention in accordance with the patent statutes. The terms of the appended claims are, therefore, not restricted to the precise structure disclosed, but are intended to cover all changes and modifications within the spirit and scope of my invention.

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

1. A belt calculator comprising a pair of members arranged to be relatively moved according to the log of belt speed, a plurality of curves logarithmically spaced according to belt width on one of said members and a scale on the other member logarithmically divided according to belt horsepower arranged to cooperate with said curves and means whereby said scale moves over said curves upon the relative movement of said members.

2. A belt calculator comprising a pair of members relatively movable linearly, a logarithmic scale on one of said members divided according to belt speed and cooperating means on the other member whereby the relative movement of said members may be adjusted according to the log of belt speed, a belt horse-power curve on one of said members and a cooperating scale at an angle to the line of relative movement of said members arranged on the other member so that said scale moves over said curve in proportion to the relative movement of said members.

3. A belt calculator comprising a member provided with a plurality of curves logarithmically spaced according to a function of the belt width varying substantially in accordance with the produce of belt width by belt thickness and a cooperating member adapted to be adjusted relatively to said first mentioned member according to the log of belt speed, said cooperating member being provided with a scale arranged to cooperate with said curves and graduated to indicate power.

4. A calculator comprising a pair of members relatively movable linearly, logarithmic scales on said members whereby the relative movement may be adjusted to secure a result involving an operation of multiplication or division, characterized by the fact that one of said members is provided with a plurality of logarithmically spaced curves corresponding respectively to quantities by which it may be desired to multiply said first result, and the other is provided with a reference line arranged to cooperate with said curves and divided logarithmically, and by the fact that said curves are plotted to oblique axes, the axis of abscissas parallel to the line of relative motion of said members and the axis of ordinates parallel to said reference line, whereby the point of intersection between any curve and the reference line is a measure of the product of said first result by the quantity to which the curve corresponds changed by an amount dependent upon the character of the curve.

5. In a belt calculator a pair of relatively movable members provided with cooperating relatively inverted logarithmic scales respectively divided according to pulley diameters and speed of revolution whereby the position of one member relative to the other will be dependent upon rim speed, a plurality of curves corresponding to belts of different widths, on one of said members, ploted with the axis of abscissas divided logarithmically according to rim speed and with the axis of ordinates divided according to belt power corrected for centrifugal force, and a reference line on the other member, divided according to belt power arranged to vary its position with respect to said curves according to the relative position of said members whereby information desired concerning proper relative values of pulley diameter, power, and belt width may be ascertained with a single setting of the calculator.

In witness whereof, I have hereunto set my hand this tenth day of August, 1921.

FREDERICK W. CALDWELL.