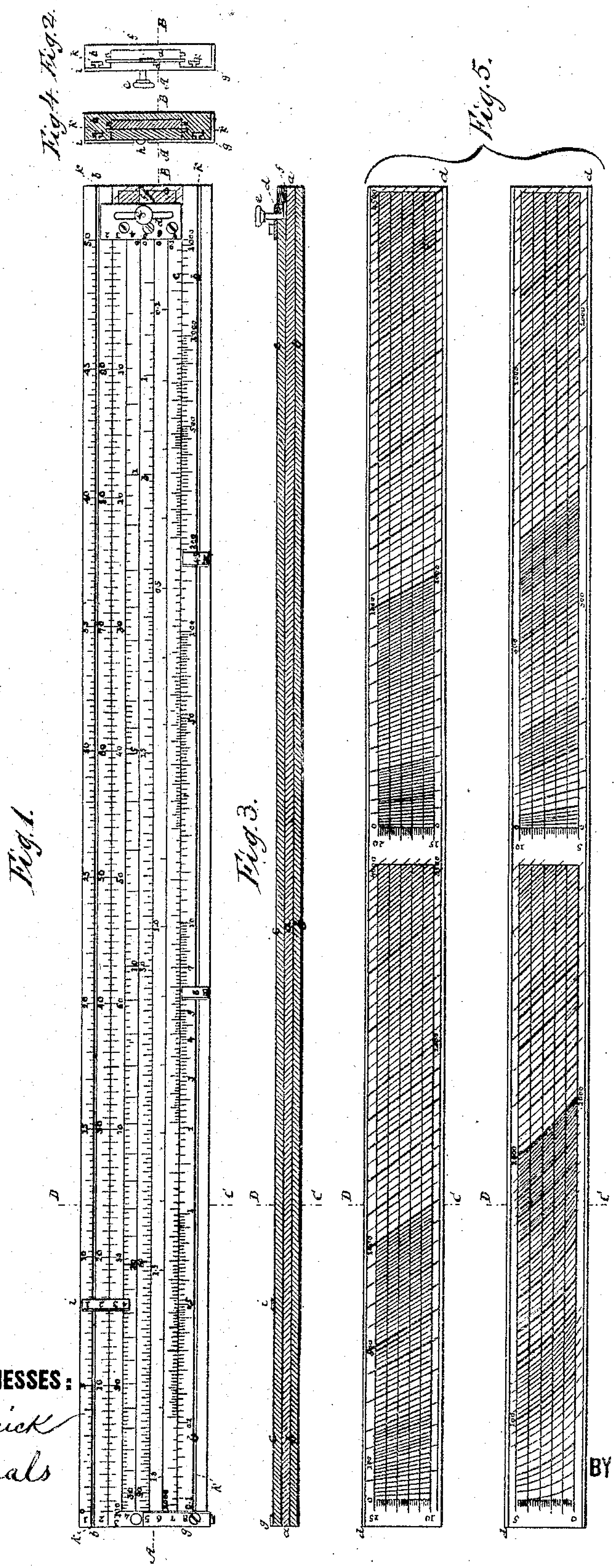
F. M. STAPFF.

Philosophical Instruments or Estimators.

No. 157,239. Patented Nov. 24, 1874.



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FREDRIC MAURICE STAPFF, OF STOCKHOLM, SWEDEN.

IMPROVEMENT IN PHILOSOPHICAL INSTRUMENTS OR ESTIMATORS.

Specification forming part of Letters Patent No. **157,239**, dated November 24, 1874; application filed October 4, 1873.

To all whom it may concern:

Be it known that I, FREDRIC MAURICE STAPFF, of the city of Stockholm, in the Kingdom of Sweden, have invented a new and Improved Estimator, of which the following is a specification:

The estimator is a sliding rule, by which the volume of prismatoidal bodies is calculated mechanically. As most of the embankments, ditches, cuts, &c., occurring in the construction of railroads, canals, fortifications, &c., possess prismatoidal shape, the estimator has the power to abridge and facilitate the important but tedious task of computing the quantities in earthwork. This task is facilitated by tables, which (in America) are based upon the prismatoidal formula, viz:

$$Q=L\left\{B\left(\frac{H+h}{2}\right)+\frac{n}{3}\left(H^2+h^2+Hh\right)\right\}$$

In this formula the letter Q indicates the volume sought; L, the length of prismatoid; n, its slope; B, its base; H and h, the vertical heights of its terminal cross-sections. If those cross-sections are not regular parallel trapezoids, H and h indicate the average (equivalent) heights—*i. e.*, the heights of ideal parallel trapezoids, which agree with the real cross-section's area F f, slope n, and base B. The average heights are then found by the formula

$$H\ h=\sqrt{\frac{F\ f}{n}+\left(\frac{B}{2\ n}\right)}-\frac{B}{2\ n}$$

Making use of those two fundamental formulas in the construction of my instrument, I have found it proper to transform the first one of them as follows:

$$Q=L\left\{B\left(\frac{H+h}{2}\right)+\frac{n}{12}\left(3(H+h)^2+(H-h)^2\right)\right\}$$

If the volume sought has to be expressed by cubic yards, while the sizes of prismatoid are measured by foot, this formula reads:

$$Q=L\left\{B\left(\frac{H+h}{54}\right)+n\left(\frac{(H+h)^2}{108}+\frac{(H-h)^2}{324}\right)\right\}$$

The following description, with drawing, refers to an estimator constructed in accordance with this last formula. But it should be remembered that the arrangement of my instrument by no means needs to be changed, and only three of its eight scales have to be modified if the proportion between unity of length and unity of volume be another one than that of foot to cubic yard.

When compared with the tables now in use, the estimator offers the following advantages: It may be applied with equal ease, whatever (within the extent of the estimator-scales) the values of B and n entering the calculation may be, while the said tables are made up but for certain often-occurring values of B and n; it allows to finish the calculation with more exactness and speed, and with less mental effort, than the tables do; it may be taken out to the field in a great-coat pocket, while an equivalent complete collection of tables would represent a little library; finally, one estimator worth about $20 will, to each railroad-office, save the expense for one or more assistants.

On the drawing adjoined to this description, and representing an estimator in reduced scale, the different scales forming essential parts of the instrument are only generally indicated.

The estimator is composed of the rule b, in which two slides, a and c, move, one above the other, parallel to the axis of the rule. The lower slide a is provided with a diagram of curves, by means of which the average heights are found. The upper slide c carries five parallel scales, (numbered 3 to 7,) and the rule b carries two scales (numbered 1 and 2) at the one side, and one scale (numbered 8) at the other side of slide c. Of those scales, No. 7 and No. 8 are used for multiplications and arithmetical operations of similar nature. The distances from the starting-points of those scales to their different graduated lines are proportional to the Briggs logarithms of the numerical values expressed by the respective graduated lines. I prefer making the graduation of one of those scales to progress from the left to the right, that of the other one in opposite direction.

For the special purpose of the estimator it is sufficient if the multiplication-scales represent the logarithms of numerical values between 0.05 and 1000; but if the same scales should be used for multiplications, &c., of greater or smaller values, it is but necessary to suppose the graduated lines to mean $\frac{1}{100}$ or $\frac{1}{10}$, or ten times or one hundred times, the values printed on the scales, and then to operate in the ordinary way. Besides, the extent of the graduation on those scales may be varied at pleasure.

For performing multiplications by means of scales 7th and 8th, the slide *c* should be drawn out until the graduated line indicating one of the factors on one of those scales is opposite that graduated line on the other scale by which the other factor is indicated. The product then is read on either of the two scales opposite the I line of the other one.

For working divisions the slide *c* should be drawn until the I line on one of the scales is in opposition with that graduated line on the other scale by which the dividend is indicated. Read then the quotient from any of the scales opposite that graduated line on the other scale by which the division is indicated.

Square roots are extracted by moving the slide *c* until the I line on one of the scales is opposite to the graduated line on the other scale indicating the power. The root is then indicated by those two graduated lines on both scales which coincide and express identical numerical values. A ⊥-shaped groove, *k*, running along scale 8th in rule *c*, contains two buttons, B and *n*, which, in this groove, are movable to and fro. These buttons are made use of for indicating factors to be multiplied by B or *n*.

The graduation of scale 2d (on rule *b*) and of scale 3d (on slide *c*) is identical and uniform on both scales, the intervals between equivalent graduated lines being equal; but one of the scales (2d) is ciphered from the left to the right, the other one (3d) in opposite direction.

The extent of the cipher series expressed on the addition-scales depends upon the extent of the work to be performed by the estimator. If the sum of the heights of both terminal cross-sections (H+*h*) does not exceed 100′, it is sufficient to express by each of the addition-scales the cipher series 0 to 100 with subdivisions.

For summing up two numerical values, *f*, *i*, H, and *h*, the slide *c* should be drawn until the graduated line on scale 2d, expressing one of the sums coincides with the graduated line by which on scale 3d the other sum is expressed. The sum then may be read from either scale opposite the zero-line of the other one. The zero-line of scale 3d being indicated by the edge of index-plate *d*, (on slide *c*,) is commonly used to read the sums by.

If two values have to be summed the sum of which is greater than 100 and less than 200, the operation is quite the same as here described; but to the value read from scale 3d, opposite the 100 line of scale 2d, 100 must be added. For summing any two values with the assistance of the addition-scales, it is but necessary to understand the graduated lines to mean 10 or 100 times the values printed on the scales, and then to operate as described hereabove.

For effecting subtractions by means of the estimator's addition-scales, the slide *c* should be drawn until the index-edge *d* meets with that graduated line on scale 2d by which the subtrahend is expressed. Read the rest from scale 3d or 2d, opposite that graduated line on 2d or 3d by which the subtractor is expressed.

By the scale 6th on slide *c* the function $\frac{H+h}{54}$ is expressed. The graduation of this scale is uniform, the intervals between equivalent degrees being 54 times wider than those on scale 2d, where the sums H+*h* are produced as described above. The scale begins at the edge of index-plate *d*, exactly below the zero-line of scale 3d, proceeds from the right to the left, is ciphered in the same direction, and read by the edge of index-plate *g*, which is fixed on rule *b*, exactly the zero-line of scale 2d. Whatever the position of slide *c* (inside the rule *b*) may be, the distance from the zero-line of scale 2d to the index-plate *d* always must be equal to the distance between the index-plates *d* and *g*. Of course, if any sum (H+*h*) produced by help of the addition-scales 2d and 3d is read from scale 2d by the edge of index *d*, synchronously the function $\frac{H+h}{54}$ may be read from scale 6th by the edge of index-plate *g*.

The subdivisions of scale 6th may be more or less extended; but, on estimators for common use, I prefer to express on this scale directly by graduated lines $\frac{1}{100}$ c. yard.

By the scale 5th on slide *c* the function $\left(\frac{H+h}{108}\right)^2$ is expressed. This scale proceeds from the edge of index-plate *g*; the distance from *d* to *g*, by which $\left(\frac{H+h}{108}\right)^2$ is indicated, always being equal to the distance from the zero-point of scale 2d to *d*, by which (H+*h*) is indicated. You will read from scale 5th, by index *g*, the function $\left(\frac{H+h}{108}\right)^2$, if you synchronously may find H+*h* on scale 2d by index *d*.

The scale is constructed by the formula $H+h=\sqrt{108x}$, H+*h* meaning the distance from *d* to the graduated line to be set out; *x*, the value to be expressed by that graduated line. The subdivision of this scale may be extended more or less; but, on estimators of common size, I prefer to express directly, by graduated lines, $\frac{1}{10}$ c. yards between 0 and 25; $\frac{1}{5}$ c. yards between 25 and the end of scale.

By the scale 4th the function $\left(\frac{H-h}{324}\right)^2$ is expressed. This scale begins at the edge of plate *d*, progresses from the right to the left, and is read at the edge of index-plate i, which may be drawn to and fro in the groove k, between the scales 1st and 2d. By means of the scale 1st (on rule b) this index can be placed so that the distance from it to edge of index-plate d expresses the difference $H-h$, while the sum $H+h$ is synchronously expressed by the distance from g to d. Scale 1st starts exactly above the zero-point of scale 2d, thence progressing to the right. Its graduation is a uniform one, the intervals between equivalent graduated lines being twice as wide as on scale 2d. Of course, if by index i any value of h is indicated on scale 1st, the value $2h$ will be synchronously indicated by the same index on scale 2d. If slide c is in such a position that the edge of plate d coincides with any graduated line on scale 2d expressing the value $H+h$, and at the same time the index i is in such a position that by it may be read h from scale 1st, or $2h$ from scale 2d, then the value $H+h-2h=H-h$ will be indicated by index i on scale 3d, and the function $\left(\frac{H-h}{324}\right)^2$ by the same index on scale 4th.

Scale 4th is constructed by the formula $H-h=\sqrt{324y}=18\sqrt{y}$, meaning the numerical value to be expressed by any graduated line the distance of which from d is $=H-h$.

In practice it will happen but rarely that $H-h$ is greater than 50. Of course, it may be needless to continue scale 4th further than to its half extent $f\,i$ to $H-h=54$, corresponding with $y=9$.

The value h, which belongs to the smaller cross-section, having been marked on the scale 1st by index i, the slide c is drawn out until that graduated line on scale 3d by which H is expressed coincides with that graduated line on scale 2d by which h is indicated.

The value $\frac{H+h}{54}$ is read from scale 6th by index g, and marked on scale 8th by the button B.

The value $\left(\frac{H+h}{108}\right)^2$ is read from scale 5th by index g, and added to the value $\left(\frac{H-h}{324}\right)^2$ as read from scale 4th by index i. The sum of both is marked on scale 8th by the button n.

The multiplication $B\times\left(\frac{H+h}{54}\right)$ is done by drawing slide c until the graduated line on scale 7th which expresses the value B coincides with the indicating-edge of button B. The product read from either of the scales 7th or 8th, opposite the I line of the other scale, is marked on scale 2d by index i. The multiplication $n\times\left[\left(\frac{H+h}{108}\right)^2+\left(\frac{H-h}{324}\right)^2\right]$ is done by drawing slide c until the graduated line on scale 7th which expresses the value n coincides with the indicating-edge of button n. The product having been read from either scale 7th or 8th, opposite the I line of the other scale, it is added to the product $B\times\left(\frac{H+h}{54}\right)$ (marked by index i on scale 2d) by drawing slide c until the graduated line on scale 3d expressing the value of the last-found product, $n\times\left[\frac{(H+h)^2}{108}+\frac{(H-h)^2}{324}\right]$, coincides with the indicating-edge of index i. The sum read from scale 2d by edge of index d expresses, by cubic yards, the volume of one running foot of the prismatoid. Let the length L be $=100'$, as commonly in America, where the distance between two station-points is $=100'$, the volume of the whole prismatoid is found simply by placing the decimal-mark of the sum next after the second fractional cipher to the right hand; but, if the prismatoid extending between intermediate or plus points be shorter than $100'$, the multiplication $L\ x$ sum is easiest done with the assistance of the multiplication-scales 7th and 8th.

Let h be $=25'$; $H=55'$; $n=1\frac{1}{2}$; $B=22.5$; $L=100$. After having marked $25'$ by index i on scale 1st, draw slide c until the graduated line $25'$ on scale 2d coincides with the graduated line $55'$ on scale 3d. Read from scale 6th, by the edge of index g, 1.48, and mark this value by index B on scale 8th. Read from scale 4th, by the index i, 2.78, and from scale 5th, by the edge of index g, 59.26. Add both values together and mark the sum, 62.04, by index n on scale 8th. Draw slide c until the graduated line 22.5 on scale 7th coincides with the indicating-edge of button B. Read the product 33.3 opposite the I line of one scale from the other one, and mark it by index i on scale 2d. Draw slide c until the graduated line 1.5 on scale 8th coincides with the indicating-edge of button n. Read the product 93.06 from either scale 7th or 8th opposite the I line of the other one. Add both products by drawing slide c until the graduated line 93.06 on scale 3d coincides with the graduated line 33.30, as indicated on scale 2d by index i. The sum 126.36, read from scale 3d opposite the 100 line of scale 2d, is the volume (in cubic yards) of one running foot of the prismatoid. The volume of the whole prismatoid, being $100'$ in length, would be 126.36 cubic yards.

The whole series of operations here described may, with some practice, easily be done in some few minutes, and in shorter time yet, if many calculations have to be carried out in which the same values for n and B enter; or if the values to be operated upon are not too complicated; or if the cross-sections are of triangular shape, (ditches $f\ i$,) in which case, B being $=0$, the multiplication $B\times\left(\frac{H+h}{54}\right)$ is dispensed with; or if the slope n is $=1$, (common cuts,) in which case the multiplication $n \times \left[\frac{(H+h)^2}{108} + \frac{(H-h)^2}{324} \right]$ is spared; or if the slope n is $= 0$, (rectangular cuts through rock,) in which case the whole product $n \times \left[\frac{(H+h)^2}{108} + \frac{(H-h)^2}{324} \right]$ disappears.

Every curve on slide is a graphical expression of the equation $Hh = \sqrt{\frac{Ff}{n} + \frac{(B)^2}{2n}} - \frac{B}{2n}$ for a given numerical value of $\frac{Ff}{n}$, and for successive values of $\frac{B}{2n}$ the average height, Hh, is expressed by the absciss distance to any point of curve the ordinate of which is $\frac{B}{2n}$.

For constructing the curves, some numerical values of $\frac{B}{2n}$ are set out as ordinates by arbitrary scale; and as abscisses are set out by the scale 2d or 3d, those values of Hh which result by substitution in the equation above of those values, $\frac{Ff}{n}$, for which the curve has to be drawn, the several points of curve set out in this way are connected by a continual line.

The values $\frac{Ff}{n}$, for which succeeding curves are constructed, increase by simple arithmetical progression. For the estimator here described the increase of $\frac{Ff}{n}$ is from curve to curve: one unit for values $\frac{Ff}{n}$ between 0 and 10; five units between 10 and 100; ten units between 100 and 1000; twenty units from 1000 upward; but, dependently upon the size and application of the estimator, the intervals between two succeeding values of $\frac{Ff}{n}$ may be taken greater or smaller than here stated.

On the drawing belonging to this description, not all the curves being indicated, the intervals between two values $\frac{Ff}{n}$ expressed by succeeding curves are wider on the drawing than stated in the description.

For common practice it is sufficient if the curves are constructed for values $\frac{B}{2n} = 0 \ldots 20$, and for values $Hh = 0 \ldots 50$; but for the rest the curve-diagram may be extended or abridged at pleasure, the exactness of the estimator and the easiness of its practice greatly increasing if the ordinates are set out by as large a scale as possible. I have taken this scale four times greater than the width of slide would have allowed if the undivided diagram had been fixed on it; and then I have cut the diagram in four ribbons parallelly to the axis of abscisses, which ribbons are fixed on both sides of slide a, the first ribbon containing that portion of the curves which comprises the ordinates $\frac{B}{2n} = 0 \ldots 5$; the second $\frac{B}{2n} = 5 \ldots 10$; the third $\frac{B}{2n} = 10 \ldots 15$; the fourth $\frac{B}{2n} = 15 \ldots 20$; but I wish my patent to cover also estimators with undivided diagrams of curves.

The ciphered graduated lines or marks of degrees along the axis of ordinates, as represented on the drawing, express numerical values of $\frac{B}{2n}$; but lately I have constructed estimators where the ciphers along the axis of ordinates indicate numerical values of $\frac{B}{n}$, while the respective graduated lines are constructed for values $\frac{B}{2n}$. Hereby the division $\frac{\frac{B}{n}}{2}$ is avoided, $\frac{B}{n}$ being operated upon directly.

When making use of the diagram of curves the slide c is drawn to the left until the edge of index d coincides with the zero-line of scale 2d; then the slide a is put in such a position as that the portion of diagram of curves which contains the numerical value of $\frac{B}{n}$ entering into calculation stands close before the plate d on slide c.

Along the plate d moves the tongue f, guided by a slot, at any point of which it may be fixed by the brake-screw e. The curves are almost normally transversed by the tongue's oblique indicating-edge, which is provided with three index-lines. The slide a is in its right position if the most convenient one of those index-lines meets the axis of ordinates of the diagram of curves. Then the tongue f should be moved up or down, and fixed so that the chosen index-line points out the graduated line on the axis of ordinates by which the numerical value $\frac{B}{n}$ entering the calculation is represented. If, now, slide a is kept in position, while slide c is drawn to the right until the chosen index-line on tongue f meets that curve by which the value of $\frac{Ff}{n}$ entering the calculation is expressed, then the value of Hh, depending on the respective values of $\frac{B}{n}$ and $\frac{Ff}{n}$, may be read from scale 2d by index d. If any value of $\frac{Ff}{n}$ has to be operated upon which is between two values represented by curves, the proper way of placing the slide a is found with the assistance of the fine arbitrary graduation between the index-lines on tongue f. Let $f\,i\,\frac{Ff}{n}$ be $= 175$, the slide a should be drawn until the index-line on tongue

f points just in the middle between the curves 170 and 180. The space between those curves, by which 10 units of $\frac{Ff}{n}$ are expressed, measuring 3 graduated lines of tongue f, (if the ordinate $\frac{B}{n}$ is $= 13$,) the slide has to be drawn until the index-line on tongue f points $1\frac{1}{2}$ degree before curve 180, or $1\frac{1}{2}$ degree behind curve 170.

The equation $H\,h = \sqrt{\frac{Ff}{n} + \frac{(B)^2}{2n}} - \frac{B}{2n}$ may be written $(H\,h)^2 + \frac{B}{n}(Hh) = \frac{Ff}{n}$, or, generally, $x^2 + a\,x = b$.

Of course, the estimator may be used directly for the solution of all second-degree equations of last-named shape, as far as the numerical values a (to be sought along the axis of ordinates) and b (expressed by the curves) are inside the limits of the curve-diagram on slide a; $f\,i\;a = 0 \ldots. 40$, and $b = 0 \ldots 2500 \ldots 4500$, if the estimator is of ordinary size.

The divisions $\frac{F}{n}\frac{f}{n}\frac{B}{n}$ having been performed with or without the help of the multiplication (division) scales 7th and 8th, that part of the curve-diagram is placed before the index-plate d on slide c which contains the ordinate value $\frac{B}{n}$ entering calculation. Previously, the slide c has been drawn to the left until the edge of index-plate d falls in with the zero-point of scale 2d, and with the edge of plate g. The tongue f is moved up or down until the index-line on same points out that graduated line on axis of ordinates by which numerical value of $\frac{B}{n}$ entering calculation is expressed. While slide a is kept in this position, slide c is drawn rightward until the index-line on tongue f meets that curve, or that point between two curves, which represents the value $\frac{f}{n}$. The value of h belonging to the respective values $\frac{B}{n}$ and $\frac{f}{n}$ may then be read from scale 2d by index b, for being marked on scale 1st by index i, as soon as this can be done without collision between index i and plate d. Slide c now remaining in place, slide a has to be drawn to the right until the axis of ordinates of the diagram of curves is met by the index-line on tongue f. In this position slide a is kept, while c is drawn rightward until the index on tongue f points out that curve, or point between two curves, which represents $\frac{F}{n}$.

Now, the value $H+h$ could be read from scale 2d by index d. But this reading can be spared, because you will find, directly, $\frac{(H-h)^2}{324}$ on scale 4th by index i; $\frac{(H+h)^2}{108}$ on scale 5th by index g; $\frac{H+h}{54}$ on scale 6th by index g. These values, and those of n, B, L, are operated upon exactly as described above for the case that H and h were given directly instead of F and f. Given: F=4500□′; f=1500□′; B=22.5; n=1.5.

From the given values follows, directly, $\frac{f}{n} = \frac{1500}{1.5} = 1000$; $\frac{F}{n} = \frac{4500}{1.5} = 3000$; $\frac{B}{n} = \frac{22.5}{1.5} = 15$.

Draw slide c until the zero-line of scale 2d is touched by the indicating-edge of d. Place right before slide c that part of slide a which contains the diagram for ordinate values $\frac{B}{n} = 10 \ldots 15$, so that the axis of ordinates is touched by the index on tongue f, and fix then this tongue so that its index-line points at the degree 15.

Slide a being held in this position, slide c is drawn rightward until the index-line on tongue f meets the curve $\frac{f}{n} = 1000$; then $h = 25'$ may be read from scale 2d by index d, and kept in mind. Slide c being held in place, slide a is drawn rightward until the axis of ordinates is touched by the index-line on tongue f; then slide a is held in place, while slide c is drawn rightward until the index-line on tongue f touches the curve $\frac{F}{n} = 3000$. From scale 2d could now (by index d) be read 7° 78′, this being $= H + h$. The value $h = 25'$, as previously read from scale 2d, now having been marked on scale 1st by index i, the following readings are done: From scale 6th, by index g, 1.35 is marked on scale 8th by index B; from scale 4th, by index i, 1.60, and from scale 5th, by index g, 49.05. The sum of both, or 50.65, is marked on scale 8th by button n.

The multiplication $B \times 1.35$ is done by drawing slide c until the 22.5 line of scale 7th is opposite the indicating-edge of button B. The product 30.37, as read from either scale 7th or 8th, opposite the I line of the other one, is marked on scale 2d by index i. The multiplication $n \times 50.65$ is done by drawing slide c until the 1.5 line of scale 7th is in opposition with the indicating-edge of button n. The product 75.97 is read from either scale 7th or 8th, opposite the I line of the other one. This product is added to the first one by drawing slide c until the 75.97 degree of scale 3d coincides with the indicating-edge of index i. The sum read from scale 3d opposite the 100 line of scale 2d, viz., 100+6.34=106.34, expresses the volume of each running foot of the prismatoid.

If the second-degree equation $x^2+36.1x=4205$ has to be solved, the slide c should be drawn until the edge of index d coincides with the zero-line of scale 2d. Then that piece of curve-diagram showing the ordinates 30 . . . 40 is placed before slide c, so that the index-line on tongue f meets the axis of ordinates, and the tongue is fixed so that its index-line points exactly between the ordinate degrees 36 and 36.2. Now the slide c is drawn (a meanwhile being held in place) until the index-line on tongue f is one-fourth of the distance between the curves 4200 and 4220 behind the curve 4200. From scale 2d may now be read, by index i, $x = 49.3$.

Invertedly, the estimator may be used for deducing mechanically from a given volume the average height of the prismatoid containing this volume. Hereby the estimator proves very useful for determining how much the grade of a preliminary railroad-line ought to be attached, or how much such a line ought to be thrown to the side for balancing as much as possible the quantities in the cuts and embankments of a given railroad-section, provided the ground on the sides of the preliminary line previously has been cross-sectioned. The different scales may be turned so as to progress in a direction opposite the present one; or the scale 1st may be applied on slide c, and synchronously the scales 4th, 5th, 6th on rule b. Then the index-plate g is left out, the scales 4th, 5th, 6th being read by index d, and the index i is made to move in a groove on slide c; or the scale 1st may be left out, the respective readings then to be done from scale 2d, which, for that purpose, should be furnished with a second ciphering, identical with that on scale 1st. Or the scales 4th and 5th may be combined, the spaces between equivalent graduated lines being thrice as wide on scale 4th as they are on scale 5th. Or the whole instrument may be constructed in the shape of a prism or a cylinder, with the scales parallel to its axis, or in the shape of a disk divided into degrees on its plan or edge, &c.

The drawing represents, in Figure 1, a plan view, and in Fig. 2 a head view, of the estimator; Fig. 3, a longitudinal, and Fig. 4 a transversal, section of same; Fig. 5, a view of slide a from both sides.

b, rule, in which, by double grooves, move the upper slide c and the lower side a, one above the other; d, index-plate attached to upper slide c; f, tongue sliding along slit of index-plate d; e, brake-screw to fix that tongue with; i, index sliding in groove k along one edge of slide c; $\frac{B}{6}, \frac{n}{4:5}$, index-buttons sliding in groove k along other edge of slide c; g, index-plate attached to rule c; h, button for drawing slide c. (May be placed elsewhere on the slide c.)

The scales 1st to 8th on rule b and slide c are on drawing, but indicated as mentioned in the ingress; likewise the diagram of curves on slide a.

Sums between 50 and 100 are found on this estimator by adding 50 to the value, as read from scale 3d, opposite the 50 line of scale 2d. The multiplication-scales 7th and 8th have such an extent as that factors from 0.07 to 10 may by them be operated upon directly, and the diagram of curves on the lower slide a is constructed for values $\frac{B}{n} = 0 \ldots 40$; $\frac{Ff}{n} = 0 \ldots \left\{ \frac{625}{1625} \right.$, and corresponding ones of $H\ h = 0 \ldots 25$. The graduated or division lines along the axis of ordinates of the diagram of curves on lower slide of estimator are ciphered by values of $\frac{B}{n}$, as referred to in the description, while the corresponding degrees on drawings are ciphered by values of $\frac{B}{2n}$.

Having thus described my invention, I claim as new and desire to secure by Letters Patent—

The combination of slides a c, working one above the other in a grooved case, constructed, notated, and provided with the auxiliaries described, as and for the purpose set forth.

FREDRIC MAURICE STAPFF.

Witnesses:
NEU. A. EFWING,
EUGÈNE FORSWAY.