3 Sheets—Sheet 1.

J. L. KNIGHT.

Device for Calculating Percentage, &c.

No. 214,510. **Patented April 22, 1879.**

FIG. 2.

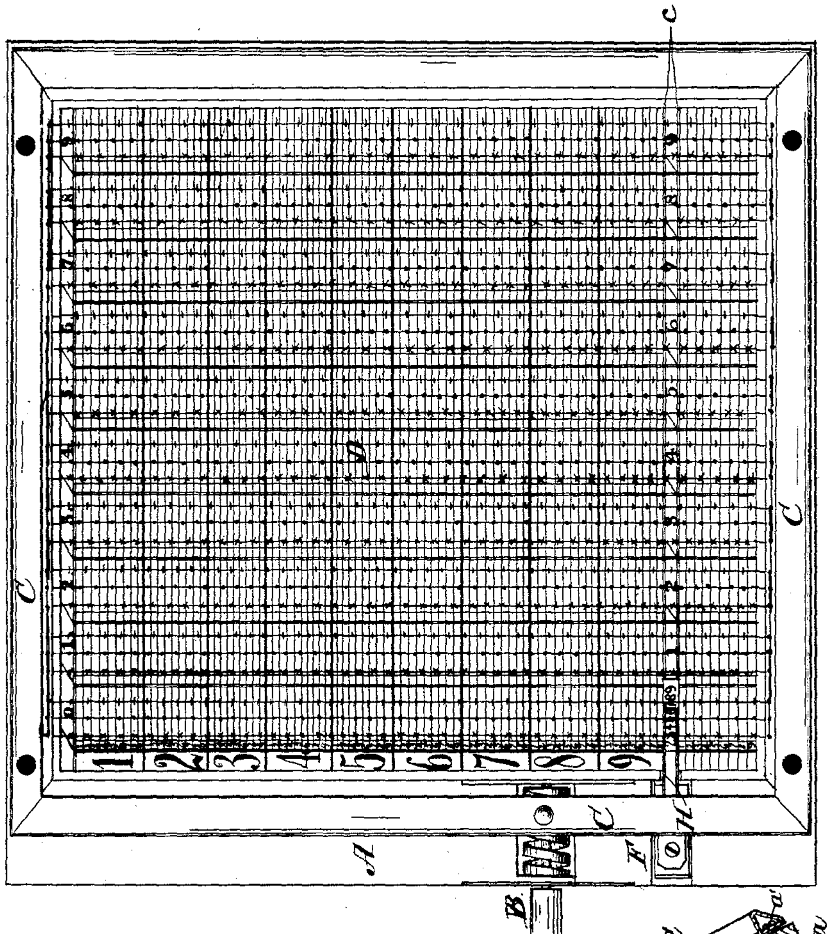

FIG. 1.

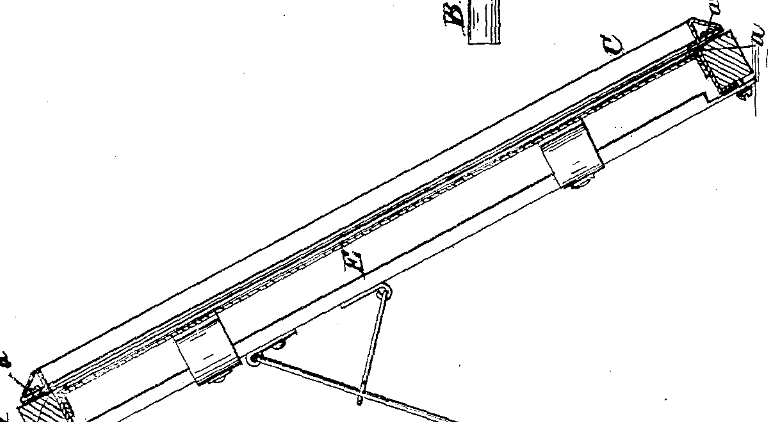

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FIG. 4.

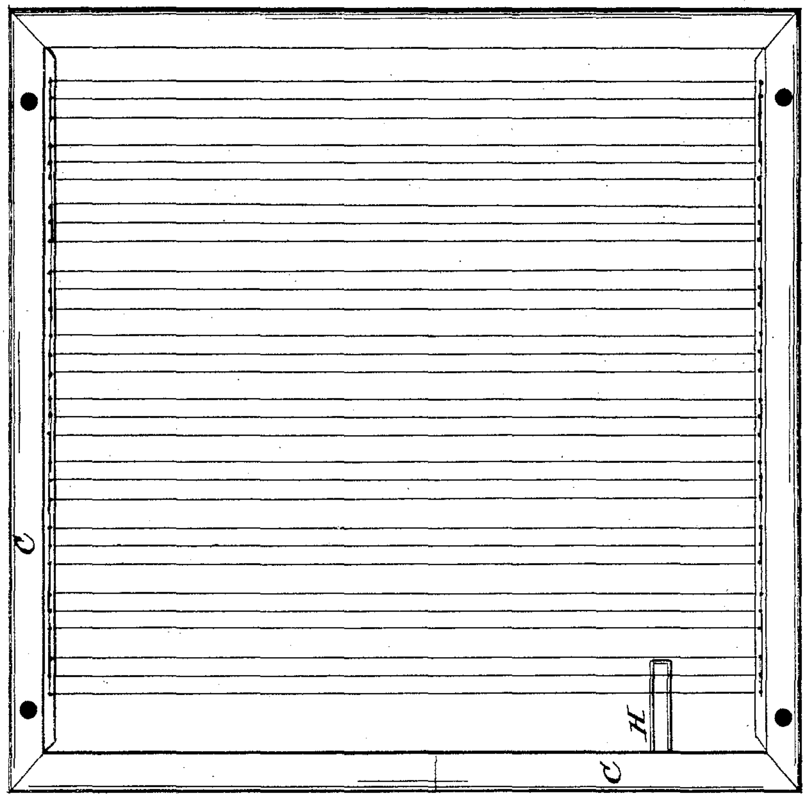

FIG. 3.

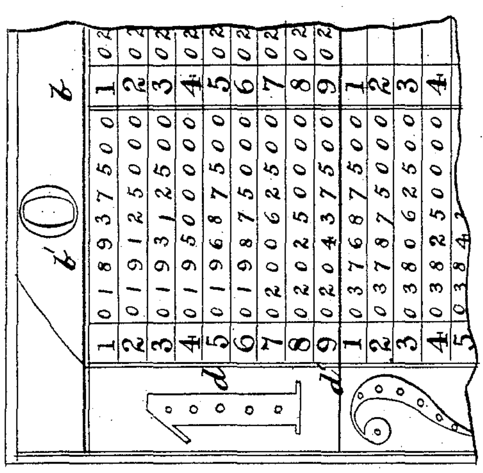

FIG. 5.

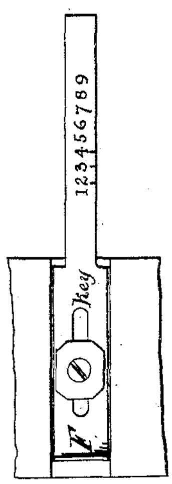

FIG. 6.

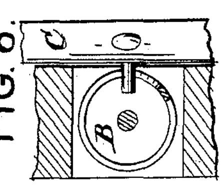

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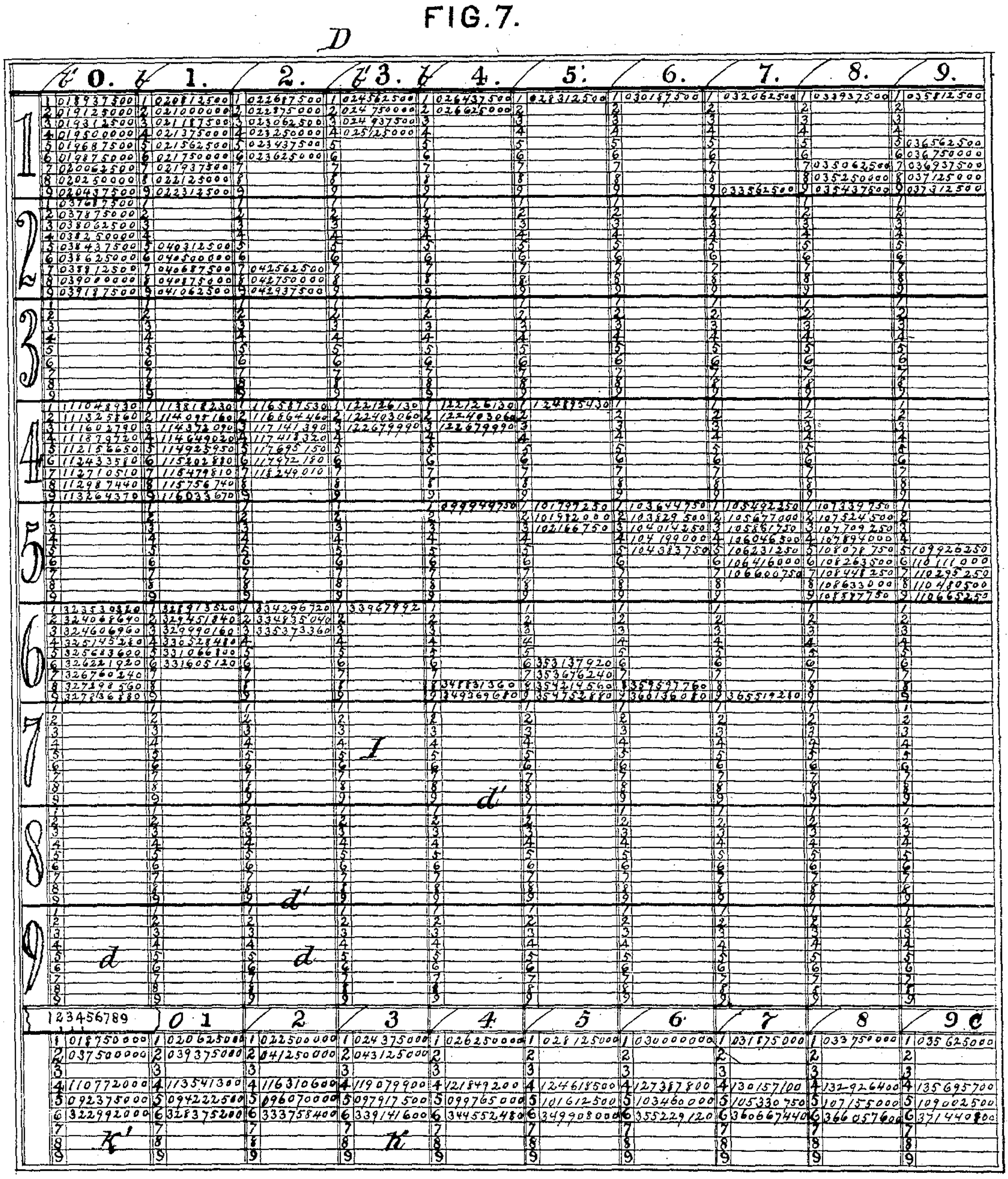
FIG. 7.



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UNITED STATES PATENT OFFICE.

J. LEE KNIGHT, OF TOPEKA, KANSAS.

IMPROVEMENT IN DEVICES FOR CALCULATING PERCENTAGE, &c.

Specification forming part of Letters Patent No. **214,510**, dated April 22, 1879; application filed April 29, 1878.

To all whom it may concern:

Be it known that I, J. LEE KNIGHT, of Topeka, in the county of Shawnee and State of Kansas, have invented certain new and useful Improvements in Calculators; and I do hereby declare that the following is a full, clear, and exact description of the invention, which will enable others skilled in the art to which it pertains to make and use the same, reference being had to the accompanying drawings, and to the letters of reference marked thereon, which form a part of this specification.

In the drawings, Figure 1 is a vertical section. Fig. 2 is a plan. Fig. 4 is the carrying-shield and frame, with the fixed tables removed. Figs. 3, 5, and 6 are detail views; and Fig. 7 is a fixed table, showing the combination partially made up on the basis of $18\frac{3}{4}$ per cent., or cost, or duty, per article or piece, or tax per head, &c.

This invention, which is a 9×9 combination calculator, is a mechanical device for showing at a glance, or by the simple addition of two or three sums indicated by the mechanism, the exact results of percentage calculations which would otherwise require extended multiplications, involving the constant possibility of error.

The machine has been so designed as to be simple in construction, easily comprehended in its operation and the formation of the tables used, and absolutely accurate in the results attained by its use.

The device is composed of a deep rectangular frame, A, of suitable material and size, provided with an actuating-screw, B, for giving motion to a superposed rectangular frame or carrying-shield, C, supported thereon. The frame has also a projecting metal flange, *a*, around the inner front margin, to serve as a catch, against which the rectangular tables D may rest, and be retained in place flush with the front or face of said frame A. The frame A is also provided with a removable back, E, to facilitate changing the table of one rate for the table carrying a different rate, and is made deep enough for the thickness of the frame material to form a receptacle for a supply of extra tables to be stored and kept clean and straight when not in use. The frame A is also provided with an adjustable key-slip, F, of metal or other suitable material, having the figures 1 to 9, inclusive, and the word "key" placed thereon.

The key-slip F is slotted and secured in position so that it may be moved back and forth and fixed at different distances as related to the permanent table, for the purpose of changing the rate carried by the same table, as will be hereinafter described.

To this principal frame A is attached another frame or carrying-shield, C, secured by screws *a'* or other suitable means, in such manner that it may be freely moved from side to side by means of a pin projecting from its under side into the open groove of the screw B. The carrying-shield is provided with ten groups of guides, stretched across from side to side, and composed of red, yellow, and blue silk-thread or other suitable material, there being three guides in each group, all being placed at fixed distances, corresponding with the lines of figures on the fixed table, to be hereinafter described. This carrying-shield is also provided with a wire-loop, H, placed at a point to correspond with the adjustable key-slip of the first-described frame, and on a line horizontally with the wide horizontal bar of division of the fixed table. This shield moves on anti-friction bearings affixed to the frame A.

The fixed tables D are made on a card or board cut to the proper size to fit snugly inside of the frame A and against the flanges *a*. They are divided by engraved or printed heavy vertical double lines *b* into ten equal vertical tiers or columns, *b'*, and again divided horizontally by one heavy or wide double line, *c*, near the lower end, into the parts or divisions I and K. The part I, above this wide dividing-line *c*, is again subdivided into nine equal horizontal spaces or tiers, *d*, by single lines *d'* drawn parallel to the wide double line *c*, and at right angles to the vertical columns *b*.

The nine horizontal spaces of the upper part, I, have at the left-hand end of each the figures from 1 to 9, respectively, and the ten vertical spaces between the wide vertical lines *b* have the ten digits 0 1 2 3 4 5 6 7 8 9 at the top of each, respectively.

On the wide double line or horizontal bar *c* are placed the figures from 1 to 9 in the lower ends of the vertical tiers *b'*, over which the corresponding figures are placed at the top of the table.

By these general divisions it is found the tables are divided into one hundred rectangular blocks or spaces, ten being below the wide horizontal bar, and ninety above it. At the left-hand margin of the horizontal tiers of spaces *d* are placed, in consecutive order, the figures from 1 to 9, inclusive.

The space in the double line or horizontal bar *c* above the lower left-hand corner block in the division K is left blank, and over it is arranged the adjustable key-slip F. These several divisions, with their marginal indices, constitute the fixed table, to be used, in connection with the frame, with key-slip and carrying-shield with loop, for the purpose of readily and accurately indicating the results of calculations in percentage. These forms of division and marginal indices, as here arranged and described, constitute a permanent and useful combination of lines and figures to be used in connection with tables of changeable figures written on the board or card for the specific purposes hereinafter fully explained.

I will now explain the manner of forming the combinations of figures to be written or printed on the fixed tables, and also the manner of using the device when completed.

Each table is supplied with a set of combinations derived from a fixed rate or per cent. or a definite whole or fractional number.

For convenience of reference the rectangular block K′, at the lower left-hand corner in the division K immediately below the key-slip, is termed the "key-block." The other nine blocks or spaces in said division are, for convenience, termed the "base-tier." The ninety blocks in the division I are termed the "upper group." For further convenience the nine combinations written or printed on the key-block are called "key combinations." The eighty-one combinations of the base-tier are called "derived combinations," and the nine hundred combinations of the upper group are called "detailed combinations."

The rate per cent. being given, which is to become the multiplier in solving the problems, is written decimally, and this decimal statement of the per cent. on one dollar at the given rate is the first key combination, from which all the others are formed. Its place in the table is at the top of the key-block, and directly to the right of and on a horizontal line with the small marginal index-figure 1 of the key-block. This key combination added to itself (or multiplied by two) gives the second key combination, to be written next below it, on a horizontal line with the marginal index-figure 2 of the key-block. The first key added to the second will give the third, the first added to the third will give the fourth, added to the fourth will give the fifth, and so on for the nine key combinations. If, now, we again add the first to the ninth, we shall have increased to tenfold, or the figures will be repeated, but located one space farther to the left, this tenth addition giving the proof that all the others are correctly added.

The derived combinations of the base-tier are formed by adding a tenth of the first key to the first key for the first derived combination of the first or left-hand block of the base-tier. To this we again add a tenth of the first key for the first or upper derived combination of the second block. To the second we add a tenth of the first key for the third; add the same to the third and we get the fourth, and so on for the nine upper derived combinations, written opposite the several small index-figures 1 of the nine blocks of the base-tier. For the second horizontal line of derived combinations, to be written opposite the index-figures 2, we take the second key combination and add to it tenths of the first key in the same way. For the third line we take as a starting-point the third key, adding successively the tenth part of the first key, which is the constant increase, and for the fourth, fifth, &c., proceed in the same way by adding to the fourth, fifth, &c., key combinations. Having added one-tenth of the first key nine successive times to form the first series of nine derived combinations, if to the ninth one we again add the tenth of first key we shall have just doubled the first key, and if the additions have been correct the result should be equal to the second key, which was formed by adding the first key to itself. In like manner we find proof of all the additions by making a tenth addition at the end of each series of nine derived combinations, which will always give the key combination of the next series.

It is seen that the key combinations increase in a ratio or progression equal to the whole ratio, while the derived combinations increase by a ratio equal to but one-tenth of the rate or number, yet both have a fixed ratio derived from the first key—*i. e.*, the rate or number.

We now have to deal with combinations having a still different ratio of increase—viz., one one-hundredth of the first key. These are the detailed combinations of the upper group. To form these we take the first key as a starting-point for the first series (of blocks) of combinations of the upper group—those occupying the space in the top subdivision which has the large figure 1 at the left-hand end—and by the addition of one one-hundredth of the first key to the first key get the first or upper combination of the block over which the large 0 stands at the upper left-hand corner of the table. To this first-detailed combination we again add the ratio of constant increase for the second combination of that block. To this another addition of the same ratio of increase will give the third, and so on for the nine combinations of that block. A proof of the several additions can be had by making a tenth addition, the result being equal to the first derived combination of the base-tier, that being first key plus one-tenth of itself, and in this case being first key plus ten-one-hundredths of first key. For the second block of first series (horizontally) we take the first derived combination of the base-tier, and to it add successively the constant ratio nine times, which will give the nine combinations of the second block, a tenth addition proving the work, as before, by giving the second derived combination of the base-tier, for the reason that here we have added twenty one-hundredths, while in the base-tier we added two-tenths. The third block is in like manner formed by successive additions to the second derived combination, the fourth block by additions to the third of the base-tier, and so on for the ten blocks of the first series, the work being proved at the end of each block by a tenth addition of the ratio of increase.

For the second series (of blocks) of combinations, on the space at the left-hand end of which the large figure 2 stands, we proceed by the same ratio of constant increase, but take the second key combination as an initial point, and, after forming the combinations for the first block of that series, prove, as before, by a tenth addition, which gives the same figures as the first derived combination of the second series in the base-tier, which, in like manner, is the starting-point or number to which an addition of the ratio of increase will give the first combination of the second block. The ratio being again added to this will give the second, and so on for the nine combinations of that block.

The tenth addition proves the work by giving the second derived combination of the second series in the base-tier, which is also the starting-point from which in the same way the combinations of the third block are formed, and so on for all the blocks of the second series.

For the third, fourth, fifth, &c., series of the upper group we take the corresponding key combination, and in regular order its derived combinations, and by successive additions of the ratio of increase form all the detailed combinations of the upper group, proving the work at every tenth step by the derived combinations of the base-tier, which were also proven at every tenth step by their key combinations, and these again were proven at the tenth step, as previously shown, by the formation of a "repetend."

We find, then, that we have combinations of three kinds—that is, formed from three different ratios of increase—viz., key combinations, increasing by a ratio equal to unity of the rate; derived combinations, formed by a constant increase equal to one-tenth the rate; and detailed combinations, in which the ratio is equal to one one-hundreth of the rate.

This system of decimal logarithmic combinations being formed and arranged on the table as here described, may now be used in connection with the guides of the carrying-shield to give the results of all multiplications by the given rate or number on any sum less than one thousand millions—that is to say, any sum or amount that can be represented by nine figures, which comes within a single unit of a thousand millions, viz., 999999999, and this by the simple addition of three sums indicated by the several marginal indices, and divided by the red, yellow, and blue guides.

Having explained the form of my device, and the manner of adjusting it to any rate or multiplier, I will give some examples of its use, as illustrated by the partially-formed combinations on the model.

The first and second key combinations as written on the model, and their corollary derived and detailed combinations, are from the fractional multiplier $18\frac{3}{4}$, and may be used to give results of percentage calculations at $1\frac{7}{8}$ mills per cent., $18\frac{3}{4}$ per cent. mills, or $18\frac{3}{4}$ per cent. cents, or for determining the value of any given number of pounds, yards, parcels, or things at either of those prices per yard, pound, &c.

EXAMPLES AND RULES.

Adjustment of the key-slip.—The key-slip, in addition to the nine significant figures, has three check-marks on the lower edge. For multiplying by $1\frac{7}{8}$ as mills, adjust the key-slip so the left-hand check-mark coincides with the right-hand line of the vertical column—*i. e.*, the line separating the small marginal indices of the key-block from the key combinations. If it be desired to multiply by $18\frac{3}{4}$ as mills, set the slip so the middle one of the three check-marks coincides with the above-named line; and if the multiplier is to be $18\frac{3}{4}$ as cents, set the key-slip so the right-hand check-mark falls at the same point of the permanent table.

In the examples given, a rate of tax or duty is assumed at $18\frac{3}{4}$ mills on the dollar, and the key-slip set, as in model, at the center check-mark. This key-slip simply fixes the initial decimal-point or base from which the guides count, and the different guides serve to fix the decimal-points of the several combinations, whereby the addition of three combinations will give the results of calculations on sums composed of seven, eight, or nine significant figures; the addition of two combinations will give the result of multiplying any number composed of four, five, or six significant figures; and the result of multiplying any sum composed of three figures will be shown in full without addition.

I will now give several examples illustrative of the manner of using this table.

First example.—What is the tax or duty on \$1 at $18\frac{3}{4}$ mills per cent.? This we term a prime problem of the first class. Prime, because it needs no addition to get the result; of the first class, because it has but a single significant figure.

Rule 1.—Set the carrying-shield so the wire loop will inclose as many figures as there are figures from left to right in the sum being multiplied. In this example there is but one figure from left to right, and applying the rule we set the shield so that the figure 1 of the key-slip falls inside the wire-loop.

Theorem 1.—All problems of a single significant figure are answered in the key-block, and the decimal-point is marked by the red or right-hand guide, the left hand or significant figure of the problem being the index to the combination which forms the answer.

Applying the theorem, we find opposite the small index-figure 1 of the key-block the first key combination divided by the red guide thus: .01875, or one cent, eight mills, and seventy-five hundredths, as the answer.

Second example.—Required the tax or duty on $20—a prime problem of first class. Apply rule 1 by setting the shield to include the figure 2 of the key-slip. Apply theorem 1 and we find the second key combination divided by the red guide thus—.375, or thirty-seven cents and five mills as the answer.

Example.—Required the tax on $18, prime problem, second class—second, because having two significant figures. Rule 1 sets the shield to include the figure 2 of the key-slip.

Theorem 2.—Problems having two significant figures in succession from the left are answered in the combinations of the base-tier as divided by red guide, the left-hand figure being the horizontal index, or index to series to be found on margin of block, and the second figure being the vertical or cross index to be found over top of block on the wide horizontal bar. Apply theorem 2, and we find in first series, eighth block of base-tier .03375 as the answer.

Third example.—Required the tax on $197, prime problem, third class—third, because having three significant figures. Rule 1 sets the shield to include 3 of the key slip inside the loop.

Theorem 3.—Problems having three significant figures in succession from the left, or two significant figures separated by a single cipher, are answered in the detailed combinations of the upper group as divided by the red guide, the left-hand figure of the problem being the horizontal index to series of blocks, the second figure or cipher being cross or vertical index to block of the series, and the third figure of the problem from the left, the detail or block-index to the combination which is the answer. Apply theorem 3 and we find 03.693 as the answer.

Fourth example.—Required the tax or duty on $2,182. This a complex problem, embodying a prime problem of the third class and an auxiliary problem of the first class—complex, because composed of more than one period of three figures; embodies an auxiliary problem, because requiring one addition to solve it.

Rule 2.—To get the result of a complex problem, divide the sum into periods of three figures, counting from the left. To the answer to first period as divided by the red guide add the answer to the second period as divided by the yellow guide; and if there be three periods, to the sum of the two, as above, add the answer to the third period as divided by the blue guide. Apply rule 1, which sets the shield so the wire loop includes the figure 4 of the key-slip. Theorem 3 gives 40.875 as answer to first period, and theorem 1 gives .0375 as answer to second period. Add auxiliary to prime answer, and we have 40.875+.0375=40.9125 as complete answer.

NOTE.—Had the problem contained five significant figures the answer to second period would have been found by theorem 2 in base-tier, and added as above; if of six significant figures, or six figures, with significant figure in the units place, theorem 3 would have indicated the answers to both periods in the upper group, and these added together as above would have given the true answer.

Example.—Required the tax or duty on $209219.13. Complex problem, composed of prime problem of third class; auxiliary problem of third class, and sub-auxiliary problem of second class. Rule 1 sets the shield to bring the figure 8 of the key-slip inside the loop. Theorem 3 gives 391875.00, red guide, as answer to first period; also, 410.625, yellow guide, as answer to second period, and theorem 2 gives .243+, blue guide, as answer to third period; therefore, 391875.00+410.625+.243=392285.86 as the answer. But this is manifestly an error if we are reckoning percentage, as the percentage of 18¾ mills gives a sum greater than the original amount. The anomaly is readily explained when we recall the fact that the original sum had a decimal point two spaces from the right; or, in other words, it was cents instead of dollars; or, more properly, dollars and cents both; but we have dealt with it as dollars only, taking no account of the decimal point, which, by its place, really divided the sum by one hundred. If, however, we divide our answer by one hundred by removing the decimal point two places farther to the left we shall have corrected the seeming error, and our true answer 3922.85+.

NOTE.—If a sum is composed of dollars only, we read the answers dollars and cents as divided by the guides. If the sum is composed of dollars and cents both, we should read the answer cents and mills, as divided by the guides, and fix final decimal-points accordingly.

Let us now readjust the key-slip and make the multiplier 1⅞ mills instead of 18¾ mills.

Example.—What commission is due from negotiating 209,219.13 of business at 1⅞ mills per cent.? The calculation is precisely the same as before, except that the decimal point will be found marked one space farther to the left in each case, and hence the answer will be $402.28+; or, in other words, the adjustment of the slip serves to divide each answer, and hence the total, by ten.

Fifth example.—What is the cost of 20,921,913 yards of muslin at 18¾ cents per yard? We readjust the key-slip so that the left-hand check-mark coincides with the line at right hand of small marginal-block index-figures. Having so adjusted the key, we set the shield to bring the figure 8 inside the loop, and then find the answer to first and second periods of three figures from the left in upper group as before, the answer to third period in base-tier, and by adding the three together, as in the first example, where these same figures represented dollars and cents, and we now find the product represented by the three added combinations or answers, as severally divided by the red, yellow, and blue guides, to be 4022858.65+.

A comparison of this result with the former shows that our principal here, or multiplicand, not only had no decimal-point, as in the former case, hence was not divided by a hundred, but that, by changing the key-slip, we have multiplied it by ten to start with.

The fourth, fifth, and sixth key combinations, and their corollary derived and detailed combinations, are based upon the following numbers, viz: the fourth equals 27693, the fifth equals 18475, and the sixth equals 53832, their aggregate being 100000. These numbers, if representing .27+ per cent., .18+ per cent., and .53+ per cent., would jointly make 100 per cent., or gross amount. Each would be completed for an entire table for use in distributing railroad earnings, &c., in combined machine, as hereinafter explained. They are given on the model, that examples may be tested by them, if thought desirable.

The above and foregoing examples illustrate the power of the machine and the uses of its various parts in accomplishing the results.

It is obvious that problems of any number of figures can be solved by finding answers to first nine figures from the left, suffixing to the result as many ciphers as there are figures more than nine in the problem, and removing the decimal-point in the answer an equal number of places farther to the right; then finding answers, as before, for the next general group of nine figures, or less, as the case may be, and adding the results together.

Two, four, six, eight, nine, or more of these tables and frames may be combined in one large frame, all the sliding shields being operated by the same swivel and pin, and thus be used to give at one motion the results of calculations at two, four, or more rates at the same time; or, each of the series of blocks of the upper group may be treated separately, having the first block from the left as a key-block, and the others in same series for derived combinations similar to base-tier. Each series could, in that case, carry a different rate.

This arrangement, by placing the guides two figures' spaces apart instead of three spaces, as in model, would give a machine carrying ten different rates, or, for tax calculations, nine different levies, and their total, and would by a single setting give results by periods of two figures, by one addition giving answers on all sums less than 10000—viz., 9999; and by two additions, on any sum less than 100000—viz., 999999; and by the addition of a fourth guide, by adding four sums, carry eight figures.

This form would probably be preferable for most purposes, and was the original form contemplated; but the form shown in the model has so many advantages, and is, moveover, so much more complete as a symmetrical device, that I submit it as being the greater, which includes the less. The device, in one or the other form, would have many uses where rapid and accurate results are required.

Having described my invention, what I claim, and desire to secure by Letters Patent, is—

1. The combination, with the frame A and the rectangular table D, divided into nine vertical and horizontal tiers of spaces or blocks, with a lower or marginal horizontal tier, all provided with combinations of figures and marginal indices, as stated, of the rectangular adjustable frame *c* and the series of groups of differently-colored parallel guide-cords stretched across the face of the table D, and having their ends secured to opposite sides of said frame C, and arranged to mark the different columns of figures, substantially as set forth.

2. The combination, with the frame A, rectangular table D, divided into nine vertical and horizontal tiers of spaces or blocks, with a lower or marginal tier, all provided with combinations of figures and marginal indices, as described, the rectangular adjustable frame C, and the series of groups of differently-colored parallel guide-cords stretched across the face of the table D, and carried and adjusted by the movement of the frame C, of the key-slip F, secured on the frame A so that it can be adjusted laterally, and key-loop H fixed to adjustable frame C and arranged over the key-loop F, substantially as and for the purposes set forth.

3. The combination of the rectangular frame A, having the guide-pins *a'* and inner flange, *a*, the adjustable key-slip F, secured to the frame A, the rectangular frame C, sliding laterally and horizontally on the pins *a'*, and having the key-loop H, and the fixed rectangular table D, all arranged substantially as and for the purposes set forth.

In testimony that I claim the foregoing as my own I affix my signature in presence of two witnesses.

J. LEE KNIGHT.

Witnesses:
C. THOMAS, Jr.,
THOS. M. JAMES.