PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

An Improved Logarithmic Calculator

I, HENRY JONES, of 94, Arden Park, Bredbury, Stockport, Cheshire, British subject, do hereby declare the nature of this invention to be as follows:—

This invention relates to an improved calculator of the kind employing a logarithmic scale.

It is well known that a calculator, such as a slide rule, employing the principle of logarithms in the form of a scale, is a rapid geometric means of making calculations involving multiplication and division, especially in the hands of a person familiar with its use. On the other hand, the ordinary slide rule is of limited accuracy, say to 2 or 3 figures, and for many commercial purposes this is not sufficient. The only alternative therefore to working out the calculation by actual multiplication and division is to use 7 figure logarithmic tables, and any person who has handled these tables will appreciate that for short calculations of two or three factors there is little or no saving of time.

Slide rules are made in different sizes but the limiting factor in a slide rule is its length. The ordinary or more common size has the scale spread over 25 cms., while half length, double length and other sizes, as well as a circular disc type, are not uncommon, but a slide rule of any known kind becomes too cumbersome in size before its scale can be sufficiently elongated to obtain the required accuracy.

A calculating machine has been proposed in which the scale has been arranged spirally on a cylinder, but such a machine, while it can be sufficiently accurate to 4 or 5 figures, is not conveniently portable, requires some skill, experience and practice in its use and finally is expensive compared with log tables or an ordinary slide rule.

The object of the invention is an improved calculator having in combination a geometric simplicity equivalent to the slide rule wherein one graduated scale is movable and comparable with another together with portability, and cheapness while possessing the required greater degree of accuracy.

The invention is based upon an appreciation of means whereby logarithmic calculations can be made geometrically by measurement over fractional lengths of an elongated logarithmic scale instead of by geometric measurements over whole portions of the scale each complete from the beginning and representing the complete logarithmic value of each factor.

According to the invention, the improved calculator comprises a chart having one or more logarithmic scales thereon, one or more of which is divided into a plurality of equal lengths, and means for adding together and/or subtracting one from another, fractional portions of such equal lengths of the scale, comprising a member preferably of unit length or marked to indicate a unit length adapted to receive pencil or other markings or carrying a movable indicator, whereby to register thereon the sum or difference of such fractional portions of single lengths, with means for indicating the unit length of the scale in which the final result is ascertainable by direct geometric comparison therewith of the residual fraction of single length resulting from such geometrically obtained sum or difference of fractional portions of the scale.

In one example of the invention, the improved calculator comprises a chart on which are 50 parallel lines of 20 centimeters each in length, equally spaced and representing 50 equal sections of a logarithmic scale measuring 1000 centimeters. Movable to register with any of such lines is a blank scale of 20 centimeters or unit sectional length on which pencil or other markings may be made. Conveniently the blank scale may be a simple and unattached strip of opaque celluloid having a straight edge and a matt surface adjacent thereto on which pencil or ink markings are easily made and equally easily removed with an india rubber or damp cloth.

The blank scale provides a simple means enabling the sum or difference of fractional portions of such equal lengths to be obtained and registered by simple geometric means.

Having registered such length result on

[*Price* 1/-]

the blank scale the next problem is to know with which particular line or length of the scale such fractional length result must be compared to give the correct result for the calculation, being given that there is one of the lines with which such comparison can be made.

There are several methods and means of solving such problem.

In one method an approximate result can be obtained from a slide rule or sometimes by mental arithmetic or by means of a second complete logarithmic scale of 1 unit or line length, from which, by means of the same blank scale an approximate result can also be obtained geometrically using the whole logarithmic scale length proportional to each factor. Then, knowing the approximate result it is simple to find the line of the scale in which such approximate result is found and which result will be somewhere near the registered fractional length result on the blank scale when the latter is placed along such line. The final accurate result is then obtainable from such line by reading the numerical value against the registered length mark on the blank scale. In such manner a 20 centimeter complete logarithmic scale can be used as a pilot scale to indicate approximate results for an elongated scale measuring 50 times 20 centimeters and would be satisfactory for a scale of 500 times 20 centimeters. Of course, the length of such pilot scale need not be equal to one line length of the elongated scale, nor need there be any length relationship between the two scales except that such equality facilitates certain measurements where the sum or difference necessitates the use of the other end of the blank scale as an index, as occurs in using a slide rule. The unit length of or unit length markings on the blank scale are then useful.

In an alternative and direct, not approximate, method of solving the problem of determining the line of the scale in which the result is to be found, the calculating device is further constructed as follows:—At one side of the chart is a channel in which is mounted a perforated slide of length equal to 50 spaces separating the lines of the elongated logarithmic scale, and having 48 pairs of holes equally spaced to divide the slide into 50 equal divisions.

The perforations are arranged in two rows at each side of the slide and the slide is adapted to be moved by means of a pencil point, pen point or stylus inserted in any one of the perforations. Stops are provided at the top and bottom of the channel to provide upper and lower limits for engagement by the pencil, which for the left hand row of holes are coincident respectively with the first line of the scale, and one line distance below the last line, while for the right hand row of holes the stops are each one line higher.

In use, assuming one wishes to multiply 139 by 23, the procedure is as follows:—

1st locate the number 139 on the chart.

2nd place the blank scale along the line in which such number appears and with its left hand edge coincident with the left hand end of the line. (The right hand edge of or unit length mark on the blank scale will also be coincident with the right hand end of the line).

3rd. Make a pencil mark on the scale coincident with the line mark for 139.

4th. By means of the pencil point, bring the top edge of the slide to the level of the same line. The number 139 may now be said to be registered on the calculator.

5th. Locate the number 23 which is the next factor of the calculation, which actually appears as 230 on the chart.

6th. Place the blank scale along this second line with the pencil mark coincident with the left hand end of the line.

7th. Make a new mark on the scale coincident with the line mark for 230 and at the same time cancel the first mark by striking a line through it. The sum of the two fractional portions of the two lines is now registered on the blank scale.

8th. Place pencil in the hole of the left hand row coincident with the bottom stop and move the slide until such hole is brought level with the line from which the last mark has been obtained.

The calculation of 139×23 has now been registered on the calculator as the relevant line and the sum of the fractional portions are now both indicated thereon, and such registration is read off by the next action as follows:—

9th. Place the blank scale on the line level with the lower end of the slide and with its left hand end coincident with the left hand end of that line. The answer is found on such line opposite the last and uncancelled pencil mark on the blank scale, and this will be found to be 3197. (The size of the divisions on this part of the scale are such that one could say readings could be taken to five figures with a reasonable degree of accuracy even allowing for errors in the making of the marks on the blank scale).

As a further example of the use of the calculator take the simple multiplication of 30×60. When 30 has been registered on the chart by steps 1, 2, 3 and 4 and 60

has been located thereon it will be found that if the mark on the blank scale is placed against the left hand edge of the chart, the scale does not reach far enough to the right for the second mark to be placed thereon. For the 6th step therefore, place the pencil mark in register with the right hand edge of the chart, for the 7th step make the new mark and cancel the old as before, but for the 8th step use the right hand row of holes, placing the pencil in the lowermost visible hole against the stop and bringing it up to the level of the line last used, as before.

The calculation is read off by the 9th step exactly as before and the answer is 1800. This example shows the use of the second or right hand row of holes in the slide.

As a third example of use of the calculator take the calculation of $30 \times 3.2 \times 2.8$. For this proceed as in the 2nd example up to the end of the 8th step, when the calculation 30×3.2 will be registered on the calculator. Then continue as follows:

9th step. Locate 2.8 on the chart which will be found as 280.

10th. Place the blank scale along this third line with the second pencil mark coincident with one edge of the chart as before. In this case, the left hand edge must be used in order to take the next step.

11th. Make a 3rd mark on the scale coincident with the line mark for 280, cancelling the preceding mark.

12th. It will now be seen that the slide is above the lowermost stop. Therefore place the pencil in the hole against the uppermost stop, using the left row of holes because the left edge of the chart had been used in making the third mark on the scale, and moving the slide until the pencil reaches the line against which the blank scale has just been marked.

13th. step. Place the blank scale on line level with top of the slide and with its ends coincident with the ends of the line, and read off the result opposite the 3rd mark, which will be 2688.

From each of the above examples, it will be seen that the slide provides the means for indicating the sum of two or more overlapping groups of whole lines while the blank scale provides the separate means for ascertaining geometrically the sum or difference of fractional lengths of single lines. In the 6th step of the 2nd and 3rd examples, it must be appreciated that although the second mark is made behind the first and appears to be a subtraction, this is not in fact the case, because the slide is then worked from the right hand row of perforations so as to add the number of the two groups of whole lines together while simultaneously adding an extra line. Thus the addition of the fraction of the line is effected by adding a whole line by means of the slide and subtracting the complement of the fraction of the line on the blank scale, and the register or mark is again brought within the length of the blank scale.

Division is effected in a similar manner to multiplication except that the end of the scale or end mark thereon is placed in register with the divisor, the blank scale is then marked to register the position of the line end and the slide is moved by placing the pencil or stylus in the hole against the line in use, and taking it to the top or bottom stop. These operations are obviously exactly opposite to those for multiplication. It still remains, however, that the left hand row of holes in the slide is used whenever the left hand end of the line is used in making the register, and the right hand row of holes whenever the right hand end of the line is used.

Also, if at any time the slide is not opposite the line for the purpose of inserting a pencil it is only necessary to insert the pencil in a hole adjacent to one stop and move the slide until it reaches the complementary stop at the other end of the channel. The one end of the slide will then register with the line with which the other end of the slide was in register but a pencil can now be inserted in a hole opposite the line containing the divisor, and the manipulation of the device can proceed without affecting the final result.

Of course, as with the use of logarithmic tables, it is necessary to guess the position of the decimal point or obtain such position by the addition or subtraction of the number of figures in the factors before the decimal points therein and the number of noughts between the decimal point and the first figure.

In another example of the invention, and where still greater accuracy is desired, a logarithmic scale is provided consisting of 1000 lines each 20 cms. long. In this case the same blank scale is employed in the same manner for adding or subtracting the fractions of whole lines in which the numbers of the factors appear, and the final result of such additions or subtractions registered as a mark on the blank scale. The device is made up in book form with 50 lines on each page. The identification of the particular line in which the final result is to be found can be obtained by the use

of a pilot device or logarithmic scale to obtain the approximate result. The single page device first described with its single line pilot scale would serve such purpose, or a pilot scale of 5 or 10 lines of 20 cms. would suffice.

On the other hand, absolute determination of the particular line in which the result is to be ascertained, can be effected in the following manner.

The lines are given consecutive numbers, say 0 to 999 at their left hand ends and from 1 to 1000 at their right hand ends. The line numbers for each factor are then noted by pencil, say on the face of the blank scale, as the fractional line length of each factor is registered thereon, and each line number is added to or subtracted from the preceding number or the result of the preceding addition or subtraction, as simple numbers according to whether multiplication or division is being effected at the time; or those to be subtracted placed in another column and the addition of such other column subtracted from the addition of the first column. These numbers are taken from the left end or right end of the line according to which end is used in registering the mark. Finally the "characteristic" taken from the number of integers or noughts of the factors is similarly entered in a column as if in the thousands column, and added and subtracted in the same manner as one does the characteristics of logarithms. If in the addition or subtraction of the figure in the hundreds column, the result is greater than 10 or less than zero one carries forward or brings down from the thousands column and only in the thousands column can the result be negative. The figure in the thousands column then gives the correct characteristic, indicating the number of integers or noughts before the decimal point for the final result, while the three other figures give the left hand number of the line in which the result will be found. Two sets of lines providing 4 columns to receive these figures could be permanently marked on the blank scale.

For such use the number of lines or their numbering must be such that they represent a round figure, such as 10, 100, 1000, 10000 etc. so that the last figure may add to the figures in the column for characteristics of the factors and provide a correct final result. There may, however, be 50 lines, marked 0, 2, 4, 6 . . . 98 at their left hand ends, and 2, 4, 6, 8 . . . 100 at their right hand ends and similarly with any other number of lines, such as 25, numbered 0, 4, 8, 12 . . . 96, and 4, 8, 12, 16 . . . 100, or with 40 lines numbered in multiples of 25 up to 1000.

As a further modification of the device, or extension of its use, there may be further lines drawn on the chart by which square roots and cube roots or any other root of a number may be extracted. A square root of a number is, of course, obtained geometrically by halving the logarithmic value geometrically. For that purpose the chart of the first example is divided diagonally with a line from a point one line above the left hand end of the top line to the right hand end of the bottom line, which we will call line A. Further lines B and C are drawn from the same point to other points half way along and one-third way along the bottom line. These inclined lines are used to effect the geometric division of the logarithmic length representing any number into $\frac{1}{2}$ or $\frac{1}{3}$rd corresponding to square root and cube root respectively.

In use, to take the square or cube root of a number, first find the number on the chart, place the blank scale along its line and register a mark on the blank scale. Next bring the scale to a position on or parallel with a line so that such mark coincides with line A. Then register a second mark on the blank scale, after cancelling the first, to coincide with the coincidence of line B or C according to whether the square or cube root is required. Then find the approximate value of the result by simple mental arithmetic to obtain the first figure and place the blank scale coincident with a line of the chart so that such figure is indicated approximately by the mark registered on the blank scale, when the accurate result can be read on the chart.

It is necessary, however, to make further and vertical dividing lines B^1 and C^1 and D^1 at half way, one-third way and two-third way respectively along the lines, which lines must be used on the single line pilot scale instead of the left hand end of the line to obtain a correct approximate result, using B^1 except when the characteristic of the number is divisible by 2 for the square root, using C^1 or D^1 for the cube root according to whether the characteristic of the number after division by 3 leaves the fraction $\frac{1}{3}$rd or $\frac{2}{3}$rds. In obtaining the accurate result on the elongated scale, the approximate result is used as a guide as to whether the end or the intersection of B^1, C^1 or D^1 with the line is to be used in setting the blank scale.

It is also possible to work with a blank scale neither of unit length nor marked with unit length, so long as in its manipulation the blank scale is long enough for the addition or subtraction of all the part

or fractional lengths of lines. For that purpose a longish blank scale with a single index line thereon could be used, which line would have to be approximately central for general use. Moreover, the blank scale would have to be about 4 or 6 times the length of a single line or even longer if more than 2 or 3 factors were to be provided for in the calculation. Also, if the final registered mark were more than a lines length from the index, a second index mark, subtracting a lines length would have to be made in order that the result could be read off on a line of the chart. The complications thereby introduced would probably be unwarrantable.

For eliminating one geometric manipulation in effecting a calculation the blank scale may be marked with such common factors as π or 240, this latter for calculation of pounds shillings and pence. When such factor occurs in a calculation as a multiplier it is taken first, but when it occurs as a divisor it is taken last and this is effected by placing such mark instead of the end of the blank scale against the end of the line when looking for the final result.

If one edge of the blank scale is marked with suitable divisions of the length of the scale, in tenths, hundredths, thousandths, etc., the scale could be used as a log table for finding the log of any particular number by using the left hand numbering of the lines added to the numbering on the blank scale to make up the number for which the logarithmic value is required and which value can then be read off on the logarithmic scale.

There are obviously other forms than above described of apparatus which could be provided to carry out the invention, the principle of which is the geometric measurement of fractions of divisions of a logarithmic scale, instead of geometric measurement of whole portions of such scale representing geometrically the full logarithmic values of the factors of a calculation, in combination with means for ascertaining in which division of the scale the answer to the calculation can be ascertained from the resultant geometric fraction.

Dated this 30th day of March, 1937.
For the Applicant,
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COMPLETE SPECIFICATION

An Improved Logarithmic Calculator

I, HENRY JONES, of 94, Arden Park, Bredbury, Stockport, Cheshire, British subject, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to an improved calculator of the kind employing a logarithmic scale.

It is well known that a calculator, such as a slide rule, employing the principle of logarithms in the form of a scale, is a rapid geometric means of making calculations involving multiplication and division, especially in the hands of a person familiar with its use. On the other hand, the ordinary slide rule is of limited accuracy, say to 2 or 3 figures, and for many commercial purposes this is not sufficient. The only alternative therefore to working out the calculation by actual multiplication and division is to use 7 figure logarithmic tables, and any person who has handled these tables will appreciate that for short calculations of two or three factors there is little or no saving of time.

Slide rules are made in different sizes but the limiting factor in a slide rule is its length. The ordinary or more common size has the scale spread over 25 cms, while half length, double length and other sizes, are not uncommon, but a slide rule of any known kind becomes too cumbersome in size before its scale can be sufficiently elongated to obtain the required accuracy.

Circular disc type logarithmic calculators are also known, and it has been proposed in such a calculator to provide a "long scale", that is to say, a scale consisting of several concentric circles each though different in length, representing an equal portion of a logarithmic scale, but such an arrangement also has its limitations. The markings on each circle are necessarily on different length scales, such scales being in proportion to their radii. Therefore, even if the scale length can be increased by this means to some 50 or 70 centimeters on a face of $2\frac{1}{2}$ inch diameter, its average accuracy can only be proportional to the scale of the mean circle, that is to say, to the equivalent of a slide rule scale, of say 30 to 40 centimeters. In addition, to such limitation, there is the fact that the approximate answer must be known in order to know on which circle the answer

is to be found when working on the long scale. There must be, therefore, a single line pilot scale and the calculation must be done twice if the long scale is to be used, or the approximate answer must be known or estimated by other means.

A calculating machine has been proposed in which the scale has been arranged spirally on a cylinder, but such a machine, while it can be sufficiently accurate to 4 or 5 figures, is not conveniently portable, requires some skill, experience and practice in its use and finally is expensive compared with log tables or an ordinary slide rule.

The object of the invention is an improved calculator having in combination a geometric simplicity equivalent to the slide rule wherein one graduated scale is movable and comparable with another together with portability, and cheapness while possessing the required greater degree of accuracy.

The invention is based upon an appreciation of means whereby logarithmic calculations can be made geometrically by measurement over fractional lengths of an elongated logarithmic scale instead of by geometric measurements over whole portions of the scale each complete from the beginning and representing the complete logarithmic value of each factor in combination with means whereby the fractional length in which the answer is to be found, may be positively determined.

According to the invention, the improved calculator comprises a chart having one or more logarithmic scales thereon, one or more of which is divided into a plurality of equal lengths, and means for adding together, and/or subtracting, one from another, fractional portions of such equal lengths of the scale, comprising a member relatively movable over said scale and preferably of unit length or marked to indicate a unit length and adapted to receive pencil or other markings and/or carrying a movable indicator, whereby to register thereon the sum or difference of such fractional portions of single lengths in combination with means for indicating positively and directly (as distinct from indirectly by ascertaining the result or approximate result), the unit length of the scale in which the final result is ascertainable by direct geometric comparison therewith of the residual fraction of single length resulting from such geometrically obtained sum or difference of fractional portions of the scale.

In the accompanying drawings:—

Fig. 1 illustrates one example of the invention.

Fig. 2 shows the movable member forming part of the calculating device shown in Fig. 1.

Fig. 3 illustrates a modified and preferred form of the invention.

As illustrated in Figs. 1 and 3, the logarithmic scale is shown divided into 10 lines each 20 centimetres long, making a total length of 2 metres (200 centimeters) or roughly 80 inches and giving 3 to 4 figures accuracy for calculations. This scale has now been adopted in place of the 50 line scale of 20 centimetres each (1000 centimeters) described in the Provisional Specification as it is found to give sufficient accuracy for general purposes. The principle is exactly the same and the substitution of the smaller scale for the purpose of illustrating the invention is not to be taken as being in any way an intention to abandon or disclaim the examples described in the Provisional Specification. The illustrative calculations have also been altered to suit the different scale.

As shown in Fig. 1, the improved calculator comprises a chart *a* on which are 10 parallel lines of 20 centimetres each in length, equally spaced and representing 10 equal sections of a logarithmic scale measuring 2 metres. Movable to register with any of such lines is a blank scale (see Fig. 2) of 20 centimeters or unit sectional length on which pencil or other markings may be made. Conveniently the blank scale is a simple and unattached strip of opaque celluloid *b* having a straight edge *c* and a matt surface adjacent thereto, on which pencil or ink markings are easily made and equally easily removed with an india rubber or damp cloth. The blank scale provides a simple means enabling the sum or difference of fractional portions of such equal lengths to be obtained and registered by simple geometric means. The blank scale itself is conveniently longer than 20 centimeters and a unit length is indicated thereon by lines *d* at each end.

In making a calculation having registered such fractional length result on the blank scale the next problem is to know with which particular line or length of the scale such fractional length result must be compared to give the correct result for the calculation, being given that there is one of the lines with which such comparison can be made.

It is obvious that, if the approximate result of the calculation is known, such knowledge can become an indirect means of ascertaining the required line, but this requires a second calculation, either mental or otherwise, to determine such result as distinct from any direct or

positive method of or means for determining the line itself independent of any knowledge of the result.

There are several methods of and means for solving the problem of determining directly the line in which to seek the result.

In one method of solving the problem of determining the line of the scale in which the result is to be found, the calculating device is further constructed as follows:—At one side of the chart is a channel in which is mounted a perforated slide *e* of length equal to 10 spaces separating the lines of the elongated logarithmic scale, and having 9 pairs of holes *f* and f^1 equally spaced to divide the slide into 10 equal divisions.

The perforations *f* and f^1 are arranged in two rows at each side of the slide and the slide is adapted to be moved by means of a pencil point, pen point or stylus inserted in any one of the perforations. Stops are provided at the top and bottom of the channel to provide upper and lower limits for engagement by the pencil, which for the left hand row of holes are *g* and g^1 coincident respectively with the first line of the scale, and one line distance below the last line, while for the right hand row of holes the stops are *h* and h^1, each one line higher.

In use, assuming one wishes to multiply 129 by 23, the procedure is as follows:—

1st. Locate the number 129 on the chart. This appears as 12.9 in the second section or line of the scale.

2nd. Place the blank scale *b* along the line in which such number appears and with its left hand mark *d* coincident with the left hand end of the line. (The right hand unit length mark *d* on the blank scale will also be coincident with the right hand end of the line).

3rd. Make a pencil mark on the scale coincident with the line mark for 129.

4th. By means of the pencil point inserted in any convenient hole of the slide *e*, bring the top edge of the slide to the level of the same line. The number 129 may now be said to be registered on the calculator.

5th. Locate the number 23 which is the next factor of the calculation and is to be found in the 4th line of the scale.

6th. Place the blank scale along this further line with the pencil mark coincident with the left hand end of the line.

7th. Make a new mark on the scale coincident with the line mark for 23 and at the same time cancel the first mark by striking a line through it. The sum of the two fractional portions of the two lines is now registered on the blank scale.

8th. Place pencil in the hole *f* of the left hand row coincident with the bottom stop g^1 and move the slide until such hole is brought level with the line from which the last mark has been obtained.

The calculation of 129×23 has now been registered on the calculator as the relevant line and the sum of the fractional portions are now both indicated thereon, and such registration is read off by the next action as follows:—

9th. Place the blank scale on the line level with the lower end of the slide *e* and with its left hand end coincident with the left hand end of that line. The answer is found on such line opposite the last and uncancelled pencil mark on the blank scale, and this will be found to be 2967. (The size of the divisions on this part of the scale are such that one could say readings could be taken to four figures with a reasonable degree of accuracy even allowing for errors in the making of the marks on the blank scale.)

As a further example of the use of the calculator take the simple multiplication of 30×60. When 30 has been registered on the chart by steps 1, 2, 3 and 4 and 60 has been located thereon it will be found that if the mark on the blank scale is placed against the left hand edge of the chart, the scale does not reach far enough to the right for the second mark to be placed thereon. For the 6th step therefore, place the pencil mark in register with the right hand edge of the chart, for the 7th step make the new mark and cancel the old as before, but for the 8th step use the right hand row of holes f^1, placing the pencil in the lowermost visible hole against the stop h^1 and bringing it up to the level of the line last used, as before.

The calculation is read off by the 9th step exactly as before and the answer is 1800. This example shows the use of the second or right hand row of holes in the slide.

As a third example of use of the calculator take the calculation of $30 \times 3.2 \times 2.8$. For this proceed as in the first example up to the end of the 8th step, when the calculation 30×3.2 will be registered on the calculator. Then continue as follows:—

9th step. Locate 2.8 on the chart which will be found as 28.

10th. Place the blank scale along this line with the second pencil mark coincident with one edge of the chart as before. In this case, the right hand edge must be used in order to take the next step.

11th. Make a 3rd. mark on the scale coincident with the line mark for 28.

cancelling the preceding mark.

12th. It will now be seen that the slide is above the lowermost stop. Therefore place the pencil in the hole f^1 against the uppermost stop h, using the right row of holes because the right edge of the chart had been used in making the third mark on the scale, and moving the slide until the pencil reaches the line against which the blank scale has just been marked.

13th. step. Place the blank scale on line level with the top of the slide and with its ends coincident with the ends of the line, and read off the result opposite the 3rd. mark. which will be 2688.

From each of the above examples, it will be seen that the slide provides the means for indicating the sum of two or more overlapping groups of whole lines while the blank scale provides the separate means for ascertaining geometrically the sum or difference of fractional lengths of single lines. In the 6th. step of the 2nd. example and 10th. step of the 3rd. example, it must be appreciated that although the second mark is made behind (to the left of) the first and appears to be a subtraction, this is not in fact the case, because the slide is then worked from the right hand row of perforations f^1 so as to add the number of the two groups of whole lines together while simultaneously adding an extra line. Thus the addition of the fraction of the line is effected by adding a whole line by means of the slide e and subtracting the complement of the fraction of the line on the blank scale b, and the register or mark is again brought within the length of the blank scale b.

In obtaining the last figure of the result, such as the 4th. figure in the chart herein illustrated, the eye is required to estimate the value of an intermediate position of the mark between markings on the chart. Actually, greater accuracy is obtainable by this visible or geometric method than is obtainable from the arbitrary and approximate end figures of say a 4 figure log table and on a thousand line chart as described in the Provisional Specification, the accuracy would be greater and the result more easily and quickly ascertained visibly than by approximation from the adjustment figures of a 7 figure log table.

Division is effected in a similar manner to multiplication except that the end of the scale or end mark thereon is placed in register with the divisor, the blank scale is then marked to register the position of the line end and the slide e is moved by placing the pencil or stylus in the hole f or f^1 against the line in use, and taking it to the top or bottom stop as may be required for the next step. These operations are obviously exactly opposite to those for multiplication. It still remains, however, that the left hand row of holes f in the slide e, is used whenever the left hand end of the line is used in making the register, and the right hand row of holes f^1 whenever the right hand end of the line is used.

Also, if at any time the slide is not opposite the line for the purpose of inserting a pencil it is only necessary to insert the pencil in a hole adjacent to one stop g or h and move the slide until it reaches the complementary stop g^1 or h^1 at the other end of the channel or *vice versa*. The one end of the slide will then register with the line with which the other end of the slide was in register but a pencil can now be inserted in a hole opposite the line containing the division and manipulation can proceed without affecting the final result.

Of course, as with the use of logarithmic tables, it is necessary to guess the position of the decimal point or obtain such position by the addition or subtraction of the number of figures in the factors before the decimal points therein and the number of noughts between the decimal point and the first figure.

As shown in Fig. 3, the logarithmic scale is the same as that shown in Fig. 1 but the lines are numbered consecutively 0 and 1 to 9 at their left hand ends and 1 to 9 and 0 at their right hand ends. At the left hand side of the chart is a small slider i. This numbering of the lines and the slider i takes the place of the perforated slide e of the first example. Also, the scale b is replaced by a slide j at the bottom of the chart, on which is mounted a cursor k having a hair line l. The slider i is adapted to form a stop or abutment for the left hand end of the slide j and facilitates setting of the end lines m thereof in register with the ends of the chart lines. The chart also has a short logarithmic scale o and a metric scale n, the purposes and uses of which will be described later.

In use, the slider i is employed for adding together or subtracting the whole lines or more correctly perhaps for indicating such addition or subtraction which is effected mentally from the numbers at the ends of the lines. Taking the same example 129 x 23, the operation is as follows:—

The slider i is brought down to form a stop for the slide j. The cursor is then moved along to bring the hair line l into register with 12.9 which is on the line marked 1 at its left hand end. The slider i is then moved up so that its lower end is

level with such line. The number 129 may now be said to be registered on the calculator by the positions of the hair line *l* of the cursor and of the slider *i*.

The slide *j* can now be moved to the left to bring the hair line into register with the left hand ends of the lines without altering the position of the cursor on the slide.

The next step is to locate the number 23 and, without moving the slide *j* to move the cursor into register with the number 23. Note is then made of the number at the end of the line from which this operation has started, which happens to be 3. The answer of this calculation will be found on the line marked 4, being the addition of the numbers 1 and 3 marked on the used ends of the used lines in which the numbers occurred. Assuming no further calculation is required, the slider *i* is moved down to form a stop for locating the slide *j* and the answer will be found in line 4 in the example above given under the hair line and will be 2967.

If the calculation is to be carried further, the slider *i* is now brought down to the line 4 to register that number, and according to whether the next step is multiplication or division, the line number taken from the end which is used, is added to or subtracted from 4. If, in addition, the number goes over 10 the integer only is considered for determining the line against which to place the slider, or in which the answer will appear. If, in subtracting, a negative figure would result it is necessary to add 10 before effecting the subtraction. Alternatively, additional numbering for minus results could be placed against the left hand line ends, but these might lead to confusion. If the right hand end of a line is used in positioning the slide *j* by the cursor previous to moving the cursor to its next position, or in positioning the cursor in division, then the number of the right hand end of the line used is the number to be added to or subtracted from the previous total.

It is interesting to note that, when the logarithmic scale is divided into 10 lines, the operation of the calculator is in fact a means of adding and subtracting logarithms in two parts; the first figures of the logarithms are represented by the line numbers and are added and subtracted by means of the slide *e* or mentally and recorded by the slider *i* while the remaining figures of the logarithms are added geometrically. If the logarithmic scale is divided into 100 lines, then the first 2 figures of the logarithms are added and subtracted directly while the remaining figures are added and subtracted geometrically. In such manner it becomes obvious that by lengthening the scale, greater accuracy is obtainable, so that with a scale of 1000 lines, each 20 centimeters long, an accuracy equal to a 7 figure log table is easily obtainable.

Actually, of course, the logarithmic scale could be divided into any number of lines, not necessarily a multiple of 10. No special adjustment would be required where a slide such as *e* of Fig. 1 is used but when making mental or direct additions and subtractions, the determination of the answer line might require firstly the addition or subtraction of a figure representing the number of lines into which the scale is divided, say 8, or a multiple thereof, to bring the result within the numbers 0 and 1 to 7. These numbers would then be a function of part of the logarithm.

Where, however, as in the example illustrated, the logarithmic scale is divided into 10 lines, the logarithm of any number is easily ascertained by bringing the hair line to the number on the logarithmic scale, reading the left hand line number as the first figure of the logarithm and the hair line position on the metric scale *n* for the rest of the logarithm. Thus lug 4.5 = .6530, as the number 45 appears in line 6 and is .530 distance along that line as read on the scale *o*.

In another example of the invention which requires no illustration, and where still greater accuracy is desired, a logarithmic scale is provided consisting of 1000 lines each 20 cms. long. In this case the same blank scale is employed in the same manner for adding or subtracting the fractions of whole lines in which the numbers of the factors appear, and the final result of such additions or subtractions registered as a mark on the blank scale. The device is made up in book form with 50 lines on each page.

The lines are given consecutive numbers, say 0 to 999 at their left hand ends and from 1 to 1000 at their right hand ends. The line numbers for each factor are then noted by pencil, say on the face of the blank scale, as the fractional line length of each factor is registered thereon, and each line number is added to or subtracted from the preceding number or the result of the preceding addition or subtraction, as simple numbers according to whether multiplication or division is being effected at the time; or those to be subtracted placed in another column and the addition of such other column subtracted from the addition of the first column. These numbers are taken from the left end or right end of the line

according to which end is used in registering the mark. Finally the "characteristic" taken from the number of integers or noughts of the factors is similarly entered in a column as if in the thousands column, and added and subtracted in the same manner as one does the characteristic of logarithms. If in the addition or subtraction of the figure in the hundreds column, the result is greater than 10 or less than zero one carries forward or brings down from the thousands column and only in the thousands column can the result be negative. The figure in the thousands column then gives the correct characteristic, indicating the number of integers or noughts before the decimal point for the final result, while the three other figures give the left hand number of the line in which the result will be found. Two sets of lines providing 4 columns to receive these figures could be permanently marked on the blank scale. The numbering of the lines provides the means by which the unit length for the answer is positively obtainable. Alternatively, any suitable scoring or registering device may be provided.

For such use the number of lines or their numbering must be such that they represent a round figure, such as 10, 100, 1000, 10000 etc. so that the last figure may add to the figures in the column for characteristics of the factors and provide a correct final result. There may, however, be 50 lines, marked 0, 2, 4, 6 . . . 98 at their left hand ends, and 2, 4, 6, 8 . . . 100 at their right hand ends and similarly with any other number of lines, such as 25, numbered 0, 4, 8, 12 . . . 96, and 4, 8, 12, 16 . . . 100, or with 40 lines numbered in multiples of 25 up to 1000. In the case where the scale is divided into 50 lines, each line may be again divided into half, thus making 100 divisions and the scale can then be reduced to half line length and so on in proportion in other cases above suggested.

As a further modification of the device, or extension of its use, there may be further lines drawn on the chart by which square roots and cube roots or any other root of a number may be extracted. A square root of a number is, of course, obtained geometrically by halving the logarithmic value geometrically. For that purpose the chart of the first example (Fig. 1) is divided diagonally with a line from a point above the left hand end of the top line to the right hand end of the bottom line, which we will call line A. Further lines B and C are drawn from the same point to other points half way along and one-third way along the bottom line. These inclined lines are used to effect the geometric division of the logarithmic length representing any number into $\frac{1}{2}$ or $\frac{1}{3}$ corresponding to square root and cube root respectively.

In use, to take the square or cube root of a number, first find the number on the chart, place the blank scale along its line and register a mark on the blank scale. Next bring the scale to a position on or parallel with a line so that such mark coincides with line A. Then register a second mark on the blank scale, after cancelling the first, to coincide with the coincidence of line B or C according to whether the square or cube root is required. Then find the approximate value of the result by simple mental arithmetic to obtain the first figure and place the blank scale coincident with a line of the chart so that such figure is indicated approximately by the mark registered on the blank scale, when the accurate result can be read on the chart.

It is necessary, however, to make further and vertical dividing lines B^1 and C^1 and D^1 at half way, one-third way and two-third way respectively along the lines, which lines must be used on the single line pilot scale instead of the left hand end of the line to obtain a correct approximate result, using B^1 except when the characteristic of the number is divisible by 2 for the square root, using C^1 or D^1 for the cube root according to whether the characteristic of the number after division by 3 leaves the fraction $\frac{1}{3}$ or $\frac{2}{3}$. In obtaining the accurate result on the elongated scale, the approximate result is used as a guide as to whether the end or the intersection of B^1, C^1 or D^1 with the line is to be used in setting the blank scale.

It is also possible to work with a blank scale neither of unit length nor marked with unit length, so long as in its manipulation the blank scale is long enough for the addition or subtraction of all the part or fractional lengths of lines. For that purpose a longish blank scale with a single index line thereon could be used, which line would have to be approximately central for general use. Moreover, the blank scale would have to be about 4 or 6 times the length of a single line or even longer if more than 2 or 3 factors were to be provided for in the calculation. Also, if the final registered mark were more than a lines length from the index, a second index mark, subtracting a lines length would have to be made in order that the result could be read off on a line of the chart. The complications thereby introduced would probably be unwarrantable.

For eliminating one geometric manipulation in effecting a calculation the blank scale *b* or *j* may be marked with any constant or such common factors as π or 240, this latter for calculation of pounds shillings and pence. When such factor occurs in a calculation as a multiplier it is taken first, but when it occurs as a divisor it may be taken last and this is effected by placing such mark instead of the end of the blank scale against the end of the line when looking for the final result; or more conveniently its reciprocal may be marked on the scale. The line number in which such factor or reciprocal occurs should be noted against the mark, the reciprocal marks being treated as multipliers.

There are obviously other forms than above described of apparatus which could be provided to carry out the invention, the principle of which is the geometric measurement of fractions of divisions of a logarithmic scale, instead of geometric measurement of whole portions of such scale representing geometrically the full logarithmic values of the factors of a calculation, in combination with means by simple addition and subtraction of the whole portions for ascertaining in which division of the scale the answer to the calculation can be ascertained from the resultant geometric fraction.

It is to be noticed particularly that the operation of the improved logarithmic calculator does not involve the use of relatively movable logarithmic scales as in a slide rule.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. An improved calculator comprising a chart having one or more logarithmic scales thereon, one or more of which is divided into a plurality of equal lengths, and means for adding together, and/or subtracting, one from another, fractional portions of such equal lengths of the scale, comprising a member relatively movable over said scale and preferably of unit length, or marked to indicate unit length, and adapted to receive pencil or other markings and/or carrying a movable indicator, whereby to register thereon the sum or difference of such fractional portions of single lengths, in combination with means for indicating positively and directly the unit length of the scale in which the final result is ascertainable by direct geometric comparison therewith of the residual fraction of single length resulting from such geometrically obtained sum or difference of fractional portions of the scale.

2. An improved calculator according to claim 1, characterised in that the number of lengths into which the scale is divided is 10^x where x is any positive whole number.

3. An improved calculator according to either of the preceding claims characterised in that the member movable over the scale is slidably mounted with respect to the scale and also carries a cursor or slide providing an index to co-operate with the markings on the scale.

4. An improved calculator according to claim 3, characterised in that stop means are provided to facilitate location of the sliding member in a zero position with its length in register with the ends of equivalent lengths on the scale.

5. An improved calculator according to any of the preceding claims, characterised in that the means for indicating positively the unit length of the scale in which the answer is to be found comprises a slide movable across the ends of the lines to register therewith.

6. An improved calculator according to claim 5, characterised in that the slide is perforated for movement by a pencil or other pointed article inserted selectively in such perforations and movable thereby selectively to positions to or from the line end immediately in use and from or to a stop, as set forth.

7. An improved calculator according to claim 1, characterised in that the line ends are numbered for the purpose of numerical addition and/or subtraction of such members.

8. An improved calculator according to claim 2 and 7, characterised in that the line ends are numbered consecutively from 0 and 1 to 10^x at the left hand end and from 1 to 10^x and 0 at the right hand end, whereby such numbering corresponds to x of the first figures of the logarithm, while any fraction of the line to a given mark on the scale corresponds to the following figures of the logarithm represented by such mark.

9. An improved calculator according to claim 8, characterised in that it is also marked with a single line which, for example, may be marked on the chart or on the relatively movable member and divided into decimal divisions and adapted to be compared geometrically with any of the lengths of the logarithmic scale, for the purpose set forth.

10. An improved calculator according to claim 7 or 8, characterised by a slide movable across the ends of the lines to register therewith to indicate the line immediately before used or the line number representing the result of the addition

and/or subtraction previously made of the line numbers plus or minus a number equal to the number of lengths into which the scale is divided or some multiple thereof, as set forth.

11. The improved logarithmic calculator constructed, arranged and adapted for use substantially as herein described and as illustrated in the accompanying drawing.

Dated this 25th day of February, 1938.

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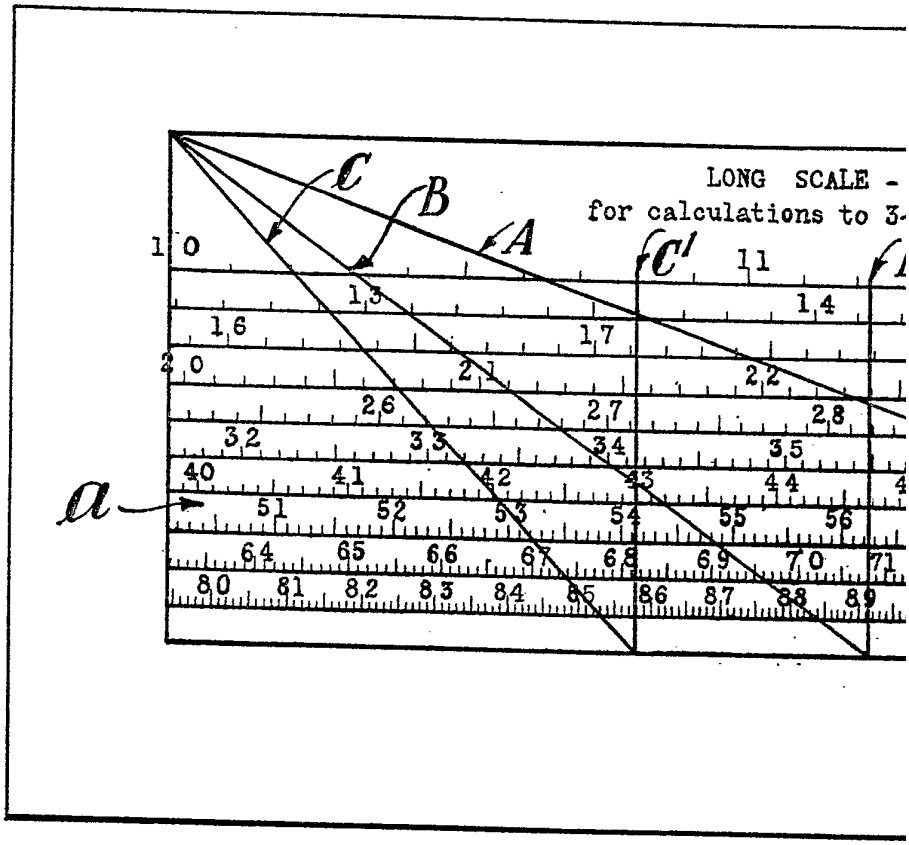

FIG

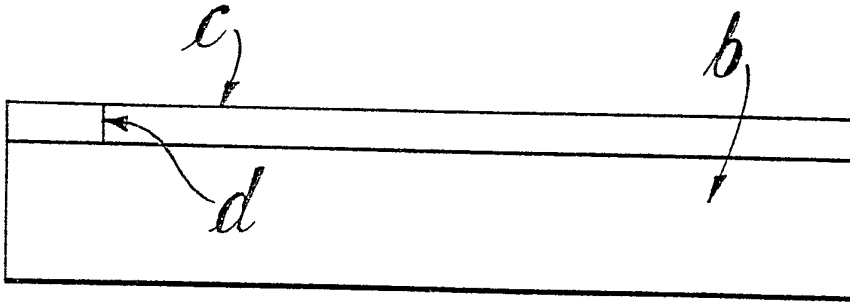

FIG.

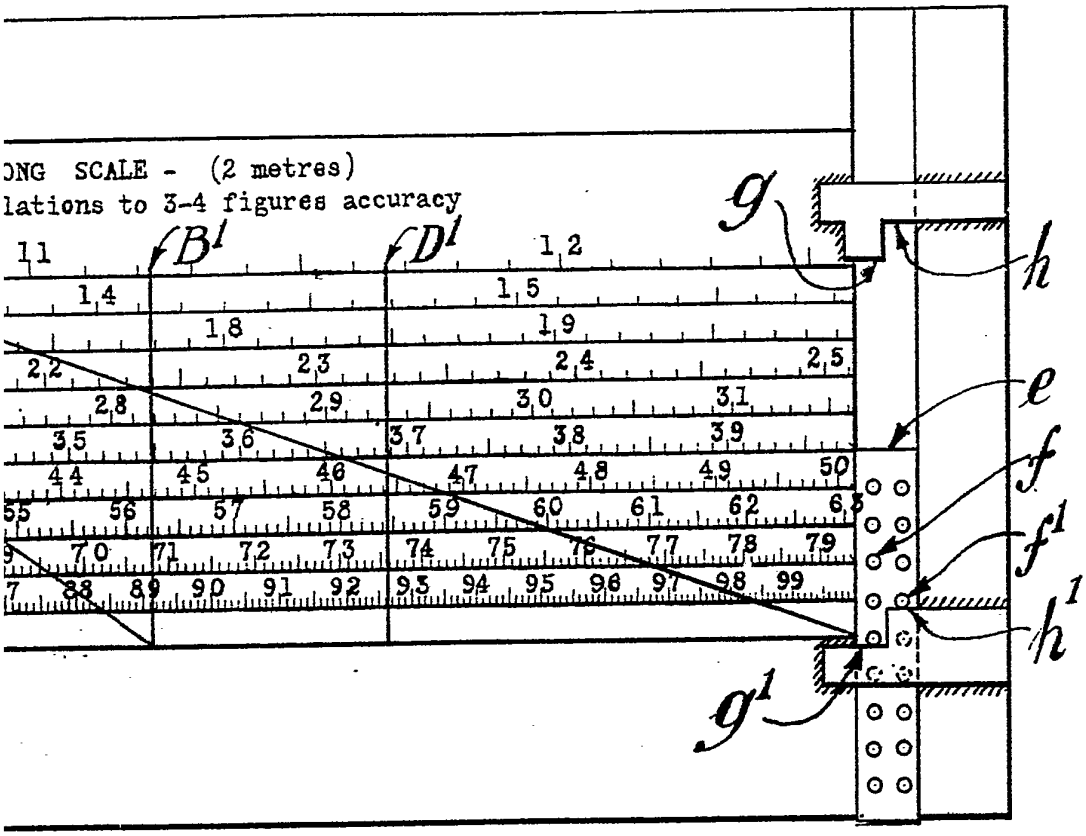

FIG. 1.

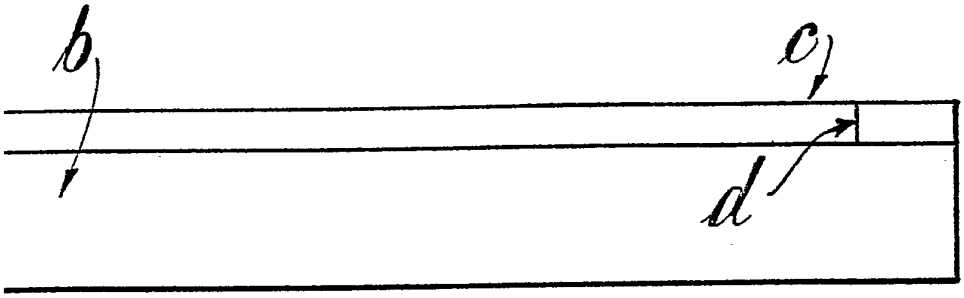

FIG. 2.

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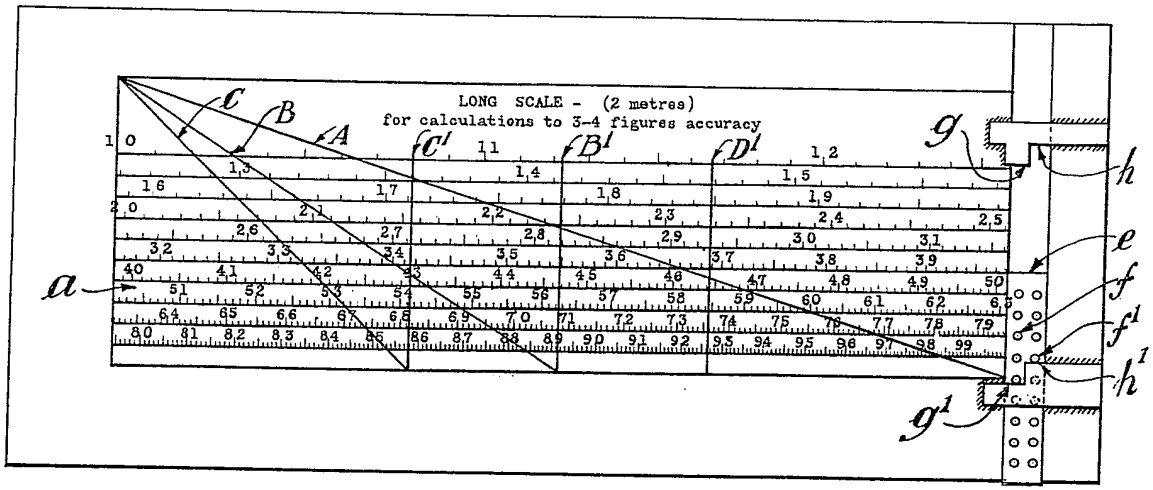

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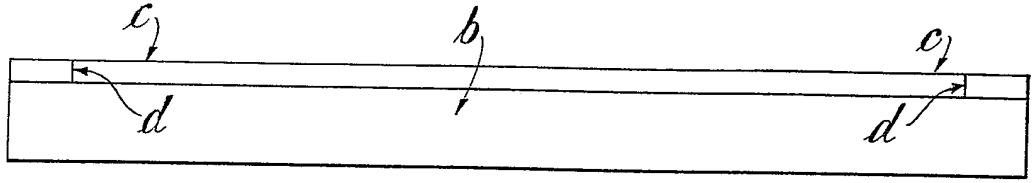

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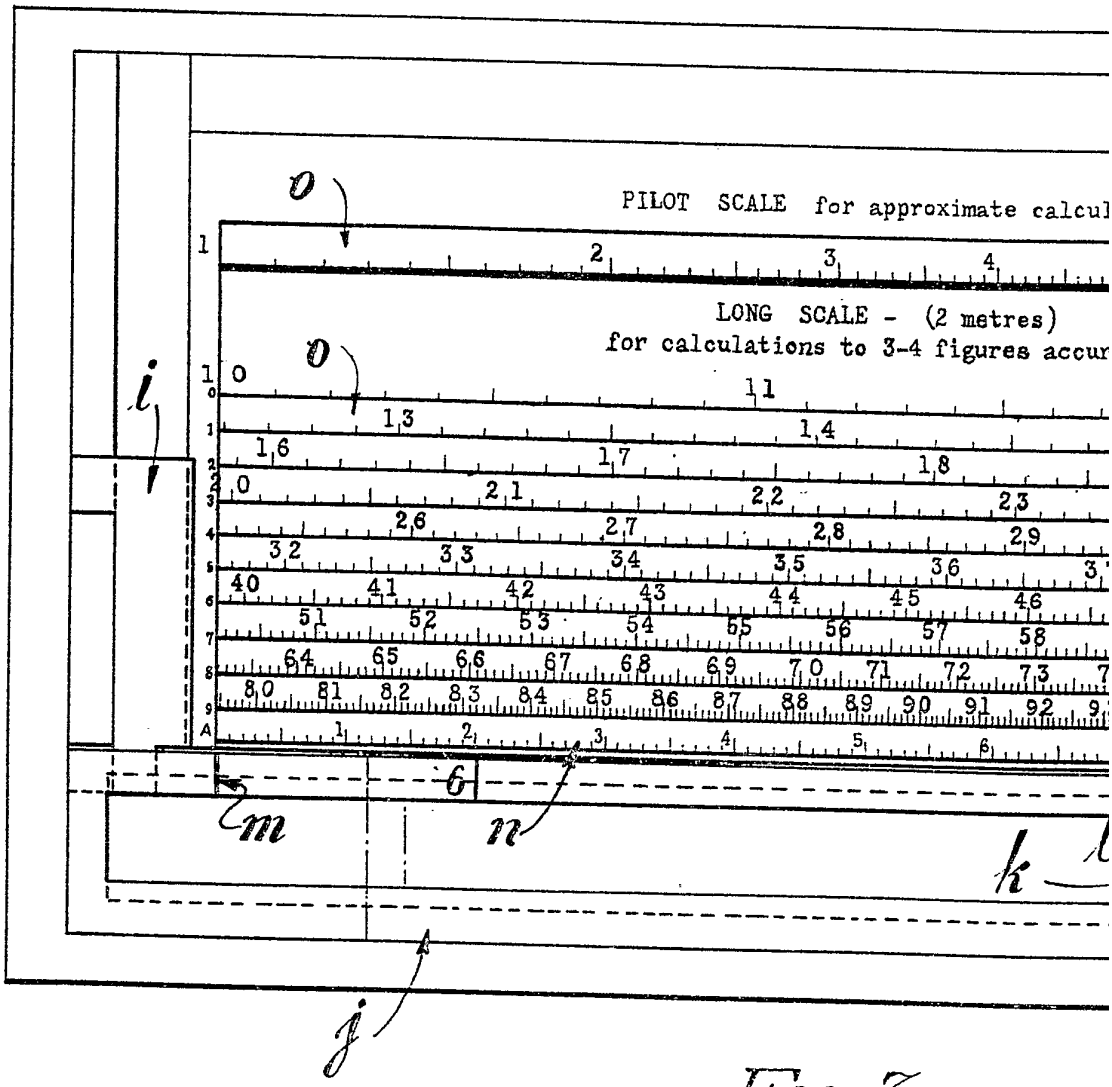
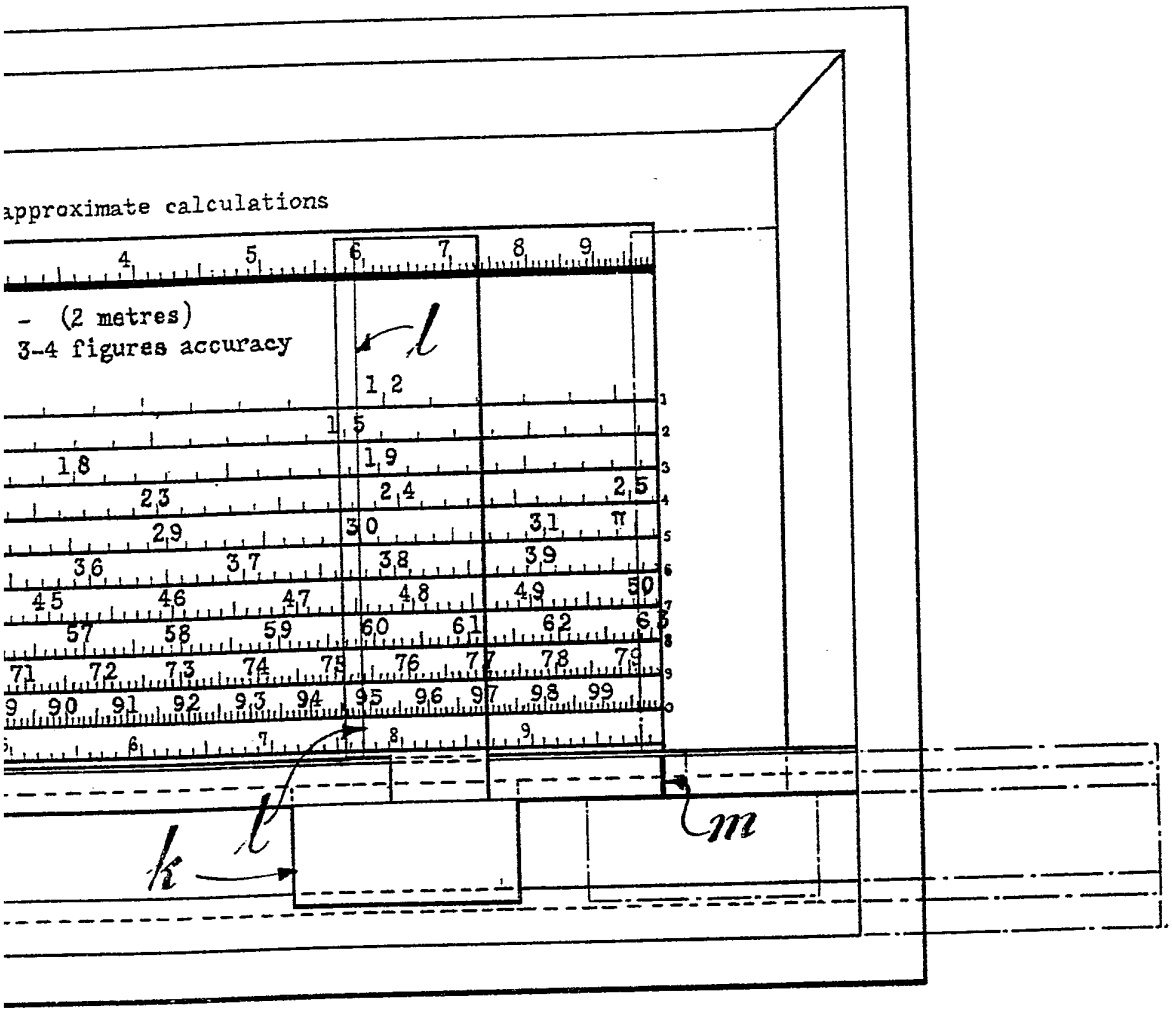


FIG. 3.



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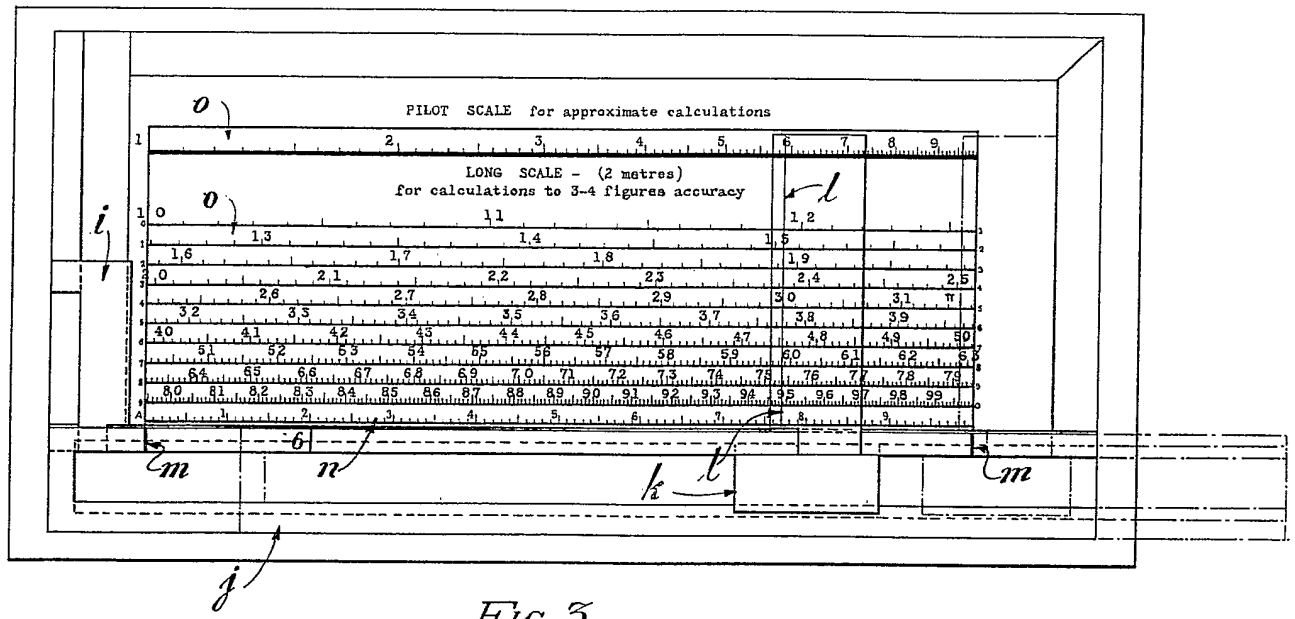

FIG. 3.

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