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PROVISIONAL SPECIFICATION.

"Improvements relating to Mathematical Calculating Devices."

I, FRANCIS JAMES ANDERSON, Major, R.E., Reconstruction Officer, of The Barracks, Waterford, in the County of Waterford, Ireland, do hereby declare the nature of this invention to be as follows:—

This invention has reference to mathematical calculating devices and is founded on the principle of the well-known slide-rule.

The object of the invention is threefold:

(*a*) To increase the accuracy and capacity of the ordinary decimally-divided slide rule without any corresponding increase in the length of the instrument.

(*b*) To do away with the necessity of the mental or mechanical calculation, necessary to obviate ambiguity as to the position of the decimal point, by giving each graduation on the scales a definite or absolute value that never varies.

(*c*) To render it possible, if desired to subdivide units on the slide rule into other parts than tenths (such as twelfths, or sixteenths, for example) thereby making it available for quantity surveyors, mechanical engineers, accountants, freight clerks and others to whose work it is not at present applicable. The ordinary rule is graduated on the face with 2 scales, one on each limb, which are duplicated on the slide as shewn in Figure 1 Sheet I of the accompanying drawings, where the upper limb is marked A the slide B and the lower limb C.

According to my said invention, however, each of the scales (instead of being in a continuous line) is split up into a series of equal parallel lines, the figures on each line being in geometrical progression with those of the adjacent lines immediately above or below them from which they are separated by a "common ratio" of 10 or of some root of 10.

If, for example, the geometrical ratio of $\sqrt{10}$ is selected, the upper scale would be graduated as shewn in Figure 2 Sheet I and the lower scale as shewn in Figure 3 Sheet I of the drawings, (omitting sub-divisions) the common ratio between lines in the upper being $\sqrt{10}$ and in the lower $\sqrt[4]{10}$.

The number of lines in each scale may be increased downwards as necessary according to the height to which calculations are to be carried, and upwards (if desired) to read numbers less than unity to any required degree of accuracy.

The face of the instrument may be graduated as shewn in Figure 4 Sheet II of the accompanying drawings, in which A and C are the upper and lower limbs respectively and B is the slide; and it is evident that the accuracy and capacity of the ordinary slide rule has here been increased four fold, without any increase in length of the instrument, the only limit to this increase of accuracy and capacity being the number of lines, which can be graduated on a limb or slide of a given width.

It will be noticed in the drawing that the units are subdivided to twelfths for part of the scale by way of illustration, but they may be equally well subdivided to eighths, tenths, sixteenths or any desired fraction and the larger subdivisions (on the upper lines) may be again subdivided to forty-eighths,

[*Price* 8*d*.]

hundredths, sixteenths or any desired parts within the compass of the instrument.

The slide bears on its face the same scale as the upper limb, but an interchangeable slide may also be provided with trigonometrical and other scales as hereinafter described.

Figure 5 Sheet III of the drawings illustrates a decimally subdivided rule with a scale of natural sines and cosines, (multiplied by 100) on the face of, and Figure 6, Sheet III, a similar scale of tangents and cotangents (multiplied by 1000) on the back of the interchangeable slide.

"Gauge points" can be used at pleasure on all scales.

The instrument, which may be of wood, brass, celluloid, vulcanite, or other suitable material or materials, alone or in combination, is, with the important exceptions noted above, similar in construction to the ordinary slide-rule, having a body with upper and lower limbs between which works a slide, said limbs and slide being graduated as above described.

Over all and overlooking all scales is a traveller working in grooves on the sides of the body of the instrument and carrying a cross-hair or cross line on its glazed surface to give the alignment of the various readings. The glazed surface may be wholly or partially of magnifying glass, or may have a travelling magnifying glass attached to it to ensure finer readings and may also have auxiliary lines parallel to the cross-hair or cross line to serve as a guide to the eye in estimating unmarked divisions.

Numbered cross-lines on said traveller indicate the positions of the various graduated lines on the rule and slide. Figure 7 Sheet IV of the drawings illustrates the general arrangement, the lines of the upper and lower edges of the body of the instrument being indicated respectively by the letters A and D, and the upper and lower edges of the slide by the letters B and C respectively.

In graduating the instrument units may be numbered in different colours from those of subdivisions, as a guide to ready identification.

The slide has at each end, and in such a position as not to interfere with the lengthwise movement, a bevelled metal arm corresponding with the index-line and extending upwards and downwards to the full width of the rule.

These arms have marked on them the line numbers of the scales on the upper and lower limbs. By their help the indices can be set without the necessity of using the traveller. The drawings Figures 8 and 9 Sheet IV shew the arrangement.

The said arms may be so arranged as to be detachable, and are capable of being re-fixed on the reverse side of the slide when the latter is in use.

The method of using the instrument is simple in the extreme.

The left side of the slide which has the numbers $1 - \sqrt{10} - 10 -$ and so on vertically over one another in the sketches may be called the left index, while the right side bearing the numbers $\sqrt{10}$, 10, $10\sqrt{10}$ &c, may be called the right index.

Similarly the left and right sides of both the upper and lower limb may be known as left and right indices.

The traveller is used to indicate the alignment of the scales and to show by its numbered cross-lines the line of the scale on which the answer will be found.

A few simple examples will best illustrate this.

Multiplication.

To obtain the results of multiplication:—

(*a*) Set index of slide (by means of its arm)

(*b*) To first factor on upper limb.

(*c*) Above second factor on slide,

(*d*) Read answer on the line (of the upper limb) whose number is the total of the three numbers of the lines in (*a*), (*b*) and (*c*).

(I) Thus to multiply $1^{6}/_{12} \times 2^{1}/_{12}$

On slide—(*a*) Set left index (line-No. 0): (*c*) Over $2^{1}/_{12}$ (line-No. 0)

On upper limb (*b*) To $1^{6}/_{12}$ (line-No. 0): (*d*) Read answer $3^{6}/_{48}$ (line-No. 0)

The answer is read on the 0 line of the limb because the sum of the various lines used in the operation (*a*), (*b*) and (*c*) is 0 + 0 + 0 = 0.

(II) To multiply $50^{1}/_{12} \times 6$.

On slide—(*a*) Set left index (line-No. 0): (*c*) Over 6 (line-No. 1).

On upper limb (*b*) To $50^{1}/_{12}$ (line-No. 3): (*d*) Read answer $300^{1}/_{2}$ (line-No. 4) since 0 + 3 + 1 = 4.

(III) To multiply 2 + 7

On setting the left index of slide to 2 on the upper limb we find that the 7 on slide has travelled beyond the limb and thus has no reading over it. Recourse is therefore had to the right index of slide (vertical line $\sqrt{10}$, 10, 10 $\sqrt{10}$ &c.) which is set to 2 on the limb, but 1 is added to the number of its line (calling it 1 instead of 0).

The setting is then as follows:

On slide (*a*) Set right index (line-No. 1): (*c*) Over 7 (line-No. 1).

On limb (*b*) To 2 (line-No. 0): (*d*) Read answer 14 (line-No. 2.) since 1 + 0 + 1 = 2.

Division

This operation is the exact converse of multiplication and therefore the line-number of the divisor (on slide) is called − (minus) and that of the dividend (on limb) + (plus) increasing the former by 1 in every case where recourse is taken to the right index *i.e.* calling the right index-1 (the left index being always 0).

(IV) Thus to divide 72 by 6.

On slide (*a*) Set 6 (line-No. 1): (*c*) Over left index (line-No. 0).

On limb (*b*) To 72 (line-No. 3): (*d*) Read answer 12 (line-No. 2.) since 3 − 1 = 2.

(V) To divide 24 by 8

On slide (*a*) Set 8 (line-No. 1): (*c*) Over right index (line-No.-1.).

On limb (*b*) To 24 (line-No. 2): (*d*) Read answer 3 (line-No. 0), since 2 − 1 − 1 = 0.

We can express the above rule differently thus:—

To obtain "line-number of answer on limb.

(*a*) When left index is used deduct "line-number" of divisor from "line-number of dividend.

(*b*) When right index is used, deduct "line-number". of divisor increased by 1 from "line-number" of dividend.

Squares & Square Roots.

Squares and square roots are obtained by inspection as the numbers on the slide are the squares of the corresponding numbers (on the same lines) on the lower limb, while conversely the numbers on the lower limb are the square roots of those in a corresponding position on the slide. By setting the slide immediately over the lower limb there is thus formed a table of squares and square roots.

Cubes

(VI) Cube 4.

On slide—(*a*) Set left index (line No 0): (*c*) Over 4 on slide (line-No. 1).

On lower limb (*b*) To 4 (line-No. 2): (*d*) Read answer on upper limb 64 (line-No. 3) since 0 + 2 + 1 = 3.

The rule is:

If left index be used the sum of the line-numbers in (*a*), (*b*) and (*c*) gives the number of the line in which the answer is to be read, but if the right index be used it must be called + 1 as in Example VII.

(VII) Cube 7.

On slide—(*a*) Set right index (line-No. + 1): (*c*) Over 7 on slide (line-No. 1)

On lower limb (*b*) To 7 (line-No. 3): (*d*) Read answer 343 (line-No. 5) since 1 + 1 + 3 = 5.

Cube Roots

In extracting cube roots the rule is to move the slide to the right or left (as may be required) until the same number on the slide appears under the number, (whose cube root is to be extracted) on the upper limb, as appears on the lower limb under the index of the slide.

If the left index be used the line-number of the upper limb, less the line-number of the slide, gives the line-number of the lower limb where the answer will be found, but if the right index be used 1 must be deducted from the resulting line-number.

(VIII) Thus if the cube root of 27 is required.

The slide is moved to the left until the same number (in this case 3) appears on the slide under 27 on the upper limb, and on the lower limb under the right hand index of the slide. The setting stands thus:

On upper limb (*a*) To 27 (line No. 2).

On slide { (*b*) Set 3 (line-No. 0)
(*c*) Under right index (line-No.—1).

On lower limb (*d*) Read answer 3 (line-No. 1) since 2 — 0 — 1 = 1.

(IX) To find the cube root of 1331:

On upper limb (*a*) To 1331 (line-No. 6).

On slide { (*b*) Set 11 (line-No. 2)
(*c*) Left index (line-No. 0)

On lower limb (*d*) Read answer 11 (Line-No. 4).

Areas of Circles.

Set π on the slide to either the right or left index of the upper limb, as may be necessary, calling the "line number" 0 if to the left index and + 1 if to the right index.

Then above the radius on the lower limb read the area of the circle on the slide in the line indicated by the sum of the line-numbers.

Thus

(X) Radius 49 feet. Find area.

On slide (*a*) Set π (line-No. 0)

On upper limb (*b*) To right index (line-No. 1)

On lower limb (*c*) Over 49 (line-No. 6).

On slide (*d*) Read answer, area 7543 sq. ft. (line-No. 7) since 0 + 1 + 6 = 7.

(XI) Radius 31.65 feet. Find area.

On slide (*a*) Set π (line-No. 0).

On upper limb (*b*) To left index (line-No. 0),

On lower limb (*c*) Over 31.65 (line-No. 6).

On slide (*d*) Read answer area 3147 (line-No. 6) since 0 + 0 + 6 = 6.

Note. By setting π on slide to the indices of the upper (instead of the lower) limb the necessity for using the traveller to give the alignment is avoided. Owing to the proximity of π to the right index it will rarely be necessary to set the slide to the left index of the upper limb.

The value of the line numbers to be assigned to the indices for the various operations may therefore be expressed thus;

Left index. + 0 in all operations.

Right index. + 1 in all operations involving multiplication including therefore cubing, and areas of circles and

− 1 in all operations involding division including cube roots.

TRIGONOMETRICAL FUNCTIONS.

The interchangeable slide may have any useful scales on its face or back as illustrated in Figures 5 and 6 (Sheet III, where the face bears a scale of sines ranging from 35′ to 90° and of cosines ranging from 0° to 89° 25′.

The corresponding figures (on the same lines) on the scale of the lower limb give the values of the natural sines and cosines (multiplied by 100) while the scale on the upper limb similarly gives the values of their squares (multiplied by 10,000).

The back of the slide (as shewn in Figure 6 Sheet III) has a similar scale of tangents from 4′ to 84° 17′ and of contangents ranging from 43′ to 89° 56′. Above them on the upper limb can be read their values (multiplied by 1000). This slide has no indices.

The instrument may be of any convenient size according to the purpose for which it is required to be used.

Dated this 22nd day of April 1903.

HASELTINE, LAKE & Co.,
45 Southampton Buildings, London, W.C.
Agents for the Applicant.

COMPLETE SPECIFICATION.

"Improvements relating to Mathematical Calculating Devices."

I, FRANCIS JAMES ANDERSON, Major, R.E., Reconstruction Officer, of The Barracks, Waterford, in the County of Waterford, Ireland, 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 has reference to mathematical calculating devices and is founded on the principle of the well-known slide-rule.

The object of the invention is threefold;

(*a*) To increase the accuracy and capacity of the ordinary decimally-divided slide rule without any corresponding increase in the length of the instrument.

(*b*) To do away with the necessity of the mental or mechanical calculation heretofore necessary to obviate ambiguity as to the position of the decimal point, by giving each graduation on the scales a definite or absolute value that never varies.

(*c*) To render it possible, if desired to subdivide units on the slide rule into other parts than tenths, such as twelfths or sixteenths, for example, thereby making it available for quantity surveyors, mechanical engineers, accountants, freight clerks and others to whose work it is not at present applicable. The ordinary rule is graduated on the face with two scales, one on each limb, which are duplicated on the slide.

According to my said invention, however, each of the scales (instead of being in a continuous line) is split up into a series of equal parallel lines, the figures on each line being in geometrical progression with those of the adjacent lines immediately above or below them from which they are separated by a "common ratio" of 10 or of some root of 10.

The number of lines in each scale may be increased in one direction as

necessary according to the height to which calculations are to be carried, and in the other direction (if desired) to read numbers less than unity to any required degree of accuracy.

The apparatus embodying the features of my invention comprises a slide rule graduated as above indicated and provided with a slide having transverse end-pieces or lateral extensions that extend across the face of the rule, and with a traveller carrying a hair or other line that extends across all the scales to give the alignment of the various readings. The said lateral extensions of the slide, and the traveller, are adapted to distinguish, by any appropriate means such as markings, the various lines or similar parts of the scales.

In order that my invention may be clearly understood and readily carried into effect I will now describe the same more fully with reference to the drawings accompanying my Provisional Specification, in which:—

Figure 1 illustrates the manner in which the scales have been distributed on slide rules of the type heretofore ordinarily employed.

Figures 2 and 3 illustrate in a simple form examples of the manner in which I propose to distribute the scales on the limbs of the rule, Figure 2 representing the upper, and Figure 3 lower, limb.

Figures 4 and 5 give two more complete examples of scales distributed in accordance with my present practice; Figure 5 also exemplifying a somewhat modified form of the apparatus.

Figure 6 shows separately another scale useful for the slide.

Figure 7 is a view showing the traveller by itself.

Figures 8 and 9 are views, partly broken away, showing separately the opposite ends of the slide.

A represents the body of the rule, B the slide and C the traveller.

The ordinary slide rule has each of its limbs graduated with a scale (Figure 1) which is comprised in a single or continuous line and which is repeated on the slide, and it has for its graduations values that are only relative.

The scales shown in Figures 2 and 3 however are each split up into five portions or lines between which are common ratios. If, for example, the geometrical ratio of $\sqrt{10}$ is selected, the upper scale would be graduated as shewn in Figure 2 and the lower scale as shown in Figure 3 (omitting sub-divisions), the common ratio between lines in the upper being $\sqrt{10}$ and in the lower $\sqrt[4]{10}$

The face of the instrument may be graduated as shewn in Figure 4, in which A and C are the upper and lower limbs respectively and B is the slide; and it is evident that the accuracy and capacity of the ordinary slide rule has here been increased four fold, without any increase in the length of the instrument, practically the only limit to this increase of accuracy and capacity being the number of lines which can be graduated on a limb or slide of a given width.

It will be noticed in the example shown in the drawing that the units are subdivided to twelfths for part of the scale by way of illustration, but they may be equally well subdivided to eighths, tenths, sixteenths or any desired fraction, and the larger subdivisions (on the upper lines) may be again subdivided to forty-eighths, hundredths, sixteenths or any desired parts within the compass of the instrument.

In the above example the slide bears on its face the same scale as the upper limb, but an interchangeable slide may be provided, having trigonometrical and other scales as hereinafter described.

Figure 5 of the drawings illustrates a decimally subdivided rule with a scale of natural sines and cosines, (multiplied by 100) on the face of, and Figure 6 a similar scale of tangents and cotangents (multiplied by 1000) on the back of the interchangeable slide.

"Gauge points" can be used at pleasure on all scales.

The instrument may be of any convenient size according to the purpose for

which it is required, and also of any appropriate material such as wood, brass, celluloid, vulcanite, or other suitable material or materials, alone or in combination; and it is, with the important exceptions noted above, similar in construction to the ordinary slide-rule, having a body with upper and lower limbs between which works a slide, said limbs and slide being graduated as above described.

Over all and overlooking all scales is the traveller working in grooves on the sides of the body of the instrument and having a glazed surface provided with the aforesaid cross-bar or cross line. Said glazed surface may be wholly or partially of magnifying glass, or may have a travelling magnifying glass attached to it to ensure finer readings and may also have auxiliary lines parallel to the cross hair or cross line to serve as a guide to the eye in estimating unmarked divisions.

Numbered cross-lines on the traveller indicate the positions of the various graduated lines on the rule and slide. Figure 7 illustrates the general arrangement, the lines of the upper and lower edges of the body of the instrument being indicated respectively by the letters A and D, and the upper and lower edges of the slide by the letters B and C respectively.

In graduating the instrument units may be numbered in different colours from those of subdivisions, as a guide to ready identification.

The slide has at each end, and in such a position as not to interfere with the lengthwise movement, a lateral extension comprising a bevelled metal arm corresponding with the index-line and extending upwards and downwards to the full width of the rule.

These arms have marked on them the line numbers of the scales on the upper and lower limbs. By their help the indices can be set without the necessity of using the traveller. Figures 8 and 9 shew the arrangement.

The said arms may be so arranged as to be detachable, and are capable of being re-fixed on the reverse side of the slide when the latter is in use.

The method of using the instrument is simple in the extreme.

The left side of the slide, which has the numbers 1, $\sqrt{10}$, 10 . . . . and so on vertically over one another in the sketches, may be called the left index, while the right side bearing the numbers $\sqrt{10}$, 10, 10 $\sqrt{10}$ may be called the right index.

Similarly the left and right sides of both the upper and lower limb may be known as left and right indices.

The traveller is used to indicate the alignment of the scales and to show by its numbered cross-lines the line of the scale on which the answer will be found.

A few simple examples will best illustrate this.

Multiplication.

To obtain the results of multiplication:—

(*a*) Set the index of slide (by means of its arm)

(*b*) To first factor on upper limb.

(*c*) Above second factor on slide.

(*d*) Read answer on the line (of the upper limb) whose number is the total of the three numbers of the lines in (*a*) (*b*) and (*c*).

(I) Thus to multiply $1^{6}/_{12}$ by $2^{1}/_{12}$:

On slide (*a*) Set left index (line No. 0): (*c*) Over $2^{1}/_{12}$ (line No. 0)

On upper limb (*b*) To $1^{6}/_{12}$ (line No. 0): (*d*) Read answer $3^{6}/_{48}$ (line No. 0)

The answer is read on the 0 line of the limb because the sum of the various lines used in the operation (*a*) (*b*) and (*c*) is 0 + 0 + 0 = 0.

(II) To multiply $50^{1}/_{12}$ by 6.

On slide (*a*) Set left index (line No. 0): (*c*) Over 6 (line No. 1).

On upper limb (*b*) To $50^{1}/_{12}$ (line No. 3): (*d*) Read answer $300^{1}/_{2}$ (line No. 4)

0 + 3 + 1 = 4.

(III) To multiply 2 by 7.

On setting the left index of slide to 2 on the upper limb it is found that the 7 on slide has travelled beyond the limb and thus has no reading over it. Recourse is therefore had to the right index of slide (vertical line $\sqrt{10}$, 10, 10 $\sqrt{10}$ &c.) which is set to 2 on the limb, but 1 is added to the number of its line (calling it 1 instead of 0).

The setting is then as follows:

On slide (*a*) Set right index (line No. 1): (*c*) Over 7 (line No. 1).

On limb (*b*) To 2 (line No. 0): (*d*) Read answer 14 (line No. 2) since 1 + 0 + 1 = 2

Division.

This operation is the exact converse of multiplication and therefore the line-number of the divisor (on slide) is called – (minus) and that of the dividend (on limb) + (plus), increasing the former by 1 in every case where recourse is taken to the right index, *i.e.* calling the right index – 1 (the left index being always 0).

(IV) Thus, to divide 72 by 6.

On slide (*a*) Set 6 (line No. 1): (*c*) Over left index (line No. 0).

On limb (*b*) To 72 (line No. 3): (*d*) Read answer 12 (line No. 2.) since 3 – 1 = 2.

(V) To divide 24 by 8.

On slide (*a*) Set 8 (line No. 1): (*c*) Over right index (line No. 1).

On limb (*b*) To 24 (line No. 2): (*d*) Read answer 3 (line No. 0) since 2 – 1 + 1 = 0.

The above rule can be expressed differently thus:—

To obtain "line-number" of answer on limb.

(*a*) When left index is used deduct "line-number" of divisor from "line-number" of dividend.

(*b*) When right index is used, deduct "line-number" of divisor increased by 1 from "line-number" of dividend.

Squares & Square Roots.

Squares and square roots are obtained by inspection, as the numbers on the slide are the squares of the corresponding numbers (on the same lines) on the lower limb, while conversely the numbers on the lower limb are the square roots of those in a corresponding position on the slide. By setting the slide immediately over the lower limb there is thus formed a table of squares and square roots.

Cubes.

(VI) Cube 4.

On slide: (*a*) Set left index (line No. 0): (*c*) Over 4 on slide (line No. 1).

On lower limb (*b*) To 4 (line No. 2): (*d*) Read answer on upper limb 64 (line No. 3), since 0 + 2 + 1 = 3.

The rule is:

If left index be used the sum of the line-numbers in (*a*), (*b*) and (*c*) gives the number of the line in which the answer is to be read, but if the right index be used it must be called + 1, as in Example VII.

(VII) Cube 7.

On slide: (*a*) Set right index (line No. + 1): (*c*) Over 7 on slide (line No. 1).

On lower limb (*b*) To 7 (line No. 3): (*d*) Read answer 343 (line No. 5) since 1 + 1 + 3 = 5.

Cube Roots.

In extracting cube roots the rule is to move the slide to the right or left (as may be required) until the same number on the slide appears under the

number whose cube root is to be extracted on the upper limb, as appears on the lower limb under the index of the slide.

If the left index be used the line-number of the upper limb, less the line-number of the slide, gives the line-number of the lower limb where the answer will be found, but if the right index be used 1 must be deducted from the resulting line-number.

(VIII) Thus if the cube root of 27 is required.

The slide is moved to the left until the same number (in this case 3) appears on the slide under 27 on the upper limb and on the lower limb under the right index of the slide. The setting stands thus:

On upper limb (*a*) To 27 (line No. 2).

On slide { (*b*) Set 3 (line No. 0)
(*c*) Under right index (line No. 1)

On lower limb (*d*) Read answer 3 (line No. 1) since 2 − 0 − 1 = 1.

(IX) To find the cube root of 1331.

On upper limb (*a*) To 1331 (line No. 6).

On slide { (*b*) Set 11 (line No. 2)
(*c*) Left index (line No. 0)

On lower limb (*d*) Read answer 11 (Line No. 4).

Areas of Circles.

Set π on the slide to either the right or left index of the upper limb, as may be necessary, calling the "line number" 0 if to the left index and + 1 if to the right index.

Then above the radius on the lower limb read the area of the circle on the slide in the line indicated by the sum of the line-numbers.

Thus:

(X) Radius 49 feet. Find area.

On slide (*a*) Set π (line No. 0).

On upper limb (*b*) To right index (line No. 1)

On lower limb (*c*) Over 49 (line No. 6),

On slide (*d*) Read answer, area 7543 sq. ft. (line No. 7) since 0 + 1 + 6 = 7.

(XI) Radius 31.65 feet. Find area.

On slide (*a*) Set π (line No. 0).

On upper limb (*b*) To left index (line No. 0),

On lower limb (*c*) Over 31.65 (line No. 6),

On slide (*d*) Read answer area 3147 (line No. 6), since 0 + 0 + 6 = 6.

Note. By setting π on slide to the indices of the upper (instead of the lower) limb the necessity for using the traveller to give the alignment is avoided. Owing to the proximity of π to the right index it will rarely be necessary to set the slide to the left index of the upper limb.

The value of the line numbers to be assigned to the indices for the various operations may therefore be expressed thus:

Left index: + 0 in all operations.

Right index: + 1 in all operations involving multiplication, including therefore cubing, and areas of circles and

= 1 in all operations involving division including cube roots.

Trigonometrical Functions.

The interchangeable slide may have any useful scales on its face or back as illustrated in Figures 5 and 6, where the face bears a scale of sines ranging from 35′ to 90° and of cosines ranging from 0° to 89° 25′.

The corresponding figures (on the same lines) on the scale of the lower limb give the values of the natural sines and cosines (multiplied by 100) while the

scale on the upper limb similarly gives the values of their squares (multiplied by 10,000).

The back of the slide (as shewn in Figure 6) has a similar scale of tangents from 4′ to 84° 17′ and of contagents ranging from 43′ to 89° 56′.

Above them on the upper limb can be read their values (multiplied by 1000). This slide has no indices.

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. A slide rule graduated as above described and having the slide furnished with lateral extensions as and for the purposes set forth.

2. The improved slide rule having its parts constructed and arranged substantially as herein described.

Dated this 30th day of November 1903.

HASELTINE, LAKE & Co.
45 Southampton Buildings, London, W.C.
Agents for the Applicant.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1904.

A.D. 1903. APRIL 22. N° 9095.
ANDERSON'S PROVISIONAL SPECIFICATION.

(4 SHEETS)
SHEET 1.

FIG. 1.

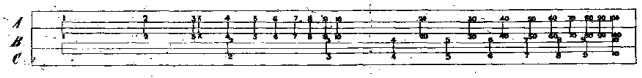


FIG. 2.

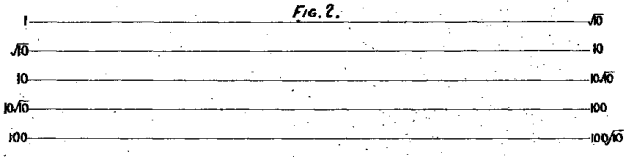


FIG. 3.

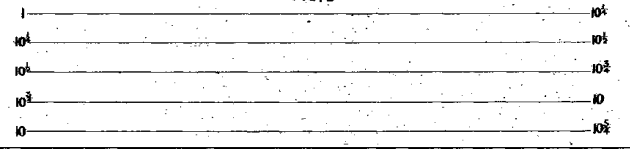
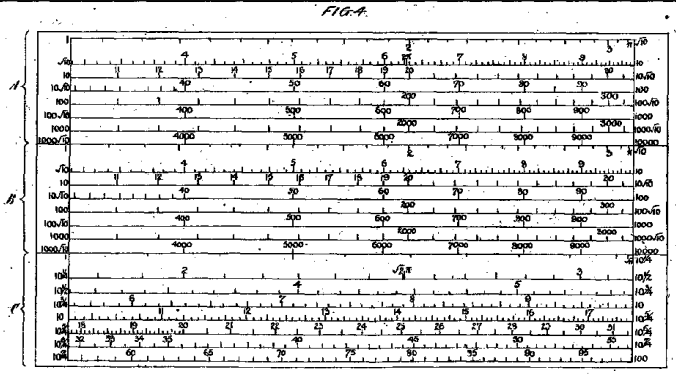


FIG. 4.

SHEET 2.



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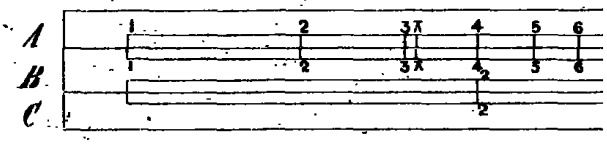
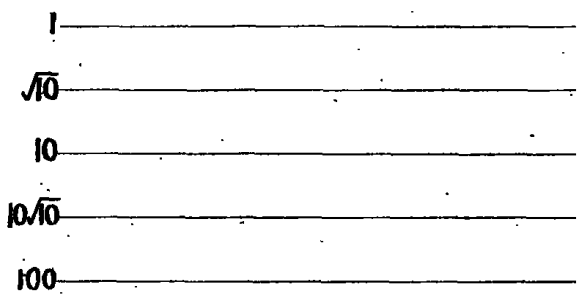
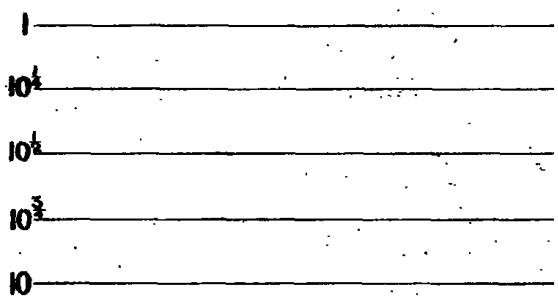
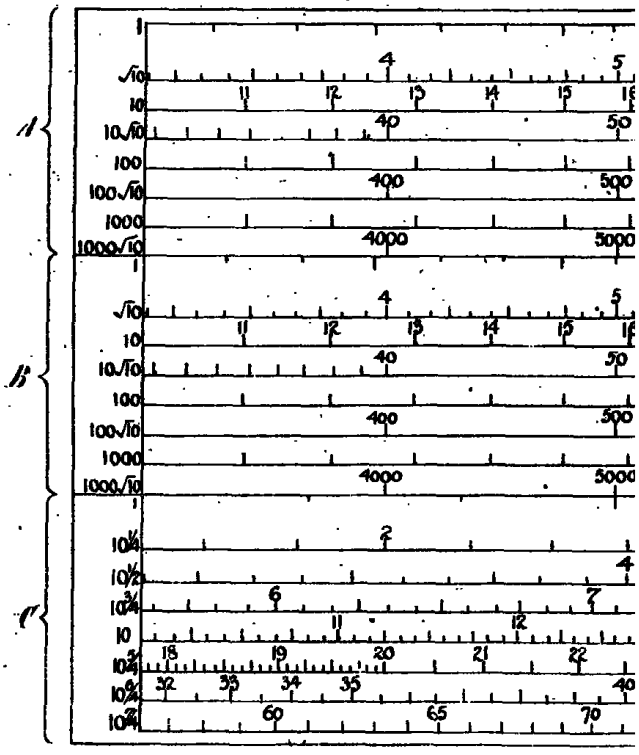








(4 SHEETS)

SHEET 1.

FIG. 1.

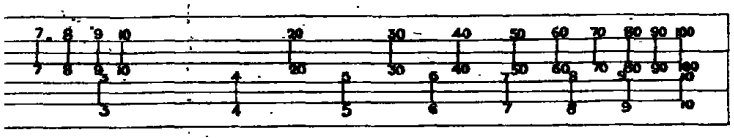


FIG. 2.

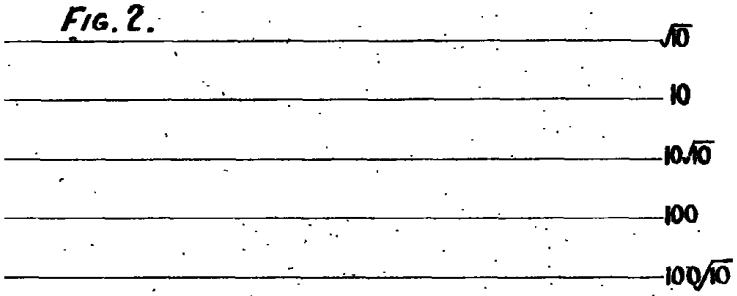
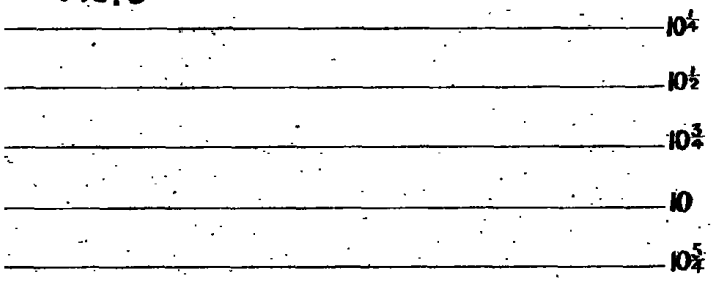


FIG. 3.



SHEET 2.

FIG. 4.

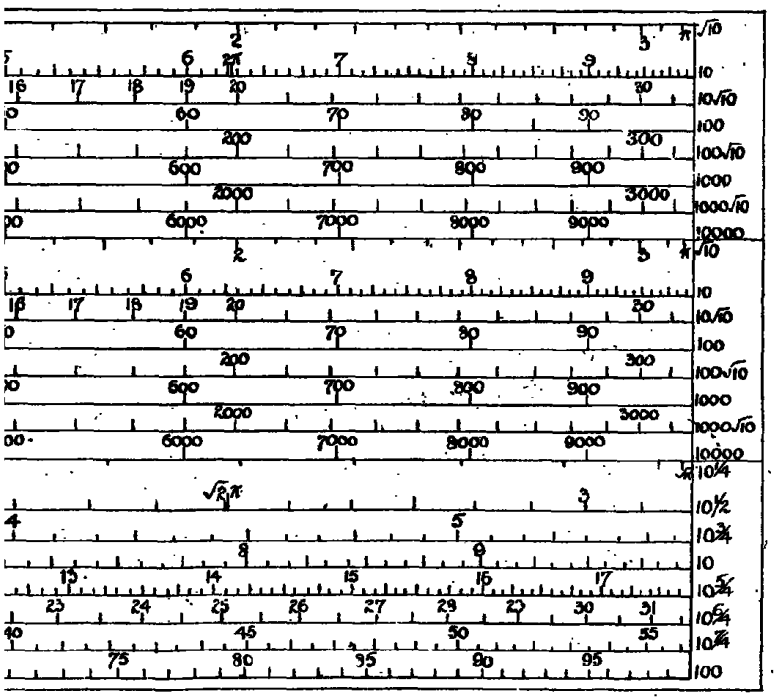


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FIG. 5.

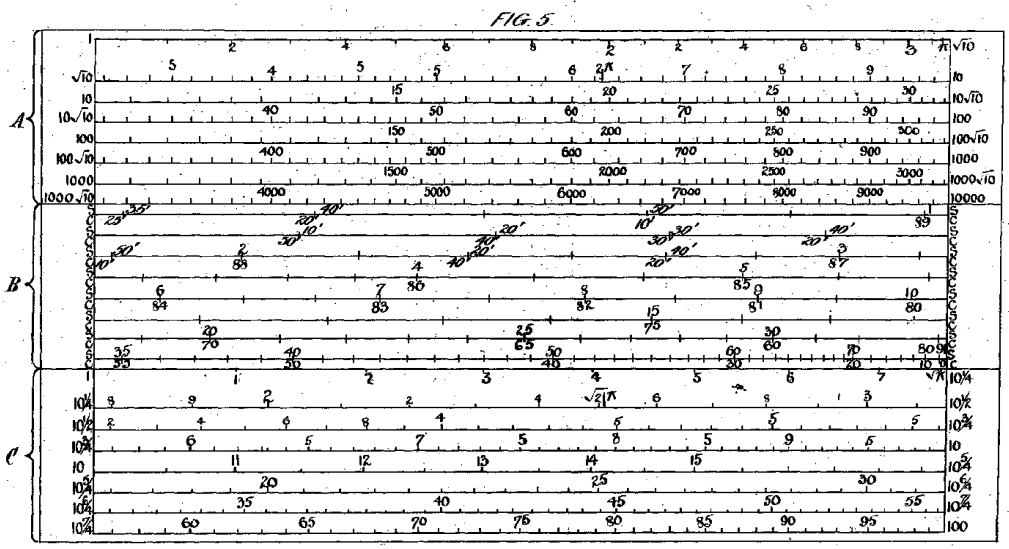
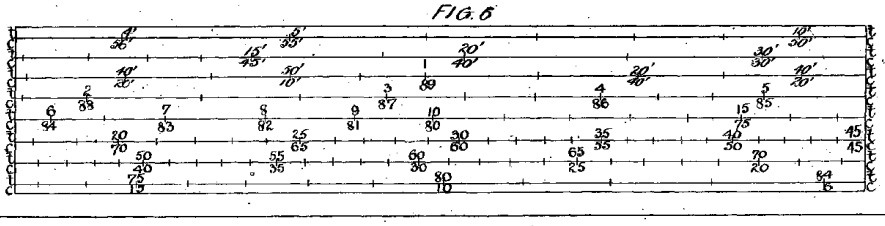


FIG. 6



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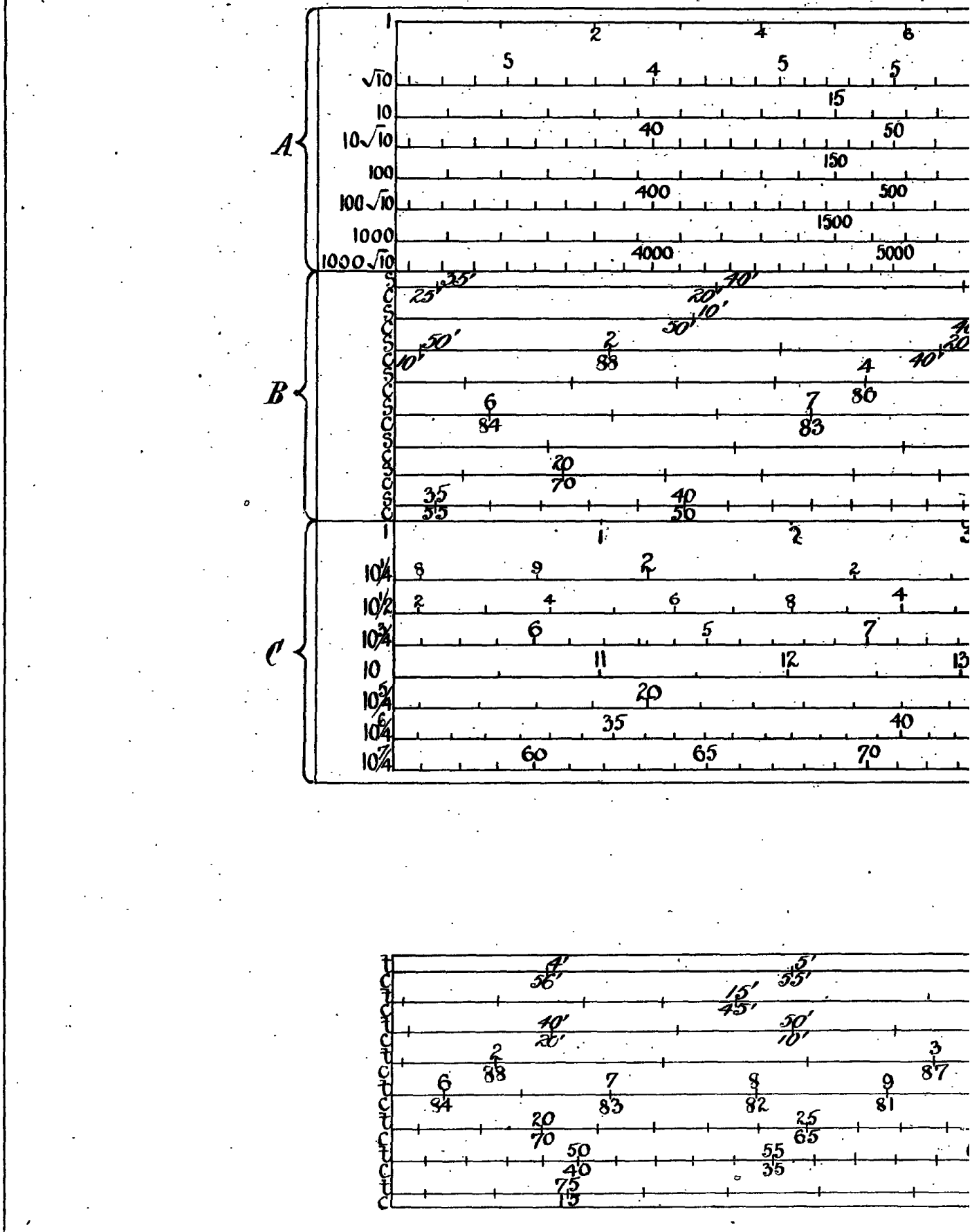


FIG. 5.

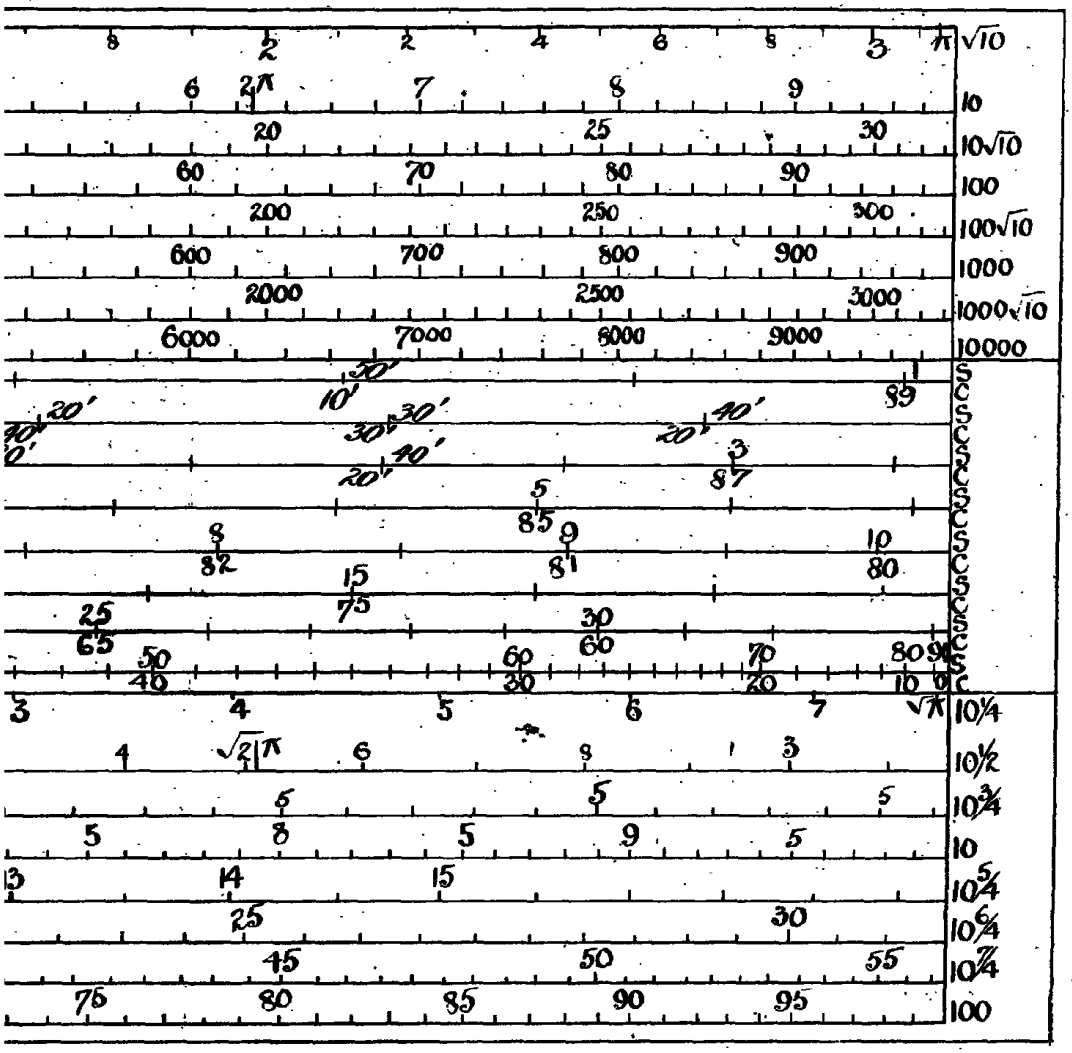
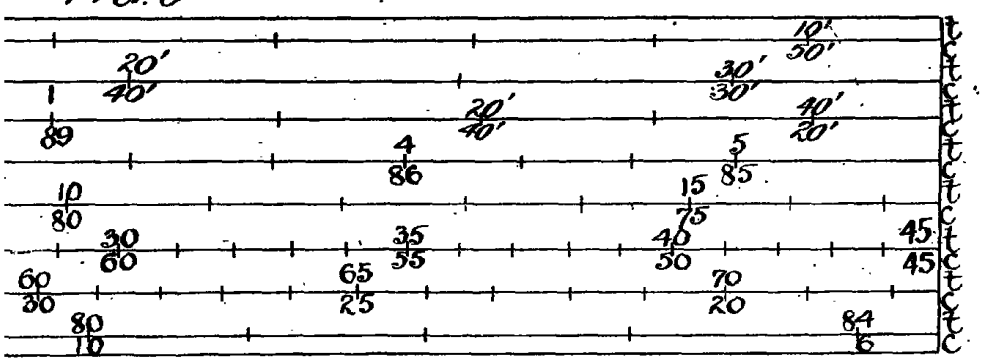


FIG. 6



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(4 SHEETS)
SHEET 4.

Fig. 7.

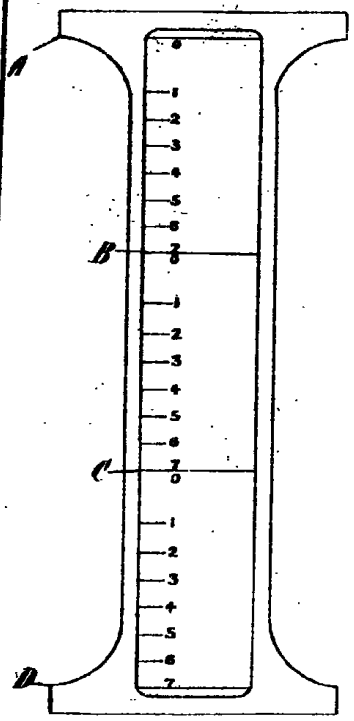


Fig. 8.

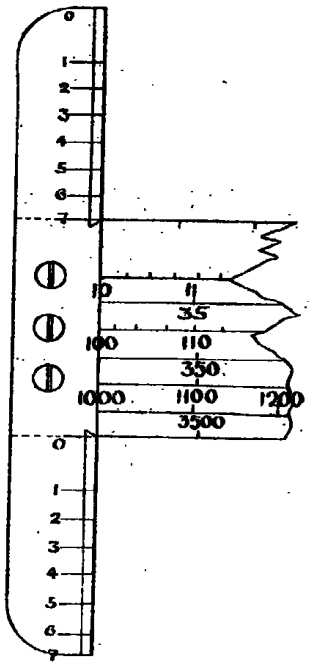
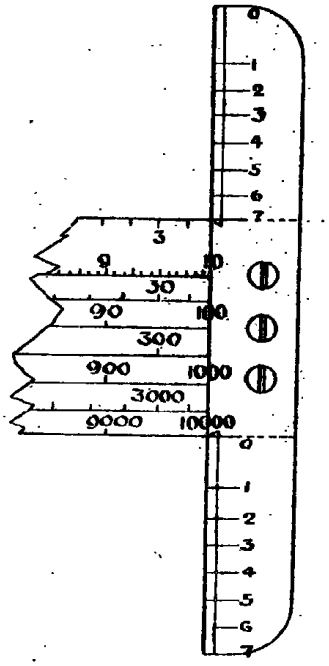


Fig. 9.



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