Jan. 13, 1948. K. R. WOOD 2,434,306

STATISTICAL SLIDE RULE

Filed June 7, 1944 5 Sheets-Sheet 1

Fig. 1.

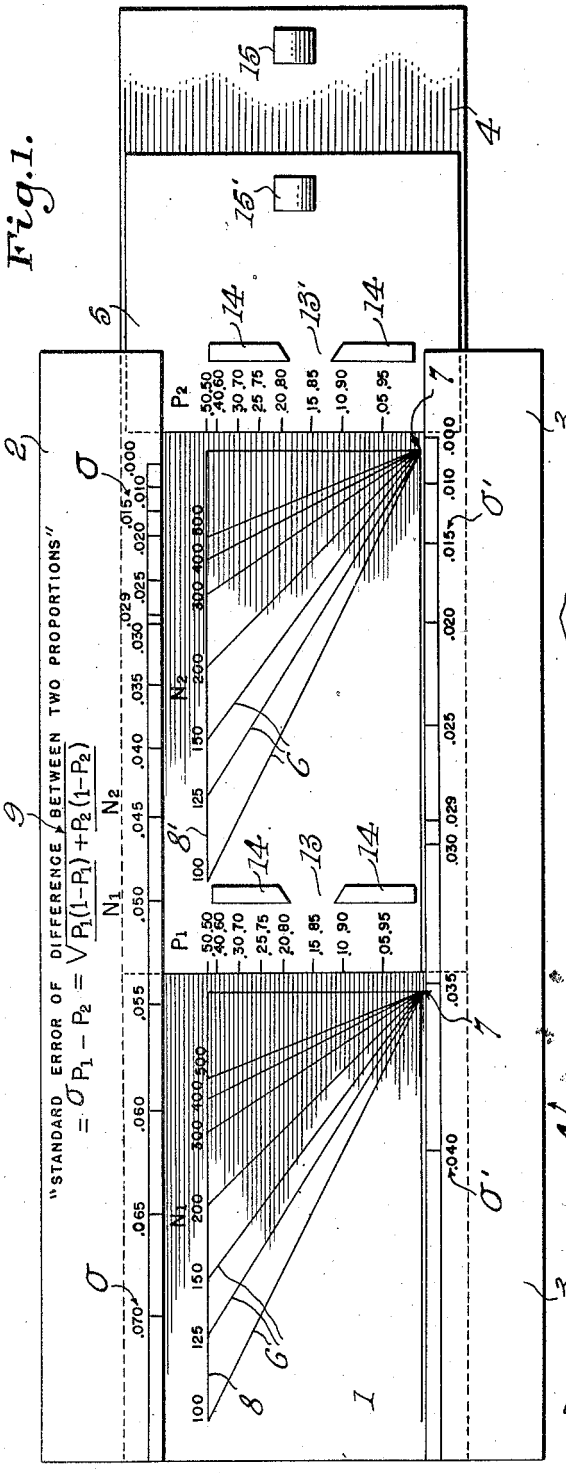
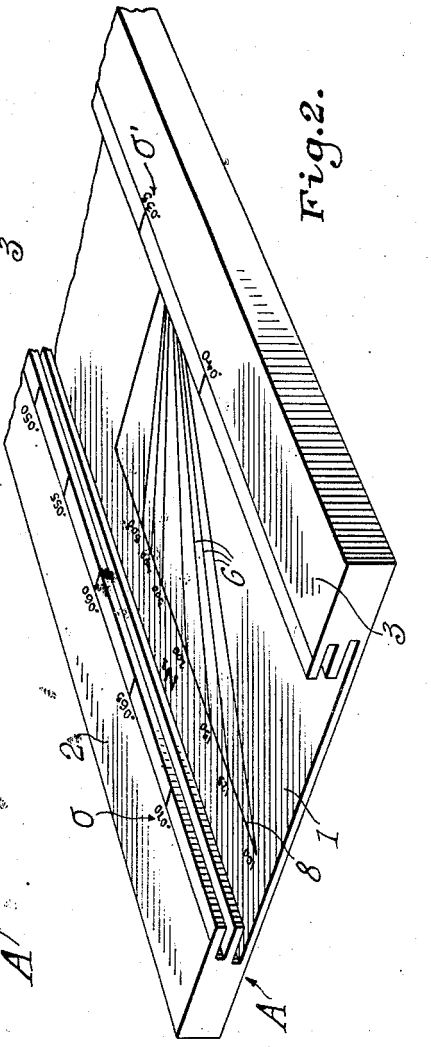


Fig. 2.



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Jan. 13, 1948. K. R. WOOD 2,434,306

STATISTICAL SLIDE RULE

Filed June 7, 1944 5 Sheets-Sheet 2

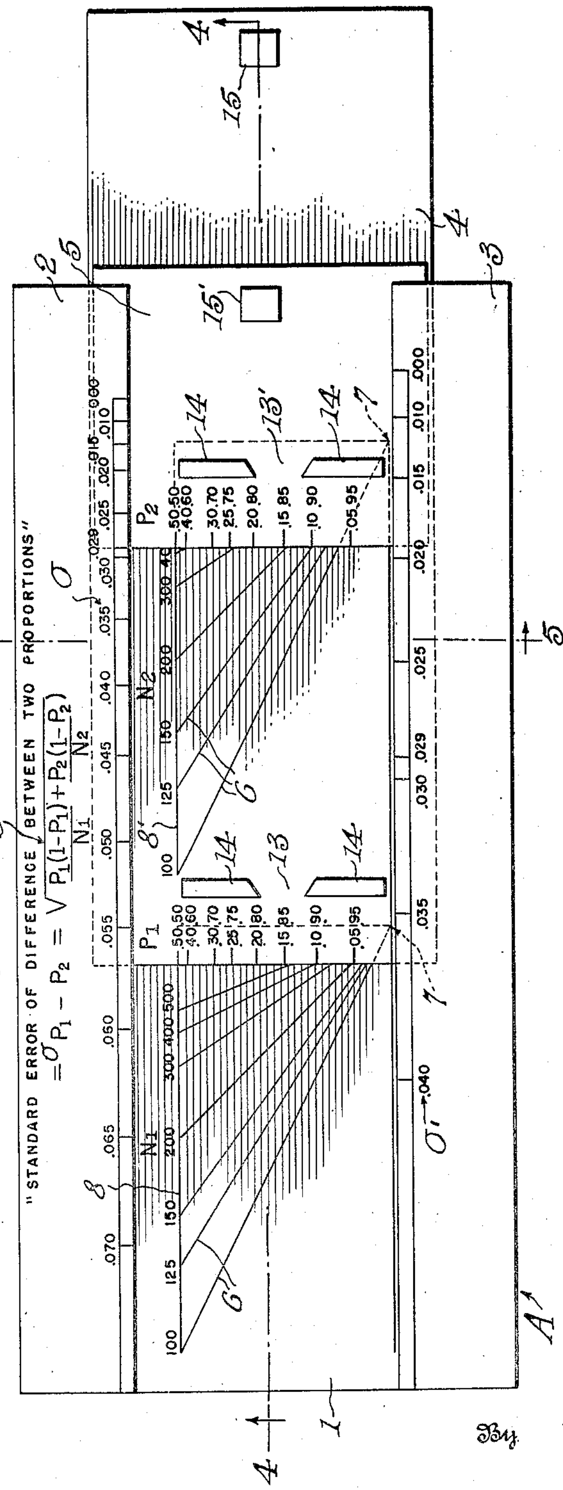

Fig. 3.

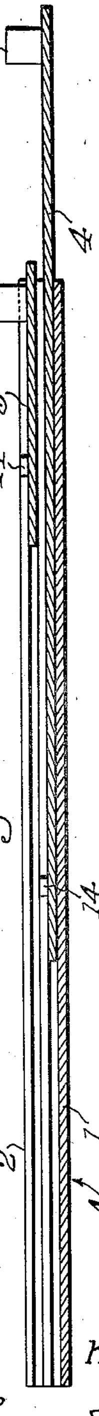

Fig. 4.

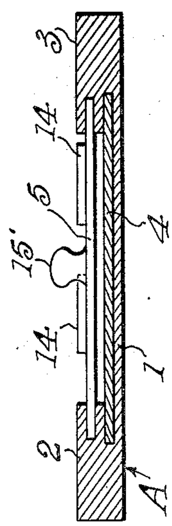

Fig. 5.

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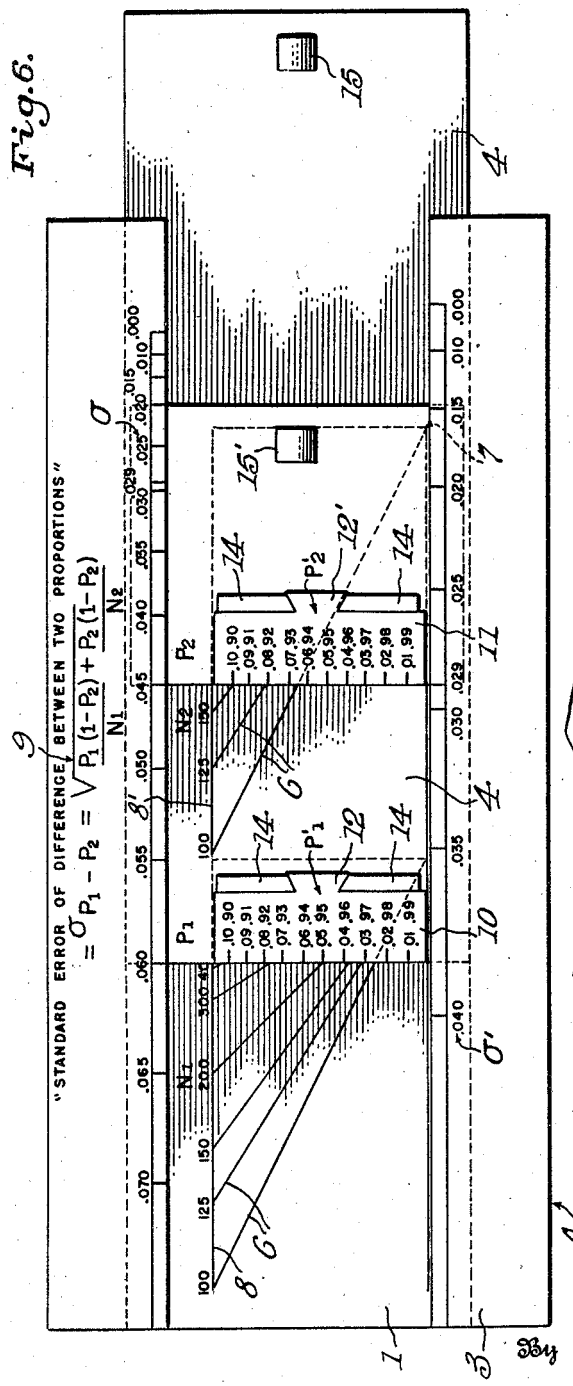
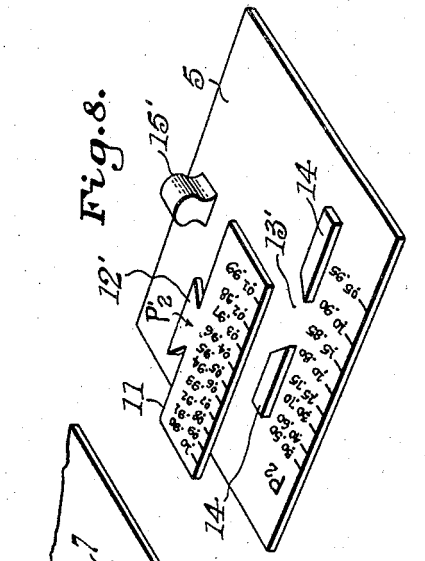
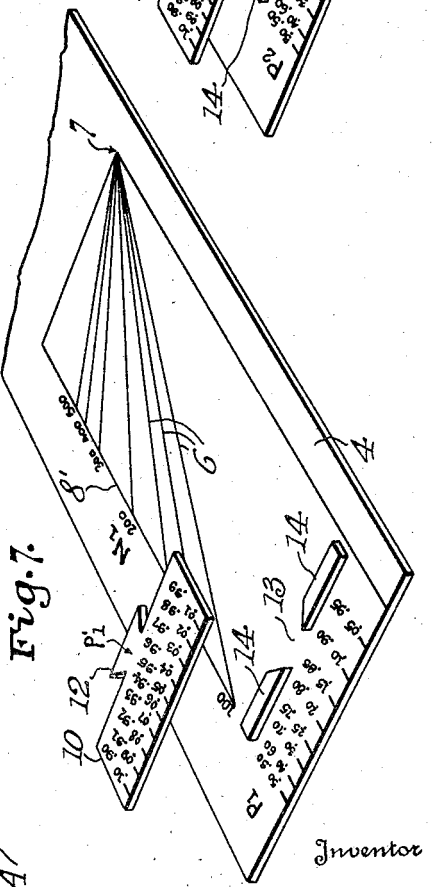
STATISTICAL SLIDE RULE

Filed June 7, 1944 5 Sheets-Sheet 3







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Jan. 13, 1948. K. R. WOOD 2,434,306

STATISTICAL SLIDE RULE

Filed June 7, 1944 5 Sheets-Sheet 4

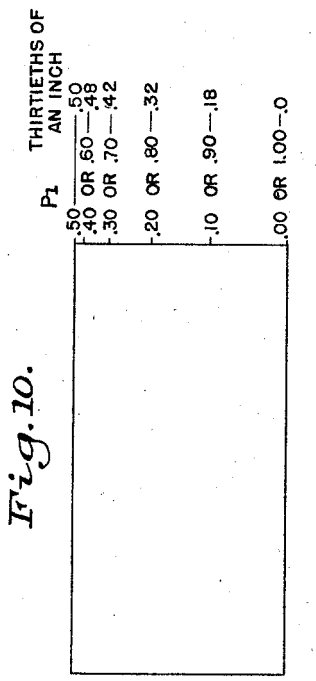

Fig. 10.

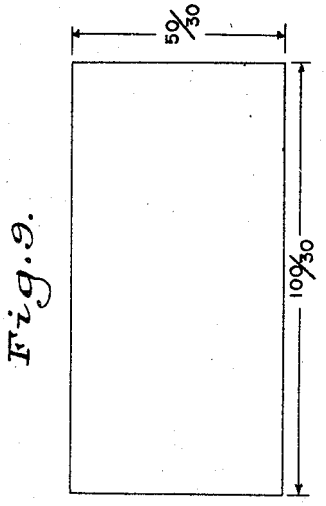

Fig. 9.

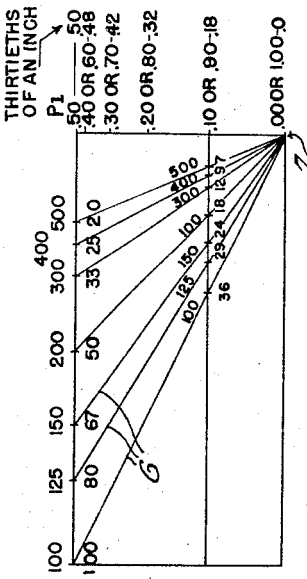

Fig. 12.

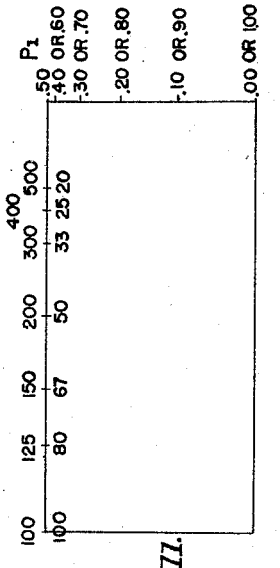

Fig. 11.

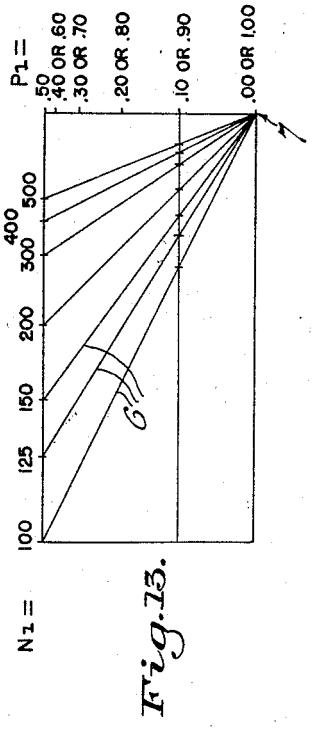

Fig. 13.

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Jan. 13, 1948. K. R. WOOD 2,434,306

STATISTICAL SLIDE RULE

Filed June 7, 1944 5 Sheets-Sheet 5

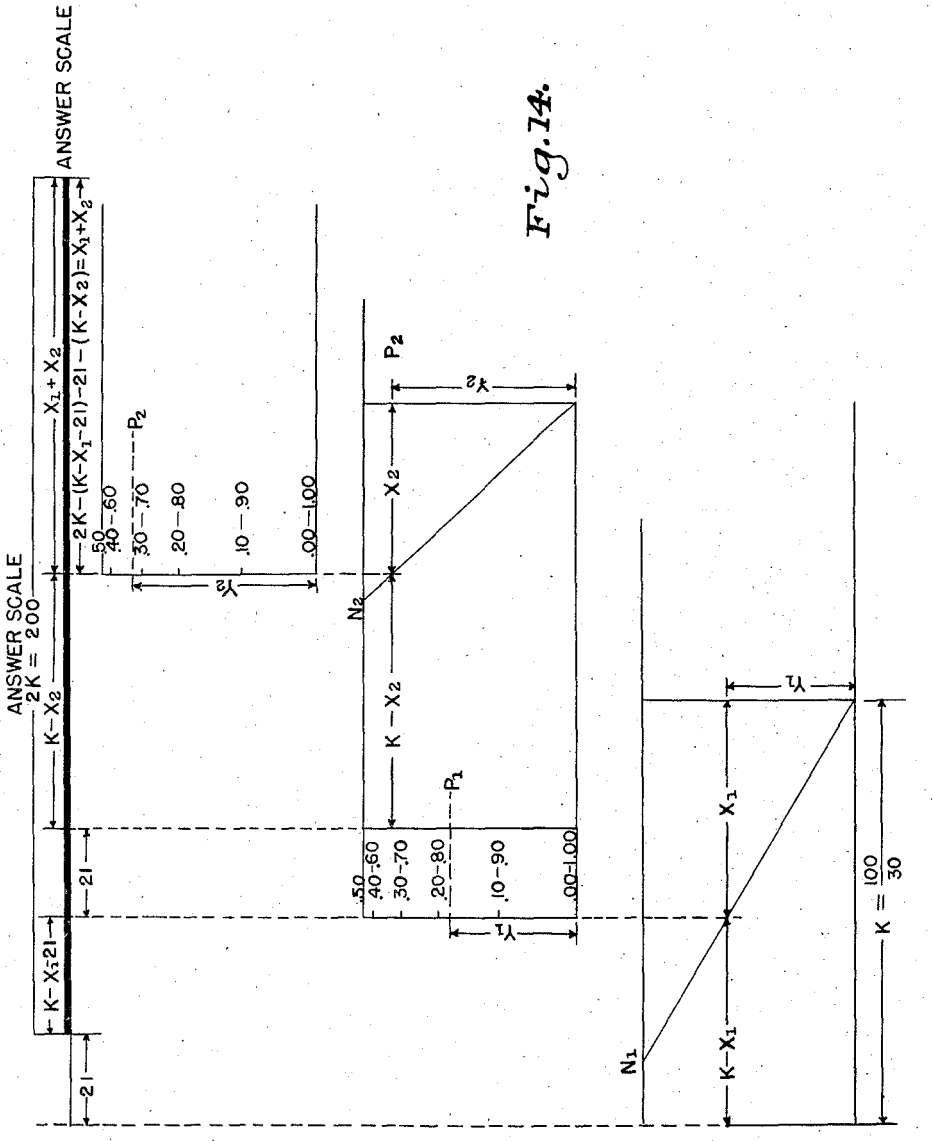

Fig. 14.

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Patented Jan. 13, 1948 2,434,306

UNITED STATES PATENT OFFICE

2,434,306

STATISTICAL SLIDE RULE

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Fort Dix, N. J.

Application June 7, 1944, Serial No. 539,167

4 Claims. (Cl. 235—61)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

1

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without payment to me of any royalty thereon.

This invention relates to a calculator and one of the objects thereof is to provide a device of this character adapted to facilitate computation of a measure frequently used in statistics.

Another object of the invention is to provide a calculating device in the form of a slide rule for computation of the standard error of the difference between two proportions.

Heretofore the most modern calculators required up to six operations and recordings in the computation of statistics thereby making the calculators complicated in operation and expensive to manufacture.

It is therefore the aim and purpose of this invention to provide a calculator which is light in weight, simple in construction, readily manipulated in computing various statistics and not liable to get out of order.

With the above and other objects and advantages in view the invention consists of certain features of construction and operation of parts which will hereinafter be described and shown in the accompanying drawings in which:

Figure 1 is a top plan view of the improved device containing a base having two slides mounted thereon, with a permanent scale provided on one of the slides and a permanent scale and graph provided on the other slide and including means for receiving removable scale members adapted to cover the permanent scales on the slides;

Figure 2 is a fragmentary perspective view of the left-hand portion of the base;

Figure 3 is another top plan view similar to Figure 1 with the slides having been actuated on the base to calculate the standard error of the difference between two proportions;

Figure 4 is a longitudinal sectional view taken on line 4—4 of Figure 3;

Figure 5 is a cross sectional view taken on line 5—5 of Figure 3;

Figure 6 is a top plan view showing the removable scale members mounted on the slides for covering up the permanent scales and providing other scales on the device in calculating when each of the two proportions of a problem are less or greater than a certain amount;

Figure 7 is a fragmentary perspective view of one of the slides having means for receiving a scale member and showing the scale member removed therefrom;

Figure 8 is a perspective view of the other slide

2

and showing its scale member removed therefrom;

Figure 9 is a rectangular shaped outline laid out in thirtieths of an inch and on which a scale and graphs used in carrying out the invention are adapted to be plotted;

Figure 10 is a similar view illustrating the manner of plotting the scale in thirtieths of an inch upwardly along a vertical edge of the outline;

Figure 11 is a view similar to Figure 10 and illustrating the manner of computing values for a line of the graph to be plotted on the outline;

Figure 12 is a view showing the graph plotted on the outline and illustrating convenient values therefor plotted in thirtieths of an inch;

Figure 13 is a view similar to Figure 12; and

Figure 14 is a functional diagram of the device, with the scales and lines of the graphs thereof aligned from left to right in a generalized problem, and with certain of the scales and certain lines of the graphs being given predetermined values.

Referring more specifically to the drawings, the device comprises a stationary body portion or stock indicated generally by A and including a flat rectangular shaped base plate 1 having any suitable width and length and provided with dual parallel longitudinally extending lateral guides 2 and 3 having slides 4 and 5 movably mounted thereon, with the slide 5 being shorter in length and movably mounted on the slide 4. The guides 2 and 3 prevent displacement of the slides 4 and 5 while allowing longitudinal movement of the same with relation to each other and with the base plate 1.

The slides 4 and 5 carry on their left vertical edges identical scales P_1 and P_2, respectively, which scales P_1 and P_2 are graduated in different divisions representing certain values for computation of the standard of error of the difference between two proportions and in the present instance the divisions are marked off in vertically arranged numbers running upwardly from the values of .05.95 to .50.50.

The scale P_1 on slide 4 is adapted to coact with a graph N_1 provided on the left end portion of the base plate 1 between the guides 2 and 3 and the scale P_2 on slide 5 is adapted to coact with a graph N_2 provided on slide 4 adjacent to the right of its scale P_1.

The graphs N_1 and N_2 are identical, each being triangular shaped and consisting of a pattern of straight lines 6 which radiate upwardly in varying spaced relation and toward the left from

common points 7 on the base plate 1 and slide 4 to aligned horizontal lines 8 and 8' provided on the base plate 1 and lower slide 4 respectively adjacent to the inner longitudinal edge of the guide 2. The horizontal line 8 on the base 1 is in alignment with the upper division representing the value .50.50 of scale P_1 and the upper division representing the value .50.50 of scale P_2 on upper slide 5 is in line with the horizontal line 8' on slide 4.

The straight lines 6 of the graphs N_1 and N_2 which connect with the horizontal lines 8 and 8' on base plate 1 and slide 4, respectively, in varying spaced relation are numbered with certain other values in computing the standard error of the difference between two proportions and in the present case the lines are numbered to represent values beginning with the value of 100 at the extreme left of the lines 8 and 8' of the graps N_1 and N_2 and increasing in magnitude to a value of 500 to the right of these lines.

An answer scale designated by the Greek letter sigma as σ is inscribed on the inner longitudinal edge of the guide 2, said scale σ having divisions decreasing in spaced relation from the left of the slide 2 toward the right and numbered to represent values in determining the standard error of the difference between two proportions beginning with the value of .070 of the first division at the left and decreasing in magnitude to .000 at the last division at the right.

A formula 9 is inscribed on the slide 2 for ready reference for the computation of the standard error of the difference between two proportions.

A nearer answer scale designated by σ' is inscribed on the inner longitudinal edge of the guide 3, which scale σ' has divisions decreasing in spaced relation from left to right and numbered to represent values beginning with the value .040 at the left of guide 3 and decreasing in magnitude to .000 at the right thereof. The scale σ' is only to be used in connection with scales P_1' and P_2' carried on removable tabs 10 and 11, respectively, as illustrated in Figs. 6 to 8, inclusive.

The tabs 10 and 11 are substantially rectangular in shape having a length and width to cover the scales P_1 and P_2 on slides 4 and 5 and are provided with keystone shaped portions 12 and 12', respectively, on one vertical side edge thereof, which portions 12 and 12' of the tabs are adapted to be removably inserted in grooves 13 and 13', respectively, formed by tab retaining elements 14 provided on the slides.

The tab retaining elements 14 are vertically arranged in spaced formation adjacent to the right of the scales P_1 and P_2 on slides 4 and 5, with the inner ends of the elements 14 being beveled to provide grooves 13 and 13' with a shape conforming to the keystone shape tab portions 12 and 12'. The left vertical edges of tabs 10 and 11 when the tabs are removably mounted on the slides 4 and 5 are flush with the left vertical edges of the slides and the scales P_1' and P_2' are inscribed on the tabs with the dimensions of these scales being numbered in values beginning with the value of .01.99 and increasing in magnitude upwardly to the value .10.90. The various graduations and markings on the scales referred to above are simply illustrations and are not intended in any way to limit the extent and kinds of markings or indications that may be provided on the device in carrying out the invention.

For the purpose of enabling a person to actuate the slides 4 and 5 in the guides 2 and 3 to cause the various scales on the device to coact with each other in computing the standard error of the difference between two proportions, finger engaging means in the form of buttons 15 and 15' are secured to the opposite ends of the slides 4 and 5, respectively, from the scales P_1 and P_2.

In plotting the various values of the different scales and lines of the graph the following steps are taken:

I. First a rectangular shaped outline of the N_1 graph is made as illustrated in Fig. 9, which outline has dimensions of 100/30 inches by 50/30 inches.

II. Compute $P_1(1-P_1)$ for convenient values of P_1 as follows:

	P_1	$1-P_1$	$P_1(1-P_1)$	
P_1 ranges from .00 to 1.00.	.00	1.00	.00	$P_1(1-P_1)$ ranges from .00 to .25 or from .25 to .00.
	.10	.90	.09	
	.20	.80	.16	
	.30	.70	.21	
	.40	.60	.24	
	.50	.50	.25	
	.60	.40	.24	
	.70	.30	.21	
	.80	.20	.16	
	.90	.10	.09	
	1.00	.00	.00	

III. Plot values of $P_1(1-P_1)$ up right hand edge of rectangle used as N_1 graph.

Thus 50/30 inches represents .25 range in value of $P_1(1-P_1)$. The values are as follows:

P_1	$P_1(1-P_1)$	Thirtieths of an inch
.00 or 1.00	.00×200=	0
.10 or .90	.09×200=	18
.20 or .80	.16×200=	32
.30 or .70	.21×200=	42
.40 or .60	.24×200=	48
.50	.25×200=	50

A demonstration of the above plotting is illustrated in Fig. 10. While values of $P_1(1-P_1)$ are plotted, only corresponding P_1 values are shown in final scale.

IV. Assuming that $P_1=.50$ compute values of

$$\frac{P_1(1-P_1)}{N_1}$$

for convenient values of N_1 and plot these values as shown below from right to left along upper edge of rectangle as illustrated in Fig. 11:

Working on .50 vertical line

$$\frac{P_1(1-P_1)}{N_1}=\frac{.50(1-.50)}{N_1}=\frac{.50(.50)}{N_1}=\frac{.25}{N_1}$$

N_1	.25/N Scale	Thirtieths of an inch
∞	.000000×40,000	0
500	.000500×40,000	20
400	.000625×40,000	25
300	.000833×40,000	33
200	.001250×40,000	50
150	.001667×40,000	67
125	.002000×40,000	80
100	.002500×40,000	100

$$\frac{100}{.0025}=40,000$$

V. Assuming that $P_1=.10$ compute values of

$$\frac{.10(1-.10)}{N_1}$$

for convenient values of N_1 and plot these values from right to left along a line parallel to upper

and lower edges of the rectangle for N_1 graph as illustrated in Fig. 12 with the line passing through a point representing .10 on vertical P_1 scale. These values are as follows:

N_1	$\frac{.09}{N_1}$ Scale 40,000	Thirtieths of an inch
∞	0 ×40,000	0
500	.000180×40,000	7
400	.000225×40,000	9
300	.000300×40,000	12
200	.000450×40,000	18
150	.000600×40,000	24
125	.000720×40,000	29
100	.000900×40,000	36

VI. Referring to Fig. 13, a straight line is then drawn through two points representing $N_1=500$ (one on top margin of rectangle of N_1 graph and one on parallel line through $P_1=.10$ in Fig. 12) and lower right hand corner of rectangle.

It can be shown by plotting values of

$$\frac{P_1(1-P_1)}{N_1} \text{ for } N_1=500$$

and various values of P_1 that all such points will lie on the above described straight line. Similarly, points for various values of P_1 and any constant value of N_1 will lie on a certain straight line which can be determined by the plotting procedure outlined above and which will pass through the corner of the rectangle as shown in Fig. 13.

VII. General derivation of lines on N_1 graph.

A. Purpose of N_1 graph in conjunction with P_1 scale is—

Given P_1 and N_1 to compute $\frac{P_1(1-P_1)}{N_1}$

B. Let

$$X=\frac{P_1(1-P_1)}{N_1}; \text{ let } Y=P_1(1-P_1)$$

C. Then $X=Y/N_1$ or $Y=N_1X$, equation of a straight line with slope N_1, and passing through point (0,0) selected for convenience in construction of rule, as lower right hand of rectangular N_1 graph.

D. In converting above values to measurements in thirtieths of an inch for scale of the size used—

$$X \text{ actually was } 40{,}000\ \frac{P_1(1-P_1)}{N_1}$$

(Steps IV and V in construction of N_1 graph.)

$$Y \text{ actually was } 200\ P_1(1-P_1)$$

(Step III in construction of N_1 graph.)

or

$$X=\frac{200Y}{N_1} \text{ or } Y=\frac{N_1}{200}X$$

where X and Y are measurements in thirtieths of an inch.

E. Thus, final the equation

$$Y=\frac{N_1X}{200}$$

might be used in plotting the lines of the N_1 graph.

For example—

F. Let N_1 be 200. Then

$$Y=\frac{200}{200}X \text{ or } Y=X$$

equation of a line with slope of one, and passing through (0,0), as is actually the case with the line representing $N_1=200$ on the N_1 graph shown particularly in Figs. 1 and 3.

G. Or let $N_1=100$. Then

$$Y=\frac{100}{200}X \text{ or } Y=X/2$$

equation, of a line with slope of one-half and passing through the point (0,0), as is the case with the line representing $N_1=100$ on the N_1 graph of Figs. 1 and 3.

H. Procedure in construction of N_2 graph is identical with the above procedure in constructing N_1 graph.

The answer scale is designated by $\sigma_{P_1-P_2}$ or in short S. E. the standard error of the difference between two proportions. There are, however, other standard errors not to be confused with that disclosed here.

Answer scale σ=S. E. scale and is constructed as follows:

I. Square convenient values in the range of expected answers. Multiply by 40,000 the number used as a multiplier in construction of N_1 and N_2 graphs as illustrated below:

	Standard Error		Thirtieth of an inch In Thirtieths of an inch
	S. E. (1)	(S. E.)² (1) squared	
Convenient divisions	.00	.00 ×40,000	0
	.02	.0004×40,000	16
	.03	.0009×40,000	36
	.04	.0016×40,000	64
	.05	.0025×40,000	100
	.06	.0036×40,000	144
	.07	.0049×40,000	198

II. Establishing starting point for answer or standard error scale 221 thirtieths of an inch to the right of left vertical edge of N_1 graph and on a separate line or scale above or beyond the N_1 and N_2 graphs.

III. Measuring from right to left from starting point, plot the distances computed and give corresponding S. E. values as labels.

Referring to Fig. 14 which shows a functional diagram of the slide rule embodying the above-described scales and graphs, with the scales and lines 8 and 8' of the graphs aligned from left to right as in a generalized problem and the scales P_1P_2 N_1 and N_2 being given certain values.

The following formula is used in determining the standard error S. E. of the difference between two proportions with all quantities and measurements being in thirtieths of an inch.

Formula

$K=100$
$Y_1=200\ P_1(1-P_1)$
$Y_2=200\ P_2(1-P_2)$
$X_1=40{,}000\ P_1(1-P_1)/N_1$
$X_2=40{,}000\ P_2(1-P_2)/N_2$

As in VII D, general derivation of N scale.

Since standard error to be computed

$$=\sqrt{\frac{P_1(1-P_1)}{N_1}+\frac{P_2(1-P_2)}{N_2}}$$

$$(\text{S. E.})^2=\frac{X_1}{40{,}000}+\frac{X_2}{40{,}000}$$

or $X_1+X_2=40{,}000$ (S. E.)² as in Fig. 14

P_1	.30
P_2	.80
N_1	200
N_2	300

$$\frac{P_1-P_2}{\text{Standard error}}$$

In using the device for statistics required for computation of the standard error of the difference between two proportions, the following data is required:

A. The number of cases or individuals in each of two samples or proportions under consideration. These two numbers are designated as N_1 and N_2.

B. The proportion of cases (in each of the two samples) which possess the attribute of central interest in the experiment. These two proportions are indicated as P_1 and P_2, being expressed as decimal fractions between 0.0 and 1.0 in value.

Example of data required:

Towns	A	B
Population	$1000=N_1$	$500=N_2$
Proportion Illiterate	$.02=P_1$	$.03=P_2$

Formula for computation of S. E. the standard error of the difference between two proportions.

$$\text{S. E.}\sqrt{\frac{P_1(1-P_1)}{N_1}+\frac{P_2(1-P_2)}{N_2}}=$$

Using the data in the above example—

$$\sqrt{\frac{(.02)(1-.02)}{1000}+\frac{(.03)(1-.03)}{500}}$$

$$=\sqrt{\frac{(.02)(.98)}{1000}+\frac{(.03)(.97)}{500}}$$

$$=\sqrt{\frac{.0196}{1000}+\frac{.0291}{500}}$$

$$=\sqrt{\frac{.0196}{1000}+\frac{.0582}{1000}}=\sqrt{\frac{.0778}{1000}}$$

$$=\sqrt{.0000778}=.0088 \text{ or } .009 \text{ approx.}$$

The operation of the slide rule to solve a problem is as follows:

A. Assumed data:

Successful answers to an Army test question

	College Group	High School Group
Number in Group	$200=N_1$	$150=N_2$
Proportion Correct Answers	$.95=P_1$ or P_1'	$.90=P_2$ or P_2'

B. First calculation of the standard error of the difference between two proportions using the permanent P_1 and P_2 scales and the answer scale σ.

1. See that the tabs 10 and 11 carrying the scales P_1' and P_2' are removed from the rule.

2. Move slide 4 in guides 2 and 3 by means of the button 15 until .95 (and .05) on P_1 scale are superimposed directly over the line 200 of N_1 scale.

3. Move slide 5 in guides 2 and 3 by means of the button 15' until .90 (and .10) on P_2 scale is superimposed directly over the line 150 of the N_2 scale.

4. Read answer standard error=.029 from answer scale σ directly in line with the vertical edge of the P_2 scale.

C. When each of the two proportions of a problem is less than .10 or greater than .90 a further calculation may be had in the following manner:

1. The tabs 10 and 11 carrying the scales P_1' and P_2' are mounted on the slides 4 and 5 by means of their keystone shaped portions 12 and 12' engaging in the grooves 13 and 13' formed by the tab retaining elements 14, with the tabs 10 and 11 covering up the scales P_1 and P_2 on the slides 4 and 5, respectively, and substituting the scales P_1' and P_2' therefor.

2. Move slide 4 in guides 2 and 3 by means of its button 15 thus moving the scale P_1' laterally until .95 (and .05) is superimposed directly over the line 200 of the N_1 scale.

3. Move slide 5 in guides 2 and 3 by means of its button 15' thus moving the scale P_2' laterally until .90 (and .10) on P_2' scale are superimposed directly over the line 150 of the N_2 scale.

4. Read answer .029, the standard error of the difference between the two proportions from the division of the nearer expanded answer scale σ' directly in line with the vertical edge of the P_2' scale.

The answer scale σ' is only used when the tabs 10 and 11 carrying the P_1' and P_2' scales have been mounted on the slides 4 and 5 over the P_1 and P_2 scales when each of the two proportions are less than .10 or greater than .90 thus greater accuracy is permitted by this arrangement under these circumstances.

It will thus be seen that there has herein been provided a novel and efficient form of calculator in the form of a slide rule which is well adapted for the purpose intended. Even though there has herein been shown the device as comprising certain features of construction and operation of parts it is nevertheless to be understood that various changes may be made therein if the changes do not depart from the spirit or scope of the claims.

Having thus described my invention, what I claim as new and wish to secure by Letters Patent is:

1. A device of the character described including a base having guides thereon, superimposed slides mounted for movement relative to each other in said guides, a pair of tab retaining elements mounted on said slides adjacent to one end of each thereof, each pair of said tab retaining elements vertically arranged in spaced formation, the inner adjacent ends of said pairs of tab retaining elements beveled and providing grooves, an answer scale on said guides, a graph on one of said slides, a graph on said base, substantially rectangular shaped tabs including keystone-shaped portions, and supplementary vertical scales provided on said tabs, said keystone-shaped portions of said tabs adapted to be inserted in said grooves formed by said spaced beveled inner ends of said tab retaining elements, whereby said tabs having said supplementary vertical scales thereon may be removably mounted on vertical edges of said slides.

2. A device of the character described including a base having guides thereon, superimposed slides mounted for movement relative to each other in said guides, an answer scale on said guides, a graph on one of said slides, a graph on said base, a pair of tab retaining elements mounted on said slides adjacent to one end of each thereof, each pair of said tab retaining elements vertically arranged in spaced formation, the inner adjacent ends of said pairs of tab retaining elements beveled and providing grooves adjacent to vertical edges of said slides, substantially rectangular shaped tabs including keystone-shaped tongues, and supplementary vertical scales provided on said tabs, said keystone-shaped tongues of said tabs adapted to be inserted in said grooves formed by said spaced beveled inner ends of said tab retaining elements, whereby said tabs having

said supplementary vertical scales thereon may be removably mounted on said slides.

3. A device of the character described including a base having guides thereon, an answer scale on said guides, a graph on said base between said guides, said graph representing certain values in a mathematical problem to be computed, lower and upper superimposed slides mounted for movement relative to said answer scale and to each other in said guides, said lower slide adapted to move over said graph, a pair of tab retaining elements mounted on each of said slides adjacent to one end thereof, each pair of said tab retaining elements vertically arranged in spaced formation, the inner spaced ends of said pairs of tab retaining elements beveled and providing grooves, substantially rectangular shaped tabs including keystone-shaped tongues identical scales provided on said tabs and representing certain other values of a mathematical problem, one of each of said keystone-shaped tongues of said tabs adapted to be inserted in one of each of said grooves formed by said beveled inner ends of said tab retaining elements, whereby said tabs having said identical scales thereon may be removably mounted on one end of each of said slides, and another graph provided on said lower slide, said last-mentioned graph being identical with said first-mentioned graph, said upper slide adapted to move over said second-mentioned graph on said lower slide whereby, upon movement of said lower slide to different positions over said graph on said base and movement of said upper slide to different positions over said graph on said lower slide, said identical scales on said slides may be combined with said graphs in computing answers to mathematical problems, which answers may be read on said answer scale.

4. A device of the character described including a base having longitudinally extending guides thereon with an answer scale consisting of a row of symbols delineated lengthwise on one of said guides and decreasing in magnitude to the right, said row of symbols representing answer values of mathematical problems, a graph inscribed on said base between said guides, said graph consisting of a line of longitudinally extending symbols adjacent to and extending parallel to said row of answer scale symbols, and a plurality of lines joined together at one end and extending upwardly and outwardly in varying spaced relation to said line of graph symbols, said line of graph symbols increasing in magnitude to the right and representing other mathematical values, lower and upper superimposed slides mounted for endwise sliding movement relative to each other in said guides and parallel with said answer scale, said lower slide adapted to move laterally over said graph, a pair of tab retaining elements mounted on one end of each of said slides adjacent to vertical edges thereof, each pair of said tab retaining elements vertically arranged in spaced formation, the spaced inner ends of said pairs of tab retaining elements beveled and providing grooves adjacent to the vertical edges of said slides, substantially rectangular shaped tabs including keystone-shaped tongues, identical vertically arranged scales provided on said tabs, said keystone-shaped tongues of said tabs adapted to be inserted in said grooves formed by said spaced beveled inner ends of said tab retaining elements, whereby said tabs having said identical scales thereon may be removably mounted on said slides adjacent to one end of each thereof, said identical scales each consisting of a plurality of divisions and symbols designating mathematical values of said divisions and increasing vertically upwardly in magnitude and a graph inscribed on said lower slide, said upper slide adapted to move laterally over said last-mentioned graph on said lower slide, said graph on said lower slide being identical to said first-mentioned graph on said base and including a line of mathematical symbols delineated lengthwise of said lower slide and in alignment with said line of symbols of said first-mentioned graph, whereby under endwise movement of said lower slide to different positions over said first-mentioned graph on said base and endwise movement of said upper slide to different positions over said graph on the lower slide, the divisions designated by said symbols of said identical vertically arranged scales on said slides may be combined with said first-mentioned graph on said base and said graph on said lower slide in computing answers to mathematical problems, which answers are indicated on said answer scale.

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REFERENCES CITED

The following references are of record in the file of this patent:

FOREIGN PATENTS

Number	Country	Date
306,349	Germany	June 1, 1920