April 19, 1955 B. K. H. BAO 2,706,600

CALCULATOR

Filed May 21, 1954 4 Sheets-Sheet 1

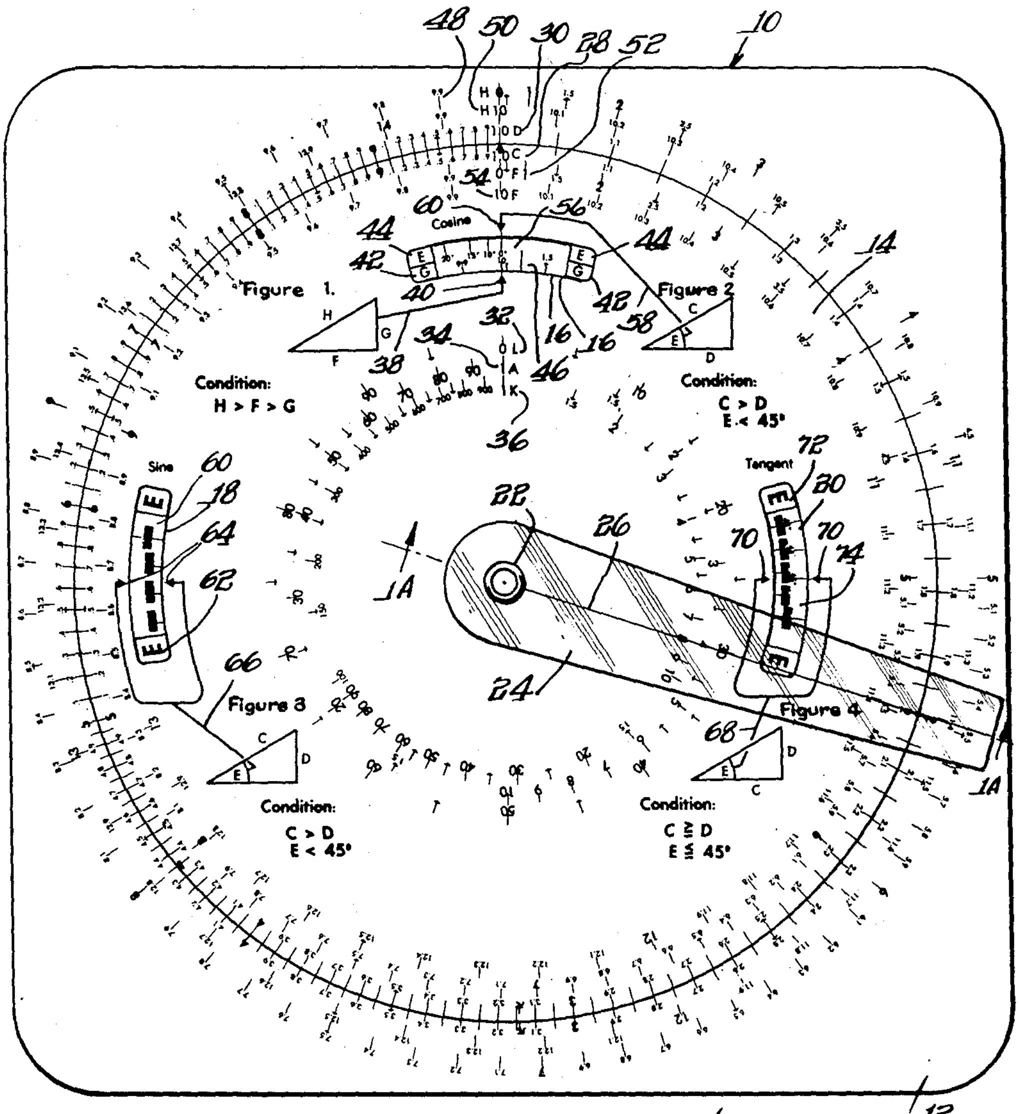
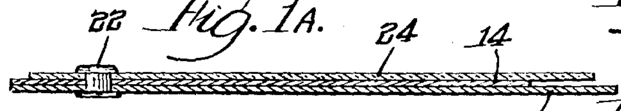


Fig. 1.

Fig. 1A.



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CALCULATOR

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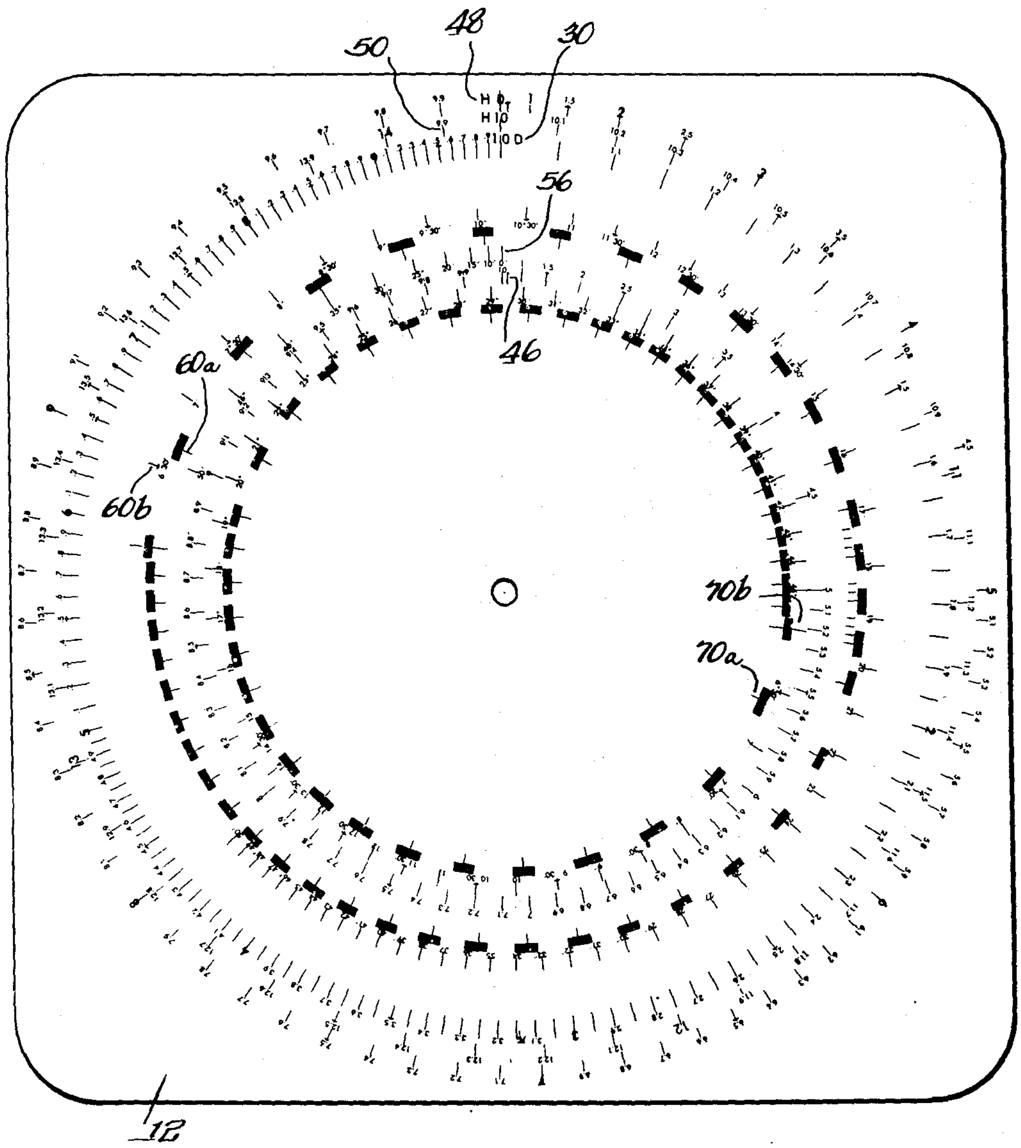

Fig. 2.

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Fig. 3.

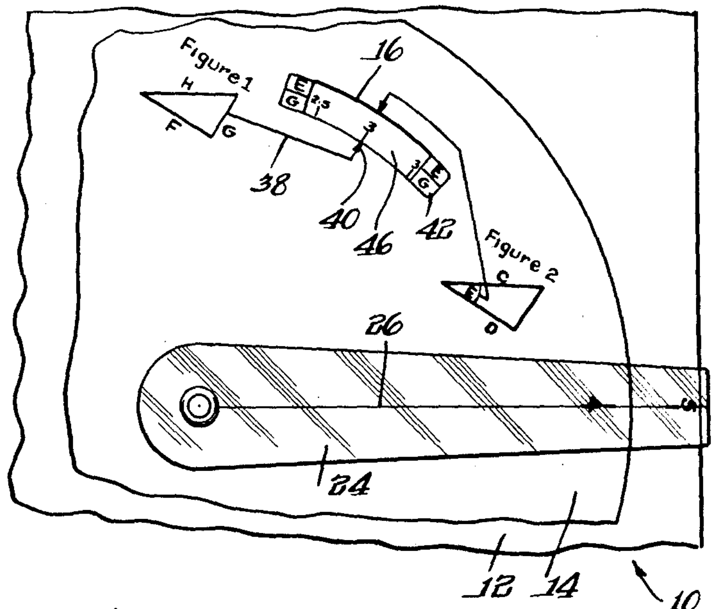

Fig. 4.

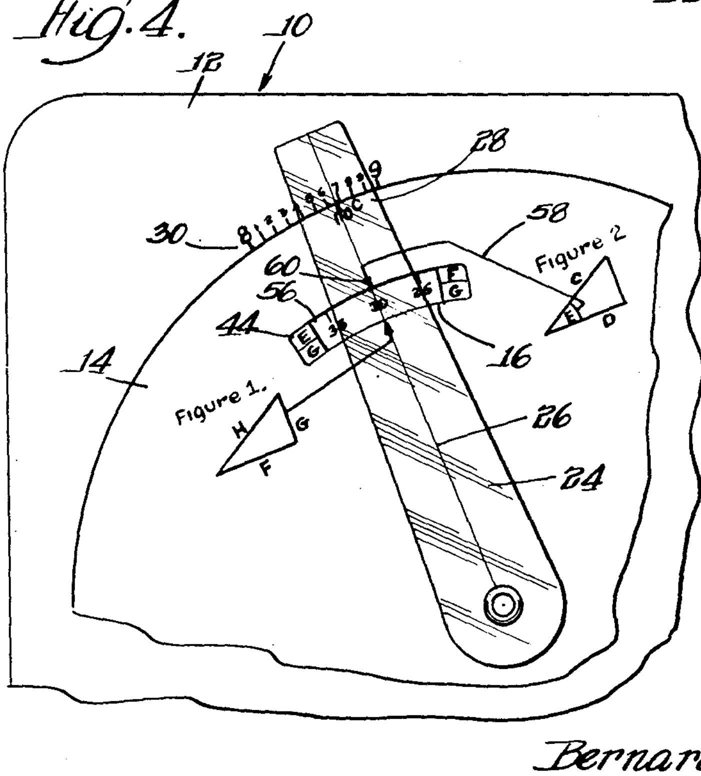

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Fig. 5.

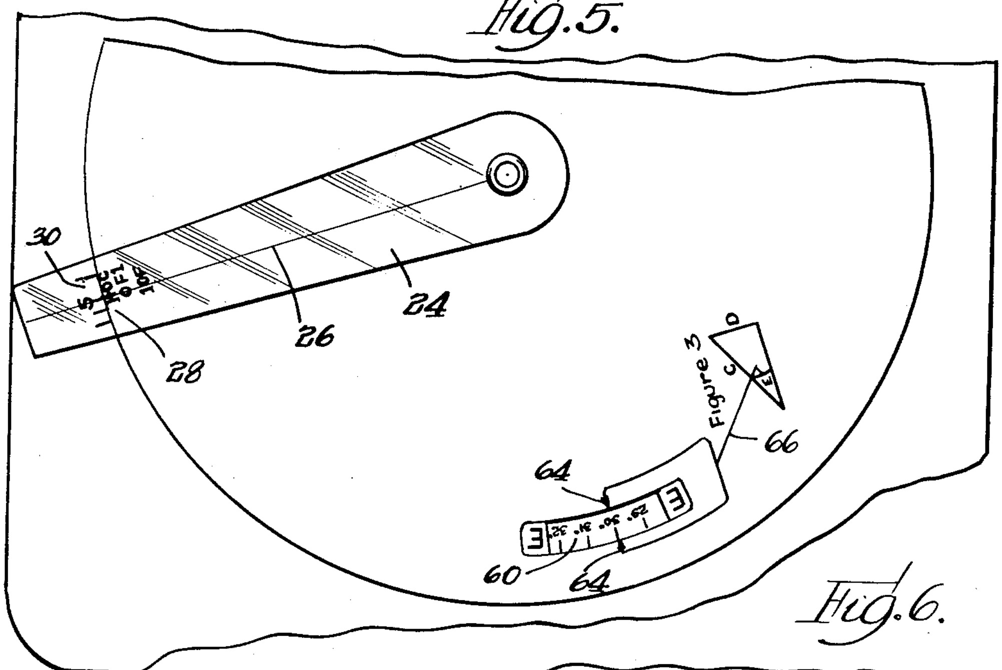


Fig. 6.

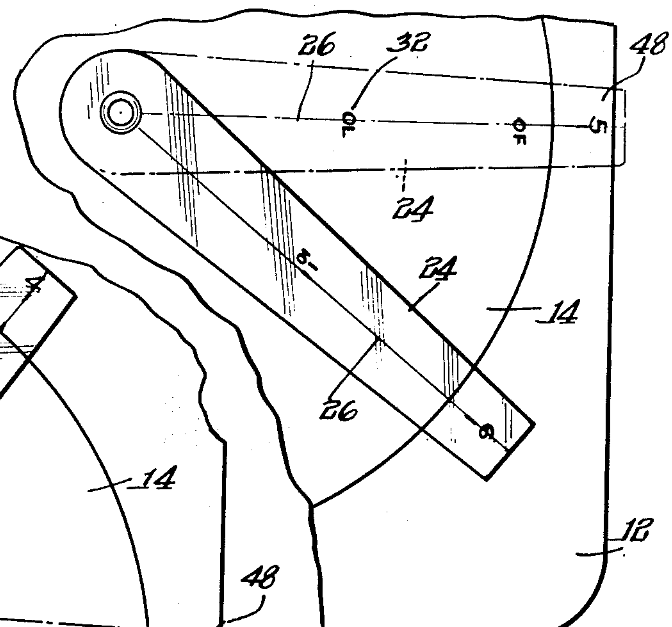
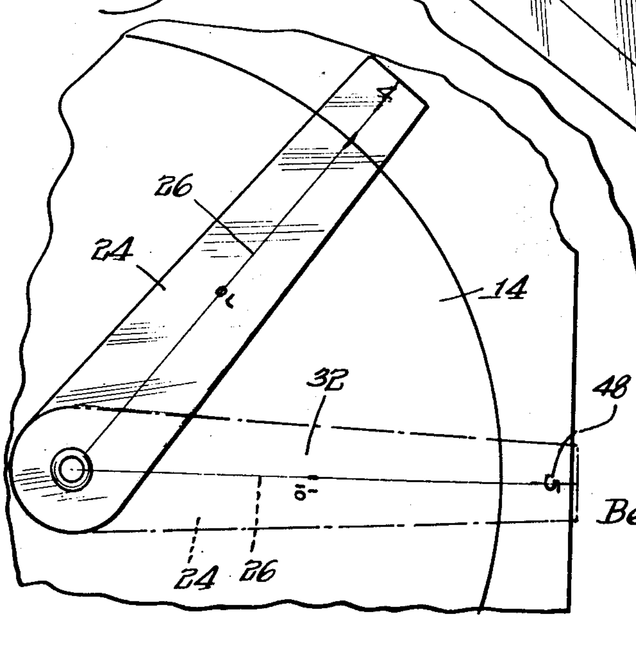


Fig. 7.



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United States Patent Office

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CALCULATOR

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Application May 21, 1954, Serial No. 431,397

7 Claims. (Cl. 235—83)

This invention is concerned generally with a calculator of the slide rule type, and more particularly with such a calculator for the direct solution of right angle triangles and other problems commonly encountered in machining.

Triangles are utilized many times every day in machine shop operations. The machinists who utilize such triangles generally are not mathematically trained, and knowing two sides of a triangle, or a side and an angle, these machinists find it difficult or impossible to calculate the values of the remainder of a triangle. Calculators of one sort or another, including common engineering slide rules heretofore have been evolved for aid in solving such triangles. However, all such previous calculators with which I am familiar have required the use of formulae, or trigonometric values, or numerical calculations, either singly or in combination.

Accordingly, it is an object of this invention to provide a calculator for ascertaining unknown values of triangles in terms of the known values without the necessity of resorting to any or all of trigonometric values or formulae, or numerical calculations.

Various formulae are available for calculating unknown values of oblique triangles. However, most machinists being insufficiently educated in mathematics hesitate to utilize such formulae. Right triangles directly take care of about 90% of machine operations, and oblique triangles can be broken down to a pair of right triangles for solution of the unknown values.

Accordingly, it is an object of this invention to provide a calculator for solving right triangles directly without resort to formulate, trigometric values, or numerical calculations.

More specifically, it is an object of this invention to provide a calculator for the direct solution of triangles as heretofore set forth giving answers over a large and continuous range.

It is an object of this invention to provide a calculator for the direct solution of the foregoing equation, and also for the direct solution of the general formula

$$\sqrt{H^2 \pm F_1^2 \pm F_2^2 \pm \ldots}$$

Blank diameters of cylindrical shells and other articles of generally similar shape are frequently developed in machine shops and rely on the general formula

$$\sqrt{H^2 \pm F_1^2 \pm F_2^2 \ldots \pm L_1 \pm L_2 \pm \ldots}$$

My invention further contemplates the provision of a calculator having features meeting all of the objects heretofore set forth and also usable as a slide rule for multiplication and division, for ascertaining squares and square roots, for ascertaining cubes and cube roots, and for obtaining logarithms and anti-logarithms.

Other and further objects and advantages of the present invention will be apparent from the following description when taken in connection with the accompanying drawings wherein:

Fig. 1 is a plan view of my calculator;

Fig. 1A is a cross-sectional view thereof taken substantially along the line 1A—1A of Fig. 1;

Fig. 2 is a plan view of the bottom part of the calculator; and

Figs. 3–7 are fragmentary plan views illustrating the solution of various problems.

Reference first should be made to Figs. 1, 1A, and 2 for an understanding of the physical construction of the calculator, calculator being indicated generally by the numeral **10**. The calculator **10** includes a base, back, or main plate **12** which is illustrated as being square with the corners rounded off, but could be rectangular to accommodate a reference to operating instructions on the rear face of the base plate. It further is contemplated that the base plate might be circular in outline. The base plate preferably is made of plastic or metal on the order of about .040″ to 1/16″ in thickness and on the order of about 10 inches across, a specific embodiment of my invention having a base plate measuring 9¾″ across.

The calculator further includes a circular plastic or metal disc **14** which is approximately 8½″ in diameter and is on the order of .020″ to 1/32″ in thickness. The disc **14** generally is opaque and is provided with three transparent or cut out windows **16**, **18**, and **20** for purposes presently to be described.

The disc **14** is rotatably mounted concentrically upon the base **12** by means such as a flanged over eyelet **22**, and this eyelet also rotatably mounts a transparent indicator **24** preferably made of plastic and having a hairline indicator **26** inscribed thereon.

The disc **14** is provided about its periphery with a logarithmic "C" scale **28** and the base plate **12** is provided with a cooperating "D" scale **30** as on conventional slide rules for multiplication and division. These scales are provided with closely spaced indicia reading directly and without interpolation to every .005 in the one to two range and decreasing to every .02 in the nine to ten range. The indicia corresponding to the finer parts of the scales have been omitted from all of the scales shown in the drawings to avoid hopeless crowding and confusion in reduction to the necessary size for a finished patent. The use of "C" and "D" scales for multiplication and division is well-known to those skilled in the slide rule or calculator art, and illustration of a solution of a problem therefore is believed to be unnecessary in this disclosure.

The surface of the disc **14** is provided with three additional scales. The outermost of these scales is indicated by the numeral **32** and comprises an "L" scale for determining common logarithms. The "L" scale is linear, and hence to determine the common logarithm the characteristic is determined in the usual manner in accordance with the number of digits preceding the decimal point, and the mantissa is found by lining up the hairline **26** with the numeral on the "C" scale. The mantissa then may be read on the "L" scale. The "L" scale is provided with closely spaced indicia allowing the scale to be read to three significant figures, but the more closely spaced indicia have been omitted from the drawings to prevent crowding and confusion in the print appearing in the patent.

The disc **14** further is provided with an "A" scale **34** positioned immediately inwardly from the "L" scale. The "A" scale is a logarithmic scale and bears a square relationship to the "C" scale **28**. A logarithmic "K" scale **36** is spaced immediately inwardly from the "A" square scale **34** and bears a cube relationship to the "C" scale. The "K" scale can be read to two or three significant figures depending upon the portion of the scale in use. The more closely spaced indicia have been omitted from both the "A" and "K" scales for reproduction purposes. To obtain the square or cube of a number, the hairline **26** is lined up with the desired number on the "C" scale and the square may be read on the "A" scale and the cube on the "K" scale. For example, in Fig. 1 where the hairline is lined up with the numeral 2 on the "C" scale, the square may be read as 4 on the "A" scale, and the cube may be read as 8 on the "K" scale. Square roots and cube roots may be obtained in a converse manner by setting the hairline on the desired number on the "A" or "K" scale respectively. The correct answer appears beneath the hairline on the "C" scale.

The disc **14** is provided on its face with four right triangles respectively indicated as Figure 1, Figure 2, Figure 3, and Figure 4. These four triangles have values marked next to them for finding the unknown third value when any other two values are known. More specifically, Figure 1 on the disc has the three sides indicated as H, F, and G, H depicting the hypotenuse, and F and G the two right angularly disposed sides. When any two of any of the three sides of the triangle are known, the third side can be found directly. For simplification of operation, a label is placed on the disc adjacent the triangle of Figure 1 setting forth that H is greater than F and F is greater than G. A lead line **38** extends from the G side of the triangle to an arrowhead **40** positioned beneath the window **16**. Pairs of rectangules **42** and **44** are located at opposite ends of the window **16**. The rectangles **42** are marked with the letter G, corresponding to the side G in Fig. 1, and the rectangles **44** are marked with the letter E, the significance of which will be set forth hereinafter. The inner, lower, or G half of the window **16** lines up with a non-logarithmic scale **46** on the base plate **12** of the calculator. This scale is shown in part through the window **16** in Fig. 1 of the drawings and in its entirety in Fig. 2 of the drawings. The "G" scale comprises a scale of the square of numbers, the scale graduations being indicated by the numbers themselves.

An outer "H" scale **48** forming an "H" scale corresponding to the H side of the triangle is arranged on the face of the base plate **12** adjacent the periphery thereof. This scale is identical with the "G" scale except for the larger radius and consequent spreading out of the indicia. The outer "H" scale **48** is continued as an inner "H" scale **50**, the value 9.9 being aligned on the inner and outer scales and forming the cross-over point. The outer and inner "H" scales together thus run from zero to fourteen.

The disc **14** is provided inwardly of the "C" scale with outer and inner "F" scales respectively numbered **52** and **54**. These "F" scales are identical with the outer and inner "H" scales except for their disposition on the disc **14** and run from zero to slightly over thirteen, the inner "F" scale being interrupted by the window **18**. The "G," "F," and "H" scales can be read directly to four significant figures and can be interpolated to five significant figures, but the more closely spaced indicia again have been omitted for clarity of reproduction.

The solution of a typical problem using the "H," "F," and "G" scales is illustrated in Fig. 3 of the drawings. One of the best known right triangles is the 3–4–5 triangle in which the sides are dimensioned in a 3:4:5 ratio. This triangle is illustrated in Fig. 3 of the drawings, and it will be seen that when the arrowhead **40** connected to the G side of the triangle of Figure 1 on the disc is lined up with 3 on the "G" scale, and the hairline **26** of the indicator **24** is lined up with the numeral 4 on the "F" scale, the value of the hypotenuse may be read as 5 on the "H" scale. In this example it was assumed that the F and G sides were known, but it will be apparent to anyone skilled in the use of calculators that a more-or-less reciprocable process could ascertain the third side regardless of which two sides are known.

The E value indicated at **44** comprises the acute included angle between the hypotenuse and the abscissa or horizontal side of the triangle shown in Fig. 2 on the disc. The hypotenuse of this triangle is labeled as side C to correspond with the "C" scale on the disc **14**, and the horizontal side is labeled as side D to correspond with the "D" scale. An "E" scale **56** which is shown in part in Fig. 1 of the drawings through the window **16** and which is shown completely in Fig. 2 of the drawings is laid out on the base plate **12**. The "E" scale comprises a logarithmic cosine scale plotted against the "D" scale. A lead line **58** extends from the angle E of the triangle in Figure 2 on the disc to an arrowhead **60** positioned opposite to the arrowhead **40** and along the outer arc of the window **16**. The more closely spaced indicia on the E scale have been omitted as in the previously described scales in order to avoid crowding and confusion in reproduction.

An example of the use of the triangle in Figure 2 is shown in Fig. 4 of the drawings. Assuming that the hypotenuse C has a value of 10 units, and the angle E has a value of 30°, the arrowhead **60** connected by the lead line **58** to the angle E in the triangle in Figure 2 is aligned with 30° on the "E" scale as shown in Fig. 4 of the drawings. When the hairline **26** of the indicator **24** is lined up with 10 on the "C" scale, the side D may be seen to be 8.66 on the "D" scale. By exactly the same setting, it may be seen that the cosine of 30° is .866. An analogous process would be utilized to find the angle if the hypotenuse and D side were known, or to find the hypotenuse if the angle and D were known.

The cosine scale is quite compressed and may be seen in Fig. 2 of the drawings to occupy an arc of less than 45° in plotting cosine values from 0 to 50°. Accordingly, for greater accuracy it may be found desirable to utilize the tangent scale shortly to be described to find the vertical side of the triangle when the angle is known, and to utilize the "H," "F," and "G" scales to find the unknown side, or when the angle is unknown to utilize the "H," "F," and "G" scales to find the third side and then use the tangent scale to find the angle. It will be appreciated that many of the indicia have been omitted from the "E" scale to avoid crowding in reproduction.

The calculator is provided with a sine scale visible through the window **18** and identified by the numeral **60**. As may be seen in Fig. 2 of the drawings the scale **60** comprises an inner scale **60*a*** reading from approximately 0°40′ to 6°0′, and an outer scale **60*b*** reading from 6° to 50°, the scales being aligned at the 6° mark. The scale **60** is identified bv the letter "E" as shown at **62** at opposite ends of the window **18**. The scale **60** comprises a sine "E" scale as opposed to the scale **56** which comprises a cosine "E" scale. It is a logarithmic cale plotted against the "D" scale. The more closely spaced indicia again have been omitted to avoid crowding and confusion in reproduction.

The typical example of a problem solvable by means of the triangle in Figure 3 on the disc **14** is shown in Fig. 5 of the drawings. Assuming that the angle E is known to be 30° and the hypotenuse C is known to have a value of 10 units, the disc **14** is rotated to bring arrowheads **64** associated with a bifurcated lead line **66** from the triangle in Figure 3 into alignment with the 30° mark on the sine "E" scale **60**. The hairline **26** of the indicator **24** is aligned with the value 10 on the "C" scale **28**, and the D side may be read from the "D" scale **30** beneath the hairline as being 5 units in length. The value of C has been chosen as exemplary in this instance so that it may be seen that by considering this value to be 1.0 the sine of the angle may be read directly as .500. At the same time the inner arrow pointing to the window **18** indicates 2°52′ and the sine of this angle may be read as .0500. It will be apparent to those skilled in the use of slide rule calculators that a similar or converse process would allow the angle E or the hypotenuse C to be found if the remaining two values were known.

The remaining trigonometric function comprises the tangent and this function is incorporated in the triangle of Figure 4 on the disc **14**. In this triangle the angle E is marked, the horizontal or adjacent side is marked as C, and the vertical or opposite side is marked as D. A bifurcated lead line **68** leads from the angle E in the triangle of Figure 4 to arrowheads **70** aligned with one another and on opposite sides of the window **20**. The window **20** is marked with an E **72** at the opposite ends thereof, and a logarithmic tangent scale **74** is visible through this window. The logarithmic tangent scale **74** is a double scale comprising an inner scale **70*a*** reading from 0°40′ to 6°, and an outer tangent scale **70*b*** reading from 6° to 45°. The double scale **70** is plotted against the "D" scale **30**.

A specific example involving use of the tangent "E" scale **74** is shown in Fig. 1 of the drawings. In this example it is assumed that the adjacent and opposite sides of the triangle are equal. The "C" scale thus is aligned with the "D" scale. The angle E from alignment with the arrows **70** may be read as being 45°. The inner tangent scale reads 5°43′ and the tangent of this angle is .100. If it is the angle and one of the sides that is known, the other side can be found by an analogous process. Again it is to be understood that the more closely spaced indicia have been omitted for clarity of reproduction.

Reference has been made to the solution of the function $\sqrt{H^2 \pm F_1^2 \pm F_2^2 \pm \ldots}$. The H and F scales are used for adding and subtracting the squares. For example, consider $H=3$, $F_1=4$, and $F_2=12$. The solution of the sum thus is $\sqrt{3^2+4^2+12^2}=13$. To solve this function on my calculator the hairline is placed over the value 3 on the outer H scale and the 0 value of the outer F scale is moved beneath the hairline. The hairline then is moved to 4 on the outer F scale.

The 0 mark on the outer F scale again is moved beneath the hairline, and the hairline is moved to 12 on the inner or extension F scale. The solution then may be read on the inner or extension H scale as 13.

It has been indicated heretofore that in addition to triangles, it is common machine shop practice to fabricate shells and other articles to the formula $\sqrt{H^2 \pm L}$, or more generally $\sqrt{H^2 \pm F_1^2 \pm F_2^2 \pm \ldots \pm L_1 \pm L_2 \pm \ldots}$ This formula can be solved directly with the H, F and L scales heretofore enumerated, and is intimately related to the triangle solutions previously explained through the use of common scales. More specifically, it has been indicated that the "H," "G," and "F" scales are plotted as squares. This readily allows solution of the equations $G=\sqrt{H^2-F^2}$, $H=\sqrt{F^2+G^2}$, or $F=\sqrt{H_2-G^2}$, all as should be apparent from the description of the solution of the three sides of a triangle with regard to Fig. 1 on the disc **14**. In an analogous fashion, the solution of the function $\sqrt{H^2 \pm F^2}$ can be found. Recalling that the "L" scale **32** is a linear scale, it will be apparent that the aforesaid function $\sqrt{H^2 \pm L}$ or the more general function can be found directly. Solutions of this function are shown in Figs. 6 and 7 of the drawings. For instance, assume that $H=5$ and $L=11$, and it is desired to find the solution of the function $\sqrt{H^2+L}$, or $\sqrt{5^2+11}$. The hairline **26** on the indicator **24** is aligned with 5 on the "H" scale **48** as shown in dashed lines in Fig. 6. The 0 mark on the "L" scale **32** is placed beneath the hairline, and the hairline is moved to **11** as indicated in solid lines in Fig. 6. The solution of the equation may be read directly beneath the hairline **26** as 6. Convenient values which readily may be checked mentally have been chosen as exemplary.

Assume that $H=5$ and $L=9$ and it is desired to find the solution of $\sqrt{H^2-L}$, or $\sqrt{5^2-9}$. The hairline **26** of the indicator **24** is aligned with the numeral 5 on the "H" scale **48** as shown in dashed lines in Fig. 7. The value of 9 on the "L" scale **32** is placed beneath the hairline, and the hairline is moved to the 0 mark on the "L" scale as shown in solid lines in Fig. 7. The solution can be read directly as 4 on the "H" scale beneath the hairline. In solving the more general function $\sqrt{H^2 \pm F_1^2 \pm F_2^2 \pm \ldots \pm L_1 \pm L_2 \pm \ldots}$ the "F" scale is utilized for adding or subtracting the successive squares of F and the L scale is used for adding or subtracting L values.

It will be apparent from the foregoing that right triangles and certain other mathematical functions can be solved directly without resort to formulae, trigonometric values and numerical calculations. Solutions are obtained over a large and continuous range.

It will be apparent that the particular embodiment of the calculator shown and described is for exemplary purposes only. Various changes might be made such as radially interchanging some of the scales or reversing all of the scales. These and other changes will no doubt be apparent to those skilled in the art, and will be understood as forming a part of this invention insofar as they fall within the spirit and scope of the appended claims.

The invention is claimed as follows:

1. A calculator for solving triangles and the like directly, comprising a base, a part carried from said base and movable relative thereto in a predetermined manner, an indicator carried from said base and movable relative to said base and to said movable part in a predetermined manner, cooperating scales on said base and said movable part for the direct solution of triangles and the like, said scales having identifying means associated therewith, means on one of said base and said movable part pictorially representing the various sides and angles of triangles to be solved directly, and means associated with said representations and with said identifying means indicating the scales to be used for obtaining solutions of said triangles directly.

2. A calculator for solving triangles and the like as set forth in claim 1 wherein the scales include similar logarithmic scales on said base and on said movable part, and further include at least one trigonometric scale.

3. A calculator for solving triangles and the like directly, comprising a base of sheet material, a rotatable disc of sheet material rotatably mounted on said base, an indicator rotatably mounted from said base and concentric with said disc, said indicator being rotatable relative to said base and relative to said disc, cooperating scales concentrically arranged on said base and on said disc for the direct solution of triangles and the like, said scales having identifying means associated therewith, means on one of said base and said disc pictorially representing the various sides and angles of triangles to be solved directly, and means associated with said representations and with said identifying means indicating the scales to be used for obtaining solutions of said triangles directly.

4. A calculator for solving right triangles and the like directly, comprising a base, a part carried from said base and movable relative thereto in a predetermined manner, an indicator carried from said base and movable relative to said base and to said movable part in a predetermined manner, cooperating scales on said base and said movable part for the direct solution of triangles and the like, said scales including at least three similar square scales for obtaining the third side of a right triangle when two sides are known, at least one of said square scales being located on said base and one on said movable part, said scales having identifying means associated therewith, means on one of said base and said movable part pictorially representing the various sides and angles of triangles to be solved directly, and means associated with said representations and with said identifying means indicating the scales to be used for obtaining solutions of said triangles directly.

5. A calculator for solving right triangles and the like directly, comprising a base, a disc rotatably mounted on said base, an inicator rotatably mounted from said base for rotation concentric with said disc for determining alignment of said disc and said base, cooperating concentric scales on said base and said movable part for the direct solution of triangles and the like, said scales having identifying means associated therewith, said disc having a plurality of transparent windows therein and some of the scales on said base being visible through said windows, the scales visible through said windows comprising trigonometric scales, means on said disc pictorially representing the various sides and angles of triangles to be solved directly, and means associated with said representations and with said identifying means indicating the scales to be used for obtaining solutions of said triangles directly, said last named means including lead lines extending from at least one of the sides and angles of a triangle to one of said windows.

6. A calculator for evaluating mathematical functions including a base of sheet material, a disc of sheet material, means for rotatably mounting said disc on said base, said disc and said base both being opaque and said disc having a plurality of transparent windows therein, a transparent indicator rotatably mounted on the disc and base by the means mounting the disc, said indicator being rotatable concentric with said disc, said indicator being transparent and having a hairline radially arranged thereon for aligning portions of said disc and said base, a plurality of cooperating scales on said base and said disc concentrically arranged and plotted for the direct solution of right triangles and for evaluating other mathematical functions, some of the scales on said base being visible through said windows and comprising a sine scale, a cosine scale, a tangent scale and a square scale, others of the scales on said base being disposed radially outwardly from said disc and including a square scale and a logarithmic scale, the scales on said disc comprising a square scale and a logarithmic scale and also a linear scale, said logarithmic scales being plotted against said linear scale, said square scales being plotted against the square roots of said linear scale, and the sine scale, cosine scale, and tangent scale being plotted against the logarithmic scales, all of said scales being alignable beneath said hairline.

7. A calculator as set forth in claim 6 and further including pictorial representations of triangles each having marked thereon at least three values of the various sides and angles, and a lead line running from one of the three values of each triangle to a corresponding alignment mark adjacent one of said windows for reading a corresponding scale through said window.

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