INSTRUCTION BOOK

FOR THE USE OF

"HEMMI" BAMBOO SLIDE RULES

(MANNHEIM TYPE)

SUN

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by

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A Word To Readers

June 1955

In order to simplify the contents of the Instruction Book of Mannheim Type Slide Rule and make it more understandable to the beginners, we have been working continuously on a whole scale revision of the Book.

Now, we have the pleasure to introduce this new revised issue which has attained our original purpose. We trust that this revision will be of great help and a useful guider to the readers.

We also wish to state that this issue has gone through a thorough checking by Mr. T. R. Atkins of The Frederick Post Company, Chicago, Ill., our sole agent in The United States and we hereby express our profound gratitude to them for their generous cooperation.

Hemmi Slide Rule Mfg. Co., Ltd.

President

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PREFACE

Treatment of "Hemmi" Bamboo Slide Rules

1. The slide rule should always be kept in a dry, cool place, strictly avoiding the damp as well as the direct rays of the sun.
2. If the silde rule has to be used in a damp place, or if the slide rule does not move with ease, it is advisable that some paraffine or vaseline be applied to the tongues of the slide and the grooves of its guides or stocks.
3. If the movement of the slide is too loose or too stiff, pull out the slide, hold the upper stock with your right hand and the lower stock with your left, pressing slightly inwards or outwards as the case may require, so that the width of the slide-groove may be adjusted. The thin metal plate fixed to the back of the slide rule, and the narrow groove in the middle of the bottom celluloid plate are provided for this adjustment.
4. Stains on the surface of the slide rule can be removed with a rubber eraser, or a rag moistened with vegetable oil. Alcoholic solutions must be avoided as they tend to dissolve celluloi...

SLIDE RULE DIAGRAM

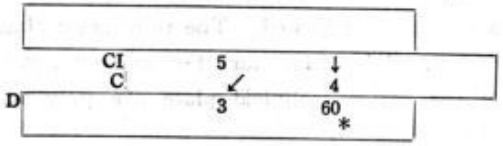
In order that the explanation on method of slide rule operations given in this book can easily be understood, the marks as explained below will be used in the slide rule diagrams.

"Slide Operation" Mark ↙ Shift slide to indicated position of slanted arrow.

"Cursor Operation" Mark ↑ Set cursor hairline on the position of vertical arrow.

"Answer" Mark * Position of answer.

The undergiven diagram shows the operation procedures of shifting the slide so that 5 on the CI scale is in line with the position of 3 on the D scale, then by setting the cursor on 4 of the C scale, 60 on the D scale is to be read under the hairline which will be the required answer.



NOTE :

The extreme right or the left vertical lines in the diagram are not the actual ends of the slide rule but are the position of the index lines.

CHAPTER I

FUNDAMENTAL OPERATION

This Chapter is written to cover the explanation of the fundamental operations which are common to all slide rules. Therefore, it will be necessary for everyone to begin their study with this chapter.

1. GENERAL DESCRIPTION OF A SLIDE RULE

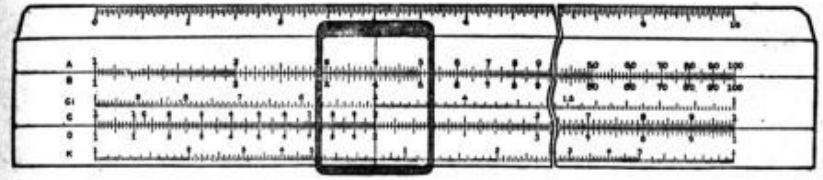


Fig. 1

All slide rules are constructed of two stocks, the upper stock and lower stock, center slide and cursor. The stocks are fastened together, between which the center slide is fitted so that it can be shifted in either direction, and on the top surface of the slide rule is the movable cursor, which is the piece of glass with usually one vertical hairline fixed in a metal rim.

On both the stock and center slide, scales of different graduations are provided each of which is referred to by a certain name or symbol. The first graduation on both ends of C and D is especially called the left or right index of the scale respectively.

On the bottom side of the slide rule, there is an inserted piece of transparent celluloid on which is shown a red line so placed as to correspond with the indexes of scales C and D called the "Rear Index".

2. OPERATION OF SLIDE RULE

To use a slide rule is, in other words, to carry out calculations by means of shifting the slide and / or cursor according to the proper method required. Shifting of the slide is referred to as "SLIDE OPERATION", which is performed to bring the specified graduation of a scale given on the slide in line with the necessary graduation provided on the stock. Shifting of the cursor

is called "CURSOR OPERATION", performed for the purpose to secure the accurate position on a certain scale in line with the given or known graduation by the aid of cursor hairline.

a. Cursor Operation

a. The cursor is shifted with the tip of the thumb.

b. To set the cursor on a position from the right to the left, the cursor is shifted with the right thumb in one big motion until it is close to the required position and then, the left thumb, as shown in Fig. 2 below, is used to steady the movement.

c. Slowly move the cursor until the hairline is exactly on the position required.

This must be practiced again and again so that it is unnecessary to shift the cursor back and forth before the correct position can be secured.

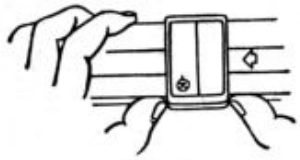


Fig. 2

b. Slide Operation

a. Push the slide with forefinger (thumb is used to hold the slide rule), with the thumb and middle finger moved along the outside edge of the slide rule.

b. At the same time, the other end of the slide is lightly held with the other thumb and forefinger.

c. When the slide is shifted to the approximately required position, the slide is then gradually advanced with the pressure of the finger tips against the stock end by squeezing the two fingers holding the slide.

d. It is necessary that during the entire slide operation, the fingers used to push the slide must not at any time leave the slide rule.

e. Practise this operation by repeating these procedures to secure position on left and right side alternately.

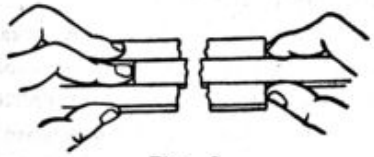


Fig. 3

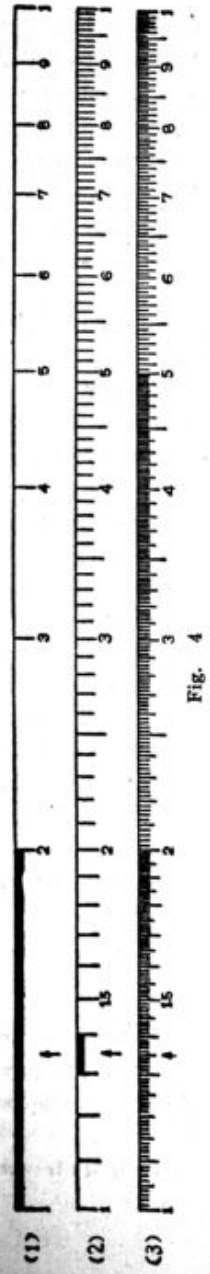


Fig. 4

3. SCALE READING

The slide rule is an instrument for performing calculations with the use of its provided scales. Therefore, it would not be an over-statement to say that the first step in mastering the slide rule is to gain the ability of accurately reading the scales.

Practically all scales are "LOGARITHMIC SCALES" and consequently, the graduations on the scales are not measures of length.

Since the D scale is the basic logarithmic scale, the explanation on scale reading will be provided using the D scale given on the 10 inch slide rule.

The D scale is divided into 9 unequal lengths of which the left edge is numbered as 1 and the right as 10 (or 1), with each division mark in between numbered 2, 3, 4, --- 8, 9, from left to right as shown in (1) of fig. 4, and the lines numbered 1 or 10 on each end are called the index.

The distance between each division mark, which is referred to as the "Primary Length", becomes gradually shorter towards the right. This may seem strange when compared with an ordinary measure, but the reading of the scale is exactly the same.

The primary length is again divided into 10 unequal divisions referred to as the "Secondary Length" in which the division marks are usually not numbered except the 1.5 line as shown in (2) of Fig. 4. However, when reading the scale, it should be read 1, 2, 3, --- from the left as if numbered in the manner reading milimeters from a centimeter measure.

The secondary length is subdivided into "Tertiary Lengths", but being impossible to subdivide these all into tenths, the second lengths are divided into tenths, fifths, or halves as shown in (3) of Fig. 4 depending to its length. It can easily be

understood that one division of the tertiary length divided into tenths equal the value of 1/10, these divided into fifths equal 1/5 and halves of 1/2.

On the scale which is graduated as explained above, any value can be found. For example, to locate the position of 1.35, first remove the decimal point and consider 1.35 as three digits, 1, 3, 5, lined in the same order, which are called Significant Figures. When transformed to significant figures, they can mean 135, 13.5, 1.35 or 0.135 since they are all actually the same 1, 3, 5, and, accordingly, these values are represented by the same graduation on D.

To locate these significant figures 1, 3, 5, the first digits 1 is to be found between 1 and 2 of the primary length (the portion drawn in the heavy line in (1) of Fig. 4) the second digit 3 is in between the secondary length of 3 and 4 of the above primary length (the portion in the heavy line in (2) of Fig. 4) and the third digit 5 is the position of the line in the tertiary length.

As it can be seen, the zone of the significant figures becomes smaller and smaller until finally with the last digit, the exact accurate position is located, as indicated in Fig. 4 with arrows showing this for the significant figures of 135.

When the value exists of 4 significant figures as in 1358, the last digit 8 must be estimated by the eye at a point of 8/10 between 135 and 136, in the manner which is usually done when using an ordinary measures. Therefore, it should be clear that with the use of slide rules, if not of special make, accurate calculations of values with more than 3 significant figures are difficult to be performed nor can this be expected.

The above explanation has been given on the D scale but the reading of the A scale or any other scale is performed in exactly the same manner, although the scale may be divided into either longer or shorter lengths.

4. DECIMALIZATION

Calculations using slide rules are peformed with significant figures and subsequently the results obtained will also be in the form of significant figures. Therefore, it is necessary that the decimal point be placed in the proper position, otherwise, the results obtained will be incorrect.

On slide rule of the old days, symbols such as $\overset{+}{\leftarrow}\overset{-}{\rightarrow}$ or P−1, Q+1, were

being shown for the purpose of decimalization, but the scales of present slide rules have been improved in various ways and methods of operation changed, consequently, the above symbols are no longer in use.

For practical computations used daily, the placing of the decimal point can be performed to a certain extent according to common sense, but even in this event, should the calculation be complicated, it is considered very convenient to do this according to the Rough Calculation method, although it can be carried out by following any method acquired from long experience.

This Rough Calculation method is used to approximate the values with the required decimal point and comparing this to the significant figures obtained by actual calculation, the proper decimalization can be made.

For example, take the calculation of

$\frac{0.058 \times 25.5}{0.032}$ in which, in compliance to the above method, all values are changed to round figures as $\frac{0.06 \times 25.}{0.03}$ Hence, the answer of approximately 50 can be obtained even by mental calculation.

Now, in contrast to 50, with the significant figures 463 secured by actual computation, it is easily seen that the correct answer is 46.3. 46,2(2)

5. MULTIPLICATION AND DIVISION

a. General Rules

A slide rule has two movable parts, the slide and the cursor, and by moving these parts, calculations can be made by either of the two methods of operation, the slide operation, or cursor operation. But in such operations, compliance of the following three factors in actual calculation is required for high computation efficiency.

(1) Always perform the calculations so answers appear on the stock.

(2) Treatment of one value should be made by one operation.

(3) Movement of the slide must be kept to its minimum.

Though the design of any slide rule of today is not sufficient to satisfy all of the above points, improvements are now at least in progress for meeting these requirements.

Concrete procedures for calculations are as follows:

(1) Set cursor on position of multiplicand or dividend on the stock.

(2) Calculation is first made by slide operation.

(3) Then, if necessary, calculate by cursor operation.

By repeating the above procedure of SLIDE OPERATION→CURSOR OPERATION, computations can quickly and efficiently be performed. The following are unchangeable principles of locating the required answer.

(1) When calculation is made by slide operation, the answer will always be found on the stock, in line with the index of C scale.

(2) When calculation is carried out by cursor operation, the answer is always located on the stock under the hairline.

b. Method of Calculation

Both multiplication and division are computed with the use of D and C or CI scales depending on the method of the calculation followed.

(i) Slide Operation Method

(1) Preparation : Set cursor hairline on the value of the multiplicand or the dividend on D.

(2) Operation : Move the slide so that multiplier on CI or divisor on C, whichever may be the case, is under the hairline.

(3) The answer will be the value of the position on D in line with either the left or right index of C.

EXERCISE 1. $2\times3=6$

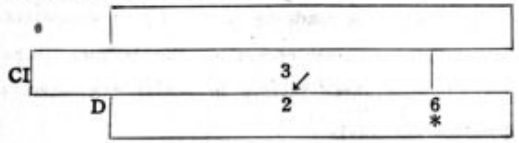


Fig. 5

EXERCISE 2. $3\times5=15$

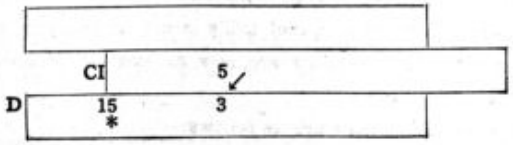


Fig. 6

EXERCISE 3. $8\div4=2$

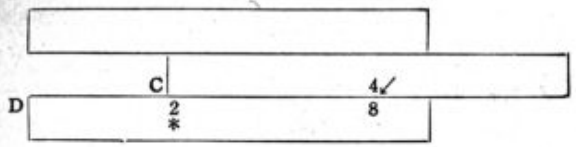


Fig. 7

EXERCISE 4. $24\div6=4$

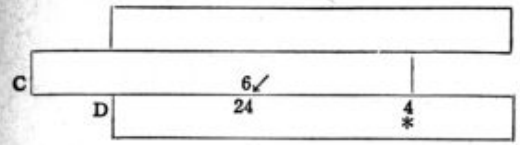


Fig. 8

(ii) Cursor Operation Method

When it is necessary to carry out another calculation after the slide operation is completed, the cursor operation is then used.

(1) Operation : Set the cursor at the multiplier on C or the divisor on CI, whichever is the case.

(2) Answer : The position of the hairline on D is the required answer.

EXERCISE 5. $(14)\times3=42$

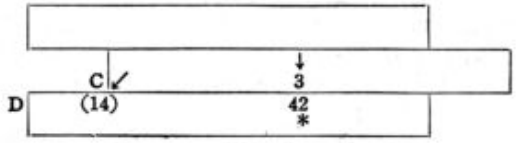


Fig. 9

Note : Number in parenthesis is the answer obtained by slide operation.

EXERCISE 6. $(64)\times4=256$

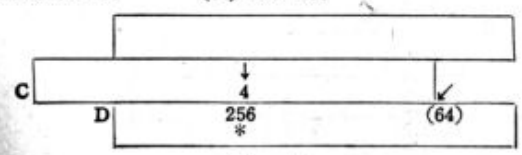


Fig. 10

EXERCISE 7. (4.8) ÷2.5=1.92

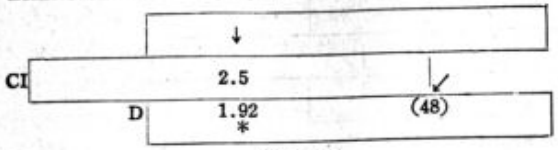


Fig. 11

EXERCISE 8. (2.6)÷3.4=0.765

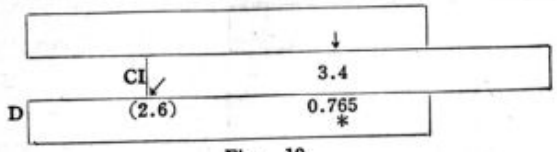


Fig. 12

c. Successive Calculations

In successive calculations of multiplication and/or division, the previously explained slide operation→cursor operation→slide operation ····· must be repeated in turn as shown by the following exercises.

EXERCISE 9. 2.3×1.6×3.4=12.5

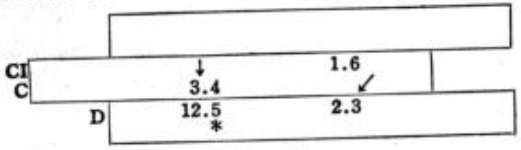


Fig. 13

EXERCISE 10. (2.5×6.4÷4.3=3.72

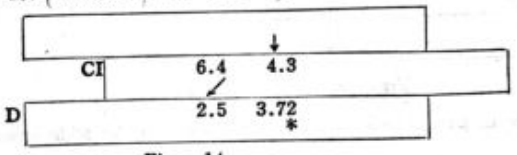


Fig. 14

EXERCISE 11. (8.5 ÷ 5.6)×2.2=~~3.26~~ 3.34

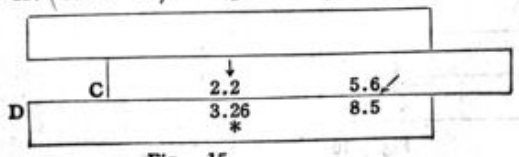


Fig. 15

EXERCISE 12. 18 ÷ 3.7 ÷ 3.2=1.52

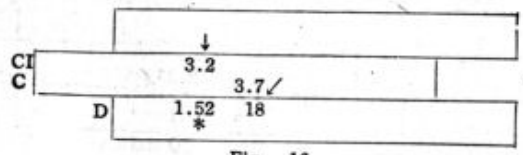


Fig. 16

EXERCISE 13. 1.8×3.6÷2.4÷4.3=0.628

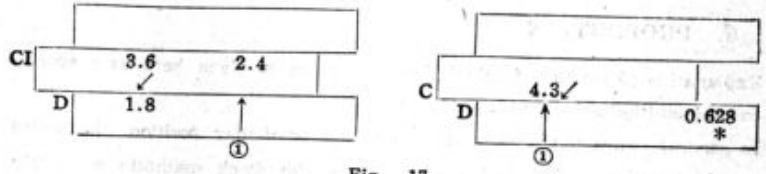


Fig. 17

EXERCISE 14. [(8.5 ÷ 5.4)× 2.1 × 1.45] ÷ 3.4 = 1.41

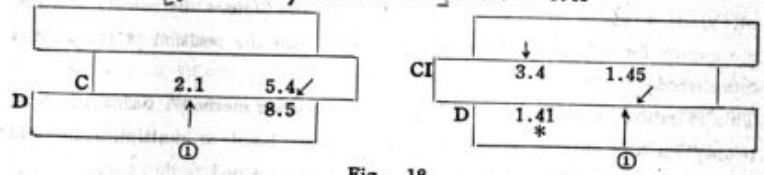


Fig. 18

d. Off Scale

During the course of successive calculations, there may be occasions when the procedure of cursor operation, the position on C or CI at which the cursor must be set falls beyond the extremity of the index of D. This is referred to as "Off scale" and in such cases, it will be necessary to set the cursor on the index of C and carry out the calculatoin by slide operation. However, on slide rules provided with Folded Scales CF and DF, the use of these scales becomes very convenient in case of "Off scale". The method for the use of folded scales will be explained in a later chapter.

EXERCISE 15. 2.63 × 2.38 × 1.24 = 7.76

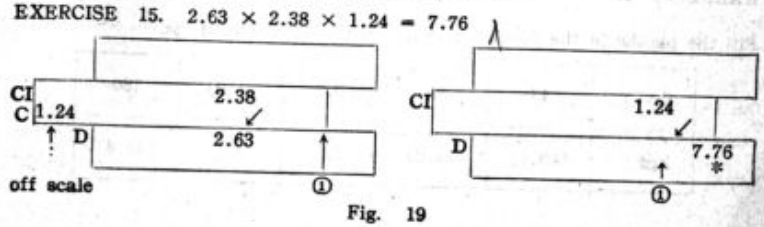


Fig. 19

EXERCISE 16. $4.62 \times 6.26 \div 2.35 = 12.3$

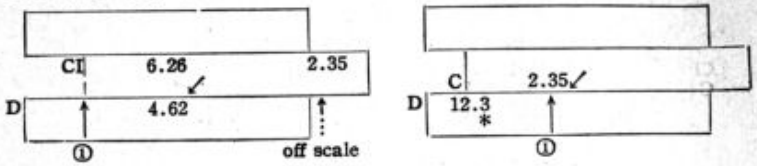


Fig. 20

6. PROPORTION

Explanation of method of calculating proportion is given here as a special case of multiplication and division.

In general, when the slide is set at any one particular position, the scales provided on the slide and the scales on the stock maintain a certain mathematical relationship and thus relationship makes it possible to carry out series of calculations which are on the factors, by merely shifting the cursor for reference of scales concerned, once the position of the slide is established.

This is called "Use of slide rule by reference scale method". Calculations of proportion and inverse proportion which are related to multiplication and division are carried out by this reference scale method.

a. Proportion

Proportion is computed by reference scale method using scales C and D, and the application of this method covers a wide field of calculations, such as Conversion, Index, Proportional Allotment, Percentage, Values in conjunction with Sales or Purchase of commodities, and etc.

EXERCISE 17.

Fill the blanks in the following chart, with 127 kgs = 280 lbs.

lbs	45	63	(50.7)	(150)	180
kgs	(20.4)	(28.6)	23	68	(81.6)

The values in parenthesis are the answers to be obtained.

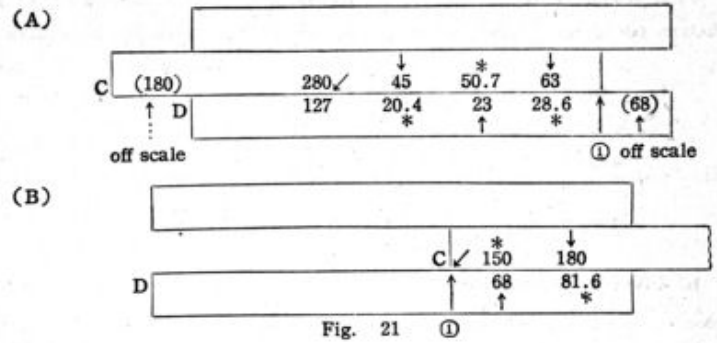


Fig. 21

In (A) above, "Lbs" is set on C and "Kgs" on D.

Now, it is important that once the scales are thus established, the specified scales used to represent "lbs" and "kgs" must not be changed throughout this entire operation.

Since the last 2 values are "Off Scale", it will be necessary to reset the slide before the required answers can be obtained, by setting the cursor on the right index of C and then shifting the slide so that the left index is under the hairline as shown in (B) above.

EXERCISE 18.

Fill in the percentage column of the chart below.

	amount	%
A	3,250 00	59.1
B	1,180 00	21.4
C	1,070 00	19.5
Total	5,500 00	100.0

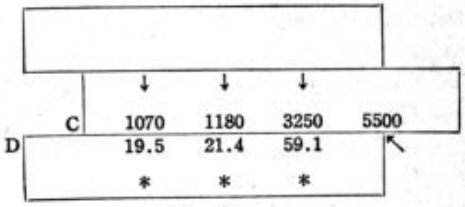


Fig. 22

Note : When the total of the percentage column does not add up to exactly 100 %, it is most practical to make the adjustment with the largest percentage value.

EXERCISE 19.

What would be the prices for 25 pieces of a certain commodity at 13 dollars per dozen ? How many pieces can be purchased for 30 dollars ?

Ans. $ 27.10, 27.7 pcs.

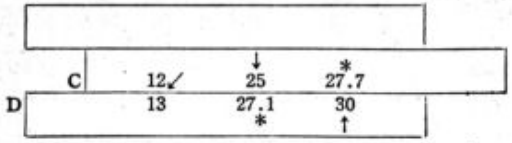


Fig. 23

b. Inverse Proportion

Inverse proportion is calculated by reference scale method using D and CI scales. However, in this operation, it will not be necessary to keep to the use of one specified scale once established for a certain unit, as was required in the operation of proportion, but one can freely switch to the other scale.

EXERCISE 20.

8 men can do a job in 30 days. How many days would 6 men take to do it ?

How many men will be necessary to do it in 12 days ?

Ans. 40 days

20 men.

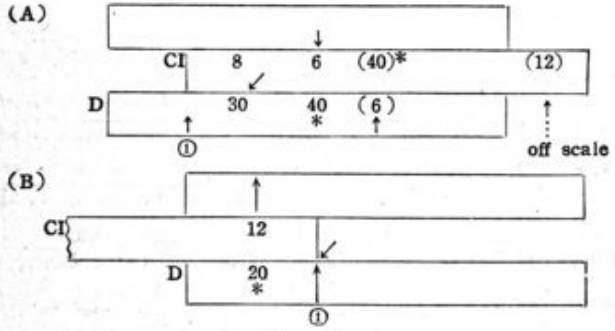


Fig. 24

In (A) above, when obtaining the number of days that would be required for 6 men, it does not matter whether scale D in reference to 6 on CI, or CI in reference to 6 on D is read, since the values obtained are of the same.

Now, when securing the number of men for 12 days, the positionis "Off Scale" and therefore, it will be necessary to reset the indexes as shown in (B) before the calculation can be continued.

7. SQUARE AND SQUARE ROOT

a. Method of Calculation

In problem of square and square root, the reference scale method with scales A and D is used.

The A scale is constructed of two D scales connected and reduced to exactly 1/2 of its original length. Therefore, multiplication and division can be calculated with the use of the A and B scales since the characteristics are exactly the same as of C and D.

EXERCISE 21. $5^2=25$ $\sqrt{64}=8$

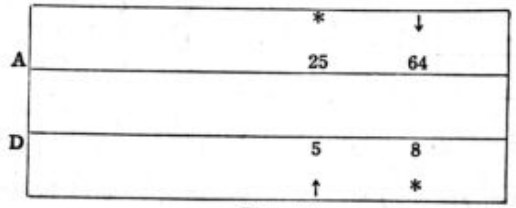


Fig. 25

The placing of the decimal point at the proper position in the obtained square value is determined in the same manner as in multiplication and division, but in calculation of square root, the given value is divided into two digit groups, counting from the decimal point to the direction of the first significant figure, and if the group which includes the first significant figure is smaller than 10, the position must be set in between the section of 1-10 (left half) and if larger than 10, in between 10-100 (right half) on A scale, whereas the decimal point is placed by considering each group of the above grouping as one digit.

b. Multiplication and Division of Square and Square Root

Calculation of $a \times b^2 = c$ and $a \div b^2 = c$ are carried out as shown by the following exercises, but it is important to remember that answers for any calculations with square values involved are always found on A scale.

EXERCISE 22. $15 \times 2.2^2 = 72.6$

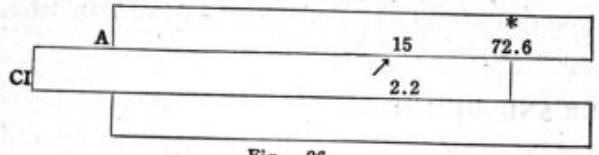


Fig. 26

EXERCISE 23. $8 \div 1.3^2 = 4.72$

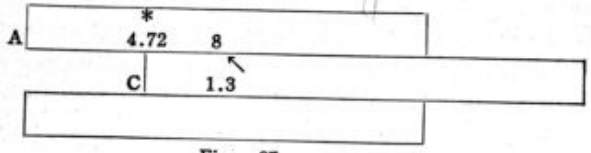


Fig. 27

EXERCISE 24. $23^2 \div 65 = 8.14$

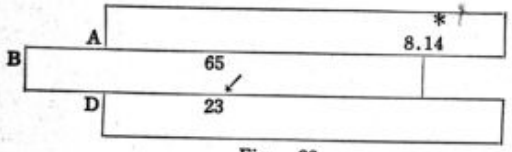


Fig. 28

Multiplication and division with square roots involved in such form as $a \times \sqrt{b}$ and $a \div \sqrt{b}$ is carried out in the manner shown below, and it is a principle that answers are always obtained on D scale.

EXERCISE 25. $18 \times \sqrt{20} = 80.5$

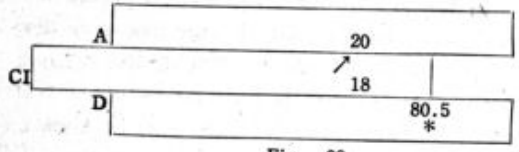


Fig. 29

EXERCISE 26. $\sqrt{12} \div 6.5 = 0.533$

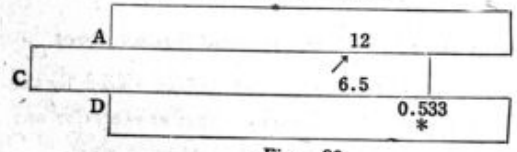


Fig. 30

EXERCISE 27. $8.5 \div \sqrt{24} = 1.735$

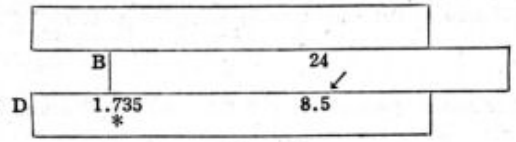


Fig. 31

c. Gauge Mark "c"

The gauge mark "c" is indicated on C scale at the position of 1.128, which is to be used for problems involving diameters and areas of circles. The position of this gauge mark "c" has been derived from the following formula.

$a = \frac{\pi}{4} d^2$ (a = area of a circle, d = diameter) by changing this form.

$a = (\sqrt{\frac{\pi}{4}} \cdot d)^2 = (d / \sqrt{\frac{4}{\pi}})^2$ is obtained.

Now, $\sqrt{\frac{4}{\pi}}$, the denominator in the parenthesis above, corresponds to the value of "c".

EXERCISE 28.

Obtain the area of the circle with the diameter of 2.3″.

Ans. $4.15''^2$

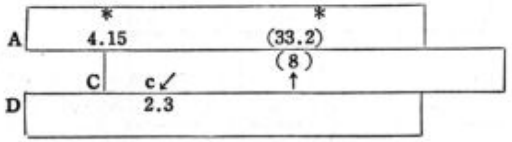


Fig. 32

If the problem is to obtain the value of cylinder with a diameter of 2.3″ and length of 8″, the procedures as in Fig. 32 are first carried out, and then after the cursor is set at 8 on B scale, the position on A under the hairline is read which is the required answer.

Note : With slide rules on which the Gauge Mark "c_1" is provided on C scale near the position of 3.57, this "c_1" mark can be used in place of "c" mark in obtaining the area of a circle when value of the diameter is located at the far right end of D scale by reading the position on A where it is in line with the center index of B. Thus, the shifting of the slide can be greatly reduced.

The below given exercise shows where areas of circles with different diameters can all be obtained at the same time by using Gauge Mark "c".

EXERCISE 29.

Obtain the areas of circles with diameters of 2.5 m, 3.2 m and 5.8m.

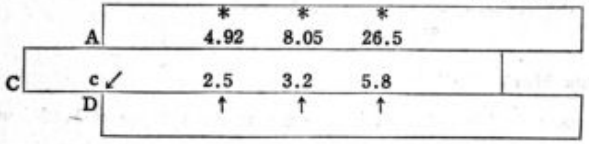


Fig. 33

8. CUBE AND CUBE ROOT

a. Method of Calculation.

K scale which is constructed of three connected D scales reduced to 1/3 its original length is provided for the purpose of calculating problems of cube and cube root, and has the same characteristics as of A and D.

Fig. 34 below shows the method of obtaining cube and cube root by reference scale method using K and D.

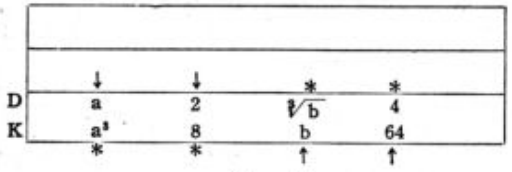


Fig. 34

NOTE : When using the slide rule with K given on the reverse side of the slide, as on No. 2640, the procedures explained on Page 21 must be followed.

When calculating the cube root of the given value *a*, *a* is divided into groups of three digits counting from the decimal point to the direction of the first significant figure, and depending on the number of significant figure, 1, 2, or 3 in the group in which the first significant figure is included, *a* is set in the section 1—10 (left), 10—100 (center) or 100—1000 (right) of K scale respectively.

The position of decimal point in the value of answer is determined upon considering one group as one digit.

b. Multipliction and Division of Cube and Cube Root

The K Scale used for cube and cube root problems being shown on only the stock without showing its corresponding scale on the slide, which is required in multiplication and division, makes it not only very difficult to carry out the various methods of such calculations as performed in square and square root, but its use also will be limited.

The following exercises show the operation of some examples.

EXERCISE 30. $1.25 \times 3.62^3 = 59.2$

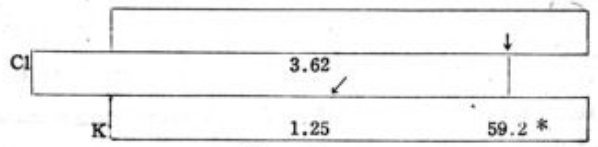


Fig. 35

EXERCISE 31. $250 \div 3.2^3 = 7.62$

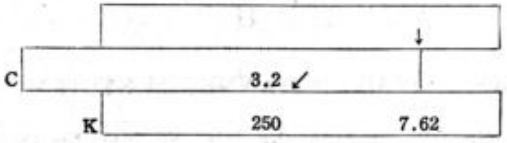


Fig. 36

EXERCISE 32. $8.55 \times \sqrt[3]{16.5} = 21.8$

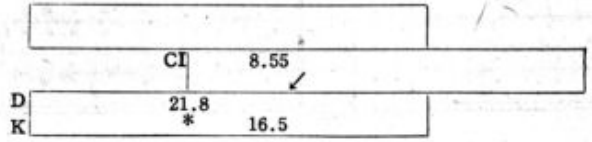


Fig. 37

EXERCISE 33. $25.3 \div \sqrt[3]{268} = 3.92$

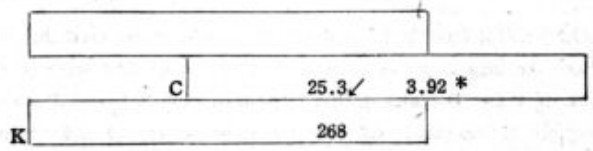


Fig. 38

The above exercise 33 shows the method of performing the calculation by obtaining the reciprocal for the answer of $\sqrt[3]{268} \div 25.3$.

C. Powers of $\frac{3}{2}$ and $\frac{2}{3}$

With slide rules that have K and A scales, calculations of $a^{\frac{3}{2}}$ and $a^{\frac{2}{3}}$ can be made by reference scale method using these two scales.

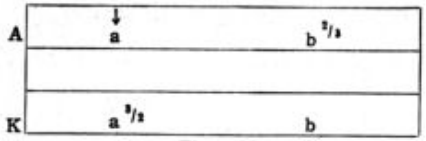


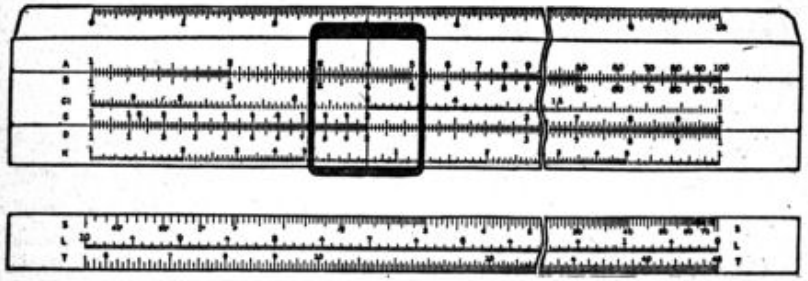
Fig. 39

NOTE : Power of 3/2 is the same as 1.5 or $(\sqrt{a})^3$, cube of square root, and 2/3 is $(\sqrt[3]{a})^2$, square of cube root.

CHAPTER II

SLIDE RULE "IMPROVED MANNHEIM SYSTEM"

No. 30, No. 32, No. 34R, No. 34RK, No. 50W, No. 2640, No. 40RK



The "MANNHEIM SYSTEM" is the basis for slide rules used throughout the world for the longest period of time. Slide rules at first were provided with only A, B, C and D scales on the front face, and S, L and T scales on the reverse face of the slide, but with the improvement of slide rules, it is usual to have CI and K scales in addition on the front face.

1. MULTIPLICATION, DIVISION, PROPORTION, SQUARE and CUBE

Calculations of the above have already been explained in the previous chapter of fundamental operation, and as the explanation has been based on this Mannheim System, it will not be necessary to repeat it here.

However, there are some models of this Mannheim System which lack the K scale, such as No. 30, No. 32, No. 34R and etc., and there are also others that have the K scale given on the reverse side of the slide as on No. 2640 for which the method of use is explained below.

K Scale on No. 2640 Slide Rule

Slide rule No. 2640 differs from others in having the K scale on the reverse side of the slide, instead of on the front face, and therefore, for calculation of cube problems, the following procedures must be used.

When obtaining the cube value a^3, a on C is set at the index of D and the required answer is the value found on K under the rear index line.

To obtain $\sqrt[3]{a}$, the procedure in reverse is followed, and for the combined calculation of multiplication or division and cube or cube root, remove and reinsert the slide reverse side up and carry out the operations as shown in the following exercises.

EXERCISE 34. $1.25 \times 3.62^3 = 59.2$

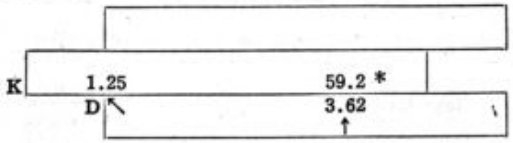


Fig. 40

EXERCISE 35. $250 \div 3.2^3 = 7.62$

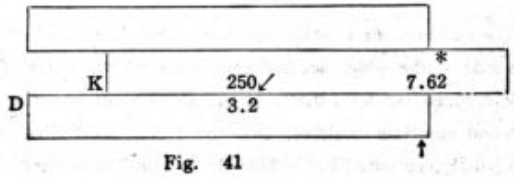


Fig. 41

EXERCISE 36. $8.55 \times \sqrt[2]{16.5} = 21.8$

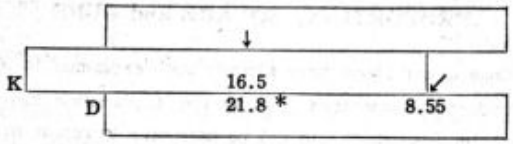


Fig. 42

2. LOGARITHM

a. Common Logarithm

Common logarithm to the base 10 includes integers, called characteristics, and decimal fractions, called mantissas. It is usual that a slide rule is provided with an equally graduated L scale in order to obtain mantissas of common logarithms.

Characteristics can be mentally calculated from the following formula:

(number of places above decimal point of given number) − 1

In other words, one less the number of places at the left of the decimal point. Now, if the given number is of m places right of the decimal point, its characteristic $\bar{m}$ is placed before or left of the mantissa.

For convenience, $\bar{m}$ can be expressed as $-m$.

EXERCISE 37. $\log_{10} 2.5 = 0.398$ $\log_{10} 0.025 = 2.398$ $-1,60206$

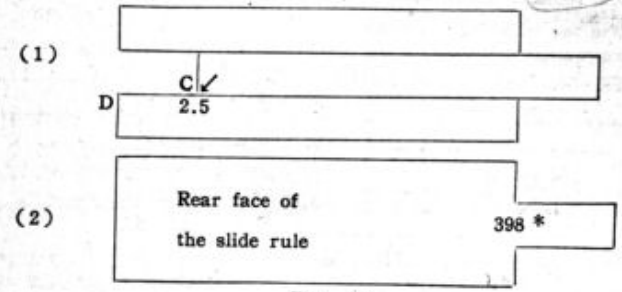


Fig. 43

Note :

When the numbers on L scale are graduated from the left to right on the reverse side of the slide, set 2.5 of C scale on the index of D scale.

In 2.398 obtained for $\log_{10} 0.025$ of the above exercise, the characteristic is negative and mantissa positive, and therefore, multiplication or division cannot be directly computed but $0.398 - 2 = -1.602$ must first be calculated.

Should it be desired that this value be directly obtained with the slide rule instead of the procedure shown in (1) above, set 2.5 on the C scale against the index of D.

NOTE : On slide rule No. 2640, the l scale is given on the front face instead, and since it is constructed to correspond to A scale, the value of $\log_{10} a$ can be obtained on the l scale under the hairline when the cursor is set at a on the A scale.

b. Anti-logarithm

In order to carry out $\log_{10}^{-1} a = x$, the procedures shown above are followed exactly in the reverse manner, obtaining the mantissa only upon omitting the characteristic and by setting this on the L scale, the significant figure for x can then be found on D. The position of the decimal point is one place added to the characteristic of logarithm a.

c. Natural Logarithm

Natural logarithm $\log_e a$ to the base e can be gained by multiplying 2.3026 with common logarithm according to the following formula.

$$\log_e a = 2.3026 \cdot \log_{10} a$$

d. Exponent

For calculation of A^n, the following three steps in operation are required.

(i) Find $\log_{10} A$ using D and L scales.

(ii) Calculate $n \times \log_{10} A$ by use of scales D and CI.

(iii) Answer is secured by computing $\log_{10}^{-1} (n \times \log_{10} A)$ with L and D.

3. TRIGONOMETRIC FUNCTION

Slide rules of the Mannheim System (except No. 2640) are provided with two scales, S(sine) and T (tangent) on the reverse side of the slide for calculations of trigonometric functions. The range of scale S is $35' - 90°$ and T scale $6° - 45°$. S scale is graduated as to be able to obtain $\sin \theta$ with the cooperative use of A and B scales, and the values obtained lie between 0.01 and 1.0. However, T scale is graduated to correspond with C and D scales instead of A and B, and the values of tangent obtained lie between 0.1 and 1.0.

a. Sine

EXERCISE 38. $\sin 35° = 0.574$ $\operatorname{cosec} 35° = 1.74$

$48 \sin 35 = 27.5$ $\dfrac{15}{\sin 35°} = 26.1$

When the slide is set so that the position of 35° on S scale is in line with the right rear index, all the above values can be obtained with the cooperative use of A and B and the cursor.

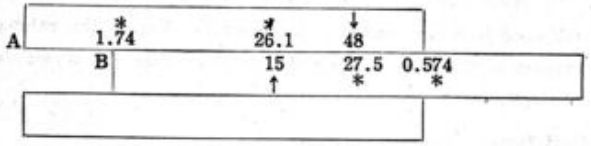


Fig. 44

NOTE : With slide rule of which the angle range of S scale is 6° – 90°, the scale is graduated to correspond with C and D scales and therefore, the calculation of the above is carried out with use of C and D instead of A and B scales. For full explanations of this arrangement of scales, see (3) -(a) (d) (e) of Chapter III given on the Rietz System Slide Rules.

b. Tangent

EXERCISE 39. $\tan 14° = 0.249$ $\cot 14° = 4.01$

$26 \tan 14° = 6.48$ $\dfrac{6.4}{\tan 14°} = 25.7$

14° on T scale is set at the left rear index and answers are obtained by cursor operations as shown below:

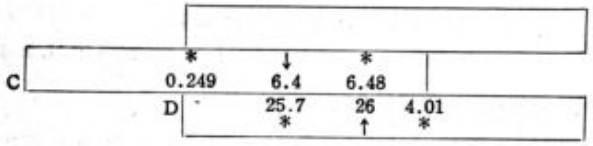


Fig. 45

For tangent angles of over 45°, the calculation can be carried out with T scale by applying the below equation.

$$\tan \theta = \frac{1}{\tan (90° - \theta)}$$

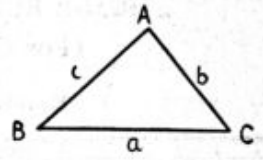
c. Cosine

In computing cos θ, equation of $\cos \theta = \sin (90° - \theta)$ is used, wherein the complementary angle $(90° - \theta)$ must first be obtained. Then, the calculation can be carried out with the use of S scale.

d. Sine Proportion

When the opposite side of the angles A, B and C of a triangle are expressed as a, b and c respectively, the following equation will exist.

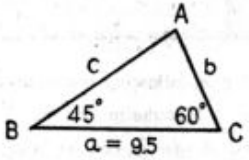
$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$



The above is called the Law of Sines and is very important in calculations of trigonometric functions. However, by using a slide rule, it can be carried out very simply by reference scale method of S and A scales, but first, the slide must be removed and reinserted with the reverse side up.

EXERCISE 40.

Obtain b and c of Fig. 46 Ans. b = 6.96 c = 8.52



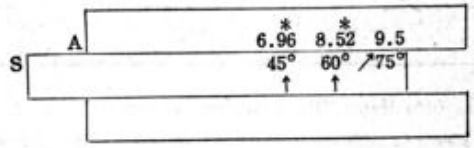


Fig. 46

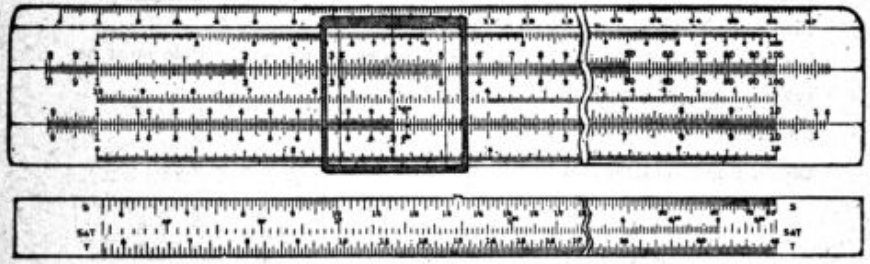
NOTE : The angle of A is first computed by A = 180° – (B + C) and then the procedures shown above are followed.

CHAPTER III

SLIDE RULES "RIETZ SYSTEM"

(For General Technicians)

No. 64, No. 66, No. 74, No. 70



Slide Rules "Rietz System" are manufactured with the following improvements in addition to the previously explained "Improved Mannheim System."

(1) Extended divisions to A, B, C and D scales are shown in red on both ends which are called "Surplus Graduations."

(2) L scale is given on the front face.

(3) Both S and T scales are arranged corresponding with C and D scales, and S&T scale is provided in addition.

(4) An indicator with three hairlines is provided.

1. MULTIPLICATION, DIVISION, PROPORTION, SQUARE AND CUBE

For calculations of the above, the A, B, CI, C, D and K scales are used according to the methods explained in Chapter I, the method being exactly the same except that with the use of the surplus graduations, in multiplication, division, and proportion, the trouble of resetting the slide owing to "off scale" that frequently occurs during these operations can be reduced, whereby the calculation efficiency is increased.

Method of Using The Three Hairline Cursor

When calculating the area of a circle with the diameter given, it has already been explained in (7)-(c) of Chapter I that Gauge Mark "c" on C scale is used, but when using the three hairline cursor, the required value can easily be obtained by merely setting the center hairline at the position of the diameter on the D scale and read the A scale under the left hairline, since the hairline is so placed as to equal the distance between the Cauge Mark "c" and the left index. In other words, such calculations can be performed by the cursor operation alone without any shifting of the slide.

2. LOGARITHM

Since L scale is provided on the front face, calculation of logarithms can be carried out by cursor operations according to referencc scale method. When value "a" is set on the D scale, the position under the hairline on the L scale is the value of log a. For full explanation, read (2) of Chapter II.

3. TRIGONOMETRIC FUNCTION

a. Sine and Tangent

Three trigonometric scales S, T and S&T, are located on the reverse side of the slide for trigonometric functions. These scales are operated when obtaining sines and tangents by corresponding with C and D scales. When S and T scales are operated, the values obtained always lie between 0.1 and 1.0.

EXERCISE 41.

$\sin 43° = 0.683$ $\quad$ $\operatorname{cosec} 43° = 1.464$

$53 \sin 43° = 36.2$ $\quad$ $2.8/\sin 43° = 4.1$

Set 43° on S scale under the right rear index, and all the above values can be obtained by cursor operations with the cooperative use of C and D scales as shown in Fig. 47.

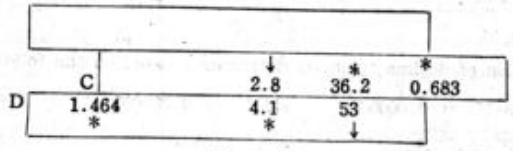


Fig. 47

Calcuations relating to tan θ are made by using T scale following the same manner as mentioned above. For cosine, and tangent angles of over 45°, see

(3)—(b) (c) of Chapter II.

b. Use of Scale S&T

The scale S&T is used when obtaining sines and tangents of a small angle between the range of 35′ and 5° 30′ and its method of use is the same as with S and T scales. By setting θ on the S&T scale at either the left or right rear-index, the position on the C scale in line with the index of D scale is the approximate value of the sin θ or the tan θ, with the decimal point placed between 0.01 and 0.1.

c. Use of ρ° ρ' ρ'' $\rho_{,,}$

When the angle is of a smaller value than the range for scales S or S&T, the operation can be carried out by assuming the unit of radian converted from degrees to be equal to the value of the sine or the tangent since difference will not exist in the result of actual operation.

For such cases are these Gauge Marks ρ°, ρ', ρ'', and $\rho_{,,}$, given on C and D scales, indicating the value of angle of 1 radian by degrees, minutes and seconds.

$$1 \text{ Radian} = \frac{360^\circ}{2\pi} = 57.29^\circ\ (\rho^\circ) = \frac{360 \times 60}{2\pi} = 3437.75'\ (\rho')$$

$$= \frac{360 \times 60 \times 60}{2\pi} = 206265''\ (\rho'') = \frac{400 \times 100 \times 100}{2\pi}$$

$$= 636620''\ (\rho_{,,})$$

EXERCISE 42.

$\sin 25' = 0.00727$

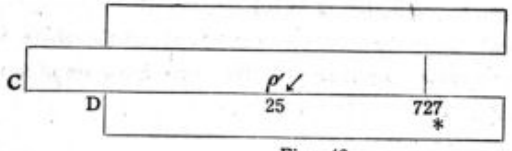


Fig. 48

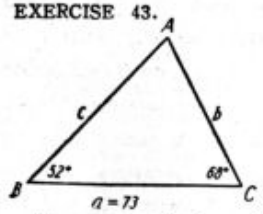
The position of decimal point is determined based on the followings:

$\sin 1' \fallingdotseq 0.0003$ $\quad$ $\sin 1'' \fallingdotseq 0.000005$

d. Sine proportion

Sine proportion can be calculated in the same manner as explained in (3) - (d) of Chapter II, but use D scale instead of A.

EXERCISE 43. Obtain b and c of Fig. 49



$\angle A = 180^\circ - (52^\circ + 68^\circ)$
$= 60^\circ$

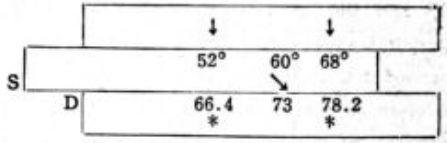
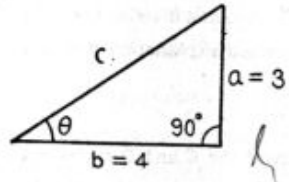


Fig. 49

Ans. b = 66.4
c = 78.2

e. Solution of Right Triangle

EXERCISE 44. Determine c and θ of the below.



Ans. $\theta = 36^\circ 50'$ c = 5

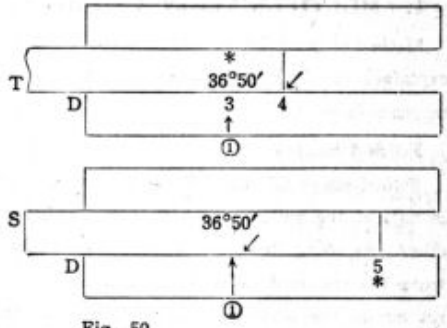
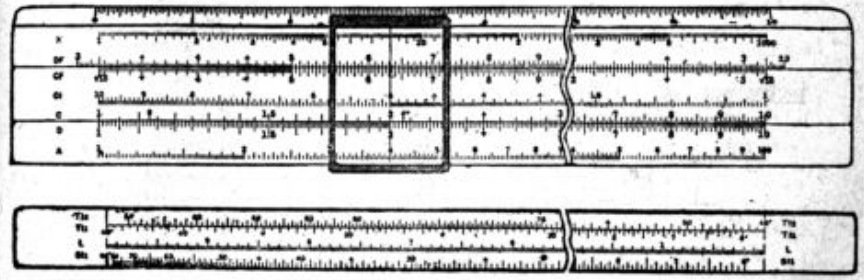


Fig. 50

CHAPTER IV

SLIDE RULES WITH FOLDED SCALES

No. 2634, No. 45 (No. 2664)



The slide rules explained in this chapter are provided with folded scales CF and DF, in addition to CI, C and D scales, for the purpose of simplifying multiplication and division which cover the majority of calculations carried out by the use of slide rules. However, since only the A scale is given on the stock with no corresponding scale on the center slide for calculations of square problems, it is inconvenient for operations involving squares when compared to slide rules which are provided with both A and B scales. On this type of slide rules, SI and TI which are inverse scales of S and T, are given for trigonometric functions, and with the use of these scales, high efficiency in obtaining solutions to right triangle problems is achieved.

1. MULTIPLICATION AND DIVISION

Method of using CI, C and D scales for multiplication and division has been explained in (5) of Chapter I and therefore repeated explanation will not be made here.

Folded Scales

Folded scales CF and DF are the reconstruction of the C and D scales cut in half at the middle which is $\sqrt{10}$, with each half interchanged with the other. By using these scales, according to the method shown in Exercise 45, when the required value on C scale happens to fall "OFF SCALE" during the cursor operation for multiplication, the trouble of shifting the slide will be avoided

EXERCISE 45. $3.4 \times 6.8 \times 5.3 = 122.5$

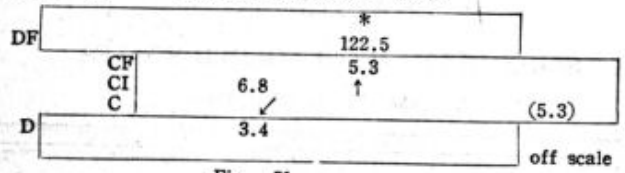


Fig. 51

EXERCISE 46. $(72 \div 16) \times 24 = 108$

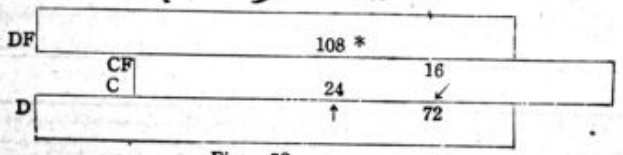


Fig. 52

In the above exercise, should $72 \div 16$ be calculated with the C and D scales, it will be necessary to draw the slide out over half its length and consequently, the multiplier 24 of the next calculation will be "OFF SCALE" on both C and CF scales. But with combined use of the folded scales as shown above, shifting of the slide can be greatly reduced and the falling "OFF SCALE" can be completely prevented. This method is called "CROSS OPERATION."

Location of answer when calculated by Cross Operation

(1) When the folded scale is used an odd number of times, the answer will be found on the DF scale.

(2) When the folded scale is used in an even number of times, the answer will be found on the D scale.

2. PROPORTION

a. Proportion

Proportion is carried out in the same manner as explained in (6) of Chapter I, and with the use of CF, DF in addition, shorter movements can be made, avoiding any occasions of values falling "OFF SCALE." For full explanation, read Chapter I-(6)

EXERCISE 47. Calculate the percentage of the chart below:

	Amount	%
A	$ 2,540	46.9
B	1,270	23.4
C	630	11.6
D	980	18.1
Total	5,420	100.0

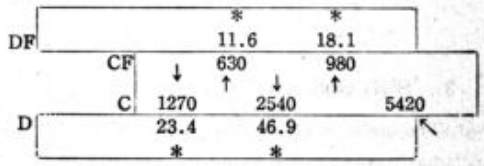


Fig. 53

In calculations of proportion, should the slide be drawn out over half its length, "OFF SCALE" will occur with even the folded scales. For such occasions, it is better to set the slide, at the beginning, with the use of CF and DF scales instead of C and D scales.

The following exercise is an example.

EXERCISE 48. What will the price of 25 pcs. be at $ 65.00 per dozen? How many can be purchased with $ 300.00?

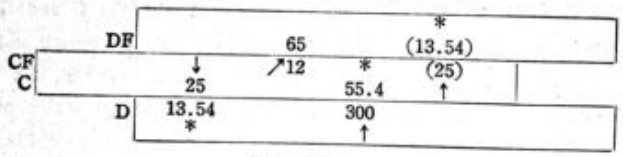


Fig. 54

b. Inverse Proportion

As explained in (6) of Chapter I, CI and D scales are used for calculations of inverse proportion, but when the folded scales are provided, the use of DF and CI scales will absolutely prevent all "OFF SCALE" which makes them very useful. However, it is important that the slide should never be drawn out over half its length when being set at the beginning of the operation.

EXERCISE 49. 30 men can do a job in 18 days. How many days would 65 men take to do it? How many men would be required to do it in 15 days?

Ans. 8.3 days, 36 men.

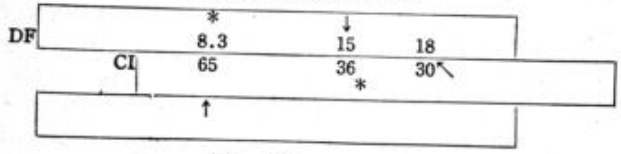


Fig. 55

3. SQUARE AND CUBE

The methods of obtaining squares and square roots and the placing of decimal points are the same as explained in (7) of Chapter I, but since the scale B is not provided, it is at a disadvantage in combined calculation of multiplication or division. The Exercise 24 and 27 of Chapter I must be carried out by the operations explained below.

(1) In Exercise 24, the same operation as for multiplication and division is carried out upon assuming

$$23^2 \div 65 = \frac{23 \times 23}{65}$$

(2) For Exercise 27, $8.5 \div \sqrt{24}$ is calculated by computing $\sqrt{24} \div 8.5$ and obtaining its reciprocal as the operations shown below.

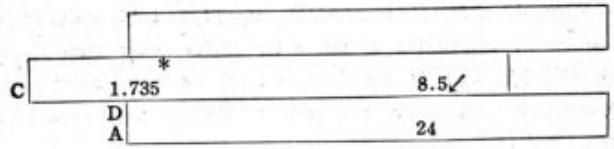


Fig. 56

Cube and cube root calculations are carried out in exactly the same manner as given in (7) of Chapter I.

4. LOGARITHM

The method of solving logarithmic problems with the use of L scale is exactly the same as explained in (2) of Chapter II.

5. TRIGONOMETRIC FUNCTION

SI and TI (TI_1, TI_2) scales are provided for trigonometric functions and are inverse scales of S and T. The outstanding features of these scales are that, not only can they be used for obtaining values of trigonometric function, but also for combined calculations of multiplication or division in relative problems, and especially for solutions to right triangle problems.

a. Sine, Tangent

EXERCISE 50. $\sin 35° = 0.574$ $\quad \text{cosec } 35° = 1.74$

$5.6 \sin 36° = 3.22$ $\quad \dfrac{\sin 35°}{2.8} = 0.205$

$\dfrac{38}{\sin 35°} = 66.2$

The above calculations can all be solved by cursor operation alone after once setting 35° of SI scale at the rear index as shown below.

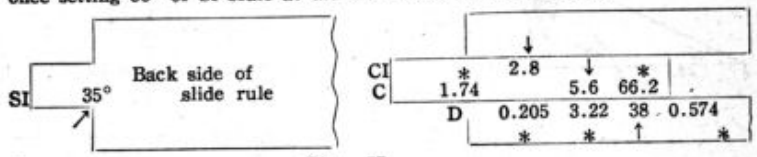


Fig. 57

Values of tan θ, and also combined calculations of multiplication or division in related problems are carried out by the same method as shown above with the use of TI scale.

NOTE : When the slide rule is provided with TI_1 and TI_2 scales for use in tangent problems, calculation of tan θ for angles larger than 45° can be performed with TI_2. This TI_2 scale is so constructed as to correspond with C and D scales, but when using this scale, the decimal point must be placed in between 1 and 10.

The method of calculating sin θ ($\fallingdotseq$ tan θ) for angles smaller than 6° by using Gauge Marks $\rho°$, ρ' and ρ'' is explained in (3)-(c) of Chapter III.

b. Sine Proportion

Remove and reinsert the slide with reverse side up and the left end at the right, thus, the relationship of the D scale with SI and TI scales will be the same as with S and T scales, Therefore, sine proportion can be calculated in the same manner as already explained in (3)-(d) of Chapter Ⅲ. But it is not often that, to use scale SI following the equation of inverse proportion given below, is much more convenient in actual calculation.

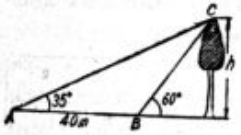
$$a \cdot \sin B = b \cdot \sin A$$

$$b \cdot \sin C = c \cdot \sin B$$

EXERCISE 51.

When observing the top of a certain tree from position A, the angle of elevation θ was 35°.

Advancing 40 meters toward the tree to position B, the angle of elevation θ observed, was 60°. What is the height of this tree ?



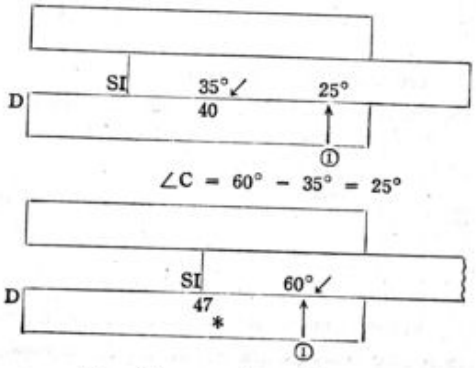


Fig. 58 Ans. 47

c. Solution of Right Triangle

Solution of right triangles can be greatly simplified by use of SI and TI scales. The below diagram shows the operation of related base angle θ and sides a, b, c.

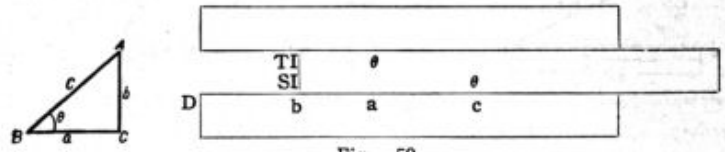


Fig. 59

EXERCISE 52.

Find θ and c of the right triangle with the given a = 5.4, b = 3.2.

Ans. θ = 30°45′

c = 6.26

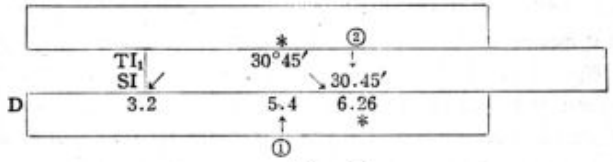


Fig. 60

This method of calculation is also applied to the form

$c = \sqrt{a^2 \pm b^2}$ which is the Pythagorean Theorem.

EXERCISE 53. $\sqrt{1.8^2 + 3.5^2} = 3.93$

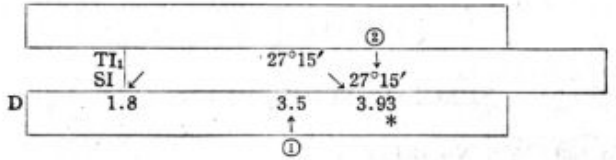


Fig. 61

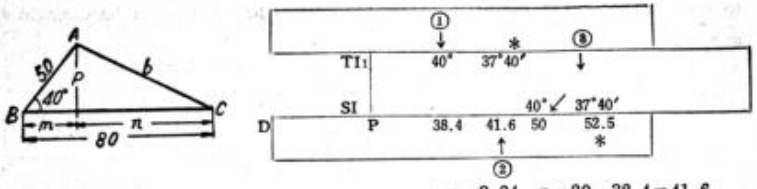
d. Solution of Oblique Triangle

By use of this slide rule, solutions of oblique triangles, when any two sides and its included angle are given, can easily be gained with the application of the relationships as shown in Fig. 62.

EXERCISE 54. Obtain ∠C and b of the triangle below.

Ans. ∠C = 37°40′

b = 52.5



m = 3.84 n = 80 − 38.4 = 41.6

Fig. 62

In such calculations, the original oblique triangle is divided into two right triangles, and as the perpendicular P is common, the answer is gained in the same manner as in the preceeding problem.

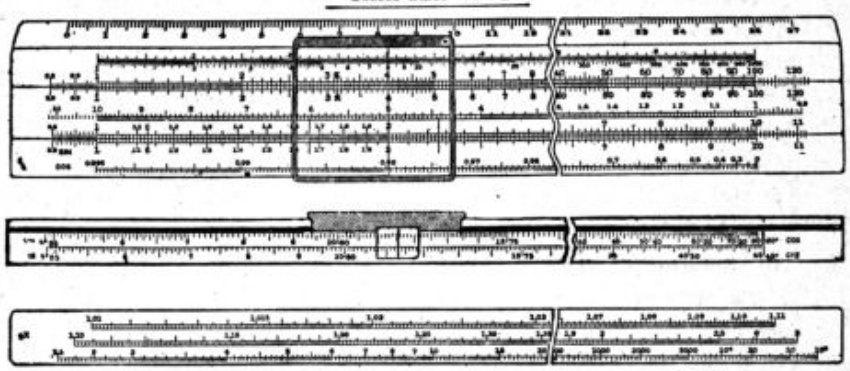
By way of interpretation, the calculation of Exercise 54 can also be considered as being the subtraction of two vectors, 50 and 80, when the phase angle difference is 40°. Addition of these two vectors, using 80 + 38.4 instead of 80 − 38.4, is easily found by following the same procedure. But in this case, it is important that DF scale is used in place of D scale. From the explanation given above, it can be understood that the use of SI and TI scales gives an advantage of calculations of right triangle problems, and also that they can be applied to conversion of coordinates in calculations of vector or complex numbers.

CHAPTER V

SPECIAL SLIDE RULES

1. No. 130 (10″) No. 136 (6″) "DARMSTADT" SLIDE RULES

This type of slide rule is provided with log log scales for exponential calculations and cos scale for calculating cos θ, in addition to the usual scales, and has the highest degree of efficiency among the Mannheim type slide rules.



a. Multiplication, Division, Proportion. Square and Cube.

As these slide rules are provided with the same C, D, CI, A, B and K scales as on the RIETZ SYSTEM explained in Chapter III, read that chapter for a full explanation on the method of these calculations.

There are three hairlines provided on the cursor of which the distance between the center and the right line is the same as that between the Gauge Mark "c" on C scale and the left index. This is used for obtaing the area of a circle directly from the diameter as explained in (1) of Chapter III. The two outer lines cover the same distance between the right index of D scale and the position of 736 (746): which is used for converting horse power to kilo watts or vice-versa, with the left line representing value of K.W. and the right line representing H.P.

b. Trigonometric Function

(i) Sine and Tangent

Sin and tg scales given on these slide rules differ from S and T scales provided on other rules, as the angle is shown by degree and its fractions, and the complementary angle is given in red. These scales are located on the side of the stock and calculations can be carried out by the operation of the cursor with reference to scale D.

EXERCISE 55. sin 23.4° = 0.476 tan 32.4° = 0.634

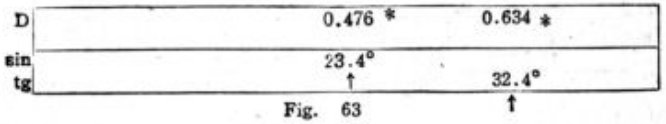


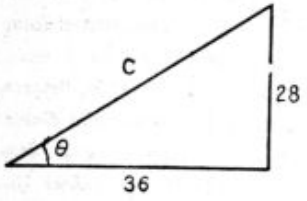
Fig. 63

Combined calculation of trigonometric functions and multiplication or division can be carried out in the same manner as in an ordinary multiplication or division problem since the values of sin θ or tan θ obtained on the D scale are considered, at the same time, to bethe multiplicand or dividend as shown in the above exercise. Sine proportion can be accomplished in the same manner as explained in (3)-(d) of Chapter III by use of C and sin scales. It is also possible to carry out the equations of inverse proportion explained in (5)-(b) of the previous Chapter by using scales CI and sin.

(ii) Solution of Right Triangle

The relationship between CI and sin, tg scales of this slide rule is the same as that between D and SI, TI, explained in (5)-(c) of Chapter IV, and consequently the solution of right triangles can easily be achieved.

EXERCISE 56. Obtain θ and c of the below triangle.



Ans. θ = 37.9° C = 45.7

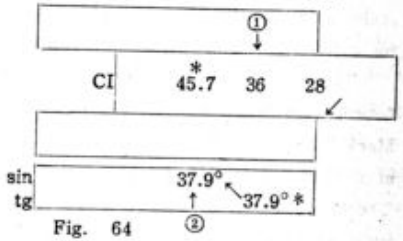


Fig. 64

For other explanations, read (5)-(c) and (5)-(d) of Chapter IV.

(iii) Cos Scale

With the use of the cos scale in reference to the angle on the sin scale, values of cos θ can be directly calculated when using this slide rule. $\sqrt{1-a^2}$ and $\sqrt{1-a}$ can be calculated very simply from equation $\sin^2\theta + \cos^2\theta = 1$ with reference use of D or A scale.

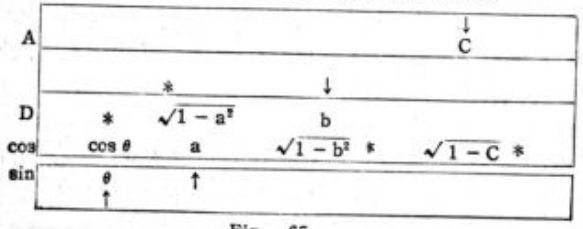


Fig. 65

NOTE : The above is limited to the fact that the value of "a" is always a fractional number and therefore, the right index of A, D and etc. must be assumed to be 1.0

c. Logarithm and Exponent

For the purpose of calculating A^x, the log log scales, which ranges from 1.01 to 10^3, are given on the reverse side of the slide, divided at the values of "e" which is the base of natural logarithms, and $e^{0.1}$. The three scales are usually referred to as LL3, LL2, LL1 respectively. To use these, the slide must be removed and reinserted with the reverse side up.

Common logarithms can be gained with the use of L scale as explained in (2) of Chapter III but the use of log log scales allows the covenience of obtaining not only the mantissa but also the characteristic at the same time.

Natural logarithms can be calculated by the operation of the cursor with reference use of the D scale, when the slide is set at its proper position.

EXERCISE 57. $\log_{10} 1.75 = 0.243$ $\log_{10}{}^{-1} 1.34 = 21.8$

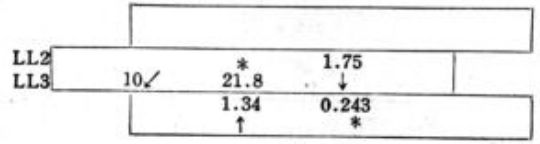


Fig. 66

EXERCISE 58. $\log_{10} 1.23 = 0.0898$ $\log_{10}{}^{-1} 0.64 = 4.37$

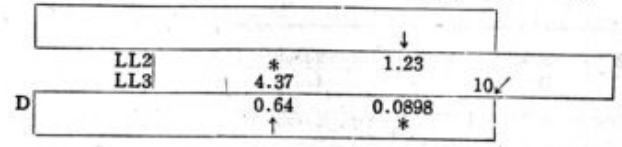


Fig. 67

EXERCISE 59. $e^{1.5} = 4.48$ $e^{0.15} = 1.162$

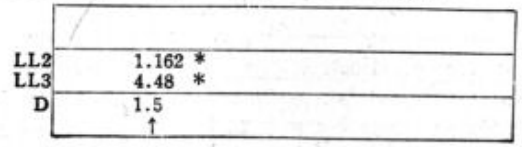


Fig. 68

EXERCISE 60. $3.2^{2.4} = 16.3$

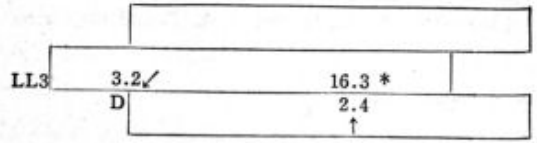


Fig. 69

EXERCISE 61. $1.75^{3.6} = 7.5$

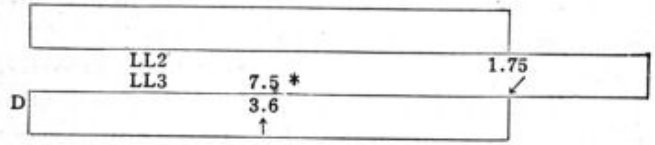


Fig. 70

EXERCISE 62. $3.76^{0.45} = 1.815$

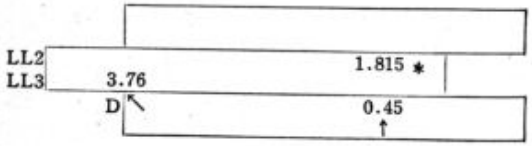


Fig. 71

EXERCISE 63. $\sqrt[4.3]{235} = 3.56$

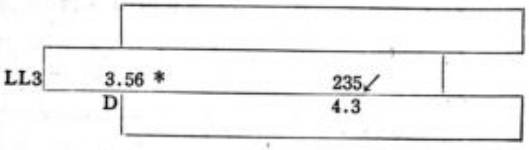


Fig. 72

EXERCISE 64. $\sqrt[5.2]{1.5} = 1.081$

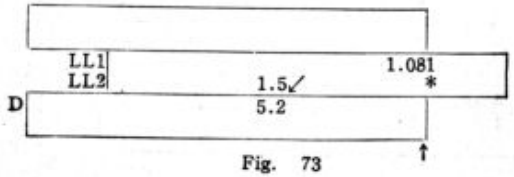
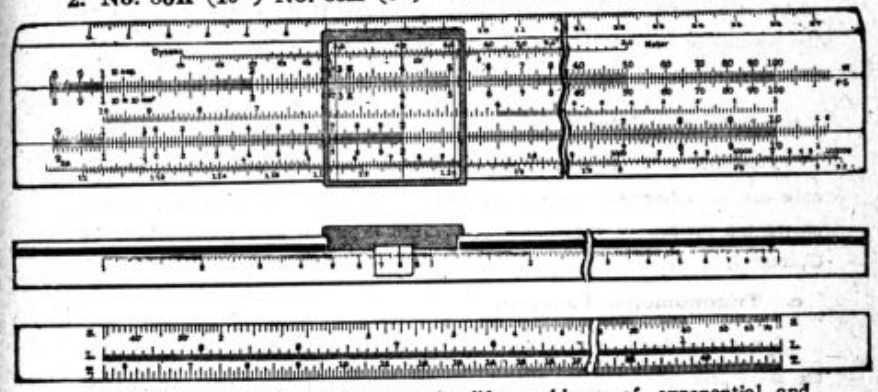


Fig. 73

In the above operations, the position where the answer on the log log scale is to be found maintains a certain relationship with the number of the digits above the decimal point in the value set on the D scale and also when the slide is shifted to the right or the left.

2. No. 80K (10″) No. 86K (6″) "ELECTRO" SLIDE RULES



This slide rule is designed to simplify problems of exponential and special calculations required in electrical engineering, by providing, in addition to the usual scales, two log log scales LL_2, LL_3, on the bottom of the front face and also Efficiency Scale and Voltage Drop Scale both given on the top of the front face.

a. Multiplication, Division, Proportion, Square, and Square root

(i) The use of the A, B, CI, C and D scales for the above calculations is exactly the same as the methods explained in Chapter III, given on the Rietz System Slide Rule.

(ii) On the A and B scales, a line numbered 28.7 and a gauge mark "M" given at the approximate position of 3.18 can be seen. 28.7 is half the value of the specific conductivity of electrolytic copper, and gauge mark "M" represents $1/\pi \fallingdotseq 0.318$.

(iii) Three Line Cursor

The cursor of this slide rule is provided with three hairlines. The distance between the center line and right line is the same as that between the left index and the gauge mark "c" of scale C which is used for calculation of diameters and areas of circles as explained in (1) of Chapter III.

There are two kinds of cursors for this slide rule with different distance between the center and the left hairlines, one kind used for the Metric system (1 H.P. = 0.736 K.W.) and the other for the Foot-pound system (1 H.P. = 0.746 K.W.) but regardless of its kind, they are both used for obtaining the conversion of K.W. and H.P. which is performed by shifting the cursor so that the center hairline is on the value of the H.P. on the A scale and the position of the left hairline on the same A scale is its converted value in K.W..

b. Cube and Cube Root

This slide rule has K scale on the side of the stock, and calculations of cube can be performed in the same manner as when the K scale is given on the top surface of the slide rule. Full explanation is given in (8) of Chapter I.

c. Trigonometric Function

S and T scales which are used for trigonometric functions are given with the same arrangement as on the Mannheim System Rules, and the method of calculation is explained in (3) of Chapter II.

d. Logarithm and Exponent

The two scales seen on the surface of the lower stock are called the log log (LL) scales which are used for calculating logarithms and exponents. The method of use is as explained on the No. 130 slide rule (see page 39), but on this rule, the scale LL1, previously explained is not given and consequently, the range of calculation becomes much smaller. However, the advantage gained compared to the No. 130 slide rule is that these LL scales are given on the front face which permits the convenience of being able to use either the C or CI scale cooperatively instead of the D scale.

EXERCISE 65. $1.45^{2.5} = 2.53$

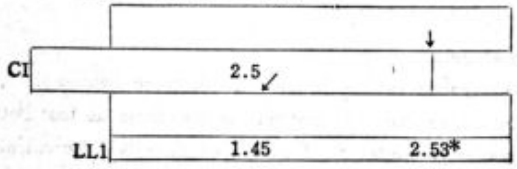


Fig. 74

EXERCISE 66. $1.64^{2.8} = 4.0$

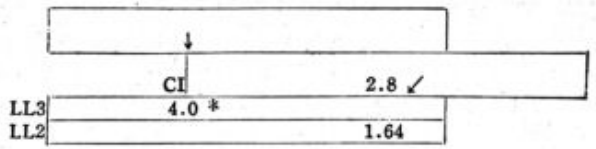


Fig. 75

EXERCISE 67. $\sqrt[3]{8.5} = 1.428$

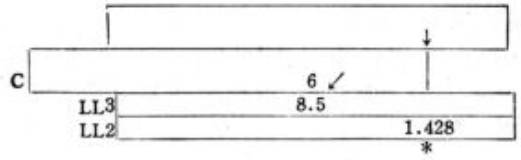


Fig. 76

e. Method of using the Efficiency Scale and Voltage Drop Scale

There are two special scales provided back to back on the upper top of the slide rule, the scale on top being called the Efficiency Scale, used for calculating efficiencies for dynamos and motors, and the bottom scale is the Voltage Drop Scale, used for calculating of a D. C. voltage drop in a 2-wire system circuit or of A. C. 2-wire system circuit with a pure resistance load.

(i) Efficiency Scale (Example in metric system)

The center of this scale is 100% and on both sides of this position are graduations representing 90, 80, 70, -- etc.

These graduations given on the right side are for the efficiency of electric motors, and the graduations on the left are for dynamos. In calculations of efficiency, the A and B scales are used in conjunction, but it is important that K.W. is always set on the A scale and H.P. (or P.S.) on the B scale.

EXERCISE 68.

There is a generator of 20 K.W. that requires an input of 28 H.P. (Metric System) at full load. What is the efficiency of this generator ?

Ans. 97%

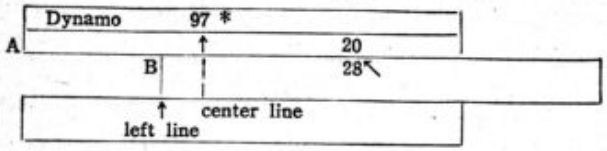


Fig. 77

Method of calculation :

(1) Set the position of 28 H.P. taken on the left half of B scale against the 20 K.W. on the right half on A.

(2) Then shift the cursor so that the left hairline is on the left index of scale B and the position under the center hairline of the Efficiency Scale, 97%, is the required answer.

EXERCISE 69.

Obtain the efficiency of a motor with an input of 38 K.W. and an output of 44 H.P.

Ans. 85.1%

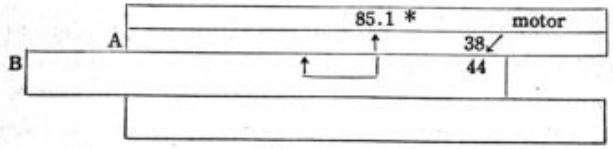


Fig. 78

Method of calculation :

(1) Set 44 H.P. on the right half of the B scale against 38 K.W. on the right half of the A scale.

(2) Shift the cursor so that the left hairline is on the center index of the B scale and the answer, 85.1, is read on the Efficiency Scale under the center hairline.

(ii) Voltage Drop Scale

When the distance from the electric source to the load is "L" metres, the cross section of the wire "q" square mm² and the electric current "I" ampares, the voltage drop (volts) in the circuit "V" can be calculated by the following equation :

$$V = \frac{I \times L}{28.7 \times q}$$

The 28.7 in the above equation is half the value of the specific conductivity of electrolytic copper. Such calculations are also performed with the cooperative use of the A and B scales. The imprinted 10 amp. given at the left end of the A scale is to indicate that the value of electric current is to be taken on this scale, and also that its graduations are to be read in units of 10 amps. This also applies to the distance and the cross section area which are set on the B scale and its values read on the basis of 10 m and 10 mm² respectively. The method of operation is as shown in the exercise given below, where the required answer is obtained on the Voltage Drop Scale under the center hairline.

EXERCISE 70.

Calculate the voltage drop in a D. C 2-wire system circuit with a distance of 50 m, cross section area of 30 mm² and an electric current of 45 amp.

Ans. 2.61 Volt.

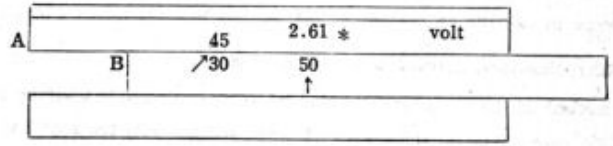


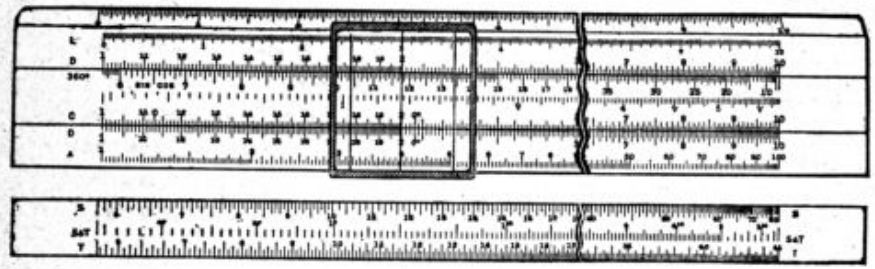
Fig. 79

Method of calculation :

(1) Set the value of 30 mm² on the left half of the B scale against 45 amp on left half of the A scale.

(2) When cursor is shifted so that the center hairline is on 50 m of the left half of the B scale, the position of the hairline on the Voltage Drop Scale is the required answer.

3. No. 2690 (10″) "STADIA" SLIDE RULE



This No. 2690 slide rule is a model especially designed for simplification of Stadia calculations that occur with the engineers in the field of civil surveying and mining, on which the "sin cos", and "cos²" scales that are not seen on any other models are given. However, the B and CI scales are omitted to provide space to show these scales on this rule, which causes inconvenience in calculating normal problems, but this cannot be avoided.

a. Multiplication, Division and Proportion

The method of the above calculations are fully explained in Chapter I but as this slide rule is not provided with CI scale and has only the scales C and D, multiplication must be carried out by cursor operation (see EXERCISE 5 and 6 on page 9) and division by slide operation. Therefore, for calculations of 3 successive multiplication or division problems, it is impossible to follow the general rules of computing by slide operation and cursor operation alternately for efficiency. In problems including both multiplication and division, it is more efficient to accomplish first the division by slide operation, and then the multiplication by cursor operation, for in this way movement of the slide can be kept to its minimum.

EXERCISE 71. $\frac{24 \times 45}{14} = 77.2$

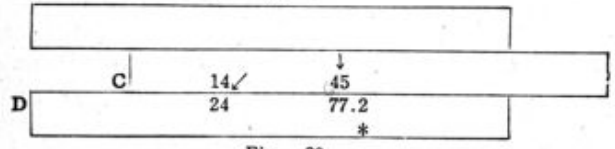


Fig. 80

For inverse proportion, the slide must first be removed and re-inserted to be in the opposite direction, whereupon the calculation can be carried out with reference use of the inverse scale C and D in the same manner as explained in (6) of Chapter I.

The Gauge Mark $\sqrt{\ }$ given on C scale indicates the position of $\sqrt{2g}$ = 4.429 of which "g" is 9.8 m/sec/sec, the constant acceleration caused by gravity.

b. Square and Cube

This slide rule is provided with only the A scale for the calculation of square problems, and its method of use is the same as explained in (3) of Chapter IV and (7) of Chapter I, but for calculation of multiplication or division which includes squares and square roots, the method of multiplication using the C and D scales explained above must be followed, since this slide rule lacks the CI scale which is used in conjunction with the A scale.

The cursor of this slide rule has three hairlines as those of the RIETZ SYSTEM slide rules, and the method to use this type cursor is explained in (I) of Chapter III. The K scale is not provided and therefore, calculation of cube problems cannot be carried out directly.

c. Logarithm and Trigonometric Function.

The L, S, T and S&T scales which are used for the above calculations are arranged in the same manner as on the RIETZ SYSTEM slide rules and the methods of use are explained in (2) and (3) of Chapter III.

d. STADIA Calculation

The "sin cos" and "cos²" scales are given on this slide rule for the purpose of Stadia Calculations, so arranged as to correspond with the D scale provided on the upper stock, with the graduation of "cos²" on the right side and "sin cos" on the left side divided at the opposite point to 5 on D scale. The "cos²" scale is used for direct calculation of horizontal distance and the "sin cos" scale for vertical height. The graduations that appear in the middle of the slide are the extended portion of the "sin cos" scale. Upon obtaining the angle θ and reading "Ka" from the Stadia instrument, the horizontal distance "d", between the position of the instrument and the object

of measurement, and the difference of the vertical heights "h" can be secured by the following equation.

$$d = Ka \cdot \cos^2 \theta$$

$$h = Ka \cdot \sin \theta \cos \theta$$

K is the given factor of the Stadia instrument which is usually set as 100.

EXERCISE 72. Obtain "d" and "h" from the Stadia reading of 538 feet and 12° 30′, obtained from the Stadia instrument.

Ans. d = 513 , h = 113.7

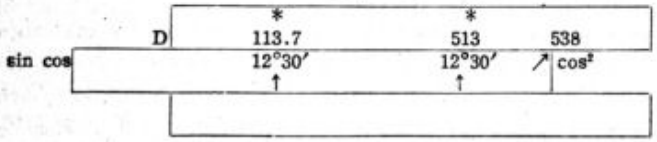


Fig. 81

In case the value on the, "sin cos" or "cos²" scale should fall "Off Scale", the operation must be repeated after resetting the index.

APPENDIX

(1) How to select slide rule

Hemmi's slide rule is divided into many kinds. Since individual kind of slide rule provides specific purpose and characteristics, it is very important to select a slide rule to meet with your requirement.

If you investigate how to select a slide rule in the following order, you never regret to find that your slide rule is not adequate to your work, after purchasing it.

(i) Remember the general characteristics of symbols of scales indicated in Table 1.

There are many kinds of scales to be used for slide rule, but their purposes are definite. It is the first step in selecting slide rule that what kind of scales should be provided for the slide rule to meet with your usage. Explanation pertaining to ordinary scales is shown by Table 1.

(Table 1)

Kind of calculation	Name of scale	Remarks
Multiplication, Division and Proportion	*C*, *D*	These are the fundamental scales of slide rule. Multiplication and division are freely available.
	CI	This is a supplementary scale for *C*, *D* scales. Speed for computation will be increased about 40% with this scale.
	CF, *DF*	There are two kinds, one is $\sqrt{10}$-fold and the other is π-fold. Speed of computation is increased and also troublesome labour is eliminated.
	CIF	Supplementary scale of *CF* and *DF* scales.

Square and Cube	A, B	These are used for computation of square and square root in joint use with C and D scales.
	K	This is used for computation of cube and cube root in joint use with C and D scales.
Logarithm	L	This is the scale to find logarithm in "reference scale" with D scale.
	l	This is the scale to find logarithm in "reference scale" with A scale.
Trigonometric Function	S. SI	These are used for sin θ computation.
	T,TI_2, TI_1,	These are used for tan θ computation.
	$S\&T$, ST	These are used for computation of sin θ and tan θ of small angle
Exponent	$LL0$, $LL1$ $LL2$, $LL3$	These are the scales to find form of A^x in joint use with C scale.
	$LL/0$, $LL/1$ $LL/2$, $LL/3$	These are the scales to find form of A^{-x} in joint use with C scale.
Vector	P, P', Q, O'	These are used for computation of absolute value $\sqrt{a^2 \pm b^2}$ of vector.
	θ, x, $R\theta$	These are graduated in degree and minute system, and also radian system. These are available for supplementary use of vector computation.
		Note : Vector computation is made with use SI and TI scales also.
Hyperbolic Function	$G\theta$	This is used for computation of hyperbolic function by use of Gudermanian.
	Sh_1, Sh_2	These are used for hyperbolic sine calculation.
	Th	This is used for hyperbolic tangent calculation.

(ii) Select slide rule with most convenient arrangement of scales which is useful for your computations frequently used.

Find out No. of slide rule with most suitable scale for your form of computations which is frequently used, after determination of characteristics and symbols of scales. Table 2 is indicated for this purpose. convenience or inconvenience depends upon the arrangement of scales, even though scales are the same.

For instance, there are 5 steps of advantage priorities for computation of trigonometric function, as shown by the Table 2. Therefore you have to make a thorough study to use it.

Table 2 indicates classification by kind of forms of computation and by advantage priority. In the right side of table, major slide rule with those arrangement of scales are listed.

(Table 2)

Form of computation	Advantage priority	Scale and arrangement	Remarks
Multiplication, Division and Proportion	1	Provides *C*,*D* and *CI*	Speed of computation is 40% quicker than slide rule with *C*, *D* scales only
	2	Provides *C*,*D*,*CI* and *CF*, *DF*	None off scale, calculation speed increases about 20% than (1)
	3	Provides *C*, *D*, *CI*, *CF*, *DF* and *CIF*	Highest class for multiplication and division.
Square	1	Provides *A* only on the stock	A little disadvantage for multiplication and division including square and square root.
	2	Provides *A* and *B*	Convenient for computation including square and square root.
Cube	1	Provides *K* on the slide	Cube and Cube root computation is available, but a little complicated.
	2	Provides *K* on the stock	Convenient for cube and cube root.
Logarithm	1	Provides *L* on the rear face of the slide	Stide operation is necessary.
	2	Provides *L* on the stock	Done only by indicator operation.

Mannheim Type			Duplex Type	
10″	Pocket Type	20″	10″	20″
50W 64 80K 130 40*RK* 2640 (8″)	30 32 34*R* 34*RK* 74 66 86*K* 136	70	153	
45 (8″)	2634			154
2664*S*			250 251 255 256 257 259	275 279
2664*S* 2690 45 (8″)	2634		256 257	154
50W 64 80K 130 40*RK* 2640 (8″)	30 32 34*R* 34*RK* 74 66 86K 136	70	250 251 255 259 153	275 279
2640 (8″)				
50W 64 2664*S* 130 40*RK* 80K	34*RK* 2634 74 136 66 86K	70	250 251 255 259 153	154 275 279
50W 80K 2664*S* 45 (8″) 40*RK*	30 32 34*R* 34*RK* 2634 86K			
64 130 2690 2640 (8″)	74 66 136	70	250 251 255 256 259 153 257	154 275 279

Trigonometric Function	1	Provides *S*, *T*	Trigonometric function of sine and tangent are found.
	2	Provides *S*, *T*, *S&T*	Trigonometric function of angle from 35' to 6° is also found
	3	Provides *SI* and *TI*	Computation including trigonometric function. Very convenient for solution of triangles and vectors.
	4	Provides TI_2, TI_1, SI_1	Tangent in item 3 is extended for angle from 45° to 84°
	5	Provides *SI*, *TI*, *DI*	The same as item 3. Especially convenient for sine proportion
Exponent.	1	Provides *LL3*, *LL2*, *LL1*	Convenient for computation of N^x or $N^{\frac{1}{x}}$
	2	Provides *LL3*, *LL2*, *LL1*, *LL0*, *LL/3*, *LL/2*, *LL/1*, *LL/0*	Range of computation in above item enlarged to N^{-x} and $N^{-\frac{1}{x}}$
Hyperbolic Function	1	Provides *Gθ*	Sin*hx* and tan*hx* are found, but multiplication and division of these values are not available
	2	Provides Sh_1, Sh_2, *Th*	Convenient for multiplication and division to hyperbolic function

50W 80K 130 40*RK* 2640 (8″)	30 32 34*RK* 86K 136			154
64 2690	74 66	70	251 259	279
45 (8″)			256	
2664*S*	2634		255	275
			250	
130(*LL*1 omitted) 80K	136(*LL*1 omitted) 86K		153 251 255 256 257	275
			259	279
			153	
			255	154 275

(III) Final decision should be made after investigating type and dimension suitable for usage.

The slide rule, which has most convenient arrangement of scales for the purpose of own use, is not limited to one kind. For example, there are difference in dimension and types such as slide rule for laboratory use with high accuracy or for pocket use which is convenient as portable type. Major Hemmi's Slide Rules are shown in Table 3. Make your final decision what kind of slide rule you select. Cuts of typical slide rules out of Table 3 are shown in Appendix (2) Those may be used for reference in selecting your slide rule.

(Table 3)

Type	Size	Cat. No.	Scale: Front face	Scale: Rear face	Characteristics
Mannheim Type	10″ (25 cm)	50W	*A B CI C D K*	*S L T*	Mannheim slide rule for general engineer
		64	*K A B CI C D L*	*S S&T T*	Rietz system with extension of red graduation on *C, D, A, B,*
		80K	*A B CI C D* LL_2 LL_3 *K*	*S L T*	For electrical engineer with efficiency and voltage drop scales.
		2690	*L D* sin cos $\cos^2$ *C D A*	*S S&T T*	For civil surveying use with Stadia scales
		130	*L K A B CI C D* cos sin tg	LL_1 LL_2 LL_3	Darmstadt slide rule with cos scale and log log scales
		2664*S*	*K DF CF CIF CI C D A*	TI_1 TI_2 *L SI*	$\sqrt{10}$-fold *CF, DF, CIF* and inverted trig. scales
		40*RK*	*A B CI C D K*	*S L T*	No. 50W propagation type
	8″ (20 cm)	2640	*I A B CI C D*	*S K T*	No. 50W for student
		45	*DF CF CI C D A*	*TI L SI*	No. 2664 〃 〃
	6″ (15 cm)	86K	*A B CI C D* LL_2 LL_3 *K*	*S L T*	No. 80K for pocket use
		66	*K A B CI C D L*	*S S&T T*	No. 64 for pocket use
		136	*L K A B CI C D* cos sin tg	LL_1 LL_2 LL_3	No. 130 for pocket use

Type	Size	Cat. No.	Scale: Front face	Scale: Rear face	Characteristics
Mannheim Type	20″ (50 cm)	70	*K A B CI C D L*	*S S&T T*	64 for laboratory.
	5″ (12.5 cm)	34*R*	*A B CI C D*	*S L T*	No. 50W for pocket use
		34*RK*	*A B CI C D K*	*S L T*	No. 50W for pocket use
		2634	*K DF CF CI C D A*	TI_2 TI_1 *L SI*	No. 2664S for pocket use
		74	*K A B CI C D L*	*S S&T T*	No. 64 for pocket use
	4″ (10 cm)	30	*A B CI C D*	*S L T*	Smallest type of No. 50W
		32	*A B CI C D*	*S L T*	Indicator with lens attached.
	1m	100	*DF CF CI C D A*	*TI L SI*	Demonstration Slide Rule
		101	*I A B CI C D*	*S K T*	
		102	*CI C D A*		
	1.5 m	103	*K DF CF CIF CI C D A*	TI_1 TI_2 *L SI*	For newly designed No. 2664S 10 inch.
Duplex type	10″ (25 cm)	250	*DF CF CIF CI C D L*	*K A B* TI_2 TI_1 *SI D DI*	$\sqrt{10}$-fold scale and *SI, TI* are provided. For general engineering and business use.
		251	*L DF CF CIF CI C D* LL_3 LL_2 LL_1	*K A B T S ST C D DI*	π-fold scale is provided for mechanical engineer.
		255	*L K DF CF CIF CI C D* LL_3 LL_2 LL_1	Sh_1 Sh_2 *Th A B* TI_2 TI_1 *SI C D* x θ	Capable of hyperbolic function. For expert electrical engineer.
		256	*L db* Neper *DF CF CIF CI C D* LL_3 LL_2 LL_1	*A* $\dot{L}$ $\dot{C}$ *SI TI D* λ *F*	Excellent for electric communication engineer.
		257	*L A DF CF CIF CI C D* LL_3 LL_2 LL_1	Various scales for chemical engineering	For expert chemical engineering.
		259	LL_1 LL_2 LL_3 *DF CF CIF CI C D* LL_3 LL_2 LL_1	*L K A B T S ST C D* LL_0 LL_0	Higher exponential computation in broad range. For expert mechanical engineer.
		153	*L K A B CI C D T* $G\theta$	θ $R\theta$ *P Q Q′ C* LL_1 LL_2 LL_3	Vector and hyperbolic function. For electrical engineer's use.
	20″ (50 cm)	275	*L K DF CF CIF CI C D* LL_3 LL_2 LL_1	Sh_1 Sh_2 *Th A B* TI_2 TI_1 *SI C D* x θ	For expert electrical engineer.
		279	LL_1 LL_2 LL_3 *DF CF CIF CI C D* LL_3 LL_2 LL_1	*L K A B T S ST C D* LL_0 LL_0	For expert mechanical engineer.
		154	*DF P′ P Q CF CI* $S\theta°$ *A D K*	*Sx Tx* $T\theta°$ *Th* Sh_1 Sh_2 *C D L x*	For electrical engineering specialist.
	16″ (40 cm)	200	C_1 C_2 C_3 C_4 C_5 C_6 D_1 D_2 D_3 D_4 D_5 D_6	CF_1 CF_2 CF_3 CF_4 CF_5 CF_6 DF_1 DF_2 DF_3 DF_4 DF_5 DF_6	Multiplication and division of 4 digits.

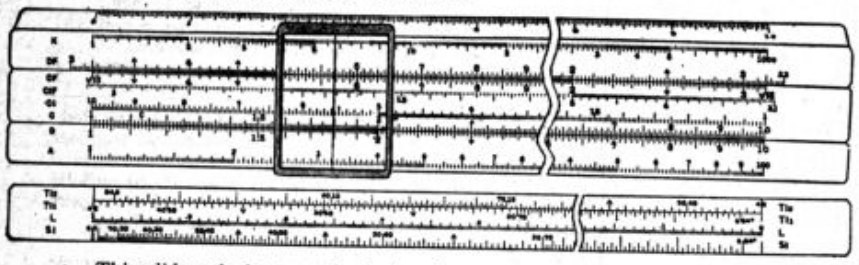
(2) Typical Hemmi's Slide Rule

Cuts shown below indicate arrangement of scales and size for various kinds of typical Hemmi's slide rules as your reference for proper selection.

(A) Mannheim Type Slide Rule:

(a) Slide rule for general business use.

No. 2664S Hemmi Bamboo 10″ Slide Rule

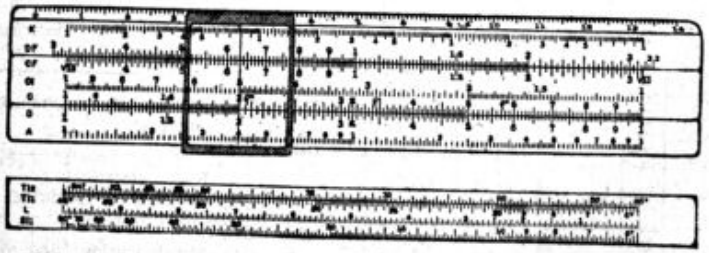


This slide rule is so newly designed as to secure the high efficiency for computation of multiplication, division, proportion, percentage, etc.

This new type of slide rule is provided with $\sqrt{10}$ folded scales DF, CF, CIF and especially the CIF scale is so clearly marked in green color that it may be very easy to read the scale graduations.

Besides, No. 2664S slide rule, having square, cube, logarithmic and trigonometric function scales, proves to be most convenient for general business and engineering use.

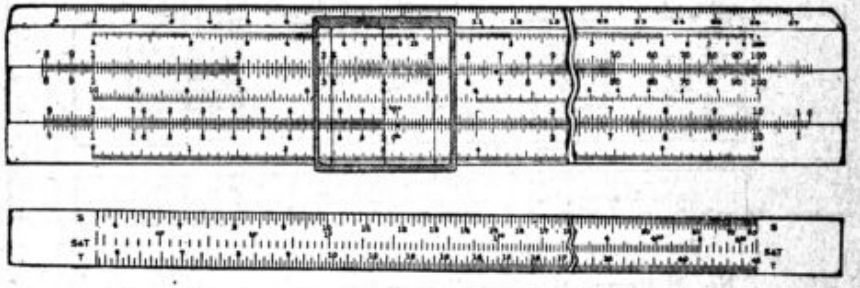
No. 2634 Hemmi Bamboo 5″ Slide Rule



Pocket type of No. 2664

(b) Slide rule for general engineer's use

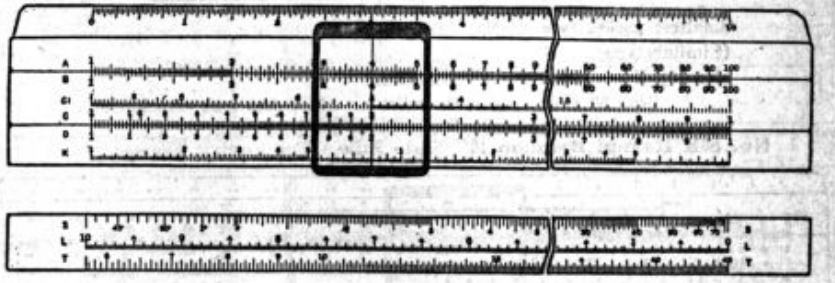
No. 64 Hemmi Bamboo 10″ Slide Rule



This is the so called "Rietz" system with extended red scales on A, B, C, D, and also the trigonometric function is provided with amall angle. (Similar type)

No. 66 Hemmi Bamboo 6″ Slide Rule Pocket type of No. 64.

No. 50W Hemmi Bamboo 10″ Slide Rule



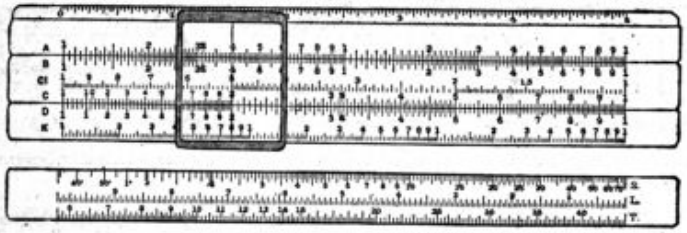
This is an advanced type of the typical Mannheim slide rule, convenient for square calculation besides multiplication and division.

(Similar type)

No. 40RK Hemmi Bamboo 10″ Slide Rule

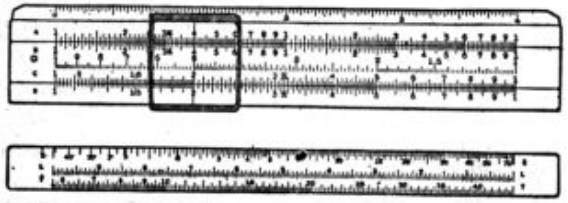
Slide Rule for practice of No. 50W.

No. 34RK Hemmi Bamboo 5″ Slide Rule



Pocket type of No. 50W.

No. 30 Hemmi Bamboo 4″ Slide Rule



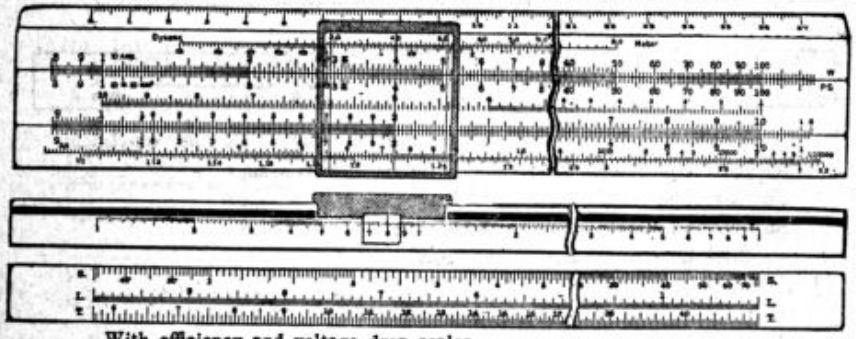
Smallest pocket type of No. 50W.

(Similar type)

No. 32 Hemmi Bamboo 4″ Slide Rule

No. 30 slide rule with indicator which has lens attachment.

No. 80K Hemmi Bamboo 10″ Slide Rule (For Electric Engineer)

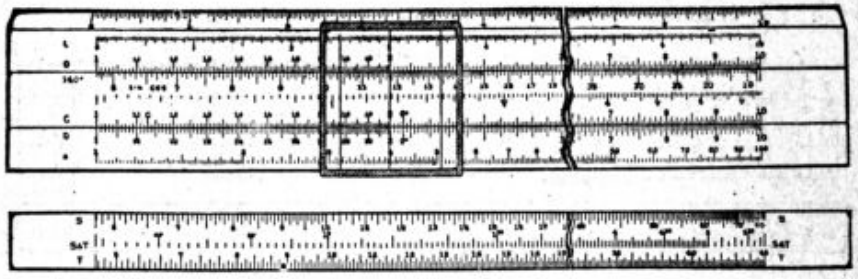


With efficiency and voltage drop scales.

(Similar type)

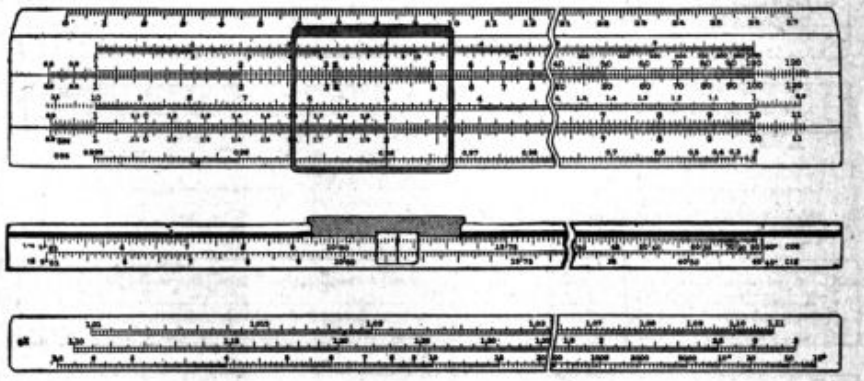
No. 86K Hemmi Bamboo 6″ Slide Rule. Pocket type of No. 80K.

No. 2690 Hemmi Bamboo 10′ Slide Rule



Slide rule with Stadia scales for civil surveying use.

No. 130 Hemmi Bamboo 10″ Slide Rule



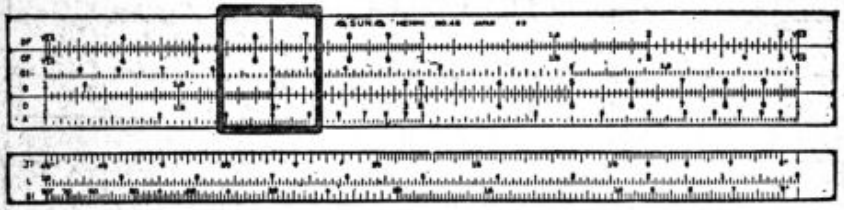
This is popularly used in Europe and is called the "Darmstadt" slide rule. cos scale, besides e^x scales for exponential computation, is the advantageous feature of this slide rule.

(Similar type)

No. 136 Hemmi Bamboo 6″ Slide Rule. Pocket type of No. 130 10″ Slide Rule

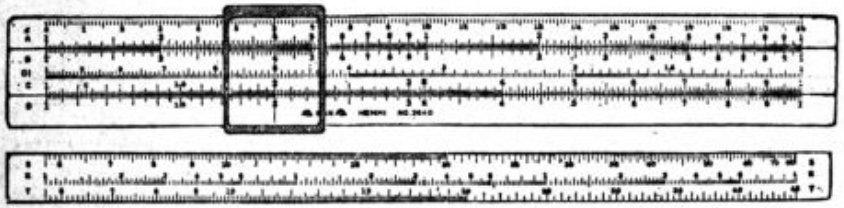
(c) Beginner's Slide Rule.

No. 45 Hemmi Bamboo 8″ Slide Rule



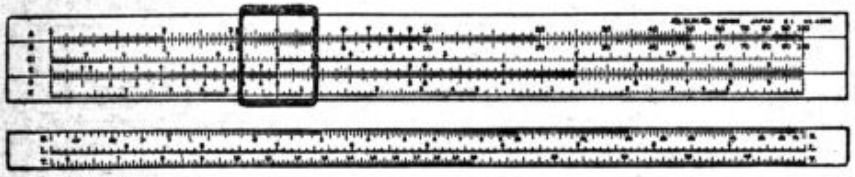
Beginner's slide rule Similar to No. 2664*S*

No. 2640 Hemmi Bamboo 8″ Slide Rule



Beginner's slide rule similar to No. 50W

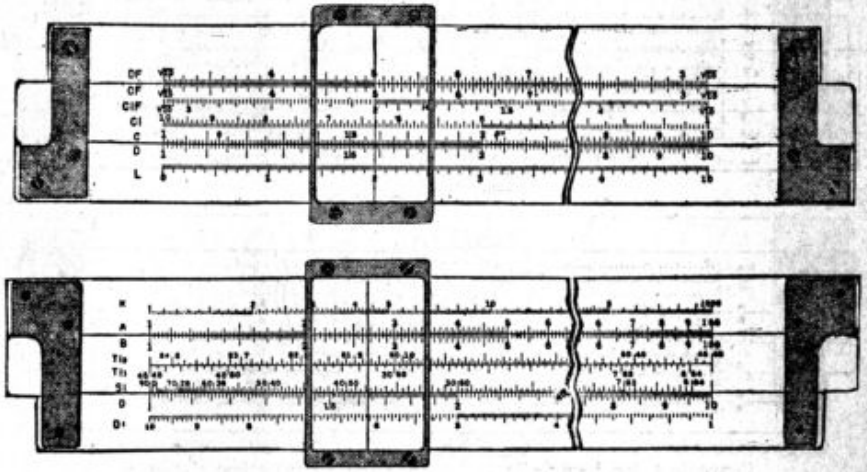
No. 40RK Hemmi Bamboo 10″ Slide Rule



Beginner's slide rule similar to No. 50W

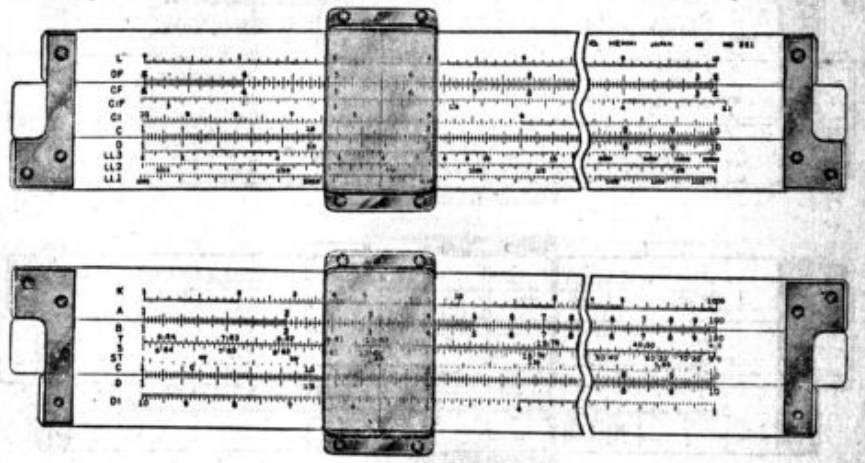
(Б) Duplex Slide Rule

No. 250 Hemmi Bamboo 10″ Duplex Slide Rule (For General Engineering and Business use.)



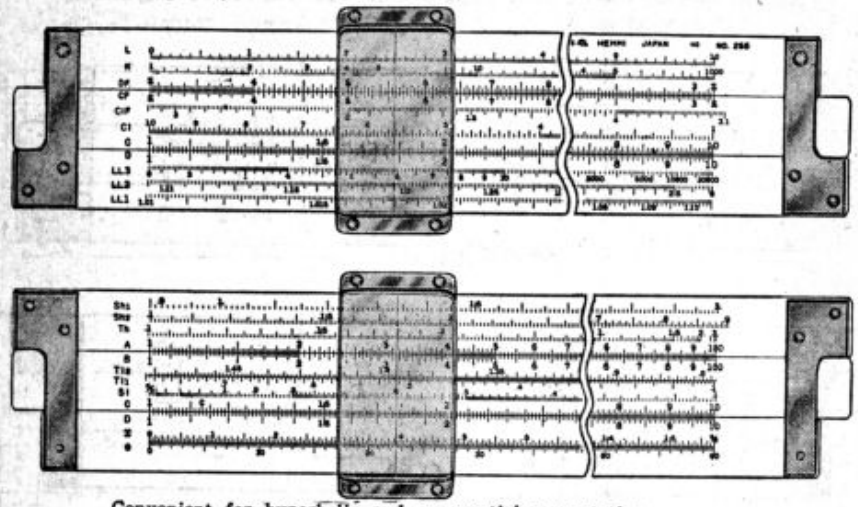
$\sqrt{10}$-fold scale and SI, TI scales are provided

No. 251 Hemmi Bamboo 10″ Duplex Slide Rule (For Mechanical Engineeer)



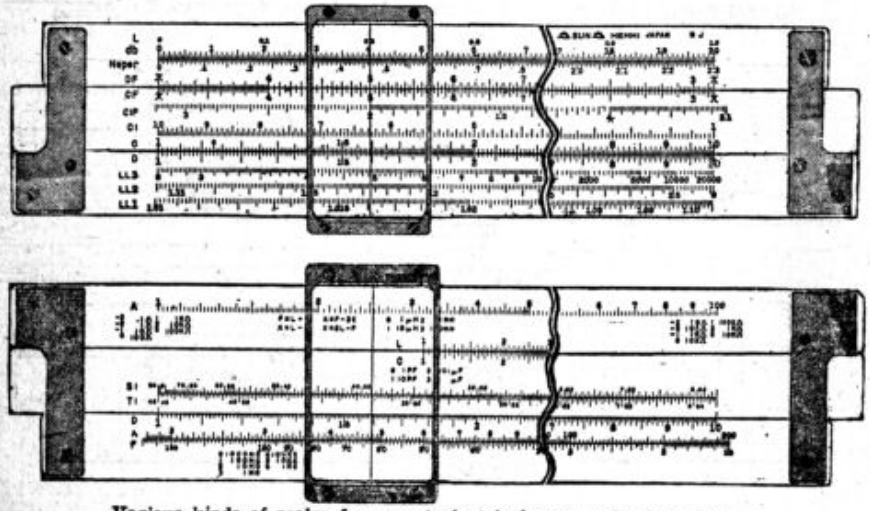
π-fold scale is provided and capable of exponential computation.

No. 255 Hemmi Bamboo 10″ Duplex Slide Rule (For Expert Electrical Engineer)



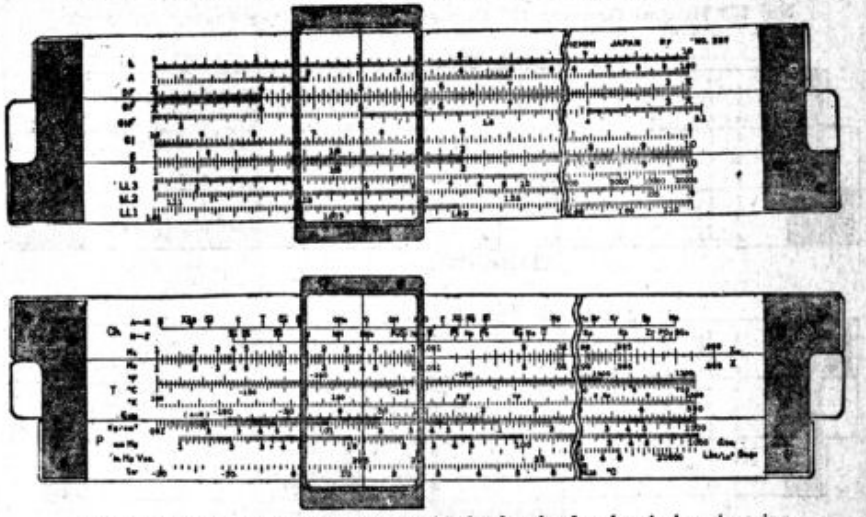
Convenient for hyperbolic and exponential computation.

No. 256 Hemmi Bamboo 10″ Duplex Slide Rule (For Electric Communication)



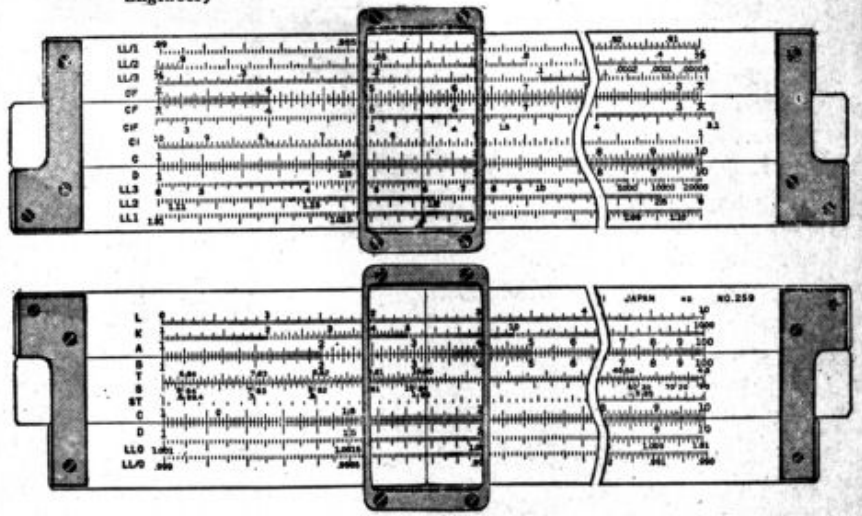
Various kinds of scales for expert electrical communication engineer.

No. 257 Hemmi Bamboo 10″ Duplex Slide Rule (For Chemical Engineer)



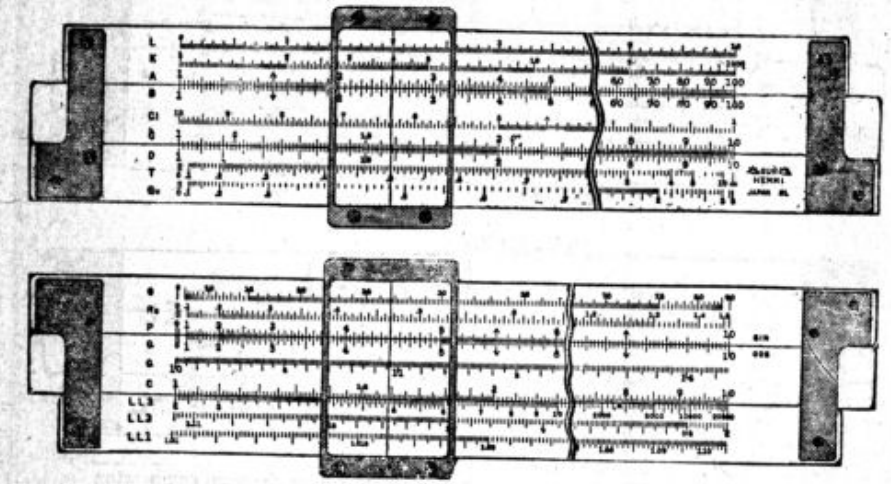
Beside ordinary computation, various kinds of scales for chemical engineering are provided.

No. 259 Hemmi Bamboo 10″ Duplex Slide Rule (For Expert Mechanical Engineer)



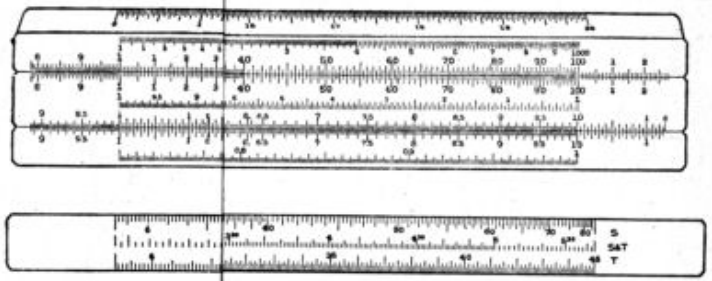
Very convenient for exponential computation.

No. 153 Hemmi Bamboo 10" Duplex Slide Rule (For Electric Engineer)



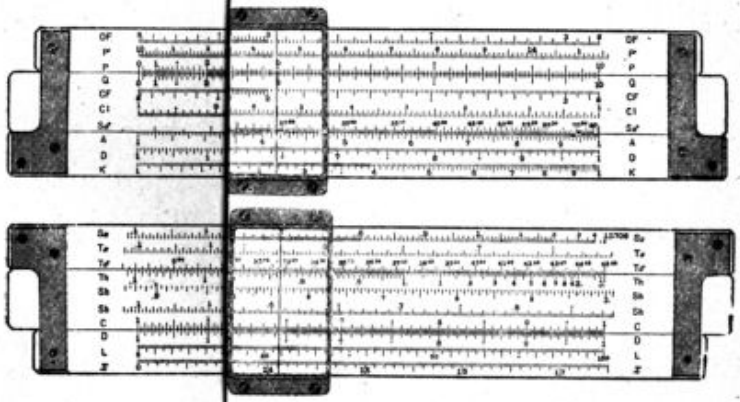
Capable of hyperbolic function and exponential computation.

No. 70 Hemmi



20" ty

No. 154 Hemmi



Slid

No. 275 Hem

20"

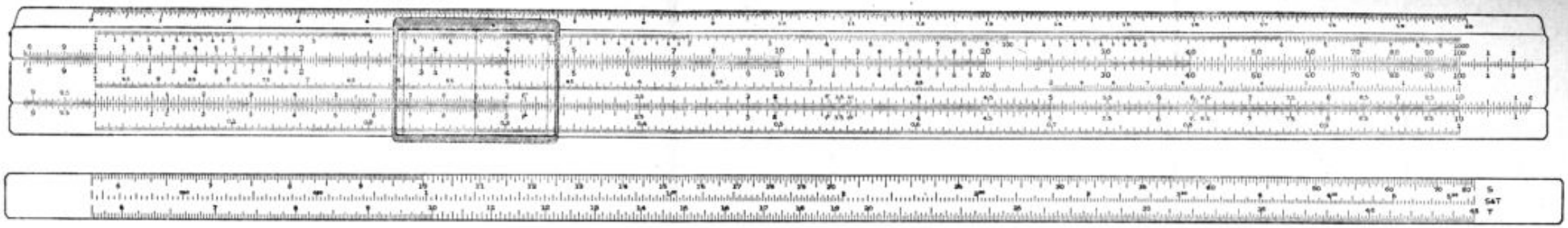
No. 279 Hem

20"

No. 200 Hem

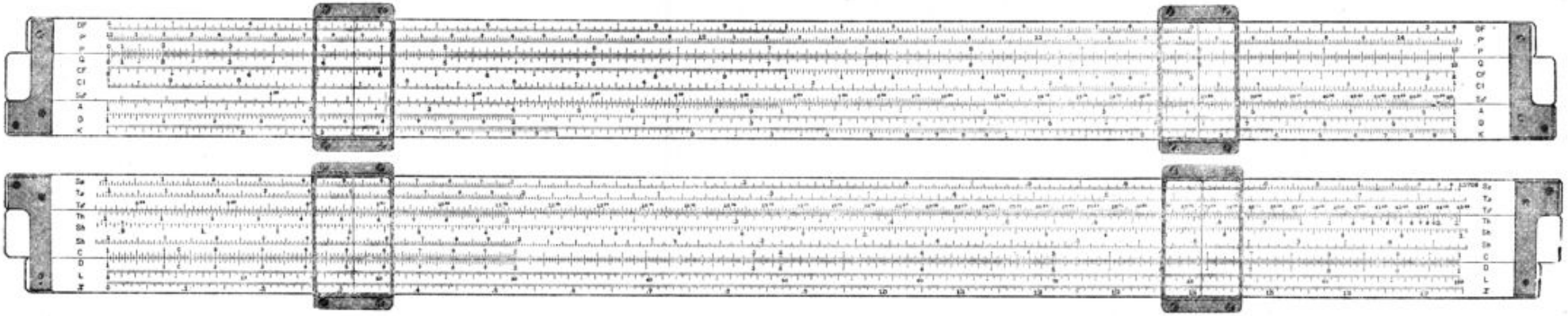
Mu

No. 70 Hemmi Bamboo 20" Mannheim Slide Rule



20" type of No. 64 Slide Rule for laboratory use.

No. 154 Hemmi Bamboo 20" Duplex Slide Rule (For Advanced Electric Engineer)



Slide rule which is very suitable for transmission line design.

No. 275 Hemmi Bamboo 20" Duplex Slide Rule (For Advanced Electric Engineer)

20" type of No. 255 slide rule (**New Praduct**)

No. 279 Hemmi Bamboo 20" Duplex Slide Rule (For Advanced Mechanical Engineer)

20" type of No. 259 slide rule (**New Product**)

No. 200 Hemmi Bamboo 16" Duplex Slide Rule

Multiplication and Division of four figures are available