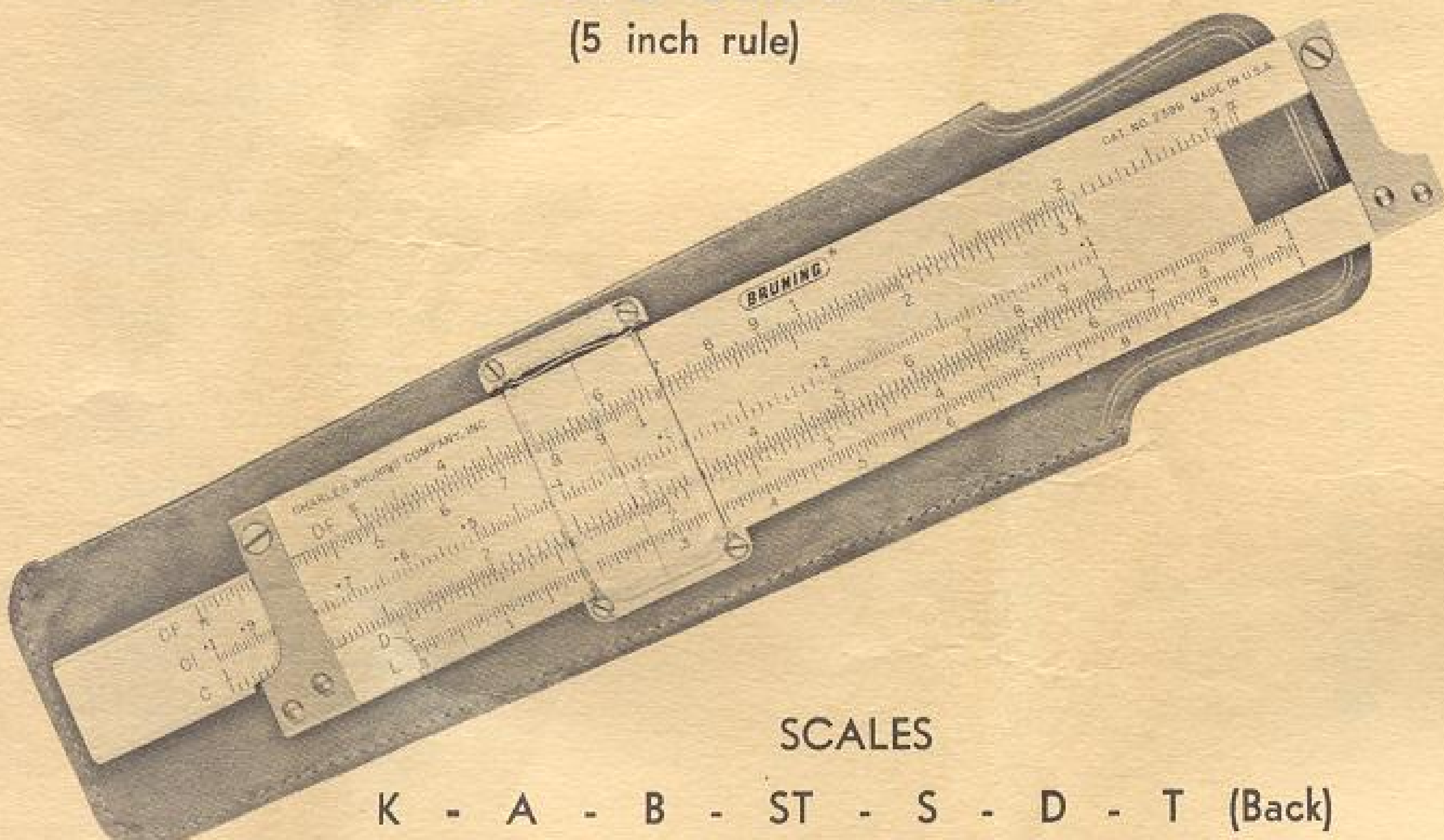
BRUNING

Instruction Manual for
NO. 2398 SLIDE RULE
(5 inch rule)



SCALES

K - A - B - ST - S - D - T (Back)
DF - CF - CI - C - D - L (Front)

TABLE OF CONTENTS

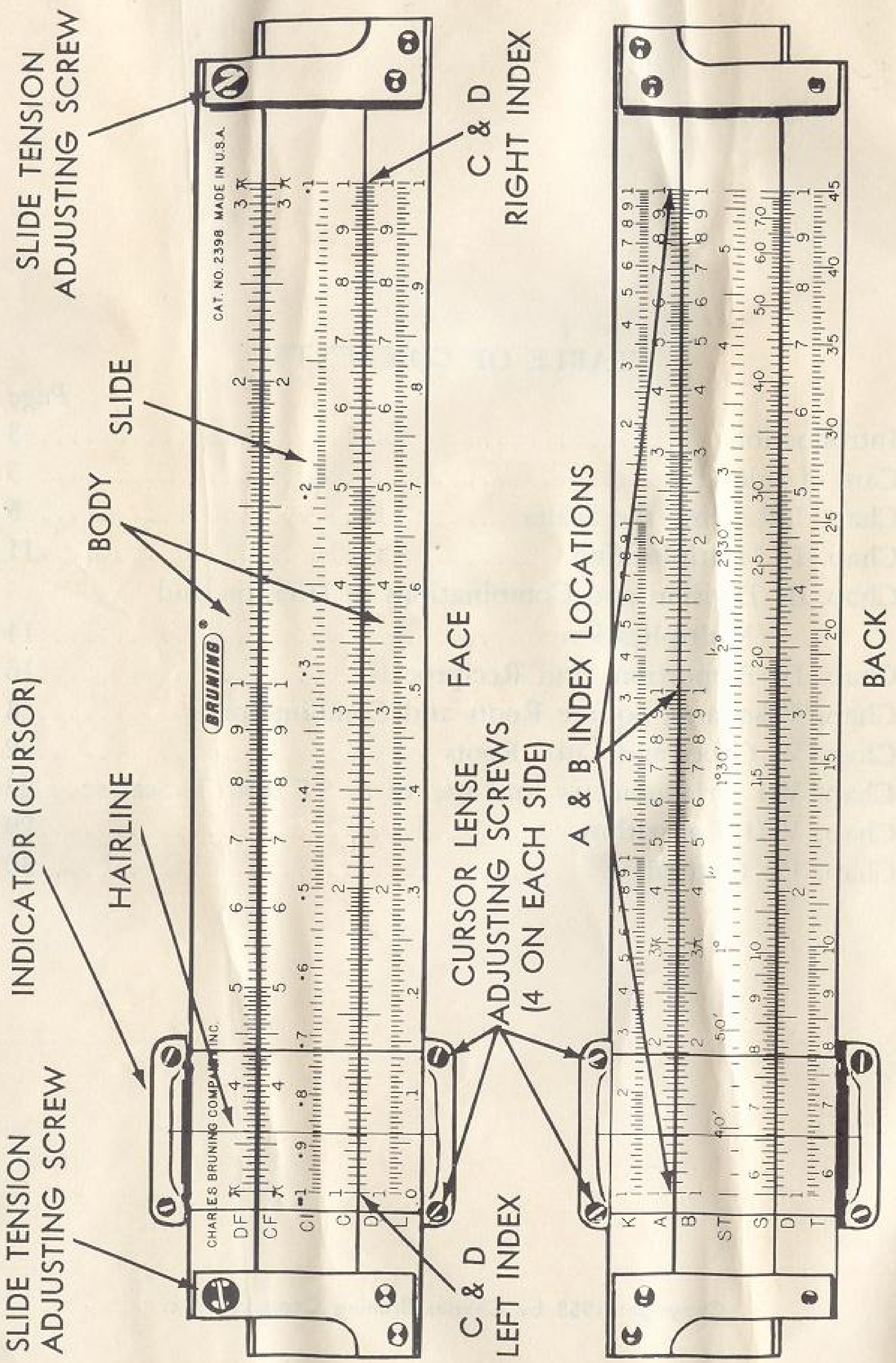


Figure 1.

Introduction – The Bruning 2398 slide rule is one of the choicest pocket rules ever made available. It is a precision tool capable of performing all basic mathematical functions inclusive of squares, square roots, cubes, cube roots, logarithms to the base 10, multiplication, division and trigonometric functions. Because it is small, light and simple to operate, you will find it extremely handy in your work.

Start right – be sure your rule is in adjustment. While this slide rule was adjusted before leaving the factory, it is possible that it may have been jarred out of adjustment. Check the rule this way before proceeding further. (See Figure 1.)

1. Move slide back and forth. It should move smoothly but not freely.
2. Align the numbers on the C and D scales so that the 1 on on the C is over the 1 on the D. When aligned, check to see if the DF and CF scales are similarly aligned. If not, loosen the two screws on the end plates and position the CF and DF scales. Tighten the screws and repeat the check procedure.
3. Set the hairline on the indicator on the line marked 2 on the D scale. Turn the rule over. The hairline on the other side should be exactly on 2 on the D scale on the back of the rule. If it is not, loosen the four screws on the *indicator* on the back side and carefully position the indicator window so that the hairline is on 2 on the D scale and 4 on the A scale. Tighten screws.

   Note – Use care in the adjustment and re-check rule after adjustment. Once set, it should not be necessary to readjust unless the rule is dropped or otherwise accidentally mishandled.

Care of Slide Rule – This slide rule has been precision molded from a durable plastic material. Within reasonable limits, it may be mishandled without damage. To insure lasting service for many years, the following recommendations should be followed.

1. Clean with luke warm (not hot) water, soft cloth and *mild* soap. *Do not use solvents.*

2. If underside of indicator gets dirty, clean by slipping a piece of paper under the indicator and move back and forth until clean.
3. Replace slide rule in the sheath when not in use.
4. Do not permit rule to be exposed to unusually high temperatures as might be the case on the back shelf of an automobile under direct sun rays.

CHAPTER 1 – READING THE SCALES

How to use this slide rule – The first step is the most important – how to read the scales. Each scale is identified at the left as follows:

DF, CF, CI, C, D, and L on the front
K, A, B, ST, S, D and T on the back . . . See Fig. 1.

The most basic slide rule functions are multiplication and division. *Both* require the use of the C and D scales. Both scales are identical.

Reading the C and D scales – Since these scales are identical, they are read in the same manner. Reading from left to right you see, in this order, the following numbers: 1,2,3,4,5,6,7,8,9,1. The 1 at either end is called an *index*.

From 1 to 2 (reading from left to right) there is a "long" line at the halfway point. This long line represents the location of 1.5. There are eight "medium" length lines representing (from left to right) 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.8, and 1.9 respectively (see Figure 2).

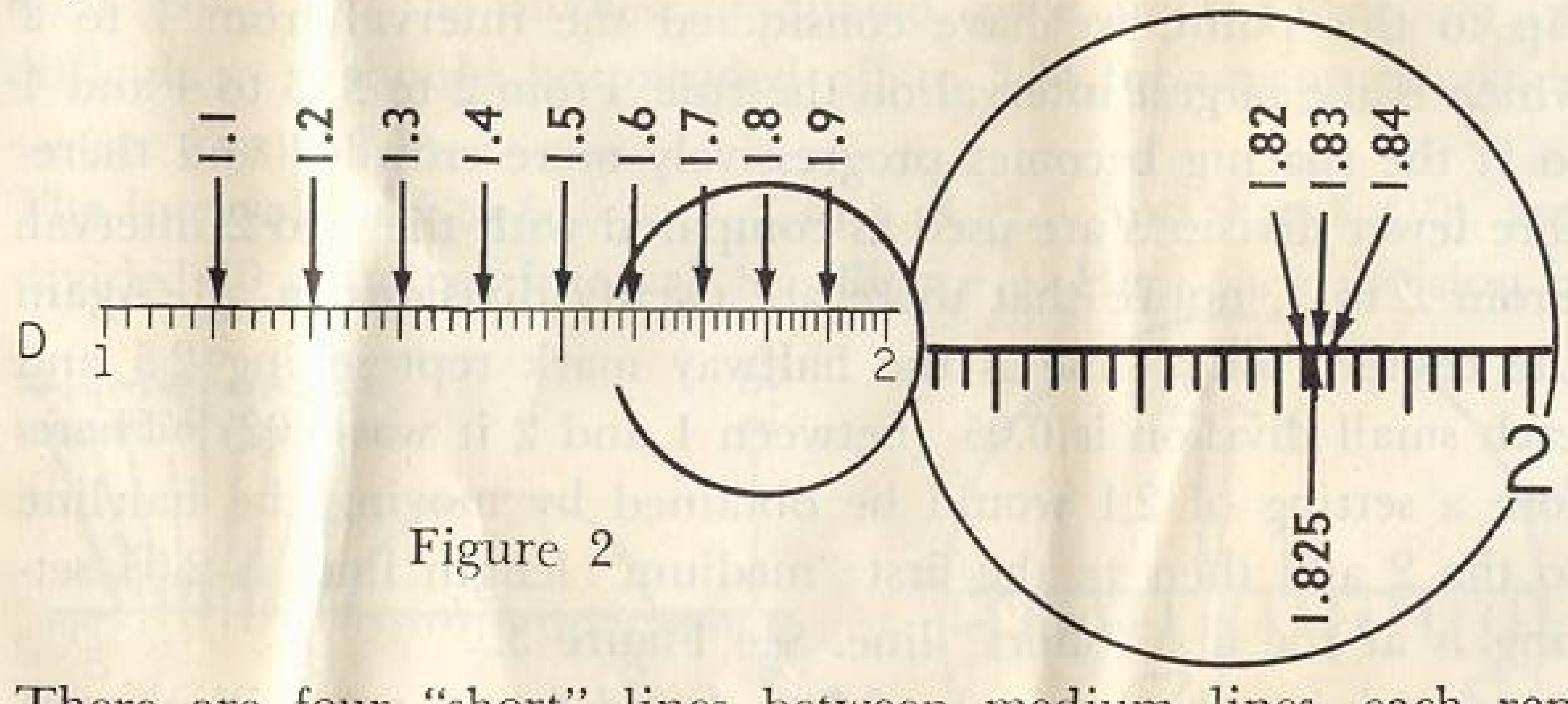


Figure 2

There are four "short" lines between medium lines, each representing 0.02 and they are read from left to right.

In setting a number always set the digits in the order of their appearance in the number. For example, set 1.82 by moving the indicator hairline between 1 and 2; then to the medium length line representing 1.8, and then to the next short line (0.02). This provides the setting of 1.82 as shown in Figure 2.

A setting of 1.83 would be set up the same way except for the third digit (3) which is halfway between the first and second short lines.
(Note, the first short line is 1.82 and the second short line is 1.84 so 1.83 is halfway between.)
Up to this point only three digit numbers have been considered. A four digit number is set up the same way but the fourth digit location must now be estimated. For example, 1.825 would be set up as 1.82 and then the hairline moved to 1/4 the distance between 1.82 and 1.84. This is estimated. (See Figure 2.)
Five or more digit numbers are rounded off to the nearest four digit number before setting. For example, 1.8265 should be set as 1.827 where the location of the fourth digit (7) is estimated.
Decimal points are not considered in making settings but are taken into account after a computation has actually been made. Therefore *the settings of* 1.82, 18.2, 182, 0.182, 0.0182 *etc. are all the same.* A later section of this book shows how decimal points are handled.
Up to this point, we have considered the interval from 1 to 2 which is the largest interval on the rule. From 2 to 3, 3 to 4 and 4 to 5, the spacing becomes progressively more crowded and therefore fewer divisions are used as compared with the 1 to 2 interval. From 2 to 3, notice that there are twenty divisions in all. Again the center "long" line is the halfway mark represening 2.5 and each small division is 0.05 (between 1 and 2 it was 0.02). Therefore a setting of 2.1 would be obtained by moving the hairline to the 2 and then to the first "medium" length line. A 2.05 setting is at the first "short" line. See Figure 3.
By examining the intervals of 3 to 4 and 4 to 5 you will observe that these are divided the same as 2 to 3. To get a setting of 3.825 you would move the hairline between 3 and 4; then to between 3.8 and 3.9; and finally 1/4th the way from 3.8 to 3.9. This latter position is 1/2 the distance between the medium length 3.8 line and the short line following it. This short line would represent 3.8+0.05 or 3.85. See Figure 3.

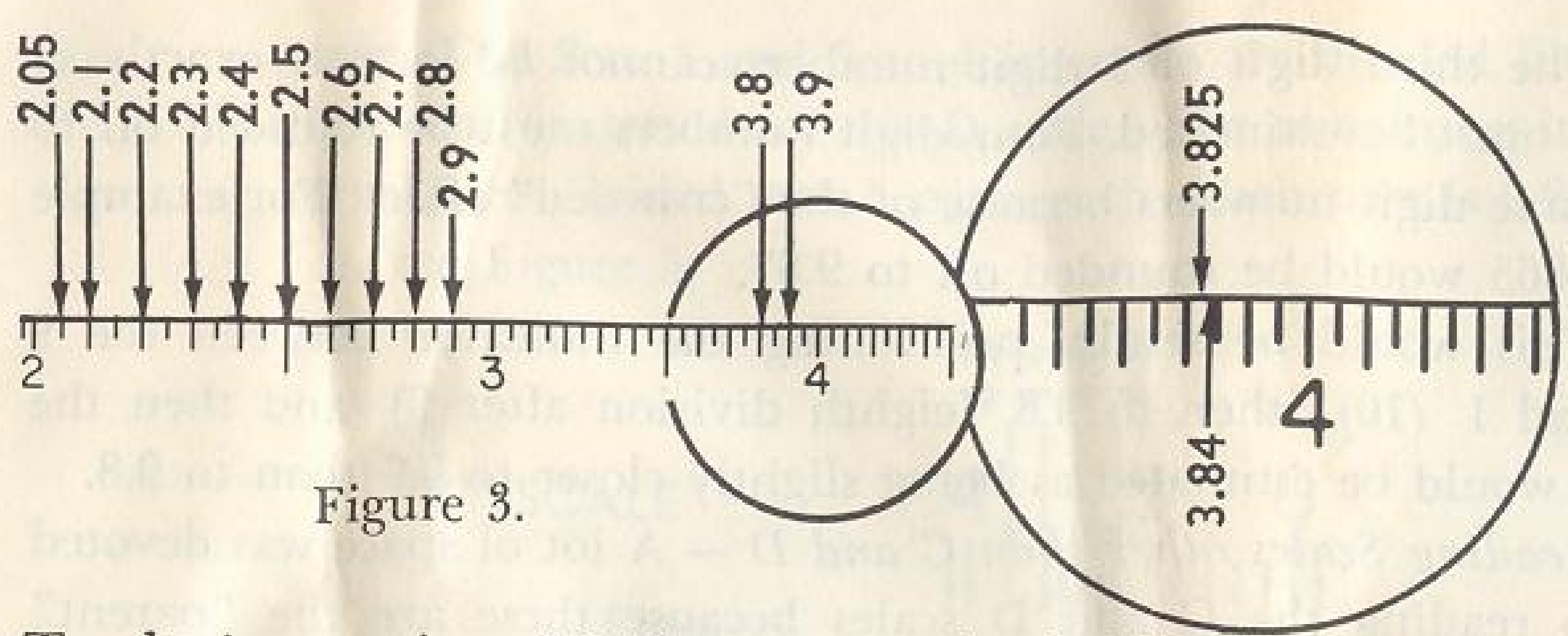


Figure 3.

To obtain a setting of 3.84 you move the hairline between 3 and 4, then to 3.8, and then almost to 3.85 – just before the next short line. The 0.84 is more than 0.825 and less than 0.85 and nearer to the 0.85, therefore the exact position is estimated "by eye."
(Note: if a four or more digit number is to be located, the fourth digit is more difficult to estimate than it would be on the 1 to 2 interval scale because the spacing is more crowded. It is good practice to round off the fourth digit in the intervals between 2 and 9. For example 3.825 is comparatively easy to set because the fourth digit (5) is 1/2 the smallest graduated space, but 3.837 would be difficult so it should be rounded off to 3.84 for setting purposes – (see Figure 3.)
The intervals of 5 to 6, 6 to 7, 7 to 8, 8 to 9, and 9 to 1 (10) are divided 10 parts per interval. See Figure 4. Here each division is

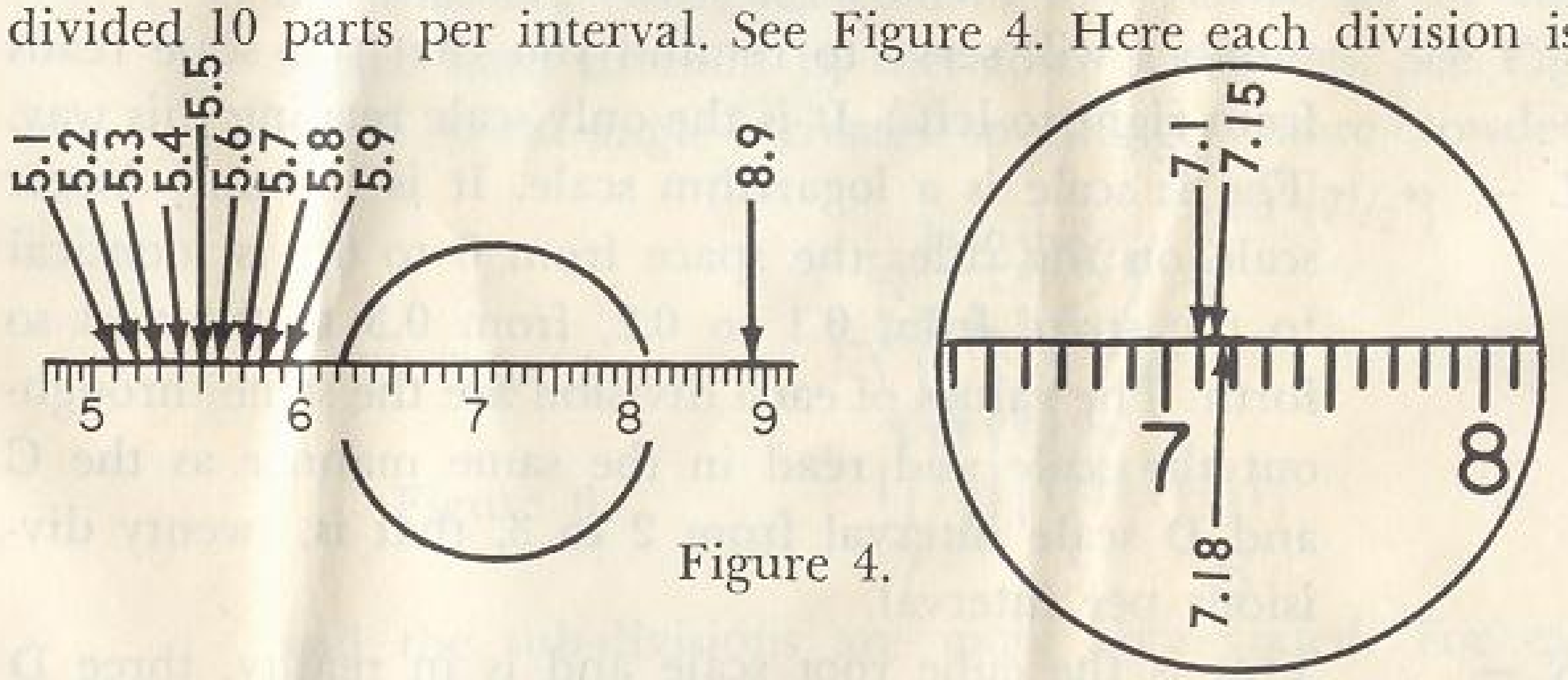


Figure 4.

0.1 (1/10) so a setting of 8.9 for example would be obtained by moving the hairline between 8 and 9, then to the 9th division after the 8. Again notice that the "long" line is the halfway point.

The third digit of 3 digit numbers cannot be located exactly so is must be estimated. Four digit numbers must be rounded off to three digit numbers because of the "crowded" effect. For example 9.865 would be rounded off to 9.87.

This would be set by positioning the indicator between the 9 and 1 (10), then to 9.8 (eighth division after 9) and then the 7 would be estimated as being slightly closer to 9.9 than to 9.8.

Reading Scales other than C and D – A lot of space was devoted to reading the C and D scales because these are the "parent" scales of the slide rule. *All* other scales are divided in a similar fashion. Following is a brief, easy-to-follow check on reading these other scales.

CF, DF – These are identical to each other and are called "Folded Scales." (C stands for C scale and F means folded). If you look at them you will see they are *divided exactly the same as the C and D scales* but are displaced in position. Instead of starting at 1 they start π (3.1416) and end at π. They are therefore referred to as being "Folded to π."

CI – The CI scale is identified to the C and D scales but it is placed on the scale in reverse – that is, it is to be *read from right to left.* (The small black dots by each number will serve to remind you that this scale reads from right to left.) It is the only scale reading this way.

L – The L scale is a logarithm scale. It is the only *linear* scale on the rule; the space from 0 to 0.1 is identical to the space from 0.1 to 0.2, from 0.3 to 0.4 and so forth. The values of each division are the same throughout the scale and read in the same manner as the C and D scale interval from 2 to 3, that is, twenty divisions per interval.

K – This is the cube root scale and is in reality, three D scales laid end to end. Note that there are three complete scales that repeat identically. The 1 to 2 intervals are divided the same as the 2 to 3 interval on the D

scale. The 2 to 3 and 3 to 4 intervals are divided like the 5 to 6 interval on the D scale. The remaining intervals are divided into 5 parts each (each part is 0.2) . . . see Figure 5.

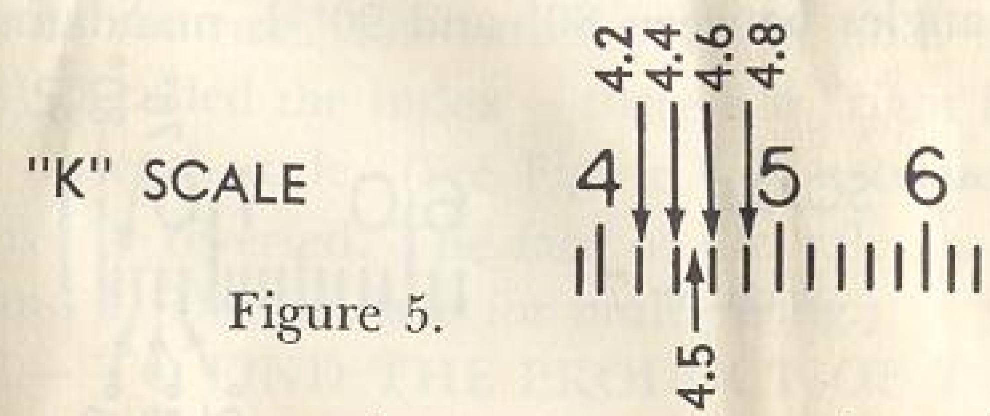


Figure 5.

A, B – These are square (or square root) scales and are identical to each other. They are two D scales laid end to end and are read as is the D scale except that space, once again, is more limited and therefore the intervals are divided similar to the K scale and higher end of of the D scale.

T – This is the tangent scale covering angles from slightly under 6° to 45°. Since degrees are broken down into minutes (60 minutes to a degree) this scale is divided accordingly. Instead of a base unit in tenths as with the C and D scales, the base units are in even parts of 60ths. For example, from 7° to 8°, there are 12 divisions. Each division is, therefore, 5 minutes. See Figure 6. As the angle increases, spacing gets more crowded

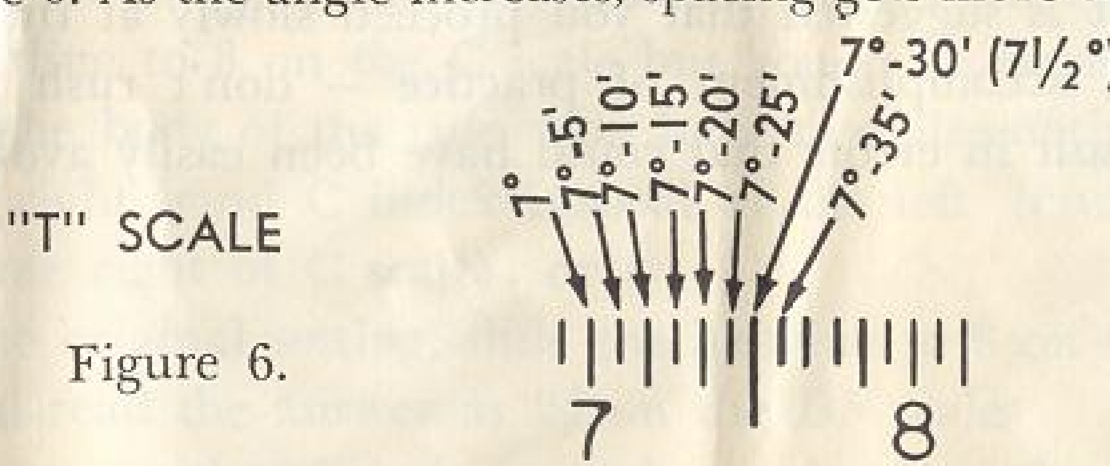


Figure 6.

and the sub-divisions are more abbreviated. For example, in the 10° to 20° intervals, each line represents 10 minutes while in the 20° to 40° intervals, each line represents 20 minutes (each long line is 1 degree).

S – This is the sine scale and is graduated much the same as the tangent scale. Pay particular note to the high end where angles over 70° are represented in a very abbreviated fashion. See figure 7. Here estimating angles between 80° and 90° is mandatory.

"S" SCALE

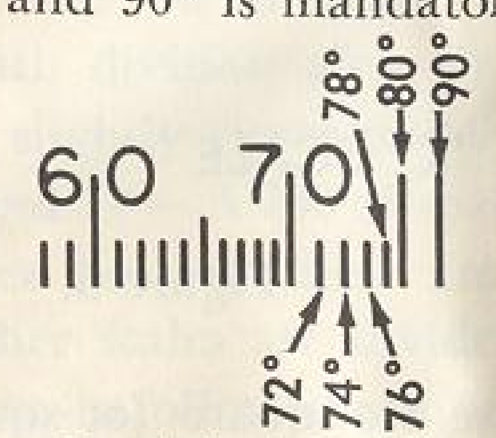
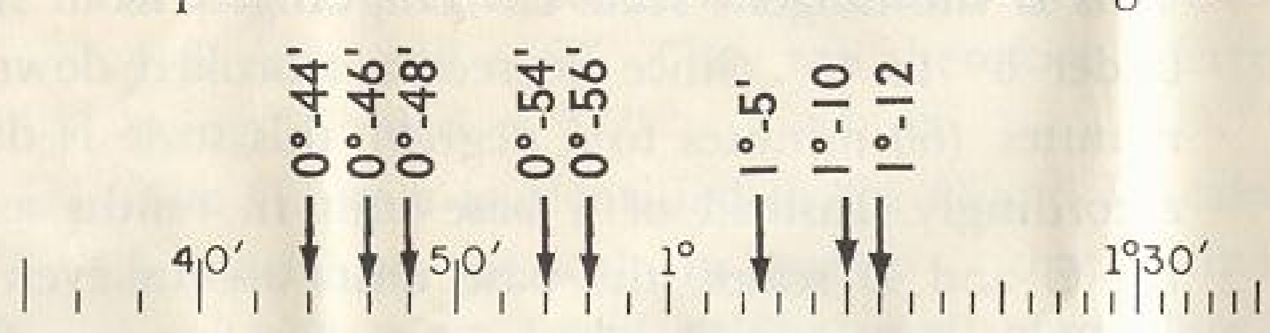


Figure 7.

ST – Though only one scale, this is really two (sine and tangent). Because sines and tangent of angles smaller than 5°45' are so close (sin 5°45'=.1002; tan 5°45'=.1007), these scales are put together as one. It is read basically the same as the S or T scales except that it is expanded rather than condensed. See Figure 8.



"ST" SCALE Figure 8.

Until you are familiar with reading these scales quickly and easily it is suggested that you proceed slowly at first. Speed is a natural accomplishment of practice – don't rush it because it will result in errors that could have been easily avoided.

CHAPTER II – MULTIPLICATION

Multiplication – The next setp in using the slide rule is to learn how to multiply. As noted before, the C and D scales are used to multiply. The C scale is on the *slide* of the rule, and the D scale is on the *body* of the rule. The number 1 (on both ends of the C and D scales) is called the index – there is a "right index" and a "left index" on each scale. (See Figure 1 if necessary. Be sure that the slide is not reversed. The face of the rule has scales DF, CF, CI, C, D and L. Use the face for multiplying.)

TECHNIQUE – TO FIND THE PRODUCT OF TWO NUMBERS, LOCATE EITHER NUMBER ON THE *D* SCALE AND MOVE THE CLOSEST *C* INDEX (NUMBER 1) OVER THE NUMBER. LOCATE THE OTHER NUMBER ON THE *C* SCALE AND SLIDE INDICATOR OVER THAT LOCATION. THE ANSWER WILL THEN BE UNDER THE HAIRLINE ON THE *D* SCALE. DISREGARD DECIMAL LOCATION UNTIL CALCULATION IS DONE.

Try this with something simple like 2 x 4. Set the nearest C scale index (number 1) – the nearest index is the left one – over 2 on the D scale. Slide the indicator until the hairline is over 4 on the C scale. Read the answer, 8, on the D scale. Practice this procedure on these other simple problems: 2 x 3, 2 x 5, 3 x 3.

Now take the problem of 3 x 8. Set the left index of the C scale over three on the D scale. Your next step would normally be to move the hairline to 8 on the C scale but you can't because the 8 is now off the body of the rule. You have two alternatives:

1. Use the right hand C index instead of the left (number 1 at extreme right of C scale), or
2. Using the original setting, slide the hairline to 8 on the *CF* scale and read the answer as 24 on the *DF* scale

Note these things: either C index may be used; when the answer would normally fall off the rule it can usually be picked up on the DF scale.

To be certain that your understanding is complete try these problems — and remember, disregard decimal points during the slide rule operation. Decimal points will be picked up after calculation as indicated immediately following these exercises.

Problem	actual answer	slide rule answer
398 x 21	8,358	8,360
226 x 533	120,458	120,500

Problem	actual answer	slide rule answer
2.1 x 0.005678	0.0119238	0.0119
4398 x .6667	2,932.1466	2930

Good slide rule manipulation will keep your answers accurate to 1/2 of 1% which is sufficiently accurate for almost every problem.

Decimal Point Location — The easiest way of locating the decimal point in any problem is by "estimation." No matter how complex a problem is, all the numbers in it can be rounded off to simple numbers which can then be multiplied mentally. For example, 2340x22 could be rounded off to: 2500x20 which mentally produces an answer of 50,000. In the actual problem of 2340 x 22, the answer is 51,480. Using the slide rule you would probably read 515 and by "estimation" you know there are five places. Therefore your answer would be 51,500.

Consider the first exercise of 398 x 21. The actual product is 8358 but the reading you might have gotten from the slide rule is 836.

To determine if it is 836. or 8360. or 8.36 do the following: the number 398 is close to 400, and 21 is close to 20, therefore 400 x 20 would give an approximate answer. Mentally 400 x 20=8000. Therefore your answer must be 8360. and not 836 or 8.36.

Consider the exercise of 2.1 x 0.005678. This is approximately 2 x 0.006 or 0.012. The slide rule provides an answer of 119 or after locating the decimal point this becomes 0.0119 which is the answer. Finally consider 4389 x 0.6667. This is approximately 4000 x 0.7=2800. The slide rule provides a number of 293 and the answer is then 2930. (four places).

Multiple Products — When multiplying more than two numbers together, it becomes a simple extension of the same operation as described before. For example, 2 x 3 x 4 is done by multiplying 2 x 3 (set index C over 2 on the D scale, slide hairline to 3 on C scale and answer is on D scale). This time though, don't write down the product of the first two. Instead move the slide being careful not to disturb the hairline setting, until the C index is over the product. Next move the hairline to 4 on the C scale and read the answer as 24 on the D scale. Don't forget that you can also use the CF and DF scales if the problem takes you off the rule. Again, to verify your procedure, try a few practice problems that are easy.

CHAPTER III – DIVISION AND COMBINATIONS OF DIVISION AND MULTIPLICATION

Division – Division utilizes the same scales as multipliction namely the C and D. In the fraction 1/4, the 1 is the *numerator* and the 4 is the *denominator.* The answer of 1 divided by 4 is the quotient.

TECHNIQUE – TO FIND THE QUOTIENT OF TWO NUMBERS. LOCATE THE NUMERATOR ON THE *D* SCALE WITH HAIRLINE. MOVE SLIDE UNTIL THE DENOMINATOR ON THE *C* SCALE IS UNDER HAIRLINE (OVER THE NUMERATOR). THE QUOTIENT IS FOUND UNDER THE *C* INDEX ON THE *D* SCALE. DISREGARD DECIMALS UNTIL CALCULATION IS COMPLETE.

Taking a simple exercise, find the decimal equivalents of the following:

1/8, 7/8, 7/16, 3/32

Figure decimal points last, by estimation as with multiplication. For example, 7/8 is read as 875. We know 7/8 is a little less than 1, and more than 0.5, therefore the answer is 0.875. Take 3/32, this is approximately 3/30 or 1/10 or 0.1. The answer on the slide rule is 938 and, therefore, the answer is 0.0938, not 0.938, 9.38 or some other variation.

Combination of Division and Multiplication – Many times problems will involve both multiplication and division as, for example,

$$\frac{29.2 \times 15.3}{0.202}$$

This type problem is handled this way: (Disregard decimals)

a. Divide 292 by 202 by setting 292 on the D scale *under* 202 on the C scale.

b. The C index is now over the quotient. Retain this setting and slide hairline over 153 on the C scale.

c. The answer to the problem is then to read the D scale as 222.

d. The problem is completed by locating the decimal point as

follows: the expression is approximately equal to $\frac{30 \times 15}{0.2} = \frac{450}{0.2} = 5 \times 450$ or 2250; therefore the answer is 2220.

The same problem could have been worked by performing the multiplication first, then the division. By alternating, that is, divide, multiply, divide, multiply, etc. problems of this type can be handled quickly and easily. The CF and DF scales can be used in these computations wherever necessary.

CHAPTER IV – PROPORTIONS AND RECIPROCALS

Proportions – *A* proportion is the equating of two or more fractions; for example 1/2=2/4 or 1/X=5/6. The later exmple is to an extent typical of an algebraic equation expressed as a proportion wherein it is necessary to establish the value of "X". Although it is simple to reduce this to an equation of X=6/5 and then reduce the 6/5 to a decimal number, the problem can be handled directly in proportion form on the slide rule.

TECHNIQUE – TO FIND AN UNKNOWN IN A PROPORTION, SET UP THE NUMERATOR OF THE KNOWN FRACTION ON THE *C* SCALE OVER THE DENOMINATOR OF THE KNOWN FRACTION ON THE *D* SCALE. THE C AND D SCALES NOW EXPRESS ALL THE PROPORTIONS RELATED TO THE UNKNOWN RATIO OF NUMERATOR TO DENOMINATOR. NEXT LOCATE WHICHEVER PART OF THE OTHER FRACTION IS KNOWN ON THE C (NUMERATOR) OR D (DENOMINATOR) SCALE AND THE ANSWER IS FOUND DIRECTLY ABOVE OR BELOW THE KNOWN PART.

For example, find X in the proportion of 2/11=X/5. Set up the 2 on the C scale *over* the 11 on the D scale. Next locate the 5 on the D scale and read your answer over the 5 on the C scale as 909. Locate the decimal point to give 0.909 as the correct answer.

The CF and DF scales may be used the same way as the C and D. This comes in handy for a problem such as 7/12=x/2 where the problem's answer would fall off the C and D scales. As a "rule-of-thumb," if the difference between the *first* digits of the numbers of the known fraction (ratio) is small, the C and D scales may be used. If large, use the CF and DF scales. Considering the examples used, the first known fraction was 2/11 and the difference between the *first* digits (2 and 1) is small.

The second example was 7 and 12 where the difference was large (7 compared with 1).

Set up some simple problems and check your knowledge of this operation.

Reciprocals – The reciprocal (sometimes called "inverse" number) of any number is that number divided into 1. The reciprocal of 4 is 1/4; the reciprocal of .02 is 1/.02 and so forth.

TECHNIQUE – TO FIND THE RECIPROCAL OF ANY NUMBER, SET THE HAIRLINE OVER THE NUMBER ON THE *C* SCALE AND READ THE ANSWER ON THE *CI* SCALE. REMEMBER, THE *CI* SCALE IS READ FROM RIGHT TO LEFT.

Example: Find the recpocal of 2.4. Set the hairline over 2.4 on the C scale and read the answer as 417; locate the decimal point to get .417 as the answer. This reciprocal function may be applied when evaluating fractions because a fraction may be expressed as the numerator times the reciprocal of the denominator.

Example: 5/7 is the same as 5 x 1/7. Thus we can evaluate 5/7 by setting the C index over 5 on the D scale and read the answer on the D scale under 7 on the CI using the hairline on the indicator.

CHAPTER V – SQUARES, SQUARE ROOTS AND COMBINATIONS

Squares – The square of any number is that number multipied by itself one time. For example, the square of 3 is 3 x 3 or 9. This is written as $(3)^2=9$. As noted before, the A scale is the square scale.

TECHNIQUE – TO FIND THE SQUARE OF A NUMBER SET THE HAIRLINE OVER THAT NUMBER ON THE *D* SCALE AND READ THE SQUARE ON THE *A SCALE.* (NOTE: USE BACK OF RULE, NOT FACE – SEE FIG. 1 IF IN DOUBT.)

Example: To find the square of 19, set the hairline over 19 on the D scale and read 361 on the A scale. Locate the decimal point by the same method as for other operations, that is, 19 x 19 is about the same as 20 x 20 which equals 400; therefore the answer of 361.0 is correct. A variation of this might be the evaluation of something like $12.3(14.2)^2$. Set the 12.3 on the *B* scale under the A index (use left A index this time otherwise your answer will be off the rule). Next move the hairline over the 14.2 on the *D* scale and read the answer as 248 on the *B* scale. Decimal location gives the answer as 2480. A typical good practical problem is the area of a circle. The formula is $A=\pi(d)^2/4$. If *d* is 12.4 the area is $\pi(12.4)^2/4$. To evaluate this, move the slide until the special extra mark at 0.785 on the right hand B scale is under the right index of the *A* scale. (Note: this special mark is $\pi/4$ or 0.785). Next set the diameter (12.4) on the D scale with the hairline, and read the answer under the hairline on the *B* scale. The reading is 122, which is the answer.

Let's analyze what we had done. Let's take the original example of $12.3(14.2)^2$. By setting the 14.2 on the D scale, its square is on the A scale. By moving the slide so that the 12.3 on the B scale is under the A index, we have set up a straight multiplication problem using the A index as a C index would be used and using the B scale as a D scale. In other words, we can multiply with the A

and B scales just as we can with the C and D scales. We learned earlier that the A and B scales are not only identical but are also short versions of the C and D scales. By using this principle plus the fact that the A scale gives squares of numbers on the D scale, we can always work this short cut to evaluate expressions like $x(y)^2$. Divisions of squares are similarly easy to perform. For example $(8.3)^2/5.6$. This expression is the same as $(8.3)^2 x 1/5.6$ and can be handled this way. Set the hairline over 8.3 on the D scale. Move the slide until 5.6 on the B scale is under the hairline, and read the answer as 123 on the A scale over *any B index.* Locate the decimal point to give 12.3 as the answer.

Square Roots – The square root of a number is the number which when multiplied by itself once gives the original number. The square root of 9 is 3 because 3 multiplied by itself once is the original number (9).

TECHNIQUE 1 – TO FIND THE SQUARE ROOT OF ANY NUMBER GREATER THAN ONE WITH AN *ODD* NUMBER OF DIGITS INCLUDING ZEROS TO THE LEFT OF THE DECIMAL POINT (1.2, 120.0, 12000. ETC.), LOCATE THE HAIRLINE OVER THE NUMBER ON THE *LEFT HAND A SCALE* AND READ THE ANSWER ON THE D SCALE.

Example: To find the square root of 110.0, set the hairline over 11 on the *left* hand *A* scale and read 1048 as the answer on the D scale. Locate the decimal (110 is about 100 for which the square root is 10.0) as 10.48 which is the correct answer.

TECHNIQUE 2 – TO FIND THE SQUARE ROOT OF ANY NUMBER GREATER THAN ONE WITH AN *EVEN* NUMBER OF DIGITS INCLUDING ZEROS TO THE LEFT OF THE DECIMAL POINT (12.0, 1200.0, 120000.0 ETC.) LOCATE THE HAIRLINE OVER THE NUMBER ON THE *RIGHT HAND A SCALE* AND READ THE ANSWER ON THE D SCALE.

Example: To find the square root of 11.0, set the hairline over 11 on the *right* hand *A* scale and read 332 as the answer on the

D scale. Locate the decimal point as 3.32 for the final answer

TECHNIQUE 3 – TO FIND THE SQUARE ROOT OF ANY NUMBER LESS THAN ONE WITH AN *ODD* NUMBER OF *CONSECUTIVE ZEROS* TO THE RIGHT OF THE DECIMAL POINT (0.0205, 0.000205, etc.) SET THE HAIRLINE OVER THE NUMBER ON THE LEFT HAND A SCALE AND READ THE ANSWER UNDER THE HAIRLINE ON THE D SCALE.

Example: To find the square root of .0705, set the hairline over 705 on the left hand A scale; read 266 on the D scale. Locate the decimal (0.2x0.2=0.04 and 0.3x0.3=0.09, therefore answer must be between 0.2 and 0.3) as 0.266 for the answer.

TECHNIQUE 4 – TO FIND THE SQUARE ROOT OF ANY NUMBER LESS THAN ONE WITH NO ZEROS IMMEDIATELY TO THE RIGHT OF THE DECIMAL POINT OR AN *EVEN* NUMBER OF *CONSECUTIVE ZEROS* TO THE RIGHT OF THE DECIMAL POINT (0.705, 0.00705, 0.0000705 ETC.) SET HAIRLINE OVER NUMBER ON *RIGHT HAND A SCALE* AND READ ANSWER UNDER HAIRLINE ON THE D SCALE.

Example: To find the square root of 0.00705, set the hairline over 705 on the right hand A scale; read 84 on the D scale. Locate decimal point (0.08 x 0.08=0.0064 and 0.09 x 0.09=0.0081, therefore answer is between 0.08 and 0.09) as 0.084 which is the answer.

As a general rule in finding square roots for an odd number of digits making a number over one use the left hand scale; an even number over one, the right hand scale. For numbers less than one, count the number of zeros immediately following the decimal point; if odd in number, use the left scale, if none or even in number, use the right scale. Here is a chart to help you remember this relationship.

If Number is:	Examples	Use	Answer is on
over one and "odd"	1.4, 140.	left A scale	D scale
over one and "even"	14, 1400	right A scale	D scale
under one and "odd" number of zeros	0.014, 0.00014	left A scale	D scale
under one and "even" number or no zeros	0.14, 0.0014	right A scale	D scale

Since the answer is always on the D scale, it is possible to perform such operations as $2.6(\sqrt{7})/15.3$ in a continuous fashion. First find the $\sqrt{7}$ on the D scale, then divide by 15.3 (move slide until 15.3 is over the $\sqrt{7}$ on the D scale), then multiply by 2.6 (move hairline to 2.6 on C scale and read answer on the D scale). Try this yourself. The answer is approximately 0.450 (slide rule accuracy). Note, you will have to turn rule over to do the multiplication and division.

Similarly, it is now possible to combine square, square root, multiplication and division operations into a continuous smooth sequence of settings to arrive at an answer without writing down intermediate results.

CHAPTER VI – CUBES AND CUBE ROOTS

Cubes – Any number may be cubed by multiplying it by itself two times. For example 3 cubed is 3 x 3 x 3 or 27. Frequently this is written as $(3)^3$.

Previously we noted that the K scale is the cube scale. It is used similarly to the square (A) scale. It is really three D scales put end-to-end.

TECHNIQUE – TO CUBE ANY NUMBER, SET THE HAIRLINE OVER THE NUMBER ON THE *D* SCALE AND READ THE ANSWER ON THE *K* SCALE.

Example: To find the cube of 5.7 which is normally written $(5.7)^3$, set the hairline over 5.7 on the D scale and read the answer as 185 on the K scale. Since 5.7 is almost 6 and since 6 x 6 x 6 =216, the decimal point should be located as 185.0 to yield the correct answer.

Note the similarity between the cubing function and the previously discussed squaring function.

Cube Roots – Cube roots are numbers which when multiplied by themselves two times result in the original number. For example, the cube root of 27 is 3.

In square root problems we made distinction between an odd number of digits and an even number of digits to determine which scale (left or right) we should use for the computation. The K scale has a left hand scale, a middle scale and a right hand scale – three D scales laid end-to-end.

TECHNIQUE 1 – TO FIND THE CUBE ROOT OF ANY NUMBER GREATER THAN ONE WITH 1, 4, 7, 10, ETC. DIGITS INCLUDING ZEROS TO THE LEFT OF THE DECIMAL POINT (1.5, 1500., 1500000.) SET THE HAIRLINE OVER THE NUMBER ON THE *LEFT K* SCALE AND READ THE ANSWER ON THE *D* SCALE.

Example: To find the cube root of 1440., set the hairline over 144 on the left hand K scale. Read the answer as 1129 on the D scale. Since 10 x 10 x 10=1000, locate the decimal as 11.29 which is the correct answer.

TECHNIQUE 2 – TO FIND THE CUBE ROOT OF ANY NUMBER GREATER THAN ONE WITH 2, 5, 8, 11, 14, ETC. DIGITS INCLUDING ZEROS TO THE LEFT OF THE DECIMAL POINT (15., 15000., 15000000.) SET THE HAIRLINE OVER THE NUMBER ON THE *MIDDLE* K SCALE AND READ THE ANSWER ON THE *D* SCALE.

Example: To find the cube root of 14.4, set the hairline over 144 on the middle K scale and read the answer as 243 on the D scale. Since 2 x 2 x 2=8 and 3 x 3 x 3=27, the decimal point should be located as 2.43 which is the correct answer.

TECHNIQUE 3 – TO FIND THE CUBE ROOT OF ANY NUMBER GREATER THAN ONE WITH 3, 6, 9, 12, 15 ETC. DIGITS INCLUDING ZEROS TO THE LEFT OF THE DECIMAL POINT (150., 150000.) SET THE HAIRLINE OVER THE NUMBER ON THE *RIGHT HAND* K SCALE AND READ THE ANSWER ON THE D SCALE.

Example: To find the cube root of 144., set the hairline over 144 on the right hand K scale and read the answer as 524 on the D scale. Since 5 x 5 x 5=125 the decimal point is located as 5.24 which is the correct answer.

TECHNIQUE 4 – TO FIND THE CUBE ROOT OF ANY NUMBER LESS THAN ONE WITH 1, 4, 7, 10, ETC. CONSECUTIVE ZEROS TO THE RIGHT OF THE DECIMAL POINT (0.0144, 0.0000144) SET THE HAIRLINE OVER THE NUMBER ON THE *MIDDLE K SCALE* AND READ THE ANSWER ON THE *D* SCALE.

Example: To find the cube root of 0.0144, set the hairline over 144 on the middle K scale and read 243 on the D scale. Locate the decimal point at 0.243 and this is the correct answer.

TECHNIQUE 5 – TO FIND THE CUBE ROOT OF ANY NUMBER LESS THAN ONE WITH 2, 5, 8, 11, ETC. CONSECUTIVE ZEROS TO THE RIGHT OF THE DECIMAL POINT (0.00144, 0.00000144) SET THE HAIRLINE OVER THE NUMBER ON THE *LEFT HAND K SCALE* AND READ THE ANSWER ON THE *D* SCALE

Example: To find the cube root of 0.00144, set the hairline over 144 on the left hand K scale and read the answer as 1128 on the D scale. Locate the decimal point as 0.1128 and this is the correct answer.

TECHNIQUE 6 – TO FIND THE CUBE ROOT OF ANY NUMBER LESS THAN ONE WITH NO ZEROS OR 3, 6, 9, ETC. CONSECUTIVE ZEROS TO THE RIGHT OF THE DECIMAL POINT, (0.144, 0.000144) SET THE HAIRLINE OVER THE NUMBER ON THE *RIGHT HAND K SCALE* AND READ THE ANSWER ON THE *D* SCALE.

Example: To find the cube root of 0.144, set the hairline over 144 on the right hand K scale and read the answer as 524 on the D scale. Locate the decimal point as 0.524 and this is the correct answer.

Here is a reminder chart to help you remember these relationships:

For numbers *greater than one*:

Number of digits including zeros to the left of decimal point	K scale to use Lft.	Mid.	Rt.	Examples
1,4,7,10,13,16, etc.	•			3.37, 3370.0
2,5,8,11,14,17, etc.		•		33.7, 33700.0
3,6,9,12,15,18, etc.			•	337.0, 337000.0

For numbers *less than one*:

Number of zeros immediately following decimal point	K scale to use Lft.	Mid.	Rt.	Examples
2,5,8,11,14, etc.	•			0.0033701, 0.0000033701
1,4,7,10,13, etc.		•		0.033701, 0.000033701
0, 3, 6, 9, 12, etc.			•	0.33701, 0.00033701

Since the answer always appears on the D scale as it did with square roots, the same variations and combinations of multiplication and divisions (using the C and D scales) may be done. For example: evaluate $3\sqrt[3]{26} / 5.2$. First move the hairline over 26 on the middle K scale. Next, turn the rule over and move the slide so that 5.2 on the C scale is under the hairline. Finally, move hairline over 3 on the C scale and read the answer as 171 on the D scale. Locate the decimal point as 1.71 which is the correct answer.

CHAPTER VII – TRIGONOMETRY AND THE USE OF THE S, ST AND T SCALES

The value and procedures of trigonometric functions are assumed to be known to the user of this slide rule so space will not be devoted to the formulae that are applicable to these operations. The slide rule can give direct tangents of any angles from less than 1° to 45° and sines to 90°. Knowing the relationships beween cosines and sines, cotangents and tangents, etc. the user can obtain all of the trigonometric values needed.

Sines of angles – The reading of these scales was covered in detail on page 10. Refer to this page if necessary before proceeding further. To find the sine of any angle on the S scale, first align the C and D scales. Turn the rule over and set the hairline over the angle whose sine is required and read the sine on the D scale. Example: To find the sine of 33°, align the C and D scales, then move the hairline over 33° on the S scale and read the answer as 0.545 on the D scale.

Since the answers are on the D scale, multiplication and division can be performed in a continuous manner. Example: Evaluate 2 sin 14°/2.33. Align the C and D scales. Move hairline over 14° on the S scale. Next, flip the rule and move slide until 233 on the C scale is under hairline. Finally move hairline over 2 on the C scale and read 2075 as the answer on the D scale. Locate decimal point as .2075 which is the correct answer.

Note that sines of angles shown on the S scale are always between 0.1 and 1.0 while the sines of angles on the ST scale are less than .1 so be careful with decimal point locations.

Tangents of angles less than 45° – To find the tangent of an angle, move the hairline over the angle on the T scale and read the answer on the D scale. All tangents of angles on the T scale are between 0.1 and 1 as in the case of sines. For smaller angles use the ST scale instead of the T scale. All tangents of angles on the ST range between 0.01 and 0.1 so again be careful of decimal point location.

As with sines of angles, the answer appears on the D scale and thereby makes it possible to perform a continuous operation of multiplication and division after finding the tangent.

Tangents of angles greater than 45° – In order to get the tangent of angles between 45° and 90° it is necessary that you use the relationship:

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

Example: To find the tangent of 70° set up the equation

$$\tan 70° = \frac{1}{\tan (90° - 70°)} = \frac{1}{\tan 20°}$$

Move hairline to 20° on T scale, flip the rule over and with the C and D scales aligned read the CI scale under the hairline. This is your answer, which in this case is 2.76 (be careful of decimal point location).

Finding angles when tangents or sines are known – This is the reverse operation of finding sines and tangents. In doing this, particularly with tangents, be careful in locating the decimal point.

If the tangent is between 0.1 and 1, then read the answer on the T scale.

If the tangent is between 0.01 and 0.1, then read the answer on the ST scale.

If the tangent is beween 1 and 10, then read the angle on the T scale and subtract from 90° to get the correct answer.

For sines between .1 and 1.0, use the S scale.

For sines less than 0.1, use the ST scale.

Remember, the D scale is the basic scale used with the T, S and ST scales.

Other Trigonometric Functions – Functions such as cos, csc, sec, and cot are all definable in terms of sines or tangents. In solving problems involving these other functions, reduce them in terms of sines and tangents.

Trigonometric proportions – These are handled identically as were the numerical proportions except that the Trig scales replace the C scale.

Example: Find X in the expression

$$\frac{\sin\ X}{1.232} = \frac{\sin\ 40°}{2.9}$$

Move hairline over 2.9 on the D scale. Move slide until 40° on the S scale is under hairline. Move hairline over 1.232 on the D scale and read the answer as 15°52'. This method will be helpful for application to the law of sines (for right triangles or oblique triangles). Don't forget that the DF scale may be used instead of the D scale where necessary but in any one problem you may not use both the D and DF — it's one or the other.

CHAPTR VIII – LOGARITHMS

A logarithm of a number consists of two parts: the *characteristic* and the *mantissa.* The slide rule provides only the mantissa. The characeristic is established in the usual way, that is, for numbers greater than 1.0, the characteristic is one less than the number of digits to the left of the decimal point. For numbers less than 1.0, the characteristic is one more than the number of consecutive zeros to the right of the decimal point and is *negative* (mantissa read from rule is always positive).

TECHNIQUE – TO FIND THE LOG TO THE BASE 10 OF A NUMBER, LOCATE THE NUMBER ON THE *D* SCALE. MOVE HAIRLINE OVER THE NUMBER AND READ THE *MANTISSA* ON THE *L* SCALE. ADD CHARACTERISTIC.

For example, find the log of 30.0. Move hairline over 3 on the D scale and read .477 (mantissa) on the L scale. Since 30.0 has a characteristic of 1, the answer is 1.4777.

If the log of a number is known and it is necessary to find the number, simply set the mantissa only under the hairline on the L scale and read answer on the D scale. Locate the decimal by using the characteristic. For example, find the anti-log of 3.752. Set the hairline over .752 on the L scale and read 56.5. Locate the decimal as 5650.0 for the correct answer.

For more information on logarithms and their use, refer to any good text on mathematics.

CHAPTER IX – GENERAL

Your slide rule can save you many hours of work. Because it is small and convenient, you can keep it in your pocket. The simple care required to maintain it will take very little time and will give you years of continuous service.

Replacement parts are available from any of the Charles Bruning Company, Inc. offices located in the United States, Canada and Hawaii. However with reasonable care, these services should not be required.

Learning the use of a slide rule can be a complete course of instruction because there are many ways of short-cutting in various fields. These points are left untouched in this manual. However, once proficiency is achieved from the notes and comments herein, you will quickly add your own "touch" and become a fast, efficient operator.

For the office, we also recommend a 12" rule which offers greater accuracy and readability.

QUICK INDEX

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