CASTELL

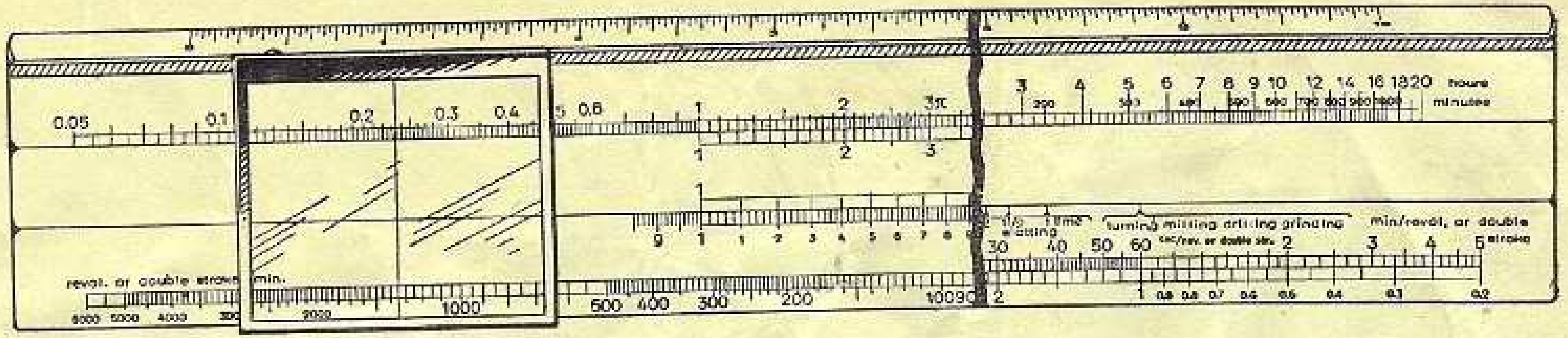
# Machining Slide Rule

**No. 1/48**

**System Dr. Winkel**
(Patented)

**INSTRUCTIONS**

A.W. FABER - CASTELL, STEIN BEI NÜRNBERG



# INSTRUCTIONS

With the slide inverted, so that the side with the shorter graduation and with the marks □ ○ ○ is to the front, it will be found that the middle of this rule is provided with the normal scales of the ordinary technical slide rule. The method of oalculating with these scales will be understood from the following explanation.

## Instructions for the Use of the Normal Scales.

**Introduction**

The slide rule is employed, with an accuracy sufficient for all practical purposes, for multiplication, division, powers, roots, percentages, and the like, with special slide rules, in addition, numerous algebraic problems, as well as technical and trigonometrical calculations, can be successfully carried out. It has proved of the greatest assistance to both practical men and students.

The following instructions can only very briefly explain the methods of using the slide rule. For a more extended study of our slide rules, our complete **Instructions, issued in book-form,** are recommended; they give numerous worked examples in various braaches of practical work.

**Definitions of the Slide Rule**

The two parts that are joined together are called the "Rule", the movable portion between these two is called the "Slide", and the metal frame and glass across which a fine line is marked, is called the "Cursor". The edge of the rule which is bevelled and carries the scale of inches is termed the "Upper Edge", and the scales on that side of the centre, which are graduated from 1 to 100, are called the

"Upper Scales". The upper scale on the rule is called "A" and the similar one on the slide is "B". The other pair of adjoining scales on the slide and rule, which are graduated from 1 to 10, are the "Lower Scales"; that on the slide is "C" and on the rule "D".

The scales are graduated with lengths proportional to the logarithms of the numbers marked on them, and the principle of their operation is similar to that of logarithms, except, of course, that the answer is read directly in natural numbers. Multiplication and division may be equally well worked on the upper or lower scales. On the upper scales the length from 1 to 10 is equal to that from 10 to 100, and the whole length from 1 to 100 is equal to the length from 1 to 10 on the lower scales. Owing to the wider spacing thus obtained on the lower scales, a more exact reading is possible than on A and B. The upper scales are to be mainly used when great accuracy is not required.

**Multiplication**

**Two numbers are multiplied together by adding the lengths representing the numbers on the rule and slide.**

Example (Fig. 1.) 2·5×3 = 7·5.

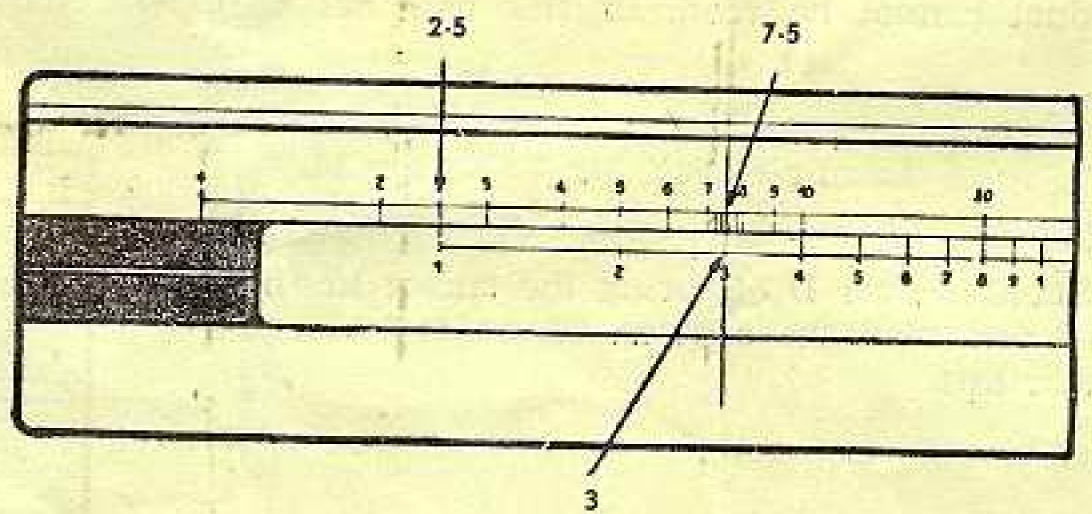



Fig. 1

Set 1 on the slide (B 1) under 2·5 on the upper rule scale (A 2·5), put the cursor line over 3 on the upper slide scale (B 3), and read the product, 7·5, on the upper scale (A 7·5) under the cursor line. On the lower scales the procedure is similar.

Example (Fig. 2). 2·45 × 3 = 7·35.

Set 1 on the lower slide scale (**C** 1) to **D** 2·5, place the cursor line over 3 on the lower slide scale (**C** 3), and read the product, 7·35, on the lower rule scale **D** 7·35 under the cursor line.

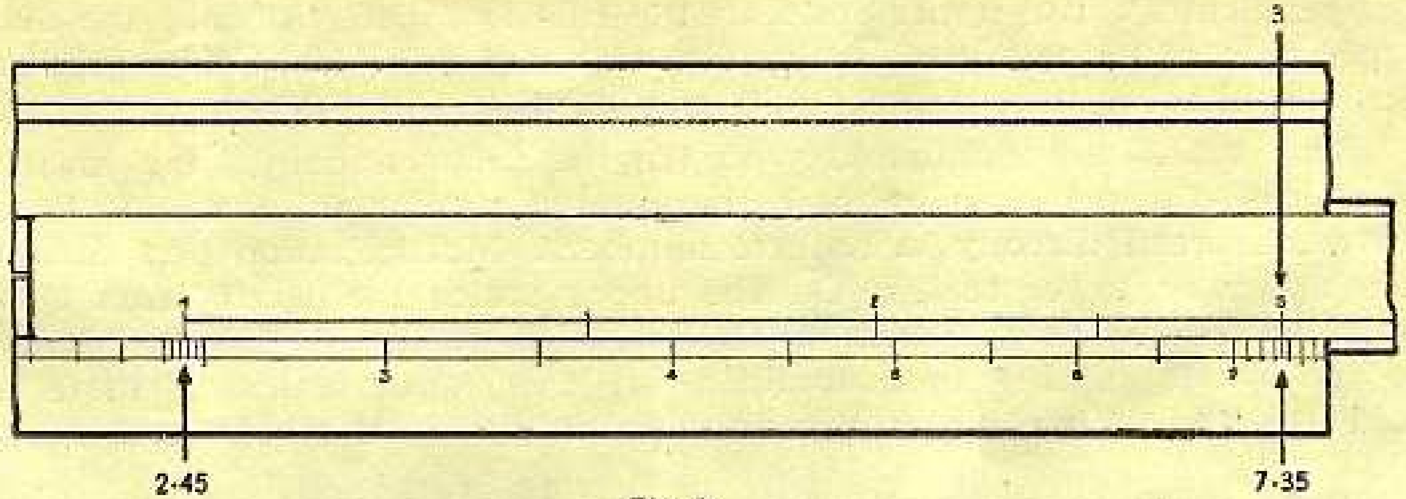



Fig. 2

When the upper scales are used the procedure is exactly as in Fig. 1, but if the lower scales are employed it may sometimes happen that the second factor is beyond the end of the **D** scale and so the product cannot be read. In this case set **C** 10 over the first factor. For instance:

Example (Fig. 3). 7·5×4·8 = 36.

Set **C** 10 over **D** 7·5, bring the cursor line over **C** 4·8 and read the answer, 36, on **D** under the cursor line.

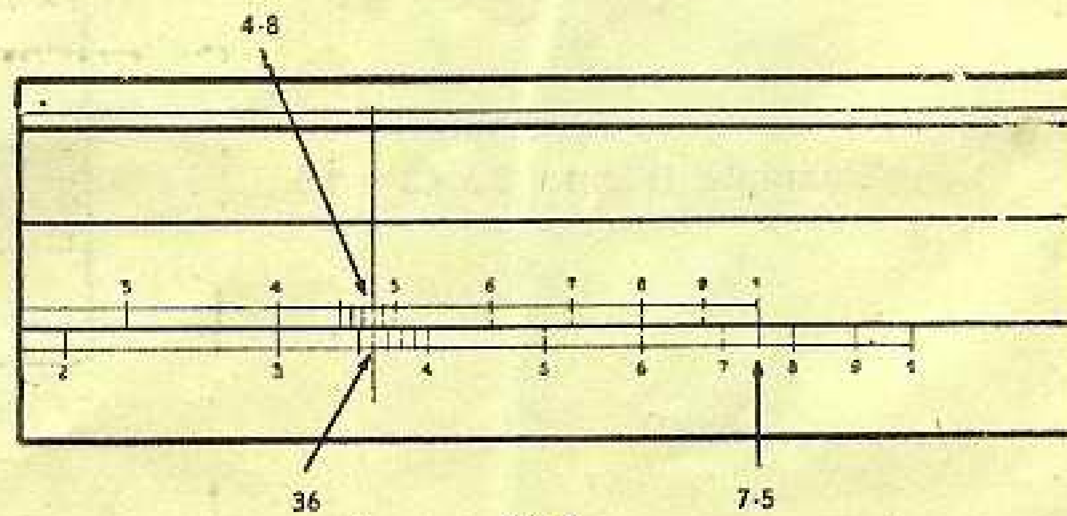



Fig. 3

From these two examples, we see that it is immaterial whether the setting is made with the left or right hand end of the slide; it only has influence on the position of the decimal point in the result.

It follows from these examples that continued multiplication —i. e., multiplication with more than two factors— is easily carried out, as no intermediate products need be read. Set the cursor line over the second factor, bring one end of the slide scale to the cursor line, move the cursor over the third factor, and read the answer on the rule scale, or if there are more factors, again bring the end of the slide scale to the cursor line and continue as before.

**Division**

**Division is carried out by subtracting the length corresponding to the divisor on the slide scale from the length corresponding to the dividend on the rule scale.**

Example (Fig. 4). 9·85 ÷ 2·5 = 3·94.

Place the cursor line over **D** 9·85, bring **C** 2·5 under it and read the answer on **D** under 1 on **C**.

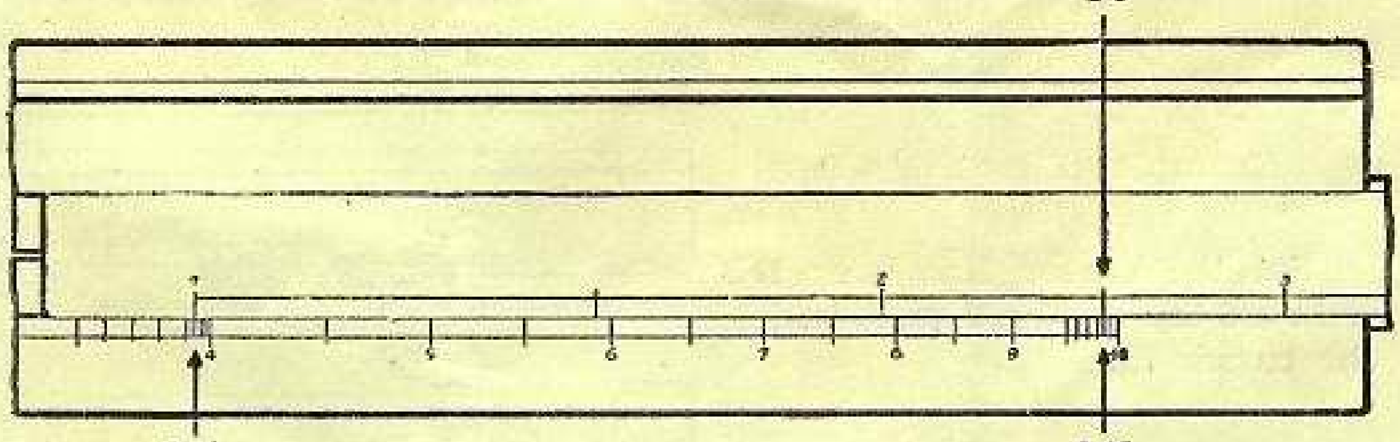



Fig. 4

Should this be calculated on the upper scales, the cursor is put over 9·85 on **A**, 2·5 on **B** is brought under it, and the result, 3 94, is read on **A** over 1 on **B**.

Calculations combining multiplication and division can be very easily worked on the slide rule, intermediate results, when not otherwise required, need not be read off. It is convenient to commence with a division followed by a multiplication, then a division, and again a multiplication, and so on.

**Readings and Decimal Points**

To calculate quickly and with certainty on the slide rule requires, naturally, a longer time for practice. Primarily, it is necessary to become familiar with the various graduations on the scales, particularly, of course, with those which are not indicated by figures. The estimation of those values that are not shown on the scales should be done with care; the operator must learn to regard the spaces between neighbouring division lines as decimal places. After some practice, the necessary confidence will be acquired and it will be found that these estimates are not at all so difficult as they appeared in the first moment.

The operator must himself affix the decimal point; in almost all practical problems the position of this will be known in advance, so that rules for the position of the point are not needed. With purely theoretical problems, when a doubt about the number of figures in the answer is possible, a rough estimate with round numbers can be made.

**Squares and Square Roots**

From the arrangements of the scales, and because the length from 1 to 10 on the lower scales equals that from 1 to 100 on the upper scales, it follows that over each number on the lower scale the square will be found on the upper. Conversely, under each number on the upper scale stands the square root on the lower.

Example (Fig. 5). $3^2 = 9$.

Set the cursor line over **D** 3 and read the square, 9, on **A** under the cursor line.

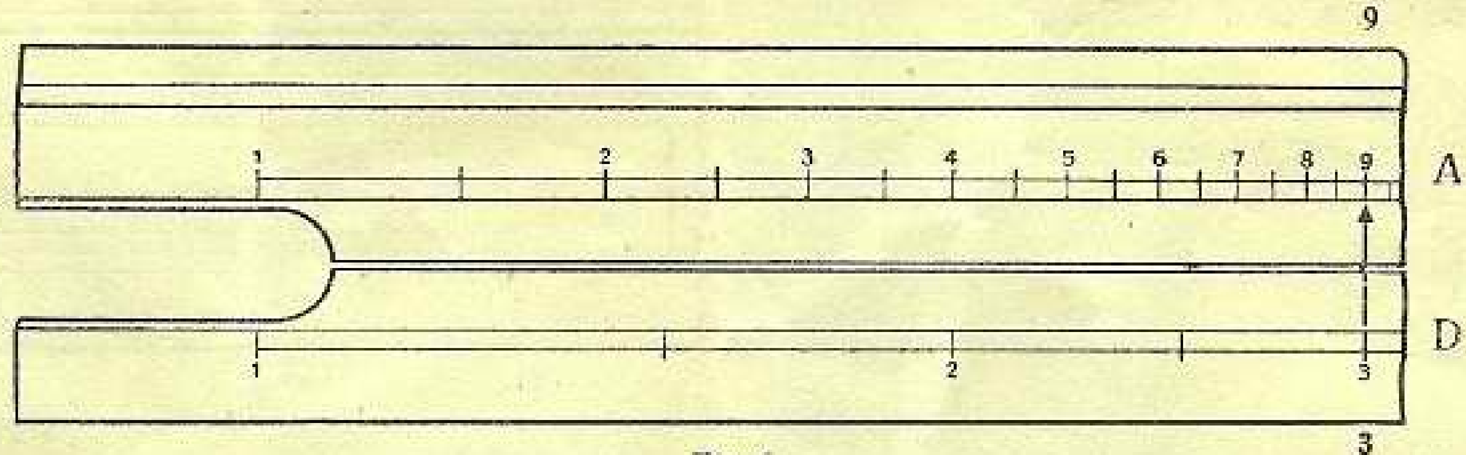



Fig. 5

Example (Fig. 6). $\sqrt{81} = 9$

Place the cursor line over **A** 81 and read the square root, 9, on **D** under the cursor line.

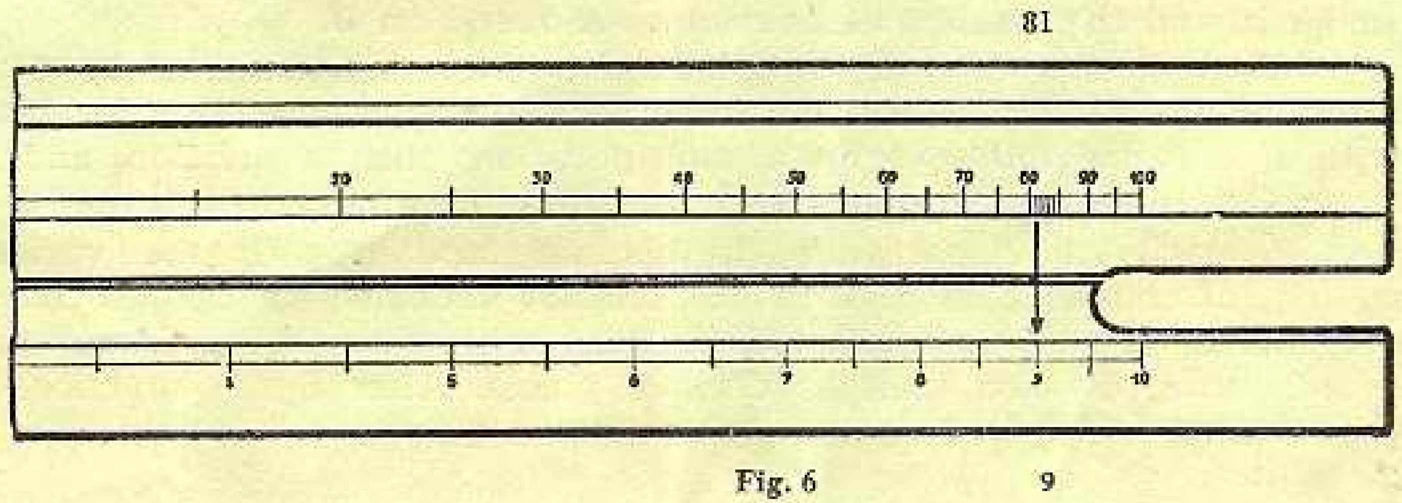



Fig. 6

**Cubes and Cube Roots**

The method used in raising a number to the third power or in extracting the cube root can best be explained by means of examples.

Example (Fig. 7). $1{\cdot}25^3 = 1{\cdot}95$.

Set **C** 1 over **D** 1·25, bring the cursor line over **B** 1·25 and read the answer, 1·95, under the cursor line on **A** (see Fig. 7).

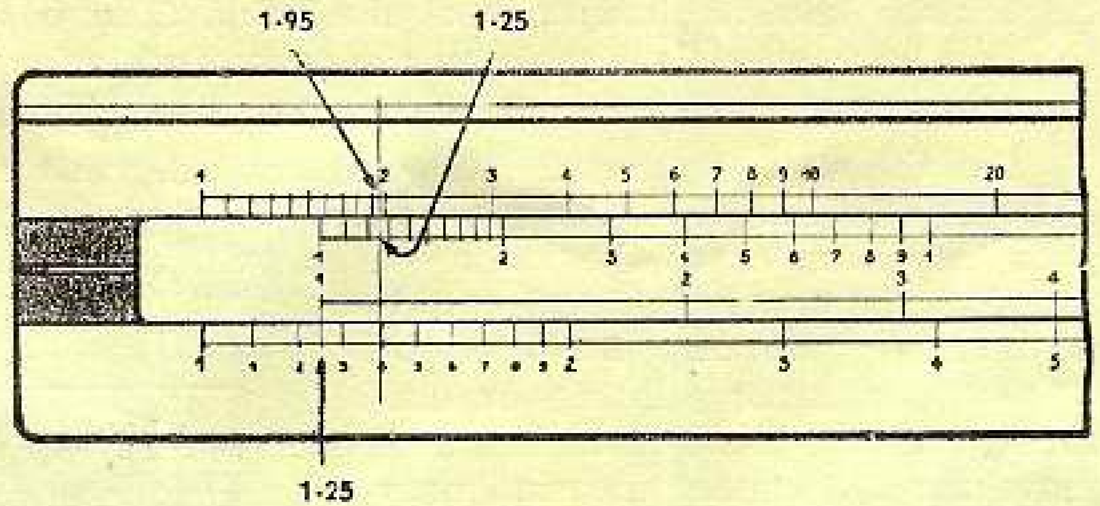



Fig. 7

Example (Fig. 8). $\sqrt[3]{12} = 2{\cdot}29$

Set the cursor line over 12 on **A**, reverse the slide, set **C 1** under the cursor line, move the cursor frame until the same two numbers appear under the cursor line on scales **B** and **D**. (In this case 2·29).

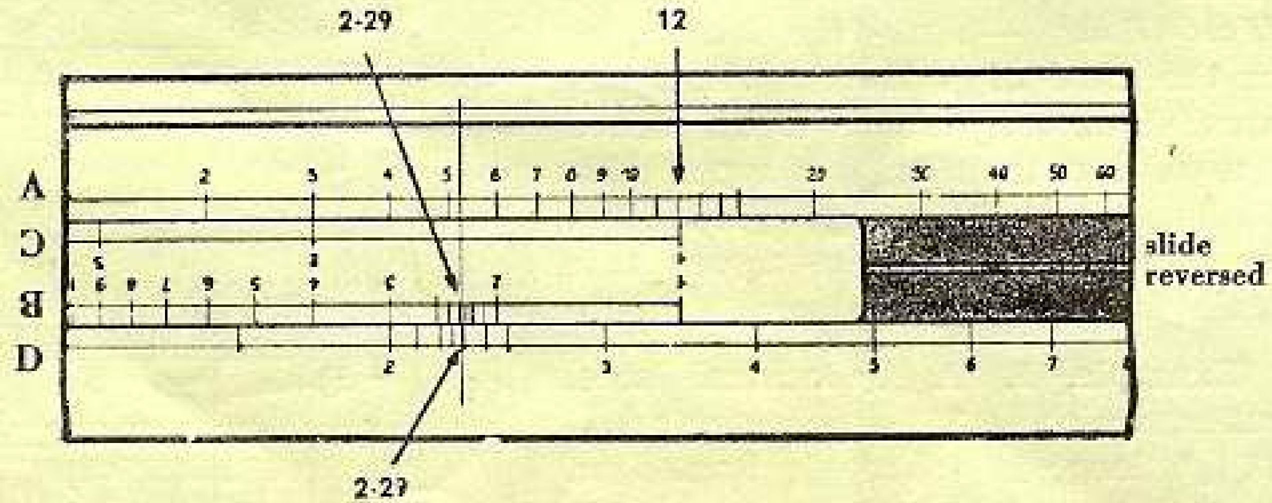



Fig. 8

# Instructions for the Use of Dr. Winkel's Special Scales

With this slide rule the time for all machine shop operations can be ascertained. For that purpose, besides the known dimensions of the work, a supposition about the cutting speed and feed is necessary; this can be found on the table on the back of the rule.

The calculations are done in the following manner:

**1. Turning** Set the slide so that the selected cutting speed on the lower slide scale, which is marked "*Cutting Speed*", is in line with the graduation "*Turning*" on the lower portion of the rule, move the cursor over the diameter of the work —i. e., over the diameter of the piece to be machined— this will be found on the upper slide scale which is marked "*Working Diameter or Stroke*" (for taper turning or flat facing take the mean diameter), then move the slide under the stationary cursor until the selected feed on the lower scale corresponds with the cursor line, place the cursor over the "*Feed Path*" —i. e.,- the length, or in the case of a flat surface, the breadth of the surface to be turned (the feed path is on the upper slide scale). Over this last graduation read the result on the upper rule scale in minutes or hours.

Example 1. A cylindrical steel roller, which is 25" in diameter and 13$^1/_2$" long, is to rough turned in a medium-weight lathe.

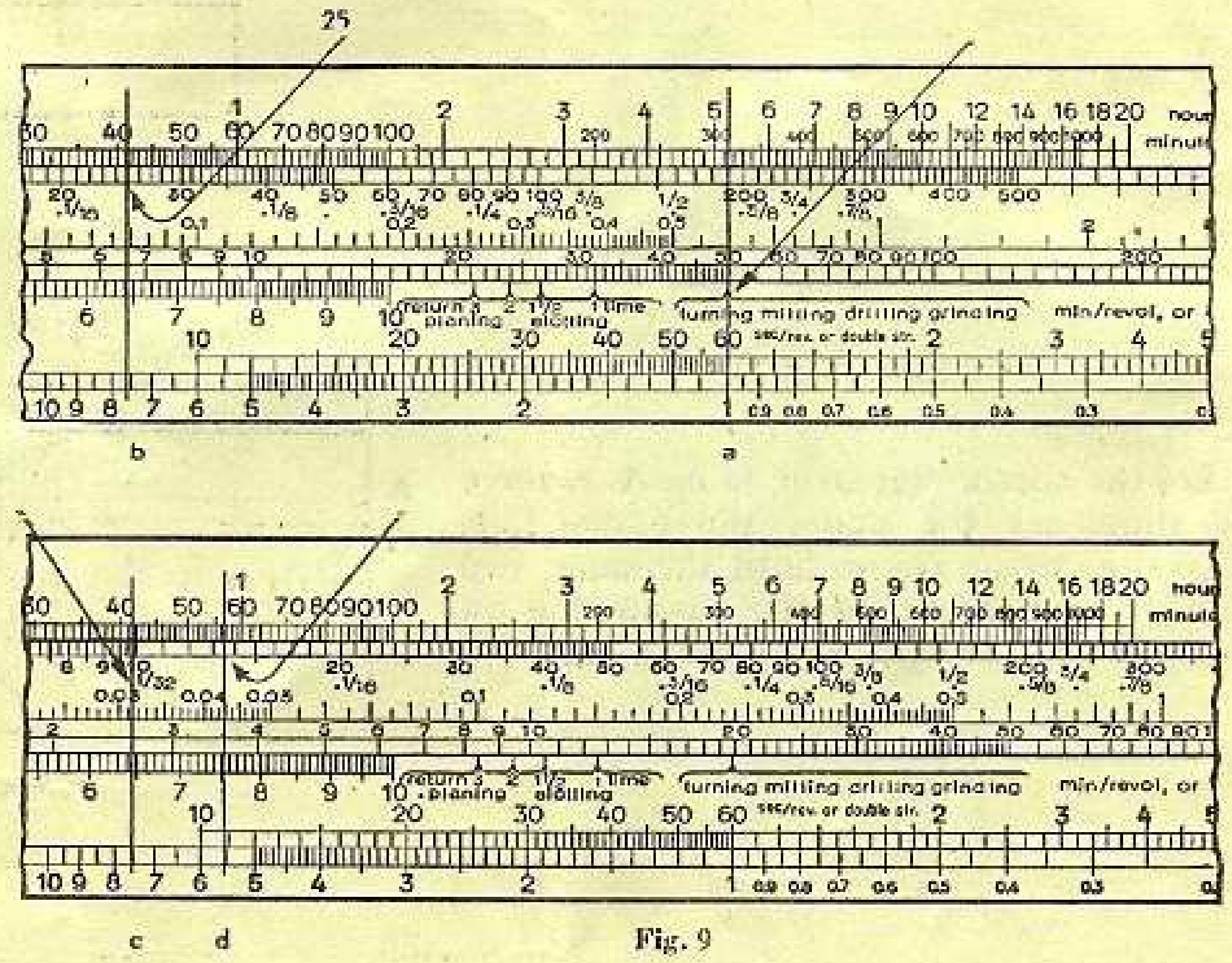



Fig. 9

On the table at the back of the rule the cutting speed for steel of medium hardness is about 50 feet per minute, and the feed for a medium-duty lathe is about 1/32 inch approximately. Set the cutting speed, 50′, on the lower slide scale over the graduation marked "*Turning*" (Fig. 9 position a), move the cursor over 25″, working diameter, on the upper slide scale (Fig. 9 position b), bring $^{1}/_{32}$″, the feed, on the lower slide scale under the cursor (Fig. 9 position c), move the cursor over the feed path, the length of the work viz $13^{1}/_{2}$″ (Fig. 9 position d), on the upper slide scale. The machining time, 56 minutes, will now be found on the upper rule scale under the cursor line.

With a heavier depth of cut than $^{1}/_{4}$ inch, a second cut will be required; a finishing cut at 60 feet per minute and $^{1}/_{64}$ inch feed may be selected for calculation.

Example 2. The side of the rim of a cast-iron wheel is to be faced with one roughing cut in a heavy duty lathe. The rim is 51 inches external diameter and 34 inches internal diameter.

The mean diameter $= \frac{51+34}{2} = 42^{1}/_{2}$ inches. The breadth of surface to be machined $= \frac{51-34}{2} = 8^{1}/_{2}$ inches.

The cutting speed is 60 feet per minute and the feed is $^{1}/_{16}$ inch (per revolution). Set 60′ cutting speed over the graduation "*Turning*", put the cursor over $42^{1}/_{2}$″ working diameter, bring $^{1}/_{16}$″ feed under the cursor line, put the cursor over $8^{1}/_{2}$″ feed path. The answer is $25^{1}/_{4}$ minutes.

Example 3. A gun-metal nut, which is 6 inches long, is to have a $1^{1}/_{4}$ inch thread cut inside it for the full length.

The cutting speed selected is 20 feet per minute, feed = pitch = 7 threads per inch = $^{1}/_{7}$ inch per revolution. To find the time required, we set the cursor over the graduation "*Turning*", bring 20′ cutting speed under it, put the cursor over $1^{1}/_{4}$″ working diameter, bring $^{1}/_{7}$″ (lying between $^{1}/_{8}$ and $^{5}/_{32}$″) feed under the cursor, and place the cursor over 6″ feed path. The required time is 0·7 minute. On account of the weakness of the tool-holder &c., only about 0·003 inch can be selected for depth of cut, so at $^{1}/_{16}$ inch = 0·063″ approximately depth of thread, $\frac{0{\cdot}063}{0{\cdot}003} = 21$ cuts will be necessary. The actual working time is, therefore, $21 \times 0{\cdot}7$ = about 15 minutes. To this must be added, depending on the arrangement of the machine, from half to full cutting time for the return feed of the tool, setting up, gauging, rounding off with the chaser, & c.

The above is only approximate.

The last calculation may be undertaken on the slide rule with the scale for working diameter and feed path; or, on the top row of graduations on the back of the slide. The cursor stands on 7 minutes, put under it 0 003 (which may be 3, 30, or 300), on the upper scale of the inverted slide, and move the cursor over 0 063 (which is also 6·3, 63 or 630) on the same row of the slide scale. Reading against the nearest graduation, we find the answer, 15 minutes. The position of the decimal point may be roughly estimated.

**2. Boring Out** Calculate exactly as turning.

**3. Milling** The calculation is as for turning, except that the working diameter is the diameter of the milling cutters or cutter heads, and the feed depends on the revolutions of the cutters.

If, for estimating, the feed is considered in inches per minute, then we must set the slide scale with the selected feed to the graduation "*Milling*" (this is the same as "*Turning*"), move the cursor over the feed path and read the answer above. In this case the assumption of a definite cutter diameter and speed is not required. The feed path has to be lengthened to provide for the entry and exit of the cutter.

Example. The surface of a cast-steel body, which is $11^3/_4$ inches long and $3^1/_4$ inches wide, is to be milled in one operation.

This requires a stronger face cutter or cutter head of about $4^1/_2$ inches in diameter, or a cylindrical cutter at least 4 inches long. The selected cutting speed is 40 feet per minute, feed $^1/_{32}$ inch per revolution (a little less for a cylindrical cutter).

We set 40' cutting speed over the graduation "*Milling*", put the cursor over $4^1/_2$" working diameter, bring $^1/_{32}$" feed under the cursor, and move the cursor over approximately 16" feed path (about one-half the working diameter being thus added for the commencement and end of the cut; for a cylindrical cutter this is somewhat less). The answer is 15 minutes.

Simplified average calculation: Selected feed: $1^1/_4$" per minute. Put $1^1/_4$" over the graduation "*Milling*"; the working time over 16" feed path will now be found to be about 13 minutes.

Gear wheel milling is, after the spacing operation, considered as usual milling; the feed path is the sum of the lengths of all the tooth spaces, including the entry and exit of the cutter, or it equals

(the width of tooth + half cutter diameter) × number of teeth.

The feed may be taken either per minute or per revolution of the cutter. In the latter case the cutter diameter and cutting speed must be selected accordingly.

In gear-wheel hobbing, the feed path is again

(the width of tooth + half diameter of hob) × number of teeth.

Proceed as in Paragraph 7 to determine the revolutions per minute of the hob. Set the feed path on the slide to the revolutions per minute of the wheel (not the revolutions of the hob), about twice the normal cutter feed can be selected, and put the cursor over the beforementioned feed path. Over this will be found the answer.

**4. Drilling**

The method of calculating is as for turning. The working diameter is the diameter of the hole, and the feed path is the depth of the hole.

If the drilling-machine is used for tapping, it is necessary to note that: for 9 or more threads per inch one tap is required, for 6—8 threads two taps, for $4\frac{1}{2}$—5 threads three taps, $3\frac{3}{4}$—4 threads four taps, and for 3—$3\frac{1}{2}$ five taps.

**5. Grinding**

In circular grinding calculate as for turning; the working diameter is the diameter of the work, the cutting speed is the peripheral speed of the work, the feed is the traverse movement of the work past the wheel, or vice versa, which is taken at so much per revolution of the work.

Surface grinding when the work rotates is considered like circular grinding.

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Example. The diameter of a bolt, which is $3\frac{1}{4}$ inches long and $1\frac{1}{2}$ inch diameter is to be reduced by $\frac{1}{32}$" or $\frac{1}{64}$" = 0·15 inch on the radius. Because of the over-run, the grinding length (i. e. the travel of the work) may be taken at $4\frac{1}{4}$ inches. Selected peripheral speed of work 40 feet per minute; feed $\frac{1}{4}$ inch per revolution of work; depth of cut 0·0005 inch.

Set 40' cutting speed to "*Grinding*" (not "*Plane Grinding*"), put the cursor over $1\frac{1}{2}$" working diameter, bring $\frac{1}{4}$" feed under the cursor line, put the cursor over $4\frac{1}{4}$" feed path; the time for one traversing movement of the table is 0·17 minutes. This multiplied by the ratio that the amount to be ground off is to the depth of cut—that is, $\frac{0{\cdot}015}{0{\cdot}0005}$ which may be calulated on the upper scales with the slide inverted in the usual manner. The time is about 5 minutes.

In plane grinding (surface grinding), it is preferable to have the feed in inches per second. Place this against the mark that is indicated by "*Plane Grinding*", move the cursor over the feed path (the length or breadth of the surface to be ground measured in the direction—relative—of the movement of the grinding-wheel) and read above it the time for one traverse, which then, in the manner before described, must be multiplied by the ratio $\frac{\text{excess of radius}}{\text{depth of cut}}$

Example. A surface 10 inches long is to be ground so as to remove 0·02 inch depth of metal. The feed is 1/2 inch, and the depth of cut is 0·0005 inch.

Set 1/2" feed to the mark "*Plane Grinding*". put the cursor over 10" + over-run = 11" feed path; the time is 0·36 minutes for one traverse. The total time is then

$$\frac{0{\cdot}36 \times 0{\cdot}02}{0{\cdot}0005} \approx \quad \text{minutes.}$$

Surface grinding on a planing machine for long work with lateral feed is calculated like planing (Paragraph 6).

**6. Planing and Slotting**

Depending on whether the speed of the return is equal to, 1½ times, double, or 3 times, that of the cutting stroke, we use the graduation 1, 1½, 2 or 3 times. The remaining calculation is as for turning: place the selected cutting speed over the suitable graduation for the forward and return stroke ratio, put the cursor on the stroke for the work (with which has to be considered the entry and exit of the tool, as well as the lowered speed at the end of the stroke; the latter must be taken from 10 inches to 20 inches longer than the surface of the work, according to the size of the work), now bring the feed under the cursor and put the cursor on the feed path - the width of the planer. Over this will be found the answer.

Example. Four cast-iron moulding boxes, 16" × 24", which are clamped in a row, to be planed on a medium-duty machine. The boxes are rough castings only slightly cleaned, and their walls are not stiffened.

Assume that the boxes are attached to each other by their long sides, and are spaced 1½" with their surfaces apart to allow room for the clamps add 10" for over-run and diminished speed at the ends of travel.

$$\text{The travel of work} = 4 \times 16 + 3 \times 1\tfrac{1}{2} + 10 = 78\tfrac{1}{2} \text{ inches.}$$

In view of the possibility of slight chipping of the castings, the following will be selected: cutting speed 25 feet per minute, and feed 1/32 inch. The planer has double return speed. Over the graduation 2 for "*Planing*" set 25' cutting speed, put the cursor over 78½" stroke, set 1/32" feed under the cursor line. Then over 24" feed path will be found the time, 300 minutes = 5 hours.

**7. Determination of the revolutions, or double strokes, per minute**

If it was desirable to calculate the number of revolutions per minute which correspond to the cutting speed and the diameter of the work, it can easily be found on the lowest scale of the rule. Set the cutting speed over the graduation "*Turning, Milling, etc.*", put the cursor over the diameter of the work, then under the cursor line read the number of revolutions on the lowest scale of the rule.

Example. At how many revolutions per minute must a lathe spindle run in order that the periphery of a wheel which is 12 inches in diameter may be machined at a cutting speed of 40 feet per minute?

Set 40′ cutting speed over the graduation "*Turning*", put the cursor over 12″ (or 1′) working diameter; the cursor is then over 12·7 revolutions per minute on the lowest scale. It must be noted that this scale, which is marked "*Revolutions or double (Working* and *Return) Strokes per minute*", is graduated from right to left. Conversely, the cutting speed may be found from the revolutions per minute and the diameter of the work.

Example. A milling cutter of 2½ inches diameter runs at 50 R. P. M. What is the cutting speed?

Set the cursor over 50 R. P. M., bring 2½″ diameter under it, then on the lowest slide scale read 33′, cutting speed, over the mark "*Milling*".

When the diameter of the work is very large it is more convenient, instead of the revolutions, per minute, to take the time of one revolution in seconds or minutes.

Example. At what cutting speed will the rim of a fly-wheel of 80 inches diameter be machined when the lathe spindle makes one revolution in 25 seconds?

Place the cursor over 25 seconds per revolution on the short scale graduated along the lower right hand half of the rule (the left hand end of this scale from 10 to 60 gives seconds per revolution, and the right hand portion is for minutes per revolution), bring 80″ working diameter under it, and over the mark "*Turning*" read 50′, the required cutting speed.

In the same manner, with planing and slotting machines, the double strokes per minute can be found from the cutting speed and length of stroke, or vice versa. The length of stroke has to be increased from 10 to 20 inches, according to the size of the machine, because of the diminished speeds at the end of the stroke.

From the number of revolutions (or the number of strokes), feed, and feed path, the machining time can be calculated in a simpler way.

Example. A lathe, or a planer, makes 30 revolutions, or double strokes, per minute, and the feed is $1/32$ inch per revolution, or per double stroke. In what time will a piece of 40 inches length be turned, or of 40 inches width be planed?

Set the cursor over 30 double strokes, or revolutions, per minute; bring $1/32$″ feed under it; put the cursor over 40″ feed path and read the time 42.5 minutes.

**8. General** Working diameter, or stroke, and feed path have to be taken many times larger than the dimensions on the drawing indicate; the quantity of material to be removed and possible irregularities of the surface, which prevents the tool cutting evenly, have to be taken into consideration, as well as the backlash in the machine.

If the work is being done on machines whose revolutions, or double strokes, and feeds are known, an exact machining time calculation can be determind in a simple way by checking the setting of the slide, after the first calculation, with the aid of the lowest scale. This will be understood from the following example.

Example. The roller of Example 1 is to be turned in a lathe which has the following speeds and feeds:

| | | | | | |
|---|---|---|---|---|---|
| Revolutions of the headstock | 2 | 5·5 | 8 | 14 | &c. |
| Feeds (per revolution) | 0,004" | 1/64" | 1/32" | 3/64" | |

Set the cutting speed, 50', to the mark "*Turning*", put the cursor over the working diameter, 25"; the cursor line is now over 7·6 revolutions on the lowest scale of the rule.

The settings are corrected according to the foregoing working conditions by moving the cursor over the neighbouring revolution graduation, 8, and bringing the actual feed, 1/32" under it. Now over 13 1/2" feed path, the time for this machine is seen to be 54 minutes. Likewise, during the execution of the remainder of the calculation, the correction can be conveniently carried out by bearing in mind the actual working conditions.

The number of cuts depend, of course, on the thickness of material to be removed and the normal depth of cut given in the table.

**9. Calculation of Weights of Steel Bars** For a convenient method of determining the weights of round, hexagonal, and square sectioned bars three marks have been added to the lower slide scale (these will be found on the normal scale with the slide inverted). Set the corresponding mark over the diameter, length of side, or width across flats on the lower slide scale and find over the length, which has to be taken on the upper slide scale (B), the weight on scale **A.**

Example. Determine the weight of a smooth roll of 2 1/2 inches diameter and 9 ft. 2 in. (110 in.) long.

Set the round mark to 2·5 on the lower rule scale, **D,** and read, over 11 on the upper slide scale, **B,** the weight, 153 lbs., on scale A.

The decimal point may be fixed by rough estimate.

Find the weight of a hexagonal bar which is 2 inches across flats and 8 ft. 9 in. (105 inches) long.

We proceed as before with the hexagonal mark and find the answer 104 lbs.

Find the weight of a square bar 1 3/4 = 1,75 in. length of side and 10 ft. = 120 in. long.

Use the square mark and read 104 lbs.

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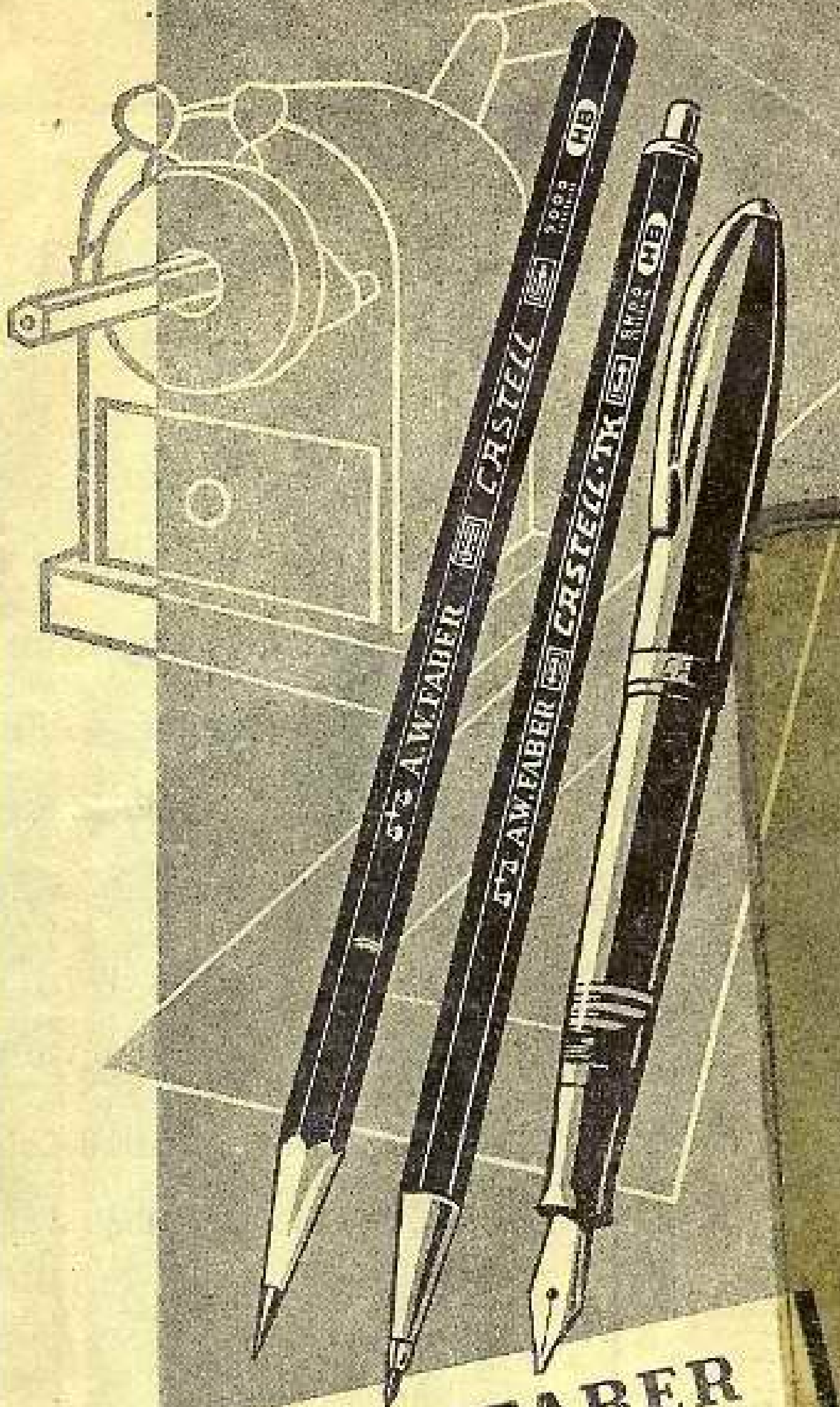
| 9100 1/2 | medium | black | 9607 | hard | dull black |
| 9101 | hard | black | 9608 | medium | 1/2 red 1/2 blue |
| 9114 | extra soft | violet | 9609 | medium | red |
| 9111 | soft | violet | 9610 | medium | blue |
| 9110 1/2 | medium | violet | 9611 | medium | dark green |
| 9110 | hard | violet | 9605 | medium | light green |
| 9116 | medium copying | black black | 9612 | medium | yellow |
| 9122 | medium copying | black blue | 9613 | medium | carmine |
| 9117 | extra hard | black | 9614 | medium | orange |
| 9121 | extra extra hard | black | 9615 | medium | brown |
| | | | 9616 | medium | dull blue |

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