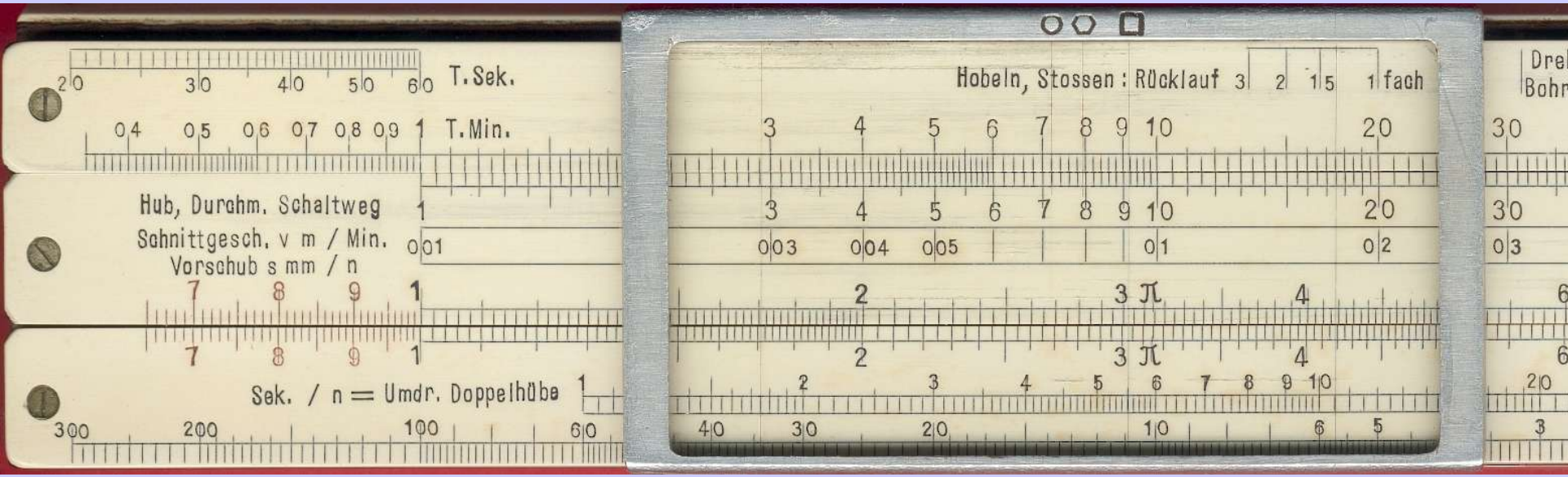
Machine-time Slide Rules



A comparison of scale systems with calculation examples

by Jörn Lütjens

(IM 2006 Greifswald 29-09-2006)

Contents

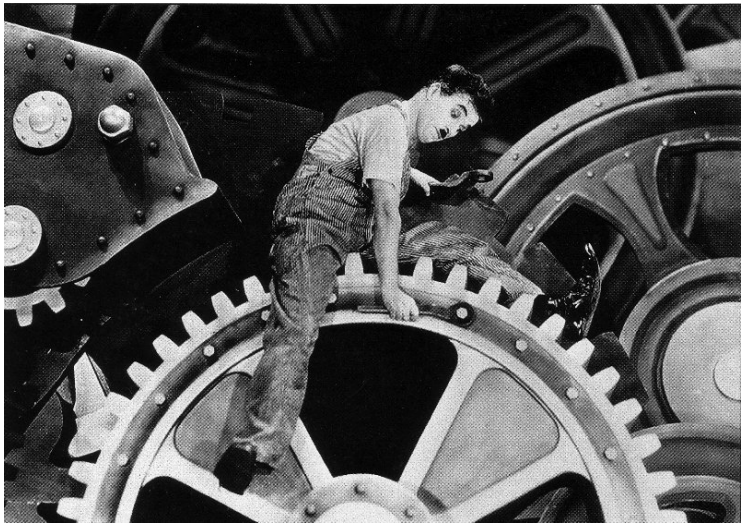
The purpose of machine-time slide rules

First of all: for a most efficient and economical utilisation of the machine tools

- real working time
- need of power
- cutting capacity
- chip volume per time

Historical background

Starting point: Industrialisation during the 2nd half of the 19th century, especially steel production and fast development in chip making machine tools and properties of materials.



But effective and economical utilisation of machine tools and working planning have not been spread.

Frederick Taylor (1856 – 1915)

- He was the first scientist on systematically chip making processes under focus of technical and economical conditions.

- From 1880 on his 25 years research included
  - about 30,000 to 50,000 experiments
  - 400,000 kg steel have been cut and
  - the total amount of costs was estimated between $150,000 to $200,000.

Questions from the workshop

- What is the appropriate cutting speed for steel?
- Which number of revolutions, which feed and which cutting depth should be set for the shortest working time by optimal utilisation of material properties?

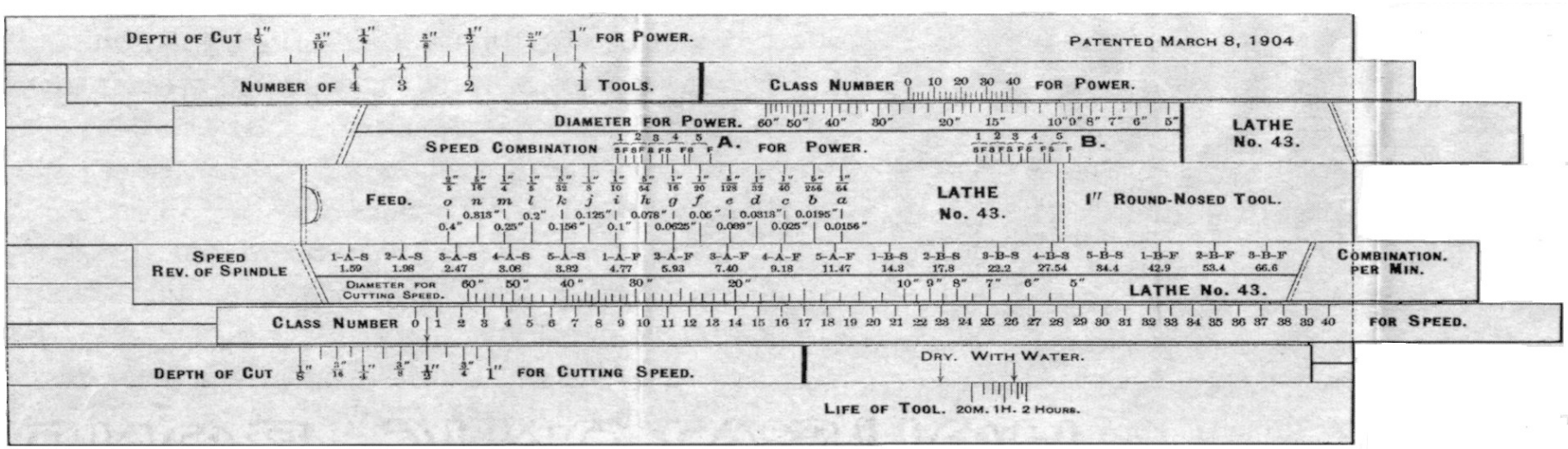
These questions seem to be simple but they include a lot of complicate mathematical problems with 12 variables!!

Taylor‘s list of variables that affect cutting speeds

1. Hardness and quality of the material being worked with.
2. Chemical composition and heat treatment of the tool.
3. Durability of the cutting edge (tool material).
4. Shape or contour of the cutting edge together with its clearance and lip angles.
5. Absolute depth of cut or metal to be removed per pass.
6. Depth cut relative to the diameter of the workpiece.
7. Cooling fluids for the tool.
8. Tool life (how long the tool can withstand the highest cutting speed).
9. Elasticity of the workpiece and the tool.
10. Diameter of the workpiece.
11. Pressure of the chip or shaving on the tool.
12. Pulling or feeding power of the lathe at various speeds.

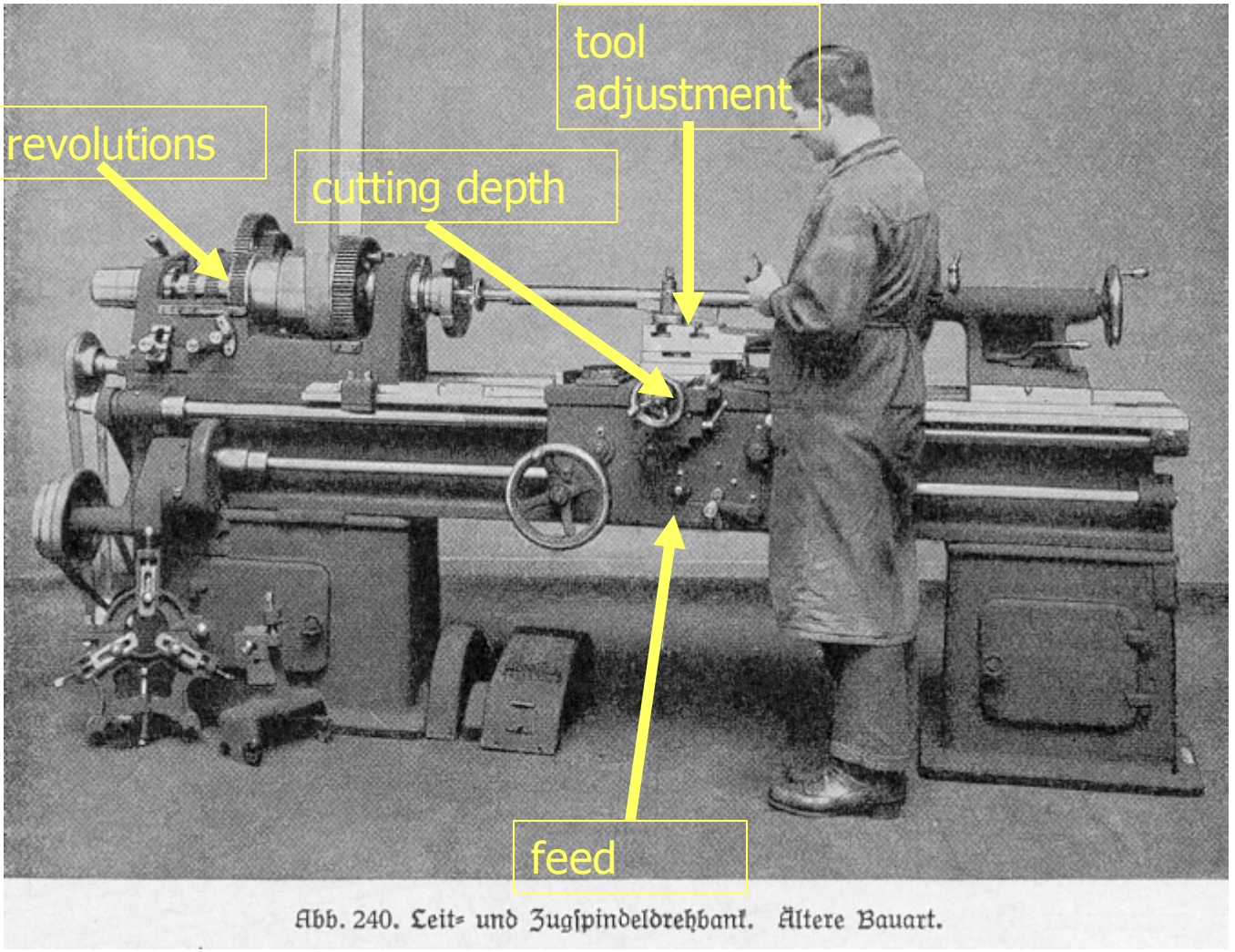
The slide rule developed by Taylor and Barth (1904)

it has 6 slides!



Source: Journal of the Oughtred Society, (9) fall 2000, No. 2, page 34

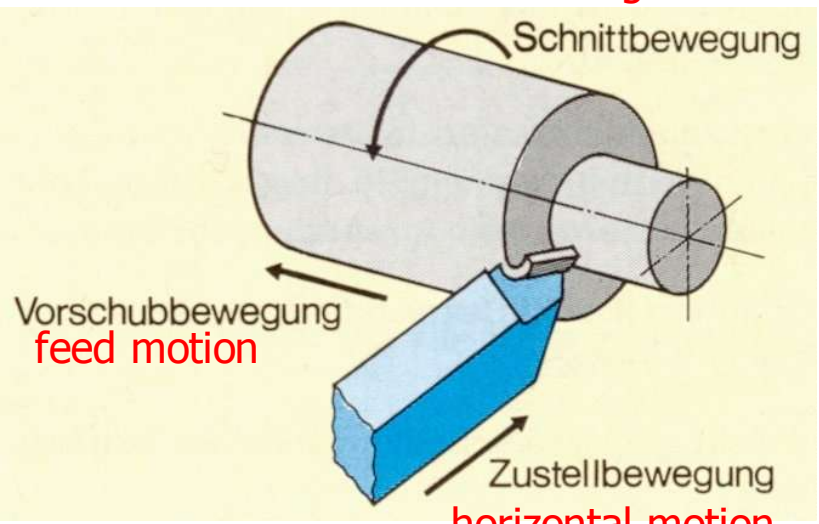
Basic settings at a lathe

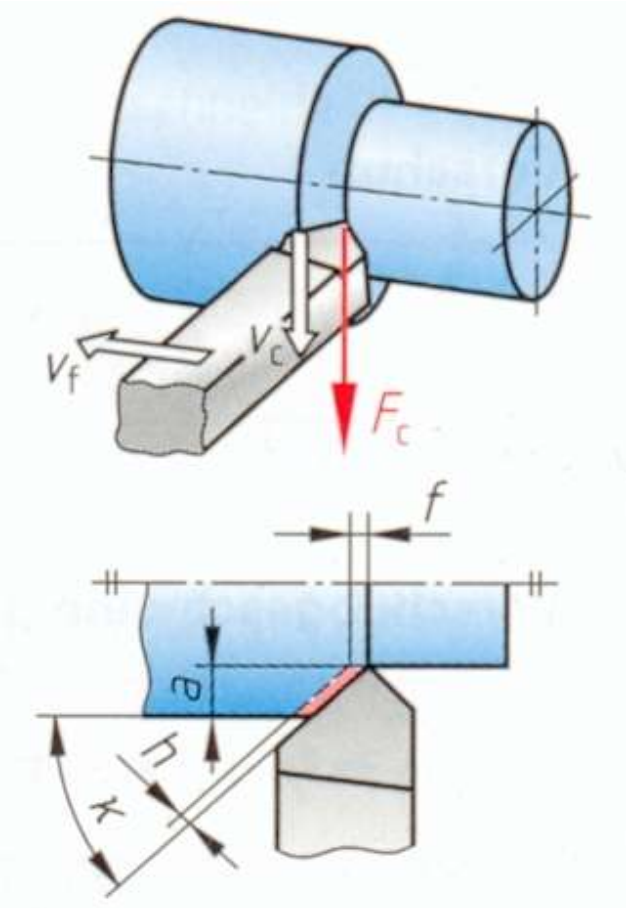


(ca. 1920)

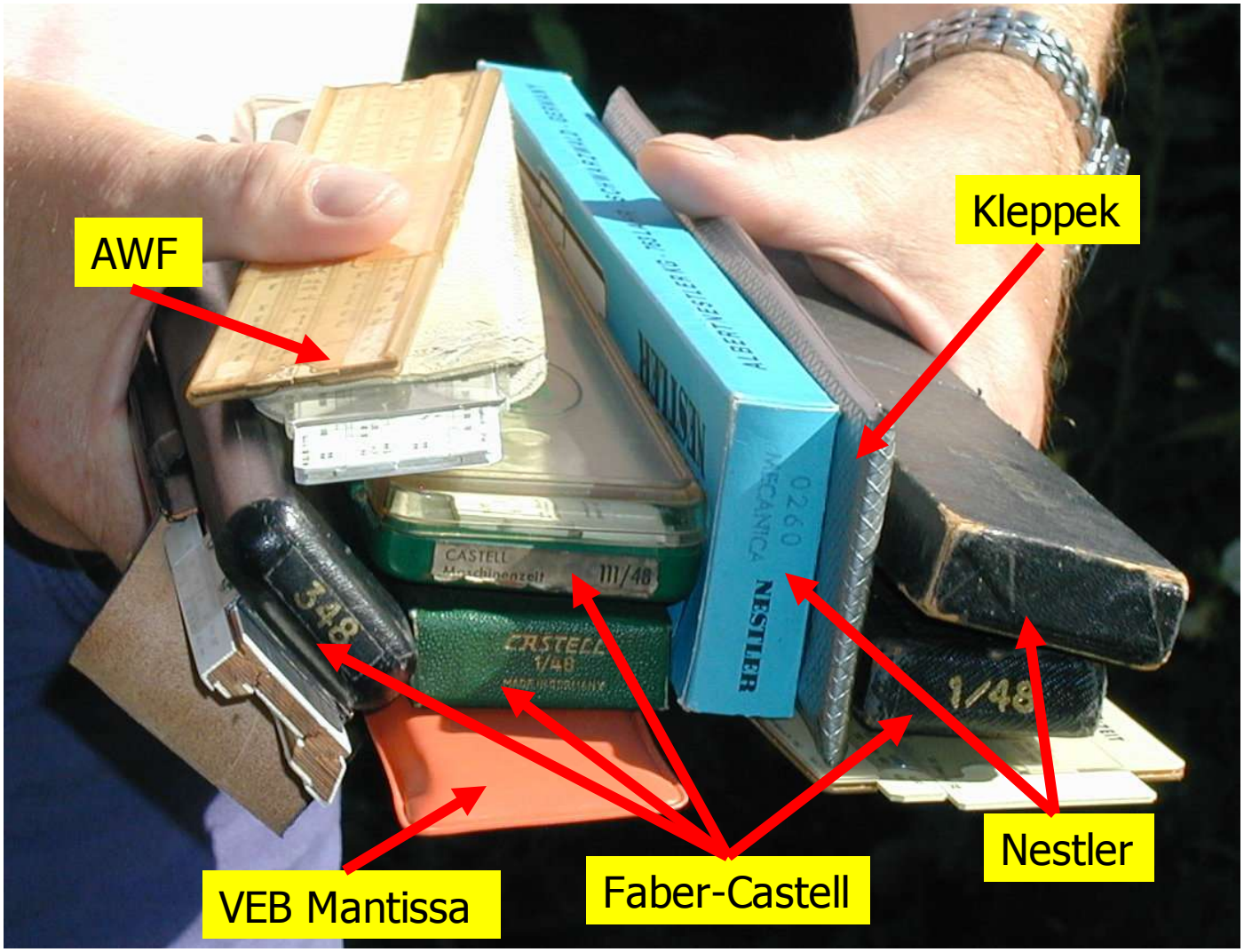
Cutting motions and forces in cylindrical turning

cutting motion

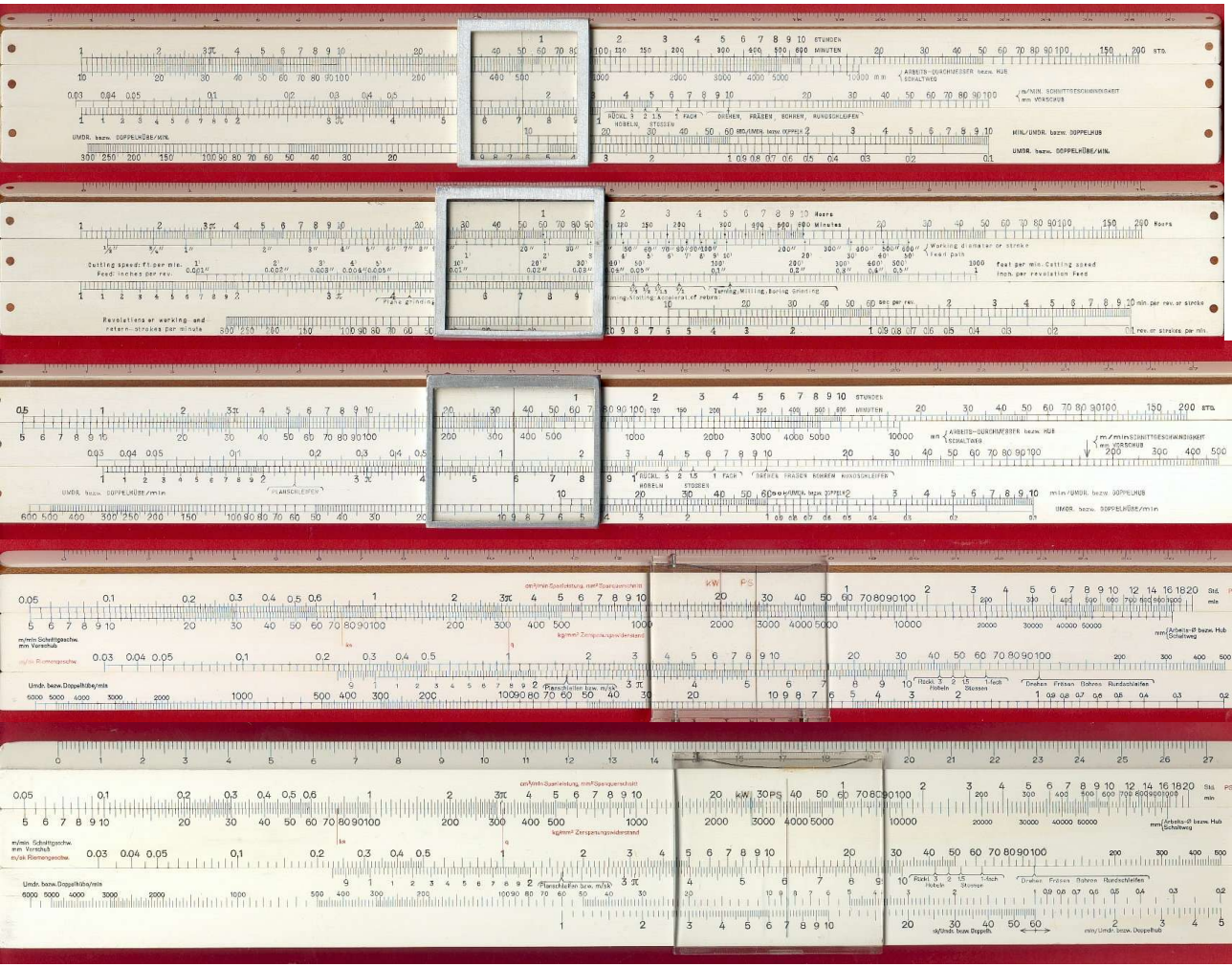




Some of German machine-time slide rules



Faber-Castell **„Maschinenzeit“**, System Dr. Winkel



type **348**
(from 1928)

348-Engl.
(from 1930)

many thanks to Dieter

1-48/348
(from 1938)

1-48
(from1958)

111-48
(from 1967)

Comparison of the scale extensions

The series (….48) are different in scale ranges because of the rapid development in metal and machining technology

like **a) power of machine tools**:

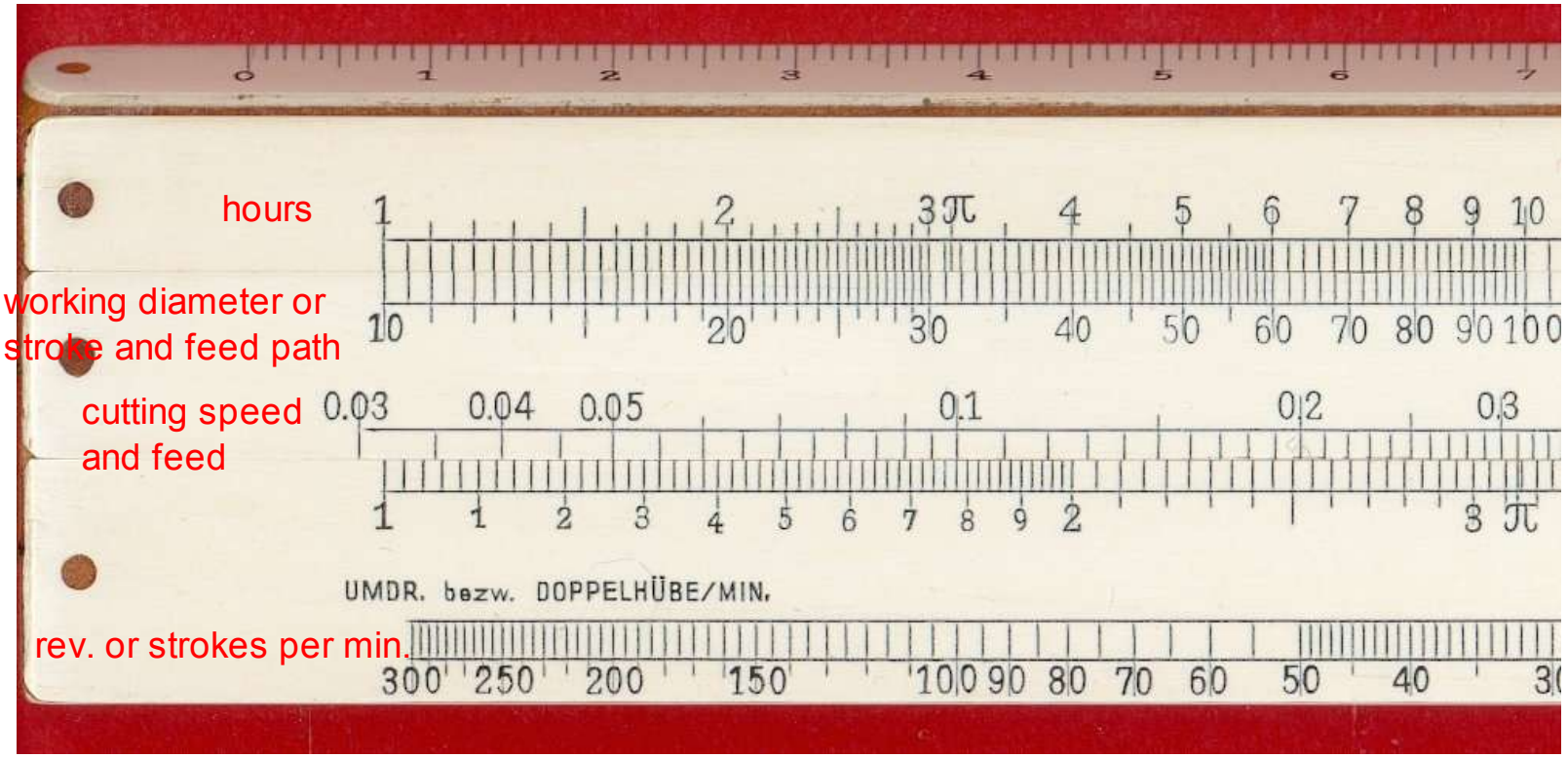
(driving technology, range of revolutions, cutting speeds, tool life) and

and **b) material:**

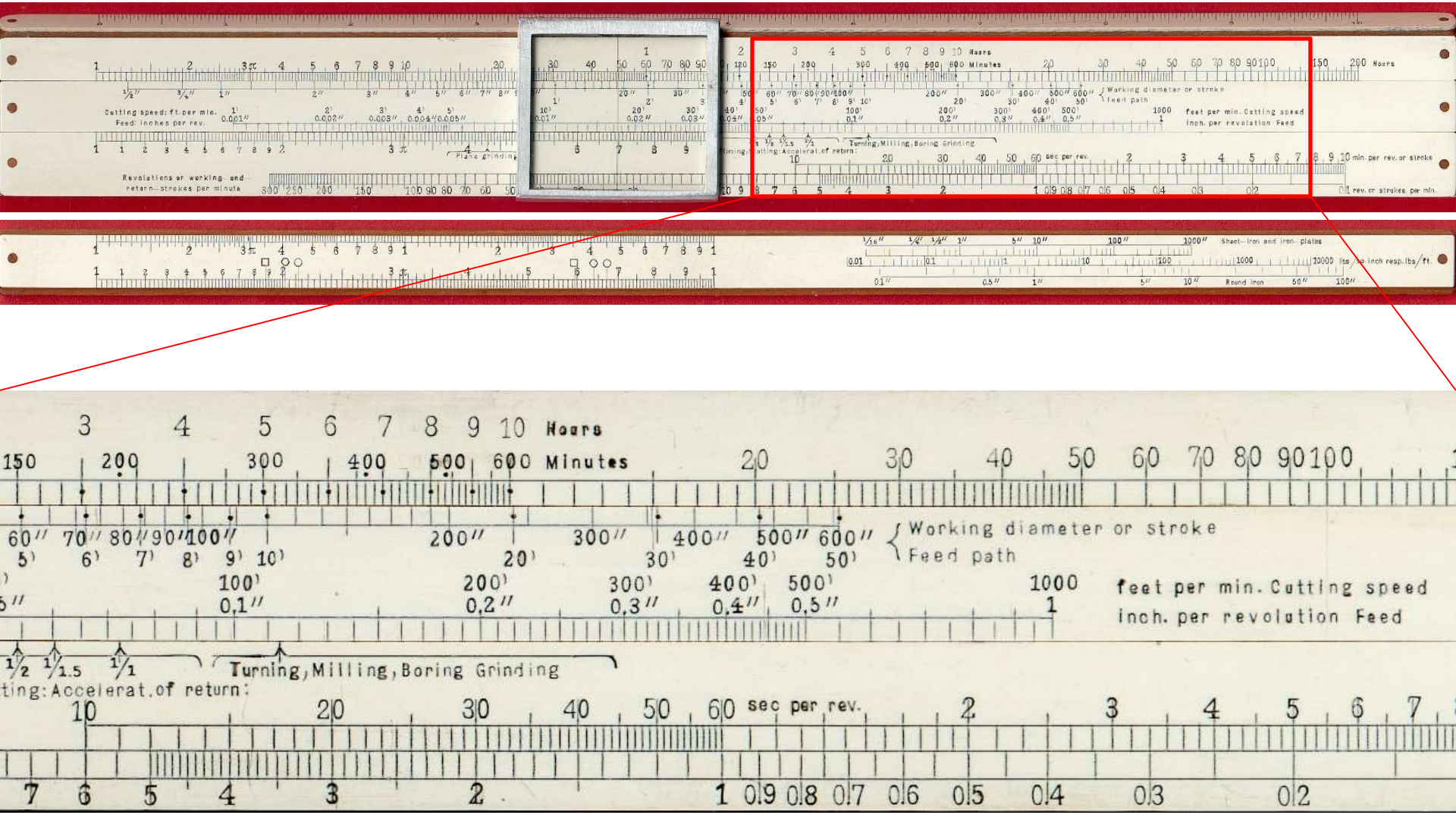
(improvement of cutting properties).

The following slides show the lengthened scales of the left and right ends of the Faber-Castell slide rules.

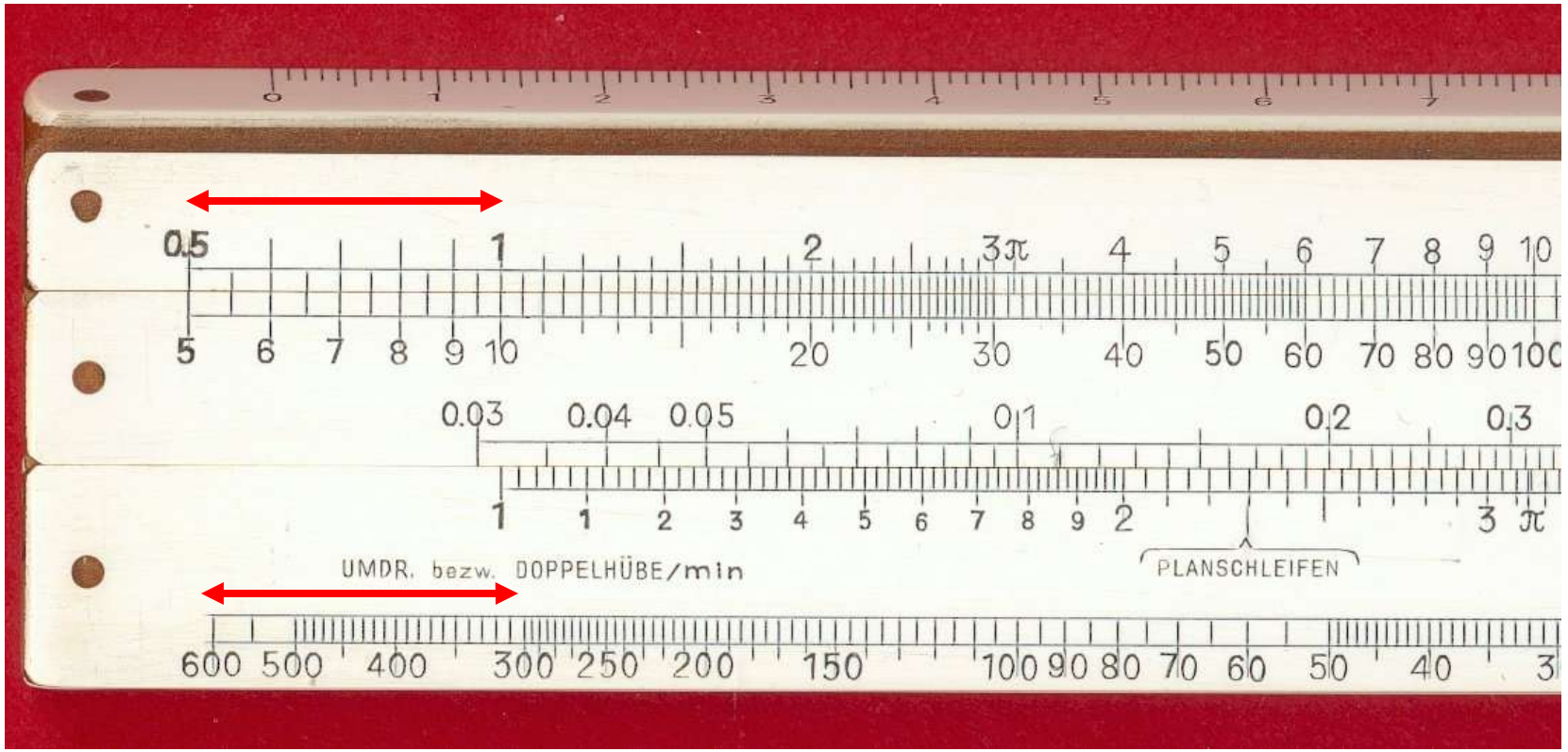
Faber-Castell 348 (from 1928)



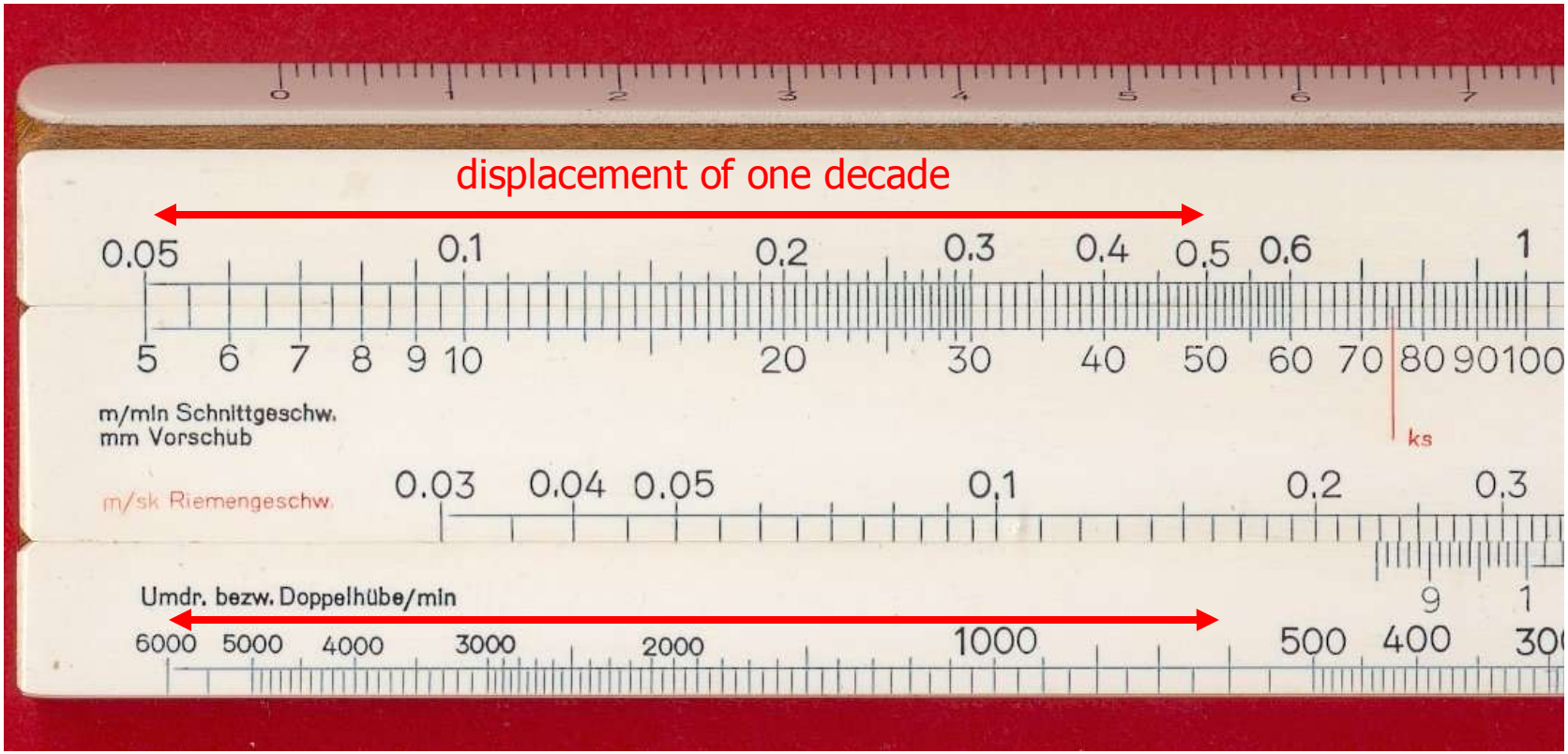
Faber-Castell 348 (English version, about 1930)



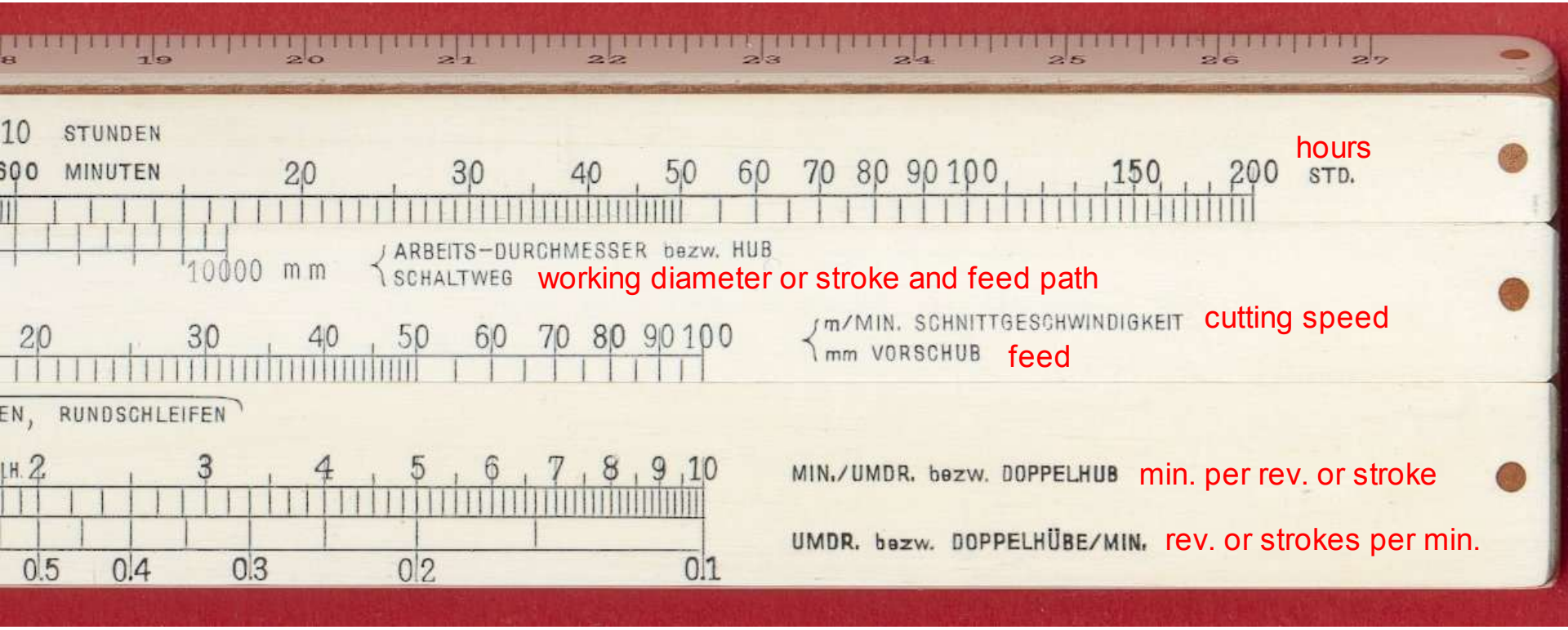
10 years later: Faber-Castell 1-48/348 (from 1938)



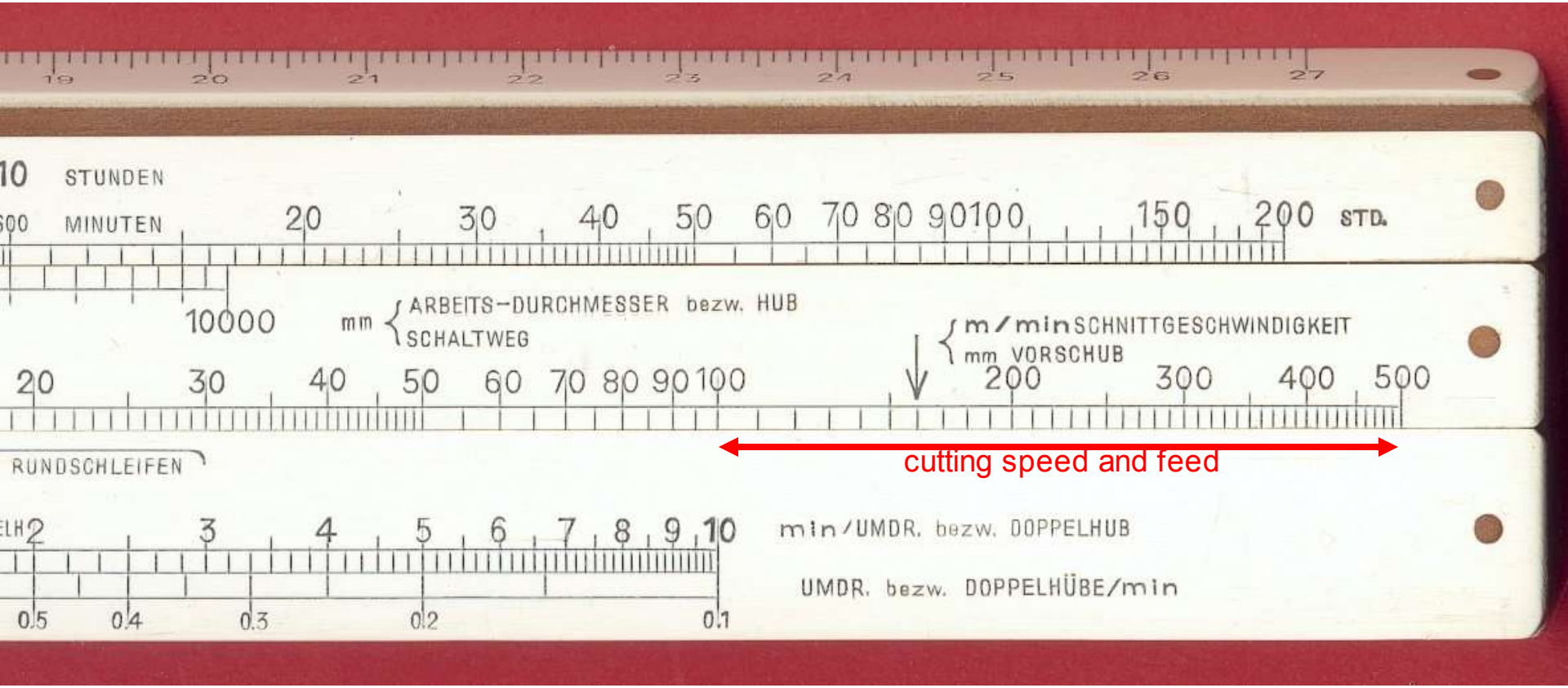
20 years later: Faber-Castell 1-48 (from 1958)



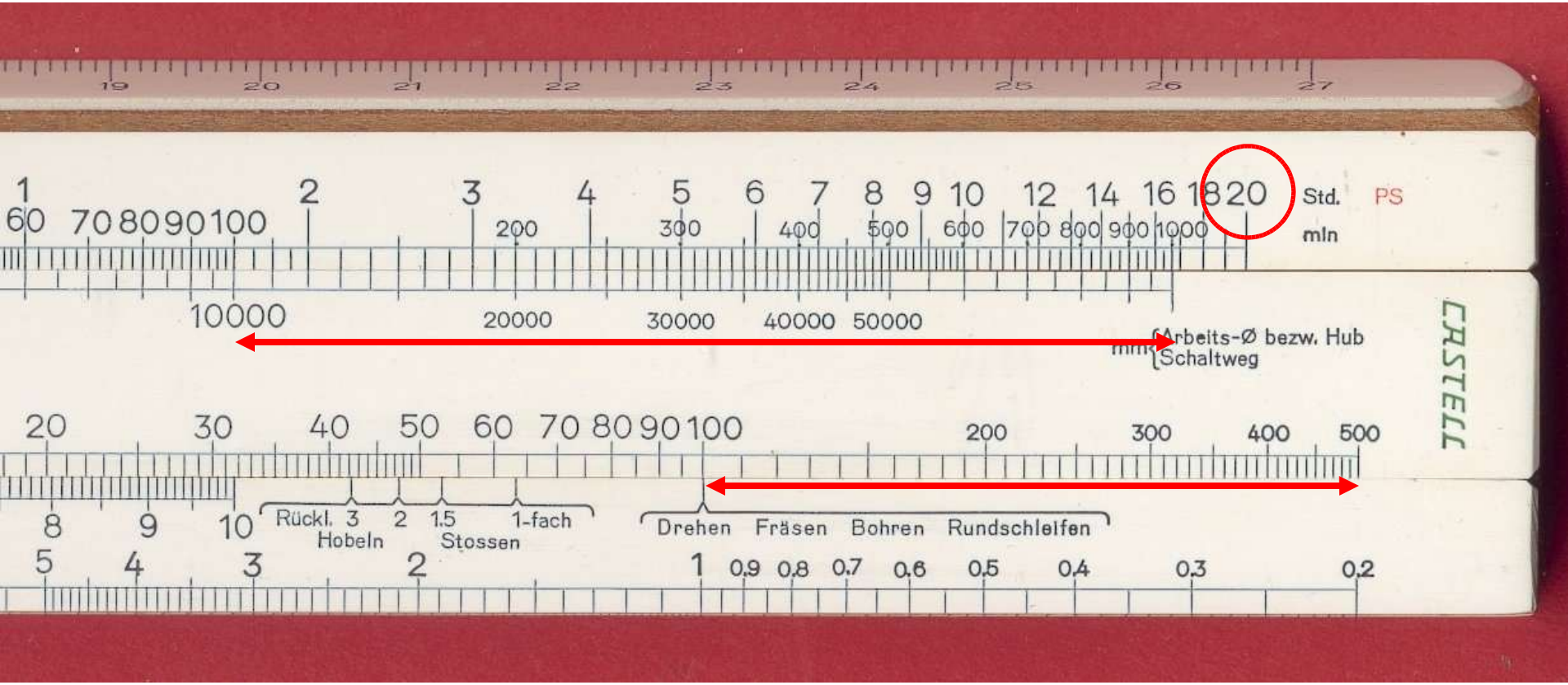
Faber-Castell 348 (from 1928 -right)



10 years later: Faber-Castell 1-48/348 (right)

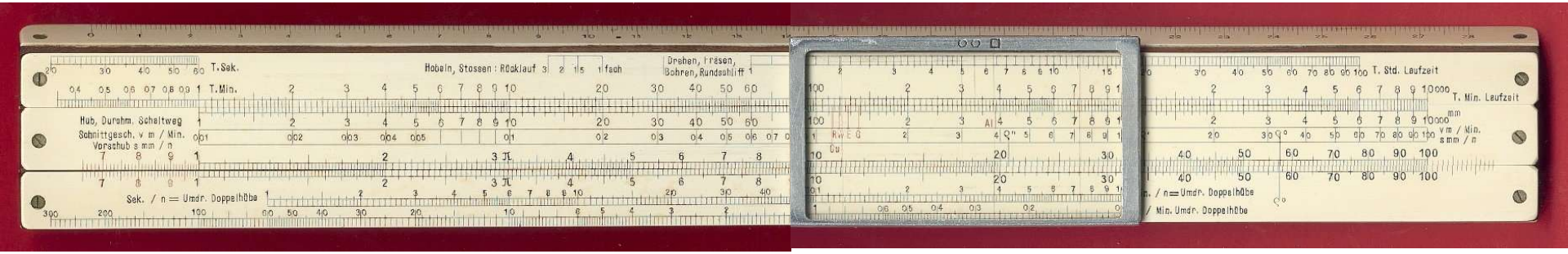


20 years later: Faber-Castell 1-48 (from 1958)

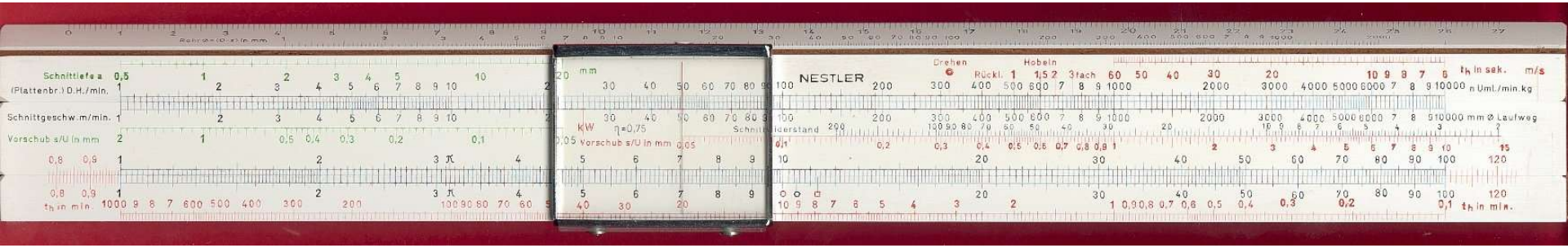


Two Nestler slide rules

Nestler 26 **„Betriebsschieber"** (from 1920 to 1930)



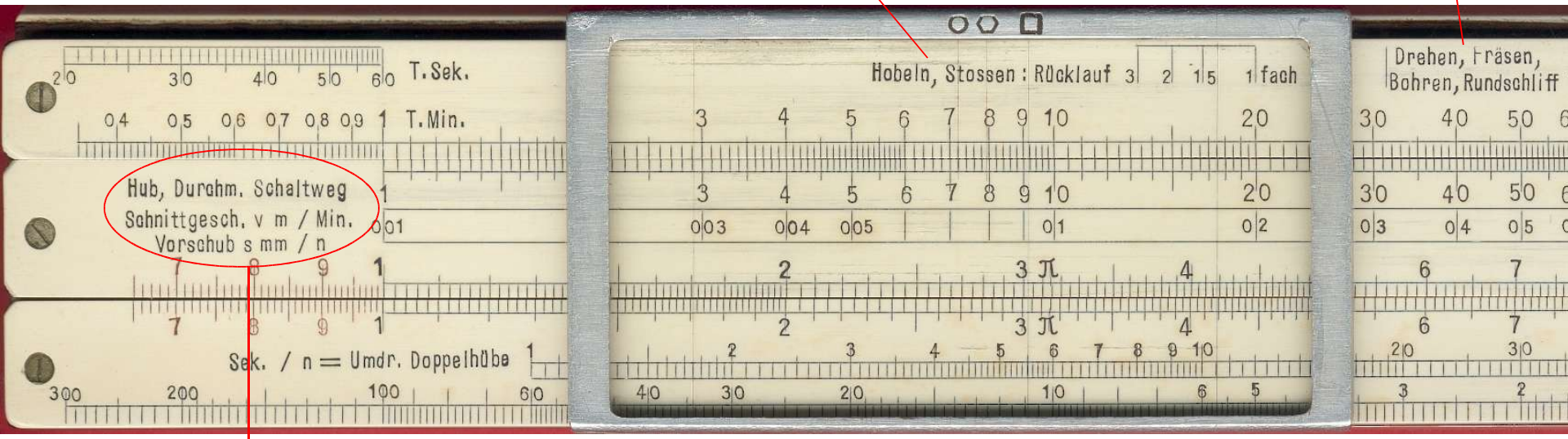
Nestler **„Betriebsrechenstab"** Mecanica 0260 (from 1955 to 1973)



Nestler 26

turning, milling, drilling, grinding

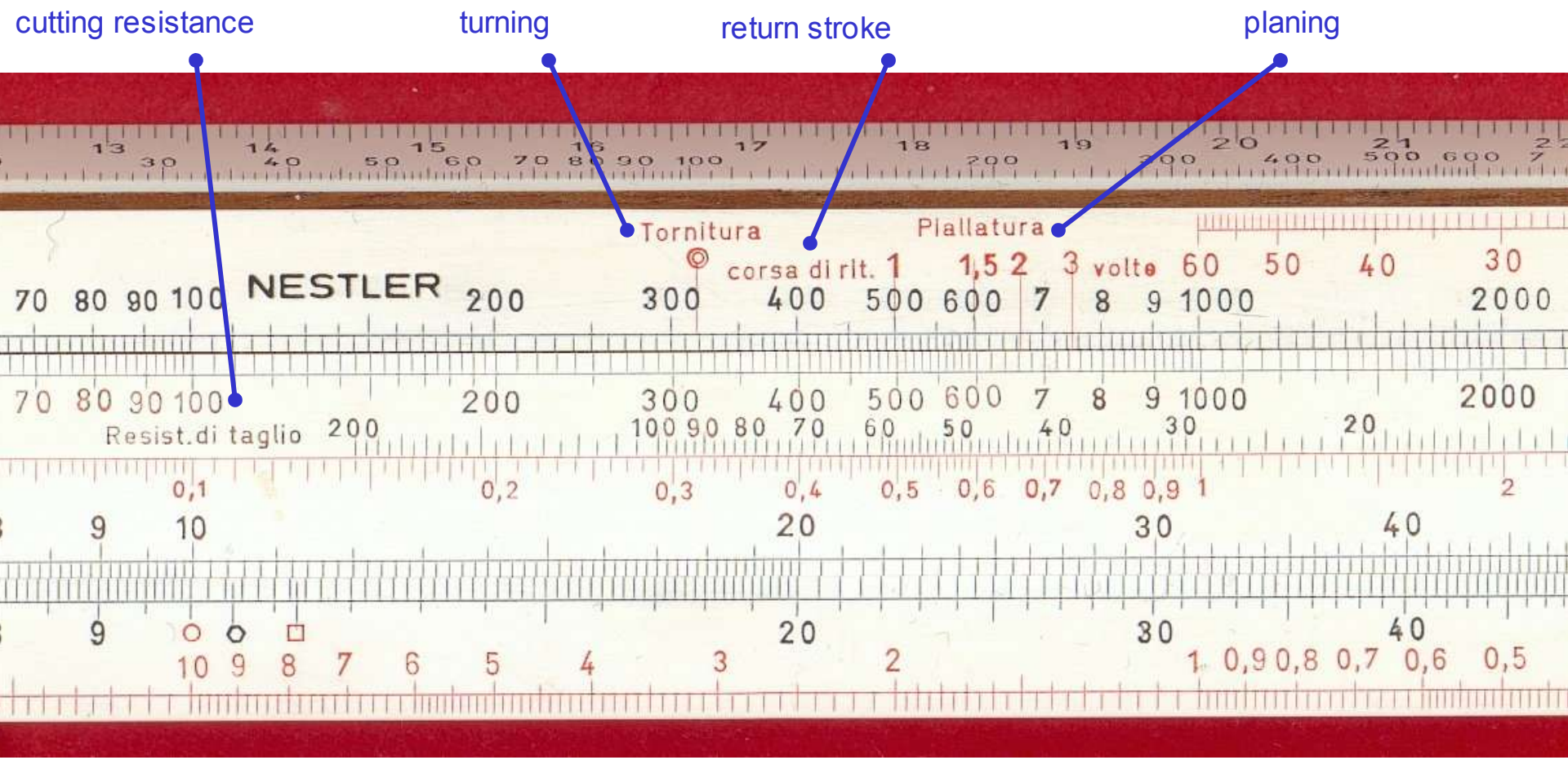
planing, shaping: return stroke



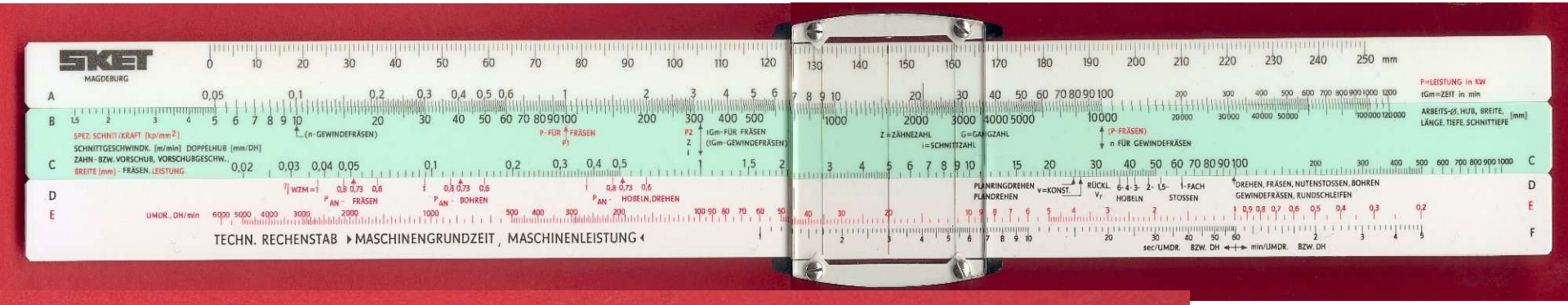
stroke, diameter, feed path, cutting speed, feed

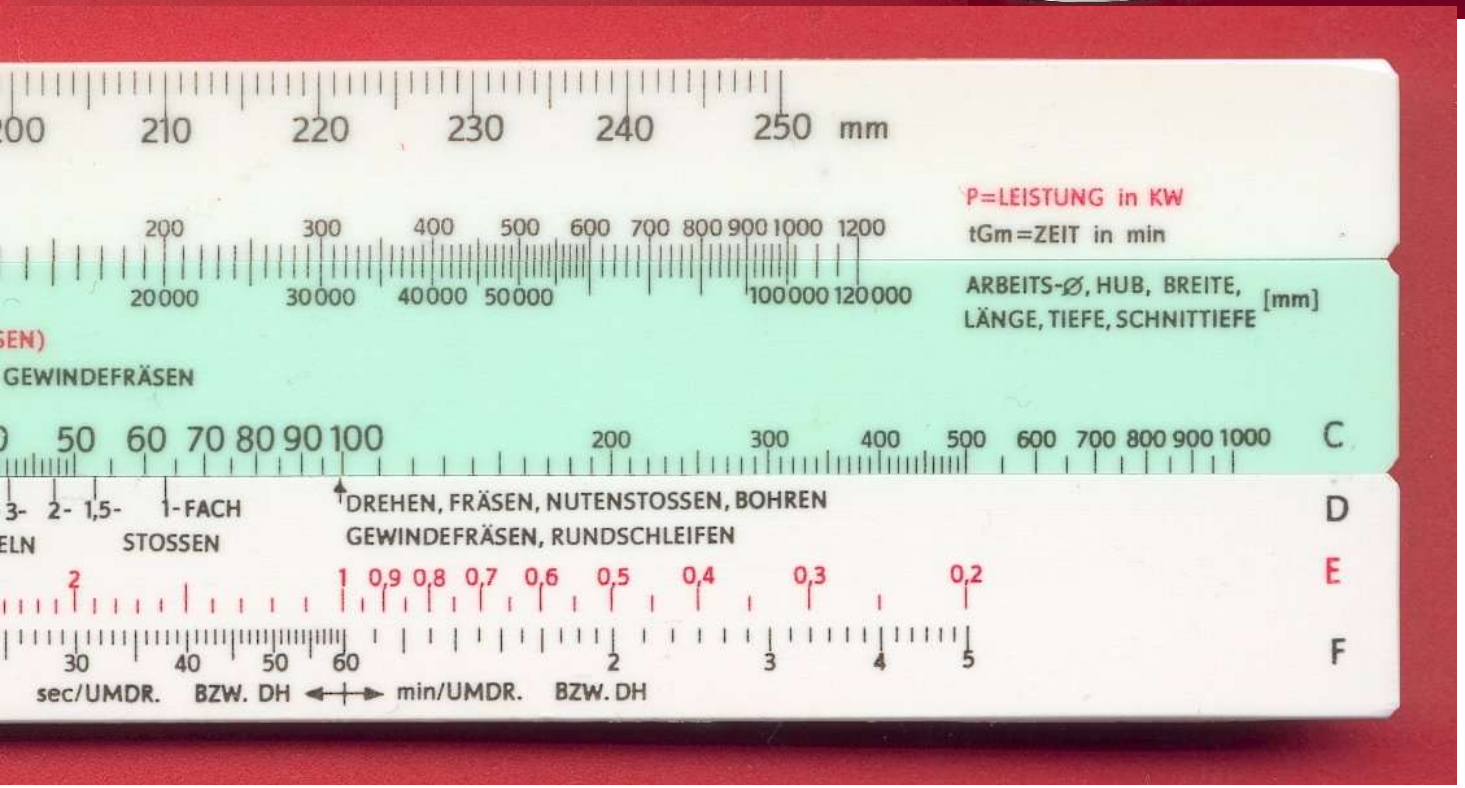
This slide rule doesn't have any scales for machine power and specific cutting force, so there are any machine power related calculations impossible.

Nestler 0260 Mecanica (Italian version)



VEB Mantissa „Maschinengrundzeit“ (approx. 1970)



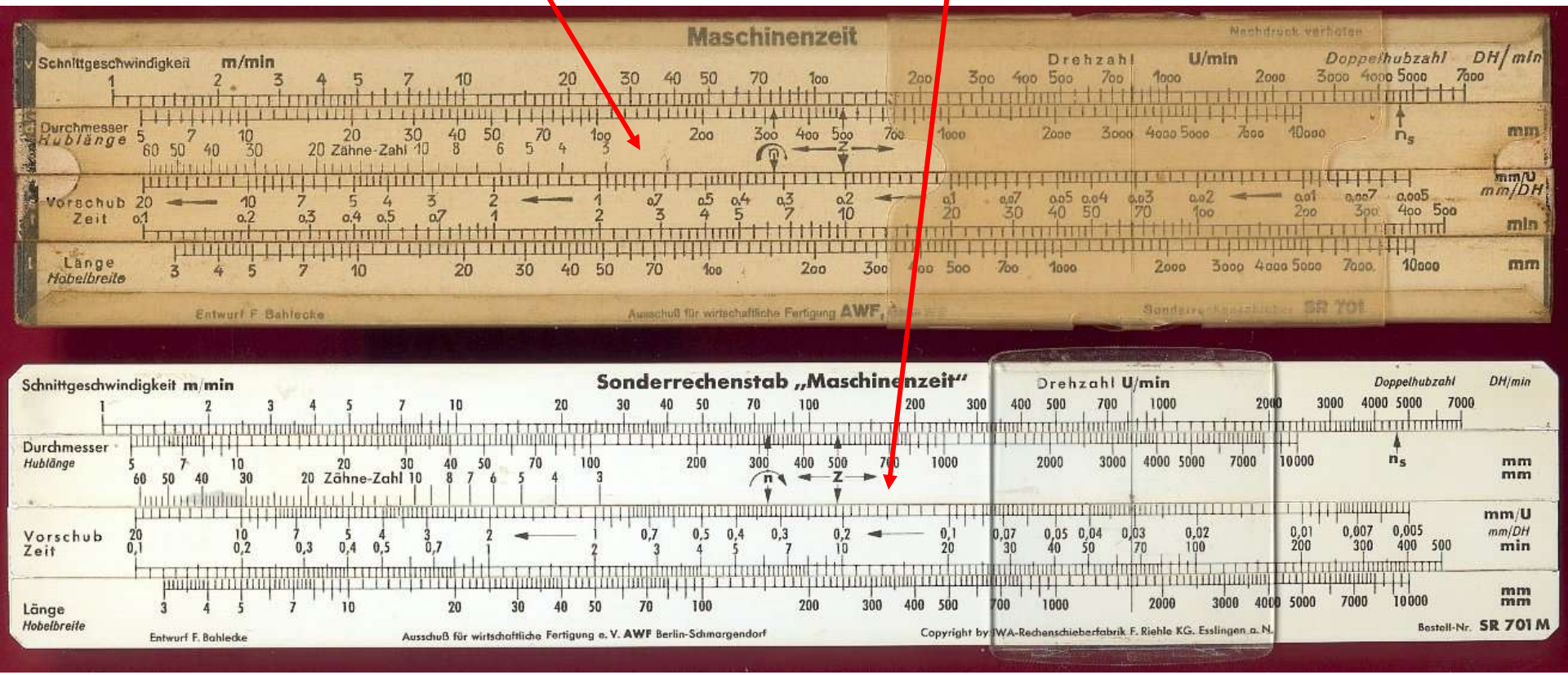


Probably an unauthorized copy of the

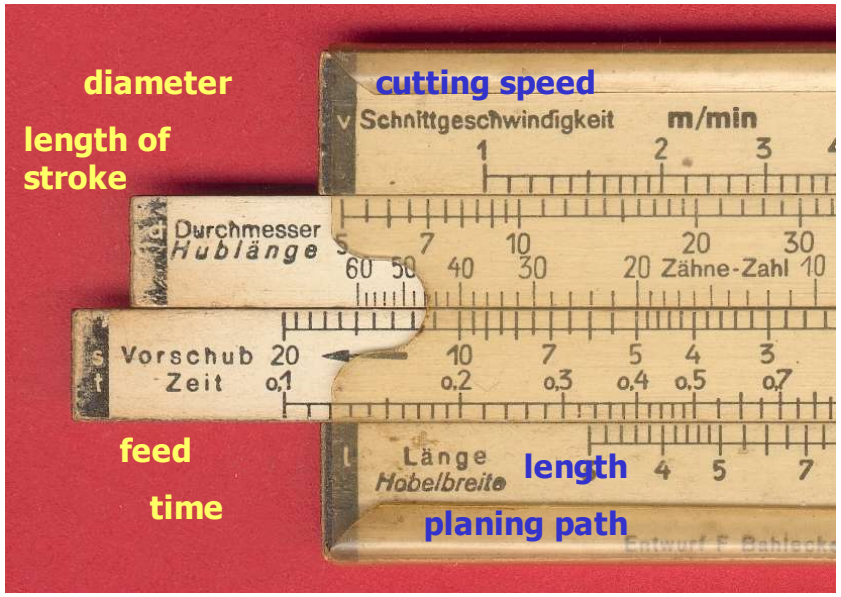
Faber–Castell 111/48 with some extended scales.

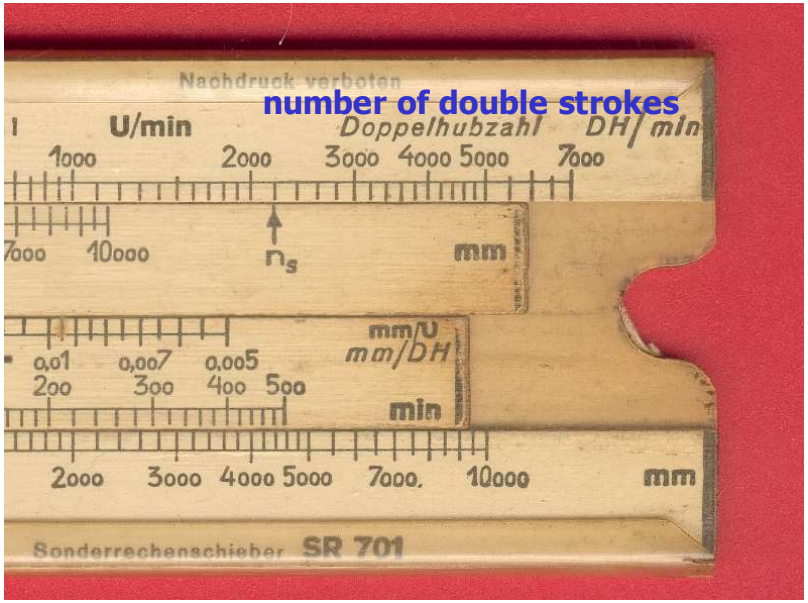
AFW 701 and IWA SR 701M

(approx.1930) (approx. 1950)

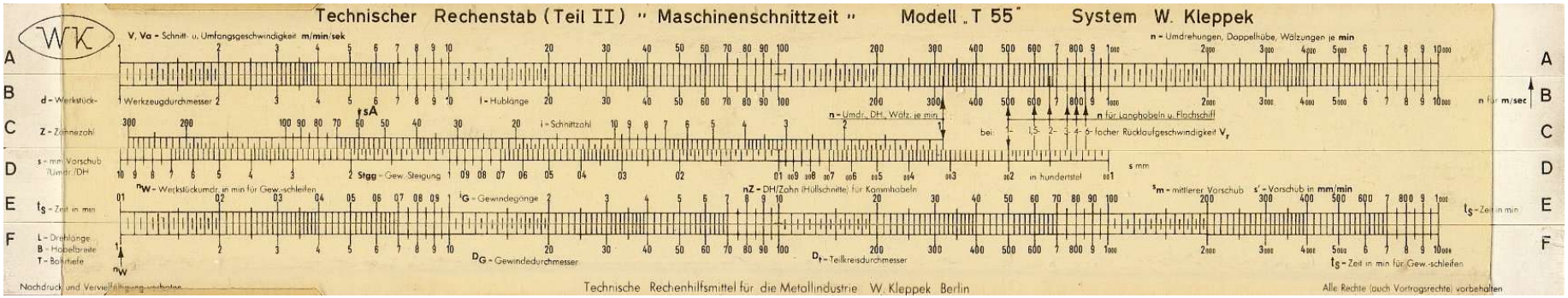


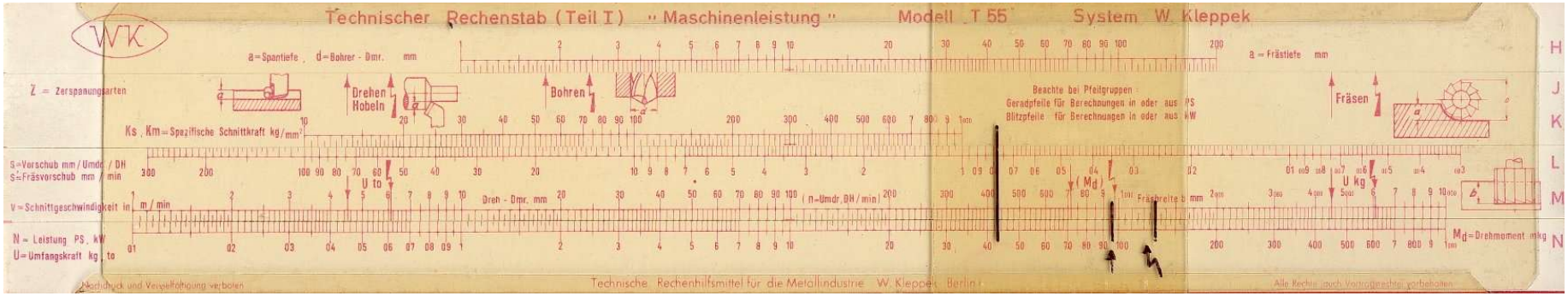
AWF 701 (left and right)



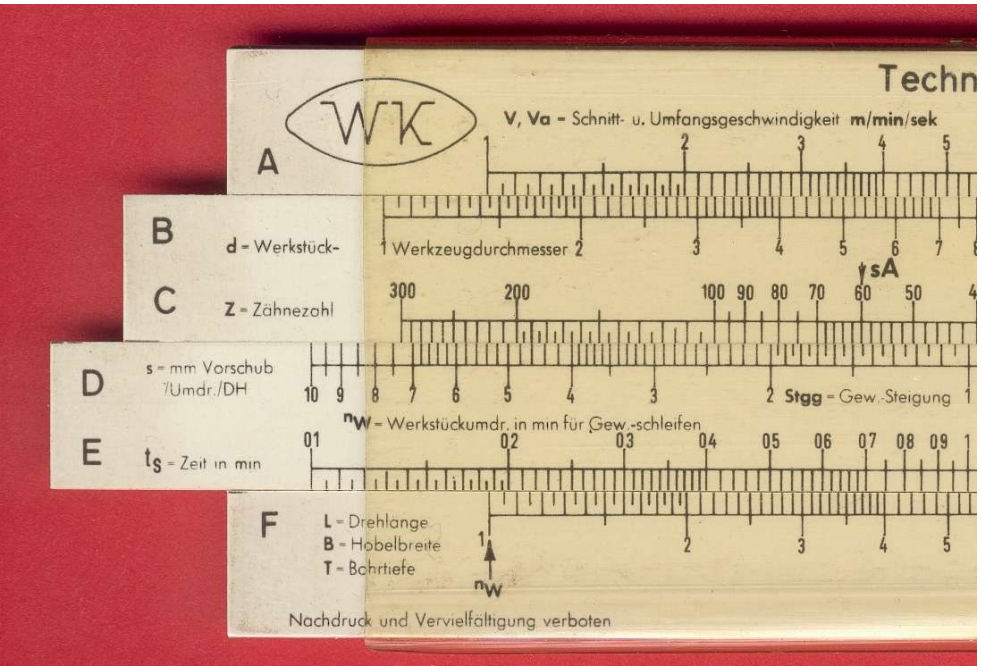


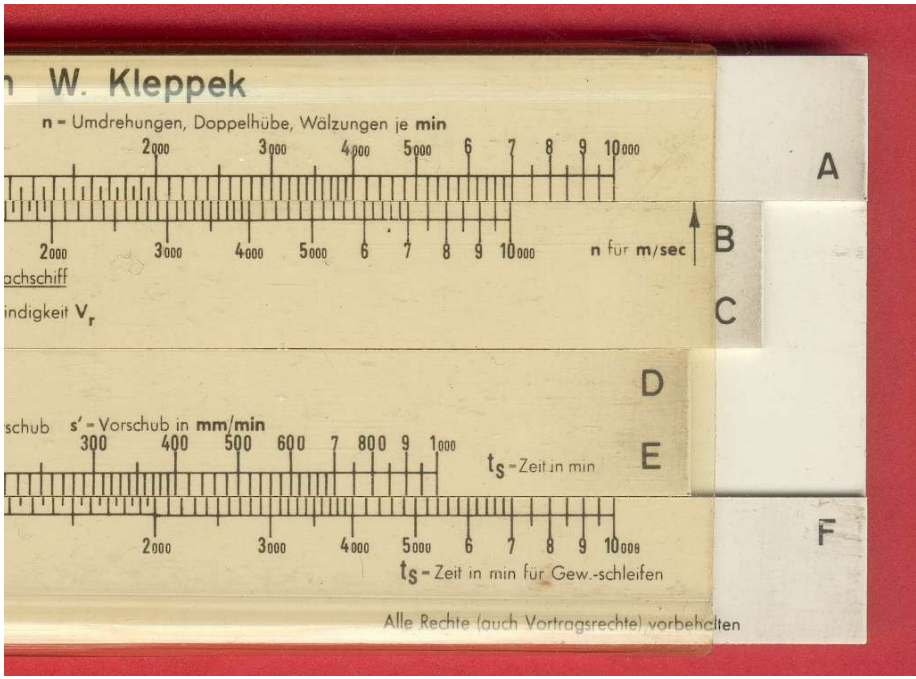
Techncal slide rule „System Kleppek“ (1960)



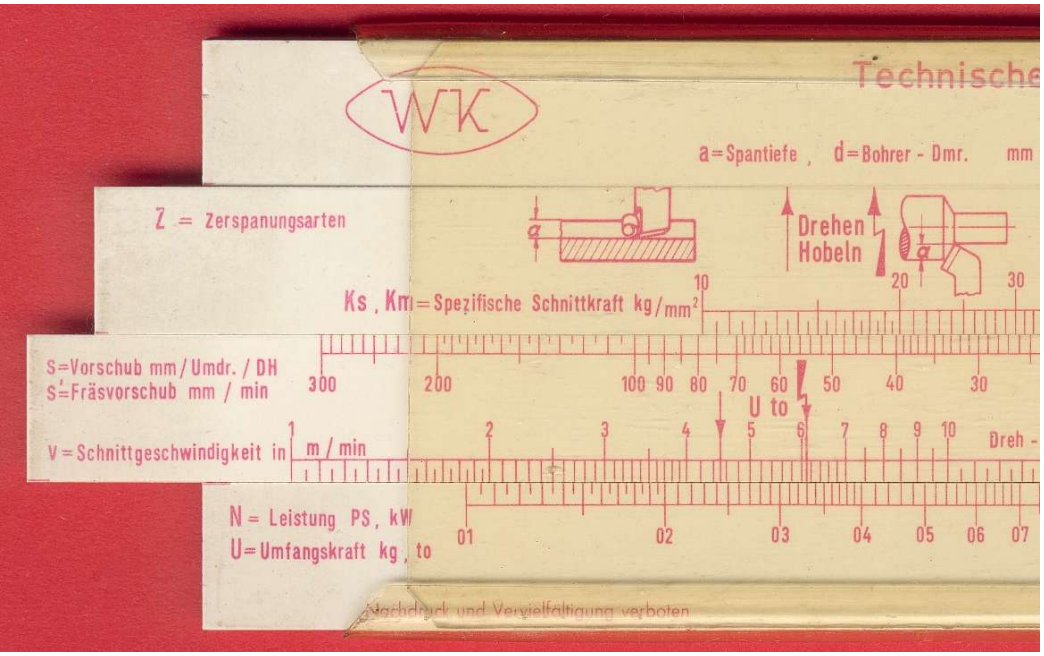


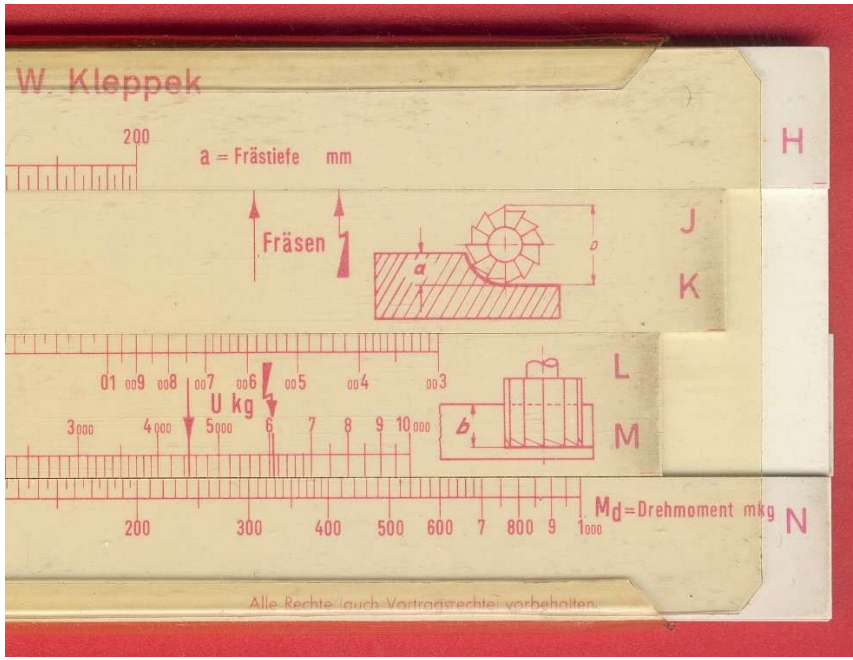
Kleppek (left and right, side II)





Kleppek (left and right, side I)





Example for calculation of the cutting depth „a“

Some parameters and their relationships have to be assumed before starting the calculation, namely:

machine power is given by 4 KW

With an efficiency coefficient η = 0.75 the real power at the tool is 3 KW (= 4 PS) only

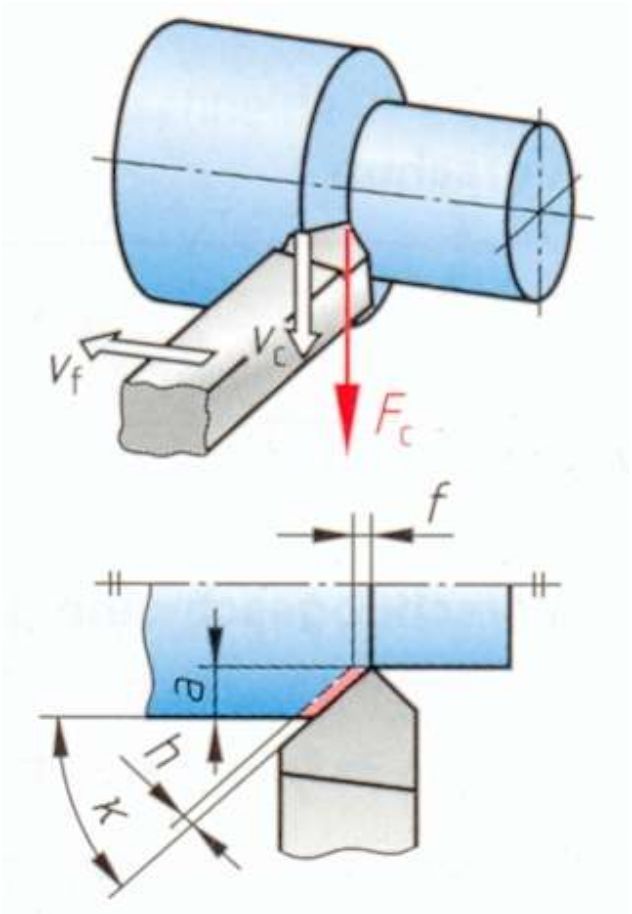
feed s = 1.2 mm/rev.

cutting speed v = 20 m/min

workpiece material: Steel St 60 with tensile strength R_m = 59...77 kg/mm²

specific cutting force k = 185 kg/mm²

time related chip-volume Q = 97 cm³/min



Mathematical procedure by using formulas only

chip section $A = a * s$

time related chip-volume $Q = A * v = a * s * v$

cutting power $P = F * v = Q * k$

$P = a * s * v * k$

equation transform to $a = \ldots$

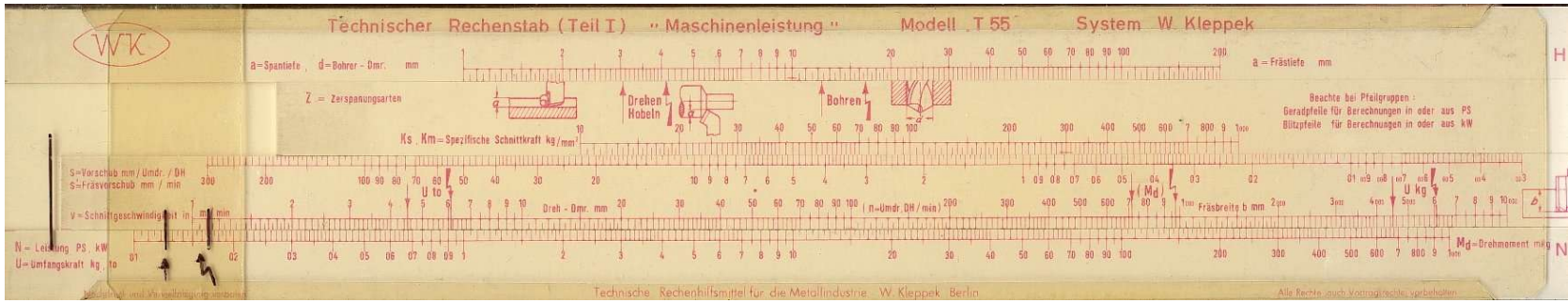
$$a = \frac{P}{s * v * k}$$

$$a = \frac{4000\ W * 0{,}75 * 60}{1.2\ mm * 20\ m/min * 185\ kg/mm^2}$$

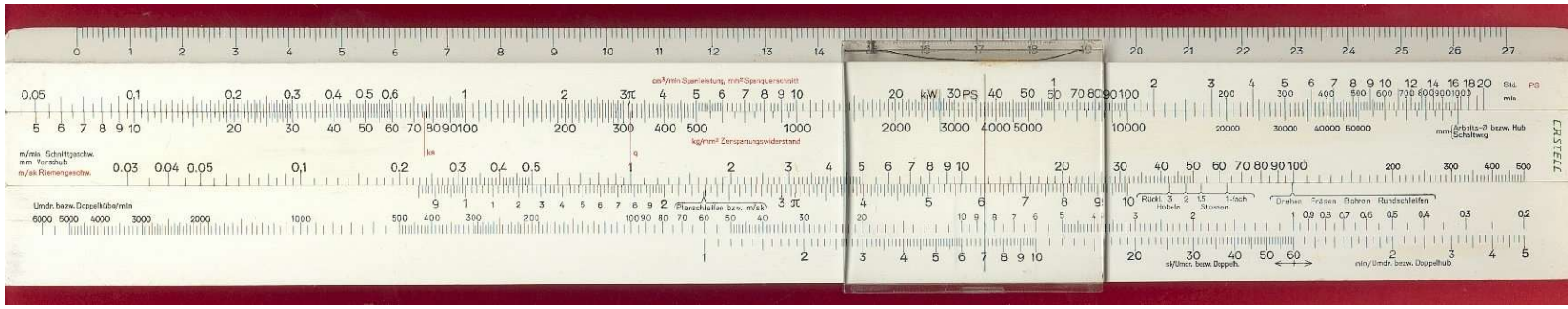
a = 4.05 mm

Calculation with slide rules

Kleppek

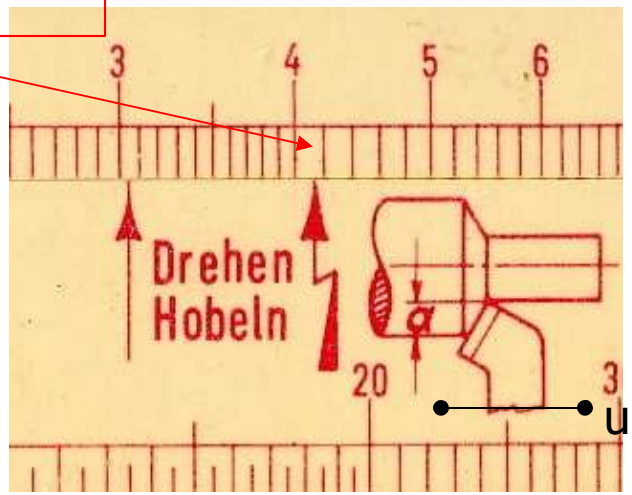


FC 111/48



How to do it with a Kleppek

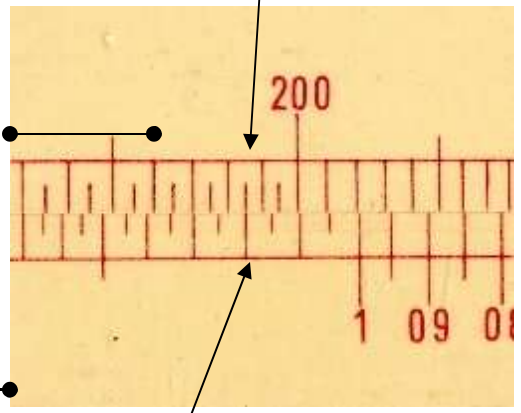
result: cutting depth
a = 4.1 mm

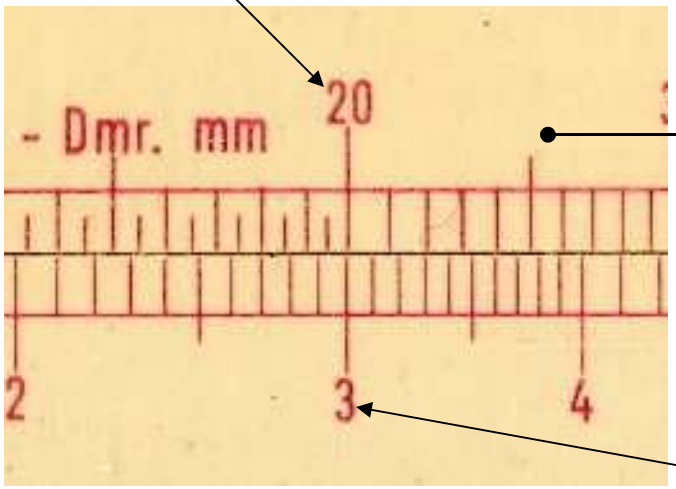


specific cutting force
185 kg/mm²

cutting speed
20 m/min

upper slide



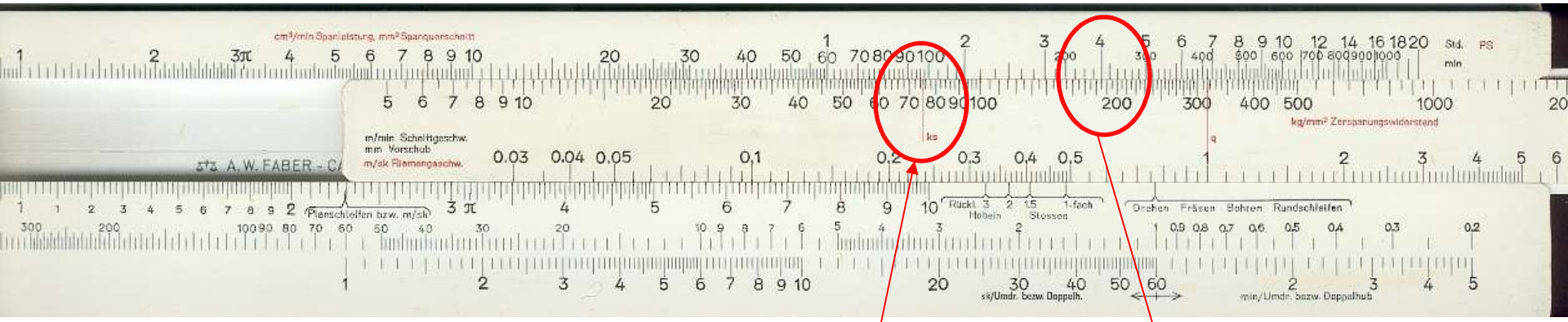


lower slide

feed 1.2 mm/rev.

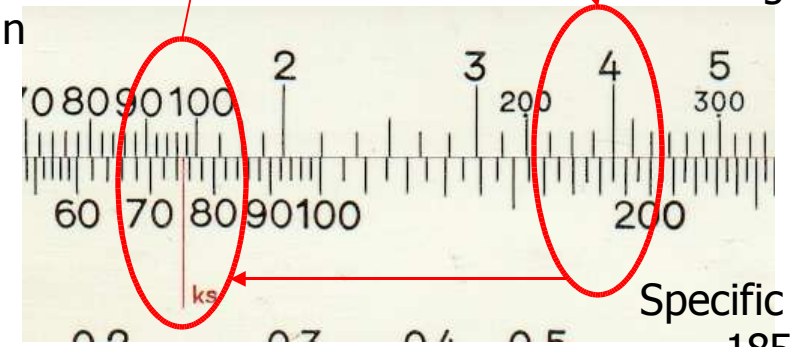
power 3 KW

How to do it with a FC 111/48 (setting 1)



time related chip volume
97cm³/min

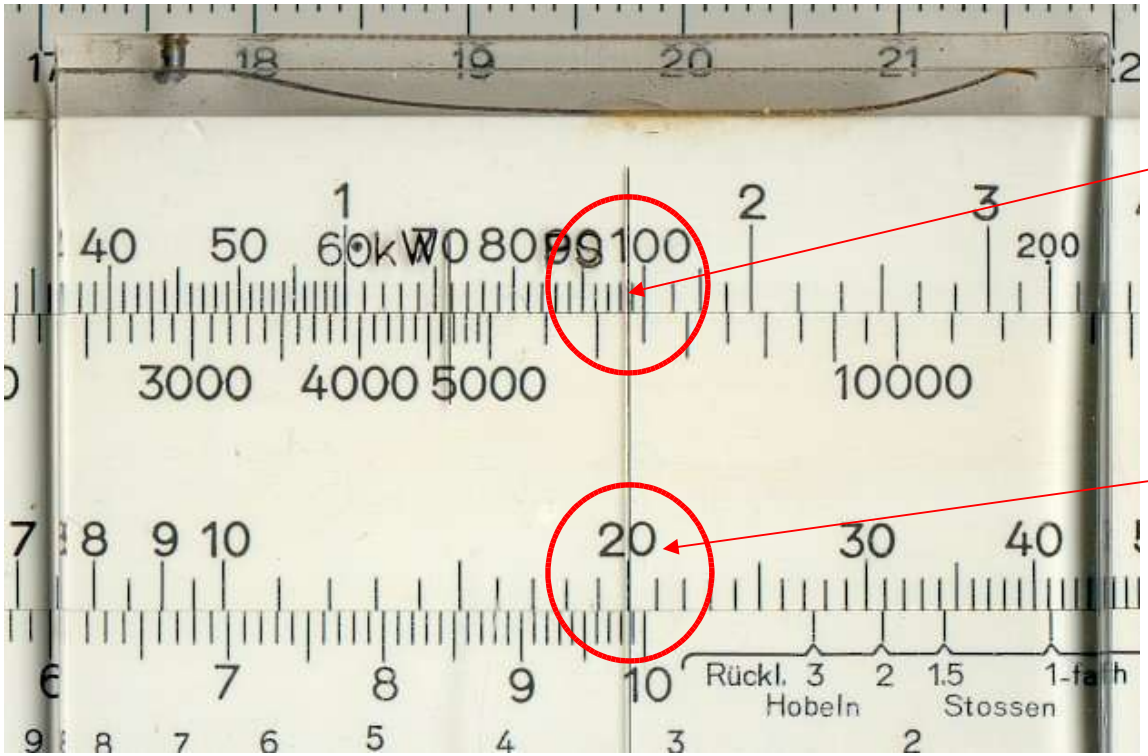
4 PS (= power at cutting edge)



Now the cursor is to set on 97

Specific cutting force
185 kg/mm²

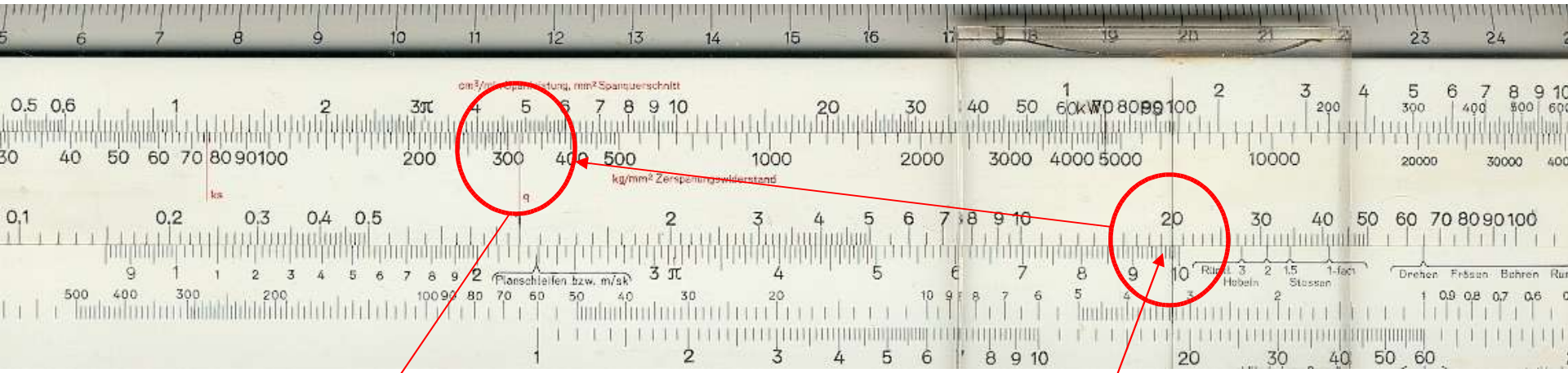
FC 111/48 (setting 2)

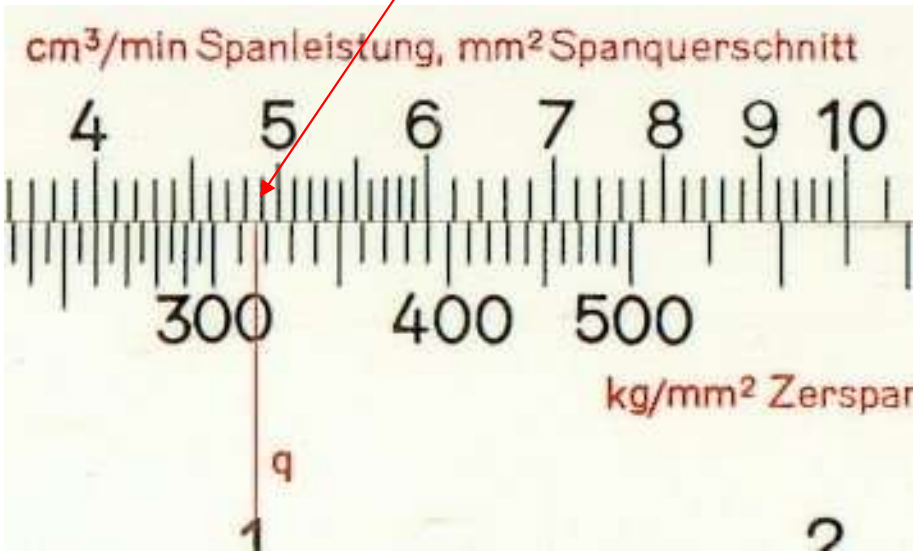


The cursor is set on 97

Then the slide has to be moved to the left until cutting speed 20 fits the cursor.

FC 111/48 (setting 3)





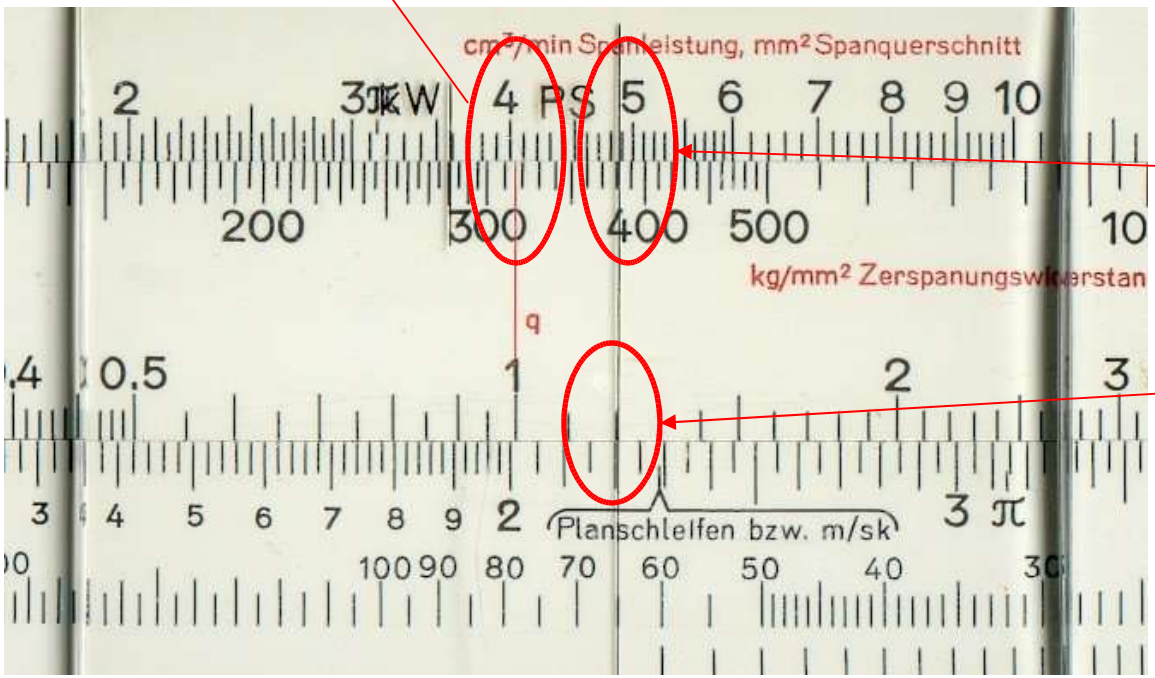
Because of the just moved slide with the value 20 under the cursor, now the **red marking q** on the slide shows the value for „chip section" = **4.85 mm²** on the stator.

FC 111/48 (setting 4)

The result **a = 4.05 mm** we'll find at the position of the red marking q.

When chip section is A = a * s

the cutting depth is a = A/s



cursor on 4,85

Move the slide a bit to the left, so the value for feed = 1.2 is under the cursor.

This was the setting of the division of 4.85/1.2

And here you see the result of a successful calculation with a machine-time slide rule:

Thank you for your attention!