DELFI BATAVORUM
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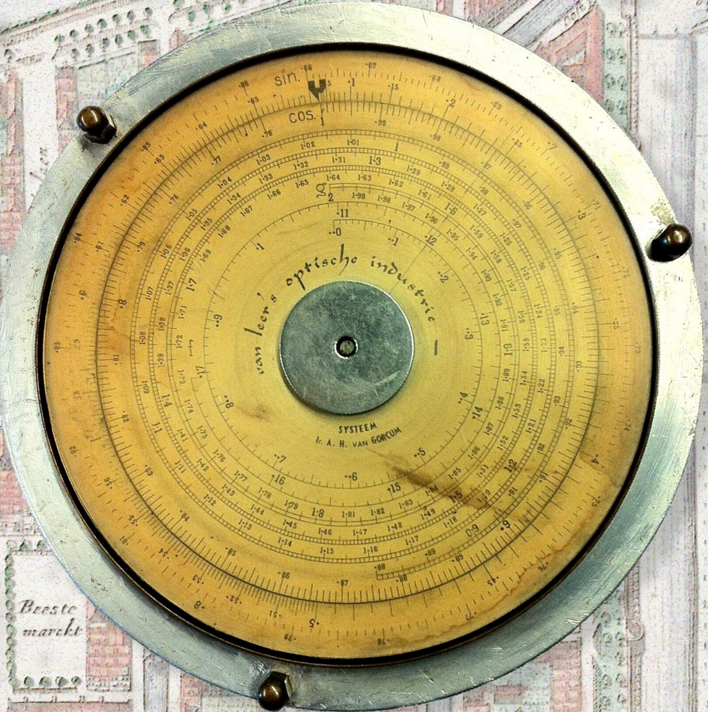
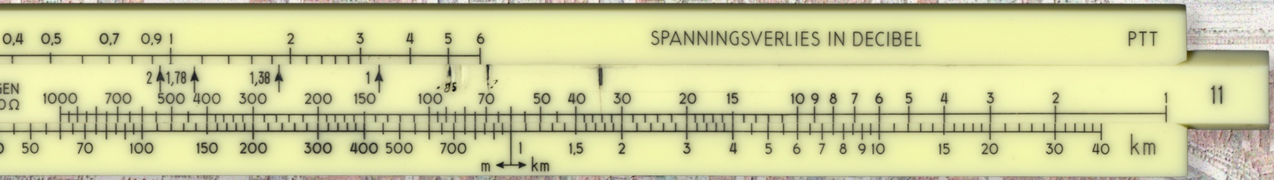
DELFT.

IM 2014



TURNING AND SLIDING



Proceedings 20th International Meeting of Collectors of Historical Calculating Instruments

September 5 - 6, 2014

Delft, the Netherlands

KRING HISTORISCHE REKENINSTRUMENTEN

20th International Meeting
of Collectors of Historical
Calculating Instruments
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PROCEEDINGS

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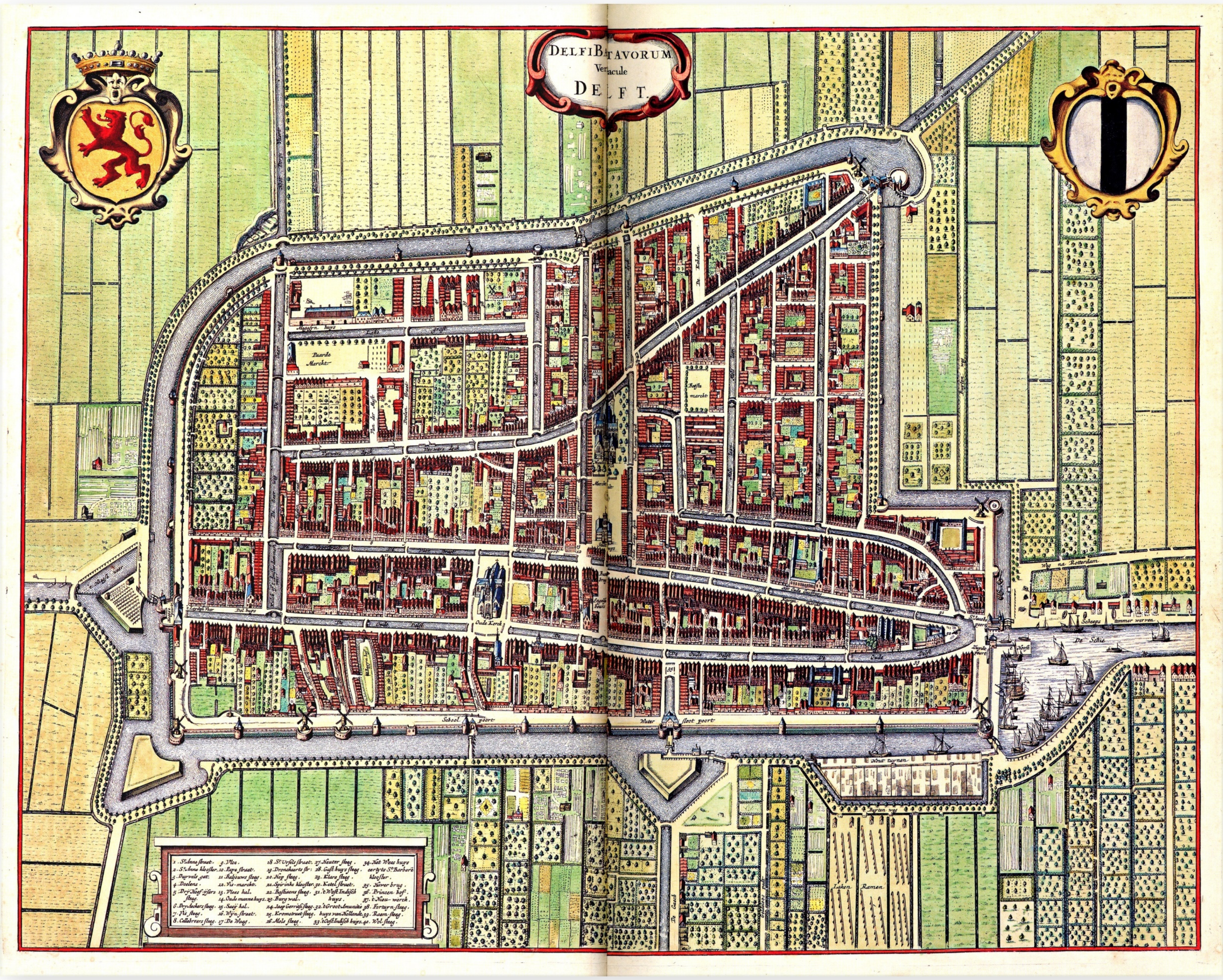

City Map of "DELFI of the Batavians", or Delft
Hand-colored Engraving in Atlas de Wit, 1698

DELFT - Host City of IM2014

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INTRODUCTION TO IM 2014

Chris Hakkaart
Chairman of the Dutch Circle of Collectors of Historical Calculating Instruments

Dear Participants and Partners

The first International Meeting was organised 20 years ago in The Netherlands by a number of enthusiastic Dutch collectors for their co-collectors in other countries. A number of these founding fathers have passed in the meantime, but others are still active. This initiative has been followed in the next years in other countries as United Kingdom, Germany, Switzerland and the United States. From the beginning on, the IM was not only for the participants, but also for the partners a program was organised.

The interest in Slide Rules, calculating machines and other related subjects has been stable over these years. People from countries as e.g. Denmark, Norway, Australia, France, Spain, Israel, Italy, Finland, etc have participated and still do.

Collecting Slide Rules started as a hobby, but changed over the years in serious research and documenting of the history of aspects as design, manufacturing, patents, education, one-offs, etc. The list of Slide rule designers and producers was ever increasing and even today new items are discovered. We have not yet reached the end of this hobby. For me, the interesting aspect of this activity was, that we - the slide rule community - was and is able to document and write books and articles in periodicals and IM's, based on information partly collected from those who had actually been involved in the design and production in the past. This increases the value of the historic documentation tremendously.

In these 20 years we and other collectors, who are not present in this IM, have done a remarkable job. I suppose that the younger generation of collectors (which have not used the slide rule in their working life as most of us have) will understand the extra value of our work.

This IM will again contribute to the knowledge concerning Slide rules, Calculating Machines and other mathematical issues. The theme is this time TURNING and SLIDING, which are the only actions which you have to do with these type of calculating devices. Most of the presentations have a certain relation to TURNING and SLIDING. All papers presented are stored nowadays on a CD and for those who wish, printed proceedings are available. This adds again a valuable book to your Slide rule library. And our experience is that, when searching in all those books, a book-marker is essential. To avoid the use of e.g. empty envelopes or such, a specially designed *slide rule book-marker*, based on 20 years International Meetings, is provided.

For our partners a day excursion to the old city of Delft is organised. It starts with a guided historic walking tour, followed by a visit to a 17th century home with original furniture. A lunch will be the preparation for a boat tour through the canals and to the famous *Porceleijne Fles*, where Delft Blue is produced. A guided tour through the production facilities will show the ins and outs of the production of pottery.

As preparation for this excursion, there will be a lecture during the diner the day before, about Delft Blue in relation to the city of Delft and our international connections. Our partners will for sure remember this.

It has never been planned, but nevertheless it has been a certain tradition that the IM's in the Netherlands have their lectures at two locations. It makes logistics somewhat more complex, but it adds to the atmosphere. Also this time we will make use of two locations. The first day we will stay in the hotel (at a few minutes from the inner city), but the second day we will walk together in the morning along the canals to the only surviving classic lecture room of the Technical University of Delft. You have to go back into the school banks. This is located near the Science Centre, where you will have lunch at an airplane wing and a free visit to the technical centre with other peculiar items.   To facilitate your need for discussions, we have an optional dinner in an inner garden in the historic centre. There is time to walk along the canals of Delft and to visit old pubs.

Additional to the standard IM, there is the option to join us to the private technical Museum Mensert, which will be exclusively opened for us on Sunday.

The IM is the yearly international opportunity to meet each other and exchange knowledge. This is still appreciated by many of us, besides the possibilities of email and internet. Eye to eye contact gives often more response than digital contact.

The Organising Committee of this TURNING and SLIDING IM wishes you interesting days.

The organising committee of the International Meeting of Collectors of Historical Calculating Instruments 2014 "TURNING and SLIDING" consist of the following persons.

ORGANISING COMMITTEE

Chris Hakkaart, chairman of the organising committee, did coordination, contacts with TUD and other Delft establishments, and all financial planning and handling.

Leo van der Lucht and **Nico Smallenburg** coordinated and handled the selection and reservation of hotel and conference sites.

Otto van Poelje took care of the design of the Proceedings book cover and of the "20 IM's" bookmarker, and prepared the Proceedings.

Gerard van Gelswijck arranged the production of the Proceedings and handled contacts with the various suppliers for the conference.

Andries de Man handled the IM2014 announcements, communications with participants, and the registration process.

List of Supporters and Sponsors of the IM 2010

This International Meeting could only be organised with the support, in a direct or indirect way, of individuals, organisations and companies. The Organising Committee expresses, also on behalf of the participants, their acknowledgement for their support.
Thanks to all the speakers and authors of the papers in the Proceedings, who have invested time during the preparation of their contribution.

Others have supported to make the IM 2010 a success:

- Paul Ruks of OP12 and the "Grafisch Atelier 't Gooi", who implemented the design of the Proceedings' cover with professional Adobe tools.
- Our sister organisations abroad, who assisted in providing information and distributing the announcements.
- Our partners, who assisted the organisation and guided the Partners program:
  Henny C. Brouwer, Daria Bouwman, Janny van Poelje.

Financial support has been received from the following sponsors:

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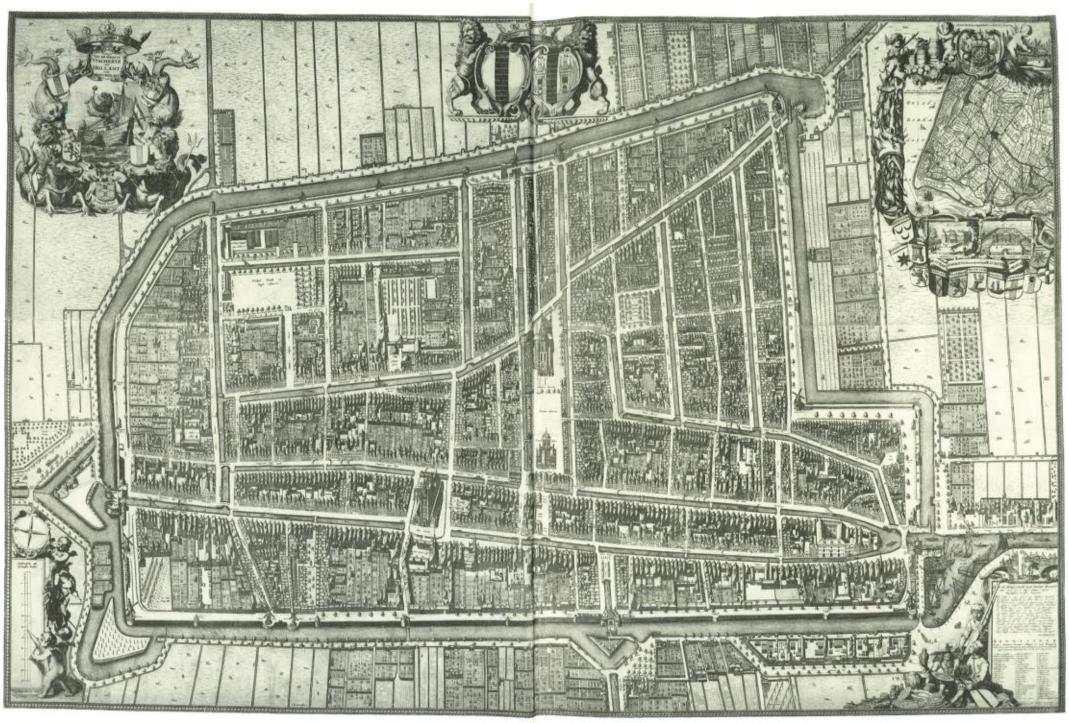
PARTNER PROGRAM IN DELFT

Chris Hakkaart & Henny Brouwer



The International Meetings are not only for the Participants, but also for their Partners. That means that the location needs to be of interest for both Participants and Partners. Often old cities offer sufficient opportunities to organise an interesting program.

This time Delft is the city. The name Delft is related to the Dutch word "delven", which means digging. In about 1100 a small local canal was dug, and a small community started around the Old Church. In 1246 city rights were honoured. After a canal was dug to Rotterdam, Delft became one of the largest cities in the seventeenth century, together with Leiden, the city of the previous IM. Between 1600 and 1800 Delft was one of the main porcelain producing cities in Europe. The *Porceleijne Fles*, the only remaining factory, will be visited. This factory was in 2003 more than 350 years old, so even older than the Slide rule !!

The canals in the seventeenth century map still exist. In 1632 the famous painter Johannes Vermeer was born and in 1723 the inventor of the microscope Antoni van Leeuwenhoek died in Delft. In 1842 the first Technical University of The Netherlands was founded.

But Delft was also famous for its breweries. The reason was something which we call nowadays environment. It was in that time not allowed to dump sewage water in the canals. So the water was clean and could be used for the production of beer. At the end of the eighteenth century, the number of breweries declined as a result of drinking attitude. They disappeared finally completely out of the inner city. Recently at the Burgwal a new brewery started, which you can visit in your free hours. The water used is *not* from the canals.

On Sunday there is an optional excursion to Museum Mensert, which is located in one of the old brewery buildings.

Delft is famous as "small Amsterdam". To get an impression, the tour starts with a walk along the canals with seventeenth century houses, along the New Church on the market, where members of our Royal Family are buried, the Prinsenhof, where Prins Willem van Oranje, the "stadhouder" of the Republic the Seven Provincien was shot and killed. A guide will explain it all to you.

The seventeenth century house of Tetar van Elven - with original furniture - will be visited. It is located at the Koornmarkt (cornmarket), the main canal where most of the breweries were located (and where I lived during my studies).

A lunch will help you to recover from all impressions. In the afternoon a boat tour through the canals will give you another view on Delft. This boat will sail to the Porceleijne Fles, where a guided tour through the factory is organised. The same boat will pick you up at the end of the afternoon and bring you back to the Koornmarkt.

Those who travel by KLM know, that in the business class passengers receive a small Dutch Blue house with "jenever". Up till now 94 different replica's from houses from Amsterdam, Delft, Leiden and other cities are made. Some of these are over 50 years old. They are a real collector item. Recently a book was published about these KLM houses. The author visited all houses and documented the architectural and constructural aspects, as well as the stories about the (original)l inmates. The author Wim Zegeling will give a lecture during the Friday dinner.
On Saturday you can start your own collection at the vintage market in the centre of Delft. These KLM houses are replica's of original houses. But in Amsterdam, in the Oude Zijds Armsteeg in the centre, a couple of new houses were built as a replica of the KLM houses!!. So the circle is round.

The day will end in the garden of a small restaurant in the inner city. Finally it is up to you if you will spend the night in the pubs.

ALRO Calculating Disc for Optical Ray Tracing

"van Leer's Optische Industrie"

Otto E. van Poelje

Introduction

The Dutch firm of ALRO, The Hague, has produced calculating discs, slide rules and charts between 1938 and the 1980's. The history of the ALRO firm and the summary of its products have been treated extensively by IJzebrand Schuitema in literature references [1] and [2], augmented with oral histories from ALRO employees and relations. A former director of ALRO, Han Wanders, has described in reference [3] his personal work experiences at the firm since the 1950's.

It was thought that by now all products from ALRO are known in collectors' circles, but recently a calculating disc by ALRO -unknown as yet to slide rule collectors, see fig. 1- was discovered in Hans Ploegmakers' heritage collection of the former "De Oude Delft/OLDELFT", a firm that produced optical instruments between 1939 and 1990.

This paper will present the newly found ALRO Calculating Disc, and explain its usage in calculations for *Optical Ray Tracing*. The starting point of the research regarding this disc was the name *van Leer's Optische Industrie* - inscribed around the centerplate of the disc.

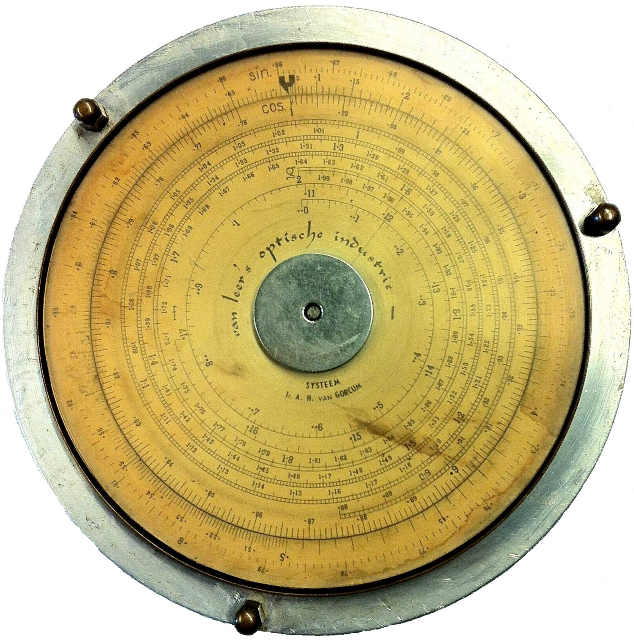


Figure 1. "van Leer's Optische Industrie" disc

History of "van Leer's Optische Industrie" in Delft

Oscar Jacques van Leer (1913-1996) was one of the two sons of well-known Dutch industrialist Bernard van Leer who founded in 1919 a factory of steel drums that grew into the multinational "Royal Packaging Industries Van Leer N.V.".

One year before World War II, 13 December 1939, Oscar van Leer established in Delft his own firm in optical instruments under the name "van Leer's Optische Industrie N.V."

In 1941 Oscar van Leer, of Jewish descent, had to take refuge in the United States.

Under the aegis of Philips N.V. his firm continued operations under a new name (Optische Industrie 'De Oude Delft'), and under the new leadership of renowned physicist Albert Bouwers from "Philips Natuurkundig Laboratorium". During the war, Oscar van Leer remained involved in commercial activities of 'De Oude Delft' in the United States until 1945 (after the war he returned to Holland, and in the 1950's he took over control of his father's company). "De Oude Delft" struggled to survive the shortage of materials in wartime by producing simple apparatus such as consumer camera's (the REWO box with meniscus lens) and even a cardboard kaleido-scope. The name of the company was derived from the address of the factory at the "Oude Delft" nr. 36, a 16-room twin mansion from 1630 along one of Delft's oldest canals, at Nickersteeg corner.

Figure 2. Two versions of the 35 mm camera lens Minor

After the war 'De Oude Delft' produced telescopes, binoculars, periscopes, special-purpose lenses and optical systems, X-ray cameras, and later specialized in infra-red and night vision optics and image intensifiers for defense systems. Also lenses for 35 mm camera's were made, for example a wide-angle "Minor" for Leica and Alpa, see fig. 2.

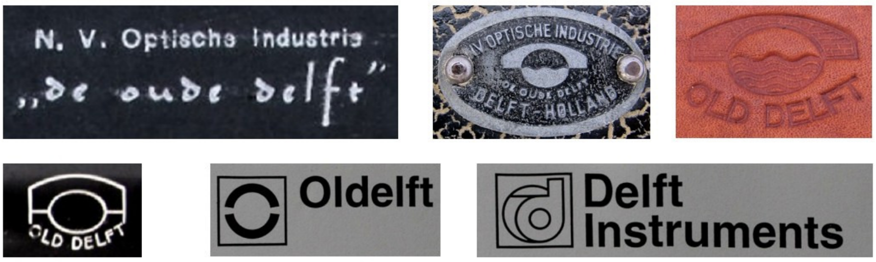


Figure 3. Logo's of "De Oude Delft" and later names

The company changed its name to English, "OLD DELFT", and eventually to "Oldelft" in 1985, developing mainly military optical systems, see fig. 3. In the late 1960's the firm expanded by a number of takeovers (e.g. NedOptiFa Dr. C.E. Bleeker, Deltronix Nuclear) and new subsidiaries in other countries, resulting after the 1990 merger with ENRAF-Nonius in the new name 'Delft Instruments'. Later the activities of the former 'Oldelft' were merged into the Thomson-CSF takeover of Philips/HSA (Signaal). Today the legacy of van Oscar van Leer's company is absorbed into the military branch of the multinational 'Thales' (the new name of Thomson-CSF since 2000).

The ALRO origin of van Leer's Optische Industrie Calculating Disc

The disc is of a well-known construction by ALRO: it is one of the desktop versions of the popular metal-boxed discs that ALRO had patented in the late 1930's. The boxed disc was produced from the late 1930's until the late 1960's in many versions – from an elementary 2-scale type 500N to the multi-scale Darmstadt type 300D and 400D, see [4]. Also a large number of boxed discs have been made for special purposes and special customers. The box could be folded into a flat pack for transport, and opened for use at a 45 degree angle - resting on the lid of the box. It was ALRO's intention to bring to market larger desktop-size versions of the most popular boxed models.

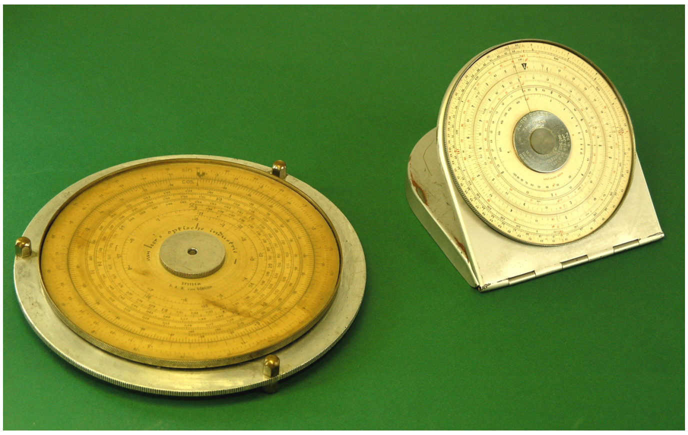


Figure 4. ALRO discs – the larger desktop version (left) and the metal-boxed version (right)

For example, desktop models are known of the Commercial type 1010, of the goniometrical disc called "GoA", and some special-purpose versions, e.g. the medical disc by Dr. A. Lips.

The boxed model had an overall diameter of 13 cm, the desktop-sized version had a 16 cm diameter, see fig. 4. The desktop model was operated in a fixed horizontal position, standing on three feet.

The *van Leer's* disc, like most ALRO's, has a inner disc with stationary scales and a rotating ring with the "sliding" scales. A hairline is printed on a transparent rotating disc, to set and keep intermediate results during a calculation, just like the cursor on a regular slide rule.

Analysis of the Scales

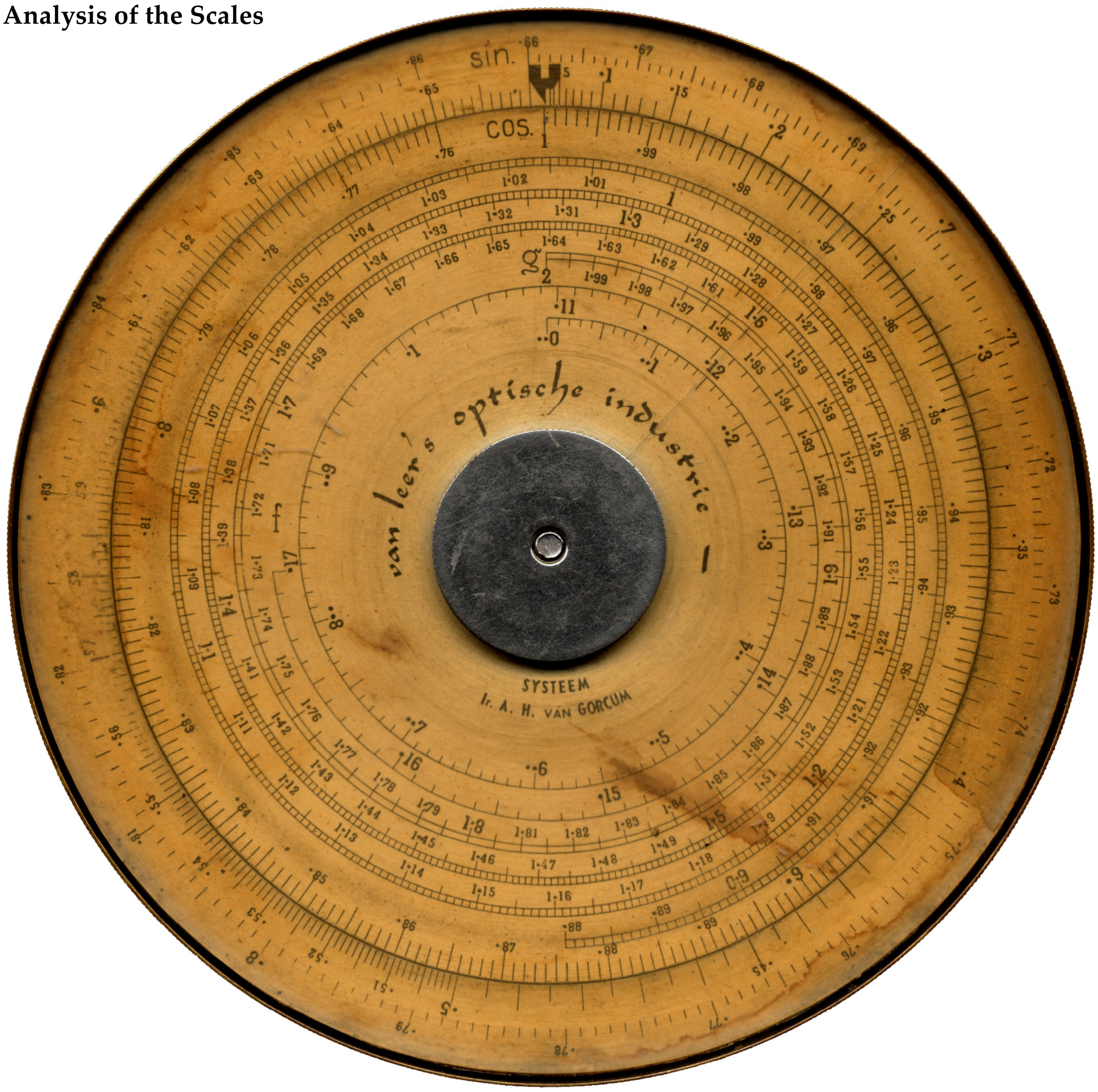


Figure 5. Scales of van "Leer's" Calculating Disc

There are four scales visible, see figure 5, titled from outside to inside:

Outer ring: ***sin*** over 2 turns

===================================

Inner disc: ***cos*** over 1 turn

g over circa 3 ½ turns

f over circa 1 ¾ turns

The *sin* scale is the outermost scale rotating around the stationary scales on the inner disc. This scale runs from value 0 to 0.6614 over the full circle along the border of the ring, and from 0.6614 to 0.86 along the extension winding. This means that the range of angles on the sine scales is from 0º to 41.41º and from 41.41º to 59.32º on the respective windings.
The initial value 0 of the *sin* scale is marked by a stylized index symbol, meaning either the symbol μ, or a **u** with a small arrow pointing to value 0. The divisions of the sine scale are related to the *cos* scale, as will be shown below.
The *cos* scale is the outer scale on the fixed disc, along which the rotating *sin* scale can be moved. This *cos* scale runs back from value 1 to 0.75 over the full circle, but the subdivisions only run from 1 to 0.76. The divisions of the *cos* scale are *linear*, and *not logarithmical* as on a regular slide rule! This means that *van Leer's* disc is not intended for multiplications and divisions of goniometrical values: *only addition* of cosine values is possible.

The goniometrical scales have been designed in such a way that *cos* and *sin* scales show the cosine and sine value respectively of the *same angle* when aligned by sin(0°) = 0 against cos(0°) = 1. It is remarkable that the value of that angle itself - in degrees - is NOT shown!
Figure 2 shows the *sin* scale positioned with index value 0 against value 1 on the *cos* scale.

When still aligned, we can check the last division of the *cos* scale, and see the value cos(40.54°) = 0.76 against the opposite value of sin(40.54°) = 0.65. Another check: under the hairline (in fig. 5) we see 0.97 = cos(14.07°) against 0.243 = sin(14.06°), a good precision.
There are no *cos* scale markings for greater angles than arcos(0.75): those are not needed because the linear 1.00 to 0.75 range can easily be read as a 0.75 to 0.50, and even further down.

The double-lined ("railroad track") *g* scale runs clockwise from inside to outside, spiraling from 2.0 to 0.88.

The innermost single-lined *f* scale runs clockwise from inside to outside, spiraling from 0 tot 0.17. The scale name of *f* is difficult to recognize because the letter *f* is somewhat removed from the end of its scale, elongated and turned over 90 degrees from the expected orientation.

Before the purpose of the disc was discovered (see next sections), further analysis of the scales was not possible because with non-logarithmical sine and cosine scales the meaning of the other scales *f* and *g* presented a mystery.

Calculations for Optical Design of Lenses

As "van Leer's Optische Industrie" started its existence in Delft, it seemed logical that there were professional connections with the Technical University of Delft (TUD), as it is called today (in 1939 it was still called "Technische Hogeschool Delft", THD). These connections were indeed found by the kind assistance of dr. ir. J.J.W. Braat, professor in "Optics" (TUD), and dr. ir. W.L. van der Poel, professor emeritus in "Computer Science" (TUD).

As it turned out, a well-known specialist in optics, dr. A.C.S. van Heel (1899-1966), was professor in "Technical Optics" at THD since 1938, and he has been actively involved in the start of "van Leer's Optische Industrie" in 1939, especially the design of its optical systems.
In the first half of the 20th century the calculations for lens design had to be done by hand because the mechanical calculators of the time did not handle goniometric and other mathematical functions beyond arithmetic. The quality of a new lens system was forecast by computing the paths of a great number of different optical rays through the glass surfaces in the lens: "Ray Tracing". For each of a number of object points, rays were chosen with different incident angles and positions to the first glass surface. The subsequent

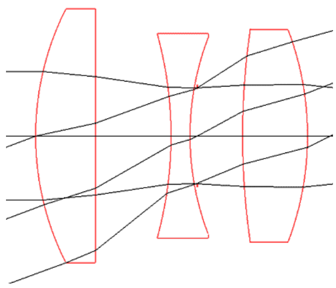


Figure 6. Example of 6 rays in a triplet, resulting in 36 refraction calculations

refractions of the ray in each glass surface resulted in a calculated position of the point image of that particular ray on the image plane, see fig. 6.

Thus the errors in the image could be assessed after tracing all rays from each point through all glass surfaces. If color was important, this even had to be done for the refraction indices of various wave-lengths.

Many employee hours were spent in the computations of ray tracing, and there was a great need for more efficiency by some level of automation. Professor van Heel and many other "Optics" specialists in the world were involved in designing fast and efficient "*computing schemes*" for the human "computers" – assisted by special tables, such as goniometrical functions.

The Ray Tracing Computation Scheme of T. Smith

One of the many ray tracing computation schemes was developed by Thomas Smith in the 1920's, see [5]. This geometrical method only handled *meridional* rays, i.e. rays in the same plane as the optical axis of a spherical lens surface. The following summary description follows section 124 in the book "*Inleiding in de Optica*" by van Heel, see fig. 7 and [6].

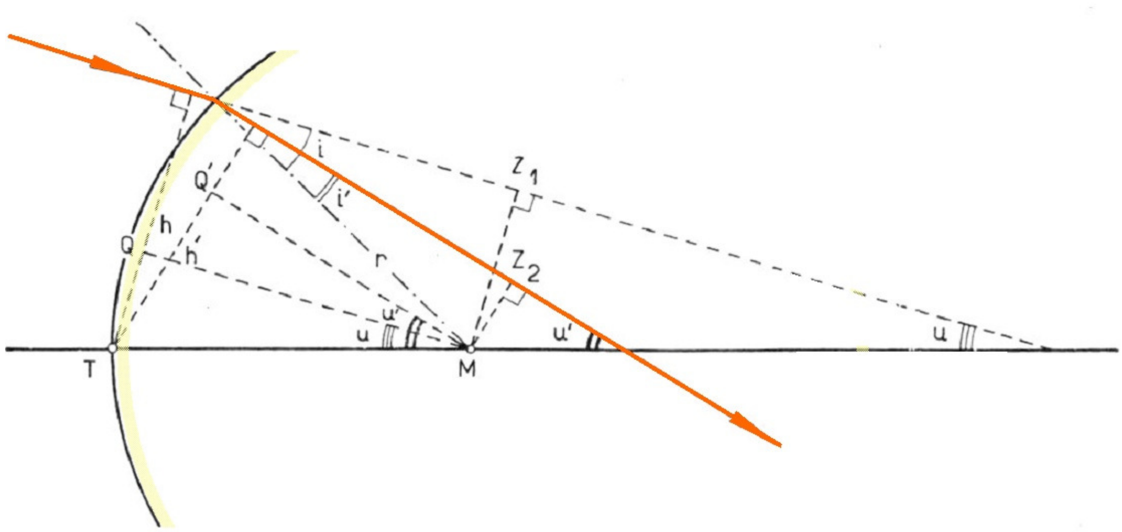


Figure 7. Incident Ray and Refracted Ray (see orange arrow lines), from [6]

The circle's arc represents the surface of a spherical lens with center point M; TM is the optical axis. The radius of the lens surface is r = TM. The incident ray makes an angle of u with the optical axis, and the refracted ray makes an angle of u' with the optical axis. A number of perpendiculars out of both T and M are shown, so that the position and direction of the incident ray is determined by u and h respectively, and the refracted ray is determined by u' and h':

$h = r\,(\sin i + \sin u)$, $\qquad h' = r\,(\sin i' + \sin u')$

By goniometrical formulae one can derive:

$h' = h + \mathrm{N/D}$

where the intermediate values N and D (after having replaced –u by ψ to conform to Smith's notation) are given as:

$\mathrm{N} = (\sin i - \sin i') \times (\sin i' + \sin \psi) \times h$

$\mathrm{D} = \frac{1}{4}\,\{(\cos \psi + \cos i + \cos i')^2 - 1\} + \{\frac{1}{2}(\sin \psi - \sin i + \sin i')\}^2$

The precise computation scheme according to Smith consists of 14 steps to derive the refracted ray parameters u' and h' (through the intermediate values N and D) from the incident ray parameters u and h, also using the lens radius r and the refraction indices n and n'.
One of the steps derives the value of i' from (sin i' / sin i) = (n' / n), using the refraction law of Snellius.

The scheme makes use of a standard sine table plus the following three special tables:

1. a sine to cosine conversion table, i.e. the function $\cos = \sqrt{(1 - \sin^2)}$, to calculate an intermediate function $s = \cos\psi + \cos i + \cos i'$ from the respective sines
2. a second intermediate function table $g = ¼(s^2 - 1)$
3. a third intermediate function table $f = \{½(\sin\psi - \sin i + \sin i')\}^2$

From those tables we can find the intermediate value D = $g + f$.

Using the tables and the derived formulae, with only the 4 basic arithmetic operations of a mechanical calculator, the refracted ray could be calculated - to be used for calculating the refraction at the next glass surface in the lens system.

Matching Smith's Ray Tracing Scheme with the ALRO Scales

Looking at the Smith computation scheme, we are tempted to believe – given the naming of the sin, *cos*, *g* and *f* scales - that "van Leer's" ALRO disc is designed to replace the three special tables of Smith: the first to determine the intermediate function *s*, the second for intermediate function *g*, the third for intermediate function *f*.

The first function $s = \cos\psi + \cos i + \cos i'$ can be calculated on the goniometrical scales of the disc: the rotating scale called *sin* and the neighboring scale on the stationary disc called *cos*.
In the first few steps of the Smith scheme the sine values (looked up in a standard sine table) are used of the relevant angles ψ, *i*, and *i'*. This means that *s* can be calculated by the following scheme of adding three cosines on the linear divided *cos* scale:

1. put index μ (=0) of the *sin* scale above the zero of the *cos* scale
2. turn the cursor line on the transparent disc to the value sin ψ on the *sin* scale
3. turn index μ (=0) of the *sin* scale to the cursor line
4. turn the cursor line on the transparent disc to the value sin *i* on the *sin* scale
5. turn index μ (=0) of the *sin* scale to the cursor line
6. turn the cursor line on the transparent disc to the value sin *i'* on the *sin* scale
7. the result *s* of adding the three cosines is now under the cursor line on the *cos* scale
8. Note that the angles ψ, *i*, and *i'* themselves are not seen in the calculations at all: the given sine values are directly converted from *sin* scale to *cos* scale and added together to get *s*.

The next scale, titled *g*, the middle one on the stationary disc, would be expected to represent the function $g = ¼(s^2 - 1)$. When we check example values on the *cos* scale and the *g* scale, there is agreement on one of the *g* scale windings.
However it is not immediately obvious which winding of the 3½ windings has to be looked at. The conclusion is that the position number of the *g* winding to be used (from 0 to 4 inside-out) is determined by the number of full-circle overflows during the adding of the cosines.

The last scale, titled *f*, would be expected to represent $f = \{½(\sin\psi - \sin i + \sin i')\}^2$. The summation within this function, including the subtraction of sin *i*, can *not* be done on the rotating sine scale because that scale is not linear; it has to be done by hand or by electromechanical calculator.

When we check example values on the *sin* scale and the *f* scale, there is agreement on one of the *f* scale windings. Which one, is again not immediately clear.

The design of *van Leer's* ALRO disc is a clever implementation of the Smith computation scheme on an ALRO's already existing disc construction. According to the inscriptions on the disc, this design is attributed to Ir. A.H. van Gorcum who appears to have been involved in optical research work of "van Leer's Optische Industrie".

The First Digital Computer for Ray Tracing - TESTUDO

During the war, the young van der Poel became already interested in binary computer design, before he started his study at the Technical University Delft, see [7]. As it happened, his study project under professor van Heel in 1949 was the design of an electromechanical computer, which was intended to perform "optical ray tracing calculations using the method of Smith"!

The machine was actually constructed and has been in use from 1952 to 1964. The components were electromechanical relays and rotary switches from telephone exchanges that had been kindly provided by the Dutch PTT. The original name was ARCO ("Automatische Rekenmachine voor Calculaties in Optica"). ARCO was housed in five tabletop cabinets, four for the relays functioning as register bits, and one for the program control unit consisting of rotary switches and a patch board, see fig. 8.

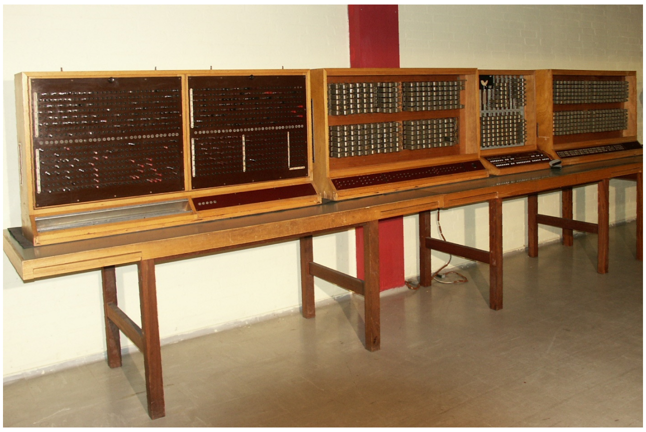


Figure 8. TESTUDO, from [8]

In private communications with professor van der Poel, he remembered clearly the conversion from sine to cosine by the formula $\sqrt{(1 - \sin^2)}$, for which a special square root function was implemented in the control unit hardwiring.

The ray tracing computer was extremely slow, bound by the 1-second cycle time of the relays: for example a multiplication – but also the sine-cosine conversion - took 45 seconds. It was slower than a human "computer" could accomplish with the ALRO disc or with an electromechanical calculator. For that reason the computer became known as TESTUDO (turtle), see [8].

On the other hand though, the TESTUDO worked during inhuman numbers of hours without getting sloppy or tired!

Conclusion

The calculating disc that was found recently in the heritage collection of the "Optische Industrie Oude Delft", is another version of the desktop-sized discs made by ALRO in the Netherlands. The disc can be dated to 1939 or 1940, mainly because of the name "van Leer" in the title. There are no logarithmic scales – which used to be standard on regular slide rules. Two goniometrical scales are arranged in such a way that summation of cosine values can be performed, given the sine values. This, together with the "optical" connotation, gave the clue that the disc must have been designed for ray tracing calculations according to the method of T. Smith in the early 1900's.

All scales of the ALRO disc can be explained by the computation steps of the Smith scheme.

The development of devices such as the "van Leer's" calculating disc and professor van der Poel's digital computer TESTUDO illustrated clearly the real need for automation of mathematical computations in science and industry at that time.

Acknowledgments

Thanks to professor Braat and professor van der Poel for giving the golden tip and more explanations on the ray tracing method, the Smith scheme, and the TESTUDO computer. Thanks to Hans Ploegmakers for letting me study the new-found specimen in his collection and for providing the images for figures 2 and 3.

Thanks to Han Wanders for alerting me to the existence of this calculating disc which he discov-

ered and photographed (see fig. 1) during the *Binocular History Society* meeting at the LOUWMAN Museum in The Hague, October 2013.

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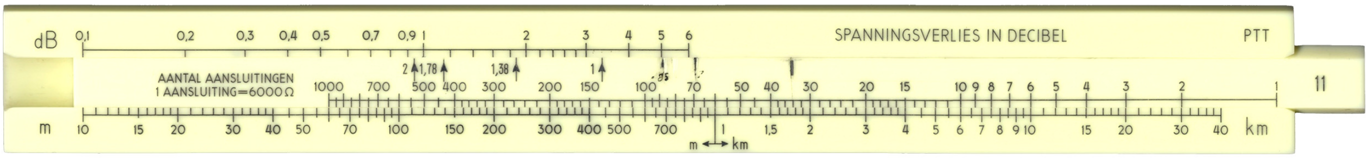
A "mystery" PTT Slide Rule from the Netherlands

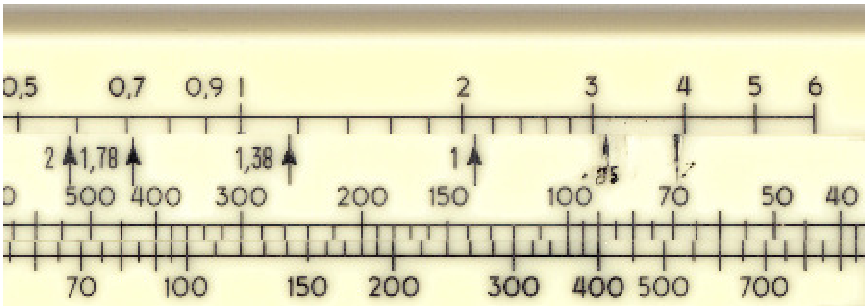
Jerry McCarthy

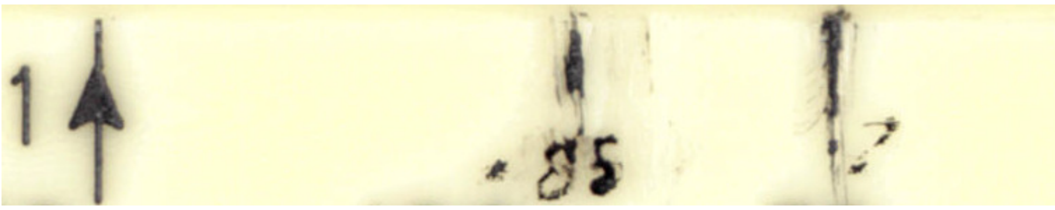


Introduction

The Slide Rule in question has four scales. From the top, we have:

- (On the upper Stator):
  Spanningsverlies in deciBel / Voltage Loss in Decibels (dB).
  This scale has a range of 0.1 dB to 6 dB.
- (On the Slide - upper edge):
  A series of pointers with the values {2}, {1.78}, {1.38}, {1}, {0.85}, {0.7} where these pointers point upwards onto the above "Voltage Loss" scale.
  The last two, 0.85 and 0.7, are hand-drawn.
- (On the Slide - lower edge):
  Aantal aansluitingen / Number of parallel connections (abbreviated AA/NoC) where
  1 Aansluiting / 1 connection = 6000Ω. This scale has a range of 1000 to 1 connection(s).
- (On the lower Stator):
  Distance in metres and kilometres. This scale has a range of 10 metres to 40 kilometres.





It was from the start assumed that what is being simulated is some number of 6000Ω parallel loads attached to a cable of some known length. All the loads are connected to the same point on the cable.

The operation of this rule is assumed to be to set the Aa/NoC on the lower edge of the slide against the distance in metres or kilometres on the lower stator. These two scales are logarithmic;

however, one runs left to right, and the other right to left. The effect is therefore one of multiplication. An increase in either or both of the distance and AA/NoC results in a larger product. Using one of the arrow pointers {2}, {1.78}, {1.38}, {1}, {0.85}, {0.7} on the upper edge of the slide results in a readout of the voltage loss in deciBels from the scale on the upper stator.

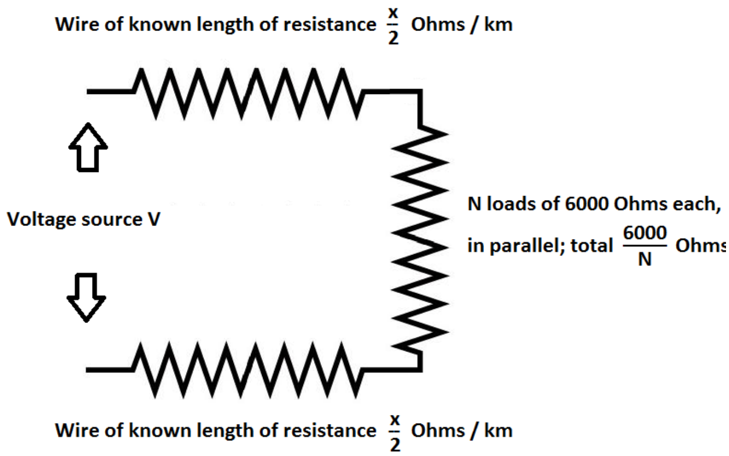
The distances and number of parallel loads suggested that the actual application seemed likely to be experimental, as more that two or three loads would be unlikely; however, a mathematical approach was applied to determine values which might apply in real-life.

A False Start

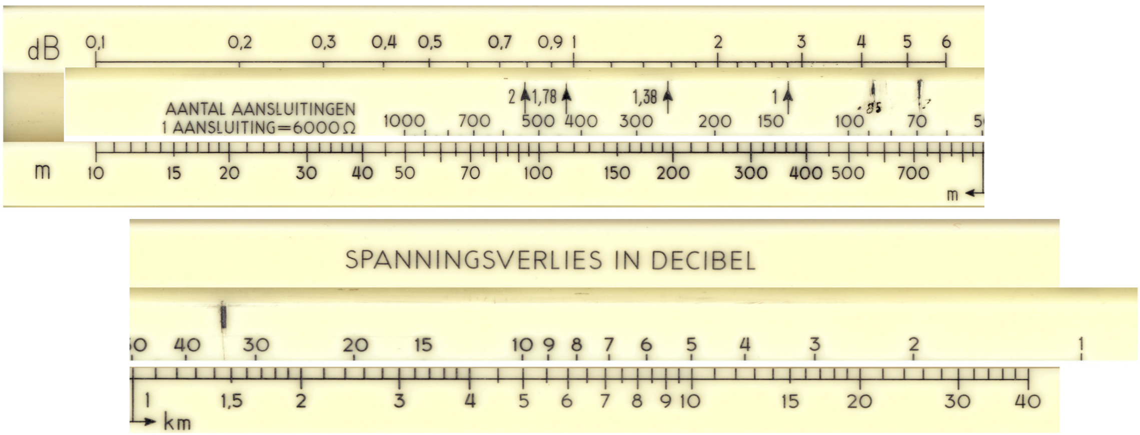
It was initially assumed, given that this rule is understood to have been related to the operations of a PTT establishment, that this rule was likely to be used in the calculations involving telephone handset devices, connected in parallel in some kind of party-line configuration.

The four references [1…4] below all broadly suggest that a 6000Ω impedance, as is inherent in the rule's use, falls in the range of likely impedances which exist when an old-style dial-phone is in the on-hook (that is, hung-up, awaiting a call) condition. The purpose of this rule would therefore seem to be to determine the voltage loss relating to the ringer (A.C.) voltage. As noted above, the number of possible parallel connections seemed to make this unlikely, but investigations proceeded none the less.

In the operation of this rule it is actually unimportant as to whether to the operating conditions are DC or AC, so in practice the 6000Ω may represent a resistance or a more complex impedance. Initially, the pointer {1} was used as a starting pointer to the "Voltage Loss" scale, with the intention that the other pointers would be studied later on.
The first task was to determine what the resistance of the wire is; a circuit something like this is assumed:



Setting the rule appropriately shows, when using pointer {1}, amongst other settings, a loss of circa 2.8 decibels with a convenient load of 2 connections at 25km.



Now, 2 x 6000Ω loads in parallel gives 3000Ω. Therefore 20 $\log_{10}$ (3000 / (3000+25x)) = -2.8dB (*note that we are working in losses, so the dB value is -ve*)

$\log_{10}$ (3000 / (3000 + 25x)) = -2.8 / 20
= -0.14
= -1 + 0.86

Taking antilog_{10} of both sides:

(3000 / (3000 + 25x)) = 0.724

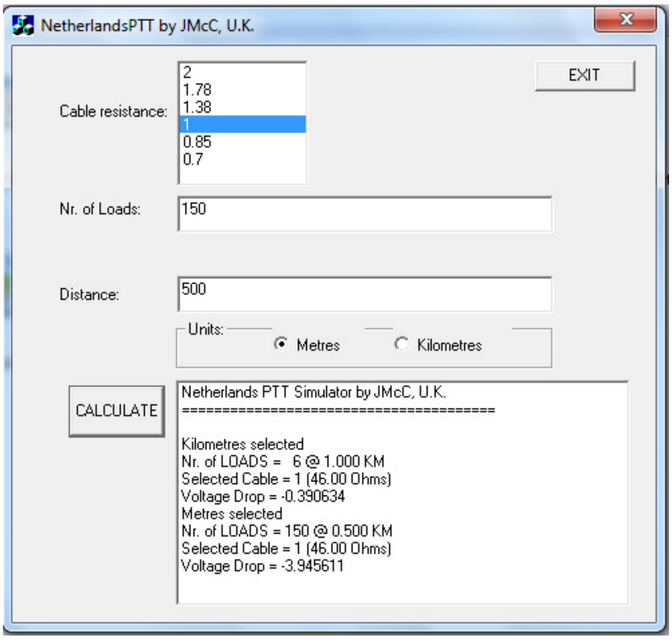
Solving for x: x_1 = **46Ω**

Trying a different number of loads and distances, still as shown on the slide rule set-up shown above, and hoping for a loss of around -2.8dB.

10 loads at 5 km:
Load = 6000 / 10 = 600 Ω.
Loss = 20 $\log_{10}$ (600 / (600+5*46)) dB
= 20 $\log_{10}$ (600/(600+230)) dB
= 20 $\log_{10}$ (600 / 830) dB
= 20 $\log_{10}$ (0.7229) dB
= 20 (-1 + 0.8591) dB
= 20 * -0.1419 dB
= -2.84 dB

170 loads at 300 metres:
Load = 6000/170 = 35.29Ω.
Loss = 20 $\log_{10}$ (35.29 / (35.29 + 46*(300/1000))) dB
= 20 $\log_{10}$ (35.29 / 49.09) dB
= 20 $\log_{10}$ (0.7189) dB
= 20 (-1 + 0.8567) dB
= 20 * -0.1433 dB
= -2.87 dB

All the above work was done using log/antilog tables; at this point it was decided to create a program in C++ to carry out the hard work:

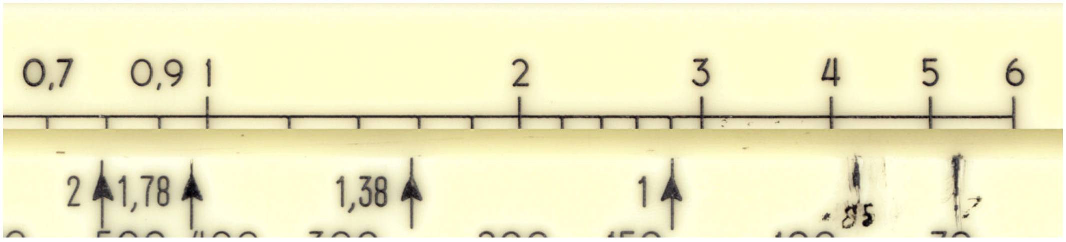


Using a hand-made facsimile slide-rule, it is possible to test many other values against the values generated by the software.
Random samples are here listed with values read from the facsimile.

```
6 loads at 1km;      Software says: -0.39 dB:     Rule reads -0.4 dB.

17 loads at 1km;     Software says: -1.06 dB:     Rule reads:-1 dB.

150 loads at 500m:   Software says: -3.95 dB:     Rule reads -4 dB.

3 loads at 8km:      Software says: -1.47 dB:     Rule reads -1.4 dB.

7 loads at 600m:     Software says: -0.28 dB:     Rule reads -0.3 dB.
```

The values given by the software and a simulated facsimile rule, although not exactly equal, are nevertheless felt to be close enough to suggest that the algorithm has been correctly understood, and that the discovered 46Ω is probably "close enough".
Note that all of the above testing was carried out using the pointer {1}.

The next stage was clearly to understand the pointers {2}, {1.78}, {1.38}, {0.85}, and {0.7}. It can be easily seen, by looking at the reported dB losses against the {1} and {2} pointers, that there is no linear relationship: {1} refers to a loss of 2.8 dB; {2} refers to a loss of around 0.8 dB. More reasonable might it be to consider that these numbers might be related to the diameter of the wires within the cable.



Given that the resistance of a wire is proportional to its cross-sectional area, and assuming wires of circular cross-section, this could imply a relationship between the voltage loss and the *square* of the pointer values.

Now, pointer {2} points to 0.8dB on the dB scale; re-running the process which gave us 46Ω when pointer {1} was in use, we get:

$$20 \log_{10} (3000 / (3000+25x)) = -0.8\text{dB}$$
$$\log_{10} (3000 / (3000+25x)) = -0.8 / 20$$
$$= -0.04$$
$$= -1 + 0.96$$

Taking antilog$_{10}$ of both sides:

$$(3000 / (3000+25x)) = 0.912$$

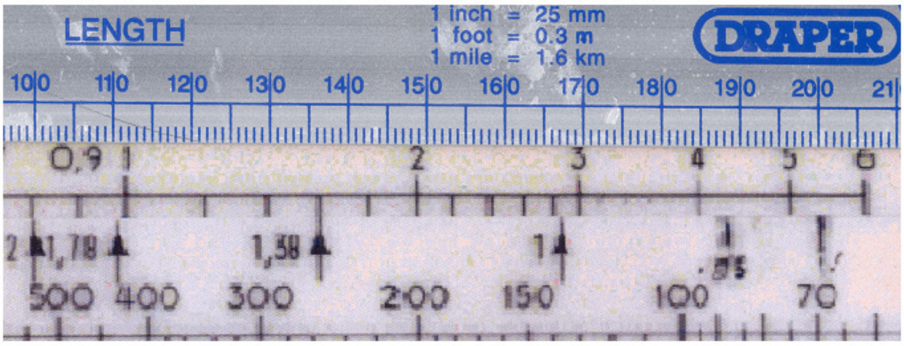
Solving for x: $\mathbf{x_2} = 11.5\Omega$.

Now, $\mathbf{x_1} / \mathbf{x_2} = 46 / 11.5 = 4 = 2^2$ QED. ☺

This process can be repeated for all the pointers, and the total set then looks like this:

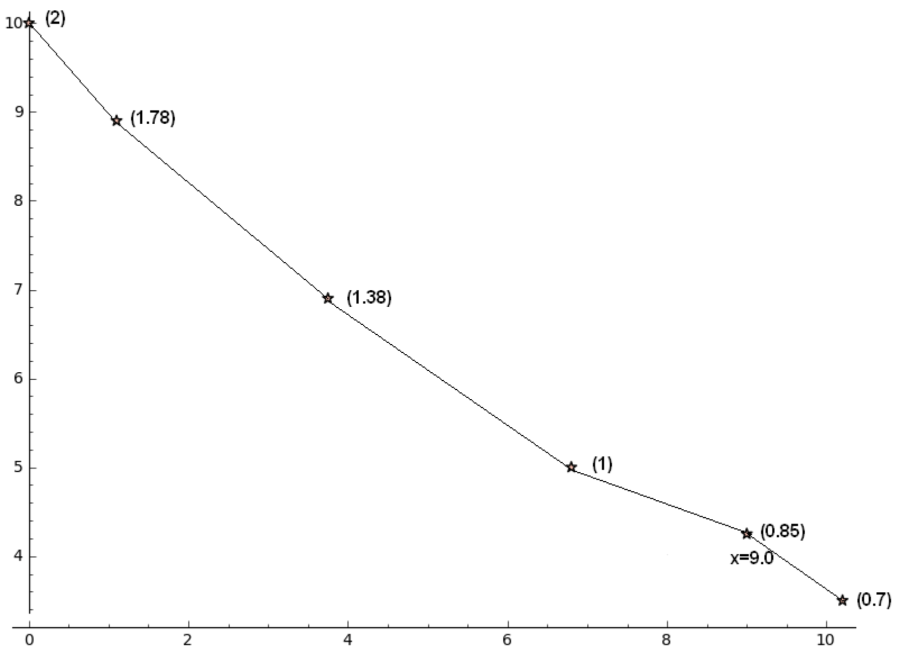
{1}	x_1/x_1	=	1		
{2}	x_1/x_2	=	4	$= 2^2$	
{1.7}	$x_1/x_{1.78}$	=	3.2	$= 1.79^2$	
{1.3}	$x_1/x_{1.38}$	=	1.9	$= 1.378^2$	
{0.8}	$x_1/x_{0.85}$	=	0.617	$= 0.785^2$	*
{0.7}	$x_1/x_{0.7}$	=	0.447	$= 0.67^2$	

* It can be seen that the value for the {0.85} pointer is quite adrift of the value expected; a quick check was done with a ruler and a copy of Sage:



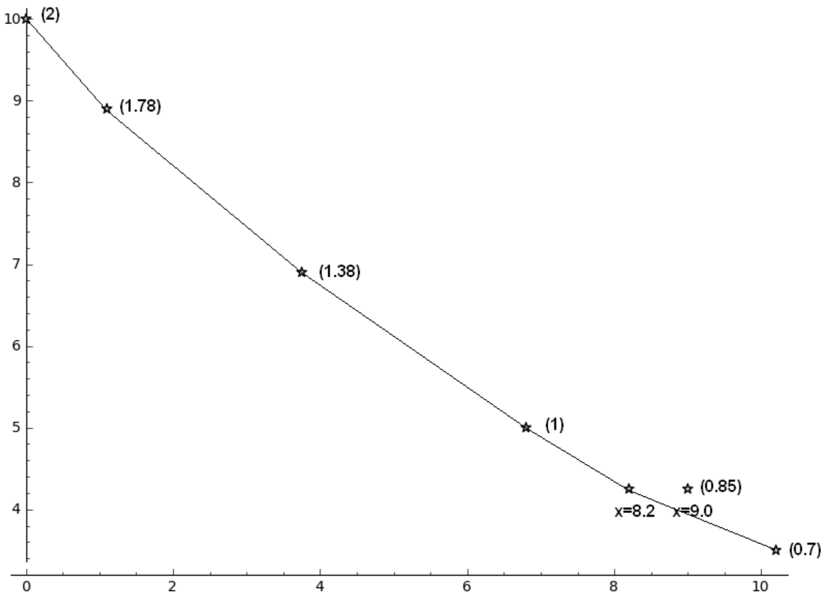
Simply by doing an graph of {pointer values}(y-axis*5) against centimetres on the ruler (x-axis), it is clear to see that the {0.85} pointer is not quite correctly positioned, as it not possible to fit a curve through it.

```
scatter_plot([[0,10],[1.1,8.9],[3.75,6.9],[6.8,5.0],[9,4.25],[10.2,3.5]],marker = '*')
```

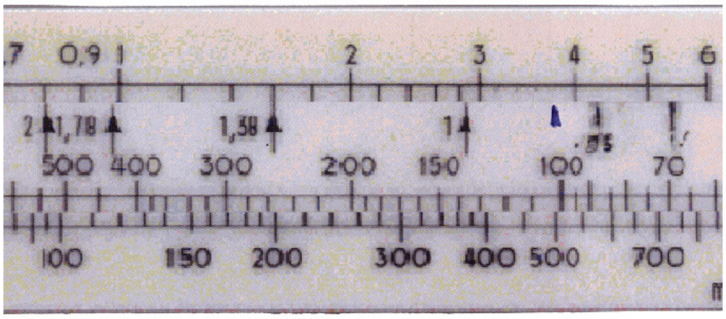


Manually creating a new pointer position for the {0.85} pointer gives:

```
scatter_plot([[0,10],[1.1,8.9],[3.75,6.9],[6.8,5.0],[9,4.25],[10.2,3.5],[8.2,4.25]], marker
= '*')
```



which, while not perfect, gives a better idea of where the {0.85} pointer might be better positioned.



Therefore $20 \log_{10} (3000 / (3000+25x)) = -3.8\text{dB}$

$$\log_{10} (3000 / (3000+25x)) = -3.8 / 20$$
$$= -0.19$$
$$= -1 + 0.81$$

Taking antilog_{10} of both sides:

$$(3000 / (3000+25x)) = 0.645$$

Solving for x: $x_{0.85} = 66\Omega.$

$\mathbf{x}_1/\mathbf{x}_{0.85} = 0.697 = 0.835^2$ which, although not perfect is much better.

A new beginning

During the development of this paper, new information arrived that the application of this rule was somewhat different than that originally assumed. It seems that, during the early part of this century, a *Draadomroep* (cable radio broadcasting) *System* was used in The Netherlands.

This is basically a system whereby houses have a loudspeaker, which is connected to a central distribution point. A small selection, for example, four, radio programs was available to the listener, selected by a rotary switch, and some volume control was available. It is understood from [5] that the loudspeaker box had the high impedance of 6000Ω so as to be able to handle as many subscribers as possible.

Incidentally, although this author has never encountered this system in the U.K., a system like this was once found while staying in a hotel in the far north of Finland; this system had a four channel: the "Kaapeliradio" system, just like that described above, with a hard-wired wall-mounted speaker in each of the guest rooms.

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Postscript

The real application of the NL PTT slide rule was discovered by Leo van der Lucht only a few months before IM2014 during interviews with members of the Dutch Association for Telecom Heritage ("Telecommunicatie Erfgoed Stichting, TELES"). Jaap Hoefsloot of TELES found the PTT Handbook for the dimensioning of the *Draadomroep* (wire broadcasting) system, also called "Radio Distributie". The chapter on calculation of losses gives criteria for maximum loss (3 dB) at the most remote subscribers, and also specifies the available diameters of the subscriber cables used. All data in the Handbook correspond fully with the values inscribed on the NL PTT rule; it is remarkable that tables and nomograms are given, but the NL PTT slide rule is not mentioned!

The subscriber equipment consisted of a rotary switch for the subscriber to select one of the four 2-wire channels and a loudspeaker, see figure "Radiodistributie Arbeidershuisje Tilburg" from Wikipedia.

No amplifier was used at the subscriber's home, hence the loss issues from central amplifiers in PTT offices. This network was set up around the 1930's when AM radio reception had low quality, and remained operated by the PTT until mid 1970's when the last "aansluiting" was disconnected – competition from the new stereo FM broadcasting was too strong!

The radio-distribution cabling was completely separate from the telephone subscriber network. The Dutch PTT had telephone switching as its main business; *Draadomroep* was just a temporary episode. Therefore most fellow-collectors studying this NL PTT rule mystery were set on a wrong foot when trying to associate the NL PTT slide rule with *telephone subscribers* whose individual lines are fundamentally different from the *Draadomroep subscribers'* shared network.

(the Editor)

Turning and Sliding in the Spinning and Weaving Factory with the LOGA Calculating Discs

Nico E. Smallenburg

The mythology of spinning

Homerus already mentioned the spinning of yarn in Greek mythology. Moira is the Greek Goddess of destiny, who exists in three different forms as a "triade". Moira is also a nickname for Aphrodite. These Moiren (plural of Moira) are three so called Goddesses of destiny, who are generally represented with a spinning wheel and a scale. In his work, Homerus refers to these Goddesses of destiny when he writes that what was fixed by Moira, was irrevocable, and that everybody and even the other Gods were bound to it.

Figure 1. The three Norns (Moira)

The names of the three appearances of Moira are Klotho, Lachesis and Atropos.

- Klotho turns the spinning wheel. The Greek word "klothein" means spinning. She spins the thread of life with her spinning wheel.
- Lachesis is the Goddess who allots your destiny. The name has been inferred from the Greek verb " lachanein" which means "obtain by destiny". She winds up the spun yarn and holds it. This symbolises the development and the direction of the destiny. To determine what must happen with the spun thread, she takes lottery tickets from an urn.
- Atropos is the Goddess who severs the life thread. This name has been inferred from the Greek word " tropos" which means turning or varying. Atropos therefore means invariable or inevitably. Her attributes are a book role and a sun's altitude clock. This last attribute refers to the function to let the wheel or the sun turn and by doing so keep creation going.

The Moiren symbolise the idea of the Goddess as creator, maintainer and destroyer. The spun thread is the symbol of life.

Everybody knows the fairy tale of the three spinners written by the brothers Grimm.

> *Once there was a lazy girl who would not spin. While her mother berates her for it, the queen, passing by, overhears and asks the reason for the scolding. Ashamed to admit that her daughter is lazy, the woman replies that the girl spins so much that her mother cannot afford to buy enough flax to keep her occupied. The queen, impressed by such industry, offers to take the girl with her.*
>
> *Once at the castle, the queen takes the girl to a room filled with flax. If she spins it all within three days, she 'll be rewarded with marriage to the queen's oldest son. Two days later, the queen returns and is amazed to find the flax untouched. The girl pleads that homesickness has kept her from spinning, but she realizes that excuse will not serve her twice.*
>
> *Three women appear in the room that night. One has a grotesquely swollen foot; the second has an overgrown thumb; the third has a pendulous lip. They offer to spin all the flax for the girl if she will invite them to her wedding, introduce them as her aunts, and seat them at the high table. She agrees, and they commence and complete the spinning.*

In the morning, the queen is satisfied to see the flax all spun. She arranges for the wedding to her son, the prince, and the girl asks to invite her three "aunts". When they appear, the prince asks how the came to have such deformities, and the three explain that they come from their years of spinning. The prince forbids his beautiful bride to spin ever again.

Introduction

This article describes the two processes in the production of cloth, *spinning* and *weaving*, in the following chapters:

I. Industrialisation of spinning
II. The mechanised weaving mill

I. Industrialisation of spinning

The spinning of yarn by hand is a monotonous and especially time-consuming job. In industrialisation the weaving mill was developed so rapidly, that an enormous lack of yarn arose, which could not be spun fast enough by hand in sufficient quantities. To be able to satisfy the increasing demand for different yarns, the need arose to also industrialise the spinning of yarns.

Figure 2. Spinning mill Oosterveld in Enschede in 1920

Spinning is the industry where the first production step is carried out to make a textile product, and in which the different raw materials (wool, cotton, flax) are made into a semi-manufacture (different yarn).

The "Spinning Jenny" was invented in 1764 by James Hargreaves. This apparatus, however, could only spin very fine and fragile threads, which could only be used in the weaving factories as weft threads. However, it was already a major improvement with respect to the spinning wheel, and you could spin 24 threads at the same time by hand.

Richard Arkwrightin subsequently invented the so called "Waterframe" in 1769. This was the first real spinning machine, because it was powered by water power. With this machine, however, it was only possible to spin coarse strong yarn which could be used as warp threads in the weaving factories.

It was not until 1779 that a combination of both machines was developed, which was given the name of " Mule Jenny". This "Mule Jenny" could spin both coarse strong – and fine fragile threads, which were necessary for, for example, the weaving of pure cotton cloth. As a result, it was no longer necessary to use linen threads as warp threads.

The so-called selfactor (self-acting) or the twisting of roving (raw material), as well as winding the spun thread on the spindle was now carried out mechanically, as a result of which the efficiency and also the quality, in terms of more beautiful and more regular spun yarn, improved immensely.

The preparation for mechanised spinning demands several steps:

- Cleaning the raw material (coarse flakes and fibres)
- Carding the fibres and with that forming a so-called "taper"
- Gathering a number of "tapers" and stretching the cord that is formed this way
- Finally the twining of the combed cord or the so-called "taper", resulting in prime yarn

Figure 3. Combing the taper

Figure 4. Cord of combed tapers

With the LOGA 30 Rtx several calculations for the ring tenon machine can be carried out, to be able to spin the right prime yarn (of the correct strength and quality).

Twisting calculations for prime yarns with the LOGA 30 Rtx calculation disc

The special LOGA 30 Rtx calculation disc has two special outer scales with yarn numbers Ne for prime yarn (is a measure for a certain thread thickness) used in the prime yarn spinning mill. The prime yarn (Vorgarn) scale runs from Ne 0,4 – 13 and partially in overlap with the scale for ring yarn, which runs from Ne 6 up to 150. Furthermore the standard calculation factors for wool (We), cotton (Be) and linen (Le) used in the textile industry are also indicated on the disc as well as several English and French length factors.

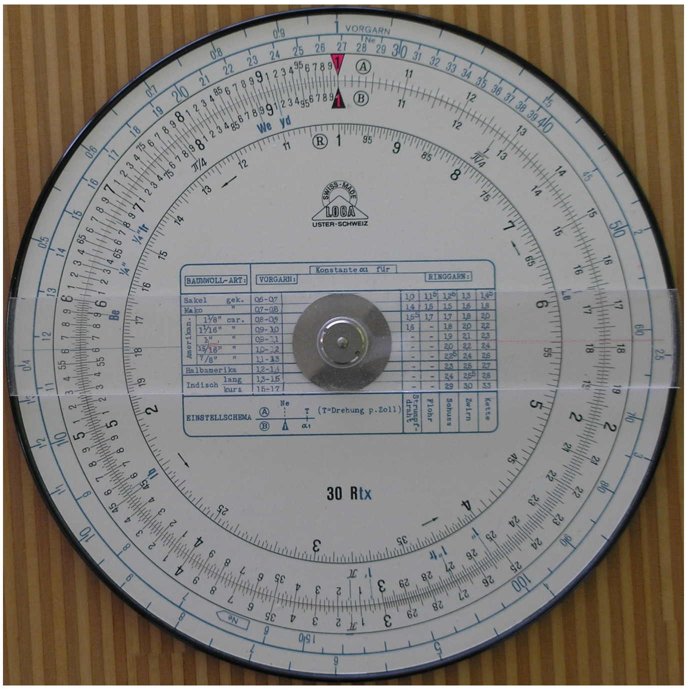

Figure 5. LOGA 30 Rtx

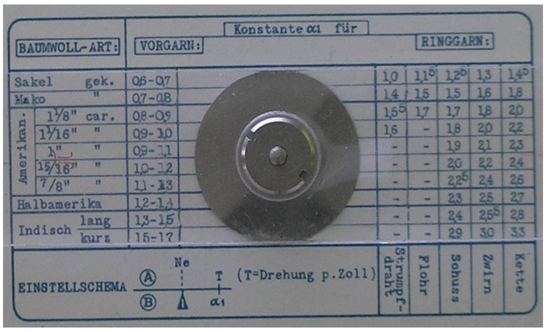

Figure 6. Detail constants table LOGA 30 Rtx

Finally a special table has been incorporated in the middle of the calculation disc with specific constants for ring yarn and prime yarn. It is possible for different weaving- and spinning mills to add specific values for their own company.

The yarn numbers

The yarn number indicates the cross-section of a specific yarn. This measure indicates the ratio between weight and length of a string of yarn. There are two systems of yarn numbering: the weight numbering, which stipulates the weight of a fixed yarn length, and the length numbering which stipulates the length of a certain weight of yarn.

Weight numbering

“Tex” is the only officially permitted numbering in weight numbering. The “Tex” is the weight in gramme of 1000 meter yarn. “Denier” (Td) comes from the silk industry and is still used for the name of the yarn of which nylon stockings or tights are made. Td is the weight of 9000 meter nylon yarn. Weight numbering uses a proportional link between the yarn cross-section and the yarn number. The thicker the yarn, the higher the yarn number.

Length numbering

Length numbering has been used for a very long time, and there are many different numbers because every country generally had its own method. In the Netherlands the English numbering (Ne) and the metric numbering (Nm) are still in use. The English numbering Ne is the number of strands of 840 yards per English pound (453,6g). Converted to metric measures it is the number of times a string of yarn of 1.6934 meter fits in 1 gramme. For cotton yarn the English numbering is still in use. The metric numbering Nm (number of meters of yarn per gramme) is used for wool yarn.

According to the systems above the following conversion factors for weight numbering and length numbering can be applied.

Tex = 1/9 Td; tex = 1000 / Nm; tex = 590 / Ne

The yarn number Ne is not only useful for the calculation of the twine number according to the formula of Lätsch, but can also be used for the calculation of a number of yarn changes or gyrations to use yarn with an adjacent larger yarn number to spin thicker yarn (of better quality) and thus with a larger yarn number.

Calculation of the gyrations (“twine”) of prime yarn in the cotton spinning mill

Spinning the prime yarn.

A cotton prime yarn Ne 8 is spun with a twine number 50. What number of thread changes (twist) must be used to spin a prime yarn Ne 10?

In general;

The number of gyrations (“twine”) per English inch is T=n gyrations / v feed rate of the prime yarn. There can be two situations.

The feed rate of the prime yarn is leading or the twine number (number of gyrations) per inch is leading.

a; If the feed rate of the prime yarn is leading and the number of gyrations per inch is following, then the following applies;

Number of gyrations per English inch is T = a constant X multiplied by the number of gyrations or;

Gyration divided by the number of thread changes = constant.

Example a: Calculation of the number of gyrations per E. inch for a different twine number. (feed rate of prime yarn is leading)

Setup scheme:

Ne prime yarn scale	8	10	Ne
B scale	50	57.8	gyrations

b; If the number of thread changes is leading, or feed rate of prime yarn is following, the following applies;
Number of gyrations per English inch T = constant divided by number of thread changes or;
Gyration multiplied by number of prime yarn changes = constant.

Example b: Calculation of the number of gyrations per E. inch for a different twine number (prime yarn change is leading).

Setup scheme:

Ne prime yarn scale	8	10	Ne
R scale	50	43.3	gyrations

Calculations of gyrations of different ring yarns

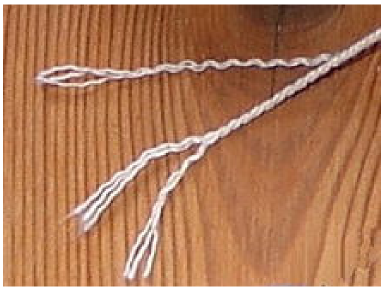

Figure. 7 Practical gyrated yarn

Figure 8. Schematic gyrated yarn

A cotton ring yarn Ne 80 has been gyrated with 30 prime thread changes. What number of prime thread changes has to be applied for a ring yarn of Ne 104?

In general: The number of gyrations per E. inch = number of prime thread changes divided by the feed rate of the prime thread.
a; If in the concerning ring yarn machine, the number of yarn changes is following, or the feed rate of the yarn is leading, the following applies:
Number of gyrations per E. in ch is T = Constant multiplied by the number of yarn changes or the gyration divided by the number of yarn changes = Constant.
a: Calculation number of gyrations per E. inch for another yarn number (feed rate is leading).

Setup scheme:

Ne ring yarn scale	80	104	Ne
B scale	30	36	gyrations

b; If in the concerning ring yarn machine the number of yarn changes is leading or the feed rate of the yarn is following, the following applies:
Number of gyrations per E. inch is T = Constant divided by the number of yarn changes or the gyration multiplied by the number of yarn changes = Constant.
b: Calculation of the number of gyrations per E. inch for another yarn number (yarn changes leading).

Setup scheme:

Ne ring yarn scale	80	104	Ne
R scale	30	25	gyrations

Calculation of a modification of a delay of the tensioner

The calculation of the modification in delay to spin another yarn number (both for the prime yarn and the ring yarn) from the aforesaid number of yarn (prime yarn) changes is possible with the A, B, and R scale, because there is a reciprocal link between the twine number Ne and the modification of delay (inversely proportional).

Example: Yarn Ne 4 was spun from a given prime yarn Ne by means of a delay of 30. You can now calculate for instance the modification in delay for spinning a ring yarn of Ne 5.

In general;

Delay = Constant divided by modification in delay or Ne 4 / Ne 5 = VW 5 / VW 4.

Setup scheme:

A scale	4	5	Ne
R scale	30	24	Delay tensioner

The calculation of the gyration number for cotton yarns with the LOGA 30 Rtx

The LOGA Rtx calculation disc has two extra number scales: for cotton prime yarns Ne 0,4 up to Ne 13 and for ring yarns Ne 6 up to Ne 150.

With the use of the A and B scales, the gyration numbers per English inch can be calculated according to the formula of Lätsch.

For a prime yarn the following applies: $T = \alpha 1 \ \ X \ Ne^{0,65}$

For a ring yarn the following applies: $T = \alpha 1 \ \ X \ Ne^{0,7}$

Example: There is a warp thread Ne 90 of cotton with the quality of " Sackel" to be spun. You can calculate the gyration per English inch as follows:

1. Put the indicator line of the cursor of the LOGA 30 Rtx over the number Ne 90 on the Ne scale,
2. Turn scale B until the digit 1 is covered by the indicator line of the cursor.
3. Take the value $\alpha 1$ = 1,45 for "Sackel" warp thread from the constants table. Put the indicator line of the cursor over 1,45 of the B scale.
4. You can now read on the A scale the gyration number 33,8 per English inch.

Setup scheme

Ne ring yarn scale	90		Ne
A scale		33,8	Number of gyrations
B scale	1	1,45	Constant from table

The LOGA calculation disc generally calculates correct indication numbers. Each spinning mill uses its own constants for its own applications, which can be noted on the back of the calculation disc. For instance, when a ring yarn Ne 90 with a number of gyrations 37 is to be spun, the constant is 1,59. On the back side can be noted: Ne 90 / 159.

Setup scheme

Ne ring yarn scale	90		
A scale		37	Number of gyrations
B scale	1	1,59	Company-own constant

Also the so-called T- values can be converted from the gyration numbers per English inch according to the relation: Number of gyrations per meter = T / 25,4. In this way T = 27 gyrations per English inch are equal to 1060 gyrations per meter.

Textile calculation systems

The textile industries uses several textile calculation systems. In the table below the most important conversion constants and calculation formulas in relation to the different textile calculation systems have been incorporated.

Textile system		Gross length	Calculation	Formula
Metric nr.	Nm	1000m/1000g	Meter/gramme	Nm = m/g
French nr.	Nf	2000m/1000g	0.5 meter/gramme	Nf = 0.5m/g
English cotton nr.	Ne	840 yds/lb	7000/840 X yds/grs	Ne = 8.33yds/grs
English wool nr.	NeW	560 yds/lb	7000/560 X yds/grs	NeW=12.5yds/grs
English linen nr.	NeL	300 yds/lb	7000/300 X yds/grs	NeL=23.3yds/grs
Legal titer, Denier	T	Lg/9000m	9000 X gramme/meter	T = 9000 X g/m
Metric titer, Grex	Tm	Lg/10000m	10000 X gramme/meter	Tm = 10000 X g/m

In this table:

yds = yard = 0,9144m (meter)
g = gramme
grs = grain = 1/7000 lb = 0,065g
lb = English weight pound = 0,4536kg.

The first five systems have been based on length by weight calculations and the last two systems on weight by length calculations.

Yarn number comparison

It is possible to convert the yarn numbers of the different textile systems to the equivalent yarn numbers in the English, French, or metric system by using the special factors for English cotton numbers (Be), English wool numbers (We) and English linen numbers (Le) with the LOGA 30 TxC.

For the calculation of the metric yarn numbers and the so-called titer T or Tm, special markers are placed on the A scale and B scale. The special constants have been incorporated in the table below.

Converting factors	Description	Calculation	Value
Be	Cotton converting factor	453,6 / 768	0,591
We	Wool converting factor	453,6 / 512	0,886
Le	Linen converting factor	453,6 / 274,3	1,654

The textile systems for the length by weight calculations are proportional. The proportion, using the constants Be, We, and Le are stipulated according to:

Nm = Ne / Be = NeW / We = NeL /Le

If, for example, the metric standard number 320 must be converted, then you place the 1 on the B scale underneath 32 on the A scale and subsequently read above Be the NeB = 190, above We the NeW=285, and above the Le the NeL = 530.

Setup scheme

A scale	32	190	285	530	Nm
B scale	1	Be	We	Le	constant

Twine calculations

The following calculations determine the resulting twine number of a twined yarn, which is twined from two yarns with random twine numbers and with or without little gyration. First of all, the different international standard numbers must be converted to metric standard numbers. Thus: Nm = m / g and, if g = 1, than Nm is the number of meters that weighs 1 gramme. If one wants to know how much gramme 1000 meter yarn weights, the value of 1000/Nm must be determined. This value can be read from the reciprocal scale.

First, the weight per 1000m twined yarn has to be calculated by determining the weight of 1000m of each of the yarns the twined yarn is composed of. Subsequently, the entire weight of the twined yarn can be determined by adding the two partial results. With this entire weight, the next step is to determine the reciprocal value, which is the twine number of the composed yarn.

Example: One wants to twine a composed yarn from two different yarns Nm 12 and Nm 18. The weight of 1000m Nm 12 yarn= 83,33 gramme and of 1000m Nm 18 yarn = 55,55 gramme. The entire weight of 1000m of the composed twined yarn =138,88g. The twine number of this composed yarn can be calculated by l / g or 1000 / 138,88 = 7,2.

Setup scheme

B scale	12	18	139	gramme
R scale	83.3	55.5	7.2	Twine number

II The mechanised weaving mill

Weaving is interlacing two distinct sets of yarns or threads at right angles to form a fabric. Before weaving a number of yarn threads is fixed taut in vertical direction. The construction on which this happens is called “warp” and the taut threads are called warp threads.

In general, weaving involves using a loom to interlace two sets of threads at right angles to each other: the warp which runs longitudinally and the weft that crosses it. The warp threads are held taut and in parallel to each other, typically in a loom.

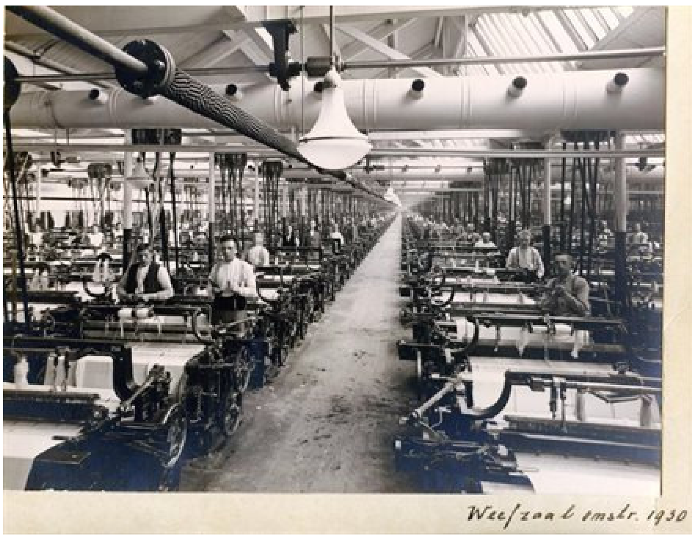

Figure 9. Weaving hall of the Royal steam weaving mill Nijverdal ca 1930

Weaving can be summarized as a repetition of these three actions:

- Shedding: where the ends are separated by raising or lowering heald frames (heddles) to form a clear space where the pick can pass

- Picking: where the weft or pick is propelled across the loom by hand, an air-jet, a rapier or a shuttle.
- Beating-up or battening: where the weft is pushed up against the fell of the cloth by the reed.

The warp is divided into two overlapping groups, or lines (most often adjacent threads belonging to the opposite group) that run in two planes, one above another, so the shuttle can be passed between them in a straight motion. Then, the upper group is lowered by the loom mechanism, and the lower group is raised (shedding), allowing to pass the shuttle in the opposite direction, also in a straight motion.In a weaving machine the warp threads can be lifted by group using combs or shafts. Patterns can be created by lowering or raising the groups in a certain order. Up to the twentieth century the weft threads were weaved by using a shuttle.

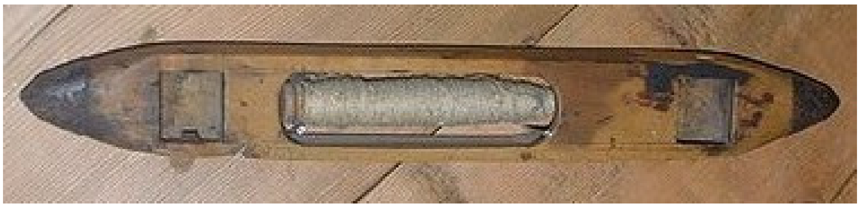

Figure 10 Shuttle weaving machine (Wikipedia)

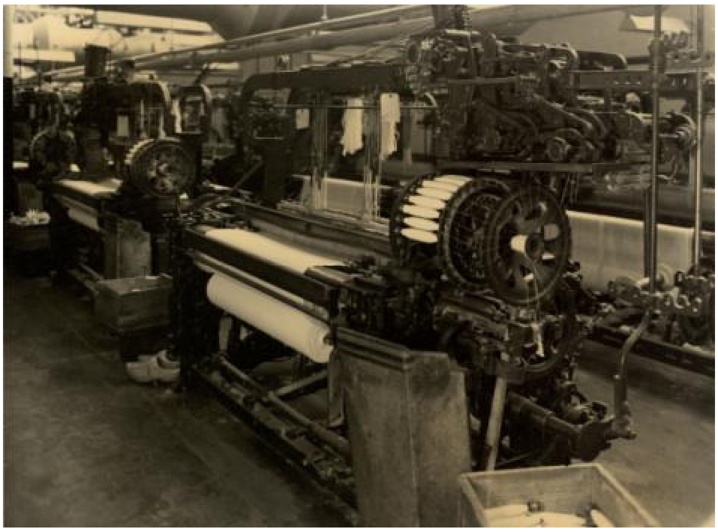

Figure 11. Weaving machine of the Royal steam weaving mill Nijverdal ca 1930

The calculation of the thread length on the shuttle is done according to the formula: L = Nm X g where g = the weight in gramme minus the weight of the shuttle.
Therefore, for instance if Nm = 40 and g = 125, then the thread length L = 5000.

The calculation of the weight of the yarn on the shuttle for instance for 100 meter weft threads, is done according the formula: Fd/cm X B X 10 / (100-p) X Nm = …..kg, in which Fd/cm = the number of threads/cm, B = width of the textile to be woven, p = waste percentage and Nm = the metric yarn number.

As for example Fd/cm = 34, B = 114cm, p = 5%, Nm = 28, then the weight of yarn on the shuttle = 34 X 114 X 10 / 95 X 28 = 14,6kg.

The use of the LOGA 30 TxC or 30 TxR by the calculations in the weaving mill.

Especially for textile calculations, the LOGA company had several types of calculation discs. The 30 Rtx was mainly for use in spinning mills and the 30 TxC was mainly for use in calculations in the weaving mill. For wool, cotton,and linen there were certain converting factors printed on the scales of these calculation discs.

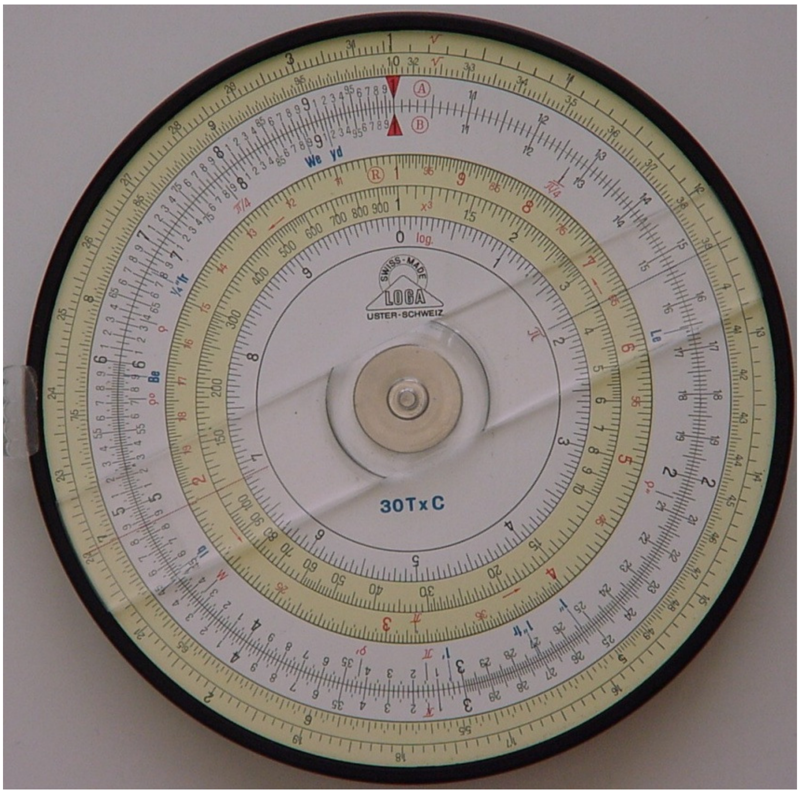

Figure 12. LOGA 30

In combination with the LOGA thread-counter it was possible to carry out specific calculations with the LOGA 30 TxC calculating disc, especially in the weaving mill.
With the application of the thread-counter you can simply count the number of threads in any woven material. The operation of this thread-counter has been based on the physical principle that if you put the thread-counter on a certain woven material, you can consider the woven material as an optical grid. An interference pattern appears perpendicular on the lines engraved in the thread-counter. This interference pattern is, as an example, roughly indicated on the thread-counter by a dark line that indicates that in this example 76 threads per English inch or 30 threads per cm can be counted.

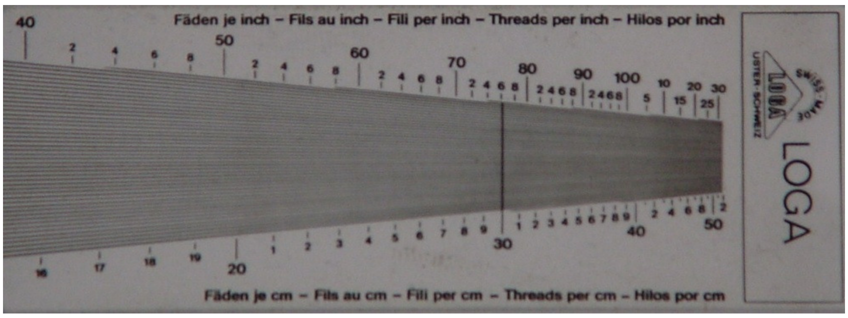

Figure 13. The LOGA thread-counter
(interference pattern indicates the number of threads per inch or cm)

Calculation of the conversion of thread compactness in the woven material.
In 1/4 " Fr. 23 threads are counted in a certain woven material. What is the corresponding thread compactness in ¼ " Engl., 1 " Fr. , 1 cm and 1 Engl. yd.? This conversion calculation can be carried out according to the setup scheme below.

Setup scheme

A scale	23	21,5	92	34	3100 Fd
B scale	1/4 " Fr.	1/4 "Engl.	1 " Fr.	1 (cm)	1 yd

Weight calculation of a woven material.

For calculation of the weight of woven material 6 factors are important.

F = the number of threads concerning the entire width of the weaving machine.
Nm = the metric yarn number.
L = the total length in meters of the material to be woven.
B = the width in cm of the material to be woven
P = the loss in percentage of the total yarn quantity.
Kg = the weight of the total yarn quantity.

The weight formula and the length formula that can be composed from the factors above, are:
Weight formula Kg = F X L/(10(100 - p) X Nm) and length formula L = 10(100-p) X Nm X Kg / F

Of a cotton material to be woven, the following is given; F = 2120, L = 108 m, p = 5%, Nm = Ne/2 = 28 (Ne = 56). From these data you can calculate the entire weight of the material to be woven, according to the weight formula Kg = (2120 X 108) / (10 X 95 X 28) = 8,6kg.

A certain quantity of yarn will be used for weaving matters. With the length formula you can calculate the maximum length L of the material that can be woven. The yarn quantity is 30kg and the expected loss p = 2%. The number of threads concerning the entire width of the material to be woven F = 4800, and Nm = 26. According to the length formula: L = 10 X 98 X 26 X 30 / 4800 = 159 meter.

For the calculation of a coloured woven material with five colours, the following has been given.

Material = Twined cotton, Ne 80/2
Entire width of the material = 111cm (including the edges)
Entire length material = 100m
Weaving length = 104m (4m weaving loss)
Number of wires per cm = 38
Loss of yarn = 6,2 %
Number of threads per pattern = 82

The width of the pattern is the number of threads per pattern divided by the number of threads per cm. Of a woven material with a certain pattern is given that the number of threads per cm F=38 and the number of threads per pattern F=82. The entire width of the material B=111cm. This means that over the entire width, a total of B/2,16 = 111/2,16=51,4 patterns or 50 patronen with a loss of 3cm can be woven. Since every woven cloth requires an edge of 1cm, it means that up to 50 patterns can be woven along the entire width of the loom.

The setup system below shows how the calculation with the LOGA 30 TxC calculating disc can be carried out.

Setup scheme

			------------- v		
	pattern	cm/pattern	B	cm	1 cm
A scale	82	2,16	111	3	1
B scale	38	1	51,4	1,4	0,46
	F/cm		=50 + 1,4 ------ ^		
			pattern		

The definite number of wires can be determined by adding;

50 patterns of 82 wires per pattern	=	4100 threads
2 times a locking of 38 threads	=	76 threads
2 times an edge of 20 threads	=	40 threads

Instead of 111 X 38 = 4218 threads a total of 4216 threads is necessary.

The weight of a cotton thread of a woven material length of 104 meter including a loss of 6,2 % in gramme is; Weight = 104 X Be / (938/1000 X 40 = 1,64 gramme. (Be = 0,5906)

The number of threads per colour is;

3280 threads white of 1,64 g	=	5380g
416 threads dark blue of 1,64 g	=	682g
208 threads light blue of 1,64 g	=	341g
208 threads dark brown of 1,64 g	=	341g
104 threads light brown of 1,64 g	=	170g
Total 4216 threads (Fd) of 1,64 g	=	6914g

With the LOGA calculating disc the weight calculation of the different colours is carried out very simply with the setup scheme below.

Setup scheme

A scale	1,64	5380	682	341	170	6914	gramme
B scale	1	3280	416	208	104	4216	Fd

Calculation of the efficiency of a weaving machine

The formula for the calculation of the efficiency of a weaving machine is:
η=F/cm X L/st/0,6 X n.
F/cm = weft number per cm (threads per cm weft material), L/st= hour production in meters, n = cycles per minute and η = efficiency of the weaving machine.
If F/cm=15,2, L/st=5,6 m, and n=170, the efficiency η = 15,2 X 5,6 / 0,6 X 170 = 0,835 = 83,5 %.

Setup scheme:

A scale	15,2	0,835	1
B scale	102	5,6	6,72
	0,6n	L/st	Lmax/st

Besides the actual production of 5,6 meter, the maximum production of 6,72 meter can be read at an efficiency of 100 % underneath 1 on the A scale.

Calculation of the production speed of a certain quantity of woven material

The formula for the calculation of the production time in hours for a certain quantity woven material is: h = L X F/cm / 0,6 X n X η .
L = the desired length per weaving device, η = cycle number per minute, F/cm = weft number per cm and η = the efficiency of the weaving device.

For instance: L = 1200m, F/cm=40, n=180, en η=0,7 (70 %), then the duration is:
h = 1200 X 40 / 108 X 0,7 = 634 hour. At a project week of 40 hour, the production time for this material length is 634 / 40 = 15,8 = approximately 16 weeks.

Literature:

Proceedings IM 2013. Engineers in Tights, Slide rules for the textile industry. David Rance
The LOGA Calculators, 2004, Nico E. Smallenburg
LOGA Calculators AG
Pictures; LOGA Calculators, photo CD

Extreme Sliding – Base Jumping with the Radix 2/10 Binary/Decimal Slide Rule

Colin Tombeur

What is in a scale?

This article describes the inspiration, design and operation of the 'Radix 2/10 – System Leibniz' slide rule, and the broader idea of the Radix model series. The rule, and then later the concept of a model series using the scale design, is my brainchild, inspired by my research into understanding how slide rule scales work.

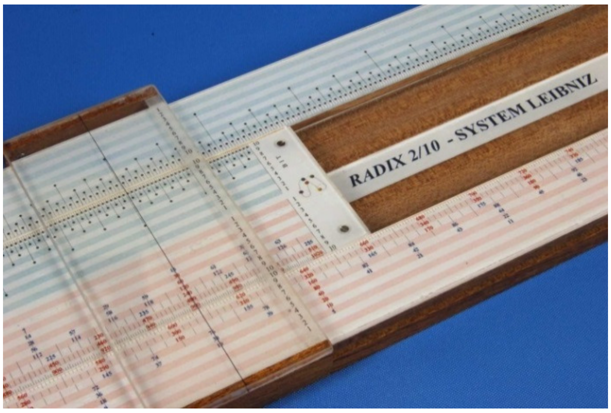

Figure 1a. Radix 2/10 – 10-BIT binary/decimal slide rule

Soon after my first encounter with slide rules my interest in them extended to creating my own novel designs, from the theoretical concept and mathematical solution through to the practical design and construction of working quasi-professional examples. This article also attempts to demonstrate the complexities and challenges involved and how they were overcome from the perspective of creating this new binary/decimal model slide rule. In addition, this project once again raised the question of the precision expected from slide rules, but unexpectedly and in a rather novel and refreshing way.

Summary

The Radix 2/10 is a logarithmic 10-BIT binary closed frame wooden desktop slide rule with decimal 'equivalent' scales (Figures 1a & 1b). Where a typical slide rule is used to perform decimal multiplication and division, the Radix 2/10 will do the same for binary numbers. In addition to the binary 'primary' scales, the equivalent scales enable numbers to be converted between binary and decimal systems. The scales are logarithmic binary but can be considered as regular decimal slide rule scales, each having a range of 1 to 1024 divided into 10 subscales truncated at the powers of 2 and stacked above one another. A full model specification and additional images can be found in the Appendix.

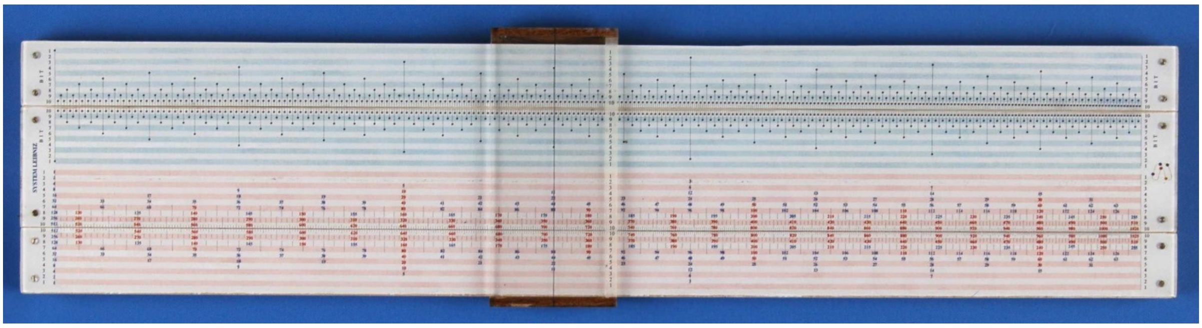

Figure 1b. Radix 2/10 – 10-BIT binary/decimal slide rule

The series is named 'Radix', radix being another term for the base of a number, and the model 2/10 is so named because of the binary/decimal (base 2/base 10) scale layout. The binary scale system is especially named 'SYSTEM LEIBNIZ' after Gottfried Leibniz who discovered the modern binary number system[1]. Other models with different primary/equivalent base pairings are possible in the series, for example, the Radix 8/16 would be a base 8 slide rule with base 16 equivalent scales.

Background and Development

When my eyes were first fully opened to the fascinating and diverse subject of slide rules in mid-2011, one of the first things I wanted to find out was how slide rules worked. This involved considerable reading around the subject, refreshing my schoolboy knowledge of logarithms, and significant work with paper and scissors. The next obvious step was designing scales for my own interests, and then designing actual physical slide rules that I would be able to make relatively easily and to a reasonable standard with my limited home facilities.

While revising my knowledge of logarithms I began experimenting with logarithmic scales in different bases. This led me to toy with the idea that perhaps a slide rule could be designed to convert numbers between many different bases. The obvious place to start was converting between the familiar base 10 and the simplest base of all, base 2. Then perhaps the design could be modified to work for additional bases. This idea ultimately proved fruitless, but it did cause me to wonder how a logarithmic binary scale could be easily represented on a slide rule.

The problem gave me an idea for some light relief and a little bit of fun at the expense of slide rule enthusiasts – a binary 'logarithmic' 1-BIT slide rule (Figure 2). This working example with just two marks on each scale is a fantastic introduction to the concept of binary scale slide rules! Technically the binary value labels should be binary 1 and 10, but that would be a little confusing given its intended purpose.

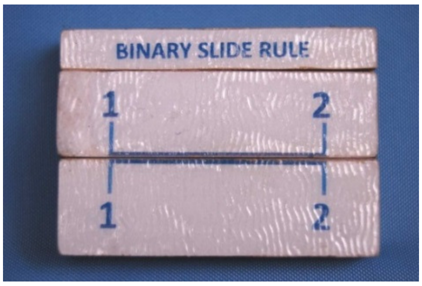

Figure 2. Binary slide rule

A few months later around spring 2012, I revisited the logarithmic binary scale problem and developed a workable layout for a linear slide rule. This might have been the end of the story but for David Rance's presentation of his paper 'Slide Rules for Computer Programmers'[2] in the autumn of 2012 at The International Meeting of Collectors of Historical Calculating Instruments in the UK. David's paper immediately chimed with my ideas for binary slide rules. The most fundamental form of computer programming is machine code, or binary code, which is programming in the hardware language of the computer using '1's and '0's. A little tongue-in-cheek, I thought that 'real computer programmers would have used machine code in the early days, and what they needed was a binary slide rule'. Since I had already designed a binary scale layout, I decided to make a prototype.

Initially I refined the design of the binary scales. Then, given that a linear slide rule has a pair of sliding edges, I considered what other scales could be added that may be useful. Thinking back to my investigations into base conversion scales, I realised that I could easily add a pair of decimal scales equivalent to the binary pair. This would enable the users to calculate in binary or decimal, and allow them to read the values and results in either base. Over the next few months I developed a prototype binary/decimal slide rule which I showed to David Rance in mid-2013. David is an enthusiast of unusual slide rules and was very complimentary of the idea and design. He offered some welcome and insightful suggestions[3], such as naming the binary scale layout SYSTEM LEIBNIZ, and encouraged me to take the idea to its logical conclusion – to finalise the design, build some examples and write a paper.

By the end of September 2013 the design was complete and I had a finished Radix 2/10 model. During this last phase of development I realised that the scale design and the layout of a primary pair of logarithmic scales in one base with an equivalent pair in another base could be used for other combinations of bases. I could have a slide rule model series in which any particular combination of two bases for the scale pairs would be a model. I decided to call the model series Radix after the term for the base of a number, and the model numbers would be a combination of the primary/equivalent base numbers of each variant.

Primary and Equivalent Scale Design

A slide rule in the Radix model series is designed to be used as a typical decimal slide rule, using the pair of primary scales. However, while the structure of the primary scales is similar to the familiar decimal scales, they are formatted in a different base. The equivalent scales then show the values for the positions on the primary scales in an alternative base. The format of the binary primary and decimal equivalent scales of the Radix 2/10 are detailed here, however the design can be applied to scales of any two different bases.

Binary Primary Scales

The design and labelling of the logarithmic binary slide rule scale system described here is especially named SYSTEM LEIBNIZ after Gottfried Leibniz who invented the modern binary number system in 1679. His system is described in his article 'Explication de l'Arithmétique Binaire'[1].

Binary Numbers

A number in any base can be stated using general notation, where **b** is the base, **n** is the number of digits and **a** is the digit value at position **k** from least to most significant digit, as:

$$a_1 \times b^0 + a_2 \times b^1 + \ldots + a_n \times b^{(n-1)} \quad \text{or} \quad \sum_{k=1}^{n} a_k b^{k-1}$$

e.g., the 6-digit decimal number 142857 comprises $7\text{x}10^0 + 5\text{x}10^1 + 8\text{x}10^2 + 2\text{x}10^3 + 4\text{x}10^4 + 1\text{x}10^5$

DECIMAL				BINARY							
Sig.:	most		least	Sig.:	most						least
digits:	3	2	1	BITs:	7	6	5	4	3	2	1
	100's	10's	1's		64's	32's	16's	8's	4's	2's	1's
			0								0
			1								1
			2							1	0
			3							1	1
			4						1	0	0
			…								…
			9					1	0	0	1
		1	0					1	0	1	0
		1	1					1	0	1	1
		1	2					1	1	0	0
			…								…
		9	9		1	1	0	0	0	1	1
	1	0	0		1	1	0	0	1	0	0
	1	0	1		1	1	0	0	1	0	1
			…								…

Table 1. Decimal numbers and their binary equivalents

Numbers are made up of a string of the digits available to the base, where each digit to the left of the point is an order of magnitude greater than the last, from least to most significant digit. The number of available digits determines the order of magnitude and characterises the base. In decimal (base 10) there are 10 digits available; 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. The order of magnitude is therefore 10, with the digits successively to the left of the point representing units, tens, hundreds, thousands and so on.

Binary, or base 2, is the simplest of all bases in that numbers are made up using the two binary digits, or BITs, '0' and '1'. The order of magnitude is 2, so the BITs successively to the left of the

DECIMAL	11			
divided by 2 =	5	remainder	1	
divided by 2 =	2	remainder	1	
divided by 2 =	1	remainder	0	(read up)
divided by 2 =	0	remainder	1	BINARY

Table 2. Converting decimal 11 to binary

BINARY			0	
(read down)	1	+ 2 x 0 =	1	
	0	+ 2 x 1 =	2	
	1	+ 2 x 2 =	5	
	1	+ 2 x 5 =	11	DECI-MAL

Table 3. Converting binary 1011 to decimal

point represent units, twos, fours, eights, sixteens and so on from least to most significant BIT. Table 1 shows some decimal numbers with their binary equivalents. It can be seen that binary numbers quickly become very long compared to their decimal equivalents. For example, the base 10 2-digit number 99 is 1100011 in base 2, 7-BITs long.

Conversions between binary and decimal numbers are relatively simple but laborious. Using the above algorithm it can be seen that the binary number 1011 comprises $1x2^0 + 1x2^1 + 0x2^2 + 1x2^3$ = 1x0 + 1x2 + 0x4 + 1x8 = 11 in decimal. Simple processes based on the algorithm enable conversion between binary and decimal numbers. A decimal number can be converted to binary by successively dividing it by 2 until the quotient becomes zero.
The remainder of each division becomes the next least significant BIT (Table 2). The process is reversed to convert a binary number to decimal. Each BIT from most to least significant BIT is added to double the previous value, starting with zero (Table 3).

Performing mathematical operations in binary is similar to decimal but more laborious and is not discussed here. Further information on binary and other number systems can be found in many online or text resources.

Scale Structure & Precision

The initial problem with binary scales was how to represent numbers on a scale where there are only two digits, 0 and 1. However the approach becomes clear when a typical logarithmic C scale of a linear base 10 slide rule is examined to understand how values are represented (Figure 3). The tick marks and value labels in this example are slightly different to normal in order to demonstrate the principles involved, and integers are represented for ease of explanation.

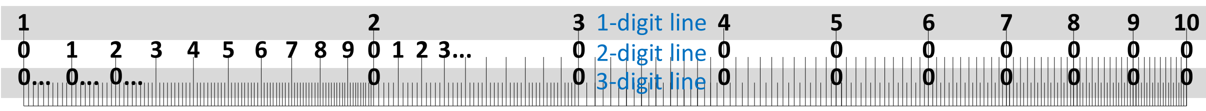

Figure 3. Typical base 10 C scale with 3 digit lines representing 1000 integers (not all tick marks shown)

The scale can be seen to have three distinct levels defined by the tick mark heights and value labels. The highest level has logarithmic tick marks labelled 1 to 9 to represent a single digit number with the final tick mark representing the zero digit of the 2-digit number 10. Thus 10 digits are represented on 1 line (where 10^1=10). This level can be said to be the 1-digit line.

The 2-digit line has 9 tick marks logarithmically subdividing each of the intervals between the 1-digit line tick marks into 10. This allows all of the 2-digit numbers 10 to 99, and 100, to be represented in addition to the 1-digit numbers. The tick marks previously used for units now represent tens, with the 2-digit line tick marks representing units. 100 integers are represented by 2 digit lines (where 10^2=100), using 91 tick marks. Note that 10 is represented at both ends but only counted once.

The 3-digit line further subdivides each interval on the 2-digit line into 10. On a typical 250mm C scale this is usually achieved with a combination of tick marks, by-eye and estimation. All of the 3-digit numbers from 100 to 999, and 1000, are represented here in addition to the 1 and 2-digit numbers, so 1000 integers are represented (where 10^3=1000), using 901 tick marks.
Table 4 shows how magnitudes are represented by the digit lines for 1, 2 and 3-digit numbers.

The 1-digit line (highest level) always represents the most significant digit and the lowest level always represents the least significant digit in a number. The number of digit lines (or levels) is the depth of the scale, which is also the number of significant digits that can be represented by it.

Digits in Number	digit line 1	2	3
1	units		
2	tens	units	
3	hundreds	tens	units

Table 4. Representation of 3-digit decimal integers

BITs in Number	BIT line 1	2	3
1	1's		
2	2's	1's	
3	4's	2's	1's

Table 5. Representation of 3-BIT binary integers

If the scale base (**b**) is raised to the power of its depth (**n**), the result is the possible number of integers (**i**) that can be represented, if they all had tick marks:

$i = b^n$ e.g. A decimal scale with a 3-digit line depth could represent 10^3 = 1000 integers.

This also indicates the absolute precision of the scale where all integers have tick marks. Absolute precision is the minimum precision of the scale that can be attained from the tick marks, without by-eye or other estimation. In the above example 1000 integers are represented, so the absolute precision is 1 in 1000, or 1/1000. If the scale does not have all possible values in the range represented with tick marks, then the absolute precision ratio, where **m** is the minimum tick mark value interval, is given by:

m / i *or* m / b^n e.g. The absolute precision of a 3-digit line decimal scale where the minimum tick mark value interval is 5 (between 995 and 1000) is $5/10^3 = 1/200$.

The number of tick marks (**t**) required to represent all the integers is given by the following formula, where **b** is the base and **n** is the scale depth or number of digit lines in the scale:

$t = b^n - b^{(n-1)} + 1$ e.g. $10^3 - 10^{(3-1)} + 1 = 901$ tick marks for a 3-digit line base 10 scale.

The same approach can be used to represent binary numbers on a scale. A BIT line is the equivalent of a digit line, where each subsequent level logarithmically subdivides the previous BIT line intervals into 2 rather than into 10 for decimal scales. The scale depth is now the number of BIT lines, which is the power to which 2 is raised to give the possible number of integers that can be represented.

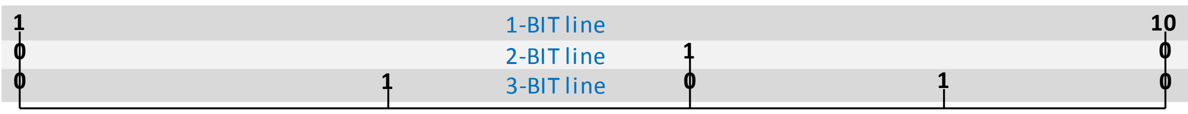

Figure 4. 3-BIT line binary scale representing 8 integers

Figure 4 shows a 3-BIT line logarithmic binary scale representing the integers 1_2 to 1000_2 (binary), or 1_{10} to 8_{10} (decimal). As with the decimal scale, the highest level, the 1-BIT line, represents the most significant BIT and the lowest level, the 3-BIT line, represents the least significant BIT.

The 1-BIT line comprises 2 tick marks, where 2^1=2, representing the 1-BIT binary number 1_2, and 10_2 (1_{10} and 2_{10}). The 2-BIT line has an additional tick mark subdividing the single 1-BIT line interval logarithmically into two. This BIT line represents the 2-BIT numbers 10_2 to 11_2, and 100_2, (2_{10} to 3_{10} and 4_{10}) in addition to the single 1-BIT value on the 1-BIT line. Thus 4 integers are represented by 2 BIT lines (where 2^2=4), using 3 tick marks. The 3-BIT line logarithmically subdivides each of the 2 intervals in the 2-BIT line in half. In addition to the 1 and 2-BIT numbers, the 3-BIT values 100_2 to 111_2, and 1000_2, (4_{10} to 7_{10} and 8_{10}) are represented. The 3-BIT scale depth represents 8 integers (where 2^3=8), using 5 tick marks. The tick mark interval is 1, so the absolute precision of the scale with 3-BIT lines is 1/8.

Table 5 shows how magnitudes are represented by the BIT lines for 1, 2 and 3-BIT numbers. Further BIT lines can be added by continually subdividing the intervals logarithmically in half, enabling longer binary numbers to be represented. Each additional BIT line, and hence BIT, doubles the number of integers represented, and so doubles the absolute precision of the scale if all integers are represented with tick marks.

Tick Mark Position

On a linear base 10 logarithmic slide rule scale, the lower level tick marks are positioned logarithmically within a higher level interval. The formula for the linear position (**d**) of a tick mark within an interval, where **l** is the length of the interval and **x** is the ordinal, is:

$d = l.\log_{10}(x)$ e.g. On a typical 250mm scale length linear rule, the '2' tick mark is positioned at 250 x $\log_{10}(2)$ = 75.3mm.

A similar formula, $d = l.\log_2(x)$, is used to position the single tick mark dividing an interval into two on the logarithmic binary scale. Calculating logarithms in base 2 is relatively simple since $\log_b(x) = \log_{10}(x) / \log_{10}(b)$, where **b** is the required base. Therefore, the formula for the position of the tick mark becomes:

$d = l.\ \log_{10}(x) / \log_{10}(b)$

Since the single lower level tick mark divides an interval numerically in half on the binary scale, the value for x is 1.5, halfway between 1 and 2. Therefore the tick mark is always at $\log_{10}(1.5) / \log_{10}(2)$ = 0.585 of the interval width.

When the tick marks on a scale are drawn (Figures 3 & 4), it can be seen that in fact only the tick marks for the lowest significant digit/BIT line are actually drawn. However, the tick marks are drawn to different heights, as appropriate, into the higher levels where they are effectively reused. If **n** is the scale depth (or number of BITs/digits/levels) and **b** the base, then the range of integers **x** that need to be drawn is:

$b^{(n-1)} <= x <= b^n$ e.g. The 3-BIT line scale in Figure 4 only needs the 5 tick marks for the range 4 to 8 to be drawn to appropriate heights for all 8 integers to be represented.

Using the range defined above, the formula below will give the position **d** from the left end, of all the tick marks in a scale of base **b**, depth **n** and physical length **l**. This range and formula can be used to draw any tick mark on a linear scale in any base.

$d = l.\ \log_{10}(x / b^{(n-1)}) / \log_{10}(b)$

e.g. The 1.11 tick mark on a typical 250mm decimal C scale can also be seen as integer 111 of 1000. $1000=10^3$, so the scale depth is 3. The position of the tick mark can then be calculated as: 50. $\log_{10}(111 / 10^{(3-1)}) / \log_{10}(10)$ = 11.3mm.

Tick Mark Format and Labelling

On a typical decimal slide rule scale the tick mark lengths and numeric labels are designed so that values can be read easily. Variation of tick mark length within line similar to a decimal scale, for example where units and multiples of 5 are different lengths, is nonsensical on a binary scale where subsequent BIT lines subdivide intervals into 2 rather than into 10. In addition, the length of binary numbers can get very large, very quickly, because they are only represented using the digits 0 and 1. The challenge was to design tick marks and a method of labelling where binary numbers could be read relatively easily, without all the lines becoming too confusing with excessive ones and zeroes. The solution eventually found is two-fold (Figure 5).

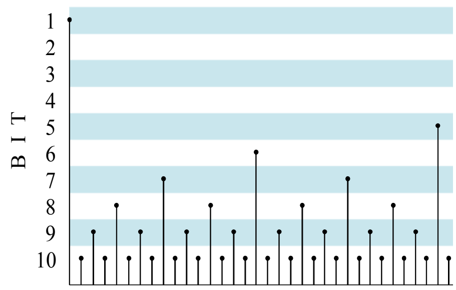

Figure 5. Left end of 10-BIT binary primary scale

On a conventional linear slide rule scale, the tick mark heights are an indicator of the order of magnitude of the digit. In the example described above (Figure 3), tick marks representing hundreds are longer than those representing tens, which are longer than those representing units. The binary scale follows this rule strictly. Tick lines for the 1-BIT line (most significant BIT) are longer than those of the 2-BIT line, which are longer than those of the 3-BIT line, and so on down to the last BIT line (least significant BIT). Each BIT line has an alternating coloured background, where the high end of the tick mark stops in the middle, and is labelled at both ends with the BIT number from most to least significant BIT. This approach makes it clear which level the tick mark 'belongs' to.

In addition, the high end of each tick mark terminates with a blob, '•', indicating that it is a '1' BIT in the BIT line that it belongs to. A plain tick mark (the stalk supporting the •) passing through a BIT line indicates a '0' BIT in that level. To avoid confusion due to the way the scale is read, the extreme right-hand end tick mark is used only as an index and so has no terminating •. Values that are usually read at either end of a conventional scale (whole powers of the base) are only read at the left-hand end of the binary scale.

The combination of these properties makes it possible to build a binary number, or string of BITs, by reading down and across the BIT lines. The number begins at the • at the left-hand end of the 1-BIT line and ends at the appropriate tick mark in the BIT line corresponding to the number of BITs in the binary number. This process is fully described later in this article.

Decimal Equivalent Scales

The equivalent scales on the Radix 2/10 show decimal values for the binary number positions on the primary scales, so their fundamental structure is the same as the binary primary scales. They are the binary scales repeated with decimal number labelling and some small formatting differences (Figure 6).

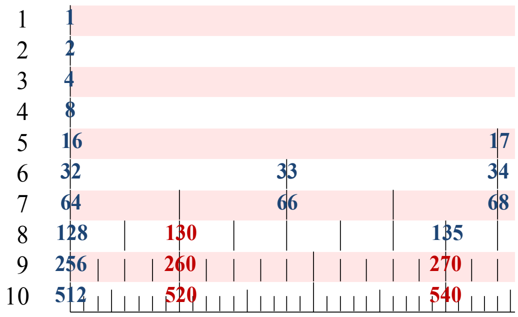

Figure 6. Left end of 10-BIT decimal equivalent scale

The decimal scales have the same number of BIT lines as the binary scales, and are similarly labelled with the BIT line numbers at each end. Every tick mark on the primary scale has a corresponding tick mark in the same position on the equivalent scales. This means that when the scales are aligned and a tick mark representing a number on one scale is located, the equivalent tick mark on the other scale is simultaneously found.

Because the decimal values are sited on a logarithmic base 2 scale rather than the usual logarithmic base 10 scale, the scale appears similar to a long decimal scale that is broken at the powers of two and stacked. This means the location of the values is not immediately familiar, so the differences in the decimal scales compared to the binary scales are primarily features designed to make the values easier to locate and read:

- The tick marks do not run always continuously across the BIT lines. Instead they can be broken across them so that a decimal-type scale hierarchy of orders of magnitude and subdivisions is maintained by the tick marks within individual BIT lines. For example, tick marks representing tens are longer than tick marks representing fives, which are longer than those representing units within each line.
- There are no terminating •'s on the tick marks, instead the tick marks are labelled with the decimal value in the BIT lines. A single tick mark on the binary scale may have multiple value labels on different BIT lines in the decimal scale.
- To avoid overcrowding not all tick marks are labelled, but the powers of two on the left-hand index end are always labelled.
- Where decimal value labels that are multiples of 10 appear, they are coloured differently.
- The colour of the alternating background of the BIT lines is different so that the two types of scale are easily distinguished.

Slide Rule Design

Having achieved a workable design for the scales, the next stage was to apply the scales in a practical slide rule design. Binary numbers tend to be precise in their construction and usage in that all BITs are explicitly stated with no rounding or shortening. Consequently some fundamental design decisions were made which had a significant impact on the final design of the slide rule.

Over the entire range of the scale depth, all of the possible values in the range should be represented with tick marks for maximum absolute precision. For example, an 8-BIT rule would have tick marks representing all 256 values in its range (2^8=256). This is in contrast to a typical 250mm linear decimal C scale where the tick mark increments vary; for example between 9.00 to 10.00 (900 to 1000) they usually increment by 0.05 (5).

For readability the minimum tick mark spacing should not be less than 0.5mm. Subsequent binary scale BIT lines are only divided into two using progressively shorter tick marks with a terminating •. The effect of these features is that tick marks can be positioned closer together than a typical linear C scale without causing significantly more confusion.

The binary primary scales can be used to represent and calculate floating point numbers containing fractional BITs after the radix point in a similar way to a normal scale. However, the decimal equivalent scales would focus on representing integer values for the range with no further subdivision, and be labelled accordingly. This is primarily to avoid unnecessarily further complicating the decimal scales with additional tick marks, but means that decimal floating point calculations and conversions cannot be achieved easily.

Scale Length and Precision

All of the integers in the binary scale range are represented by tick marks, so the range gives the absolute precision for the scale. A 4-BIT scale depth gives a precision of 1/16, since 2^4=16, and an 8-BIT depth gives a precision of 1/256 (2^8=256). The initial idea was that the scale depth should be either 8, 16 or 32-BITs. These lengths of binary strings are significant in computer architecture and machine code programming, which was the original (if redundant) inspiration for an actual binary slide rule.

As seen in the scale design section, the ratio for the absolute precision of a scale is m / b^n, where **m** is the minimum tick mark value interval, **b** is the base and **n** the depth of the scale. Using this ratio a typical 3-digit depth decimal linear C scale with a minimum tick mark interval from 9.95 to 10 has an absolute precision of 1/200. However, an experienced operator can achieve a workable precision of 1/1000 from such a scale. Against this an 8-BIT scale with an absolute precision of 1/256 was not appealing. Every extra BIT added to the scale depth results in an approximate doubling of the number of tick marks required to represent all values. Because the desired 8, 16 or 32-BIT depths are each double their predecessor, an investigation of practical scale length was necessary.

The formula $t = b^n - b^{(n-1)} + 1$, also previously identified, gives the number of tick marks (**t**) for a base (**b**) and scale depth (**n**). The following formula on the left gives the minimum (right-hand most) tick mark interval width (**w**) for a scale length (**l**), base (**b**) and scale depth (**n**), where all integers are represented by tick marks. On the right this formula has been rearranged to give the scale length for these variables:

$$w = l.(\log_{10}(b^n) - \log_{10}(b^n-1)) / \log_{10}(b) \qquad l = w. \log_{10}(b) / (\log_{10}(b^n) - \log_{10}(b^n-1))$$

Table 6 shows calculations of the number of tick marks, the minimum tick mark interval width for a 250mm scale length, and the scale length for a minimum interval width of 0.5mm, for the preferred binary scale depths. Clearly with the exception of an 8-BIT depth, the number of tick marks required is completely impractical and results in unfeasibly small minimum interval widths, or huge scale lengths. (For 64-BIT computing the scale length for a minimum interval width of 0.5mm would be over half a light-year!)

Scale Depth (**p**)	No of tick marks (**t**)	Min tick width (**w**) for 250mm scale	Scale Length (**l**) for 0.5mm width
8-BIT	129	1.4mm	88.5mm
16-BIT	32,769	5.5 x 10^{-3}mm	22.7 m
32-BIT	2,147,483,649	8.4 x 10^{-8}mm	1,489 km
10-BIT	513	0.35mm	374.7mm

Table 6. Specifications for preferred scale depths

However, a 10-BIT scale depth with 513 tick marks gives a scale length of 354.7mm for a 0.5mm minimum tick mark width (Table 6). This order of magnitude is perhaps not too surprising given the scale length (250mm) and precision (1/200) of a typical decimal linear C scale. 10-BITs is not a preferred scale depth and it is not a power of two as are other 'computer friendly' binary string lengths, but it does have several positive and appealing points:

- The scale length would make a practical desktop rule.
- A 10-BIT depth with conversion scales to the familiar base 10 gives a pleasing symmetry.
- The absolute precision is 2^{10}=1024 when all integers are represented with tick marks, which is approximately equal to the familiar workable precision of 1/0000 for a typical decimal 250mm linear C scale.
- With 513 tick marks the 10-BIT scale is significantly more detailed than the relatively simple 8-BIT depth, but not overly long and confusing that it becomes too difficult to read.

For these reasons 10-BITs was chosen as the optimum depth of the binary scales. Calculations involving binary numbers with more than 10-BITs can still be performed in a similar way to those on a decimal slide rule where the number of digits exceeds the precision.

Slide Rule Layout, Construction & Appearance

Since I began making my own slide rules in 2011 I have honed a design and method of construction for single sided closed frame linear slide rules that optimises my practical skills and the resources available to me. The actual construction method and its evolution are not detailed in this article, but the key features of the design as well as scale positioning, rule size and appearance are described here.

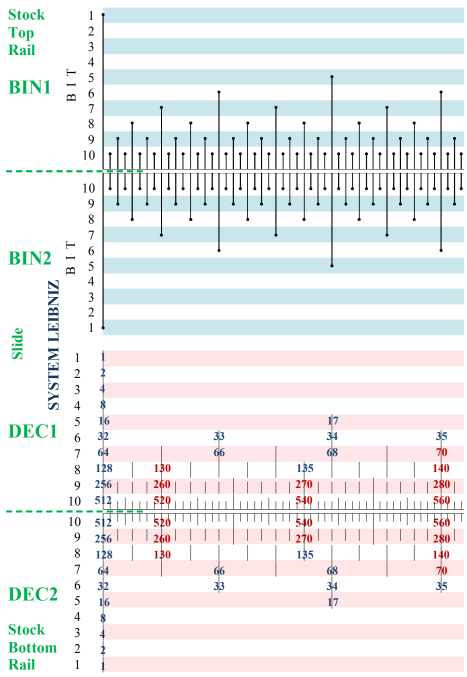

Figure 7. Radix 2/10 scale layout

Primary and Equivalent Scale Position

The binary primary scale pair are positioned on the top rail of the stock and adjacent upper half of the slide, 'BIN1' and 'BIN2' respectively (Figure 7). The decimal equivalent scale pair, 'DEC1' and 'DEC2', are positioned on the lower half of the slide and bottom rail of the stock respectively. Therefore the BIN1 and DEC2 scales are fixed relative to each other on the stock with their index ends precisely aligned, and the BIN2 and DEC1 scales are similarly fixed and aligned on the slide. As is usual with scale pairs on linear slide rules, the two scales in each pair are mirror images of each other. The upper binary scale is read top to bottom, most to least significant BIT, whereas the lower binary scale is read bottom to top, most to least significant BIT. The order of the BIT lines is similarly reversed between the upper and lower decimal equivalent scales.

The main reason for positioning the binary scales above the decimal scales is that it is marginally easier to read the binary scales working downwards from most to least significant BIT, rather than upwards. Usually in a single multiplication or division operation on a linear slide rule, the fixed scale is read twice (first factor or dividend and then the answer) and the sliding scale is read once (second factor or divisor). Therefore the easier to read binary primary scale should be on the top rail where it can be read top to bottom. The two equivalent scales are of secondary importance and therefore of secondary consideration in terms of position, but regardless, there is no real difference between them when locating decimal values.

Slide Rule Size and Construction

The stock and slide are fashioned from hardwood, either walnut or mahogany, with printed paper scales faced with Perspex for protection. The final size of the slide rule was governed largely by practical limitations imposed by home construction, the main considerations being:

- Equipment and skills available for accurate construction.
- Availability of sizes of hardwood required.
- The largest paper size economically printable to produce the scales.

My aim is to make slide rules to a reasonably high, albeit non-professional standard, using my limited home equipment and artisan skills. To achieve this, the construction method I developed involves laminating pieces of hardwood strip-wood to form the stock, slide and cursor, including the tongues and grooves necessary for the device to work properly. The strip-wood used must be purchased in the appropriate thicknesses, and consequently the width of the rule is limited by the width of the strip-wood economically and readily available to me, which is 100mm. Due to the machining required to make the rule, the actual finished width is a little narrower at 92mm. Each scale is approximately 21mm high, with each BIT line approximately 2mm high.

Thanks to huge advances in computer hardware and software, scales can be created on a PC relatively easily. With care, good results can be achieved using standard office applications with drawing capabilities. To facilitate this process I have designed and written a program to build scales in one such application. The program calculates and draws scales from individual design parameters as accurately as possible ready for printing, taking into account subtleties such as tick mark line width and the resolution of both the software application and print output. The scales are then printed onto paper using a standard laser or ink jet printer. However, experience has shown that to achieve good quality results considerable care must be taken with actual print configuration and paper used.

I avoid printing scales over more than one piece of paper and then joining them together because of potential problems with accuracy and alignment. The maximum paper size I can economically print is A3, which would make a compact desktop size slide rule. This size is also close to the maximum length I can practically work using my equipment and still achieve the desired accuracy and precision of construction. The longest dimension of A3 paper is 420mm. In order to maximise the scale length, and hence maximise the minimum tick mark width and readability, I set the scale length at 390mm leaving 15mm at each end of the scale. This scale length of 390mm gives a minimum tick mark interval width of 0.55mm for the 10-BIT binary scale.

Scale Colours and Labels

As previously described, both pairs of scales have all integers from 1 to 1024 represented by tick marks (10-BITs = 2^{10} = 1024), with the binary scale tick marks indicating a 1 BIT value by a terminating • in the appropriate BIT line. All tick mark lines and terminating •'s are black.

The decimal equivalent scale tick marks are labelled as follows: all 1 to 6-BIT integers (1-63); even 7-BIT integers (64-127); 8-BIT integers divisible by 5 (128-255); 9-BIT integers divisible by 10

(256-511); 10-BIT integers divisible by 20 (512-1023). All powers of 2 at the start of each BIT line are also labelled on the decimal scales. Integer value labels are blue, except multiples of 10 which are red for ease of location.

The background of alternate BIT lines on both scale pairs is shaded for ease of tracking along the lines. To help distinguish between the scales, the alternate lines are coloured blue for the primary scales and red for the equivalent scales. BIT lines on each scale are labelled in black from 1 (most significant) to 10 (least significant) at both ends.

Cursor

The size of the rule and the way the binary scales are read by constructing the number across and down the levels, means that a single hairline cursor is essential for place-holding, alignment and tracking between the primary and equivalent scales. The free view[4] style cursor is made from hardwood runners with a Perspex pane, and features a wire tension spring. An extremely useful addition suggested by David Rance[3] is the labelling of the BIT lines on the underside of the cursor pane at the right end. This labelling is across all of the four scales and provides an immediate reference point on the long scales.

Other Text

On the front of the slide at the left and right-hand ends are printed SYSTEM LEIBNIZ and my maker logo respectively. Rebated into the well is a Perspex faced label featuring the model name in the centre and the maker's name and logo at the right-hand end. The back of the slide rule features a paper label with summary instructions for conversions and mathematical operations. The label is rebated into the stock to protect it when the slide rule is placed on a surface.

Slide Rule Operation

The Radix 2/10 initially appears somewhat unfamiliar, complicated and confusing, so special care must be taken to avoid errors when reading the scales!

Reading the Scales and Conversions

Conversions between binary and decimal numbers effectively demonstrate how the scales are read. Either of the fixed scale pairs, BIN1/DEC2 on the stock or BIN2/DEC1 on the slide, can be used for conversions (Figure 7). Both pairs have their advantages; the scales on the slide are closer together, but the binary scale on the stock is slightly easier to read scanning downwards from most to least significant BIT. In either case the cursor hairline can be used to accurately track from one scale to the other.

Note that while fractional BITs can be read on the binary scales, there are no tick marks for fractional components on the decimal scales, which should be estimated if required.

Building a Binary Number and Converting to Decimal

The process for building a binary number is described here and demonstrated by the following example.

To convert a binary number to decimal, first construct the binary number on the BIN1 scale. Position the cursor hairline over the • at the left-hand index end of the 1-BIT line. This represents the most significant '1' BIT of the binary number; any leading '0' BITs are ignored. Consider each remaining BIT in the number. If the BIT is a '0' move on to the next BIT. If the BIT is a '1' move the cursor hairline to the right from its last position, along the corresponding BIT line until it reaches a •, and position the hairline over the supporting tick mark. When complete, note the number of integer BITs in the original binary number, ignoring any leading '0' BITs. Refer to the DEC2 scale. On the BIT line corresponding to the noted number of integer BITs, read the decimal value at the tick mark under (or immediately to the left of) the cursor hairline. With practice it is possible to build the binary number moving the cursor only once across to its final position.

If the binary number has more than 10-BITs, only the first 10-BITs from the first '1' BIT can be built on the BIN scales. The equivalent value found on the 10-BIT line of the decimal scale must be factored by 2 for each additional BIT.

Example 1: Convert 00001010_2 to base 10 (Figure 8).

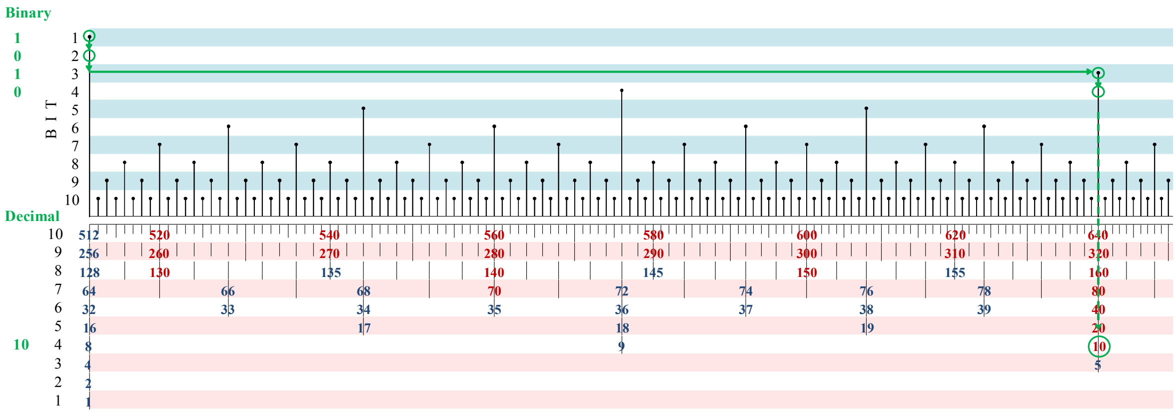

Figure 8. Converting 1010_2 to decimal (note BIN1 and DEC2 scales are shown adjacent)

Set the cursor hairline over the left-hand index end of the BIN1 scale on the stock upper rail. Ignore the leading '0' BITs. The • under the hairline on the 1-BIT line represents the first '1' BIT in the binary number. The second BIT is a '0' and so is ignored. The third BIT is a '1', so move the cursor hairline to the right along the 3-BIT line of the BIN1 scale until a • is reached, and align the hairline over the supporting tick mark. The fourth and final BIT is a '0' and so is also ignored. In the original binary number, 00001010, ignoring the leading '0's there are 4 integer BITs. Refer now to the DEC2 scale on the stock lower rail. Under the cursor hairline on the 4-BIT line, read the answer of '10'. Therefore $1010_2 = 10_{10}$.

Decimal Number Location

As described previously, decimal values on the equivalent scales are simply decimal integer labels on a logarithmic binary formatted scale. As such, the values in each BIT line are not organised as a range of a power of 10 as on a decimal slide rule, but rather as a range of a power of 2. This makes locating decimal values a little difficult at first.

To assist in locating a value, labels for multiples of 10 are coloured red, and tick marks between these follow a conventional height hierarchy within the BIT line. Not all tick marks are labelled due to space limitations. A decimal value can be found by simply scanning the decimal scale and locating the value label and tick mark. If the required value is in a range where not all tick marks are labelled, locating the nearest value label and counting to the appropriate tick mark.

Alternatively the left-hand end of the scale, where all of the powers of 2 are situated and labelled, can be studied to determine the BIT line containing the required decimal value (Figure 6). The value label on the left-hand end of a BIT line indicates the start of the range of the BIT line, with the left-hand end label on the next least significant BIT line indicating the end of the range. Once the appropriate BIT line has been determined it is simply a matter of scanning along the BIT line, using value labels as a guide, to locate the tick mark representing the value.

Numbers with a binary length of more than 10-BITs can be approximated, but the process is complicated. First the range of the 10-BIT line of the DEC scale must be successively doubled until the required value is in the range; for example 11-BITs is a number in the range 1024_{10} to 2048_{10}, 12 BITs is 2048_{10} to 4096_{10} etc. Next the tick mark (or approximate) representing the value on the 10-BIT line is located by factoring up the value labels by the same amount; x 2 for 11-BITs, x 4 for 12-BITs etc.

Converting a Decimal Number to Binary

As with converting a binary number to decimal, it is easier to understand the process by following the example, but a general description is also given here.

To convert a decimal number to binary, first locate the integer tick mark for the value on the DEC2 scale and position the cursor hairline over it (approximate any fractional component). Refer to the BIN1 scale. Scrutinise each of the BIT lines in turn starting from the 1-BIT line (most significant BIT), and ending at either the 10-BIT line or a BIT line where there is a • with a supporting tick mark directly under the hairline. For each BIT line, examine the range starting from beneath the hairline and ending to the left, either at the nearest • on the BIT line or a tick mark that crosses it and extends to a lower BIT line, whichever comes first. If there is a • with a tick mark directly under the hairline, this is both the start and end of the range. At the left end of each BIT line range scrutinised, if there is a • write a '1' BIT or if there is a crossing tick mark write a '0' BIT. When complete, note the number of the BIT line on the DEC2 scale in which the decimal number is located. This indicates the number of integer BITs in the equivalent binary number. Append trailing 0's to the binary string written as required so that its length is equal to the number of integer BITs noted (or insert a point after the noted number of BITs if appropriate). The string of BITs written is the equivalent binary of the decimal number. Note that the first BIT will always be '1' from the leftmost end of the 1-BIT line.

For numbers with a binary length greater than 10-BITs, the value is located as described above and the first 10-BITs of the binary equivalent built. An appropriate number of '0's are appended to make the binary length string correct.

Example 2: Convert 154_{10} to base 2 (Figure 9).

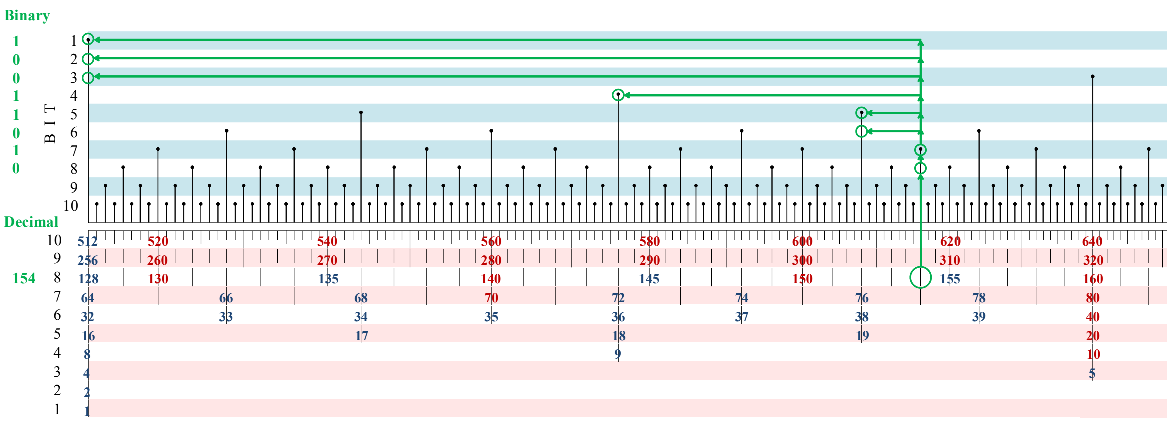

Figure 9. Converting 154_{10} to binary (note BIN1 and DEC2 scales are shown adjacent)

Find the tick mark representing '154' on the 8-BIT line of the DEC2 scale and position the cursor hairline over the tick mark. Refer to the BIN1 scale. Look at the 1-BIT line from beneath the hairline and to the left. There is no • under the hairline and no tick marks cross the BIT line before the • at the left-hand end, so write a '1' as represented by the •. Next look at the 2-BIT line, there is no • under the hairline nor to the left before the tick mark from the first bit crosses it at the left end, so write a '0'. Similarly, the 3-BIT line has no • under the hairline nor to the left before the tick mark from the first and second bit crosses it, so again write a '0'. The 4-BIT line is clear under the hairline, but there is a • to the left of it before a crossing tick mark, so write a '1'. The 5-BIT line has nothing under the hairline but to the left of it there is a • before a crossing tick mark, so write a '1'. The 6-BIT line has no • under the hairline nor to the left before the tick mark from the fifth bit crosses it, so write a '0'. The 7-BIT line has a tick mark with a • under the hairline which means this is the last BIT line that needs to be scrutinised, so write a final '1'. The original value '154' was found on the 8-BIT line of the DEC2 scale, meaning there are 8 integer bits in the equivalent binary number. The binary string written is '1001101' which has seven bits, so an additional '0' must be appended to give it the required 8 integer bits. Therefore 154_{10} = 10011010 in binary.

Performing Multiplication and Division

Multiplication and division are performed in similar way to using the C and D scales on a standard logarithmic linear slide rule. Either of the binary primary, decimal equivalent or a combination of both scale pairs can be used for the calculations, and conversions read if required.

When calculating with binary numbers greater than 10-BITs, only the first 10 BITs from the first '1' BIT are used. The full count of BITs in each number is then used to determine the magnitude of the final answer. Answers with more than 10-BITs are padded with trailing '0's to the required length. Decimal values and equivalents must be factored as described above if they are beyond the 10-BIT range.

Multiplication

To multiply two numbers, construct the first factor on the BIN1 scale (or locate it on the DEC2 scale) and position the cursor hairline over the tick mark. Move the slide so that either the left or right-hand index end is underneath the hairline, as appropriate to enable the answer to be read in the stock scale range. Construct the second factor on the BIN2 scale (or locate it on the DEC1 scale) and position the hairline over the tick mark. Read the answer on the BIN1 scale (or the DEC2 scale), determining the number of integer BITs as follows:

(No. of integer BITs in answer) = (No. of integer BITs in first factor) + (No. of integer BITs in second factor) - (0 if the slide protrudes to the left, or 1 if the slide protrudes to the right).

Example 3: What is 100011_2 multiplied by 1001_2 in binary, and what is the completed sum in decimal?

Construct the 6-BIT first factor, 100011, on the BIN1 scale (Figure 10a). The • on the left-hand end of the 1-BIT line represents the first '1' BIT in the factor, so position the cursor hairline over it. Ignore the second, third and fourth BITs as they are '0's. The fifth BIT is a '1' so move the hairline to the right along the 5-BIT line until it is over a •. The last (sixth) BIT is also a '1', so continue moving the hairline until it is over a • on the 6-BIT line. Refer to the 6-BIT line on the DEC2 scale and read the decimal equivalent of the first factor to be '35'.

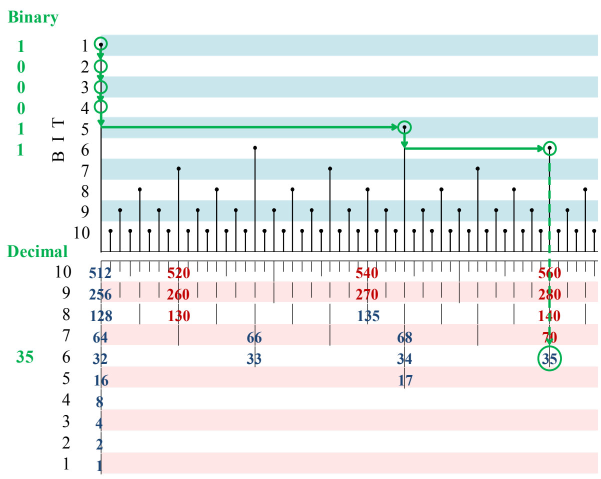

Figure 10a. Constructing 100011_2
(note BIN1 and DEC2 scales are shown adjacent)

Next, move the slide so that the left-hand index end is under the hairline (Figure 10b). Now construct the second factor, 1001, on the BIN2 scale. The • on the 1-BIT line under the hairline represents the first '1' BIT. The second and third BITs can be ignored as they are '0's. The fourth (last) BIT is a '1', so move the hairline to the right along the 4-BIT line until it is over a •. Refer to the 4-BIT line on the DEC1 scale, and under the hairline read the decimal equivalent of the second factor to be '9'.

Read the answer to the multiplication on the BIN1 scale (Figure 10c). The first BIT is a '1', represented by the • to the left of the hairline at the left-hand end of the 1-BIT line. The 2-BIT and 3-BIT lines do not have a • under the hairline, and there are no •'s to the left of the hairline before the tick mark from the first BIT crosses them, so write '00'. The 4, 5 and 6-BIT lines are clear under the hairline, and each have a • to the left of the hairline, so write '111'. To the left of the hairline on the 7-BIT line is the tick mark crossing from the sixth BIT, indicating a '0' in this position. The

8-BIT line is clear under the hairline and has a • to the left of the hairline, so write a '1' for the eighth BIT. On the 9-BIT line there is a • under the hairline, so write a final '1'. The first factor has 6 BITs, the second factor has 4 BITs and the slide protrudes to the right, so there are 6 + 4 – 1 = 9 integer BITs in the result. The binary string written, '100111011', is 9 BITs long and so is the final answer. Refer to the DEC2 scale to read the decimal equivalent of the answer to be '315' under the hairline on the 9-BIT line. The decimal sum is therefore 35 x 9 = 315.

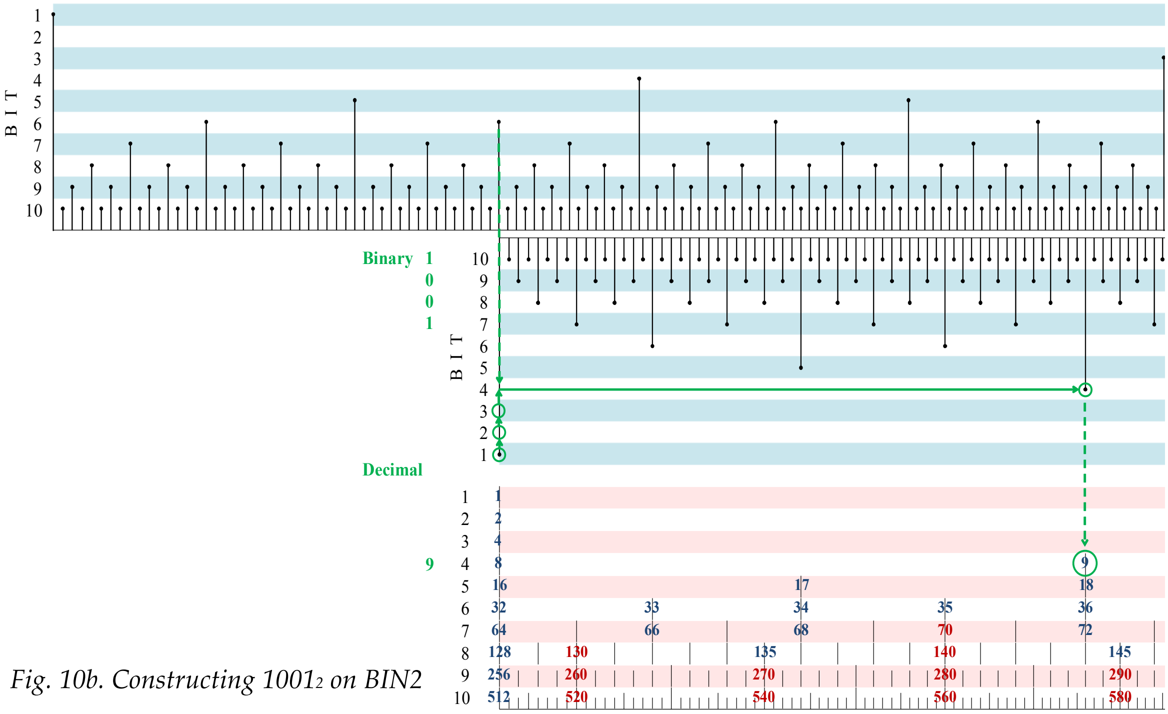

Fig. 10b. Constructing 1001_2 on BIN2

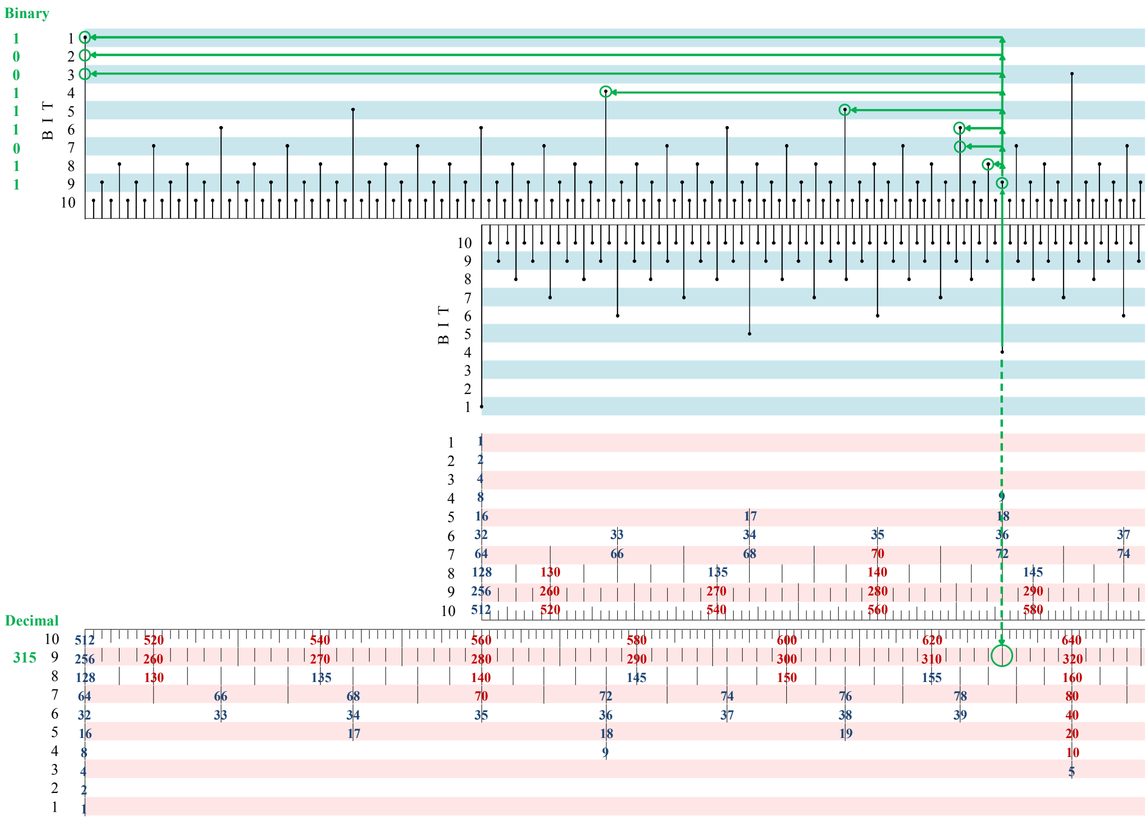

Figure 10c. Reading answer 100111011_2 on BIN1

Division

To divide two numbers, construct the dividend on the BIN1 scale (or locate it on the DEC2 scale) and position the cursor hairline over the tick mark. Construct the divisor on the BIN2 scale (or locate it on the DEC1 scale) by moving the slide under the cursor hairline until the appropriate tick mark is underneath the hairline. Position the hairline over the index end of the slide that is inside the stock scale range. Read the answer on the BIN1 scale (or the DEC2 scale), determining the number of integer BITs as follows:

(No. of integer BITs in answer) = (No. of integer BITs in dividend) - (No. of integer BITs in divisor) + (0 if the slide protrudes to the left, or 1 if the slide protrudes to the right).

Example 4: what is 10101100_2 divided by 101_2 in binary?

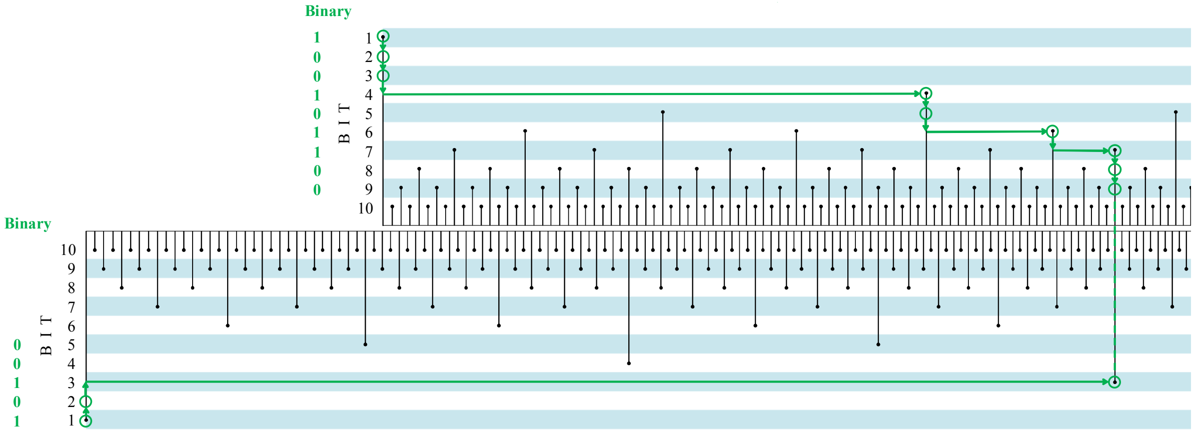

Figure 11a. Constructing 10101100_2 divided by 101_2 on BIN1 and BIN2

First construct the dividend 100101100 on the BIN1 scale (Figure 11a). Set the cursor hairline over the • at the left-hand end of the 1-BIT line, representing the first '1' BIT. The second and third BITs are '0' so ignore them. The fourth BIT is a '1' so move the cursor to the right along the 4-BIT line until the hairline is over a •. Ignore the fifth BIT as it is a '0'. The sixth BIT is a '1' so move the cursor to the right until the hairline is over the next • on the 6-BIT line. The seventh BIT is also a '1', so again move the hairline to the right along the 7-BIT line until it is over a •. The last two BITs can be ignored as they are both '0'.

Next, construct the divisor, 101, on BIN2 scale on the slide by moving the slide rather than the cursor hairline (Figure 11a). Move the slide under the cursor so that the • on the left-hand end of the 1-BIT line is under the hairline, representing the first BIT. The second BIT is '0' so ignore it. The last BIT is a '1' so move the slide to the left until there is a • on the 3-BIT line under the hairline.

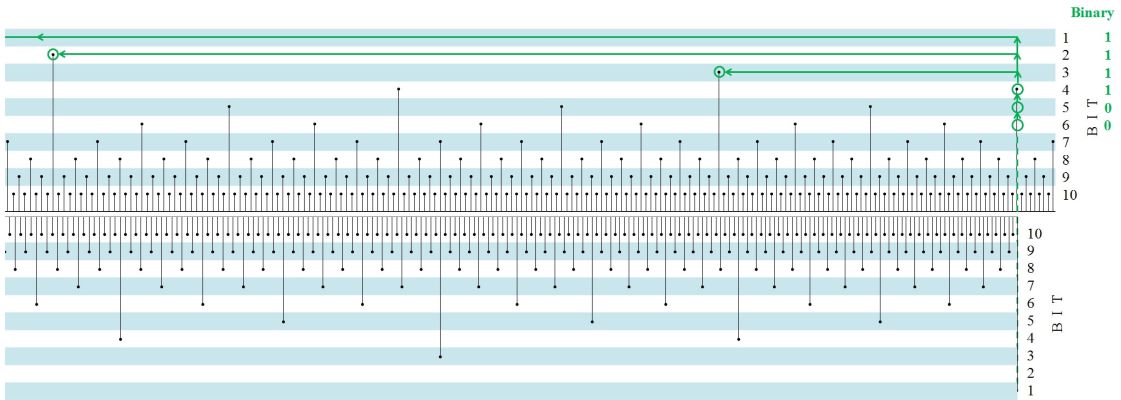

Figure 11b. Reading answer 111100_2 on BIN1 (most significant '1' BIT at left end of 1-BIT line not shown)

Now move the hairline over the right-hand index end of the slide and refer to the BIN1 scale to read the answer (Figure 11b). There is a • to the left of the hairline at the far end of the 1-BIT line, so write a '1'. Both of the 2 and 3-BIT lines are clear under the hairline, and there is a • to the left of it so write '11'. Under the hairline on the 4-BIT line there is a •, so finish by writing '1'. The dividend has 9-BITs, the divisor has 3-BITs and the slide protrudes to the left, so the answer has 9 – 3 + 0 = 6 integer BITs. The number of BITs written out is 4, so 2 '0's must be appended, giving the answer as 111100_2.

Example 5: What is 355_{10} divided by 113_{10} in binary (Figure 12)?

First, locate the tick mark for 355 on the 9-BIT line of the DEC2 scale and position the cursor hairline over it. Next, locate the tick mark for 113 on the 7-BIT line of the DEC1 scale and move the slide so that the hairline is over it, thus aligning 355 on DEC2 with 113 on DEC1.

Now move the cursor so the hairline is over the right-hand index end of the slide. Refer to the BIN1 scale to read the binary answer. On the 1-BIT line there is a • to the left of the hairline at the extreme left-hand end, so write a '1'. On the 2-BIT line there is also a • to the left of the hairline, so write another '1'. The 3-BIT and 4-BIT lines have the tick mark from the second BIT crossing them to the left of the hairline, so write '00'. The 5-BIT line has a • to the left of the hairline, so write a '1'. The 6-BIT and 7-BIT lines both have the tick mark from the fifth BIT crossing them to the left of the hairline, so again write '00'. The 8-BIT line has a • to the left of the hairline so write a '1'. Finally the 9-BIT and 10-BIT lines both have the tick mark from the eighth BIT crossing them to the left of the hairline, so write '00'. At no stage is there a • under the hairline and there are no more BIT lines to scrutinise. The 10-BIT binary string written is '1100100100'. The number of integer BITs in the dividend is 9 (355 is on the 9-BIT line of DEC2), the number of integer BITs in the divisor is 7 (113 is on the 7-BIT line of DEC1) and the slide protrudes to the left. The number of integer BITs in the answer is therefore 9 – 7 + 0 = 2 BITs, so a point must be placed after the second BIT in the binary string, making the answer 11.001001_2.

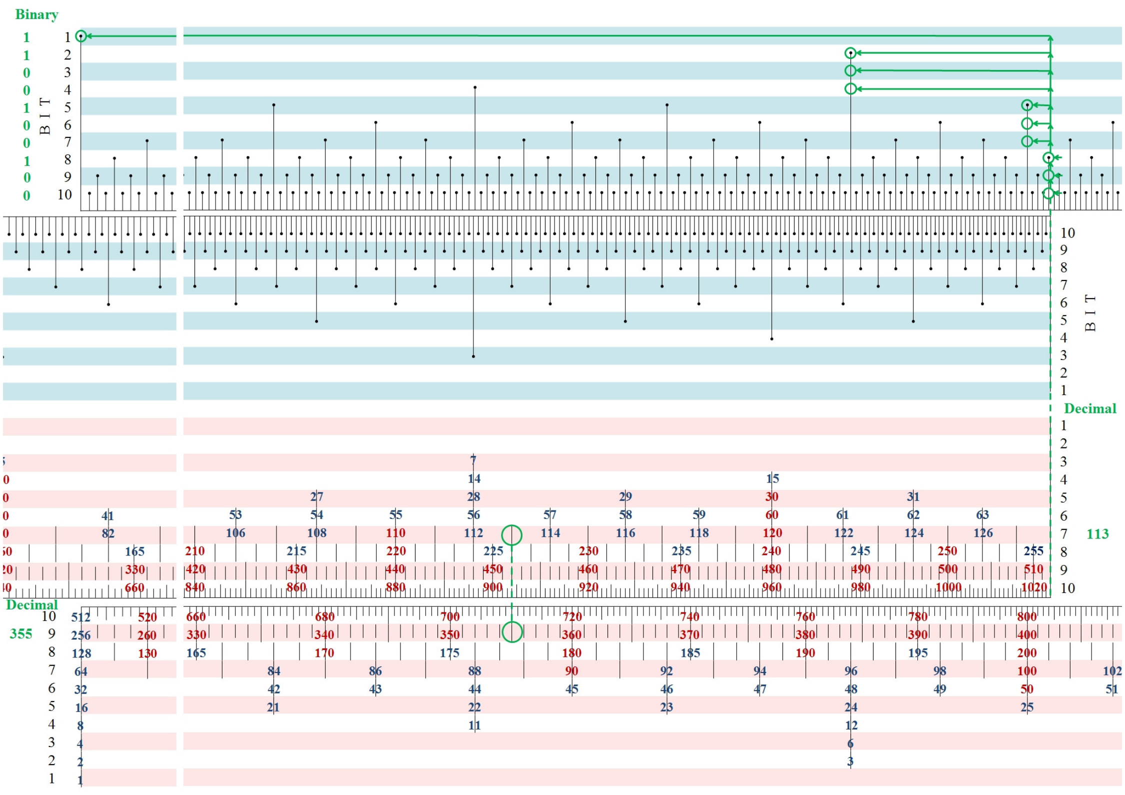

Figure 12. 355_{10} / 113_{10} = 11.001001_2 (note scales shortened)

Radix Model Series

The scale layout and slide rule design can be used to create Radix series slide rules with other combinations of bases for the primary and equivalent scales. The logarithmic primary scales in one base are designed in a similar way to the base 2 scales, but using digit lines and value labels rather than the SYSTEM LEIBNIZ markings. The equivalent scales in another base would have the same structure as the primary scales, but the values are labelled according to the alternative base. Reading the scales, multiplication and division in the primary base are performed in the same way as using a typical decimal linear slide rule, but with base conversions possible between the primary and equivalent scales.

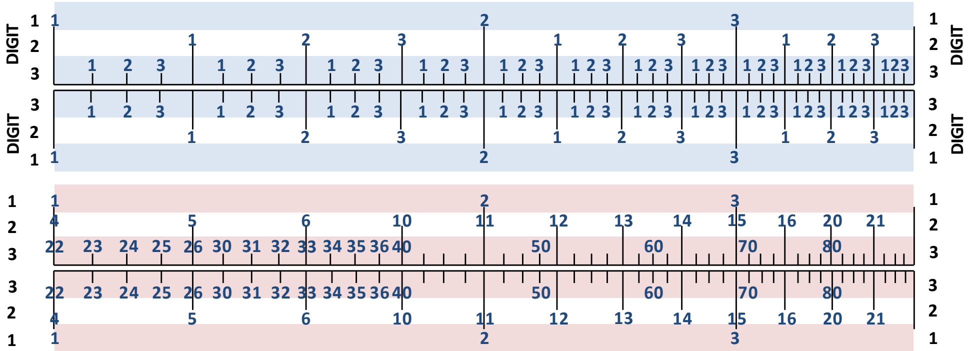

Figure 13. Scale layout for 3-digit depth base 4 / base 7 slide rule

Figure 13 shows a simple example of how the layout would work for a base 4 primary and base 7 equivalent scale slide rule with a 3-digit depth scale. In this example, the scales span the integer range 1_4 to 1000_4 (base 4) and 1_7 to 121_7 (base 7), which is 1_{10} to 64_{10} (decimal). Each of the three digit lines has a range as follows:

1-digit: 1_4 to 10_4 and 1_7 to 4_7 (1_{10} to 4_{10})

2-digit: 10_4 to 100_4 and 4_7 to 22_7(4_{10} to 16_{10})

3-digit: 100_4 to 1000_4 and 22_7 to 121_7 (16_{10} to 64_{10})

The scale depth and tick marks on a finished model would be determined by the required specification of precision and physical size. A model with this base configuration would be a Radix 4/7 according to the naming convention.

Conclusion

The idea behind the Radix 2/10 and then a model series based on the design was born while trying to broaden my understanding of the workings of slide rules. Developing the scale design certainly achieved this as well as presenting new avenues for investigation. Taking the design to its conclusion in building semi-professional working examples was perhaps a little excessive, but even that process posed new challenges concerning the practical design of the slide rule and its physical construction.

I suspect that the binary/decimal slide rule would not have been a must-have for the computer programmer if it had been around when digital electronic computing started and low level programming was more widespread than it is today. In fact, it probably would not have been used at all. However, I now have a device that, with a little practice and care, can be used to convert between binary and decimal numbers and perform binary multiplication and division relatively quickly and accurately. The design also has the potential to be used to create linear logarithmic slide rules with these functions in other dual base configurations.

The Radix 2/10 slide rule may be of limited practical use, but neither this nor whether it would have been used by programmers is really the point - it has been an interesting exercise.

Addendum - Final Thought on Precision

A typical 250mm scale length base 10 linear slide rule with an absolute precision from tick marks of 1/200 has a minimum tick mark interval of 0.54mm between 9.95 and 10.00. A binary slide rule of the same scale length and minimum tick mark interval width would have a theoretical absolute precision of 1/663 ($2^{9.37}$), which is 3.32 times more precise.

Looking at it another way, a base 10 linear slide rule with a minimum tick mark interval of 1mm and absolute precision of 1/1000 would have a 2.3 metre scale length. This is about half as long again as an Otis King scale[5] which has the same absolute precision. The binary scale with the same minimum tick mark interval and precision would be only 0.693m long, or 3.32 times shorter than the linear decimal scale.

In terms of absolute precision a binary scale would be 3.32 times more precise than a decimal scale for the same scale length and minimum interval width, or 3.32 times more compact for the same absolute precision and interval width. Accepting that an experienced user can achieve the usual quoted working precision of 1/1000 from a typical 250mm decimal scale, then it is not unreasonable that the user could accurately determine a single further unmarked BIT. With the same scale length and minimum tick interval width of 0.54mm, the binary scale would have a theoretical working precision of about 1/1326 ($2^{10.37}$). This is still 33% more precise than a decimal scale for the same scale length.

The greater precision is achieved due to the greater efficiency of the binary scale over the decimal scale in its re-use of tick marks. The binary scale re-uses every other tick mark for each additional BIT, whereas a decimal scale re-uses only one in ten for each additional digit.

Perhaps what a logarithmic binary slide rule really provides is a scale that can achieve a much greater precision for its length than a base 10 scale. Maybe those obsessed with precision, making ever longer decimal scales, should really have been looking to binary scales?

Acknowledgements and Bibliography

Special thanks to David Rance for his interest and enthusiasm for this project without which it may not have seen the light of day, and also for his insight and thoughtful suggestions which have enhanced the final design. Thanks also to Otto van Poelje and Rod Lovett for their suggestions and editorial work on this paper.

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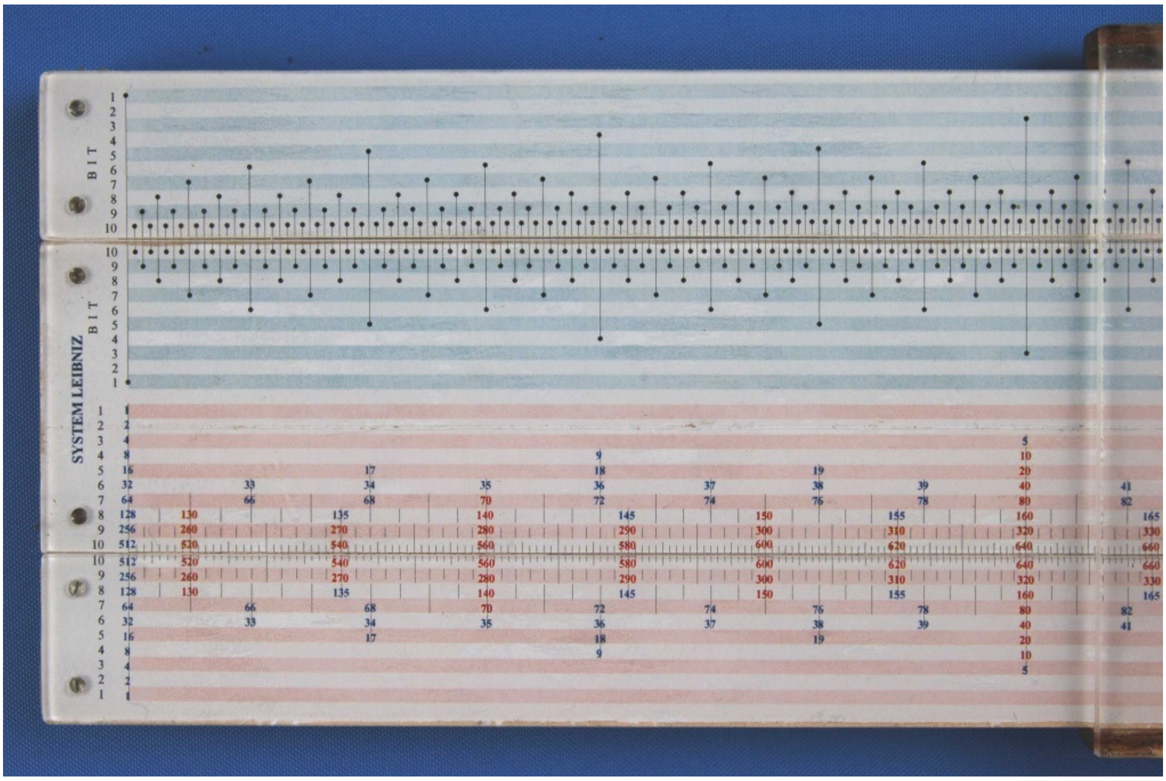
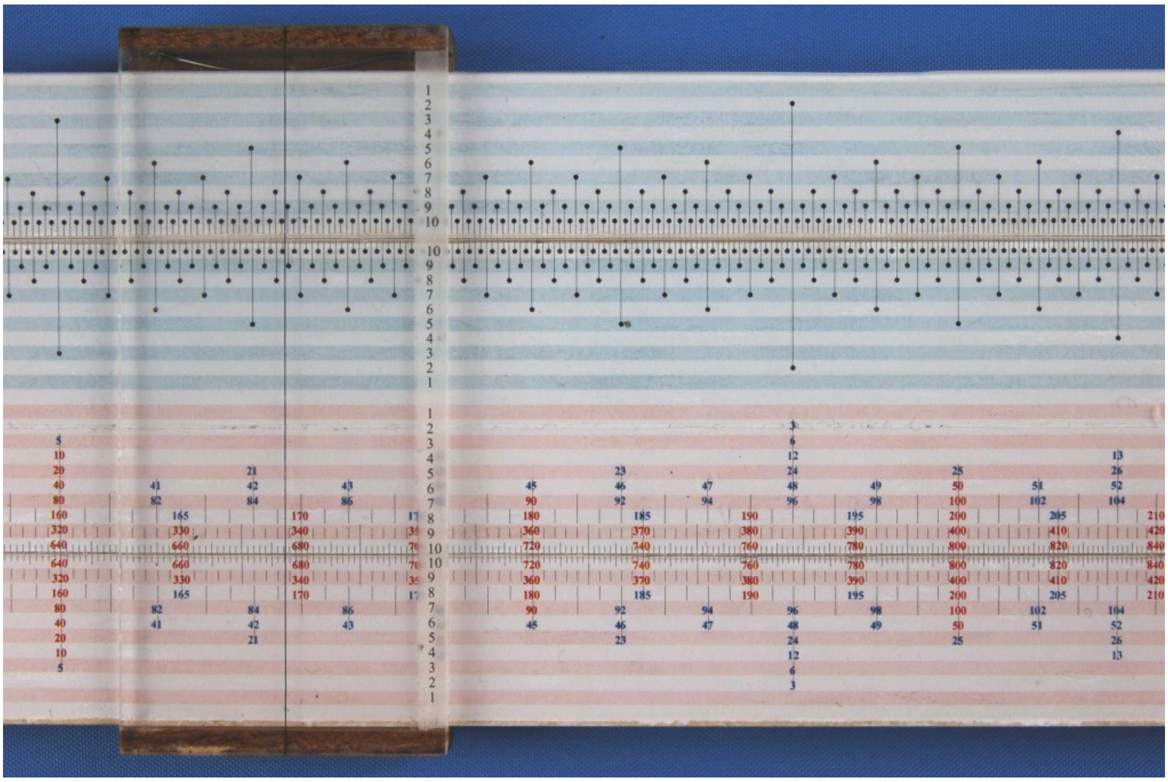
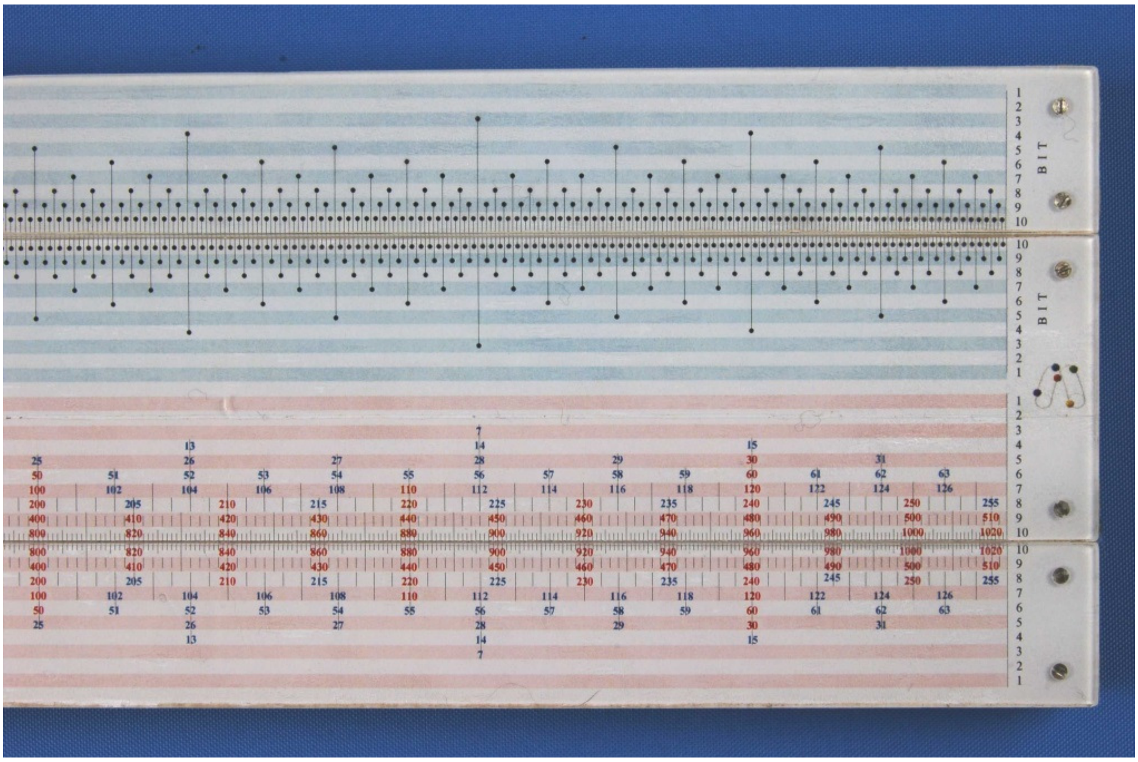
Appendix – Radix 2/10 Specification and Images

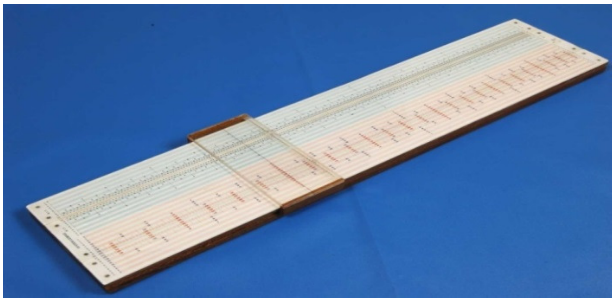
Scale Details







Specifications

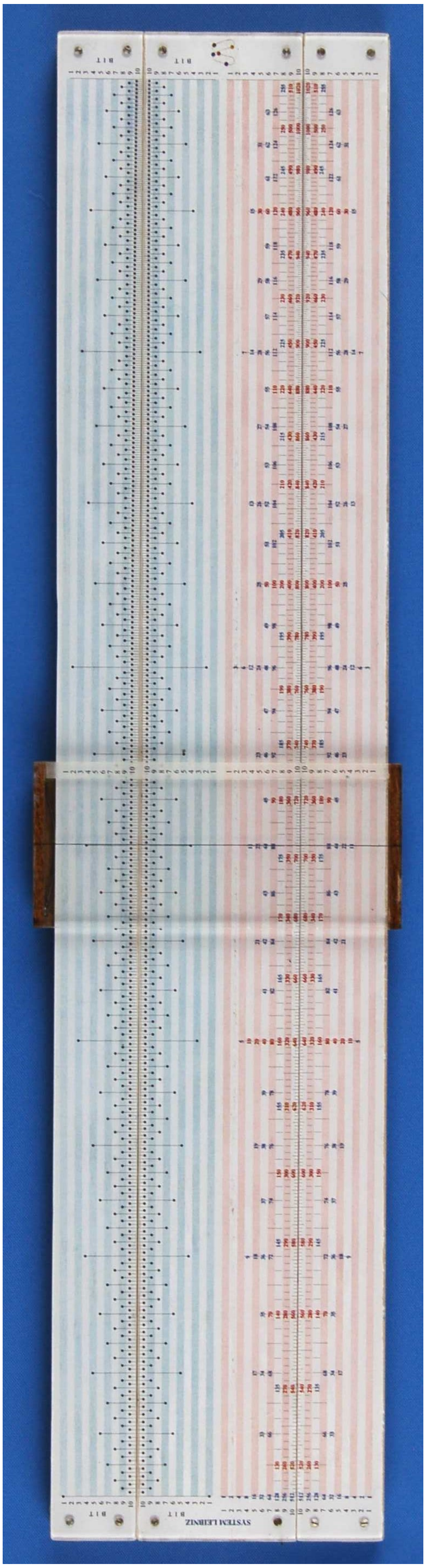


Summary			
System:	System Leibniz		
Specialization:	Binary calculation		
Type:	Closed frame, single sided		
Material:	Mahogany laminate		
Facings:	Perspex/paper		
Scale Length:	390mm	No of	4
Front Length:	420mm	Front	92mm
Language:	English	Origin:	England
Date:	2013, October		

Features/Notes:	Desktop logarithmic 10 bit binary rule with decimal conversion.		
Scales (colours as shown)			
Front:	§ [§, §] §		
Labels Left:	BIT 1 2 3 4 5 6 7 8 9 10 [BIT 10 9 8 7 6 5 4 3 2 1, 1 2 3 4 5 6 7 8 9 10] 10 9 8 7 6 5 4 3 2 1		
Labels Right:	BIT 1 2 3 4 5 6 7 8 9 10 [BIT 10 9 8 7 6 5 4 3 2 1, 1 2 3 4 5 6 7 8 9 10] 10 9 8 7 6 5 4 3 2 1		
Style:	Multi-line 10 BIT	Typeface:	Serif
Extensions:	-	Decimals:	-
Gauge Marks:	-	Rulers:	-
Features/Notes:	Printed on paper with Perspex facing. § scale on upper stock rail is a specialist 10 bit logarithmic binary scale, comprising 10 lines (1 for each bit) where a '1' bit is indicated with a '•', ordered most to least significant bit. § scale on upper edge of slide is a specialist 10 bit logarithmic binary scale, comprising 10 lines (1 for each bit) where a '1' bit is indicated with a '•', ordered least to most significant bit. § scale on upper edge of slide is a specialist equivalent decimal scale, comprising 10 lines of integer tick marks, ordered most to least significant bit. § scale on lower stock rail is a specialist equivalent decimal scale, comprising 10 lines of integer tick marks, ordered least to most significant bit. Alternate lines of the binary scales are shaded light blue for ease of reading. Alternate lines of the decimal scales are shaded light red for ease of reading. Numbers on the decimal scales are blue, with multiples of 10 in red for ease of location. Integers are labelled as follows: all 1-6 bit integers (1-63); even 7-BIT integers (64-127); 8-BIT integers divisible by 5 (128-255); 9-BIT integers divisible by 10 (256-511); 10-BIT integers divisible by 20 (512-1023); all powers of two.		

<table>
<tr><th colspan="4">Construction</th></tr>
<tr><td>Stock:</td><td colspan="3">Solid stock constructed from laminated 3.2mm and 6.4mm thick mahogany strip to make well, slide and cursor grooves.
Upper and lower rails equal widths - 24mm.
12mm wide rebate in well with paper/Perspex facing.
Front and well rebate faced with 1mm Perspex.
Paper scales and Perspex fixed with clear double-sided tape and anchored with M1.2 machine screws, two each at left & right ends of upper and lower rails (8 in total).
High cursor grooves.
No bevel to top and bottom edges.
Shallow rebate in back for paper tables.
Varnished excluding sliding contact surfaces and Perspex.
Length x Width x Height (mm) - 420 x 92 x 14</td></tr>
<tr><td>Slide:</td><td>Single sided
Constructed from laminated 3.2mm mahogany strip to form locating tongue.
Shallow rebate in back to reduce friction.
Front faced with 1mm Perspex.
Paper scales and Perspex fixed with clear double-sided tape and anchored with M1.2 machine screws, two each at left & right ends (4 in total).
Varnished exc. sliding contact surfaces / Perspex.
Front face width – 44mm.</td><td>Cursor:</td><td>Single central black hairline.
3mm thick Perspex pane attached to separate top and bottom runners.
Runners fashioned from laminated 3.2mm mahogany strip.
Varnished excluding sliding contact surfaces and Perspex.
Steel spring on top runner, mounted at left end with a M1.2 machine screw.
Width x Height (mm) - 45 x 100</td></tr>
<tr><th colspan="4">Printing (colours as shown)</th></tr>
<tr><td>Stock:</td><td colspan="3">“RADIX 2/10 - SYSTEM LEIBNIZ” in centre of well.
“MADE IN ENGLAND BY C TOMBEUR” + juggling pattern logo at right end of well.</td></tr>
<tr><td>Slide:</td><td colspan="3">“SYSTEM TOMBEUR” vertically at left end.
Juggling pattern logo at right end.</td></tr>
<tr><td>Cursor:</td><td colspan="3">-</td></tr>
<tr><td>Labels:</td><td colspan="3">On back, summary instructions, with footer “www.countbelmiro.com”
On cursor, “1 2 3 4 5 6 7 8 9 10 10 9 8 7 6 5 4 3 2 1 1 2 3 4 5 6 7 8 9 10 10 9 8 7 6 5 4 3 2 1” line number reference sticker on right edge of underside of pane.</td></tr>
</table>

Front & Back



Old Computing & New Generations

This will be the presentation of my project. I'll not be saying anything new and many of you may think that it's not very interesting, because you already know those facts; but for the general public it can be very interesting, precisely for the same reason: they do not know them!

We are all slide rule collectors, when we speak about our hobby we always communicate with people who have the cultural base to understand what we say and who like it.

It is different at an exhibit, or at a school. Most people do not understand or are not interested in what I am saying. Most of the time neither professors nor students have the slightest idea of what a slide rule is. A different approach is needed.

All I can do is to introduce people to the old computing tools and systems. If I am not so boring, they may afterward search additional information themselves.

All I can do is to sow a seed and sometimes it happens that I've created a monster: another slide rule collector!

I'm an amateur, there are no funds or organizations behind me.

Information communication technologies | Nicola Marras

Old Computing & New Generations
teaching slide rules and other historical calculating instruments at schools and science fairs

Nicola Marras

Introduction

The landscape framed by skyscrapers and everything we associate with modernity was designed with computers conceived in the 17th century, but young people have no idea of the tools that have made it possible. The modern world has short memory and soon the remembrance of the ancient calculating instruments will disappear.

This is my effort to keep them alive, through exhibits, conferences and lectures where analog and mechanical calculators can be tested by the public: it takes just a few minutes to communicate the existence of a world *before the computer*, a world where man reached the Moon!

Using my collection I explain the most significant calculators, from the abacus to the HP 35. The minimum *exhibit kit* is easily transportable, but I can create a true museum exhibition, with educational aids and interactive simulations. Sometimes I add a brief panorama of the traditional methods of navigation and, to complete the history of ancient technologies, I can show a telegraph station, telephones, typewriters and anything else necessary to recreate an office of the era.

My typical stand, with ancient calculators and navigational devices

Different locations for the history of computing

From 2008 I show every year at *Cagliari Festival Scienza*, an Italian science fair sponsored by the U.N.E.S.C.O. with more than 10,000 visitors, a brief history of calculators and slide rules.

The opportunity to touch and try the calculators has made the difference and there were always many people waiting to visit my stand. In 2013 I had more than 1,500 reservations: it was an average of three shows for 30 people each hour … no time to rest! The best compliment I got from a group of young girls who advised everyone: *"go to see the old computers, they are so cool"*. An unexpected success for a boring topic!

In 2013, I won the *Science on Stage Italy* contest for the best 12 innovative teaching projects of the year, and I was invited as official Italian delegate at Science on *Stage Europe 2013*, a biennial festival where around 350 pedagogues from 29 countries met to share their most innovative teaching ideas. The slipstick is still alive: examiners have decided that my exhibit on slide rules awake the mind and will be beneficial to the students, a great satisfaction for the work done.

It was possible for me to *teach to the teachers* how to present the old calculators and I made for the Polish television a short program, entitled *"Unplugged calculators: making a bridge between past and future"*.

Science on Stage 2013 and online at Polish television

The theoretic program

Nowadays calculations are delegated exclusively to electronic devices and the results are sometimes uncritically read on the display, without any idea of how they are produced. People punch numbers into a calculator and expect it to provide the correct answer: the skills of estimation and carrying decimals are no longer practiced.

With a calculator, modified to give *incorrect* results, I can show how easy it is to run into errors and that we should not blindly trust electronic aids. The digital display is not *"Word of God"*, this is what I hope will remain imprinted.

For many students the result of 2+3x4 is 20 (not 14!), but with slide rules they learn to recognize the order of operations. With *pascalines* and *addiators* children understand easily the addition and the Consul Monkey is the best way to teach the multiplication table.

The digital display is not *"ipse dixit"*: students must learn to understand and criticize what they do. Think *"if an expert says it, then it must be true"* is the base of the Authority Principle and of the mental slavery.

Teaching today slide rules and mechanical calculators to improve the basis of democracy may seem an exaggerated statement, but nobody can be a free citizen if he isn't conscious of what he does and ready to discuss it, in case an error is suspected. A believer can easily trust in an obviously false conclusion, despite being able to see that the answer is incorrect.

Not by chance the democracy was born in the same country in which maths and geometry were born. The use of critique is essential: it is a school of life rather than only of mathematics!

Also, scientific thinking is not a natural product of intelligence, it goes against human beliefs: even today most people still believe in astrology, UFOs, ghosts, etc.

Scientific thinking and independence of ideas must be cultivated. A simple lesson about traditional calculation may help ...

For a better vision of mathematics, my exhibits aims to:

- arouse curiosity about ancient computers;
- illustrate an entertaining history of computational tools;
- explain the difference between digital and analog;
- emphasize the differences between the ancient and modern methods of design;
- teach the practical use of pascalines, addiators, nomograms and slide rules;
- demonstrate that it is essential to use calculators and computers critically.

I strongly believe that nobody can learn mathematics without having a rough idea of how calculations were carried before the digital era: it would be like studying history starting only from the Industrial Revolution. I fully subscribe the IT History Society's mission *"ensuring the future by preserving the past"*.

As a static exposition of scientific instruments causes just a mild curiosity, I make a *dynamic* exhibit focused on quickly teaching *how to* use them. Math on the move!

With my educational material, downloadable for free from my website, the teachers can afterwards easily illustrate in the classroom the working methods of a past so recent.

Demonstrations of slide rules, pascalines and Consul Monkey

It is also useful to point out how the methods of design have changed over time: to draw the Brooklyn Bridge, it was necessary to have in mind from the beginning the finished product and the magnitude order of its weight.

Everything had to be calculated by hand and you could not disperse time in bad projects. Today, however, we can insert into the computer more than 1,000 different ideas and see what is feasible in a few minutes. A big difference: before there were many experienced engineers, today just a super-programmer and a multitude of simple users.

It is important to know how to calculate; Asimov's science fiction story *"The feeling of power"*, assuming a return to the old methods of calculation, ends with these words: *"Nine times seven, thought Shuman with deep satisfaction, is sixty-three, and I don't need a computer to tell me so. The computer is in my own head. And it was amazing the feeling of power that gave him"*.

Facing the reality

I make a test in the town streets, showing a slipstick: 99% of the people don't know what it is and they cannot believe that such a ridiculous tool made possible the conquest of the Moon. Many people think to be on candid camera television, in a program that searches for idiots who believe in those things.

The typical attitude of many students is:

- I do not know logarithms, not interested either;
- I do not know what a slide rule is, not interested either;
- I am a fast guy, I do not like boring topics.

So, about what is your lesson?
Hard to approach, I have to do it carefully, like walking on thin ice.

Solutions

We, the collectors, do not realize that our beloved slide rules can become terribly boring for the public, the approach must be careful to overcome the resistance. People dislike calculators that don't give quick results and we must at first wake up their interest, and then grow it up.

First I start with a classic pascaline, it is very easy and people can see as I am sometimes faster than a modern calculator, but slide rules are too difficult for students with no idea of logs.

I show a linear scale and a log scale, giving some example to solve with the last: *"obtain the fuel required for a trip when the rate of fuel consumption is 20 liters per hour and the estimated running time is 3 hours"*.

Nomograms and pascaline, an easy way to teach

A practical problem shows how these instruments are not theoretical absurdities but useful tools. Then I use the nomograms, easy to read, to introduce the slide rules.

What slide rule is best? A normal one is too difficult for those modern students. In my experience it is the E6-B. I use the model designed by Ben Jackson: can be built in few minutes just with the help of a pair of scissors and it is very easy to read.

I have also classical models of paper slide rules, mostly designed by the ARC members, but these must be taught in school. No time in a 10 minutes show!

The E6-B is useful to solve practical problems that captivate the youngsters: *"we are flying from Rome to Venice, then an unexpected front wind slows our speed of 20 miles/hour: with our rate of fuel consumption the gasoline will be sufficient, or we must search for an alternate landing?"*

My paper E6-B is useful on aircraft and once I exposed a real one!

Of course I can show only simple problems: no time for the graphic wind triangle, this can be done later by the teacher or by themselves, if interested.

Once, with my aero club, I exposed an airplane in the fair. A great success and the Italian Air Force supported me in the teaching. With my easy to build E6-B the students feel immediately like Mr. Spock, but it is a real instrument and can also be used on an aircraft!
I also explain how slide rules can be used in rallies, another fascinating topic for boys: "*a car in a competition must average 28 m.p.h. and the distance to be covered is 42 miles: how long should it take?*"
I also show the E6-B watch and how I use it in classic races: the attention is always guaranteed!

From 2014, due to restrictive laws, I cannot teach anymore in schools, neither for money nor for free. The only solution left is to organize informal meetings with the teachers, to illustrate my program, and give conferences to *teach how to teach* the old calculation systems. From my website it's possible to download all the needed material. I hope this program will become official in some schools.


The teachers first needs a lesson: those who don't knows can't teach!

I can just keep working with the Science Fairs. I have presented the application to participate at *Science on Stage 2015* in London with my project "*Old Computing, Science Thinking & Democracy*". I'm also trying to produce a short TV spot about old computing.

Also very important to me is my *teachers program*: most teachers have never seen a slide rule or heard about it: a real problem: those who don't know can't teach! I show them the old calculators, so afterwards they can explain them in the classroom.

Conclusion

This is my effort to keep the old calculators alive, for more information my book "*Was There Life Before Computers*" and all the didactic material are in the freely distributed CD, or can be downloaded for free at www.nicolamarras.it/im14 .

Let us remember those who helped to create the modern world *using* technology, not *depending* on it. We often use electronics as the alcoholic does with the streetlight: to lean on and not to make light.

Fermi, Oppenheimer and von Braun had a slide rule less powerful than any smartphone and calculation is now within the reach of everybody, how many will be able to do better?

Special Thanks TO

A.R.C. - CagliariFestivalScienza - Jorge Fabregas Zazza - fare ScienzA - Alvaro Gonzales Firpi - The Oughtred Society - PhotoCalcul - Science On Stage Europe - Science On Stage Italia – Otto van Poelje

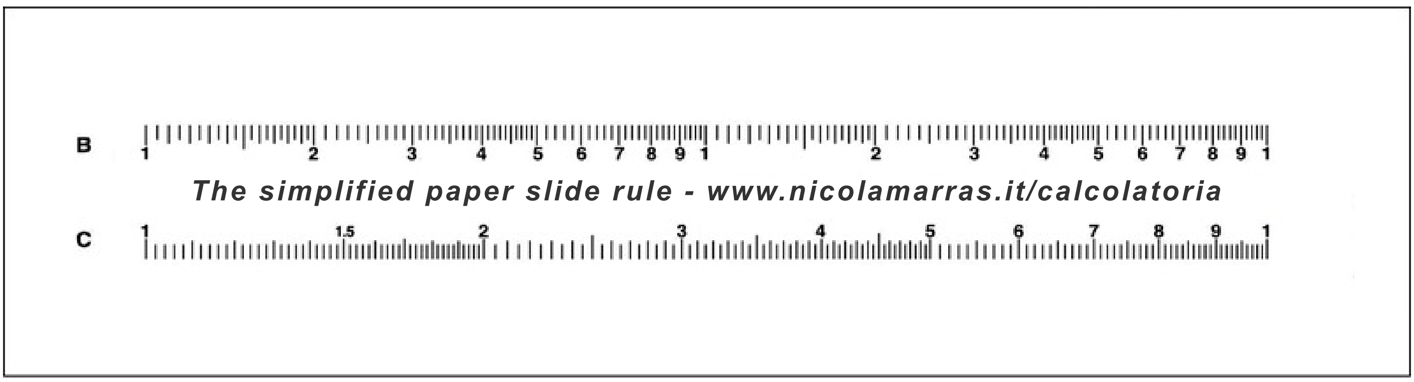
Paper Clip Slide Rule Appendix →

The paper slide rule

See how calculations used to be done before the days of electronic calculators, find out about an important piece of engineering history with this paper slide rule, ideal to learn without getting confused between many scales. Cut along the solid lines, fold along the dotted lines and put the slide inside the body. As cursor use a clip of approx. 5 cm.

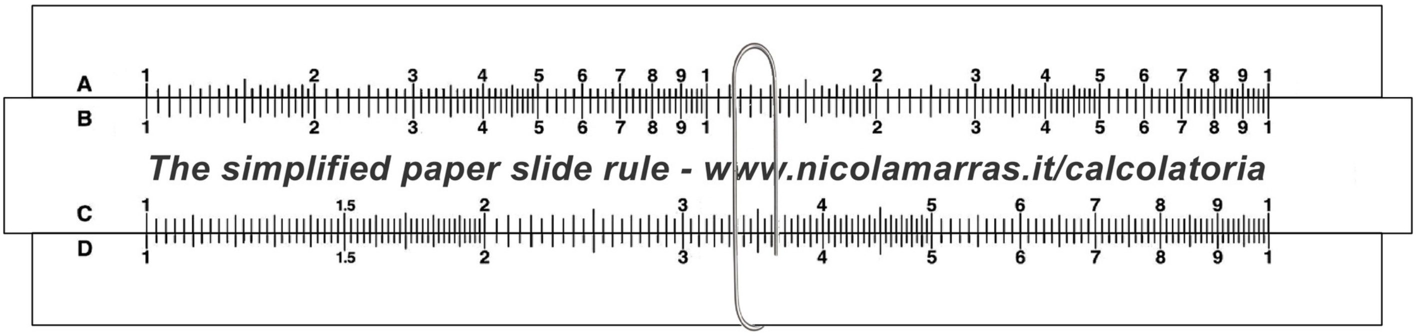
Body

Slide



Instructions

The slide rule and its clip cursor



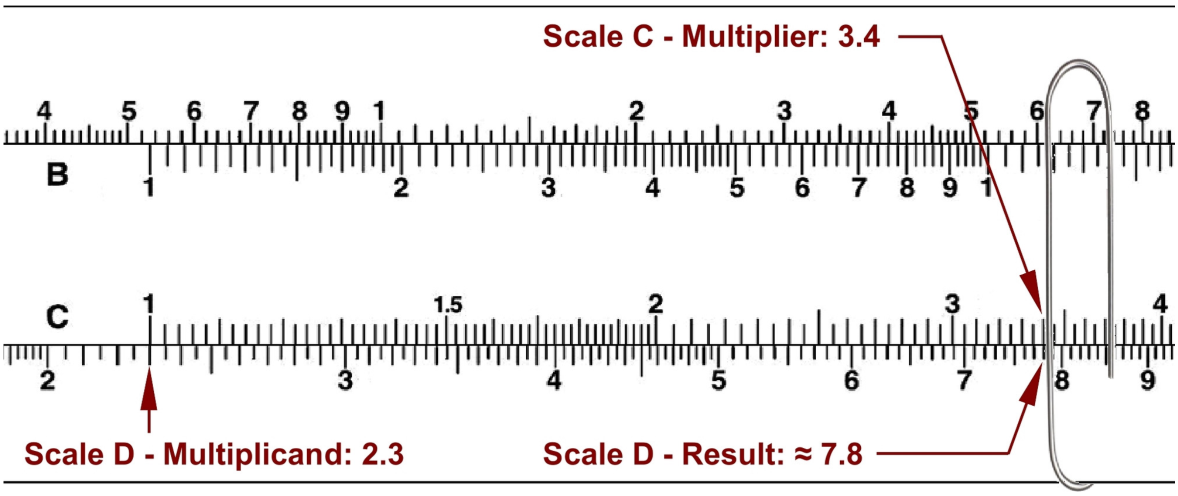
Slide rule: examples to practice

In the slide rules the scales are indicated by letters: the two most important are on the slide (C) and on the body (D). The others are used to simplify the calculations when you are in the presence of square roots (A and B), cubes and cube roots (K), exponential (LL), etc. up to more than 30. In this simple slide rule we find only the essentials: A-B-C-D. As cursor we will use just a clip, then the numbers should not be placed under it, but immediately to his left side.

Multiplication (uses C and D scales)

Example: 2.3 x 3.4

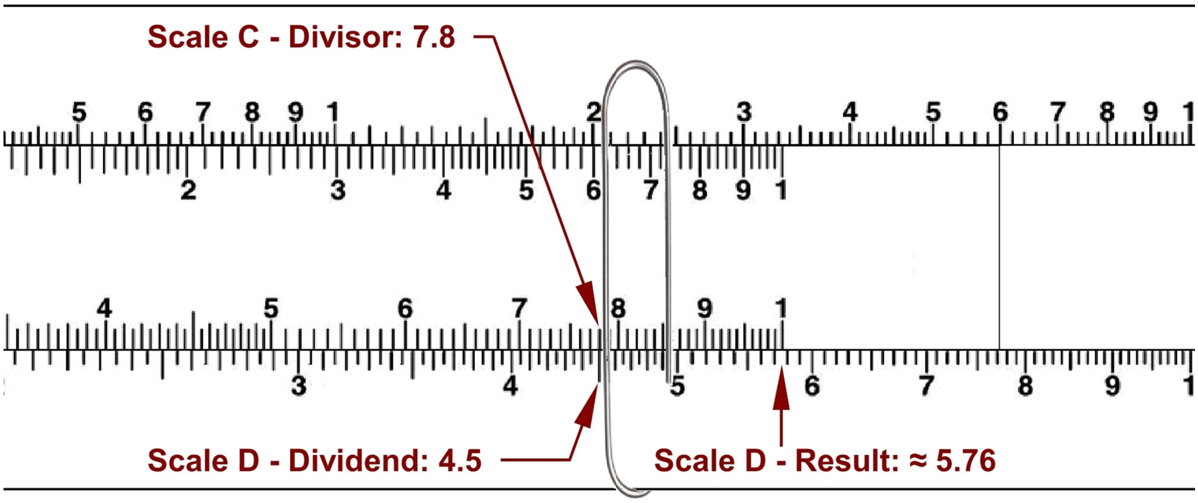
- slide the **C** leftmost '1' on by side 2.3 on the **D scale**;
- move the cursor by side 3.4 on the **C scale**;
- the cursor is now on the **D scale** just a bit over 7.8. The correct answer is 7.82.



Division (uses C and D scales)

Example: 4.5 / 7.8

- move the cursor by side 4.5 on the **D scale**;
- slide 7.8 on the **C scale** by side the cursor;
- the **C** rightmost '1' is now at 5.76 on the **D scale**. We know that the result of 4/8 is near 0.5, so we adjust the decimal place to get 0.576. The correct answer is 0.576.



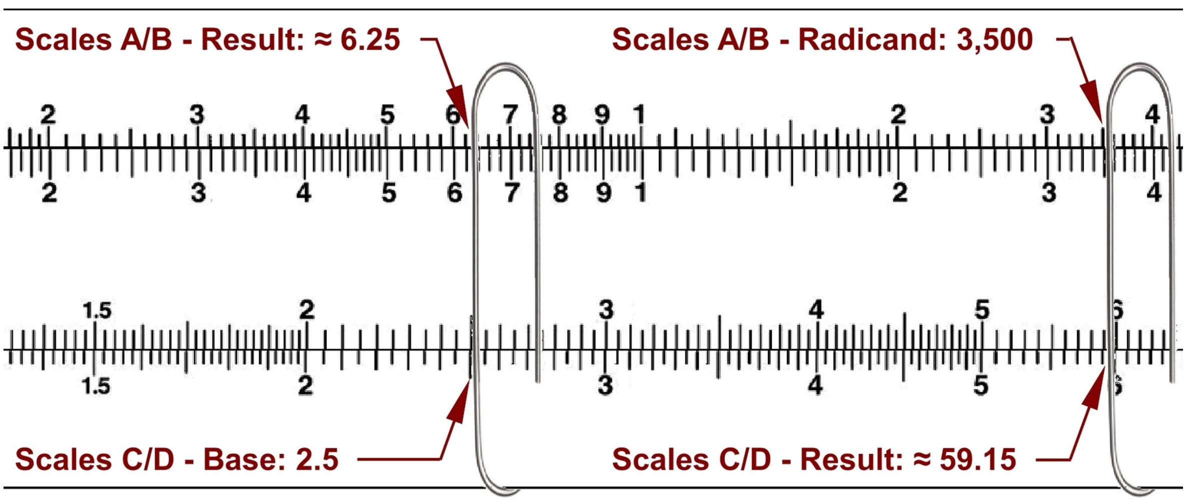
Squares and Square roots (uses A and D or B and C scales)

Example: $2,5^2$

- moving the cursor by side 2.5 on the **C scale**; we get on the **B scale** ca. 6.25; The correct answer is 6,25.

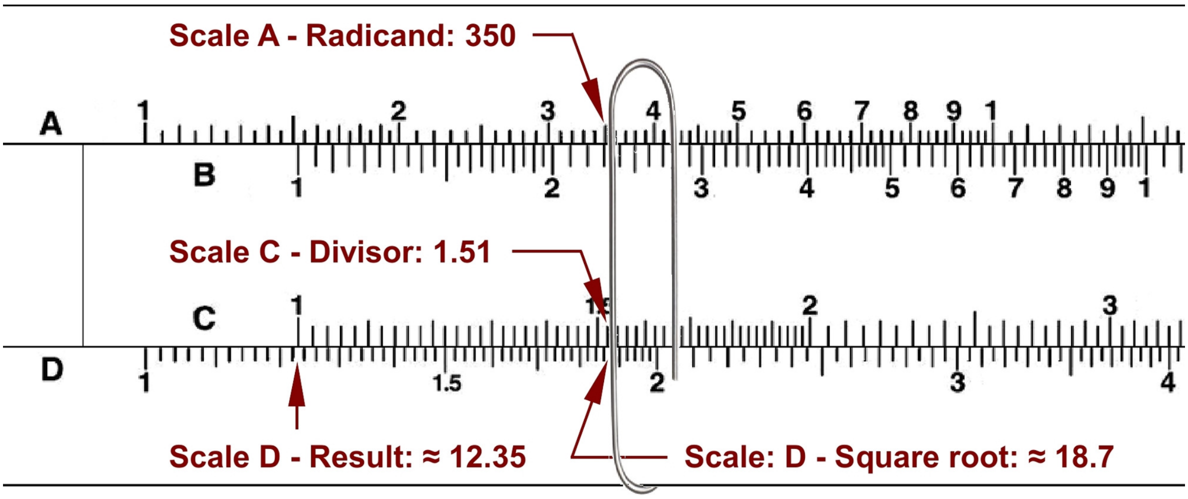
Example: $\sqrt{3.500}$

- the **A and B scales** have two similar halves. The left half is used to find the square root of numbers with odd numbers of digits; the right half is used for numbers with even numbers of digits. Since 3.500 has an even number of digits we'll use the right half of the scale. Moving the cursor by side 3,5 of the **A/D scales** we get on the **C/D scales** ca. 59,15. The correct answer is 59,16.



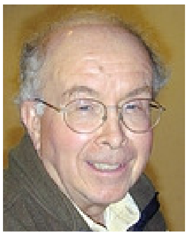
Now we can try this operation: √350 / 1,51

- moving the cursor by side the 350 of the **A scale** (odd number of digits, then the left side) we get its square root, 18.7, on the **D scale**;
- now we match 18.7 with 1.51 of the **C scale**: on the **D scale**;
- in correspondence with the **C** leftmost index '1', we can read the answer: ca. 12.35.



Not bad in a couple of seconds, armed only with a piece of paper and a paper clip! An electronic calculator would have been just a little more precise, finding 12.3896. This slight approximation has not prevented von Braun to send Man on the Moon: the slide rule is in fact less difficult than it sounds, the secret is just to practice, to practice and to practice ...

The Ross Precision Computer - Types I & II
A New Perspective



Edwin Chamberlain PE

Introduction

I have long been interested in the Ross Precision Computer, a circular spiral slide rule manufactured in San Francisco, California in the early 1900s. I have written about the Ross several times (1, 2, 3) in my papers on long scale slide rules. But it was not until recently that I became aware of two different versions of the Ross Precision Computer; two versions that have the same spiral scale, but look and operate differently. Here I will describe these two different slide rules, and will also discuss their operation. But first I want to introduce the Ross Precision Computer and Louis Ross, its inventor.

The Ross Precision Computer

In 1915 & 1916, Louis Ross made a series of press releases to several (at least 16 by my count) engineering and science journals. Here is an example of the introduction of the Ross Precision Computer (Fig.1) as reported in *The Colliery Engineer* journal in October of 1915 [5]:

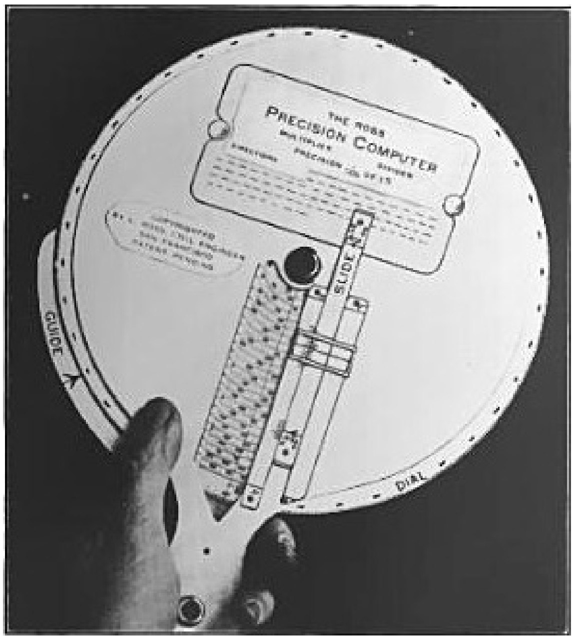


Figure 1. The Type I Ross Precision Computer from press release [4]

" **New 5-Place Computer** *Figuring is the bane of the engineer. The slide rule is a life-saver, but most tantalizing. It is just inaccurate enough to be insufficient for practical, precise engineering calculations. Attempts to increase its accuracy have resulted only in bulky, costly, and complex machines.*

A new calculator for engineers which gives an accuracy 100 times as great as the slide rule has recently been devised and placed on the market. Though only 8 inches in diameter, its accuracy is equivalent to that of a slide rule 100 ft long; it combines the accuracy of five-place, interpolated logarithms with the speed and convenience of a slide rule, without the drawbacks of either.

The length of the scale is 120 times as great as that of the A and B scales in the ordinary 10-inch slide rule; the system of graduations is uniform throughout, and reads five figures throughout, like 67342, 99893, etc.; the variable graduations of the slide rule have been eliminated in this computer. Most engineering data have accuracy from three to five figures, and calculations have therefore been carried out heretofore by logarithms to five places. The precision computer has been devised to do this work mechanically. Provision is made for obtaining instant, approximate results, more directly and simply than by use of the ordinary slide rule, where that accuracy is sufficient.

The Ross Precision Computer consists of a graduated dial rotating under a slotted cover, a floating guide, and a slide (rule) mounted at the right of the slot. The operation of the dial gives results to an accuracy of *five significant figures throughout. The slide(rule) carries a miniature of the dial scale, and may be used alone to obtain an accuracy of three figures; it cooperates with the dial to check and point out the precise answer, and to locate its decimal point.*

If desired, the computer may be used to read five-place logarithms of all numbers and antilogarithms of all numbers directly, much faster than from logarithmic tables. Powers, roots, and other complex operations may be carried out either approximately, or to a high degree of precision, as desired. Trigonometric calculations made by the precision computer give an accuracy of from three to five seconds of arc.

The precision computer is made of metal throughout; the graduations are engraved on silvered surfaces, like a surveyor's compass or transit. It has been invented by Louis Ross, civil engineer, San Francisco, and is manufactured by the Computer Mfg. Co., 25 California Street, San Francisco."

Louis Ross & His Slide Rules

Louis Ross was born in 1879 in the Ukraine, then a part of Russia [6]. He immigrated to the US with his mother and sister in 1892 when he was 13 years old. In 1900 when he was living in Boston, Ross enrolled as an engineering student at Harvard University in Cambridge, Massachusetts [7]. He graduated with two degrees, an arts degree in Civil Engineering in 1904 and a science degree in Civil and Topographical Engineering in 1905. After leaving Harvard, he went to work for the United States Geologic Survey (USGS) in Washington, DC [8], where he worked as a *Deputy Surveyor* in their Hydrographic Branch. While with the USGS in Washington, Ross wrote a comprehensive report on the *"Work of a (USGS) Deputy Surveyor"* for the Harvard Engineering Journal [9]. His primary interest in his early professional years, was thus, in land surveying.

In Ross's time, all surveying was done with mechanical-optical surveying instruments, surveying rods, measuring chains or tapes, pins, etc. All raw data was in the form of angles from the horizontal and vertical, and linear distances. The sun, stars and fixed survey datum points were used in conjunction with a Solar Ephemeris to reference survey plots and routes to true north and to longitude and latitude. All of this data had to be reduced by hand to surveyed routes, plots, contours, etc. using tables of logarithms or slide rules. By Ross's time, large diameter cylindrical slide rules, such as the Thacher, Fuller and the Swiss Rechenwalzen were seeing increased use to obtain the high degree of accuracy needed for surveying calculations. These precision calculating instruments could replace the tedious reading and interpolation of logarithms from tables to get the 5- digits precision needed for quality surveying work. But these cylindrical slide rules were not very portable, and their paper scale surfaces were easily damaged by rain or knocking during fieldwork. While the spiral slide rule had been invented long before this time in 1630 [10], no maker had yet successfully mass-produced a spiral slide rule that could give 5-digits precision. It would be Ross that would first achieve some success in doing this.

By 1908, Ross had made his way to San Francisco, California [11], where he continued to work for the USGS. He was, perhaps, drawn to California by family. From the 1910 US Census records [6], I found that he initially lived with his grand-aunt and her family in San Francisco. They were also immigrants from Russia. Ross continued working with the USGS in San Francisco, with a special interest in surveying and mapping, and soon prepared a colored topographic map for all of California and Nevada [12].

In 1913 [13] he began devising charts and diagrams for determining true north from observations (with a surveying transit) of the position of the sun in the sky. In the same year, Ross left the USGS, and began a private practice as a civil engineer. But he found, as we have read in his press release [4] for his Precision Computer, that his calculating tools (straight slide rules and log tables) were insufficient for making surveying calculations. To solve the true north calculation problem, he designed and began marketing a circular slide rule that he called the *Meridiograph* [14]. It was a circular slide rule for determining true north based on the methods that he described in his 1913 paper [13]. The Meridiograph was Ross's first slide rule. He made it in disk form of Celluloid plastic, and starting in 1914, he began describing this slide rule in a series of announcements in engineering journals.

In 1915, Ross began making announcements [15] in technical journals for a *"New 5-Place Computer"*, which he named the *"Ross Precision Computer"* (Fig. 1). As I will discuss later, this was a unique spiral slide rule. With the introduction of the Meridiograph and the Ross Precision Computer", Ross began his foray into the slide rule design and manufacturing business. In 1915 he also founded the Computer Mfg. Co. in San Francisco to make and sell his slide rules. His first announcement of the Ross Precision Computer was followed in the next 2-years by at least 16 more news releases describing this slide rule and its merits.

In August of 1916, Ross announced in the *Water & Sewage Works* journal [16] a *"New Trigonometric Numerical Computer,"* a circular slide rule with 2 disks, consisting of a smaller diameter disk nested flush with a larger diameter disk. He named this new slide rule the Ross Rapid Computer. Ross described the scale set on his Rapid Computer as being designed after the principles of *"Polyphase"* slide rules. His new slide rule was 8 inches in diameter and was made of Celluloid plastic. It had both number (A, B & BI) and trigonometric (10 different) scales in addition to *"degree to radian conversion"* and *"equal parts"* scales. It did not have log log scales, which had only been introduced by the Keuffel & Esser Co. a few years before Ross introduced his Rapid Computer. In 1921, Ross announced [17] an improved version of his Rapid Computer. This version was about 5 inches in diameter and made of metal with *"silvered"* scale surfaces. It had a similar size and form (but not scales) to what would a decade later be the Dempster RotaRule. Ross offered a table clamp and a magnifying glass as accessories for this new metal version of the Rapid Computer. I have named the 8 inch diameter Celluloid Rapid Computer the Type I version, and the 5 inch diameter metal version the Type II version.

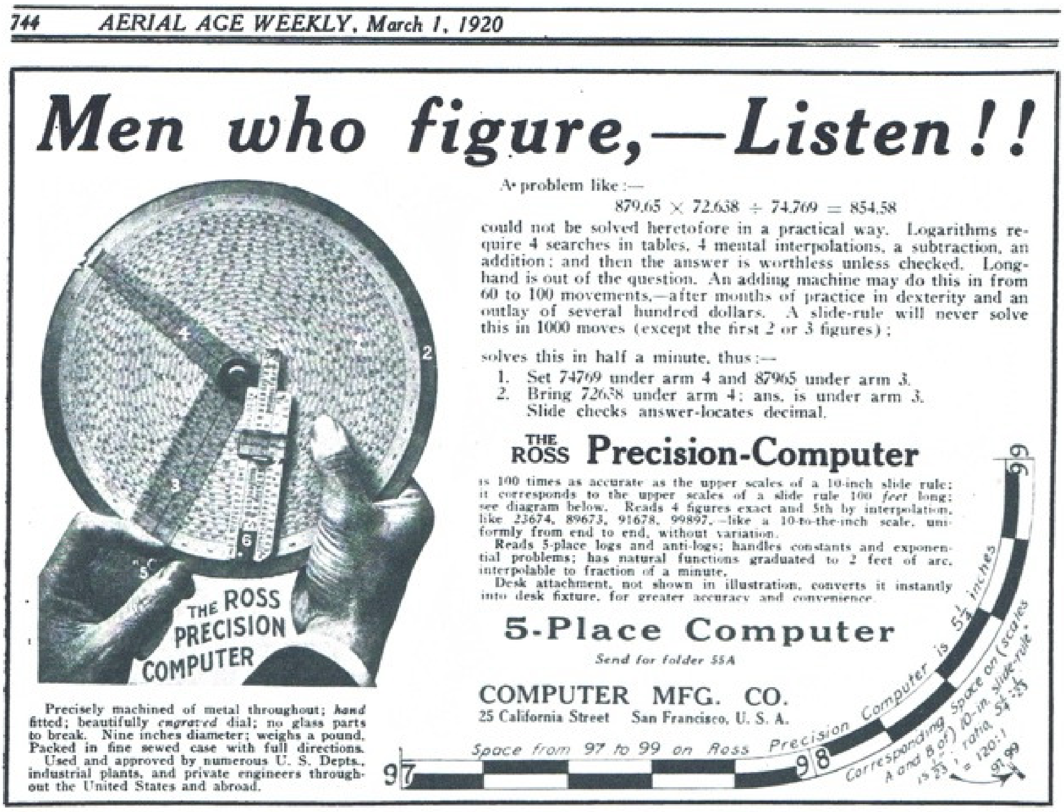


Figure 2. The Type II Ross Precision Computer from a press release in the Aerial Age weekly [18]

In 1920, before introducing his new Rapid Computer, Ross introduced [18, 19], a new version of the Ross Precision Computer (Fig.2), this version having the same spiral scale and the short linear slide rule as the first version, but with the spiral calculating scale fully revealed. This new version of the Ross Precision Computer was easier to operate than the first version. For the purposes of this discussion, I refer to the first version of the Precision Computer as the Type I closed-face version and the second as the Type II open-faced version. I will go into details of both versions and their operation later in this report.

For the next few years, Ross continued making and marketing his slide rules from his Computer Mfg. Co. in San Francisco [20]. He continued to tweak the designs with new surfacing materials and designs for his scale disks. Later, I will discuss some problems that he faced with the materials he used for his scale disks.

His literature told of many famous industrial firms using his slide rules. However, it appears that his slide rule business was not a great success. His short articles in technical journals stopped being published by 1923. The last article in *The Surveyor* [21] was for his Rapid Computer. The last article for the Precision Computer was in 1920 [19]. That was after a flurry of 17 articles from 1915 to 1916 for the Type I Ross Precision Computer, and just 1 article and 1 advertisement for the Type II version in 1920.

Ross also listed his slide rules in the Lietz Company engineering instruments catalog in 1919 [22] and 1926 [23]. The 1919 Lietz catalog [22] lists 4 of his slide rules; the Precision Computer (Type II), the Rapid Computer (Type I), a Commercial Rapid Computer (without technical scales), and a Miniature Rapid Computer (5-inch dia. Celluloid circular). The 1926 Lietz catalog [23] lists, in addition to all of the above, the Rapid Computer (Type II version), and it renamed the Miniature Rapid Computer the Student's Rapid Computer. The price for the Precision Computer was $19 in 1919 and $28.50 in 1926. . . . . It made sense that Ross would connect with Lietz to sell his slide rules, as the Lietz factory was just a 10-minute walk from Ross’s place of business in San Francisco.

Perhaps Ross also employed Lietz to place the spiral scales on his calculating disks. In the 1919 Lietz catalog [22], Lietz advertised a service *"to regraduate surveying instruments"* with their new *"Circular Dividing Engine"* at their factory on Commercial Street in San Francisco. Lietz was already placing scales on their surveying and nautical instruments. They, maybe, also engraved the scales on some of the other circular slide rules that they sold in their catalogs. Contracting with Lietz seems like it would have been a natural opportunity for Ross, and would have saved him great expense and time of developing his own circular dividing engine. However, because the surfaces of many of his metal slide rules have suffered distress, they don't appear to be up to the standards of a quality company like Lietz. So, it may be that Ross, himself, did the scale engraving or printing work.

By 1928, the Computer Mfg. Co. was no longer listed in the San Francisco business directories [20], and Louis Ross once again advertising his professional services as Louis Ross, Civil Engineer. While he may have had some old stock to sell, he was apparently no longer making slide rules. The Great Depression followed the Wall Street crash in 1929, and Ross’s business must have suffered loss of sales, if it was still in business. If it was already in a precarious financial position at that time, the great downturn in the US economy may have spelled the end of his firm, and the sales of Ross Computers.

A decade later, in 1937, Louis Ross was working for the San Francisco Department of Public works as a building inspector, and at the age of about 63 in 1943, he was no longer listed in the San Francisco directories [20] and voter registration lists [24]. What happened to Louis Ross after 1943 is a mystery.

More About Louis Ross

Little is known about Louis Ross other than his professional life that I have discussed above. At one time in 1914, the voter registration records [24] in San Francisco show that a Hazel Ross was living with him. We know that Ross had relatives in San Francisco from the 1910 census [6], so it makes sense that Hazel Ross might be a sister or cousin, or maybe a wife. However, she does not appear in any other of the yearly San Francisco records, so perhaps she was just a relative visiting Ross in 1914. Louis Ross also appears to have lived at least 16 different addresses [20 & 24] in San Francisco, most of the places clustered within a few miles of where his Computer Mfg. Co was located. Most of his addresses are listed as rooms, so he was living quite a basic existence. Ross's frequent moves might be explained by the fragility of his slide rule making business and a resulting meager income. He may have been frequently changing addresses to keep his living expenses down. It is a shame that he left little legacy of his memory other than a few of his *"computers"*, some articles in technical journals, and a long list of street addresses where he lived.

The Ross Precision Computer, Type I - The Closed Faced Version

I show a picture (with the parts labeled) of an example of the closed faced version of the Ross Precision Computer in Figure 3. The two main components are a 10 cm long linear *Slide Rule* and a 25-revolution *Spiral Calculating Scale* on a 20 cm diameter *Dial Disk* (Fig. 4). The *Slide Rule* is mounted on an aluminum frame next to a window opening that allows a partial view of the spiral scale. A detailed description is given below. Note that all parts of the Ross Precision Computer named by Ross are indicated in italics.

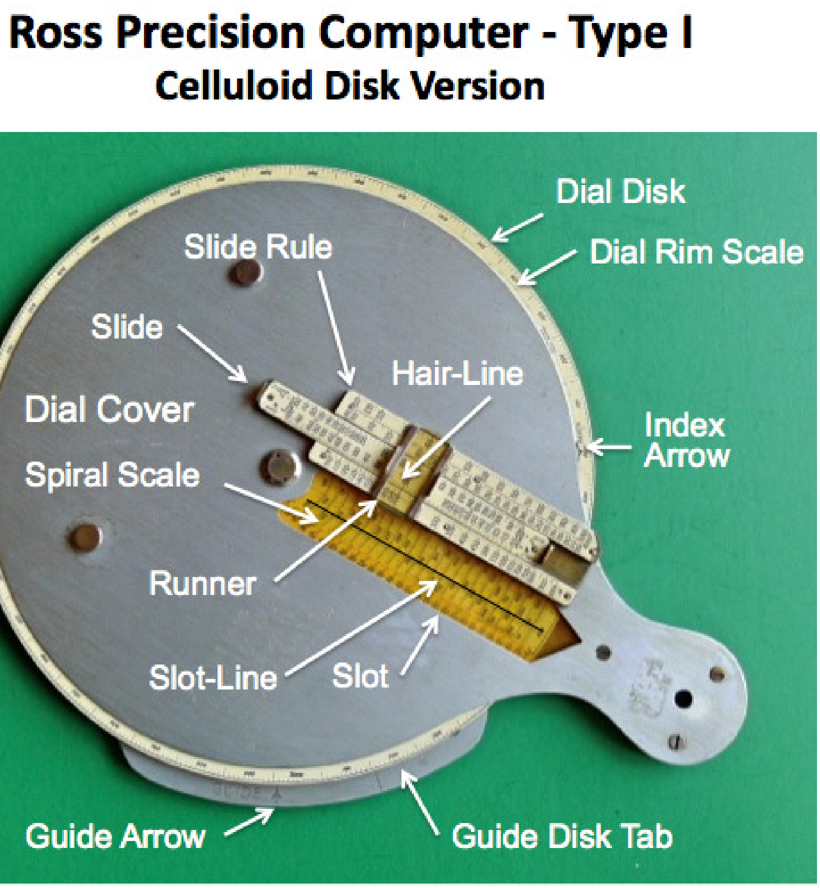


Figure 3. The Type I Ross Precision Computer with celluloid scale facings (parts are labeled to help follow description and operation method)

Figure 4. The Dial Disk *with spiral scale on the Type I Ross Precision Computer (Celluloid scale version)*

The *Dial Disk* and the facing of the *Slide Rule* are made of Celluloid plastic, and the *Slide Rule* is made of brass. According to Ross [15], the *Slide Rule* component gives *"3-place answers"* instantly, while the *Spiral Scale* on the *Dial Disk* gives results to *"5-place numbers."* with manipulation of the of the spiral disk and its components.

The Parts of the Type I Ross Precision Computer (Figs. 3, 4, 5 & 6) include:

a) ***Dial Disk*****:** the disk with the *Spiral Calculating Scale*
b) ***Rim Scale:*** scale on the outer edge of the *Dial Disk* running from 0 to 4000 for determining the mantissa of logarithms.
c) ***Index Arrow:*** an arrow on *Dial Disk* at '0' on *Rim Scale*.
d) ***Dial Cover*****:** an aluminum disk that covers all, but a *Window Opening*, of the *Dial Disk*.
e) ***Slot*****:** a *Window Opening* in the *Dial Cover* with a hairline and scale identification labels.
f) ***Slot-Line*****:** the hairline in the *Dial Cover Window Opening*.
g) ***Guide Disk:*** an aluminum disk (with a *Tab*) mounted behind the *Dial Disk*.
h) ***Guide Tab*****:** a tab extension on the *Guide Disk*.
i) ***Guide Arrow*****:** arrow on *Guide Disk Tab*
j) ***Runner*****:** a cursor with a transparent window and *Hair-Line;* on the *Linear Slide Rule.*
k) ***Hair-Line:*** a hairline on the *Linear Slide Rule's Runner*.
l) ***Slide*****:** the sliding part of the *Linear Slide Rule*.
m) ***N-Scale:*** 1-cycle log scale running from 100 to 1000.
n) ***M-Scale*****:** 1-cycle inverted log scale on *Slide* running from 1000 to 100.

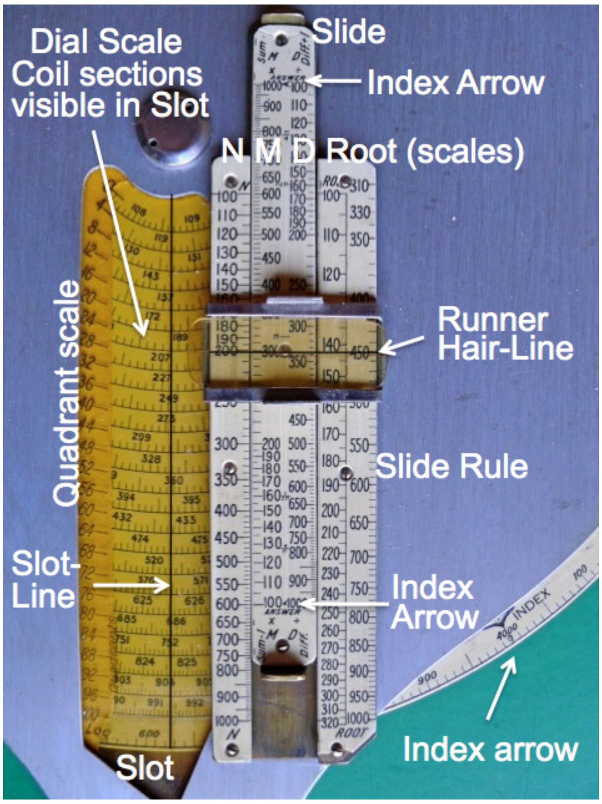


Figure 5. The "Slide Rule, Slot & Index Arrow on the Dial Disk" on the Type I Ross Precision Computer (Celluloid facing version)

The *Spiral Calculating Scale* on the *Dial Disk* coils around and around for 25 revolutions, starting near the center of the *Dial Disk* to near its *Rim*. See Fig.4. It has a scale length of 9.14 meters. The *Spiral Scale* numbers run from 100 to 1000 in logarithmic form, with 10 gradation marks for every interval of 1 unit. This allows direct readings of four digits and interpolation of the fifth digit for the entire scale range. This is in contrast to interpolated readings of 3 digits at the left end of a conventional 25 cm slide rule and about 2.75 digits at its right end. The *Slide Rule* (Fig. 5) is mounted just to the right of the *Slot*. Its calculating scales are 8.5 cm long. The *N-scale* (N for number) on the stator adjacent to the *Slot* runs from 100 to 1000, starting opposite 100 at the beginning of the *Spiral* scale, and ending at 1000 opposite 1000 at the end of the *Spiral Scale*. This arrangement allows the scale gradation labels on the *N-scale* to be indicators of the scale range on each coil of the *Spiral Scale*. Because the *M-scale* (M for multiply) on the *Slide* is inverted, running from 1000 to 100, multiplication is accomplished by setting the multiplier number on the *M-scale* opposite the multiplicand number on the *N-scale.* The result is found on the *N-scale* opposite the Index of 100 or 1000 on whichever end of the *M-scale* is in range of the *N-scale.*

The Index not only points to the result on the *N-scale*, but it also points to the coil on the *Spiral Scale* where the more precise 5-digit result can be determined. The *Slide* also has a *D-scale* (D for divide) at its right edge. It runs from 100 to 1000.
The *D-scale* is used for dividing operations, the result always being on the *N-scale* opposite one of the indices at the ends of the *D-scale*. The right-most stator on the slide rule has 2 scales (labeled *ROOT*) for determining squares and square roots.
The 8.5 cm long scale on the slide rule reads results to 2 to 3 digits, while the 9.14 m long spiral scale gives results to 5 digits. It took extending the scale length by more than two orders of magnitude to gain the two extra digits of precision.

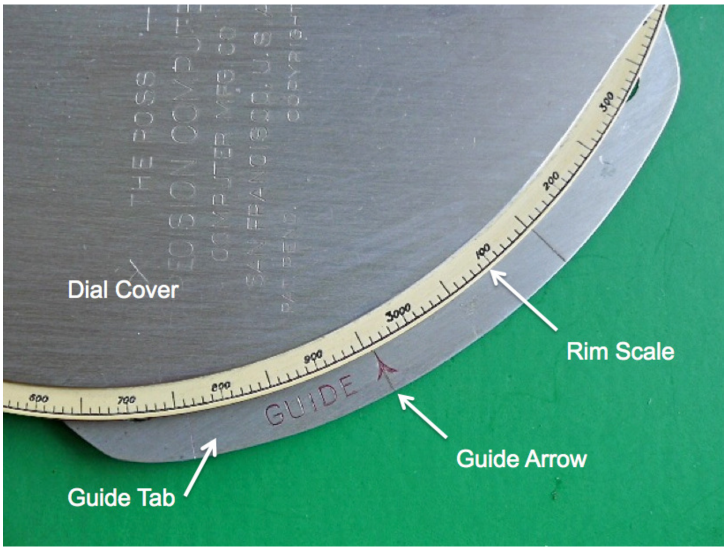


Figure 6. The Rim Scale, Guide Tab, Guide Arrow & Dial Cover on the Type I Ross Precision Computer

At the left inside edge of the *Slot Window* (Fig. 5), there is a *Quadrant* scale running from 0 to 100. This scale is used in conjunction with the *Rim* scale on the *Dial Disk* to determine 5-place logarithms and anti-logarithms. The *Rim* scale (Fig. 6) runs from 0 to 4000 in equal parts, each quadrant of the *Rim* scale having 1000 parts. The *Quadrant* scale provides the first 2 digits of the logarithm's mantissa and the *Rim* scale provides the next 3 digits. One finds the log of a number by setting the number under the hairline in the *Slot* window. Then one reads the first 2 digits of the mantissa from the *Quadrant* scale. That number is found on the *Quadrant* scale opposite the coil on which the number is set. Finally, the last 3 digits of the mantissa are read on the *Rim* scale. The ordinate for the logarithm is determined in the normal way by counting the number of digits to the left or right of the decimal point in the subject number.

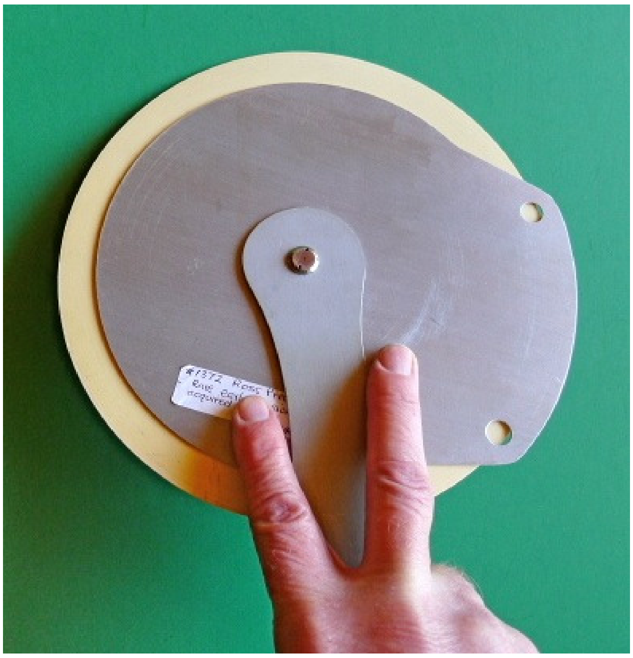


Figure 7. View of the back of the Type I Ross Precision Computer showing finger position during calculations. Finger pressure on back disk

The Ross Type I Ross Precision Computer is operated by holding the *Handle* in the palm of ones hand (Fig.1) and placing two fingers on the *Guide Disk* on the back (Fig. 7) of the *Dial Disk*, one finger on either side of the *Handle*. Finger pressure restricts the *Guide Disk* from turning when turning the *Dial Disk.* Below is an example of multiplying one number by another. I show this example not so much as an instruction on how to multiply with the Ross Precision Computer, but to show the complexity of the process. See Figures 3, 5, 6 & 7 to follow the example calculation.

Example Calculation: How to Multiply 20 x 30

1) *Short Linear Slide Rule Settings*:

set 300 on *M-scale* (on *Slide*) opposite 200 on *N-scale* & *Hair-Line* on *Runner* to 200 on *N-scale*. *Index Arrow* at end of *M-scale* on *Slide* points to answer 600 on *N-scale.*

2) *Dial Disk Settings*:

a) set 200 on *Dial Scale* under the *Slot-Line* (*Runner Hair-Line* on *Slide Rule* points to the correct *Spiral Coil* on the *Dial Scale*);

b) set *Guide Arrow* on *Guide Tab* pointing to the *Index Arrow* on *Rim Scale*;

c) hold *Guide Disk's* position with fingers at its backside;

d) turn the *Dial Disk* at its *Rim* until 300 on *Dial Scale* is under the Slot Hairline (do not turn Guide *Disk* while rotating *Dial Disk*);

e) read the *Rim Scale* on the *Dial Disk* as 3717;

f) rotate *Dial Disk* while holding *Guide Disk* in place until the *Guide Arrow* points at 3717; and

g) answer: 600 should be under *Slot-Line* on *Dial Scale* opposite *Index Arrow* at bottom end of the M-scale on the *Slide*.

I have tried this sample problem several times, and never obtained a result of exactly 600, as it should be. Taking great care in the last try, the result was 601.2. The error results from difficulties in holding the *Guide Disk* in fixed place while turning the *Dial Disk* to position the setting on the *Spiral Scale* under the *Slot-Line.* It was a challenge to put just enough finger pressure on the underside of the *back of the Guide Disk* to keep it from turning, while at the same time keeping pressure low enough to allow the *Dial Disk* to turn. Because of this, I experienced problems with the *Dial Disk* sticking and not rotating smoothly.

I also tried making the same calculation with the other example of the Type I Ross Precision Computer in my collection, the example with a brass *Dial Disk*. The sticking and suddenly sliding (stiction) problem was worse with the brass disk version. This problem seems to be endemic with the design, as I was unable to eliminate the stiction problem. The *Dial Disks* in both the Celluloid and the brass versions were in excellent condition, with no apparent damage. However there were some circular wear marks on their back faces, where they pressed against the aluminum *Guide Disks*. But even after gentle cleaning, I could not eliminate the sticking of the *Dial Disks*.

The Ross Precision Computer, Type II, The Open Faced Version

I show a picture of an example of the open-faced version of the Ross Precision Computer in Figure 8. Like the Type I version, the two main components are a 10 cm long linear *Slide Rule* and a 25-revolution *Spiral Scale* on a 20 cm diameter *Dial Disk*. The *Spiral Scale* and the *Slide Rule* are both identical to those on the Type I version, except that the *Spiral Scale* is engraved on a stainless steel disk (Fig. 9). The *Spiral Scale* is fully visible [Fig. 8], instead of being mostly covered as it is on the Type I version [Fig. 3]. The scale is easily read through 2 transparent indicators. One is named the *Base Indicator* (Figs. 8 &10). It is mounted on the Computer's *Handle*, instead of in a *Slot Window* as on the Type I Ross (Figs. 3 & 5). The second is a fixed transparent indicator named by Ross the *Float Indicator* (Figs. 8 & 11). It replaces the *Guide Disk* and its *Guide Arrow* on the Type I version of the Precision Computer (Fig. 6). It is mounted at the center of the *Dial Disk* at one end and fixed to the back disk at the other end.

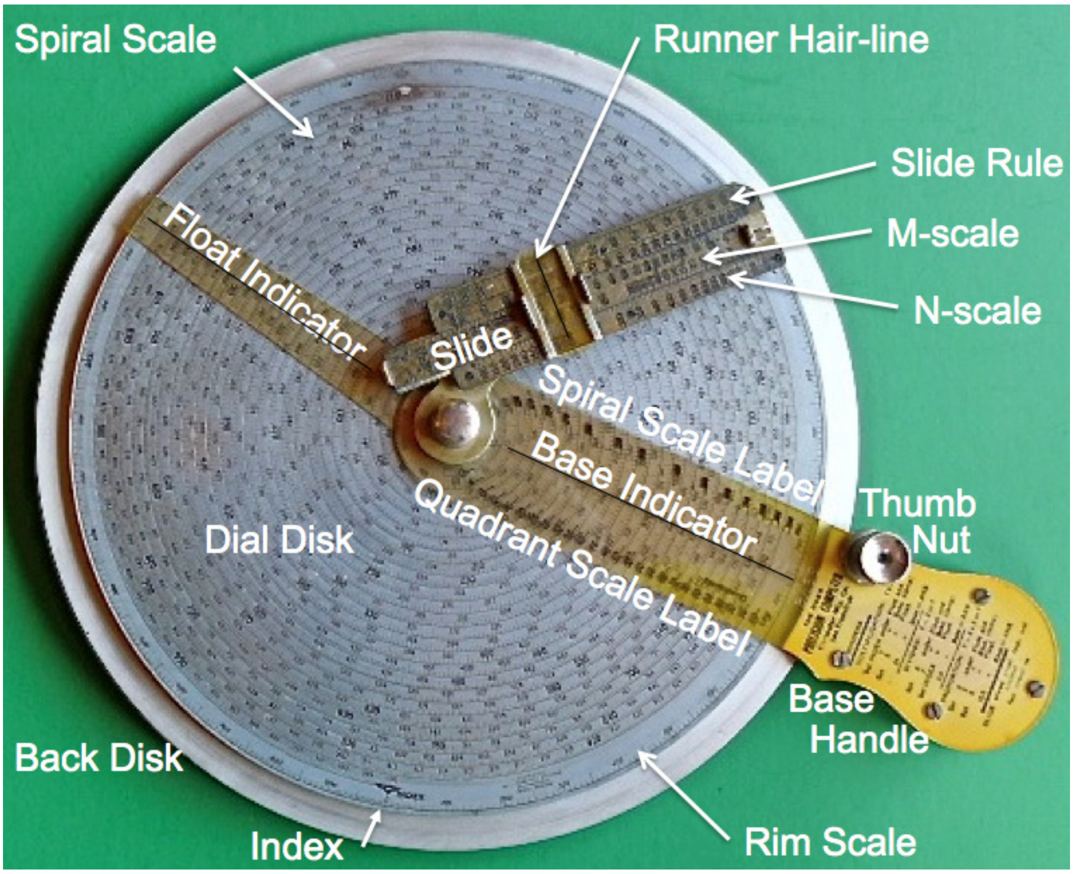


Figure 8. Type II Ross Precision Computer with Stainless Steel Dial Disk

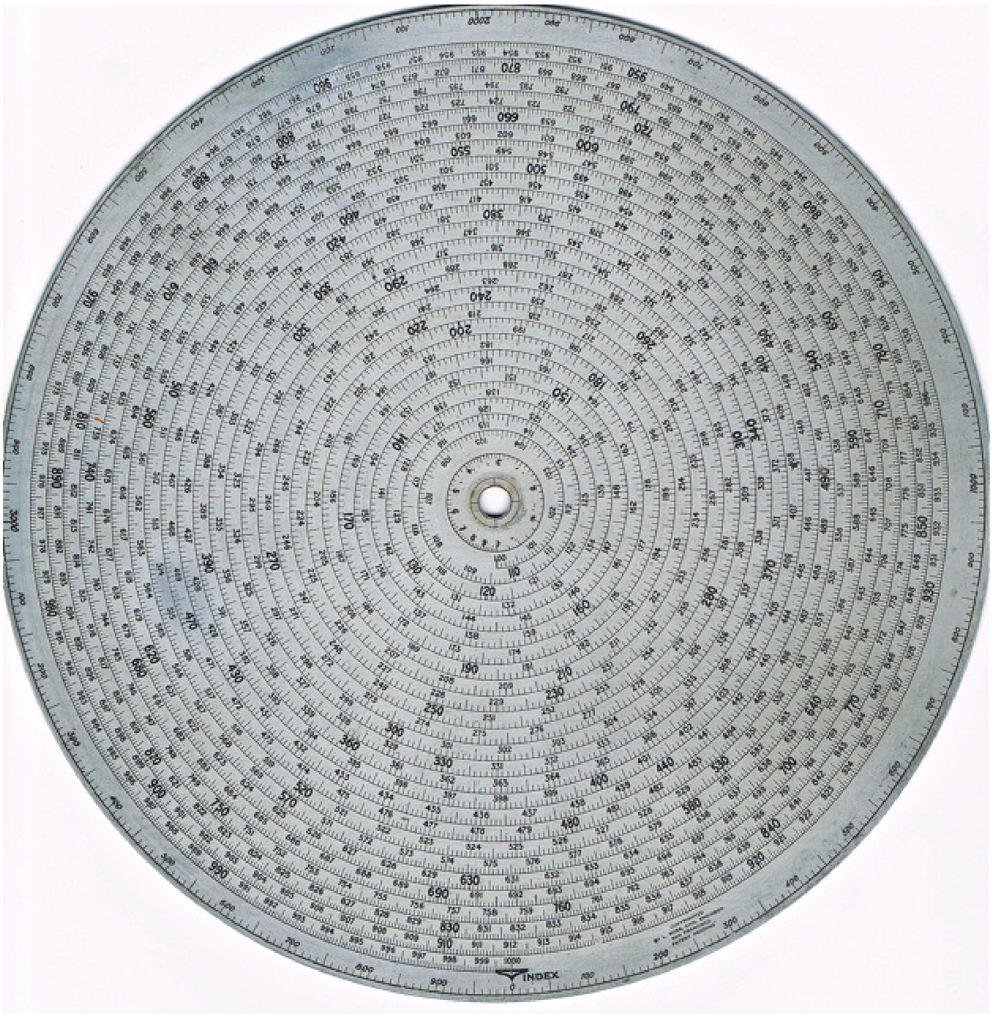


Figure 9. The spiral scale on the Type II Ross Precision Computer (engraved stainless steel version)

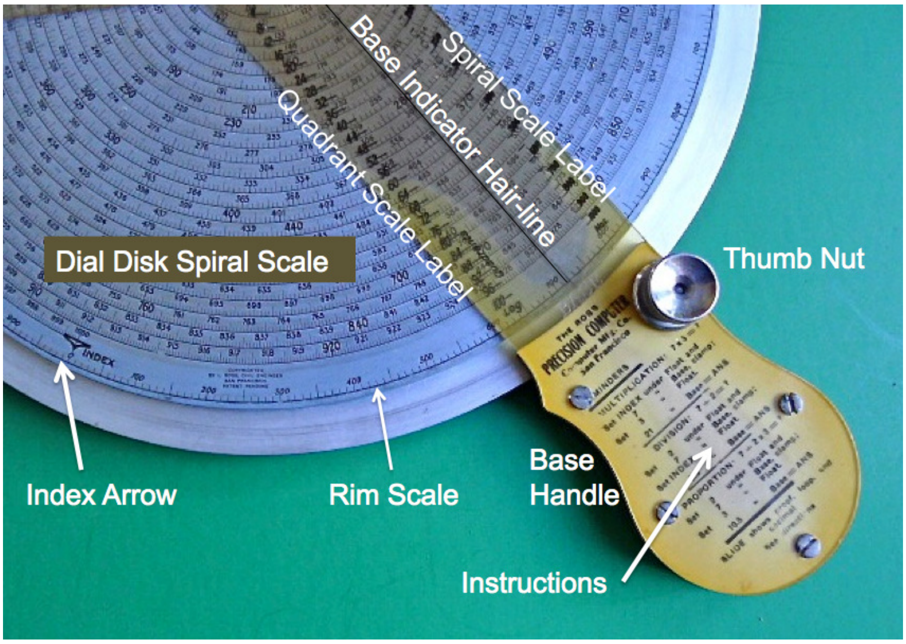


Figure 10. Details of the Base, Dial, and Handle on the Type II Ross Precision Computer

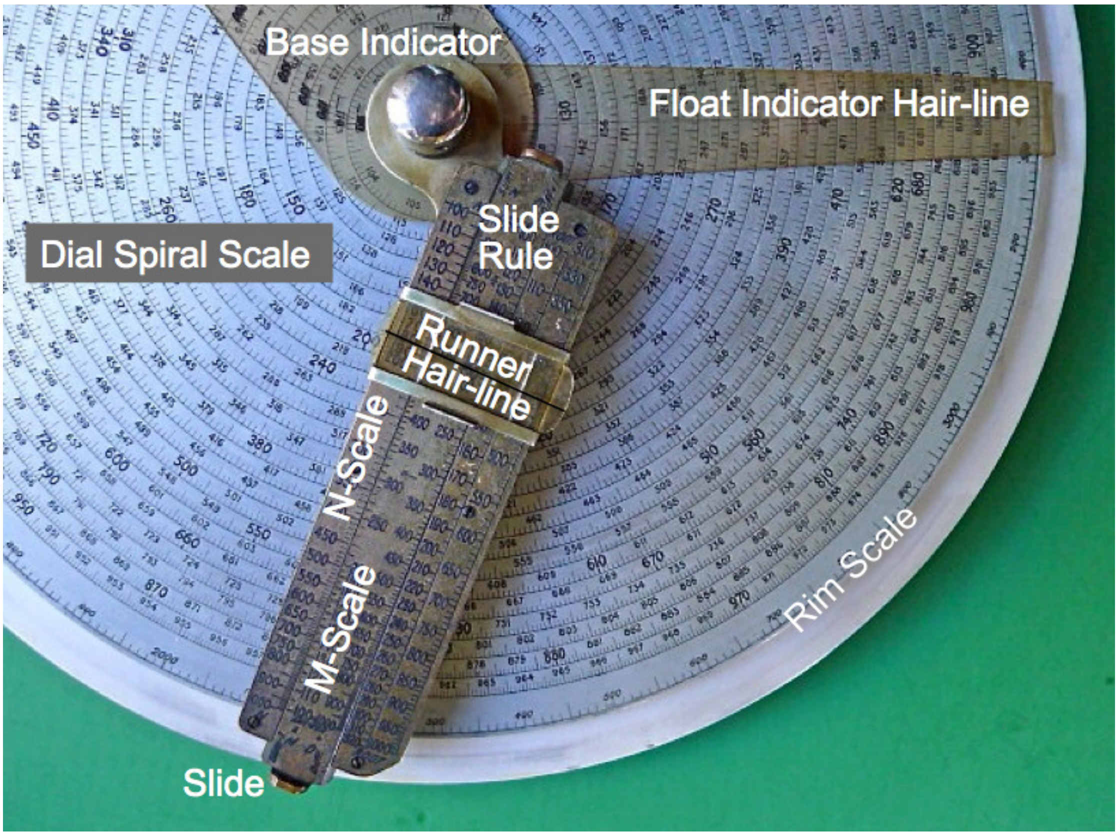


Figure 11. Details of the Dial, Slide Rule, Base & Float on the Type II Ross Precision Computer

These two indicators, the *Base* and the *Float* are used like dividers on a Gunter scale to make calculations. Unlike the indicators on the Type I version, their use is intuitive, and easy to learn. The *Dial Disk* with the *Spiral Scale* (Fig. 8) rotates freely under both indicators when the *Base Indicator* is locked at its rim to the *Back-Disk* by tightening a *Thumb Nut* on the *Base Handle*. When locked, the angle between the *Hair-lines* on the two *Indicators* remains constant, and thus the multiplier (or the divisor) is fixed. For instance, to multiply, set the *Float Indicator Hair-line* on 100 on the Spiral Scale and the multiplier under the *Base Indicator Hair-line.* Then tighten the *Thumb Nut* on the *Base Handle* to fix the angle between the two *Indicators*. Then rotate the *Dial Disk* under the two *Indicators* until the multiplicand is under the *Float Indicator Hair-line*. The result will be under the *Base Indicator Hair-line.* To multiply another number by the same multiplier, just rotate the *Dial Disk* to position the new number under the *Float Indicator Hair-line*. The new result will, as before, be under the *Base Indicator Hair-line*. In this way, a series of calculations, such as those done when converting one currency to another, can be done with just one setting for each calculation.

Like on the Type I version, the small linear *Slide Rule* (Fig. 11) gives *"2 to 3-place answers",* while the *Spiral Scale* gives results to *"5-place numbers."* The *Slide Rule* on the Type II version of the Ross is made from brass, the scales embossed on a coated surface.

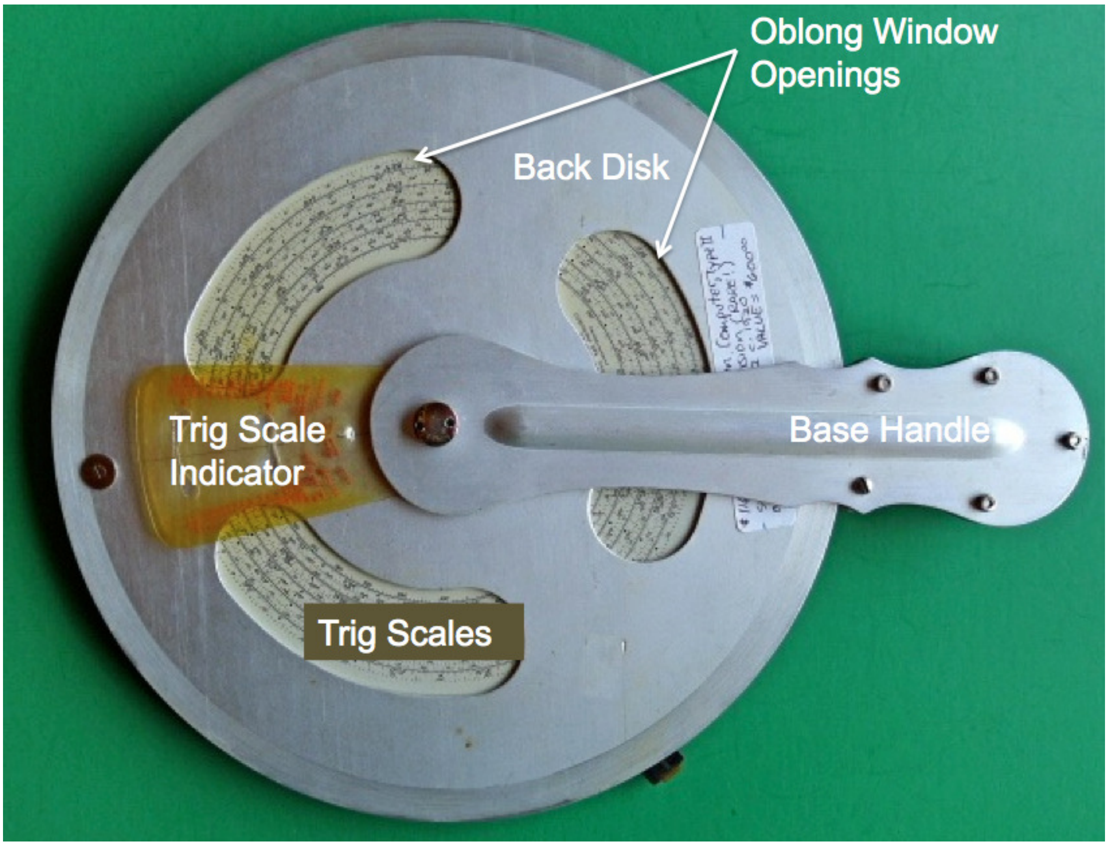


Figure 12. The reverse side of the Ross Precision Computer showing the Trigonometric scale through three circular windows

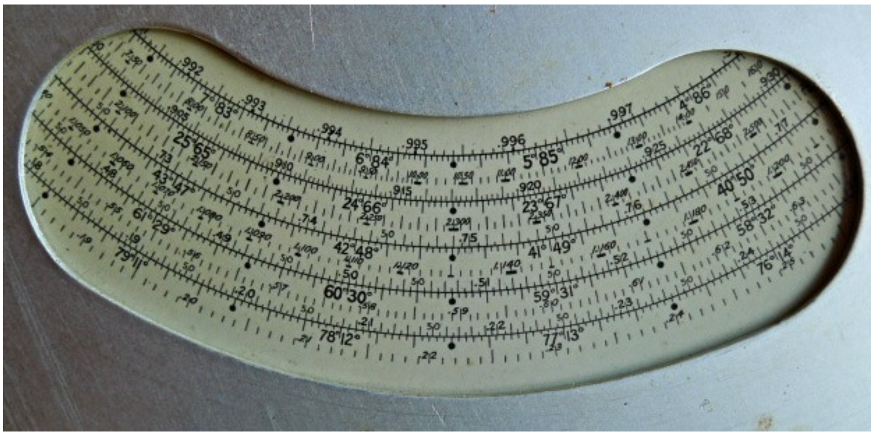


Figure 13. Detail of the Trig scale on the Type II Ross Precision Computer

The reverse side (Fig. 12) of the Type II Ross has a 5-cycle spiral *Trig Scale* for angle functions, and a transparent *Indicator* to assist in reading the *Trig Scale* (Fig. 13). The scale is printed on glossy card stock, and is only partly visible (at any one time) through 3 oblong windows. The *Trig Scale Disk* can be rotated by pressing and pushing with fingers in the oblong window openings to expose different parts of the scale. The *Trig Scale* is about 2 m long, and is used to read the functions of angles, but not to calculate directly with them. Ross claims [19] that this instrument *"handles . . . trigonometric problems to an accuracy better than 1 minute of arc, 1 inch per mile."* However, the printing on the *Trig Scale* and its indicator is so fine that it takes a practiced eye, with the aid of a magnifying glass, to make readings. A separate table of Trigonometric functions might have been more practical for obtaining values of Trig functions.

The Parts of the Type II Ross Precision Computer (see Figures 8, 10, 11 & 12)

a) ***Precision Computer***: a *Circular Spiral Slide Rule* with a *Short (accessory) Linear Slide Rule.*
b) ***Dial Disk***: the disk with the Spiral Calculating Scale.
c) ***Rim Scale***: scale running from 0 to 4000 for determining logarithms.
d) ***Index***: arrow on *Dial Disk* at '0' on *Rim Scale*.
e) ***Back-Disk:*** aluminum disk mounted forming back frame for the *Dial Disk*.
e) ***Float Indicator***: transparent indicator with hairline fixed to the center of the disk and to the rim of the *Back Disk*.
f) ***Base Indicator***: transparent indicator with Quadrant, *Hair-Line* and Scale Identification Labels; attached to center of the *Dial*; with *Handle* & *Clamp Thumb Screw* at *Rim* of *Back-Disk.*
g) ***Runner***: a cursor with a transparent window and hairline on the *Linear Slide Rule.*
h) ***Runner Hairline:*** hairline on the *Linear Slide Rule's Runner*.
i) ***Slide***: the sliding part of the *Linear Slide Rule*.
j) ***N-Scale:*** 1-decade log scale running from 100 to 1000.
k) ***M-Scale***: 1-decade inverted log scale on *Slide* running from 1000 to 100.
l) ***Trig Scale***: 5-rev. scale, 2 meters long.

Like on the Type I Ross, the *Spiral Calculating Scale* on the *Dial Disk* coils around and around starting near the center of the *Dial Disk* for 25 revolutions to near its *Rim* (Fig.9). Calculations with the Ross Type II are made much like calculations on other spiral slide rules with two cursors.

The *Slide Rule* (Fig. 8 & 11) is mounted on an arm that pivots about the center of the *Dial Disk*. The left side of the *Slide Rule* always remains perpendicular to the *Spiral* coils, no matter where it is positioned. As for the Type I Ross, the indexes at the beginning and ending of the *M-scale and the D-scale*, point to the result on the *N-scale*, and also point to the coil on the *Dial Disk* where the more precise result is found.

At the left side of the *Base Indicator* (Fig. 10), there is a *Quadrant* scale running from 0 to 100. As for the Type I Ross, this scale is used in conjunction with the *Rim* Scale on the *Dial* disk to determine 5-place logarithms and anti-logarithms. The right side of the *Base* window has a straight scale with labels running from 100 to 1000, matching the labels on the *N-scale* on the *Slide Rule*. This scale is used to help select the *Spiral Coil* when making readings or settings with the *Base Indicator Hair-line*. The *Slide Rule* can also be used for this purpose.

The Type II Ross Precision Computer is much heavier than the Type I version, weighing about 700 g vs. 270 g for the Type I version. Thus the Type II Ross is best held in two hands to hold the instrument steady, and to temporally free a hand to position the *Dial Disk* under the *Float Indicator* and the *Base Indicator* over the *Spiral Scale*. Another option would be to grip the *Handle* in a vice like bracket that Ross sold as an option with the Precision Computer.

Below is an example of multiplying one number by another. Again, I show this example not so much as an instruction on how to multiply with the Ross Precision Computer, but to show the complexity of an operation, and how the operation of the two versions of the Ross differ.

Example Calculation: How to Multiply 20 x 30

1) *Short Linear Slide Rule*:

set 300 on M-scale (on slide) opposite 200 on N-scale & *Hair-Line* on Runner to 200 on N-scale. Arrow at end of M-scale on slide points to answer 600 on N-scale

2) *Dial:*

a) set *Index Arrow* on *Dial Rim Scale* under *Float Indicator* hairline.
b) loosen *Clamp Thumb Screw* on *Handle.*
c) rotate *Base Indicator* by its *Handle* until 200 is under its *Hair-Line.* Scale identification labels on the *Float Indicator* window aid in finding the correct *Spiral Scale* winding.
d) turn *Thumb Nut* to lock *Base Cursor* to the *Back-Disk*.
e) turn *Dial* until 300 on the *Spiral Scale* is under hairline of *Float.*
f) the answer; 600 is under the Base indicator hairline. The arrow on the end of the M-scale on the *Slide* points to the proper coil on which to read the answer.

I have tried this sample problem several times, and always got a result of exactly 600, as it should be. There were no problems of the *Dial Disk* sticking as was the case for the Type I version. The operation of the Type II version was not only easier and the results more accurate, but the operation was more intuitive. The operation of the Type II Ross was much more like other spiral slide rules such as the Gilson Atlas Computer, which was first marketed just a few years after the Type II version of the Precision Computer was introduced.

Variations of the Two Ross Precision Computers

Type I

The literature [ref. 15 for example] for the Type I Ross Precision Computer states that *"the graduations are engraved on silvered metal surfaces."* However, I have not seen a Type I Ross Precision Computer with *"silvered metal surfaces."* I have 2 examples of the Type I version in my collection, one with a Celluloid *Dial Disk* (Fig. 4) and the other with a brass *Dial Disk* (Fig. 14).

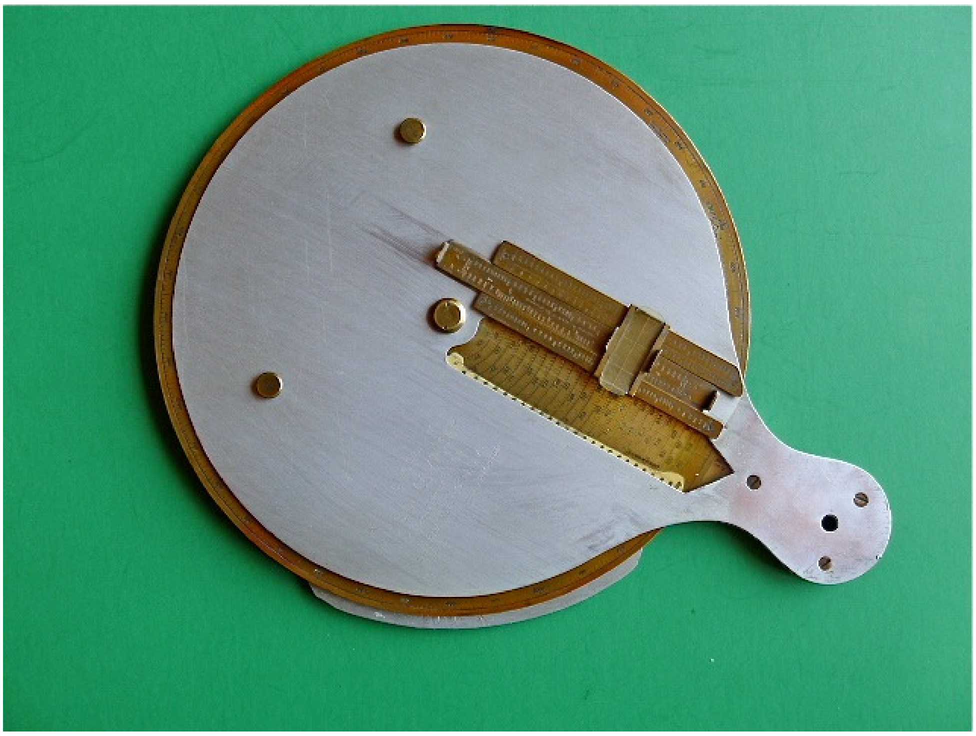


Figure 14. Type I Ross Precision Computer with Brass Dial & Slide Rule

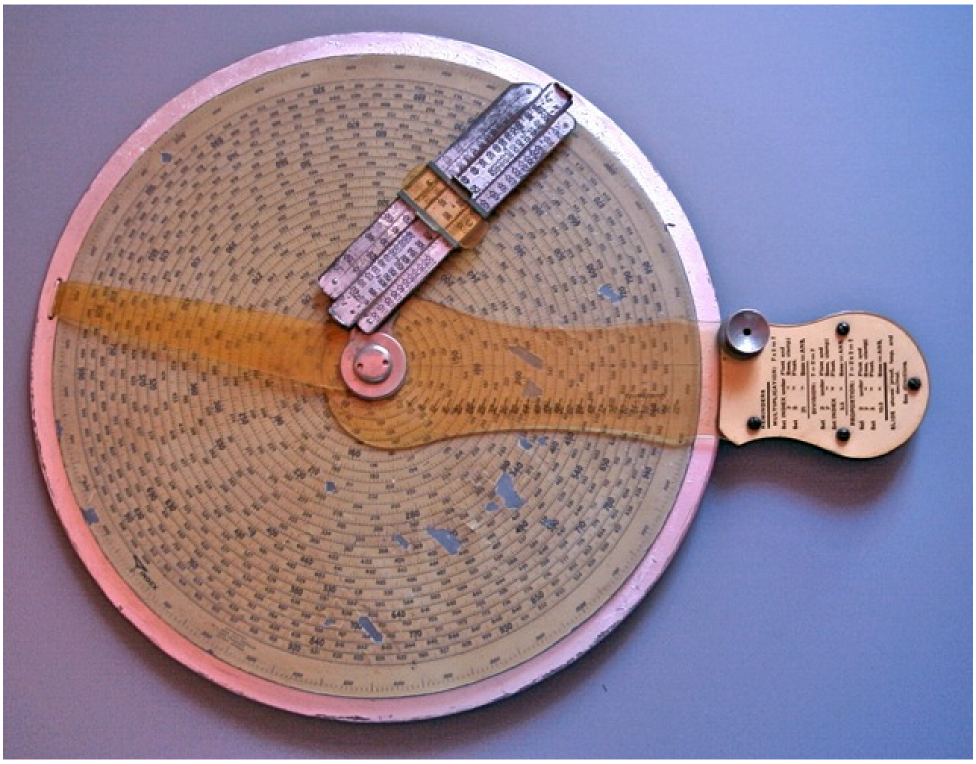


Figure 15. Type II Ross Precision Computer with a spiral scale on a painted scale 'Dial' surface. The Dial disk is made of 'pot meta'. Note scale damage due to blistering of paint

The facing on the *Slide Rule* on the Celluloid *Dial Disk* version is also made of Celluloid, while the brass *Dial Disk* version has a coated brass slide rule. The coating on the brass *Slide Rule* could be a *"silvered"* coating as Ross claimed in his advertising [15], as its darkened color could be the result of tarnishing of a silvered surfacing. However, the scales and their labels are not engraved, but they have raised features. . . . It is a mystery why all of the articles about the Type I Ross Precision Computer describe the scales as being *"engraved on silvered surfaces"*, when none of the *Dial Disks* on known examples have *"engraved silvered surfaces."* It may be that the silvered surfaces did not wear well, and that for the Type I Precision Computer, Ross changed to the Celluloid and the brass surfaces to try something better.

I have a Ross Rapid Computer with silvered surfaces (Fig. 16) that might help explain this. The scales are completely worn off the surface. Only very faint vestiges of the original scales can be seen. I will probably never resolve this mystery as there are so few examples the Type I Ross Precision Computer, perhaps 5 or 6, known to exist.

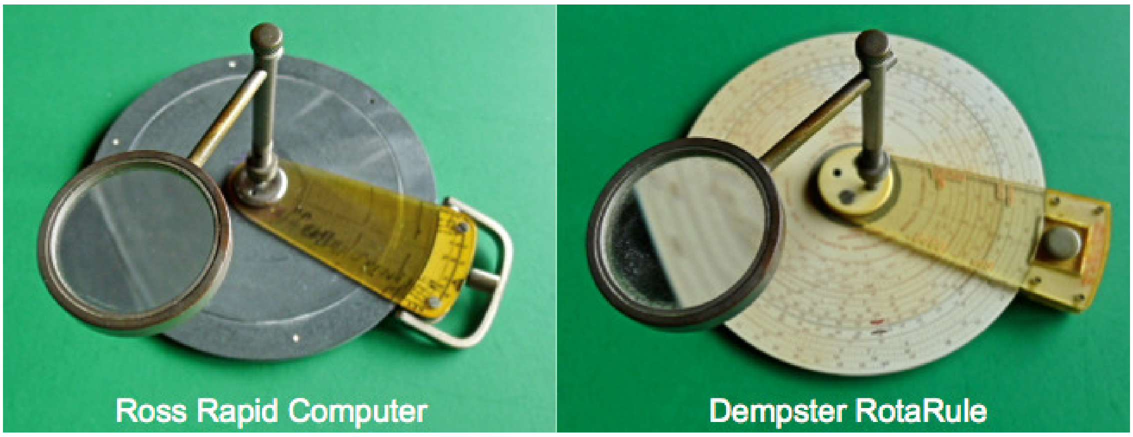


Figure 16. The Ross Rapid Computer and the Dempster RotaRule

Type II

The literature [18,19] for the Type II Ross Precision computer states that "the instrument *is made of metal . . . . precisely machined . . . and beautifully engraved"*. The spiral scale example (Fig. 8) in my collection is indeed very nicely engraved on a stainless steel disk as described above. I also know of a very nice example with the spiral scale engraved on a brass disk, but the spiral scales on most of the examples of the Type II Ross Precision computer that I know of are printed on enameled *"pot metal"* disks. And in most cases these scales are damaged as the result of the painted surfaces blistering on the cheap metal surfaces. . . . This, too, is a mystery because Louis Ross did not leave an explanation.

The Ross Precision Computer vs. The Gilson Atlas Calculator - Was There Competition?

It came to me, as I was writing this report, that perhaps Clair Gilson knew of the Ross Precision Computer when circa 1922, he began making his Atlas Calculator (Fig. 17). The Atlas was to be a popular spiral slide rule in the US. Ross had then been making his Type II Precision Computer for about 4 years in 1922. Both Ross and Gilson were Civil Engineers, interested in making precision calculations, particularly for surveying. Both had learned the mathematics and drafting skills necessary for designing and laying out slide rule scales during their university studies. And both could have crossed paths as members of professional organizations, or in reading professional journals.

That Ross's work inspired Gilson is possible, because the Ross and Gilson spiral slide rules have some distinct similarities:

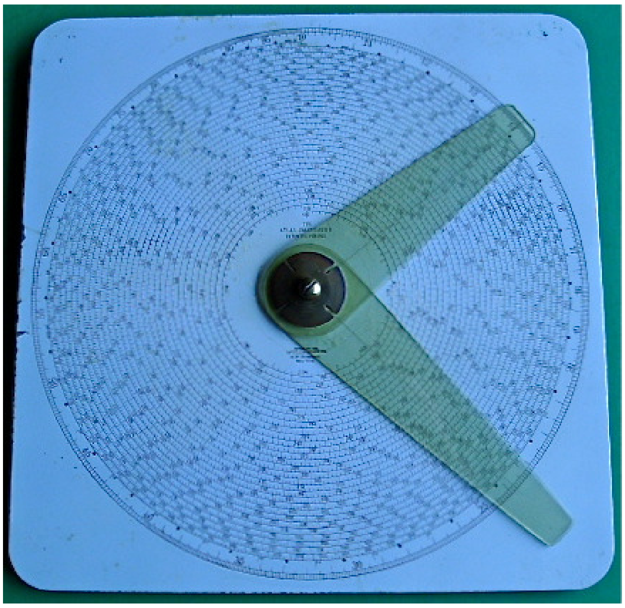


*Figure 17. The Type I "*Square*" Gilson Atlas Calculator*

1) both were made in small workshops, Ross in San Francisco, CA, and Gilson in Michigan and Florida;
2) Ross began making his Type II Precision Computer in 1918, and Gilson started making his Type I Atlas Calculator in 1922, just 4 years later;
3) Both had spiral scales laid out on a single disk. However, the spiral scale on the first Atlas (Fig. 17) was laid out for 30 revolutions on a square aluminum plate (vs. 25 revolutions for the Ross on a circular metal plate). The circular diameter of the outside wrap of the spiral was about 25 cm for the Gilson, versus about 20 cm dia. for the Ross. The scale length on the Gilson Atlas was about 14 m vs. the 9.14 m on the Ross Precision Computer;
4) Both had methods for determining the approximate values to 2 or 3 digits, but the methods were different. The Gilson Atlas models had a single circular scale at its rim for determining the approximate values, while the Ross models had an attached slide rule for making the approximate calculations;
5) Both had 2 transparent indicators, but they were operated a little bit differently. On the Gilson, the indicators are turned to make a calculation, while on the Ross, the indicators are fixed and the disk is turned;
6) Both had methods for determining the logs and anti-logs of numbers, but they were very different methods;

7) Both had Trig scales on their reverse side, but the layouts were different;
8) And in their final versions, both had their spiral scales printed on metal disks with painted surfaces.

The Gilson Atlas models appear to follow traditional designs for spiral slide rules, and they are definitely not copies of the Ross Precision Computer models. Physically, they are much more like the other circular slide rules with spiral scales that preceded Gilson's Atlas [3]; those made from 1635 (the Johannes Hullet Circulariter sed Vitato Circuito) to 1912 (the Lilly Improved Slide Rule). In the era between 1635 and 1912, there were at least 13 makers of spiral slide rules, and they all used the same physical design, with spiral scales on circular disks and two rotating indicators to make the calculations. That is the design that Clair Gilson used; but Ross's designs were very different and truly unique.

Almost all of the early spiral slide rules are in museums, or are only memories in obscure publications. The only one of the early spiral slide rules that I know of where more than one example exists is the Lilly, and two examples are in Ireland, and the third in England. The Lilly is also patented, so the patent could have inspired Gilson, but he makes no mention of it in his work. Nor does he mention the Ross Precision Computer.

The Gilson Atlas slide rule was a match for the Ross Precision Computer for making precision calculations, and was easier to hold and to operate. It weighed just 340 g vs. 700 g for the Ross. The Gilson Atlas, most importantly, was much less expensive. The price for the Ross was $20 in 1919 [22] and $28 in 1926 [23], while the price for the Gilson was $6 in 1922 [25] and $7.50 in 1932 [26]. The price of the Ross was greater than 3 times the price of the Gilson when they were being sold in head to head competition. Furthermore, Clair Gilson's Atlas models were much simpler, and probably less expensive to make, with just 9 parts vs. 40 parts for the Type I Ross and 32 parts for the Type II Ross.

Evidence that the Atlas spiral slide rules were more widely sold and accepted can be seen in the differences in numbers of Atlas and Precision Computers sold on eBay. I found on Rod Lovett's eBay search web page [27] that more than 430 Atlas spiral slide rules sold on eBay over the past 15 years. That is in sharp contrast to fewer than 20 of the Ross Precision Computers. Clair Gilson should be given credit for having designed and made the most commercially successful and functionally reliable of all spiral slide rules. Because of its commercial success, Gilson's Atlas slide rule may have had a role in the failure of Ross's Computer Mfg. Co.

Conclusions

It is my opinion that The Ross Precision Computer was one of the most innovative spiral slide rules made, in both of its forms. The physical link and interaction of the small straight slide rule with the long spiral scale on the *Dial Disk* was an idea unique only to Ross.

However, Ross's business was ultimately not very successful because of the relatively high cost of his slide rules and their relatively poor durability. Ross's business enterprise, the Computer Mfg. Co. was active for just 12 years - from 1915 to 1927. The $20 price tag for Ross's Precision Computers was a princely sum for most engineers and scientists in the 1910s and 1920s, perhaps as much as a week's pay for many. The high cost of the engraved disks probably discouraged enough buyers of his computers to make his business profitable. And when he changed to cheaper and less expensive metals and surfacing materials, his *"Computers"* proved to be less durable. And finally in the 1920s, the competition with Gilson and his $6 Atlas, and the *"Great Depression"*, would have been impossible to overcome.

Ross's invention of his Precision Computer was undone by its complexity, costs, a failing economy, and a competitor, Clair Gilson, who made a simpler calculating instrument, more equal to the task of Louis Ross's Precision Computer.

A Mystery! - Louis Ross and John Ross Dempster - Was there a Connection?

I have been investigating a possible link between Louis Ross and John Ross Dempster, the inventor and maker of the Dempster RotaRule. But so far I cannot find a family or professional connection. The possibility of a connection arises from my observations that:

1) the Dempster RotaRule looks (Figs. 16 & 18) very much like the metal version of Ross Rapid Computer including the size, the double disk nested format, the single cursor with a handle and a locking mechanism, and the magnifying glass and its mount;
2) Ross and Dempster were both engineers, and they lived just 12 miles apart;
3) Dempster started making the RotaRule at about the same time that Ross was shutting down his Computer Mfg. firm;
4) John Dempster had a middle name of Ross, the family name of his mother;
5) Dempster's mother, a born Ross, was a transplant from the East Coast of the US, and she had Ross family relatives living and conducting business in San Francisco, and Louis Ross was also transplant from the East Coast of the US, and also had relatives living in San Francisco.

The Rapid Computer and the RotaRule are shown side by side in Figure 16. I have taken the liberty of placing a RotaRule magnifier on the Rapid Computer, as the original for the Rapid was missing. A picture (Fig. 18) from the literature [28] of the Rapid Computer shows a magnifier and its support post much like that on the RotaRule. Note the similarities in their physical appearances in Figures 16 & 18. While taking note of the similarities, it is important to also note that the calculating scales on the two devices are very different. However, there is a form of a spiral scale on the RotaRule, so maybe Dempster also got that idea from Ross.

Figure 18. The Ross Rapid Computer from Engineering Mining Journal [28]

There is another strong argument for the RotaRule being patterned after the Rapid Computer. The Rapid was the first *compact double-disk scientific circular slide rule* with a single cursor to read the scales. The double disk idea was conceived by Delamain [10] in 1630, but it had never been executed for a *scientific* slide rule before Ross's Rapid Computer. The RotaRule was the second to adopt this format, just a few years after the Rapid was introduced. How could this be a coincidence, given all the other similarities and the close proximity of Dempster's home and workshop in Berkeley, CA to Ross's place of business in San Francisco? Currently Richard Davis, a Dempster RotaRule and Dempster family expert, is studying genealogy records and is in discussion with family descendants of John Dempster to determine if there was a family or professional connection between the two men. That study may be the subject of another paper.

Acknowledgements

I need to recognize the utility of the Internet in making this report possible. Without it and its contributors, there would have been big holes in the story that I have told. For instance, I found almost all of more than 40 references for Ross's slide rules by searching the web. It would have been almost impossible task to do this from my office, on a farm in rural New Hampshire, without a computer and a link to the Internet, and without the efforts of many individuals and organizations to digitize the information and to make it accessible. I encourage other writers to also use search engines and Internet web sites to find elusive reference materials.

Now, I will dare omitting someone or some organization by mentioning a few of the individuals and organizations that I remember have contributed to this paper. The web sites for Oughtred Society, Mike Konshak's International Slide Rule Museum, Rod Lovett's eBay slide rule search page, Harvard University, the National Museum of American History, Google Search, Maps & Books, and Ancestry.com, are but a few of the Internet places that I have visited over the past few months while writing this paper.

Of course, there is also eBay, the Internet site where I made 2 of my 3 Ross slide rule purchases, and the Gemmary where I made my third. I also want to acknowledge a gift of a Ross Rapid Computer from Rodger Shepherd. That was the first Rapid Computer and *"silvered surface"* that I had seen first hand. I also want to acknowledge the email conversations that I have been having with Richard Davis about the possibility of a Louis Ross and John Dempster connection. And finally I want to thank Peter Holland for reading and commenting with a German perspective on my sometimes rambling writing, and to thank Otto van Poelje, the editor for this conference's proceedings, for his patience with me in getting the subject and title for this paper in order.

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20. San Francisco City Directories, 1914 to 1945
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23. A Lietz Company Catalog of Engineering, Surveying, Mining & Nautical Instruments, Drawing Materials & Field Equipment. 15th edition 1926. [price for the Ross Precision Computer was $28 with case.]
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FUJI - Circling the World with Straight Slide Rules

Jose G. Fernández

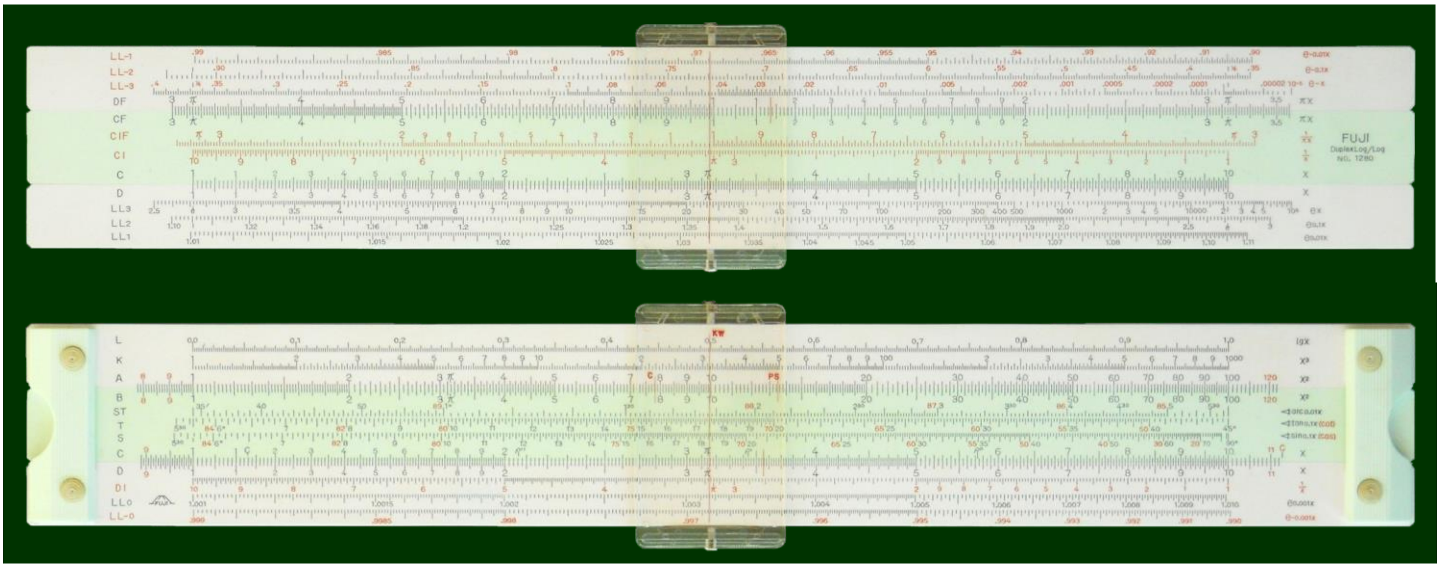
1. FOREWORD

Little I have read about strategies of worldwide commercialization for slide rules, and much less from Japanese manufacturers (maybe with the exception of Hemmi).

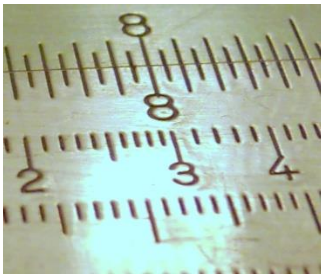
Thus, it was interesting for me to find out that Fuji was more or less present in a lot of countries apart from Japan. I am going to show data on how this company "circled" the world selling their (straight) slide rules.

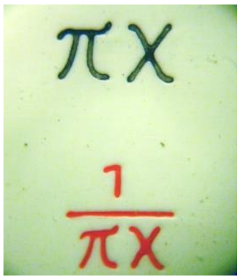
2. THE "TYPICAL" FUJI SLIDE RULE

It is a little bold to define a typical Fuji slide rule, but let us consider this example as having the common features I have seen in the majority of rules being sold abroad.



This is a Fuji 1280, a duplex model. Apart from the number of scales, what we can easily see in it is the light green colour of the slide and body brackets. It is not painted but it is the colour of the plastic material. The next we can observe are the surface finish and the scales:





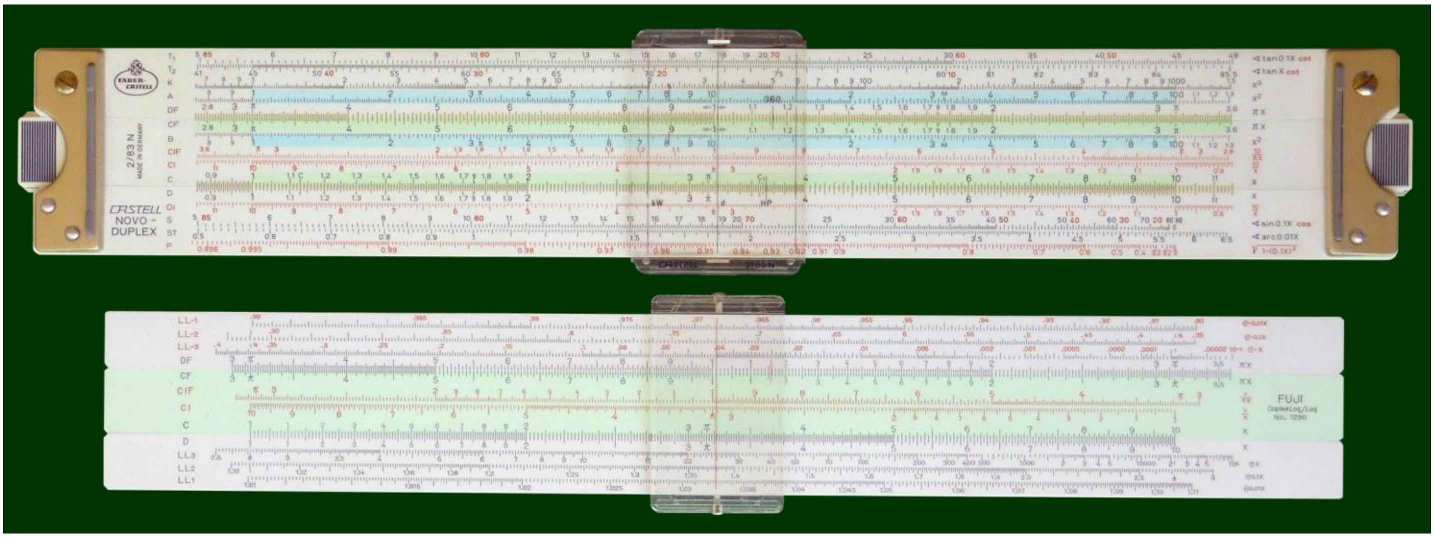
The surface has a matt finish instead of a shiny, glossy one. The scales are engraved and painted with good definition (some dirt is seen over the black ink, with a magnifier, possibly due to the red inking being a process following after the black inking). Looking at the smoothness of the surface around marks and numbers, my guess is that these came directly from the mould from which the body pieces were injected (that is, these were engraved in the mould internal walls).

The cursor is made of two transparent plastic halves and is closed with two screws, one at each end. Finally, four rubber pads top the brackets. These two details may be slightly different in other common designs:

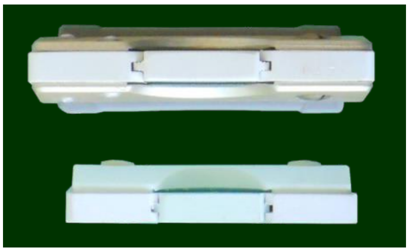
Some models may have the cursor with separated light-green runners to which the cursor faces are screwed with four screws. Also, in some models the brackets are complemented with four round stoppers, also ended in rubber pads, on the other side of the rule.

3. SLIDE RULE COMPARISON

Another characteristic that can be sensed in the Fuji slide rules is their robustness. It is not something outstanding but let us see it in a comparison:



Put aside with a Faber Castell 2/83N the Fuji specimen is clearly smaller in all aspects. All? Let us see the thickness of the two slide rules:



Now we can see that the two slides have the same thickness of the body, 5 mm, providing this feeling of robustness. This is more obvious if we measure one Aristo 0968 or even a 0969 that have a thickness of 4.5 mm.

Then, if we now compare the thickness of a Fuji 129 with an Aristo 0903LL (we will see that later, but these are more or less alike), the first one has 4.0 mm and the second 3.8 mm. And a Faber Castell 52/80 is 3.9 mm.

4. THE COMPANY

Very little is known about the history (evolution) of this company. I have only been able to get fragments or short phrases related to it, (like in [1]). I suppose that the greatest source of information is in the Japanese Slide Rule Museum [3] or the different websites of Japanese slide rule collectors [5]. However, I have to admit that these are nearly invisible to me, as I know nothing of Japanese, and Google translator is very poor with this language.

Nevertheless, it seems that Fuji may have started after WWII, between 1945 and 1949, and ended by 1975 or 1978, with all others. As company names one may find Fuji Keiki Manufacturing Co., Fuji Keisanjaku (slide rule), and Fuji Slide Rule Manufacturing Co. Ltd.

Furthermore, I found an indication, [4], that it was a kind of evolution from the brand Giken (their predecessor), although the same source mentioned a catalogue of Giken by 1960, a clear proof that they were still selling by that time. And in the Japanese museum Fuji, Giken and Taisho are presented as a single pack, maybe indicating a single source.

All the slide rules of these three brands have traits in common, starting with the fact of all specimens being of plastic.

Said this, it was a common strategy in Japanese manufacturers to change their brand names to occidental ones whenever it was sought to sell abroad, as Japanese products were not well considered in the beginning [4]. Even Hemmi, who quickly gained a prestige with their bamboo models, used the Post company or Ahrend to sell them in the US or Europe.

In this case, however, Giken might have changed to use the reference to Mount Fuji, a Japanese national symbol, for this purpose, maybe due to a time when Japanese brands were already well recognized, or maybe to mimic Hemmi, who already had the Japanese rising sun in their logo. I could imagine, then, that the brands Giken and Taisho would have stayed for the Japanese market and Fuji to sell abroad.

Apart from that, in the cardboard box of a Fuji specimen, I found the words “precision slide rules” written in Japanese, English, Spanish, French, Finish, Swedish, Norwegian, German and Italian. This is a clear indication of the countries Fuji was sold, although not of their success!

On the other hand, Fuji was also branded into occidental companies, in an effort, similar to that of the other Japanese manufacturers, to improve the expansion into such markets. Thus, in this document I will present some of the Fuji models and some from those other occidental companies, as a guide to identify the Fuji-Giken rules around the world.

To be able to make these descriptions, I started with listing all the Fuji, Giken, Taisho and branded models I could find. In the later ones I only included the specimens I could trace directly (or nearly) to a Fuji model. You will see, by the end of this article, that sometimes it was not easy…

To make the list and comparisons I have used the specimens I have, (I could “see and touch”), but also all the pictures I have been able to find in the Internet. I have listed in the bibliography all the origins of the pictures I have included here, but there are also some others, not shown, that I have used as complementary proof or in an effort to decide on doubtful

models. I have even gotten some from E-Bay and other similar websites.
This has taken a lot of time and, although most of the collectors I contacted offered the option to provide better pictures, the amount of data and the relatively “little” time I had did not let me ask for these. In any case, the complete list I have generated is included in the “Fuji Illustrated Catalogue 140905.doc”, where I have included the pictures I was able to find to show the specimens, regardless of their sometimes low quality.

There are also some references to some Fuji models without pictures. I got those from two Fuji manuals that included a slide rule list (I found also a list of Giken rules but I considered not relevant to include them there as I was focusing on Fuji).

5. OTHER “TYPICAL” FUJI SLIDE RULES

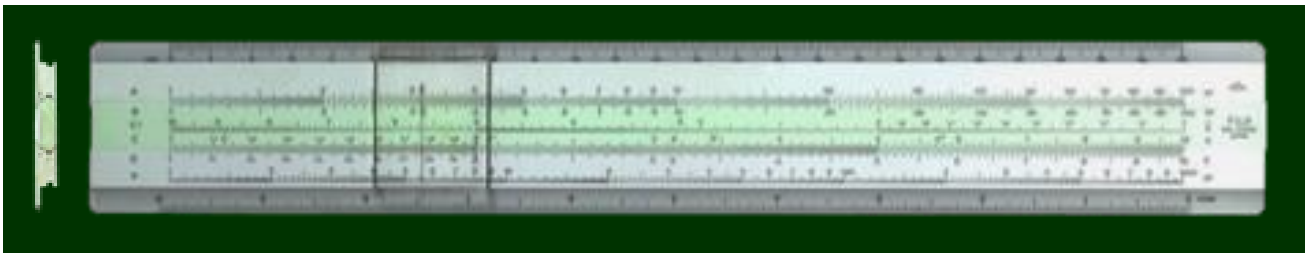
Belonging to the same family of the rule shown in chapter 3 we can find quite a long list of rules, being of all types, pocket or desktop sizes and of simplex or duplex structure. Here I include some as a short reference for the comparisons afterwards.

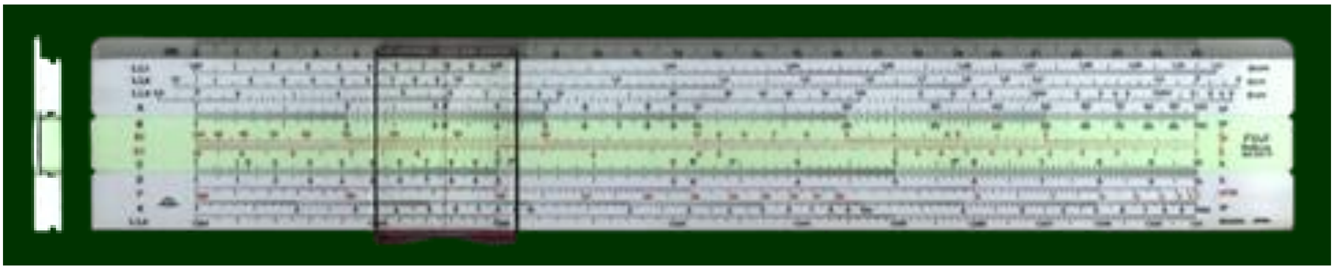

52 [3]


505 [2]

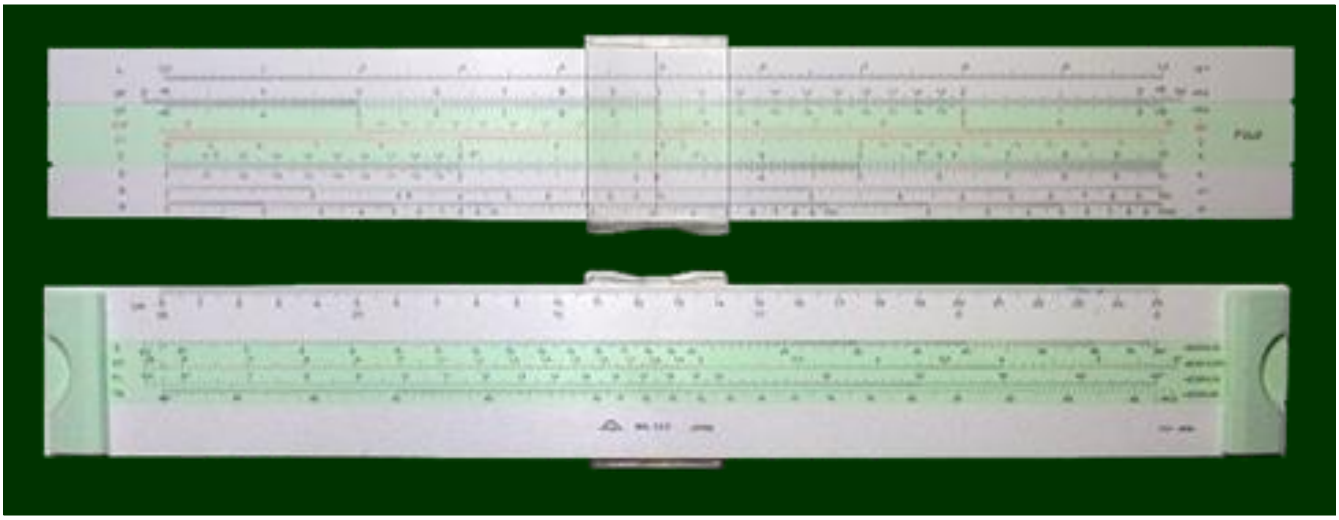

552P [2]


553P [2]


203B [2]

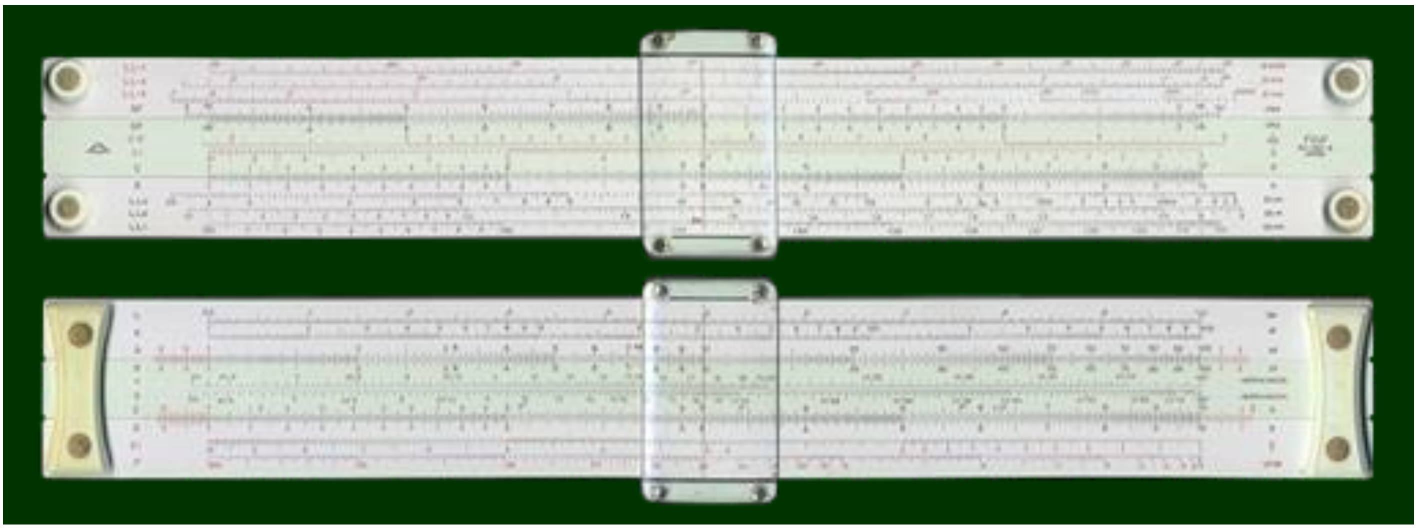


201P [2]



102 [3]

129 [2]

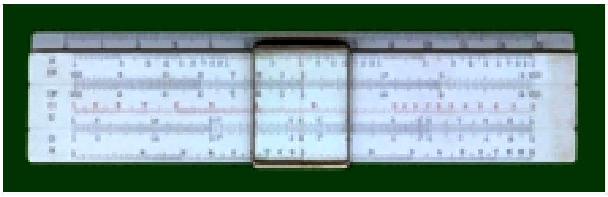


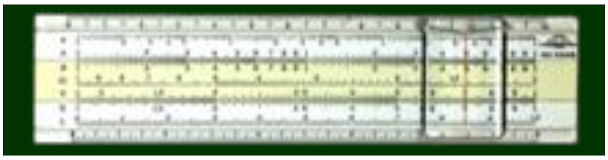
330D [3]

6. MORE FUJI SLIDE RULES

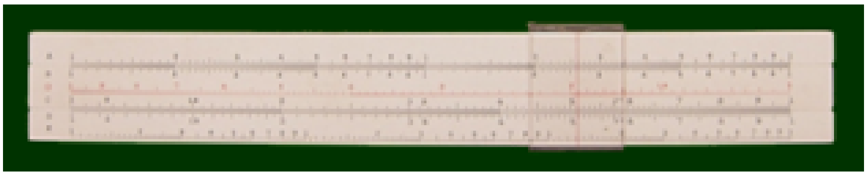
Apart from the ones already described, Fuji had another "line" of slide rules quite different in style from those. It seems as these were not part of the commercial strategy for the foreign markets, as I have only found a single foreign brand related to them.

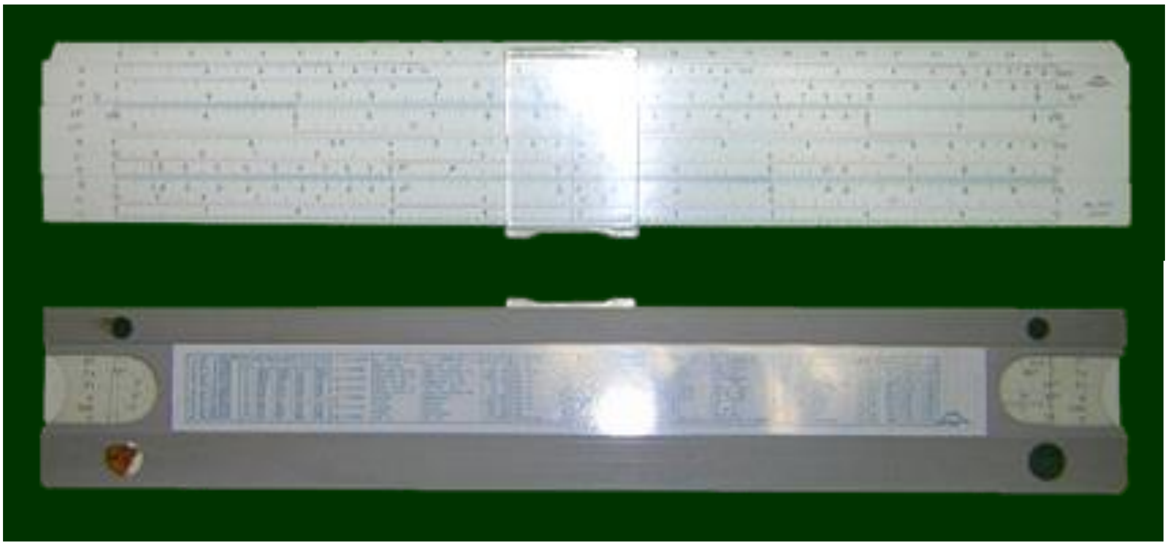

51 [3]

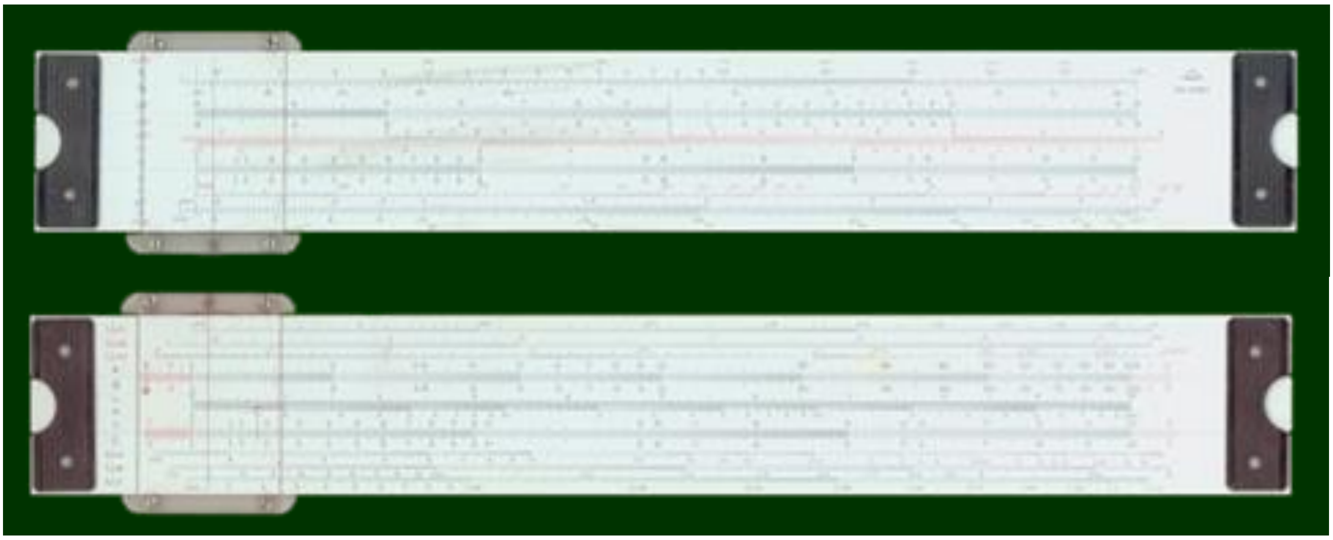

502 [3]

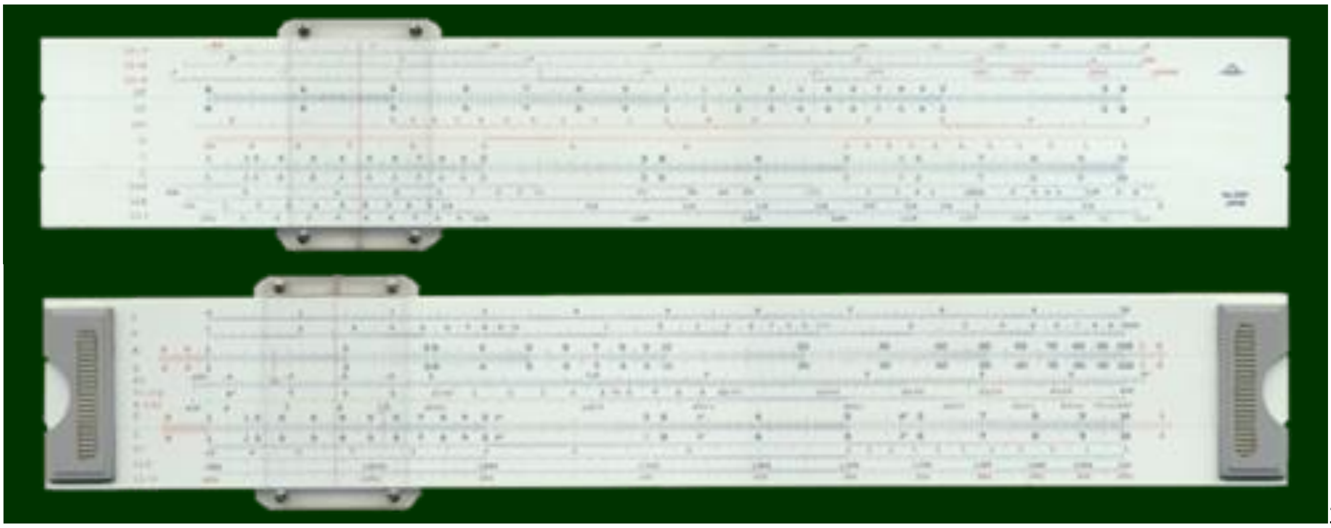

534S [2]


83 [3]


84 [7]


2125 [3]


1250 [9]


1280 [10]

As an hypothesis, these designs might have been intended for internal market (Japan) use, as there are some similarities with the Giken models found. An exception would be 534S. This type, with yellow-painted slide, (I found three models) shows manufacturing savings, maybe due to the final years of production and also for foreign market.

Finally, two models were found made of bamboo. However, when checked with the expert Paul Ross http://hemmicat.srtco.us) it came out that these two might have been made by Hemmi.

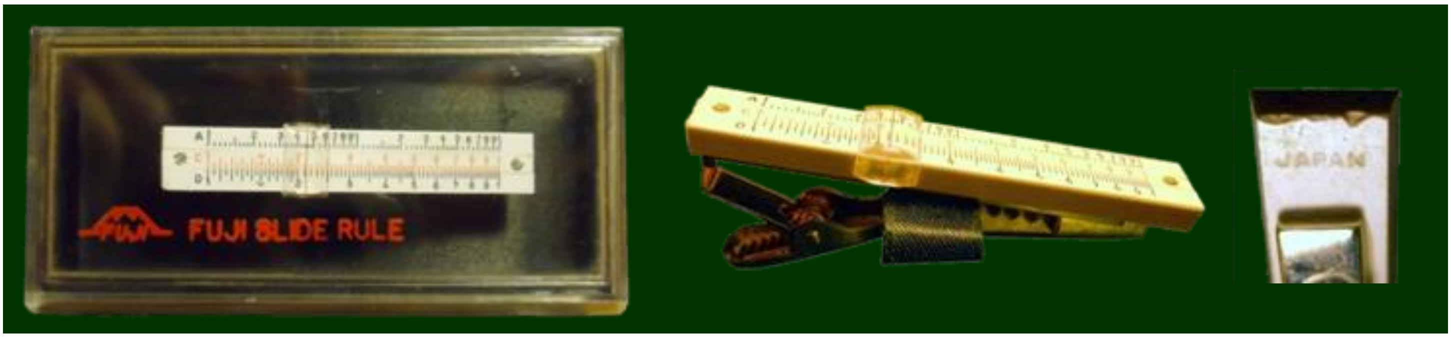

41 [8] (presumably Hemmi 30R)

85 [8] (presumably Hemmi 40F)

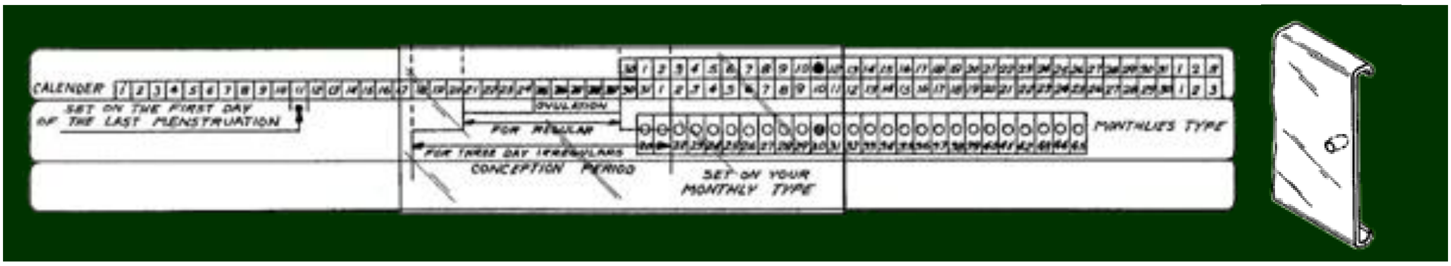
Considering this, and knowing that in the Japanese collectors group website [5] there are some pictures comparing the plastic models of Fuji and Hemmi, it remains open for me what the relationship had been between these two manufacturers.

7. FUJI SPECIAL SLIDE RULES

From one of the list of Fuji slide rules, I found that Fuji had made at least two slide rules for teaching (1,2 m long), named 1 and 2. Also there is a tie clip model, of which I am happy to own a specimen.

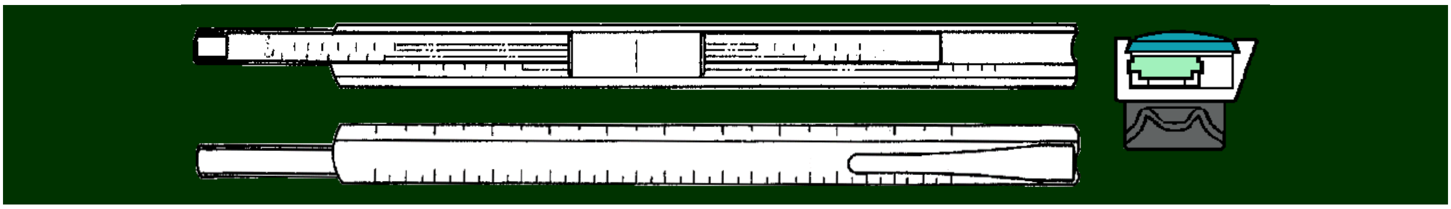


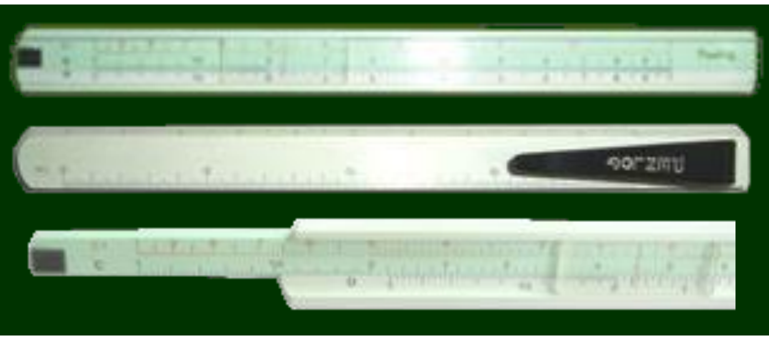
In that list there was also a reference for a Birth Control slide rule, of which Andries de Man found a US patent (US3146943).



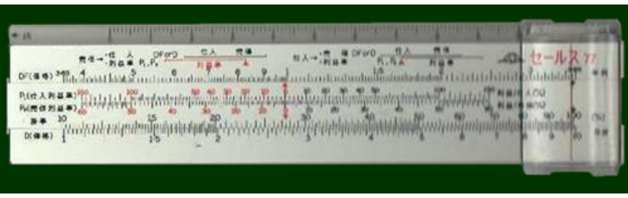
It seems that the cursor had a kind of pin to enter some hole in the slide and enabling the movement of cursor and slide at the same time. It is up to the reader to look into that patent and try to find how that would be used.

Andries de Man found another patent, this time Japanese, with another design (JP47-005203 Y). Fortunately, I had been able to find pictures of said model in a Japanese website. It shows a “pen-like” design. In fact, this is called PenLog slide rule. It is a minimum expression of a slide rule (only C, CI and D scales) in order to have the size of a pen and be able to carry it in the pocket.





Finally, I was able to find a Fuji 77 model in a website from Taiwan. This has a special scale layout that cannot be studied due to the poor picture resolution. Nevertheless it is included in the Word list. My guess is that it is for finance calculations

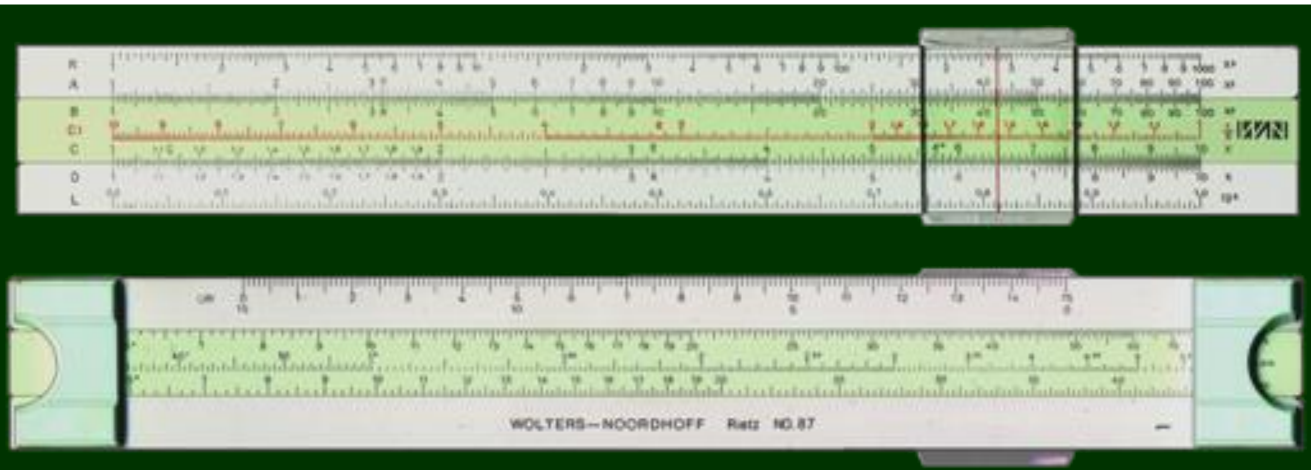


77

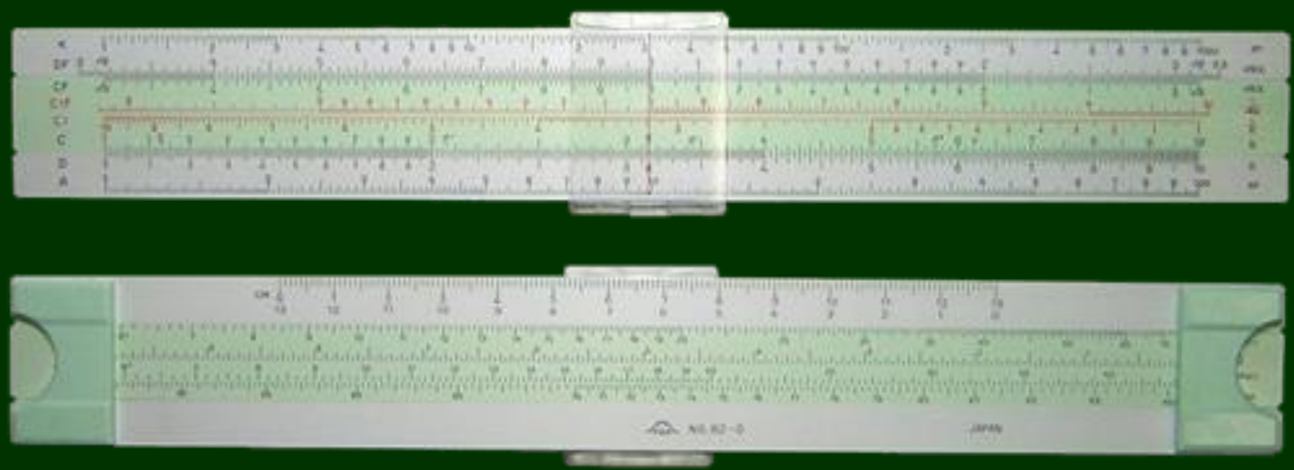
8. FUJI BRANDING: WOLTERS-NOORDHOFF

I chose this as the first of the companies branding Fuji slide rules because in some models the Fuji name was still kept. In the following two examples I present the model with the most similar Fuji original that I have found, to facilitate the comparison. The last two ones are left to the reader to find the Fuji equivalent. This brand is from The Netherlands.

8.1. Wolters-Noordhoff 87 vs Fuji 82D (I guess there should be a Fuji 87D)

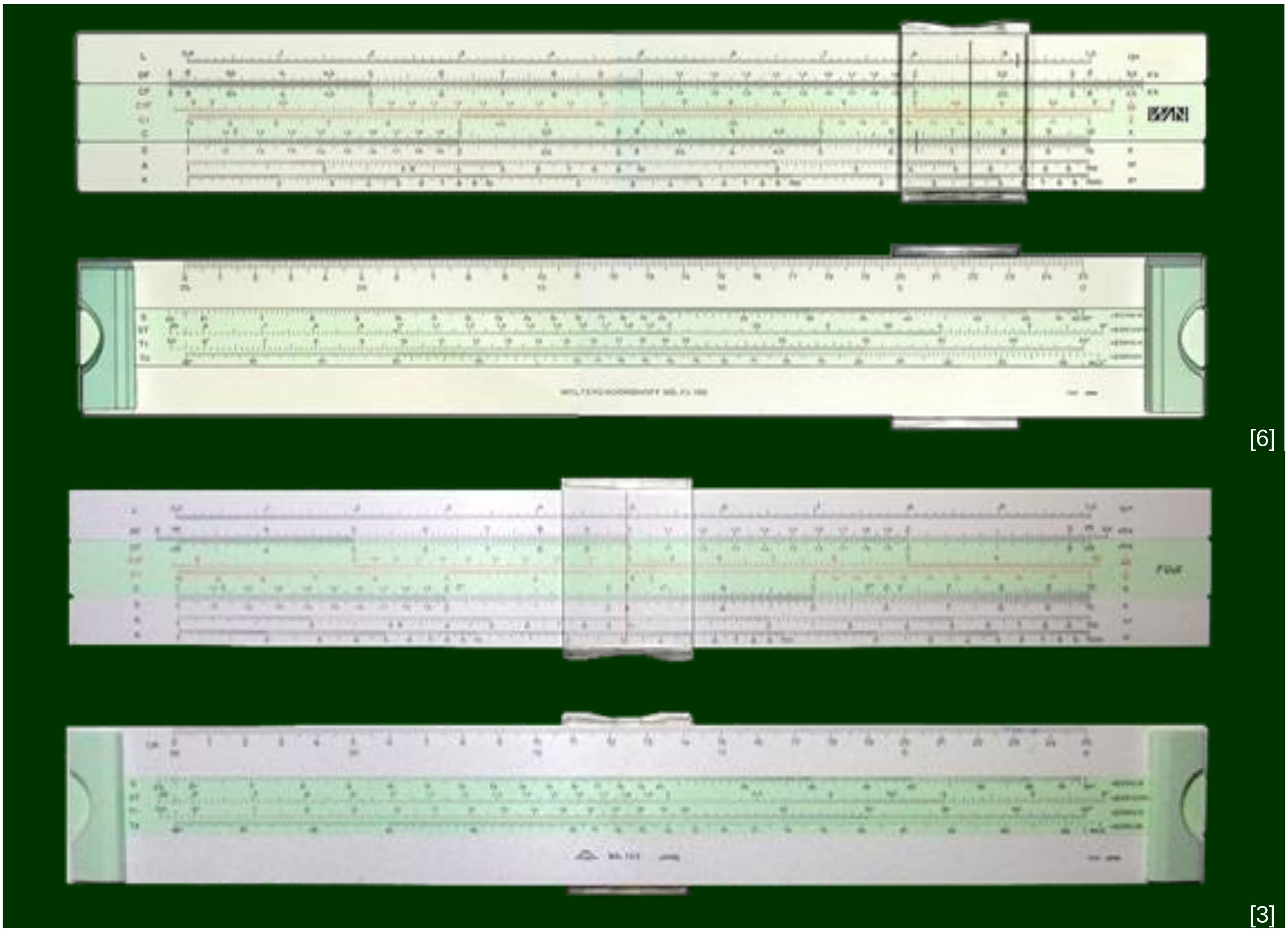


[6]



[3]

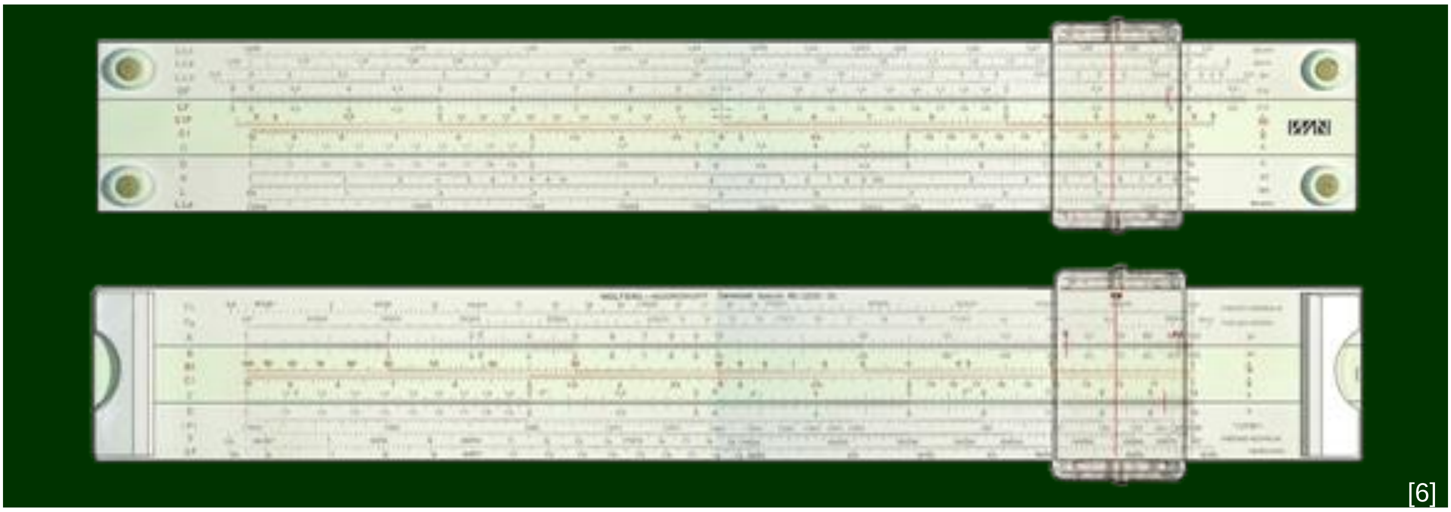
Wolters-Noordhoff FJ102 vs Fuji 102



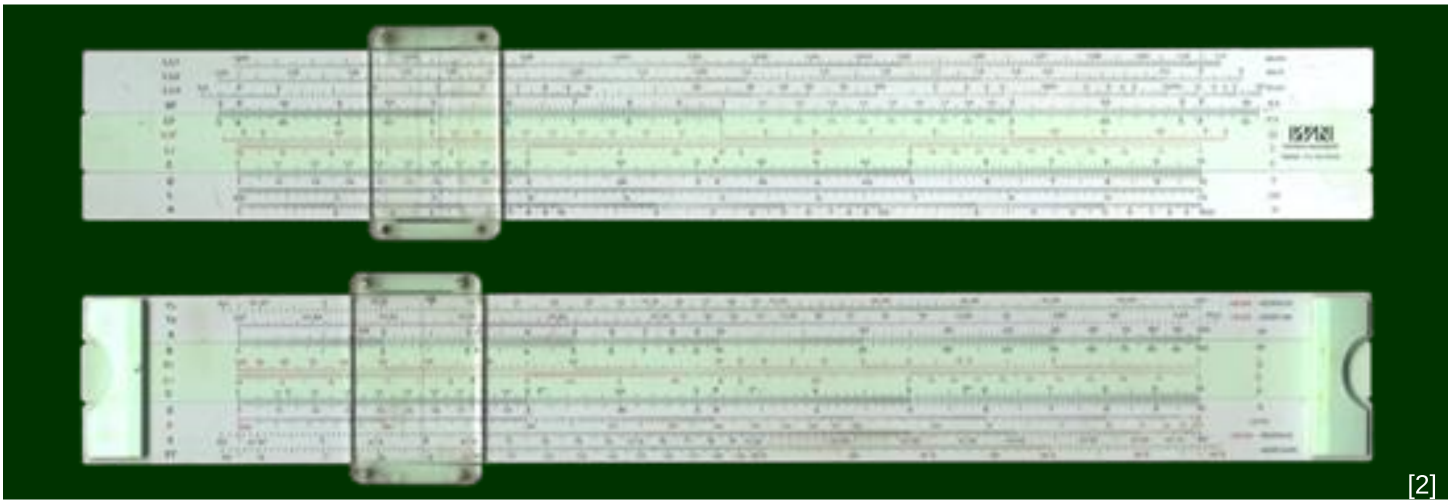
[6]

[3]

8.2. Wolters-Noordhoff 1200 01 & Wolters-Noordhoff FJ1200



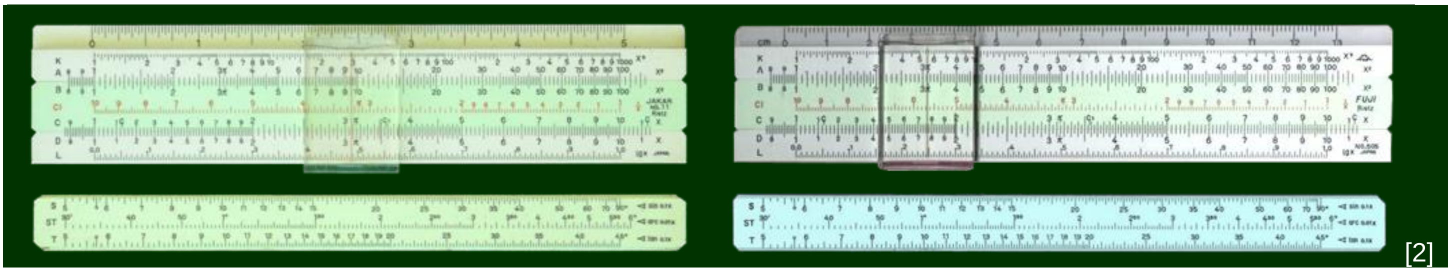
[6]



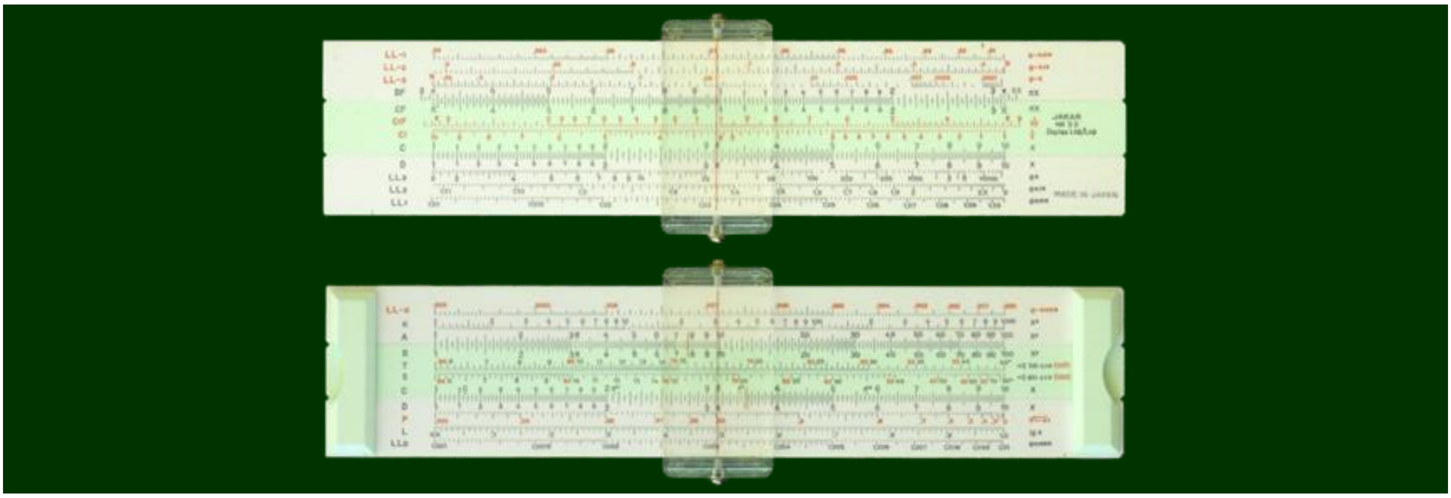
9. FUJI BRANDING: JAKAR

Although sold in Great Britain, it is well known that Jakar slide rules came from Japan, and even that they were manufactured by Fuji. Then, although it is not a surprise, we can compare with Fuji originals.

9.1. Jakar 11 vs Fuji 505

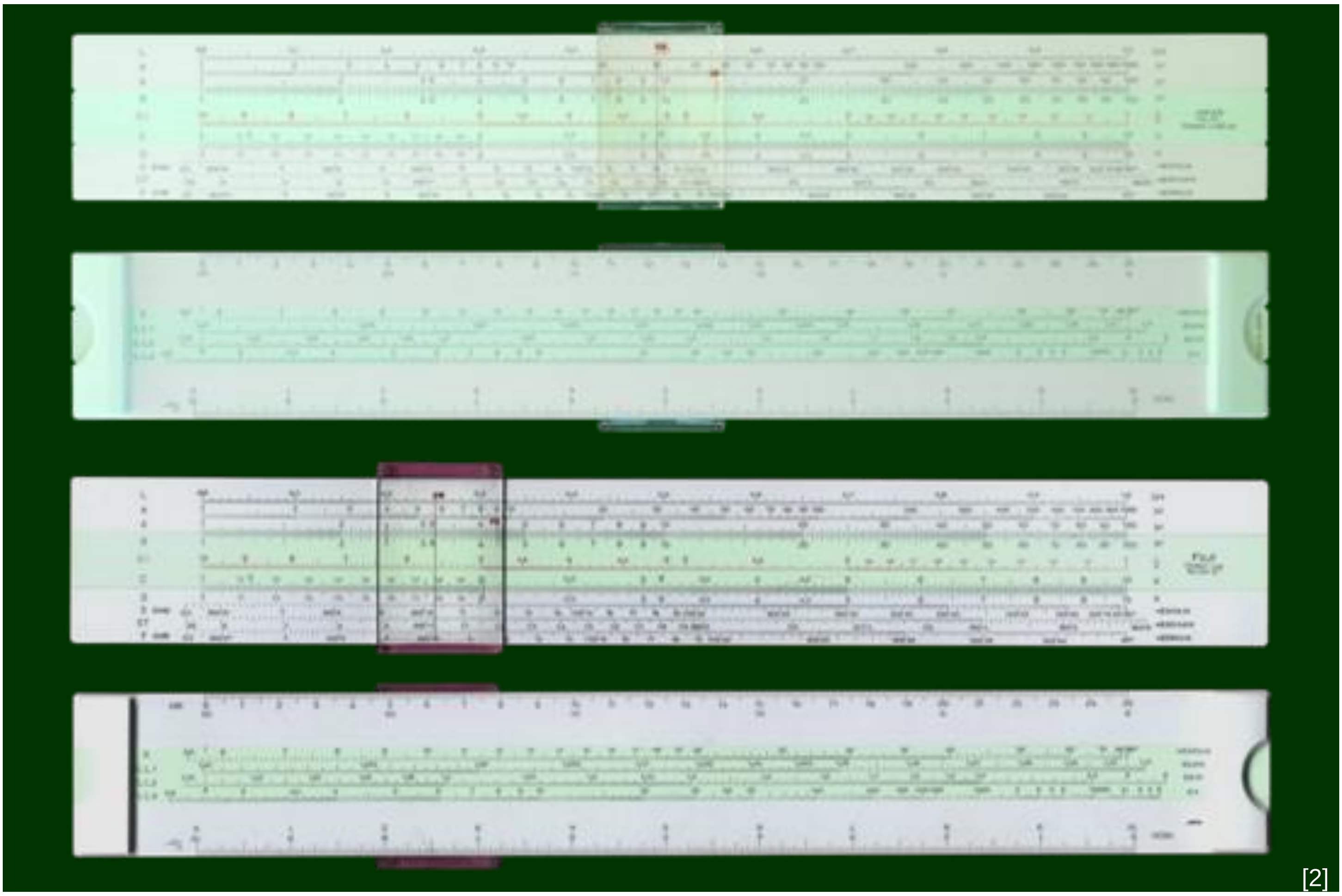


9.2. Jakar 33 vs Fuji 552P



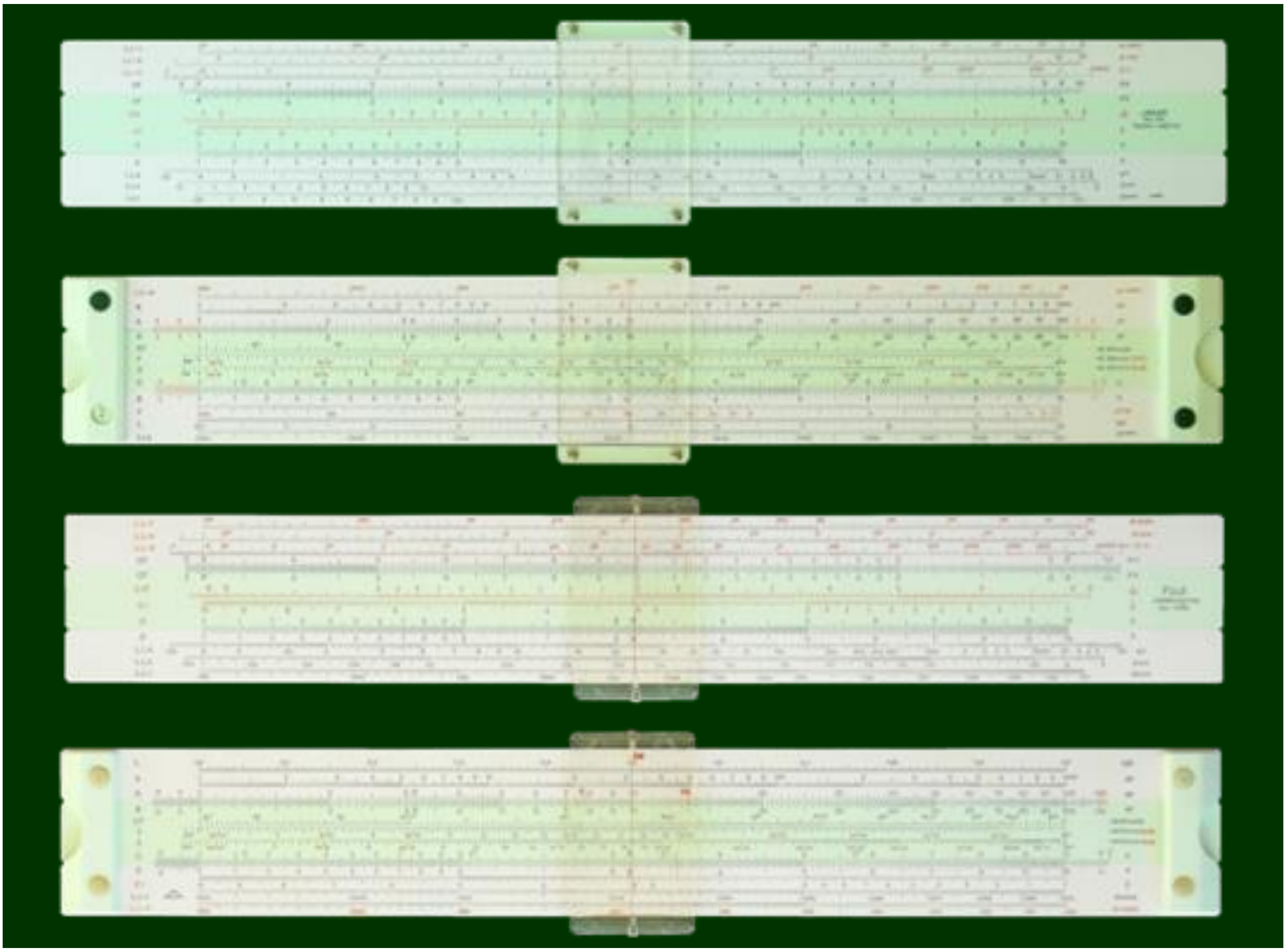
[2]

9.3. Jakar 29 vs Fuji 129 01



[2]

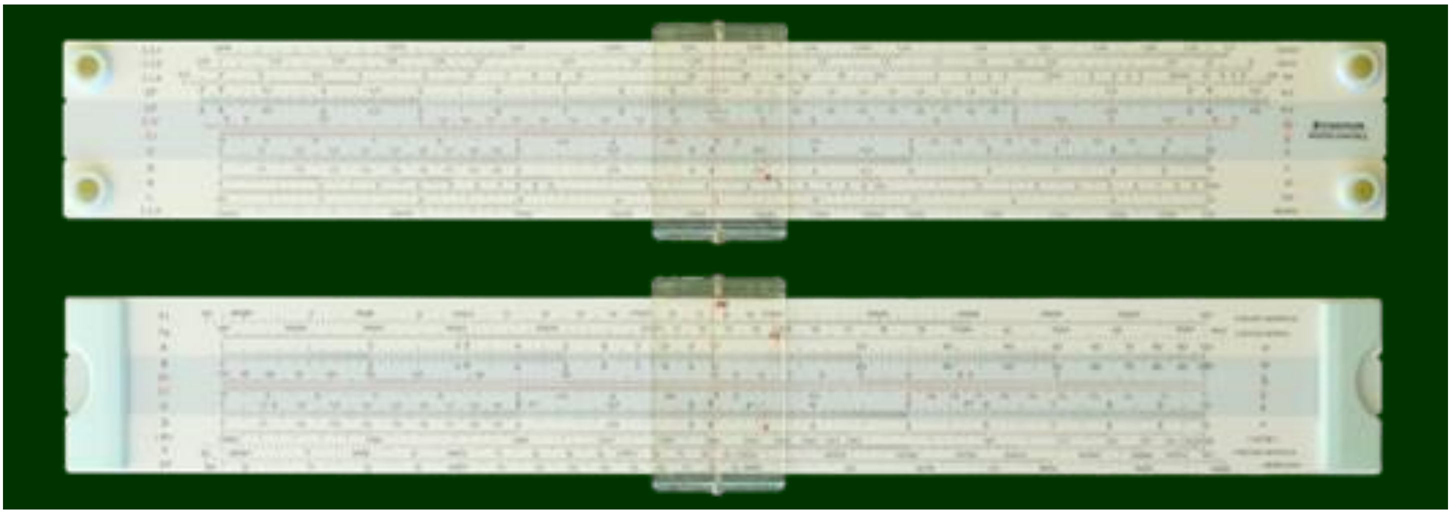
9.4. Jakar 99 vs Fuji 1280



10. FUJI BRANDING: STAEDTLER

I cannot tell what might be the reasons for Staedtler to shift from Nestler into Fuji (from a German maker to a Japanese one). Maybe it was a desire to differentiate from the other sellers in Germany, while still keeping a high level of quality in their slide rules. However, in Staedtler specimens it is easy to see that the light-green colour has been changed by light-blue. But all the other characteristics will make it easy now, that we have seen so many Fuji and Fuji-branded specimens, to identify them also as being manufactured by Fuji. Then, I will not include the Fuji equivalent specimens.

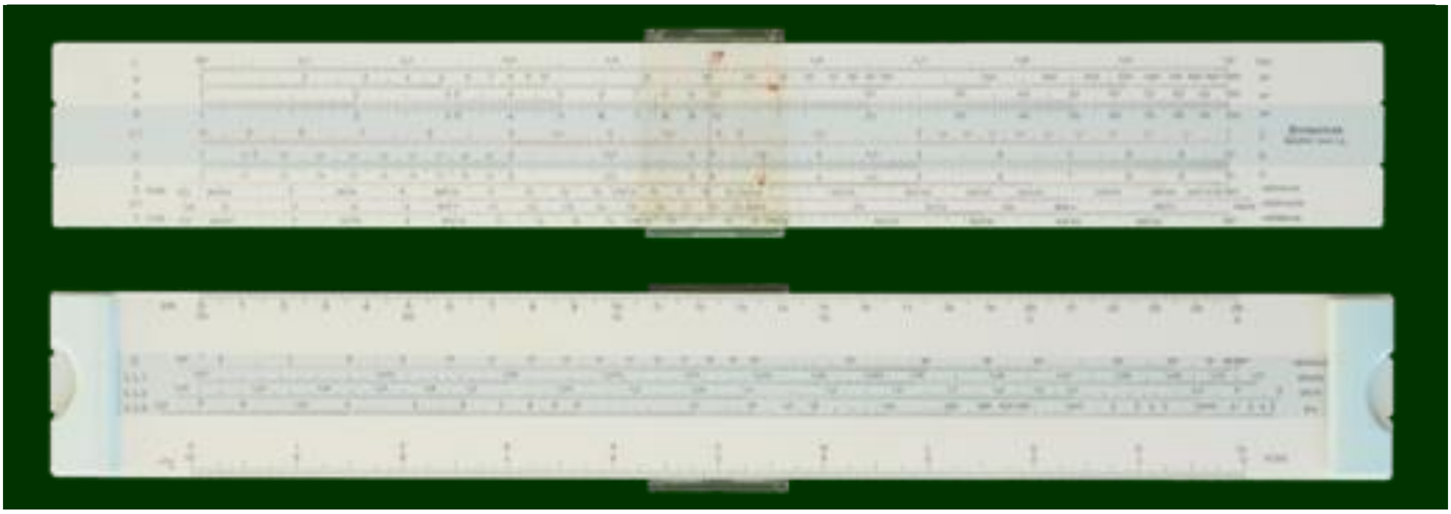
Staedtler-Mars 544DLL:



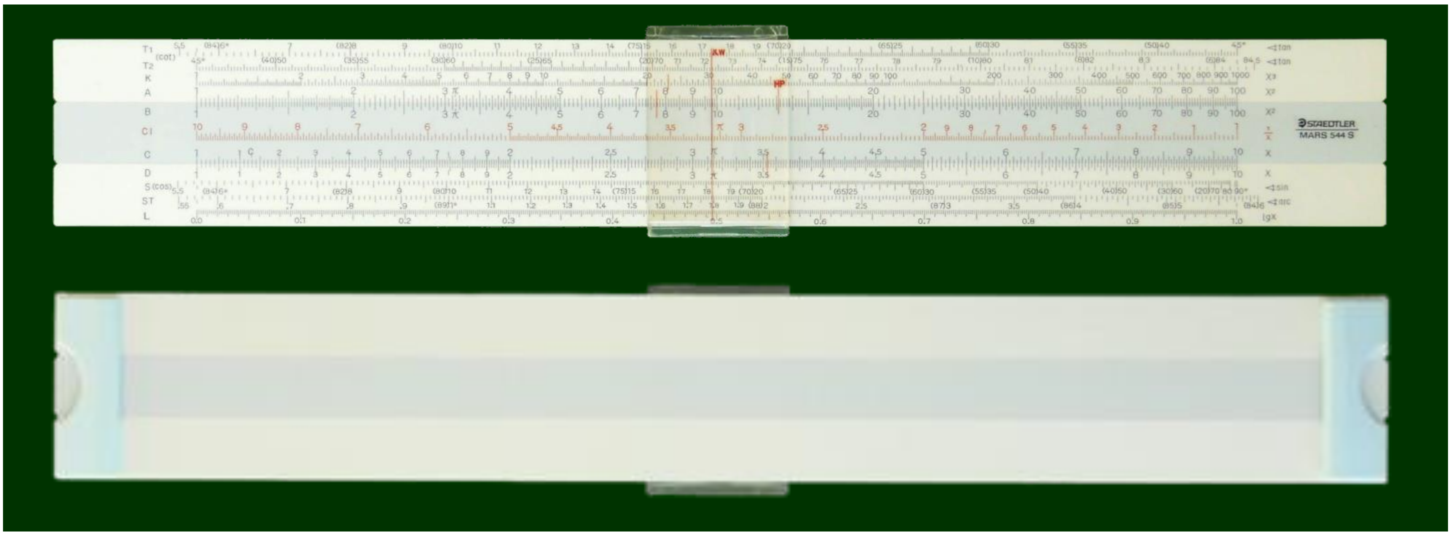
Staedtler-Mars 944 82:

[2]

Staedtler-Mars 544LL:



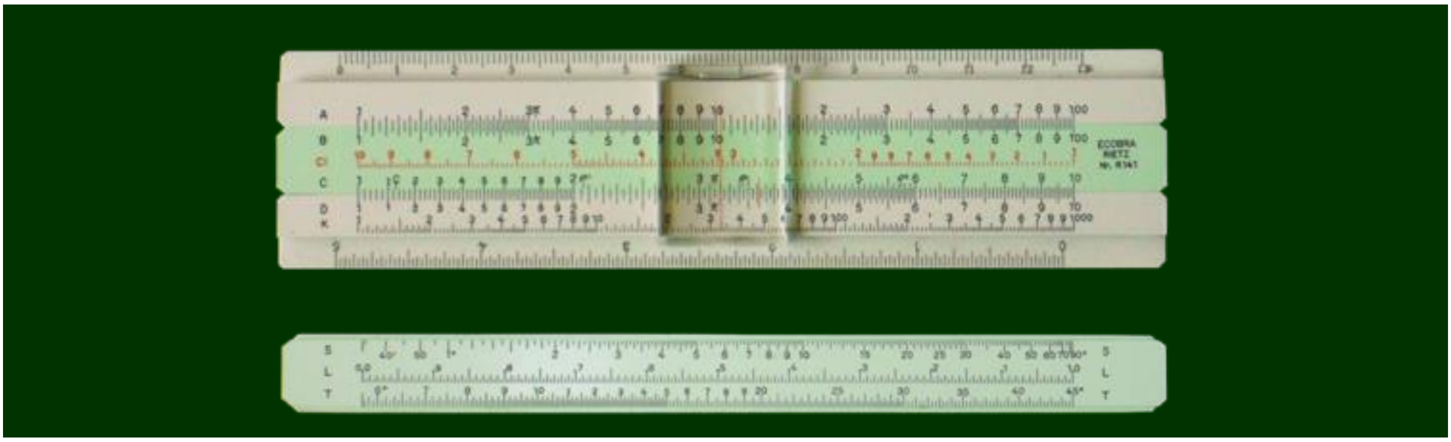
Staedtler-Mars 544S:



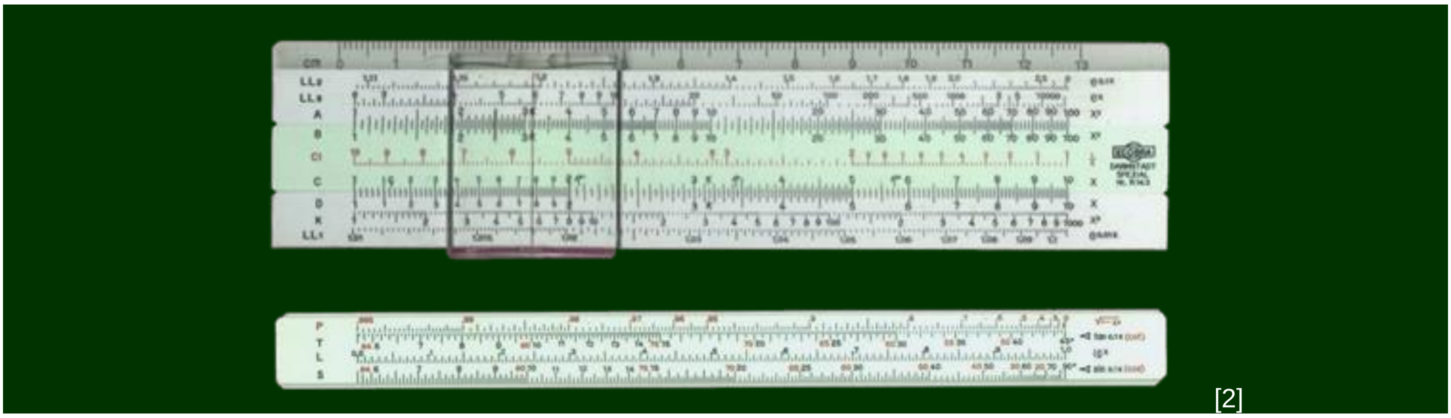
11. FUJI BRANDING: ECO-BRA

It was a surprise to me to find also Fuji-Branded specimens in Eco-Bra, that I knew for metal-body slide rules. Maybe the need to have a greater portfolio, or maybe the need for cheaper models. But, again, we can recognize the typical traits in the following models.

Eco-Bra R141 Rietz:

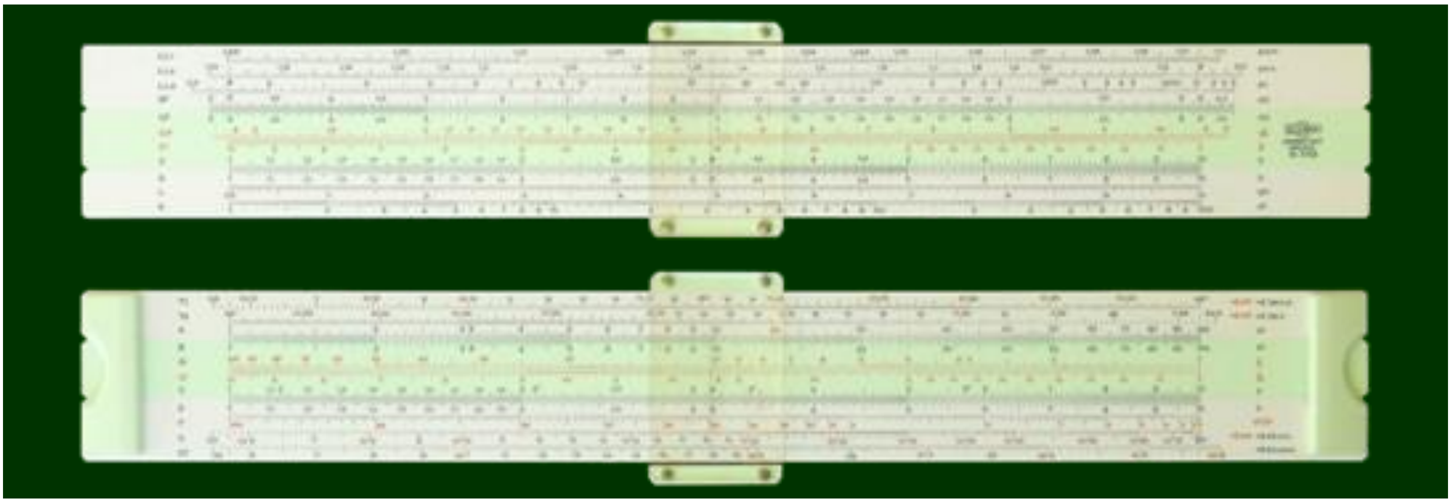


Eco-Bra R143 Darmstadt:

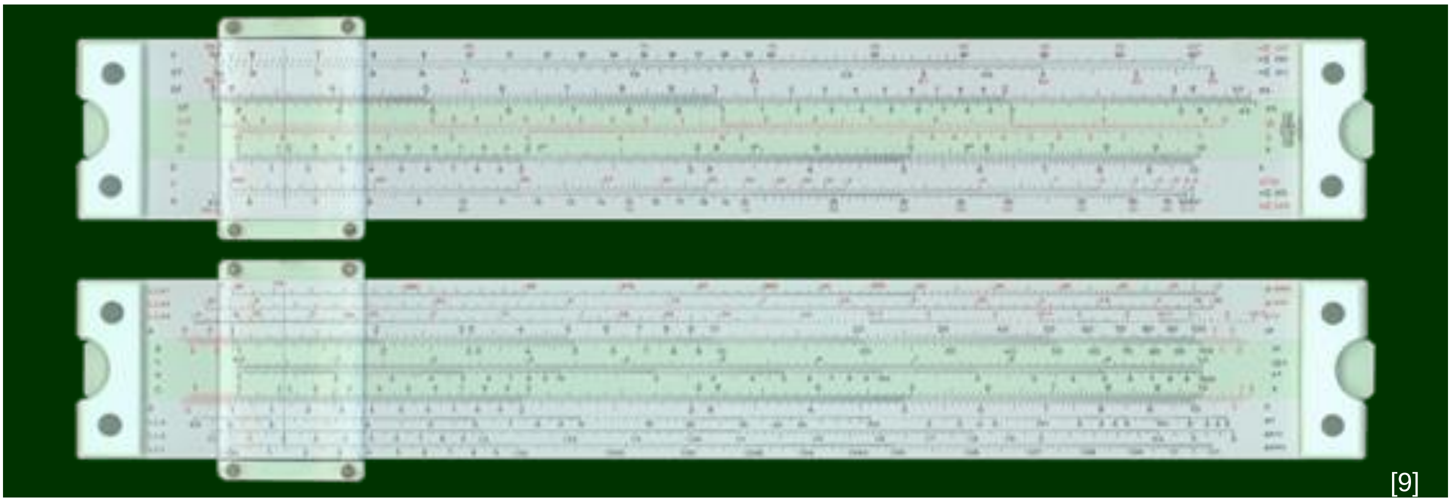


[2]

Eco-Bra R153 Darmstadt Special:



Eco-Bra R154 Cosmos:



[9]

12. FUJI BRANDING: DIETZGEN

I think it was while reviewing past threads in ISRG, [4], that I found a comment of a Dietzgen 1768 having been manufactured in Japan, maybe by Fuji. Well, the next minute I was looking through the Internet for this specimen pictures and after some search I could confirm that statement and add it to my list of Fuji-branded models. Here it is:

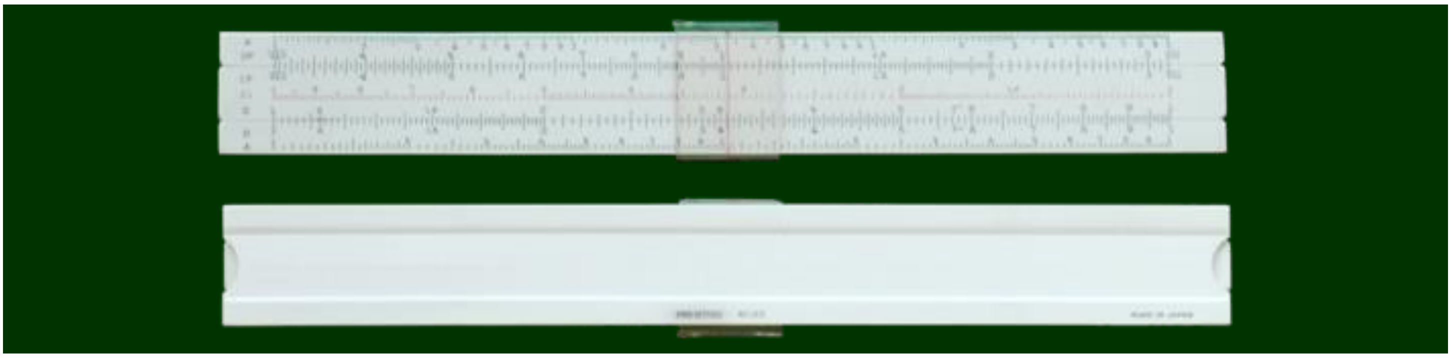
[2]

In any case, in the end I got one specimen, and in it I found that the manufacturing process in this model is different and, thus, I wish I would be able to have a Fuji equivalent (as regards manufacturing process), to be completely certain.

13. FUJI BRANDING: PRENTISS

In ISRG I also read about a brand, Prentiss, where a 1250 specimen “looked like” some Fuji model. I was not able to find pictures for that model, but after looking for Prentiss in Lovett’s list of E-Bay sales, I found three other Prentiss numbers 41, 401 and 83 and, furthermore, in the end I was able to find one Prentiss 83 on sale in the Internet. Both the model numbers and that 83 specimen I got, looked as being Fuji, although that 83 matched the white-type ones. Thus, I would say this was another company that branded Fuji slide rules and would be eager to confirm that this is the only one that commercialized the “other” type of slide rules, not to mention the reasons for that…

Prentiss:



14. NOT FUJI-BRANDING: WOLTERS-NOORDHOFF

Well, the story would not be complete without the “other side”. I had to see if the relationship between Fuji and those companies did change with time. And I found proof that things changed indeed. For example, this Wolters-Noordhoff JE650:

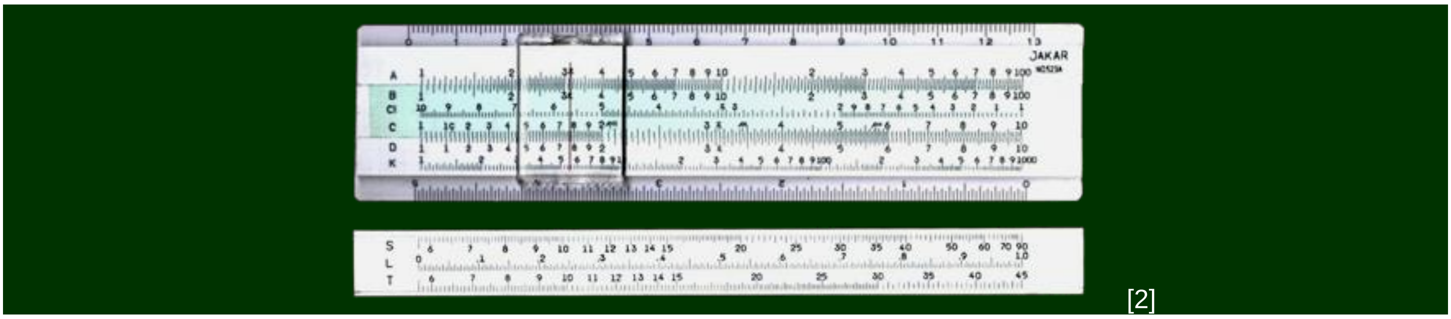
[6]

Have you seen the similarities with the Faber-Castell 57/80?

[11]

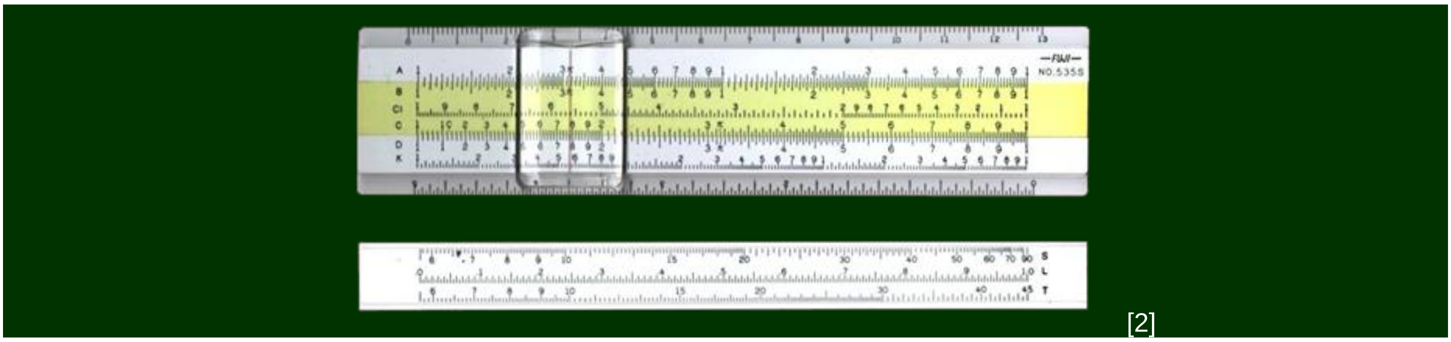
15. NOT FUJI-BRANDING: JAKAR

And also Jakar had models from others. Unfortunately, again, no time data is available to get a better view of this change. As a guess, either prices had to go lower than feasible by Fuji, or Fuji had already stopped producing. Let us see the models, like this 523A:



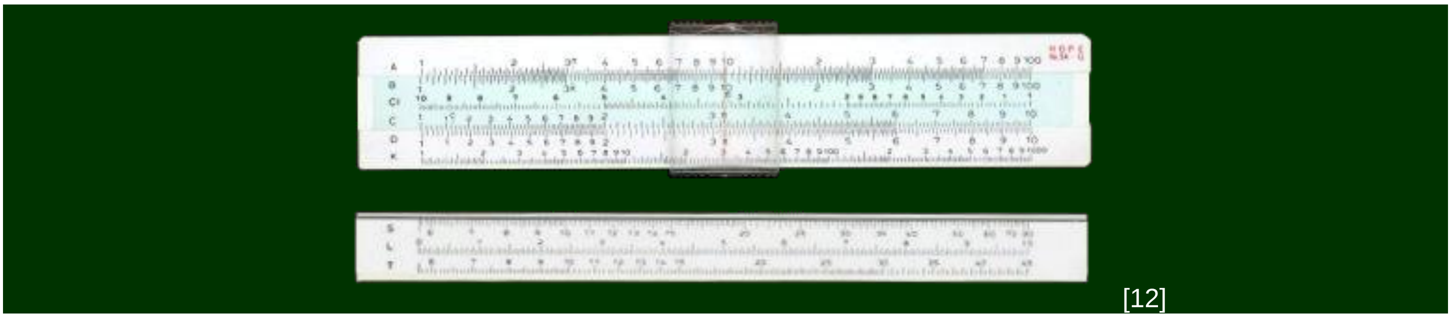
[2]

It may seem similar to the Fuji 535S:



[2]

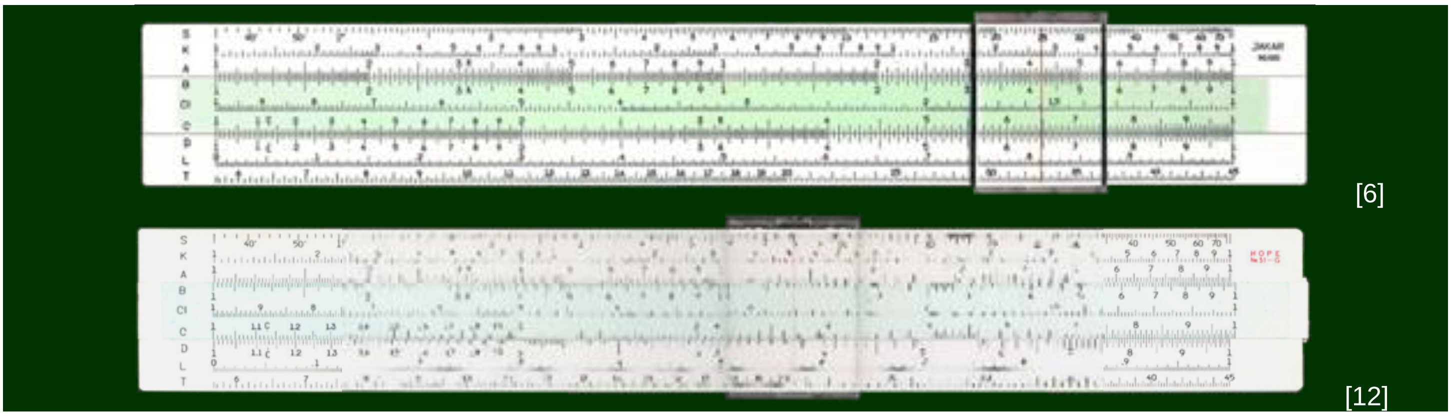
But, apart from a change of model numbering series (like in previous Jakars shown), it is much more similar to the Hope model 54G:



[12]

Most significant is the short-ending of the light-blue painting in the front of the slide, or the shape of the cursor. The cursor has undulated gripping areas, and the spring strap touches the rule in two points (bent and fixed in the centre), while the Fuji ones have a single touching point (with fixing at the spring ends).

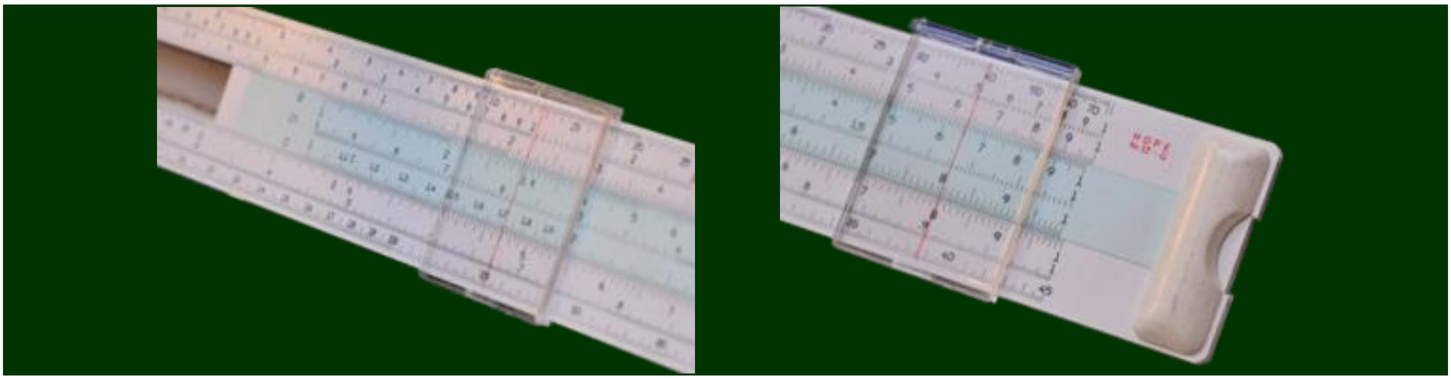
Other model series from Jakar but not from Fuji are the 100X, like this 1005 specimen, like Hope 51G:



[6]

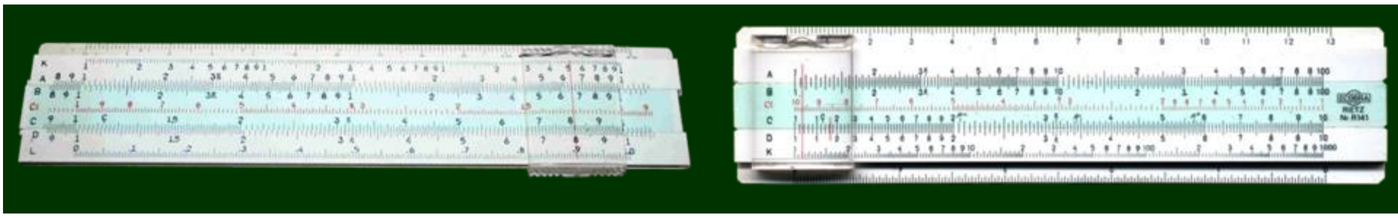
[12]

As I told, I had not enough time to get better pictures, and in this case this is needing a little more. This I got from a Hope 52G, where also the body fixing brackets show a characteristic "Hope design" that I saw in other Jakar rules of this series.



16. NOT FUJI BRANDING: ECO-BRA

We already know of Eco-Bra slide rules surely not from Fuji: the metal ones. But, were all the plastic ones from Fuji? Here the answer is not easy. I have already shown an R141 model that I assigned to Fuji, but let us see these other two:



[9]

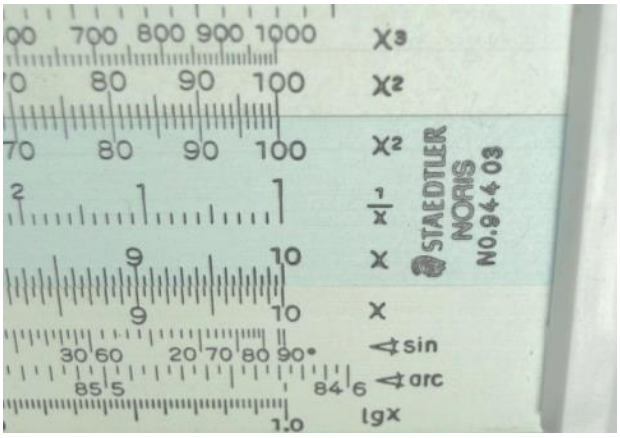
The first one can be easily assigned to Hope, for the same reasons like the Jakar "Hope-like" models. But the second one, an intermediate step between the Fuji-Branded Eco-Bra and the one related with Hope, is doubtful. If it is a Fuji, why to change the colour? (or is it the picture?). But the slide is completely light-blue, is it the colour of the plastic ("Fuji-like") or a painting on the top face ("Hope-like")? And, then, the cursor may have changed from the original one that could have been "Fuji-like"… Something that is still open…

Maybe it is time now to speak of Japanese manufacturers. I have found about 36 brands that are assigned to Japanese manufacturers. But I believe that only about 8 where real manufacturers: Hemmi, Fuji, Concise, Ricoh, Uchida, Hope, Alco and Delta. But I have no idea of the relationships between these or I have little proof of this list of eight. For example, was Hope in fact a (low-cost?) brand of Fuji?

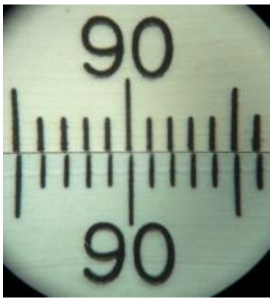
17. NOT FUJI-BRANDING: STAEDTLER

And last but not least (I had to write this!), Staedtler at a given time changed from "Mars" to "Noris". Did this mean a change in the sourcing of their products? Are Staedtler-Noris from another manufacturer? What I can tell from the specimen I have, 944 03, is that it is clearly differently manufactured from the Fuji slide rules I have. But it is also different from any other slide I have been able to compare…

First, we have the front surface of the rule. I would say it is slightly shiny, but without a totally smooth surface, like if it was somehow treated (sorry I could not make a better picture):



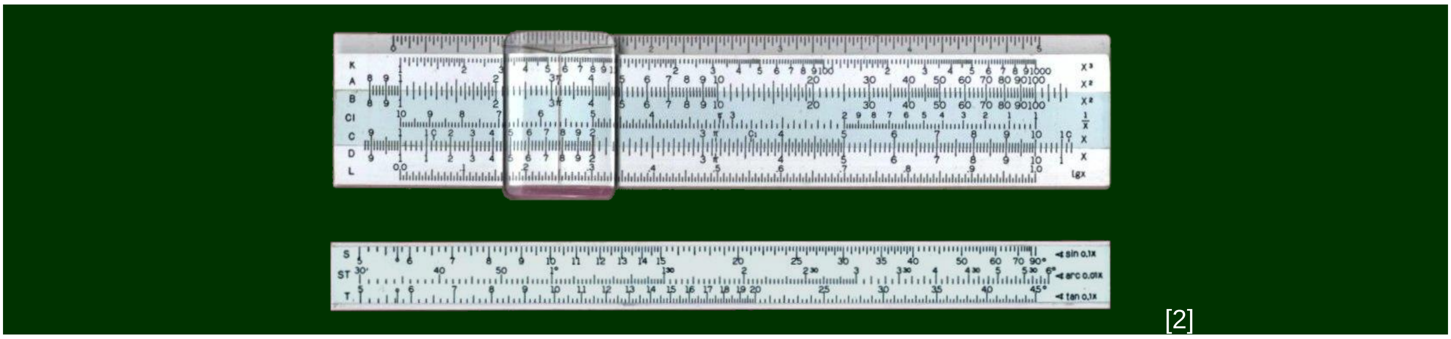
Then there is the printing. When looked with a magnifier we can see the scales and marks are engraved (not clear if from the moulding), but the printing is not neat (the parallelism distortion seen is due to the magnifier!).



My hypothesis here is that the printing (or the marks engraving) is done by somehow heating the front surface. Thus, the body (extruded?) plastic (see the parallel lines in the magnified images) are somehow melt when printing (or engraving marks?), providing this slightly-shiny surface.

Then, was it a new manufacturing process from Fuji? Or was it from another manufacturer? The scale layout is similar to previous versions, but this might be a Staedtler requirement. As I do not have a Fuji specimen similar to it in manufacturing process, or from another manufacturer, I have to leave this point open.

And this can also be said for other Staedtler-Noris versions, like the 944 02 that can be seen in the ISRM [2], or this other one 945 03, with a cursor very similar to the Fuji ones:



[2]

18. WHAT I HAVE UP TO NOW: AN ILLUSTRATED LIST

So, in summary, I have completed a list of Fuji and Fuji-branded slide rules, the “Fuji Illustrated Catalogue 140905.doc”. There you can find:

- 64 Fuji models with different reference (numbering)
- 77 Fuji models when counting also versions of each reference (due to different years of manufacture?)
- 27 (+6 versions) Fuji-branded Models
- 8 Giken and Taisho models (Giken list found in [3] with other 21 models referenced)
- 118 models in total

This file will be found as an annex to this work in the IM2014 CD. And afterwards it may be downloaded from www.reglasdecalculo.com

19. FUJI… WHAT ELSE?

Up to here is what I have been able to do on Fuji models (for IM2014). But, as I guess the reader will have realized, there is still quite a lot to be done:

- ➢ Get better pictures to improve the catalogue list of Fuji models so that it may become a working reference. However to achieve this something else will be needed.
  - Involve other collectors, museums… This is obvious. I will never have all the models at home. Thus, pictures from other sources will be a must.
  - Agree on a minimum quality. I know very little of picture processing, but I believe that all the collaborators should provide the pictures in a format that might be adapted to get equal photos for all models.

- ➢ Detailed History of Fuji, Giken, Taisho and their relationship with the other Japanese manufacturers. For this, the best would be to contact the Japanese museum and colleagues, once the language handicap is overcome! As a summary, the following would need more details:
  - Get company history milestones and complete exporting portfolio (“white-type” slide rules?).
  - Identify relationship with Giken and Taisho.
  - Clarify relationship between Fuji and other manufacturers (Hemmi, Hope…).
  - Find slide rule changes (evolution) through years. Fuji commercial catalogues would be priceless here.

- ➢ More specimen details. With better pictures or with other colleagues’ direct participation it will be easier to complete the Fuji list with other models, and to decide if the today doubtful models are Fuji-branded or not. Then, it might be possible to identify the “Fuji” typical details per version and production year.

Anybody ready to take the lead? or to collaborate? It will be quite a long run…

20. ACKNOWLEDGEMENTS

This study would have not been possible without the comments and indications from Panagiotis Venetsianos, Otto van Poelje, Barbara Haeberlin, William Lise, Paul Ross, and Andries de Man, although the errors and inconsistencies are only my fault!

Also, some collectors have facilitated their pictures of specimens. The ones I have used are listed in the bibliography, although there were others to whom I must be grateful too, as I could compare specimen details to reach the conclusions presented.

Finally, not to mention, I owe to the patience and support of my wife and children, without which I would not have been able to complete this study.

21. BIBLIOGRAPHY

[1]: Peter Hopp “Slide Rules, Their History, Models and Makers”, page 176 Astragal Press
[2]: International Slide Rule Museum (ISRM): http://www.sliderulemuseum.com/

[3]: Japanese Slide Rule Museum: http://www.keisanjyaku.com/
[4]: International Slide Rule Group (ISRG): https://groups.yahoo.com/neo/groups/sliderule/info
[5]: Japanese collectors forum (?): http://groups.yahoo.co.jp/group/keisanjyaku/; http://jeykanz.way-nifty.com/jeykanz/; http://app.m-cocolog.jp/t/typecast/40715/4/category/4946515
[6]: Herman van Herwijnen Archive: http://sliderules.lovett.com/herman/hermansearch.html; www.rekenlinialen.org
[7]: MIT Museum: http://webmuseum.mit.edu/
[8]: Shinichiro Osaki: http://www.dentaku-museum.com/hc/computer/sliderule/sliderule.html
[9]: Giovanni Breda: http://www.sliderule.it/
[10]: Rod lovett: http://sliderules.lovett.com/
[11]: Jorge Fábregas: http://www.reglasdecalculo.com/
[12]: Gillermo Castarés: http://www.idccc.com.ar/
and many more…

Maximator Valorect – A New but Unsuccessful Treatment of Logarithms with a Decimal Adder

Stephan Weiss

The *Addiator GmbH* Company, founded 1920 in Berlin and deregistered 1975, is well known for its various types of slide adders[i]. Those adders are useful for addition and subtraction, in multiplication and division they provide almost no assistance. Aware of that disadvantage, the founder and owner up to WWII of *Addiator* Company, *Carl Kuebler*, designed and offered decimal aids for multiplication in form of attachments to the adders as well as stand-alone devices or complete multiplication tables.

In 1930 he invented the so-called *Maximator Valorect* slide adder[ii]. One side of the device is used for additions (Fig. 1) and, having turned down the device, the rear side for subtractions. With the additional part *Valorect* at the left side, the slide adder can handle decimal numbers as intended, whereas multiplications and divisions are replaced by the usage of logarithms.

Figure 1. Maximator *with* Valorect, *side for Addition*

To the device belongs a printed graphical logarithmic table, consisting of two sheets of paper with dimensions 11 x 17.5 cm (4.3 x 6.9''), the columns printed with white background for the numbers and green background for the logarithms (Fig. 2). The scale itself is 408 cm (13.4 ft.) long in total and allows to read off four decimal places. In an advertising description from July 1931, the table is correctly called *mantissa* table and not *logarithmic* table[iii].

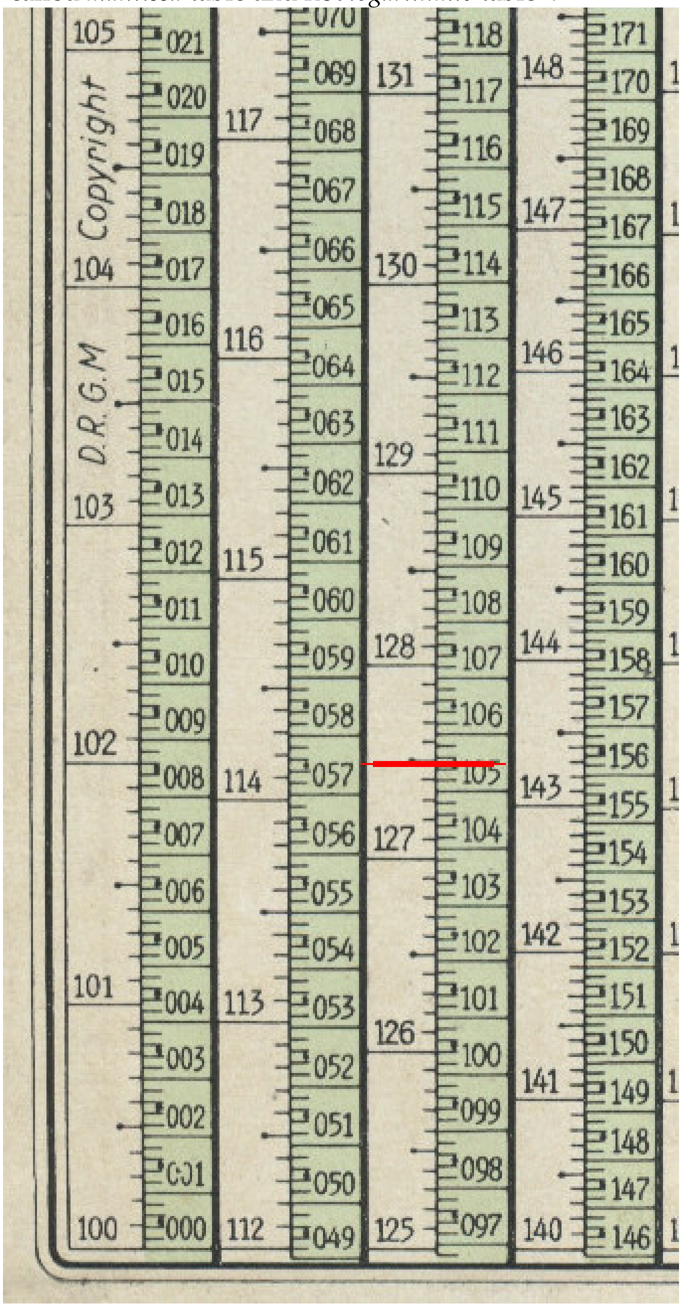


Figure 2. Detail of the enclosed Logarithmic Table
(The red mark gives 1275 white, equals 1055 green)

In *Kuebler's* first opinion it is a too difficult task for the user to determine the characteristic in logarithms of given numbers[iv], especially in decimal fractions. His idea is to split the logarithms into mantissas and characteristics with the latter new defined and treated separately.

Since Kuebler doesn't work with real logarithms, he thoroughly avoids the words *logarithm* and *anti-logarithm* and uses instead *green numbers* for the mantissas and *white numbers* for the real numbers according to the colors of columns in the logarithmic table. Probably he uses these new words not to remind his readers of maths with logarithms at school.

To go into details with the calculating process, mantissas read from the table are added or subtracted with help of the four slots to the right of the framed area *VALORECT* (see Fig. 3). Thus a carry is ported to the adder for characteristics. Next the sum of mantissas is *de-logarithmised* with the table.

In a third step, the position of the decimal point within the result must be determined by adding or subtracting the number of digits within the product factors. In case of numbers greater than 1 the number of digits equals the numbers of digits left of the decimal point. In case of numbers less than 1 the number of digits is negative and refers to the number of zeros right of the decimal point. Written in a formula: number of digits = characteristic + 1.

A calculating example (1.893 * 262.50 * 0.025 / 365), taken from an instruction for use and performed in detail, may clarify the whole procedure.
We read from the table and add the *green numbers* 2772 (for *white number* 1893), 4192 (for *white number* 2625), 3979 (for *white number* 2500) and subtract *green number* 5623 (for *white number* 3650) on the reverse side[v].
The sum 5320 is a *green number.* Its corresponding *white number*, read from the mantissa table again, is 3404.

In an early design of *Valorect* two sliders are available for the addition of numbers of places: slot A for numbers greater than 1 and slot B for numbers less than 1 (see Fig. 3-A from an instruction for use).
In our example now we add the number of places 1 for 1.893 in slot A, 3 for 262.50 in slot A too, 0,0 for 0.025 in slot B and, subtract 3 in slot A on the reverse side for 365. One of the two small windows displays 0,0 and, having appended the intermediate result white number 3404, we get the final result 0.03404. For a result greater than 1 the other small window would display the number of places left of the decimal point.

To add 1 in slot A isn't really possible. Fig. 3-A and the red arrow there show why. The hole in the slider for digit 1 is placed at the lower end of the slot. So when the user adds a number *n* by moving the slider down with a stylus he really adds *n* – 1. On the rear side the same arrangement is used. There the user subtracts *n* + 1. In fact the *Valorect* adder doesn't work with number of digits, it works with characteristics. The arrangement of symbols and sliders subtracts 1 from every entered number and a complicated mechanism adds 1 to the result again.

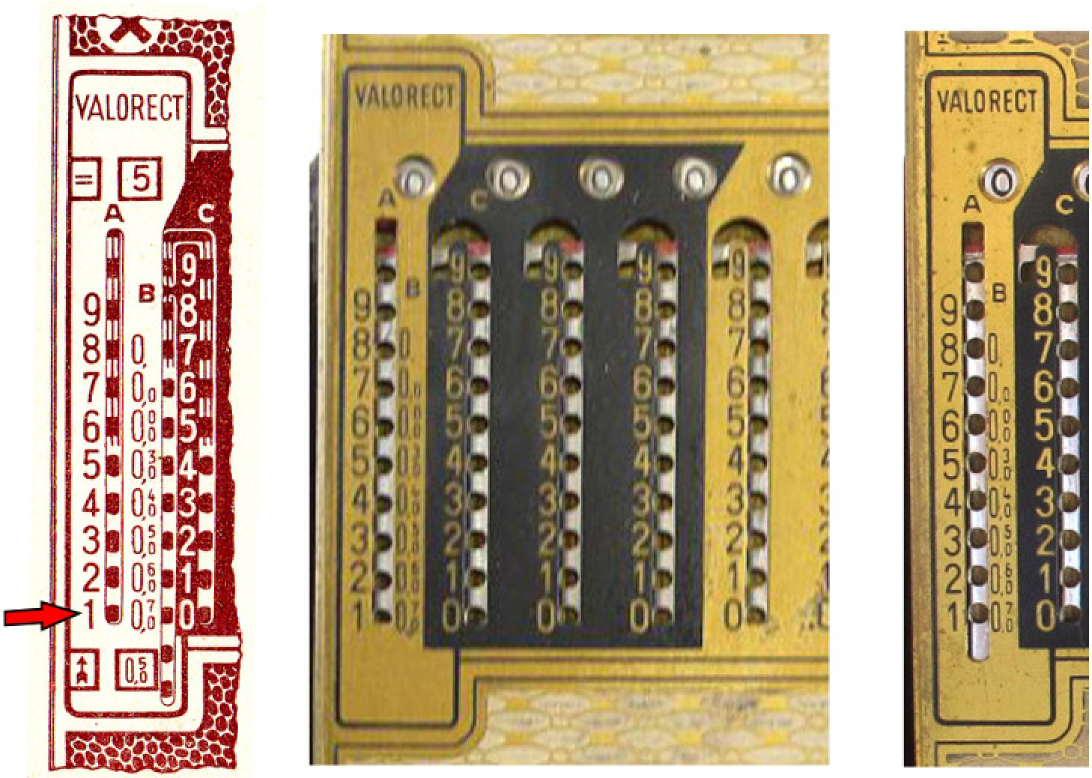
Kuebler held several patents and property rights for his adders[vi]. In January 1931 he tried to obtain a patent for his *Valorect*, named (in free translation) "apparatus to automatically determine the number of digits in logarithmic calculations". Two months later the claim has been refused. The official in charge at patent office in Berlin argued that the new invention wouldn't be a improvement to the original invention of the slide adder. Appeals by the patent attorney couldn't change the decision. I'm not a legal expert, but having read the papers thoroughly, from a technical point of view it seems to me that the official didn't understand what *Kuebler* really intended.
In May 1933 *Kuebler* withdrew claims for the patent, and in July for the registered design of *Valorect* [vii].

Before WW II the adder for characteristics has been demonstrably built and offered in three different designs:

A) with two sliders for numbers greater and smaller than 1, with four signal windows (Fig. 3-A)
B) with one result window (Fig. 3-B)

C) with one result window and a slider that doesn't subtract 1 (Fig. 3-C).
For this variant I don't know any instruction for use and therefore cannot definitely reconstruct its usage with respect to logarithms. I only have a substantial assumption.

A fourth design with four signal windows and one slider (comparable to Fig. 3-A, but not shown here) is mentioned in the patent claim. I don't know whether the latter variant has ever been sold.



A B C

Figure 3. Details of the Maximator Valorect

Years later but definitely before WWII the *Addiator* company offered a graphical logarithmic table, almost identical to the preceding one, with two pages too, but bigger in size. The table is named *Maximator Logarithmen Tafel* (M. Logarithmic Table). For me this title implies, that sometime in the following years *Carl Kuebler* dropped his idea of replacing characteristics by numbers of places and returned to genuine logarithms. Otherwise he wouldn't have used the word *Logarithmen*. With the return to logarithms there is no longer any need to subtract 1 and in my opinion that is the reason why *Valorect* adders of type Fig. 3-C were offered. The machine number on my adder of variant C is almost 400 items higher than the number on my adder variant B, a detection, that supports my assumption.

From Kuebler's daughter, who lead the company after WWII, we know that *Valorect* has been her father's very special hobby. At least three sold variants confirm this statement. On the other hand three variants indicate, that he got into trouble with the implementation of his idea. Besides the replacement of characteristics by the numbers of digits doesn't really simplify calculations. Maybe exactly because of that *Maximator* plus *Valorect* had only little success. Only a few adders in combination with the logarithmic table were sold[viii].

After WWII, between 1950 and 1962, the slide adder *Maximator* has been offered again, without *Valorect,* optionally in conjunction with a printed multiplication table.

All figures produced by the author and from items in the author's collection.

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[i] From begin of the Thirties of last century on renamed *Addiator Rechenmaschinenfabrik* (Addiator Factory for Calculating Machines) *C. Kübler*.

[ii] I assume that the artificial name *Valorect* has been derived from a combination of the Latin words *valor* (value, sth. is valid or effective) and *recte* (correct, the right way).

[iii] Those graphical logarithmic tables were already known. See Hans Loewe: *Rechenscalen für numerisches und graphisches Rechnen, Heft 1: Logarithmische Rechenscalen,* R. Reiss, Liebenwerda, 1893 or Anton Tichy: Graphische Logarithmen-Tafeln, Wien 1897.

[iv] An example: log(24) = 1.38 and log(240) = 2.38 with 0.38 as mantissa and 1 and 2 respectively as characteristic.

[v] log 1.893 = 0.27715; log 262.5 = 2.41913; log 0.025 = 0.39794 - 2; log 365 = 2.56229

[vi] Among many others German patents DE367599 (since 1919 base patent for a two sided slide adder), DE586918 (1930 for a slide adder that calculates below zero), registered trademarks WZ436143 for *Maximator* (1931 up to 1981) and WZ437021 for *Valorect* (1931).

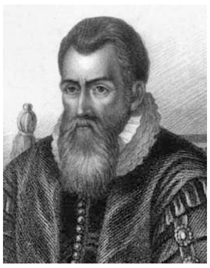
[vii] Sources for this article were the original correspondence between *Carl Kuebler*, his patent attorney and the Patent Office in Berlin, as well as copies of original documents concerning the registered design. My thanks go to Mr. Friedrich Diestelkamp, who lent me these papers for inspection and gave me valuable informations about *Carl Kuebler*.

[viii] Attention should be drawn here to Faber-Castell with Addiator, a combination offered since 1935.

Graphic Logarithmic Tables[1]
A Picture Should Be Worth A Million Numbers[2]

David Rance

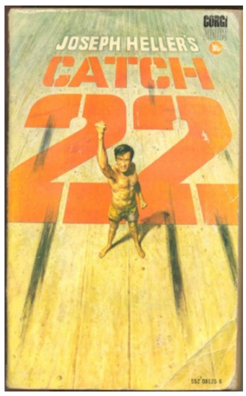
Given what they replaced it feels disparaging, impolite and almost blasphemous to point out that logarithmic tables were sadly error prone and irritatingly awkward to use. Surely graphic logarithmic tables must have been the answer!



It is fitting to remember in 2014, the year of their 400th anniversary, that before John Napier (1550-1617) invented logarithms most forms of computation were complex and enormously time-consuming. In fields like navigation and astronomy it took elite mathematicians of the day[3] literally years to finish some calculations. So what on earth could there be about logarithmic tables to complain about?

Catch-22

The work on logarithms undertaken by Napier was a classic Catch-22 style paradox[4]. First he had to work through the tedious calculations needed to create all the entries in a set of logarithmic tables and then find a way to verify them. But the supreme irony is that once the tables existed, they would have made it much easier to do the calculations in the first place! A modern-day Catch-22 analogy would be computer programming. Once a program compiler was developed, programmers no longer had to write programs in machine code. But first someone had to write a compiler in machine code.



Napier, aided by his own "Napier bones", did set about the enormity of the task with considerable insight and ingenuity. His first challenge was to shake off 16th century mathematical thinking of the time.
Before Napier invented logarithmic tables mathematicians of the day relied on fixed sequences.

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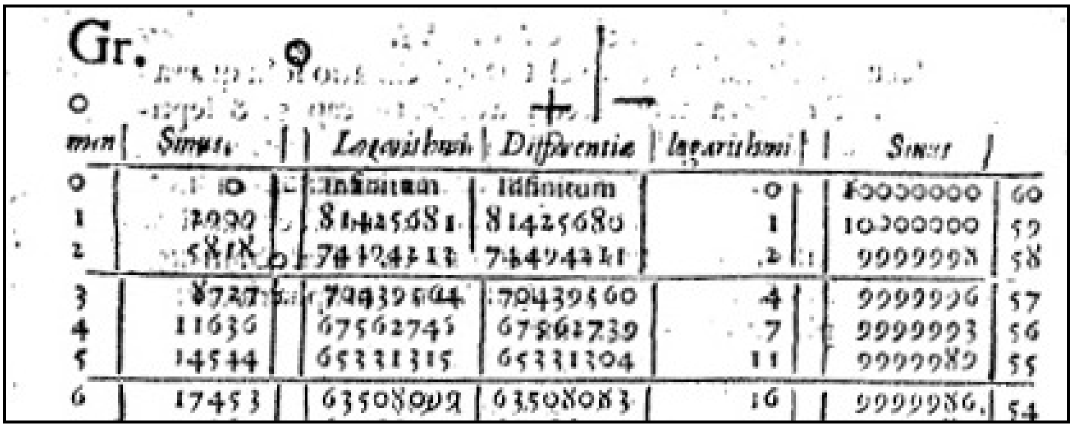
[1] Research findings by the author published in 2013 as part of the *"Collectanea de Logarithmis"* DVD.
[2] Derived from a 20th century phrase coined by American Frederick R. Barnard.
[3] In Napier's day such calculation experts were known as: "Reckoners".
[4] The impossible paradox famously introduced in Joseph Heller's 1953 book of the same name.

For example, the fixed arithmetic sequence of 0, 1, 2, 3, 4, etc or the fixed geometric sequence of 1, 2, 4, 8, 16, etc. This worked fine when stepping through a series of whole numbers but clearly overlooked all the values in between. So Napier broke with tradition and decided to adopt a *kinematic approach* for building his tables. This way he would have "no numerical gaps" – i.e. he defined: (i) an arithmetic and continuous movement of a point along a single straight line with a constant speed AND (ii) a proportional and continuous movement of point along a straight line with a proportional speed.

The completeness of his tables was not the only "Catch-22" dilemma Napier had to overcome. He had no precedent for the degree of accuracy the values in his tables needed to have. With this quandary came another conundrum – for a given degree of accuracy, how much work would that involve to generate the full table? So Napier came up with what today would be called a *meta process*. Having developed a means of calculating a series of values, he would then evaluate the values obtained to see how they could be used to generate more values i.e. a meta calculation process.

So by adopting a kinematic approach and a meta process, Napier achieved an insightful balance between the desired degree of accuracy and the tedious longhand calculations needed to generate the table entries.



Gr. 0

min	Sinus	Logarithmi	Differentiae	logarithmi	Sinus	
0	0	Infinitum	Infinitum	0	10000000	60
1	2909	81425681	81425680	1	10000000	59
2	5818	74494213	74494211	2	9999998	58
3	8727	70439564	70439560	4	9999996	57
4	11636	67562745	67562739	7	9999993	56
5	14544	65331315	65331304	11	9999989	55
6	17453	63508099	63508083	16	9999986.	54

Part of Napier's "Mirifici Logarithmorum Canonis Descriptio"

Published errors

Inevitably a few errors did creep into Napier's original calculations and indeed into the calculations made by later authors who devised extended versions (e.g. greater number of significant places) or designed new types of logarithmic tables. Some of the earliest errors went unnoticed and were repeated or compounded in some of the tables published much later. But even if it had been humanly possible for Napier to generate and note down all the entries needed for his logarithmic table totally error-free, many mistakes got introduced during the typesetting and printing.

When copying or duplicating a long list of numerals, apart from any other oversights, unintentionally transposing two adjacent numbers is a known human weakness. Then came the thankless task poorly paid typesetters had to face. Typesetting row upon row of seemingly random numerals in a printing block must have been a really mind-numbing task. It was unintentional but understandable how typesetting errors ended up in many logarithmic tables. For example, errors made in the last decimal place were particularly difficult to spot. Such mistakes often remained unnoticed for decades and were perpetuated when inherited from one publishing house to another and logarithmic tables got reissued or republished.

Logarithmic tables can be a pain

Arguably, given the longhand nature of calculating the table entries and then the mind-numbing typesetting needed to publish them, the odd error was a small price to pay for how logarithmic tables made all kinds of multiplication and division much simpler and momentously quicker to perform. As it turned out, the immeasurable gains that logarithmic tables made possible far outweighed the more obvious tangible benefits. Top of the list of immeasurable gains were:

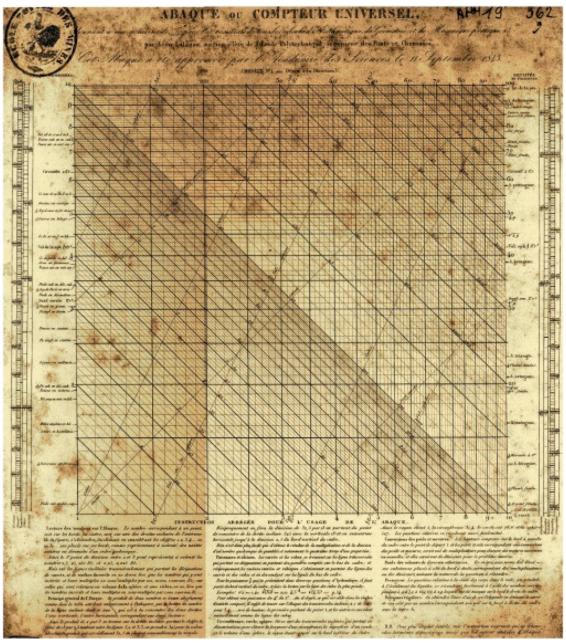
1. individuals other than "mathematical geniuses" could now attempt complicated calculations
2. scientists and mathematicians could now (in their lifetimes) unlock and solve many mathematical conundrums which in turn lead to many advancements and discoveries in many different fields

However, despite being a paradigm shift when compared with the old pre-logarithm ways, the very nature of the concept meant using tables had distinct disadvantages. The ritualistic look-up process could be irritating and so long-winded that without fastidious care, it could itself easily became error-prone. Also some factors commonly found in calculations could make using early logarithmic tables tricky and a real pain to use. For example, negative numbers or answers needing a high degree of accuracy - say significant to at least 7 or 8 significant places. A work-around for negative numbers was to handle the sign separately. Often the drawbacks got magnified many times over when attempting complex calculations. Finally the sheer number of times an interim solution had to be looked up in a logarithmic table became a test of concentration and patience.

So despite the many obvious advantages, logarithmic tables were not error-free and using them was error-prone and irritating. But centuries after logarithmic tables were first published an innovative and elegant solution was found most of the drawbacks and the tedium - *graphic logarithmic tables.*

Nomograms showed the way

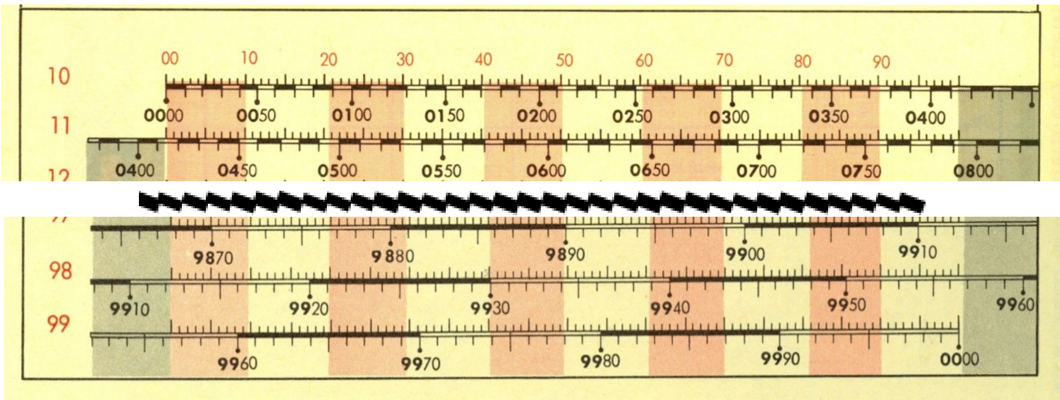
Like many great ideas, the appeal of a nomogram comes from its simplicity. It is a two-dimensional diagram designed to show the approximate "graphic calculation" of a mathematical function. The most basic nomogram having two parallel outer scales representing the values of two quantities involved in a function. Where the lines joining quantities used in the calculation intersect, gives the result of the function. An early advocate of the nomogram was Frenchman *Leon Louis Lalanne* (1812-1892). In 1843, with his "Universal Calculator", he probably created the first log-log plot.



Sadly some nomograms became so complex that the function(s) they represented were just as difficult to grasp as their inherent longhand mathematical formula. However, it is the same basic idea that a picture is easier to understand than a long list of numbers that led to graphic logarithmic tables being developed.

So what are graphic logarithmic tables?

Printed as a single linear scale (end-to-end scale lengths varying from as little as 4.1m to as much as 115m – see *Appendix A* for the details) they clearly look strikingly different from the many rows and columns of similar looking numerical entries in a traditional logarithmic table.



The beginning and the end of an example graphic logarithmic table

Instead they somewhat reflect the concepts of a calculation aid based on rods and scales Professor Johann Gottfried Steinhäuser theorised about in 1807. A closer match is the intriguing prototype disc for a graphic logarithmic table[5] proposed by a medical officer in the French Army, Dr Haro, in 1887. Regardless of the inspiration, the differences when compared to traditional logarithmic tables are much more than just an innovative printing or formatting style.

In a graphic logarithmic table:

- all the entries in the log and antilog sections of a traditional logarithmic table have been integrated into a single, much shorter "endless" entry
- the look-up process is simpler, quicker and much more intuitive

But it is also important to set boundaries on what constitutes a graphic logarithmic table as they come in various shapes and sizes and many loosely related "cousins" exist. For example, a slide rule (in its many forms) has logarithmic scales that provide answers without needing to resort to antilogs. However, for practical reasons the logarithmic scales normally found on slide rules only ever represent a subset of all the entries found in any traditional or graphic logarithmic table. By using a subset or leaving out rarely needed parts of the range was one of the few ways slide rule designers could usefully compact the length of a scale and ultimately, the length of the slide rule. Only the largest drum and grid-iron types had enough room for a range of values that got close to the full range of values included in any logarithmic table. Without these boundaries, a plethora of other printed calculating aids and slide charts could arguably have been called types of graphic table.

So unlike slide rules and similar calculating devices, graphic logarithmic tables still rely on a table look-up process and apart from one exception, all known examples exist as some form of printed page or more commonly, a slim book.

[5] As far as is known the concept was never developed further than the paper Dr Haro submitted to the "*Association Francaise pour lÁvancement des Sciences*" 1887 conference in Toulouse.

Graphic logarithmic tables – how did they work?

The easiest way to show how such graphic logarithmic tables were used is a worked example. However, the developers of such tables chose an eclectic variety of ways to achieve the same goal. Despite these design differences, the way they were used, when compared with a traditional logarithmic table, is universal.

The chosen example, ***2.5 x 5***, looks trivial but enough to show the generic process. The only drawback is that the simplicity of the example hides the full tedium of and error-prone nature of the repetitive look-up process when using traditional logarithmic tables for complex calculations. Conversely the advantages of a graphic logarithmic table are amplified many times over for such complex calculations.

Using a traditional table of logarithms

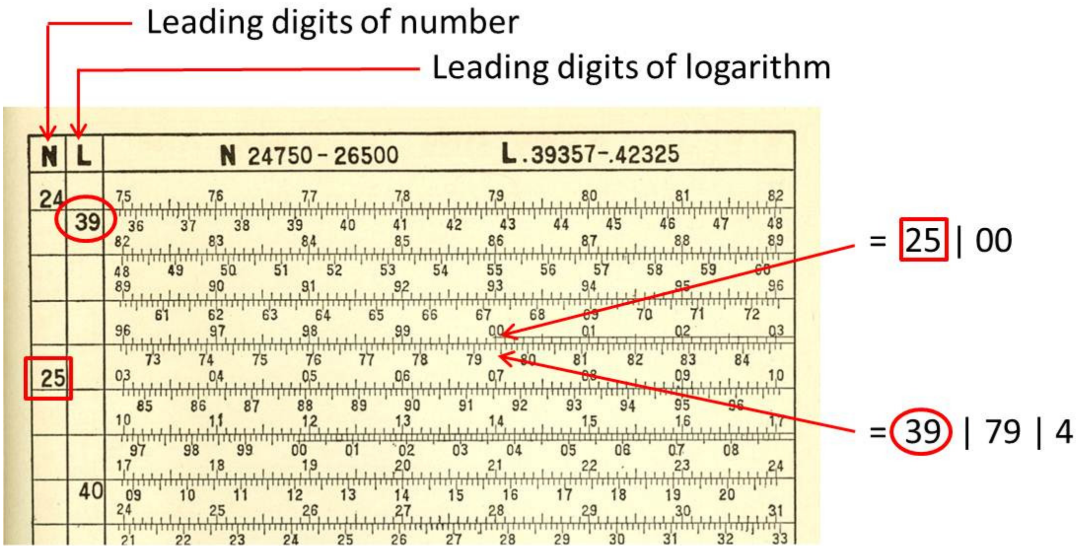
With a table compiled for 5 decimal places[6] the minimum calculation steps are:

	=
1. Look-up the logarithm of 2.5	0.39794
2. Look-up the logarithm of 5	0.69897
3. Add the Log of 5 to the Log of 2.5	1.09691
4. Look-up the antilog of the mantissa 09691	12500
5. Use the characteristic "1" before the mantissa to fix the decimal point	**12.5**

Depending on the notation form/style of the entries (especially the antilog entries) in a traditional table each look-up step in more complex calculations could well have required extra interim interpolation steps to determine the logarithm of each number and the antilog of the resulting mantissa.

Using the graphic logarithmic table by Lacroix and Ragot

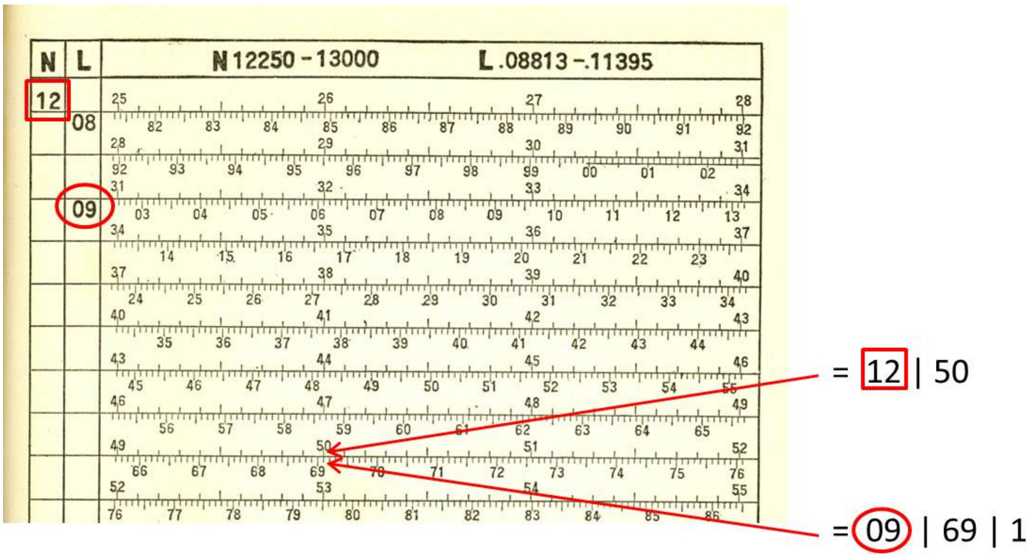
Opting for the longer 40-page table for five decimal places in the book by *Lacroix and Ragot* (see *Appendix A* for the details) the logarithm of 2.5 can be quickly and easily found.



[6] Half of all the traditional logarithm tables ever published were versions for 4 or 5 decimal places.

Ignoring the decimal point and looking up the leading "**25**" digits in the "**N**" column is enough to find the right page in the table. In the adjacent column "**L**" the leading digits of the logarithm, "**39**", are shown. The next step is to locate the following two "**00**" digits of the number on the upper scale of graduations for log section "**39**" of the table. The 3rd and 4th digits, "**79**", of the logarithm can found on the lower scale to the left of the tick mark "**00**". Finally counting the extra divisions/tick marks that come after 79 before lining up with 00 on the upper scale, gives the last digit of the logarithm: "**4**". So, the complete readout is 39 | | 79 | | 4 or log 2.5 = 0.39794.

The logarithm of "**5**" can be found equally easily. Adding the two logs (39794 and 69897) gives the same 1.09691 interim answer. But as the log and antilog entries are combined in a graphic logarithmic table, the antilog of the mantissa, "**09691**", can be quickly and easily "reverse engineered" using the same intuitive process.

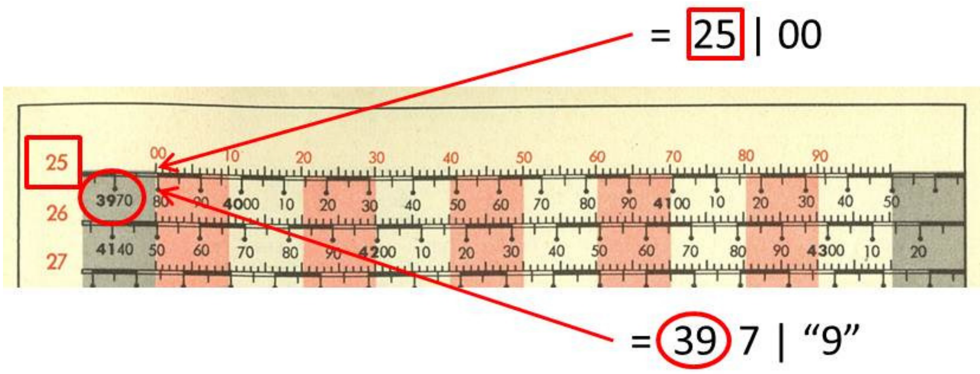


This time looking-up leading "**09**" digits of the mantissa in column "**L**" are enough to find the right page in the table and from the column alongside, read off the leading digits of the answer: "**12**". Having found the next two digits, "**69**", in the log "**09**" section, one tick mark further for the trailing "**1**" in the mantissa and the corresponding last two digits of the antilog number can be read off the upper scale – i.e. "**50**". After concatenating the two parts and the using the characteristic of the mantissa to fix the decimal point, **12.5** is the answer.

Superficially the steps look similar to using a traditional table of logarithms. However, the graphic version, with its fewer pages and combined log and antilog entries, is certainly less error-prone and much more intuitive to use. Also although both types of tables are compiled for five decimal places, only the graphic version has the inherent potential for accuracy to six decimal places. The values in the worked example finish exactly on a "tick mark" in the scales. But when needed and much like using a slide rule, accuracy to a sixth decimal place by interpolating between two tick marks would be simple and easy to achieve with this table.

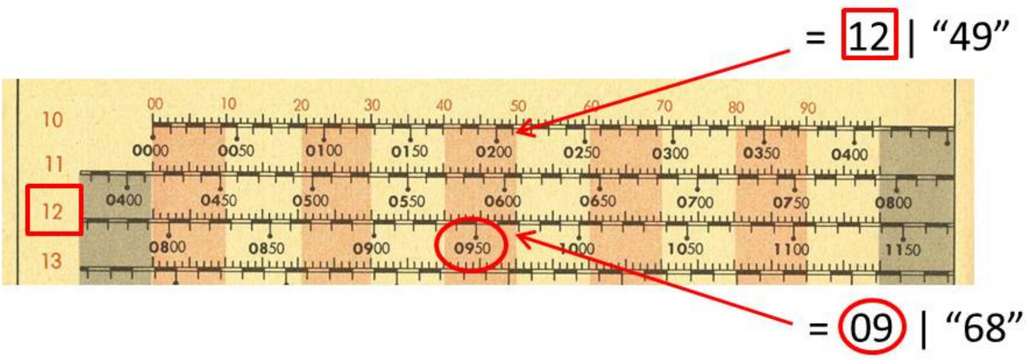
Using the graphic logarithmic table by Koch and Putsbach

By contrast the table by *Koch and Pulsch* (see *Appendix A* for the details) needs interpolation to achieve accuracy to four decimal places. But strikingly the table is just 4 pages long – highlighting the compactness possible with graphic logarithmic tables compiled for a limited number of decimal places. Needless to say the logarithm of 2.5 can be just as easily found with this version.



Ignoring the decimal point, the leading “**25**” digits of the number is found in the 1st column on the 2nd page of the table. The next step is again to find the following two “**00**” digits of the number on the upper scale of graduations for line 25. The corresponding logarithmic value for “**00**” on the upper scale is between “**3970**” and “**3980**” on the lower scale – in fact nearly but not quite “**3980**”. Using interpolation for the 4th digit, the full readout is 397 | | 9 or with this table log 2.5 = 0.3979.

Again the logarithm of “**5**” can be found equally easily. Although this time, the interim answer after adding the two logs (“3979” and “6989”) is not unsurprisingly slightly less accurate: **1.0968**. As with all such graphic logarithmic tables, the antilog of the mantissa can be just as quickly “reverse engineered” using the same intuitive process already described.



Again the leading “**09**” digits of the mantissa are used to find the right page in the table and to read off the leading digits of the answer: “**12**”. The “**0968**” mantissa lies between two “tick marks”: “**0950**” and “**1000**”. Using interpolation to fix “**0968**” on the scale, the corresponding last two digits of the antilog number can be read off the scale at the top of the page – i.e. “**49**”. The characteristic of the mantissa again gives the final answer but this time the cumulative effect of working to fewer decimal places means the answer comes out as less precise: **12.49**.

Graphic logarithmic tables – no panacea

Given my opening *“A Picture Should Be Worth A Million Numbers”* gambit, graphic logarithmic tables should surely have superseded the tedious use of traditional logarithmic tables. They did not. Instead graphic logarithmic tables are largely unknown and rare.

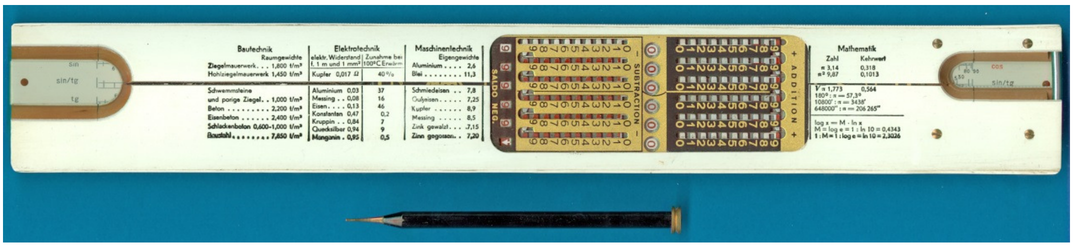
This could be because schools and educational institutions of the day preferred to stick largely to using conventional (and cheaper) mass-produced books of traditional logarithmic tables. But the more probable explanation is that most examples of graphic logarithmic tables are early 20th century developments and some telling inherent limitations meant *they were outdated almost as soon as they were published*.

But who were the intended users of graphic logarithmic tables? Clues can be found in the *"Introductions"* of the more well-known graphic logarithmic tables such as *Pressler*, *Lacroix and Ragot* and *Leder*. The advantages commonly quoted are speed and size. Reducing the labour-intensive and error-prone process of using a traditional logarithmic table would have obviously appealed to many professions and trades. Condensing the hundreds of pages of a traditional logarithmic table down to a slim volume would also have been preferable to carrying around a bulky book. A modern-day analogy is how the slim *iPad* is commonly preferred to a bulky laptop computer. Ernst Leder goes on to suggest that graphic logarithmic tables could also be: *"a good tool for further education."* However, early 20th century students who could have been attracted by the advantages of a graphic logarithmic table would almost certainly have opted instead for one of the superior aids of the day – such as the slide rule. Therefore it is even more surprising that a renowned German slide rule maker decided that selected slide rules models would be sold with a graphic logarithmic table!

"Selling fridges to Eskimos"

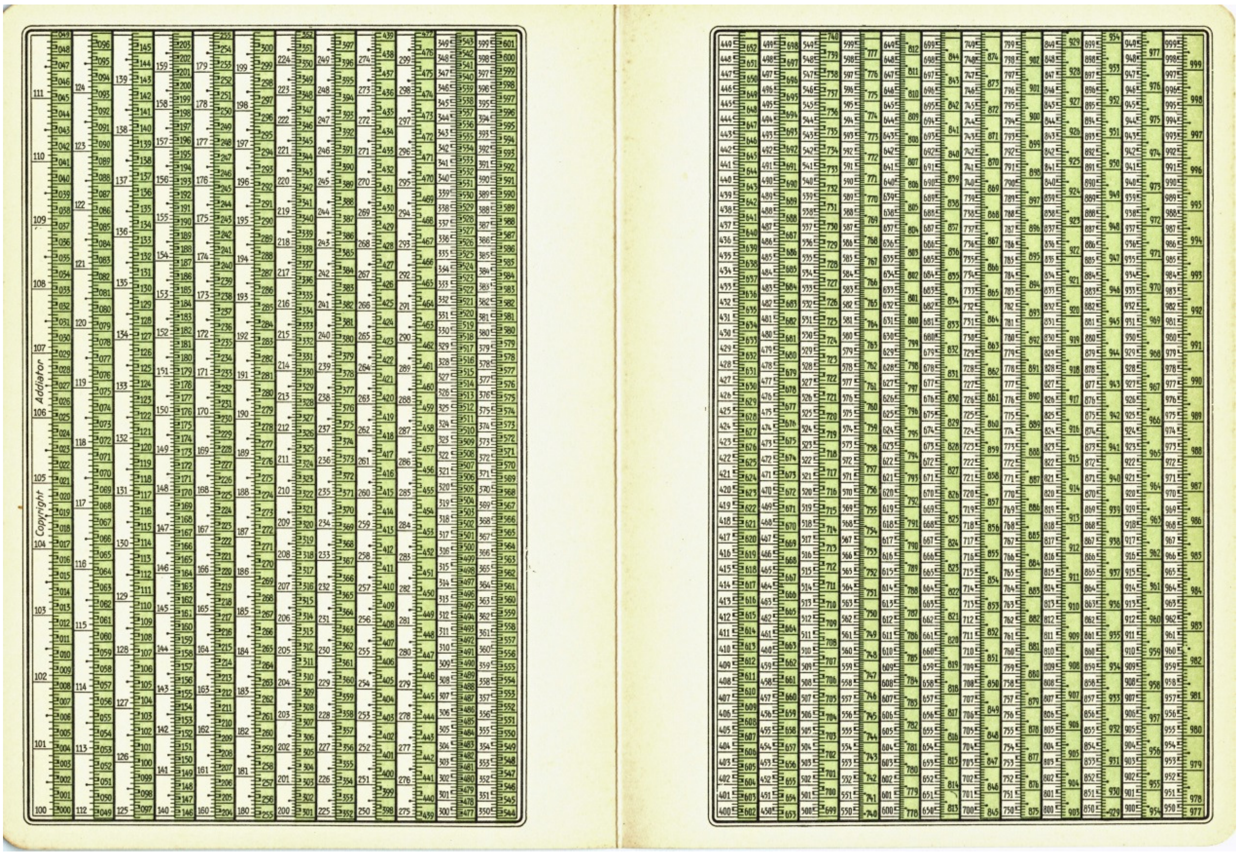
Apart from sharing logarithmic roots, slide rules and graphic logarithmic tables have little in common. They are competing rather than complementary calculating aids. However, German Carl Kübler (1875-1953) must have been a great salesman.

In 1940 Faber-Castell (F-C) decided to supplement their existing portfolio of slide rules with a series of "combination" models. They uniquely were the first to incorporate a mechanical flat sliding bar adder for addition and subtraction into the back of their more popular models. These hybrids became known as their Addiator slide rules[7] because F-C bought the metal Troncet-type slide adders with an accompanying stylus from *Addiator GmbH*, a company founded by Carl Kübler in 1920. This made good commercial sense as the company was the leading maker of slide adders or Addiators.



What is less clear is how Kübler persuaded F-C they also needed to buy an accompanying 2-page "*Maximator*" paper graphic logarithmic table he had earlier copyrighted. It is illogical but for a brief inexplicable initial two-year period (1940-1942) F-C sold their **1/22A** (Disponent), **1/54A** (Darmstadt) and **1/87A** (Rietz) hybrid models with a "*Maximator*" graphic logarithmic table inserted behind a glued paper strip at the back of the respective instruction booklets (booklet no.'s: 1/702, 1/704 and 1/707). All the booklets included a page on how to use the table.

[7] Model numbers suffixed by "A" (**A**ddiator) for 25cm and by "R" (Addiato**r**) for pocket 12½cm.



The "Maximator-Erweiterungs-Tabelle" graphic logarithmic table

After 1942 F-C dropped the "*Maximator*" and opted for a generic instruction booklet for all their Addiator models!

Final paradox

Ironically having started with a *Catch-22* paradox I conclude with another. Early in their evolution compiling and typesetting traditional logarithmic tables was a challenge. Although inherently less error prone, in such times that the graphic printing possibilities were extremely crude and virtually non-existent. By contrast, in the 20th century the possibilities for printing complex images and graphically complex figures were bountiful. This meant graphic logarithmic tables were now relatively easy and economical to publish. However, by the 20th century demands for accuracy had risen sharply. By their very "picture" nature most graphic logarithmic tables, even with the most precise printing or production techniques, only offered 4 or 5 significant places of accuracy. But by now traditional logarithmic tables of 7, 8 or many more significant places had been common place for decades.

Once early 20th century cheaper printing and production techniques became readily available, graphic logarithmic tables could flourish. But sadly by now their level of accuracy had been surpassed and they faced competition from slide rules and other mechanical aids. This meant almost as soon as they became a practical reality, graphic logarithmic tables *were outdated and inferior*. So unlike the traditional logarithmic table, graphic logarithmic tables (even the often reprinted *Lacroix and Ragot*) *never fulfilled their promise and never became well-known or widely used*.

Acknowledgements & Bibliography

Without the motivating and guiding hand of Klaus Kühn my original research would have been difficult and at best, inconclusive. I am also indebted to Prof. Joachim Fischer for reviewing early on my take on the historical steps associated Napier's development of logarithms.

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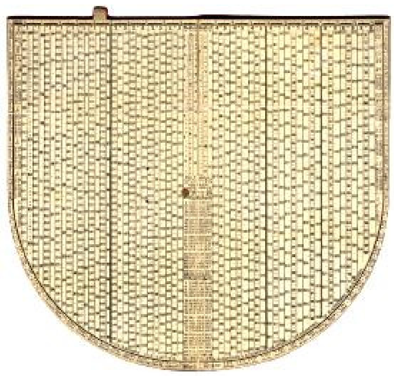
Appendix A: Known Graphic Logarithmic Tables

Such tables defy inclusion into any existing classification scheme for similar aids such as Ready Reckoners, Tabular Calculators, etc. So in this compendium (others may well exist) of all the known commercially printed examples[8] are listed, with a thumbnail image, by the year they were first published.

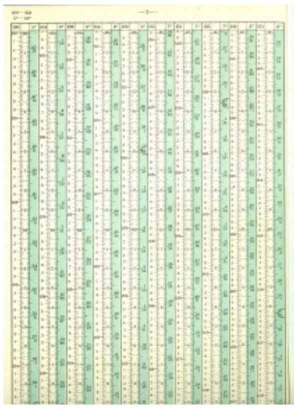
+/-1852: *Pressler* - Dresden, Germany



Title:	*Ingenieur-Messknecht*
By:	Maximilian Robert Pressler
Type:	Slip cased folding set of tables (with built-in clinometer) printed on escutcheon or shield shaped double-sided stiff cardboard
Size:	20.7cm (longest point i.e. from the Chief to the Base) x 22.4cm (widest point i.e. from the Dexter to the Sinister) x 0.4cm
Published by:	Unknown
Patents?	None found
Style of table(s):	Front and side edges: mixture of tables and conversion factors Back: mainly a four-place graphic table organised in columns
Length(s) of graphic table:	≈ 5.5m
Comments:	Probably the <u>first</u> graphic logarithmic table ever published. It was mainly intended for use in the field by forestry workers. But Pressler also claimed it was a universal aid for students calling it a *"Mathematical Cinderella"* – possibly a cryptic reference to it being able to do all kinds of mathematical chores. Pressler also wrote a book to accompany his Messknecht. Various editions of the Messknecht and the book exist.

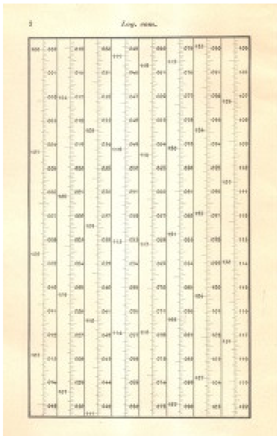
[8] As defined in the main part of this paper.

1893: *Loewe* – Bromberg, Germany



Title:	*Rechenscalen für numerisches und graphisches Rechnen*
By:	Loewe
Type:	Hardback book (50 pages) with a brown cover
Size:	23.3cm x 16.3cm
Published by:	Verlag des Technischen Versandgeschäfts R. Reiss[9]
Patents?	None found
Style of table(s):	(i) 5-page four-place graphic table organised in columns (ii) Three other tables for trigonometrical functions
Length(s) of graphic table:	≈ 10.4 metres
Comments:	Interestingly Loewe also includes *"how to calculate"* instructions for using a pair of dividers.

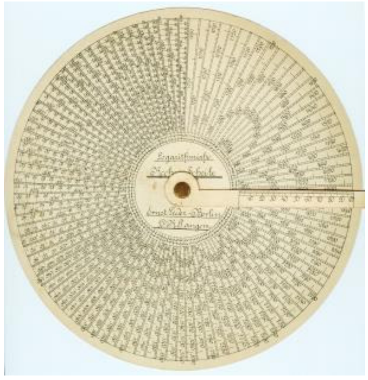
1897: *Tichy* – Wien, Austria



Title:	*Graphische Logarithmen-Tafeln*
By:	Anton Tichy
Type:	Hardback book (30 pages) with light fawn cover
Size:	24.5cm x 16.0cm
Published by:	Verlag des Oesterr. Ingenieur- und Architekten-Vereines, Wien
Patents?	None found
Style of table(s):	(i) Four-place graphic table organised in columns (ii) Other tables for trigonometrical functions
Length(s) of graphic table:	≈ 16m
Comments:	-

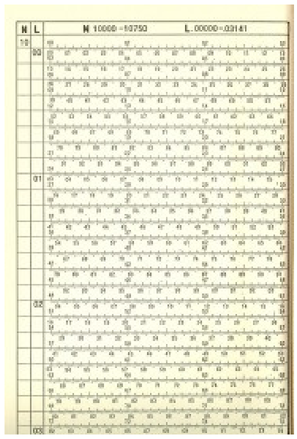
[9] Nearly two decades later, in 1912, the same Reiss started making slide rules.

1908: *Leder* - Berlin, Germany



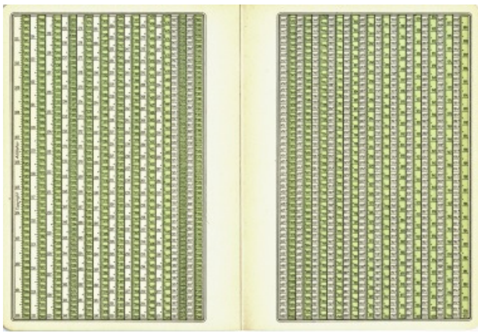
Title:	*Die Praxis des Logarithmen-Rechnens*
By:	Ernst Leder
Type:	Circular cardboard chart with a cardboard cursor as part of a hardback book (125 pages) with pale blue linen cover
Size:	Chart: Ø 21cm Book: 27.8cm x 21.9cm
Published by:	Verlag der Cito-Rechenmaschinen-Werke G.m.b.H., Berlin
Patents?	DE104927 – 15th August 1899 DE223529 – 24th June 1910
Style of table(s):	Four-place "graphic table" (antilogs only) organised as radii from the centre of the chart
Length(s) of graphic table:	≈ 6.1m
Comments:	This is the exception to all the other book-style listings. Instead of tables, the entire book consists of advice and worked examples of how to use logarithms in a myriad of calculations. A sleeve, pasted onto the inside back cover, holds a circular graphic antilogarithm chart. Using the chart as an "antilog table" is explained in the book but the author assumes that the looking-up of logarithms (not possible with the chart) is done with a traditional logarithm table.

1925: *Lacroix and Ragot* - New York, USA



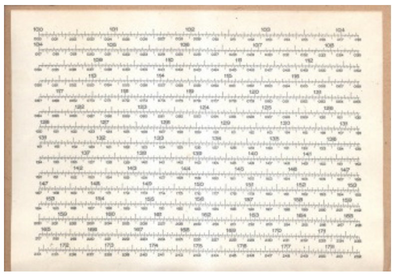
Title:	*A Graphic Table combining Logarithms and Anti-Logarithms*
By:	Adrien Lacroix and Charles L. Ragot
Type:	Hardback book (52 pages) with green linen cover
Size:	23.6cm x 15.2cm
Published by:	The Macmillan Company, New York
Patents?	US1610706 – 14th December 1926
Style of table(s):	(i) 40-page five-place without interpolation graphic table organised in rows (ii) 6-page four-place graphic table organised in rows
Length(s) of graphic table:	Long version ≈ 115m Short version ≈ 13.8m
Comments:	Book reprinted in 1927, 1936, 1938, 1941, 1942 and 1943.

+/-1926: *Kübler* - Berlin, Germany



Title:	*Maximator Logarithmen Tafel* *Maximator-Erweiterungs-Tabelle*
By:	Carl Kübler
Type:	Folded card (2 pages)
Size:	27cm x 18.6cm
Published by:	Addiator GmbH and later A. W. Faber-Castell Vertrieb GmbH
Patents?	None found but design Copyrighted by Addiator GmbH
Style of table(s):	2-page four place graphic table organised in columns
Length(s) of graphic table:	≈ 4.1m
Comments:	It was originally sold with the *"Maximator"* - a desk stand mounted mechanical slide adder from Addiator GmbH. Later included with the early versions (1940-1942) of the Faber-Castell hybrid Addiator models: 1/22A, 1/54A and 1/87A.

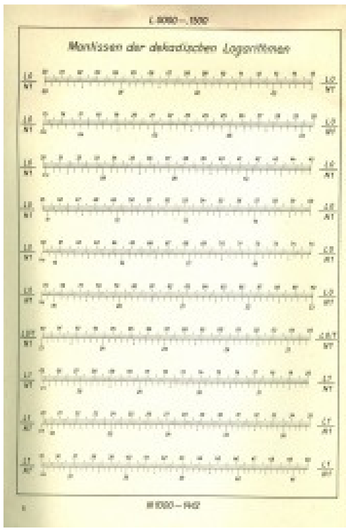
1946: *Kienbaum* - Gummersbach, Germany



Title:	*Skalog - Der Skalen-Schnellrechner nach Kienbaum, eine graphische Logarithmentafel*
By:	Gerhard Kienbaum[10]
Type:	Hardback book (12 pages)
Size:	22.4cm x 15.2cm
Published by:	Ingenieurbüro Dipl.-Ing. Kienbaum, Gummersbach
Patents?	None found
Style of table(s):	(i) 4-page four place graphic table organised in rows (ii) 4-page numeric table for trigonometrical functions
Length(s) of graphic table:	≈ 10.7m
Comments:	Probably a private publication by Kienbaum.

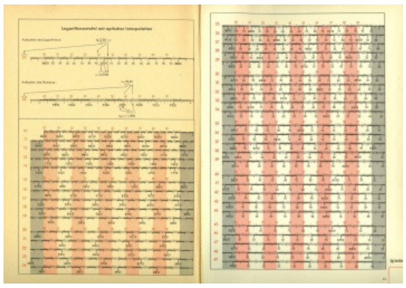
[10] Started a one-man business that later became one of Germany's leading consulting companies.

1949: *Rohrberg* - Berlin, Germany



Title:	*Graphische Funktionentafeln* *Graphical Table of Functions* *Tables Graphiques des Fonctions*
By:	Prof. Albert Rohrberg[11]
Type:	Softback book (30 pages) with pale blue cover
Size:	29.9cm x 20.9cm
Published by:	Fachverlag Schiele & Schön, Berlin
Patents?	None found but copyrighted in 1949
Style of table(s):	(i) 7½-page four place graphic table organised in rows (ii) Four other tables for trigonometrical functions
Length(s) of graphic table:	≈ 11.7m
Comments:	Multi-language: German, English and French.

1957: *Koch and Putschbach* - Hannover, Germany

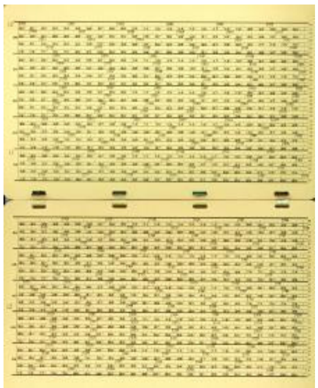


Title:	*Schroedels Mathematische und Naturwissenschaftliche Tafeln - Logarithmentafel mit optischer Interpolation*
By:	A. Koch and R. Putschbach[12]
Type:	Hardback book (51 pages) with dark-blue cover
Size:	22.9cm x 16.2cm
Published by:	Hermann Schroedel Verlag KG, Berlin, Hannover and Darmstadt
Patents?	None found
Style of table(s):	(i) Grids of mathematical and scientific constants (ii) Assorted mathematical tables (iii) Assorted scientific tables (iv) 4-page four-place graphic table organised in rows
Length(s) of graphic table:	≈ 11.2m
Comments:	As a handy "all-in-one" mathematical reference compendium for students it was clearly aimed at schools, etc.

[11] Rohrberg also designed Faber-Castell model 342 Columbus "System Rohrberg" specialist slide rule.

[12] Attributed authors of the graphic logarithm table included in the book published by Schroedel.

1957: *Obbink* – Den Haag, The Netherlands



Title:	*Rekentafel ABACUS Graphische Logaritmentafel*
By:	J. B. Obbink
Type:	Softback book (36 pages) with a mottled grey cover
Size:	22.5cm x 13.5cm
Published by:	Roos en Roos, Arnhem
Patents?	None found
Style of table(s):	22-page five-place without interpolation graphic table organised in rows
Length(s) of graphic table:	≈ 88m
Comments:	Unlike the rest of the book, the graphic log table pages are printed on a much thicker grade/weight of paper. Probably a "private publication" by Obbink.

NuPuBest and EFluBest

Andries de Man

Introduction

Before the advent of Computer Aided Design, construction offices relied on drawing boards, pencils, rulers, slides rules and an occasional calculating machine to design buildings and analyze their structures. For novel construction types or high-stakes projects a *structural model* could be built to prove the validity of the structure.
Structural modeling methods can be distinguished into two types: direct methods and indirect methods[1,2].

Direct methods use models that are flexurally similar to the prototype.[1] Forces, moments and displacements due to applied forces and moments are measured in the model and scaled back to the prototype. The models should be built to as large a scale as possible with materials that, after scaling, mimic the properties of materials in the prototype. This requires a laboratory with balances, cathetometers, dynamometers, strain gauges etc.

Indirect methods deal with models that are much smaller and made of simple materials such as cardboard, celluloid, perspex or thin metal strips. The models are usually built to the same scale as the drawing. In indirect methods, no known forces are applied and no forces are measured. Instead, only deformations are imposed and measured. Indirect methods can be regarded as a calculation aid: they are part of a computing process.

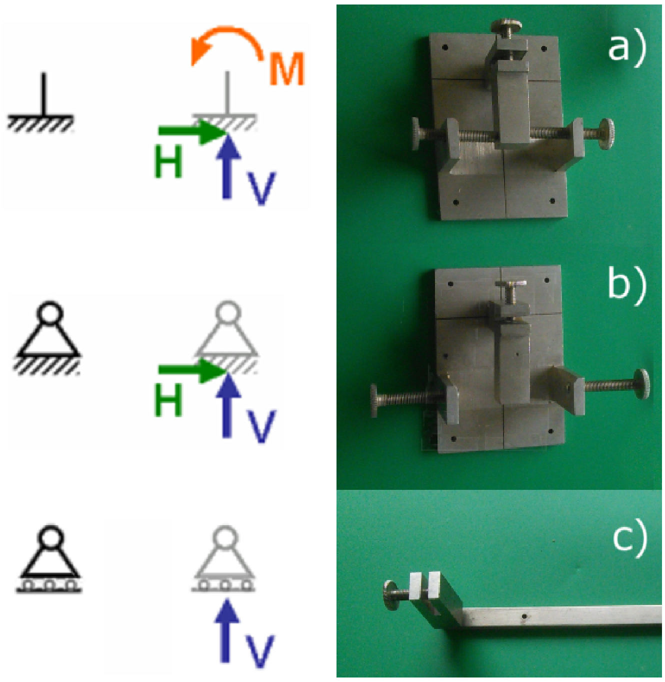


Figure 1. Encastred (a), pinned (b), and rolling (c) supports, with NuPuBest equivalents

Background

We consider structures that are made from members that are either rigidly connected or pin-jointed to each other. The structures themselves are rigidly connected ("encastred"), pinned or resting on the ground or another fixed support Figure 1). The stress-strain relationship for the members is assumed to be linear (Hooke's Law).

In structural analysis forces are traditionally split into a horizontal part **H** and vertical part **V**, which are treated separately. Structural analysis also deals with moments **M**. A distinction is made between *external* forces, such as loads and reaction forces from supports, and *internal* forces (axial forces, shear forces, bending moments inside the structure). The external forces can cause internal forces.

[1] "Prototype" is used here for a real-size structure, which is still imaginary at this stage of the design process but has all characteristics of a "real-world" structure. Hopefully, one of the prototypes will finally be built.

Structural analysis looks for structures that are in equilibrium: the sums of the forces and the sums of the moments (to any point) should be zero. This analysis is complicated for structures that are *statically indeterminate*. To tell if a two-dimensional beam structure is *statically indeterminate*, one should calculate

$$n = a + 3\cdot(p - k) - r \qquad \text{(eq.1)}$$

in which

a = number of reactive forces (incl. moments) at the supports (see Figure 1)
k = number of joints (incl. those of the supports)
p = number of beams between joints
r = number of additional conditions (excl. supports) = $m - 1$, in which
m = number of hinged beams

If $n > 0$, the structure is *statically indeterminate*, if $n < 0$, the structure can move around, which is usually not to be desired, and if $n = 0$, the structure is *statically determinate*. Statically indeterminate structures are not "bad", they are just difficult to analyze.

The analysis can be performed graphically by drawing *influence lines*. An influence line shows the effect of a unit point load on a certain force or moment at a certain point if the unit load is moved across the structure. The coordinates of the influence line give the position of the unit load and the size of the effect. It is assumed that if the size of the load changes, the effect changes proportionally.

Influence lines are derived using the Müller-Breslau principle[3]:

Figure 2a shows a statically undetermined structure: $a = 1+2+1$, $k = 3$, $p = 2$, $r = 0$, so $n = 1$. A unit load 1 is placed at a random point P. The influence line for the vertical reaction force V_A at point A is obtained by the following steps. Remove the roller bearing at A and replace it by an (unknown) force V_A which causes the deflection at point A to be zero (Fig. 2b). Place a unit load 1 at a random point P and keep V_A zero (Figure 2c). This will deflect A by δ_{AP} and P by δ_{PP}. Remove the force at P and apply a unit reaction force at A (Figure 2d, note the change in direction!) Now A will be deflected by δ_{AA} and P by δ_{PA}. For the deflection Δ of A to be zero if a load of 1 is applied at point P (as in Figure 2b), the reaction force V_A should be $-\delta_{AP}/\delta_{AA}$. Now the Maxwell-Betti reciprocity theorem is used, which states that, for linear-elastic structures, the deflection at point P due to a unit force at point A equals the deflection at point A due to a unit force at point P. In other words: $\delta_{AP} = \delta_{PA}$ so $V_A = -\delta_{PA}/\delta_{AA}$. This means that the influence line for the reaction force at A (caused by a unit load at any point P) corresponds to the deformed structure that is obtained by displacing point A from its equilibrium position (Figure 2e). No explicit measurement of forces is needed!

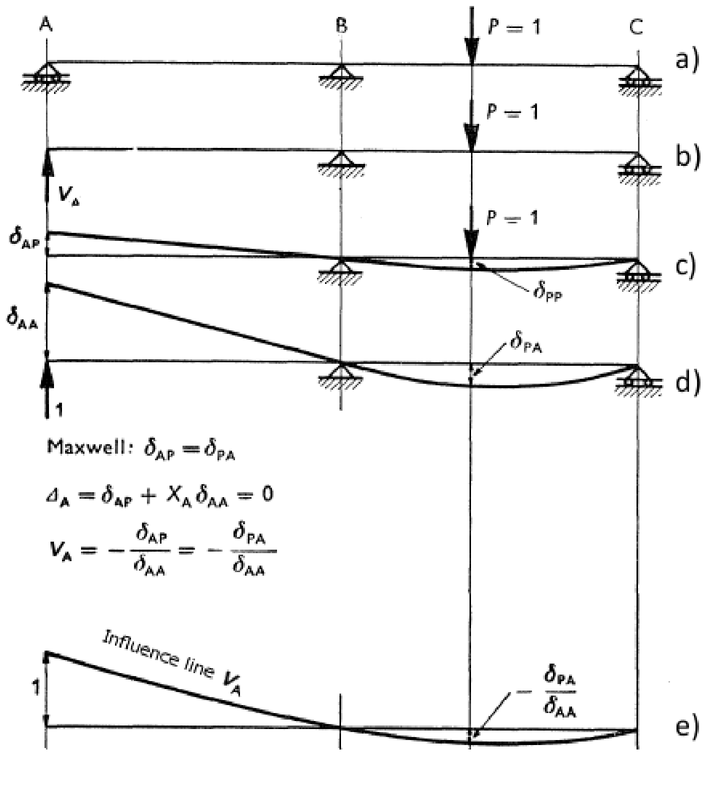


Figure 2. Derivation of the Influence line for VA

Early history

In the second half of the 19th century several graphical and computational methods were developed for the complete analysis of statically indeterminate structures.[4] These methods were tedious and often relied on trial-and-error. Later, in 1930, H. Cross published the iterative “distributed moment” method[5], which improved the chances of getting an analysis done in a reasonable time.[6]

Meanwhile, in 1916, G.E. Beggs, of Princeton University, developed a method using two-dimensional cardboard or celluloid models with metal “deformator gauges” and measuring microscopes[7,8, 30] (Figure 3). The deformator gauges are clamps in which calibrated gauge plugs (with tolerances of 0.0002 inch!) can be inserted to cause displacement, shear or rotation. The model is placed horizontally, with some gauges screwed to the supporting table and parts of the model riding on tiny balls to reduce friction. The system is sensitive to temperature changes and vibrations, as illustrated by the position of the operator’s hands in Figure 4. It is also said to cause considerable eye strain.[2]

W.J. Eney, of Lehigh University, developed a cheaper variant of the Beggs’ deformeter in 1939.[9]

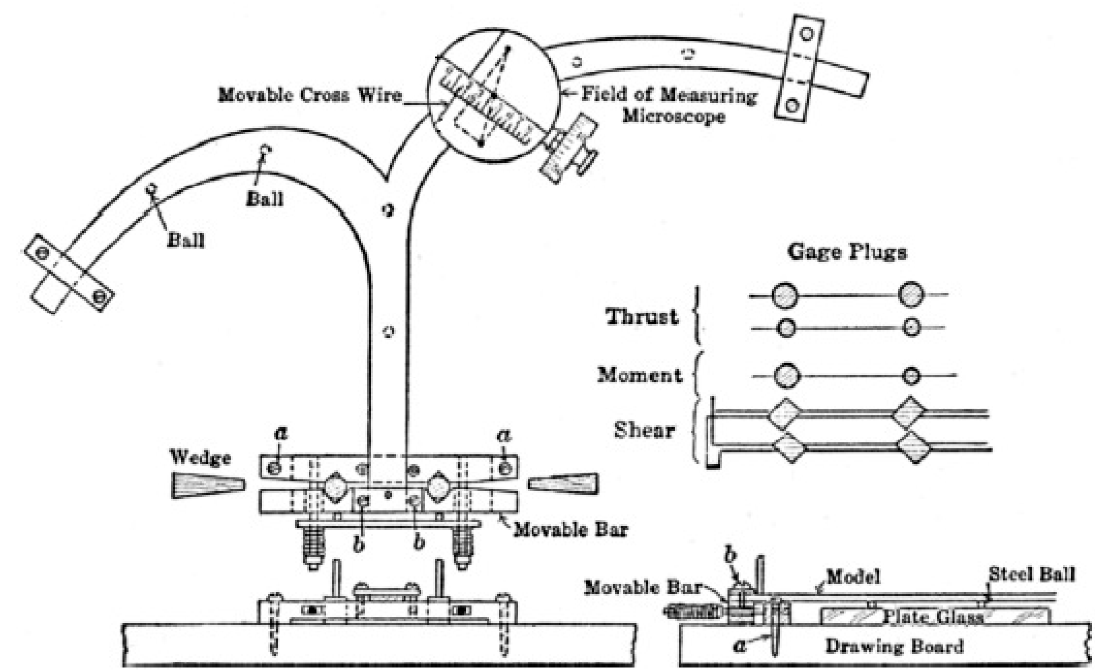


Figure 3. Sketch of Beggs’ deformeter apparatus [10]

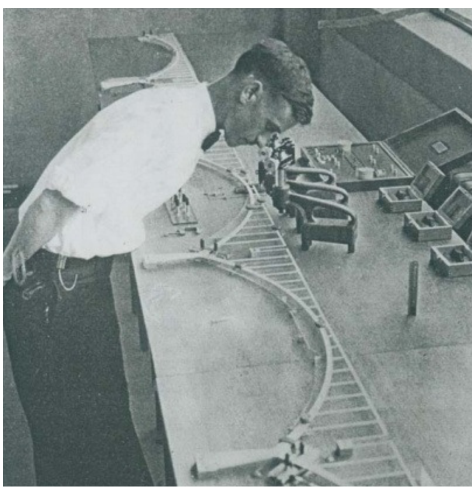


Figure 4. Using a Beggs deformeter [27]

Continostat

The disadvantages of Beggs' method led Otto Gottschalk, from Buenos Aires, to propose another modeling method: one using very large deformations on a vertically mounted model.[11] The model uses steel splines as building material, and therefore does not resemble the prototype as well as Beggs' shaped celluloid models. A heavy horizontal rule is used as a base, on which clamps are placed that hold struts that support the model. The German patent 380,528[12] describes the struts as having a rack and pinion to deform the model. This seems to be omitted in the actual device.[13] Small pullies and a piece of rope with two weights can be used to impose forces, and thereby deformations, on the model.[12,14] Gottschalk made two versions of his device[15]: the Continostat and the Continostat-A or Mechanostat. The latter contained a larger variety of linking elements and could also be used for modeling ships, airplanes, engine parts etc.[16]

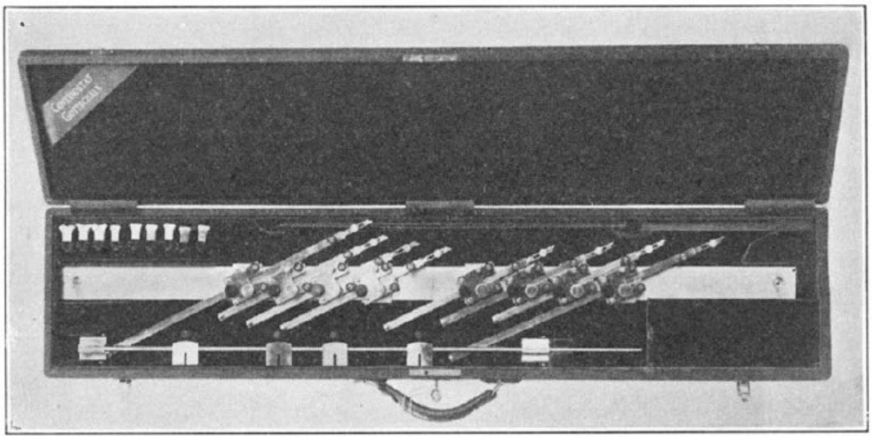


Figure 5. Continostat [15]

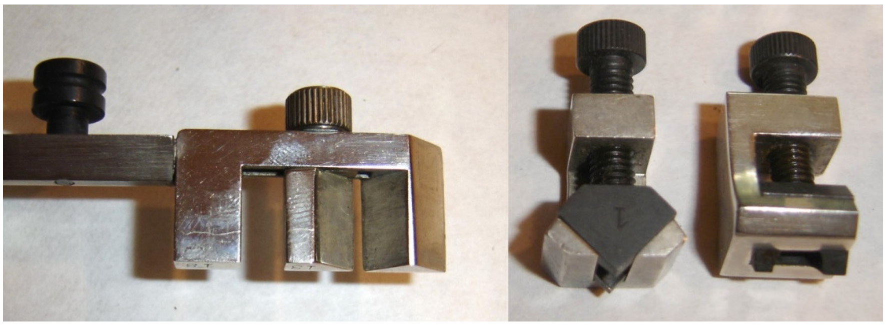


Figure 6. Continostat clamps

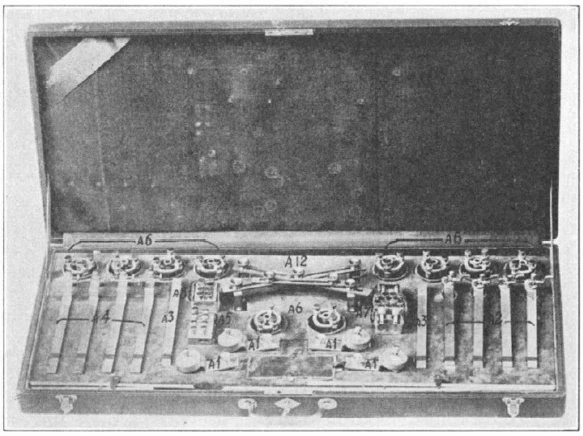


Figure 7. Continostat-A [15]

Figure 8. NuPuBest: first version (left[28]) and third version (right)

NuPuBest

Shortly after the invention of the Continostat[17], Christian Rieckhof proposed the NuPu-Best (Figure 8). The NuPuBest also uses simple metal splines. Links between the splines are made using cross-cut metal cubes with screws or small cups on which clamps can be fixed (Figure 9). Small balls are put under the links to reduce friction.

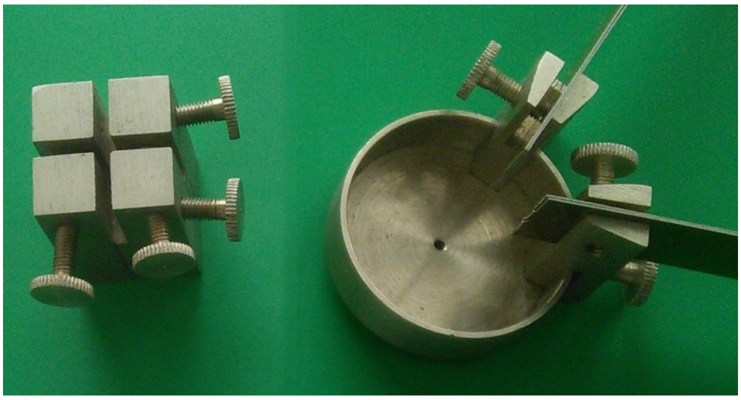


Figure 9. Basic NuPuBest links

The model is built in a horizontal plane on a drawing board using drawing tacks to pin the model supports to the board. The supports are shown in Figure 1. The rolling support is a long strip, with one end pinned to the board and the other, movable, end carrying a swiveling clamp for the spline.

The name "NuPuBest" stands for "NullPunktBestimmung" (Zero-point finder) which indicates a special feature of the device. While Beggs and Gottschalk focused on drawing influence lines, Rieckhof equipped the NuPuBest with a curvature meter (Figure 10c) to find the points of zero curvature in the deformed structure. At points of zero curvature moments are zero. A statically indeterminate structure might be cut up at these points into a set of (hinged) determinate structures (remember the *r* in equation 1). This simplifies the numerical analysis of the structure.

The curvature meters are standard devices as used in the optical industry. They have scales and are sometimes marked with a refractive index of glass, but for the NuPuBest only the "zero" mark is significant. The position along the spline of the zero deflection is marked on the drawing. Because there is some distance between the spline and the drawing, Rieckhof recommends applying one of the unused construction elements as a plumb line. Instead of marking the points, they can also be measured by the tangent pointer ("Tangentenzeiger", Figure 10b) which can be clamped to a reference point on a spline.

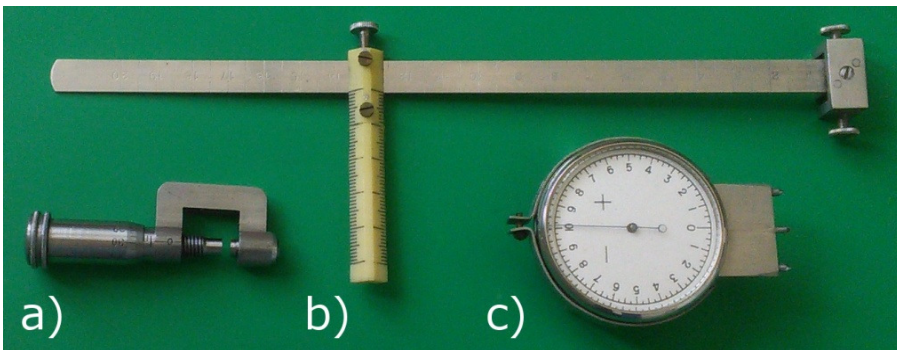


Figure 10. NuPuBest measuring devices

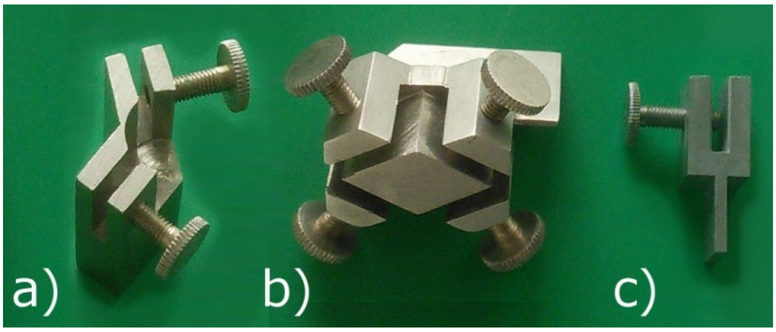


Figure 11. Special NuPuBest links

EFluBest

Influence lines could also be drawn with the model. Rieckhof called this the "EFluBest" method (EinFlusslinienBestimmung).

Both methods use large displacements, like the Continostat. However, the structural analysis is based on linear elasticity theory, leaving out second and higher order terms. The model displacements are so large that second order effects cannot be neglected. The solution is to deform the structures twice, in opposite directions, and use the absolute sum of the applied and measured displacements, which cancels the second order terms[2]. The shape of deformed spline is usually drawn onto the drawing board. Rieckhof gave detailed instructions on how to apply the deformations, and even patented them.[29] In some cases a temporary fixation of some of the links is required, for which long hat pins are used.

The influence line for an internal moment of a beam is determined by replacing the corresponding spline by two similar shorter splines and connecting them by a special bent link (Figure 11a) which has an angle of 123° (the complement to 1 rad). The influence line for a moment at a joint is obtained by less radical change of the model: a special rhomboid link (Figure 11b) is placed in a basic link instead of one of the splines. This spline is put in one of the slots of the rhomboid, and thereby rotated but also lifted. The other end of the spline also has to be lifted, by putting the bottom of a simple clamp (Figure 11c) into its basic link, and locking the spline in this clamp. The disadvantage of this procedure is that, because the spline is lifted further from the drawing board, transferring its shape to the drawing board is more difficult.

The splines are not provided with the NuPuBest: the user should acquire them separately. These splines should be 0.5 to 1.0 mm thick, 10 mm wide strips of spring steel ("Federbandstahl"). If the prototype consists of beams with different cross sections, giving different moments of inertia, the model should be built from strips of various thicknesses. For this purpose a micrometer gauge is included in the NuPuBest set (Figure 10a).

Example

A prototype can be analyzed using both methods (NuPuBest and EFluBest) with just one model.

Take for example a horizontal beam resting on 4 pinned supports *A*, *B*, *C* and *D* (Figure 12). This structure is statically indeterminate: $n = 2 + 2 + 2 + 2 - 3{\cdot}(3 - 4) + 0 = 5$.
Instead of the vice-like support of Figure 1b, we use the strip-support of Figure 1c, but now each strip (*b* in Figure 12) is fixed to the drawing board with <u>two</u> pins *c*. Each strip carries a clamp *d* that can freely rotate around a vertical axis.

Let's assume we need to know the vertical reaction force at support *B* when a unit downward load is put at point *P*, 2 meters to the right from *B*. For the NuPuBest method this means pulling

[2] Strictly speaking, for force-influence lines one should project the displacement onto the direction of the force.

down the beam at *P* using a clamp on an additional strip *g* , after loosening all screws in the clamps *d* at *A*, *B*, *C* and *D*. During the pull-down, the spline representing the beam can shift and deform, and the clamps *d* may rotate. The pull-down distance does not really matter: about one-tenth of the beam length is fine. Finally the structure is fixed by pinning down the strip *g* and fastening the screws of all *d*'s. Now one can start searching for the points of zero curvature using the curvature meter. There are two zero-points *a*, near *B*, and *a'*, near *C*. They are marked on the drawing board.

Next the screws of the clamps *d* are loosened again, and the strip *g* is shifted up twice the distance it was shifted down, giving a mirror deformation in which also two zero-points *a* and *a'* can be found. The "positive" and "negative" zero-points are interpolated pair-wise, giving the zero-points of the un-deformed structure.

With this information a classical analysis for three *determinate* structures[3] can be performed.

The structure between *a* and *a'* is a simple beam resting on two pinned supports (which have non-zero reaction forces and zero moment). The load is distributed over the two supports: the vertical reaction force V_a at support *a* equals $|Pa'|/|aa'|$ and the reaction force at *a'* is $|aP|/|aa'|$.

We now turn to the second structure, the one containing *A*, *B* and *a*. The moment M_B at *B* becomes $V_a \cdot |Ba| = |Ba| \cdot |Pa'|/|aa'|$ At B there are two contributions to the reaction force: one from the right, equal to V_a, and one from the left, equal to $M_b/|AB|$. So the vertical reaction force V_B at *B* for a unit force at *P* is $|Pa'|/|aa'| + |Ba| \cdot |Pa'|/|aa'|/|AB|$.
In the current prototype that would be $V_B = 0.854$. To check if all signs are OK a moment plot is drawn, such as the fourth drawing in Figure 12.

For the EFluBest method we deform the structure by shifting support *B* up and down (we are still interested in the *vertical* reaction force at *B*). The ratio between the vertical components of the deformation of the structure at P and B gives the reaction force at B for a unit force at P. If the total deformation at *B* equals 1, we read directly from the model: $V_B = 0.86$, which is quite close to the calculated value. If we need V_B for a unit load at another point *P'*, we can also read that value directly from the deformation at point *P'*

It is obvious the EFluBest method is much faster than the NuPuBest and gives more results in one go.

[3] The 3 structures are only determinate for vertical forces, which is what we happen to be interested in.

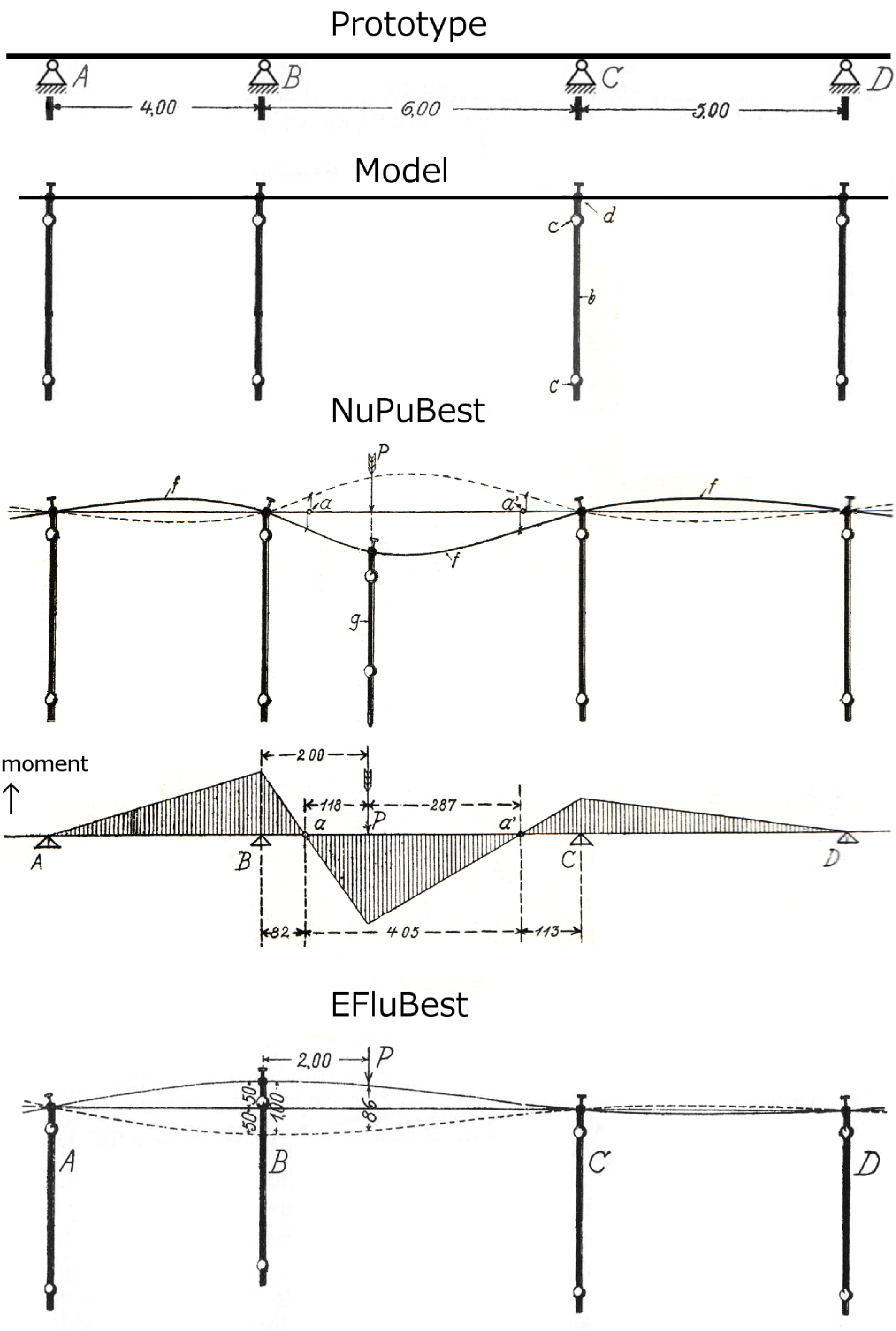


Figure 12. Derivation of the Influence line for VA

Versions

There are three known versions of the NuPuBest. The first version consisted only of the construction set[28]. The position of the zero point should be derived graphically from the deformed model.

In the next two versions different curvature meters are added. The old curvature meter is mounted in a three-legged ring while the newer one is being balanced on the spline (Figure 13). The newer NuPuBest has a magnetic strip to put the friction-reducing balls into position, while the older ones provide a simple cardboard fork for that purpose (Figure 14).

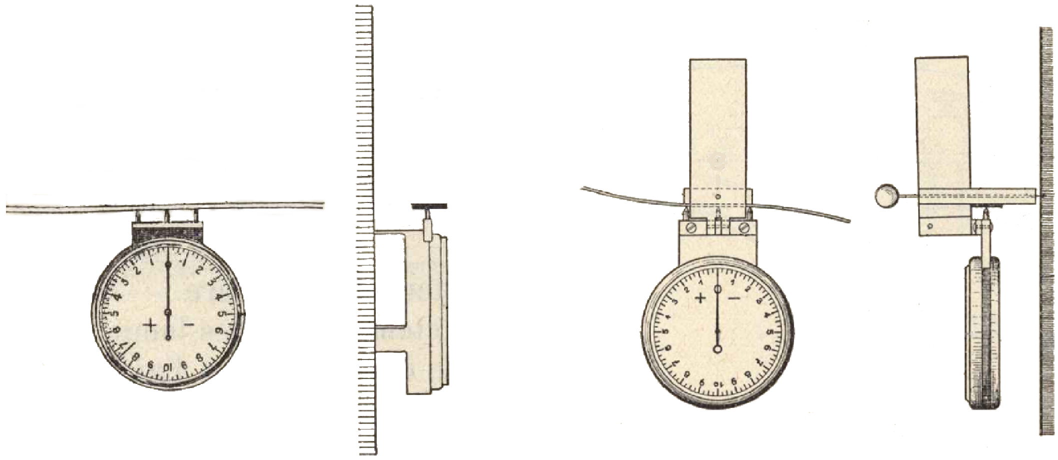


Figure 13. Two versions of the NuPuBest curvature meter: old (left) and new (right)

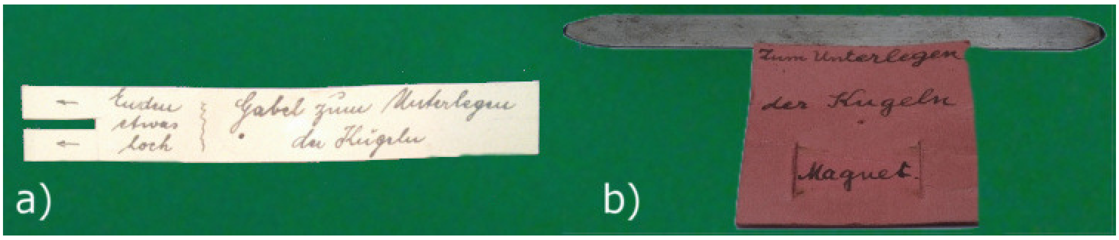


Figure 14. Old (a) and new(b) devices for putting NuPuBest ball bearings into place

Commercial history

The NuPuBest was originally sold by the Aktiengesellschaft für Baubedarf, Ludwigsstraße 15, Darmstadt[18]. Around 1927, this company, of which Rieckhof was "Direktor"[17], ceased to exist and the NuPuBest was sold privately by Rieckhof, then living at Moosbergstraße 97, Darmstadt. Rieckhof wrote a series of textbooks on the NuPuBest and EFlubest that were partly published privately[18] and partly by technical publishers (VDI, Editions du Constructeur de Ciment Armé[19]). In the early 1960's the NuPuBest was sold by E. Gerdenitsch, Roquetteweg 45, Darmstadt, who also published the manual "Experimentelle Statik" privately. It is unknown when Gerdenitsch took over business. We only know that a 1958 letter to "Chr. Rieckhof (or Successor), Moosbergestraße 97, Darmstadt" ended up in the archive of Gerdenitsch.
Beggs' and Gottschalk's devices were made commercially, but details are lacking.

Practical use

One might wonder if these modeling devices were actually applied in practical calculations, or were merely used in an educational context. Almost all contemporary accounts[20] mention the value of the models as a teaching aid. In fact, the Beggs deformeter is still being used in engineering courses[21] and is still being manufactured[22].

Continostats show up in various university collections and old course descriptions[23]. E. Gerdenitsch, the NuPuBest dealer in the late 1950's, only gives testimonials from university professors in his advertising pamphlets. This does not rule out commercial construction offices as customers, maybe it is just good German marketing. In fact, the second hand NuPuBest the author acquired originated from a pre-WWII Yugoslavian construction office.

The practical use of the NuPuBest is also indicated by the acceptance of the combined NuPu-Best-EFluBest method by the Prussian Building Authority (Preussische Baupolizei)[24]. However, while it is easy to find references to Beggs' deformeter in actual use, only four references have been found to construction projects that used the NuPuBest[25, 26].

The Delft Connection

In 1956, D. Reinders of Delft University of Technology improved Rieckhof's modeling method by simplifying the clamps, in order to minimize the distance between the splines and the drawing board[16]. He also improved modeling with flat-lying perspex strips (figure 15) with or without "internal joints" that were simplified versions of Beggs' deformator gauges, but now for large displacements.

Reinders pointed out that small sections of additional stiffness introduced by the clamps could result in large errors. The Continostat clamps are either knife edges, causing no additional stiffness, or flat clamps, causing maximum stiffness (Figure 6). The NuPuBest clamps are in between: a screw pressing the spline against a flat plane. But because the NuPuBest and EFluBest methods both require deformations in two opposite directions, additional stiffness cannot be avoided. This might be another reason the more "exact", but also more expensive, Beggs deformeter overshadowed the NuPuBest-EFluBest and the Continostat.

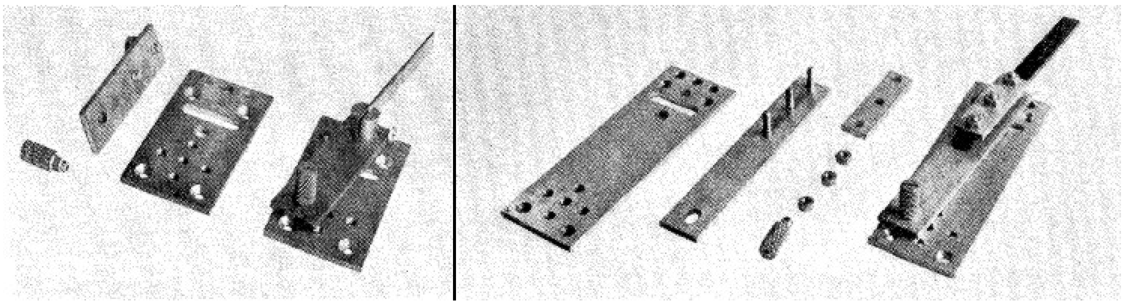


Figure 15. Reinders' clamps for metal (left) and perspex (right) models

Acknowledgements

Thanks to Daniel Toussaint for putting me on the track of the NuPuBest, discussing the various versions and providing photographs and pictures.

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How to Draw a Logarithmic Curve

Stefan Drechsler
Barbara Haeberlin

Introduction

In 1752 Count Giambattista Suardi from Brescia published a book with the title "Nuovi istromenti per la descrizione di diverse curve antiche e moderne" [Suardi-1752]. His "Istromento V", "Per la logaritmica e trattoria", is outstanding in two aspects:

- It is a mechanism for integrating the hyperbola mechanically. So it is a planimeter for a special curve, long before planimeters were invented.
- It uses a knife-edged wheel mechanism to keep trace. After Suardi this mechanical primitive was forgotten for more than 100 years, until it was rediscovered by Abdank-Abakanowicz, Prytz and others in the late 19th century.

This paper gives a (very brief) overview of the development of the concepts *curve* and *mathematical mechanism.* In the middle of the 18th century these concepts together with the concept of *logarithms* had just the right stage of maturity to allow for such mechanisms.

Antiquity

The most famous mathematical description of a curve appears at about 300 B.C. in Book I of Euclid's Elements: "A circle is a plane figure contained by one line such that all the straight lines falling upon it from one point among those lying within the figure are equal to one another. And the point is called the center of the circle. A diameter of the circle is any straight line drawn through the center and terminated in both directions by the circumference of the circle." [Euclid-Heath-1908, pp. 153f].

As [Brieskorn-Knoerrer-1986] states: "This type of definition of curves as loci was typical of the way the Greeks handled curves. They were defined as the loci of points having certain distance relationships (specific for each curve) to given points, lines and circles."

Some paragraphs later in Euclid's first book we find what became dogma, restriction and challenge for generations of mathematicians to come:

"Let the following be postulated:
To draw a straight line from any point to any point.
To produce a finite straight line continuously in a straight line.
To describe a circle with any center and distance." [Euclid-Heath-1908, p 154f].

This self-imposed limitation to only two tools, the straightedge and the compass, and to the objects that could be constructed by them, was not always strictly adhered to.

The antique Greeks already knew that there were practical and mathematical problems for which their theoretical instrumentarium, consisting only of straight lines and circles, was too restricted and they enhanced their geometer's toolbox reluctantly by other tools, primarily curves and mechanisms for drawing them. They knew (if only intuitively), that straightedge and compass alone were not enough to solve the three classical problems (squaring the circle, trisecting arbitrary angles and doubling the cube). The final word about the limits of the Euclidean toolbox had to wait until 1832, when Evariste Galois laid the foundations for his exhaustive Galois-Theory.

Meanwhile the geometers helped themselves by creating various auxiliary devices:
Plutarch reports that Plato scolded his contemporaries Eudoxus, Archytas and Menaechmus who had used mechanistic and instrumental concepts for solving the Delian Problem [Cantor-1907 p.

233]. Nevertheless even Plato himself is credited with a mechanism that constructs mean proportionals for solving the Delian Problem [Cantor-1907 pp. 226f].

At about 240 B.C Eratosthenes created his *mesolabium*, an instrument to construct cubic roots. He was excited by his invention in such a way that he had his mechanism together with an instruction sheet hung up at the temple wall [Cantor-1907 p. 331].

Another instrument which was known in antique times is a device to construct the *conchoid* (shell curve) of Nikomedes [Cantor-1907 p. 351], a curve that was used to solve another of the three classical Greek problems: the problem of angle trisection.

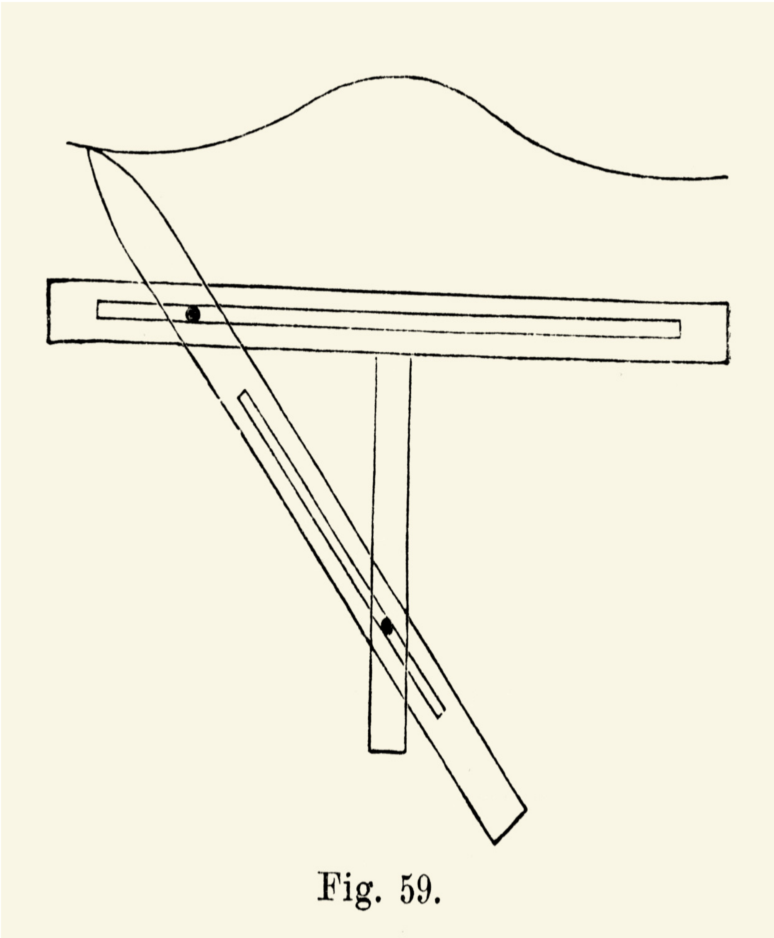

Figure 1. Device for drawing the conchoid of Nikomedes [Cantor-1907, p. 351]

For the Greek mathematicians curves were viewed for their own sake or as useful helpers in solving mathematical and practical problems.

Middle Ages and Renaissance

The European Middle Ages saw almost no development in geometry, and for Renaissance artists curves were not mathematical concepts but tools and aids for arts, crafts and architecture.

Albrecht Dürer is known to have constructed several devices for drawing curves. In his book "Underweysung der messung mit dem zirckel und richtscheyt in Linien ebnen unnd gantzen corporen" he presents various algorithms for constructing curves together with hints for what they could be used for ("Dise Lini dint zu eynem Bischofstab"), and he presents a mechanism for drawing a curve he calls *muschellini* ("muschellini" translates to "shell curve" but it is not the conchoide of Nikomedes) [Duerer-1525].

In da Vinci's Codex Atlanticus a drawing of a parabolic compass can be found, and an *elliptic chunk*, an ellipse drawing machine, is attributed to Leonardo da Vinci by Franz Reuleaux [Reuleaux 1875].

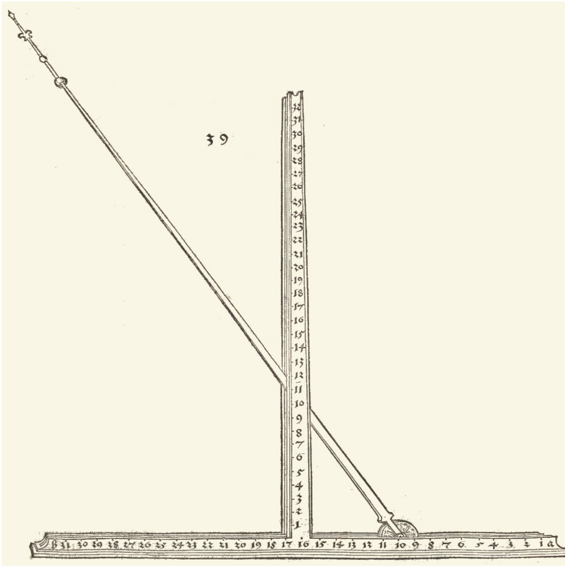

Figure 2. Dürer's device to draw a "muschellini"

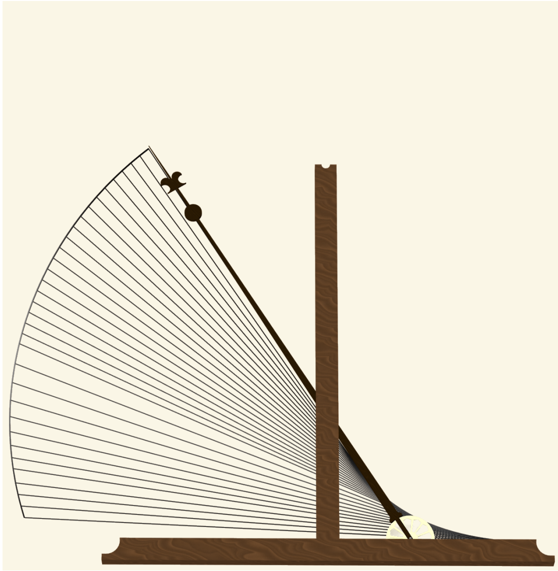

Figure 3. Model of Dürer's instrument

The 17th century

In the 17th century Descartes and Fermat made it possible to solve geometrical problems algebraically and to describe curves by equations.

Descartes still distinguished between "geometrical" and "mechanical" curves, the first ones being polynomials, the latter ones being the transcendental curves which in his opinion could not be treated mathematically. Like Euclid he distinguishes between "good" and "bad" objects and only allows the "good" ones.

Only a short time later in the 1670s the great era of differential calculus started. The naïve understanding of the concepts "curve", "area" and "tangent" were replaced by solid definitions, and reliable mathematical methods to deal with these concepts were given by Newton and Leibniz. The first differential equations were (first clumsily and naïvely, later professionally) treated with great interest.

Physical phenomena could now be modeled into mathematics with much greater ease, and many attempts were made to map reality to curves.

Galileo himself was wondering what form a rope might take hanging freely between two fixed points, and he observed that it was approximately a parabola. Later, in 1691 a correct description of this transcendental curve, which was named *catenaria* by Leibniz, was given independently by Leibniz, Huygens and John Bernoulli [Kline-1972 p. 472].

In 1673 Huygens investigated the curve from which an object without friction slides down to the lowest point in exactly the same time, independent of its starting point on the curve. Huygens found, that the resulting curve, the *tautochrone*, is a cycloid.

In 1696 John Bernoulli asked for the path in a vertical plane down which an object would move, driven by gravity, in the shortest time. And he answered his question by giving the parametric description of the resulting curve, called the *brachistochrone*.

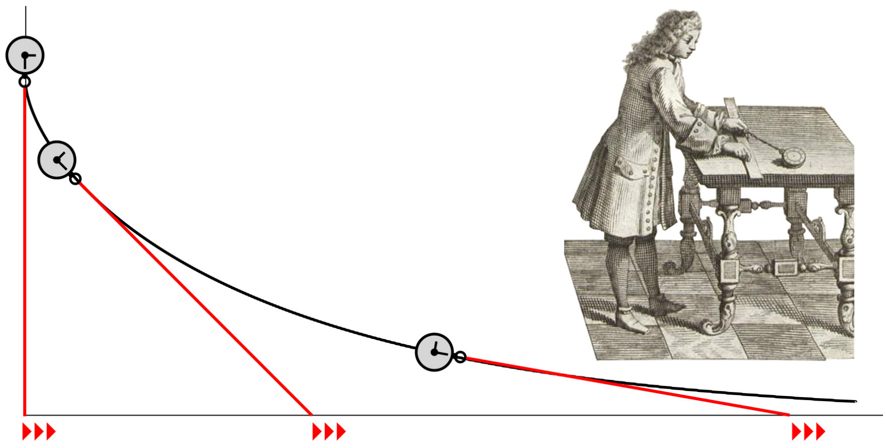

Figure 4. Drawing a tractrix (upper right part from [Poleni-1729])

Legend has it that around 1670 the French mathematician Claude Perrault took his watch out of the pocket, placed it on the table, pulled the end of the watch chain along a straight line and invited his colleagues to determine the shape of the curve traced by the watch. In 1693 in his "Supplementum geometriae dimensoriae" Leibniz addresses the problem and attributes it to Perrault.

In 1676 Huygens describes this curve and calls it *tractoria.* Later the name *tractrix* (from latin trahere, to pull) became common. Huygens was also the first one to construct a device for drawing tractrices [Bos-1993].

In 1638 the French mathematician Florimond Debaune, who was a friend and follower of Rene Descartes proposed four problems, which required the reconstruction of a curve from certain properties of its tangent lines. Unfortunately his questions got lost, but from later texts it can be deduced that his third task was to find all curves with a constant subtangent [Scriba-1961 p. 408]. The solution was given by Leibniz in 1676 [Scriba-1963, p.123].

All these effords deal with transcendental curves and go beyond the framework set up by Descartes, while testing the limits of geometric-mechanical approaches.

The subtangent of a given point P = (x,y) on an (at least at this point) differentiable curve is the length K of the line segment that connects M, the projection of P onto the x-axis, with the intersection T of the point's tangent and the x-axis (Figure 5).

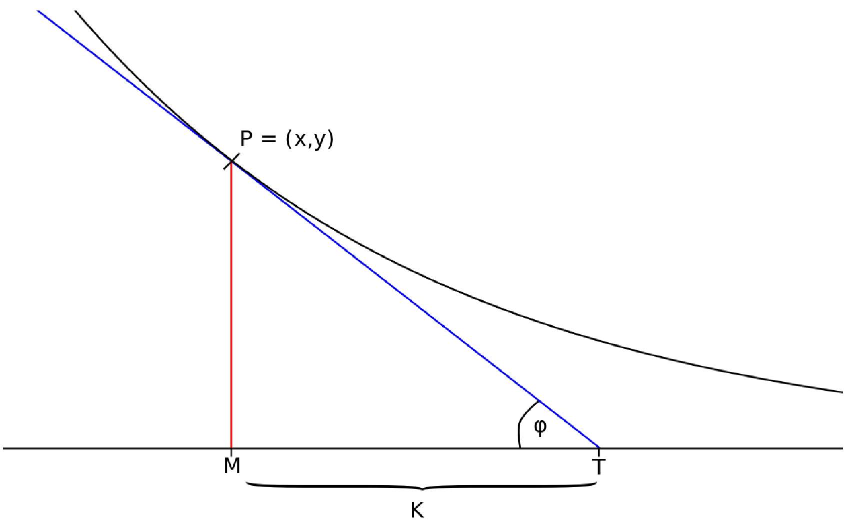

Figure 5. Finding curves with constant subtangent

To find all curves with constant subtangent K, first observe that: $K = y / \tan(\varphi)$

With $\tan(\varphi) = dy / dx$, we get $K = y \cdot dx / dy$, or equivalently: $dx = K \cdot dy / y$

Integrating both sides gives us $\int dx = \int (K/y) \cdot dy$, so: $x = K \cdot \ln(y) + c$

Juggling the variables leads via $x - c = \ln(y^K)$ to: $y^K = e^{x-c} = e^x \cdot e^{-c} = c_2 \cdot e^x$

Therefore these curves are exponential, or by interchanging the variables, logarithmic curves.

The 18th century

In 1706 a paper with the title "The Construction and Properties of a new Quadratrix of the Hyperbola" [Perks-1706] was handed to the Royal Society by Abraham de Moivre.

About its author, Master John Perks, little is known. It is assumed that he was “not a recognized mathematician”, but rather an amateur [Pedersen-1963], and his complete oeuvre consists of three articles, one about the quadrature of the lunulae of Hippocrates of Chios [Perks-1699], one titled “An easy mechanical way to divide the nautical line in Mercator's projection” [Perks-1714] and the one mentioned above, in which he presents a device to construct the tractrix and with minor modifications also the logarithmic curve.

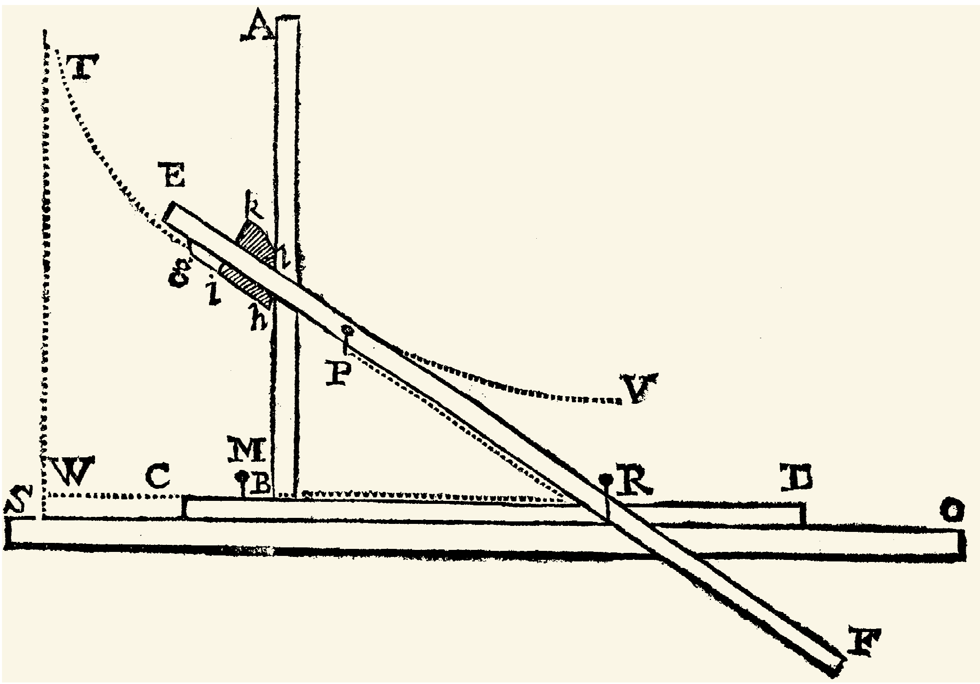

Figure 6. Perks' mechanism [Perks-1706]

Giovanni Poleni, otherwise known as the inventor of the first pinwheel calculating machine, described in 1728 in a letter "De Organica Curvarum Tractoriae, atque Logarithmicae Constructione" to Johann Hermann a similar mechanism [Poleni-1729 pp. 118ff].

Poleni, born 1683 in Venice, was professor for physics and mathematics at the University of Padua. In 1740 he founded the Teatro di Filosofia Sperimentale, a collection of scientific instruments. Until his death in 1761 this collection has grown to more than 400 devices [Mirandola-2011].

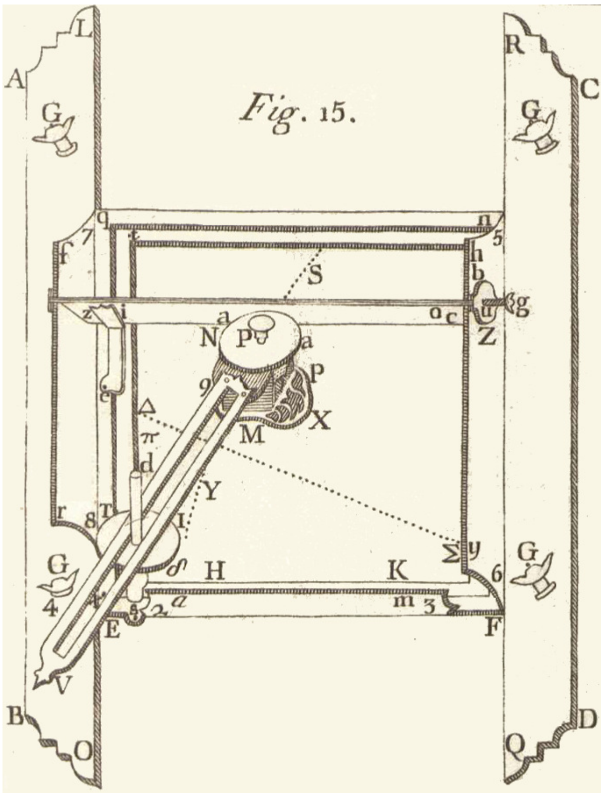

Figure 7. Poleni's machine [Poleni-1729]

In 1752 Count Giambattista Suardi of Brescia published his book „Nuovi istromenti per la descizione di diverse curve antiche e moderne" [Suardi-1752] which contained ten instruments for drawing curves, the most remarkable of them his "Istromento V" "Per la logaritmica e trattoria".

Suardi was born in 1711 in Brescia. As a member of a noble and rich family he was well educated. He studied in Padua. One of his teachers was Giovanni Poleni from which Suardi learned a lot about mechanical instruments. Between 1736 and 1747 he worked on his „Nuovi Istromenti". After the death of his father in 1754 he had the opportunity for a study tour to other mathematicians. In 1764 he published his „Trattenimenti matematici", an opus on recreational mathematics. He died in 1767 [Mirandola-2011].

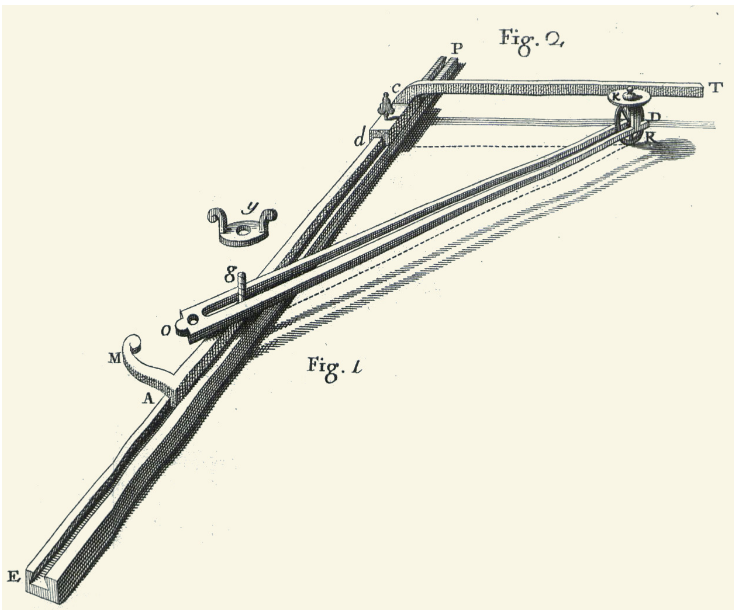

Figure 8. The instrument of Suardi [Suardi-1752]

The three instruments of Perks, Poleni and Suardi share a common principle in constructing the tractrix and the logarithmic curve. The mechanisms must be based on two properties: They should guarantee the property of the tangent and they should provide a constant length of the (sub-) tangent.

As the mechanism of Suardi adheres to these properties in the clearest way, we focus on this instrument and explain Poleni's and Perks' constructions as variations of it.
Suardi uses for the x-axis a fixed rod PE (Figure 8) which has a groove shaped like a dove-tail, so that another rod AC can slide along this x-axis using the handle M. A ruler CT is fixed perpendicular to the sliding rod, that while sliding pushes some kind of carriage D, which draws the curve. As CT is always parallel to the y-axis, the distance Dd is the mechanized f(x). The tangent property is granted by a knife-edged wheel in the carriage, so that the curve is drawn along the movement of the wheel. Therefore the ruler DO, which is guided in the moving direction of the knife-edged wheel, realizes the tangent of the drawn curve. A peg *g* on the sliding rod is used in two different ways. Putting the peg in the hole *o* of the tangent rod guarantees that the length of the tangent remains constant. In this case the carriage is pulled by the tangent rod and ruler CT is not necessary to push the carriage. While the tangent is turning around peg *g* the wheel is drawing the tractrix.

Instead of placing peg *g* in hole *o* the peg can also be put into a long slit in the tangent rod so that the tangent can slide along the peg. In this case the carriage has to be pushed by the ruler CT. As this ruler is fixed at the sliding rod, the distance *dg* remains constant, which constitutes the subtangent, so that the wheel will roll along a logarithmic curve.

Instead of a single rail in the fixed rod PE, Poleni uses two rails AB and CD (Figure 7) on both sides of a frame EFnq. This may stabilize the perpendicular angle of the ruler zZ, but may cause the problem of canting the frame while sliding.

Suardi's disk k on the carriage is used to keep the distance between the ruler CT and the line dD constant, because the knife-edged wheel is touching the paper not on the line CT but on the line dD. Perks chose another solution for this problem; instead of a whole disk he used a quadrant ikh which is placed on the other side of the ruler AM (Figure 6). This is necessary because in Perks' mechanism the carriage is not pushed by the ruler but it is pulled by a string PRB so that the quadrant ikh pushes against the ruler AM. The string is redirected by a pin R fixed to the sliding rod CD. This construction might bear the risk of jamming because of the chaining of the movement: the string pulls the tangent rod which pushes the ruler.

All three devices can be modified slightly to draw the tractrix instead of the logarithmic curve. But Suardi's instrument displays this modification most clearly: One may change from the tractrix to the logarithmic curve by interchanging turning and sliding.

Summary and outlook

The three mechanisms described above integrate a special class of functions so that with considerable justification they may be considered as planimeters – more than half a century before the first universally applicable planimeter was invented in 1814 by the Bavarian surveyor Johann Martin Hermann.

They combine cutting edge mathematics of their time with a new mechanical building block, the knife-edged wheel. The use of the knife-edged wheel to maintain the slope of a curve was forgotten after Suardi until the 1880s when Bruno Abdank-Abakanowicz used it in his integraph.

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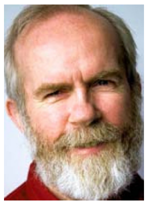
Milling Numbers - Discovering the Millionaire

Dirk Rietveld



Introduction

I will take you on an adventurous journey, at least for anyone interested in mechanical calculators. It is my own journey in finding out more and more about millionaires, not the human ones, but the calculators. Although, if you want to own one, it helps if you are a millionaire.

I am used to the fact that when I want to multiply numbers on a mechanical calculator, it is by repeated additions. That is, until I began to find out about the Millionaire. The Millionaire is not the first machine that does direct multiplication, but it is the first that became a commercial success.

Meeting the Millionaire

The first time I saw a Millionaire, I could only see the controls, as you can see on this photo (Fig. 1). It shows a basic Millionaire, with the standard controls in neutral positions.

In the centre, you may set the number to be multiplied. In this case up to eight digits. Millionaires with six, ten or twelve digits have also been made, not unlike the human millionaires.
Just a bit to the right you'll find a lever to be set to Addition, Multiplication, Division or Subtraction, the four functions this machine can perform.
Again to the right, you see a crank, the actual driving mechanism of the Millionaire.
Back to the left of the machine, you see a lever that may be set to a number from zero to nine. This lever lets you form the multiplier, one digit at a time.

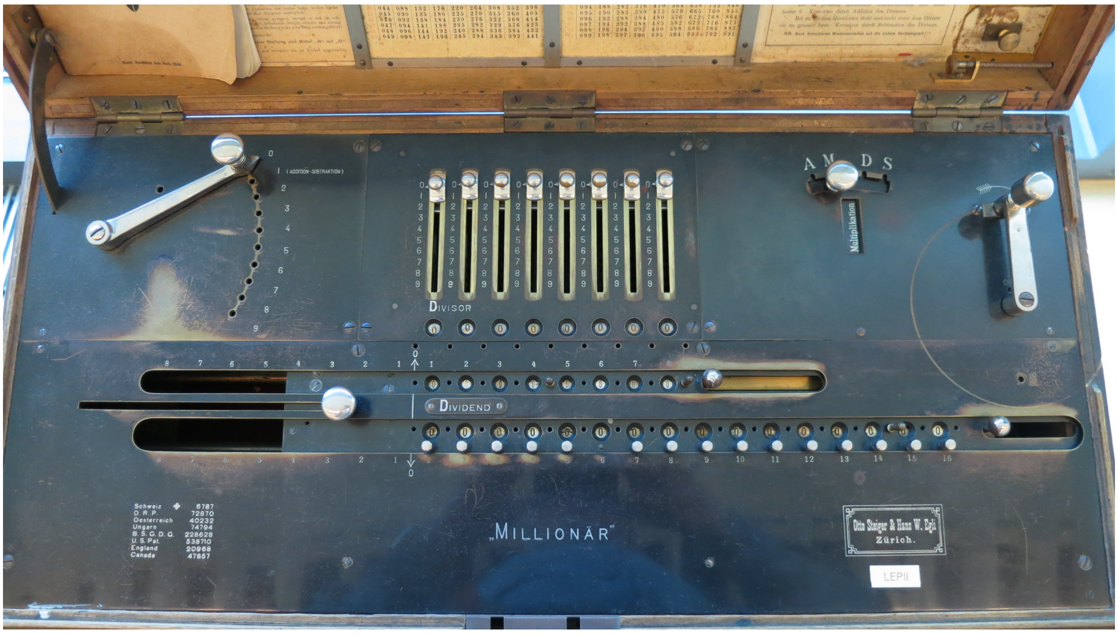


Figure 1. Basic Millionaire at the Arithmeum, Bonn

Finding a Millionaire for discovery

If I had turned to the internet after I met my first Millionaire, my adventure would not have been nearly as wondrous as it has been, and I'm happy I didn't. Instead, I went a lot further than the internet, all the way to Bonn in Germany.

In Bonn, not far from the railway station, there is a unique museum, dedicated to the art of calculating. This museum, the Arithmeum, is part of Bonn University, and houses a collection, ranging from ancient and far away ways of depicting numbers and doing calculations, to the modern day computer. Yet, the main part of the collection is a huge number of mechanical calculators, which, to my knowledge, must be the largest and most complete collection to be found anywhere. At least, for a collection in a museum that can be seen and for a part also touched.

This collection houses several Millionaires of various types, with three on display and the others stored in the very full depots.

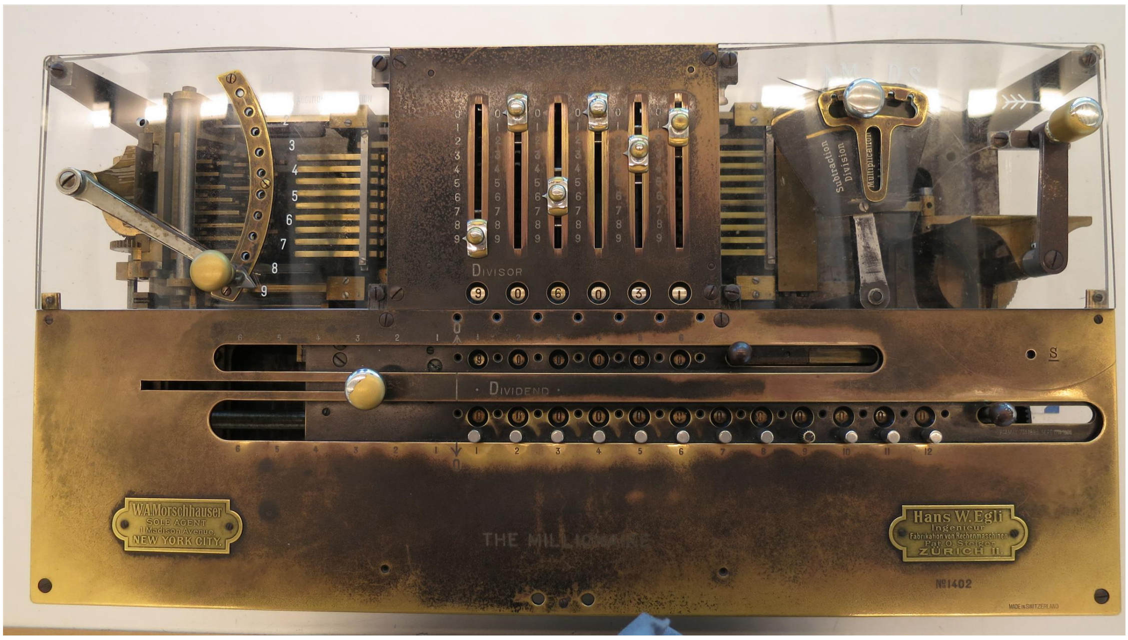


Figure 2. See-through and hands-on Millionaire at the Arithmeum, Bonn

One of the Millionaires has been made transparent by exchanging several metal plates with perspex ones (Fig. 2). It is this Millionaire that I have visited five times in the past twelve months, and which has given me insight into its inner workings. It also gave me the opportunity to make the photos for my story.

From miracle to reality

Let's go back to my first moment of amazement with a Millionaire. Mind you, this was not a see-through machine. Once I got the hang of multiplying on it, I had absolutely no clue as to what mechanism could do what I saw happening. It really seems to do a direct multiplication, one digit at a time for every turn of the driving crank. When you don't know what is happening inside, it feels like seeing a miracle.

The first time I went to Bonn, it had to do with the exposition of the Schuitema collection of slide rules. Yet, I soon found the see-through Millionaire and started to try it out. At first, that was no success, but after I opened the manual, all four functions were more or less quickly mastered. But still I had no idea of the way it operated.

Then I saw this strange piece of metal next to the Millionaire (Fig. 3). In the description I found that it is called an ein-mal-eins. In English that would be a one-times-one. And that is the first line in the tables of multiplication as all of us have most probably learnt in elementary school. On the ein-mal-eins you see the tables from one on the left to nine on the right, and the number of times from one at the bottom up to nine at the top. The tables are made up of two vertical rows, the left one with the units, and the right one with the tens. For instance, on the left side, the table of one has only units, in a neatly ascending order from one to nine. The next one, the table of two, on the left you see two, four, six, eight, zero, two, four, six and eight. On the right you see four times zero and five times one. Together they make 2, 4, 6, 8, 10, 12, etcetera. On the far right, the table of nine, the left row neatly descending from nine to one, and the right one, ascending from zero to eight.To me, after understanding just this, most of the mystery was now gone from the Millionaire. Of course, some things still have to be done, but with those tables firmly implanted in the machine, as a read-only-memory, it seems clear that direct multiplication is now a possibility.

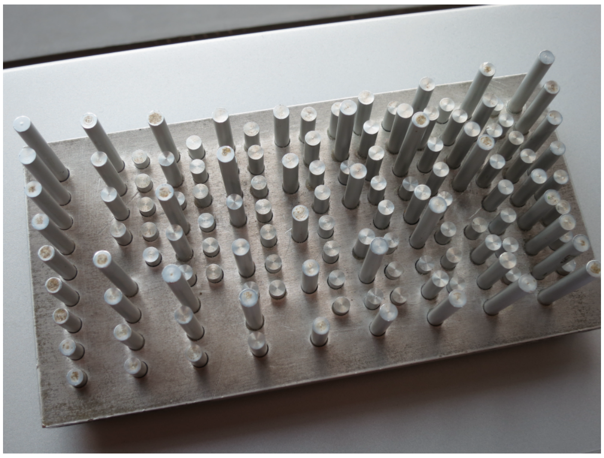


Figure 3. Modell of an ein-mal-eins

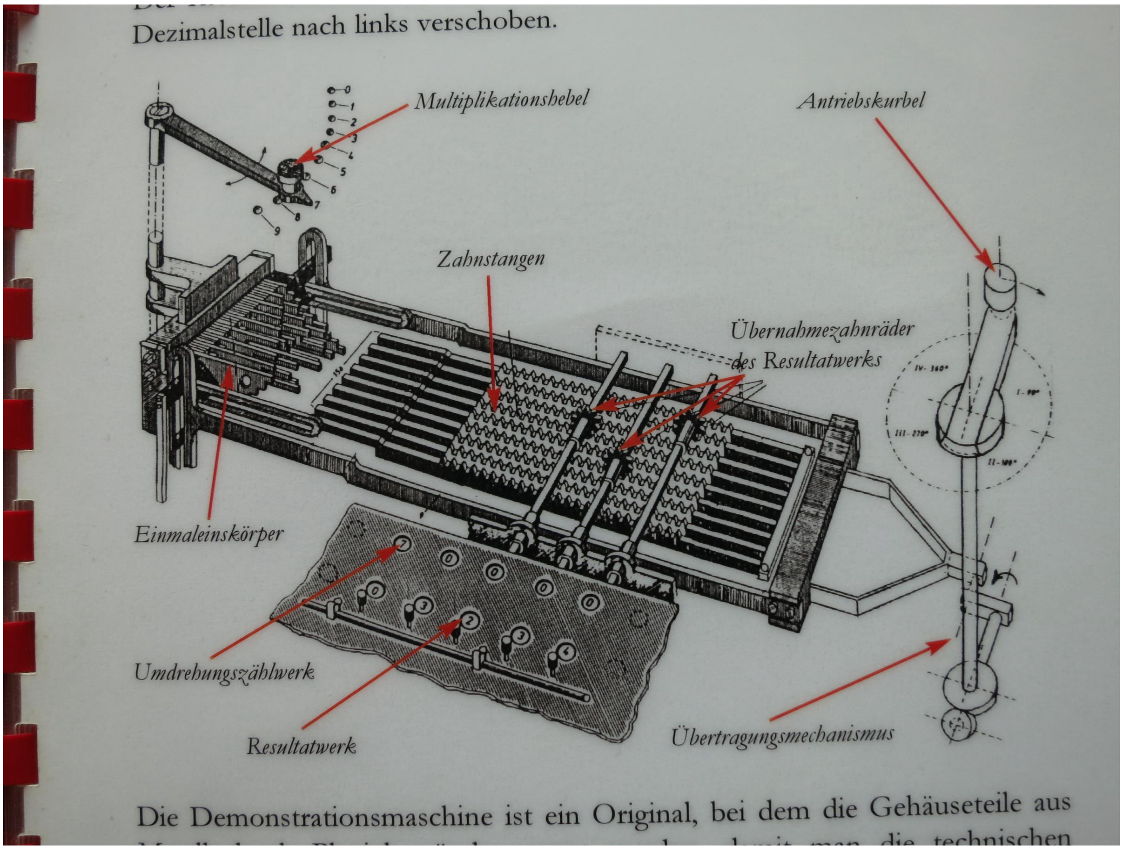


Figure 4. Schematic inside of a Millionaire

A quick look at the mechanics

In this diagram (Fig. 4), copyright the Arithmeum, Uni/Bonn, the basics of the inner workings are depicted. When you move the left lever from zero to nine, the ein-mal-eins moves from down to up, aligning the line of corresponding steps in the tables with the line of toothed rods that by moving will turn the perpendicular axles that drive the result counter. And by setting the numbers of the multiplicand, you choose the rod that will be used for that number.

By now it could be clear that this machine is not really multiplying, but is doing additions based on the tables of multiplication, much like we all have learnt to do in school. I was a bit disappointed when I thought of this, it does take away some of the magic. There is also a difference with the way we have learnt to do multiplications in school. The Millionaire works the multiplier from left to right instead of from right to left. I think this is to avoid having to change the direction of the automatic movement of the carriage when switching between multiplication and division.

Figure 5. Setting a digit of the multiplicand

Digging deeper

Now, let us look closer at the inner workings of this machine. A proper starting point is to set all levers and counters to zero, move the carriage all the way to the right, and set the machine to multiplication. Also have the driving crank in the neutral position, which is pointing upwards.

Use the sliders from left to right to set the number to be multiplied. On this photo (Fig. 5) you see what is happening inside.

Moving one of the sliders moves a cogwheel across a square axle, and aligns it with the desired step in the tables of multiplication. This leads to the correct number being added to the counter in the carriage when the rods are moved by the ein-mal-eins.

With the left crank we set the first digit of the multiplier. When you do this, the ein-mal-eins moves up so that the proper line in the tables aligns with the rods, as you can see here (Fig. 6). In this photo, taken from the back of the machine, the ein-mal-eins is in position seven.

Figure 6. The ein-mal-eins in position for the table of seven

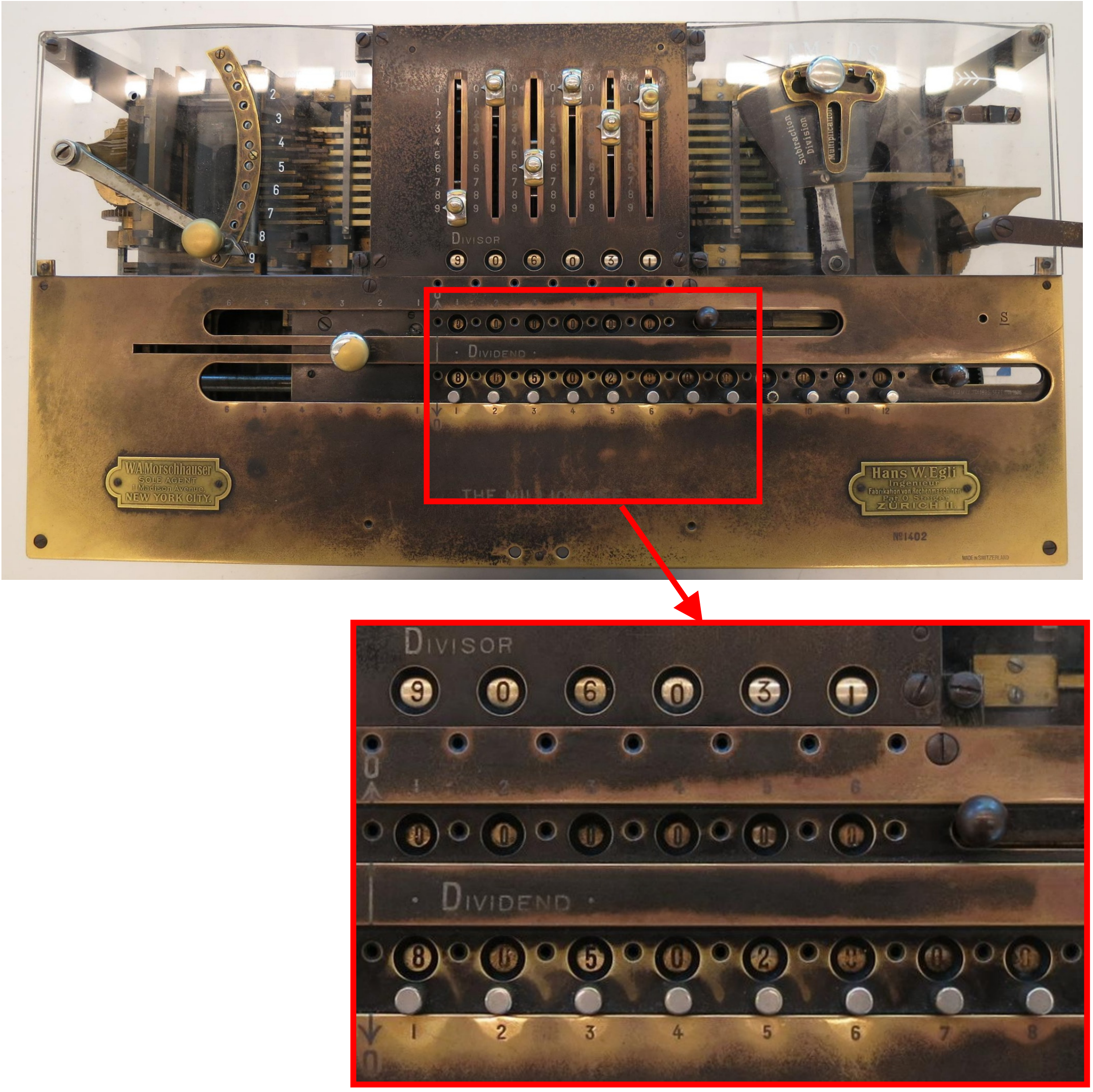


Figure 7. After the first quarter turn of the crank

Multiplication in four quarter turns

First we set the machine for the multiplication 906031 times 9 (look back at Fig. 2). Now we can rotate the crank to see the multiplication with the chosen number. We will stop between the four distinct parts of the turn, where different things happen.

In the first quarter of the turn (Fig. 7 above), the ein-mal-eins is moved a bit to the side, as to align the tens of the tables with the rods. Then the ein-mal-eins moves forward and pushes the toothed rods away. The toothed rods turn the cogwheels and the square axels, thus counting the tens into the result counter on the carriage, leaving the number 805020.

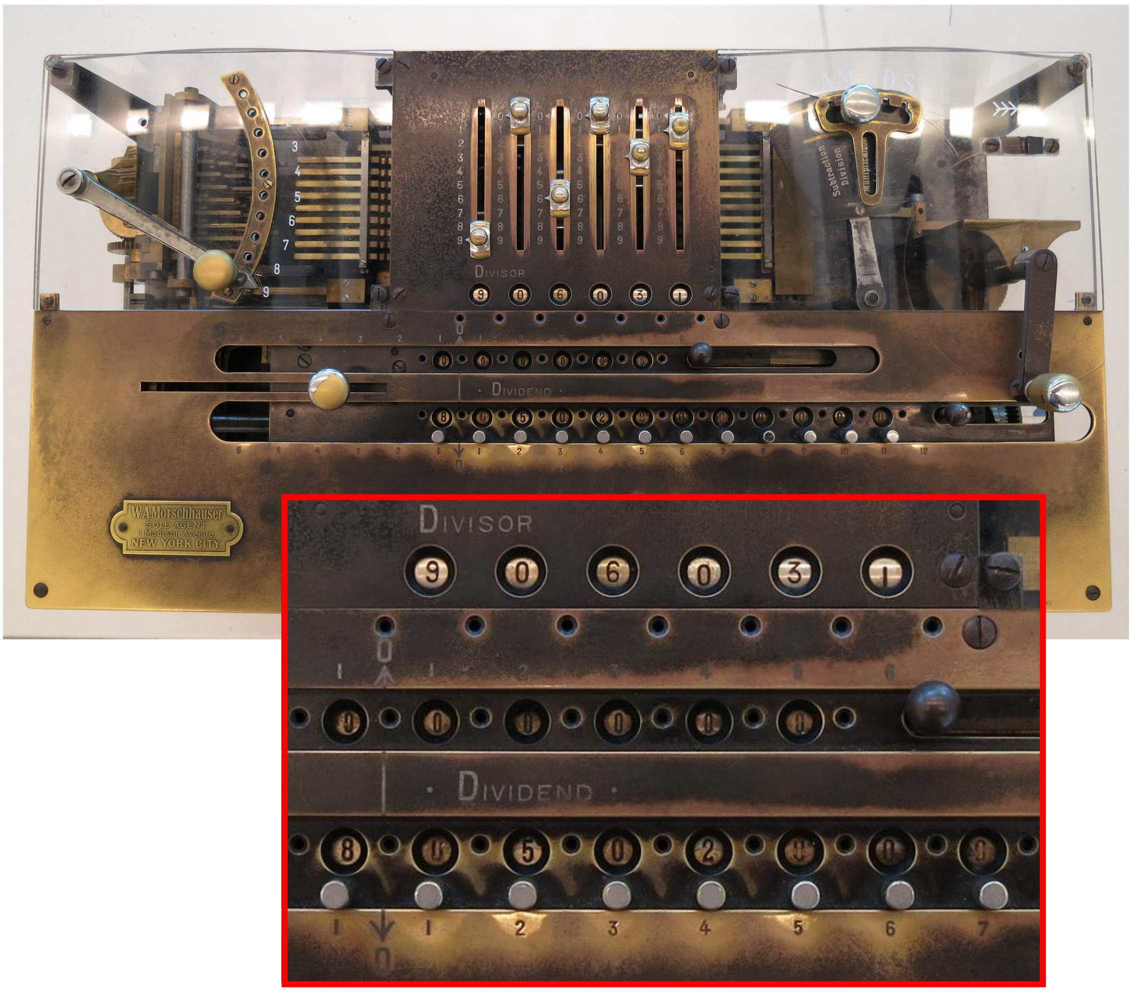


Figure 8. After the second quarter turn

In the second quarter turn (Fig. 8 above), the ein-mal-eins is pulled back, the rods are pushed back, the carries are performed (none in this case), and the carriage is moved one step to the left, ready to receive the units.

During the third quarter turn (Fig. 9, next page), the ein-mal-eins is moved a bit to the other side, to allow the units to do the work. With the same sequence the units are brought to the counters, which, as you remember, had moved one step to the left, and the units are counted into the result one position to the right of where the tens were counted, leaving 8154279 in the counter. At the same time, the multiplier 9 is counted into the multiplier counter, just above the result counter.

The last quarter turn (Fig. 10, next page) moves the ein-mal-eins and the rods back, and performs the carries, resulting in the completion of the multiplication with the first digit. Of course, in our simple example there are no carries to be performed.

After the last quarter turn the machine is ready for the next digit of the multiplier. This shows that multiplying with the Millionaire is very quick, alternating between setting the digit and turning the crank. If the next digit is the same, turning the crank a second time is all that has to be done. For example, 99 times 99 only requires setting the lever to 9 and turning the crank twice.

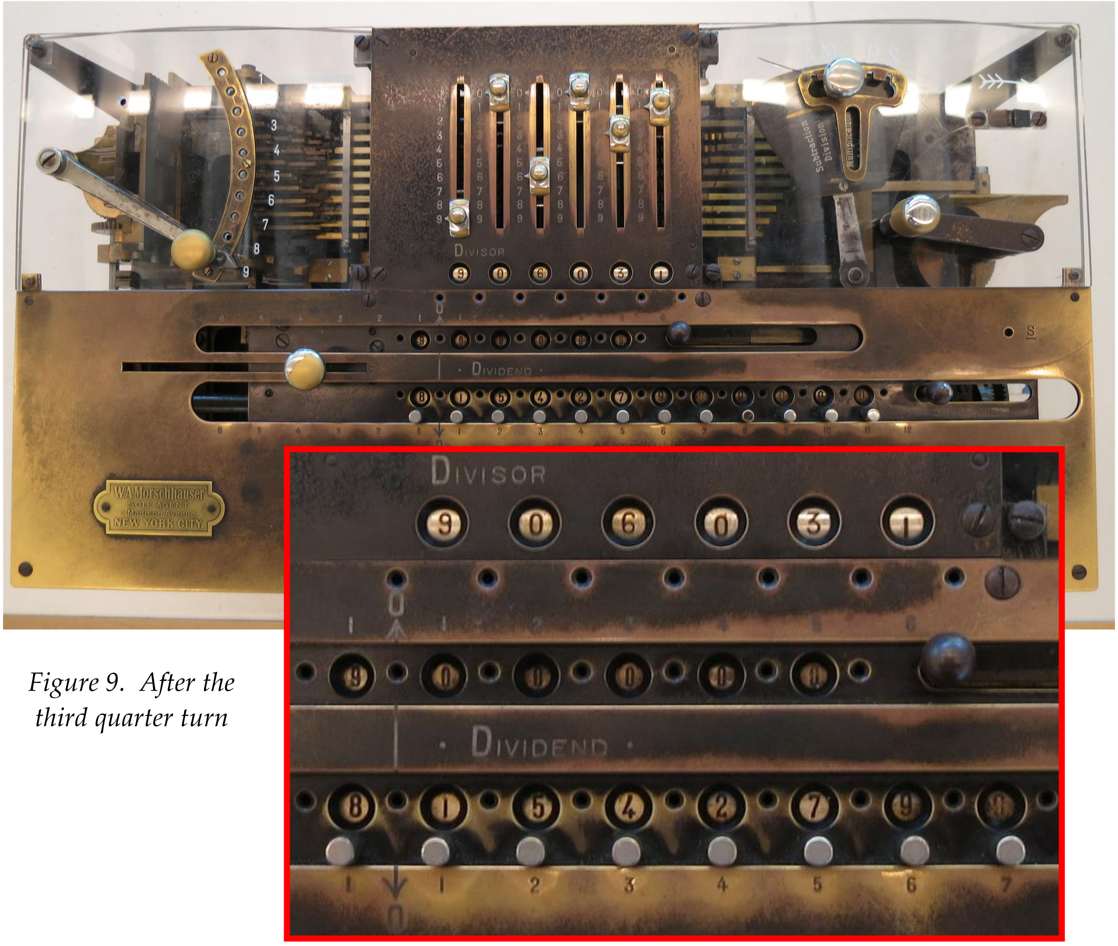


Figure 9. After the third quarter turn

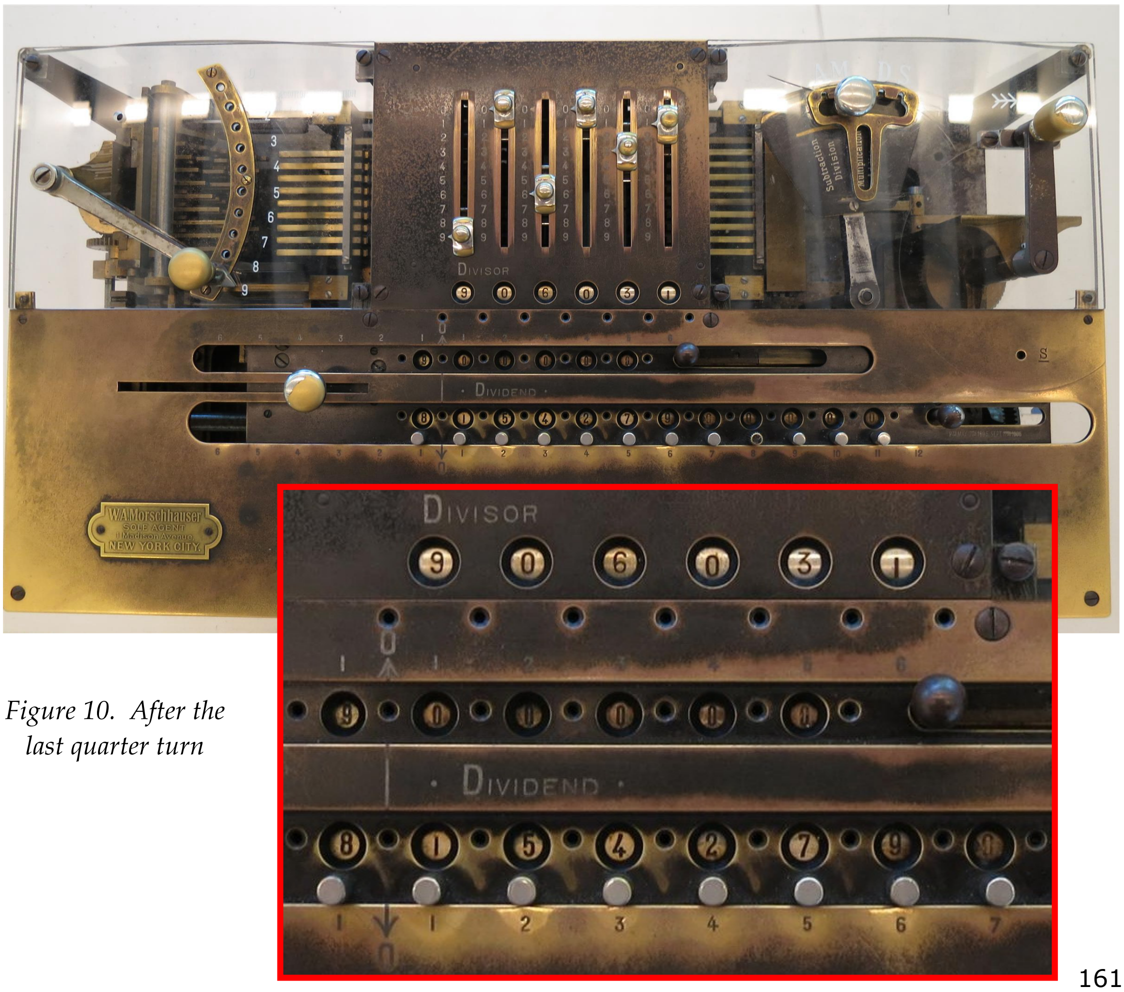


Figure 10. After the last quarter turn

Addition and Subtraction

Now that we have seen how the multiplication is performed by the machine, the addition is a no-brainer. The moving mechanism of the carriage is now disconnected, and you have to set the multiplier lever to one. So, addition is now a multiplication by one, and the result is added into the total counter. Subtraction is just as simple, with the counters working in reverse.

Division needs a lot of thinking

The last function, division, is not as simple. Essentially it is quite the same as how we learnt to divide in elementary school. First you set the divisor using the sliders, then set the number to be divided into the total counter, using the small turning knobs. Take care that you start with a zero if the divisor fits at least one time in the first part of the number to be divided. Reason for this is that subtraction starts at the second position of the total counter. Alternatively, you may always start with a zero in setting the number to be divided, at a possible loss of one digit in the precision of the result. Now you have to estimate the number of times, from zero to nine, the divisor fits into the first part of the number to be divided, set that number with the multiplier lever, and turn the crank. Proceed with estimating the next number and continue until the carriage has reached its final position, announced by the sound of a bell. The result of the division is now visible in the upper counter on the carriage.

This procedure may seem fairly simple, but if you make a mistake with the first position zero, or in estimating the number of times the divisor will fit, then you are in a bit of trouble. Correcting your mistake is not complicated, but you have to stick to the manual, or you will get lost. To help in estimating the number of times the divisor fits, a table on paper (Fig. 11) is delivered with the Millionaire, on the inside of the top cover. Essentially, this table shows the tables of multiplication from 1 to 99. Yet, when in doubt, the use of a slide rule might be the answer.

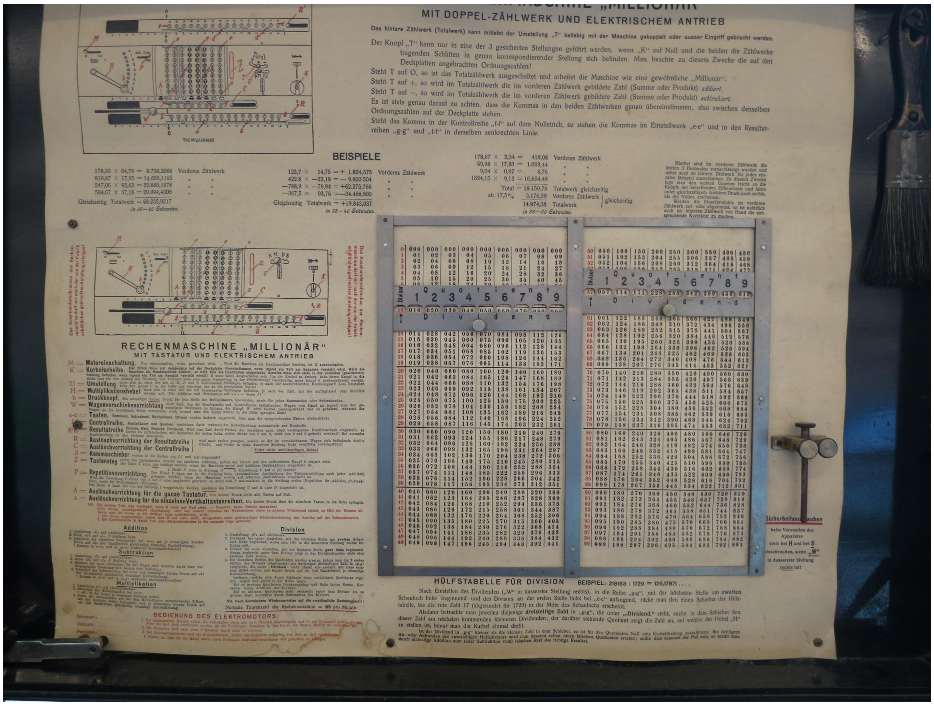


Figure 11. Paper table with the tables of multiplication from 1 to 99

You may have noticed that I said very little about what happens inside the Millionaire during division. Reason for this, is that the Millionaire is again only doing multiplications to be subtracted, and the division is really done by you.

Division at ease

If you get frustrated doing divisions the Millionaire way, you might decide to set the top lever to subtraction, and move the carriage by hand. In that case you have to leave the left lever at one, start with the carriage one position from far right, and give the number to be divided a preceding zero if the divisor fits at least one time in the first part of the number to be divided. Now you have to turn the crank as many times as needed, move the carriage one position to the left and turn the crank again, etcetera. In doing so, corrections are no problem at all, and the chances for frustration are minimized.

The carry mechanism

As Millionaires have total counters ranging from twelve to twenty digits, a carry that goes all the way, may lead to a very heavy job. To avoid this, the Millionaires perform the carries separate from the counting.

To get this done, another complicated mechanism was designed. The logic behind this is as follows. During addition, when a digit reaches the zero, a carry needs to be prepared. Yet also, when a digit gets up to nine, a carry may be provoked by a carry from the preceding digit. During subtraction, reaching nine downwards, a carry needs to be set aside, and also, getting to a zero, a carry may be provoked by a carry from the preceding digit.

The mechanics of these actions may be seen from the front of the machine (Fig. 12). Under the total counter, a cylinder is connected to the carriage. Above this cylinder, small pointed rods are dangling down. When a carry is needed, the pointed rod is pushed in the direction of the next digit. When a carry is prepared, the same happens, but only halfway.

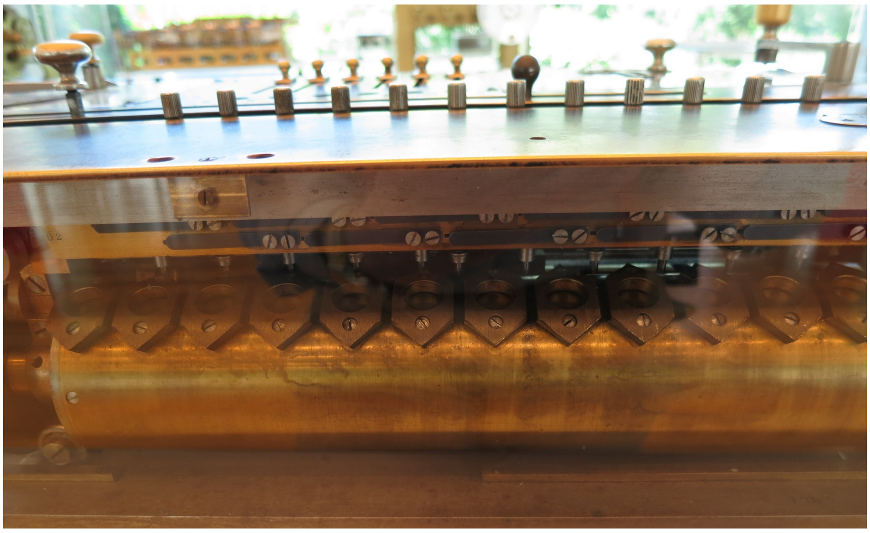


Figure 12. Cylinder for the carry mechanism

During the second and fourth quarter turns, following the first and third counting quarter turns, the carries are performed by small objects on the turning cylinder that interact with the dangling pointed rods. At the same time the dangling rods are pushed back to their original position. To let the carries follow each other from right to left, the objects on the cylinder to the left of the previous one are placed a little bit downwards from the previous one.

In this case, to give more clarity to the way this mechanism operates, seeing is believing.

Variations in Millionaires

The Millionaire was patented by engineer Otto Steiger in 1892/1893. Production started in 1899 by the firm of Hans Egli in Zurich, Switzerland. The last one of the 4655 Millionaires that were produced, was sold in 1935.

Some Millionaires had six by six by twelve digits, most had eight by eight by sixteen digits, some had ten by ten by twenty digits, and some had twelve by eight by twenty digits.

At some point in time the sliders could be replaced by a keyboard.
On the keyboard version an extra mechanism could be added for setting one of two constant values by pushing it down onto the keys.

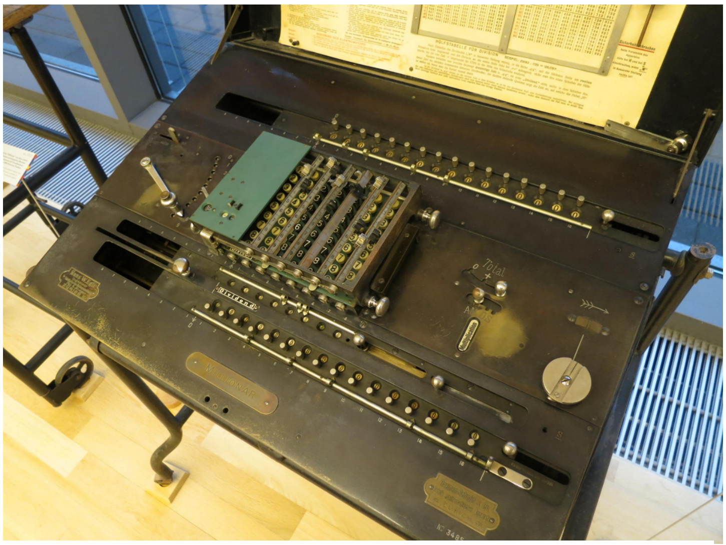
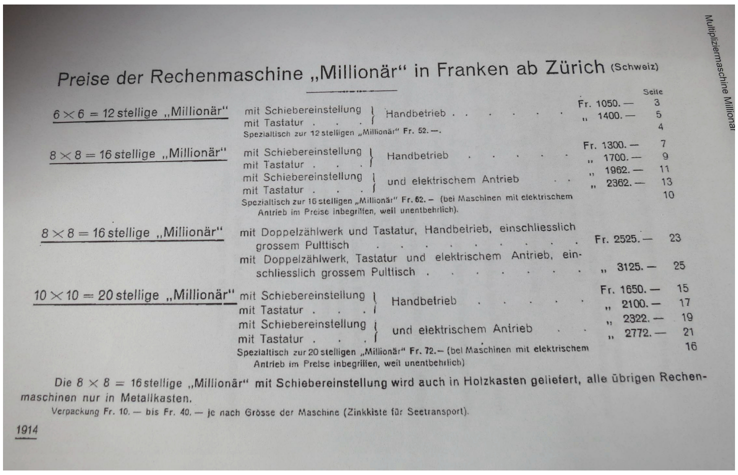


Figure 13. Motorized Millionaire with keyboard, constant mechanism and second total counter, on a custom made table

The driving mechanism could be motorized. In that case the starter knob was on the left lever, so setting the multiplier lever and starting the mechanism was a one-handed operation.

Some Millionaires have been made with a second total counter above the setting mechanism. This counter could be switched between idle, adding and subtracting. This made it possible to get a grand total of a number of multiplications, or to subtract a percentage at the end of a calculation.

All these extras put together make for an impressive Millionaire (Fig. 13, on display at the Arithmeum, Bonn).
From 1927, also the left lever could be replaced by a keyboard.



Multipliziermaschine Millionär

Preise der Rechenmaschine „Millionär" in Franken ab Zürich (Schweiz)

				Seite
6 × 6 = 12 stellige „Millionär"	mit Schiebereinstellung	Handbetrieb	Fr. 1050. —	3
	mit Tastatur		„ 1400. —	5
	Spezialtisch zur 12 stelligen „Millionär" Fr. 52. —.			4
8 × 8 = 16 stellige „Millionär"	mit Schiebereinstellung	Handbetrieb	Fr. 1300. —	7
	mit Tastatur		„ 1700. —	9
	mit Schiebereinstellung	und elektrischem Antrieb	„ 1962. —	11
	mit Tastatur		„ 2362. —	13
	Spezialtisch zur 16 stelligen „Millionär" Fr. 62. – (bei Maschinen mit elektrischem Antrieb im Preise inbegriffen, weil unentbehrlich).			10
8 × 8 = 16 stellige „Millionär"	mit Doppelzählwerk und Tastatur, Handbetrieb, einschliesslich grossem Pulttisch		Fr. 2525. —	23
	mit Doppelzählwerk, Tastatur und elektrischem Antrieb, einschliesslich grossem Pulttisch		„ 3125. —	25
10 × 10 = 20 stellige „Millionär"	mit Schiebereinstellung	Handbetrieb	Fr. 1650. —	15
	mit Tastatur		„ 2100. —	17
	mit Schiebereinstellung	und elektrischem Antrieb	„ 2322. —	19
	mit Tastatur		„ 2772. —	21
	Spezialtisch zur 20 stelligen „Millionär" Fr. 72.– (bei Maschinen mit elektrischem Antrieb im Preise inbegriffen, weil unentbehrlich)			16

Die 8 × 8 = 16 stellige „Millionär" mit Schiebereinstellung wird auch in Holzkasten geliefert, alle übrigen Rechenmaschinen nur in Metallkasten.

Verpackung Fr. 10. — bis Fr. 40. — je nach Grösse der Maschine (Zinkkiste für Seetransport).

1914

Figure 14. Millionaire variations and prices from a 1914 catalogue

As the Millionaires are quite large and heavy, the more so with extras, custom tables were made for Millionaires. And in tune with the customs of the period, the tables were made in different heights, for use by both sitting and standing operators.

The last item I will show is a page from a 1914 catalogue which gives an idea of the variations and pricing (Fig. 14).

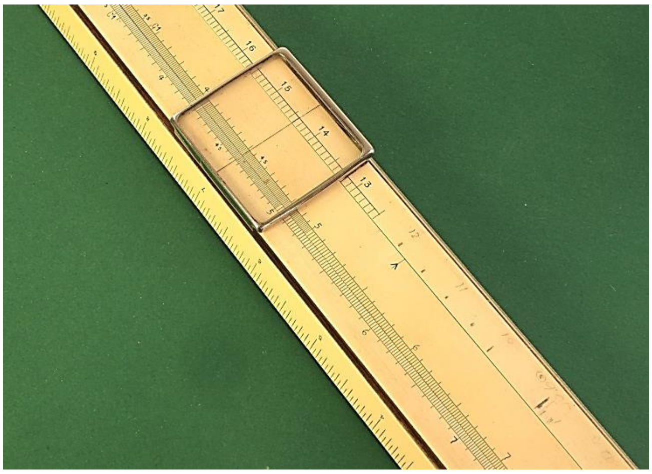
And that concludes my knowledge of the variations in Millionaires, as well as my story about them.

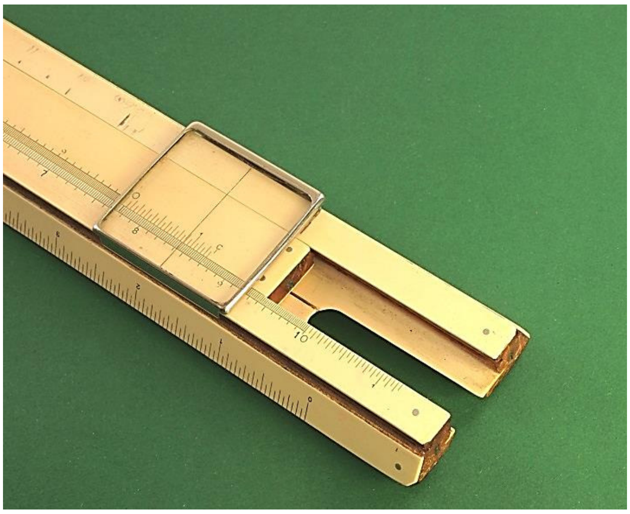
TWELVE SPECIMENS "ONE OF A KIND"
also known as "One-Off's"

Nr. 1: Mystery Desktop No. 1 (Thornton)

Owner: David Rance

Pictures[1]**:**





Purpose of the slide rule:

The purpose of this desktop 20 inch/50 cm model is a mystery. There seems to be no good reason for either the scale layout or for it being the size it is!

Dimensions:

- **Overall** (*LxWxD*): 56.8 cm x 4.7 cm x 1.4 cm.
- **Slide** (*L*)**:** 57.8 cm
- **Length of scales:** 23 cm (upper) and 50 cm (lower two without their scale extensions)

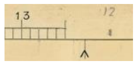
---

[1] Courtesy of the Otto van Poelje "photo lab".

Material:

- **Base & slide:** mahogany base with pinned celluloid facings and stamped scales coloured black & red
- **Cursor:** chrome and glass with a single black hairline
- **Case:** dark mottled green stiff cardboard box with horizontal/flat diamond box identification marks

Layout and scales:

- Closed frame with: cm \ ? / C / D \ Inch
- the top bevelled edge has a 50 cm length scale
- the mysterious "A" scale (centred) is an inverted (30 to 13.5) shifted logarithmic scale
  n.b.: it is difficult to see on the pictures but the right-hand end of the scale has been extended by hand in pencil down to 9.0
- in the place of a B scale is there a single upward pointing arrow presumably for lining up against the mystery inverted "A" scale
  

  n.b.: the upward pointing arrow lines up against +/- 5.48 on the C & D scales
- the C and D scales are standard 30 cm versions but the scale extensions are a bit unusual – the left-hand extension runs down to 0.89 whereas the right-hand extension runs out to 11.25
- handwritten in the well of the stock is: "R.8005"
- the back of the stock, at either end, is cut away in the manner normally used for cursor windows for reading off results from the back of the slide
- the bottom bevelled edge 20 inch length scale is "upside down"

Designer & Manufacturer:

Although unmarked the nature of the construction, the bevelled upside-down 20 inch scale and the horizontal/flat diamond box identification marks are convincing pointers that the design and manufacture can be attributed to UK maker **A.G. Thornton Ltd** before the company became British Thornton in 1967. This provenance is partially confirmed by the style of the cursor. Sadly there is no blind "year" stamp in the back but Thornton were using such chrome and glass cursors in the late 1950s/early 1960s. However, for a desktop model the cursor would normally have been "double-width".

Speculation:

So far the most fitting explanation is that it is an unfinished factory prototype – other Thornton prototype/experimental rules with pencilled markings are known to have existed[2]. Its desktop size maybe just coincidental – having no relationship to the design other than it was a readily to hand blank.

Outstanding questions:

The list is long:

- if it is an unfinished prototype, what type of use or function could be served by the mysterious inverted 30-13.5 (or even 9.0) scale?
- the upward pointing arrow more or less lines up on the C & D scales coincidently at the value for √30 but is this just a "red herring"?
- what, if any, is the significance/meaning of the handwritten reference "R.8005" in the well of the stock?
- is the cursor original?
- if it is a prototype, why incorporate such a small footprint design onto a large and "expensive" desktop blank?

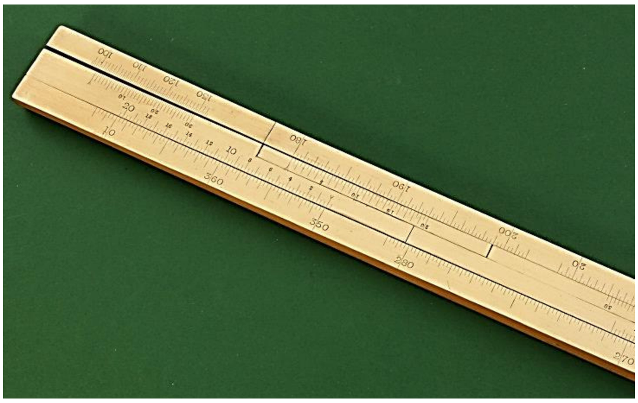
Can anyone help solve any part of the mystery?

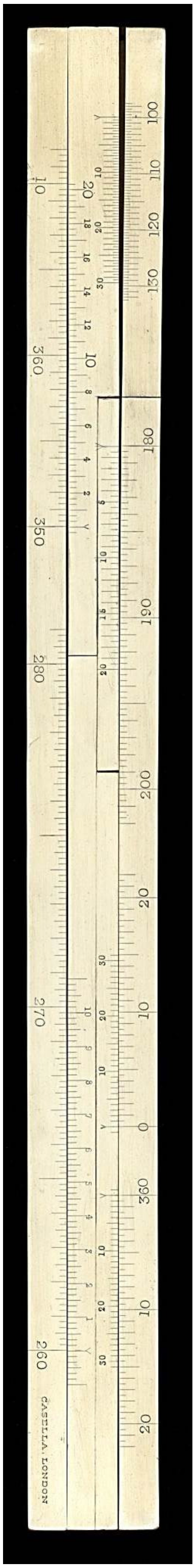
[2] Source: Thornton "expert" and collector friend Colin Barnes of the UKSRC.

Nr. 2: Mystery Desktop No. 2 (Casella)

Owner: David Rance

Pictures[3]:





Purpose of the slide rule:

The purpose of this desktop 20 inch/50 cm model is a mystery. Its desktop size accommodates various scales, many of which are expanded versions for extra accuracy. All the scales appear non-standard.

Dimensions:

- **Overall** (*LxWxD*): 44.4 cm x 3.9 cm x 1 cm.
- **Slide** (*L*): 44.4 cm
- **Length of scales:** various: longest 21 cm (upper) and shortest 5 cm (slide)

Material:

- **Base & slide:** boxwood or pearwood base with glued celluloid facings and stamped scales coloured black
- **Cursor:** none – not needed (also no channels for a cursor)
- **Case:** heavy-duty stitched reinforced brown leather pouch + flap with a leather strap & a metal buckle (unbranded apart from 1st owners name/address)

[3] Courtesy of the Otto van Poelje "photo lab".

Layout and scales:

- **Closed frame with: ?,?,?,?/ ?,?,?,?,?,?,? / ?,?,?,?**
    - o the upper part of the stock is removable (tongue-and-grooved with a horizontal celluloid strip underneath)
    - o the four scales on the upper stock (22 to 360, 0 to 22, 220 to 180 and 130 to 100) are upside down
    - o to run in the stock, the slide has a conventional tongue-and-groove construction BUT strangely the horizontal tongues are made of celluloid and rebated into the side edges of the slide
    - o the upper row of the scales on the slide (31 to 0, 0 to 31, 20 to 0 and 30 to 0) are upside down and all include a "V" gauge mark that maybe a line-up point
    - o the lower row of scales on the slide (21 to 0.3, 12 to -1) both have a "V" gauge mark that may be a line-up point
    - o the two scales on the upper stock (370 to 350, 282 to 260) are both inverted n.b.: the scale annotation for the value "370" is inexplicably stamped as "10"

Designer & Manufacturer:
It is branded *CASELLA, LONDON* in the bottom right-hand corner of the stock. But most Casella catalogues just list slide rules from well-known makers - suggesting they were chiefly a retailer. The unique nature of this construction cannot be attributed to a known maker. However, the way in which numbers like "2" are stamped, has a strong resemblance to known slide rules made by UK maker **W.H. Harling** (almost all are 20 inch models) before the company was acquired by slide rule maker Blundell in 1964. Also Casella was a known reseller of slide rules made by Harling. So if this provenance is correct, this suggests it dates from the 1930s.

Speculation:
Having one row of upside-down scales on the slide may be a design feature (as there is no cursor) so that when the slide is put in upside down, the second band of scales (now the right way up) can be directly set against the respective sets of scales on the front face of the stock. The extra tongue-and-grooving could indicate that the upper part of the stock and the slide are in some way "interchangeable".
The similarity between the various scales ranges and that many are inverted scales suggests that the slide rule was designed for a specific function, trade or purpose.

Outstanding questions:
The list is long:

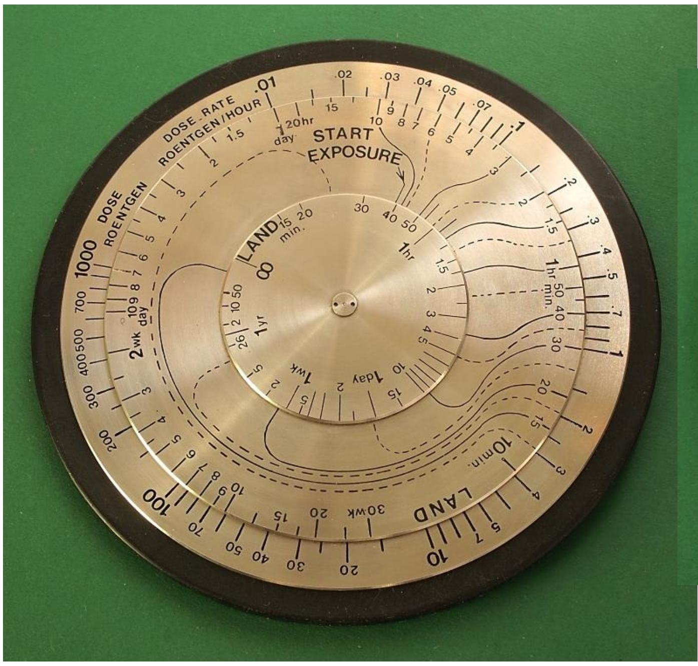
- are there any similarities with any other (desktop) slide rules?
- why tongue-and-groove the removable upper part of the stock?
- why have celluloid tongues on the slide?
- why stamp some rows of scales upside down?
- what, if any, is the significance/meaning of the "V" gauge marks?
- is the out of sequence "10" on the bottom most left-hand scale just been "miss stamped" or does "10" rather than "370" have significance?
- why leave off a cursor or could it just be a construction try-out or prototype for a variety of different potential design elements?

Can anyone help solve any part of the mystery?

Nr. 3: Tribute show prototypes (van Beek, TUD Delft)

Owner: David Rance

Pictures[4]**:**



Purpose of the slide rules:

These calculators, professionally made to the highest standards, were “specially commissioned” by a Dutch engineer, *Dr. Ir. Ing. J.W. van Beek,* in the 1970s. He had them made so that they could become lasting tributes to the much-loved originals he had personally used.

Dimensions:

- Bases: Ø 5½ inch (black) and Ø 4¼ inch (white)
- Rules: Ø 5 inch (left) and Ø 3¾ inch (right)
- Cursors: none – not needed

Material:

- Bases: solid coloured PVC mounting disc
- Rules: stainless steel discs photographically etched in black
- Finishing: bottom of bases covered with non-slip green baize
  etched stainless steel finely polished

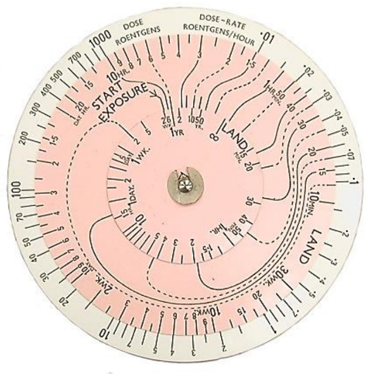
Layout and scales:

- Radiation Dosage Calculator for Contamination Over Land (black base):
  - Single non-standard scale on each of the three discs (only the intermediate and inner discs rotate)
  - Fixed outer (0.01 - 1000) scale for the exposure rate in roentgens/hour
  - Rotating intermediate (10 minutes - 30 weeks) scale is for reading off past or future dosage rates (in roentgens/hour) at the time of monitoring
  - Rotating inner (0 minutes – 50 years) scale for setting the start of the exposure time for a given monitoring reading and consequently reading off the total dosage of radiation exposure (in roentgens/hour)

[4] Courtesy of the Otto van Poelje “photo lab”.

- Dark-Room Exposure Time Calculator (white base):
    - Single non-standard scale on each disc (only the inner disc rotates)
    - Fixed outer (12.5 - 58.5) scale for the diagonal length in cm of photographic paper
    - Rotating inner (3 - 150) scale for the exposure time in seconds

Designer of the Radiation Dosage Calculator for Contamination Over Land:
The original design for the calculator was by American William Orr in 1951. Given its subject matter many makers were commissioned by national governments to make it under licence. For example, the stainless steel tribute version is identical (size, use of fonts, scales and scale annotations, etc) with the plastic Blundell Rules Ltd (BRL) *Radiac[5] Calculator No 1* made in the UK in the late 1950s. However, unlike the BRL version, the stainless steel intermediate and inner discs are not also reversible for calculating radiation exposure from nuclear fission products detonated over sea.



Designer of the Dark-Room Exposure Time Calculator:
The design cannot be attributed to an individual. The original version was "home-grown" from dark room developing notes and experiences. Usually working out the optimum exposure time for each different enlargement size from the same negative was largely done by "trial-and-error". This was irksome and potentially costly. The calculator was a breakthrough. Now, once a successful print was made (e.g. a contact print) and the noted exposure time lined up with the size of photographic paper used, the calculator showed the optimum exposure times for that negative for other (larger or smaller) photographic paper sizes.

Manufacturer:
The *Technical University of Delft* (TUD), The Netherlands has a world-wide academic reputation. In the 1970s the TUD had, as part of the Mechanical Engineering faculty, a central workshop specialising in making prototypes for various research or academic needs. The rich spectrum of skills available from the workshop included instrument makers allied to the Precision Engineering section. However, all the skilled professionals working in the workshop were university employees rather than students. At this time Van Beek was an associate of the TUD. As a favour to him the two prototypes were made in-house. Production of the stainless steel discs and the main construction work was done by central workshop instrument makers. On both calculators the stainless steel discs rotate almost frictionless or as if they were: "floating on air". The high-quality photographic etching work was undertaken by an instrument maker specialising in this technique: *Frans van Rongen*.

Remarks:
The Radiation Dosage Calculator prototype is a tribute to Van Beek's work as an NBC[6] officer in the Dutch army during military service. The second Exposure Time prototype is a tribute to the time when Van Beek was a keen certified portrait photographer.
In November 2011, after hearing about my collection, Van Beek decided the best way his tribute show prototypes could continue to be appreciated was if they became part of my collection. I am now the lucky "custodian" of these two magnificent and unique calculators.

[5] Term RADIAC is derived from: Radio-Activity Detection, Identification and Computation.

[6] Abbreviation NBC stood for: Nuclear, Biological and Chemical warfare.

Nr. 4: Dennert & Pape Nr. 7 Metallic Slide Rule Disk

Owner: Delft Technical University
Contact: Ch.J.A. Hakkaart

In the Depot of the Delft Technical University many special instruments as well as slide rules and calculating machines are stored. This is one of them which is up till now not yet catalogued and traceable.
Probably you can assist to identify this Sliderule or supply information.
This object will probably be displayed during the IM.

Pictures:

Purpose of the Slide Rule:

This is without doubt a Dennert & Pape Slide rule from before the Aristo period. The Aristo book does not present information about this slide rule. The only information found up till now is that brass straight slide rules were made between 1879 and 1882. No information about circular brass slide rules is available. D&P started in 1862 as an geodetic instrument company. Till 1910 no code numbers were used, but only catalogue numbers which changed often.

The number 7 could be an add-on to a geodetic device. There is indeed a collection of geodetic instruments in the depot. The number 7 could also indicate 1907.

It is not documented in the ARISTO book.

Dimensions:

- **Base disk:** diameter 270 mm .
- **Inner disk:** diameter 250 mm
- **Indicator Arm:** length 270 mm

Material:

- **Base disk:** brass plate. The inscriptions are very difficult to read due to deterioration of the brass.
- **Inner disk:** brass plate which turns in the base plate. The inscriptions are very difficult to read due to deterioration of the brass. There are 3 lines with data.
- **Indicator arm**: metal with black coating. A loupe can be mounted at the end of the arm to read the scale on the outer disk. At 3 positions along the arm are pointers that can be turned downwards, to each of the circular scales at the inner disk.

Layout and scales:

	Opposite	Range Values on Scales	Remark
Base outer ring (fixed)			
Scale 1		from 10 to 95	logarithmic scale 10 to 100, comparable to a regular D-scale
Inner disk (rotating)			
Scale 2	scale 1	from 10 to 95	logarithmic scale 10 to 100, comparable to a regular C-scale
Scale 3		from appr 5.5 to 90	gives sine times 10^{-2} on Scale 2
Scale 4	scale 3	from 84 to 10	gives cosine times 10^{-2} on Scale 2
Scale 5		from appr 0.33 to appr 5.45	gives sine times 10^{-3} on Scale 2
Scale 6	scale 5	from appr 89.28 to 84.18 in steps op 60 units	gives cosine times 10^{-3} on Scale 2
Scale 7		from 03 to appr 034	gives sine times 10^{-4} on Scale 2
Scale 8	scale 7	from 56 to 30	gives cosine times 10^{-4} on Scale 2

- Near the centre the engraved text: "**DENNERT & PAPE | HAMBURG ALTONA | 7**"

Interpretation:
The two outer scales are actual D- and C-scales for multiplication and division, as usual.
The remaining six inner scales show angles (in degrees and seconds), to which sine and cosine values correspond on the C-scale.
Each scale pair (3-4, 5-6, 7-8) gives a range of sine (or complementary cosine) values on the C-scale:
scale 3 & 4: starts at arcsin(0.1) = 5.73917° = 5°44'21'' (comparable to a regular S-scale)
scale 5 & 6: starts at arcsin(0.01) = 0.572967° = 0°34'22' (comparable to a regular ST-scale)
scale 7 & 8: starts at arcsin(0.001) = 0.057296° = 0°3'26''
A regular slide rule has an S-scale for sine and cosine values from 0.1 to 1.0, while some rules have an additional small angle range ST-scale for sin/cos values from 0.01 to 0,1. This disc has an extreme small angle range on scales 7 and 8 to use angles from a few arcseconds, with sine or cosine values from 0.001 to 0.01. The question is: why these very small angles?

The origin of this DuPa 7disc is the geodetic faculty of the Technical University Delft. This leads to the assumption that the disc may have been used by surveyors. One of the tasks of a surveyor consisted of converting theodolite measurements into rectangular map coordinates. Distance to, and angles between terrain marks such as church towers would be used to calculate coordinates by sine/cosine functions in a rectangular triangle. Some of those measurements could involve small angles.

Designer: Dennert & Pape ?

Manufacturer: Dennert & Pape.

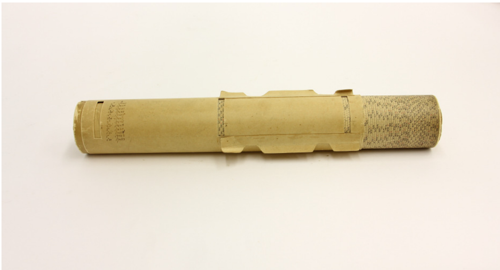
Acknowledgments:
Thanks to *Karl Kleine* and *John Vossepoel* for their analysis and interpretation of the scales.

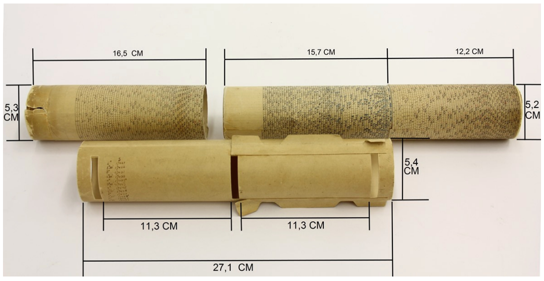
Nr. 5: Cylindrical Cardbox Slide Rule

Owner: Delft Technical University
Contact: Ch.J.A. Hakkaart

In the Depot of the Delft Technical University many special instruments as well as slide rules and calculating machines are stored. This is one of them which is up till now not yet catalogued and traceable. Probably you can assist to identify this slide rule or supply information.
This object will probably be displayed during the IM.

Pictures:





Purpose of the Slide rule:
On the cover a handwritten description says it is a slide rule. Unknown is, if this is written by the designer or later on by somebody.
It looks like a Fuller type slide rule, but is not equal.
The working of it is still unknown.

Dimensions:

- **Outer tube:** diameter 54 mm * length 271 mm
- **Inner bottom tube:** diameter 51 mm * length 157 & 122 mm
- **Inner top tube:** diameter 53 mm * length 165 mm

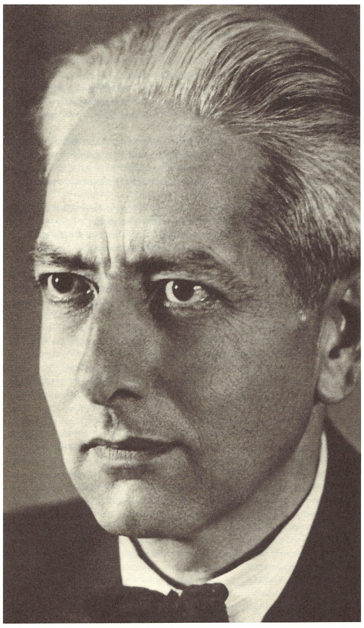
Material:

- **Outer tube:** cardboard self made with two cardboard strips glued. It has 3 windows of about one third of the circumference at top, middle and bottom of the tube with the marks A, B and C.
- **Inner bottom tube:** cardboard self made**.** This part has 2 slightly different diameters and is provided with 2 sets of logarithmic scales like a Fuller. It slides in the outer tube and the upper half slides in the inner top tube. The distance is fixed to each other and are visible in the middle and lower windows. Both scales cannot be changed in position to each other.
- **Inner top tube:** cardboard self made. It slides in the outer tube and over the upper half of the inner lower tube. It has one logarithmic scale like a Fuller

Layout and scales:

- **Outer tube:** none
- **Inner bottom tube:**
    - 2 sets of logarithmic scales like a Fuller
- **Inner top tube:**
    - 1 set of logarithmic scales like a Fuller

Designer:



J.M. Tienstra (1895-1951)
hoogleraar landmeten, waterpassen en geodesie van 1935 tot 1951,
rector magnificus in 1946/1947

Professor Jacob Menno Tienstra (7 april 1895 Sneek - 15 sept 1951 Delft)
He became professor in 1935 at the Technische Hogeschool te Delft. In the book Delft Goud (The Life and Work of 18 outstanding professors) ISBN 90 75961 200 NUR 950, all his surveyor and geodetic activities as well as the mathematical development of more accurate calculation methods for position finding is described.
This slide rule was developed during WWII.
Another slide chart for the calculation of the Easter Date of this designer was presented during the IM 2007. See the IM2007 Proceedings.

Manufacturer:
Jacob Menno Tienstra.

Remarks:
No manual available
This typical tube slide rule needs more investigation.

Nr. 6: Mechanical Engineer Pocket-watch slide rule

Owner: Peter Hopp

Pictures:



Purpose of the Slide rule:
This delightful pocket-watch slide rule is a one-off due to its extremely idiosyncratic mechanism, and the resulting questions that raises. As with most pocket-watch slide rules it would have been used for general calculations.

Dimensions:

- **Case Diameter :** 57 mm.
- **Scale Diameter:** 45 mm

Designer:
It is not known and not obvious even though it carries a standard set of “The Mechanical Engineer” scales as found on their more usual models from c1898 to 1910.

Manufacturer:
Possibly Scientific Publishing (the fore-runner of Fowler) but again it is not proven.

Remarks:

There is no manual available. The more usual examples of Mechanical Engineer slide rules come in a closed pocket-watch case with a crown and a side winder, in either of 3 sizes or 4 styles with some minor variations also known.

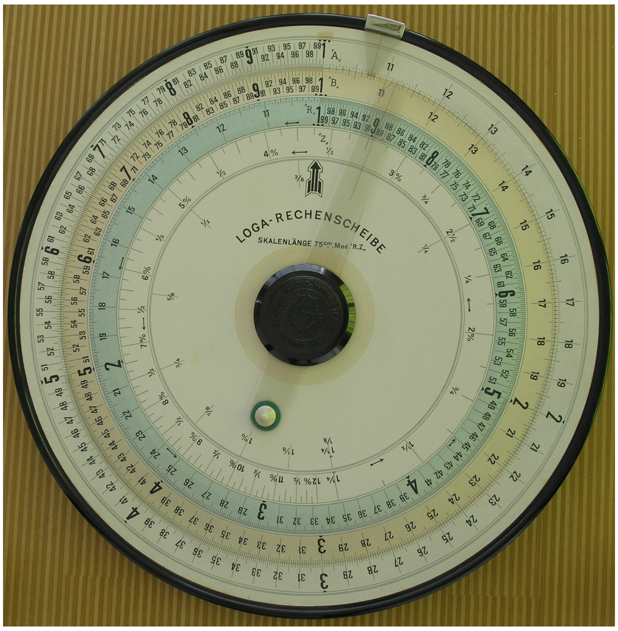
This example is totally different. While still being in a pocket-watch case, this has both an opening back and an opening front and a very unusual gear train to replace the crown. The question is whether this is a "scratch-built" device, a prototype or some other explanation.

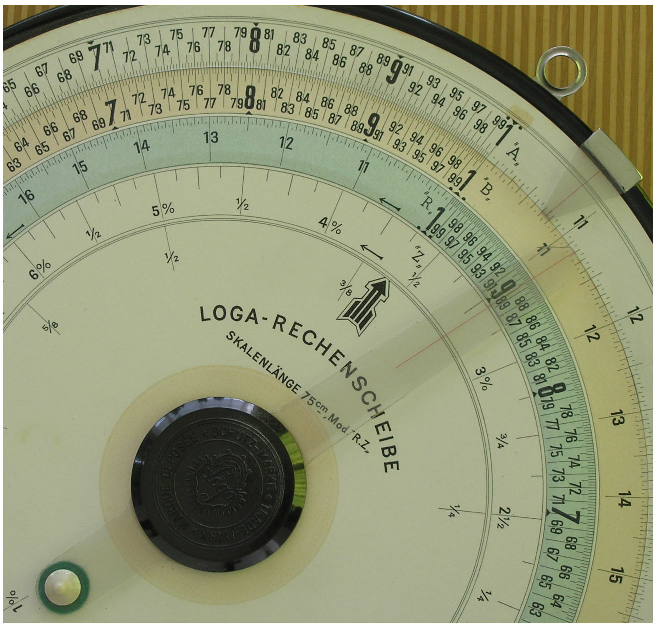
Can we draw any obvious conclusions t about this device? No. There are "marking" lines and punched dimples on the inside of the back, and the finishing is obviously "hand made", so it may be a prototype. Or indeed, it may be a "one-off" made by someone who was a very capable mechanic. Or it may be a very short lived ME model from Scientific Publishing. The balance of probabilities is that Scientific Publishing had a hand in its manufacture, as the face/scales is the same size and uses a "proper" Mechanical Engineer scale as on other Scientific Publishing MEs. The workmanship? Just possibly a prototype, more probably a one-off device! How did it get "out of captivity"? We will probably never know. Which makes it such a lovely mystery one-off device.

Nr. 7: LOGA Circular Calculating disc, Type "Modell 75 R-Z", especially for Interest Calculations

Owner: Nico Smallenburg

Pictures: LOGA calculation disc type "Modell 75 R-Z" and detail of the two cursors.





Dimensions:
Base: Circular plate, diameter 300 mm.
Scale length: 750 mm
Middle cursor: 180 mm, red hairline.
Rand cursor: 30 mm, red hairline.

Material:
Base: Brown bakelite base plate.
Slide: An inner revolving circular disc.
Rim cursor: celluloid with red hair line,
bent around the edge of the disc.
Middle cursor: celluloid,red hair line
turning round a bakelite centre plate.
Finishing: Paper/metal sandwich on bakelite base plate.
Layout and scales:
A-scale, B-scale, R scale and a special Z – scale (interest calculations).

Remarks:
In the centre bakelite plate is engraved the LOGA Trade Mark.
On the back side is a flippable metal ring to hang the disc on the wall.
On the back side is a bakelite knob to turn the inner disc and a free turnable ring from bakelite to turn the whole disc.

Designer: Daemen-Schmid **Manufacturer**: LOGA Calculator A-G, Uster, Switzerland.

Nr. 8: Astacalcolo, the "new way to compute" that never was

Owner: Nicola Marras - www.nicolamarras.it/calcolatoria

Picture:

The original Astacalcolo, with this layout does not work!

History:

in the 50 's the eclectic Italian engineer Aldo Nanni invented this peculiar calculator, calling it *"Astacalcolo, regolo calcolatore semplificato". Astacalcolo* means *"calculating ruler"* and in Italian the expression *"regolo calcolatore semplificato"* (en. *simplified slide rule*) can be applied both for a traditional slide rule than for a simple ruler like this.

The idea was to market a cheap and popular instrument without slide and cursor, but the *Astacalcolo*, not easy to use, was never patented and never went into production. Only a few prototypes were built and, as far as I know, this is the only survived. Was planned as the first of a small collection of calculating instruments, called *"Strumentario"*, that was never produced either.

Purpose:

general computing, other models for specialist calculations were planned but never built. Its peculiarity is to operate with a mix of logarithmic and metric measurements.

Dimensions: 170 mm; 25 mm; 1 mm.

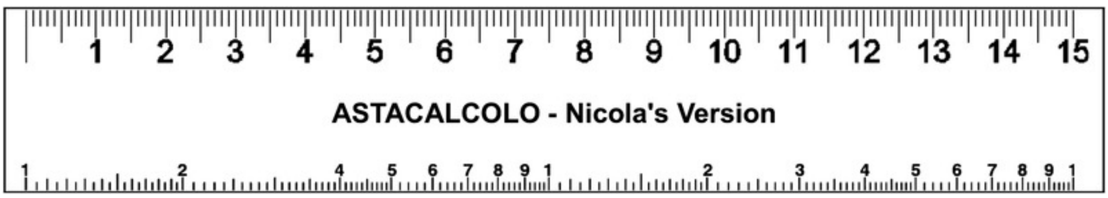
Material: transparent acrylic, it was also planned a metallic model.

Layout and scales:

Base above: metric scale of 15 centimetres;
Base below: double log scale;
In the middle: three sets of numbers, used to determine the numbers of digits to give to the results of the operations.

Remarks:

I think my ruler is one of the first prototypes: the scales are badly designed and does not works! I made some corrections and below you can see it as described in its instructions booklet. A printable template and its instructions (only in Italian) can be downloaded from my website, www.nicolamarras.it/oneoff.



The Astacalcolo corrected

Designer:

Ing. Aldo Nanni, born in Bologna, professor of Applied Mechanics at the Ferdinando II University (Naples) in the 50's. I have not found any other information.

Manufacturer:

Aennotecnica. Was not possible found any information about this brand, that was never officially registered in Italy.

Remarks:

the instruction booklet was printed by Raffaele Pironti in Naples, but it is not a final version as it is full of errors and widely corrected with a red pen.

Use:

in spite of its name, calculate with *Astacalcolo* is difficult. I think the inventor's idea was to eliminate the estimating problems that people have with a slide rule through an even more difficult process. The *Astacalcolo* has to be used with a sheet of paper and a pencil, these are the steps needed to multiply two numbers:

1. trace a line on the paper, marking a point in correspondence of the index (the left 1) of the log scale;
2. identify the two factors on the log scale and mark their position on the line;
3. turn the ruler upside down and measure the two distances on the metric scale;
4. sum the two distances an divide the result for 75;
5. turn upside down and mark the remainder of the division on the line, using the log scale;
6. turn upside down and measure the result on the metric scale.

We get the result, but not finish yet, now we have to determinate the quantity of the digits:

1. count the total digits of the factors and subtract one;
2. sum the quotient of the division for 75 and you get it.

There is also a so called *rapid system* to do it using the numbers that are in the middle of the ruler, but it seem to be more complicated.

An example, from the amazing booklet that declare "*the instructions are written in a simple way in order to be understood by all, you will learn to use Astacalcolo in a few minutes*":

moltiplicando	132	**multiplicand, to be marked on the log scale**
moltiplicatore	0,67	**multiplier, to be marked on the log scale**
misura del moltiplicando	9	**metric measure of the multiplicand**
misura del moltiplicatore	62	**metric measure of the multiplier**
somma delle misure	71	**sum of the measures**
somma delle misure divise per 75	71 : 75	**sum of the measures divided for 75**
quoziente q	0	**quotient (q)**
resto	71	**remainder, to be marked on the metric scale**
lettura del resto	88	**reading of the remainder on the log scale**
somma delle cifre — 1	4	**sum of the digits of the factors -1**
somma delle cifre — 1 + quoziente q	4 + 0 = 4	**sum of the digits of the factors -1+ q**
cifre del prodotto senza decimali	4	**digits of the result without decimals**
prodotto dopo separazione dei decimali	88,00	**correct result**

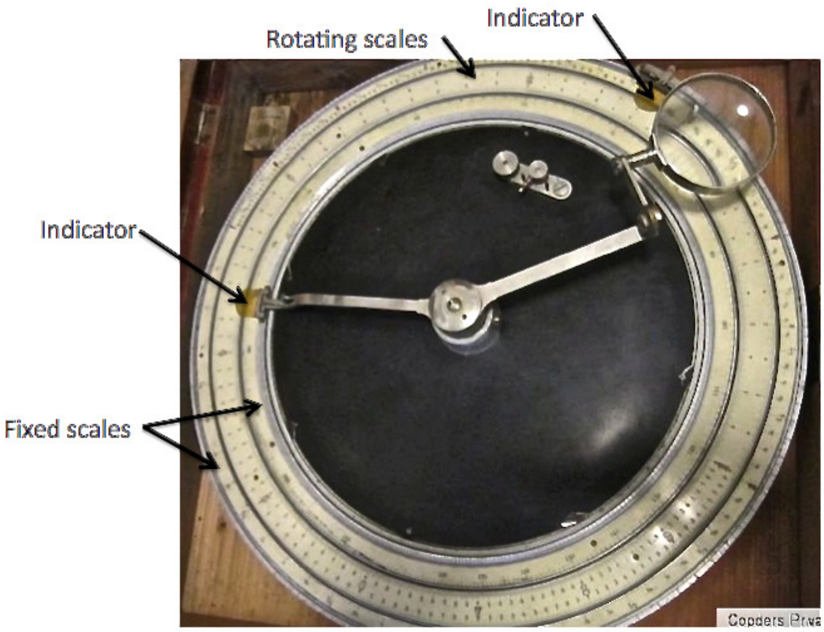
Conclusions:

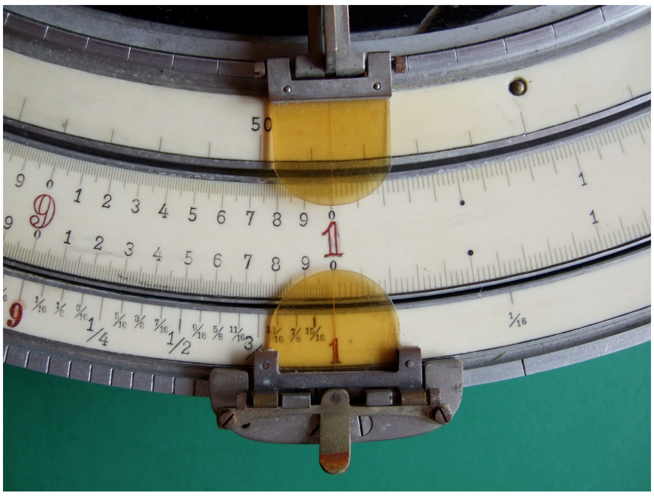
during the 50's in Italy only the happy few could use a slide rule, regarded as too difficult from the public. Ing. Nanni tried to make an easier instrument, but his *Astacalcolo* was unnecessarily complicated to come into production. There was no real need of it: the popular calculators in my country were the nomograms, easier to use. In the magazines of that years was possible found a lot of them, for any imaginable purpose.

Nr. 9: Gebruder Fromme Circular Slide Rule

Owner: Ed Chamberlain

Pictures:





Purpose of the Slide rule:

The purpose of this Item may be for banking and commerce calculations. The fractional units on one scale and days in a year units on another indicate that this slide rule was used to calculate interest. Thus, it may have been a merchant or banker's slide rule.

Dimensions:

- **Out-side diameter:** 450 mm
- **Outside scale dia:** 412 mm
- **Circular slide scales:** 412 mm outside dia. x 362 mm inside dia.
- **Inside scale dia:** 362 mm
- **Indicators:** one @ 412 mm dia. & one @ 362 mm dia. (see bottom photo)

Material:

- **Base:** Heavy cast iron base supported by a wooden disk, with 3 separate concentric (and flush) metal rings with Celluloid scale surfaces.
- **Scales:** The inside and outside scale rings each have one calculating scale and are fixed to the base. The middle circular sliding-ring has two calculating scales, one on each edge. It freely rotates between the inside and outside scale rings
- **Circular Slide:** Metal with a Celluloid scale surface. This metal ring is finely machined, and freely rotates between the inside and outside scale rings.
- **Indicators**: Two small Celluloid indicators are mounted across the margins between the middle sliding ring and the inside and outside scale rings. One indicator is used for the inside scale pair and the other for the outside scale pair. Each can be moved independently of the other to set a multiplier or a divider for the middle sliding scale pair, or for operations between the inner and outer scale on the fixed rings and the sliding ring scales.
- **Finishing**: The scale surfaces are made of celluloid. The scales are machine engraved.

Layout and scales:

- **Inside fixed scale ring:**
  - Single log cycle line labeled 40; 50; 60; 70; 80; 90; 100; 110; 120; 130; 140; 150; 160; 170; 180; 210; 240; 270; 300; 330; 330; & 360. With gradation marks for all whole numbers running from 1 to 365. There are no scale divisions for fractional parts. This scale appears to be for the number of days in a year. Scale runs clockwise.
- **Middle sliding-ring:**
  - Top and bottom edges of sliding ring have identical single log cycle lines running from 1 to 10. Scales are finely divided to read directly 1002 at lower end and 999 at upper end. Both scales run clockwise. With interpolation, scale reads 1001 at lower end of scale and to 9995 at upper end.
- **Outside fixed scale ring:**
  - Fractional single log cycle line running from 1 to 10. Each unit divided and labelled in 1/16ths. No sub-division between 1/16th fractional units. Gauge Factor [**Z**] between 3 9/16 and 3 5/8. Scale runs counter clockwise. Scale appears to be for interest calculations.

Designer:
No information

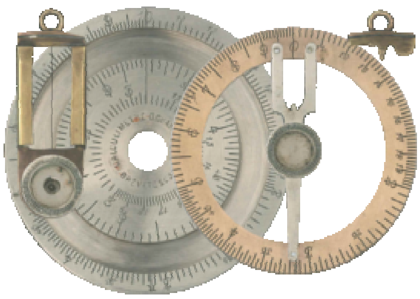
Manufacturer:
Austrian; Gebruder Fromme, Wien

Remarks:
With glass & metal magnifier. No manual available; dates to c.1920; weight = 6 kg; with heavy wooden case and maker's label. Device is not labelled. The middle sliding-ring scales can be used for conventional multiplication and division operations. . . . Purpose of this slide rule determined by Otto van Poelje.

Nr. 10: Virtualization of Disk-Shaped Devices, e.g. the Calculimètre by Charpentier

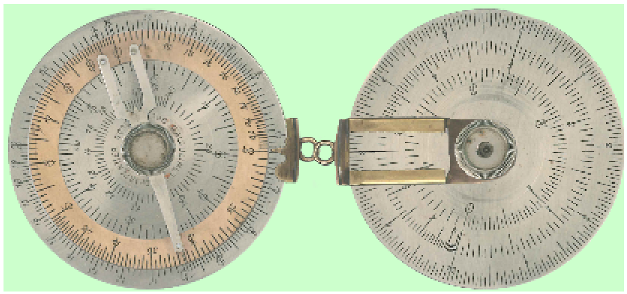
Owner: Wolfgang J. Irler

Pictures:



Calculimètre - parts

KE catalog 1895



*Calculimètre - virtualization on: 2 * π = 6.28*

Purpose:
Proud collectors of slide-rules and slide-disks present their treasures with possibly perfect photos, eventually printed in physical books or albums, recently present also in browsable web-sites. The double goal of showing the existence and especially the ownership of these rare instruments, however, is often only exciting a small community of like-minded specialists. The real objects are often unreachably buried in private or public glass vitrines and as such dead and abstract. Bringing to a virtual life these once essential engineering devices requires, however, only some computer know-how for the picture-filtering and programing skills to do the animation or mouse-dragging.

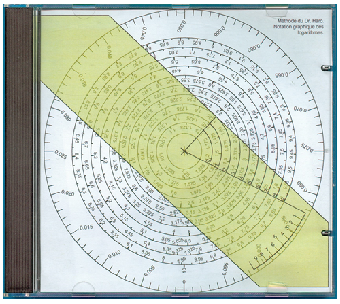
I tried this at first with my specimen of a Charpentier. As one can immediately see on the computer screen, the result collocates in-between virtualization and simulation: by dragging and rotating the disks and cursors, the user virtually operates the devices, but has to adjust and read-off the numerical results like in the physical object.
In order to achieve a high resolution of the necessarily separated disk pictures, I had to deconstruct the objects. In the case of the Calculimètre, this is really easy, since all parts are screwed together. Rather than photographing them, the parts are scanned in a flat-bed scanner and then elaborated. As a by-product, you can zoom the high-resolution images and read the result much more easily and precisely than from the real device. If convenient, the sliding of the cursor is shown from both sides simultaneously, as if seen in a mirror.

Two relatively unknown Chinese slide-disks I had already for some time in my collection, apart from their rarity, were challenging because of their Chinese inscriptions. These have also been virtualized, likewise a big cardboard Tröger-disk.

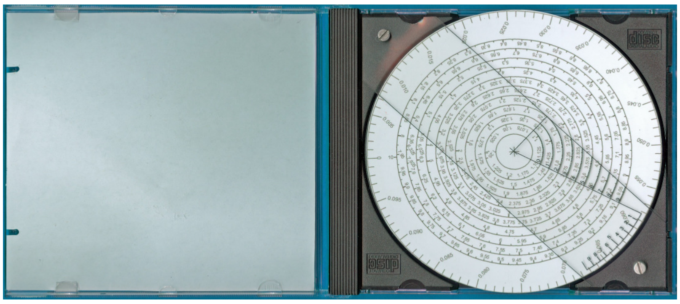
Nr. 11: Dr Haro's *new* method of graphical notation of logarithms

Owner: David Rance

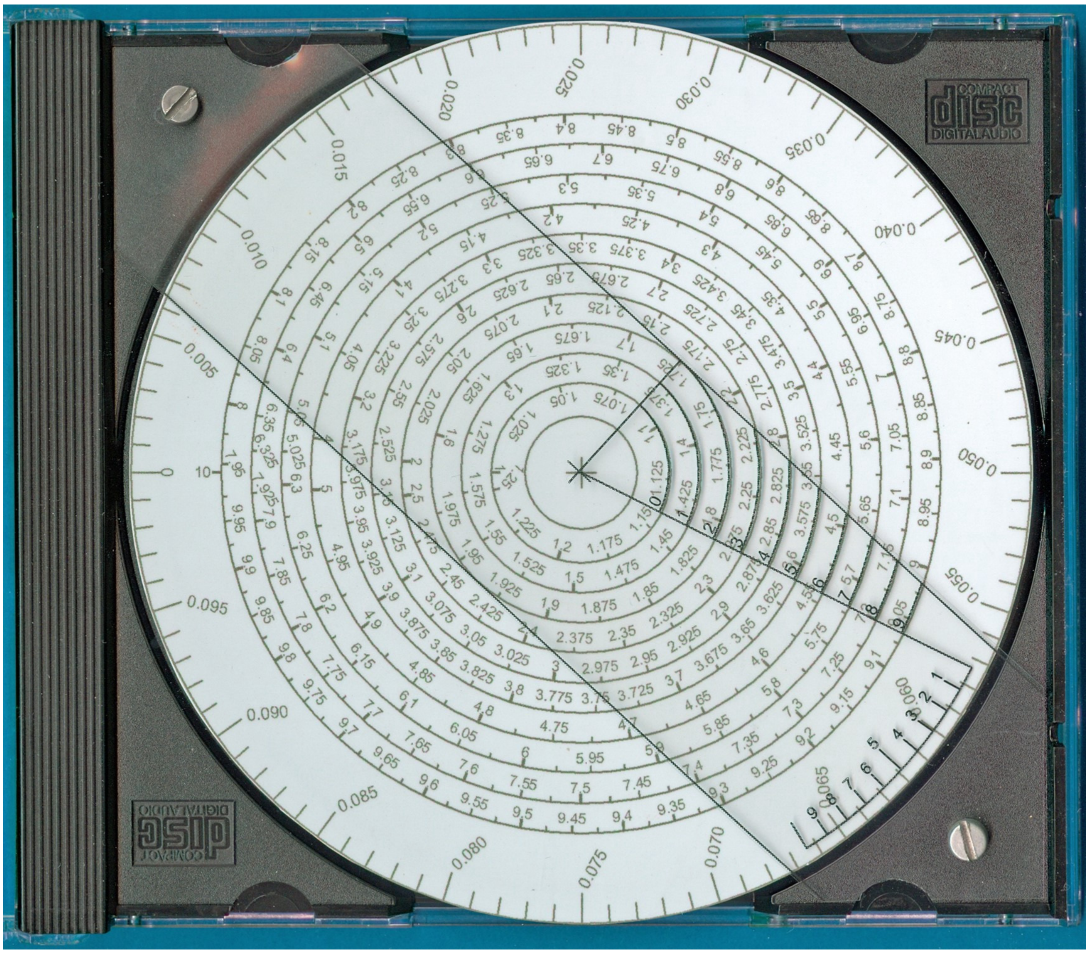
Pictures:



Front face of the CD-case



Case open



Dr Haro's portable analog table of logarithms (scale about 1:1)

Purpose:
The purpose of this instrument is to find the logarithms of numbers comprised between 0 and 10.

Dimensions:

- **Case:** CD case 142mm x 125mm x 10mm.
- **Disc:** CD ø 120mm x 1.5mm
- **Indicator:** 170mm x 40mm x 0.2mm

Material:

- **Case:** classic CD case made of plastic.
- **Disc:** probably polycarbonate.
- **Indicator**: probably acetate (transparency film).
- **Finishing**: colourfast adhesive vinyl printed on an inkjet printer.

Layout and scales:

- **Concentric circles:** ten concentric circles bearing the digits 0 to 9, beginning from the centre, are used to determine the first decimal of the logarithm.
- **Limb:** the limb is divided in 100 equal parts and allows to read the second and the third decimal of the logarithm.
- **Indicator:** the indicator comprises a vernier allowing to read the fourth decimal of the logarithm.
- **Graduation marks:**
  The numbers from 1 to 10 are inscribed on the ten circles by steps of 0.025.
  To mark the graduations on the circle one needs to know the logarithm of the number which is taken into consideration.
  Let's say one wants to determine the position of the graduation corresponding to the number 2.3 which has a logarithm equal to 0.3617.
  - The disc is rotated until the alidad is set past the graduation 0.061 of the limb (61 being the second and third decimals of the logarithm).
  - The disc is then rotated and fine-tuned —using the vernier— to set the alidad to the fourth decimal of the logarithm (in this case the digit 7 of the vernier).
  - The graduation corresponding to the logarithm of 2.3 is then registered at the intersection of the alidad with the third circle (3 being the first decimal of the logarithm).

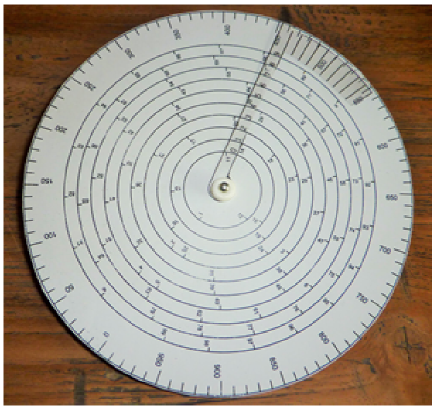
  The above method was the one used by the inventor, back in the 19th century. The models pictured in the present document were made using AutoCAD®.

Designer:

This instrument was invented by a certain Dr Haro, a medical officer in the French army. He presented his invention to the *Association Française pour l'Avancement des Sciences* in a conference [7] held in Toulouse the 24th of September 1887.

Manufacturer:

Probably never produced commercially at the time it was invented.
The CD case model (photographs at the top of the present document) and the reconstruction mock-up of the original (see photograph on the right), made by Panagiotis Venetsianos.



Remark:

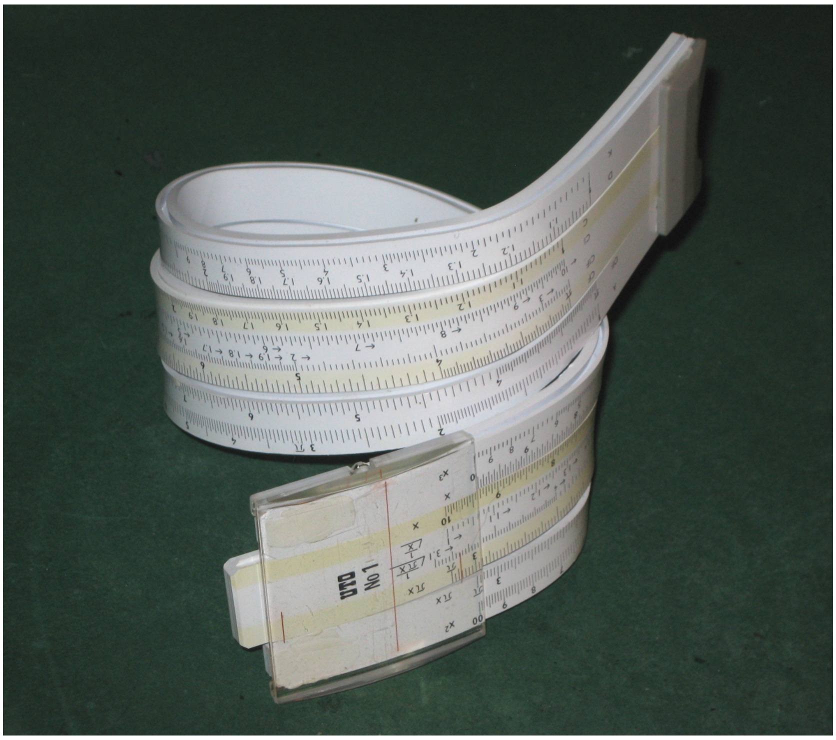
The model described by Dr Haro looked probably more like the prototype shown on the picture on the right, with a rotating indicator.

[7] http://gallica.bnf.fr/ark:/12148/bpt6k201167p/f131.image.r, p. 128 : Nouvelle méthode de notation graphique des logarithmes.

Nr. 12: SLIDING and TURNING of the slide rule *UTO Nr. 1*

Owner: Gerard van Gelswijck, Otto van Poelje

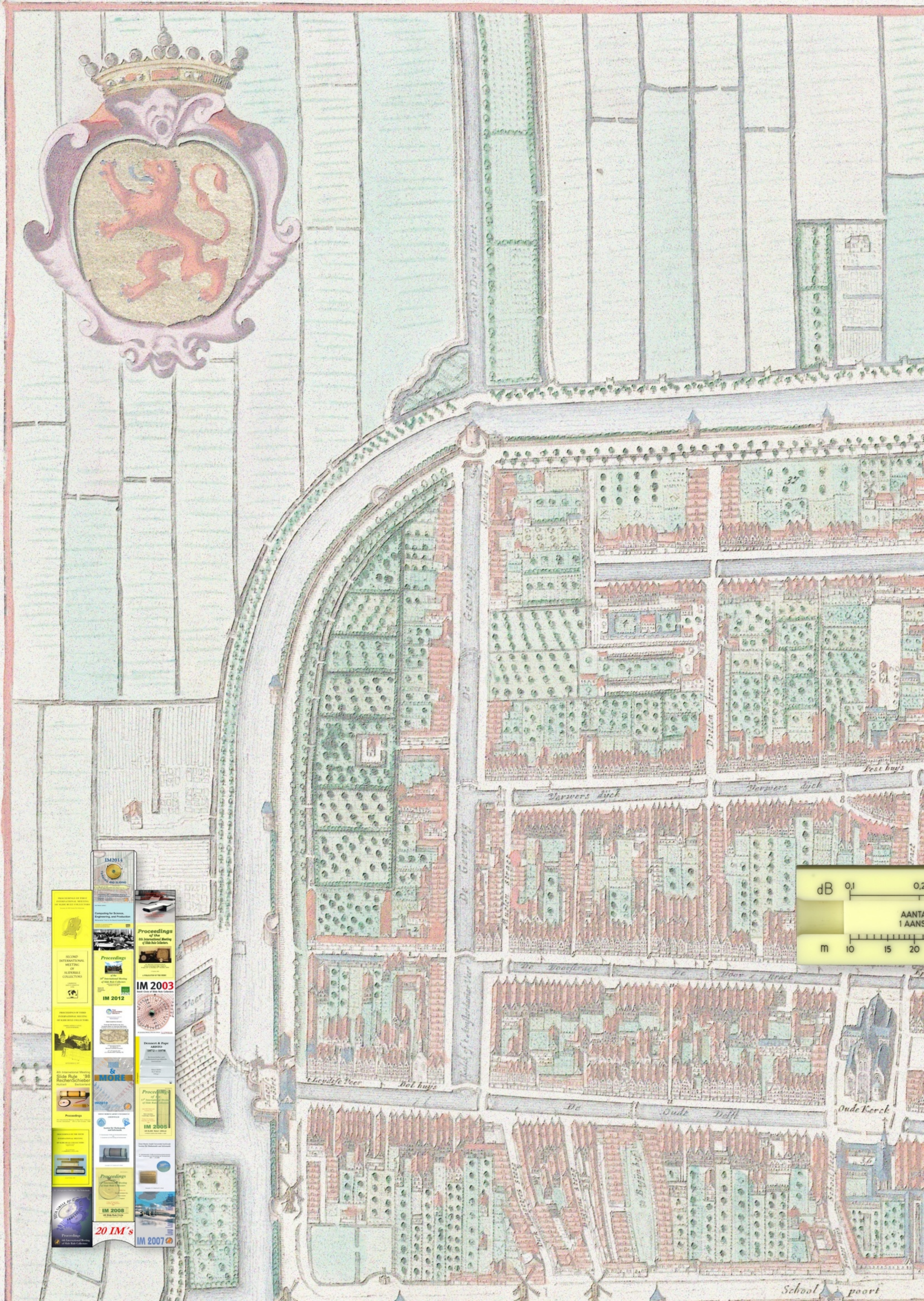
Pictures:



Purpose:
The theme of the IM2014 conference is: ***Turning and Sliding***. IM2014 participants will have noticed that most slide rules and mechanical devices presented in the conference fit nicely in this theme, except perhaps the “unmovable” logarithmic tables.
As a more playful diversion, Gerard and Otto have made efforts in “turning” the well-known slide rule *UTO no. 1* into a circular form. The result shown above is actually more of a helix. Regrettably, the “sliding” function of the *UTO no. 1* has been lost in the attempt, but the visual impression is quite artistic - although perhaps alarming for the real slide rule aficionado.

Dimensions:
The 33 cm length of the original *UTO No 1* slide rule has been turned into an external diameter of 7 cm and a height of 8 cm.

Manufactured:
The PVC body of the *UTO No 1* becomes mouldable above 80° C. There are different ways of reaching that state. One can wait for a hot summer day, but in Holland that would take too long. Blow torches often cause scorched patches. A microwave oven is large enough for the UTO (if there is no rotator plate), but that approach was forbidden by the master of the kitchen.
Eventually we acquired a oversized turkey roaster, and boiled the *UTO No 1* in water until it became soft enough for our “turning” exercise.



Verwers dyck
Verwers dyck
Pest huys
Doelen straet
De Geerweg
Oude Kerck
Oude Delft
Wel huys
School poort
IM 2003
IM 2012
IM 2008
IM 2007
20 IM´s
dB
m

http://imagenesfotos.com/fotos-del-monte-fuji/

Fuji Illustrated Catalogue

including branded slide rules

2014-05-18
by J.G. Fernández

1.- FOREWORD

The purpose of this document has been to catalogue as many Fuji slide rules as possible, including as many significant images as could be found, for the sake of a complete description. In this sense, then, some of the pictures have been included although they are clearly deficient.

Of course, it is not the fault of the picture owners, but mine as I had little time to ask for better ones. Not to mention, if someone is able to get them or data of other Fuji models, I will gladly update this document, or even if any errors are found.

There are at least two bamboo Fuji slide rules that look as having been manufactured by Hemmi. But these are included as they have the Fuji logo.

Regarding slide rules from other brands, ("branded" Fujis) these have been compared to found Fuji specimens and have been included in the list whenever the similarities have been significant. There are, however, some doubtful specimens that have been included (indicating such doubt in "comments") in order to ensure completeness of the list.

2.- HISTORY

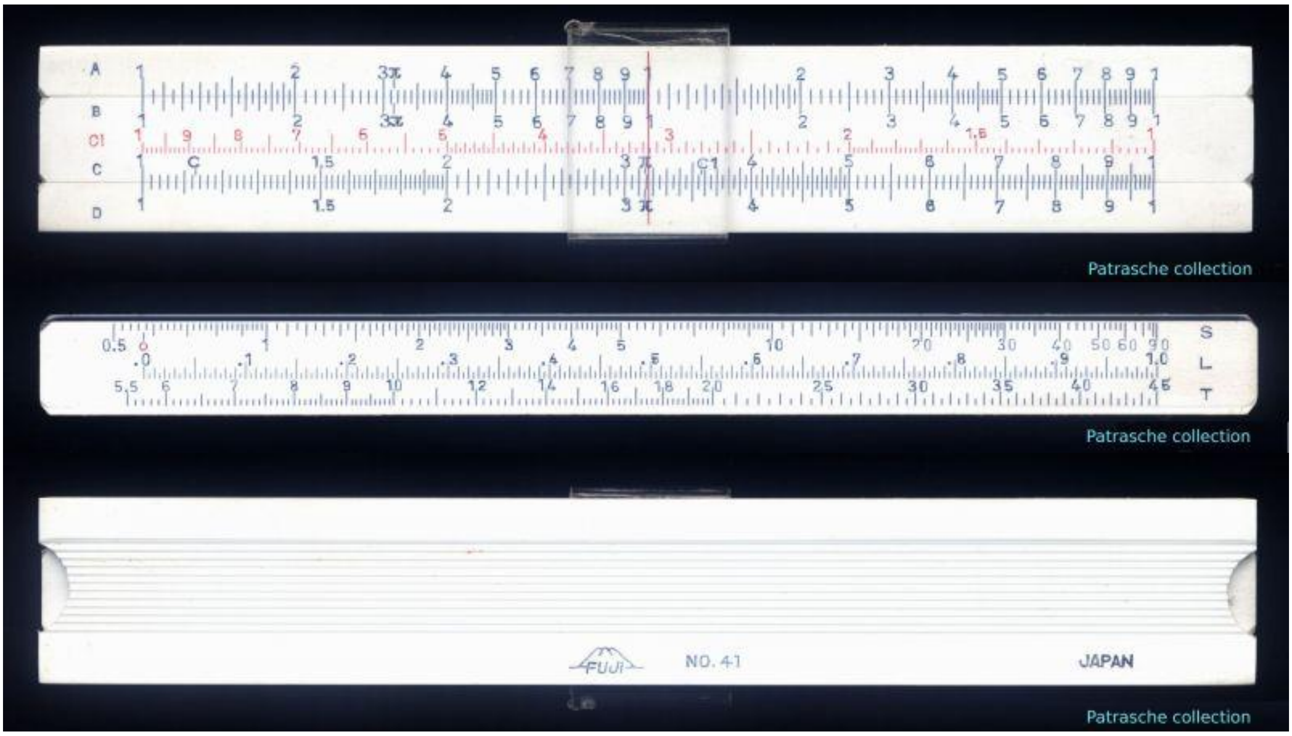
Although I have not been able to find clear data, it seems that Fuji slide rule company started in 1947-49, maybe as a derivative of Giken, and changed their name into Fuji Keiki Mfg. Co. Ltd., Fuji Keisanjaku and into Fuji Slide Rule Manufacturing Co Ltd.

Said this, it was a commercial strategy of this company to also sell their slide rules to other brands, probably in order to increase their business abroad. Refer to the article "Fuji - Circling the World with Straight Slide Rules" in IM2014 Proceedings document, or to the file "Fuji - Circling the World with Straight Slide Rules 140518 EN.doc" in www.reglasdecalculo.com for a more detailed study in this activity.

Thus, this is an illustrated list of the slide rules I have been able to locate in the Internet (some of them I own) that I believe can be recognized as manufactured by this company. In this sense, to the Fuji and Giken models, I have included Taisho, that it seems was a Japanese brand belonging to them, and Dietzgen, Eco-Bra, Jakar, Prentiss, Staedtler and Wolters-Noordhoff as Occidental brands that at one time commercialized their products.

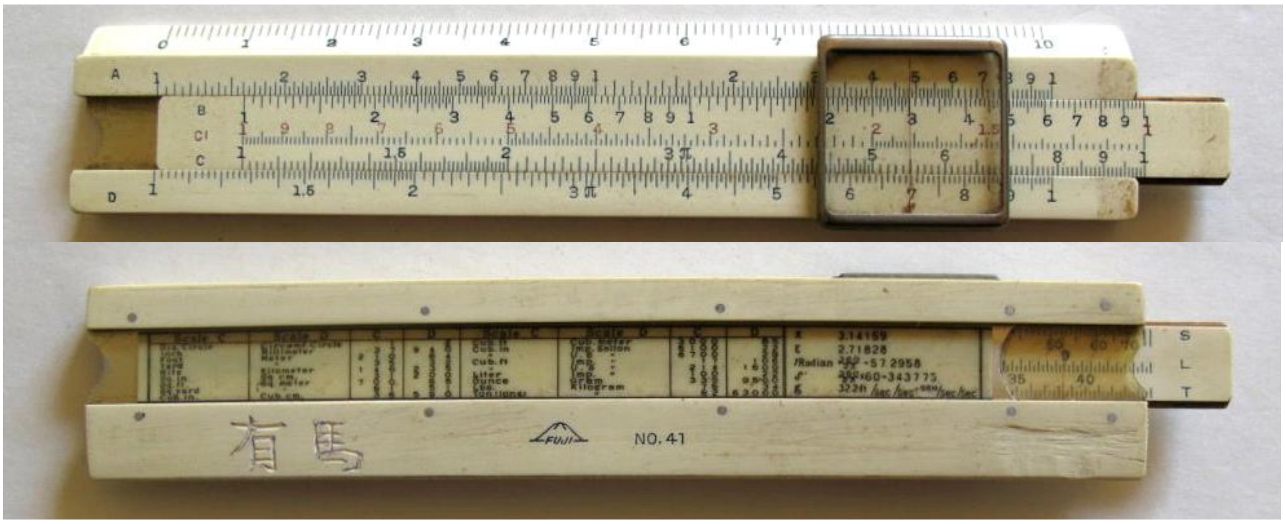
There are some models without a picture. These come from two Fuji instruction manuals, that also included a list of models, (in fact there is a third one from Giken but I have not included them).

3.- FUJI 41 (1ST VERSION)



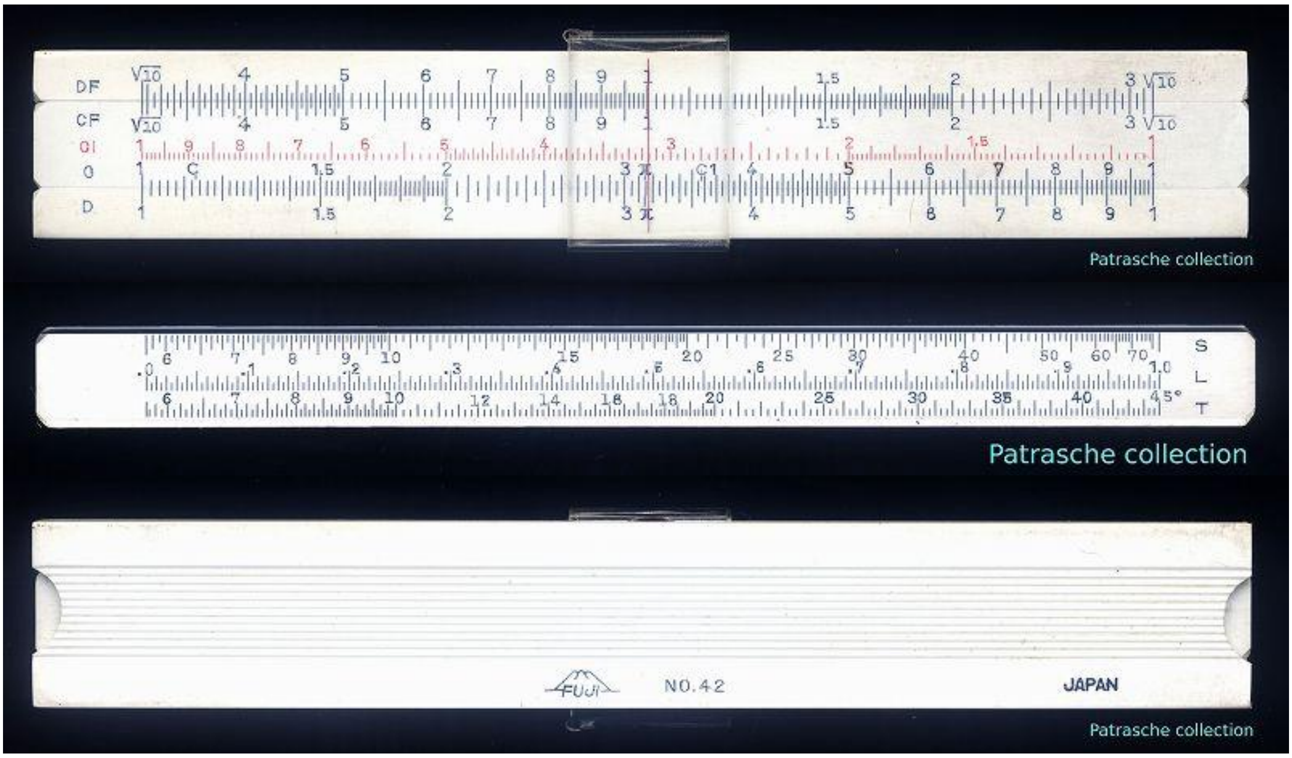
Model	41 (1st version)
Front Face Scales	A//B, CI, C// D
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	10
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref., "Made in"
Made in Data	Japan
Source	www.keisanjyaku.com
Name/Logo	Logo
Colours	White only
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Horizontal lines in back

4.- FUJI 41 (2ND VERSION)



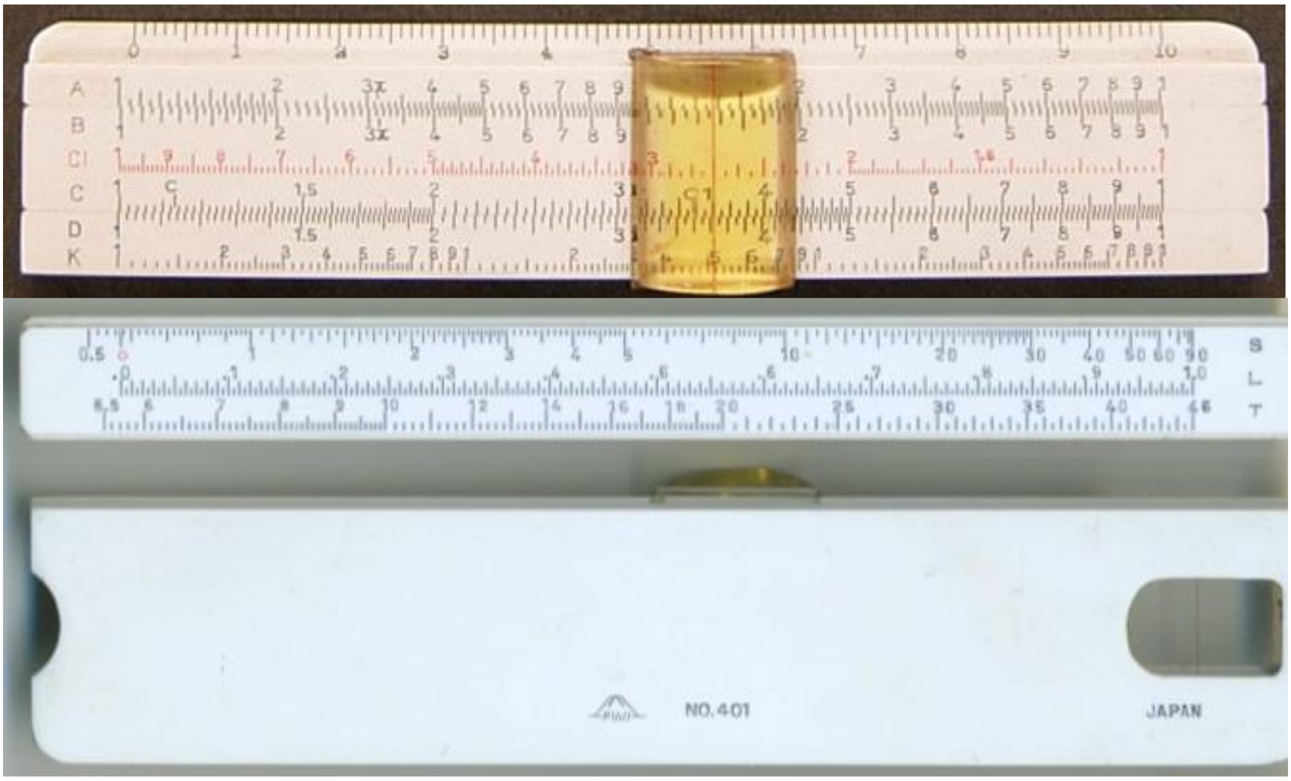
Model	41 (2nd version)
Front Face Scales	A//B, CI, C// D
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	10
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref.
Made in Data	?
Source	www.dentaku-museum.com
Name/Logo	Logo
Colours	White
Cursor Materials	Metal framed, single sided
Cursor Marks	None (black hairline)
Comments	Bamboo slide rule possibly made by Hemmi (30R)

5.- FUJI 42



Model	42
Front Face Scales	DF//CF, CI, C//D
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	10
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref., "Made in"
Made in Data	Japan
Source	www.keisanjyaku.com (Herman van Herwijnen's catalogue)
Name/Logo	Logo
Colours	White only
Cursor Materials	Transparent, single sided
Cursor Marks	None (red)
Comments	Horizontal lines in back

6.- **FUJI 401**



Model	401
Front Face Scales	cm//A//B, CI, C//D, K
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	10
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, Logo, Ref., "Made in"
Made in Data	Japan
Source	http://webmuseum.mit.edu/
Name/Logo	Logo
Colours	White
Cursor Materials	Transparent, single sided
Cursor Marks	None (red), magnifier effect
Comments	Rear windows. Magnifier cursor. In catalogue, cm scale is indicated as "m" after "K"

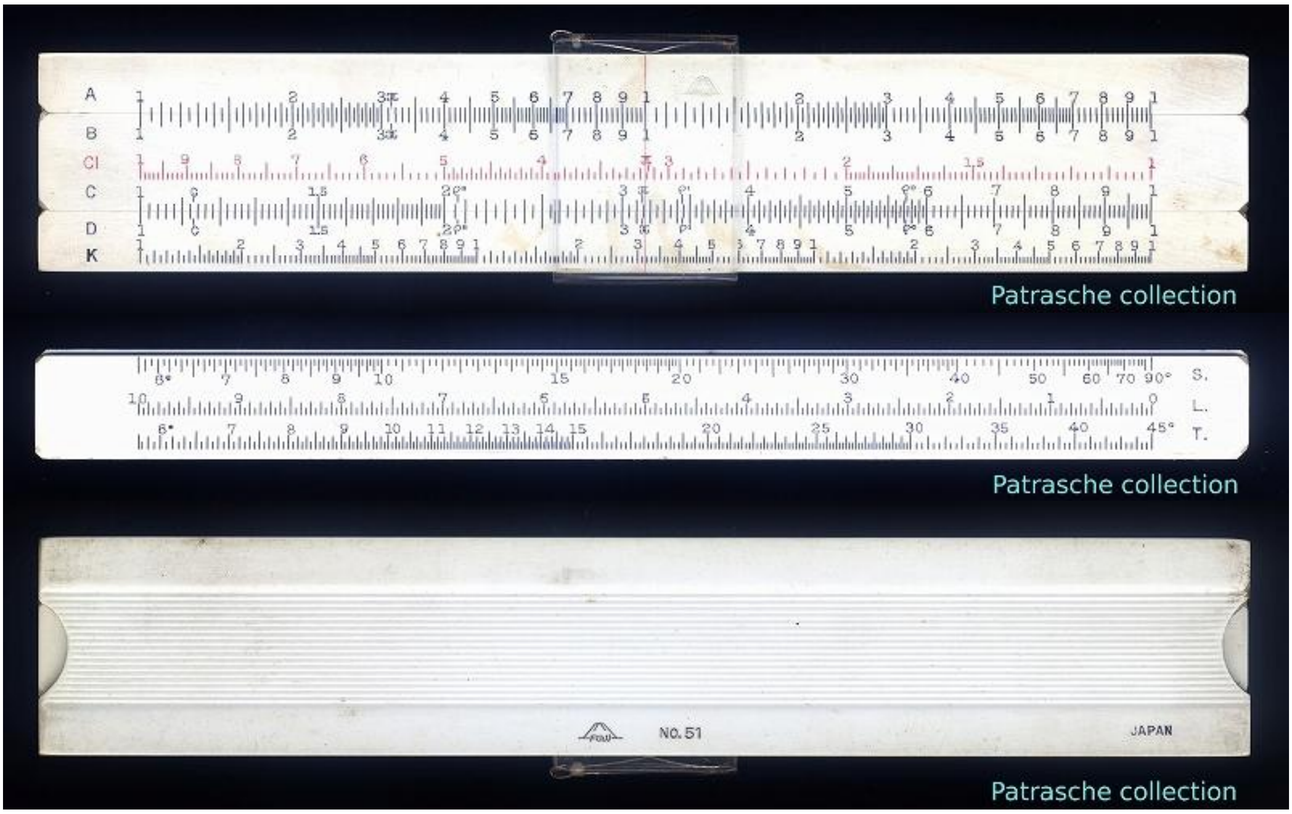
7.- FUJI 401R

Model	401R
Front Face Scales	A, B, CI, C, D, K, m
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	10
Type	Single
Name	---
Catalogue Referenced in	1
Comments	"m" may stand for cm scale (on separated top flap)

8.- FUJI 402, 402R

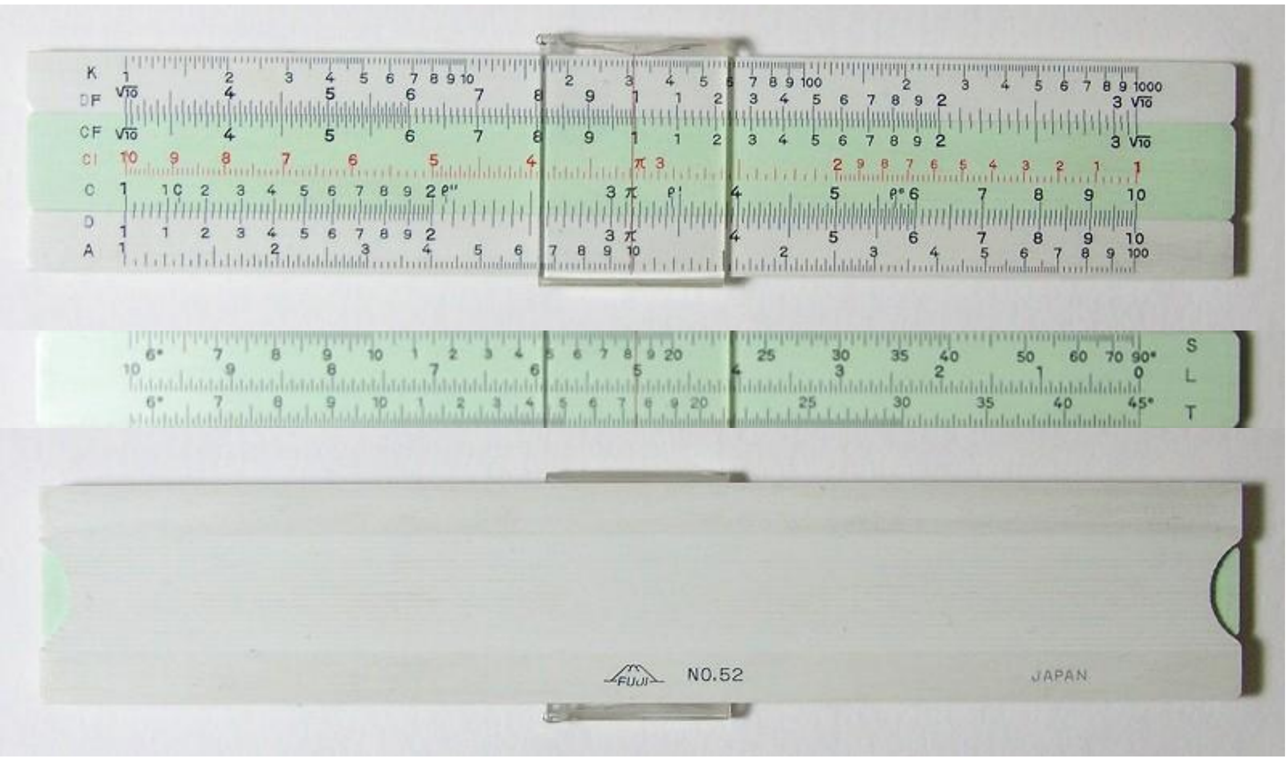
Model	402, 402R
Front Face Scales	DF, CF, CI, C, D, A, m
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	10
Type	Single
Name	---
Catalogue Referenced in	1
Comments	"m" may stand for cm scale (on separated top flap)

9.- FUJI 51



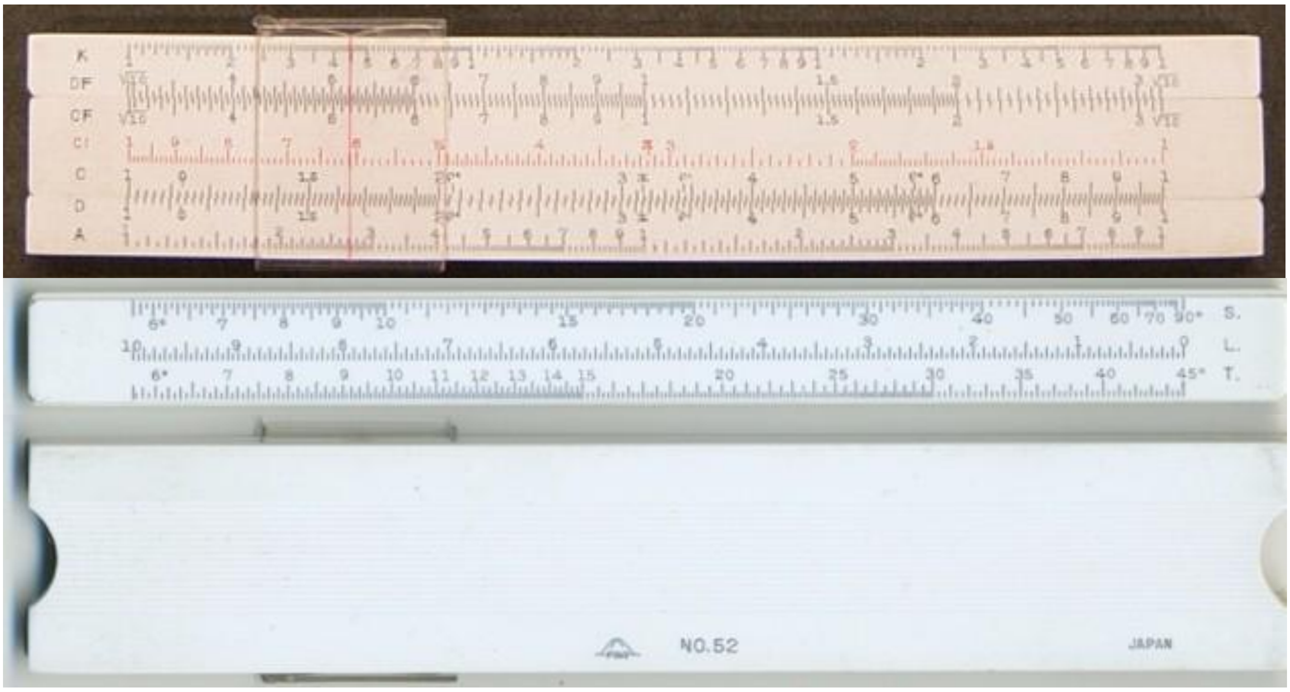
Model	51
Front Face Scales	A//B, CI, C//D, K
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref., "Made in"
Made in Data	Japan
Source	www.keisanjyaku.com (Herman van Herwijnen's catalogue)
Name/Logo	Logo
Colours	White only
Cursor Materials	Transparent, single sided
Cursor Marks	None (red), Fuji Logo
Comments	Horizontal lines in back

10.- FUJI 52 (1ST VERSION)



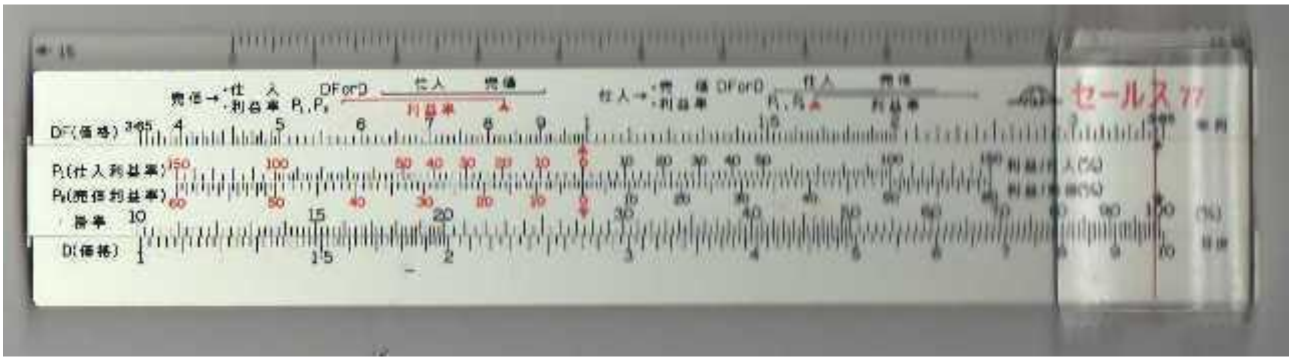
Model	52 (1st version)
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref., "Made in"
Made in Data	Japan
Source	www.keisanjyaku.com
Name/Logo	Logo
Colours	White body with light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	None (red)
Comments	Horizontal lines in back

11.- FUJI 52 (2ND VERSION)



Model	52 (2nd version)
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref., "Made in"
Made in Data	Japan
Source	http://webmuseum.mit.edu
Name/Logo	Logo
Colours	White body
Cursor Materials	Transparent, single sided
Cursor Marks	None (red)
Comments	Horizontal lines in back

12.- FUJI 77

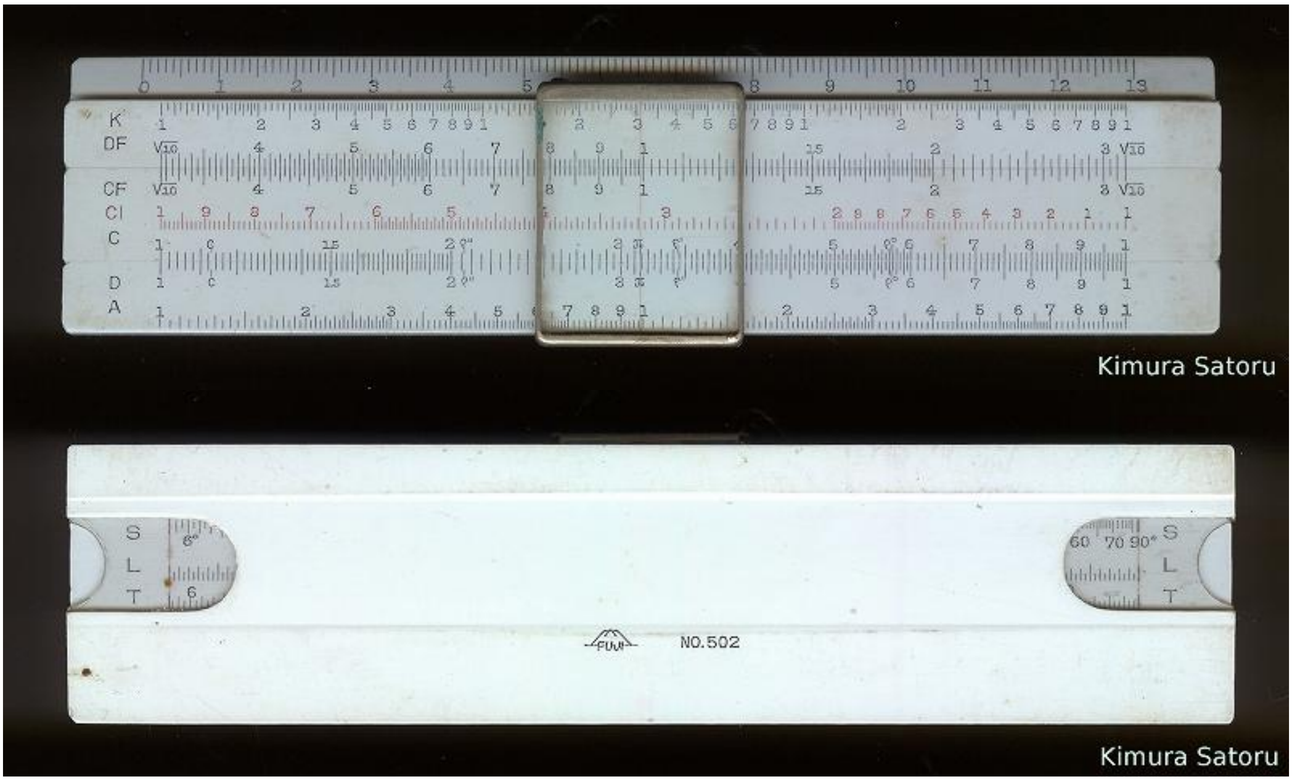


Model	77
Front Face Scales	cm//DF// P1, P2, %//D
Rear Face Scales (or rear slide only)	? (picture might show the reverse of the slide)
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	?
Made in Data	?
Source	http://www.pcstore.com.tw/liehen4201/M10794684.htm
Name/Logo	Logo
Colours	White
Cursor Materials	Transparent, single sided
Cursor Marks	None (red)
Comments	Japanese text and maybe indications of use on top of front face.

13.- FUJI 501, 501R

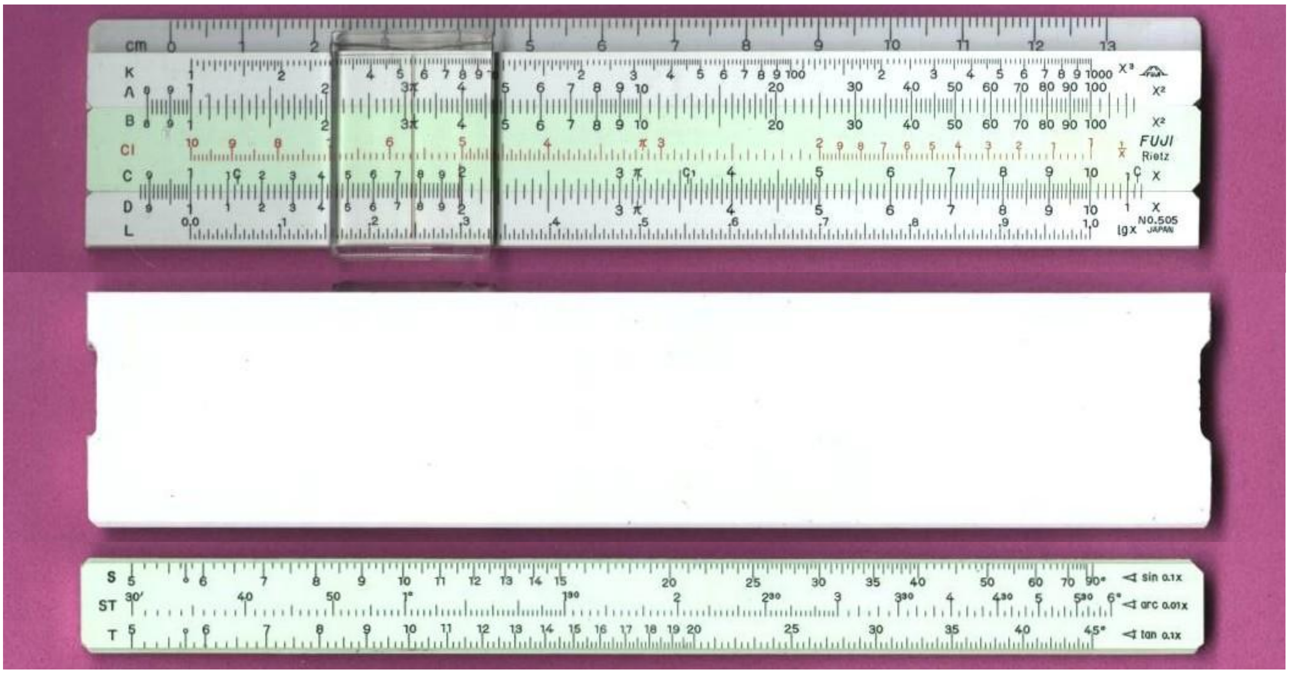
Model	501, 501R
Front Face Scales	A, B, CI, C, D, K, m
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	1
Comments	"m" may stand for cm scale (on separated top flap)

14.- FUJI 502



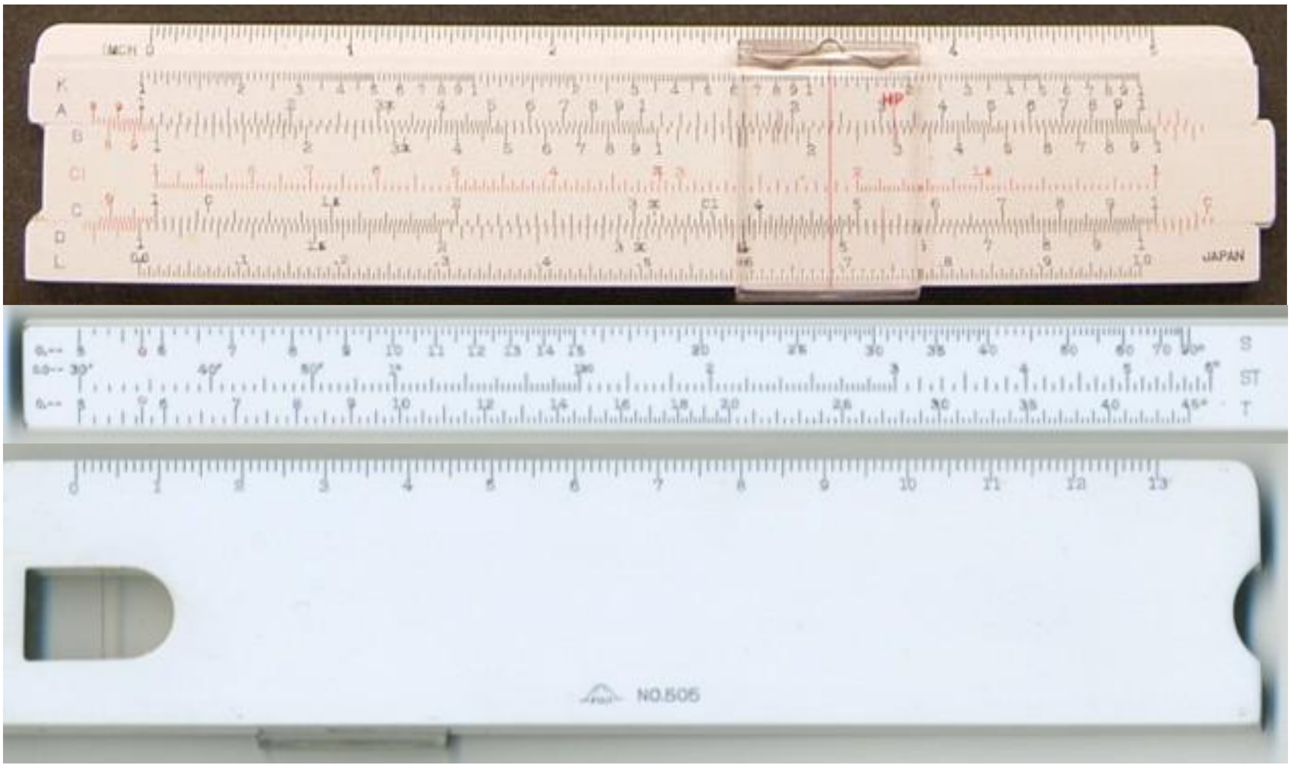
Model	502
Front Face Scales	cm//K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref.
Made in Data	---
Source	www.keisanjyaku.com
Name/Logo	Logo
Colours	White body
Cursor Materials	Metal framed, single sided
Cursor Marks	None (black hairline)
Comments	Reverse: windows for S, L, T and recessed centre with horizontal lines

15.- FUJI 505 (1ST VERSION)



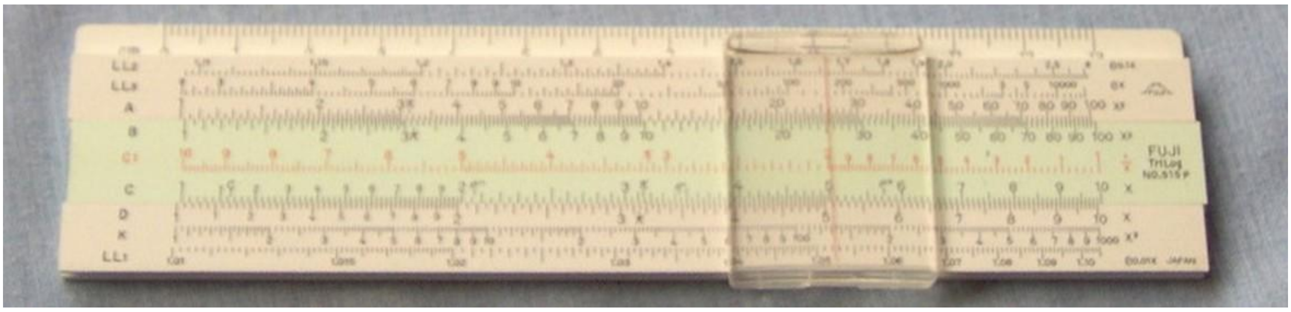
Model	505 (1st version)
Front Face Scales	cm//K, A//B, CI, C//D, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	12,5
Type	Single
Name	Rietz
Catalogue Referenced in	1
Data in Back (no duplex)	Blank
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Name & Logo
Colours	White body with light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	d (black)
Comments	

16.- FUJI 505 (2ND VERSION)



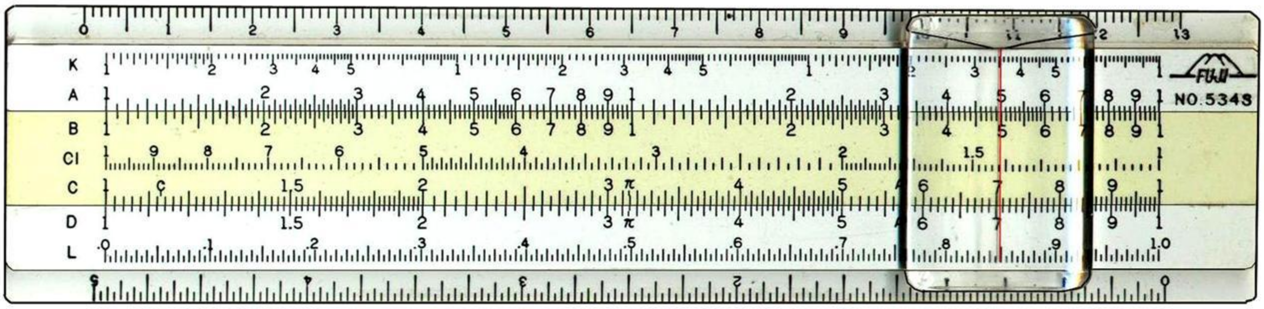
Model	505 (2nd version)
Front Face Scales	inches//K, A//B, CI, C//D, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	12,5
Type	Single
Name	Rietz
Catalogue Referenced in	1
Data in Back (no duplex)	cm, Logo, Ref.
Made in Data	Japan
Source	http://webmuseum.mit.edu
Name/Logo	Logo
Colours	White
Cursor Materials	Transparent, single sided
Cursor Marks	d, q, HP (red)
Comments	One window in the back side

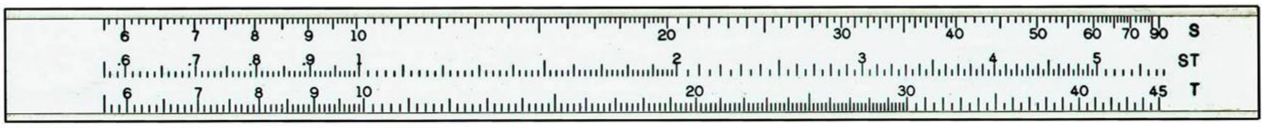
17.- FUJI 515P



Model	515P
Front Face Scales	cm//LL2, LL3, A//B, CI, C//D, K, LL1
Rear Face Scales (or rear slide only)	P, T, L, S
Size (cm)	12,5
Type	Single
Name	Trilog
Catalogue Referenced in	2
Data in Back (no duplex)	Blank
Made in Data	Japan
Source	E-Bay auction
Name/Logo	Name and Logo
Colours	White body and light-green slide
Cursor Materials	Transparent and single sided
Cursor Marks	None (red hairline)
Comments	Reference in Herman van Herwijnen's catalogue

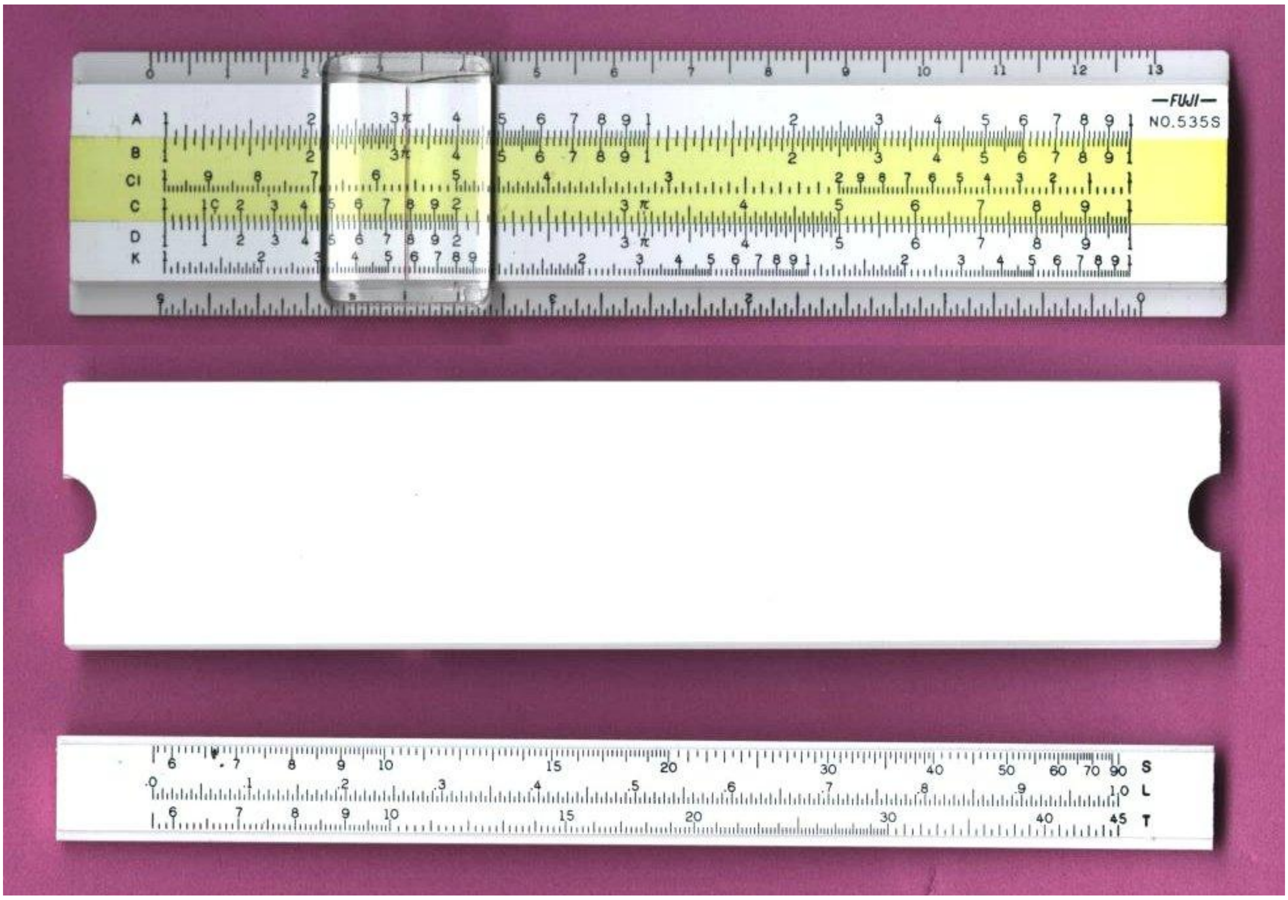
18.- FUJI 534S





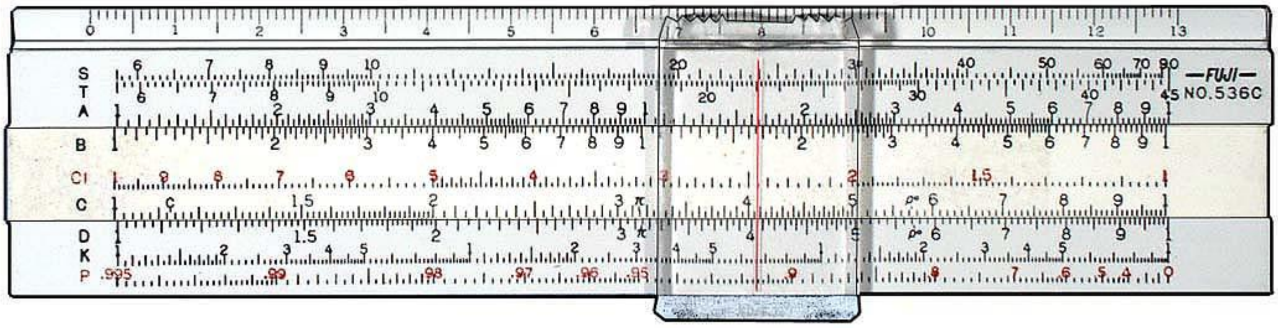
Model	534S
Front Face Scales	cm//K, A//B, CI, C//D, L//inches
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	12,5
Type	Single
Name	Student
Catalogue Referenced in	2
Data in Back (no duplex)	Blank
Made in Data	---
Source	Herman van Herwijnen's catalogue
Name/Logo	Logo
Colours	White body with one-side light-yellow slide
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	No picture of the back of the rule (assumed full blank)

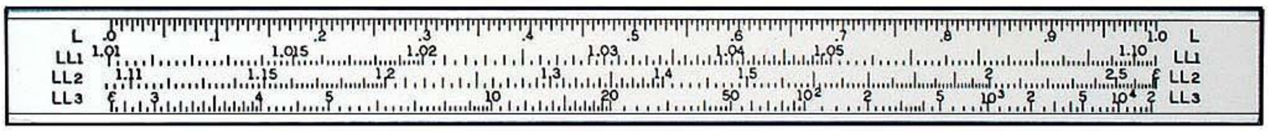
19.- FUJI 535S



Model	535S
Front Face Scales	cm//K, A//B, CI, C//D, L//inches
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	2
Data in Back (no duplex)	Blank
Made in Data	---
Source	International Slide Rule Museum
Name/Logo	Simplified Logo
Colours	White body with one-side light-yellow slide
Cursor Materials	Transparent, single sided
Cursor Marks	None (black hairline)
Comments	

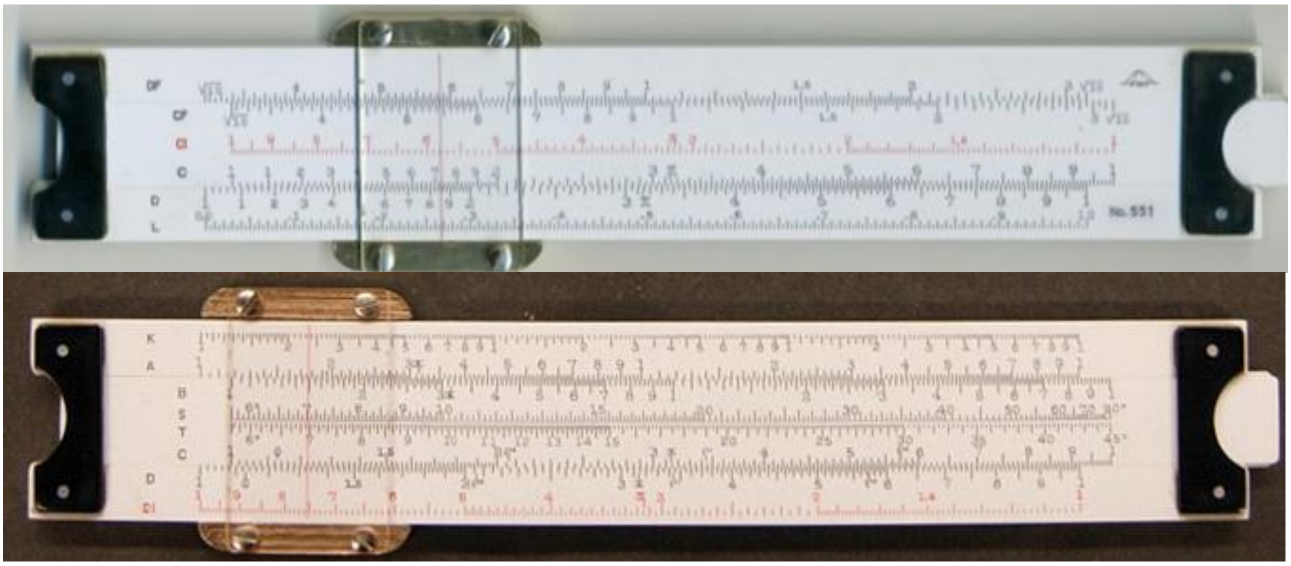
20.- FUJI 536C





Model	536C
Front Face Scales	cm//S, T, A//B, CI, C//D, K, P
Rear Face Scales (or rear slide only)	L, LL1, LL2, LL3
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	---
Source	Herman van Herwijnen's catalogue
Name/Logo	Simplified Logo
Colours	White body with one-side light-yellow slide
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	No picture of the back of the rule (assumed full blank)

21.- FUJI 551

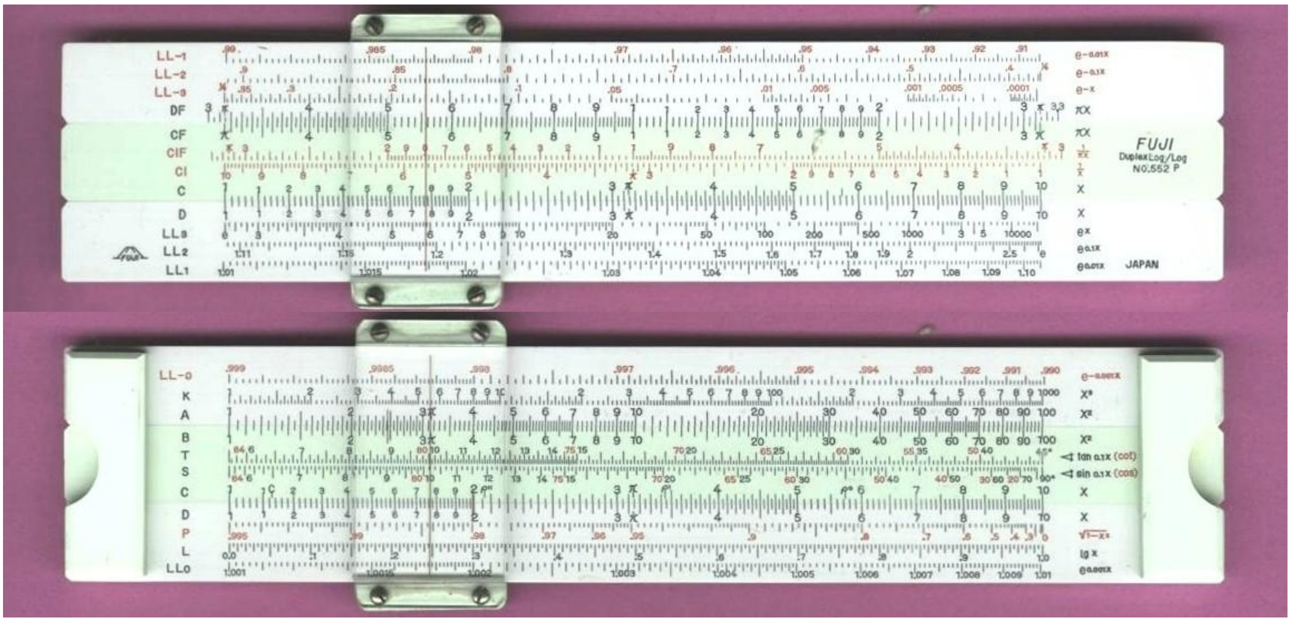


Model	551
Front Face Scales	DF//CF, CI, C//D, L
Rear Face Scales (or rear slide only)	K, A//B, S, T, C//D, DI
Size (cm)	12,5
Type	Duplex
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	N/A
Made in Data	---
Source	http://webmuseum.mit.edu
Name/Logo	Logo
Colours	White body with riveted black brackets
Cursor Materials	Gold-plated? metal runners, double sided
Cursor Marks	None (red hairline)
Comments	

22.- FUJI 552

Model	552
Front Face Scales	LL/3, LL/2, LL/1, DF, CF, CIF, CI, C, D, LL1, LL2, LL3
Rear Face Scales (or rear slide only)	L, K, A, B, T2, T1, cos, S, C, D, DI, LL0, LL/0
Size (cm)	12,5
Type	Duplex
Name	---
Catalogue Referenced in	1
Comments	

23.- FUJI 552P

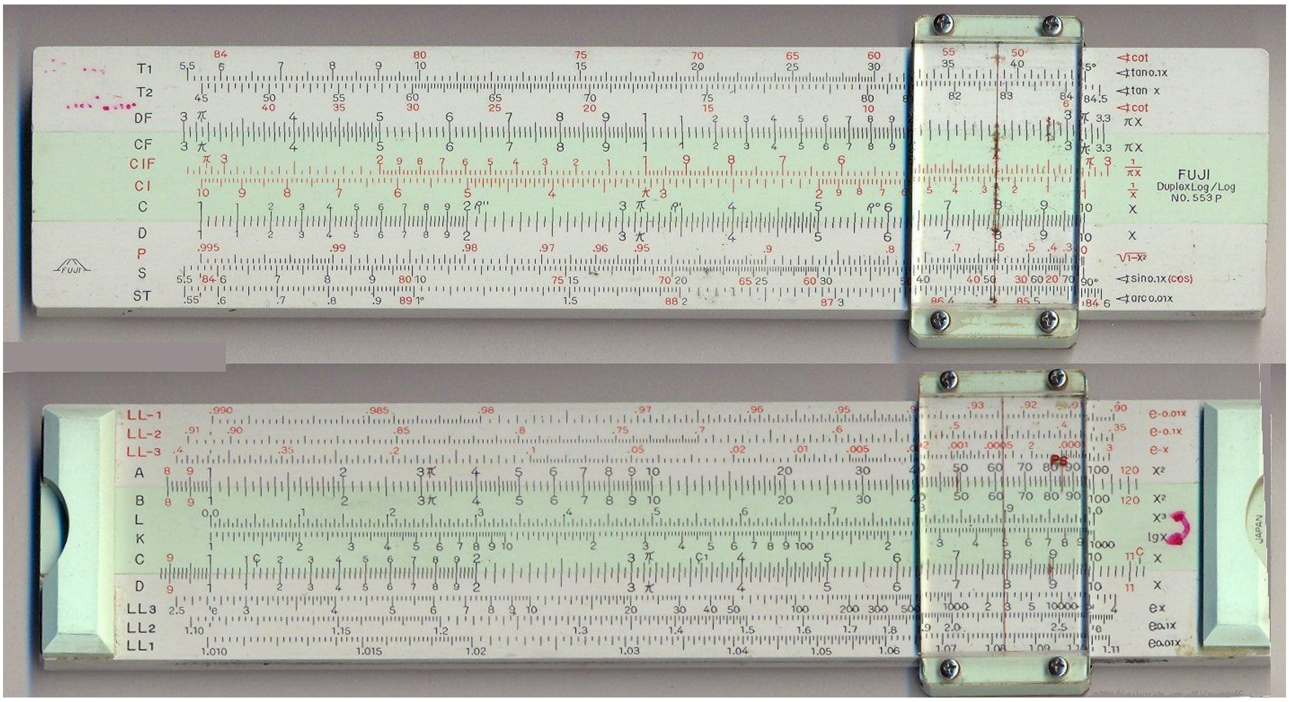


Model	552 P
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	LL-0, K, A//B, T, S, C//D, P, L, LL0
Size (cm)	12,5
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Name and Logo
Colours	Light-green slide and fasteners
Cursor Materials	All plastic with light-green runners, double sided
Cursor Marks	d, q (black)
Comments	

24.- FUJI 553

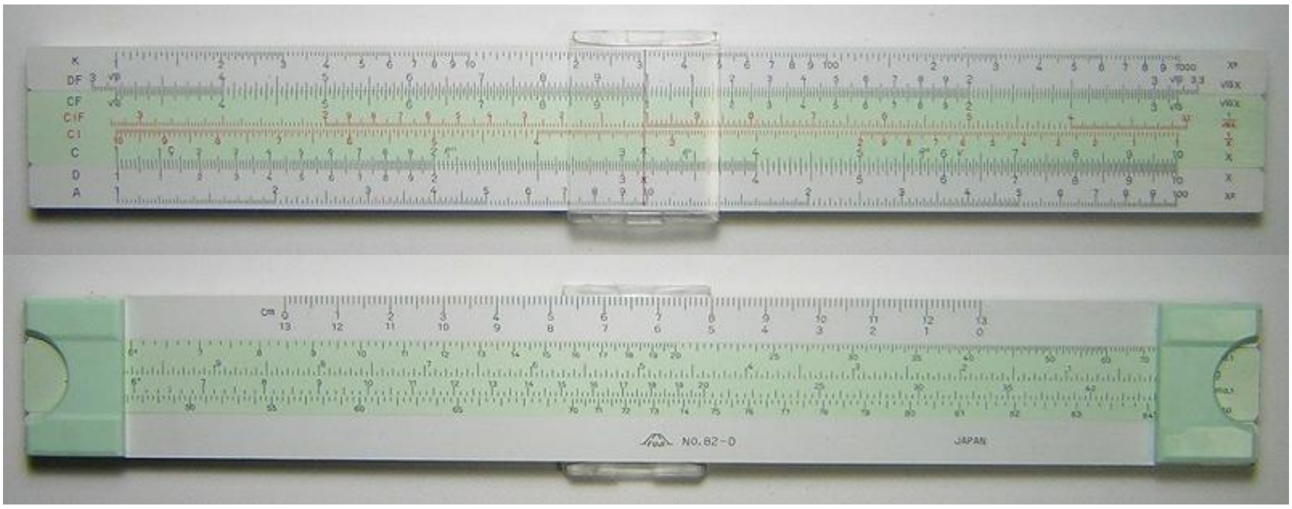
Model	553
Front Face Scales	LL01, LL02, LL03, A, B, L, K, C, D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	T, ST, DF, CF, CIF, CI, C, D, P, S, T1, T2
Size (cm)	12,5
Type	Duplex
Name	Duplex Log
Catalogue Referenced in	2
Comments	

25.- FUJI 553P



Model	553 P
Front Face Scales	T1, T2, DF//CF, CIF, CI, C//D, P, S, ST
Rear Face Scales (or rear slide only)	LL-1, LL-2, LL-3, A//B, L, K, C//D, LL3, LL2, LL1
Size (cm)	12,5
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Name and Logo
Colours	Light-green slide and fasteners
Cursor Materials	All plastic with light-green runners, double sided
Cursor Marks	36 \\\ PS, q, d (red)
Comments	

26.- FUJI 82D

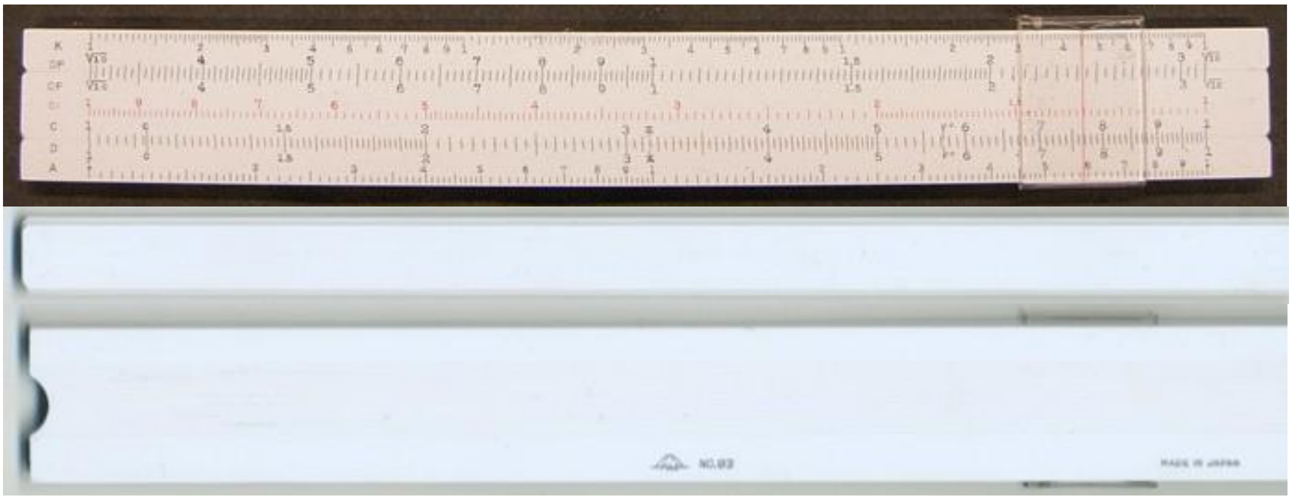


Model	82D
Front Face Scales	K, DF//CF, CIF, CI, C//D, A
Rear Face Scales (or rear slide only)	cm//S, L, T1, T2
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	cm, logo, ref., "Made in"
Made in Data	Japan
Source	www.keisanjyaku.com
Name/Logo	Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	none (r)
Comments	Wide fasteners

27.- FUJI 83 (1^{ST} VERSION)

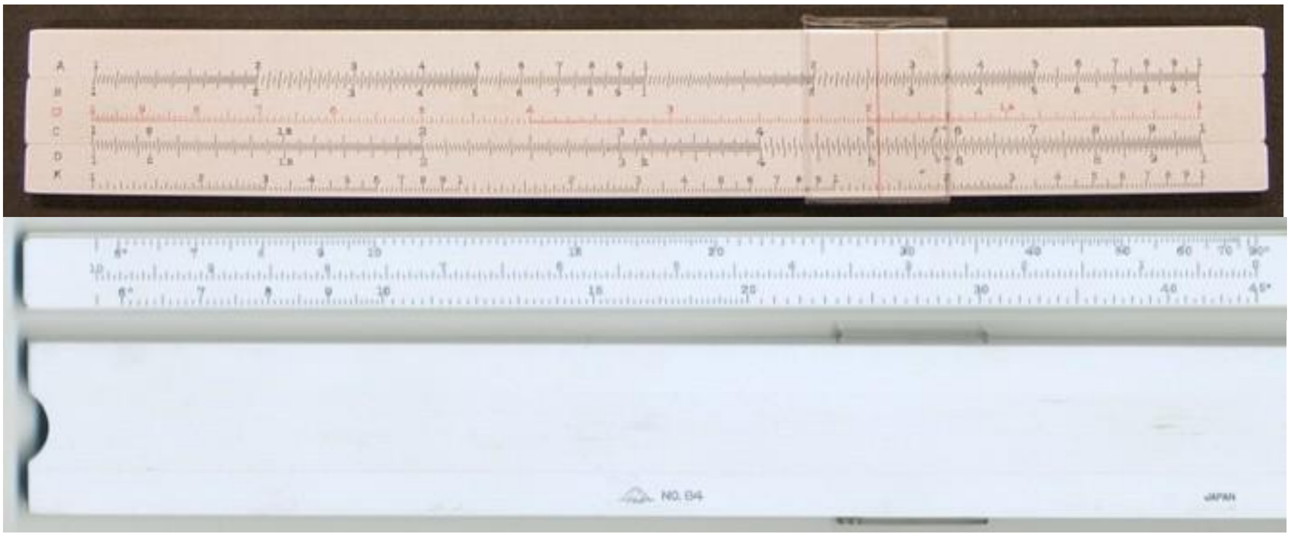
Model	83 (1^{st} version)
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	Blank
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref.
Made in Data	---
Source	www.keisanjyaku.com
Name/Logo	Logo
Colours	White
Cursor Materials	Metal frame, single sided
Cursor Marks	None (black hairline)
Comments	

28.- FUJI 83 (2ND VERSION)



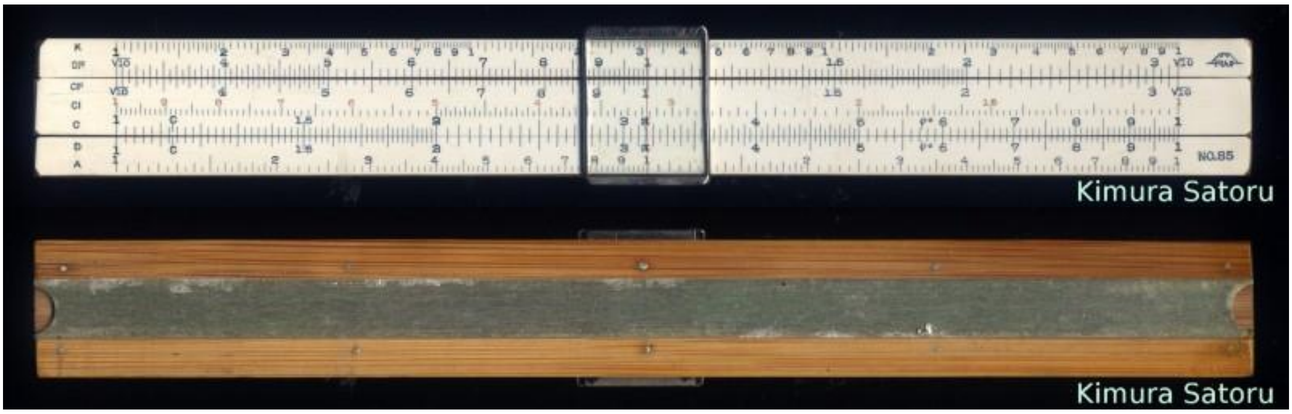
Model	83 (2nd version)
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	Blank
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref., "Made in"
Made in Data	"Made in Japan"
Source	http://webmuseum.mit.edu/
Name/Logo	Logo
Colours	White
Cursor Materials	transparent, single sided
Cursor Marks	none (red hairline)
Comments	Horizontal lines in recessed centre of back side

29.- FUJI 84



Model	84
Front Face Scales	A//B, CI, C//D, K
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank, logo, Ref., "Made in"
Made in Data	Japan
Source	http://webmuseum.mit.edu/
Name/Logo	Logo
Colours	White
Cursor Materials	transparent, single sided
Cursor Marks	none (red hairline)
Comments	

30.- FUJI 85

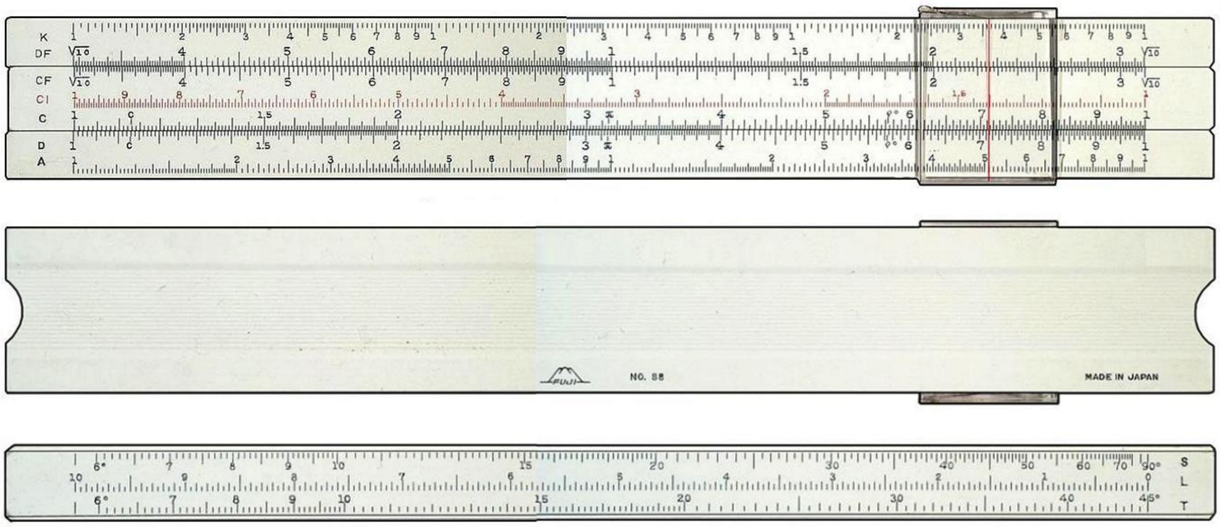


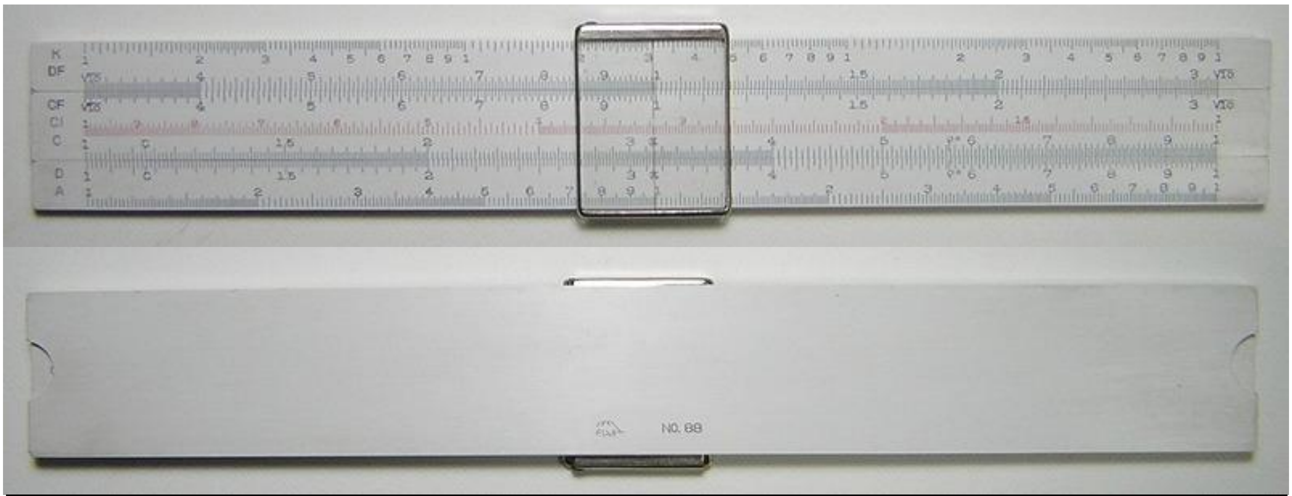
Model	85
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	Blank
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	---
Source	www.keisanjyaku.com
Name/Logo	Logo
Colours	White (bamboo)
Cursor Materials	Metal frame, single sided
Cursor Marks	None (red hairline)
Comments	Bamboo slide rule possibly made by Hemmi (40F)

31.- FUJI 87

Model	87
Front Face Scales	K, A, B, CI, C, D, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	1
Comments	

32.- FUJI 88





Model	83
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, logo, Ref., "Made in" \\\ Blank, logo, Ref.
Made in Data	Made in Japan \\\ ---
Source	Herman van Herwijnen's catalogue www.keisanjyaku.com
Name/Logo	Logo
Colours	White
Cursor Materials	Plastic frame, single sided \\\ Metal frame, single sided
Cursor Marks	None (red hairline) \\\ None (black hairline)
Comments	Two versions of a single reference

33.- FUJI 802

Model	802
Front Face Scales	K, DF, CF, CIF, CI, C, D, A
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	1
Comments	

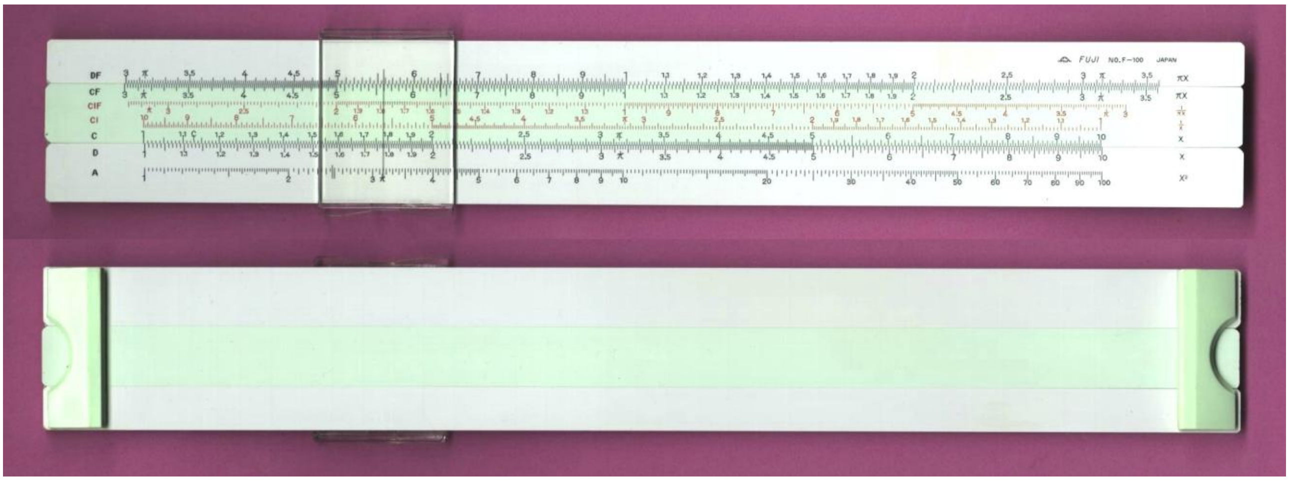
34.- FUJI 805

Model	805
Front Face Scales	A, DF, CF, B, CI, C, D, K, m
Rear Face Scales (or rear slide only)	S, L, T1, T2
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	1
Comments	"m" may stand for cm scale (on separated top flap)

35.- FUJI 806

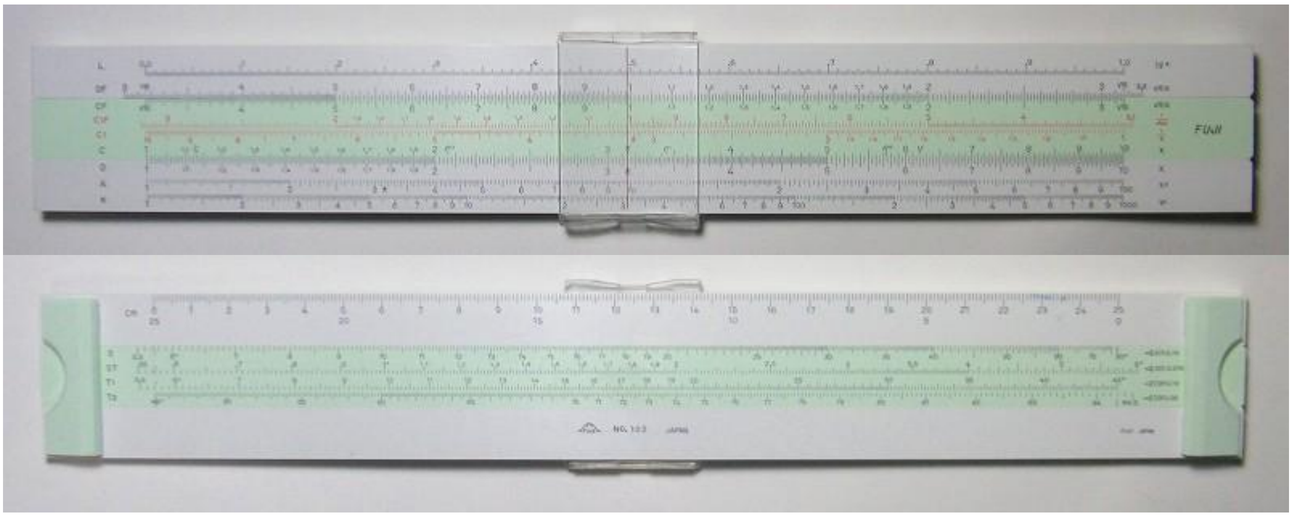
Model	806
Front Face Scales	K, DF, CF, CIF, CI, C, D, A, m
Rear Face Scales (or rear slide only)	S, L, T1, T2
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	1
Comments	"m" may stand for cm scale (on separated top flap)

36.- FUJI F-100



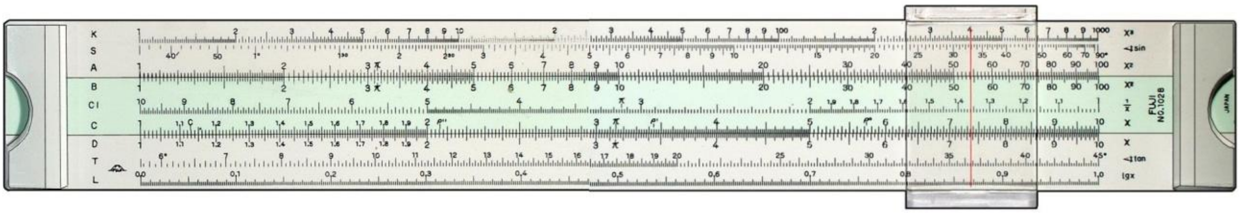
Model	F-100
Front Face Scales	DF//CF, CIF, CI, C//D, A
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	36, q (black)
Comments	

37.- FUJI 102



Model	102
Front Face Scales	L, DF//CF, CIF, CI, C//D, A, K
Rear Face Scales (or rear slide only)	cm//S, ST, T1, T2
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	cm, logo, ref., "Made in"
Made in Data	Japan (two times!)
Source	www.keisanjyaku.com
Name/Logo	Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	none (red hairline)
Comments	Fuji name in front and rear, "Japan" two times in rear

38.- FUJI 102B

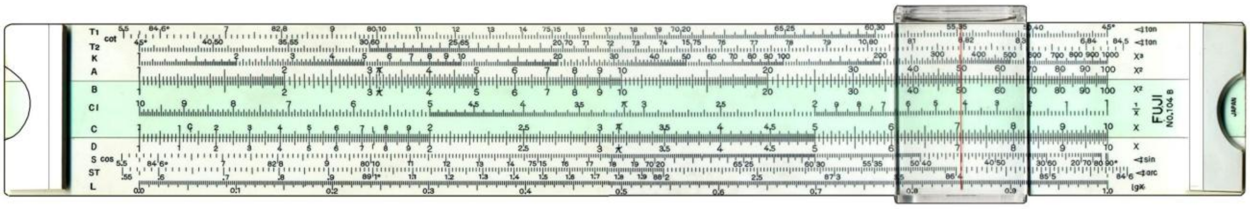


Model	102B
Front Face Scales	K, S, A//B, CI, C//D, T, L
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	blank
Made in Data	Japan
Source	Herman van Herwijnen's catalogue
Name/Logo	Name and Logo
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	none (r)
Comments	White fasteners in front face

39.- FUJI P104

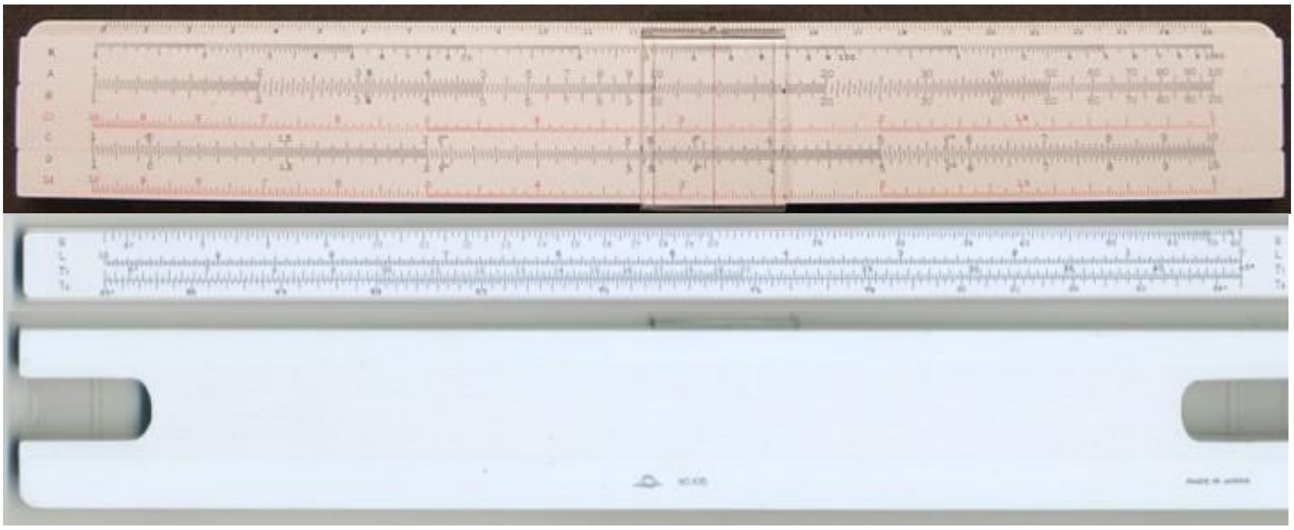
Model	P104
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	?
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	?
Made in Data	?
Source	http://jeykanz.way-nifty.com/jeykanz/
Name/Logo	?
Colours	White
Cursor Materials	Metal framed, single sided
Cursor Marks	none (black hairline)
Comments	(specimen named as in website)

40.- FUJI 104B



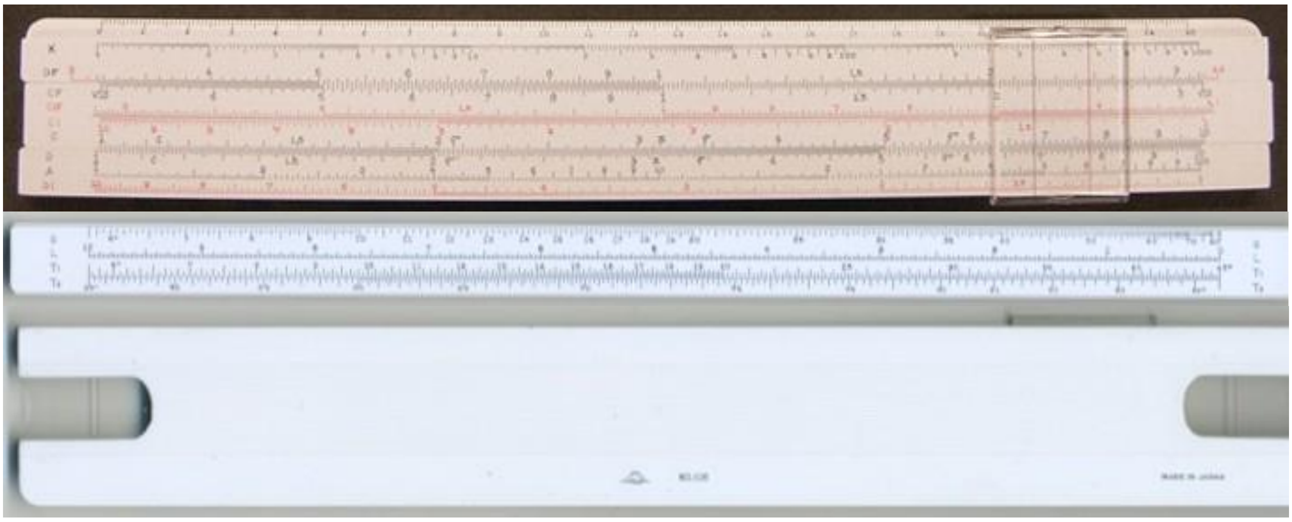
Model	104B
Front Face Scales	T1, T2, K, A//B, CI, C//D, S, ST, L
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	2
Data in Back (no duplex)	blank
Made in Data	Japan
Source	Herman van Herwijnen's catalogue
Name/Logo	Name
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	none (r)
Comments	White fasteners in front face

41.- FUJI 105



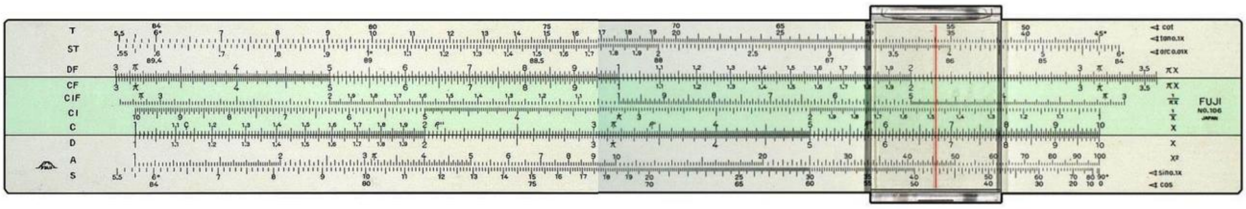
Model	105
Front Face Scales	cm//K, A//B, CI, C//D, DI
Rear Face Scales (or rear slide only)	S, L, T1, T2
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, Logo, Ref., "Made in"
Made in Data	"Made in Japan"
Source	http://webmuseum.mit.edu/
Name/Logo	Logo
Colours	White
Cursor Materials	Transparent, single sided
Cursor Marks	Peripheral hairlines (d?, q?, black), central hairline red
Comments	Windows in back and recessed centre with horizontal lines. In catalogue, cm scale is "m" after "DI"

42.- FUJI 106 (1ST VERSION)



Model	106 (1st version)
Front Face Scales	cm//K, DF//CF, CIF, CI, C//D, A, DI
Rear Face Scales (or rear slide only)	S, L, T1, T2
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, Logo, Ref., "Made in"
Made in Data	Made in Japan
Source	http://webmuseum.mit.edu/
Name/Logo	Logo
Colours	White
Cursor Materials	Transparent, single sided
Cursor Marks	One hairline red and one black (d distance?)
Comments	Windows in back and recessed centre with horizontal lines. In catalogue, cm scale is "m" after "DI"

43.- FUJI 106 (2ND VERSION)

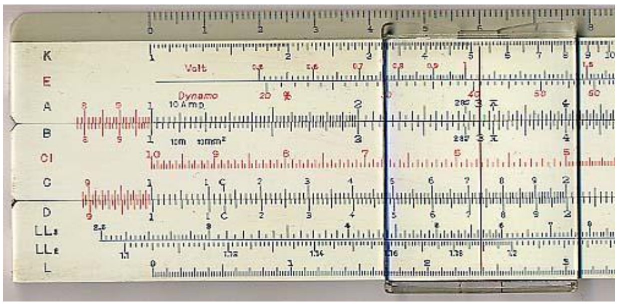


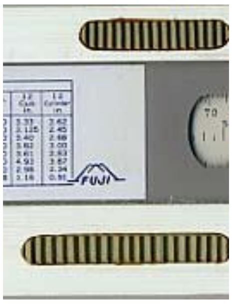
Model	106
Front Face Scales	T, ST, DF//CF, CIF, CI, C//D, A, S
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	2
Data in Back (no duplex)	blank
Made in Data	Japan
Source	Herman van Herwijnen's catalogue
Name/Logo	Name and Logo
Colours	light-green slide (fasteners not seen)
Cursor Materials	Transparent, single sided
Cursor Marks	none (r)
Comments	No details of the back (and fasteners)

44.- FUJI 106B

Model	106B
Front Face Scales	T, ST, DF, CF, CIF, CI, C, D, A, S
Rear Face Scales (or rear slide only)	Blank
Size (cm)	25
Type	Single
Name	Minor
Catalogue Referenced in	2
Comments	Equivalent to model 106 2nd version

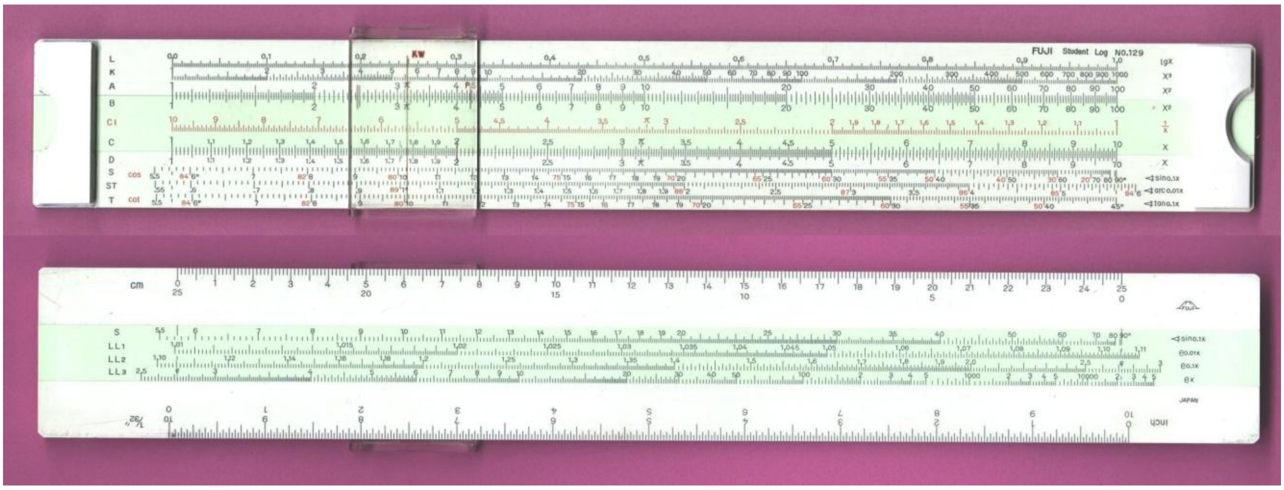
45.- FUJI 108





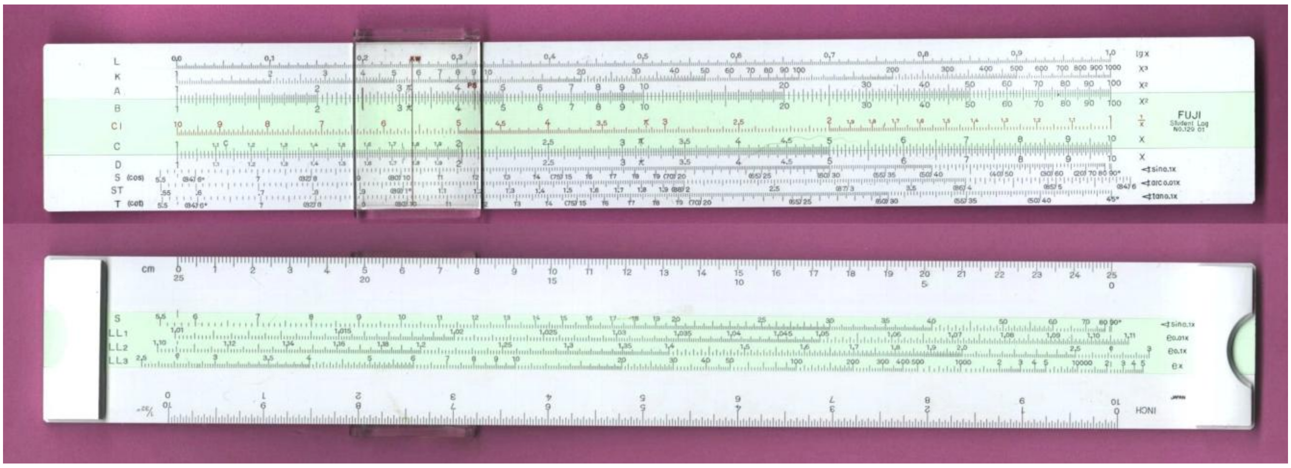
Model	108
Front Face Scales	Cm//K, E (Volt Dinamo-Motor), A//B, CI, C//D, LL3, LL2, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Logo, table
Made in Data	?
Source	http://jeykanz.way-nifty.com/jeykanz/
Name/Logo	Logo
Colours	White, grey windows at back
Cursor Materials	Transparent, single sided
Cursor Marks	none (red hairline)
Comments	"Electro" model. Rubber stoppers at back side (specimen named as in website)

46.- FUJI 129



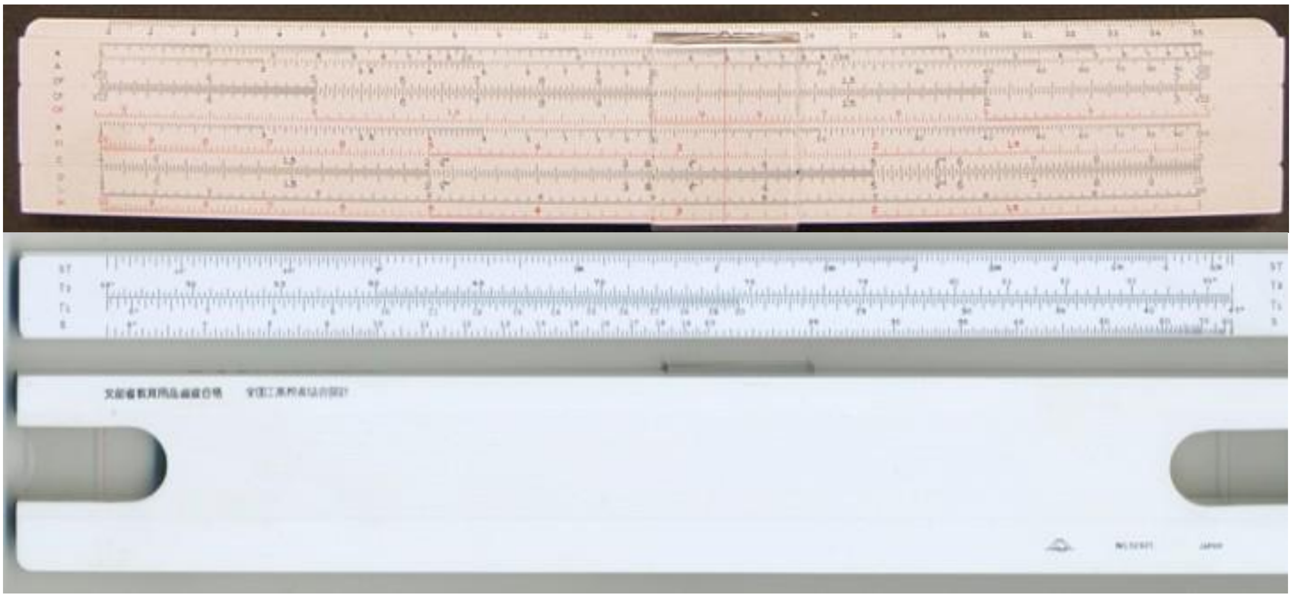
Model	129
Front Face Scales	L, K, A//B, CI, C//D, S, ST, T
Rear Face Scales (or rear slide only)	cm//S, LL1, LL2, LL3//inches
Size (cm)	25
Type	Single
Name	Student log
Catalogue Referenced in	2
Data in Back (no duplex)	cm, inches, logo, "Made in"
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Name and Logo
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	PS, q, d (red)
Comments	White fasteners in front face

47.- FUJI 129 01



Model	129 01
Front Face Scales	L, K, A//B, CI, C//D, S, ST, T
Rear Face Scales (or rear slide only)	cm//S, LL1, LL2, LL3//inches
Size (cm)	25
Type	Single
Name	Student log
Catalogue Referenced in	2
Data in Back (no duplex)	cm, inches, "Made in"
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Name
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	PS, q, d (red)
Comments	

48.- FUJI 129 21

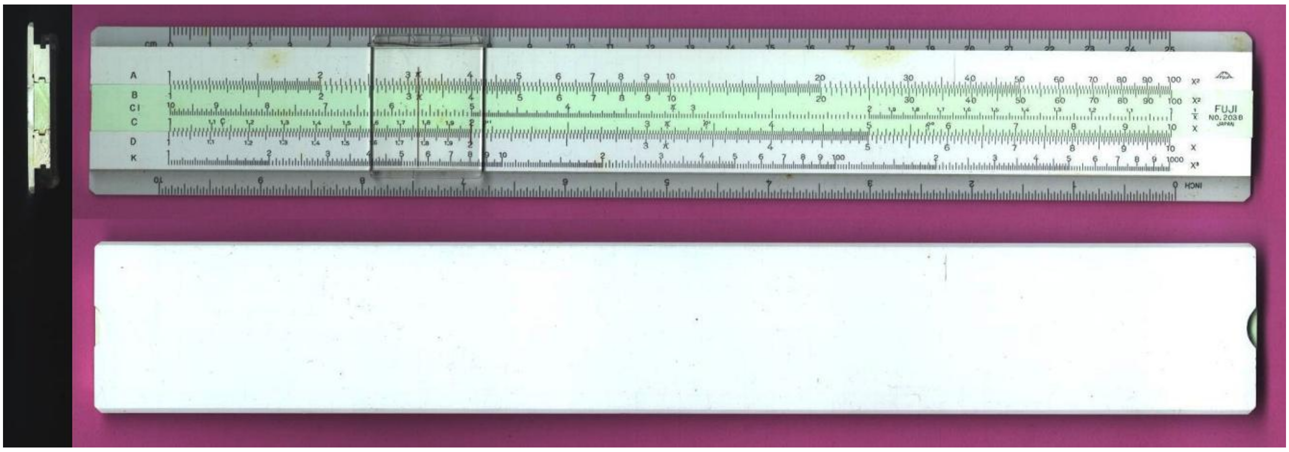


Model	129 21
Front Face Scales	cm//K, A, CF//DF, CIF, B, CI, C//D, L, DI
Rear Face Scales (or rear slide only)	ST, T2, T1, S
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	Japanese text, Logo, Ref., "Made in"
Made in Data	Japan
Source	http://webmuseum.mit.edu/
Name/Logo	Logo
Colours	White
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Windows in back and recessed centre with horizontal lines. In catalogue, cm scale is "m" after "DI"

49.- FUJI 201P

Model	201P
Front Face Scales	cm//LL1, LL2, LL3, A//B, BI, CI, C//D, P, K, LL0
Rear Face Scales (or rear slide only)	T2, T, L, S
Size (cm)	25
Type	Single
Name	QuateLog
Catalogue Referenced in	2
Data in Back (no duplex)	cm, inches, "Made in"
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Name and Logo
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	None (black hairline)
Comments	

50.- FUJI 203 B

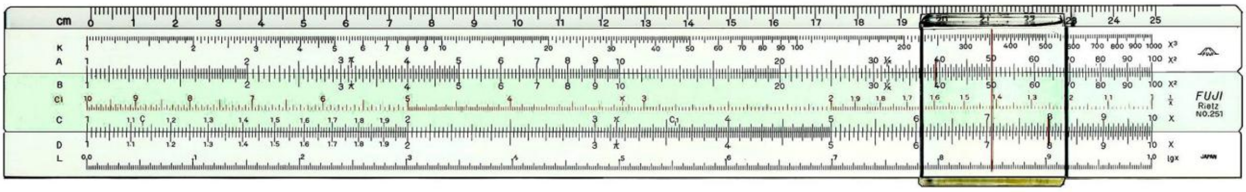


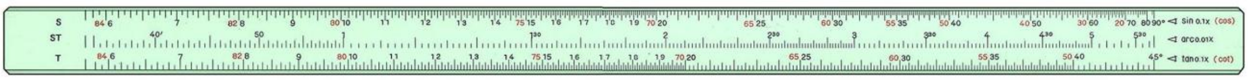
Model	203B
Front Face Scales	cm//A//B, CI, C//D, K//inches
Rear Face Scales (or rear slide only)	Blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Name and Logo
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	d? (red hairline)
Comments	

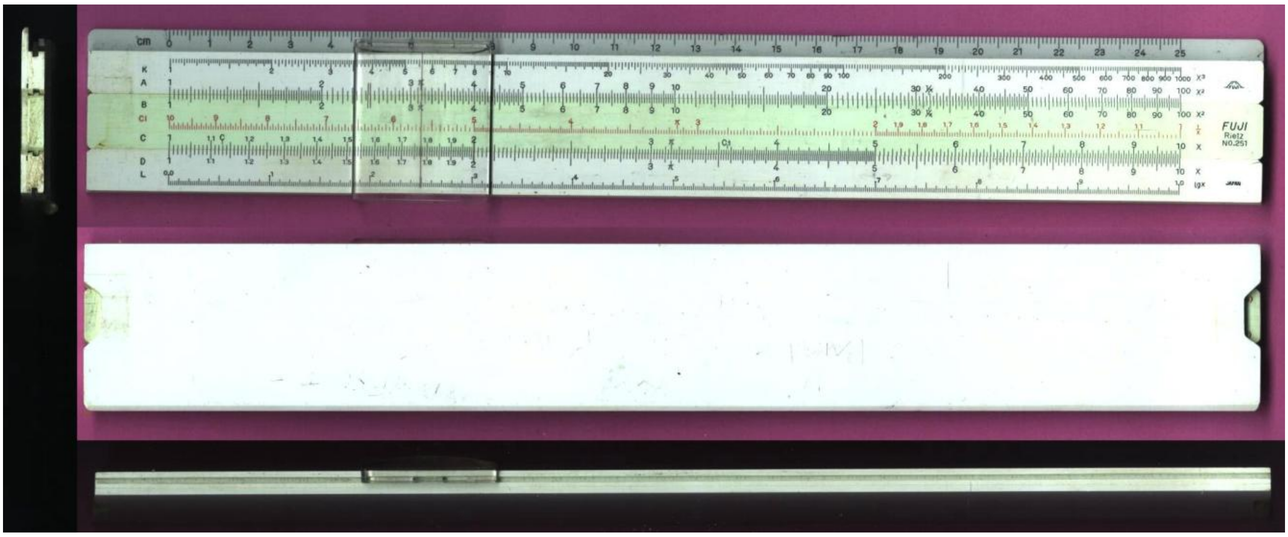
51.- <u>FUJI 208</u>

Model	208
Front Face Scales	cm//K, E, A//B, CI, C//D, LL3, LL2, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	25
Type	Single
Name	Electro
Catalogue Referenced in	2
Comments	"Electro" model (E is Volt and Dynamo-Motor scales)

52.- FUJI 251

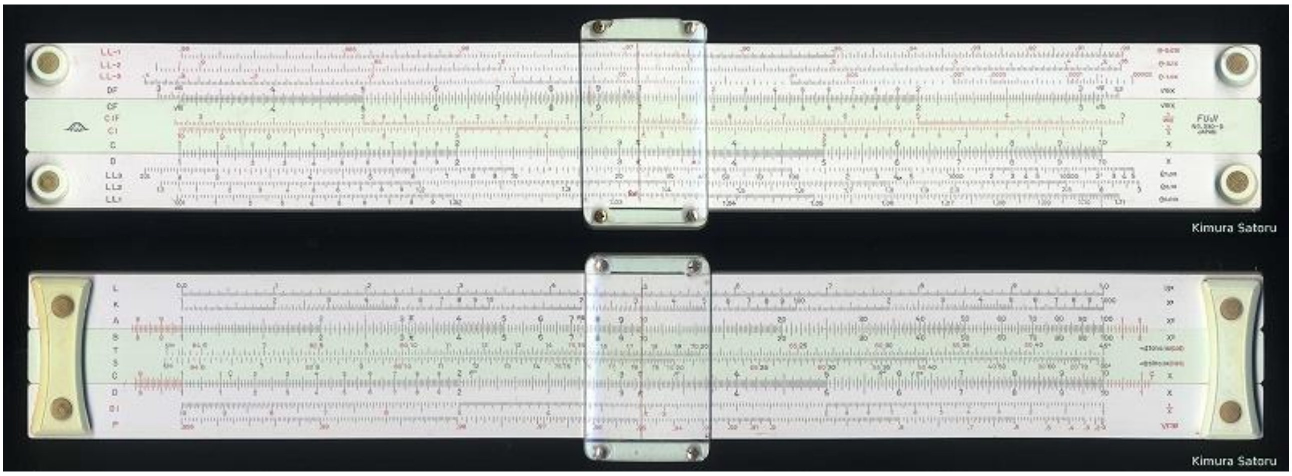






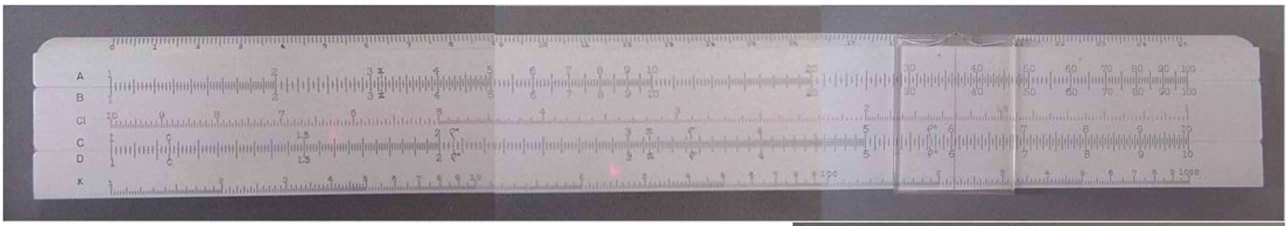
Model	251
Front Face Scales	K, A//B, CI, C//D, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	25
Type	Single
Name	Rietz
Catalogue Referenced in	2
Data in Back (no duplex)	Blank
Made in Data	Japan
Source	Herman van Herwijnen's catalogue International Slide Rule Museum
Name/Logo	Name and Logo
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	d, q (red \\\ black)
Comments	Being so similar, colour of second cursor marks might be red

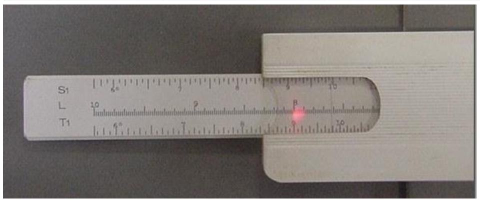
53.- FUJI 330-D

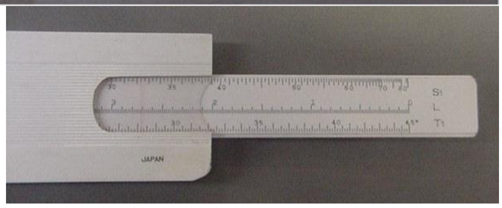


Model	330-D
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	L, K, A//B, T, S, C//D, DI, P
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	Japan
Source	Jap
Name/Logo	Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	light-green runners, double sided
Cursor Marks	kW, d (red)
Comments	The cursor is placed front to back in the specimen. Rounded stoppers opposite to fasteners, both with rubber tips.

54.- FUJI 900





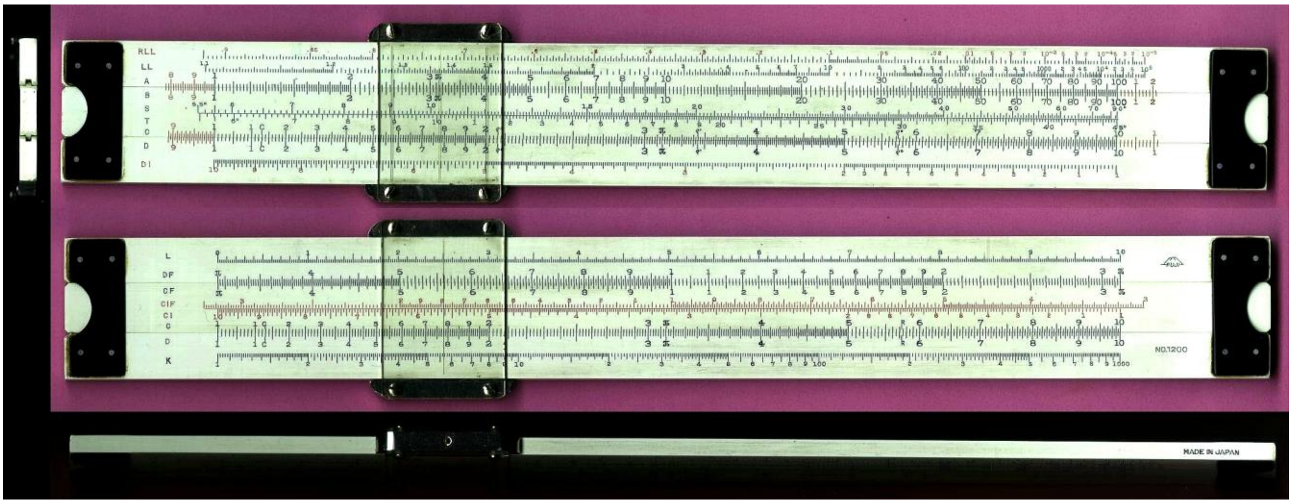


Model	900
Front Face Scales	cm//A//B, CI, C//D, K
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Logo, reference, “Made in”
Made in Data	Japan
Source	Robert Parrish (http://www.antiquesurveying.com)
Name/Logo	Logo
Colours	White
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Windows in back and recessed centre with horizontal lines. In catalogue, cm scale is "m" after "K"

55.- FUJI 1000

Model	1000
Front Face Scales	K, DF, CF, CI, C, D, A, m
Rear Face Scales (or rear slide only)	S, L, T1, T2
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	1
Comments	

56.- FUJI 1200 (1ST VERSION)



Model	1200 (1st version)
Front Face Scales	L, DF//CF, CIF, CI, C//D, K
Rear Face Scales (or rear slide only)	RLL, LL, A//B, S, T, C//D, DI
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	N/A
Made in Data	Made in Japan
Source	International Slide Rule Museum
Name/Logo	Logo
Colours	light-green all rule body with black fasteners
Cursor Materials	metal runners, double sided
Cursor Marks	d, q, both full length (black)
Comments	Body fasteners fixed with four thin rivets per end

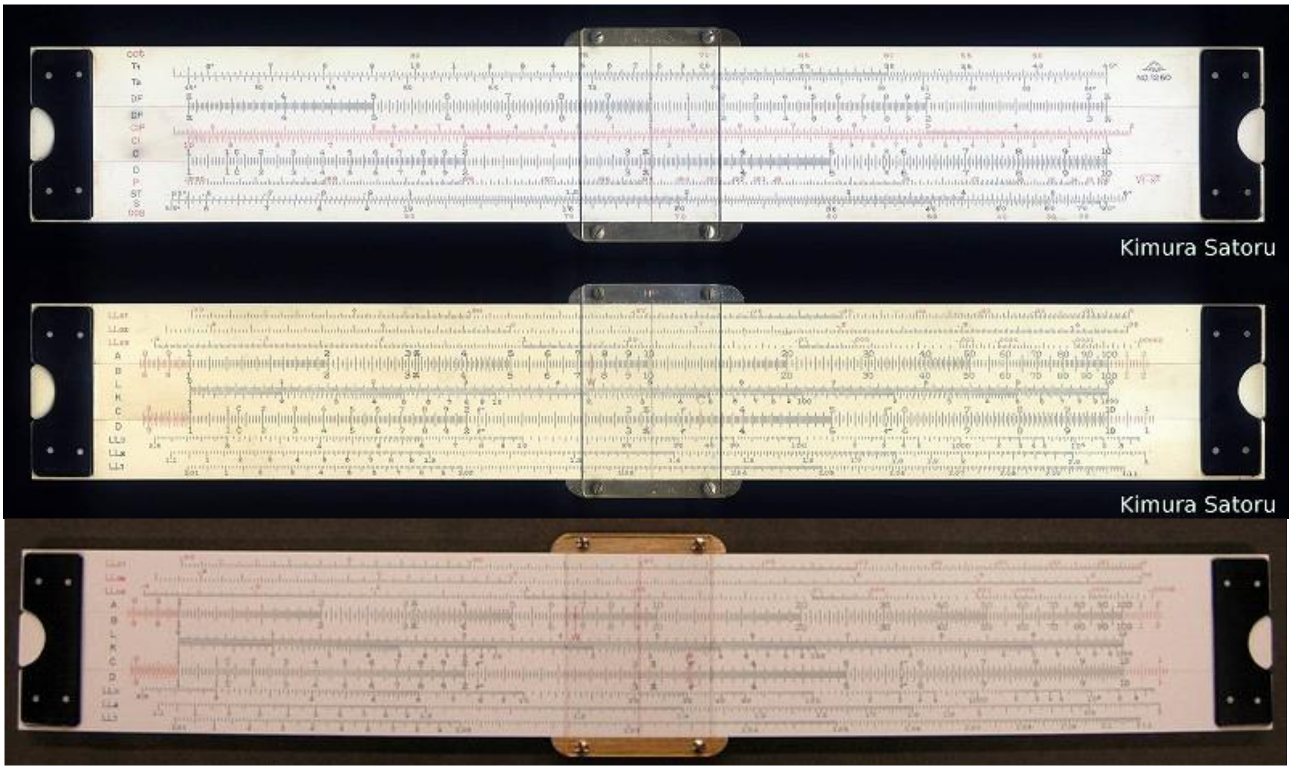
57.- FUJI 1200 (2ND VERSION)

Model	1200 (2nd Version)
Front Face Scales	T1, T2, A//B, BI, CI, C//D, P, S, ST
Rear Face Scales (or rear slide only)	LL1, LL2, LL3, DF//CF, CIF, CI, C//D, K, L, LL0
Size (cm)	25
Type	Duplex
Name	Darmstadt Special
Catalogue Referenced in	2
Comments	Might be referenced as 1200 01 in H.van H. archive.

58.- FUJI 1250 (1ST VERSION)

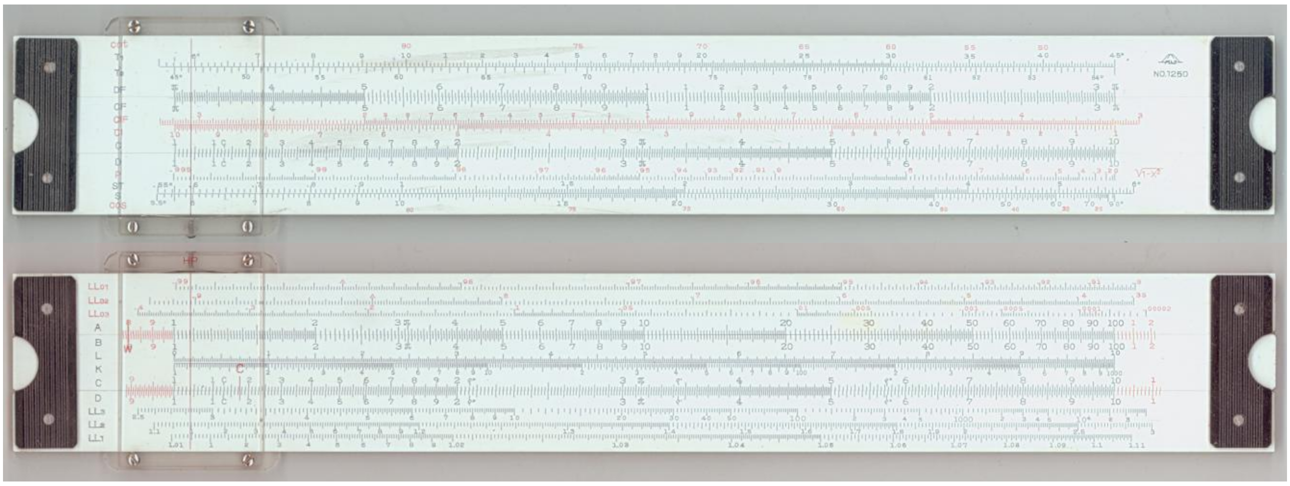
Model	1250 (1st version)
Front Face Scales	LL/1, LL/2, LL/3, A, B, L, K, C, D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	cot, T1, T2, DF, CF, CIF, CI, C, D, P, ST, S, cos
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	1
Comments	

59.- FUJI 1250 (2ND VERSION)



Model	1250 2nd Version
Front Face Scales	T, ST, DF//CF, CIF, CI, C//D, P, S
Rear Face Scales (or rear slide only)	LL01, LL02, LL03, A//B, L, K, C//D, LL3, LL2, LL1
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	N/A
Made in Data	Made in Japan in the border? (like 1200, but not seen in pictures)
Source	www.keisanjyaku.com \\\ http://webmuseum.mit.edu
Name/Logo	Logo
Colours	white body with black fasteners
Cursor Materials	metal runners, double sided \\\ gold-plated? metal runners, double sided
Cursor Marks	// d, W (red)
Comments	Body fasteners fixed with four thin rivets per end

60.- FUJI 1250 (3^{RD} VERSION)



Model	1250 3^{rd} Version
Front Face Scales	cot, T1, T2, DF//CF, CIF, CI, C//D, P, ST, S, cos
Rear Face Scales (or rear slide only)	LL01, LL02, LL03, A \\\ B, L, K, C \\\ D, LL3, LL2, LL1
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	N/A
Made in Data	---
Source	Giovanni Breda (www.sliderule.it)
Name/Logo	Logo
Colours	white body with black fasteners (having vertical lines)
Cursor Materials	Transparent plastic runners, double sided
Cursor Marks	d, W (red)
Comments	Body fasteners fixed with two thin rivets per end

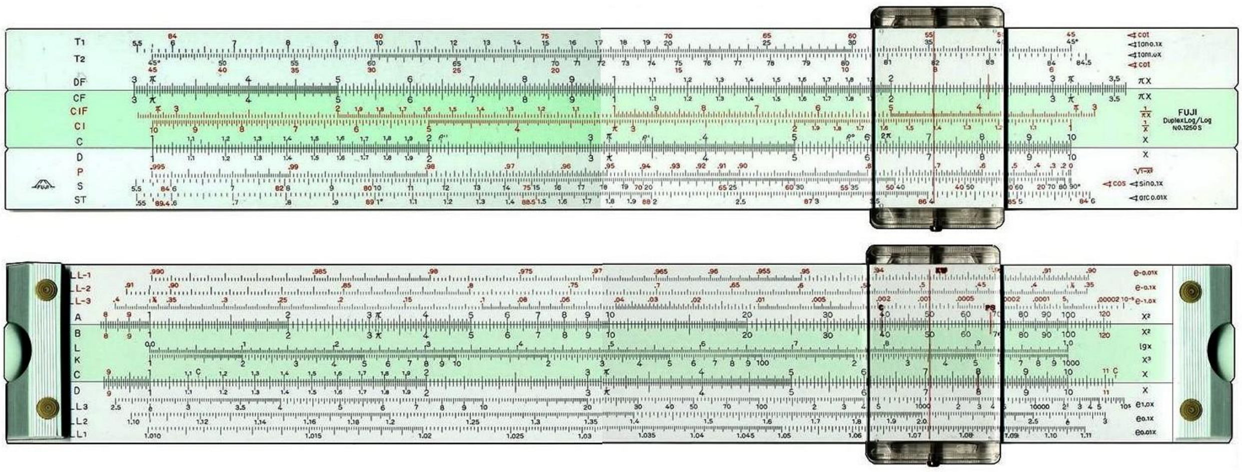
61.- FUJI 1250 (4TH VERSION)

Model	1250 4th Version
Front Face Scales	T, ST, DF//CF, CIF, CI, C//D, P, S
Rear Face Scales (or rear slide only)	LL01, LL02, LL03, A \\\ B, L, K, C \\\ D, LL3, LL2, LL1
Size (cm)	25
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	Japan
Source	Owned specimen
Name/Logo	Name and Logo
Colours	Light-green slide and light-brown fasteners
Cursor Materials	One runner light-green, one runner light-brown, double sided
Cursor Marks	d, W (red)
Comments	Rounded stoppers opposite to fasteners, both with rubber tips

62.- FUJI 1250 S (1^{ST} VERSION)

Model	1250 S (1^{st} Version)
Front Face Scales	LL01, LL02, LL03, A, B, L, K, C, D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	T, ST, DF, CF, CIF, CI, C, D, P, S, T1, T2
Size (cm)	25
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	2
Comments	

63.- FUJI 1250 S (2ND VERSION)

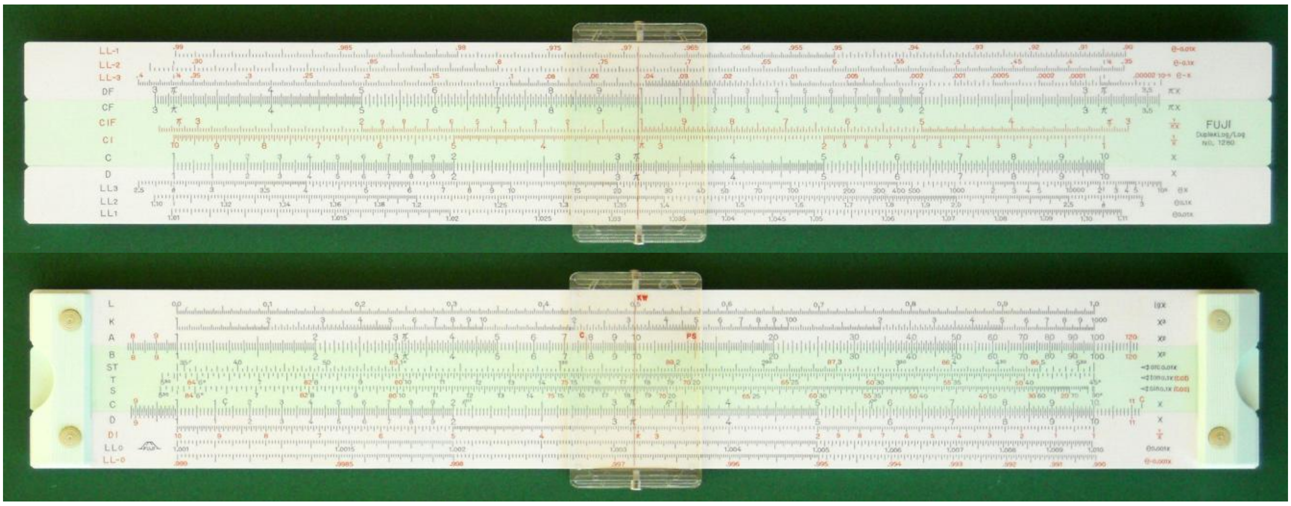


Model	1250 S 2nd Version
Front Face Scales	T1, T2, DF//CF, CIF, CI, C//D, P, S, ST
Rear Face Scales (or rear slide only)	LL-1, LL-2, LL-3, A//B, L, K, C//D, LL3, LL2, LL1
Size (cm)	25
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	none
Data in Back (no duplex)	N/A
Made in Data	none
Source	Herman van Herwijnen's catalogue
Name/Logo	Name and Logo
Colours	lignt-green slide and fasteners
Cursor Materials	Transparent, double sided
Cursor Marks	36 \\\ PS, q, d (red)
Comments	Round rubber tips on fasteners

64.- FUJI 1280 (1^{ST} VERSION)

Model	1280 (1^{st} version)
Front Face Scales	LL/1, LL/2, LL/3, DF, CF, CIF, CI, C, D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	L, K, A, B, ST, T1, cot, S, cos, C, D, DI, LL0, LL/0
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	1
Comments	

65.- FUJI 1280 (2ND VERSION)



Model	1280 (2nd version)
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	L, K, A//B, ST, T, S, C//D, DI, LL0, LL-0
Size (cm)	25
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	2
Data in Back (no duplex)	N/A
Made in Data	Japan (in the slide under a fastener)
Source	Owned specimen
Name/Logo	Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, double sided
Cursor Marks	36 // PS, q, d (red)
Comments	Round rubber tops on fasteners

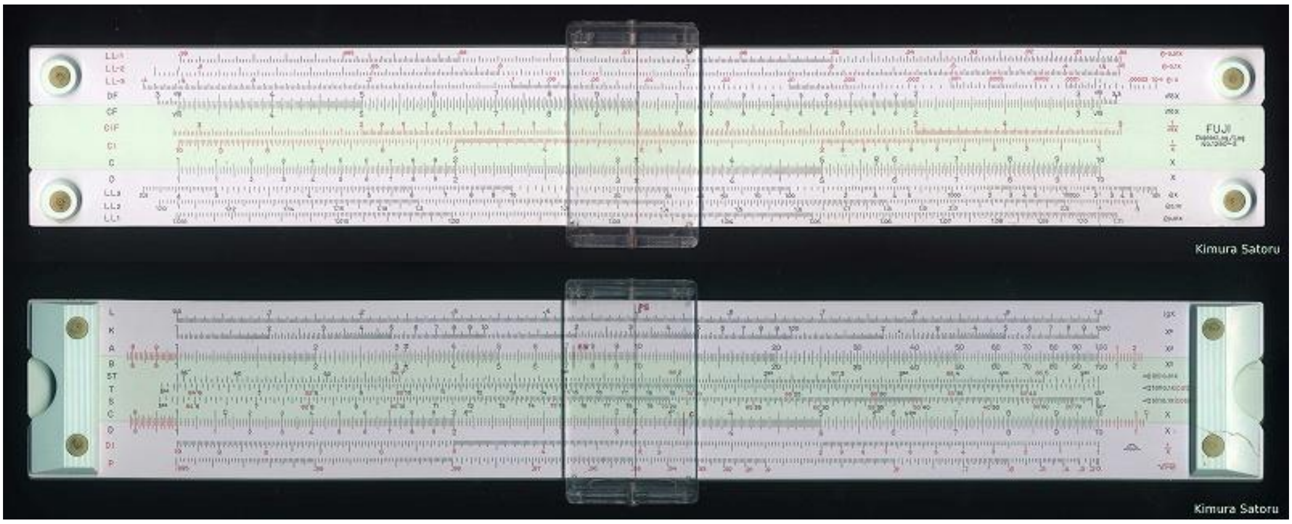
66.- FUJI 1280 (3RD VERSION)

Model	1280 (3rd version)
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	L, K, A//B, ST, T, S, C//D, DI, LL0, LL-0
Size (cm)	25
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	2
Data in Back (no duplex)	N/A
Made in Data	Not seen
Source	steves-sliderules.info
Name/Logo	Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	light-green runners, double sided
Cursor Marks	// kW, d(red)
Comments	Round rubber tops on fasteners. "For electrical mechanical engineers" on front face

67.- FUJI 1280 (4TH VERSION)

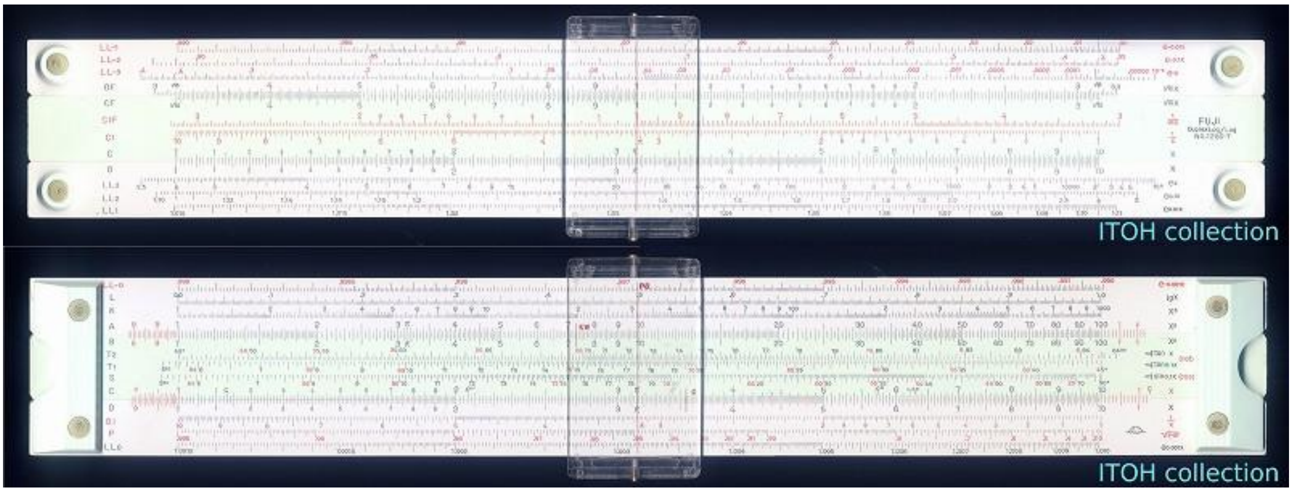
Model	1280 (4th version)
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	L, K, A//B, ST, T1, S, C//D, DI, LL0, LL-0
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	N/A
Made in Data	Japan
Source	Rod Lovett (sliderules.lovett.com)
Name/Logo	Logo
Colours	White body and grey fasteners
Cursor Materials	Transparent, double sided (with separated transparent runners)
Cursor Marks	// W, d (red)
Comments	Long rubber tops on fasteners

68.- FUJI 1280 S



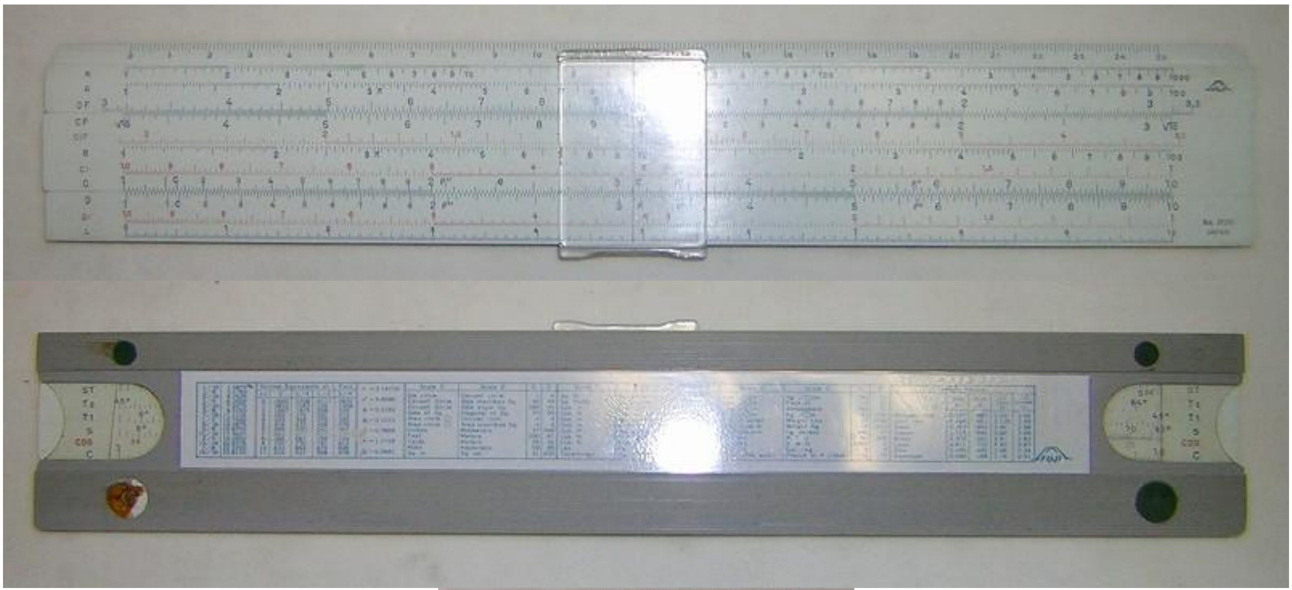
Model	1280 S
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	L, K, A//B, ST, T, S, C//D, DI, P
Size (cm)	25
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	none
Data in Back (no duplex)	N/A
Made in Data	("Japan" might be under a fastener)
Source	www.keisanjyaku.com
Name/Logo	Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, double sided
Cursor Marks	// kW, d (red)
Comments	Rounded stoppers opposite to fasteners, both with rubber tips

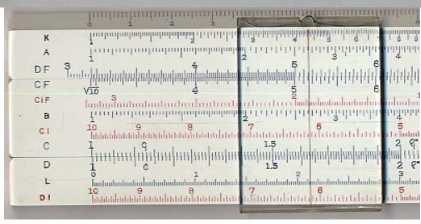
69.- FUJI 1280 T



Model	1280 T
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	LL-0, L, K, A//B, T2, T1, S, C//D, DI, P, LL0
Size (cm)	25
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	none
Data in Back (no duplex)	N/A
Made in Data	("Japan" might be under a fastener)
Source	www.keisanjyaku.com
Name/Logo	Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, double sided
Cursor Marks	// kW, d (red)
Comments	Rounded stoppers opposite to fasteners, both with rubber tips

70.- FUJI 2125





Model	2125
Front Face Scales	cm//K, A, DF//CF, CIF, B, CI, C//D, DI, L \\\ cm//K, A, DF//CF, CIF, B, CI, C//D, L, DI
Rear Face Scales (or rear slide only)	ST, T2, T1, S, cos, C \\\ ?
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	1
Data in Back (no duplex)	Table and Logo \\\ ?
Made in Data	Japan \\\ ?
Source	www.keisanjyaku.com \\\ http://jeykanz.way-nifty.com/jeykanz/
Name/Logo	Logo \\\ ?
Colours	white front body and slide, grey back body
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Rear windows, recessed centre holding the table, and the rest of surfaces with horizontal lines. Rounded rubber tips. \\\ (specimen named as in website)

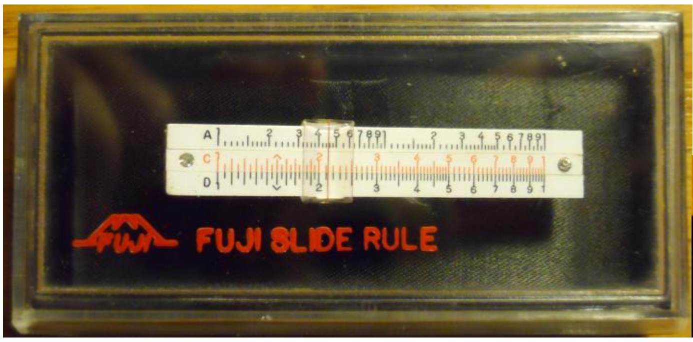
71.- FUJI 2125 C

Model	2125 C
Front Face Scales	cm//K, A, DF//CF, CIF, B, CI, C//D, DI, L
Rear Face Scales (or rear slide only)	ST, T2, T1, S, C
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	Table
Made in Data	Japan
Source	www.keisanjyaku.com
Name/Logo	Logo
Colours	white front body, green slide and grey back body
Cursor Materials	Transparent, single sided
Cursor Marks	None (black hairline)
Comments	Rear windows, recessed centre holding the table, and the rest of surfaces with horizontal lines. Rounded rubber tips.

72.- FUJI 2125 D

Model	2125 D
Front Face Scales	cm//K, A, DF//CF, CIF, B, CI, C//D, DI, L
Rear Face Scales (or rear slide only)	ST, T2, T1, S, C
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	Table
Made in Data	Japan
Source	www.keisanjyaku.com
Name/Logo	Name and Logo
Colours	white front body, green slide and white-grey back body
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Rear windows, recessed centre holding the table, and the rest of surfaces with horizontal lines. Rounded rubber tips.

73.- FUJI TIE CLIP




Model	Tie Clip
Front Face Scales	A//C//D
Rear Face Scales (or rear slide only)	blank
Size (cm)	3,8
Type	Single
Name	T.B
Catalogue Referenced in	1
Data in Back (no duplex)	Blank, "Made in"
Made in Data	Japan
Source	Owned specimen
Name/Logo	none
Colours	white
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	In a demonstration box. One "glass diamond" at each end of the slide.

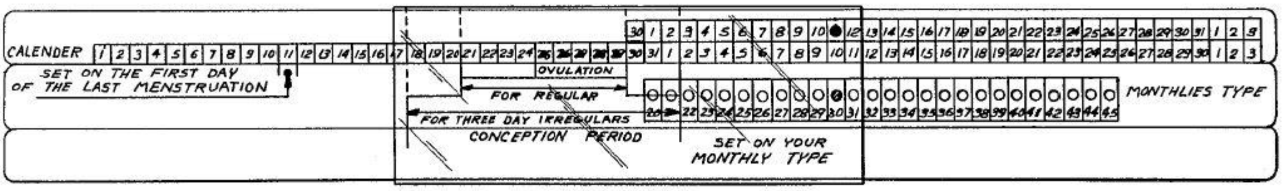
74.- FUJI 2

Model	2
Front Face Scales	K, DF, CF, CI, C, D, A
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	120
Type	Single
Name	---
Catalogue Referenced in	1
Comments	Teaching slide rule

75.- FUJI 3

Model	2
Front Face Scales	K, A, DF, CF, CIF, CI, C, D, DI, L
Rear Face Scales (or rear slide only)	T2, T1, S, C
Size (cm)	120
Type	Single
Name	---
Catalogue Referenced in	1
Comments	Teaching slide rule

76.- FUJI B.C



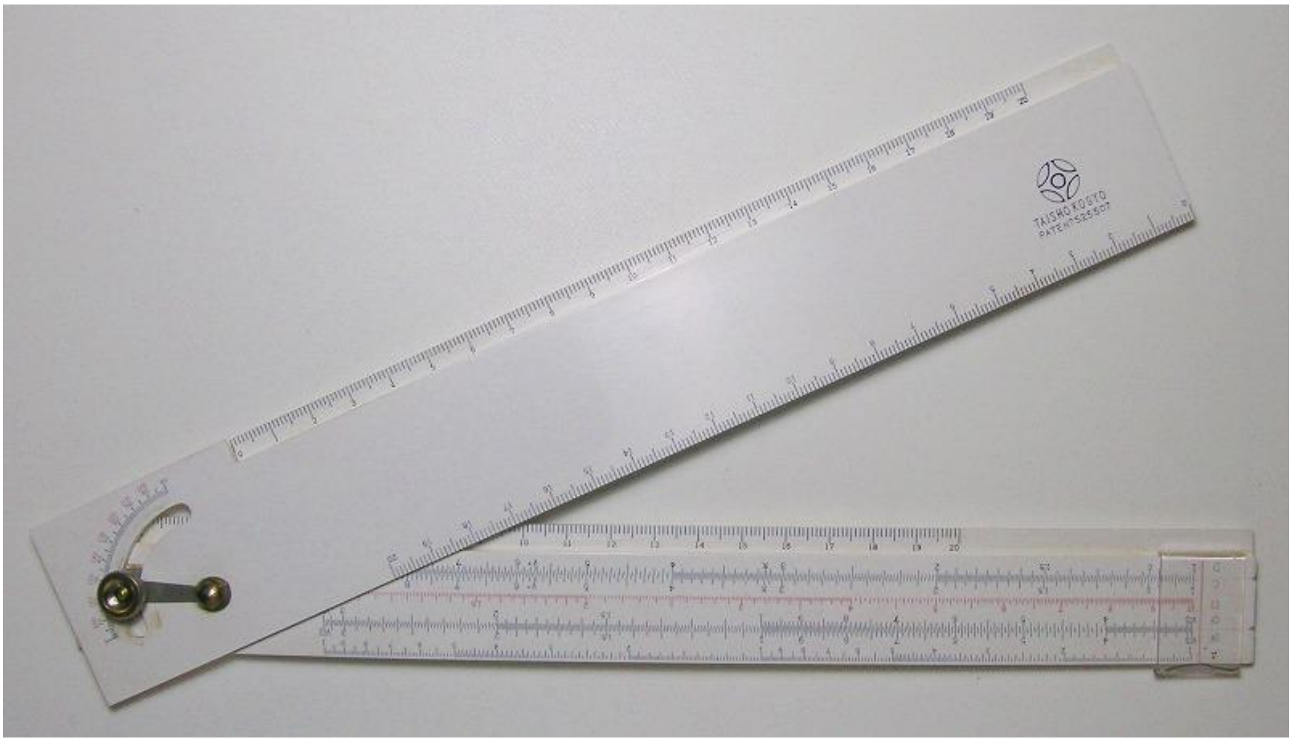
Model	B.C
Front Face Scales	"Birth Control"
Rear Face Scales (or rear slide only)	"Calculating Scale"
Size (cm)	16
Type	Single
Name	Birth Control
Catalogue Referenced in	1
Comments	Image from patent US3146943A

77.- FUJI PENLOG



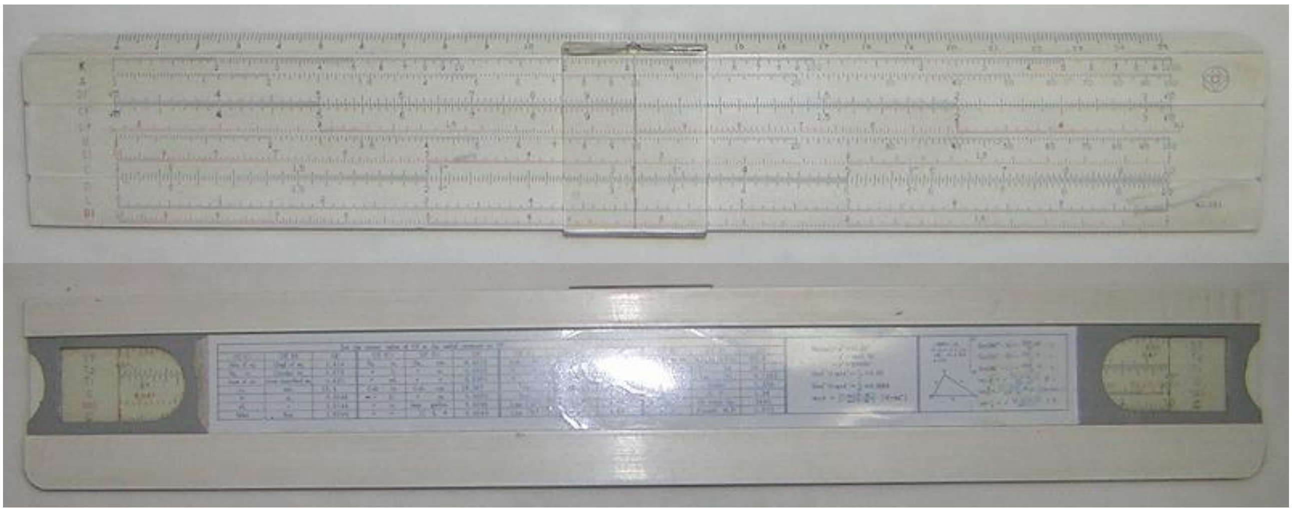
Model	PenLog
Front Face Scales	CI, C, D
Rear Face Scales (or rear slide only)	---
Size (cm)	13 x 1 x 0,4 (without clip)
Type	Single
Name	PenLog
Catalogue Referenced in	Patent JP47-005203 Y
Data in Back (no duplex)	cm, inches
Made in Data	None
Source	http://z-iimono.shop-pro.jp
Name/Logo	None
Colours	Light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Slide rule in the size and shape of a pen, (with clip)

78.- TAISHO 210



Model	Taisho 210
Front Face Scales	cm//A, DF//CF, CI, C//D
Rear Face Scales (or rear slide only)	Blank
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	Table
Made in Data	None
Source	www.keisanjyaku.com
Name/Logo	Taisho Logo and Name (Patented model)
Colours	white
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Folding rule complement for angle measurement

79.- TAISHO 251

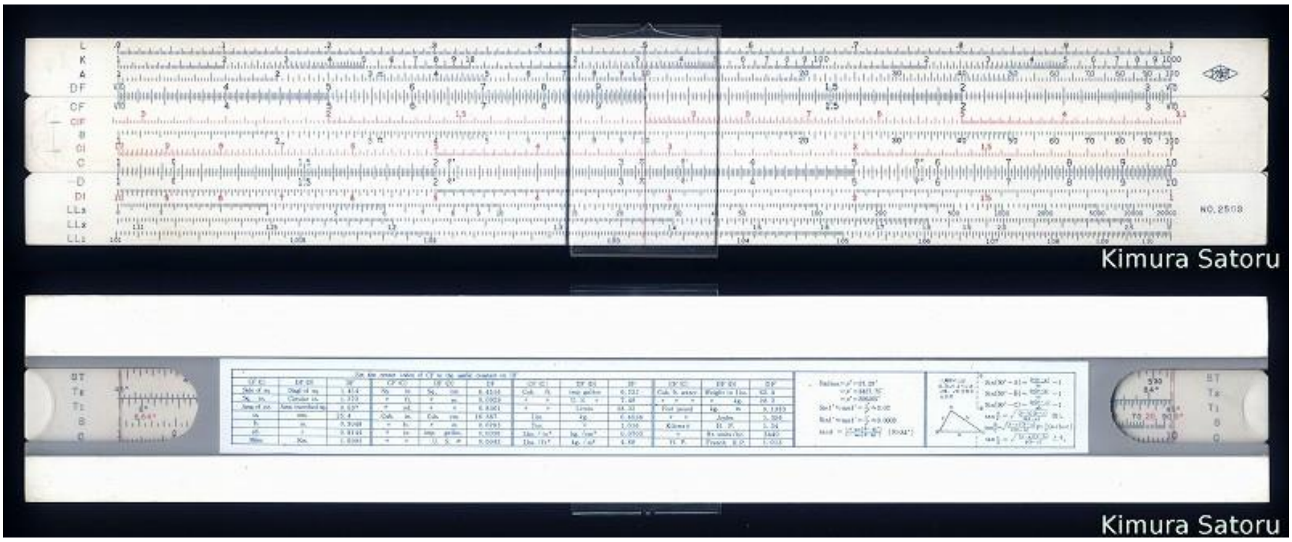


Model	Taisho 251
Front Face Scales	cm//K, A, DF//CF, CIF, B, CI, C//D, L, DI
Rear Face Scales (or rear slide only)	ST, T2, T1, S, cos, C
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	Table
Made in Data	None
Source	www.keisanjyaku.com
Name/Logo	Taisho Logo
Colours	white, grey back window frames
Cursor Materials	Transparent, single sided
Cursor Marks	None (black hairline)
Comments	Rear windows, recessed centre holding the table. Equivalent to Fuji 2521

80.- GIKEN 120

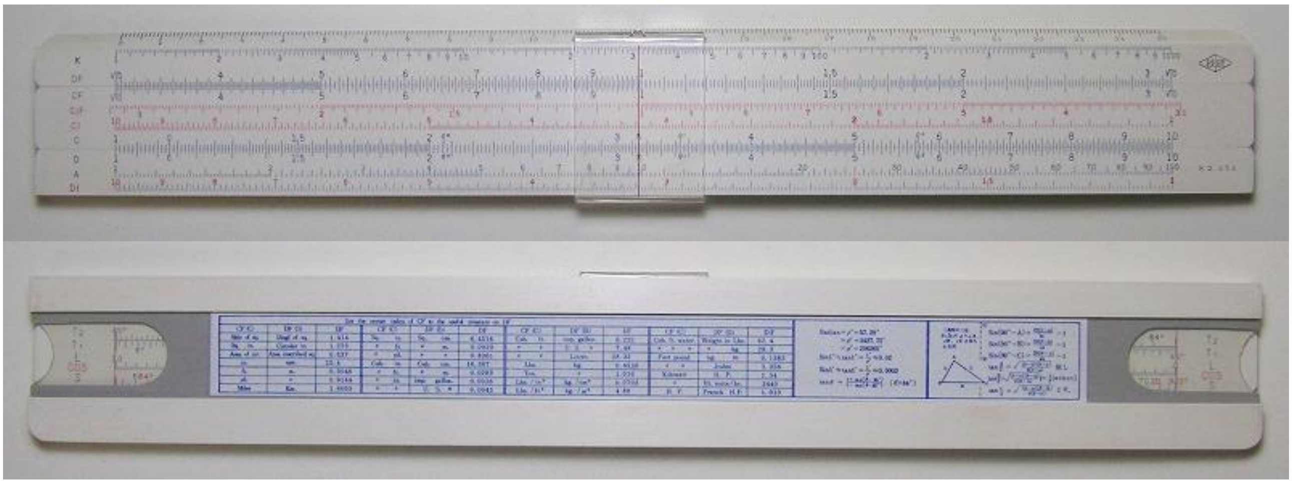
Model	Giken 120
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	?
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	?
Made in Data	?
Source	http://jeykanz.way-nifty.com/jeykanz/
Name/Logo	Giken Logo
Colours	White
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	

81.- GIKEN 250S



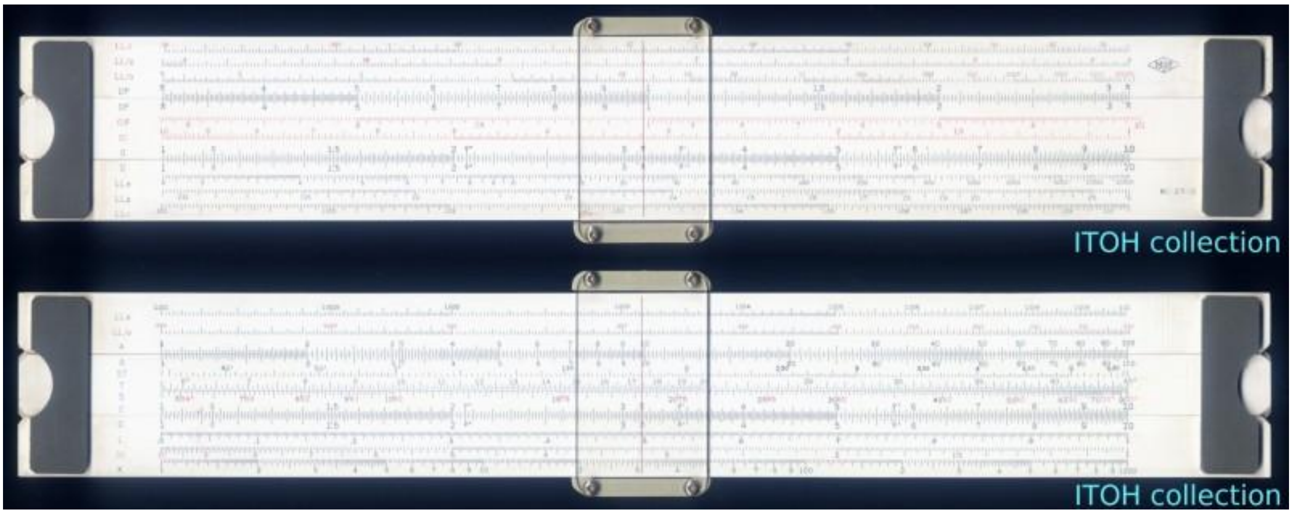
Model	Giken 250S
Front Face Scales	L, K, A, DF//CF, CIF, B, CI, C//D, DI, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	ST, T2, T1, S, C
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Table
Made in Data	None
Source	www.keisanjyaku.com
Name/Logo	Giken Logo
Colours	white, grey back window frames (back central surface)
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Rear windows, recessed centre holding the table.

82.- GIKEN 252



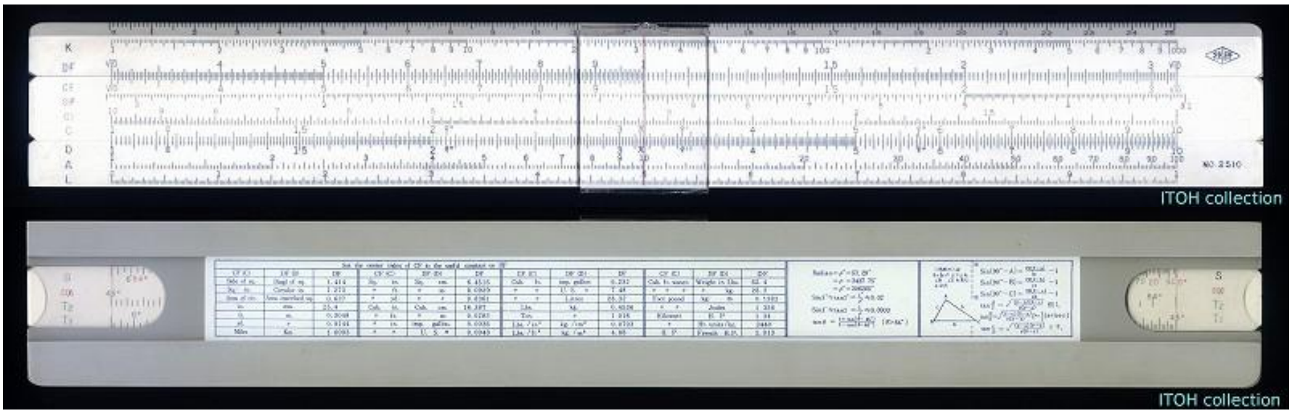
Model	Giken 252
Front Face Scales	K, DF//CF, CIF, CI, C//D, A, DI
Rear Face Scales (or rear slide only)	T2, T1, L, cos, S
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Table
Made in Data	None
Source	www.keisanjyaku.com
Name/Logo	Giken Logo
Colours	white, grey back window frames (back central surface)
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Rear windows, recessed centre holding the table.

83.- GIKEN 2510 (DUPLEX)



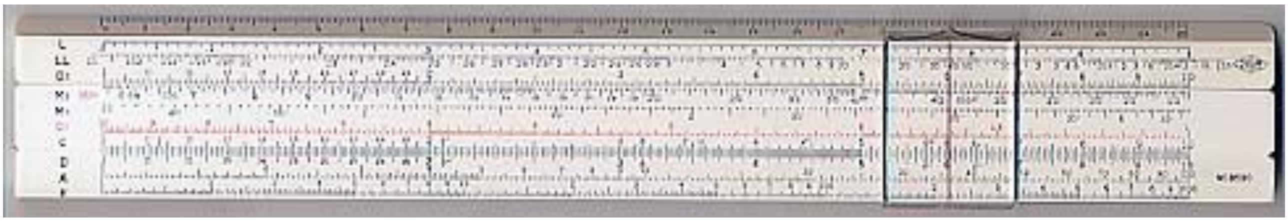
Model	Giken 2510 (Duplex)
Front Face Scales	LL/1, LL/2, LL/3, DF, CF, CIF, CI, C, D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	LL0, LL/0, A//B, ST, T, S, C//D, L, DI, K
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Table
Made in Data	None
Source	www.keisanjyaku.com
Name/Logo	Giken Logo
Colours	white, grey fasteners
Cursor Materials	Anodized aluminium? runners, double sided
Cursor Marks	None (red hairline)
Comments	

84.- GIKEN 2510 (SIMPLEX)



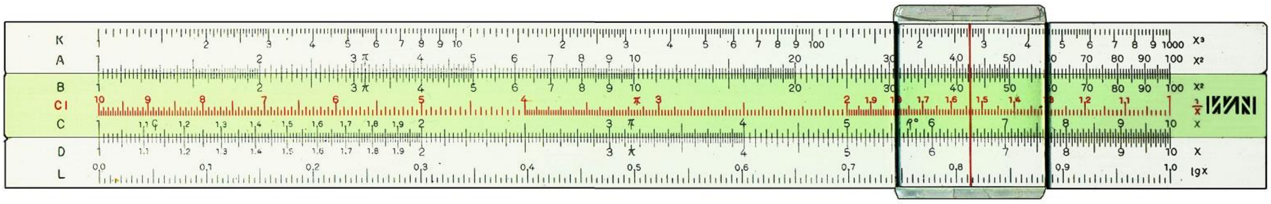
Model	Giken 252
Front Face Scales	K, DF//CF, CIF, CI, C//D, A, L
Rear Face Scales (or rear slide only)	S, cos, T2, T1
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Table
Made in Data	None
Source	www.keisanjyaku.com
Name/Logo	Giken Logo
Colours	White, grey back
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Rear windows, recessed centre holding the table.

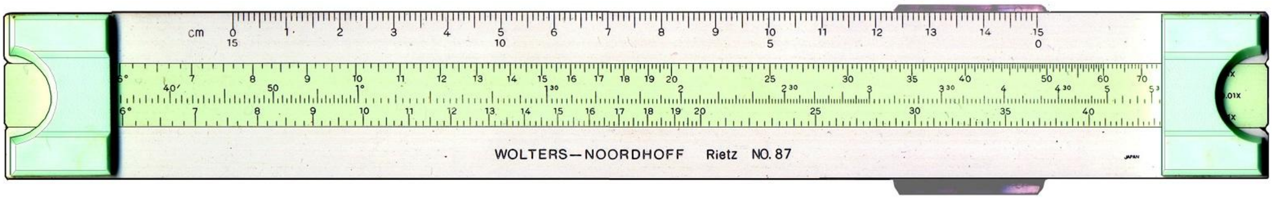
85.- GIKEN 9590



Model	Giken 9590
Front Face Scales	L, LL, D1//M2, M1, CI, C//D, A, K
Rear Face Scales (or rear slide only)	S, ST, T ?
Size (cm)	25
Type	Single
Name	(Stadia?)
Catalogue Referenced in	None
Data in Back (no duplex)	?
Made in Data	?
Source	http://jeykanz.way-nifty.com/jeykanz/
Name/Logo	Giken Logo
Colours	White (grey back?)
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	(specimen named as in website)

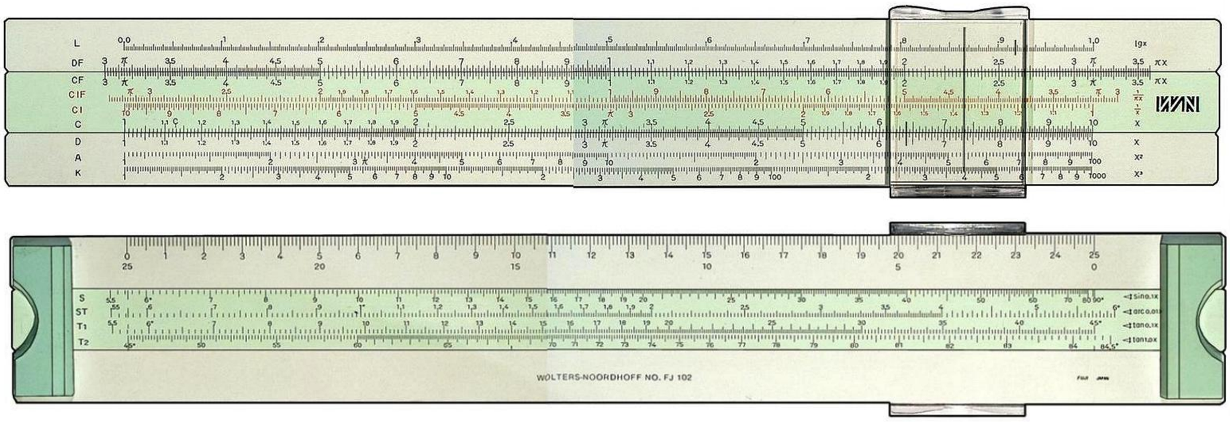
86.- WOLTERS NOORDHOFF 87





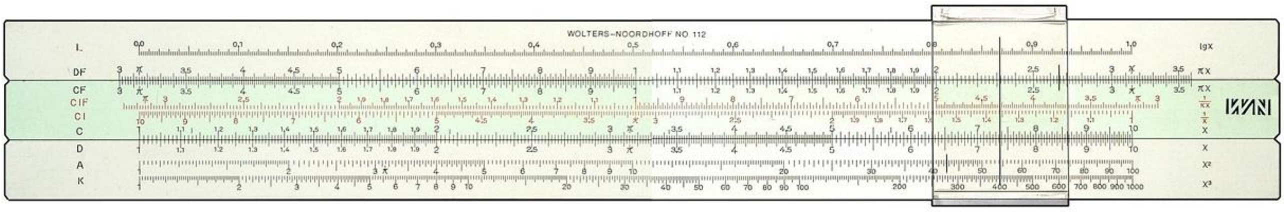
Model	WN 87
Front Face Scales	K, A//B, CI, C//D, L
Rear Face Scales (or rear slide only)	cm//S, ST, T//
Size (cm)	20
Type	Single
Name	Rietz
Catalogue Referenced in	N/A
Data in Back (no duplex)	cm, WN name, Ref., "Manuf"
Made in Data	Japan
Source	Herman van Herwijnen's catalogue
Name/Logo	WN Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Wide fasteners (like Fuji 82 specimen). Similar to Fuji 87

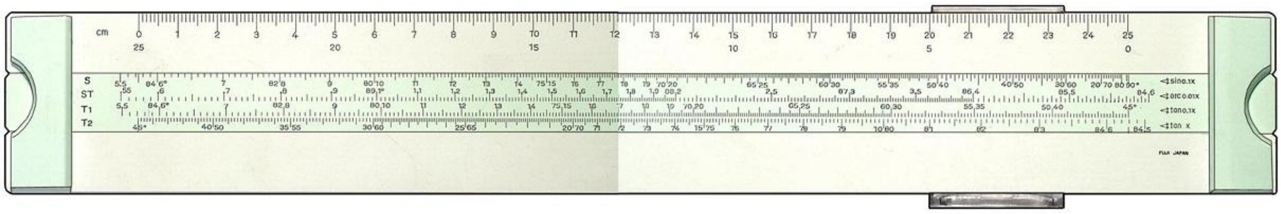
87.- WOLTERS NOORDHOFF FJ102

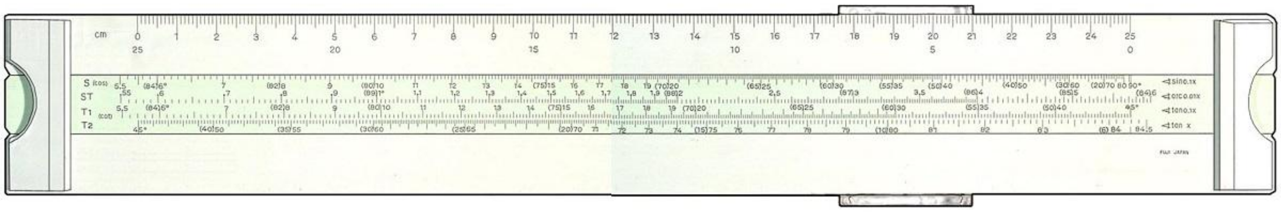


Model	WN FJ102
Front Face Scales	L, DF//CF, CIF, CI, C//D, A, K
Rear Face Scales (or rear slide only)	cm//S, ST, T1, T2//
Size (cm)	25
Type	Simplex
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	cm, WN & Fuji names, "Made in"
Made in Data	Japan
Source	Herman van Herwijnen's catalogue (International Slide Rule Museum)
Name/Logo	WN Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	36, q (black). Upside-down in the picture
Comments	Similar to Fuji 102

88.- WOLTERS NOORDHOFF 112

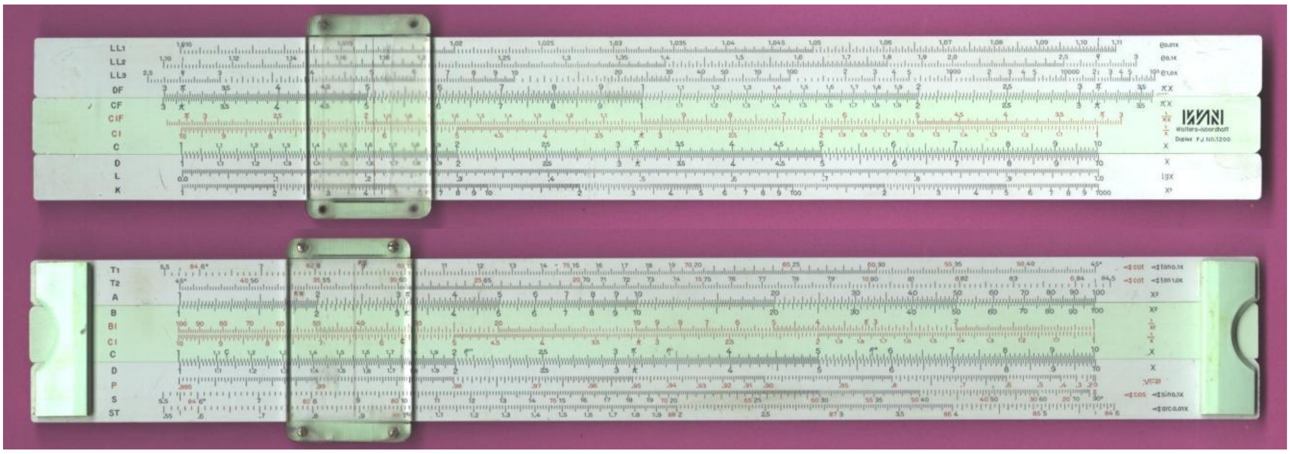






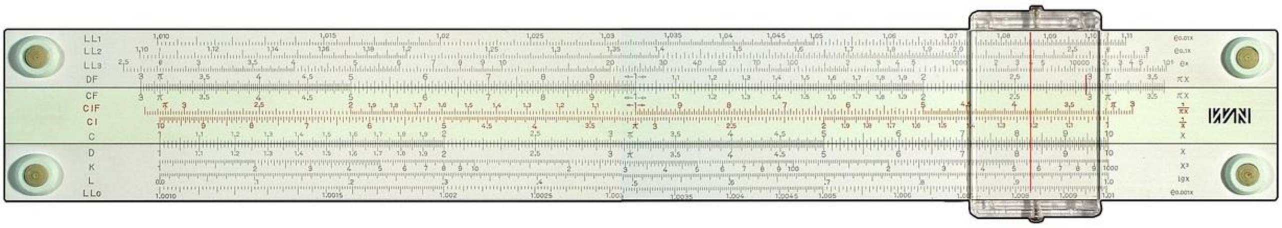
Model	WN 112 (two versions)
Front Face Scales	L, DF//CF, CIF, CI, C//D, A, K
Rear Face Scales (or rear slide only)	cm//S, ST, T1, T2//
Size (cm)	25
Type	Simplex
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	cm, Fuji name, "Made in"
Made in Data	Japan
Source	Herman van Herwijnen's catalogue (International Slide Rule Museum)
Name/Logo	WN Name and Logo
Colours	light-green slide and fasteners \\\ light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	d, q (black)
Comments	Similar to Fuji 102

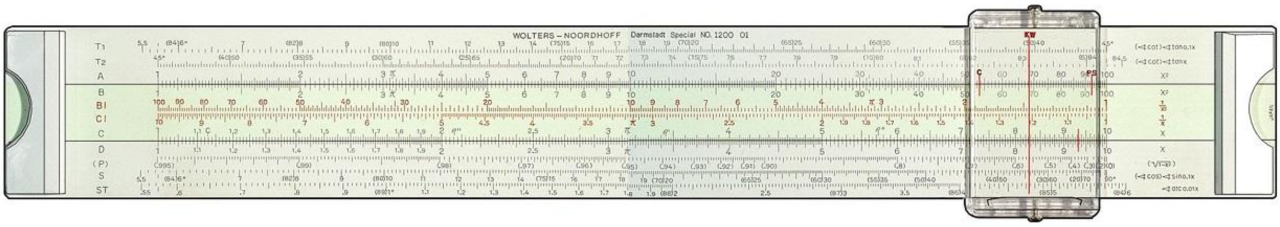
89.- WOLTERS NOORDHOFF FJ1200



Model	WN FJ1200
Front Face Scales	LL1, LL2, LL3, DF//CF, CIF, CI, C//D, L, K
Rear Face Scales (or rear slide only)	T1, T2, A//B, BI, CI, C//D, P, S, ST
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	
Source	International Slide Rule Museum (Herman van Herwijnen's catalogue)
Name/Logo	WN Name and Logo
Colours	light-green slide and fasteners
Cursor Materials	All plastic, light-green runners, double sided
Cursor Marks	// kW, d, (red)
Comments	Similar to Fuji 1200

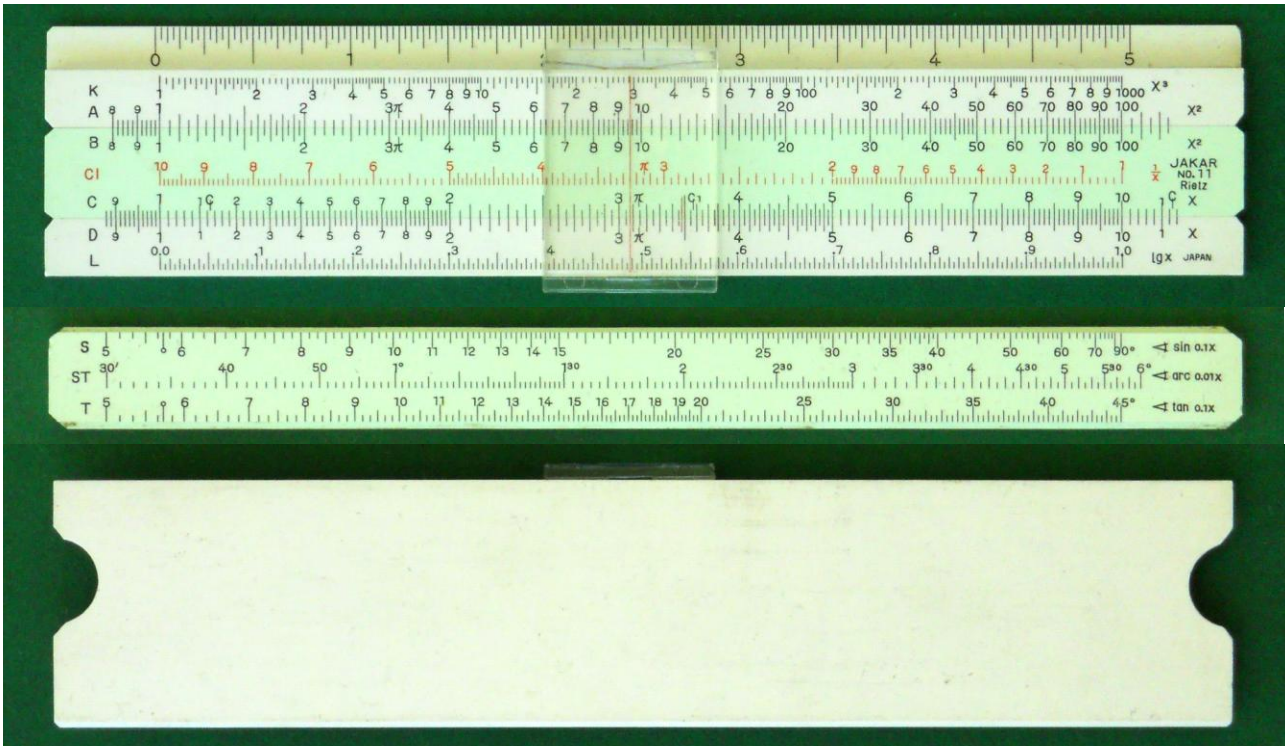
90.- WOLTERS NOORDHOFF 1200 01





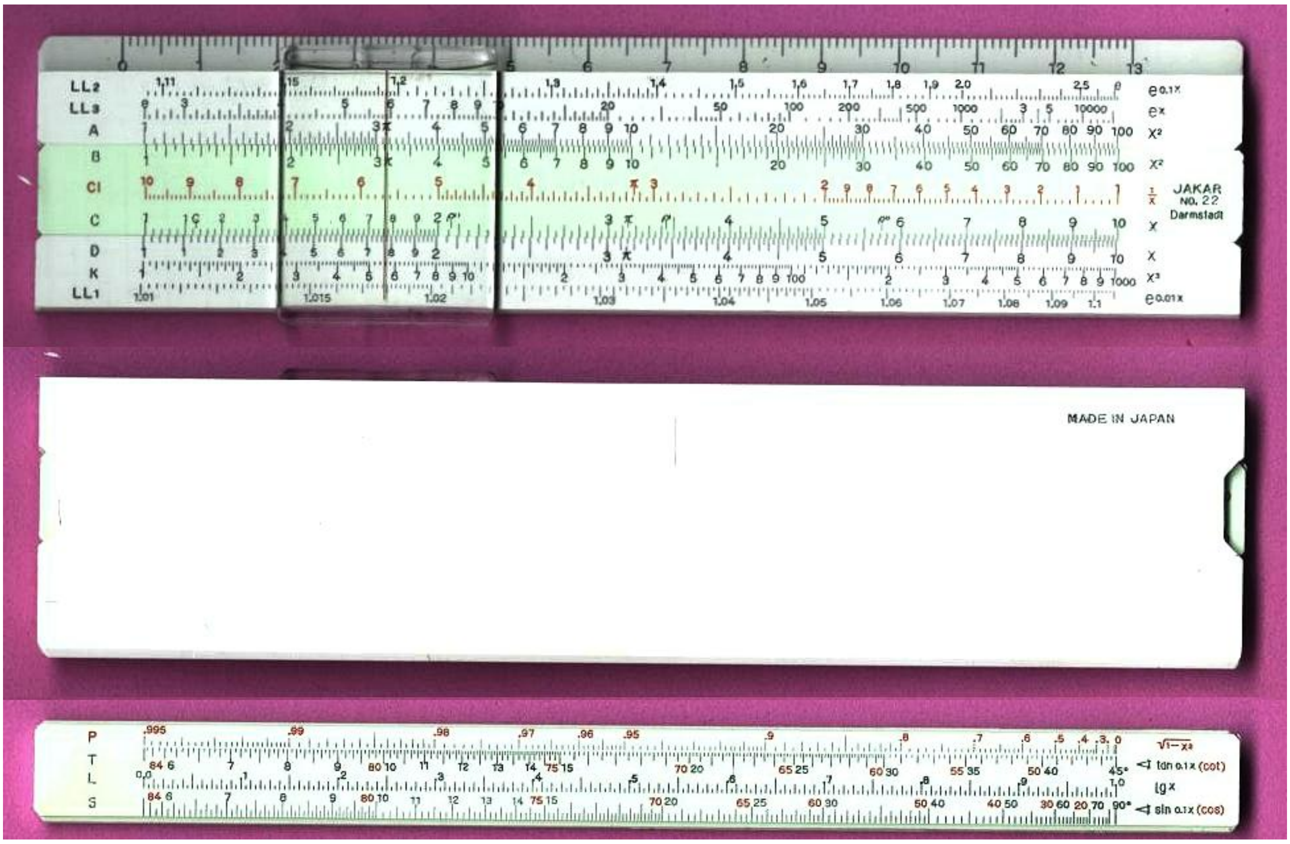
Model	WN 1200 01
Front Face Scales	LL1, LL2, LL3, DF//CF, CIF, CI, C//D, K, L, LL0
Rear Face Scales (or rear slide only)	T1, T2, A//B, BI, CI, C//D, (P), S, ST
Size (cm)	25
Type	Duplex
Name	Darmstadt Special
Catalogue Referenced in	None
Data in Back (no duplex)	cm, WN name, "Made in"
Made in Data	Japan
Source	Herman van Herwijnen's catalogue
Name/Logo	WN Name and Logo
Colours	light-green slide
Cursor Materials	Transparent, double sided
Cursor Marks	36 \\\ PS, d, q (red)
Comments	Rounded stoppers opposite to fasteners, both with rubber tips. Similar to Fuji 1200 (a 2nd version also referenced but without pictures)

91.- JAKAR 11



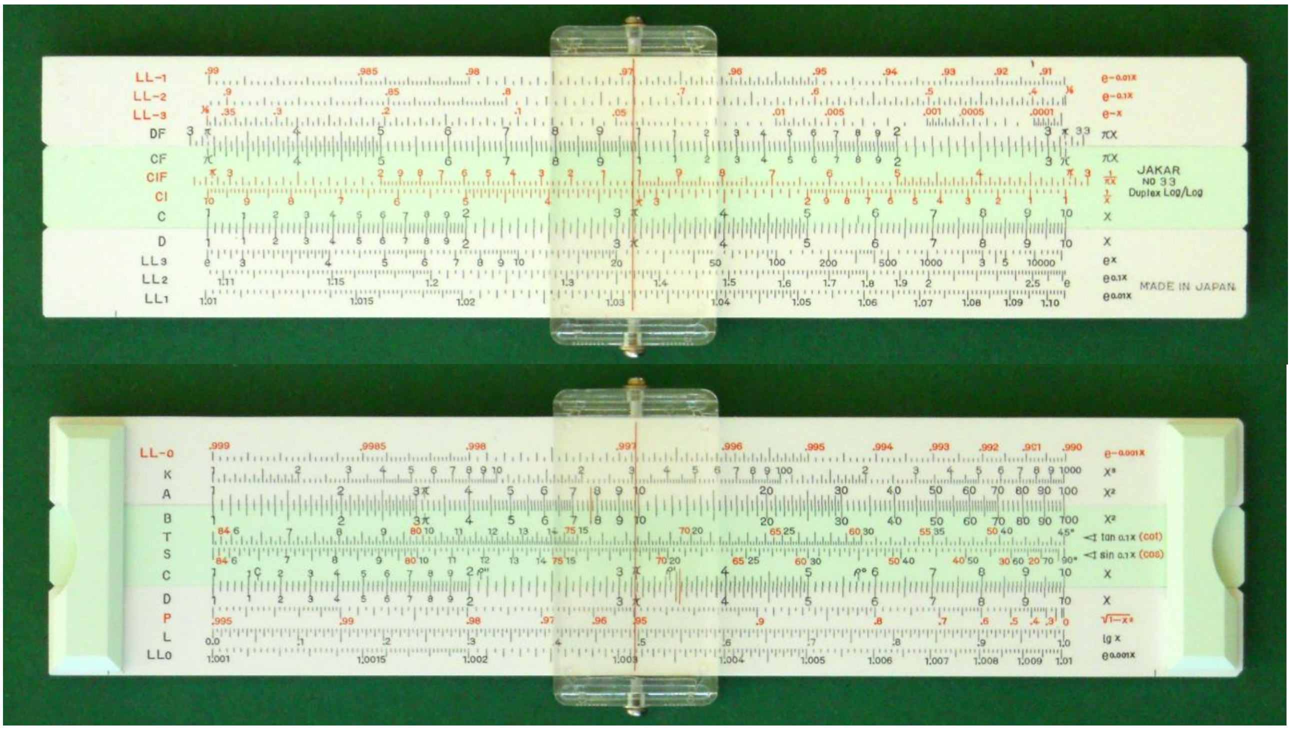
Model	Jakar 11
Front Face Scales	K, A//B, CI, C//D, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	12,5
Type	Single
Name	Rietz
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	Japan
Source	Owned specimen
Name/Logo	Jakar name
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	d (red)
Comments	Similar to Fuji 505

92.- <u>JAKAR 22</u>



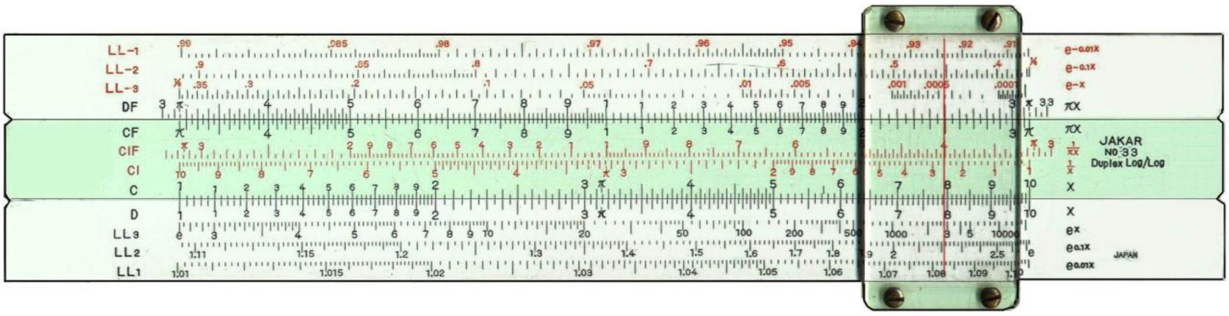
Model	Jakar 22
Front Face Scales	LL2, LL3, A/B, CI, C//D, K, LL1
Rear Face Scales (or rear slide only)	P, T, L, S
Size (cm)	12,5
Type	Single
Name	Darmstadt
Catalogue Referenced in	none
Data in Back (no duplex)	blank, "Made in"
Made in Data	Made in Japan
Source	International Slide Rule Museum
Name/Logo	Jakar Name
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	None (black hairline)
Comments	Similar to Fuji 515P

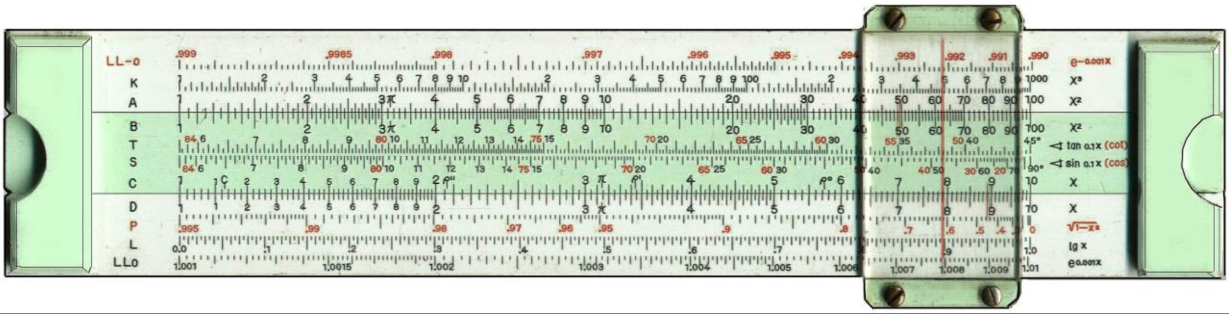
93.- JAKAR 33 (1ST VERSION)



Model	Jakar 33 (1st Version)
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	LL-0, K, A//B, T, S, C//D, P, L, LL0
Size (cm)	12,5
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	Made in Japan
Source	Owned specimen (International Slide Rule Museum)
Name/Logo	Jakar Name
Colours	light-green slide and fasteners
Cursor Materials	Transparent, double sided
Cursor Marks	// d, q (red)
Comments	Similar to Fuji 552P

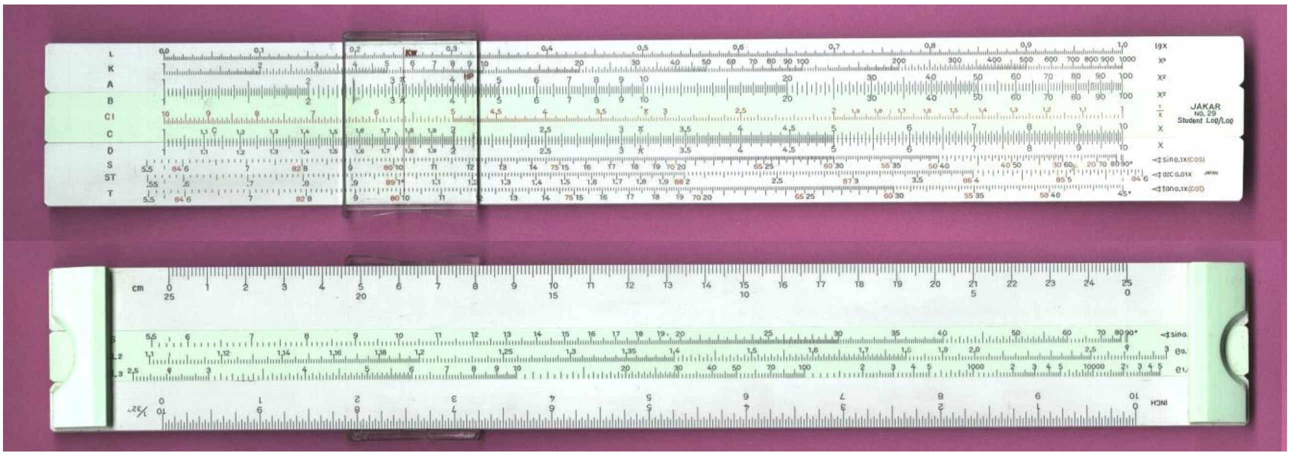
94.- JAKAR 33 (2ND VERSION)





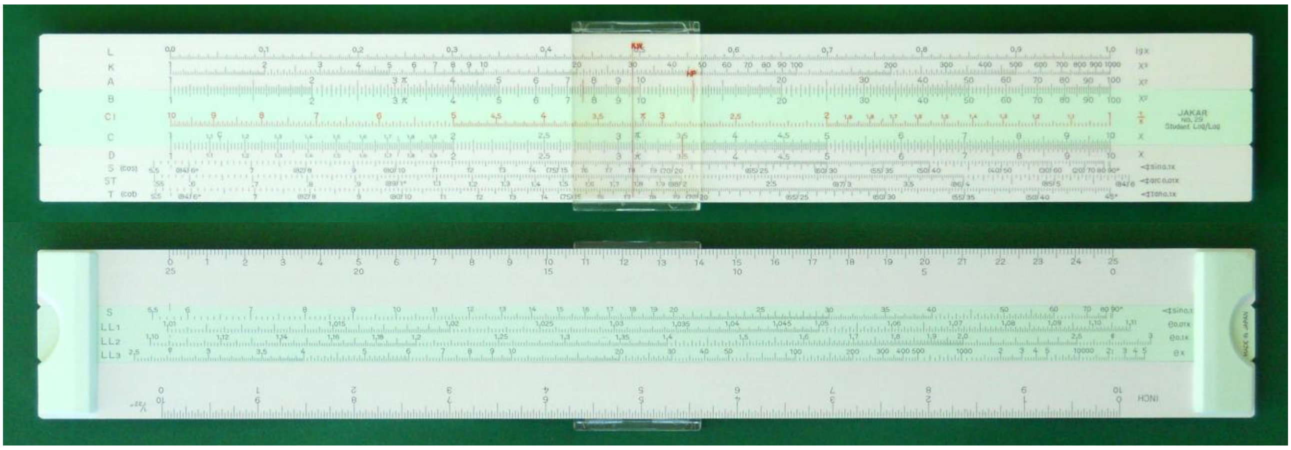
Model	Jakar 33 (2nd version)
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	LL-0, K, A//B, T, S, C//D, P, L, LL0
Size (cm)	12,5
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	Japan
Source	Herman van Herwijnen's catalogue
Name/Logo	Name
Colours	Light-green slide and fasteners
Cursor Materials	All plastic with light-green runners, double sided
Cursor Marks	d, q (red)
Comments	Similar to Fuji 552P

95.- JAKAR 29 (1ST VERSION)



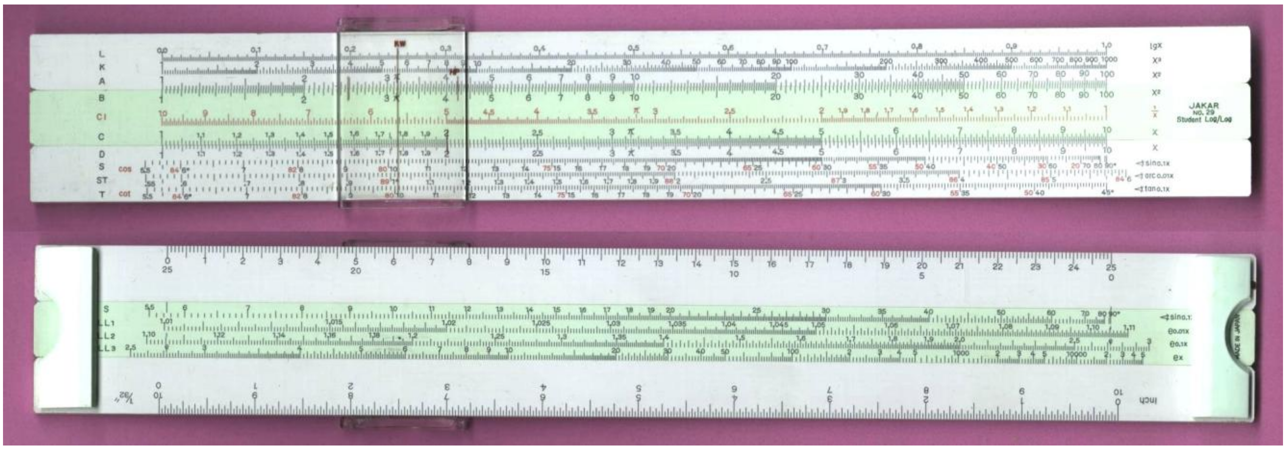
Model	Jakar 29
Front Face Scales	L, K, A//B, CI, C//D, S, ST, T
Rear Face Scales (or rear slide only)	cm//S, LL2, LL3//inches
Size (cm)	25
Type	Single
Name	Student log/log
Catalogue Referenced in	None
Data in Back (no duplex)	cm, inches
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Jakar name
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	HP, q, d (red)
Comments	Nearly similar to Fuji 129 01

96.- JAKAR 29 (2ND VERSION)



Model	Jakar 29 (2nd version)
Front Face Scales	L, K, A//B, CI, C//D, S, ST, T
Rear Face Scales (or rear slide only)	cm//S, LL1, LL2, LL3//inches
Size (cm)	25
Type	Single
Name	Student log/log
Catalogue Referenced in	None
Data in Back (no duplex)	cm, inches
Made in Data	Made in Japan
Source	Owned specimen
Name/Logo	Jakar name
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	HP, q, d (red)
Comments	Similar to Fuji 129 01. "(cos)" indication in black. Text at front right, left aligned.

97.- JAKAR 29 (3RD VERSION)

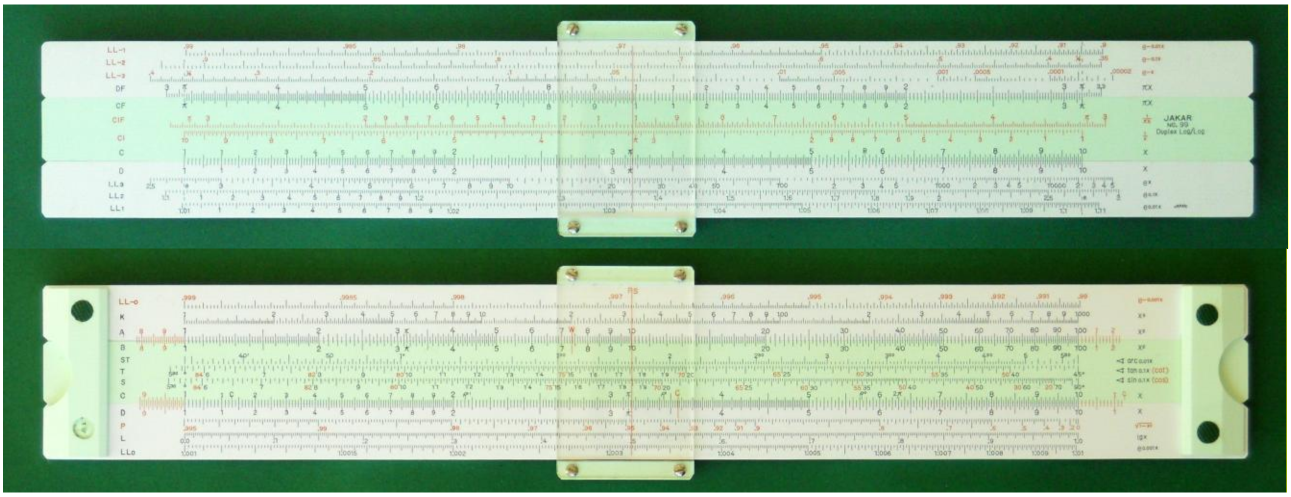


Model	Jakar 29 (3rd version)
Front Face Scales	L, K, A//B, CI, C//D, S, ST, T
Rear Face Scales (or rear slide only)	cm//S, LL1, LL2, LL3//inches
Size (cm)	25
Type	Single
Name	Student log/log
Catalogue Referenced in	None
Data in Back (no duplex)	cm, inches
Made in Data	Made in Japan
Source	International Slide Rule Museum
Name/Logo	Jakar name
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	HP, q, d (red)
Comments	Similar to Fuji 129 01. "cos" indication in red. Scales text at front right centred.

98.- JAKAR 66

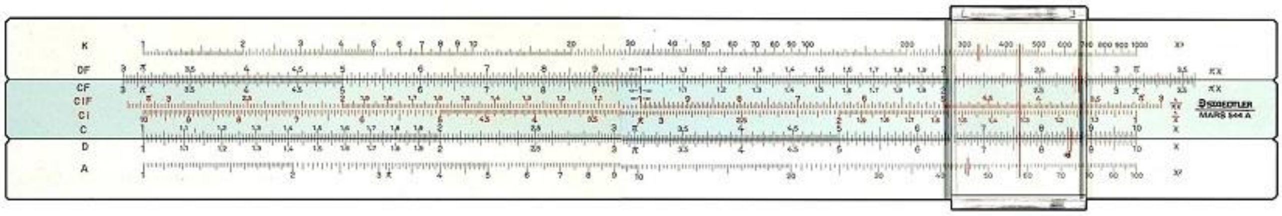
Model	Jakar 66
Front Face Scales	inches//K, E, A//B, CI, C//D, LL3, LL2, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	25
Type	Single
Name	Electro
Catalogue Referenced in	none
Data in Back (no duplex)	blank
Made in Data	Japan
Source	Owned specimen (International Slide Rule Museum)
Name/Logo	Jakar name
Colours	light-green slide
Cursor Materials	Transparent, double sided
Cursor Marks	HP, q, d (red)
Comments	Similar to Fuji 208

99.- JAKAR 99



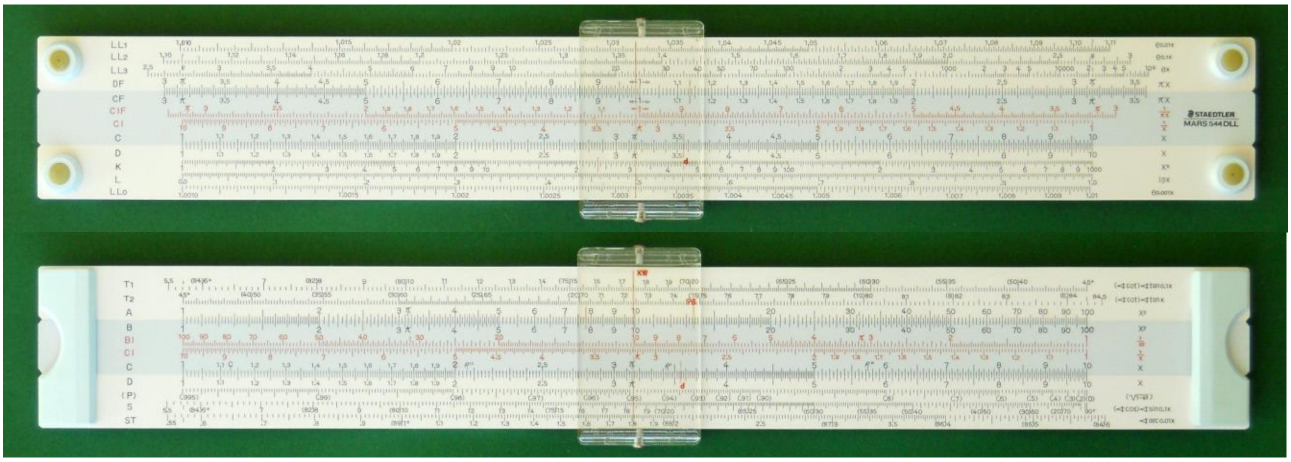
Model	Jakar 99
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	LL-0, K, A//B, ST, T, S, C//D, P, L, LL0
Size (cm)	25
Type	Duplex
Name	Duplex log/log
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	Japan
Source	Owned specimen
Name/Logo	Jakar Name
Colours	light-green slide and fasteners
Cursor Materials	light-green runners, double sided
Cursor Marks	// W, d (red)
Comments	Rubber tops on fasteners. Similar to Fuji 1280

100.- STAEDTLER MARS 544 A



Model	Staedtler Mars 544 A
Front Face Scales	K, DF//CF, CIF, CI, C//D, A
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	??
Source	H&H
Name/Logo	N(S)+L(S)
Colours	l-b slide
Cursor Materials	trans./s.s.
Cursor Marks	PS, q, d, v?
Comments	Scales like Fuji P104 (possible Fuji 104?)

101.- STAEDTLER MARS 544 DLL

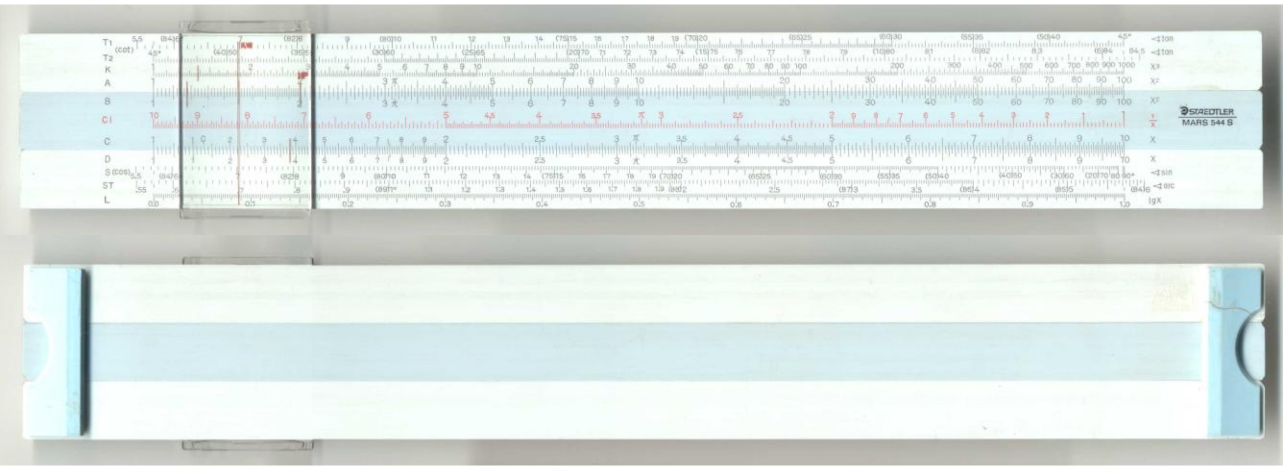


Model	Staedtler Mars 544 DLL
Front Face Scales	LL1, LL2, LL3, DF//CF, CIF, CI, C//D, K, L, LL0
Rear Face Scales (or rear slide only)	T1, T2, A//B, BI, CI, C//C, (P), S, ST
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	---
Source	Owned specimen (Herman van Herwijnen's catalogue \\\ www.sphere.bc.ca)
Name/Logo	Staedtler Mars Name and Logo
Colours	light-blue slide and fasteners
Cursor Materials	Transparent, double sided
Cursor Marks	36, d, v? // PS, d, q (red)
Comments	Rounded stoppers opposite to fasteners, with rubber tips

102.- STAEDTLER MARS 544 LL

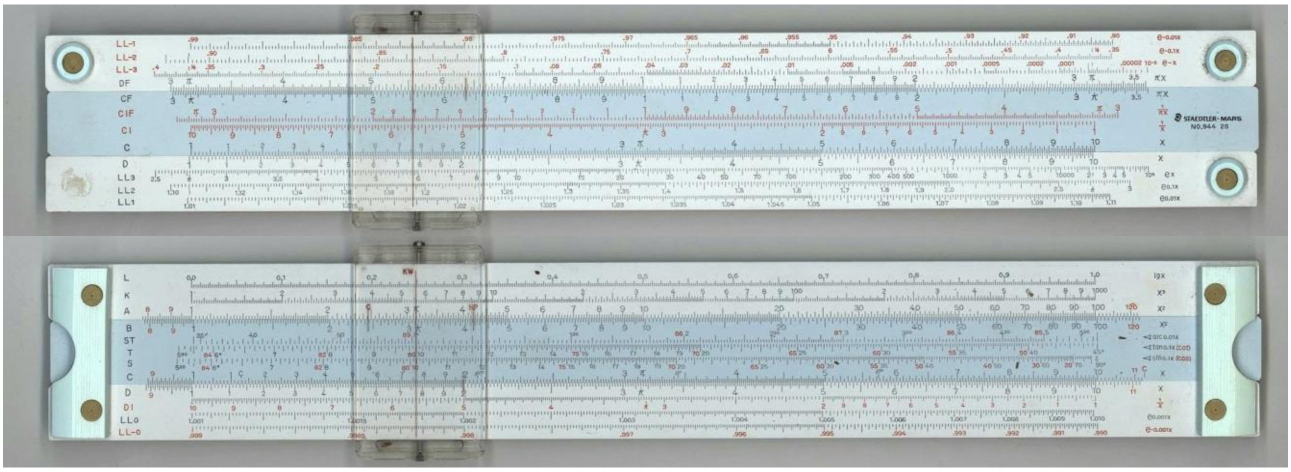
Model	Staedtler Mars 544 LL
Front Face Scales	L, K, A//B, CI, C//D, S, ST, T
Rear Face Scales (or rear slide only)	cm//S, LL1, LL2, LL3//inches
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	cm, inches
Made in Data	None
Source	Owned specimen (International Slide Rule Museum)
Name/Logo	Staedtler Mars Name and Logo
Colours	light-blue slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	PS, q, d, v? (red)
Comments	Similar to Fuji 129

103.- STAEDTLER MARS 544 S



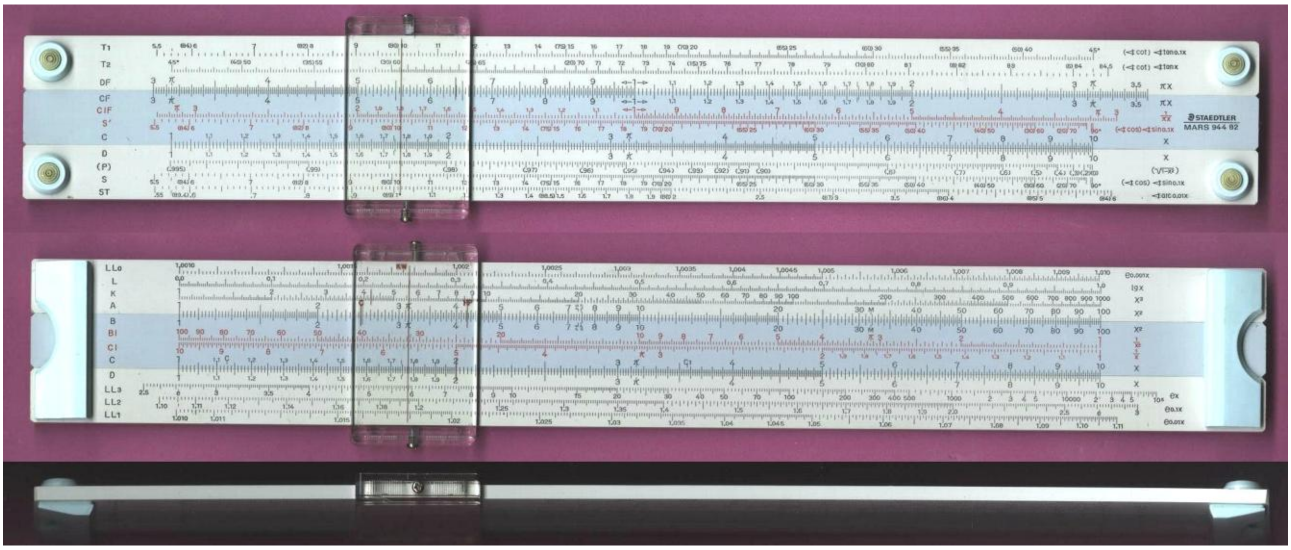
Model	Staedtler Mars 544 S
Front Face Scales	T1, T2, K, A//B, CI, C//D, S, ST, L
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	none
Source	Giovanni Breda (www.sliderule.it) (owned specimen)
Name/Logo	Staedtler Mars Name and Logo
Colours	light-blue slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	PS, q, d, v?
Comments	Similar to Fuji 104B

104.- STAEDTLER MARS 944 28



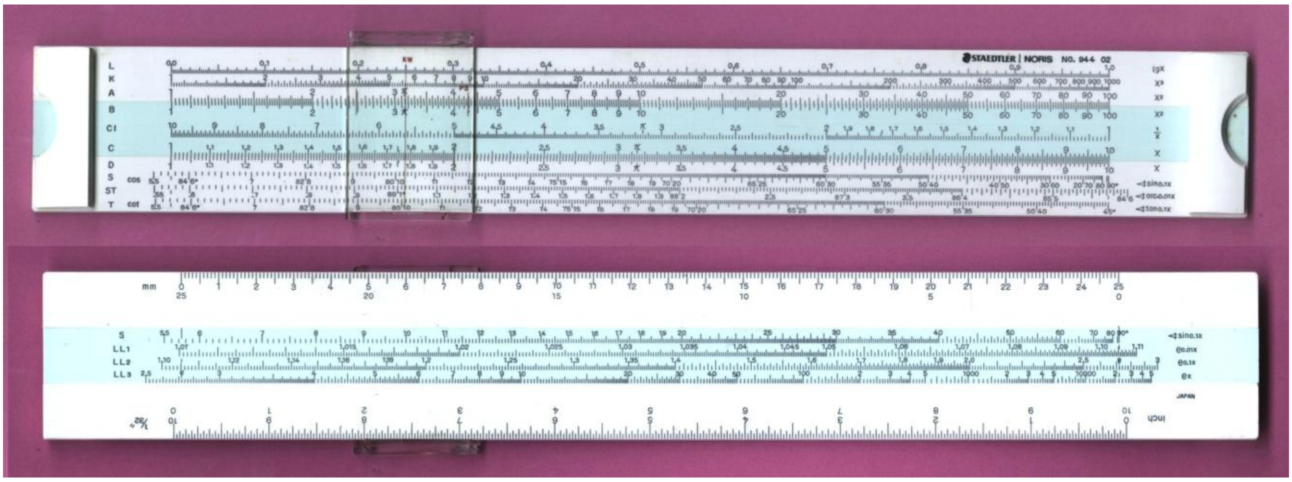
Model	Staedtler Mars 944 28
Front Face Scales	LL-1, LL-2, LL-3, DF//CF, CIF, CI, C//D, LL3, LL2, LL1
Rear Face Scales (or rear slide only)	L, K, A//B, ST, T, S, C//D, DI, LL0, LL-0
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	---
Source	International Slide Rule Museum
Name/Logo	Staedtler Mars Name and Logo
Colours	light-blue slide and fasteners
Cursor Materials	Transparent, double sided
Cursor Marks	36 // HP, q, d
Comments	Rounded stoppers opposite to fasteners, both with rubber tips. Similar to Fuji 1280

105.- STAEDTLER MARS 944 82



Model	Staedtler Mars 944 82
Front Face Scales	T1, T2, DF//CF, CIF, S', C//D, (P), S, ST
Rear Face Scales (or rear slide only)	LL0, L, K, A//B, BI, CI, C//D, LL3, LL2, LL1
Size (cm)	25
Type	Duplex
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	---
Source	International Slide Rule Museum
Name/Logo	Staedtler Mars Name and Logo
Colours	light-blue slide and fasteners
Cursor Materials	Transparent, double sided
Cursor Marks	36 // HP, q, d, v?
Comments	Rounded stoppers opposite to fasteners, with rubber tips

106.- STAEDTLER NORIS 944 02

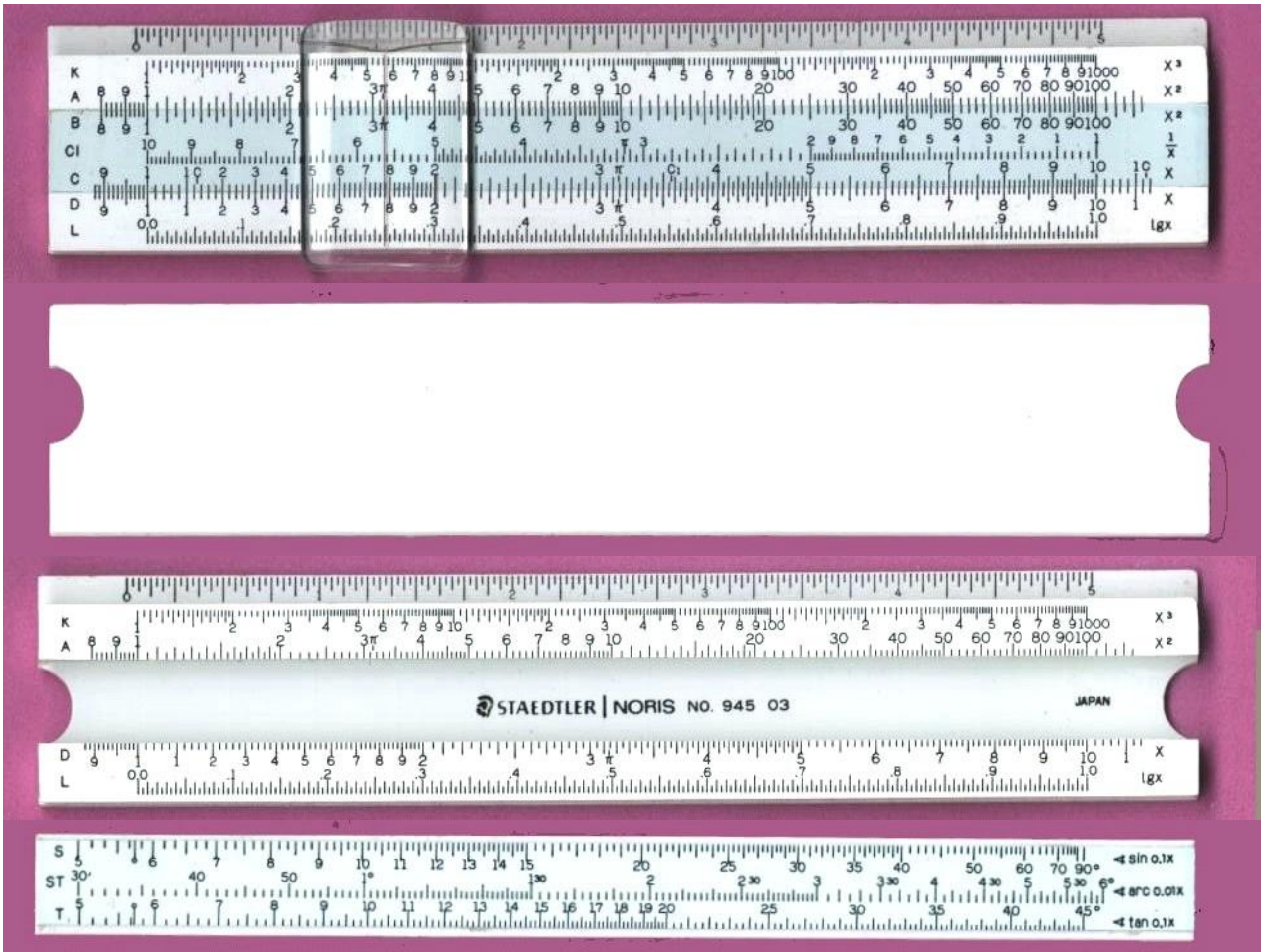


Model	Staedtler Mars 944 02
Front Face Scales	L, K, A//B, CI, C//D, S, ST, T
Rear Face Scales (or rear slide only)	cm//S, LL1, LL2, LL3//inches
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	cm, inches, "Made in"
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Staedtler Noris Name and Logo
Colours	light-blue slide
Cursor Materials	Transparent, single sided
Cursor Marks	PS, q, d (red)
Comments	Similar to Fuji 129. (Might not be a Fuji).

107.- STAEDTLER NORIS 944 03

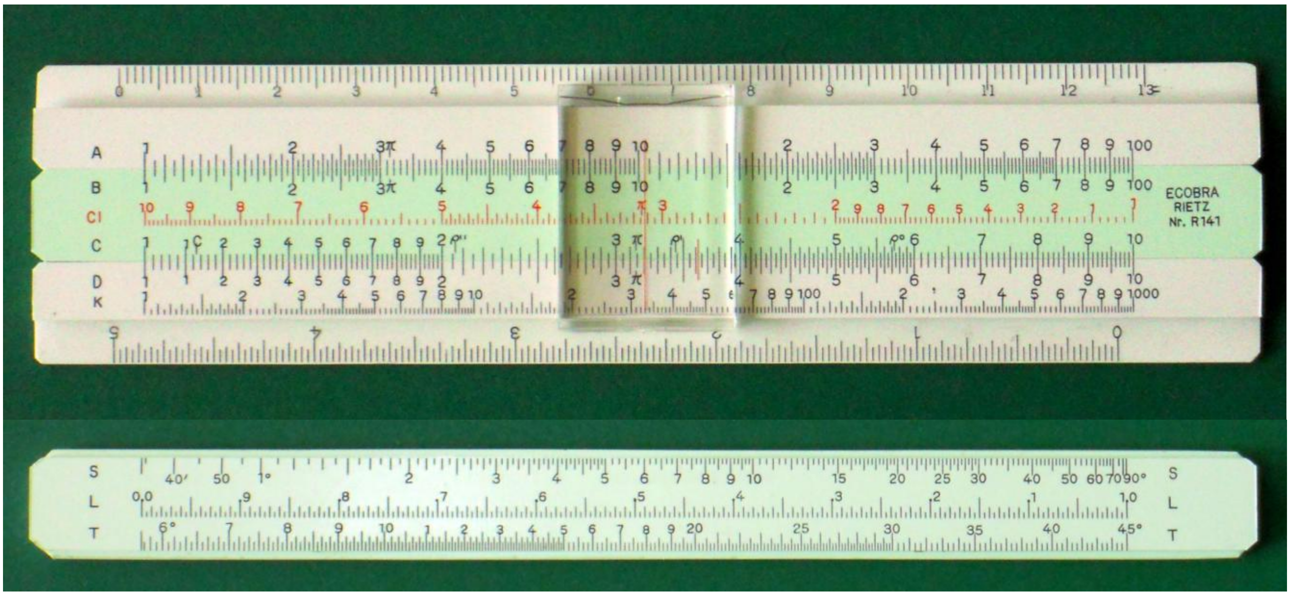
Model	Staedtler Mars 944 03
Front Face Scales	T1, T2, K, A//B, CI, C//D, S, ST, L
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	Japan
Source	Owned specimen (International Slide Rule Museum)
Name/Logo	Staedtler Noris Name and Logo
Colours	light-blue slide
Cursor Materials	Transparent, single sided
Cursor Marks	None (red hairline)
Comments	Similar to Fuji 104B. Manufacturing of scales different from studied Fuji specimens (might not be a Fuji).

108.- STAEDTLER NORIS 945 03



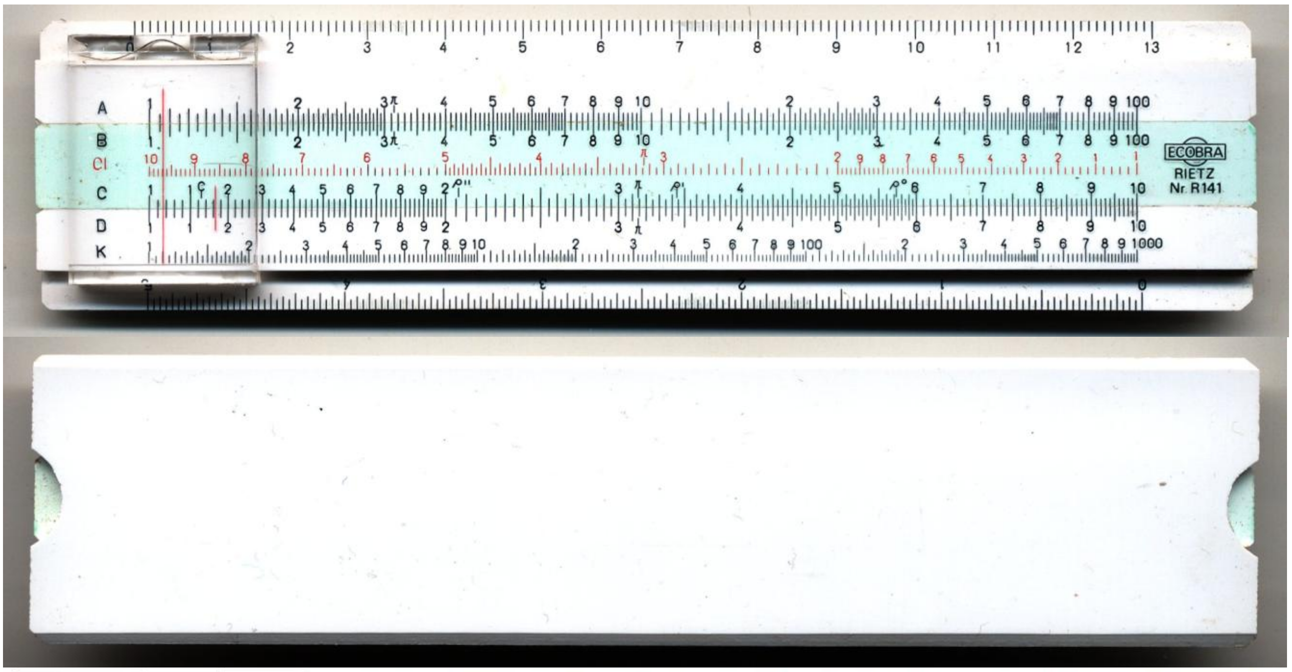
Model	Staedtler Mars 945 03
Front Face Scales	Inches//K, A//B, CI, C//D, L
Rear Face Scales (or rear slide only)	S, ST, T
Size (cm)	12,5
Type	Single
Name	---
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Staedtler Noris Name and Logo.
Colours	light-blue slide (single side?)
Cursor Materials	Transparent, single sided
Cursor Marks	d? (black)
Comments	Similar to Fuji 505. Might not be a Fuji

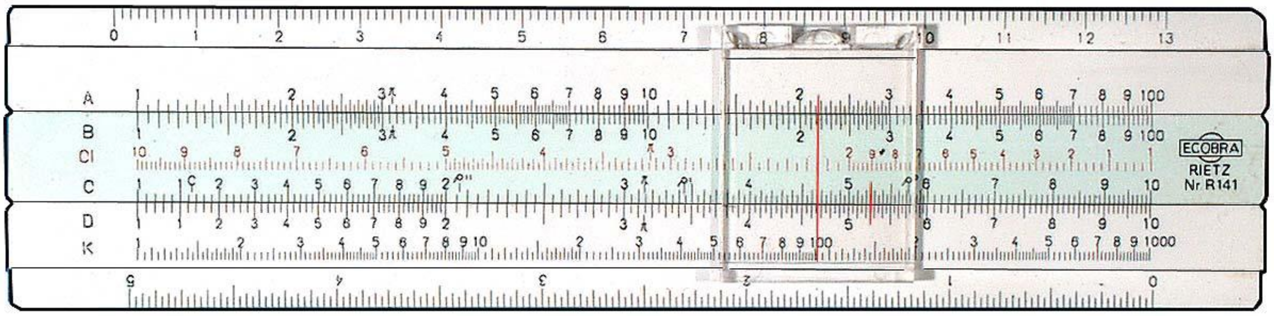
109.- ECO-BRA R141 (1ST VERSION)



Model	Eco-Bra R141 (1st Version)
Front Face Scales	cm//A//B, CI, C//D, K//inches
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	12,5
Type	Single
Name	Rietz
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	---
Source	Owned specimen
Name/Logo	Eco-Bra name
Colours	light-gren slide
Cursor Materials	Transparent, single sided
Cursor Marks	d (red)
Comments	Similar to Fuji 501?

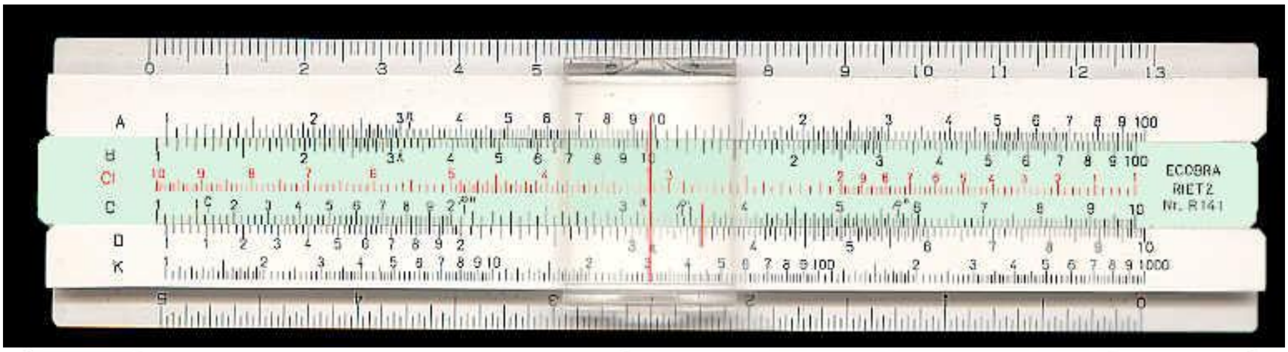
110.- ECO-BRA R141 (2[ND] VERSION)

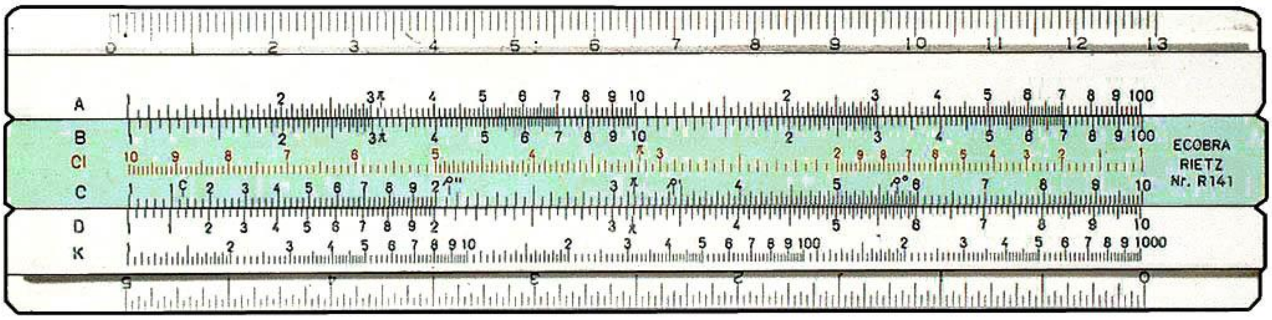


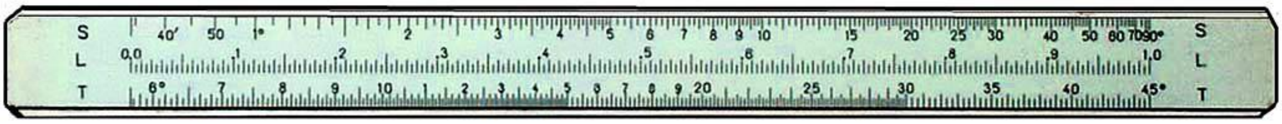


Model	Eco-Bra R141 (2nd Version)
Front Face Scales	cm//A//B, CI, C//D, K//inches
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	12,5
Type	Single
Name	Rietz
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	---
Source	Giovanni Breda (www.sliderule.it) Herman van Herwijnen's catalogue
Name/Logo	Eco-Bra Logo
Colours	light-blue slide
Cursor Materials	Transparent, single sided
Cursor Marks	d (red)
Comments	Might be Hope, not Fuji

111.- ECO-BRA R141 (3RD VERSION)





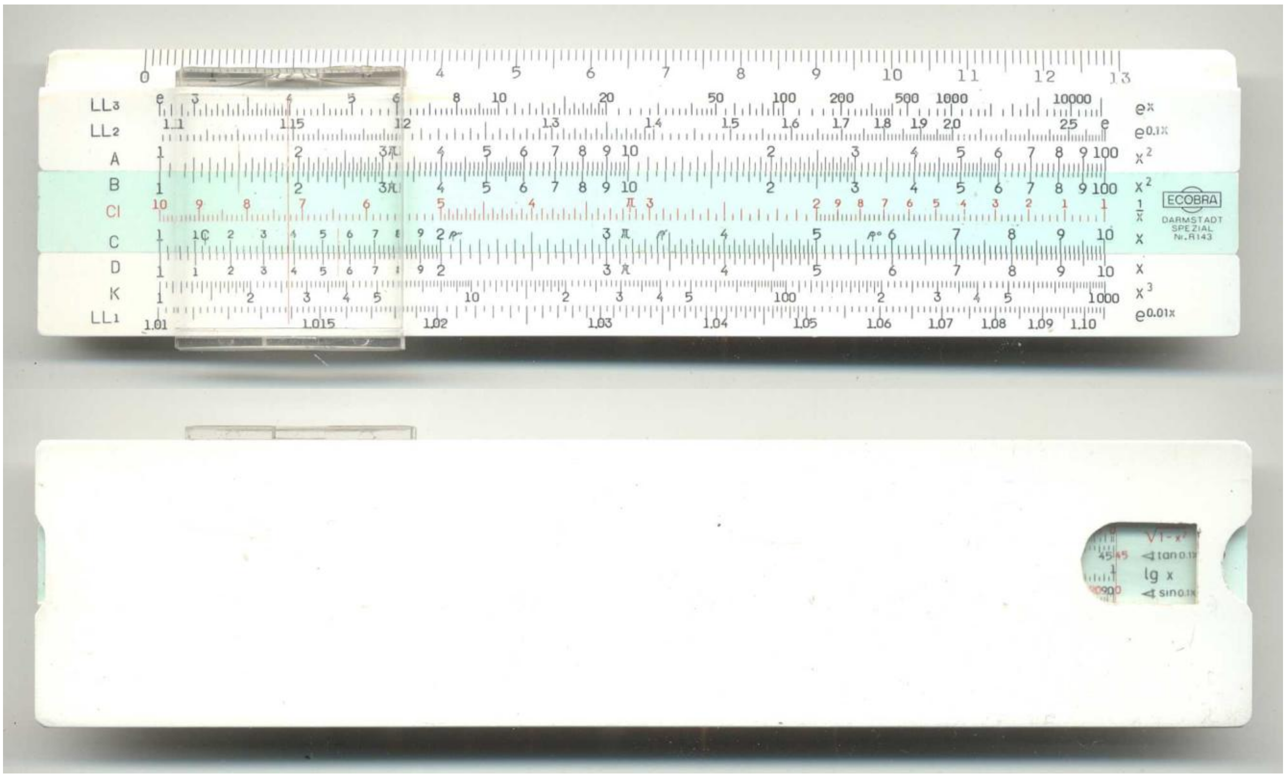


Model	Eco-Bra R141 (3rd Version)
Front Face Scales	cm//A//B, CI, C//D, K//inches
Rear Face Scales (or rear slide only)	S, L, T
Size (cm)	12,5
Type	Single
Name	Rietz
Catalogue Referenced in	None
Data in Back (no duplex)	Blank
Made in Data	---
Source	Ron Manley's site (www.sliderules.info) Herman van Herwijnen's catalogue
Name/Logo	Eco-Bra Name
Colours	light-blue slide
Cursor Materials	Transparent, single sided
Cursor Marks	d (red)
Comments	Might be Hope, not Fuji

112.- ECO-BRA R143 (1ST VERSION)

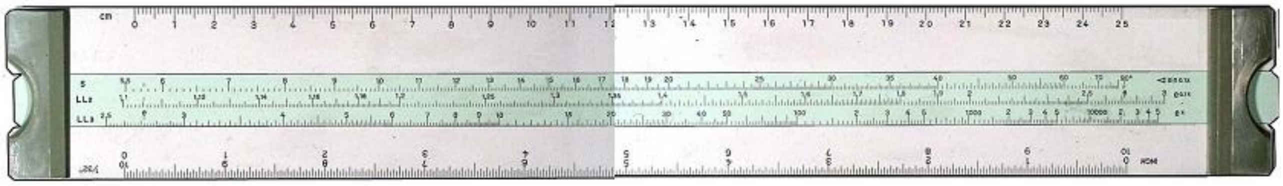
Model	Eco-Bra R143 (1st Version)
Front Face Scales	cm//LL2, LL3, A//B, CI, C//D, K, LL1
Rear Face Scales (or rear slide only)	P, T, L, S
Size (cm)	12,5
Type	Single
Name	Darmstadt Spezial
Catalogue Referenced in	none
Data in Back (no duplex)	blank, Advertisement
Made in Data	---
Source	International Slide Rule Museum
Name/Logo	Eco-Bra Logo
Colours	light-green slide
Cursor Materials	Transparent, single sided
Cursor Marks	d, q (black)
Comments	Similar to Fuji 515P

113.- ECO-BRA R143 (2ND VERSION)



Model	Eco-Bra R143 (2nd Version)
Front Face Scales	cm//LL2, LL3, A//B, CI, C//D, K, LL1
Rear Face Scales (or rear slide only)	P, T, L, S
Size (cm)	12,5
Type	Single
Name	Darmstadt Spezial
Catalogue Referenced in	none
Data in Back (no duplex)	blank
Made in Data	---
Source	Giovanni Breda (www.sliderule.it)
Name/Logo	Eco-Bra Logo
Colours	light-blue slide
Cursor Materials	Transparent, single sided
Cursor Marks	d, q (black)
Comments	Not sure it is a Fuji. Similar to Fuji 515P

114.- ECO-BRA R152

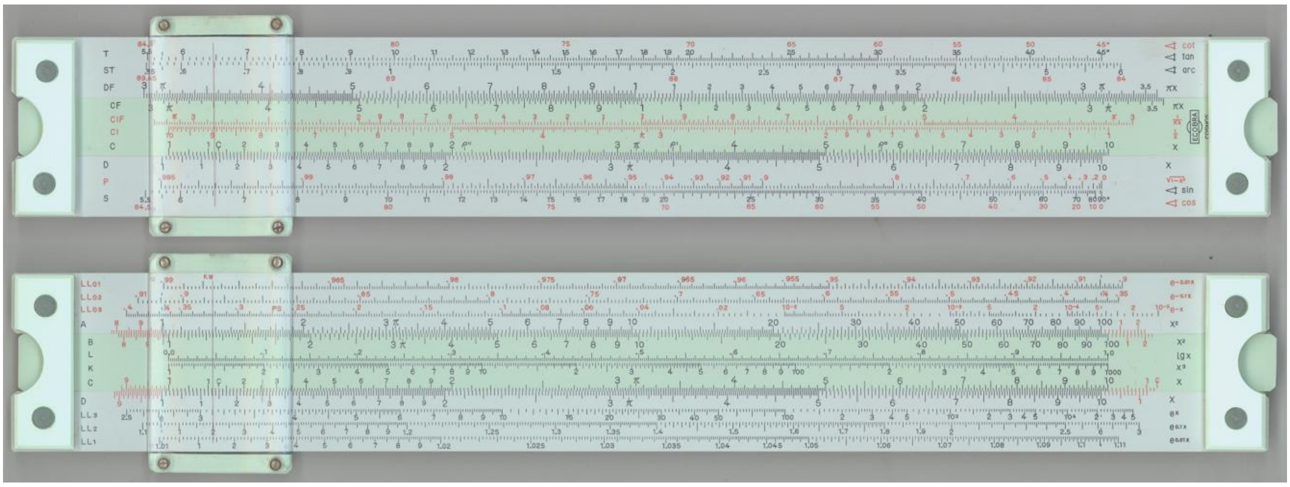


Model	Eco-Bra R152
Front Face Scales	L, K, A//B, CI, C//D, S, ST, T
Rear Face Scales (or rear slide only)	cm//S, LL2, LL3//inches
Size (cm)	25
Type	Single
Name	Perfekt
Catalogue Referenced in	None
Data in Back (no duplex)	cm, inches
Made in Data	---
Source	Herman van Herwijnen's catalogue
Name/Logo	Eco-Bra Logo
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided?
Cursor Marks	?
Comments	Similar to Fuji 129. Colours may be misleading.

115.- ECO-BRA R153

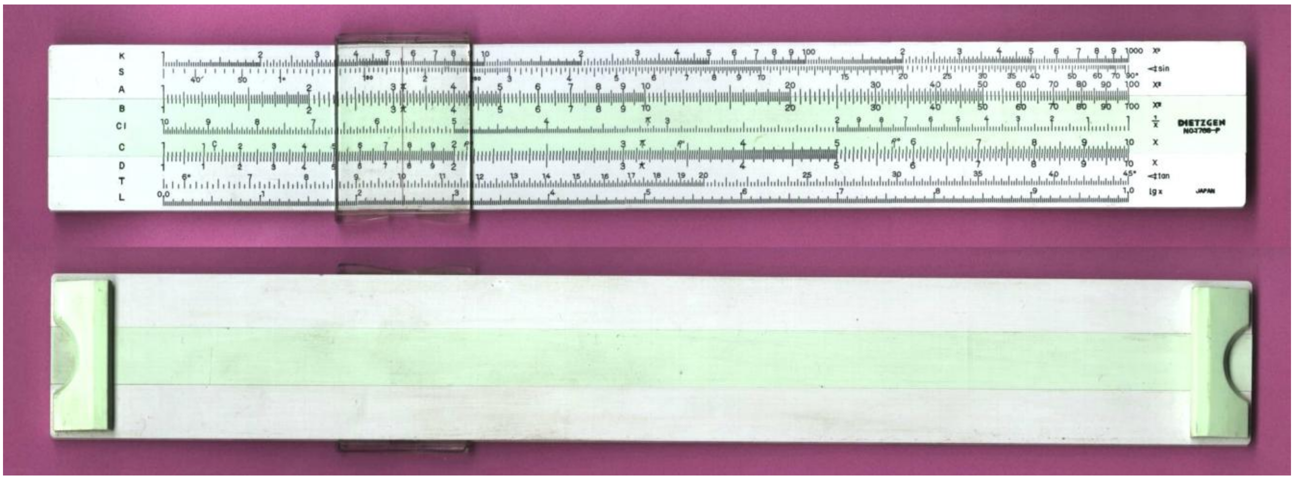
Model	Eco-Bra R153
Front Face Scales	LL1, LL2, LL3, DF//CF, CIF, CI, C//D, L, K
Rear Face Scales (or rear slide only)	T1, T2, A//B, BI, CI, C//D, P, S, ST
Size (cm)	25
Type	Duplex
Name	Darmstadt Spezial
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	---
Source	Owned specimen
Name/Logo	Eco-Bra Logo
Colours	light-green slide and fasteners
Cursor Materials	Light-green runners, double sided
Cursor Marks	36 // PS, q, d (red)
Comments	

116.- ECO-BRA R154



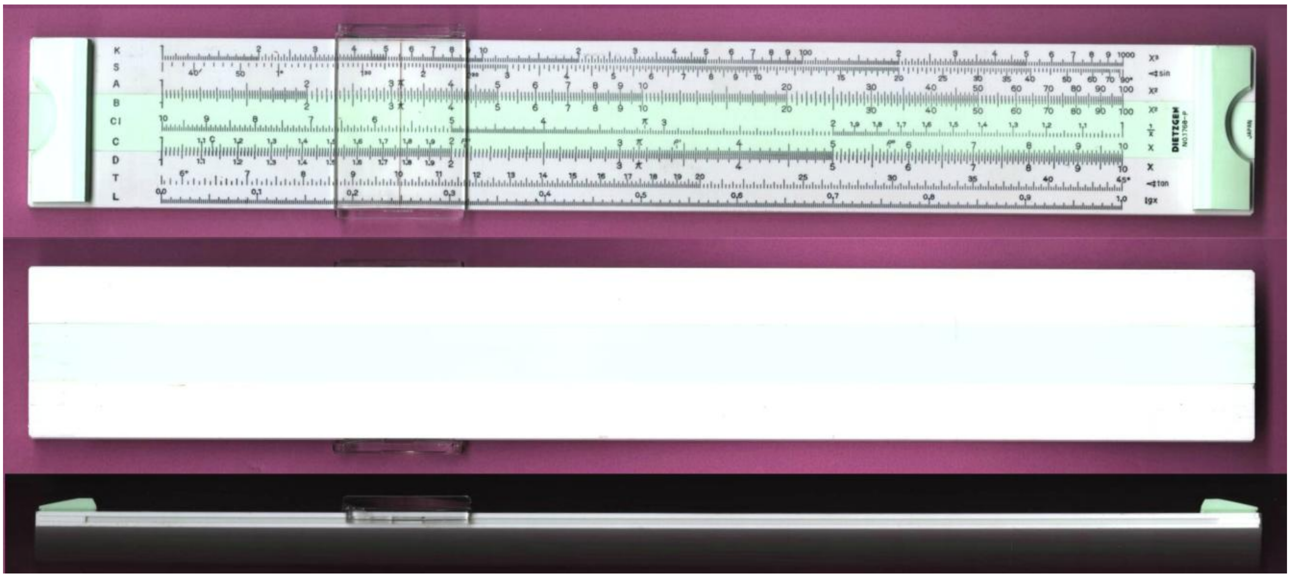
Model	Eco-Bra Cosmos
Front Face Scales	T, ST, DF//CF, CIF, CI, C//D, P, S
Rear Face Scales (or rear slide only)	LL01, LL02, LL03, A // B, L, K, C // D, LL3, LL2, LL1
Size (cm)	25
Type	Duplex
Name	Cosmos
Catalogue Referenced in	None
Data in Back (no duplex)	N/A
Made in Data	---
Source	Giovanni Breda (www.sliderule.it) (International Slide Rule Museum)
Name/Logo	Eco-Bra Logo
Colours	light-green slide and fasteners
Cursor Materials	Light-green runners, double sided
Cursor Marks	36 // PS, q, d (red)
Comments	Fasteners at both sides with round rubber tips. Similar to Fuji 1250.

117.- DIETZGEN 1768P (1ST VERSION)



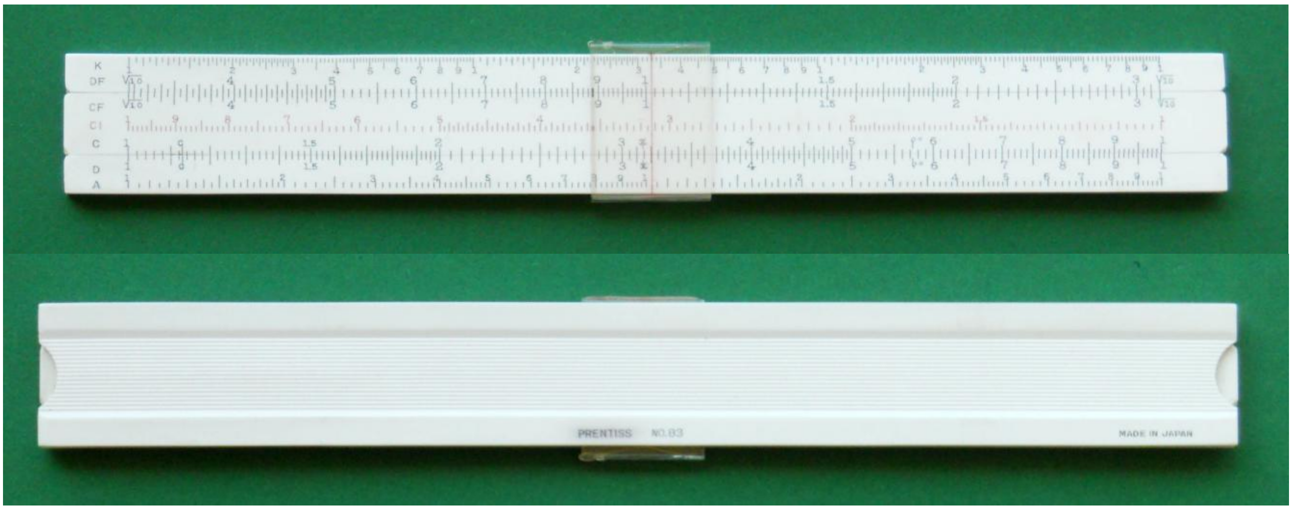
Model	Dietzgen 1768P (1st version)
Front Face Scales	K, S, A//B, CI, C//D, T, L
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	blank
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Dietzgen Name
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	none (b)
Comments	Similar to Fuji 102B. In owned specimen, scales manufacturing process different from known Fuji specimens.

118.- DIETZGEN 1768P (2ND VERSION)



Model	Dietzgen 1768P (2nd version)
Front Face Scales	K, S, A//B, CI, C//D, T, L
Rear Face Scales (or rear slide only)	blank
Size (cm)	25
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	blank
Made in Data	Japan
Source	International Slide Rule Museum
Name/Logo	Dietzgen Name
Colours	light-green slide and fasteners
Cursor Materials	Transparent, single sided
Cursor Marks	none (b)
Comments	Green fasteners in front face. Similar to Fuji 102B

119.- PRENTISS 83



Model	Prentiss 83
Front Face Scales	K, DF//CF, CI, C//D, A
Rear Face Scales (or rear slide only)	Blank
Size (cm)	20
Type	Single
Name	---
Catalogue Referenced in	none
Data in Back (no duplex)	Blank, name, Ref., "Made in"
Made in Data	"Made in Japan"
Source	E-Bay
Name/Logo	Name
Colours	White
Cursor Materials	transparent, single sided
Cursor Marks	none (red hairline)
Comments	Horizontal lines in recessed centre of back side. Like Fuji 83.

*** End of Document ***