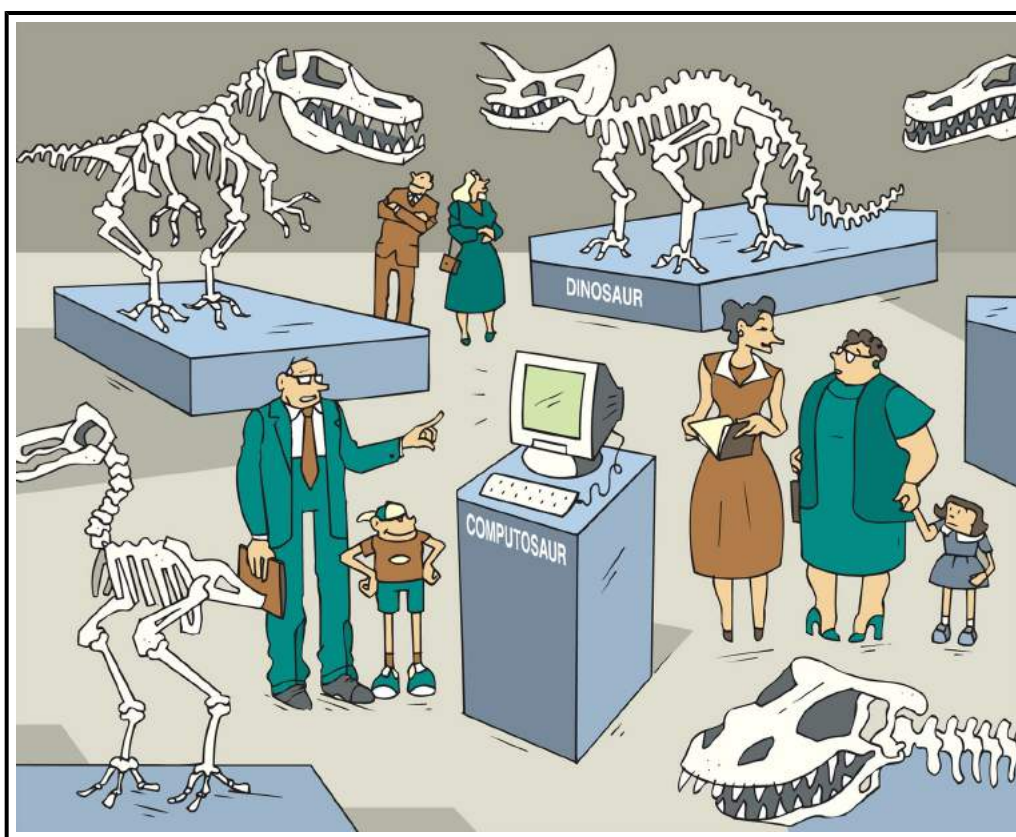# IM 2016 Proceedings

Someone's Trash is Our Treasure

The Collector as a Preserver of Material Culture

A museum would not be complete without a display of dinosaur bones. It would also be incomplete without a display of old calculating devices, for these are the fossils of today!

THE
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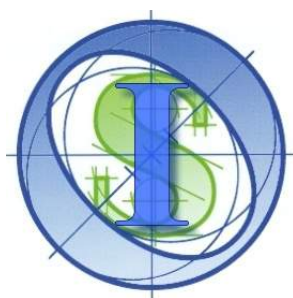SOCIETY Italy

IM 2016

Someone's Trash is Our Treasure
the Collector as a Preserver of Material Culture

PROCEEDINGS

22th International Meeting for Collectors
of Historical Calculating Instruments
16th - 18th September 2016
Science Museum MUSE of Trento, Italy

The Oughtred Society Italy

www.im2016.eu - www.facebook.com/oughtreditaly

www.nicolamarras.it/im16

TRENTO - Host City of IM 2016

Trento Cathedral (*Duomo di Trento*) is the mother church of the Roman Catholic Archdiocese of Trento. Construction began in 1212 over a pre-existing 6th-century church devoted to Saint Vigilius (*San Vigilio*), patron saint of the city.

From 1545 to 1563 the Cathedral hosted the Council of Trent, one of the Roman Catholic Church's most important ecumenical councils. Prompted by the Protestant Reformation, the Council has been described as the embodiment of the Counter-Reformation.

The MuSe of Trento

In a former industrial area of about 19,000 square meters, the Autonomous Province of Trento asked Renzo Piano to build not only a museum, but a center for reflection on the relationship between nature and man. And MuSe was born, so successful that it is the only Italian museum that has earned an honorable mention at the European Museum of the Year Awards 2015.

Part of the IM 2016 will take place in the Museum's big atrium.

For more information visit: www.muse.it/
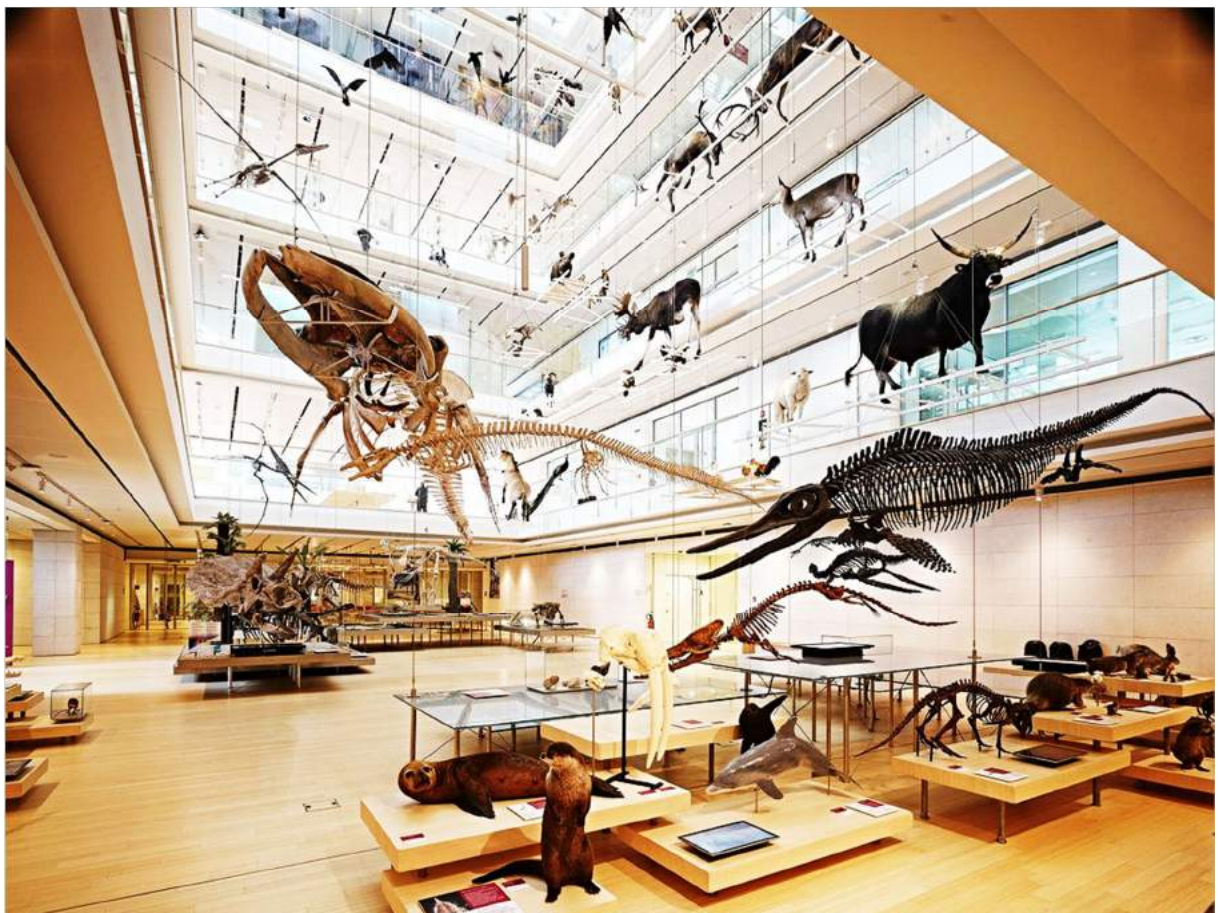
Introduction

The 22nd International Meeting 2016 for Collectors of Historical Calculating Instruments, including Slide Rules and Other Calculating Devices: IM 2016 will be held on September 2016 in Trento - Northern Italy, a historic town in the Dolomites.

Apart from the surrounding alpine scenery, the newly built Science Center, MuSe, designed by Renzo Piano, attracted more than half a million visitors last year. With the display of numerous mathematical devices already shown in its spring exhibition MadeinMath, this museum will be the principal meeting site for the 2016 meeting.

European and overseas participants can expect to attend a concentrated scientific program. The theme for the meeting is inspired from the planned exhibition about the Extinction of Species and Technology.

Partner Program in Trento

Trento and its surroundings offer so many different attractions for the tourist that any fixed selection for the Saturday's Partner Program could never satisfy all interests.

For this reason we propose that attendees and guests reserve and purchase Trento-Rovereto-Cards during registration for each accompanying persons (children under 18 free).

A detailed list of 25 potential sightseeing places are contained in the Brochure, which may be downloaded directly from im2016.eu/wiki.htm#Welcome. This also details the card's usage conditions and benefits.

Those who would like to coordinate their sightseeing with others may make arrangements during the first Friday meeting. The registration personnel will be available to help with arrangements. A special guided tour to the Castel Buonconsiglio on Sunday morning will also be available for card holders and participants.

Since the card is valid for 48 hours, participants can even acquire one for use on Sunday or perhaps for a longer stay. Remember that public transportation is included!

Someone's Trash is Our Treasure
The Collector as a Preserver of Material Culture

Wolfgang Irler

The comparison of extinct species to the extinct technology of mechanical calculating devices has led to the idea of reconsidering these historical calculation-related artifacts, putting the main emphasis, not on the achievements of past technology, but on the "material culture", taking into account the historical context that makes these artifacts worthy to be collected, analyzed, and used to explain its evolution.

Consequently, the actual collector may be considered as having equal status to a paleontologist who digs for fossil remains or an archaeologist who searches for human artifacts, rummaging in forgotten cellars and flea-markets.

What someone had thrown away became the collector's treasure.

In times past, user manuals were the "programs" to be learned ("compiled") by man and "executed" by hand, operating a crank or handle or sliding a wooden rule and then noting the result.

In the depths of today's computers, tablets, and smart phones, the underlying algorithms are invisible to the normal user. A mere button press delivers an immediate result. Antique procedures may therefore usefully serve as a didactic methodology to explain the internal functioning of modern devices.

Our Treasure is a World Treasure
Sharing our Knowledge against the Uncle Scrooge Syndrome

Nicola Marras

```
The power of objects regulates our lives in this faltering era,
they becoming the consolation capable of absorbing all  our
anxieties about time and death.
```

This is the thinking of the French sociologist Baudrillard, who continues the argument:

```
The passion for objects climaxes in
pure    jealousy.   Here    possession
derives its fullest satisfaction from
the prestige the object has for other
people, and the fact that they cannot
have it.
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For Baudrillard, collecting is basically a longing to prohibit any sharing of one's objects.

But, of course, not everybody acts in the same manner and many do not think that objects are the narcissistic equivalent of oneself: Freud was an avid collector, but his collecting aspired to achieve a public and social function. His collection was not a sequestered treasure, but was viewable by others.

Freud's impulse to treat his collection as "*public*" was perhaps inspired by the attitudes and customs of mid-19th century scientific collectors.

At the time many researchers exchanged specimens and ideas with other collectors; to acquire, one had to give first. A collector who only collects to satisfy a thirst for possession, without sharing his treasures, is socially useless.

I know the problem; I started exhibiting just to fight my attitude of being selfish and jealous of my toys. At the beginning seeing people touching my collection was terrible, but later I found this experience a great occasion of personal growth.
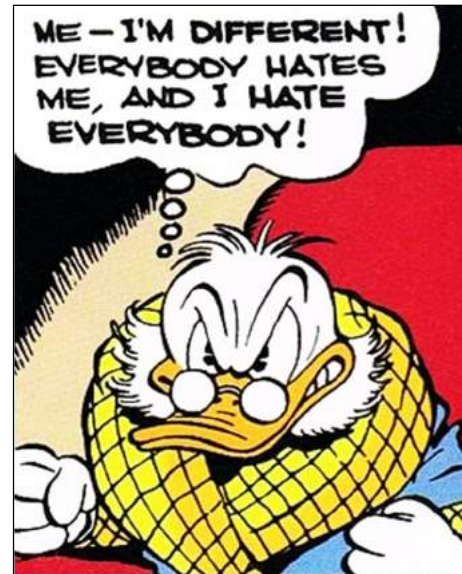
The collector's nightmare: calculators touched by everybody in a live exhibit

A belief in the value of old Calculating Instruments is required for understanding the past and to create a vision for research and teaching.

Our model should be David Wheatland, curator for the Harvard Collection of Historical Scientific Instruments. 40 years ago people did not see any value in the old instruments; thus, rescue missions became a legendary part of Mr. Wheatland's program.

He ensured the future of the Collection: all items were conserved, documented, and shared by his unstinting generosity and efforts.

Guaranteeing the future is essential, I see too many collections dispersed - a sad end for a life's passion.

Luckily, in the Oughtred Society we have excellent examples of this mentality: many members present their collections on-line, with documentation, often otherwise unedited, but now available to all.

In many cases they have revived forgotten instruments, lacking almost any information. This is an archaeologist's task and in this meeting, for example, we will hear about a Babylonian slide rule and see a working model of it.

This is a job that goes beyond the mere egoistic col lecting, rather true scientific research. All artifacts, before being old and precious, became just obsolete and were thrown away. By preserving them, the collector becomes the curator of the material culture.

Operating in this way, the joy of providing a collection gives us not only the whim of a moment, but also leaves something solid and valuable to the whole community.

The history of calculating is under appreciated and will be forgotten. Students who learn mathematics, without learning the history of mathematical ideas and discoveries, are missing much of the fun.

We have to collect to avoid extinction; without our work there will be little left of the physical history of calculating instruments.

A museum would not be complete without a display of dinosaur bones. It would also be incomplete without a display of old calculating devices, for these are the fossils of today!

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A Babylonian Slide Rule

Cesare Baj

This paper documents a circular Babylonian logarithmic slide rule, utilizing the sexagesimal system and carved with cuneiform figures.

I presented it as an ancient artifact, "forgotten in the ship of an expedition of archaeologist, traveling from Latakia to Venice in the 1920's".

The story of the discovery was supported by an old album of pictures, letters from the ship captain who had come into possession of the material, and notes from a high representative of the Italian Mathematical Society who endorsed the discovery.

The artifact was a demonstration of the fact that Babylonians had the theoretical knowledge and the practical know-how to invent and produce the slide rule two millennia before it was "re-invented" in the Western civilization by William Oughtred.

I easily succeeded in demonstrating the assumption that Babylonians were capable of managing logarithms. Mathematical documents in the form of clay tablets found in the Fertile Crescent proved my case. But the artifact, the old album, and the letters were fake, as they had been created by me.

Why did I take the trouble to organize this fraud (soon declared as such)? Simply to play a joke on the lovers of legendary archaeological findings, such as the "Baghdad battery", or on those who believe that pre-Columbian civilizations had been regularly visited by aliens.

Being one of the founders of the Italian sister-association of the American CSI, the *Committee for Skeptical Inquiry*, whose mission is "to promote scientific inquiry, critical investigation, and the use of reason in examining controversial and extraordinary claims" played a part in it.

Translation of the letter sent by Professor Mario Astolfi to the editor of the Bulletin of the History of Mathematical Sciences department of the Pisa University:

```
The Editor in Chief
"History of Mathematical Sciences Bulletin"
Istituti Editoriali e Poligrafici Internazionali
Pisa


Bologna, 2nd march 2016


Dear Enrico,
I am sending you a communication regarding an extraordinary discovery,
which is of the utmost historical importance.
The text is written in the form of an article, almost ready to be
published in the Bulletin.
The article is accompanied by a technical document, which has been
prepared by a certain Cesare Baj, an "amateur mathematician" from
Cernobbio, who has much of the responsibility for the discovery.
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Mr. Baj transmitted to our department a document revealing archaeological finds in the Fertile Crescent, this document having been forgotten for almost a century in the cellar of his cousin's house.
Baj is truly passionate about maths. Thirty years ago he founded and edited the first science magazine for the young in Europe, named "Newton". Many of my students became interested in science thanks to that journal, and probably many of yours as well. As all useful things in Italy... it only lasted a short time.
Baj is also fond of analog computing instruments and slide rules.
His cousin is a very nice person and expressed the will to donate the finds to a university or a museum. We will soon make an application for the donation!
The idea that this incredible find could have ended in the hands of unlearned people, an anonymous ebayer, or a junkyard guy, makes me shiver.
But I do not want you to waste your time. Please read this, and tell me if it isn't a great coup.

Yours,

Babylonian Logarithms

A recent discovery in Northern Italy sheds new light on the mathematical knowledge of the Mesopotamian peoples.

As far as we knew up to now, logarithms and the logarithmic slide rule were totally a product of seventeenth century British mathematicians. John Napier (1550-1617) discovered logarithms, while William Oughtred (1575-1660) constructed the first slide rule, as an evolution of the "Gunter Scales" prepared around 1620 by Edmund Gunter (1581-1626). Now, however, we need to think again.

The evolution of the mathematics of the Sumerians, Babylonians, and of the other peoples who followed them between the Tigris and Euphrates, is known. Four millennia ago these peoples knew how to perform the four basic operations, the operations of exponentiation and root extraction, knew the quadratic formula of quadratic equations (although they considered only the positive root), knew the Pythagorean triples, as was well illustrated in the famous tablet known as "Plimpton 322", and, moreover, they were able to calculate the value of the square root of 2 almost exactly, as shown in the equally famous tablet YBC 7289.
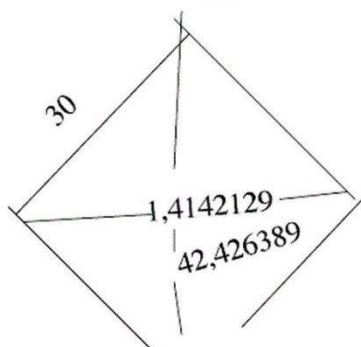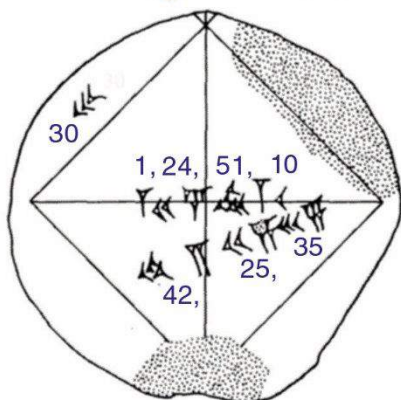
They could also solve a variety of problems which had to do with areas and volumes and the major problems we now call mathematical finance and valuation, as would have been necessary in an advanced urban and agricultural society.

In particular it should be noted that the mathematicians of Babylon knew how to calculate powers of numbers.

This follows for example from the tablet *Ist. O 3816*, initially described by H. de Genouillac and later analyzed in detail by O. Neugebauer. It presents a table of powers, starting from the second power, of the sexagesimal number 3;45 (corresponding to 225 in decimal notation).

But the most precise testimony of knowledge of Babylonian mathematicians in this area is provided by the tablet *MLC 2078*, described by O. Neugebauer in *Mathematical Cuneiform Texts* (New Haven, 1945), and now part of the Yale Babylonian Collection.

It shows tables that provide the answer to the question: to what power *n* must you raise a number *a*, to get a given number x? In modern terms this represents the determination of the logarithm in base *a* of a given number *x*.

This shows unequivocally that the Babylonians not only possessed the theoretical tools to address the creation of logarithms, but that they actually used logarithms of numbers, even if they never defined a precise, universal base value, such as the number *e*, as used in Napier's work, and the number 10, by Briggs, many centuries later.

How did the Babylonians arrive at the concept of the logarithm? It seems to be possible to exclude that they arrived at this concept by a theoretical route in the context of pure mathematical research. Instead, they probably got there through computing practices within the branch of applied mathematics that is financial which is a major discipline in an urban civilization.

Above, the tablet YBC7289, showing the value of the ratio between the diagonal and the side of a square, equal to the square root of 2, in sexagesimal numbers (in blue) and in numbers of the decimal system (below). It is quite close to the true value that is 1.4142135.
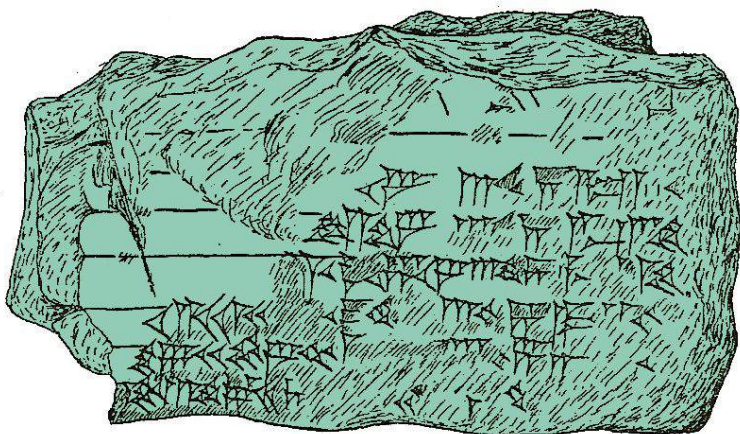
Having to calculate the compound interest of a loan, or the performance of a capital sum with the passage of time, inevitably leads, albeit unwittingly, to working with logarithms and

Tablet O 3816, described by O. Neugebauer, which shows the exponential function xn for n = 2,3,4,5,6, … for the number 3;45 (corresponding to 225).

to prepare tables which are tables of logarithms. It is unnecessary to emphasize that the correct resolution of problems related to the loan, interest, or capital is of fundamental importance in a civilized society, such as had the Babylonians, and how this need was therefore able to stimulate the development of appropriate and adequate means of calculation mathematics,.

Tablet MLC 2078, of the Yale Babylonian Collection. The lowest part shows the logarithms in base 2 of numbers 2, 4, 8, 16, 32, and 64. The upper part shows the antilogarithms in base 16 of numbers 1/4, 1/2, 3/4 and 1.

Going from knowing the concept of the logarithm and having elaborate rudimentary tables of logarithms of series of numbers, in any base, to a graphical representation and then to their representation on two scales capable of moving relative to one another is only a matter of time. The British accomplished this step in a "flash" of fewer than fifteen years (Napier's logarithms in 1614, Briggs logarithms to base 10 in 1617, Gunter's scale in 1620, Oughtred's linear slide rule calculator in 1627) and immediately after the circular slide rule.

It is not unlikely, therefore, that the Babylonians were able to make the same conceptual and design progress in the many centuries during which their mathematical knowledge evolved. Note that the basic concepts, in the path described above, requires, in fact, just a little desire to "play" with numbers, which certainly the peoples of Mesopotamia did not lack. Given their level of mathematical knowledge, it is indeed to be wondered that the use of logarithms was not found in a much more obvious way. We wonder, in fact, as we explain the discovery of this unique artifact, which has no parallel in other artifacts of the time. It demonstrates such a full mastery of logarithms that presupposes widespread use of the same.

With this instrument in our hands, we would be led to imagine an extended background of computation capability with logarithms and production of logarithmic tables. Nevertheless, among the tablets found up till today, a great number of which present tables of multiplication, reciprocal numbers, fractional numbers, powers and roots of numbers, only a very

few show evidence of logarithms of numbers, and then only as a way to solve very specific problems.

It is thus evident that Babylonians did not commonly use logarithms. The application of logarithms in the construction of the discovered instrument doesn't seem to be a consequence of a methodology of logarithmic computation, as it will be millennia later, in the XVII century, but an ingenuous and possibly casual, empirical invention, made upon trials to find a graphical solution to problems involving powers of numbers. An invention probably sprung from a learned environment, among people who had the time to play with mathematics, an invention that never had the chance to spread across the society for the resolution of practical problems.

Another reason for the missed diffusion of this revolutionary invention, having a great potential in many professions, could be found in the will of keeping secret a powerful computation tool, to be used only for military purposes. A secret jealously kept, no less than the Enigma code or the huge prime numbers used in contemporary cryptography by secret services and banks.

Whatever was the reason of the construction of the instrument now in our hands, we can say that it's an extremely rare find, unique at the moment, of great historical and scientific significance.

History of the Discovery

The lucky discovery has a long and engaging history, worth being narrated in some detail. It was possible thanks to the perspicacity and correct behavior of the persons who came across the find and who decided to get the scientific community involved before thinking of getting a personal advantage from the discovery, and also thanks to the fact the first consulted person had all the theoretical means to understand what that object really was.

This person is Cesare Baj, living in Cernobbio, on Lake Como, a science writer and editor of scientific magazines. Just for this reason Cesare was called by his second cousin to view some strange material found in a cellar of his house in Telve Valsugana, near Trento. But let's proceed in stages.

Great-uncle of Cesare, the brother of his maternal grandmother, was Admiral Giuseppe Lombardi. "Uncle Pin", as he was called within the family, had a brilliant career in the Italian Navy in victorious campaigns during WW1. Before and during WW2 he was the commander of the Italian Fleet and plenipotentiary Minister in the Far East.

But let's follow Uncle Pin at the end of WW1. Recently discharged by the Navy, he set up with a couple of partners a maritime line, operating a ship, the *Duivendyk*. The ship had a Dutch name, but was German and was acquired by the Italian State as spoils of war. Giuseppe Lombardi and his partners won it in an auction at a very good price.

The ship was used for a mixed cargo / passenger service along the route Venice-Ancona-Athens-Istanbul-Cyprus-Beirut.

Giuseppe Lombardi managed the company for some years, until the Italian Navy called him up when the new war was around the corner.

In one of the trips between Italy and Lebanon, Uncle Pin had to accomplish a special task, necessitating an unexpected stop at Latakia, Syria. The ship had to load the members of a French

archaeological expedition, coming back to Europe at the end of a three-year long excavation campaign in the Fertile Crescent, with all the collected material. More than 300 boxes of finds were loaded on the ship.

The Lombardi family in 1921. Giuseppe Lombardi, wearing his Navy officer's uniform, and his sister Maria, Cesare Baj's grandmother are highlighted.
(Photo given by Cesare Baj)

In those years Syria was ruled by a French administration, under a mandate of the League of Nations, following the dissolution of the Ottoman Empire, defeated after the unfortunate alliance with the Central Empires.

Uncle Pin never talked about that trip and the existence of the French expedition. The details about the stop in Syria and the load transported could be deduced only from the inscriptions on the box and the pictures of an album kept by the family.

Let's come now to the discovery of the material. Admiral Lombardi passed away at the age of 96, thirty years before his nephew, living in the same big family house where his uncle lived when he wasn't on duty, found in a cellar a wooden box with strange inscriptions.

A map of the *Proche Orient* in the early '20s. The arrow indicates the port of Latakia, where the French archaeological expedition and all their boxes were loaded on the *Duivendyk*, including that containing the Babylonian terracotta finds.

Forgotten for decades among old furniture and all kinds of junk, the box was approximately the size of a case for six bottles of Champagne. It was covered with dust, but perfectly sealed. In the interior, well preserved and protected by layers of straw, a few terracotta artifacts were to be found. Their Mesopotamian origin would appear evident to any layman, as they showed cuneiform inscriptions.

Two of these artifacts had a circular shape and showed on their surfaces series of lines placed according to a precise order.

The label present on the box containing the Mesopotamic instrument. It clearly shows that the material was loaded on the *Duivendyk* at Latakia, in February 1924.
(Photo taken in the house of Giuseppe Lombardi's nephew).

Admiral Lombardi's nephew is a learned person, and immediately understood he had in his hands objects of archaeological significance and value, probably a scientific, astronomical or navigation instrument.

After the finding, he remembered he had a second cousin who is a science writer and, after 35 years since the last contact when they were boys, he called Cesare. After having re-established a warm family atmosphere, he informed Cesare about the finding of "strange, probably Mesopotamian artifacts".

He said he had thought of donating the material to the local museum, but he was afraid it could pass one more century or so in some other cellar. He then decided to get an opinion from someone who could evaluate the material with some scientific or archaeological knowledge.
As it was said, Uncle Pin never talked about that box and nobody could imagine why he entered into possession of it. It could have been forgotten in the ship and found after some considerable time had passed, with no possibility of returning in to the owners. It may have been donated as a souvenir by a member of the French expedition.

Misappropriation was excluded, as Uncle Pin was a man of integrity (in this case, the material would have been kept better and possibly shown, for example, in a museum, if not sold). The box simply got into possession of Giuseppe Lombardi and was abandoned in the cellar.

Nobody in the house came across the box until now and its history could be deduced from a label glued on a side of the box, carrying easily readable inscriptions, referring with no doubt to that trip.

Cesare, after a quick examination, found immediately something familiar in those finds and asked his second cousin to keep the material for some time for a deeper study.

This is a stroke of luck, as Cesare has a good experience in the design of replicas of ancient astronomical instruments and sundials and for some years he was a professional designer of slide rules. He loves the history of mathematics and has a notable personal library on the subject.

He doesn't know any Mesopotamian language, but he brushed up on the works on the Mesopotamian mathematics, especially Georges Ifrah's *Histoire Universelle des chiffres*, Roger Caratini's *Les Matématiciens de Babylone* and the classic works of Oscar Neugebauer.

In a couple of weeks he familiarized himself with the sexagesimal system and with the notations used across a couple of millennia by the peoples who lived around the Tigris and the Euphrates.

This study allowed Cesare to fully understand the meaning of those inscriptions and the use of that artifact coming from a far past.

It is now indisputable that the Babylonians invented the logarithmic slide rule, and this is revolutionary discovery concerning that civilization.

We have the pleasure of presenting, here attached, Cesare Baj's technical documentation concerning the characteristics and the use of the Babylonian slide rule.

Using his experience, Cesare then prepared a working replica of the instrument, with numbers both in cuneiform, sexagesimal notation and in Arabic, decimal notation.

The Lombardi family decided to donate the artifact to a suitable university, museum, or scientific institution, still to be identified.
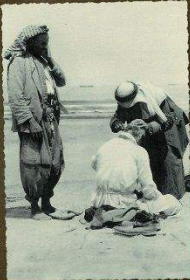
Dr. Mario Astolfi
Professor of Mathematics - Bologna University
Member of the scientific board UMI - Unione Matematica Italiana

Next pages: two sheets of the Giuseppe Lombardi's photo album, kept by the Lombardi family, carrying photos taken during the stop at Latakia in February 1924.

In a picture the ship can be seen. In others the boxes of the French expedition being loaded.

Scalo a Laodicea
21-2-24

Scene di
vita quoti-
diana

Di fronte all'ufficio
consolare italiano

Scavi

La nostra
nave

Laodicea
21-27 feb. 24

Scene
nelle strade

Componenti della
spedizione

Carico delle casse
della spedizione
archeologica francese

Dalla nave,
alla partenza
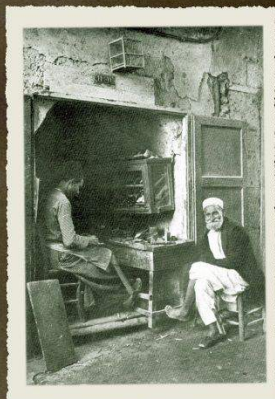
Technical report on the Mesopotamian Instrument Recently Discovered
Cesare Baj Como, Italy - December 2015

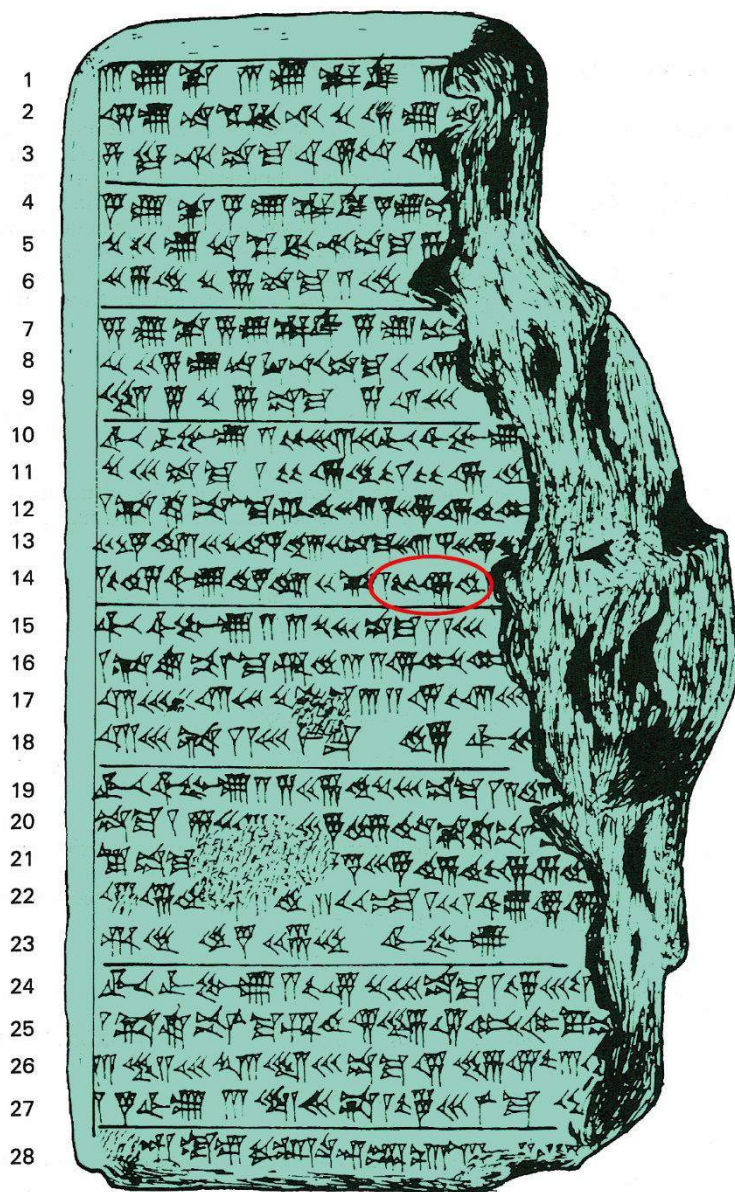The instrument is composed of two disc-shaped pieces of different diameter, the larger being approximately 20 cm / 8 in. wide. They are in a fairly good state of conservation, though a few small scratches and abrasions are present here and there.

Each disc carries on one face lines and inscriptions in cuneiform characters, drawn with notable precision, which is higher than that normally seen on tablets carved with text.

The fact that the two pieces have to be coaxially combined is demonstrated by the presence in both of them of a central hole, by the shape of the discs and by the disposition of the inscriptions.

The discs were likely fixed together by a pivot, may be made of metal, but more probably of wood. In any case the part is missing, as it became lost or did not resist the passage of time. Only the parts made of terracotta, a material whose durability is proverbial, came to us. The edge of the larger disc shows a hollow or groove (more on that below).

$$1 \quad ; \quad 0 \quad ; \quad 0 \quad ; \quad 16 \quad ; \quad 40$$
$$1\times60^4 + 0\times60^3 + 0\times60^2 + 16\times60^1 + 40$$
$$12.960.000 + 0 + 0 + 960 + 40$$
$$= 12.961.000$$

Tablet AO 6484 found at Uruk during clandestine excavations, presently conserved at Louvre. It dates to the 3rd century before the Common Era. Number zero is present two times in the number highlighted in line 14.

The incredible and scientifically interesting element is the sequence of radial lines that are carved on the surface of both discs, equally spaced on both discs, so that there is a position in which the line of a disc exactly match with those of the other disc. Their arrangement reveals, even at a first glance, a pattern that results from a precise computation. Divisions, i.e. the space between the lines, have a variable amplitude, according to a growing progression. Again at a first glance, it

clearly appears that the scale of lines is divided into two parts, each occupying a semi-circle, the scale of one of the semi-circle being exactly repeated on the other.

With no need to interpret the inscriptions, each scale appears immediately as a double-cycle logarithmic scale, each being 180° wide on the discs, as the A or B scale of a modern slide rule. The inscriptions can be easily interpreted as numbers, which were written in cuneiform characters in sexagesimal notation. They represent the numbers from 1 to 60 in the first semi-circle and from 60 to 3600 in the second.

The sexagesimal number system was adopted by the Sumerians and later by the Babylonians and other peoples settled in Mesopotamia. It is based on number 60, with 10 as a subsidiary base.

So the instrument is nothing other than a logarithmic slide rule for a sexagesimal system. It corresponds exactly to a modern slide rule having just the scale of the squares or "1-100" in 360°; in the modern instrument, designed for a decimal number system, the values represented are 1-10 in the first semi-circle and 10-100 in the second.

The instrument allows the execution of multiplications, divisions, and proportions, with all the advantages and disadvantages of any slide rule. The advantages are the rapidity of execution of the computations and the versatility and portability of the instrument, granted by the small dimensions.

The disadvantage is that the precision of the setting and reading of data has a limit, needing an interpolation effort by the user. Another is that the order of magnitude of the results has to be pre-calculated based on the order of magnitude of the input data.

Despite these inconveniences, numerous practical situations, when high precision is not necessary but when results are sought within a short time, a slide rule can play quite a role for the benefit of engineers, surveyors, agronomists, merchants and financial operators, which are all trades common to both the ancient Mesopotamian and to our present civilization.

Two working reconstructions of the instrument are attached to this document, one with sexagesimal numbers written in cuneiform characters, the other with decimal numbers written in the common "Arabic" notation.

This is not the place to present an "Operating Manual" of this Mesopotamian instrument, but anybody who is familiar with the use of slide rules can easily verify how simple its use is. And indeed it offers an opportunity to practice computations in the sexagesimal system.

Let's now try to date the Mesopotamian slide rule. Terracotta tablets and objects carved with cuneiform characters have been produced for three millennia, initially in Mesopotamia and later in a far greater area of the Middle-East. This is a demonstration of how useful and economic this writing system is, also taking into account the extreme low cost of the medium: clay.

In the case of numbers, we can observe strict similarities between the most ancient Sumerian notation and the subsequent Akkadian, Assyrian, and Neo-Babylonian notations. On the other hand it must be noted that the representation of numbers has evolved in those three millennia, from an additive sexagesimal system to a positional sexagesimal system, with number 10 as a subsidiary base, and finally to a positional decimal system.

Our instrument works with numbers strictly belonging to a positional sexagesimal system, the one used by the erudite Neo-Babylonians for mathematical and astronomical computations. The evidence for a precise dating comes from the two small signs **XXX**, indicating number zero with a positional function. This notation is a late invention, made in the last half-millennium BCE. Before that time, the number zero was not indicated, or was sometimes indicated by leaving a blank space between numbers. This practice used to generate difficulties in the interpretation of the value of numbers, unless the context suggested it. The regular use of a figure indicating "zero" in the very last centuries BCE solved the problem.

An example of the use of figure zero as it was done in our Mesopotamian instrument, can be found in tablet *AO6484*, conserved at Louvre Museum (*see* image), where in line 14 we can read the sexagesimal number 1;0;0;16;40 (correspondent to decimal number 12.961.000). So it's quite credible, not to say certain, that the instrument dates to what historians call "Neo-Babylonian" or "Seleucid period".

Talking about the use of figure zero, many scholars thought for long that it was used only in a median position, as in the number of the tablet conserved in the Louvre, and never in a final position. Neugebauer eventually demonstrated that this is not true, and he did it through a number present in tablet *BM 32651*, conserved at the British Museum, showing in line 11 of the 2nd column the number 60 in the form of a final position. This instrument further and unambiguously testifies to the use of the figure zero with its full positional value in the Neo-Babylonian epoch.

Let's now examine a few other properties of this slide rule. I was able to understand them thanks to my direct personal experience in designing logarithmic slide rules for different functions in the most disparate fields, a work I did until the eighties and sporadically in more recent times.

To start with, the density of the divisions is quite low, but this is exactly what we expect in scales to be carved in a disc made of clay of that diameter. The choice of representing two scales in 360° is for certain due to the need to represent a wide numerical range; however this choice compromises somewhat the precision that would have been maximized by distributing the numbers 1-60 in a 360° scale. The representation of numbers is neat, so that those missing could be very easily reconstructed. In order to avoid superimpositions, the expedient of lengthening a few lines and displacing the related numbers is quite effective and modern.

The two orders of magnitude are easily recognizable, as we have seen, by the presence of the little figures zero in the scale of higher magnitude. In addition, number 60 is represented with a larger sign, to mark clearly the passage from the scale of lower to that of higher magnitude.

The presence of number 10 as subsidiary base is evident in the representation of the submultiples of number 60, repeated from number 60 to 120 (XXX and XXX; in modern transcription [1 ; 0] and [2 ; 0]).

It is to be noted that the analogous interval in the scale of higher order represents numbers counted in 60s. This marks a difference between the Mesopotamian slide rule and a modern one. If the former would be designed according to more modern criteria, the interval 1-60 would be divided not into 6 parts of value 10, but in 10 parts of value 6 (as it has been done in the interval 600-1200 of the Mesopotamian instrument). Obviously if in the found slide rule the division of number by 60s between 600 and 1200 would present sub-divisions, number 10 would re-appear as a subsidiary base, as in the interval 60-120. But in this case the lines would be too closely packed to be readable.

It remains to understand the meaning of the hollow or groove at the edge of the larger disc. In the opinion of the writer, it's a rail for a cursor, probably lost having been made of a perishable material like the pivot. We can conjecture on how this cursor was made, and to do so let's identify with our original constructor of mathematical instruments and follow his design path.

The cursor, that couldn't be transparent for lack of suitable materials, has to allow readings covering the minimum part of the scales; it must have a certain solidity so as not to be spoilt during the use; it must slide along the instrument at a constant height, but not too high, in order to minimize the parallax error during the reading of data; it must slide in a soft and progressive way; and it must be lightly fixed in the position to which it is set, so that it doesn't move if lightly touched or when the instrument is manipulated.

The solution that best complies with these requirements is a small wooden frame pivoted in the center, with a runner sliding in the peripheral groove, slightly compressed against the instrument thanks to a flexible, wooden leaf spring sliding on the back of the instrument. The cursor line could be a bundle of hairs in tension on the axis of the frame, set radially from the pivot.

An additional consideration regards the scales, which increment in a clockwise manner, like that of modern slide rules. Clockwise operation seems then to be somehow "natural" for the representatives of our species, a fact also evident in the movement of the hands of clocks. We might hazard a guess that this is a consequence of the imprinting we had since the most ancient times from the rotating celestial sky (this is true in the Northern hemisphere, where the *Homo sapiens* species developed). Also the reading of data is the same as in modern slide rules: from the center of the instrument toward the periphery.

Slide rules are products of a typical "soft technology", i.e. a technology that can be applied in all places and times, requiring only simple materials present in nature or producible with elementary processes, provided the constructor is in possession of the necessary know-how.

It is curious that this terracotta instrument, as all Mesopotamian tablets, will exist in a future time when all the information presently carried on paper, magnetic and gelatin media, as well as in all electronic devices, will have been lost some millennia earlier.

To put it another way, if it is considered important not only to live one's own times intensely, but also to leave a heritage, the Babylonians and the other ancient peoples of Mesopotamia have brilliantly beaten our glittering technological society. In 10,000, 100,000 or a million years, the signs carved on humble pieces of clay, and not the terabits flowing among the silicon atoms of our sophisticated devices, will be there to testify the existence, in a far past, of a civilization.

The Finds

The image represents the finds in their present state, as they were taken out of the wooden box originally containing them, delicately cleaned, and assembled. In this image, the markings have been graphically enhanced to make them more recognizable.

Reconstruction of the Instrument
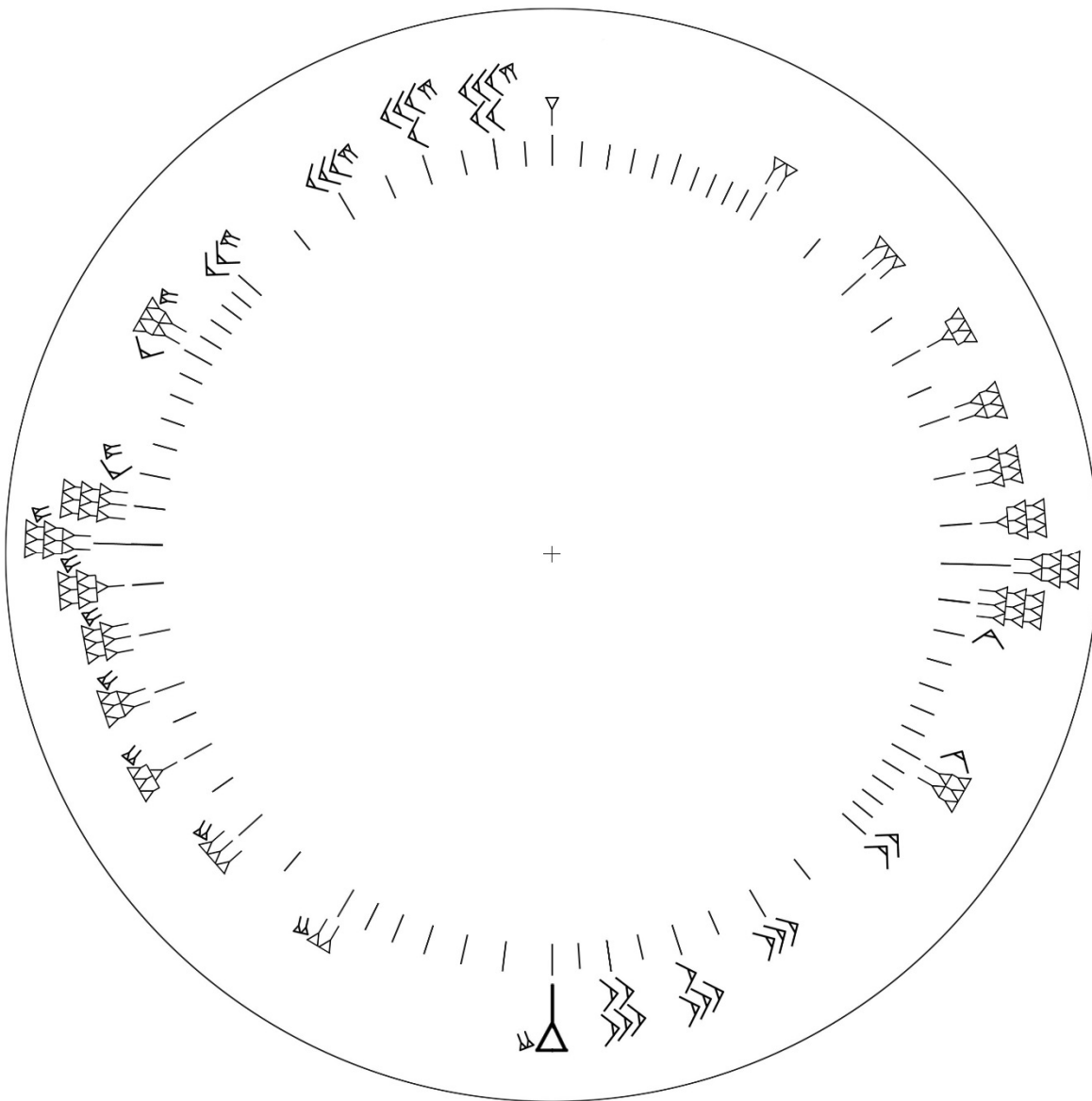
The instrument showing the original cuneiform numbers of the sexagesimal system
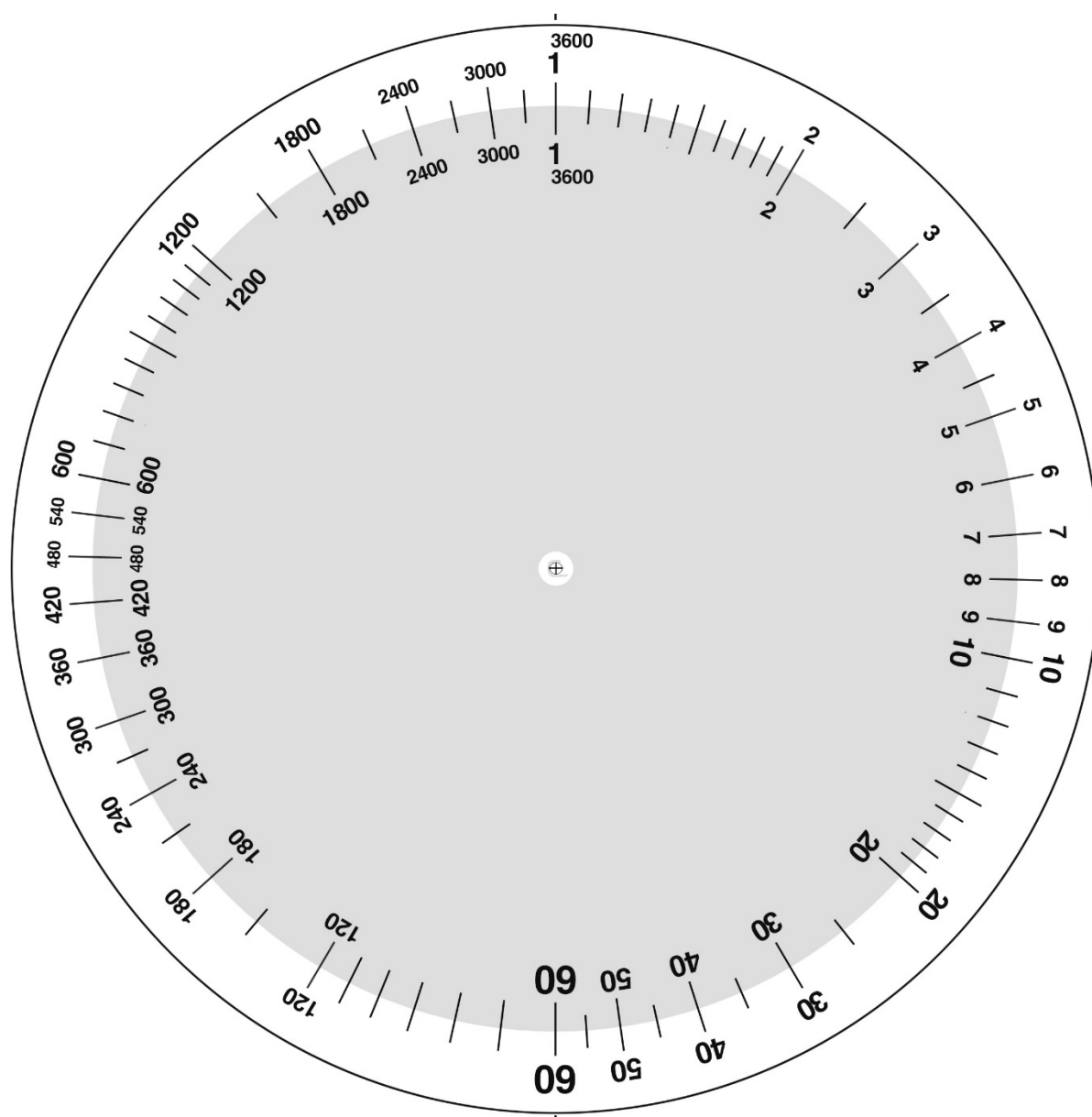
**The instrument showing numbers transcribed
into the Arabic figures of the decimal system**

A Working Copy of the Instrument

Whoever would like to grapple with the use of the Babylonian slide rule can cut the pieces printed on these pages and assemble the parts to get a working instrument. Both the discs reproducing the original instrument and those with numbers transcribed into the decimal system are presented. In the first page, the upper disc, with the inner scale; in the second the lower disc, with the outer scale.

Instructions:

-     Cut out the discs.
-     Apply a piece of adhesive tape in the central area of each disc, on one or both sides, to reinforce the area where the hole has to be made.
-     Make the holes, well centered on the printed point, using a device for making holes in belts or another cutting device.
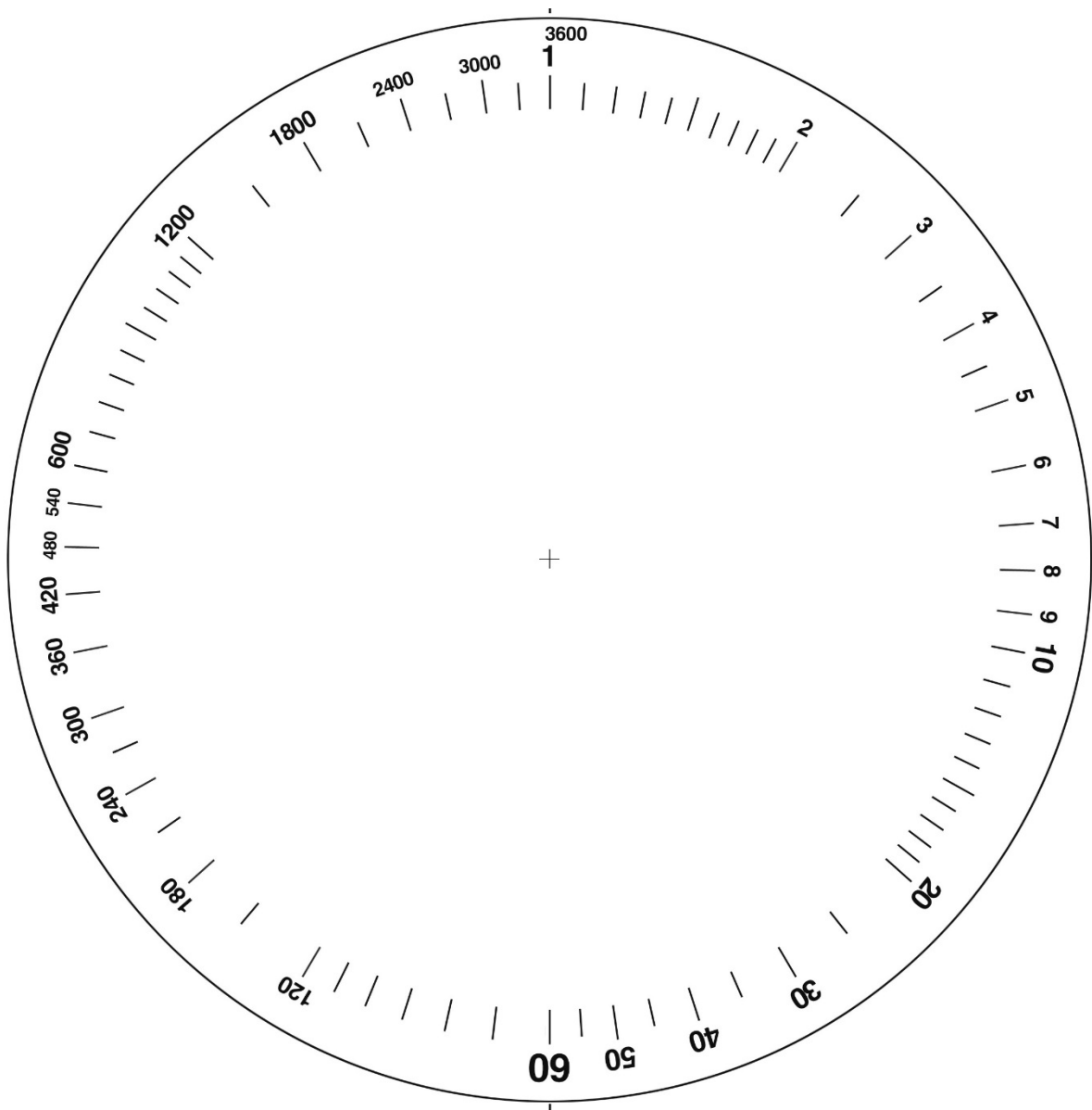-   Assemble the discs with a split pin or a rivet.
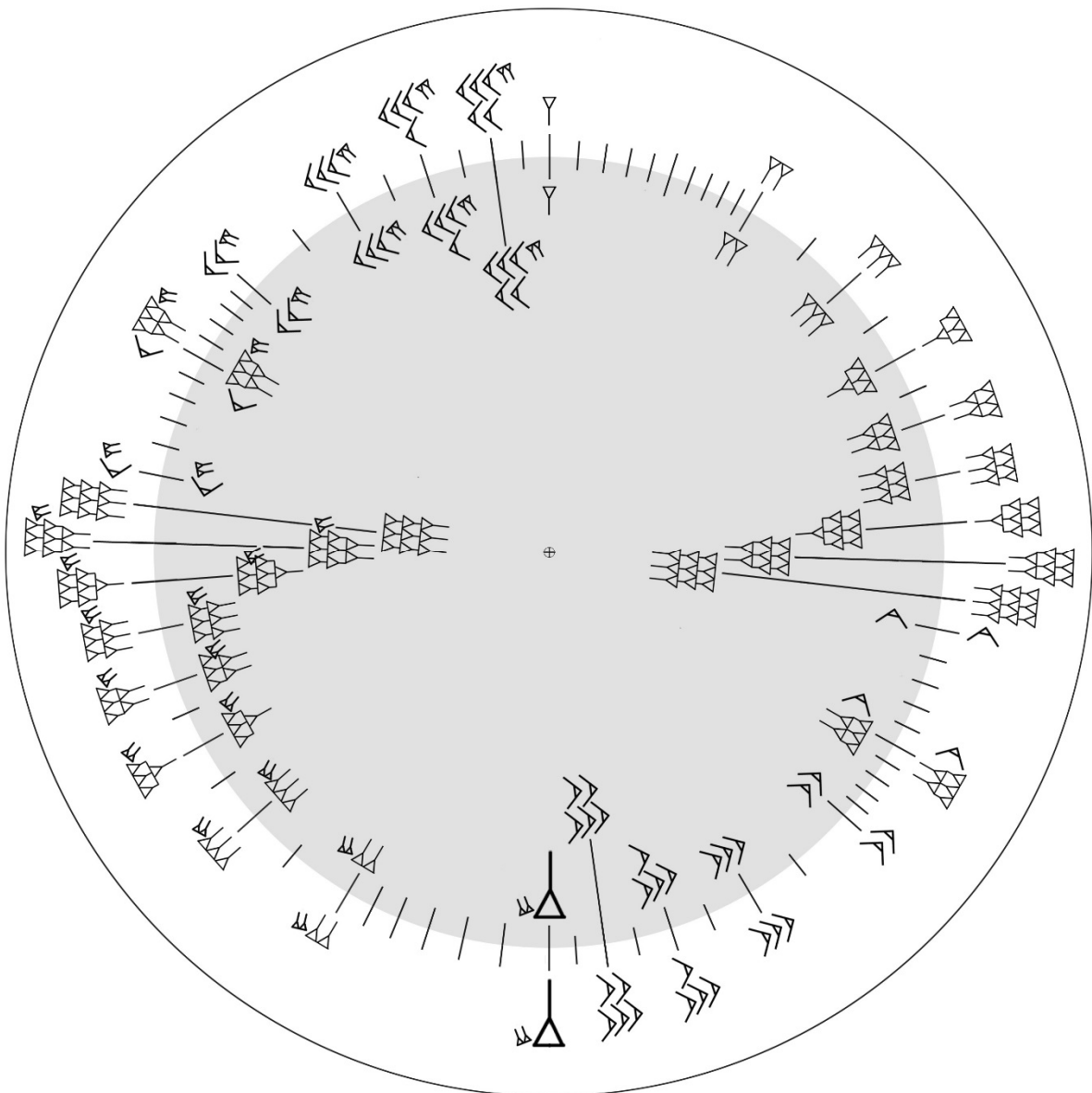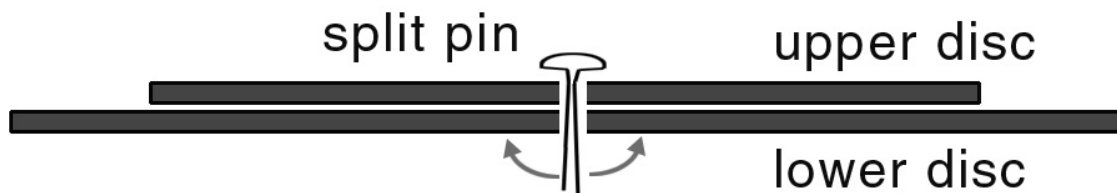
Upper Disk: Cuneiform
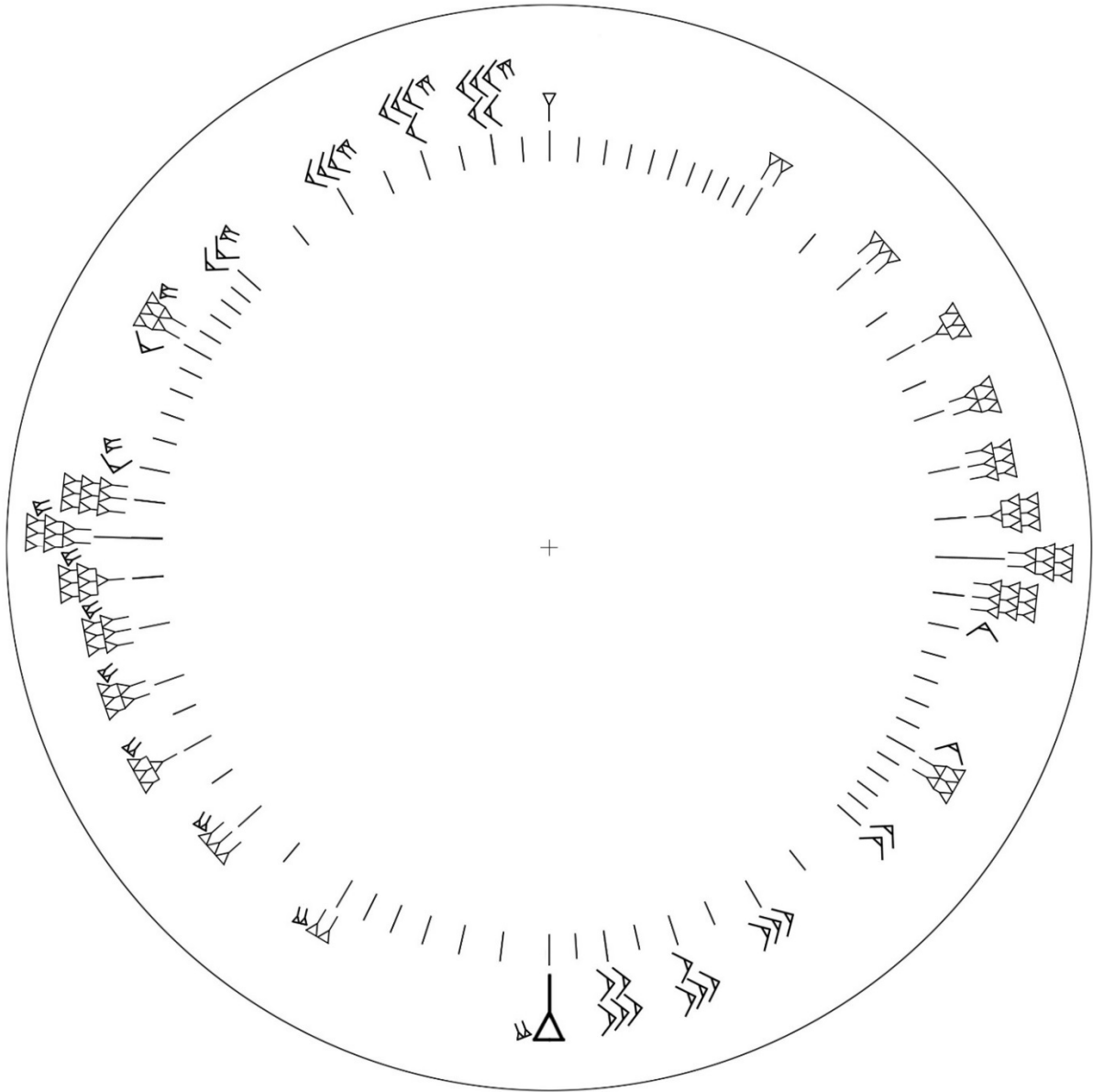
Lower Disk - Cuneiform
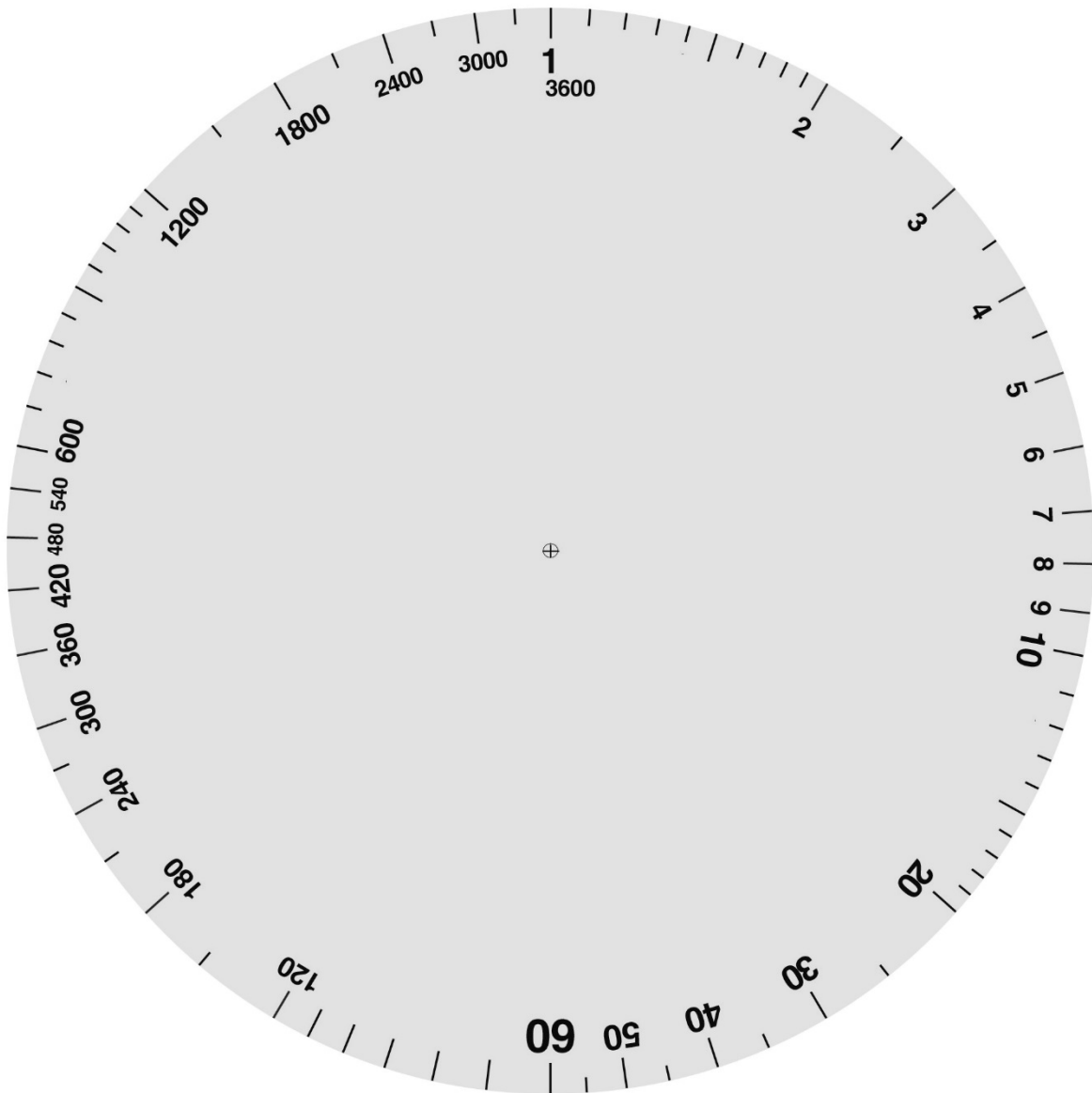
Upper Disk: Arabic

Lower Disk: Arabic

Cesare Baj was born in 1950. He operated for many years as a science writer and an editor of scientific magazines and encyclopedias. He designed dozens of slide rules for the editorial and advertisement industries and produced many kits of astronomical and navigation instruments for educational purposes.

In 1986 the J. Walter Thompson Company, the world's leading marketing communications group, granted him the "David Campbell Harris The Future of Communication" award, for the report "Second generation slide rules – Interesting applications in the field of mass communication and advertisement of a sophisticated technology of the past".

He is slowly preparing a book on his experience in designing slide rules, with a concise catalogue of his production.

A seaplane pilot since 1970, he is the author of many technical and historical books on aviation.

He is also a member of the Italian CICAP, a sister association of the American CSI, the Committee for Skeptical Inquiry, of which the mission is *"to promote scientific inquiry, critical investigation, and the use of reason in examining controversial and extraordinary claims";* it had among its members Isaac Asimov and Martin Gardner.

He is about to launch in the market a kit for prospective pilots, including several analog computing devices, and he has a project to develop in the field of educational/recreational mathematics.

Correlation Machines
Andries de Man
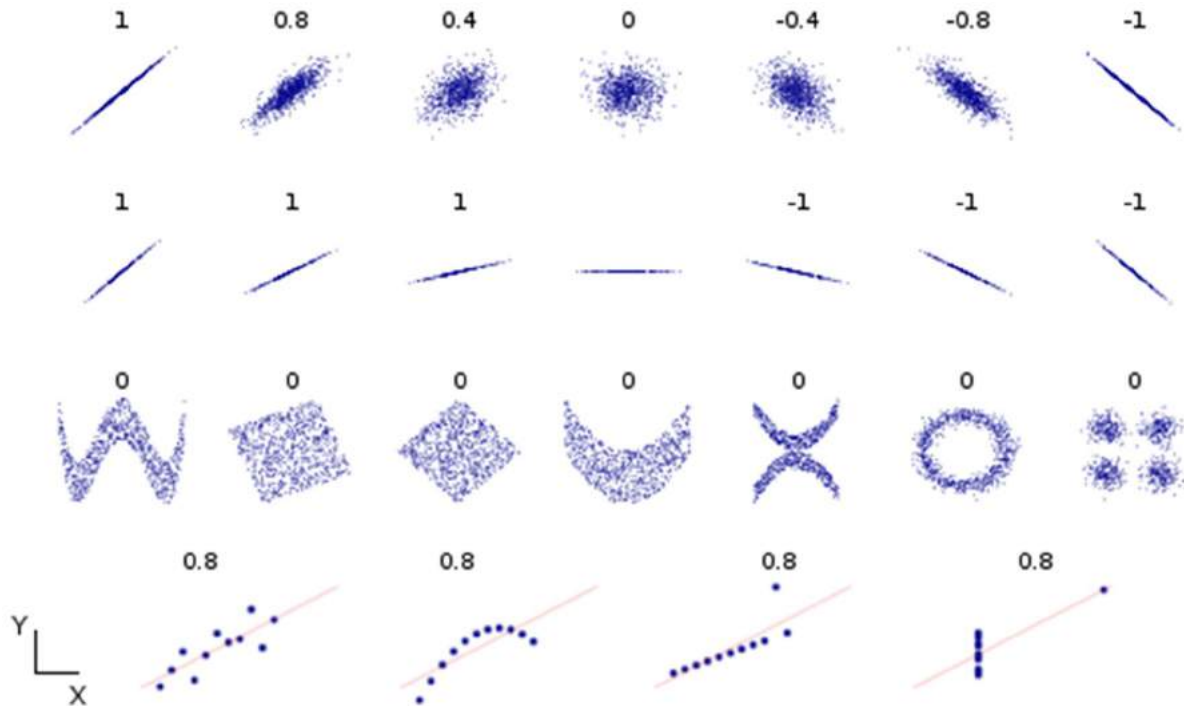
Figure 1: Pearson r value for various datasets (Source: Wikipedia)

Correlation is a statistical concept that is used in many scientific areas. Two or more quantities are correlated if there is a "connection" between the pairwise values they can assume. Correlation is usually quantified with the "Pearson coefficient of correlation" r, spanning −1 to 1.

In this presentation we will use two quantities: X and Y. Figure 1 shows a number of datasets with these quantities, and the corresponding Pearson coefficient of correlation r.

The interpretation of correlation coefficients is tricky. A high (absolute) coefficient of correlation does not necessarily indicate a linear relation between X and Y. The four datasets in the lower row of Figure 1 all have the same r, but look quite different. Data with a low (absolute) coefficient of correlation can still show a clear pattern. The datasets in the third row of Figure 1 have a zero coefficient of correlation, but still seem to have some connection between X and Y.

The Pearson coefficient of correlation was introduced in 1895 by Karl Pearson and started to be used at a large scale in the beginning of the 20th century by, amongst others, economists, psychologists, agricultural experts, and brewers.

How is r calculated?

If there are n "subjects" in the dataset, and the subject i has a value x_i for X and y_i for Y, then r is given by:

$$r = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n \sum x_i^2 - (\sum x_i)^2}\sqrt{n \sum y_i^2 - (\sum y_i)^2}}$$

TABLE IV.—SUPPLEMENTARY CORRELATION SHEET
x-variable 1, y-variable 2, Data sheet (Table I)

$(x+y)$	Tabu-lation	f	$(x+y)^2$	$(x-y)$	Tabula-tion	f	$(x-y)^2$
29	1	1	841	15	.	.	225
28			784	14			196
27	11	2	729	13			169
26	1	1	676	12			144
25	1	1	625	11			121
24			576	10		..	100
23			529	9			81
22			484	8			64
21			441	7			49
20	11	2	400	6			36
19			361	5		..	25
18			324	4	IIII	5	16
17			289	3	111	3	9
16			256	2	IIII	5	4
15	1	1	225	1	IIII 111	8	1
14	11	2	196	0	111	3	0
13	1	1	169				
12	1	1	144	$\Sigma(x-y)^2 = 135$			
11	11	2	121				
10	11	2	100	$\Sigma x = 167.$			
9	..		81	$\Sigma y = 152.$			
8	1	1	64	$\Sigma x^2 = 1599$			
7	1	1	49	$\Sigma y^2 = 1458$			
6	11	2	36				
5	.		25	$m_x = 6.958$			
4	1	1	16	$m_y = 6\ 333$			
3	..		9	$s_x^2 = 18\ 211$			
2	1	1	4	$s_x = 4\ 27$			
1	11	2	1	$s_y^2 = 20\ 643.$			
0	.		0	$s_y = 4\ 54$			
$E(x+y) = 319$				$N = 24$			
$E(x+y)^2 = 5979$							

Preliminary checks

Operation	Value	Check
$\Sigma x + \Sigma y$	319	$\Sigma(x+y)$
$2\Sigma x^2 + 2\Sigma y^2$	6114	$\Sigma(x+y)^2 + \Sigma(x-y)^2$

Computations

Operation	Value	Check
$\dfrac{\Sigma(x+y)^2}{N}$	249 125	$r_{(x+y)}$
$\dfrac{\Sigma(x-y)^2}{N}$	5 625	$r_{(x-y)}$
$m_x + m_y$	13 291	$(m_x + m_y)$
$(m_x + m_y) \times (m_x + m_y)$	176 651	$(m_x + m_y)^2$
$m_x - m_y$	625	$(m_x - m_y)$
$(m_x - m_y) \times (m_x - m_y)$	391	$(m_x - m_y)^2$
$2s_x^2 + 2s_y^2 + (m_x + m_y)^2 + (m_x - m_y)^2$	254.570	$r_{(x+y)} + r_{(x-y)}$ (check)
$\sqrt{4s_x^2 s_y^2}$	38 77	$2s_x s_y$ (check)
$r_{(x+y)} - (m_x + m_y)^2 - s_x^2 - s_y^2$	33 620	n
$s_x^2 + s_y^2 + (m_x - m_y)^2 - r_{(x-y)}$	33.620	n (check)
$\dfrac{n}{2s_x s_y}$	87	r

(Do the last computation twice)

Figure 2: Correlation form, for a method using (xi + yi) [Cureton 1929]

So one needs the following sums: $\sum x_i$, $\sum y_i$, $\sum x_i^2$, $\sum y_i^2$, and $\sum x_i y_i$. The first four sums are also needed for the calculation of averages and standard deviations. If there are more quantities (X, Y, Z ...) one will need all primary sums, square sums and (at least) pairwise cross sums. And one would like to do all these calculations by entering the data only once…

By 1900 Hollerith tabulators and punch cards could be used for this purpose, but this equipment was large and expensive. Another method consisted of employing human "computers" who, without any knowledge of statistics, performed calculations using pre-printed forms. A large variety of these forms were offered commercially, with small variations of the formula for r and built-in error checking (Figure 2).

The first step in the calculation of a correlation coefficient usually consisted in "transmutation" of the data: the range of the values was normalized to (generally) integer numbers between 1 and 20. After this step one could use a printed multiplication table, and mental addition to calculate

the correlation. This calculation could also be performed with a "normal" mechanical calculating machine, preferably one with a very wide result register. The appendix describes how these calculations were done.

It is clear that this was a time-consuming error-prone job. That's why a need arose for dedicated, inexpensive correlation calculators.

Dedicated Machines
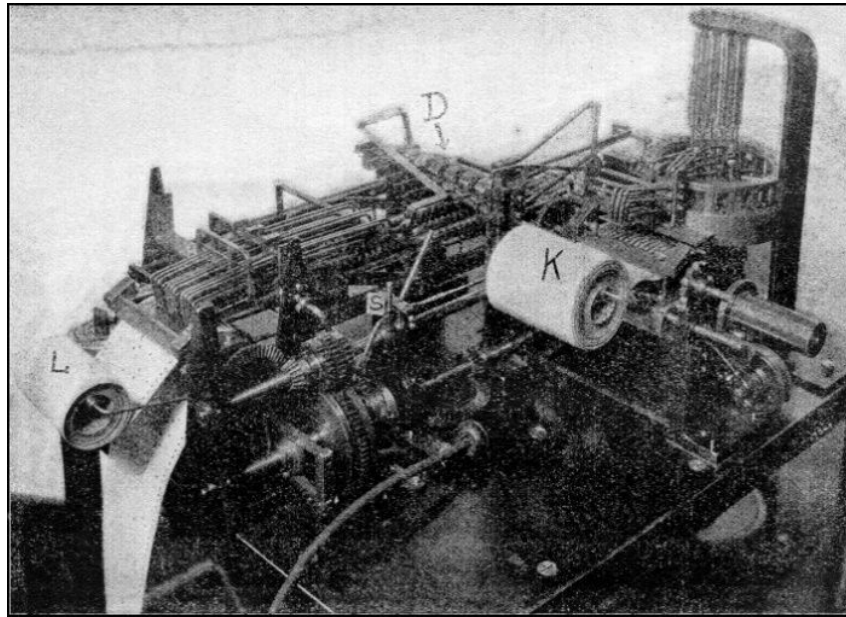
Figure 3: Hull's machine

Hull

By 1921 Clark Hull, a psychologist from Wisconsin, constructed a purely mechanical machine (Figure 3) for calculating the sums mentioned above [Hull 1925]. The data, having integer values between 0 and 999, was punched into paper tape that had to be fed multiple times through the machine. Hull could then calculate correlations between a large number of quantities. The resulting averages, standard deviations, and correlation values could be registered in thin metal strips for use in correlation-based predictions. The machine was used to give occupational advice for 40 professions based on 60 psychological parameters [Mechanix 1929]. Two versions of this machine were built, one for the Wisconsin Psychological Laboratory and one for the National Research Council. Because some researchers started sending Hull data for processing, he proposed to establish a Central Correlation Bureau that would compute correlations on demand. At the time, it was thought that two machines would be enough for all the correlation-needs in the United States.

Dodd

Around 1925 Stuart C. Dodd, a psychologist at Princeton University, made a simpler correlation calculator [Dodd 1926]. This machine (Figure 4) contained drums on which square numbers were represented by pins of different lengths (separate pins for units and tens). These drums are the square number equivalent of the multiplication bodies as used in the Millionaire calculator.

Dodd designed different versions of this device. Later development was continued by the Cambridge Instrument Co. Inc., New York, who sold these correlation machines to the universities of Harvard, Berkeley, and Chicago.
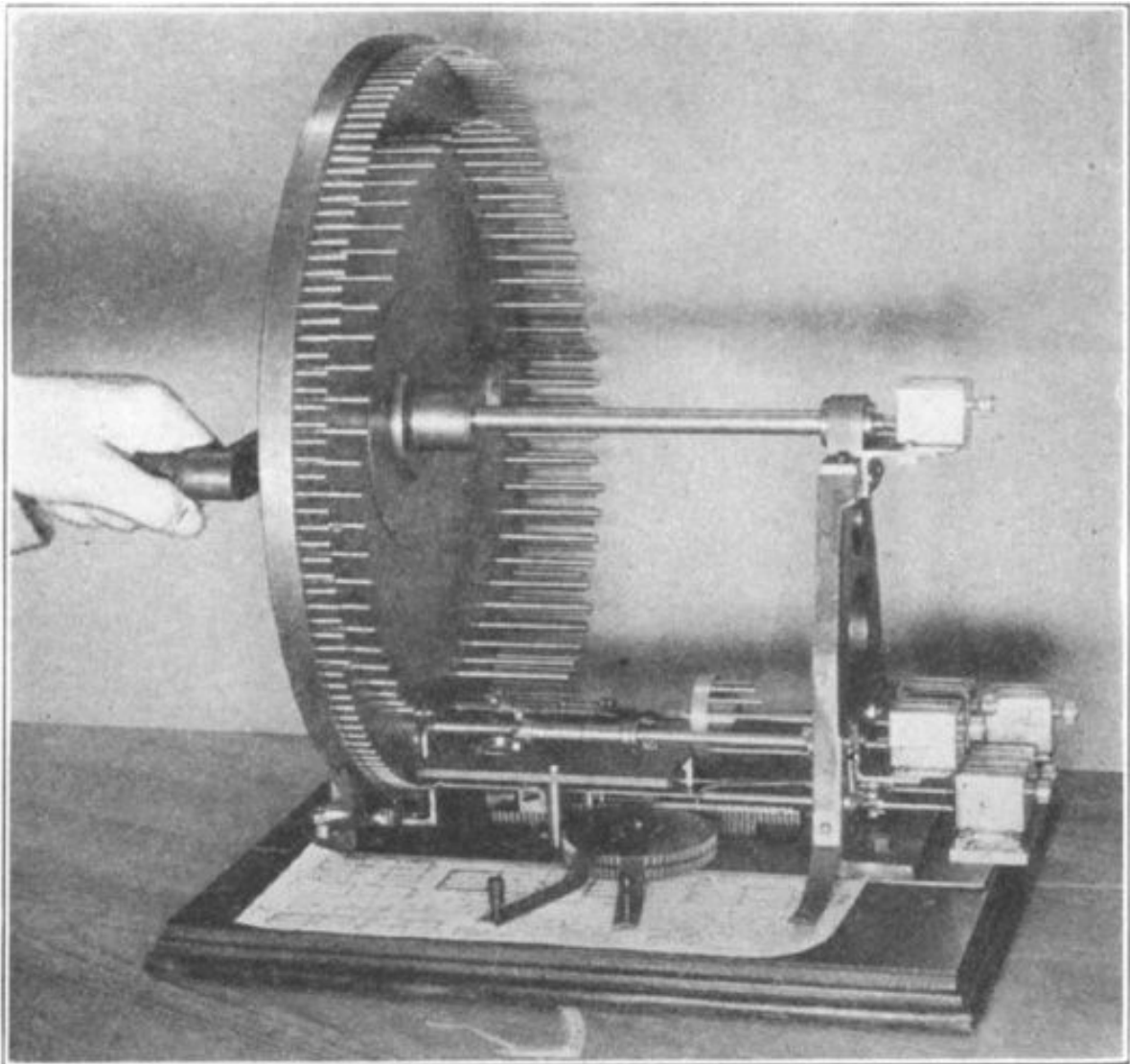
Figure 4: Prototype of Stuart Dodd's machine
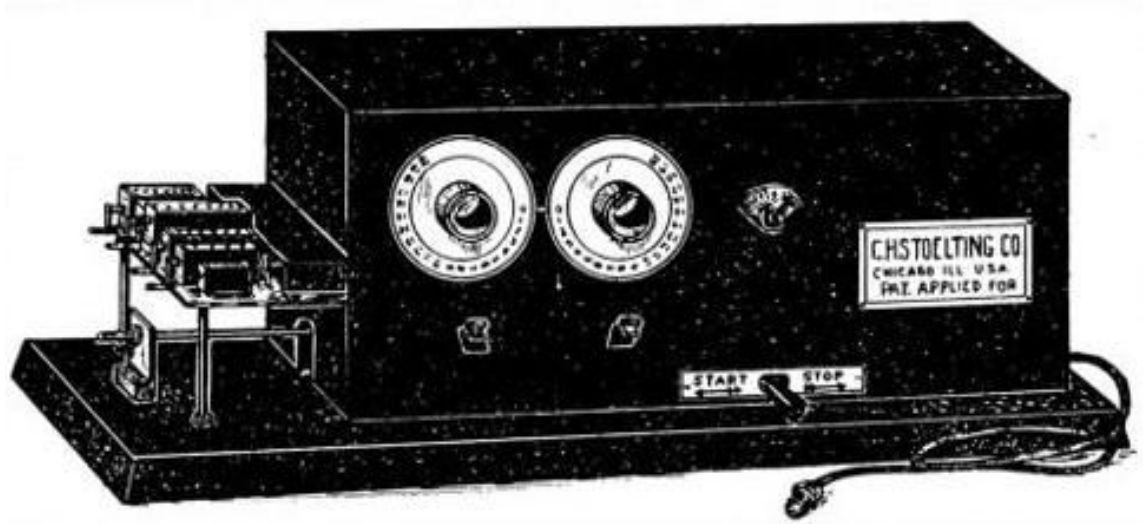
Figure 5: Seashore's machine (Stoelting catalog, 1930)

Seashore

A third correlation machine (Figure 5) carries the name of Carl Emil Seashore (Sjöstrand), again a psychologist. This machine was sold around 1930 by the C.H. Stoelting Company from Chicago, for $550. The machine calculated $\sum x_i$, $\sum y_i$, $\sum x_i^2$, $\sum y_i^2$, and $\sum (x_i - y_i)^2$, using a slightly different formula for r.

Analog Methods

If X and Y are regarded as coordinates of point masses in a two-dimensional space, then $\frac{1}{n}\sum x_i$ and $\frac{1}{n}\sum y_i$ give the center of mass, and $\sum x_i^2$ and $\sum y_i^2$ give the moments of inertia with respect to the X and Y axes.

Price

In 1935 the psychologist Bronson Price [Price 1935] proposed to use these properties for the calculation of: construct a bed of nails on which the data is attached using thin rings, and determine the center of mass and the moments of inertia of the whole shebang. The practical problem was that the bed and the nails had to be very light, or the rings had to be very heavy. Price never tried it himself...

Harsh and Stevens

C.M. Harsh and Stanley Smith Stevens, psychologists at Harvard, created an analog correlation machine working with small balls (Figure 6).

**Figure 6: Harsh and Stevens' analog "instrument"** [Harsh 1938]
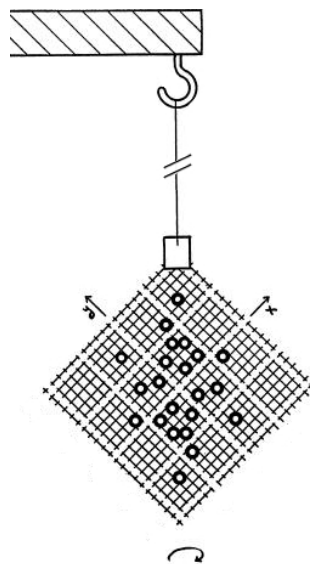
Figure 7: Platt's analog "instrument" [Platt 1943]

Platt

Later John R. Platt revived the idea [Platt 1943]. Platt was a biophysicist from Michigan who ended up in sociology. He used a flat metal sieve in which the data was set with lead pins (Figure 7). The center of mass was determined by hanging the thing twice, from different vertices, getting the two plumb lines from these vertices, and then obtaining their intersection. For the determination of the moments of inertia the thing was regarded as a torsion pendulum: the whole thing was given a rotation around a vertically placed X-, Y- or diagonal-axis and then released, and the time needed for at least 20 to-and-fro rotations was measured. Platt claimed that, this way, he could determine r with an accuracy of 0.01.

The Hydraulic Device of Schumann

A somewhat more complicated, and more dangerous, device was made by the South-African meteorologist Theodor Eberhardt Werner Schumann [Schumann 1940]. This device contained glass tubes filled with mercury in which iron rods were floating. His machine was also used to solve sets of linear equations. A trained human computer would need 5m² + m³/4 minutes to solve a set of m equations with m variables, while Schumann's machine could do that in 6m minutes.
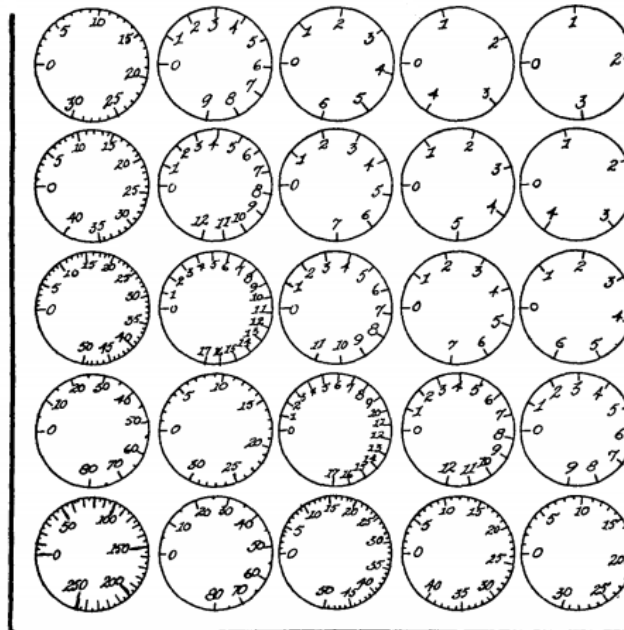
Figure 8: Ford's Correlator: a quarter section of the panel with potentiometers for entering data

The Electrical Device of Ford

Adelbert Ford, a psychologist of Michigan University, built an electrical correlation machine in 1931 [Ford 1931]. The data was entered on a panel with 100 potentiometers (Figure 8). The position of a potentiometer corresponds with the (transmuted) X and Y value of a data point. For each data point the corresponding potentiometer is turned 1 unit. The actual rotation angle for one unit changes with the position of the potentiometer, and this way squares and cross products are "calculated". Each potentiometer is connected to its own coil, and all these coils together form the secondary side of a transformer. To the primary side a voltmeter is attached which is used to read $\sum x_i y_i$. Since the transmuted data is required to average to zero, for the calculation

of r Ford only needs $\sum x_i y_i$ and $\sqrt{\sum x_i^2 \sum y_i^2}$, with the latter being set with a complicated calibration procedure.

Post Processing

The mechanical correlation machines only calculated sums. To calculate r, square roots and quotients had to be computed using a slide rule or log table (or a mechanical calculating machine, if you have time to spare). Fortunately, the required accuracy for r was usually only one decimal (in a −1 to 1 range).

Epilogue

The correlation machines present a unique contribution of psychologists, sociologists, and the like to the development of computing devices. This was clearly brought about by practical needs and a contemporary inclination towards technology among psychologists [Draaisma 1992].

I have been unable to find correlation machines of European origin. On the contrary: in 1929 the German mathematician Wilhelm Cauer attempted to buy a Hull machine for Göttingen University [Petzold 2000].

Of the mentioned machines no surviving specimens are known to me, except for the Hull machine that was rediscovered in 1997 by Hartmut Petzold in a depot of the National Museum of American History [Petzold 2000]. Psychological institutes seem to be as careless regarding their material heritage as are institutes of science and technology.

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Appendix

The calculation of the sums for r using a mechanical calculator:

Suppose we have a simple pinwheel calculator with 12 digits in the input- and revolution register, and 20 in the result register:

Revolution	0 0 0 0 0 0 0 0 0 0 0 0
Input	0 0 0 0 0 0 0 0 0 0 0 0
Result	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Take $x_i = 12$ and $y_i = 13$.
Put x_i and y_i in the input register (separated by zeroes!)

Revolution	0 0 0 0 0 0 0 0 0 0 0 0
Input	0 0 0 0 1 2 0 0 0 0 1 3
Result	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Shift the input register over half its width:

Revolution	0 0 0 0 0 0 0 0 0 0 0 0
Input (shifted)	0 0 0 0 1 2 0 0 0 0 1 3
Result	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Turn the crank 2 times (units van x_i)

Revolution	0 0 0 0 0 2 0 0 0 0 0 0
Input	0 0 0 0 1 2 0 0 0 0 1 3
Result	0 0 0 0 0 0 2 4 0 0 0 0 2 6 0 0 0 0 0 0

Shift the input register over 1 position and turn the crank 1 time (tens of x_i)

Revolution	0 0 0 0 1 2 0 0 0 0 0 0
Input	0 0 0 0 1 2 0 0 0 0 1 3
Result	0 0 0 0 0 1 4 4 0 0 0 1 5 6 0 0 0 0 0 0

We now have x_i in the revolution register, and x_i^2 and $x_i y_i$ in the result register. Shift the input register back completely.

Revolution	0 0 0 0 1 2 0 0 0 0 0 0
Input	0 0 0 0 1 2 0 0 0 0 1 3
Result	0 0 0 0 0 1 4 4 0 0 0 1 5 6 0 0 0 0 0 0

Turn the crank 3 times (units of y_i)

Revolution	0 0 0 0 1 2 0 0 0 0 0 3
Input	0 0 0 0 1 2 0 0 0 0 1 3
Result	0 0 0 0 0 1 4 4 0 0 0 1 9 2 0 0 0 0 3 9

Shift the input register and turn the 1 time (tens of y_i)

Revolution					0	0	0	0	1	2	0	0	0	0	1	3	
Input						0	0	0	0	1	2	0	0	0	0	1	3
Result		0	0	0	0	0	1	4	4	0	0	0	3	1	2	0	0	0	1	6	9

We now have x_i and y_i in the revolution register, and x_i^2 and $2x_iy_i$ and y_i^2 in the result register.

Shift the input register back completely, and repeat the procedure for x_{i+1} and y_{i+1} without clearing the revolution- and result registers.

Finally the revolution register will contain $\sum x_i$ and $\sum y_i$, and the result register $\sum x_i^2$ and $2 \sum x_i y_i$ and $\sum y_i^2$.

We see that each value of x_i and y_i has to be entered twice: once in the input register and once when cranking. But, because the revolution register is not cleared, it is difficult, after the first pair of values, to check if the correct value has been "cranked in". Electrically driven machines that allow entering multiplicators via a separate keyboard or pin setting would be a great help in this case.

It is also clear that, depending on the number of data-points and the range of the data, the registers should be rather large: for 100 data points with a range of 0…100 (integer numbers!) $\sum x_i^2$ can grow to 106, needing 7 digits. The result register will have to accommodate 3 sums of this size, so should have at least 21 digits.

Andries de Man (1964) trained as an applied physicist, turned into a computational chemist and ended up as an e-learning developer at Leiden University Medical Center, The Netherlands. He has been collecting calculating instruments since the 1990's, with a special interest in mechanical calculators and planimeters.

The IGN Logarithmic Circle
"Studying a Masterpiece"

José Fernandez

Introduction

This picture shows an apparatus created by someone mastering both the art of manufacturing and the use of logarithmic calculators. We have named it the IGN Logarithmic Circle, in reference to where it is found.

www.ign.es

What comes next is a study of the craft of this master of about a century ago, trying to understand his purpose and the details of his work. A lot of work hours and ingenuity were spent looking for a very specific benefit: better calculations in less time.

The Overview

This calculating disc is located in an exhibition at the delegation of the IGN in Murcia. IGN stands for *Instituto Geográfico Nacional*, or National Geographic Institute. This Spanish institution is in charge of the official works on radio astronomy, geodesy, geophysics, geodynamics, seismicity, gravimetry, volcanology, geomagnetism, cartography, etc.

The Logarithmic Circle is dated about 1910 and was assigned a Spanish origin. It has an external diameter of about 40 cm (bigger than an old music LP, or about two open hands), and is totally made of brass. It is described as [1]:

```
Desktop slide rule of circular shape, specially designed for topographic
calculations. Apart from logarithms, trigonometric calculations could be
done both in sexagesimal and centesimal degrees.
```

Apart from that, a close picture of its sliding cursor shows a lot of data, indicating that this is a very specific instrument with a great functionality.
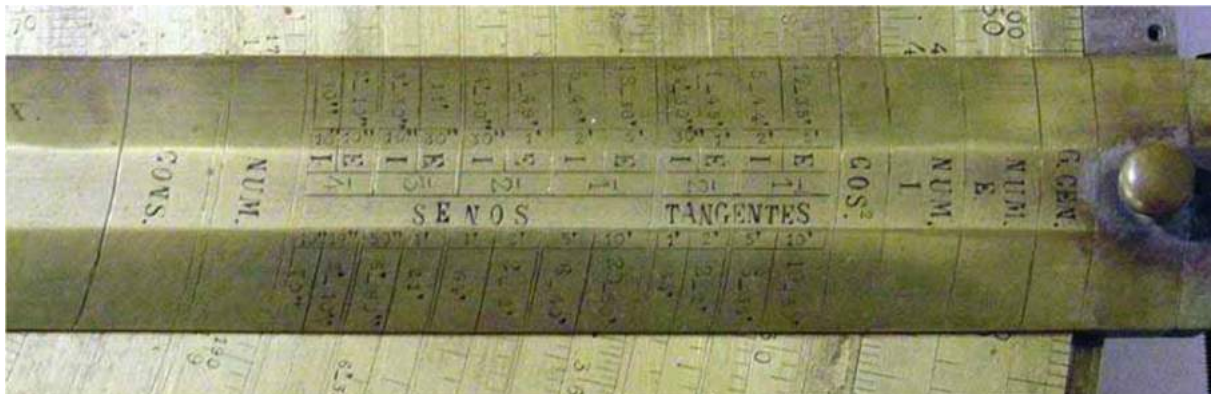
Brief History of the Search

We first knew about this device from the Internet, in an exhibition taking place in said IGN delegation in Murcia. Then, a look into the IGN website (www.ign.es) led us to a catalogue of historical instruments that had been used by the IGN in the past, where it was also listed.

With this information our colleague Gonzalo Martín was able to contact a person in the IGN in Madrid and get a pdf copy of the instrument manual. In fact, it was like a hand-written first draft, and it had deteriorated through the years.
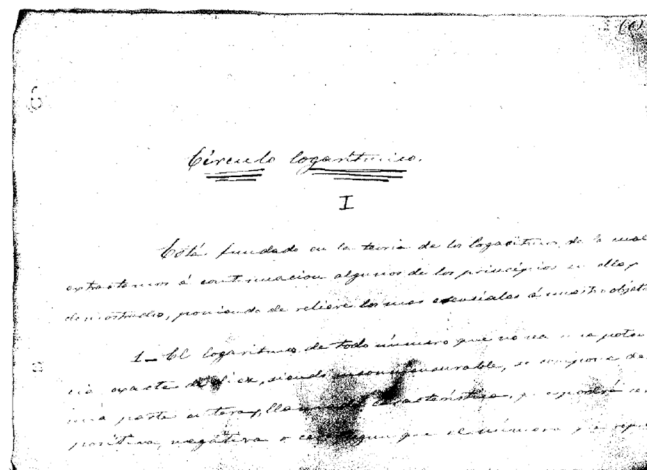

After a general (quite difficult) reading, Gonzalo [2] was able to understand that the device included the scales L, DF, and D in the fixed external ring, and Cos^2, T, S, C, constants, and degrees, from outside to inside in the central movable disc.

This calculating disc appeared very interesting and intriguing. Thus, I went into a detailed reading, guessing at and attempting to understand the old, hand-written, and deteriorated text, and generated a Word document. Far from satisfying, some of the details that could not be understood made me eager to see the device. There was a very long explanation of the capability to calculate with 5 decimals!
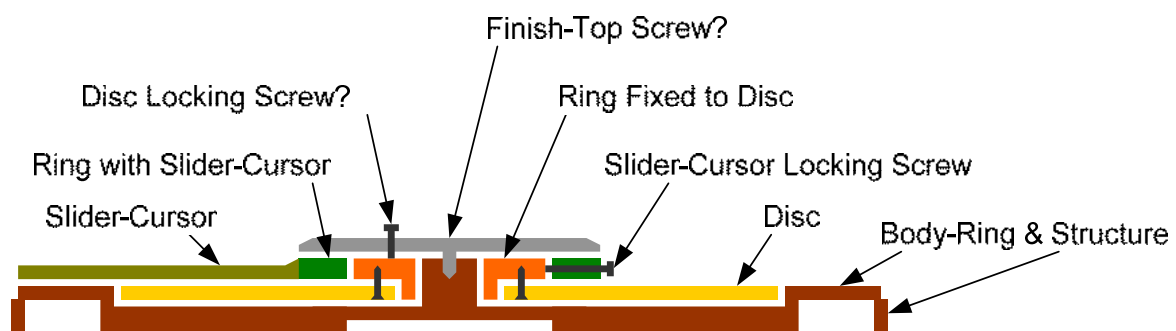
Next was to get a contact in IGN-Murcia, Mr. Angel Crespo, and get his welcome to go and study the instrument. Although I am a poor photographer with basic means, I got enough details for documenting the features of the apparatus.

Structure

This calculating disc has a supporting frame, with three feet, that includes the external ring of scales. Over this frame the disc is placed in level with the ring and rotates freely. Over the disc there is the radial sliding cursor with the micrometric system.


Cursor

External Ring & Frame

(Micrometric System)
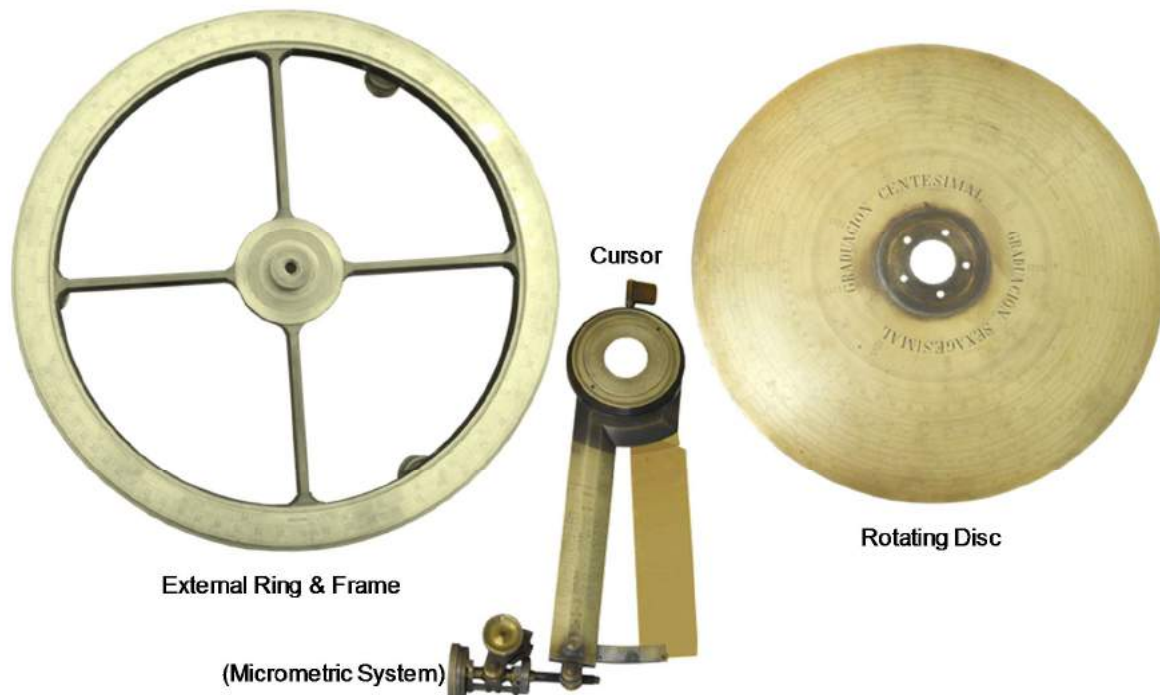
Rotating Disc

To better understand the assembly, I have prepared a cross-section drawing:

Finish-Top Screw?

Disc Locking Screw?

Ring Fixed to Disc

Ring with Slider-Cursor

Slider-Cursor Locking Screw

Slider-Cursor

Disc

Body-Ring & Structure

Around the frame's central axle there is a rotating ring to which the disc is fixed with five screws, and exterior to it the slider-cursor is also fixed but allowing for a separate rotation. There is half-turn screw to lock this separate cursor movement from the disc. And in the manual we have learnt that there should be a finish-top screw, fixed to the bottom frame axis, with another locking screw to stop the movement of the disc. We can only see the screw hole for this component.

Scale Layout

There are nineteen circular scales in the IGN logarithmic circle, in ten different groups. I think it is better to start with a general view and continue with the details afterwards:
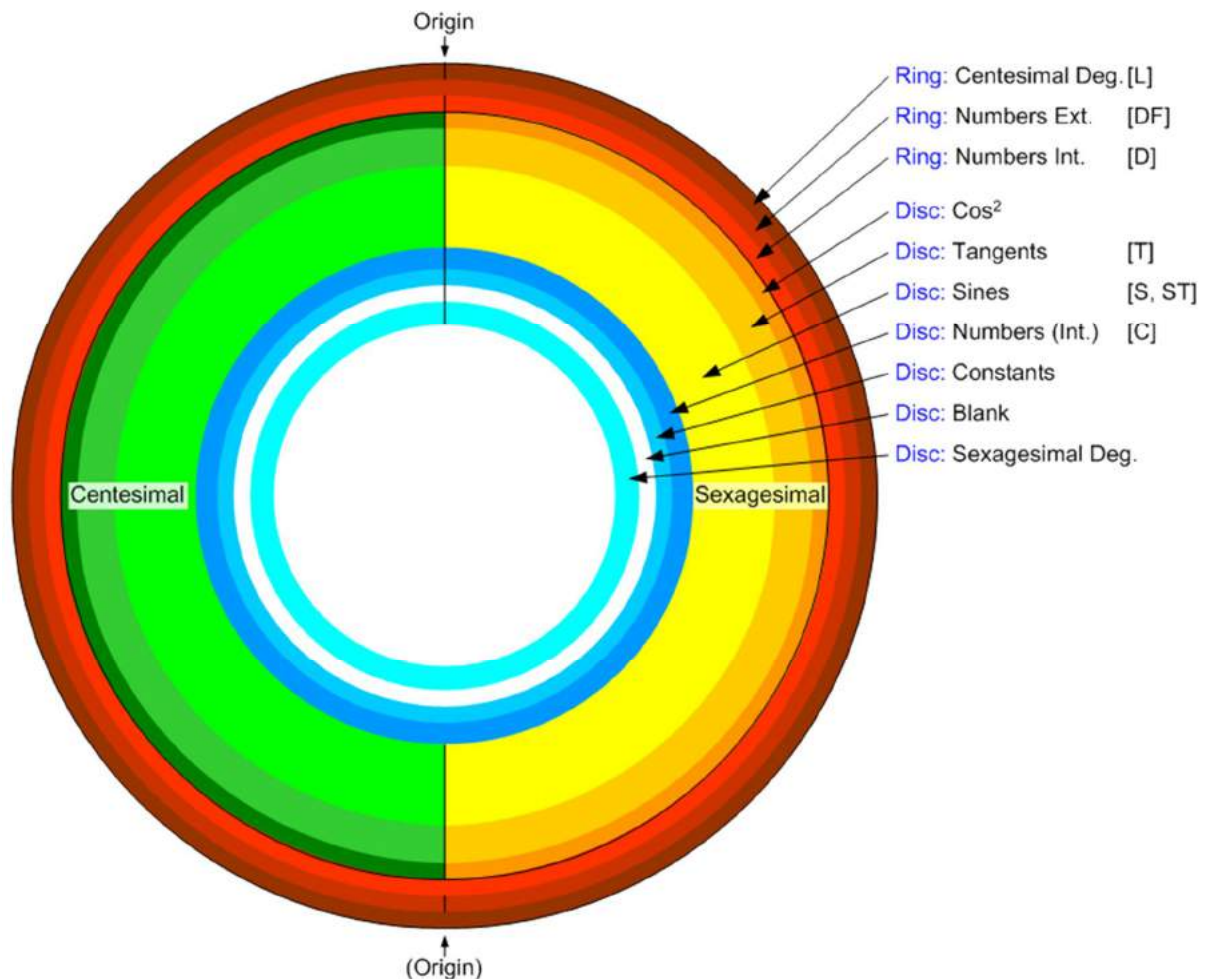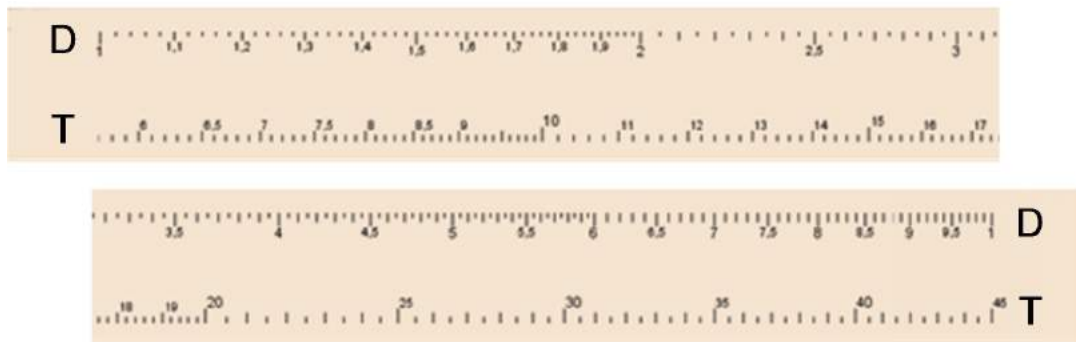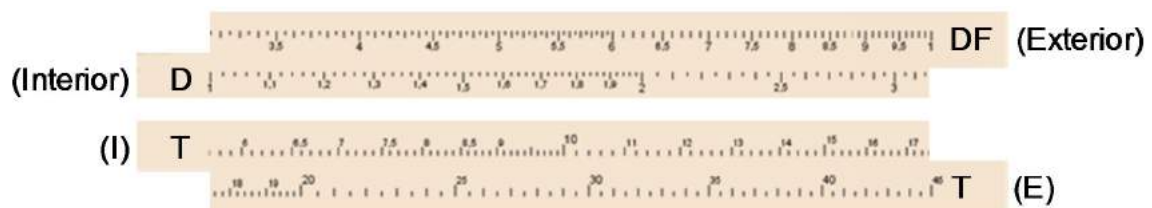

Halved Trigonometric Scales

The first that catches our eyes is the halving of part of the scales in the disc (yellowish "sexagesimal" and greenish "centesimal" areas). To explain this, I will start from a linear D and T scales layout.

If we cut this by half, and put one half over the other, we obtain:

That now, ordering the scales, leads to:

So, we can have both D and T scales in half the length, only being careful to refer each half of the T scale to the corresponding D half. Furthermore, the "exterior" half of D if continued to a complete cycle, would convert into a DF scale, in respect to the "interior" half if then also continued to complete the cycle.

With this exercise and a little complexity increase, we reduce the length of our movements when working with such a "halved" T scale. Also, we have the other "half" of the D and DF scales to add another pair of T halves. But this time this T scale shows centesimal degrees (those that range from 0^g to 400^g), in contrast to the sexagesimal degrees in the first T scale (those from 0º to 360º).

In the end we get two separate disc regions where all calculations may be done (with shorter movements) in either sexagesimal degrees or centesimal degrees.

Logarithmic Scales (D, DF & C)
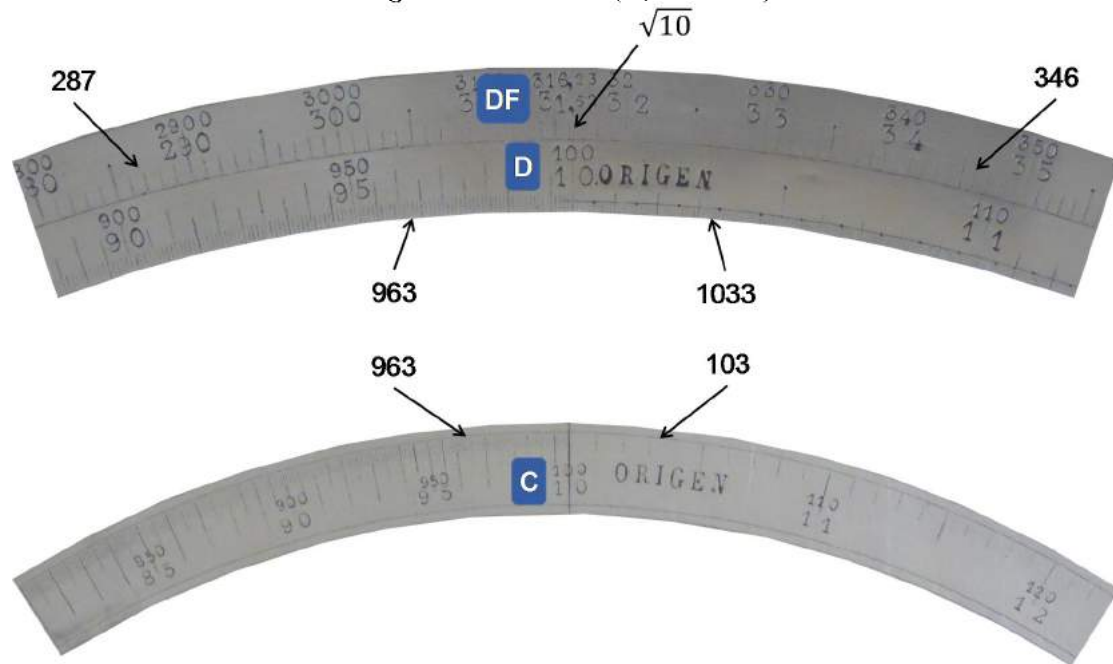
There is no difficulty in recognizing DF and D in the external ring, and C in the disc. As explained above, DF is folded at half D. You can read three digits in all the scales' length, except from 1 to 2 in D and DF, where the readings have 4 digits. DF is referred as "E" for External, and D as "I" for Internal. These scales are named the scales of "numbers" (NUM I & NUM E).

Cos² Scales

Although they occur in a single circumference, there are two scales for both ranges of degrees, each pair in the respective half:


The first scale of each pair (from 0º to 45º and from 0^g to 50^g) is inverted so that it is read clockwise, like the other scales, but then direct reading into D, or DF, is not possible. The second

scale reads counter-clockwise and is "a little farther" on the available space of the respective half. There is not a clear reason in the manual for the need of such layout.
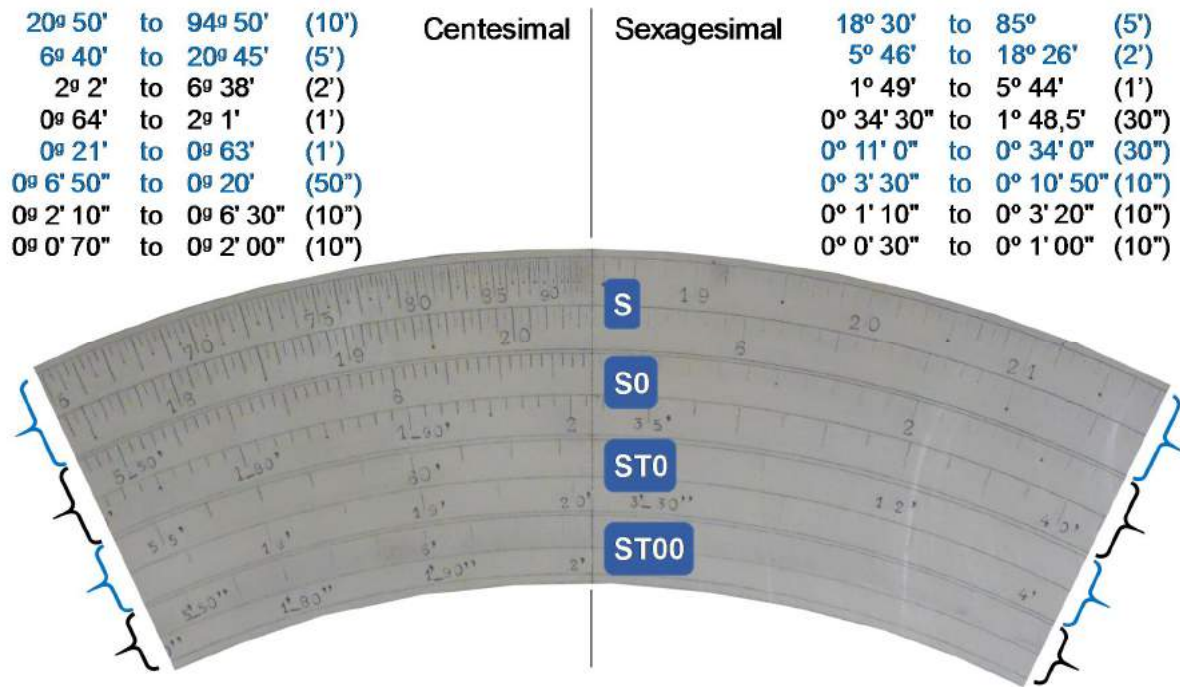
Tangent Scales

Being a precision disc, it is possible to differentiate the sines and tangents in the scale cycle that in desktop slide rules we know as S&T. So, together with the two halves of T, we have other two halves for the lower cycle that I have named T0:
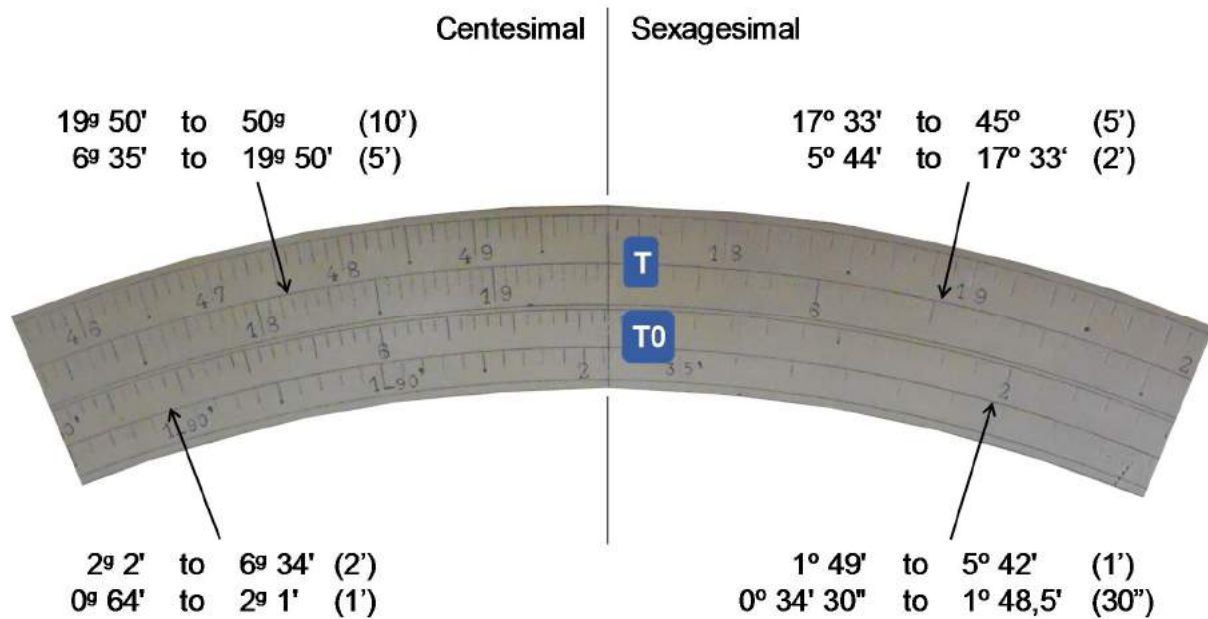
In the figure the ranges of readings of each of the T and T0 scales are shown, both for sexagesimal and for centesimal angles. In parentheses there is the value of the distance between two marks of the respective scale.

Sine Scales

In a similar way, there are four cycles of the sine, decreasing from the standard S. I have named the other three S0, ST0, and ST00. It can be easily understood that ST0 and ST00 can be used also for tangent calculations, as the number of digits does not enable a differentiation of sines from tangents.

20ᵍ 50'	to	94ᵍ 50'	(10')			
6ᵍ 40'	to	20ᵍ 45'	(5')			
2ᵍ 2'	to	6ᵍ 38'	(2')			
0ᵍ 64'	to	2ᵍ 1'	(1')			
0ᵍ 21'	to	0ᵍ 63'	(1')			
0ᵍ 6' 50"	to	0ᵍ 20'	(50")			
0ᵍ 2' 10"	to	0ᵍ 6' 30"	(10")			
0ᵍ 0' 70"	to	0ᵍ 2' 00"	(10")			

Centesimal | Sexagesimal

18° 30'	to	85°	(5')
5° 46'	to	18° 26'	(2')
1° 49'	to	5° 44'	(1')
0° 34' 30"	to	1° 48,5'	(30")
0° 11' 0"	to	0° 34' 0"	(30")
0° 3' 30"	to	0° 10' 50"	(10")
0° 1' 10"	to	0° 3' 20"	(10")
0° 0' 30"	to	0° 1' 00"	(10")

The manual does not explain why the design goes so "low" in the angles marked (30" in sexagesimal and 70" in centesimal). Maybe for the layout of train railways.
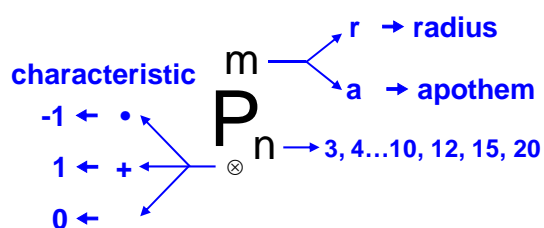
Scale of Constants

Interior to the last sine scale is a scale with gauge marks for calculation with constants. To begin with, there is a series of pi factors:
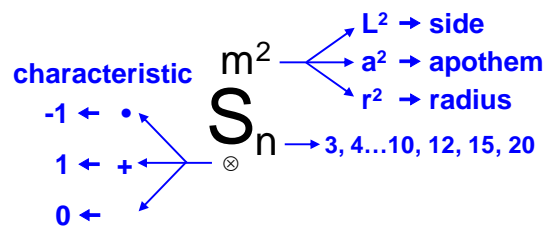
$$\pi \quad 2\pi \quad 3\pi \quad 4\pi \quad \tfrac{1}{2}\pi \quad \tfrac{1}{3}\pi \quad \tfrac{1}{\pi} \quad \tfrac{2}{\pi} \quad \tfrac{3}{\pi} \quad \pi^2 \quad \pi^3 \quad \sqrt{\pi} \quad \sqrt[3]{\pi} \quad \tfrac{4}{3}\pi \quad \tfrac{3}{4}\pi \quad \tfrac{2}{3}\pi$$

Then, there are constants to get the perimeter or the area of a series of polygons, from 3 sides to 10, and 12, 15, and 20 sides. The starting value could be the radius, the side, or the apothem. Here, the designer has used a very specific nomenclature (I had never seen it before):
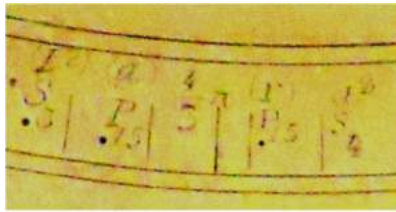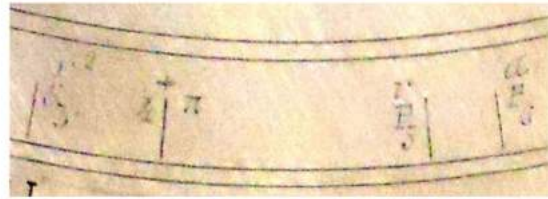
To calculate the perimeter:
To calculate the area:

The "P" or the "S" indicates what you are getting. The "m" is the value with which you have to start. The "n" indicates the polygon (its number of sides), and the symbol below (or on top) is to give the value of the characteristic of the factor. For example, 4π is 12.57, with a characteristic of "1" and so it will show a "+". Examples of these factors, as seen in the scale:
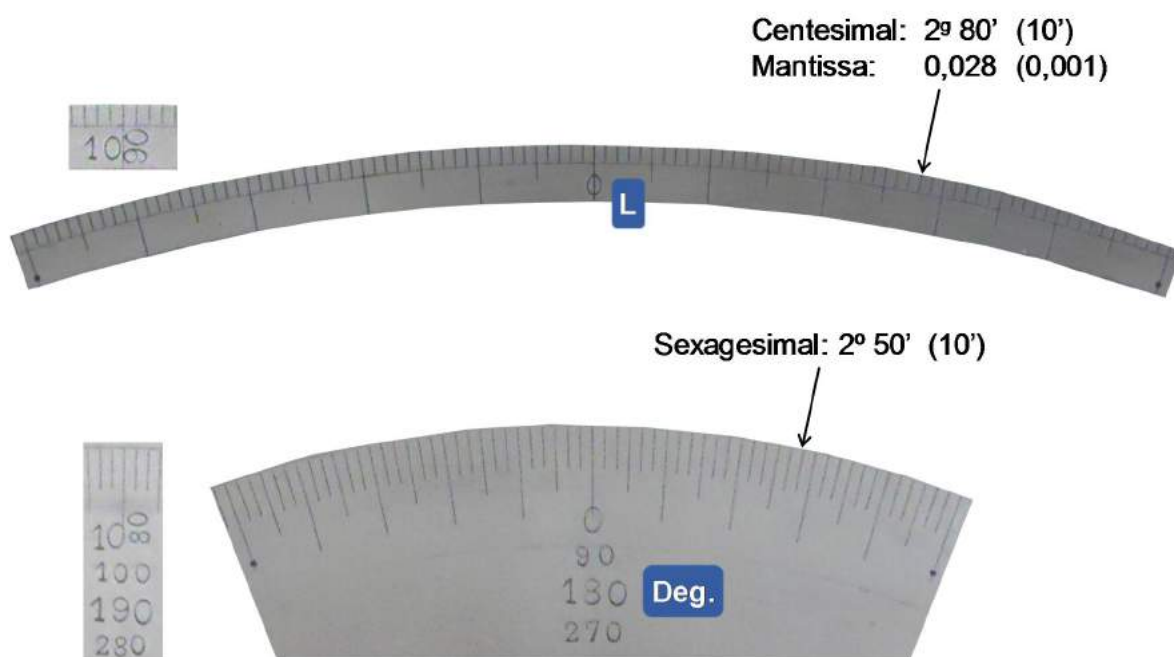
$$S\;^{L^2}_{\bullet\;3}\;;\;P\;^{a}_{\bullet\;15}\;;\;\tfrac{4}{3}\pi\;;\;P\;^{r}_{\bullet\;15}\;;\;S\;^{a^2}_{4}$$

$$S\;^{r^2}_{\bullet\;3}\;;\;4\pi^+\;;\;P\;^{r}_{5}\;;\;P\;^{a}_{6}$$

Linear Scales (L, Deg.)

The outermost and the innermost scales are both linear. The first is used both to get the logarithms (L) and to work with the first quarter of the centesimal degrees (goes from 0 to 100). The second is only to work with sexagesimal degrees as a degree conversion table (with the first one).

Both scales mark the first quarter of angles in both senses, clockwise and counter-clockwise with perpendicular labels. The sexagesimal (Deg.) scale, also marks the values for the other three quarters.

Nonius (Vernier) Addition

These last two scales, being linear, enable the use of a Nonius (Vernier) so that to get another digit in the reading (0.0001 or 1' in L and 1' in Deg.). The two Nonius are placed in the cursor that is explained in the following section.
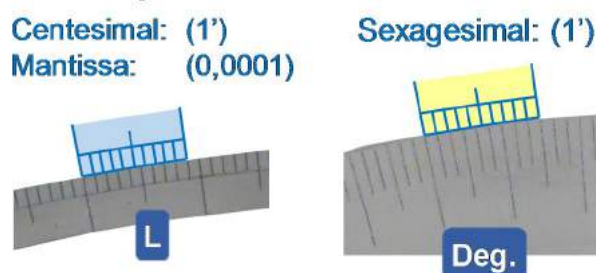
The Cursor Structure

The cursor in this device is quite specialized. As we see in the picture we can distinguish the fixation ring, the slider, the celluloid, the Nonius (double), and the micrometric system.
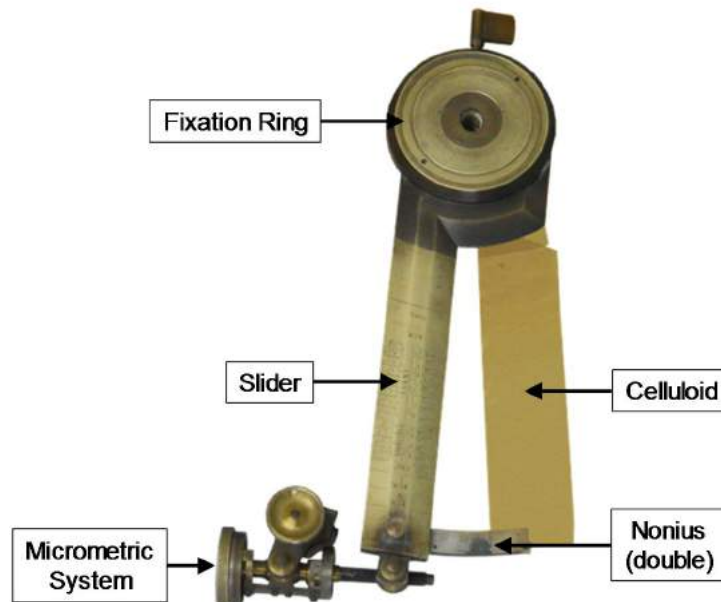
The fixation ring is the outermost ring in the central rotating structure. It may be locked to the next rotating section that is fixed to the scales disk, by means of a half-turning flap that screws in and out.
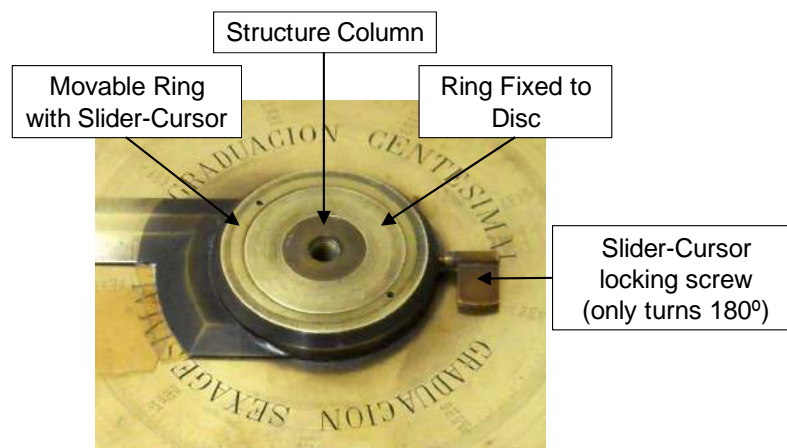

The celluloid part is clearly broken and glued afterwards in the inner part and fixed with some small square celluloid stopper and a small screw.

Although it is a replacement it has also clearly deteriorated (one corner bending downwards).

The Cursor Slider

The most outstanding part of the cursor is the metal slider, as it has a lot of data engraved into it. In fact, it is a table to remember how to read the different scales.
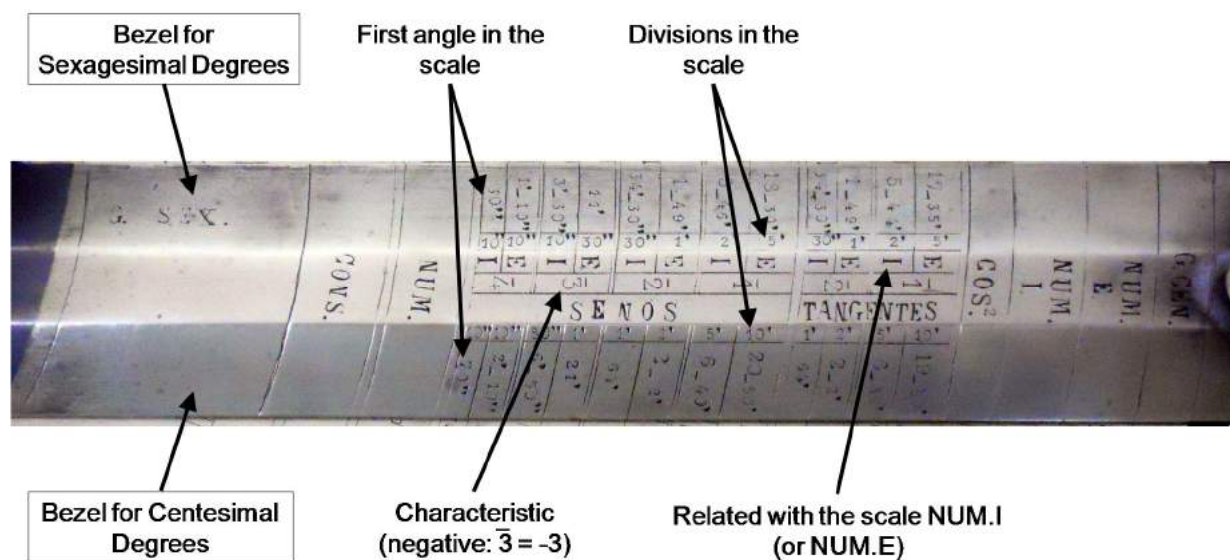

First, there are three longitudinal sections, formed by two bezels and the central planar surface. Each bezel provides data to one of the sexagesimal or centesimal degrees, while the central section gives data common to both.

In the planar section we have the scale name, the characteristic value to be used at each scale, and whether the scale in the disk refers to the internal (I) or the external (E) scale in the ring (D or DF). Note that the letters "I" or "E" are near the sexagesimal bezel, as for the centesimal calculations the letters have to be interchanged.

At each bezel you can read the first value at the respective scale and the value of the divisions.

The Cursor External Nonius

We have mentioned in the section on the linear scales that the labelling in both is doubled to consider counting in the two rotating directions: clockwise and counter clockwise. So, if we are to use a Nonius to get another digit, we should also use it counting in the respective rotating direction. For this reason, this instrument includes two Nonius, side by side, sharing the 0 value.
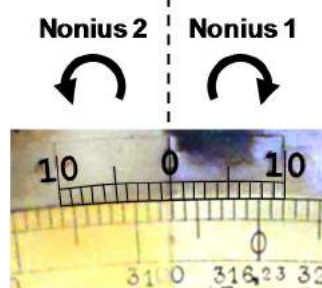

And once we have discovered that this 0 is the centre of the reading we figure out this point should also be the end of the cursor hairline and we understand that this celluloid addition was done to have its edge as said hairline.

Simulation of the Original Cursor

It is clear for any experienced collector that the normal way to design the hairline of a cursor (in most of XX century slide rules) is having it marked and coloured in the centre of a window, made of glass or some transparent plastic material. So, now that we know the position of the cursor hairline, it is easy to conceive how the celluloid would have originally been. Furthermore, we can place the double Nonius intended for the internal linear scale.
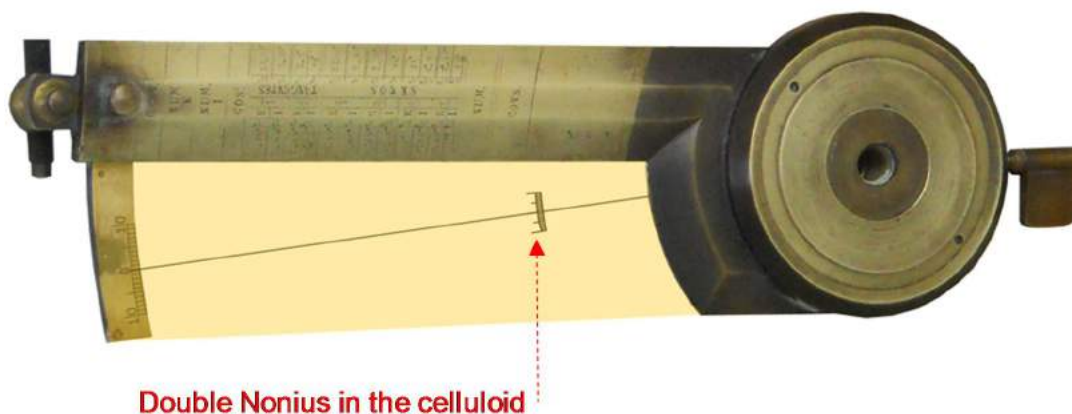

This celluloid Nonius runs over the blank sector between said linear scale and the scale of constants, so that it can easily be read.

The Micrometric System

This is the most intriguing part of the instrument, even though it is clearly explained in the manual. It runs over an external guiding rail surrounding the base structure (and the ring with the fixed scales). To this guide it may be locked by means of a vertical pressing screw and jaw system. From this fixation element, a micrometric screw enables the cursor to be precisely adjusted.

In this way, with the vertical screw loose, the cursor moves freely, and with system locked the cursor may be finely positioned. This is done operating a horizontal knob, related with two dial scales.
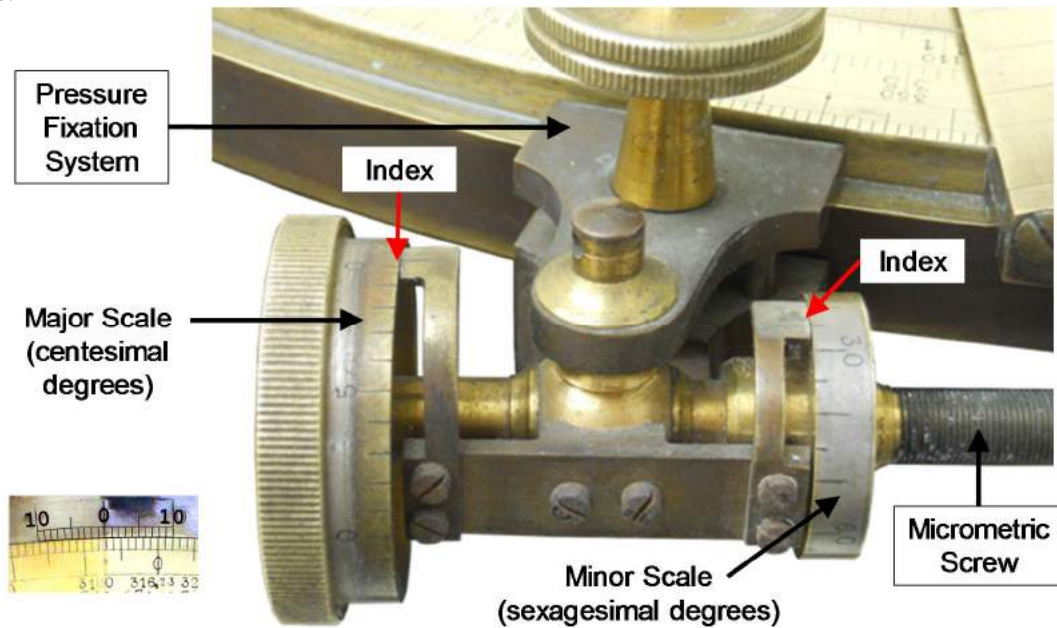
The purpose of this micrometric system is to get another digit in the calculations, after the digit provided by each of the Nonius. Therefore, it can only be used with the linear scales. The major dial scale provides ten divisions per each of the divisions in the external Nonius, for the L or centesimal scale. This means 0.00001 if working with logarithms, or 0.1' (10 centesimal seconds) if working with angles.

Similarly, the minor scale dial enables reading steps of 5 sexagesimal seconds. Nevertheless, what is not explained is the benefit of this so precise movement when the final reading is done with the naked eye or how to ensure the right zero positioning with the vertical screw… A magnifier might be missing…

Designer? Manufacturer?

At the end of the manual, there is the author signature: topographer Antonio Cabezas:

But after sharing the Word file with some colleagues, including one retired from the IGN, there was a doubt that the manual author had been the designer of the apparatus.

Apart from that, during the study of the apparatus no label indicative of the manufacturer was found, and not even the marks of having been one. This, together with the hand-made manual draft would indicate that this was a first prototype of a calculator.

The only hints might be the apparatus being labelled in Spanish and its location in Spain, both maybe pointing at a Spanish master craftsman.

Who was the man that designed this device? Who was the manufacturer? What was the use it was intended for? (Small angle trigonometric functions, constants scale, micrometric system…). Maybe we are already too late to find the answer to these questions…

Bibliography

[1] Description of item 149 at "Colección de Instrumentos" in IGN web page:
 http://www.ign.es/ign/layoutIn/museoInstrumento.do?codigoInstrumento=149
[2] "las reglas de cálculo taquimétricas en España" by Gonzalo Martín (2013) in Photocalcul web page:
 http://www.photocalcul.com/Calcul/Regles/Notices-regles/reglas%20taquimetricas%20es_v1.pdf
[3] "Círculo Logarítmico: su fundamento, descripción y uso", by Antonio Cabezas (about 1910)
[4] "El Círculo Logarítmico del IGN" Complete investigation article by Jose Gabriel Fernández (2016) (English version to be published in JOS in a near future)
 http://reglasdecalculo.com/presentaciones/circulo_ign.html
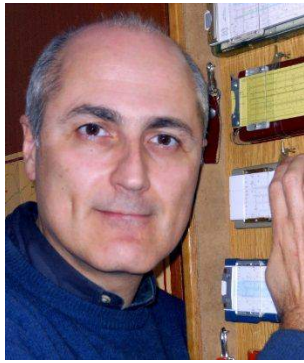
José Gabriel Fernández-Bañares - (1963-) Spanish collector, member of the *Amigos de las Reglas de Cálculo* (ARC), and of the Oughtred Society (OS). Friend of the ISRM. He has several slide rule articles in Spanish and English at www.reglasdecalculo.com, some of which have also been published in the UKSRC Gazette, the Journal of the Oughtred Society, and in several IM Proceedings. Jose earned an electronics engineering degree in 1990 and started working in electronic products development, currently being an employee for American company Tier 1 which is in the automotive market. His father bought him his first 'antique' slide rule at a flea market while Jose was attending the university. Jose writes: "In those days I found very little information on slide rules, even looking in the library at my university. I had to wait until the Internet was global to access sales and specialized websites in Spain and other countries like UK, Germany, and the USA".

Born in 1963, José earned a degree in electronic engineering in 1990 and started working in electronic products development for the fire detection and alarm market.

In 2000 he joined the American company Tier 1, which is in the automotive electronics market, and remains there till the present day.

All his study was carried out using electronic calculators with no mention of slide rules. However, it is true that, when young, he had seen some "strange artifacts" at some specialized shops. However, it was not until his university years that his father bought him his first slide rule, albeit as an antique at a flea market.

During those days he found very little information on slide rules, even when looking in the library of his university. He had to wait until Internet was global to access selling and specialized websites in Spain and other countries like UK, Germany, USA, The Netherlands, and France.

Thus, he became a member of the Spanish association ARC (*Amigos de las Reglas de Cálculo*) and started participating in http://arc.reglasdecalculo.org/, collaborating in making all the slide rule know-how accessible to the Spanish-speaking people.

On the other hand, he wants all his works about slide rules to be in Spanish and English, in order to make them available to as many people as possible. As a consequence, after some years he also joined the Oughtred Society, additionally being a friend of the International Slide Rule Museum (ISRM).

In this sense, José has publications in the UKSRC magazine, the OS journal, and in some IM proceedings, with copies of all of them in Spanish (and English) at www.reglasdecalculo.com .

Finally, he has developed some fully working DIY prototypes of slide rules, and some pictures of slide rule collections to be put on mugs.

A Mysterious "Old Calculator" Reveals
Its Forgotten Polish Seller: G. Gerlach

Wolfgang J. Irler

Summary

An unexpected acquisition of an unknown calculating machine opened the curiosity about its former seller: G. Gerlach from Warsaw. Internet research and information from collector friends revealed a fascinating connection between technology, linguistics and German, Swedish, Russian, and Polish history. The fate of the Gerlach family who had immigrated in 1855 from Berlin to then tsarist Warsaw and founded a thriving business with scientific instruments, is entangled with the story of the inventor of a well-known calculating machine, the so-called Odhner. Its inventor, W.T. Odhner, a Swedish engineer, working in tsarist S. Petersburg in a Nobel factory, had patented at the end of the 19th Century one of the first mechanical calculators and produced it there until the October Revolution, when he was obliged to flee back to Sweden. Gerlach's son had seen the potential of selling this machine and added it to his own offers. Apart from other Odhners, even a typewriter and slide rules bearing the Gerlach brand have recently been identified in the treasures of some collector. This adds another forgotten memory to the Polish company with the German name. It had unfortunately the same fate as whole Warsaw, destroyed by German troops in retaliation to the Warsaw uprising and by the WWII end-fighting.

The Machine

Which collector of calculating machines would have bid 500 Euro on an "Old Calculator" (*Alte Rechenmaschine*), with use traces on smooth black paint, totally lacking a brand name?

A nearer look on the attached images, however, should have accelerated an informed Collector's heartbeat; above the visible serial number 7484, one could guess some Cyrillic letters (presumably the beginning of "*Арифмометръ*", hence Arithmometer).

It can only be an early Odhner. But where is the normally present logo at the left of the brass cover? One notices only a smooth black surface. A prudent bid just a little bit above the starting price seemed adequate to declare an interest. Unexpectedly, no other collector has recognized or wanted the machine, and it becomes mine. It arrives well packed and even with a well preserved wooden box.

An immediate search for the expected Odhner-logo remains unsuccessful. The brass cover is totally smooth without any traces on the thick paint. After disassembling, a faint circular impression on the reverse side behind the supposed logo position arises some suspect. There must be something under the paint on the front side.

Now turns up the conscience question for a serious antique collector: remove the paint, like some brass-fanatics do? However, the provenance of the machine can only be documented by this sacrilege, hence it gets done. Some chemical and a delicate scrubbing reveals a brilliant brass cover.


On the supposed position is indeed faintly visible an Odhner logo with written *С.ПЕТЕРБУРГЪ*. The machine is therefore from the Odhner factory in S. Petersburg. On the upper side is now clearly legible "*Арифмометръ В.Т.Однеръ*" (Arithmometer W.T. Odhner).

The Identification of the Name

Someone must have violently sanded the logo place on the machine cover, almost rendering it smooth and unrecognizable. Above it, some handwritten lettering seem to indicate a name. To make it short: after a lot of re-tracings, the result becomes sure: it must be **G.Gerlach, Varsavie**. Probably name and Polish town of the owner or seller. A pretty common German surname.
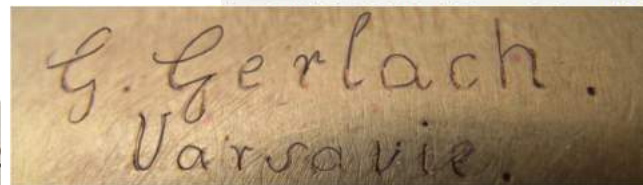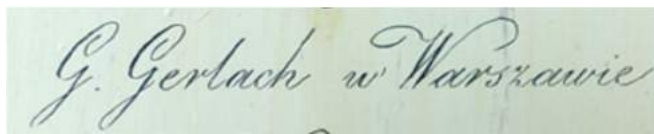
An Internet search confirms the hypothesis, because some antique shops are offering different scientific instruments from the beginning of the 20th century with this name; prevalently theodolites, compasses, and planimeters. Also one slide rule is among them.

Gerlach History

Now, awoken the interest in the seller, all its history must be researched. Here an extract from the life of the patron "reported in the Polish refoundation of G.Gerlach *Fundacja Rozwoju Polskiej Myśli Technicznej i Mechaniki Precyzyjnej*", a watch factory which tries to revive the tradition of the technological-mechanical production in Poland:

Gustaw Gerlach (1827-1915), Warsaw, Polen

"...This story begins in 1845, when the eighteen-year old **Gustaw Gerlach** arrives in Warsaw from Berlin, …...He is doing well enough that at first he becomes a partner, and in 1852 repays the previous owner and takes over the factory...From now on the products will be marked as „**G.Gerlach**".….When he turns 60, Gustaw Gerlach retires and passes the company onto his two sons – Emil and Gustaw. They receive the brand name and decide to keep developing the family business...The product range now includes binoculars, *typewriters*, manometers.….In 1919 the Gerlachs sell the factory to their cousins – Henryk, Gustaw, and Emil Ludwik Voellnagl, who will extend the product line by e.g., airplane instruments and compasses. Manometers made by G.Gerlach will be fitted to the "PZL.37 Łoś and PZL.23 Karaś" bombers as well as the PZL.11 fighter planes. They will also be used in the reborn, Polish naval industry...Unfortunately, the factory and residential buildings on Tamka Street were destroyed during the Warsaw uprising in 1944 and were never rebuilt...."

The description includes even the offered typewriters, but neither calculating machines nor slide rules. In any case, the deciphering of the name seems confirmed. Remains the question, why someone would scrape off the proof of provenience covering it with thick paint.

Other "Odhners" from the Same Period

The oldest known short-crank Odhner with a Gerlach engraving on it is from W.S. It has SN 1341, Latin lettering and bordered "Arithmometer – patent W.T.Odhner". "G.GERLACH – WARSCHAU" is barely readable. The serial number dates it well before the turn of the century.

Let us concentrate now on the machine details of the here treated. The serial number 7484 suggests a production year of around 1905. A bit earlier machine with SN 5786 from Cris resembles ours the most; same writing, vertical zeroing screws, without bell and the long carry cover to the left. The identical one with SN 5824 will be nominated later. Another similar same machine appears in the "Soviet Digital Electronics Museum", with the curved letters written "*Арифмометръ В.Т.Однерь*" (observe the "*ф*"!) and the same long crank, but probably an erased serial number. The logos with *С.ПЕТЕРБУРГЪ* seem all identical.
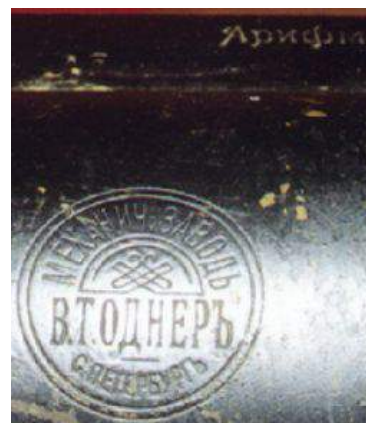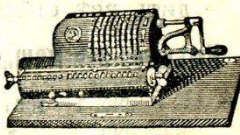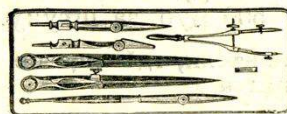

A later machine with SN 13097 omits Odhner's "B.T." given name but we read grammatically different "*Арифмометръ Однера*" (always with the "*ф*" of the 1918 spelling reform, but with an ending "a" genetive!). One from the Museum of the Technical University of St. Petersburg with SN 13554 has a similar Cyrillic lettering as the here described one; another one in the Soviet Museum has SN 14452 and in Latin letters written: "Original Odhner".

Classic Cyrillic lettering appears in a 1912 journal advertising, where we are informed about the whole range of geodesic and precision instrument offerings from the "*Г.ГЕРЛАХЪ ФАБРИКА*" (G.GERLACH FABRIKA). Among the objects offered, we read "*Арифмометры*" (Arithmometers), but no Odhner mention, although the depicted machine is one, seemingly the type here described. Further on, there are recommended slide rules, planimeters and pantographs, yardsticks, draughtsman equipment, and theodolites.

A couple of years later there must have been also a dealership for Underwood typewriters; here the cover of a machine with, among others, Petrograd as the representative's branch. This means that this item had been in stock from 1914 to 1917, because of the change of the town's name during WWI.

A small, simple slide rule from still tsarist Poland shows faintly the Russian Eagle impressed above G.GERLACH VARSOVIE. The collector who sent me the image, could not identify it, and it lacks the slide. It should be from the beginning of the 20th Century.
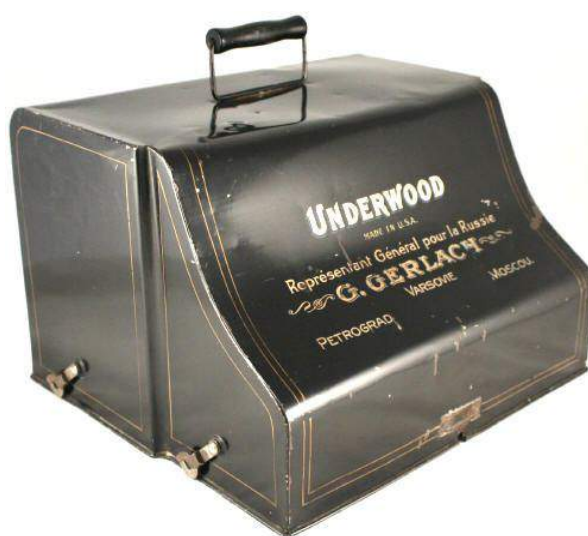
Another slide rule from the same Polish collector only shows the name GERLACH imprinted on the back, beneath the slider. More slide rule collectors should have a more detailed look on their items and search for other evidence.

In the Odhner-Hommage website from Kevin Odhner we find other, not-easy-to-verify similarities to the machine here described: the oldest long-crank Odhner there with SN 4941, owned by V.B. resembles ours the most, because its zeroing thumbscrews stand vertically, too. The Cyrillic writing "*Ариѳмометръ Однеръ*"; however, has block form and the abandoned Cyrillic letter "fita", "*θ*" instead of the "*ф*", without the final "a".

A following machine with SN of about 62~~00~~, owned by S.F. cannot be identified clearly because of the half-destroyed SN; it has horizontal zeroes which lets date it to about 1903, similar to another with SN 6536; horizontal thumbscrews there, like in another with SN 9397. But two from the Rechnerlexikon, SN 5815 and SN 6153, with Latin lettering have vertical zeroes.

Analyzing the Logo Destruction

Later on, the machines were always named "Original Odhner", both in Latin and Cyrillic lettering. My next machine SN 18790 was intended for exportation; lettering is Latin, from St.Petersburg. My next Odhner SN 22425 must have been produced between 1914 and 1917, because in the logo appears "*ПЕТРОГРАДЪ*" (Petrograd, as on the typewriter case on page 53).

Apart from the uncertain production years, there seem to exist vertical and horizontal zeroing thumbscrews in parallel. On the other hand, these machines were often refurbished during revisions. The cited sources indicate for our SN 7484 a production year between 1904 and 1906. Gerlach must have sold it (for the first time) shortly after this years. The Latin writing " *Varsavie*" (seemingly not "Varsovie") seems to indicate an exportation attempt to France (Brunsviga had bought Odhner's patent rights already 10 years before and sold their machines in France, sometimes together with "*Chateau*" under the brand name "*Dactyle*").

The well preserved wooden box has the characteristic angular form. Inside one observes only a pencil inscription of the serial number and the remains of a formerly glued paper. The above mentioned SN 5824 from H.S. is especially interesting for the same angular wooden box, because it shows the serial number with the same handwriting inside; moreover, even an almost intact sheet with the engraved machine.

My machine had probably never left Poland and had been arrived to me from Chemnitz, a town near the Polish border. In the turmoil after WWI and the subsequent Polish independence, a declared Russian product had certainly image problems; the provenience had to disappear, when a new seller tried to offer it. An attempt to anonymize the machine after theft seems rather improbable, because the identifiable serial number remained explicitly visible. The re-seller in the twenties was perhaps even Gerlach, since then it was the sole licensee of Odhner-machines in Poland after the separation from Russia and perhaps tried to sell older machines scrupulously repainted.
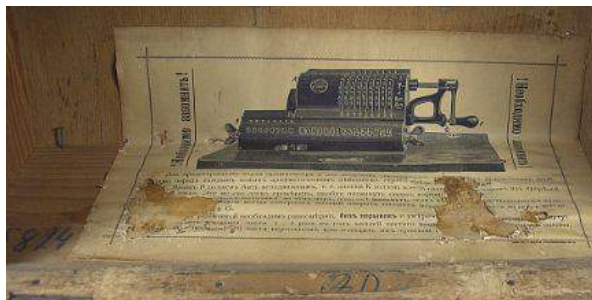
After 1920

With the Russian revolution, the Odhner family returned to Sweden and soon built there a new fabrication of Original-Odhners. They were named initially "Arithmos" instead of the former Petrograd-logo, which in about 1922 was abandoned and the machines were named only "Original Odhner". Probably during Polish-Russian war time, Gerlach could not sell these Odhners, at least no "Arithmos" is known that identifies this Polish seller.

In the new Polish republic G.Gerlach recommenced, however, to sell scientific instruments and Odhners now published as "Swedish Arithmometers" (*Szwedzkie Aritmometry*) obviously without reference to hated Russia.
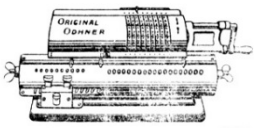
The Polish advertising from just after 1922 shows an Original-Odhner-6 with rapid-zeroing butterfly screws. But the round circle on the cover seems to be like the former Petrograd logo. It could effectively be a machine from the Petrograd production.

The image extracts, above to the right are from a later Original-Odhner-9(b) and an Odhner-7 (SN 7-102523). You see the typical two carriage-mover buttons and G.GERLACH, WARSZAWA on the cover. The rightmost picture is from an ended auction announcement; the new owner is unknown.

The 1926 Polish advertising, up there, shows a normal Original-Odhner-6, but fictitious "ORIGINAL ODHNER" as logo.

Its same *Ossolińskich* adddress near the *Marschal-Piłsudski* Place appears also in another Original-Odhner advertising; but for an ad of drawing instruments appears the much earlier Czysta.

The G. Gerlach shops for scientific instruments remained until the end connected to the Gerlach family which was also known for their caritative engagement. Another Warsaw Gerlach business that produced cutlery seems to have no direct connection to them.

The factory Gerlach and Pulst, however, had been nationalized and renamed F.K., *Fabryka Karabinów*, "Rifle Factory" already in 1920; it produced pistols and, it seems, typewriters, after the liberation also rifles and other military equipment. Later on, there was probably also a pilot watch production line. A recently founded factory of high-precision watches tries to revive the Gerlach brand as an internationally recognized name.

A casual photo during an independence celebration 1936 shows the front of the Gerlach shop near the *Piłsudski* Place. The business existed there until the total destruction in 1944. It marketed successfully licensed and self-produced high-precision instruments.

Up to now, only the few showed Gerlach-branded relicts are known, but hopefully this off-the-track history mélange enlarges the interest of collectors to search in their treasures for other items with a reference to Gerlach. Together with the re-founded G. Gerlach watch production, the present reminiscence to this former technological German-Polish connection tries to be another step forward to the difficult European reconciliation.

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Dr. Wolfgang J. Irler

Since my studies in the 70's I have collected calculating devices as a compensation to daily computer programming. I still happened to use logarithmic tables, slide rules, and mechanical calculators, but the ever growing complexity of computer science has obliged me to apply sophisticated algorithms understandable to only a handful of specialists. Much easier is it to show, how all these mechanical devices work and how their instruction manuals explain simple mathematical operations. My other hobbies are languages, violin playing in a local orchestra, the bonsai trees in my garden, and enjoying art exhibitions with my wife and my daughters.

Thanks to David Sweetman, Jerry McCarthy, and Mark McCormick for revisions of the text.

Armand Hammer's Contribution to Russian Slide Rules

Timo Leipälä

1. Introduction

American industrialist, art collector, and philanthropist Armand Hammer (1898-1990) was born in New York to Russian-born Jewish immigrants Julius and Rose Hammer. His father ran a general medical practice and five drug stores, and was a founding member of the US communist party. Armand Hammer also studied medicine and he graduated in 1921. In the same year he travelled to the Soviet Union, saw the famine there and organized the exchange of American wheat for Russian furs and caviar. The Russians were grateful for this and Hammer even personally met Lenin; this meeting was very important for his future Russian businesses. In fact Lenin suggested to Hammer that he should take a concession of an asbestos mine in the Urals. In addition to this mine, he also started as a successful agent, based in Moscow, of American machinery, especially Ford cars, Fordson tractors, and Underwood typewriters.

However, the Soviet Union soon founded the Amtorg organization to trade with the USA and made business through foreigners undesirable. Instead of being in the import business, some kind of industrial production was then suggested to Hammer. He found the decision difficult, but after buying a pencil, which cost as much as fifty kopeks (26 cents), which would have been only 2-3 cents in the USA, he decided to start a pencil factory without knowing anything about the subject. In the Soviet Union, there was an immense shortage of pencils, which were imported from Germany. Hammer's pencil factory concession was approved in October 1925 for ten years, even though a Russian state organization, which was planning to produce pencils, opposed it. The concession contract has recently been published, see [2] and it allows production and sales of pencils, pen-nibs, thumb tacks, and other stationery items. Hammer then travelled to Nürnberg, Germany, where, after some difficulties, he succeeded in hiring German engineers and professionals who had been working for Faber-Castell. With the help of these people he also acquired the necessary machinery. The Germans would come to Moscow with their families, so Hammer promised to arrange for them homes with gardens, schools for their children, and even German beer. Fortunately, the imported beer was not needed because they found Russian beer sufficiently to their liking. Hammer then continued to Birmingham, England, where he made similar arrangements for the pen department.

After returning to Moscow, Hammer was able to hire for his plant an abandoned soap factory, which had plenty of land for houses, schools, etc. By April 1926 the machinery arrived and at the end of the month the first pencils were produced. Most of the materials had to be imported from foreign countries, but the factory was very successful. During the first year, instead of the million dollars' worth of pencils in the concession agreement, the factory managed to turn out two and half millions' worth. The produced amount of pencils was soon 72 million in a year and about 20 per cent was even exported.

Figure 1. Hammer pencil advertisement in magazine Krasnaya Niva, 1929, Nr. 2,
scan @National Library of Finland

Still today it is possible to buy unused Hammer pencils like the ones shown in Figure 2.

Figure 2. Unused Hammer pencils available at Russian internet sites

Hammer writes that, by the end of 1929 "our single pencil factory had now grown into a group of five factories, manufacturing metal articles, celluloid and allied products" [1, p. 209]. Evidently some of the Germans also had experience of Faber-Castell celluloid and slide rule production, so these could be added to the product palette. The group "allied products" also contained slide rules as we shall see.
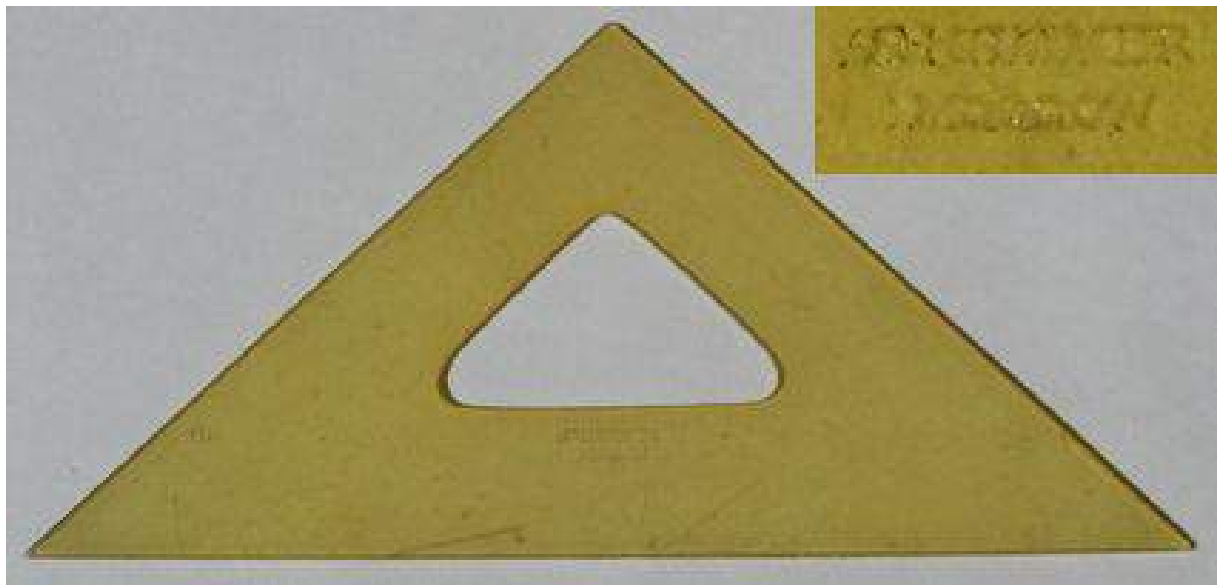
Figure 3. Triangular celluloid ruler with engraved English text "A. Hammer Moscow"

With this expansion the need for credits increased, but the foreign situation was unfavourable for any financing. The best solution seemed to be to sell the factory to Soviet government and this coincided with their five-year plan. In the spring of 1930 the negotiations began and final settlement was made in August 1931 even though Hammer had left the Soviet Union in 1930. Sutton [7] claims that Hammer was about the only concession holder who received compensation for their investments. Hammer was allowed to export the profits and his valuable collection of antiquities acquired during his stay in Moscow. The buyer was factory group Moskhimtrest (Moscow chemical trust), which gave to the former Hammer factory the name "Moscow plant of writing instruments named after Sacco and Vanzetti". Nicola Sacco and Bartolomeo Vanzetti were Italian-born US emigrants who were executed as criminals in 1927, but the Soviet Union considered the sentence political. Probably some of the German specialists continued their work at least for some time after the change of ownership.

2. Slide rules

The only reference of Hammer slide rule production that I know about can be found on the web site of the Kuban State Agrarian University (which is not available at the time of this writing). It states that M.E. Podtyagin, who invented a cylindrical slide rule [4], was totally relieved of his academic duties in 1929-1931 in order to be able to work on the production of his invention at the Sacco and Vanzetti factory. This slide rule was patented in Soviet Union (Nr. 9921, applied for on 17.6.1926, granted on 29.6.1929), France (Nr. 639371, applied for on 3.8.1927, granted on 6.3.1928), Great Britain (Nr. 314609, applied for on 5.4.1928, granted on 4.7.1929) and it consisted of nested celluloid tubes. Thus, it is not easy to make and the production of these slide rules began after Hammer had sold his company to Moskhimtrest. The instruction manual [3] was printed in 1931, but the number produced was evidently small. The celluloid tubes are quite thin and fragile. The stationery appliance handbook [6] printed in 1940 briefly describes the Podtyagin slide rule, but mentions that it is no longer produced. The Russian Polytechnic Museum in Moscow has four Podtyagin cylinders:

1. Ø 20 mm, length of instrument 230 mm, length of scale ≈ 21 cm
2. Ø 25 mm, length of instrument 245 mm, length of scale ≈ 21 cm, Figure 4
3. Ø 40 mm, length of instrument 393 mm, length of scale ≈ 36 cm, Figure 5
4. Ø 22 mm, length of instrument 240 mm

It is interesting that of the smaller size cylinders all are somewhat different as if they were not at all produced as a series.
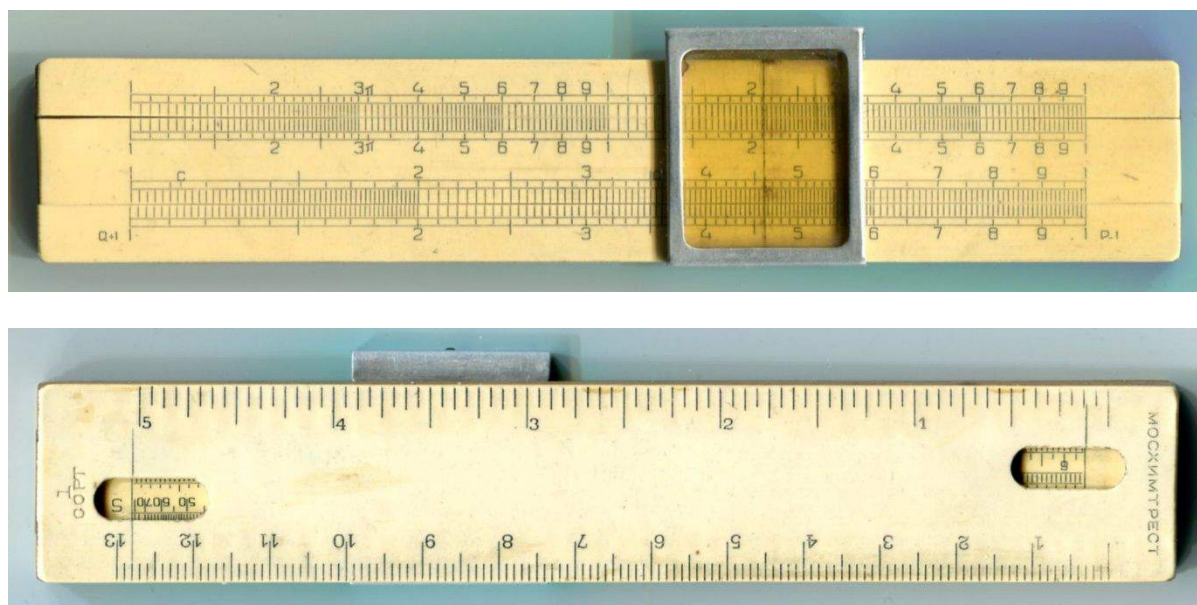
Figure 4. Podtyagin cylinder, photo ©Polytechnic Museum, Moscow

Figure 5. Large Podtyagin cylinder, photo ©Polytechnic Museum, Moscow

In addition to these Moskhim also made linear slide rules with celluloid on wood. A small Mannheim rule, as shown in Figure 6, is the only one that I know about. Evidently it has been made around 1931, but no sources are known.

Figure 6. Simple Mannheim slide rule with Moskhimtrest logo on the right back side

The circular slide rule system P.L. Kozhevnikov [4] has no producer markings, but I believe that it has been made by Moskhim, because:

  a) there were not too many Soviet plants capable of making it,
  b) it has similar geometric square and cubic scale symbols as the Podtyagin slide rule,
  c) it was produced just at the time when Moskhim made slide rules. Maybe this was Kozhenikov's private business.

The slide rule has a metal body, a movable celluloid shield and a cursor. Kozhevnikov has three Russian circular slide rule patents and of these Nr. 97654 applied 15.11.1931 and granted 31.3.1933 is just for this slide rule. Thus it has been made at around that time.

In addition to Moskhim some other Russian organisations started to make slide rules in the beginning of 1930s. Of these, the Prometei plant [5] in Leningrad was so successful that it almost achieved a monopoly in the Russian markets. Thus Moskhim quit its slide rule business, evidently around 1932-1933.
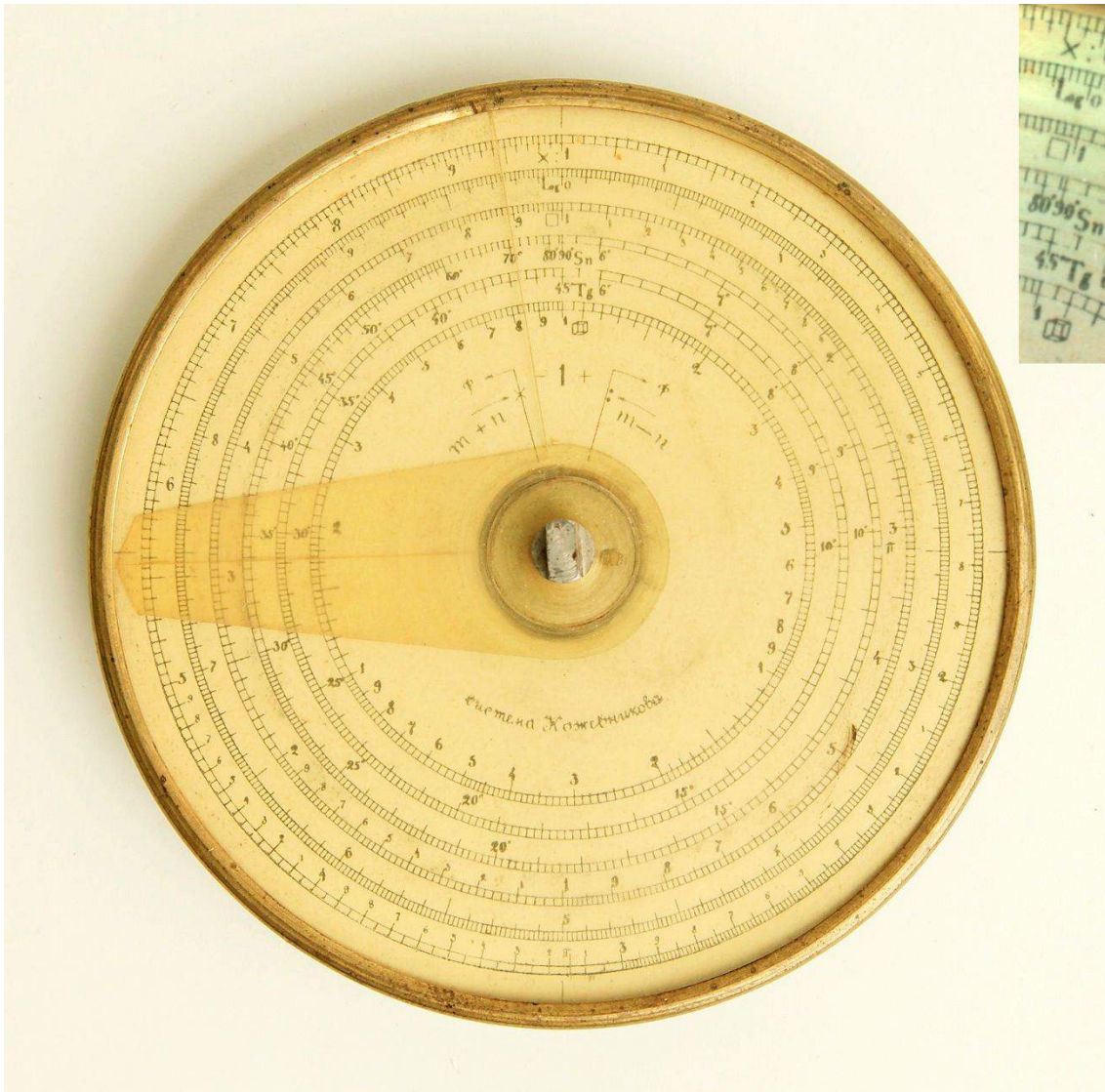
Figure 7. Kozhevnikov circular slide rule with geometric square and cubic scale symbols, scan ©Arithmeum, Bonn
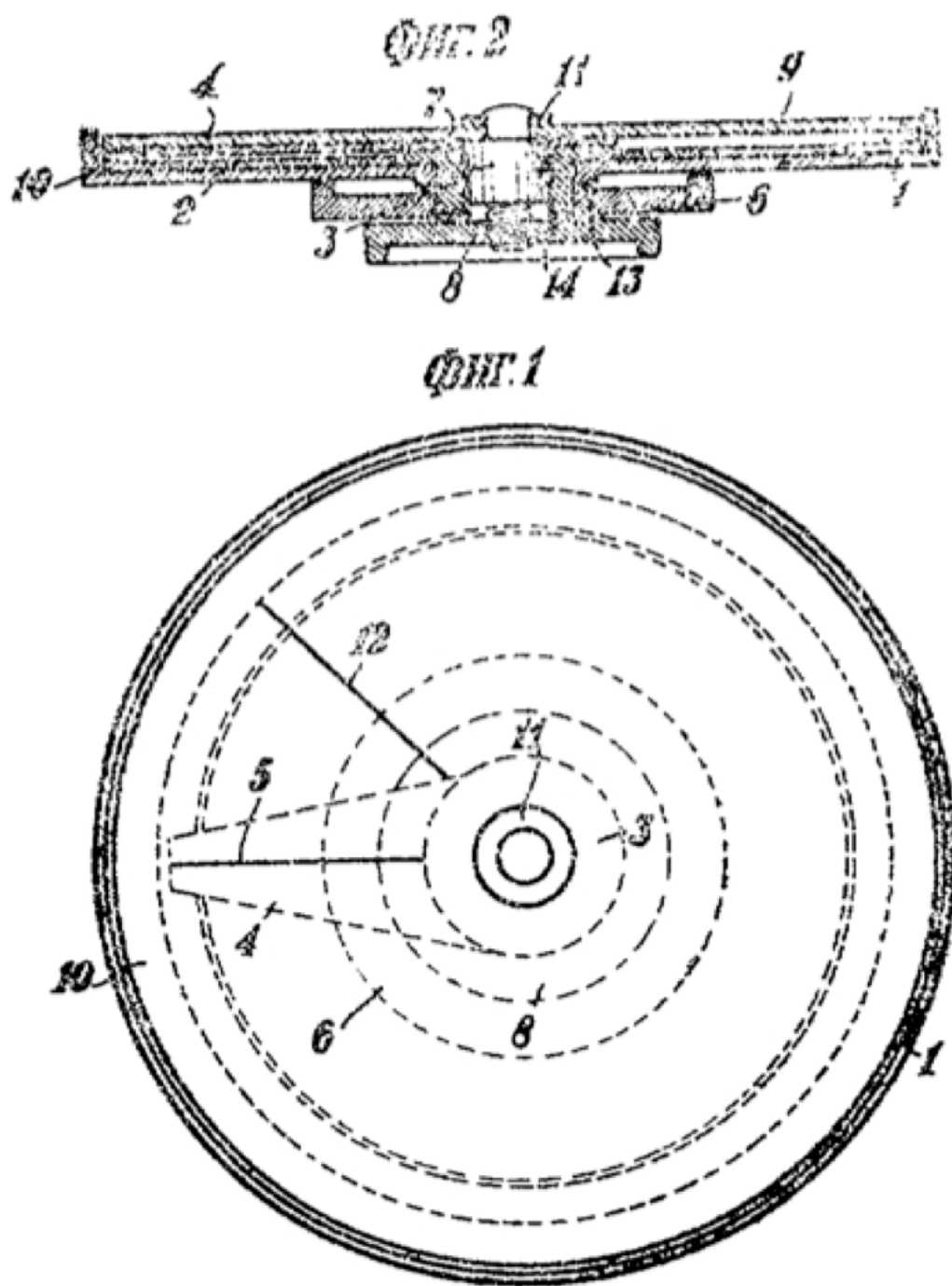
Figure 8. Kozhevnikov's Russian patent Nr. 97654

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Timo Leipälä, born 1945, studied in Turku university, M.A. majoring in applied mathematics in 1968, Ph.D. in 1976, associate professor of computer science at Oulu university in 1978, associate professor of applied mathematics at Turku university 1985-2008, retired in 2008, researcher in optimization.

Too Weak To Survive
Reviving an Analog Calculator Long Ago Eaten by Digital Technology

Nicola Marras
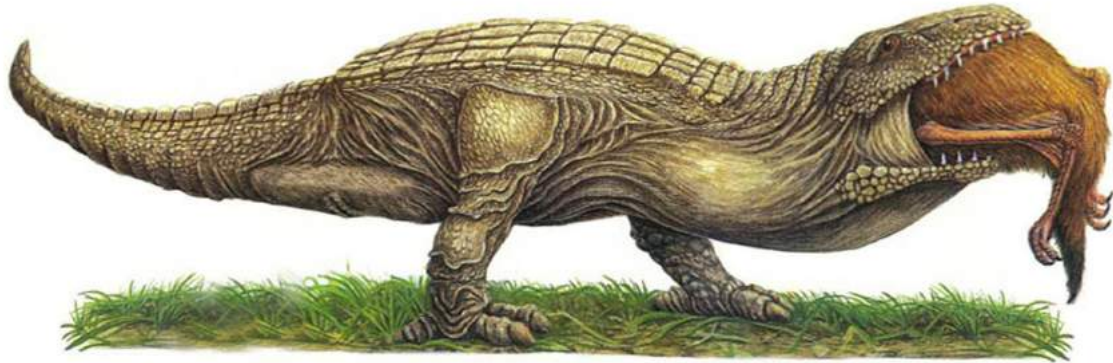
Technologies often became obsolete like living animals and lose the *Struggle for Life*. Here you can see one *Ipodius* and one *Cellarius*. They both appeared later in the time-line and were a short lived devices; they soon merged together to form the *Ego-Phonus*, which now dominates the personal communication chain.

These amazing fossils are produced by Chris Locke

Computer technologies have also had their struggle for existence; at the beginning of the information age analog and digital processing struggled for dominance.

Today, most computers are digital, but this technology dominated only after winning the practicality struggle. Previously, there were several different analog computers, such as the Goodyear GEDA, used in the first flight simulators.
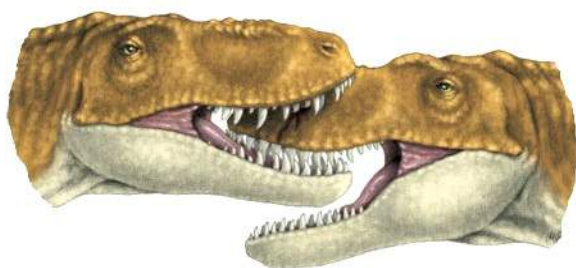
What's 500 times faster than a slide rule?

The new Goodyear analog electrical brain GEDA L3 differential engine!

The fight between analog and digital is not ended yet and still we do not know which will survive. Perhaps they will merge into a new species. Hybrids have more chances of evolutionary success!

The dominance of digital technologies has led to the temporary dearth of analog computers. Analog computers are faster for specific unique tasks, but digital computers are more practical for general and various tasks. The Pentium type CPU is not the most efficient computer solution for a given specific problem, but is more effective for the wide variety of most problems.

A few analog computers are still in use, mostly for specialized real-time tasks that need fast computing.

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A few analog computers are still in use, mostly for specialized real-time tasks that need fast computing.

Their market presence is insignificant, but their potential to solve dynamic problems that are too challenging for today's digital processors may change with recent technology breakthroughs.

Researchers are investigating a brand-new way of doing computing without the digital processors. The aim is to build analog computer chips a whole lot more power-efficient, even if they make mistakes every now and then.

The analog computers wait in the dark, often inside sound synthesizers, and we shall see: the competition is not yet over.

An adjunct of analog computers is a curious calculator that was developed in the 1960s; a revolutionary branch that is now definitely extinct after a brief golden age.

The publicity boasted: "buy a sophisticated analog instrument that prepares you for the vital role computers will play in the future". An ambitious task: they were just *electric slide rules*, which arrived in the market too late to win the race against real electronics calculators.

At the time, many were sold as self-building kits; hobbyists were once makers, not just users. Today obtaining one is difficult as only a few fossils have survived, but we can build one using my circuit, based on articles published in various magazines of the era.

Review this diagram: the center zero ammeter is connected to the battery on one side through potentiometers P1 and P2 and on the other side through P3. All potentiometers have a graduated scale from 1 to 10. When the output of the two sets of potentiometers is equal the ammeter will read zero.
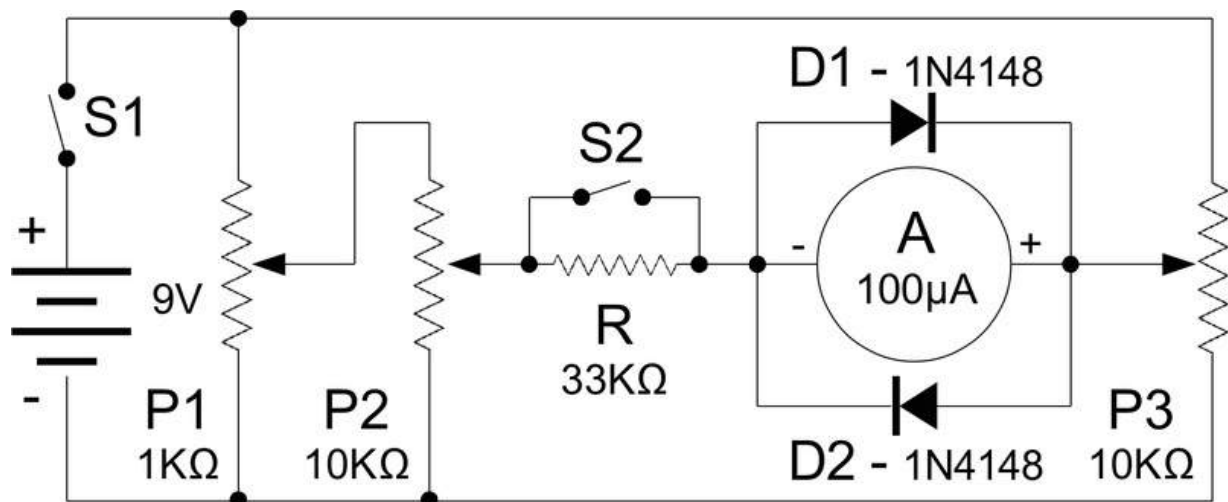
The schematic is quite simple but yet ingenious

Remarks:

• the battery voltage and the pots' resistance value do not affects the results;

• the value of P2 and P3 must be 10 times that of P1 to limit the loss of linearity due to the load;

• the potentiometers must have a linearity of ± 0.25%;

• because the ammeter is *zero-measuring*, it does not have to be very sensitive;

• the instrument is protected by a series resistance of 33 KΩ which limits the current;

• the two diodes protect further, by limiting the voltage;

• the S2 button short-circuits the resistance and allows the ammeter to calibrate to a precise zero;

To multiply 5x5 we have to set P1 on 5 (50% of the scale) and its output will be 50% of the voltage. This voltage feeds P2, positioned also on 5 (50% of the scale), so now we will have 25% of the original input. This voltage moves the ammeter's needle from zero, now we rotate P3 until the needle goes back to zero: this will happen when P3 is at 2.5 (25% of the scale) because its output matches P1 and P2. We push S2 for fine zeroing and mentally set the decimals to find the correct result: 25.

To multiply 5x5 we have to set P1 on 5 (50% of the scale) and its output will be 50% of the voltage. This voltage feeds P2, positioned also on 5 (50% of the scale), so now we will have 25% of the original input. This voltage moves the ammeter's needle from zero, now we rotate P3 until the needle goes back to zero: this will happen when P3 is at 2.5 (25% of the scale) because its output matches P1 and P2. We push S2 for fine zeroing and mentally set the decimals to find the correct result: 25.
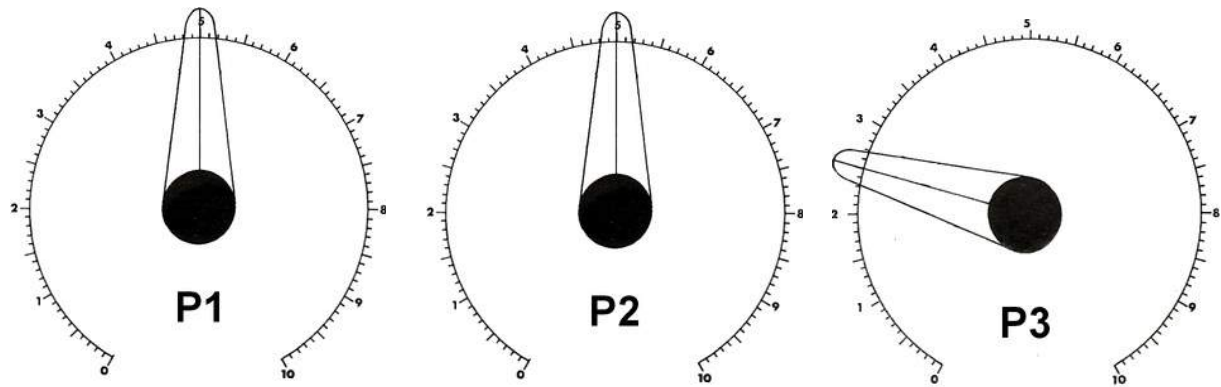
Easy to understand: 50% of 50% give 25% of the original input

The operations are similar to those of a slide rule; the decimal point location is mentally determined as usual.

To perform a multiplication we need just to set multiplicand and multiplier on the P1 and P2 dials, turning P3 until the ammeter needle is at zero, push the S2 button for fine zeroing, and then read the result on the P3 dial.

To perform a division we have to use the same method, but dividend and divisor are set on the P3 and P2 and the result read on P1.

Powers, square and cube roots, logarithmic functions and reciprocal are similarly performed. There are many interchangeable scales: linear, logarithmic, speed-time and trigonometric, to solve a wide range of problems.

In some models the ammeter has been replaced by a headset and the potentiometers were powered by an audio signal generator. In this case null sound is equivalent to a zero reading from the ammeter.
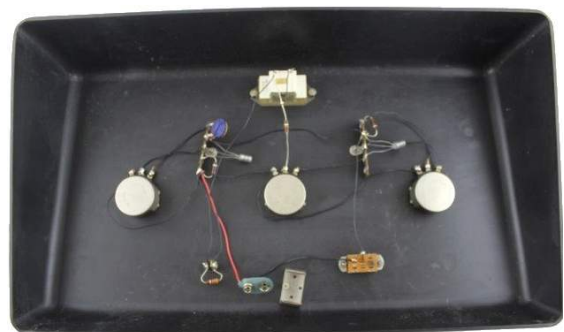
Apart from the battery there is practically nothing inside this analog calculator!

To build one require only a little soldering, we just need to buy three linear 10-turn pots with their precision knobs:

• one 1 kΩ;

• two each 10 kΩ;

And:

• one analog 100 μA ammeter with a center zero;

• two each 1N4148 diodes;

• one 33 kΩ resistor;

• one power switch;

• one push-button switch;

• one 9 v battery with its snap connector;

• one mounting base.

Our calculator is very easy to build, mounting it in a Plexiglas photo frame

Such analog calculators are easy to build, but at the time precise potentiometers were so expensive that their marketing was not cost effective. Today instead we can have inexpensive multi-turn pots with a low linearity error and precision scales.
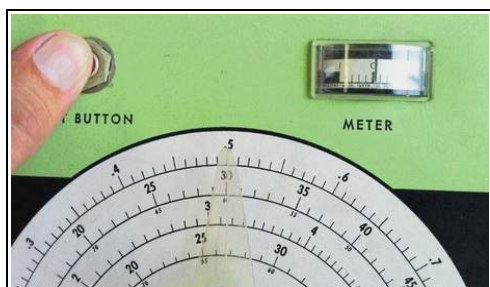
Old dials were large, modern knobs have 3 digits precision

The components available permitted just a precision of ∼ ± 5%, while today we can reach ∼ ± 1%, but now we no longer need such devices. They evolved too late!

In the search to take the *sweat out of math*, this evolutionary endarkenment appears briefly: the two potentiometer calculator, where the operations are performed by adding or subtracting voltages and the results are read on a logarithmic voltmeter.

The precision depends of the voltage value and a stabilized power supply is required. It is highly unpractical, but somebody still tries to build one!
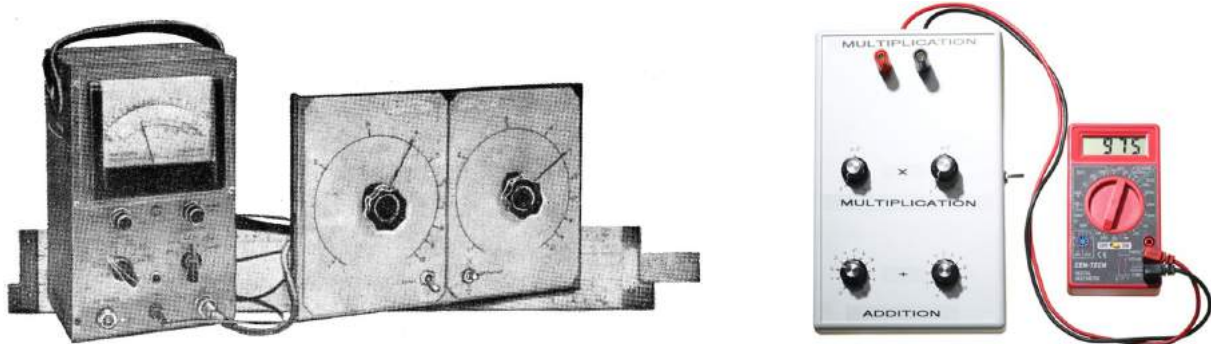
On the right the input is set in 7+3, but the battery is weak and the result is only 9.75

All these calculators were evolutionary dead ends, but they came equipped with blank dials so people could develop scales to fit their own needs. In this way many young people were helped through the arithmetic barrier.

They were easy to build and understand: students practiced soldering and so on. A blank dial wakes up the brain, an educational stepping-stone in the sunset of the Era of the Maker.

Now we are just simple consumers, sometimes techno-wilds (on right) with a clock around the neck who can only read it and charge it. I don't know if this is a positive change, but evolution will tell us soon which is the best line!

The potentiometer-based calculator is extinct, but maybe the analog computer will return as an evolutionary advancement, representing a zero or a one using voltage and doing probabilistic math without forcing transistors into an absolute one-or-zero state.

The 1958 analog video game *tennis for two* has mutated into modern digital games ushering in the computer consumer era, and the story is not yet finished!

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Nicola Marras – Italy, 1954. Collector, member of ARC, and fellow of the Oughtred Society, promotes through exhibits and educational courses the memory of old calculating devices and ancient navigation systems.

Nicola wants young people to know that the world as we see it now, skyscrapers, atomic energy, space exploration and the computer, was only possible because of calculators conceived in the 17th century.

His main event is the yearly exhibit at the Italian science fair *Cagliari FestivalScienza*. In 2013 and 2015 his projects were presented at the Europe-wide education festival *Science on Stage*. Nicola's website (both in Italian and English) is: www.nicolamarras.it/calcolatoria.

Calcolatoria Educational Solutions   Nicola Marras
                                      make learning easier   www.nicolamarras.it/calcolatoria

The Official Digital Calculator of The Zlotnian Space Program

A science without decimals never misses ... the point

Nicola Marras
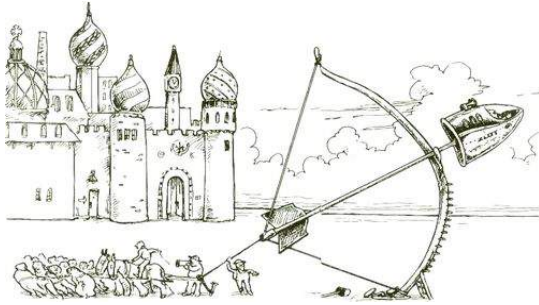
The fingers calculators had a brief popularity around 1970. A best seller of the time was the *The Official Digital Calculator Of The Zlotnian Space Program*. The most the device's promoters could say with a straight face was that it might help you count on your fingers.

The Zlotnian Calculator looks like plastic brass knuckles with some bank-check numbers on it. It came equipped with a five-foot "memory line" - a shoelace - *"to facilitate all those operations which require a recall or mode reversal function."* You were supposed to tie the shoelace on your finger.

The Duchy of Zlotnia and its space program never existed. The country was described as a billiard table flat land located somewhere in the old USSR. This Duchy was believed to be all that remained of the Holy Zlotnian Empire that once dominated the known world. Pretty amazing!

Hamlet Flatopsky

The developer was Fingerbrain Company, but the inventor was not "*Hamlet Flatopsky, the noted Zlotnian physicist*" as written in the leaflet. It was invented by Audris Skuja, a Latvian immigrated in the US, to make a gag present to a Boeing engineer, who was always calling for an innovative calculator.

The idea was not original; similar calculators were built before by Texas Instruments, Nixdorf, and other computer companies for the same purpose: a gag corporate present or a joke device.

The calculator is presented with these words:

```
In the world of calculators too little credit has been given to
fingers, despite the fact that they do most of the work. We
Zlotnians hope the advent of our calculator will reaffirm the
importance of fingers to the world. When calculating, ignore
decimals. A science without decimals never misses the point.
We Zlotnians use only whole numbers and our mathematics is the
healthiest in the world.
```

A great declaration and a great program for a 4 dollars "solid state" device! It was sold from 1976 to 1983, guaranteed as waterproof and shock resistant.

Good work and remember: you do not have to care anymore about power supply or batteries. Forget all the laces (keep only the memory line) and be free with your Zlotnian Calculator!

Zlotnia and its calculator have a very similar shape. This country does not exist, but could be identified with Zakarpattia, a Ukrainian province in the Transcarpathian area. On the right a similar calculator: the Execulator developed by Texas Instruments.

Counting On The Fingers

Although in general, "counting on the fingers" is discouraged in educational institutions, it has been found that the hands can be used as a form of calculator to aid in the performance of multiplication and addition, which trains the mind in these operations and avoids the over-dependence on electronic devices.

Shown on the right is the so-called "Finger's Calculator", an aid for the schools made by Wilhelm Wlecke in Germany in 1919. The invention was targeted at all children and adults who used their fingers to count.

Though marginalized in modern societies by Arabic numerals, finger-counting flourished in many cultures and is studied by ethno-mathematicians. Cultural differences in counting are sometimes used as a *shibboleth*, particularly to distinguish nationalities in war time. These form a plot point in the film *Inglorious Basterds,* by Quentin Tarantino, and in the novel *Pi in the Sky,* by John D. Barrow.

Table of finger numerals as described by The Venerable Bede – Unknown artist, 16th century.
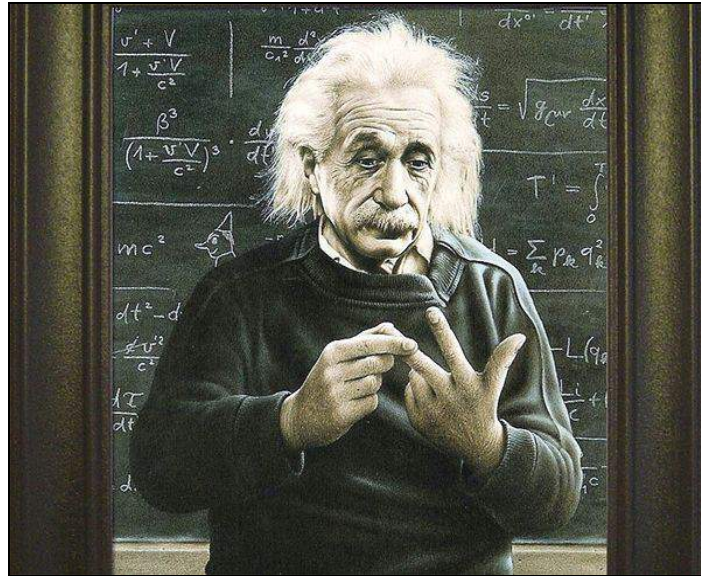
Finger numerals were used by the ancient Greeks, Romans, Europeans of the Middle Ages, and later the Asiatics. You can still see children learning to count on their fingers today.

Our current numerical system has evolved from the Hindu numerals to present day numbers. The journey has taken us from 2400 BC to present day and we still use some of the old numerical systems and symbols.

Our system of numbers is ever changing and who knows what it will look like in 3140 AD? Will we still count using our fingers or will mankind invent a new numerical tool?

Maybe the Zlotnian or Finger Calculators will back on scene; the story is not yet finished!

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Before the Nomography

Nicola Marras

In 1844, Léon Lalanne created the first logarithmic graph table, calling it *"Abaque Compteur Universelle"*. The product of two numbers x and y is found from their intersection with the 45° lines.

The *Abaque* was adopted by the French Railways and distributed in various versions, each designed to solve specific problems. It was indispensable for the construction of bridges, which no-one today would know how to design without 8 decimal digits at hand; in its time it was widespread but today it is very rare. I think fewer than 15 copies survived, included mine.

This interesting system had little success and was abandoned for the easier and more practical nomography, but the proportions between the numbers are harmonious and some *Abaques* are really beautiful.

One of the few surviving copies of the *Abaque Compteur.*

How many would be able today to design a railway bridge with no other help?

The *Abaque Compteur* of Léon Lalanne
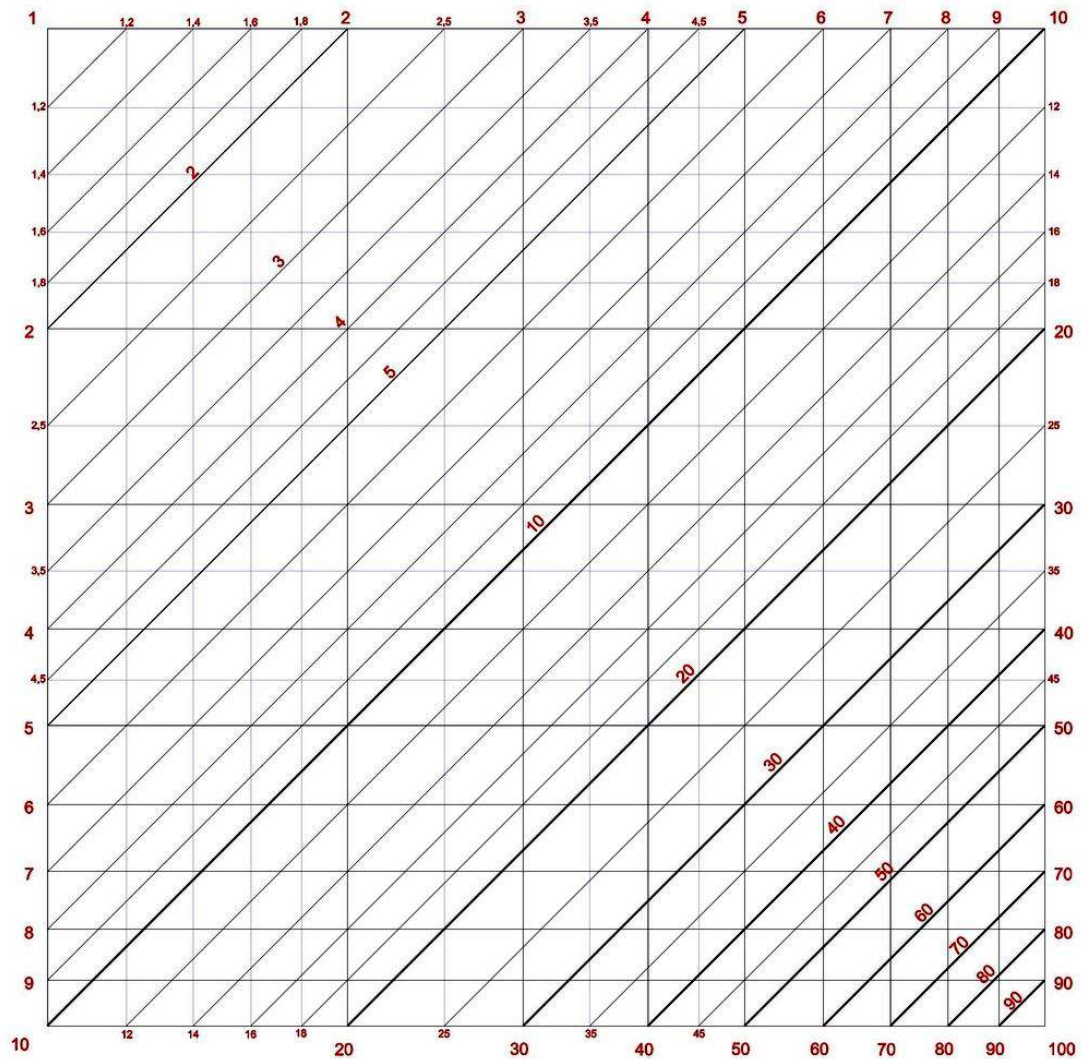
Lalanne's Abaque allows very quick operation at the expense of a small loss of precision. To perform 3.5 x 4.5 just search for the two factors on the lateral scales, look for their intersection on the diagonal and read the result. In this case the intersection is close to 16 and we can evaluate the result in circa 15.7-8. The exact result is 15.75, within the accuracy range of 2% which was considered acceptable by Lalanne.
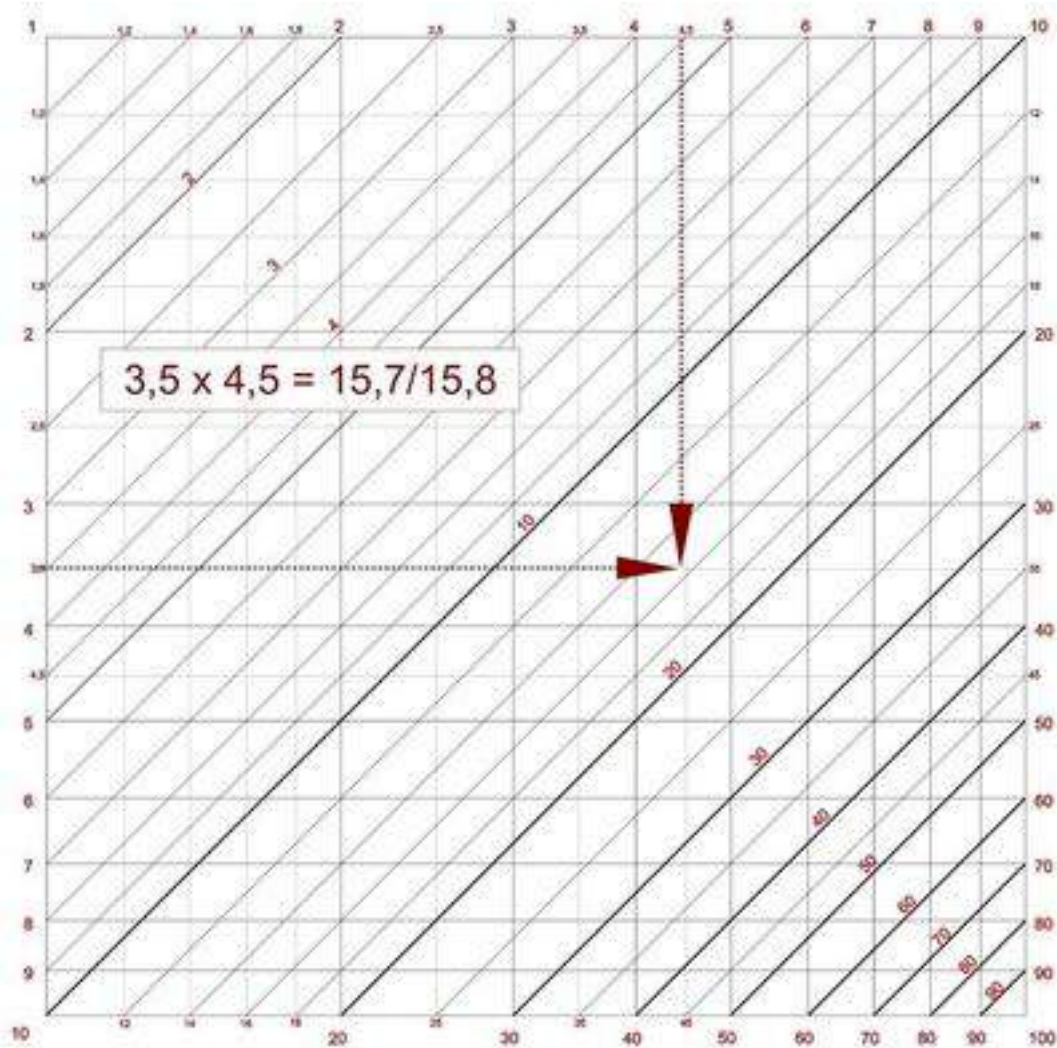
To perform 35/8 go on the diagonal value of 35 and seek for the intersection with the horizontal line of value 8: this point is close to the vertical line 4.5, and we can read a value between 4.3 & 4.4. The exact result is 4.375, again an error of less than 2%.

This is a simplified graphic, the original *Abaque* also allows the user to raise numbers to powers and to extract roots.

The Lost Scales of Unknown Riches[1]

## Your eyes can deceive you, don't trust them[2]

David Rance

It takes something exceptional to excite die-hard collectors. Most of us reach a point when acquiring yet another plastic slide rule is boring and unlikely to enhance our collection. However, this trait has a downside – there are always exceptions and sometimes we only see what we want to see. I still dream of finding a rare slide rule in a jumble sale or discovering something different. Sadly my "discoveries" usually expose how little I know. But on this occasion something genuinely unusual lurked unseen in my collection for years.

Surprises can come in small packages

Most of the slide rules ever made are of the 25 cm/10″ rectilinear variety. Next in popularity are the Pocket sibling versions. But to me the even smaller, typically 10 cm/4″, Lilliput models have always had a strange appeal – possibly because they are the dichotomy of the giant Desktop models. Originally thought of as toys these "tiddlers" have panache and even if horizontally challenged, they still qualify as miniature analogue calculators.

Although rarely shown in their catalogues most major slide rule makers made Lilliput models – e.g., Faber-Castell, Nestler, etc. But tellingly most Lilliput's are attributable to Japanese makers. However, I was caught out by a well-made unassuming specially commissioned Lilliput slide rule from UK maker: *A.G. Thornton*.
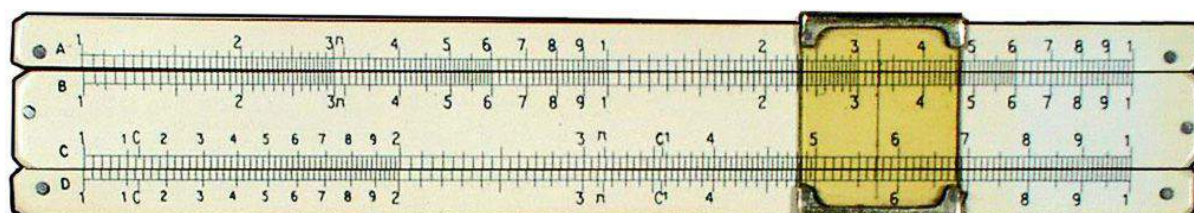
**Figure 1. A.G. Thornton made wooden 5″ Lilliput slide rule
with a chrome & yellow plastic cursor**

Reciprocal illusion

Although unbranded, the tell-tale aluminium pegs used either end for extra secure pinning of the celluloid facings to the mahogany closed frame stock are indisputable proof it was made by *A.G. Thornton*. Instead of a model number "ENGLISH ELECTRIC" and "PAT.APPLN. 304121/38" are stamped into the well of the stock. Untypically for a Thornton made slide rule there is no blind date stamp – just "MADE IN ENGLAND" is also stamped into the well of the stock.

The original application was made in 1938 and the full patent, **GB520442**, was granted in 1940. This is an aid to dating and as the Lilliput model in Figure 1 carries the patent application number,

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[1] Conjointly published in the UKSRC *Slide Rule Gazette* Issue 17, Autumn 2016.
[2] Jedi master Obi-Wan (Ben) Kenobi's immortal advice to Luke Skywalker in the original *Star Wars* film.

it must date from the late 1930s. But sadly warranting a patent was not enough to stop me missing something unusual. When originally cataloguing the item I suspect I simply flipped it over and slid the slide out just enough to note the scales on the back. But in doing so I mistook the B_1 and C_1 scale annotations for **BI** and **CI** or the inverse versions of the conventional **B** and **C** scales - i.e., respectively the reciprocal functions: $1/x^2$ and $1/x$.
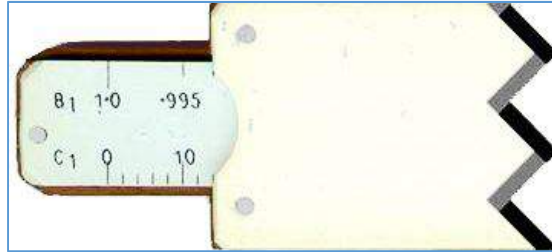

Figure 2. "Optical illusion"

My mistaken cataloguing meant this charming but otherwise unremarkable mini calculator was destined for obscurity. It stayed lurking in a drawer until a fellow collector asked for details of Lilliput models in collections. While preparing an inventory I discovered how I had been fooled by an "optical illusion". In my defence because both the B_1 and **BI** scales run down from 1.0, it was an easy mistake to make. The pair of lost B_1 and C_1 scales was devised by **Albert John Riches** when working at the Stafford works for the UK industrial manufacturer: *The English Electric Company Limited*.
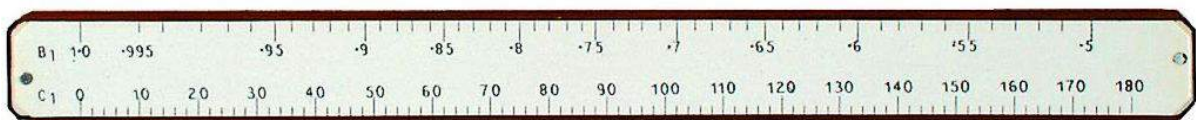

Figure 3. Easily mistaken scales on the back of the slide

The B_1 scale is logarithmic (1.0 - 0.5) but the C_1 scale (0 - 180) is linear. Together they can determine how efficiently power is being used within an electrical system. This is done by calculating the "**Power Factor**" in an alternate current (a.c.) circuit.

Power Factor Efficiency

An a.c. system, as the name suggests, uses alternating current – i.e., the polarity or the direction of the flow of electric current continually reverses. The rate it alternates is controlled by the inherent frequency of the system. This is standardised but varies around the world. For example, in Europe it is 50 cycles/second but in the United States of America it is 60 cycles/second. In some countries like Japan, different regions use different frequencies.

But whatever the frequency of an a.c. circuit, electrical power is used efficiently when the current to drive any connected equipment is aligned, as in Figure 4, with the voltage cycle or "electrical potential". However, in practice because of the many motors and other inductive loads most electrical equipment draws current from a circuit with a degree of delay. This means, as in Figure 5, it is no longer ideally aligned with the voltage cycle and expensively draws more current than is strictly needed. The Power Factor (PF) is an industry recognised standard for measuring how efficiently (or not) a piece of equipment is drawing power.
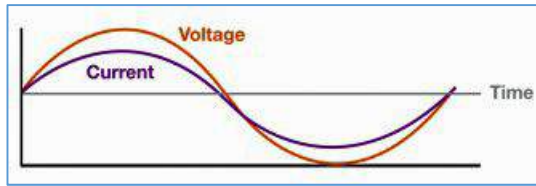
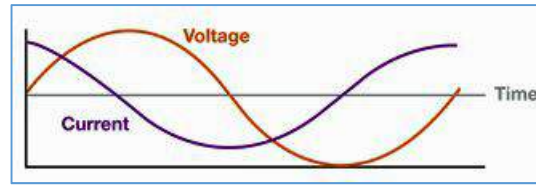**Figure 4. Aligned voltage & current cycles**

Figure 5. Current cycle slightly delayed

So to be meaningful the PF calculation must take into account the relationship between the various components of electric power in an a.c. circuit. These are:

⇒ **Real (or active) Power (kW)**
  the power in Kilowatts needed (or consumed) to run the equipment
⇒ **Reactive Power (kVAr)**
  the power in Kilovolt-amperes needed to magnetise and start up the equipment
⇒ **Apparent Power (kVA)**
  the combination of real and reactive power in Kilovolt-amperes

Therefore the resulting formula is:

$$\text{Power Factor} = \frac{\text{Real Power (kW)}}{\text{Apparent Power(kVA)}} = \frac{kW}{\sqrt{(kW)^2 + (kVA)^2}}$$

However, the easiest way to understand how the formula works is to consider the ratio of the three components as a triangle.
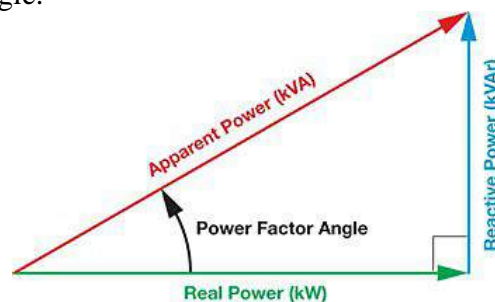
Figure 6. Right-angled triangle showing the PF angle

Albert Riches obviously appreciated this way of showing the relationship and used it to get a patent for his design. The **B₁** scale is the **trigonometric cosine function** (Cos x) of the angle shown in Figure 6 - i.e., the **Power Factor Angle**.

Calculating Power Factors

The slide needs reversing in the stock before the **PF** scales can be used. But uncommonly after that calculations using the special **B₁** and **C₁** scales are fully self-contained. So apart from the right-hand index lines providing arbitrary line up points, the conventional **A** and **D** scales on the upper and lower front face of the stock play no part in any PF calculation. This is reflected in the billing used in a set of instructions for a later version of the mini calculator: *"Combined Slide Rule and Power Factor Calculator"*.

The challenge for any power systems engineer is to get the PF angle as small as possible; as any PF less than or greater than 1 means that the circuit's wiring has to carry more current than necessary and therefore additional losses proportional to the current squared will occur in the supply circuits. The **B₁** and **C₁** scales are for calculating the changes needed to improve the PF for a given load on a power system. For example:

What kVAr increase is needed to raise a known PF to given value?

⇒ Set the known PF of 0.7 on **B₁** against the right-hand index line of **A;**
⇒ Set cursor hair-line over the desired PF of 0.85 on **B₁** as in Figure 7;
⇒ Set left-hand index line on **C₁** under the cursor hair-line;
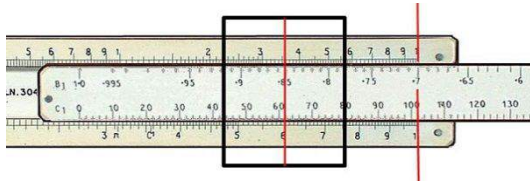⇒ Read off **C₁** the improvement needed by right-hand index line of **D** as in Figure 8.
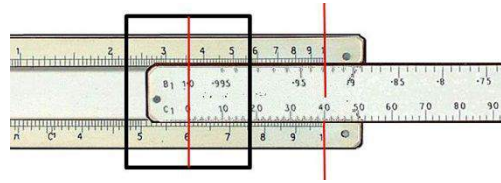

Figure 7. Setting known & desired PF's

Figure 8. Reset C₁ index line to find %

Answer: To raise an existing 0.7 PF to 0.85 the **kVAr** (inductive) needs reducing by 40%.

To achieve the desired 40% reduction a power system engineer would normally add suitable capacitance to the circuit. But the worked example shown is simple – reducing the inductive volt-amperes by adding capacitive volt-amperes. In practice both real power and apparent power can be either positive (lagging) or negative (leading) and power system engineers need to resolve such problems for circuits with multiple kW loads of different magnitude and PF's. Such calculations are much more complex, requiring many interim steps, but all can be done easily using just the **B₁** and **C₁** scales.

Who was Albert Riches?

Sadly, information about the Riches family history is largely unknown. He is also no known relation of *UKSRC* member and renowned collector: David M. Riches. The bibliographic data in the patent application tells us he was working for the *English Electrical Co.* in the late 1930s. As his place of work was the company's Stafford Works, it is reasonable to assume he lived in the West Midlands area of the UK. Moreover he was a loyal long-serving company employee. Figure 9 shows an award ceremony held in Stafford on 23rd

Figure 9. Long-service Awards Ceremony

December, 1963. The Works Manager, Mr. J.R. Scully (front row, 3rd from the left), presented the awards to *English Electric* employees who had worked for the company for 40 years or more. Sadly the Award Ceremony programme only lists recipients alphabetically. Mr. A.J. Riches is listed but unfortunately as the recipients are unlikely to have lined up alphabetically for the photograph, it is unknown which of the award winners in the photograph he is.

Was it useful?

Surprisingly the **B₁** and **C₁** scales are unique to the *English Electric* Lilliput. No other slide rule exists with such **PF** scales. The closest are slide rules with a specially chosen scale layout to

make the solving of trigonometric problems easier – e.g., the Trigonometry Calculator by UK maker *Fearns*. This could suggest such scales and PF calculations were of little use to electrical professionals. However, it is more a case of a missed opportunity.

Notably various slide charts were marketed specifically for solving PF calculations. They did what the B_1 and C_1 scales could do and are proof that the electrical industry clearly used PF calculation aids. Moreover, "Principal Strategist in Network Strategies" for *ElectraNet SA* and leading expert on Electro slide rules, Robert Adams, has assured me he would, with hindsight, include a pair of B_1 and C_1 scales on his theoretical "ideal" Electro slide rule.

But was it a success?

No production numbers are known for the original *English Electric* Lilliput but it was more than a specially commissioned "one-off" slide rule. Two decades after producing an unbranded version, *A.G. Thornton/PIC* issued an almost identical branded plastic version.
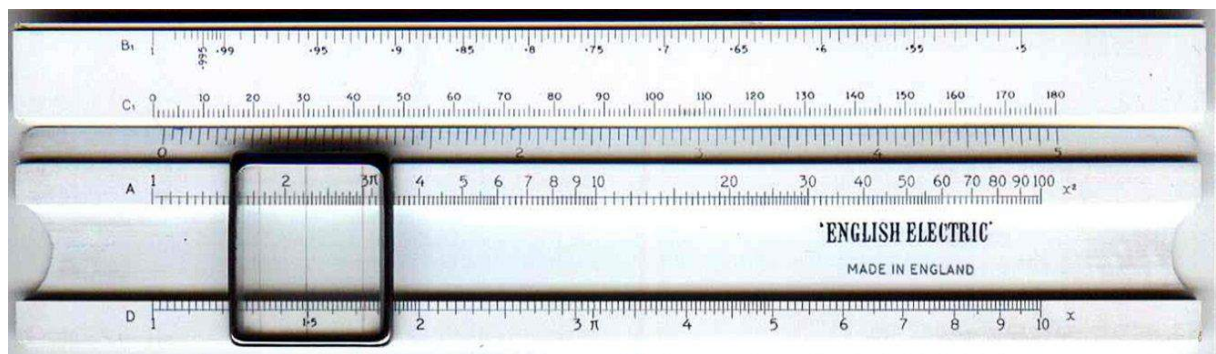
Figure 10. Later A.G. Thornton/PIC plastic 5″ Lilliput slide rule with slide reversed

Again there is no model number but apart from a top bevelled edge inch scale and a PIC "pickaxe" logo on the front of the slide, the scale layout is identical. Mysteriously on this blind date-stamped version from 1959, reference to the Riches patent has been dropped. There is also no mention of it in the accompanying instructions. This could indicate that sometime in intervening years *English Electric* stopped paying the annual patent renewal fees. What is more surprising is that *Thornton/PIC* did not use a wider body on this later version. Repositioning the **PF** scales in between the **B** and **C** scales on the front of the slide would have saved the need to reverse the slide. Revealingly such a layout improvement is even suggested by Riches in the patent application. But the bigger mystery has to be why such **PF** scales were never part of any Electro slide rule. For most leading makers the specialist type of slide rule they all had in their product line was one or more ubiquitous Electro models. On such models electrical engineers, if they were lucky, could use the rarely included Pythagorean function $\sqrt{1-(0.1x)^2}$ or **P** scale for such calculations. But compared with the elegant simplicity of using the **PF** scales, doing the same calculations with the **P** scale was clumsy and awkward.

Ironically now, eight decades later, the *English Electric* Lilliput PF slide rule would probably be a "best-seller". Carbon dioxide emissions as the cause of global warming were only confirmed in 1987. So these days limiting the burning of fossil fuels and energy efficiency is as much a personal as a business challenge. In electrical engineering the PF is still the industry recognised standard for measuring how efficiently a piece of equipment is drawing power. Although these days an extra way of measuring efficiency of an a.c. circuit is to compare power input (watts) to power output (watts). What has changed is that now utility companies will often fine or charge a

higher cost to industrial or commercial electricity users if their systems are drawing power below a set PF limit. Typically the limit is set at a PF of **0.9** or **0.95**. The required automatic PF efficiency monitoring is part of the modern digital electricity meters issued to industrial or commercial users.

Currently such fines or surcharges are not levied on residential electricity users – but it might come. There is already pressure for suppliers of modern electrical devices and household electrical white goods to comply with the *Energy Star™* standard. This internationally adopted stringent rating system originated in the US. It helps consumers judge how much, on average, it will cost to run a consumer appliance for a year. Therefore it is a measure of an appliance's energy consumption rather than its PF rating – the lower the consumption the more stars an appliance gets. However, since 1995 there is also the European **EN 61000-3-2** standard. Essentially it stipulates the power quality (for harmonics) electrical and electronic equipment should adhere to when connected to public low voltage distribution systems. PF efficiency is part of how the standard defines the quality such equipment needs to meet. It already covers many consumer appliances such as PC's and TV equipment. But outside the European Union national governments can discretionally decide whether to adopt it as a standard or just as a guideline. Had the EN 61000-3-2 standard been around back in the 1930s it would have the undoubtedly raised the sales potential of the *English Electric* Lilliput PF slide rule.

In the 21st century the "green lobby" cannot be ignored. However, the PF efficiency benchmark is not the "silver bullet" many greens are looking for. But it is likely that utility companies will increasingly use PF efficiency to show they are doing their bit and coincidently help them put off having to invest in ever larger transformers and upgraded power cables.

So look out for Lilliput's and especially any with the unique **PF** scales. But the moral of this story must be: *"you never can be sure what you have until you have had a really good look!"*

Postscript - *"In a galaxy far, far away[3]…"*

Or as Obi-wan Kenobi would surely have said to any apprentice Jedi knight: "do not be misled by the scale of the (un)inverse, it is just the power factor of the force!"

Acknowledgments and Bibliography

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[3] Part of the credit line that crawls up the screen at the start of every *Star Wars* film.

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David G. Rance

Before taking early retirement in 2002 I worked 25 years for an Oil & Gas major - ending up as a *Global I.T. Strategist*. Five years later I retired for a second and last time after working for a London/Brussels based "I.T. Think Tank".

I started collecting slide rules in 1991 as an analogue contrast to the digital day job. I have a special interest in acoustic and desktop models but also anything with a "whacky" scale. One day I will finish uploading (and rediscovering) my collection to www.sliderules.nl/.

Since 1975 the family home has been in one of the largest bulb-growing areas of The Netherlands. I hold dual GB/NL nationality and I am still happily married with one daughter and two adorable grandchildren.

Paolo Ballada de Saint Robert and His Hypsologista

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Abstract: The Count Paolo Ballada de Saint Robert (1815-1888) was an Italian scientist working mainly in mechanics and thermodynamics. Well known also as a distinguished savant and zealous mountaineer, he invented an ingenious slide rule (the Hypsologista) for determining the difference in the altitude of two locations from a pair of barometer observations, without the necessity to use tables or to make any arithmetical calculations. This slide rule was also known and appreciated by The Alpine Club of England.

Today we have only a description of it but no original copy.

In our talk we describe how Saint Robert arrived to his personal hypsometrical formula (through the observations made by J. Glaisher concerning the barometric formula, and the Laplace formula) and we explain how his Hypsologista was built (the reduction, using a slide rule, of an equation in three variables) and how it works (through three examples); these subjects are strictly related to the figure of the scientist/mountaineer at the end of the 19th century and to the first Italian ascent of Mount Viso in August 1863; therefore, a part of this paper will be about these subjects also.

Keywords: Hypsologista, hypsometrical formula, slide rule, scientist mountaineers, digital reconstruction.

1. Count Paolo Ballada of Saint Robert

1.1. Biography

Count Paolo Ballada de Saint Robert was born in 1815 in Verzuolo, a town in Piedmont in the Italian Province of Cuneo. As a very young boy he entered the Turin Military Academy soon obtaining the promotion to lieutenant of artillery and afterwards professor of Ballistics in the School of Applied Artillery and Engineering of Turin. When he was 45 years old, he left the army with the rank of lieutenant colonel and devoted himself to the study of his beloved science. In 1878 he retired to *Castagnole Lanze*, before moving to Turin where he died in 1888.

Thanks to his studies and researches, he ranged over various fields of science where he obtained very important accolades both in Italy and abroad. He was a member of the *Reale Accademia delle Scienze* (Royal Academy of Sciences) of Turin, of the *Reale Accademia dei Lincei* (Royal Lincean Academy) of Rome and of the *Società Italiana* (Italian Society), also known as the XL (forty) Italian Society because it gathered together Italy's forty most eminent scholars. Being a character of high genius, he performed numerous studies of precursors of modern theories in different fields of Science.

His studies of ballistics, artillery, mechanics, and barometric hypsometry were published in three volumes entitled *Mémoires Scientifiques: Réunis Et Mis En Ordre*.

His best-known work, preserved in many university libraries, and which brought him widespread fame, was *Principes de Thermodynamique* published in Turin in 1865 and adopted as a textbook in English and German universities.

He studied also entomology and botany, collecting an important herbarium richly filled with rare plants. An avid mountaineer, he made numerous ascents including the first Italian ascent of Mount Viso in 1863 together with a close friend Quintino Sellawith whom he founded the prestigious Italian Alpine Club; in 1885 he was among the first Italians to be accepted as an honorary member of the Alpine Club of London.

1.2. The Figure of the "Scientist Mountaineer"

Hypsometry, like botany, geology, and mineralogy, was one of the sciences which were investigated in the Alps by the early explorers: the so-called "scientist mountaineers".

From the second half of the eighteenth century until the first half of the nineteenth century, the first explorers of the Alps were all scientists. Mountains were seen as an open-air laboratory by scientists like Spirito Benedetto, Nicolis di Robilant, and Horace Benedict de Saussure. The figure of the "scientist mountaineer" symbolically finished around 1865, when Edward Whymper climbed the Matterhorn for the first time, not for a scientific purpose but only for the pure pleasure of the sport. Saint Robert instead remained a "scientist mountaineer" until his health allowed him to practice mountaineering; he made numerous climbs on the western Alps and the Gran Sasso, always together with other scholars, in order to turn every trip into a scientific campaign; occasionally[4] he was accompanied by the young and promising italian artist Alberto Maso Gilli (1840-1894) who realized great scientific illustrations.

2. Hypsometry and Hypsologista

2.1 The Contribution of Saint Robert to Hypsometry

One of the aspects that most captured the interest of the Count was hypsometry, the science that deals with determining the altitude of a location by measuring the atmospheric pressure there. The first experiments in this direction were made in 1648 by Blaise Pascal and later, in 1846, by Edmund Halley; the work done by Pierre Simon Laplace was important and his barometric formula enjoyed a lot of credit until the middle of the nineteenth century[5]. In the nineteenth century Paul Ballada de Saint Robert was among the most active in the study and development of hypsometry, hoping to assist in wide-spread hypsometric survey campaigns (displayed at the Academy of Sciences of Turin in March 1871) in order to improve the knowledge of the territory's orography (the study of the topography of mountains) and the drawing of detailed maps.

In 1864 he published the results of his studies almost simultaneously in the most important international scientific publications[3]: the English *Philosophical Magazine* (among the prestigious

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[4]   There are pictures signed by Gilli in publications relating to the ascent of Torre d'Ovarda and of Gran Sasso; it is very likely that the artist has produced other illustrations concerning Saint Robert, but they are probably lost or are in untraceable handwritten correspondence.

[5]   For a detailed description of the development of hypsometry and its main formulae, we recommend: Stefanini, L. (2014), *Measuring the heights of mountains: the contribution of Count Paolo Ballada Saint Robert* , Bologna, SIF, pp.93-110 (Giornale di Fisica)

[3]   Saint Robert had a full knowledge of French and English, as demonstrated by his friend William Mathews in the memorial of February 1889 in the Alpine Journal, in which he reported that the article about hypsometry, published on the Philosophical Magazine, had previously been sent to his friend John Ball for English translation and correction, and it was found to have been completely free of mistakes.

authors such as Hamilton, Maxwell, Brewster, Cayley, and Tyndall); the French magazine *Les Mondes* and the Italian *Il Nuovo Cimento*. From this wide range of publications, it is clear how important Saint Robert considered his studies to be, and how they were well accepted by the scientific European community.

His contribution to hypsometry can summarized as being the changes that he made to Laplace's barometric formula by starting from the data collected by Glaisher (during his balloon ascents of 1862) and observing from these a linear decrease of air density and air temperature with increase of altitude. He also built new hypsometric tables and, aware that there didn't exist an instrument capable of measuring the air temperature due to the strong influence of soil temperature, he proposed a method for determining the difference in altitude between two points without the use of a thermometer and using only the barometer, the clinometer, and the measurement of the travel time of the sound of a gunshot from one location to a second location.

2.2 The Hypsologista and its Digital Reconstruction

In 1867 William Mathews (famous English mountaineer, founder of the Alpine Club, and scholar of hypsometry and topography) wrote to the editor of the Alpine Journal:

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Count of Saint Robert ... has invented a ingenious instrument to
determine the elevation difference between two points using two
barometric observations without the help of tables and arithmetic
operations... it was named by its inventor "Hypsologista of Saint
Robert" and it consists in a graduated wooden scale and two
graduated rulers, and due to its small size (20 cm x 4 cm) it can
be easily brought in your pocket. Saint Robert gave me a model and
a detailed description...
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Mathews commissioned the construction of a copy from James Joseph Hicks (1837-1916), student of Louis Pascal Casella, and builder of scientific instruments in London. Hicks, as well as producing this copy, also published a user guide in 1865. We have found a copy of this manual on the shelves of a London public library: in addition to the description of how the slide rule works, it shows the graphical representation (Fig.1) of the instrument, with very refined drawing but showing small inaccuracies in the scales in order to prevent "unauthorized copies" of his precious instrument. In 1874, in *Volume III* of the *Mémoires Scientifiques: Réunis Et Mis En Ordre* Saint Robert devotes an entire chapter to the Hypsologista, with a detailed explanation of its use and how it was built; here we find another graphical representation (Figure 2).

The slide rule consists of two distinct series of logarithmic scales engraved on wooden pieces: the first two scales, marked with the letter "P" (Proportion), are graded in the same way, but while the first scale is fixed, the second one can slide. The second group includes the scales indicated by the letters "B" (which stands for the barometric pressure in centimeters of Mercury (Hg)), "T" (for the temperature in °C), and "H" (height above sea level) for the altitude; the B and H scales are fixed while the scale T can slide. It was possible to customize the rule with some engraving: for example, in the track within which the P slide runs, there could be a scale divided in centimeters and millimeters, while on the back there could be a table of altitudes below 100 meters, and on the side a small table of tangents.
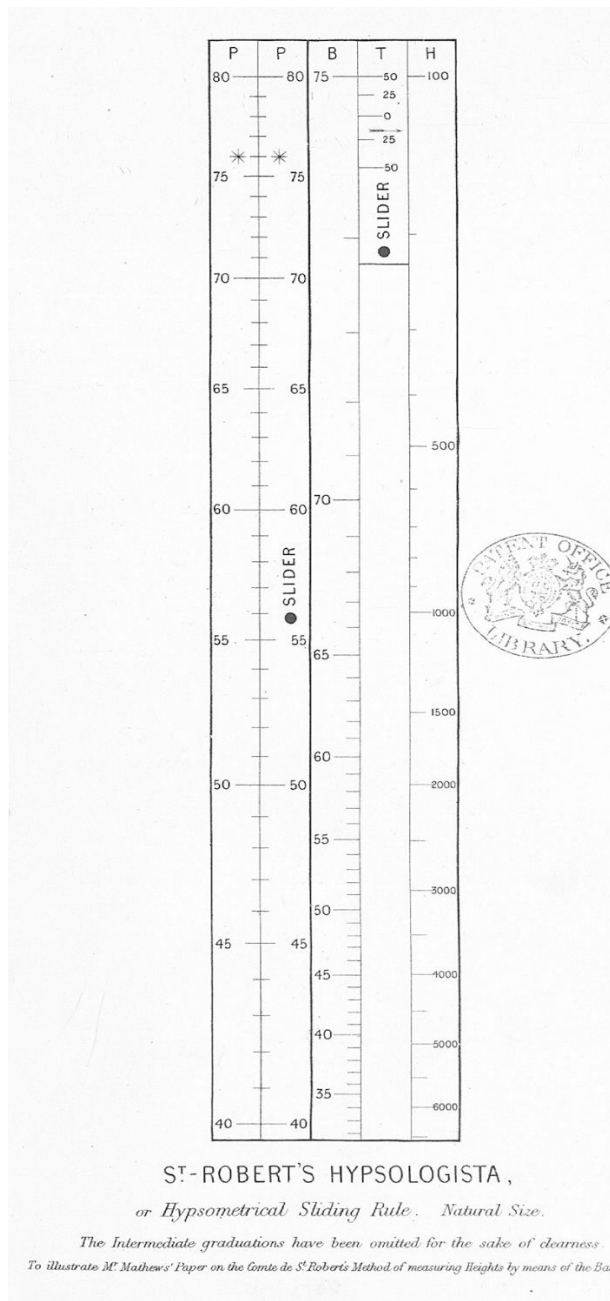
Figure1. Hypsologista represented by J.J. Hicks
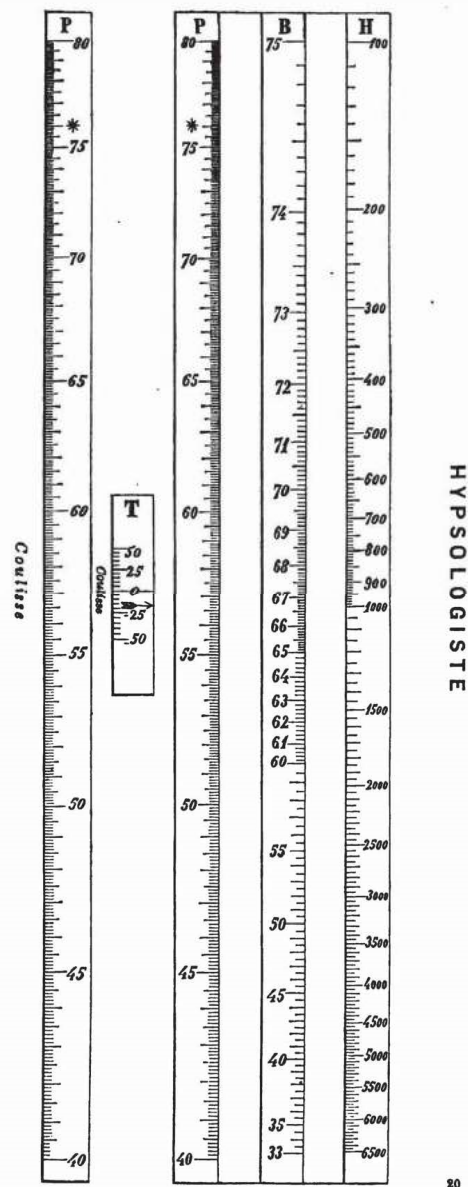
Figure 2. Hypsologista represented by Saint Robert

The pressure scale "B" extends from 75 to 32cm and is graduated in millimeters from 75 to 65 cm, every two millimeters from 65 to 60 cm, and finally every five millimeters from 60 to 33 cm. The scale of the units "H" extends from 100 to 6500 meters and is graduated every 10 meters from 100 to 1000 m and then every 50 meters from 1000 to 6500 m. The scale on slide "T" extends from 50°C to -50°C and is graduated every 5°C; this scale is not very detailed and it is therefore difficult to identify the intermediate temperatures. On the "T" scale, there is engraved an arrow that functions as an index.

Thanks to the instructions and graphical representations thus found, we have been able, using CAD software and 3D modelling software, to create a digital reconstruction of the instrument, functionally similar to the original; for the definition of the graduated scales we used the precision of the Saint Robert illustration, adopting however the more elegant design of the Hicks version

(see Figure 3 and Figure 4). We would like to produce a few copies of the Hypsologista, with the hope that it will be accepted by some collections of scientific instruments and in order to stimulate discussion about this slide rule and its inventor.
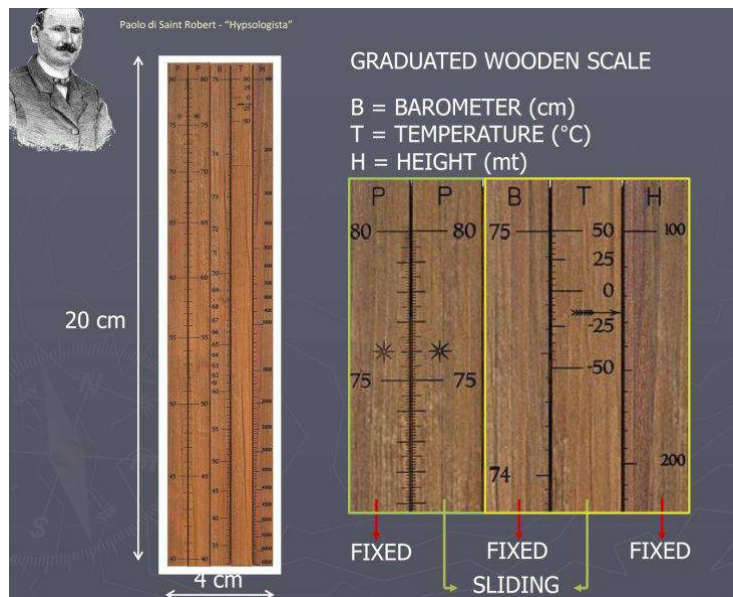
Figure 3. Digital reconstruction of the Hypsologista

Figure 4. Digital reconstruction of the Hypsologista

By using this slide rule, once the temperature and the atmospheric pressure at a given location have been measured, you can solve three kinds of problems:

1. *First Problem:* to find the altitude above sea level of a location by observing atmospheric pressure and temperature there.

To solve this problem we must use the scales B, T, and H. Matching the measured temperature with the measured pressure shown by the barometer, the arrow on the T slide shows the altitude on scale H.

As an application of this problem (Figure 5), Saint Robert reports the determination of altitude above sea level of Mount Viso during the first Italian ascent to its summit, which took place in 1863 of which he was, together with Quintino Sella, the promoter and organizer. At a measured barometric pressure of 48.4 cm and an air temperature of 6 °C, moving the slide T and matching the 6 °C with 48.4 cm of scale B, the arrow on the slide T indicates the altitude of Mount Viso as being 3850 m (we now know that the correct altitude is 3842m).
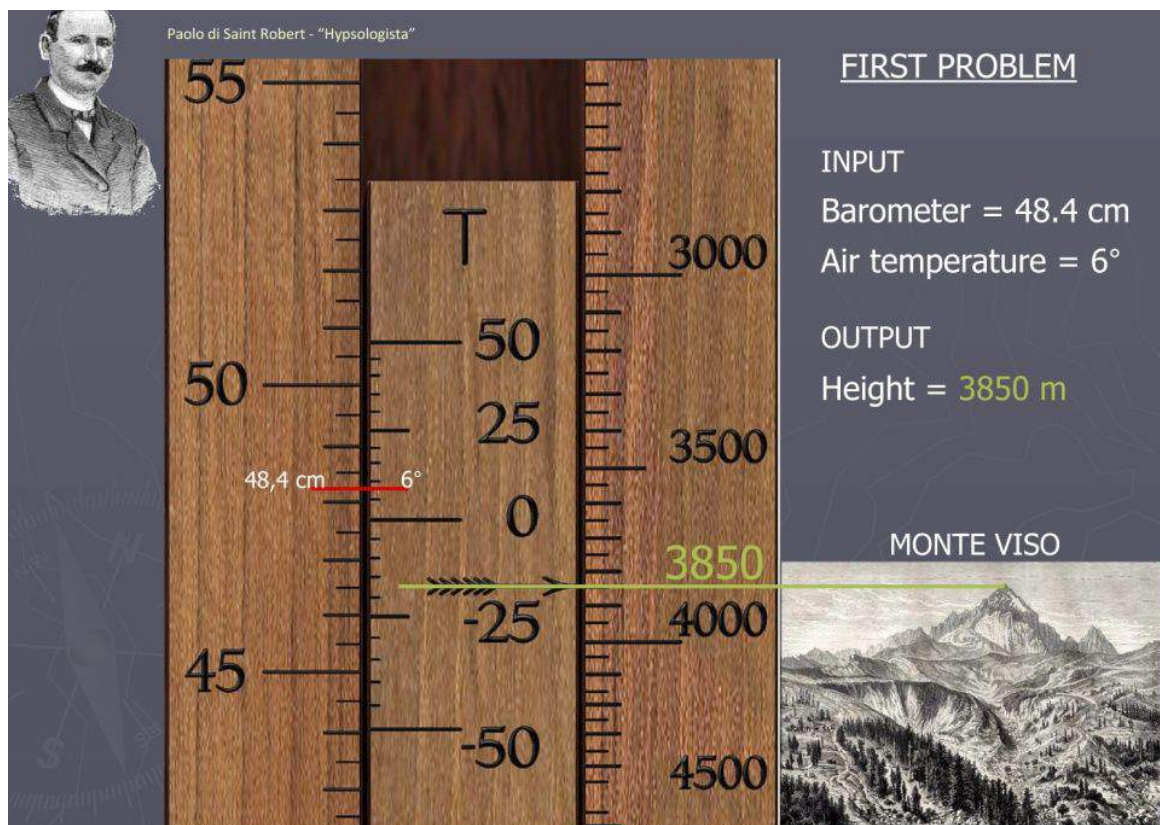
Figure 5. Determination of the altitude of Monviso

2. *Second Problem*: to determine the difference in altitude between two locations, given the barometric pressure and the air temperature at the first location, and the barometric pressure at the second.

To solve this problem we have to do two operations. Firstly, we have to move the slide P up to match the barometric pressure of the second location with the 76 cm subdivision, which is indicated with an asterisk on the fixed scale P. Then we read on the fixed scale P the barometric pressure in centimeters corresponding to the barometric pressure measured at the first location. By using the second set of scales, we now move the slide T by matching the temperature detected in the first location with the barometric pressure found in the previous step. The value on the scale H, indicated by the arrow on the T slide, is the difference in altitude between the two locations.

As an application example: suppose that at the time of previous surveys on the summit of Monviso the barometric pressure in the village of Casteldelfino is measured as 65.3 cm. To find the difference in elevation between the top of Monviso and Casteldelfino we start by aligning 65.3 on the P slider with the value 76 on the fixed scale P. Then reading the second barometric pressure, 48.4 on the P slider, we see that it corresponds to 56.3 on the fixed scale P (Figure 6).
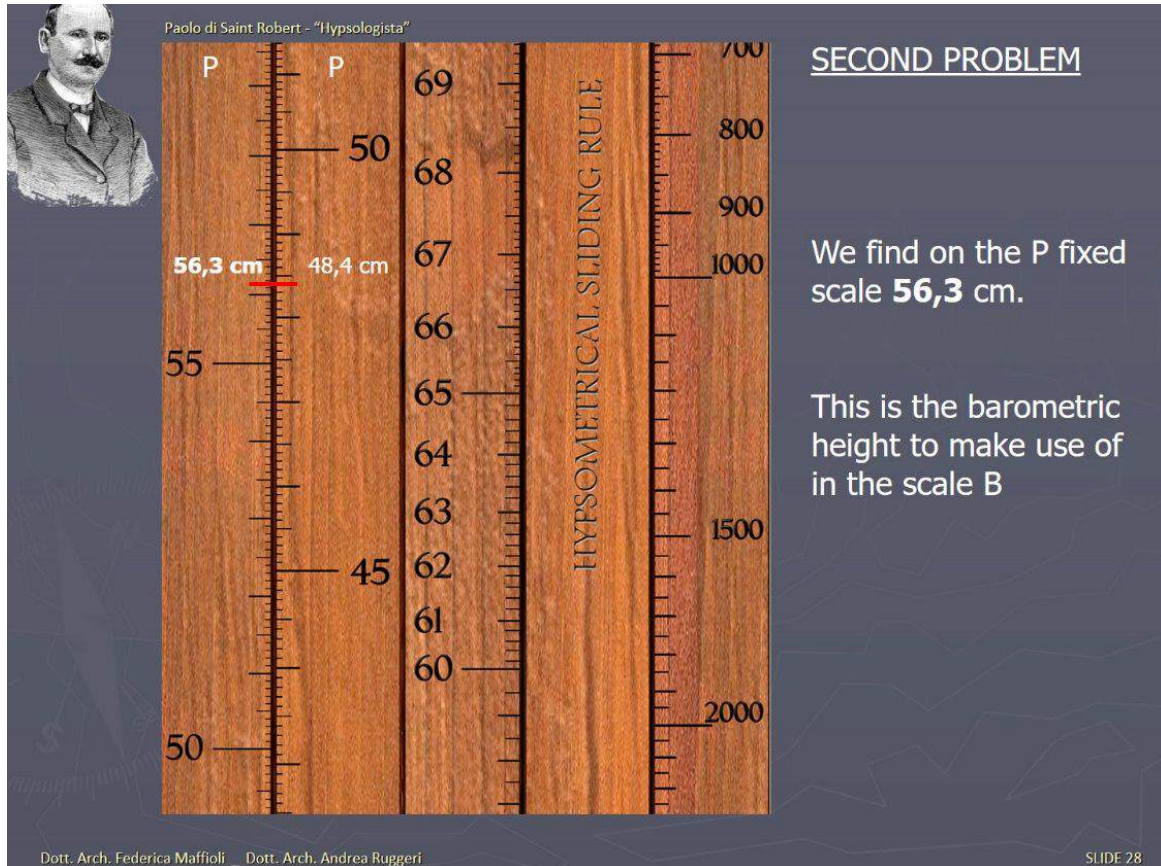
Figure 6. Determination of the difference in elevation between two locations

This is the barometric pressure to be used later on scale B. Aligning the temperature of 6 °C measured on the summit of Mount Viso with the barometric pressure of 56.3 cm found previously, the arrow indicates on scale H the value of 2555 meters (Figure 7): this is the difference in altitude between the top of Monviso and the village of Casteldelfino.
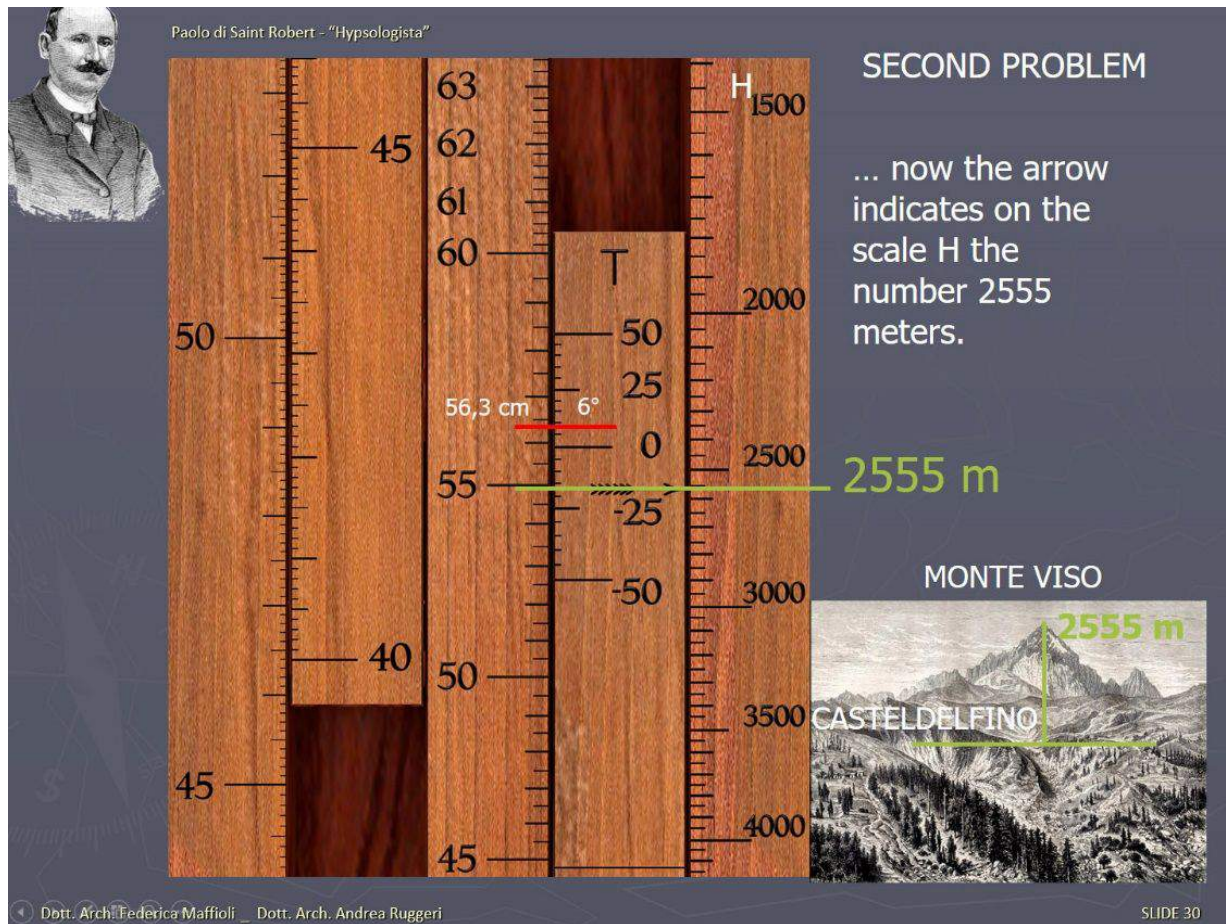
Figure 7. Determination of the difference in elevation between two locations

3. *Third problem*: to find the barometer pressure that you will find at a first location, given the difference in altitude between the two locations and values shown by a barometer and a thermometer in the second location.

To resolve this problem we start matching the arrow on slide T with the absolute value of the level difference between the two locations on scale H. Then on scale B we read the value which is now aligned with the measured temperature. Then we match the value just found on slide P with the barometric pressure physically measured reported on the fixed scale P. In front of the value 76 on the fixed scale P we now read on slide P the sought barometric pressure.

As an example: at an altitude of 550 meters the air temperature is 16 °C, and the barometer shows 71 cm; we want to find the barometer pressure at a second location 200 meters higher. To solve the problem, we bring the arrow on slide T against 350 (difference in altitude between the two locations).

Corresponding to the value of 16 °C on slide T, we read the number 72.96 on the fixed scale B (Figure 8).
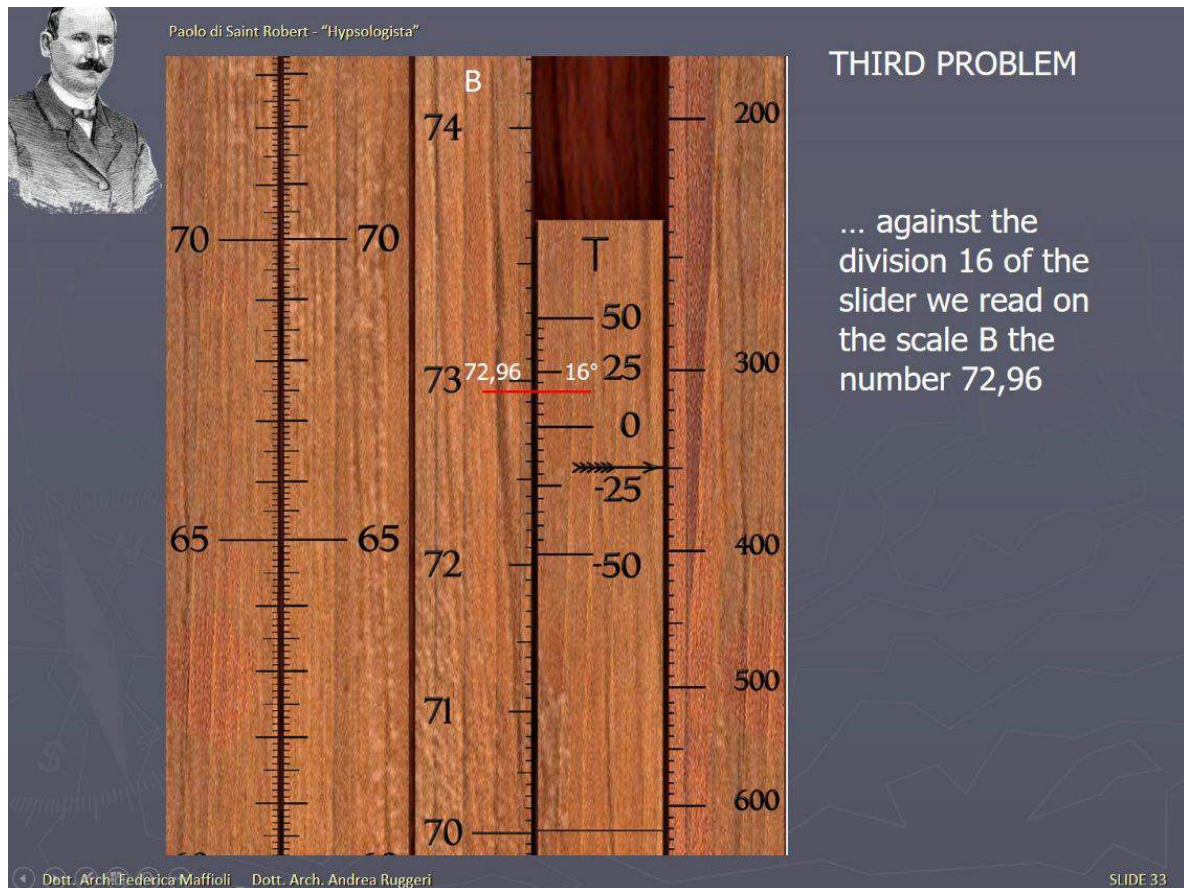
Figure 8. Determination of the barometer value in the first location

Then we align the value 71 on the sliding scale P with the value 72.76 on the fixed scale P. Next the value 76 on the fixed scale P, we read the value 73.96 on the sliding scale P (Figure 9). This is the barometric pressure which we are looking for.
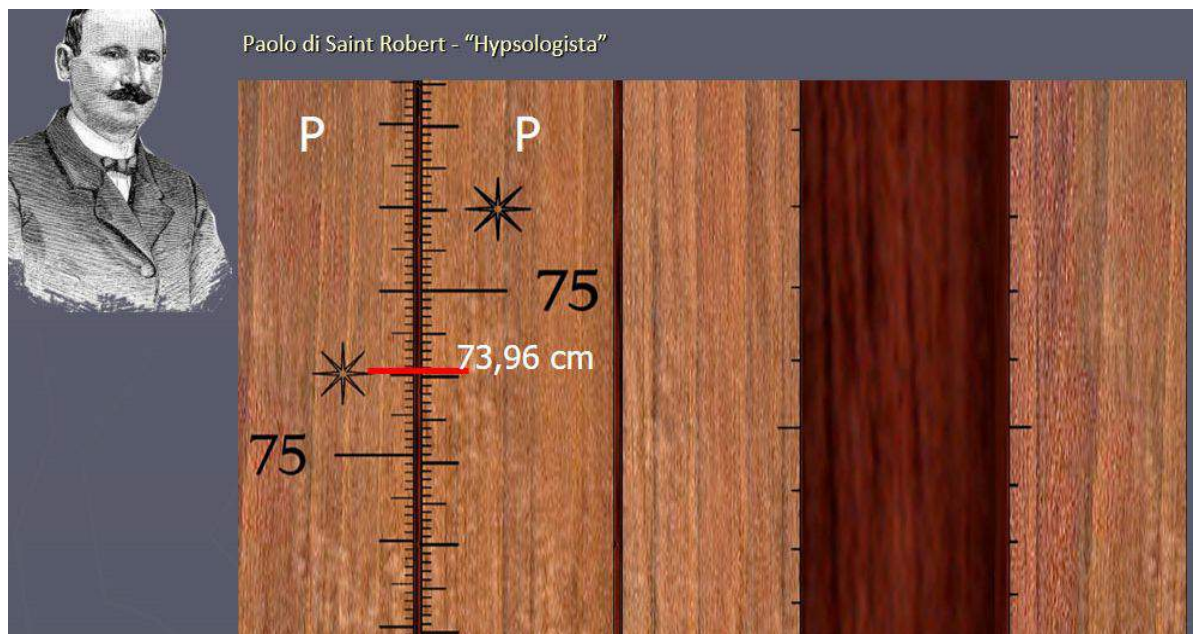
Figure 9. Determination of the barometer value in the first location

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 Federica Maffioli and Andrea Ruggeri, both architects, are mainly involved in architectural design and museum exhibitions. They are interested not only in architecture, but also in divulgation of science. They began to study the Count Paolo Ballada de Saint Robert during the university thesis of Federica. In 2012 they designed the exhibition path and the museum on the Count Ballada in Castagnole Lanze. They participated in international conferences of SISFA 2012 in Rome and 2013 SISFA in Acireale discussing articles about Count Ballada.

Collectanea de Logarithmis

Klaus Kühn
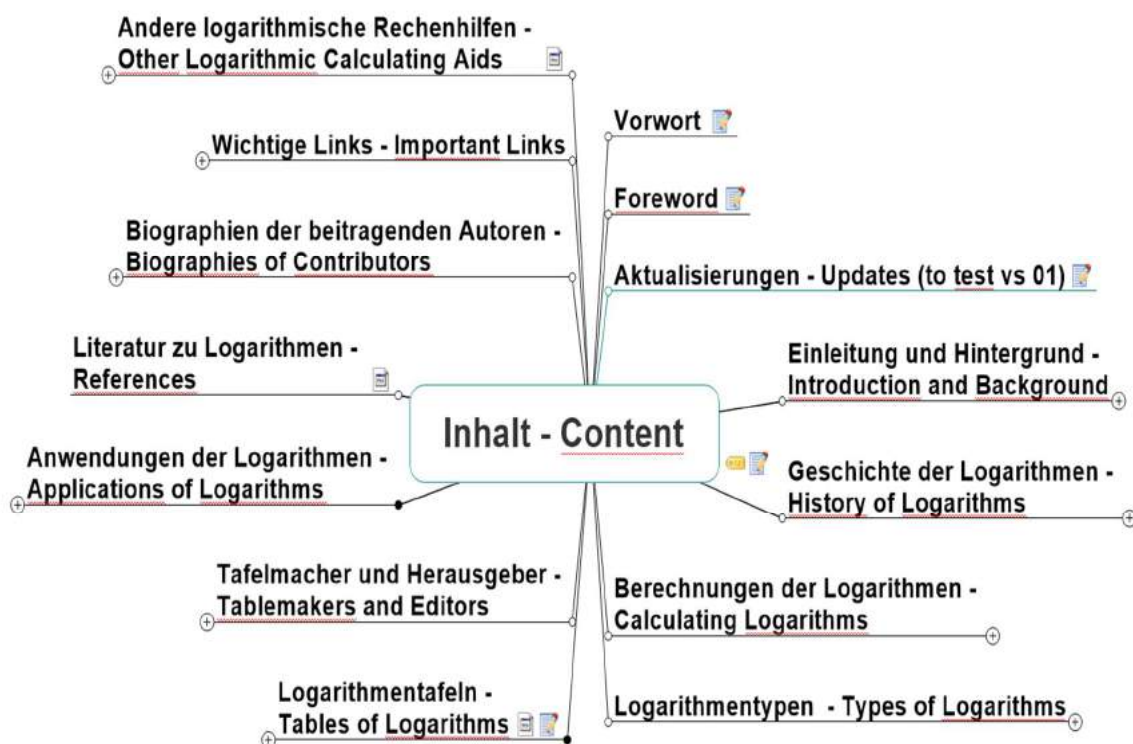
2014 was the 400th anniversary of a calculating paradigm shift: the logarithm. The first Table of Logarithms, *Mirifici Logarithmorum Canonis Descriptio*, was published in 1614 by John Napier. It seemed fitting to mark this milestone by chronicling everything known about this revolutionary invention as a compendium: the content of the *Collectanea de Logarithmis* will be introduced at the IM 2016 and is shown above as a "mind map".

The bilingual German/English content of the *Collectanea* consists of more than 3200 entries representing umpteen articles, many tables and Internet links relevant to the logarithm. This logarithmic "labour of love" took more than 10 years of research to collect and compile.

For example, the topic *"Tables of Logarithms"* includes a unique 121-page worldwide inventory of more than 3100 tables by the year they were first published, the author, the title, the publisher/city, the language and for many, a link to an online source. However, nearly a quarter of the links is to 700 digitised original tables and most are downloadable. This in turn creates the opportunity to study such tables in-depth and to learn first-hand how their content and design evolved over time.

Whereas the many specialised articles included with the *Collectanea* compendium cover logarithm-related areas such as science, engineering, economics, transportation and academic study. They provide a theoretical and in-depth insight into the part played by logarithms during the last five centuries. Over 90 of these articles, 27 in English, have never been previously published or are not readily available anywhere else.

So the *Collectanea de Logarithmis* provides a rich historical account of the role and calculating importance of logarithms. It represents an invaluable resource for further study or reference. Importantly being a unique "one-stop shop", it will doubtlessly save hours of unfruitful Internet surfing and library visits as everything you are ever likely to need is to hand with the *Collectanea*.

The sheer volume of the contents practically and financially precluded publishing the *Collectanea de Logarithmis* as a book. So it is only available digitally as a DVD. To protect against plagiarism, copies of the *Collectanea* come with a USB-stick security device. This PC device activates an offline "home page" on the DVD. Very much mirroring the experience of commercial Internet browsers, the intuitive inbuilt browser makes it easy to navigate through the *Collectanea* and discover its "Aladdin's Cave" encyclopaedia of information.

Klaus Kühn, Editor
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Some Particular Italian Slide Rules
Andrea Celli

Introduction and History

At the beginning of the twentieth century, the Italian industry of precision engineering was almost non-existent and, in particular, completely absent from the production of computational tools.

This article will follow the first steps in the history of the Italian production of slide rules, which never managed to break through on the international markets despite some good premises and the introduction of some very original products. So Italian slide rules are little studied and often ignored by the most experienced collectors. This makes these pieces often unfairly undervalued, and so they may be the subject of fortunate and unexpected discoveries.

Also the Italian production of "digital" calculators had a very rough start. Between 800 and 900, there had been some interesting Italian inventors projects in the field of adding machines, but were built by French industries: the adding machine "Indispensable"[6] by Carlo Fossa Mancini, produced by Japy, and the "Eclair"[7] calculator by Roberto Piscicelli Taeggi, produced by Sanders. Piscicelli had also sold his patent for cash registers at the NCR Company.

The Italian industry was to be born only in the early 1930s with Logistea calculator (made by PSIC, an acronym for First Italian Calculators Factory). However, the production was very limited: in 1939 no more than 30 calculators and 3,000 adding machines were produced[8].

The turning point would be after the Second World War[9] when thanks to a meteoric rise in production, Italy would become the first exporter of calculating machines in 1963. Olivetti and their designer, Natale Capellaro[10] , was the leading manufacturer, but there were a multitude of small and medium sized enterprises (Everest, Lagomarsino, Inzadi, Stiatti...).

The history of the Italian analogue instruments is much longer, but it would not lead to a commercial success even remotely comparable to that obtained from mechanical calculators.

In the 16th century the first proportional compass appeared in Italy built by Fabrizio Mordente (Salerno, 1532-1608).

A few decades later Galileo not only elaborated a more perfected form (*Compasso geometrico et militare*) but he started its production and sales, advertised it with modern methods, selling throughout Europe accompanied by a comprehensive instruction booklet entitled *Le operazioni del Compasso*[11].

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[6] http://www.rechenmaschinen-illustrated.com/Fossa-Mancini.htm
[7] http://www.rechenmaschinen-illustrated.com/LEclair.htm
[8] A. Tarchi: "Prospettive autarchiche, Rassegna economica delle produzioni nazionali e lineamenti dei problemi autarchici", Casa editrice Carlo Cya, Firenze, 1941
[9] Centro di documentazione della Presidenza del Consiglio dei Ministri: "Produzione ed esportazione delle macchine per ufficio" in "Documenti di vita italiana", anno V, n. 38, gennaio 1955, Roma,
[10] G. Silmo: "M.D.C. macchine da calcolo meccaniche e non solo. Natale Capellaro IL genio della macchina", pubbl. `Tecnologic@mente Storie, Ivrea (2008)`
[11] G. Galilei: "*Le operazioni del compasso geometrico et militare*" Padova (1606)

A form of business that we find in many current IT companies. Just as modern was the dispute between Galileo and Baldassarre Capra on "copyright" of the invention. Capra Galileo allegedly copied a compass invented by him[12]. Galileo turned the accusation[13] and brought Capra to trial in front of the University of Padua Reformers, who recognized his priority.

The first developments of the logarithmic computing in the 5th century did not represent large contributions from Italian mathematicians. The only important albeit partial exception is given by the Spaniard Juan Caramuel y Lobkowitz, who lived in Italy for many years when he published the *Mathesis Biceps* (1670) which set forth the general principles of the representation of numbers in a base other than 10, and developed their logarithms.

When, in the nineteenth century, the slide rules began their diffusion, Italy seemed to start on the right foot.

Quintino Sella, solid technical and man of scientific culture, president of the Academy of the Lincei and an influential finance minister, published in 1859 a text on the use of the slide rule which would promote its rapid spread in Italy[14].

The First Italian Companies

In the mid-nineteenth century a company capable of producing precision instruments already existed and then actually produced the slide rules. It was the Filotecnica-Salmoiraghi. The Filotecnica had been founded in 1865 by Ignazio Porro, a surveyor and inventor of optical instruments. Porro's name is most closely associated with the prism system he invented around 1850 and which is used in the construction of prismatic binoculars[15]. Moreover, Porro had experience with logarithmic scale graduations in one of his books on topography[16].

In the beginning the Filotecnica was just a school workshop. It turned into a real company in 1870, when the management and ownership was assumed by Angelo Salmoiraghi, a disciple of Porro. He expanded the factory and the production spread rapidly to all types of precision instruments.

In 1910, the catalog *Filotecnica - Ing. A. Salmoiraghi* of *Tools for Engineers and Surveyors* had almost 150 pages and included several slide rules. Unfortunately we cannot determine which slide rules were actually produced by them. Other calculation tools produced by Filotecnica-Salmoiraghi include the polar planimeter No. 236[17], which had good success in the United States, and the period estimates analyzer of Francesco Vercelli[18].

Another historical firm was founded in 1886 by Vittorio Martini in Bologna as a factory of "Articoli tecnici per disegno" (Technical drawing instruments).

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[12] B. Capra: "*Usus et fabrica circini cuiusdam proportionis*" *Padova (1607)*
[13] G. Galilei: "*Difesa contro alle calunnie et imposture di Baldassar Capra*" *Venezia (1607)*
[14] Q. Sella: "Teorica e pratica del regolo calcolatore", Stamperia Reale, Torino, 1859.
[15] The Emperor Napoleon III has used a Porro binoculars to follow the developments of the battle of Solferino.
[16] I. Porro: "*La Tachéometrie, ou, L'art de lever les plans et de faire les nivellements avec une économie considérable de temps*", Zecchi e Bona, Torino, 1850
[17] http://www.catalogo.beniculturali.it/sigecSSU_FE/schedaCompleta.action?keycode=ICCD10877091
[18] http://www.museodifisica.unito.it/index.phtml?Museo&id=496&mark=vercelli

The firm, now named *Antica Fabbrica Vittorio Martini*, is still producing drawing instruments. A recent Martini's catalog claims that, in 1899, the 9th Congress of Italian Engineers and Architects expressed high praise for a slide rule produced by Martini. Dieter von Jeziersky [19] observed that the "Universal slide rule" was one of the more unusual Martini product quoted in 1970's catalog. This rule had an unusual scale arrangement. There were only two fixed scales on the lower stator: a one-cycle and a logarithmic scale. On a very wide slide were K, S&T&arc, T, S, and a one-cycle C. This arrangement made the slide rule unusual and quite difficult to use.

Nevertheless von Jeziersky gave no evidence that Martini continued to produce slide rules in the first decades of XXth century. Actually, evidence of slide rule production is absent in several of Martini's documents of this period, but production came back in 1956, when the company registered a new logo. This could be the reason why another firm, Marcantoni, claimed himself to be the oldest Italian factory of slide rules. Actually, we do not have any data about the founding of the company. The oldest allowable document is a trade mark registration on 19 July 1937. John St. Clair[20] gives us an accurate description of nearly twenty Marcantoni slide rules. He noticed that some logarithmic instruments are extremely similar to the Nestler's equivalents, except for some assembling details. So we could assume that these slide rules were made by assembling Nestler spare parts. But several other instruments are not similar to products of other major companies, so we must assume that Marcantoni produced them directly.

An example is given by a rather special rule that one sees occasionally in online sales. It is the "convergence slide rule" patented in 1912 by Major Alfonso Mattei (image on page 104).

It was used for aiming the artillery pieces and would remain in use for a very long time, at least until 1931, as evidenced by a military manual of the series "Training for the artillery" [21], and perhaps until after the last war.

During these years it was manufactured by different companies, including the Filotecnica-Salmoiraghi, the Marcantoni, and S.A. OCIP of Florence. Of the latter no news can be found. The operation of the slide rule is described in detail in an article of the same Mattei, available on the Internet[22].

The situation in which the ruler was used is one where an observer indicates more batteries of the remote cannons and the direction in which the target is to hit. Thanks to this slide rule, each battery could be quickly corrected, based on their distance from the observation point and the data that have been communicated.

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[19] D. von Jeziersky: "Review of Slide Rules – A Journey Though Three Centuries", translated by Rodger Shepherd, Astragal Press, 2000.

[20] J. St. Clair: "Marcantoni – An unusual discovery", Slide Rule Gazette, issue4, page 91, autumn 2003.

[21] Vol. IV Istruzione sul tiro, parte 5° Strumenti tecnici per il tiro, Fasc. I "Strumenti e mezzi tecnici per il tiro contro obiettivi terrestri". Libreria Istituto Poligrafico dello Stato, Roma. 1931.

[22] A. Mattei: "Regolo calcolatore della correzione di convergenza" in *Rivista di Artiglieria e Genio*, anno XXV vol. III, pages. 243-248, 1908.
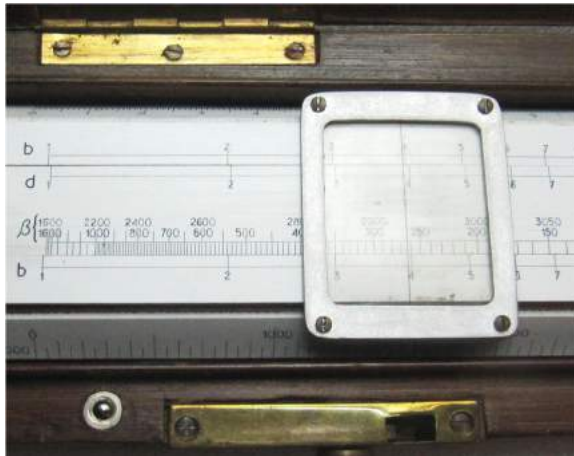
The "Mattei Slide Rule"

From the point of view of innovative engineering, there are plenty of interesting Italian contributions from the 1800s. Here we will see some projects in which particular attention is paid to the creation of slide rules with a very long scale in proportion to the actual instrument.

The original documentation of the first was found by chance among the papers of an old collector. The other two, of which very few are known, have been found at reasonable prices thanks to online sales sites.

In 1881, Carlo Alberto Castigliano[23], presented his "New aritmografo" (image on page 105) at the National Show in Milan, a slide rule based on similar principles to those underlying the famous cylindrical Thatcher, patented in the same year. The most substantial difference consists in the fact that the Castigliano's aritmografo is flat, rather than cylindrical. Then the logarithmic scale can be broken down into a few segments and must use a special cursor created by Castigliano and called "compasso".

Two accurate descriptions of this rule are available in an article of the same Castigliano [24] and in the, *Enciclopedia delle Arti e Industrie*[25] , curated by Raffaele Pareto[26] and Giovanni Sacheri in 1885. The encyclopedia also reports an improvement due to C. Berri [27] about the "ingenious idea of Castigliano" that allows one to switch from the division into four segments of the original model to a division in 10 segments.

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[23] He was an Italian mathematician and physicist known for Castigliano's method for determining displacements in a linear-elastic system based on the partial derivatives of strain energy.

[24] A. Castigliano: "Descrizione ed uso di un nuovo aritmografo", from *Il Politecnico - Giornale dell'ingegnere architetto civile ed industriale* , Volume 13, December 1881.

[25] G. Pastore: "Macchine da calcolare", in "*Enciclopedia delle Arti e Industrie*", vol. V, pag. 482-575, UTET, Torino, 1885.

[26] Father of the famous economist Wilfredo Pareto.

[27] C. *Berri: "Modo di costruirsi una scala logaritmica* con una grande unità ed in poco spazio" in *L'ingegneria civile e le arti industriali*, pag 169, 1881.

Castigliano - NUOVO ARITMOGRAFO

Fig. 1. Scala

Fig. 2. Compasso
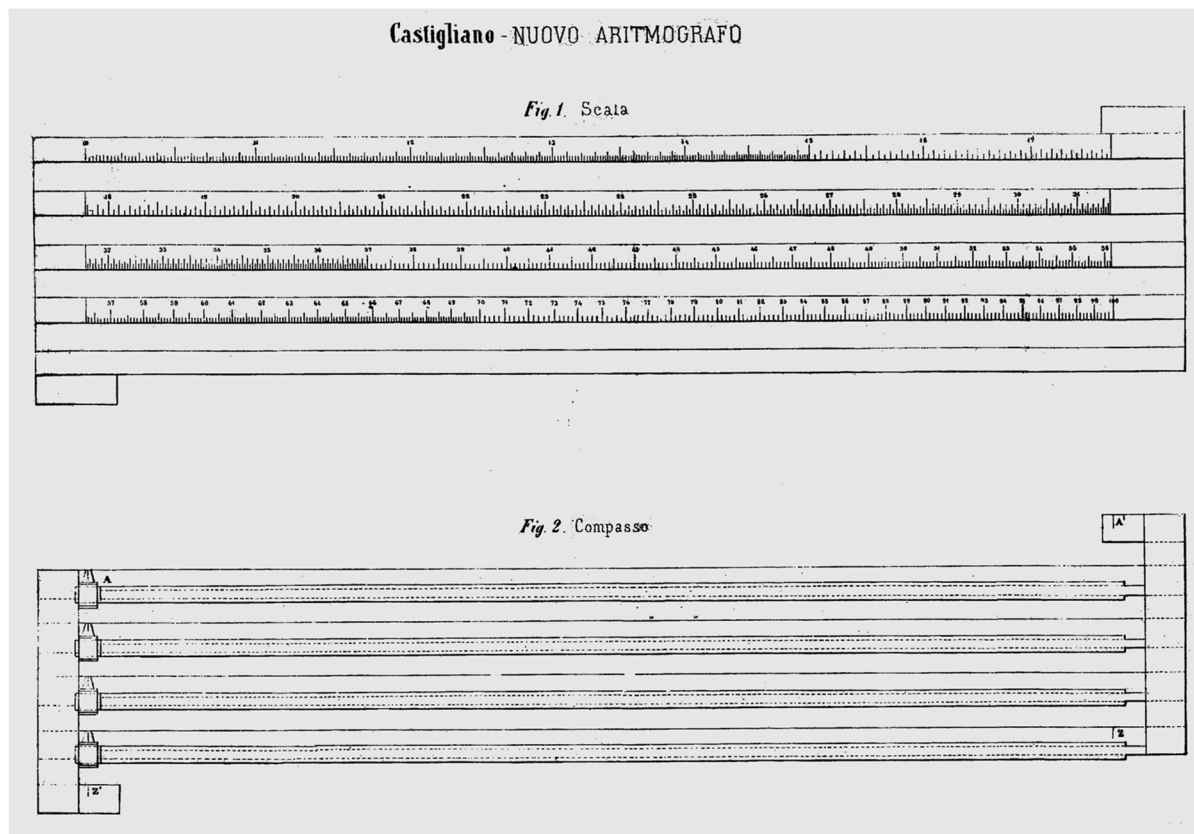
Mario Abeille and Vincenzo Aquilecchia, two practically unknown designers, designed in the 50's two slide rules that are really interesting and original in concept. The only information we have about Abeille and Aquilecchia is that they were both professional soldiers.

A distant relative of Aquilecchia states[28] that he reached the rank of general and recorded several patents to his name. Those identified are on different topics and are always in collaboration with others.

As for Abeille it could be established that, from 1931, he patented several rulers:

- "Regolo rapportatore per il calcolo di distanze e parallassi" (1931 Italian Patents N. 295419 and 305451)
- "Calcolatore logaritmico ottico" (Brevetto italiano N. 425463 del 1947)
- "Calcolatrice logaritmica a due approssimazioni" (1948 Italian Patent N. 440316).

Finally, in 1954, he published some logarithmic tables[29], obtained using its own mantissa system, on the validity of which had asked for the opinion of the Institute of Mathematics of the National Research Council with whom I work. In the institute's records he is mentioned with the rank of colonel.

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[28] Personal phone call with Andrea Celli.
[29] M. Abeille: "Nuove *tavole logaritmiche* finanziarie a otto decimali", Zanichelli.

The collaboration between the two inventors seems to start with the "optical micro calculator with rotary ring", patented in 1949[30]. It is a very original instrument that does not resemble any other slide rule, as seen from the photos, it looks like a Zippo lighter.

Also the dimensions are similar: 7.6 x 5.1 x 1.5 cm. The size and the type of closure make it pocketable and sturdy. It is very suitable for military use. This hypothesis is reinforced by the fact that on the surface of the instrument there is no logo of the manufacturer. The serial numbers of the few examples known -all greater than 30,000- and the precise finishing suggests that it was a product of a medium to large company, specializing in military supplies such as Filotecnica-Salmoiraghi or Ottico-Meccanica Italiana. The name engraved on the instrument, *Microcalcolatore Tipo 2A*, suggests that an earlier version had been made, of which we do not have any information. A reasonable assumption is that it was the first optical slide rule patented by Abeille in 1947. The design principles are quite similar: a tiny tool whose scales are magnified by a lens. The major difference is that in the first patent the scales are helical. This allows a greater length, but it posed problems in setting to zero. Moreover, the external appearance is much less nice and appealing.

The noteworthy feature of this slide rule is the apparent length of about 50 cm of scales. Actually, these scales are far shorter. They are engraved on a small internal ring using a reduced photo of large scales. The original length is restored because they are observable from outside through a window surmounted by a powerful magnifying glass, placed in the position of the flame of the lighter. On the window the hairline is drawn. Two knurled wheels allow you to rotate independently or jointly the ring with scales and a mobile pointer. This permit the calculation with a high degree of approximation of logarithmic, arithmetical, and trigonometrical expressions, as well as exponential operations.
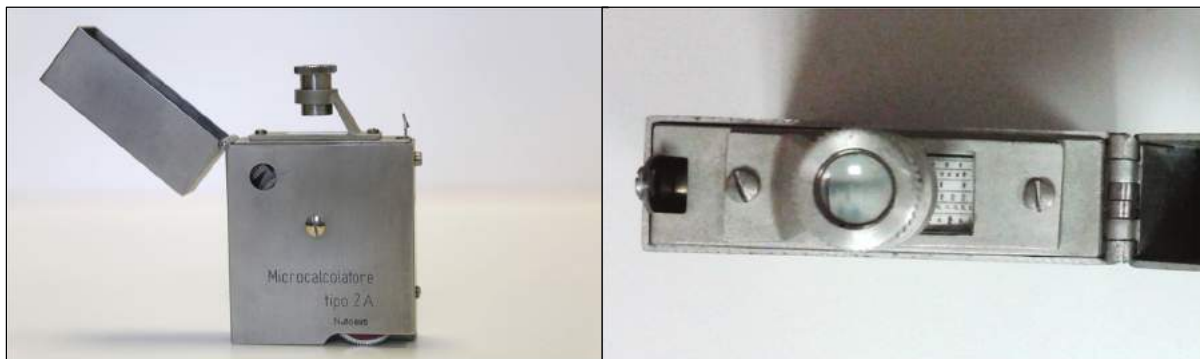
Microcalcolatore Tipo-2A   **The magnifying glass**

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[30] The patent of this slide rule has also been deposited in England and France (patents UK-688639 and FR-1015947).

A second interesting slide rule due to Abeille and Aquilecchia is the Calcolatore Logaritmico-Trigonometrico a Proiezione (image on page 108). Presented in 1950, he obtained the Italian patent no. 468929 in 1952[31]. Unlike the previous device it is a desktop calculator with the shape of a small television (11 x 24 x 21 cm). On the inside there are two glass discs on which the scales are engraved in negative. An optical system allows it to project the magnified image of the scales on the instrument screen. The patent, slightly different from the actual realization[32], indicates an amplification factor of 8 applied to 25-cm long scales. So you would get an apparent length of 2 meters. Even Francis Jay, who has thoroughly examined a real slide rule[33], estimates that the apparent length of the scales is about 75 inches, or slightly more than 190 cm. The sales brochure states that this slide rule is equivalent to a linear 2.5 meters long, perhaps taking advantage of the availability of an additional mechanism that allows for micrometric movements, a kind of vernier. This is a very good performance for a compact slide rule. Moreover, unlike the majority of cylindrical and helical slide rules, it has different scales. There are in fact those of the square, cubic, reciprocal and logarithms, with the abbreviations N², N³, 1 / N, and log N.

Abbreviations for the trigonometric scales are typically Italian: *sen* stands for sines, *tan* for tangents, and *archi* for archs corresponding to a small angle on the unit circumference[34]. Operation is very simple: two knobs allow you to rotate independently or simultaneously the two discs that contain the scales and a vertical line drawn on the screen works as hairline. This allowed the manufacturer to write in the instructions that "a person of average education, who had never used an ordinary slide rule, with the sole guide of this booklet has succeeded in a few hours to learn the use of the projection calculator, operating with an average error of 0.019% and with a maximum error of 0.045%".

This slide rule was produced by Filotecnica-Salmoiraghi and was presented in its own catalog with the name "logarithmic calculator mod. 201". So you can think that production has been quite higher than the 5 pieces estimated by Jay. The commercial deployment has been hampered by the high price and they are not very "ornamental"; very few survived. If we assume that the catalog is from 1955, the selling price of (90,000 lire) would amount to about 1,350 current Euros.

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[31] The patent of this slide rule has also been deposited in England and France (Patents UK- 719080 and FR-1046852)

[32] In the patent the screen is rotated and, except in the British patent, the scales are engraved on the outer surface of rings, not on discs.

[33] Jay, Francis: *"The Back-Light Screen Projection Slide Rule"* in *Journal of the Oughtred Society* 9:1, Spring 2000 Pages 27-31.

[34] Jay misunderstood the meaning of this scale in his beautiful article.

CALCOLATORE LOGARITMICO MOD. 201

Caratteristiche

Apparecchio a scale graduate circolari, di minimo ingombro, che consente di ottenere una precisione pari a quella di un normale regolo lineare lungo m 2,50

Basato su principi di funzionamento identici a quelli dei normali regoli calcolatori, può essere facilmente usato da chi conosca tali principi

Manopole di comando azionabili con la mano sinistra, per consentire all'operatore di scrivere con la destra

L'immagine della scala si proietta, fortemente ingrandita, sul vetro smerigliato anteriore

Ingombro e peso . . . . . . 12 × 24 × 20 cm - 4,0 kg

Prezzo dello strumento

Per contanti	L. 90.000
A rate: 6 rate da	L. 13.020
oppure { 12 rate da	L. 6.690
18 rate da	L. 4.580
previo acconto di	L. 18.000

I prezzi fissati per pagamento rateale sono già comprensivi del 3% I. G. E. e delle spese di imballo e trasporto

Filotecnica Salmoiraghi Catalog

Filotecnica logarithmic calculator with optically projected scale

A similar slide rule is the "Film Type of Slide Rule", filed August 15, 1946 and patented on June 7, 1955 by George R Stibitz. It is described in an article by D. von Jezierski and D. Rance [35]. In this case, however, the length of the scales is given by films that are held on reels, not by a magnification system. The bobbins, without projection system, were used in about twenty other projects listed by the authors in an addendum to the Journal of the Oughtred Society article.

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[35] D. von Jezierski and D. Rance: *George R. Stibitz's Film Slide Rule: a computing machine with logarithmic scales*.

Other interesting Italian slide rules were those for reinforced concrete. In particular there are some "logarithmic machines" such as those built by Washington Sabatini and Giuseppe Arici. Some of these will also be displayed by Wolfgang Irler at this Meeting. However, even a summary of these would require too much space, so on the following pages we will just include the images.

Washington Mod. E for reinforced concrete (1925)
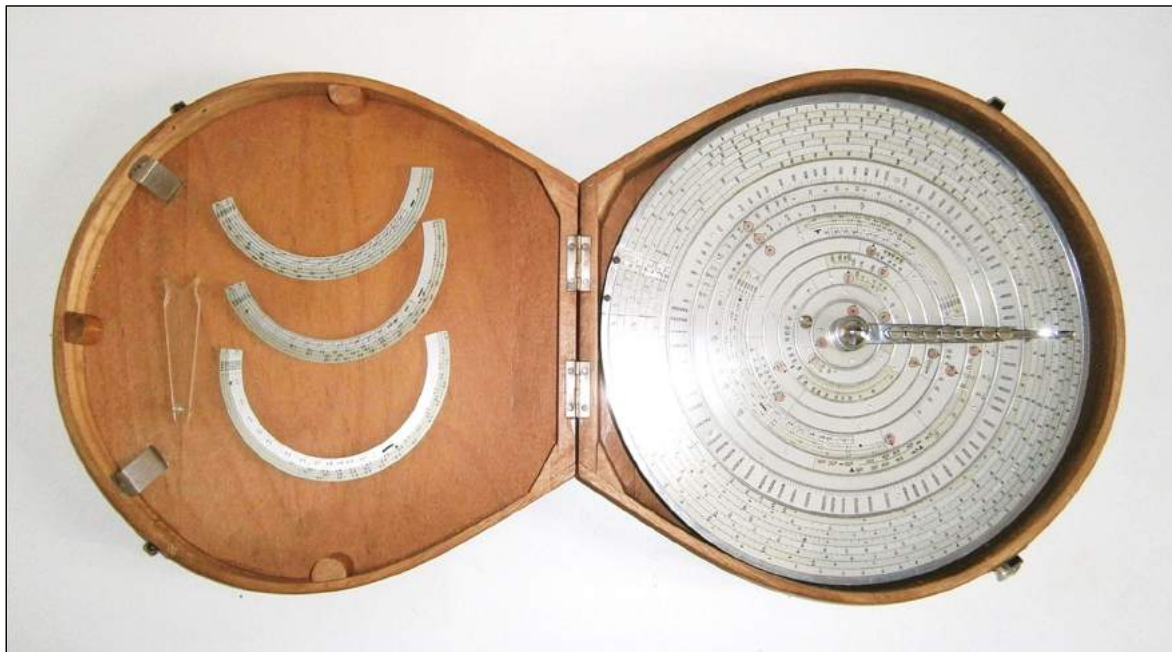
Washington-Ferrero Mod. Fer-H39 for reinforced concrete (1930)

Arici-55 for reinforced concrete (1955)

Ferrero R8 for reinforced concrete (1936)

Andrea Celli, was a "primo ricercatore" (senior researcher) of Istituto per le Applicazioni del Calcolo. He was involved in applied mathematics and numerical analysis researches. Now he is retired and cooperates with his institute in studies about History of Mathematics and of Computing Instruments.

From a Slide Rule Collection to a Ph.D. Thesis

Marc Thomas

I used to be a high school mathematics teacher until 2010, when I retired. This story begins in the mid-1990s, when I found at the bottom of a drawer my slide rule (Graphoplex Neperlog 690) and my father's slide rule (Nestler 23R3) that I had used in the years 1963-1970 during my studies, and then forgotten for almost twenty years.

I then wondered what had become of this instrument, not in use any more since the appearance of electronic calculators. I had at that time no idea of the history of the slide rule. I only remembered some trademarks, Graphoplex, Nestler, Faber-Castell, maybe Hemmi-Sun.

I thus began to look at what could be found in the secondhand trades, the flea markets, at some antique dealers … I bought many rules that didn't have any interest, and some that were more interesting. One day, an antique dealer of Nantes offered me an obviously old rule which was entirely made of wood; he indicated to me that there was a name and an address, almost erased. We managed to read "Lenoir, 14 rue Cassette", Paris. This told me absolutely nothing, but however gave me a clue to follow. It was the early days of the Internet. I then discovered the Oughtred Society and I noticed that the name of Lenoir represented something very important for a number of collectors, and also for the history of science. I contacted Bob Otnes, who was then the editor of the Journal of the Oughtred Society (JOS); he kindly sent me a copy of JOS Spring, 2002, which contained two articles (one from Francis Wells and Tom Wyman, the other one from Bob Otnes and Conrad Shure) on the French rules of the 19th century and their makers; this was an impressive discovery for me, who knew nothing of this period.

I can say that it was the beginning of my research.

The Curiosity

At this moment, I did not absolutely intend to throw myself into an academic search. However, I was very interested in all that these articles had made me discover, and even more by the unknown elements of this period. Thus, I began to look for documentation, books, and of course rules of this time. Slide rules were still well known of many people who had used them, either during their studies, or during their professional activity. I had the opportunity to talk with some of them, and the memories of some users were sometimes very precise: the exact model, but also the way of using it and the striking periods of their use. I regret simply not having looked for catalogs which could be found with certain booksellers, because ten years later, they had become almost untraceable. However, I could get some of French instruction manuals of the 19th century, for example three of the four editions of the Mouzin's manual, one of the first ones which appeared in France by 1830. Also I was lucky to acquire, often at very moderate prices, some beautiful French rules, in particular 36 cm Tavernier-Gravet and particularly one of the first rules made by Lenoir, a 36 cm Jomard model, which I have described in Journal of the Oughtred Society, 19:1.

I was very surprised to notice that French books on slide rules seemed very rare, not to say non-existent, except the 20th century instruction manuals, and that practically nobody knew the names of Gravet or Tavernier. Only the name of Lenoir was known a little more by people interested in the history of science.

Resumption of the Studies

In 2007, one of my colleagues with whom I spoke about slide rules and my most recent finds indicated to me that there was a course of the History of Science at the University of Nantes, and that she was a PhD. in this subject, something about which I knew nothing at all. I answered that I did not intend to resume studies at age 57 and thus three months later I joined the Master's degree of research at the University of Nantes! When I proposed to the director, Professor Evelyne Barbin, great specialist of the History of Science, especially the History of Mathematics, to work on a report on the History of the Slide rule, she seemed very surprised, but trusted me after I explained further. I believe that she had never envisaged that one could work on the History of the Slide rule, even though she is interested in mathematical instruments. She often says that a mathematical instrument is "a theorem in action". So I could show her that it was exactly the case with logarithmic scales, and she advised me very well and encouraged me during all this research; her great experience as a researcher was particularly precious to me and I thank her for her encouragement and knowledge.

I thus followed courses in history of mathematics, of physics, techniques, and the philosophy of sciences, all with great interest and presented in 2009 a report the subject of which was: "The introduction of the slide rule in France (1815-1851)". This report was my first experience of scientific research. I noticed that practically nothing had been written in France on the subject, and especially that there were many things to be studied and to be discovered. This research work had interested me a lot. Furthermore, I retired the next year. So I decided, with the support of my study leader, to dig deeper into this subject and try to write a thesis.

The Thesis

A PhD. thesis is quite a different job of work, long-term and at a high scientific level. I began this work in 1999.

The search for documentation, readings of the existing texts, and the creation of the most complete possible bibliography occupied me for the first two years. Then it was necessary to limit the subject, to choose the problem area, and finally to write a draft. For that purpose, I went to visit, in particular, the reserves of the Museum of The Centre National des Arts et Métiers in Paris, which possesses a considerable number of rules, especially French ones. I strongly recommend this visit to all the collectors of scientific instruments. It is an Aladdin's cave full of scientific and technical instruments. It is necessary to ask for a meeting because these objects are not on display; the reserves building, which is of recent construction and very modern, gathers together an incredible quantity of scientific and historic treasures, and really merits a journey.

I had already realized a few years before (during a discussion in the IM of Leiden or Boston) that the introduction of the slide rule in various countries seemed to follow the route of industrialization in Europe, in the USA, and even in Japan. In particular, when I discovered the role played by James Watt in the improvement of the English rules, I said to myself that it could not be a coincidence that this character so symbolic of the industrialization needed to use slide rules adapted to the industrial production. That is why I chose to entitle my thesis: " *The slide rule, the instrument of the industrial era; the French example*".

I did not wish that my thesis be a catalog of manufacturers and models, especially as the extraordinary work of Peter Hopp was already there (and it helped me a lot), nor a presentation on the diverse scales and the techniques of use, because many excellent articles already exist. Thus I tried to replace the history of the slide rule in a more general context, bound to the

incredible industrial development of the 19th and 20th centuries. I especially wanted to speak about people, often unknown, and the institutions which allowed, particularly in France, the manufacturing and the distribution of this instrument. I also wished to reveal how the slide rule spread, from Great Britain of course, towards France then Germany, the USA and Japan, and how it accompanied the development of techniques, taking a considerable importance after the WWII, until its almost complete disappearance in the years 1970-75. I also studied the way its use was presented in the programs of education in France. Well, now I was ready: work was in progress.

During all this time, there were good days, when everything moved forward well, and bad ones, of course. I think that one the best was when I finally discovered who Mister Tavernier was. This character about whom nothing was known and whose name, associated with Gravet, is so famous to collectors intrigued me a lot. The name Tavernier (*Innkeeper*) is rather common in France. I needed other indications. I found the initials of his first name in a report on the World Fair of Paris in 1878: " Scientific instruments, gold medal: Tavernier-Gravet (C.-A.) ". I supposed that C meant Charles: bingo! Well then in the database of the archives of Paris, I found Mr. Charles-Alexandre Tavernier's certificate of marriage to Miss Léontine Gravet. Thus Tavernier is the son-in-law of Gravet. I remember those days as the best of my research time.

On 7 April 2014, I defended this thesis at the University of Nantes. A great day of course, the end of 5-years of work. Many friends of mine were there, even if they did not know anything about slide rules! And my children and great-children (3 years old…). I will remember this afternoon with great joy and satisfaction.

The Collectors, the Museums, and the Science Research

Most of the university works in history of science and techniques concern either the evolution of the ideas or the evolution of techniques themselves, but few are about the instruments (of measure or calculation) having allowed these evolutions. It is true that since some years, the situation seems to change, and the number of publications concerning the methods and instruments are increasing. Also, the university institutions are more attentive to the preservation of the former instruments that become obsolete, which are now listed for better preservation.

That is the reason why the role of we collectors is important. We also play a very big role in other disciplines, for example the mineralogy, the entomology, where some private collections are of great scientific interest. However the motivations of the collectors and the academic researchers are not the same. A collector tries first to enrich his own collection, even if we all know here some collectors who made important contributions in the general knowledge of instruments. Often a researcher is more interested in the theoretical study of objects, their evolution, their situation in the history; he uses more documents and archives than the actual instruments. For instance, in geometrical instruments, like ellipsographs or planimeters, the researcher will show how the instrument transforms mathematical theorems in a drawing on the paper, or in a number measuring the area defined by some curve. Generally, he knows who conceived the instrument, but the maker himself can remain unknown for him.

The role of the museums of the sciences is also fundamental. Their purpose is the preservation of objects as world heritage, as well as at the education of the public. However the experience shows that certain museum lacks people or material to completely perform this mission, and are obliged to content themselves with the most spectacular or the most famous instruments. Furthermore the cost of certain particularly rare or precious objects is also an obstacle for many

museums. Thus it sometimes happens that more "ordinary" objects are a little neglected. It is probably the case of slide rules, the big variety of which does not appear clearly to an uninitiated public: all look the same, as it is often heard.

That is why it seems to me essential to develop the relations between these three levels of interest, so that each makes a better contribution in the knowledge and the preservation of instruments.

Marc Thomas, French, aged 66, is a retired high school math teacher.

His interest in slide rules dates from about 1995. In 1997-1999, he studied for a Master's degree in The History of Sciences at the University of Nantes, and then began to research the history of the slide rules. He defended his Ph. D. thesis in April 2014 on the title: "The slide rule, instrument of the industrial era: the French example".

He has published some articles in the Journal of the Oughtred Society, and is a Fellow of the Oughtred Society since 2013.

His interests about slide rules cover earlier French rules, and the history of French slide rule makers in the 19th century.

Slide Rules for Use in Civil Hydraulic Engineering

Stefan Heimann

Abstract

Before the invention of the electronic calculator, slide rules were the most common tool for calculating in engineering practice. Besides the standard slide rules for arithmetic and trigonometric operations, manifold slide rules with branch specific scales had been developed for professional use, such as civil engineering. Typical applications of slides in civil engineering were structural, geodetic, or hydromechanical (fluid dynamics) calculations.

This paper gives a brief overview on slide rules for the use in civil hydraulic engineering.

Introduction

Civil hydraulic engineering comprises the design of structures and facilities for water supply and sanitation including storm water, flood control, river training, hydropower, irrigation, and drainage plus others. Typical fields of application for slide rules were:

- design of pressure pipes (e.g., water supply)
- design of sewers (waste water, storm water)
- design of open channels (flood control, river training)
- design of hydraulic structures (e.g., weirs, culverts)
- others (hydrological problems, irrigation systems, pumps)

Besides this, many slide rules were developed for fluid dynamics in mechanical engineering, such as pipe flow of steam and vapor, oil-mechanical-systems, valves, orifices, and others. However, as such slide rules are not serviceable for civil engineers they are not considered herein.

Pressure Pipe Flow

Pressure pipe flow has been the most frequent application for slide rules in civil hydraulic engineering. In contrast to open channels (e.g., rivers, canals) pressure pipes are characterized by fully filled profiles, usually with circular shape. Consequently, the cross-section of a pressure pipe can be defined by one parameter only (the pipe diameter), simplifying the formulas, and facilitating thereby the implementation of slide rules. The typical problem to be solved is the correlation between the pressure drop (or energy loss) and the discharge. Besides the discharge, the pressure drop depends on the pipe roughness (inside), pipe length, and pipe diameter.
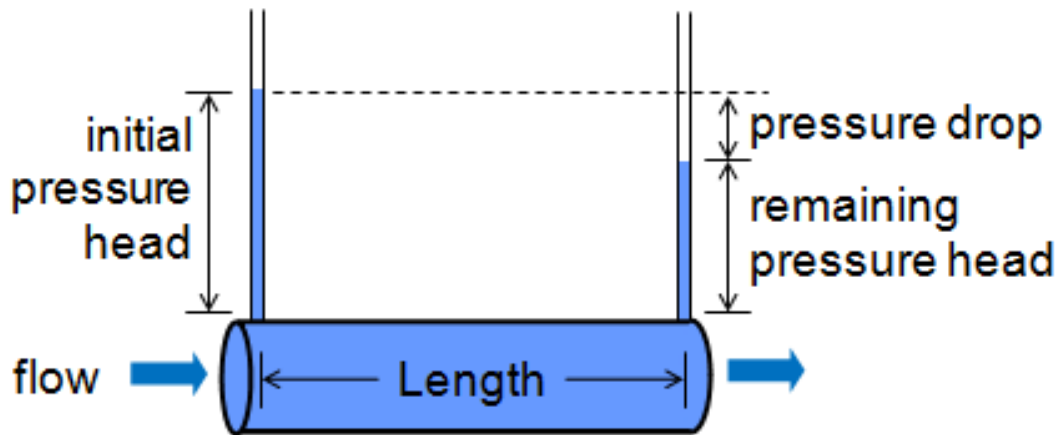
Figure 1: Illustration of pressure drop in a pressure pipe

The problem is typically solved by the formula of Hazen-Williams, the Manning equation, or the flow rule of Darcy-Weisbach, which appear for circular pipes as follows:

Hazen-Williams $\qquad Q = 0.432 \cdot C \cdot D^{2.63} \cdot S_E^{0.54}$

Manning $\qquad Q = 0.312 \cdot \dfrac{1^*}{n} \cdot D^{2.67} \cdot S_E^{0.50} \qquad$ *) 1 m¹ᐟ³/s or 1.486 ft¹ᐟ³/s*

Darcy Weisbach $\qquad Q = 1.111 \cdot \dfrac{\sqrt{g}}{\sqrt{\lambda}} \cdot D^{2.50} \cdot S_E^{0.50}$

Where Q = discharge; C, n, and λ =coefficients of resistance; D = inner diameter of pipe; g = gravitational acceleration; S_E = energy or pressure gradient = h_L/L with h_L = head loss (= pressure drop); and L = length of pipe. The constants in the above formulas apply for standard SI units (meters and seconds) and differ when other units are used.

Some slide rules compute the flow velocity instead of the discharge. The relation between the flow velocity and the discharge obeys the law

$$ v = \frac{Q}{A} \qquad\qquad = \frac{4 \cdot Q}{\pi \cdot D^2} \quad \text{(for circular pipes with diameter D)} $$

With v = flow velocity and A = cross section of pipe.

The coefficients of resistance depend mainly on the pipe material (roughness) but in more detail also on the flow properties. Usually the coefficient of resistance has to be determined separately and is then introduced into the formula. However, some slide rules provide tables or scales to determine the coefficients.

Though the above flow equations are quite simple and very similar, the slide rules differ very much in the allocation of the scales, the range of values, the adjustment of the formulas (e.g., energy slope or head loss, discharge, or velocity), and in size and shape (e.g., linear or circular). The following figures give an impression of the variety of slide rules.

117
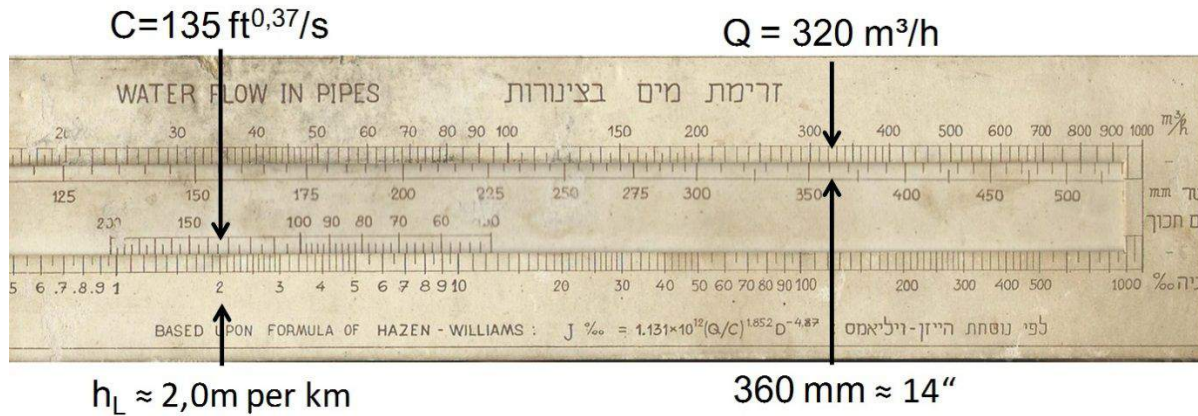
Figure 2: Reading example for the discharge in a pressure pipe
(Model of Israel / Eng. M. Poreh / Hazen-Williams formula / Paper / mixed units)
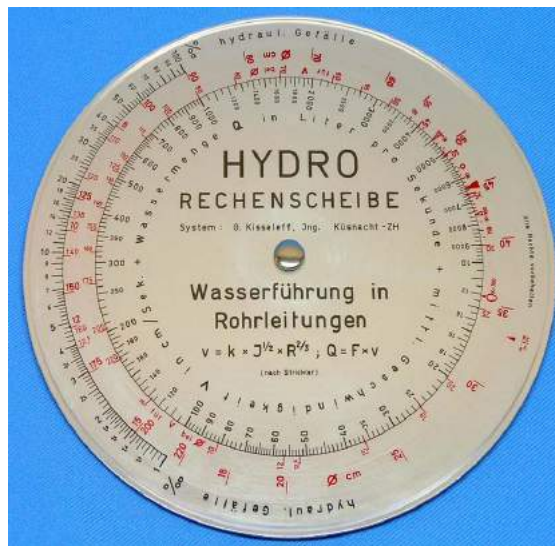
Figure 3: Disc calculator for pressure pipes
(Küsnacht, Switzerland / Eng. G. Kisselef / Manning equation / Aluminium)
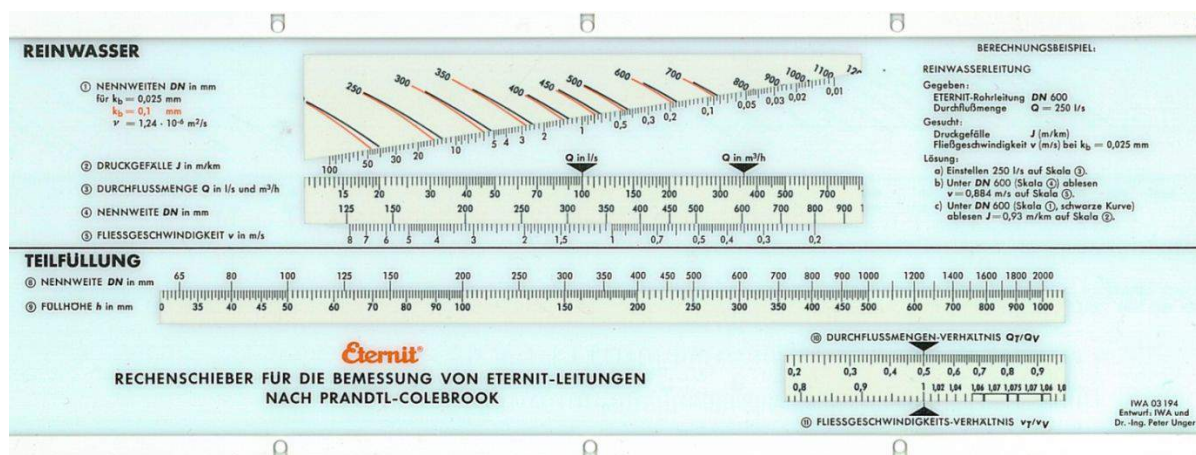
Figure 4: Slide rule for pressure pipes
(Model IWA 03 194 / Dr. Peter Unger / Germany / Prandtl-Colebrook formula / Plastic)
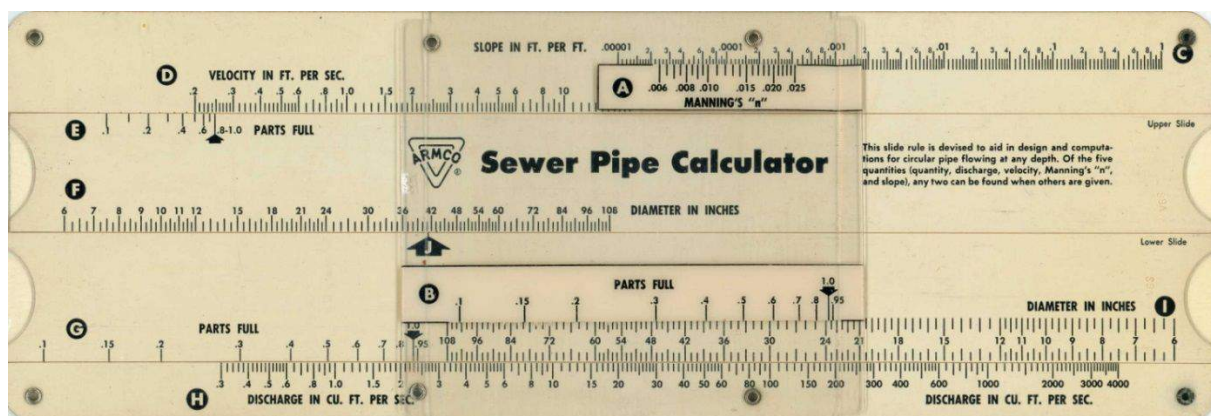
Sewer Pipe Flow

Waste water and storm water are usually collected and conveyed in closed pipes with circular or ovoid shapes similar to the pressure pipes presented before. However, under usual design conditions sewers are not completely filled with water. The corresponding slide rules therefore provide additional scales for partial filling. Another difference to pressure pipes is that the pressure gradient corresponds to the sewers slop, so that the pressure drop is already known and the question to be solved is now "What is the capacity of the sewer"?

The coefficients of resistance are typically larger for sewer pipes than for fresh water pipes. Besides the flow equations given above, some slide rules employ the formerly used Kutter-formula, which basically coincides with the Darcy-Weisbach equation, but with a different coefficient of resistance (Kutter coefficient), specially adapted to the situation at sewers:

Kutter $$Q = 0.393 \cdot K \cdot D^{2.50} \cdot S_E^{0.50}$$

The constant in the formula applies for circular pipes and the SI-system and has to be adapted accordingly for ovoid pipes and/or imperial units. The Kutter coefficient K depends on the roughness of the pipe and its slope. Two variations of the Kutter coefficient exist, a simplified formula ("small Kutter"), which is calibrated for the SI-System and not transferrable to other unit systems and a more complex formula that is applicable to all unit systems. The Kutter coefficient must be determined separately before using the slide rule. Some slide rules provide tables for the determination of the Kutter coefficient.

Figure 5: Hydraulic Calculator for Sewer Design
(Perrygraf / Armco Drainage & Metal Products / USA / Manning formula / Plastic and Paper)
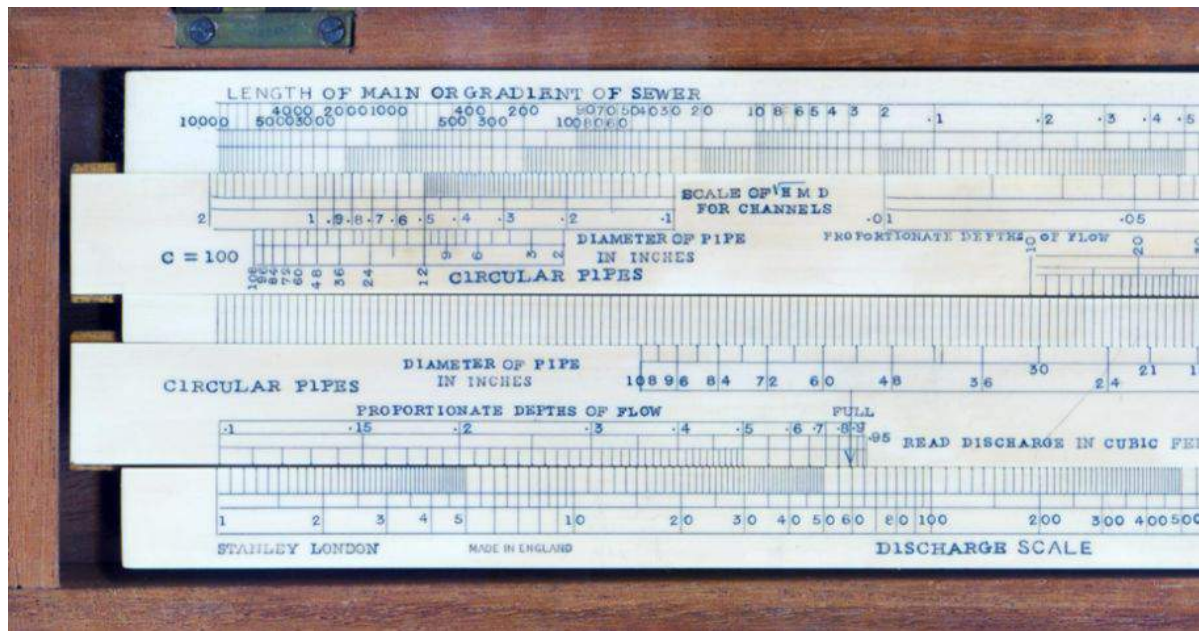
Figure 6: Detail of very old slide rule for Sewer Pipes
(Stanley, England / E. H. Essex / Kutter formula / in wooden box)

Open Channel Flow

The next major group of slide rules for hydromechanical computations in civil engineering is slide rules for open channel flow (natural and artificial water courses). In contrast to pressure pipes and sewers, open channels can have arbitrary cross-sections. A typical problem to be solved is "What is the discharge in a channel at a certain flow depth?" or vice-versa. This problem is usually solved with the Manning equation, where the diameter in the above formula is replaced by the so called "hydraulic radius" and the constant (that depends on the shape of the pipe) is omitted. In former times, also the de Chezy formula was used. In the general form (for any cross-section) the formulas appear as follows:

Manning $\qquad v = \dfrac{1^*}{n} \cdot R^{0.67} \cdot S_E^{0.50}$ $\qquad$ *) $1 m^{1/3}/s$ or $1.486\, ft^{1/3}/s$

de Chezy $\qquad v = C \cdot R^{0.50} \cdot S_E^{0.50}$

Where R = hydraulic radius = A/P with A = cross-sectional area, P = wetted perimeter (zone of interference of the water with the boundary, see Figure 6), n = Manning coefficient, C = de Chezy coefficient. Under design conditions (= uniform flow), the energy gradient S_E corresponds to the average slope of the channel. The discharge is finally computed from:

$\qquad$ Q = A·v.
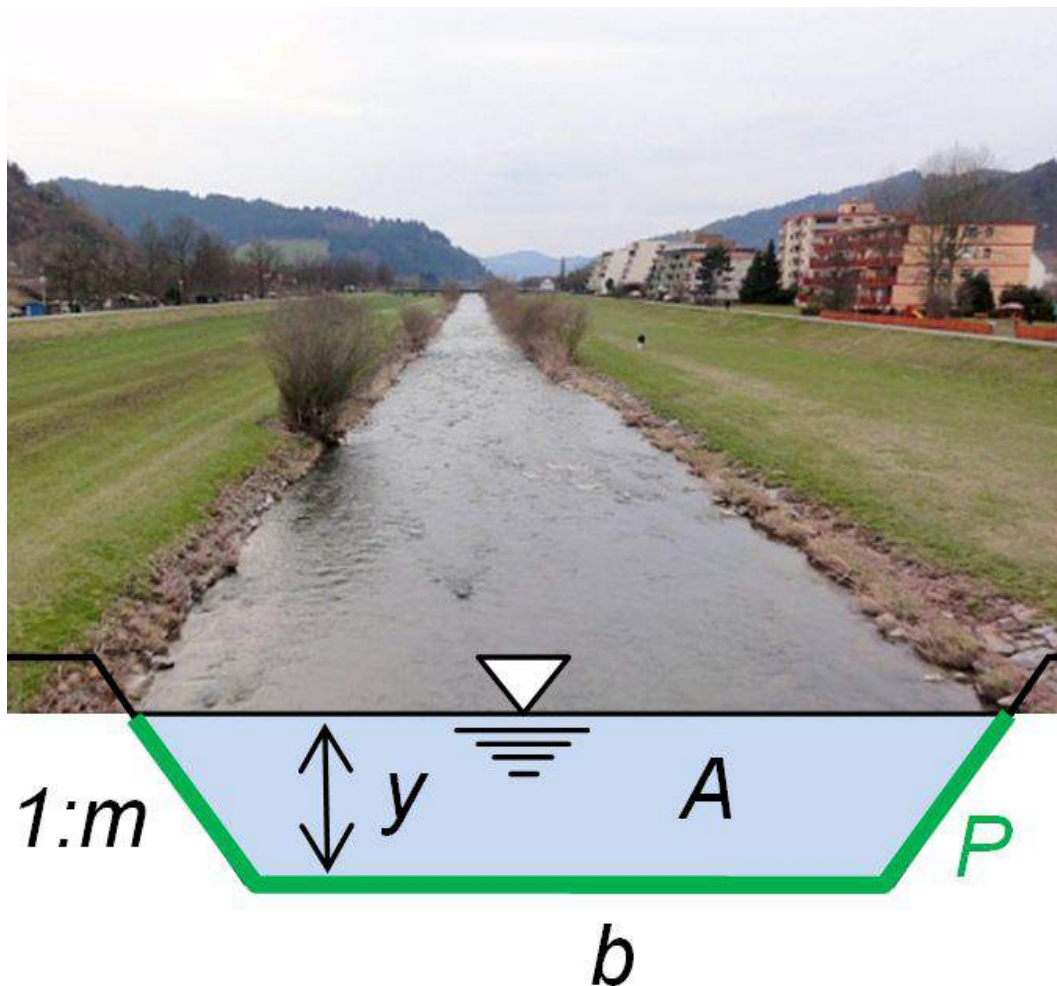
Figure 7: Definition sketch for open channels (here with trapezoidal shape)
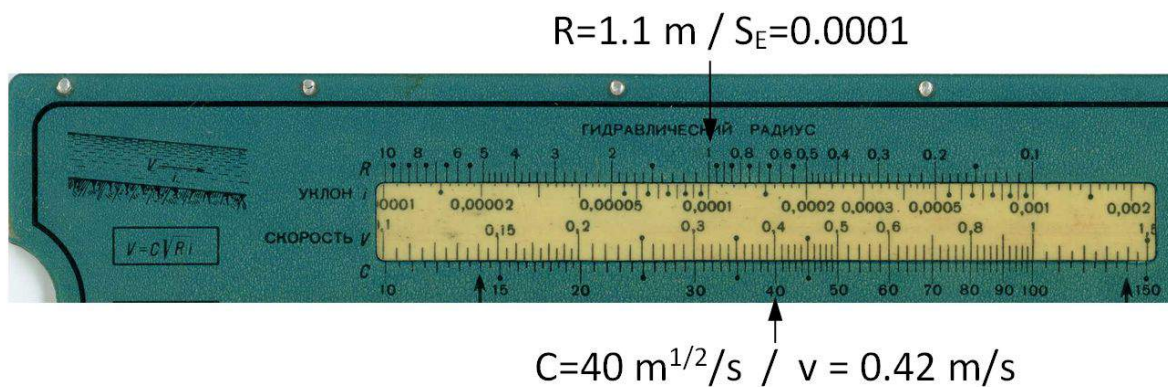
Figure 8: Reading example for the flow velocity in an open channel
(Russian slide rule / de Chezy formula)

A and P have to be determined using standard geometric methods. In many cases the channel cross section can be idealized by a trapezoid. The exceptional slide rule of Russian origin (see Figure 9) provides scales to compute A and P for channels with trapezoidal shape (where 1:m = bank slope and ß = b/y, see Figure 7).
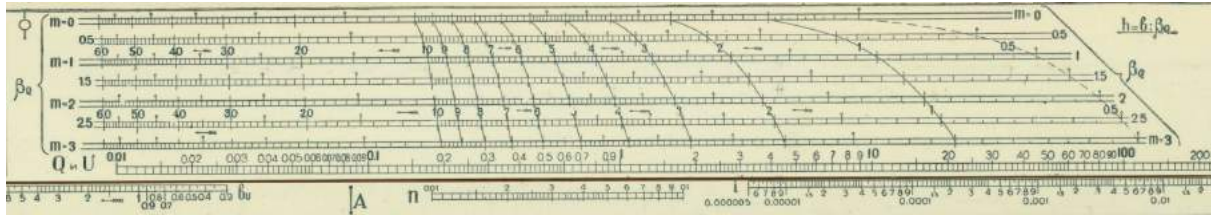
Figure 9: Scale for computing A and P for trapezoidal cross-sections
(Russian slide rule, wood)

Other Applications

There are a few slide rules for computing the discharge at weirs. Weirs are hydraulic structures at rivers or canals that serve to control water level (head regulator), to measure the discharge or to control the discharge at intakes or bifurcations. Some examples can be seen in Figure 10. Hydraulically it must be distinguished between overflow weirs (where the water flows over the weir) and undershot or outflow weirs (where the water passes below the weirs gate), see Figure 10. Accordingly, the discharge can be computed by the following formulas:

Outflow / undershot $\quad Q = C \cdot A \cdot \sqrt{2g} \cdot H^{0.5}$

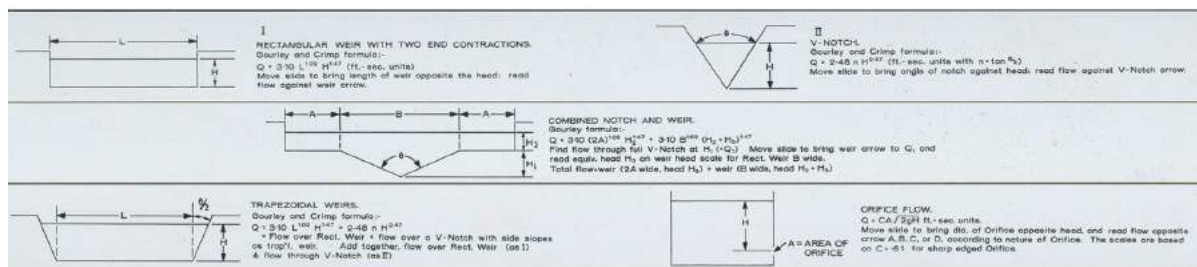Overflow $\qquad\qquad Q = C \cdot B \cdot \sqrt{2g} \cdot H^{1.5}$

Where Q = discharge, C = discharge coefficient, B = width of weir, H = pressure head, and A = area of opening.

$$Q = C \cdot B \cdot \sqrt{2g} \cdot H^{1.5} \qquad Q = C \cdot \tan\left(\frac{\alpha}{2}\right) \cdot H^{2.5} \qquad Q = C \cdot A \cdot \sqrt{2g} \cdot H^{0.5}$$

Figure 10: Examples of weirs (left and middle: overflow / right: underflow)
with corresponding formulas / below: backside of Tarrant Hydraulic Slide Rule for weirs,
notches, and orifices (Patterson / England / J. Tarrant / imperial and metric units)
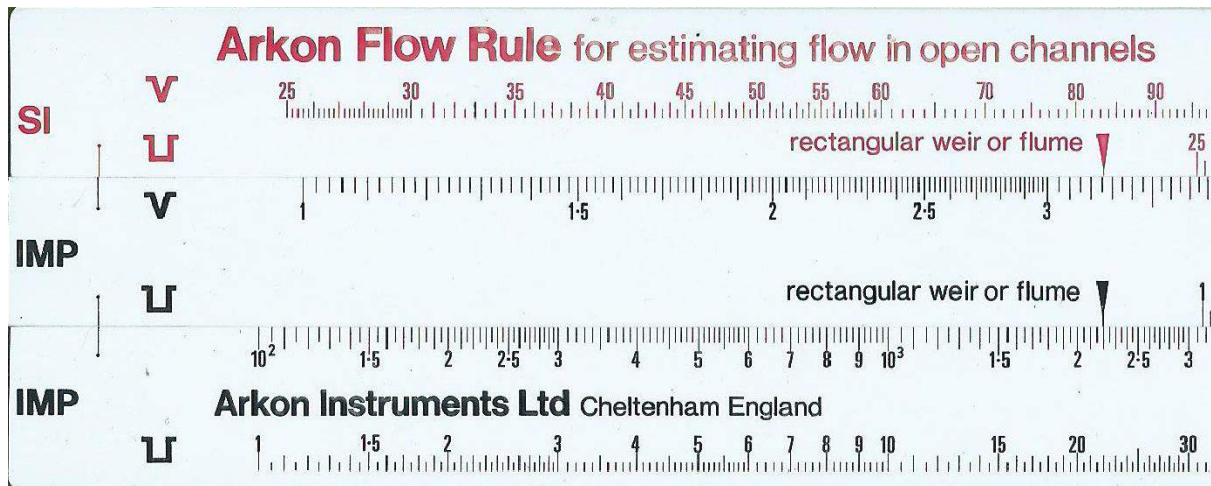
Figure 11: Detail of Arkon Flow Rule for open channels and weirs
(Blundell Harling Ltd. / England / imperial and metric units)

Other applications that were solved with slide rules are:

- the run-off from a catchment area after a rainfall;
- the capacity of pumps;
- the water demand for irrigation areas and the design of sprinkler systems;
- the hoop stress at pressure pipes.

However, the number of slide rules to be found for such applications is much smaller than that for pressure pipes and sewers, which are by far more frequent. One example for the design of sprinkler systems is shown in the following figure. The slide chart is a special order produced by Perrygraf (USA) on behalf of the Rain Bird Company.
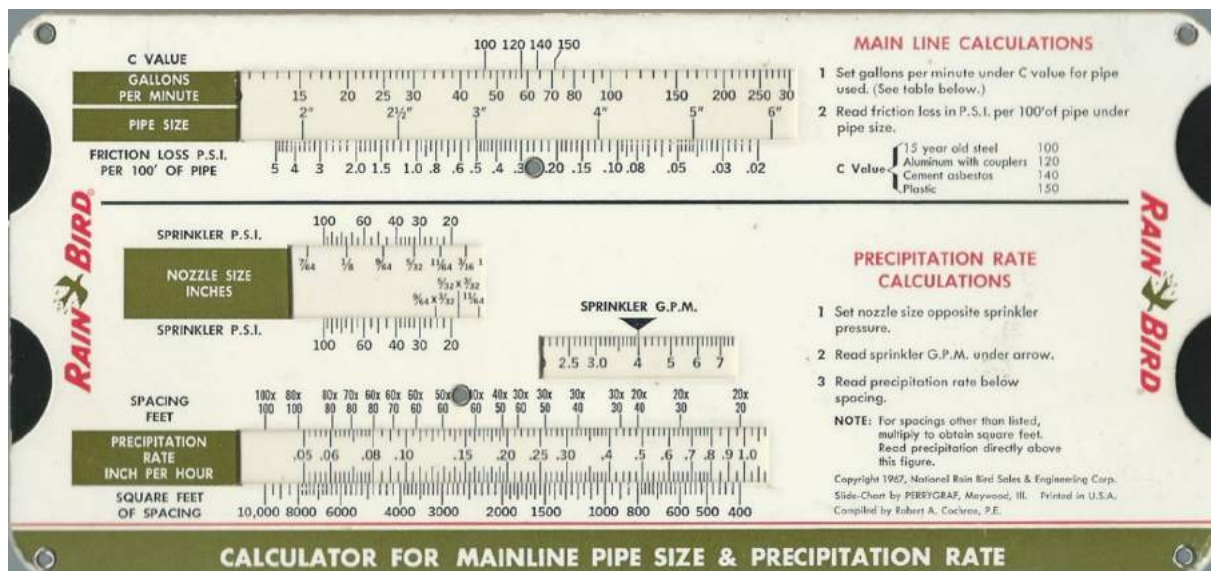
Figure 12: Calculator for the design of sprinkler systems
(Rain Bird / USA / Paper)

Summary

Many slide rules had been developed to solve hydromechanical problems in civil hydraulic engineering. The most frequent applications were the flow in pressure pipes and sewers, followed by open channel flow. Some examples have been presented herein. More slide rules for civil hydraulic engineering can be viewed under
http://prof.beuth-hochschule.de/heimann/rechenschieber-fuer-das-bauwesen/wasserbau/ .

The author is Professor for civil hydraulic engineering at the Beuth University for Applied Sciences in Berlin, Germany. Professor Heimann is a member in the following Professional Societies:

- DWA (German Association for Water Resources, Waste Water, and Solid Waste)
- HTG (German Association for Harbour Engineering)
- BWK (German Association for Hydraulic and Environmental Engineering)
- Deutsche Gesellschaft für Geotechnik e.V., Essen
- Member of the EAU- Committee of the HTG and the DGGT
- Network FluR for urban water courses, Member of Board of Directors

Forty Years of Activity of an Italian Slide Rule Designer…
…with some products still being marketed

Cesare Baj
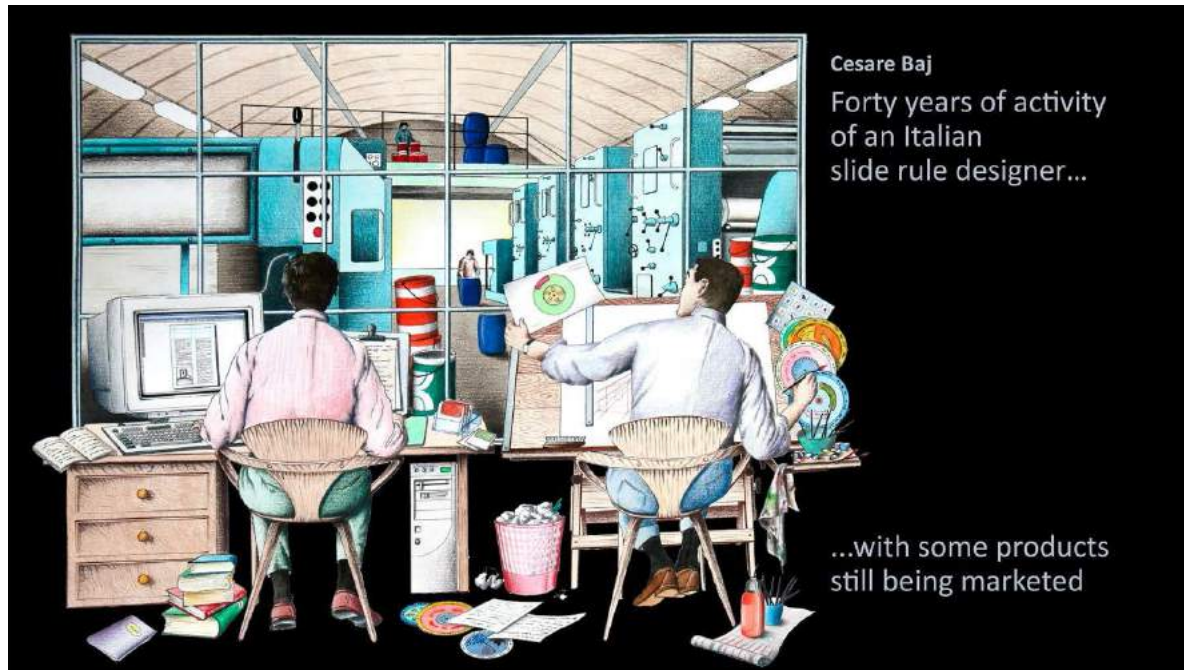
It is a pleasure and honor to be here with so many people from all over the world who share the passion for those marvelous fossils of science and technology that are slide rules.

Personally, I have a collection of more than 300 slide rules and other computing devices, but here I will talk about my personal history as a designer and constructor of slide rules and surrogate slide-rule-type instruments.

I was so lucky as to get in touch with a slide rule soon after I got out of the cradle. My father, a mechanical engineer, always had one in his pocket and a larger one, a 25 cm A. W. Faber 317, at home. I cannot number the times I kept that mysterious tool in my hands, making the movable parts slide one into the other, astonished by the precision of all the lines and the numbers printed on its smooth surfaces.

The use and the meaning of that object was unknown to me, a child 4 or 5 years old, but I could grasp that there was something of great value in it. I also used the instrument for many practical and trivial works, as drawing lines with a pencil, recovering something from under an armoire or a table, or gently beating my little sisters' hands when they tried to grab something of mine.

All in all, that Faber slide rule exerted on me a form of imprinting that I am sure conditioned my life somehow. I was in fact so lucky as to grow up in a family fully living the tradition of the Enlightenment, where science, technology, and an independent use of reason were highly considered. So I became very soon an amateur astronomer, a reader of science books, as well as of science fiction novels.

It is worth telling that in the formation of a young mind, very small stimuli can produce big effects. For the formation of my prone-to-math mind, not only my father's slide rule, but also picture cards played a role. Today youngsters collect almost only football players' cards. When I was a child there were series of cards and albums on subjects as astronomy, biology, and mathematics.

The "Amusing Numbers" ("Numeri che Divertono") album that I hardly completed in months of collection, probably produced in Italy more mathematicians than any math course in the primary school. For sure it had an influence on me.
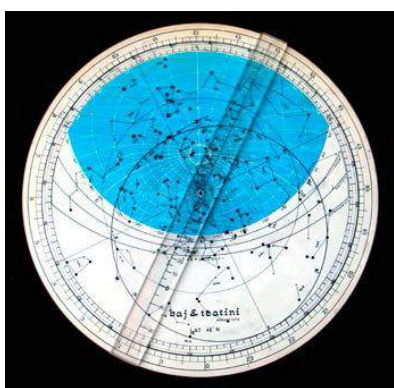
As an amateur astronomer I developed an interest in the ancient instruments used by astronomers and particularly in sundials. I learnt as a teenager how to construct them and when I was 24, I tried to transform my passion into a work, producing usable replicas of the instruments of the Renaissance, sold as toys. The initiative had some success and in the following years I produced various editions of those instruments, and finally produced 60,000 of twenty or so usable astronomical instruments in cardboard and plastic, attached as gadgets to an encyclopedia of astronomy. In the same period I produced 650,000 plastic sundials for an important weekly magazine – this could be a Guinness record as far as sundial production is concerned!
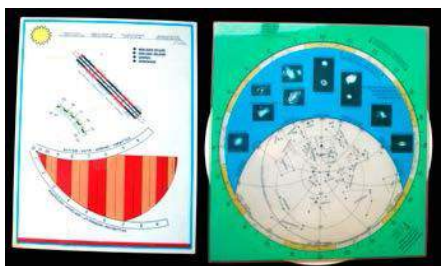
My most technical production in this field was a series of astrolabes for 8 latitudes, offering the special feature of graphically presenting the position of the True Sun, in the form of the small lemniscuses, or figure-eight shaped curve, on the transparent cursor, a feature I have never seen in any other astrolabe.

Another high-end production was the Planetario Tascabile Hoepli; designed and produced for the Hoepli, a major publishing house, which specialized in scientific books. This Planetarium is a special universal astrolabe, i.e., working at all latitudes, designed around an orthographic projection studied by the Spanish Juan de Rojas y Sarmiento in the 16th century.

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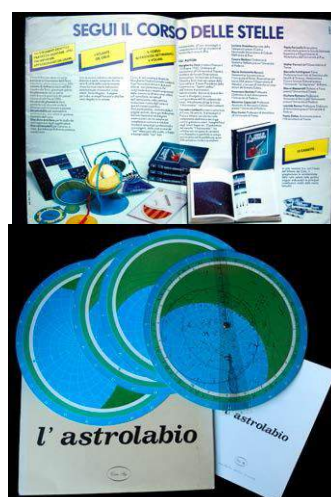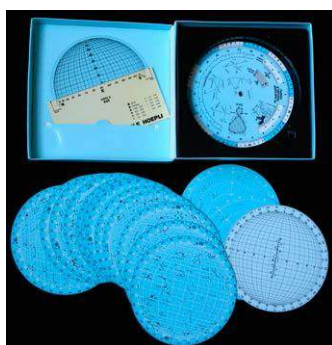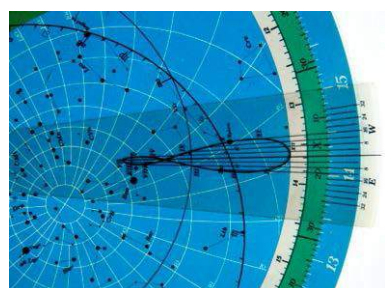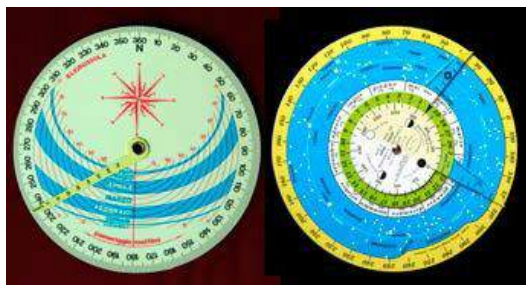
A simple, popular instrument was the Trovastelle – a Star finder, composed of two extremely cheap pieces of cardboard, offering a vision of the sky valid for two fundamental latitudes of the Italian territory, one on each side, the sky being represented both as a normal map and a blank map.

In the early Eighties I extended my production to replicas of the instruments of navigators and topographers of the past. So I produced the kit "Orientation, navigation, topography", including more than 30 cardboard instruments. Among them, many slide rules with logarithmic scales, a time/distance computer, and computers to be used in various sports and activities.


I am an airplane pilot since my youth, more specifically a seaplane pilot, and the author of many technical and historical books on aviation on and over water. So I could not help testing myself in the design of some types of aviation computers. In the Eighties I produced an "Advanced Pilot Computing and Plotting kit", including, among many plotting instruments, a typical flight computer, with a logarithmic side and a wind side, the latter allowing a graphical solution of the wind triangle. Other logarithmic slide rules to compute various data of interest for the pilot were included.
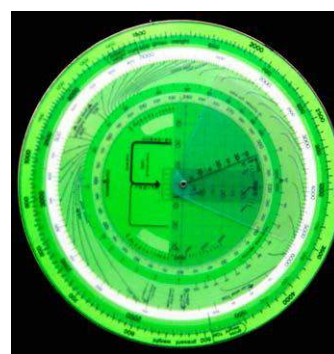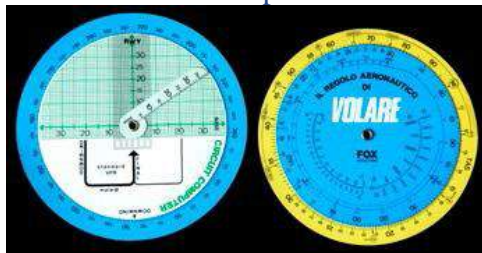
A very complex computer to establish the takeoff run, a maneuver affected by quite a number of parameters, was designed, but never produced. Another important kit I produced, still for the Hoepli publishing house, is a rich compendium of instruments to construct sundials, including a series of computing slide rules, to design all types of normal and strange lines on the dial, various instruments to compute data related to time and the calendar, many cardboard sundials, and a few plastic instruments to be used in the field to construct sundials.

Orologi solari

orologio cubico, orologio solare polare, orologio polare zodiacale, orologio universale, orologio bifilare
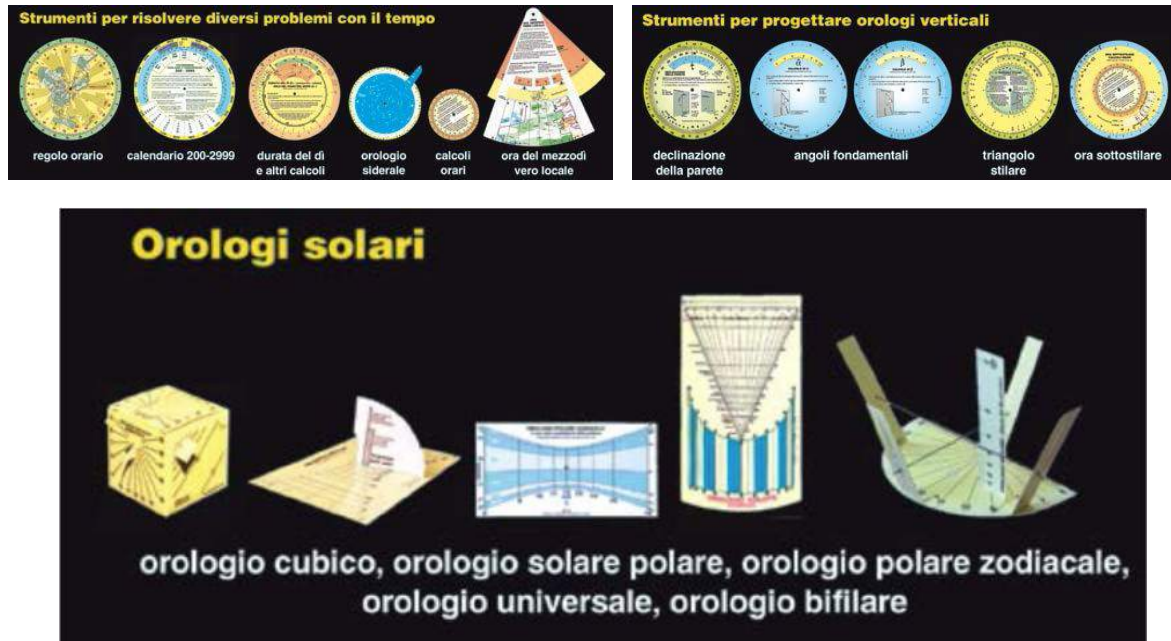
It is to be noted that the general philosophy of all those products was to offer instruments that could be readily used by amateurs of different disciplines and in the field of education, with an extensive documentation, but at a very affordable price thanks to the cheap cardboard production, occasionally with some printed plastic parts when transparency was fundamental. To give an example, my navigation kit with its 30 and more instruments cost half the price of a single plastic aviation computer.

In the glorious Eighties all magazines and newspapers in Italy competed through the offer of gadgets. In those years I produced dozens of "Perrygrafs" on the most disparate subjects, many of which with a computational function, i.e., logarithmic scales. Examples: slide rules to establish the most suitable diet, to learn how to use a pressure cooker or microwave oven, to choose the right combinations of foods, to calculate a woman's fertility period, to know the correct use of sun cream depending on the user's skin type, where to look in the sky to spot the Halley comet, how to compute the rate of exchange or the performance of an investment, and so on.

As it can be imagined, I did not invent all the slide rules I produced, resorting in some cases to well tested designs of the past. This is the case of the distance computers I prepared for Italy and the USA, thanks to the patience of my sister, who had to place something like three thousand dry-transfer digits onto a disc of three and half inches of diameter, each one at a precise place and with a precise orientation.

Probably the strangest slide rule I ever designed was – as it could be called in English – the "Govern-o-Meter", conceived to compute the possible governments to be formed after General Elections. Italy is a complicated country, where tens of political parties compete for a place in the Sun, hence the need for serious calculations! This instrument presented also a logarithmic scale, to compute a datum normally hidden and disliked by politicians, intended to answer this question: given the percentage of non-voters and unmarked and spoiled ballot papers, by what percentage of the whole voting population the winner has been elected? So it became very simply computable that a government could be the expression of just 20-25% of the population, raising issues of political philosophy about the social system in which we live.

In many cases I produced more than 500,000 pieces of a specific gadget of this type. This was happening just a little time after millions of slide rules had been made suddenly obsolete by billions of electronic calculators. To be noted that electronic calculators did not really occupy the whole scene, leaving to slide rules a function when non-numerical information had to be presented or when very specific computations were involved. In addition those gadgets, printed in joyous colors and embellished by images, played a role in popularizing the slide rule, no more a cryptic instrument reserved for the rarefied levels of engineers.

The second life I gave in Italy to the slide rule or to objects resembling slide rules very closely, was perceived in 1986 by the J. Walter Thompson Company. The world's leading marketing communications group granted me the "David Campbell Harris – The Future of Communication Award", for my report "Second generation slide rules– Interesting applications in the field of mass communication and advertisement of a sophisticated technology of the past".

It is curious, and obviously a source of satisfaction that in the era of space and electronics one could win a prize, awarded by a big Communication Company, for a technology invented three centuries before.

Before talking about what I am producing in present times, I would like to expose an amusing experiment I made as a member of the CI-CAP, the Italian sister association of the American CSI, the Committee for Skeptical Inquiry, whose mission is "to promote scientific inquiry, critical investigation, and the use of reason in examining controversial and extraordinary claims".

The idea was playing a joke on the lovers of legendary archaeological findings, such as the "Baghdad battery", or on those who believe that pre-Columbian civilizations had been regularly visited by the aliens.

So, I prepared a circular Babylonian logarithmic slide rule, working in accordance with the base 60 system and carved with cuneiform figures. I presented it as an ancient artifact, "forgotten in the ship of an expedition of archaeologist, traveling from Latakia to Venice in the " 1920s". The story of the discovery was based on real facts and supported by an old album of pictures, documents from the ship captain who had come into possession of the material and notes from the president of the Italian Mathematical Society who endorsed the discovery.

The artifact was a demonstration of the fact that Babylonians had the theoretical knowledge and the practical know-how to invent and produce the slide rule two millennia before it was "re-invented" in the Western civilization by William Oughtred.

I easily succeeded in demonstrating the assumption that Babylonians were capable in managing logarithms. Mathematical documents in the form of clay tablets found in the Fertile Crescent proved my case. But the artifact, the old album, and the letters were all fake, as they had been created by me.

Another instrument I designed as a member of the community of the Skeptics was a Zodiacal sundial, showing not the dates of the entrance of the Sun into the zodiacal signs, but its entrance into the zodiacal constellations, and among them the "outsider" Ophiuchus, unfairly excluded in the classic zodiac.

I have now to make a confession. At a certain point I have been requested to design a set of instruments to make horoscopes. I completely disbelieve in astrology, but designing such a special astrolabe was a technical challenge to me, even though similar instruments were realized centuries before. I gave myself two excuses for this blasphemy. Firstly, I just had to design an astronomical instrument indicating the moment the Sun enters into the 12 houses, which are precisely defined sectors of the sky. I said to myself: a producer of knives intended to be used in the kitchen is not responsible if one of his knives is used by a husband to kill his wife or vice versa. So I am not responsible if an astronomical instrument is used to prepare horoscopes.

Yes, I admit this smells of hypocrisy a mile away, and this leads to my second excuse: even the great Galileo Galilei had to make a horoscope to carry on with his family now and then. The question now is: in today's technological landscape what could be the role of analog computers, i.e., slide rules?

Certainly slide-rule-type products, which present data in a graphically pleasant way, occasionally with a computational capability, can continue to be used in the educational field and as cheap gadgets. I present here, as an example, an "Aromatic herbs" computer of which I produced 25,000 copies last year, as a gadget to be given to every visitor of a botanical fair. It is for sure not a computational device, but for the people it is "a slide rule", a "regolo" in Italian, and in some way it will help keeping the concept alive.
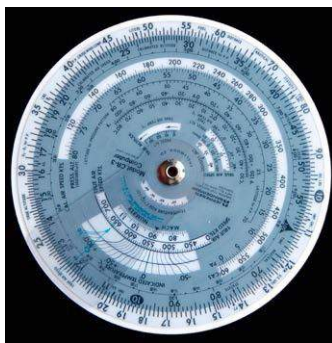

For the record, it was much appreciated and will be conserved in tens of thousands of homes. Indeed, we are dealing with a material object, may be old-fashioned and naïve, but something that has substance, fated to exist for centuries; thus, having some value, be it large or small. We are not dealing with pixels, flowing on a screen for few seconds, thanks to software that will likely be unavailable within weeks or months or a year.

Let us note now that there is a field in which a classic slide rule is still in use: aviation. One could wonder why this happens. Let us say that when one needs an approximate, but quick solution to a problem – this is exactly the case when flying an aircraft – and an instrument whose functionality must have a 100% reliability, a slide rule can honorably accomplish the task, even better than a complex programmable computer. Let us remember that it is important to be able to rely on a device that does not depend on anything, electricity included. For the same reason, pilots prefer to use a stick to measure the fuel level rather than trust the electro-mechanical level indicator.

In the specific field of aviation the slide rule, in the form of the Flight Computer, belongs to the equipment of every pilot, and its use is still taught in flight schools. Unfortunately, only few continue to use it after their exams and rely more and more on complex devices in the cockpit and on the instrument panel. One of the side effects of these intricate devices is that their setting requires a good deal of time and attention, as a result of which pilots look less and less out of the windows of their aircraft. All in all, a simple instrument made out of three discs of cardboard or plastic, but with an infinity of calculation possibilities, can still play a practical role in the life of a pilot.

I would like to add that it is the opinion of many that the younger generations are less and less capable in using their hands, as they are used to living in a virtual world of pixels and are accustomed to ask computers for quick solutions to any problem that might arise.
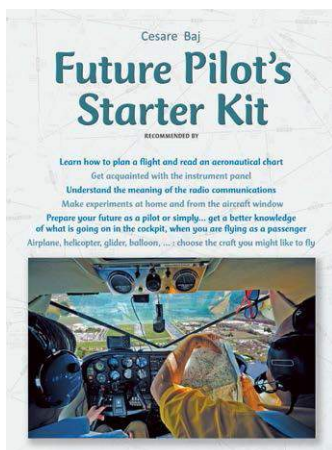
As a reaction, there is now a tendency to step a little back and offer the youngsters the pleasure of understanding and managing themselves the processes they are involved in, in our case through the use of slide rules. That is why flight examiners more and more often switch off all modern cockpit equipment and say to the candidate-pilot "Now take your map, your chronometer, your flight computer, and plotter and take me to this or that destination".

These concepts induced me to design a product for the prospective pilot, to promote aviation within the general public, people interested, eager to know and understand, but not, or at least not yet, involved in the field. It is the "Future Pilot's Starter Kit", now in the pre-production phase.

The kit comprises of a brochure presenting all possibilities of becoming a pilot of the various flying machines, a 224-page book with all the basic aviation knowledge explained in simple terms, an atlas of aviation communications, a 10 foot long sheet with the history of aviation, various minor gadgets, and a series of slide rules to make computations of various kinds. Two words on these instruments, which will be produced before the end of this year.
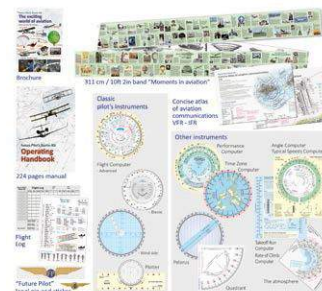
One is the classic flight computer, with several minor improvements. It is supplied in two editions: basic and advanced, so that the prospective pilot will not be scared by his/her first glance at the instrument, and to allow a step by step approach. This is obtained with just the substitution of the upper disc.
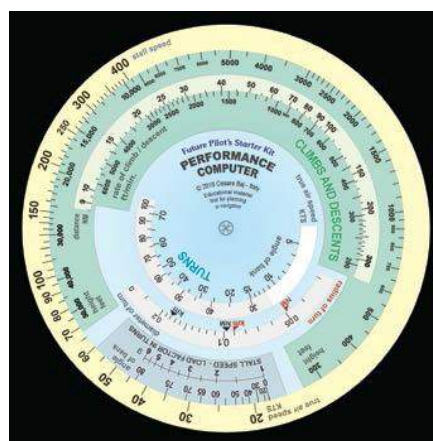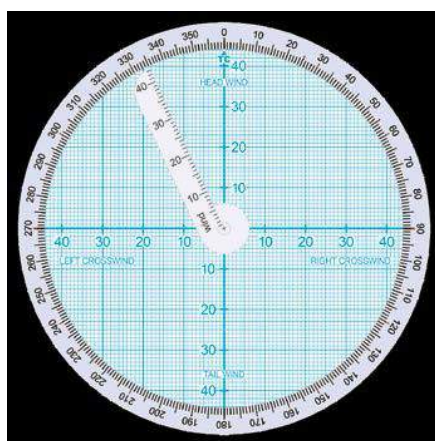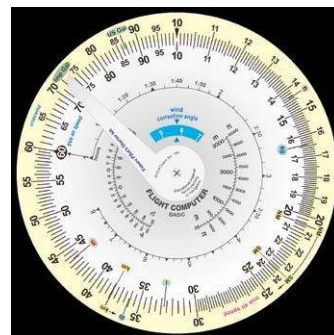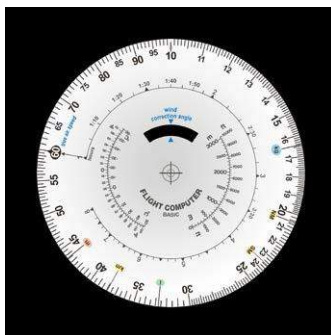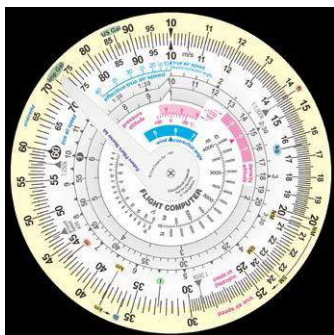
The computer has a wind side, used to compute those components of the wind, which are interesting for a pilot, i.e., the crosswind and the head/tailwind. The Performance Computer is a new product allowing the user to compute data about turns, climbs, and descents. This computer can have an important role in the safety of flying, as many potentially dangerous flight situations can be easily simulated in exercises in the comfort of an armchair, so that the pilot is prepared to face them when they occur in real flights.

In the use of this instrument, all the advantages of an analog computing instrument, i.e., a slide rule, become evident. With a slight continuous movement of the fingers, the parameters vary in a continuous way and the results we are interested in are automatically displayed, as well in a continuous way. It is only a matter of looking in the proper places of the scales during the movement of one disc over the other. Simple, quick, effective, and very elegant. Using an electronic device, all data must be input for every single variation. In the book of the kit, at the end, I have included four pages summarizing the history of slide rules, explaining all their features and why they can continue to be faithful companions of the pilot.

The kit, when distributed through associations as the AOPA, the Aircraft Owners, and Pilots Association, will include a special gift: a replica, with its case, of the 1943 Computer Type D-4. This slide rule was used by WW2 pilots of the B-17 "Flying Fortress", the P-58 "Mustang", and other aircraft of the time. Even if the readers do not use the computers within the kit for computation, at least the D-4 replica will survive as a historical curiosity on the desk of thousands of people and might imprint on some young mind as it happened to me with my father's Faber 317. For the future I have been thinking for a dozen years about producing a series of 20 or more small kits on the theme of mathematics, aimed at young adults and passionate adults. It is probable that they will include slide rules in several cases.

It is an ambitious and demanding project that in the last years I had not the time and energy to develop, but it could possibly represent the last of my productions and the top of my career as a designer of scientific education products and slide rules.

Mathematical knowledge needs to percolate into forming minds through play, toys, curious stories, and strange and intriguing objects. And I am sure that familiarity with mathematics produces mental order and the habit to use reason in managing one's own life; in other terms, mathematics produces better men and women for our future societies. That is why I guess that this series could be remembered as the most useful of my productions, if I will succeed in realizing it.
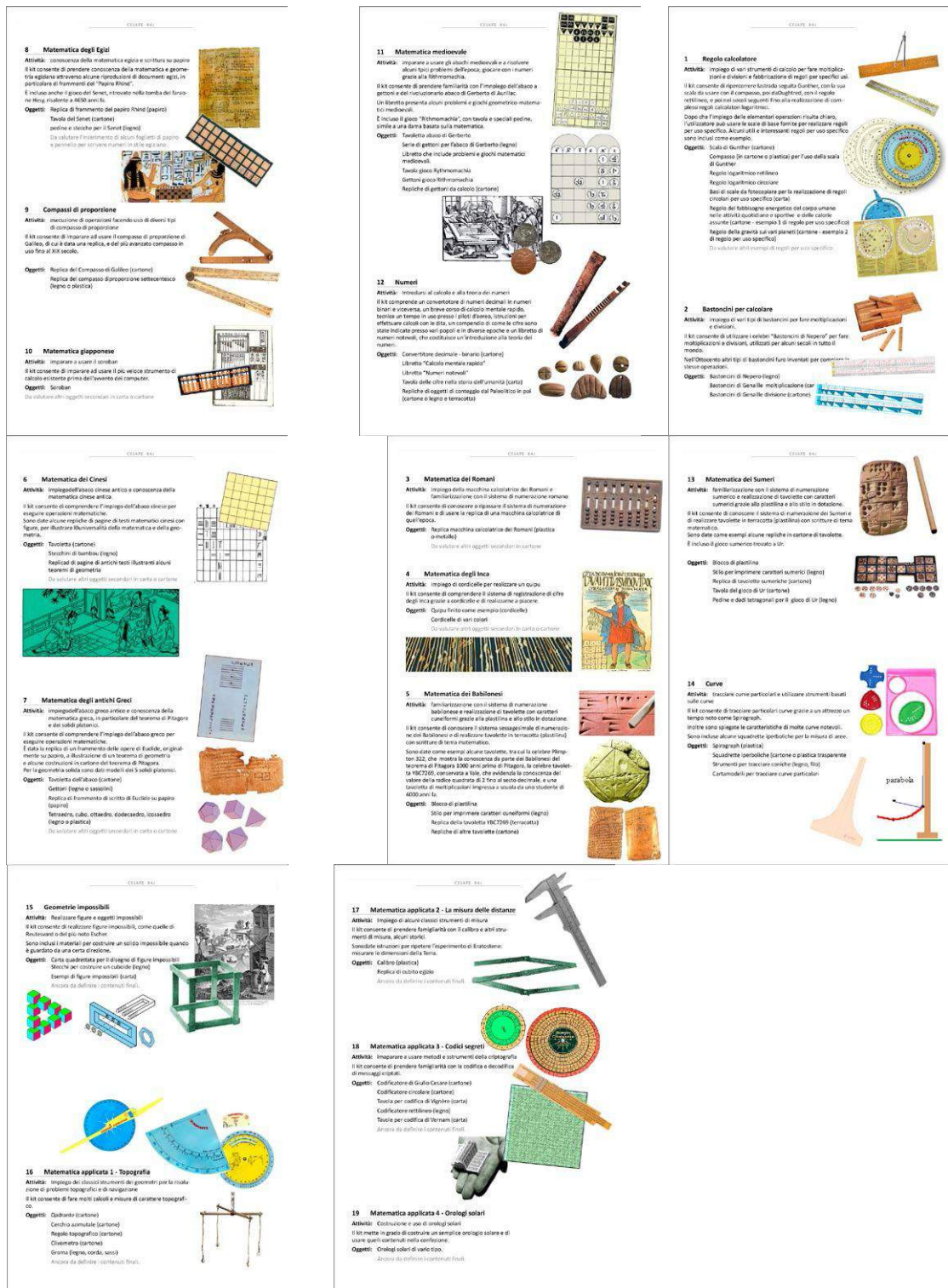
Another project I am very slowly developing is a book on slide rules, including a catalogue of my productions, having a title such as "The Last of the Mohicans – Memoirs of a Slide Rule Designer". But the project on mathematics has the priority, of course.

To conclude, I grew up during the twilight of the slide rule era, but I felt an irresistible attraction for those intriguing objects, every slide rule being a small universe giving a sense of precision, completeness, and elegance. And I tested myself in trying new ways to make those objects live and evolve, in order to offer some kind of service.

What I can say is that I got a lot of satisfaction and amusement from this activity and it is really a pleasure to know that there is a well-structured organization such as the Oughtred Society, with its mission of preserving this noble and magnificent tradition.

Thank you. And finally:

If anybody would like to view or handle the instruments described, the author has them available and will be happy to give more information.

The author has prepared a small gift for everybody who attends the conference.

For the record, the system of representing a working slide rule on the screen of a computer has been studied by Tomaso Baj, Cesare's son, who is present in this hall, and who is very interested in the graphical aspects of slide rules.

NOTES
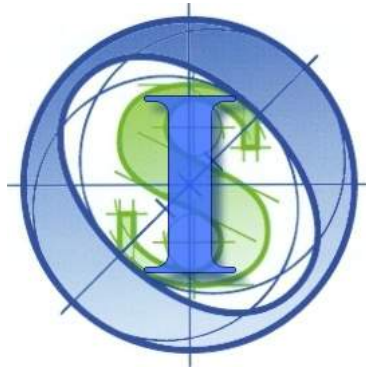
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