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& MORE

IM2010

Proceedings 16th International Meeting of
Collectors of Historical Calculating Instruments
September 17th and 18th, 2010
Leiden, The Netherlands

Kring Historische Rekeninstrumenten

PROCEEDINGS IM2010

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mini and MORE

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KRING HISTORISCHE REKENINSTRUMENTEN

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19 . t Werck ſtraetgen
20 . Lange en Korte Sant ſtr.
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22 . De Koolſtraten
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26 . Vrouwen ſteegh
27 . Goe Gerrets ſteegh
28 . Barrevelts ſteech
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66 . Lange Nieuſtraet
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68 . De Luyterſche Kerck
69 . Den Middel wech
70 . De Coppelingh ſteegen
71 . Vleere ſteeghen
a . Hout marckt
b . Verwers ſtraet
c . Weſt haven ſtraet
d . Ooſt haven ſtr.
e . Loyers ſtraet
RHENUS FLU.

LVGDVNVM BATAVORVM

Vernacule *LEYDEN.*

Map of “the Lyon of the Batavians”, or Leiden
Hand-coloured Engraving in Atlas by J. Blaeu
1649

Leiden - Host City of IM2010

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INTRODUCTION TO IM2010

Chris Hakkaart

Dear Participants and Partners

This is the 16th International Meeting and the fifth time the Dutch are organising it for the International Slide Rule Community. Many of you have participated in one or more of the previous meetings and we welcome you, and the new participants and the Partners.

This symposium confirms that historical calculating instruments are a very interesting subject. Investigation and research is still going on and many more subjects need study. That happens in such an enthusiasm, that quickly after the start of the preparations for this IM so many proposals were submitted that we had to announce a stop. These days will be very busy for you with many interesting presentations. It also shows that there is plenty of interesting material for future IM´s.

Each of the organising countries have their characteristic aspects for their IM´s. The Dutch often have a title. This time it is *mini & MORE*. It reflects the content of this program by the quantity of presentations of subjects about different types of “minis” by Participants and for the first time also by Partners. It seems that Partners have also very interesting collecting hobbies! The “MORE” reflects to others subjects. French Slide Rules are known, but have never had the attention they deserve. It has taken a lot of effort, but we succeeded to organise a set of presentations about French Slide Rules by French experts. It will broaden our knowledge. On previous IM's English or German was the language. Now French will be added, but with a simultaneous translation.

The presentations we will see these days have a high value of science. When collecting sponsorships for the IM, I used the words meeting, congress and symposium. Without sponsorships it would not be possible to organise a meeting like this at such a high level. We are very happy that the sponsors make these days possible. But what is the best name to use. Well, a Congress is a meeting of people mostly of international level. A Symposium is a scientific congress. I am convinced that the level of presentations can easily compete with other scientific meetings. So the word Symposium fits in my view the best to us today.

The organising committee realizes that our community becomes older, although still new and younger collectors join us. Organising an IM requires a lot of effort and (financial) responsibility. The number of participants is mostly in the order of 50 to 70. Anticipating on the future, when the format of these IM's may change due to a possible reduction of participants, we decided to organise an experiment for those who are not able to visit the IM, but are still interested. At the second day a Virtual Meeting via the WEB is planned. Those who are interested can log in with their computer without extra software and costs and follow a presentation. This may be a future way of communication for our community. We will evaluate this experience afterwards.

Often Dutch IM's are at two locations. In 2003 these were Breukelen and Amsterdam and in 2007 Lelystad and Enkhuizen. It requires a lot more organisation, but the experience is that travelling together early in the morning has a special ambiance. This time the city is Leiden, but we have two meeting locations, the hotel and the University. And travelling will be done at the way travelling was done in this area in the eighteen century, by boat. I hope you will enjoy it.

The stocks of slide rules have been dried up. So we are not able anymore to give an old slide rule as a present. That has urged us to some creativity, which resulted in the N-cards. A unique specially developed present. During the diner some entertainment will be provided.

Thanks to the members of the Organising committee who are listed below. On the background we were supported by many of you with ideas and suggestions.

We all wish you interesting and enjoyable days !!!

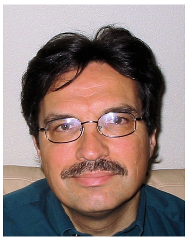
ORGANISING COMMITTEE

The organising committee of the International Meeting of Collectors of Historical Calculating Instruments 2010 "MINI & MORE" consist of the next persons.

Chris Hakkaart, chairman of the organising committee, did coordination, all financial planning and handling, arranging of sponsoring and –last but not least- supplying pastries during our meetings:

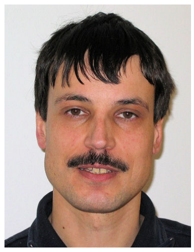
"I am now for over 10 years involved in collecting objects which belong to our scope, mostly slide rules and slide charts, but also sometimes an interesting calculating machine. Beside that I am interesting in drafting templates, especially after the IM 2007. The scope is wide and the time available is limited, especially when you have a fulltime job. Most time spent today is to accommodate the Kring and the IM's by taking part in the organisation. Time for really collecting and study is limited. But as I have said previously, the interest in slide rules, etc is twofold. First I admire the dedication of people who have developed all those sorts of instruments to facilitate their job. Second, I like the slide rule community because of their broad interests. And also the broad interest of their Partners and their knowledge about very typical objects, as we will see at this IM. And I can mention a third reason: we have and are documenting the history of heritage at a moment that it is possible to collect information from original sources. In future it will become clear that the value of our documentation will be appreciated. The special subjects of this MINI & MORE Symposium and your presence will be another step in the pleasure of collecting slide rules."

Otto van Poelje handled the IM2010 registration process and prepared the Proceedings. Otto also developed the N-card.



Leo van der Lucht coordinated the graphic designs and organised the printing of the Proceedings.

Together with **Andries de Man, Leo** planned and prepared the first Virtual Meeting on the Web.



Gerard van Gelswijck arranged the locations and the boat transports in between.

Ronald van Riet had a major job in organising the French input during this Symposium, and taking care of all French-English translations.

List of Supporters and Sponsors of the IM 2010

This International Meeting could only be organised with the support, in a direct or indirect way, of individuals, organisations and companies. The Organising Committee expresses, also on behalf of the participants, their acknowledgement for their support.

Thanks to all the speakers and authors of the papers in the Proceedings, who have invested time during the preparation of their contribution.

Others have supported on occasional basis, to make the IM 2010 a success:

- Willem van der Veere, the designer of the impressive cover and the N-card.
- Our sister organisations abroad, who assisted in providing information and distributing the announcement.
- Our partners, who assisted the organisation and guided the Partners program: Henny C. Brouwer, Daria Bouwman, Janny van Poelje.
- Inge Rudowski and Daria Bouwman, ladies collectors, who presented two lectures about mini's.
- IJzebrand Schuitema and David Rance who supplied many ideas.

Financial support has been received from the following sponsors:

Bouwen met Staal
The National Dutch organisation on Steel
Boerhavelaan 40, 2713 HX Zoetermeer, The Netherlands
http://www.bouwenmetstaal.nl

Dutch Circle of Historical Calculating Instruments
ovpoelje@rekenlinialen.org
http://www.Rekenlinialen.org

The Oughtred Society
International organisation of collectors dedicated to the preservation and history of slide rules and other calculating instruments (USA)
http://www.oughtred.org

Shell Pensioenfonds
The Retirement Organisation of Shell
PB 162, 2501 AN Den Haag, The Netherlands
http://www.Shell.nl

Exact Education
Educational Consultancy
S.Salm@kpnmail.nl

Intop Bedrijfsopleidingen
Institute for electrotechnical and mechanical education
http://www.Intop.nl

Intop Zorgsector
Courses concerning medical technology
http://www.Intopzorgsector.nl

SHORT HISTORY OF LEIDEN
Host City of IM2010 and of the Partners Program

Chris Hakkaart & Henny Brouwer

The International Meetings in The Netherlands are often at two locations. This time however, it is only Leiden, but we will still visit two locations within Leiden. The first day we will stay at a hotel with history located at the Rhine. The second day we will sail by boat from this hotel to the inner city of Leiden, where the participants will walk along the old canals to Plexus, a University building. Our partners will continue with a tour with the boat through the canals of Leiden. At the end of the day we will travel back by boat. Detailed information about Leiden can be found in bookshops and the Internet, but some specials are mentioned hereafter.

Leiden is a very old city. It is located at a point where two arms of the Rhine join each other. Figure 1 indicates the growth of the city from before the year 1000 up till today. Around the inner city with canals, suburbs are located. We will stay in the old area of the city.

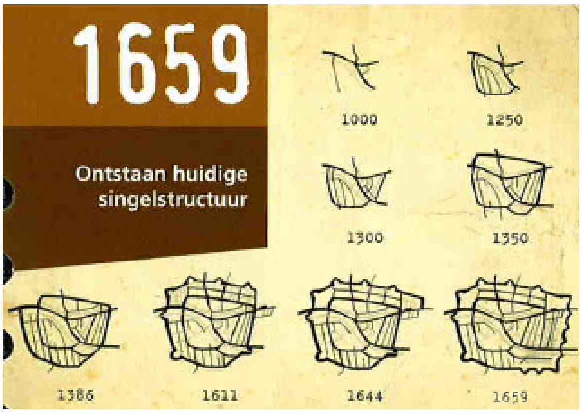


Figure 1 - Leiden through the centuries

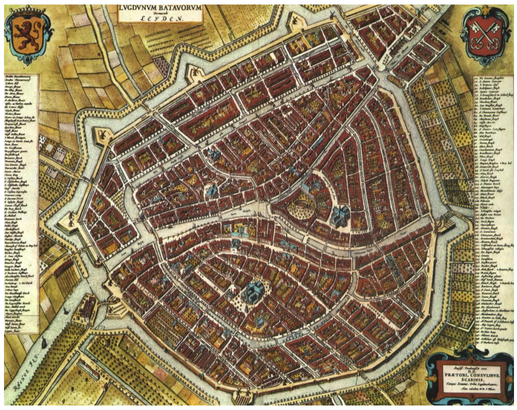


Figure 2 - Map of Blaeu

In the seventeenth century many maps were made of The Netherlands, Europe and the world. One of the famous map makers was Blaeu. He was involved in the production of a map of Leiden, where you even can see the fronts of the houses (Fig 2, also see the larger image following the front page). This map has recently been transferred in a 3D animation. During the IM 2010 this animation will be shown, to give you an impression of Leiden in the seventeenth century. Besides slide rules, maps have my interest, maybe because one of my possible ancestors, Jan Hackaert, was a cartographer in the seventeenth century. He lived in the same period as Blaeu and it is known there were contacts between the different cartographers. Hackaert however painted perspective views of landscaping and mountains and is well known in Switzerland and Austria. But that is another story.

Leiden is also the city where Rembrandt was born in the Weddesteeg. When we sail by boat on Saturday, it is one of the first streets of Leiden at your right hand. A DVD portraying his life in Leiden will be shown during the IM 2010. Leiden has 1320 historical buildings which is the largest number of historical buildings/km^2 in The Netherlands. It was an important city in 17th century mainly from the production of linen. It became a city of refugees: in the 13th and 14th century the Flemish, in the 16th century the French, in the 17th century the English Pilgrim Fathers, who departed in 1620 to America. Also Germans refugees found a place in Leiden and in the 18th century the Huguenots. The first University of The Netherlands was founded by Willem van Oranje. This University has a "sweat" room, where the final examinations were held and where the successful candidate writes his or her name (already for centuries) on the wall (fig 3).

Figure 3 - Names with successful candidates

Figure 4 - Boerhaave Museum with exhibition

The Boerhaave Museum has a large collection of interesting medical and other laboratory equipment. It is recommended to visit this museum after the IM 2010. Instruments developed by Huygens and other famous scientists in the seventeenth century are displayed (fig 4).
There is a Millionaire on display.

The University also houses a Hortus Botanicus (fig 5). Clusius was a researcher who promoted the development of the tulip. There is a special section of the garden dedicated to him.

Figure 5 - Tulips developed by Clusius in Hortus Botanicus

Figure 6 – Canal with fish market

Leiden is a city of canals, which is attractive. With good weather many small boats sail through the canals (fig 6). And because of its age it has many old houses.

Almhouses (Leiden has over 35) were built since 12th century, for the beguines of the church and for poor people. They were often built by rich people which made their money in the textile industry. They could name an almhouse (fig 7) to themselves for eternity. Mostly the portrait of the founder was in the trustees room ("regentenkamer"). Sometimes the inhabitants had to pray for the founder of the almshouse. Often generations of the family managed the almshouse.

Figure 7 - Almhouse

From Leiden the pilgrim fathers departed to the west and founded the U.S.A. Several U.S.A. presidents are descendents from these Pilgrims. The Pilgrim Museum shows how they lived in an original 14th century old house in the inner city (Fig 8, 9 & 10). This Pilgrim House is housed in the oldest -not restored- set of two houses in Leiden. The museum shows how they lived. But also of interest are these very old houses from the 14th century. Because these houses were covered with a blind wall, all century old details were saved. A very interesting location.

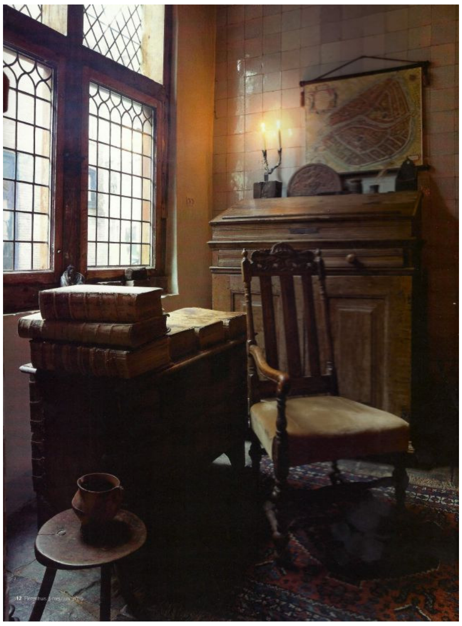
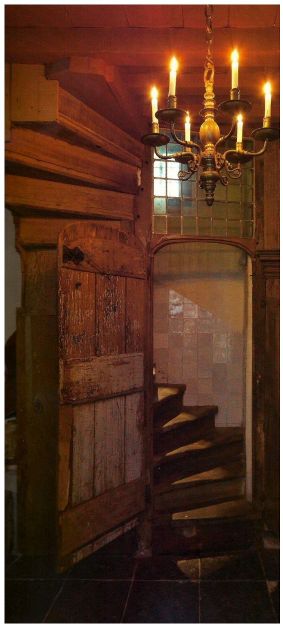




Figure 8, 9 & 10 – Pilgrim Museum in 14th century Building

A ladies or Partner program belongs to the International Meetings. It is appreciated by the ladies and plays an important part in a successful IM. So the choice of the location is also of importance for a successful IM. The location need to be in an area were an interesting program can be organised. Sometimes it is possible to organise an excursion to a collector's home, like Snowshill in England (2008), which has made an enormous impression.

For the ladies program we have to rely on the willingness of our partners. In 2003 Henny Brouwer, an architect specialised in 17th century buildings guided the excursion through Amsterdam. In 2007 Henny Brouwer, Daria Bouwman and Janny van Poelje drove by bus through the polders around Enkhuizen and visited century old houses.

For the IM 2010 the same team has prepared a walking tour through the old city of Leiden, visiting many of the special locations described above, and admiring some old buildings like those shown below.



MINIATURE BOOKS
Beautiful Small Pieces of Literature

Daria Bouwman

I'm working as the Attaché for Culture and Education at the Austrian Embassy in the Hague. My work is to organize Austrian cultural events in the Netherlands and to support every kind of cultural exchange between these two countries, also in the German lessons at Dutch schools. Since some years I'm also active in a European working group that presents European culture "United in diversity". I grew up in West-Berlin bilingual, Dutch and German. I studied German literature in Berlin and what I loved and love most in my life is reading. I'm addicted to literature but also to the language itself. On the one hand I love everything from German literature, especially the great classic authors as Goethe, Schiller and Thomas Mann. On the other hand I'm addicted to language, the physical structures of our brain and the function of language for communication. I'm one of those lucky people who's hobby is their business.

So also my hobby's are about culture in general and literature in particular. Beside old books and special editions, I have two collections: bookmarks and miniature books.

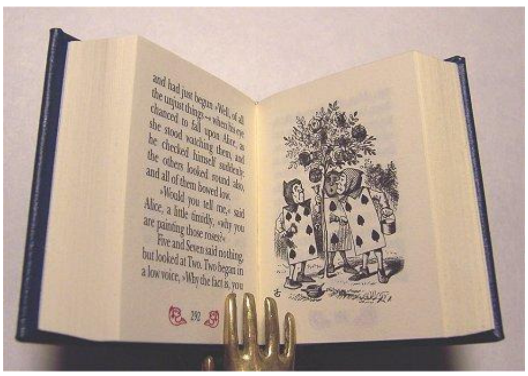
Introduction

What do people do who are not addicted to figures but to letters? They read – they read books, newspapers, magazines; old books, new books, famous books, novels, short stories etc. Do they also collect things? Yes, they do. A lot of people are collecting old books, or special editions, first editions, leather-bound copies. But there are a few people who collect something special: miniature books.

Miniature books are not as rare or strange as most people would think. Miniature books exist for centuries. One of the most famous and largest libraries of miniature books in Europe belonged to Napoleon. He took his library with him on his 'tours of war'.

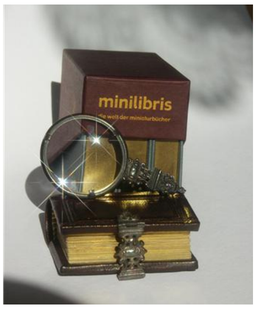
The fancy thing about miniature book is the fact that despite its small size it possesses all the features of the book - the greatest of all treasures in human wisdom, reservoir of human genius, and this fact compensates the difficult and complicated work of saving and multiplying miniature books.

What is a Miniature Book?



A miniature book is a very small book, sized at a maximum: in Europe 10 x 10 cm, in America 7.5 x 7.5 cm. But there are some other requirements for a good miniature book. Miniature books described here are not an item 'just for show or for fun'. They want to be read.

So another significant demand is the letter-type, but of course the whole layout. They have to have a readable layout. And as you can see in the examples you can read them. Those real miniature books are not toys or doll's house books.



Micro books

There is another category of miniature books, a very special one, the so called micro books – books that are mostly not bigger than 10 x 10 mm. They normally just can be read with magnifying glasses. They are particularly rare and only printed in limited editions.

History of Miniature Books

One of the oldest examples of miniature books is a special Chinese edition "The Art of War", a more than 2500 year old text, composed of 13 chapters, each of which is devoted to one aspect of warfare, it is said to be the definitive work on military strategies and tactics of its time.

Since the 18th century they were printed in higher editions, but became really popular in the last few decades of the 19th century when people began to travel. These books had a handy size and weight - they were portable and easy to conceal. One could carry a vast number of books in a small case for a long journey. So the publishers put more effort in their works and tried to make the most beautiful pieces of literature in a miniature format. Many of them were bound in fine Moroccan leather, gilt and contain excellent examples of woodcuts, etchings and watermarks.

The most popular topics at that time were – besides novels and classical literature - dictionaries, language translators, religious stories and readings, and occasionally tourist guides. And they are used until today. Most of us know these handsome dictionaries e.g. by Langenscheidt in Germany, or other publishers, for a lot of languages.

Range of Subjects

The subjects of the actual editions range from the Bible, encyclopaedias, music, stories, rhymes, famous speeches and the miniaturization of well known books such as the classical literature especially from Germany, France and Great Britain. Shakespeare, Goethe, Molière, Charles Dickens, Flaubert, Pushkin, Andersen, Da Vinci, Tolstoy are just some names of a long list of famous authors. But also the old Greek and Roman philosophers are printed in this small format. And of course there was and is erotic literature like the "Decamerone" or "Josefine Mutzenbacher". This kind of books where especially popular in a small format because they were not meant to be seen by everybody and could be hidden easily.

Very popular until today are miniature books with quotations. You can find books with all those famous lines by Shakespeare or Schiller or just from one novel as from Goethe's "Faust".

And there are all those small gift books everybody knows. In the bookshop they are always lying next to the counter and they are offered in abundance before Christmas, Easter and Mother's Day. The titles are like "For my dearest mother/grandma/daddy/grandpa/ sister..." or "Wise advice for life/love/happiness", "Chinese wisdom" etc. They are also collected. But no serious collector of literary miniature books will ever touch them.

Where were they made?

All the old books such as the Chinese "Art of War" or those from the 18th and 19th century belong of course to the collector's items. They are rare, difficult to find and very expensive.

In the 20th century – especially since the invention of the paperback - the miniature books and their advantage fell into oblivion. But there were still some places where those treasures were made. In Europe this was above all in Eastern-Europe. The former GDR, USSR, Hungary and Czechoslovakia were the countries were miniature book were produced since the 1950s. And they are still the European countries with the most important tradition for this business. Some famous Central-European publishers for miniature books are "Miniaturbuchverlag Leipzig" in Germany, Minerva in Budapest etc.

Fifteen Criteria for a nice Miniature Book

To make a miniature book a nice, usable and readable book it has to fulfil some criteria. The conditions for a nice miniature book are:

1. the book must contain the complete original text
2. it may not be bigger than 100 x 100 mm and not smaller than content and letter type do require, not too big and not too small
3. constant black or coloured, clear and nicely printed
4. without misprints and faults in the content, corresponding to the valid orthography, depending on the time or peculiarity of the original text
5. the characters have to look regular and readable in all applications, a font that shows every letter to advantage and gives a clear expression
6. the spaces between the chapters, paragraphs and lines have to be in a way that irregularities are avoided, to please the reader
7. printed on a paper of a pleasant colour and quality, depending on content and format, that makes reading as easy as possible
8. character size of the title and the headings have to correspond with the text, so the pages are looking well
9. illustrations, pictures, photographs, ornaments or decorations may not be too big or too small
10. the pages have to be in good proportions, so there's enough space on the inner side for the binding

11. the outside presents itself in a nice and artistic design
12. with even and exact edges - corresponding to the size of a miniature book – not too big, the same is valid for the cover
13. with a cover of cardboard that's not too strong and lying flat
14. with a nice combination of colour and ribbon
15. it has to have compact edges

Collecting Miniature Books

The collectors mostly have specialised collections such as books in one language, made by one publisher, bibles, novels, dictionaries, special themes like sports or tourist guides or, like I do, classical literature. There are no limits of diversity. Also in the Guinness Book of records, miniature book collectors are listed with more than 5000 titles.

In his book "Miniaturbücher von den Anfängen bis Heute" (Verlag K. Pressler München 1988) - "Miniature books from the beginnings until today" - Louis Wolfgang Bondy writes:

> *"In this small world, books deserve a place of honour. They combine the great skill which is specially needed for this process of creation with the highest fame of the human mind, kept in their texts. No wonder that the number of collectors who appreciate or even admire them is growing constantly …"*

Storage and Display

The next question is how to keep them and how to present them. As any collector also miniature book collectors are very proud of their collections and want to show them in a proper way. Lucky collectors do know a cabinet-maker who can make a miniature bookcase to measure.

I have a copy of an old bookcase design even with the appropriate decoration and base. On photographs without comparing objects you can't see a difference between a normal bookcase with his contents. But there are also standard bookcases, made of wood or acryl. And some collectors are presenting their precious objects in glass cabinets.

Collectors Organisations

Worldwide there are some organised groups of miniature book lovers and collectors. The biggest group is the Miniature Book Society in the USA, next to clubs in the Czech Republic, Germany, France and Japan. As all collectors these days they communicate worldwide, they have an active exchange of information, they sell and buy their items all over the world.

For more information

http://www.mbs.org/index.html
http://www.miniboox.de/index.php
http://www.minilibris.de
http://en.wikipedia.org/wiki/Miniature_book
http://www.indiana.edu/~liblilly/miniatures/index.shtml

Photographs by Daria Bouwman and Falk Thielicke (Minilibris, Berlin)

Note by the Editor

The booklet at the right, more in line with the logarithmical focus of IM2010, regrettably does *not* meet the Miniature Book requirements, with its over-size spine length of some 5 inches.

PORTRAIT MINIATURES
Masterpieces in Little

Inge C. Rudowski

Inge C. Rudowski, née Malcus, worked as a travel agent. Some 30 years ago she bought her first portrait miniature in England and English miniaturists are still her favourites.

But Inge also shares her husband's hobby for calculating instruments. She is particularly interested in the people "behind" or responsible for developing such instruments or using them. Their life and portraits of them has been subject of several articles and presentations.

Inge is also active in the parish of her home town and gives lectures on arts, clerical mathematicians and foreign countries.

The Beginning

In the 15th and 16th century photography was not yet invented. But people also liked to have portraits of their beloved either in their pocket or as part of their jewellery. At the end of the 15th century some painters tried to reduce normal portraits. This was done normally at courts or for the upper-class members.

The name miniature does not come from "mini = little", as one can think. The origin is the Latin word *minium*. It means a colour, a special red, which we know as red lead.

One of the first miniature painters was **Gerard Horenbout**, a member of a well-known Flemish generation of painters. He started with illuminations of religious manuscripts. He lived and worked in Gent and had a son – **Lucas** and a daughter – **Susanna**. Both became miniature painters. 1521 Albrecht Dürer visited Horenbout in Gent and acquired a miniature painted by Susanna, very special for that time. The siblings went to England in 1522 and Lucas became court painter to Henry VIII. One can say he was the founder of the portrait miniature painting in England. Nowadays 23 portrait miniatures by him have been recorded; nearly all portraits of members of the court in England.

One of his pupils was **Hans Holbein the Younger** (1497/8 – 1543). He was born in Augsburg, lived in Switzerland – Lucerne and Basle. He was a well-known artist of his time and worked in France 1523/24. 1526 – 1528 he was in England for the first time. He then went back to Basle for another four years, where he was a member of the guild. He bought two houses there, but when the iconoclasts banned imagery in churches and destroyed some of his religious paintings he went back to England in 1532. He painted members of the Boleyn family and Thomas Cromwell. In 1536 he became court painter to Henry VIII and painted one of his most famous images of the king. Now he altered his style in portraits, in miniatures as well as in large portraits. He painted the court members and the members of the Royal family as i.e. Prince Edward as a child. 1538 he was on the continent to paint Christina of Denmark and Anne of Lorraine for Henry VIII, who was searching for a new wife. In 1539 he painted Anna of Cleves (Fig. 1). But Henry was disillusioned and married Anna only for a few months. Holbein was no longer a favourite at the court; he no longer portrayed members of the Royal family but still had private commissions. He died 1543 in London, but the location of his grave is unknown. His style in painting portraits, either life-sized or miniatures was painting people not laughing but looking very serious. His miniatures were often copies of normal portraits, the background mostly blue with golden inscriptions. One does not have any hint of the scholars trained by him.

Figure 1 (65 x 48 mm)

Figure 2 a (56 mm high)

Figure 2 b (detail 18 mm high)

Elizabeth I and Nicholas Hilliard

A very important miniature painter was **Nicholas Hilliard** (1547 – 1619). Like his father he was a goldsmith, but he became a limner (origin is the illuminator of manuscripts) or miniaturist. It is not known when he became court painter to Elizabeth I but the first known portrait of the Queen is from 1572. A painted *Booke of Portraitures* for Lord Leicester, a favourite of the Queen, could have been the first connection to the court. In 1576 he left England for France, perhaps he thought he could demand higher prices on his return. He stayed in France until 1578/79 and painted several dignitaries attending the court. After his return to England he received an annual allowance from the Queen of £ 40. In 1617 he obtained a monopoly on producing miniatures and engravings of James I. Hilliard worked as goldsmith as well and produced several outstanding lockets or boxes for miniatures. He was not a painter of the faces, he painted the Queen's face without shadows, but he was a master painter of cloths and jewels. He often dotted the paint to emphasize the lace, the jewels and to give a three-dimensionality of pearls (Fig. 2a, b). This miniature was sold at Christie's in London in June 2007 for about £ 276,000.

In November 2009 there was a sale at Bonhams, London, where two little portraits of Hilliard were sold; both 19 mm ø. They show Elizabeth I and Robert Dudley, Earl of Leicester. The hammer price was £ 72,000. One of his pupils was his son Laurence, who took over his father's business in 1613. Nicholas died 1619 and was buried in the Church of St. Martins-in-the-Fields.

Another pupil was **Isaac Oliver** (1565 – 1617), who in the 1590s became a competitor and in 1604 was appointed as limner to Queen Anne of Denmark and later in 1610 to the Prince of Wales. He had developed a more modern style; Fig. 3 shows a portrait of the Prince of Wales.

Figure 3 (67 mm high)

The next very important miniature painters were **John Hoskins** (ca. 1590 – 1665) and his nephew **Samuel Cooper** (1609 – 1672), who was called the van Dyck of the miniaturists. He was a master in painting amours and very shiny clothes. Cooper lived in London, near Covent Garden and the well-known Samuel Pepys (1633 – 1703) made many references to Cooper in his diary. He told us that the painter was also a talented musician. In 1668 Cooper painted a miniature of Mrs. Pepys, the price was £ 30. Pepys' diary, which he wrote from 1660 to 1669, is a very good source for the English Restoration period. During the IM 2008 we have heard about Pepys by Thomas Wyman, see *Proceedings IM 2008 – Diarist Samuel Pepys and Slide Rules*.

Techniques and Materials

The miniatures are painted in oil, watercolour, or in enamel. First they were done on vellum or parchment, later on ivory. Vellum is the very fine skin of lambs. Often this was mounted on playing cards to give a better stiffness (Fig. 4). Many miniatures were painted in oil on copper. Fig. 5a and 5b are examples painted around 1600. Then the enamellists became very famous. Enamel painting is a very special technique. In the next section we will have a closer look.

On the continent, at the end of the 17th century, **Rosalba Carriera** (1675- 1757) started to paint with watercolour on ivory. In England **Bernhard Lens** (1682 – 1740) was the first who took over this medium (ca. 1707). One could now paint with more colours and more shades and it was translucent. Lens was one of the most famous miniaturists from 1710 to 1740. Also some of his sons became miniature painters.

Figure 4 (80 mm ø)

Figure 5a & 5b (Flemish, 1600, 33 mm high)

The painting materials were pigments which the painters had to pulverize and to merge with special oils. They also used gum arabicum or sugar as binding agent. Very important were the brushes, sometimes one hair, i.e. from the tail of a squirrel or a sable. Fig. 6 and 7 give an impression of the colours and the ivory.

Figure 6

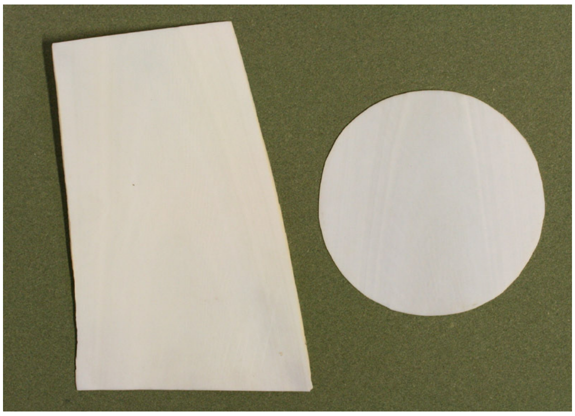


Figure 7

As you can see in Figure 8 there are more materials for miniatures; we have portraits as plumbago on paper. Some were painted with silverpoint. Other possibilities are watercolour on paper or paintings on porcelain.

Base Material	Paint/ Technique	Advantages/ Disadvantages
Parchment, Vellum	Watercolour, Oil	Watercolour: sensitive to light Oil: Background has to be stiffened, i.e. with a Playing card
Copper	Oil, Enamel	Oil: resistant to light Enamel: very resistant to light but susceptible to cracking
Gold	Enamel	Resistant to light, high susceptible to cracking and in general: injurious to health and change of colours when firing
Ivory	Watercolour	More colours, translucent but great sensitivity to light
Paper	Plumbago, Silverpoint, en Grisaille, Waterco-lour	Great sensitivity to light
Porcelain		Resistant to light, but susceptible to cracks

Figure 8

Enamel Painting

As said above enamel painting is very special. The enamellists mostly were goldsmiths, possibly because they were used to enamel from their work with dial-faces for watches and later specialized in enamel painting. The portraits have very clear colours and do not fade over the years. But the painters had to be very careful when working with enamel. It was difficult to use large plates, the surface could crack easily. Most of the artists use copper or gold plates. They had to enamel both sides, the plates were convex and the reverse was called counter enamel.

Sometimes one can find a signature or/ and a date on the counter enamel (Fig. 9). Both sides were first painted white, after the firing process – there could be up to 20 firings – the obverse was painted. The firing time was 2 to 15 minutes, depending on the properties of the paint. One had to start with the colour taking the longest firing time. So the painters had to take this into account before they started painting a miniature. Every firing process was dangerous; there could be a crack or a bubble which could not be replaced. The colours had to be prepared in a mortar and later mixed with oil (lavender or sandal wood) to get a kind of paste.

Figure 9 (25 mm high)

Enamel painting was very common on the continent in the 17^{th} and 18^{th} century. We found it on snuff boxes, watches, pendants, etc. There have been very famous enamel painters in Sweden, France, Switzerland, Germany and England. In Italy we found only very few, but nearly unknown was enamel painting in Spain and Portugal. It should have had a great success in those countries, because the very bright light was dangerous for watercolour paintings on paper or ivory.

Jean Petitot was one of the first painters who brought enamel painting to England in the 1630s. Later there was a Swedish artist – **Charles Boit** – who arrived in England in 1687. He visited the continent 1700 to 1703 and found a very talented painter in Dresden – **Christian Friedrich Zincke** (1683/4 – 1767). He is one of my favourites. His father was a goldsmith in Dresden and he was apprentice to him, but soon he discovered enamel painting as his medium. He came to England in 1706 and was pupil of Boit but soon he became better than his master. He was court painter to Queen Anne, King George I and King George II. Despite of an eye-illness which started in 1725 he was one of the most popular painters of his time. He painted the women as they wanted to be seen. That is he might have had half-finished miniatures ready and the ladies could choose their robe and the colour. Fig. 10 shows Zincke working, Fig. 11 and 12 gives some idea of his style. He had many pupils, i.e. **Jean Rouquet** (1701 – 1758), **William Prewett** (fl. 1735 – 1750) and **Abraham Seaman** (fl. ca. 1730). One of his best apprentices was **Jeremiah Meyer** (1735 – 1789), a son of a painter in Tubingen. He came to England at 12 or 14 years old and was learning from Zincke for two years. He started as an enamellist, but later switched to watercolour. 1764 he became court painter to Queen Charlotte and enamel painter to King George III. His style was very fine. He also was one of the founders of the Royal Society which had the first exhibition in 1769.

In the next generation of painters there was one very good enamel artist: **Henry Pierce Bone**. He lived from 1779 until 1855 and was enamel painter to Her Majesty & H.RH. Prince Albert. His father **Henry Bone** was a Cornish enamel painter (1755 – 1834).

Figure 10

Figure 11 (25 mm high)

Figure 12 (46 mm high)

Miniatures on Ivory

But in the 1750s new young miniature painters came on to the scene. They all preferred ivory as base material. The first were Richard Cosway and his contemporaries and competitors John Smart, George Engleheart and Andrew Plimer.

Richard Cosway (1742 – 1821)

He was born in Devon and came to London in the age of 12. 1755 he was the winner of a competition of miniature painters. The runner-up was John Smart, we will learn about him later. On 18 January 1781, Cosway married the Anglo-Italian artist Maria Hadfield. Maria was a painter, composer, musician and authority on girls' education and was much admired by Thomas Jefferson, who wrote letters to her decrying her marriage to another man and kept an engraving made from one of Cosway's paintings of Maria at Monticello (his home in Virginia). The Cosways had a so called grand salon which became fashionable for the London society. So his customers were mostly coming from this part. He also painted well-known people in France, as there was Madame Dubarry.

John Smart (1741 – 1811)

He was born in Norfolk, but very little is known of his early life. In 1755 he was second in a competition for young painters under 14 years old. He mainly painted watercolours on ivory, and often clearly signed and dated his work. Quite a number of his preparatory drawings and sketches also survive (Fig. 13). Smart exhibited at the Society of Artists, in London, from 1762 onwards; and became its president in 1778. From 1788 until 1797 he lived in Madras (India). There he painted maharajas, people of the local high society, and members of the colonial troops and the tradesmen of the East India Company. They still were his clients in England after his return. His only son was also a painter of miniatures. Like his father, he also went to India, where he died in 1809.

In Kansas City, USA, the Nelson-Atkins-Museum has 50 miniatures by Smart; a collector bought one miniature from every year between 1761 and 1811. I think that makes an outstanding portfolio.

Miniatures of John Smart are a highlight in every collection. He is one of my favourite painters, even his sketches are wonderful. Fig. 14 -16 shows his style.

Figure 13 (32 mm high)

Figure 14

Figure 15

Figure 16 (86 mm)

George Engleheart (ca. 1750 – 1829)

He is thought to have been born in Kew as the son of a German plaster modeller (named Francis Engelhart). After his father's death he changed the name to a more English version. In 1769 he entered the new Royal Academy School and was a pupil of George Barrett and Sir Joshua Reynolds. In 1773 he started his own business.

Engleheart was a prolific artist: during the period of 39 years covered by his fee book, no less than 4,853 miniatures are recorded as having been executed by him. His fees ranged from 4 guineas in 1775, up to 25 guineas by 1811. His professional income for many years exceeded £1,200 per annum. He lived and worked in London, mainly in the Hertford Street in Mayfair. He signed most of his work with E or G.E. Some paintings have a signature and date on the reverse. His style is unique; especially his eyes are very deep. I like his portraits and you can see some examples in Fig. 17 – 19.

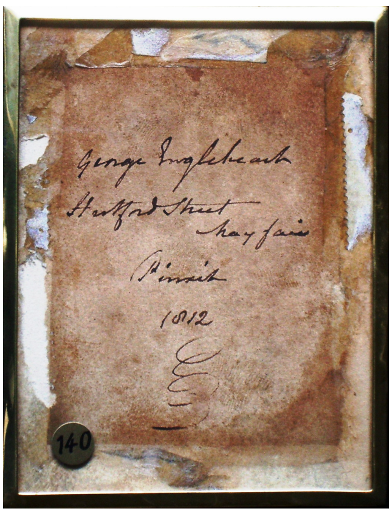


Figure 17a & b (84 mm high)

Figure 18 (41 mm high)

Figure 19 (62 mm high)

Andrew Plimer (1763 – 1837)

Plimer was a son of a clock-maker. He and his brother Nathaniel joined a group of roaming gypsies and travelled with them, eventually reaching London in 1781. He presented himself to Mrs. Cosway and was engaged as studio junior. Richard Cosway very soon detected Plimer's skill in painting and so he was sent to a friend to learn drawing. Afterwards he worked and learned in Cosway's studio until 1785, when he started his own business. He exhibited many times in the Royal Academy. His miniatures are of great brilliance and they are to be distinguished by the peculiar wiry treatment of the hair and by the large full expressive eyes (Fig. 20).

Figure 20 (79 mm high)

There were many, many more painters I could have included, but I think these examples give a good summary.

It is very interesting that miniature painters have always earned their money; there is no comparison with normal painters. Miniatures were painted on commission. So they had their regular income.

Other Forms of Portraits

As said at the beginning, there are more materials for miniatures. Sometimes we find reliefs in ivory, or reliefs in paste – a very special field of **James Tassie** (1735 – 1799), a Scotsman. He was a gem engraver and modeller and used also wax for his portraits. Another method is the silhouette. Two of the well-known artists are **John Field** (1772 - 1848) and **John Miers** (1758 – 1821). But this is such a complex subject it has to fall outside the scope of this paper. Very special portraits were finished *en grisaille* or as plumbago. Fig. 21 -23 shows these varieties.

Figure 21 (90 mm)

Figure 22 (57 mm)

Figure 23 (45 mm)

The Reverse of Miniatures

A very interesting part of miniatures is the reverse side. We often find blue glass or opalescent glass and artistically arranged hair of the sitter with pearls and gold wire; sometimes as a monogram or decorated as flowers or just plaited hair (Fig. 24a - d).

Figure 24a (69 mm)

Figure 24b (50 mm)

Figure 24c (54 mm)

Figure 24d

Miniaturists nowadays

When photography was invented the portrait miniature painting nearly came to an end. But there are still some painters working, i.e. in England and in the States. They have their own Societies and annual exhibitions.

One of them is **William P. Mundy**. He is a very interesting and colourful person. Coming from the advertising business he became a fulltime painter after his return to England. He worked for a very long time in Asia. In Singapore, Bangkok and Hong Kong he painted miniatures of maharajas, their families, princes and princesses and people of society even in those countries. He wrote an autobiography with the title "A life with a Brush". He presented this book to the public at the end of 2008 in the Raffles Hotel, Singapore. He lives in Henley-on-Thames, nearly one hour from London. He also painted HRH Prince Philip, Duke of Edinburgh. His work is represented in the Royal Collection, the Cincinnati Museum of Art in the

Figure 25

USA, the Thai Royal Collection, and the Malaysian Royal Collections in Pahang and Johor. He was commissioned to paint an equestrian miniature portrait for HM Queen Elizabeth II. Miniatures by Bill Mundy are the only works by a living artist on display at the Victoria and Albert Museum in London. He has received lots of awards and has exhibited every year at the Royal Academy Summer Exhibition. Fig. 25 shows him at work.

Different Fittings for Miniatures

Portrait miniatures were not only fitted in frames of different shapes. The very first miniatures were inside pendants or part of valuable jewellery. One can find them as a bracelet clasp, in a ring, on a watch-case or on top of snuff boxes or sometimes as hidden miniatures inside gold or tortoiseshell boxes; on top of *carnets de bal* or small ivory boxes for tooth picks (Fig. 26). Two very special forms should not be overlooked: First painted by Engleheart, the eye-miniature was intended as a love token (Fig. 27). The second form was the mourning miniature. Mostly found on the reverse, these miniatures often show a person in mourning beside an urn.

Figure 26 (70 mm long)

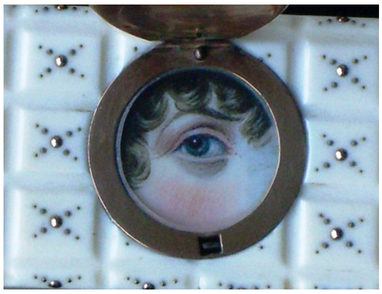


Figure 27 (eye = 16 mm ø)

Portrait Miniatures of Mathematicians

Up to now I know of two portrait miniatures of people connected to either mathematics or slide rules. The first is a portrait of Charles Babbage which was sold at Bonhams, London in November 2005. It was painted by Sir William Newton, signed and dated 1851 (Fig. 28). The estimate was GBP 1,000 – 1,500. The new owner had to pay slightly more than GBP 8,000 due to the high interest. Another miniature came up in May 2007. It shows Robert Burns, the famous Scottish poet, who was an excise man for several years and had to use an Everard's slide rule in his daily work. The miniature was painted ca. 1790, Scottish School (Fig. 29). The reverse side of the gold frame was engraved "Robert Burns". The total price was GBP 2,640. I think it was bought because of the famous poet. In various Gazette one can find articles on both images.

Figure 28 (162 mm high)

Figure 29 (55 mm high)

Where are Portrait Miniatures on Display?

There are several museums which have a Portrait Miniature collection. The most famous are the Victoria & Albert Museum, the Wallace Collection, The Royal Collection, the Gilbert Collection, the National Portrait Gallery all in London, the Fitzwilliam Museum in Cambridge, the Ashmolean Museum Oxford, the Boman Museum in Celle (Germany), the Bruni Tedeschi Collection in the Palazzo Madama in Turino, and so on.

Conclusion

One can see this is a fascinating field in the large world of art. There are so many different styles not only in the technique, but also in the fittings chosen for mounting the miniatures. Any collector will always find new and interesting items.

Acknowledgement

I have to thank Jo Langston (Christie's) and Camilla Lombardi (Bonhams) for supplying most of the excellent images and the permission to publish them. Also, I have to thank Bill Mundy for the allowance to show his photograph and his miniatures.

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L'INTRODUCTION DES RÈGLES À CALCUL EN FRANCE[1] au XIXe Siècle (1815-1852)

Marc Thomas

Marc Thomas est professeur de mathématiques en lycée à Nantes. Il vient de prendre sa retraite en juillet 2010. Il prépare une thèse de doctorat en Histoire des Sciences et Techniques au Centre François Viète de l'Université de Nantes, sur les premiers fabricants français de règles à calcul.

Résumé

Les règles à calcul ne sont vraiment apparues en France qu'au début du **XIX**e siècle. Auparavant, on trouve quelques références aux instruments logarithmiques du type "règles de Gunter", en particulier dans des ouvrages destinés aux élèves des écoles d'hydrographie de la marine. C'est à partir de 1815 que Jomard présente cet instrument et demande à Lenoir d'en fabriquer. Les premières règles à calcul françaises sont mises en vente en 1821. Les premiers manuels d'instruction paraissent peu de temps après. Les ateliers Gravet-Lenoir, puis Tavernier-Gravet prennent ensuite le relais. En 1851, Mannheim conçoit le nouveau système d'échelles qui porte son nom et l'année suivante, le maniement de la règle à calcul fait partie des connaissances exigées par les candidats aux écoles d'ingénieur. C'est le début de la règle à calcul moderne. Nous voulons présenter les principaux acteurs de cette période qui a vu la diffusion de la règle à calcul en France.

Introduction

Denis Henrion, mort en 1640, est un de ceux qui ont introduit les logarithmes en France, dans son *Traité des logarithmes*, publié en 1626. Cette même année, il publie le *Logocanon*, dans lequel il décrit la manière de construire un instrument logarithmique, sur le modèle de la règle de Gunter.

La gravure ci-dessous, extraite de l'ouvrage, montre bien, en haut, "l'échelle" et les "lignes" des logarithmes, tangentes et sinus; l'instrument comporte d'autres échelles, celles des compas de proportion, ainsi que tout un système de calcul graphique.

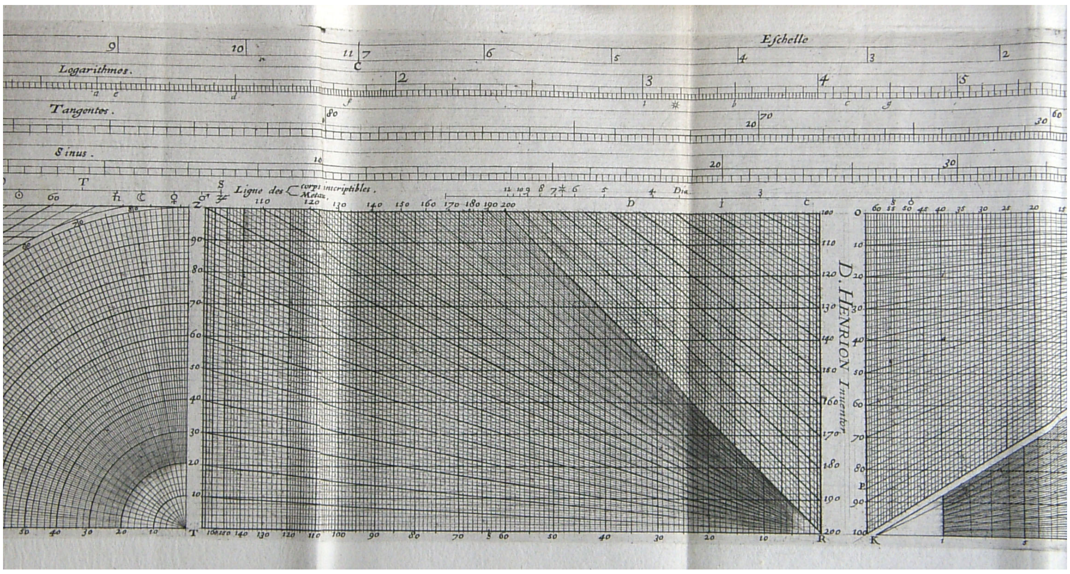


fig. 1 - Le Logocanon

[1] An English translation of the text follows this article, on page 31

Contrairement à la Grande-Bretagne, avant le XIXe siècle en France, il n'est nulle part fait mention de fabricants d'instruments de mesure qui produisent régulièrement des règles à calcul. Les seuls instruments logarithmiques utilisés ou préconisés sont tous basés sur le modèle d'Henrion, c'est-à-dire pratiquement la règle de Gunter, qui fera autorité pendant plus d'un siècle et demi. Ces règles sont souvent appelées "règles anglaises" dans les descriptions.

Il faut citer en particulier *Joseph Sauveur* (1653 – 1716), qui publie à la fin du XVIIe siècle les "*Eléments de géométrie*", republiés en 1753 en version corrigée et augmentée par Leblond sous le titre "*Géométrie élémentaire et pratique*". Dans cet ouvrage, on trouve l'article "De la règle logarithmique". Sauveur précise alors que "cette règle est utile pour les calculs dont l'erreur de un ou deux pour mille est comptée pour rien."

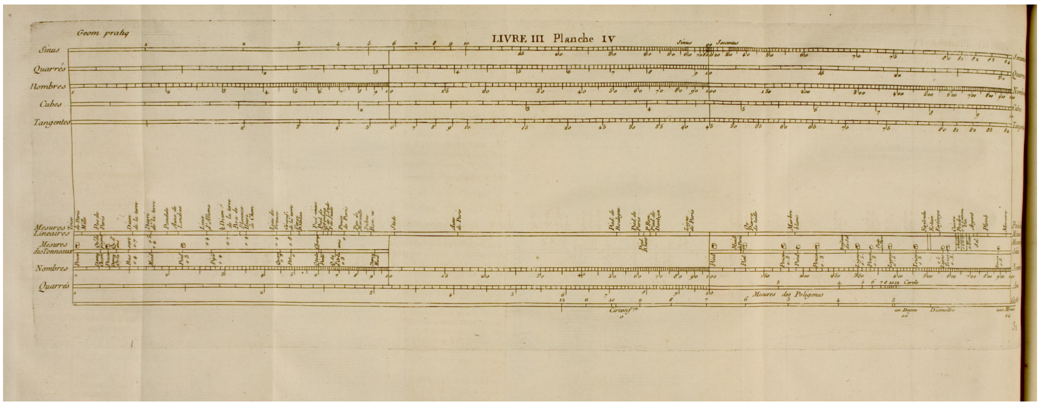


fig. 2 - La règle de Sauveur

Sauveur n'ajoute pratiquement rien à Henrion. Il indique cependant d'autres possibilités: par exemple, "l'on pourrait ajouter sur cette règle la ligne des monnaies, si elles avaient un rapport fixe". Il a fait réaliser une règle de ce type en 1700, par Sevin et Le Bas, constructeurs réputés d'instruments scientifiques. Cette règle de laiton, d'une construction très soignée, est exposée au musée du CNAM à Paris.

On trouve également des références aux instruments logarithmiques dans les manuels d'hydrographie, en particulier celui de *Pierre Bouguer* (1698-1758). Il publie, en 1753, à la demande du ministre de la marine, un "*Nouveau traité de navigation, contenant la théorie et la pratique du pilotage*", qui servira de référence dans toutes les écoles d'hydrographie. Dans ce traité, il donne deux moyens de faire les calculs: le quartier de réduction, instrument classique à l'époque, et l'emploi des logarithmes et des échelles logarithmiques. Il précise aussi qu'il avait envisagé de fabriquer une règle à calcul circulaire, mais il ne semble pas l'avoir réalisée.

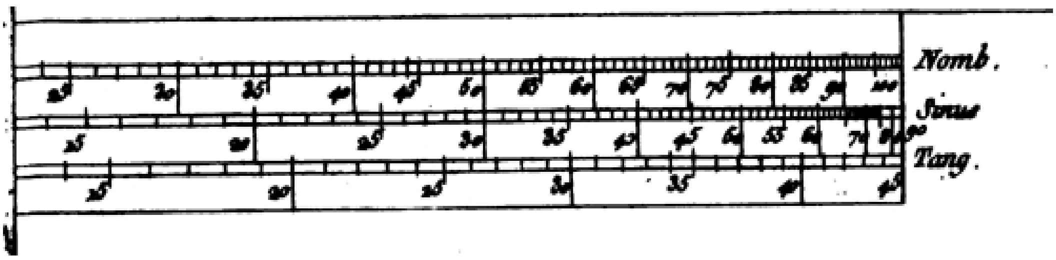


fig. 3 - L'échelle des logarithmes dans le traité de Bouguer

Les premières règles à calcul de Lenoir

La règle à calcul sera véritablement introduite en France et commencera à y être fabriquée de manière permanente seulement au début du XIXe siècle. Cela ne se fera pas sans peine: le rôle joué par quelques hommes, soutenus par la Société d'Encouragement pour l'Industrie Nationale, est essentiel dans cet épisode. Voici les principaux acteurs.

Edme-François Jomard

Edme-François Jomard (1777-1862), élève brillant et précoce, est entré à l'École polytechnique dans la première promotion (1794). Quelques années plus tard, il participe à l'expédition d'Égypte en qualité d'ingénieur géographe. En 1814, à la Première Restauration, il est envoyé en mission en Angleterre pour des questions liées aux antiquités égyptiennes: il y reste jusqu'à la chute définitive de l'Empire. C'est au cours de ce séjour qu'il est enthousiasmé par la règle à calcul et l'usage qui en est fait, et dont il rapporte quelques exemplaires en France. Il s'empresse alors de faire partager son enthousiasme autour de lui, comme nous le verrons. Jomard poursuivra une brillante carrière de géographe, et, savant reconnu et homme de réseau, entretenant une importante correspondance, il deviendra membre de l'Institut et de nombreuses sociétés savantes, tout en continuant à militer pour une généralisation de l'enseignement élémentaire.

fig. 4 - Edme-François Jomard

fig. 5 - Etienne Lenoir

Etienne et Paul-Etienne Lenoir

Etienne Lenoir (1744-1832) est déjà depuis un certain temps, à l'époque qui nous intéresse, un des artistes les plus reconnus en France pour la fabrication d'instruments scientifiques. Il dispose à Paris d'un atelier spécialisé dans la construction d'instruments de précision, situé à cette époque au 340 rue St Honoré. En particulier il utilise déjà des machines à diviser qui permettent de graver des graduations d'une manière très précise, qu'il s'efforce de perfectionner sans cesse. Il continuera à travailler pratiquement jusqu'à la fin de sa vie.

Son fils Paul-Etienne (1776-1827), tout comme Jomard, fait partie de l'expédition d'Égypte. Nous ne savons pas s'ils s'y sont rencontrés… Ensuite il travaille avec son père dans leur atelier. Ce sont les Lenoir qui, les premiers en France, ont fabriqué des règles à calcul destinées à une diffusion importante.

La Société d'Encouragement pour l'Industrie Nationale (SEIN)

La Société d'Encouragement pour l'Industrie Nationale a été fondée le 1er novembre 1801, sous l'impulsion de Chaptal, qui en sera le premier président. Son but est de mettre la science au service de l'industrie et de susciter l'innovation technologique et sa diffusion. A cette époque, il s'agit aussi de combler le retard technologique par rapport à l'Angleterre, et le Premier Consul Bonaparte soutient cette initiative. La Société d'Encouragement existe toujours. C'est à la SEIN que Jomard fera, entre 1815 et 1820, une série de communications que nous présentons maintenant.

Les communications de Jomard à la SEIN

Jomard a été admis à la Société d'Encouragement en date du 1er janvier 1815, et sa première communication, faite à la section des Arts Mécaniques, a été publiée en août 1815 dans la Bulletin de la Société d'Encouragement. Il y décrit la règle à calcul:

> "qui est une espèce de machine, aujourd'hui portée à un grand degré de perfection. C'est un moyen de faire tous les calculs sans plume, sans crayon, ni papier [...], et sans savoir l'arithmétique. [...] Elles peuvent servir aux savants, aux ingénieurs, aux négociants, aux ouvriers, à presque tout le monde. [...] Il est donc à désirer qu'elle devienne d'un usage tout à fait populaire, et que le prix en soit mis à la portée de tout le monde, sans perdre de vue cependant la parfaite division, faute de laquelle cet instrument serait absolument à rejeter. A Londres, la règle d'un pied vaut aujourd'hui 5 shillings. Je crois qu'on pourrait ici la fabriquer pour 4 ou 5 francs."

La règle à calcul est donc perçue et présentée par Jomard comme un instrument simple, d'usage général, accessible à beaucoup. Elle doit être mise entre toutes les mains et utilisée dans la vie quotidienne. Il a déjà pris des contacts pour faire fabriquer des règles: il faut en effet calculer les divisions des échelles logarithmiques, et les faire exécuter par un atelier compétent, car la précision d'une règle à calcul dépend évidemment de la qualité des échelles.

> "On s'occupe de fabriquer à Paris des règles à calculer, assujetties aux mesures françaises, et qui sans être beaucoup plus longues, auront deux fois plus de précision que la règle anglaise d'un pied. C'est à M. Lenoir, habile ingénieur en instruments que j'ai confié ce travail. Je suis redevable de tous les calculs qu'exige la parfaite construction de cette règle, à M. Corabœuf, capitaine au Corps Royal des ingénieurs géographes."

Cette communication présente à bien des égards un intérêt capital pour l'introduction de la règle à calculer en France. C'est à partir de ce moment que, avec le soutien de la Société d'Encouragement, et en particulier de Francœur, du comité des arts mécaniques, va se développer un réel intérêt pour cet instrument.

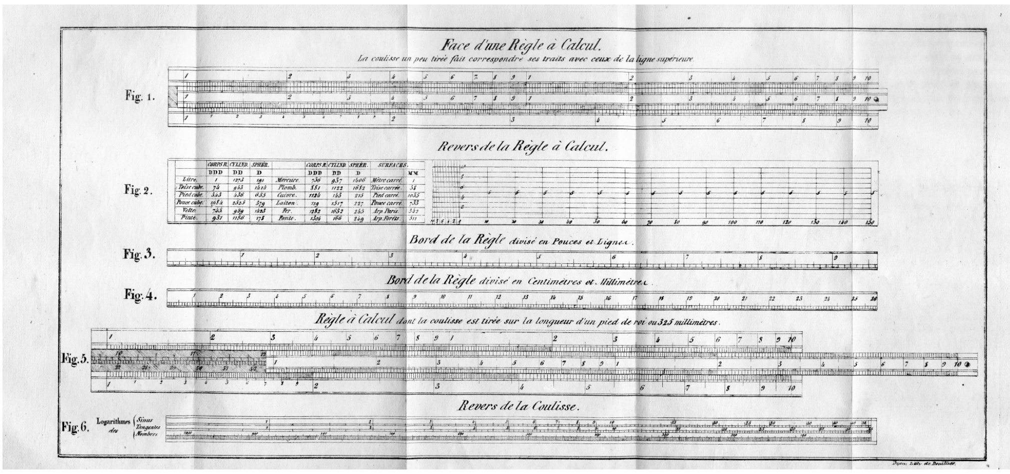


fig. 6 - La règle à calcul type Soho (gravure extraite de la communication de Jomard)

La fabrication et ses difficultés

Il faut attendre 1820 pour que Lenoir fournisse le premier prototype de ses règles à calcul. Voici ce que dit Jomard dans une communication à la Société d'Encouragement le 7 février 1821: "La promesse que l'on faisait alors [en 1815], est aujourd'hui réalisée. On a déposé, à la fin de l'année dernière la première de ces règles, exécutée en cuivre et réalisée avec soin; les règles pour l'usage ordinaire sont en bois." Il s'agit donc ici du dépôt, sans doute à des fins de protection, du modèle d'une règle à calcul en cuivre, qui n'est pas le modèle courant. Mais ce passage nous donne un renseignement très précis: en France, c'est en 1820, à la fin de l'année, dans les ateliers de Lenoir à Paris, qu'a été fabriquée la première règle à calcul de type Soho, c'est-à-dire en fait la première règle à calcul réellement utilisable par les ingénieurs et les techniciens de toutes spécialités. Cette date est assez précise et nous permet donc de bien situer cet événement. Ce modèle est en cuivre, comme indiqué, et mesure 36 cm de long. Il s'est donc passé cinq ans entre le premier article de Jomard et la fabrication effective d'une règle à calcul (il s'agit là d'un prototype) telle qu'il la souhaitait.

Francœur nous fournit de précieuses indications sur les problèmes et les difficultés rencontrés par Lenoir:

> "M. *Jomard* […] ne tarda point à reconnaître qu'il ne suffit pas de signaler un bon instrument pour déterminer les uns à le construire, les autres à s'en servir. Il confia à l'habile ingénieur, M. *Lenoir*, le soin d'exécuter ces échelles d'après ces données. L'opération ne s'est faite que très lentement, à raison des difficultés attachées à ce travail, qu'il fallait produire en grand et à bas prix. […] M. *Lenoir*, comprenant que cette invention ne pouvait se répandre dans le public qu'autant que ces règles seraient livrées à bas prix, a conçu et établi, avec le soin qui distingue toutes ses productions, une machine qui marque à la fois les divisions sur huit règles, et bientôt il pourra en diviser ensemble un plus grand nombre."

> "M. *Collardeau*, ancien élève de l'Ecole Polytechnique, considérant que les règles, sous la dimension que M. *Jomard* leur a donnée, étaient trop longues pour être commodément portatives, et avaient leurs divisions trop serrées pour pouvoir être manœuvrées par les hommes du peuple, en a fabriqué de la longueur de 26 centimètres. Ce jeune homme, embrassant la carrière des fabricants d'instruments de mathématiques, s'est fait apprenti et travaille dans les ateliers de M. *Lenoir*, où il s'occupe maintenant à diviser les règles. Ces règles n'ont pas la même précision que celles de M. *Jomard*, mais elles sont plus portatives, et pourront, dans plusieurs cas, mériter la préférence. Leur exécution est supérieure à celles des meilleures règles anglaises, auxquelles on les a comparées avec soin."

Les prix sont de 10 francs pour le modèle de Jomard et de 5 francs pour celui de Collardeau. Ils sont donc modérés, On retrouve une volonté de la part de tous les intervenants de rendre la règle à calcul abordable. La commercialisation commence donc au premier trimestre 1821. Lenoir a fabriqué également certains modèles plus luxueux, certainement beaucoup plus coûteux, puisqu'il existe au musée du CNAM à Paris un modèle portant sa signature de 36cm en ivoire présenté dans une boîte capitonnée…

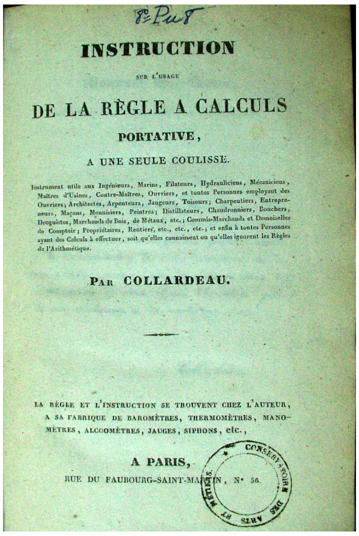
Les premiers livres d'instructions sur la règle à calcul

En 1824, le *Bulletin des sciences mathématiques* fait le point sur les manuels d'instruction qui ont été publiés. Nous apprenons dans la même note que Lenoir a organisé des cours gratuits dans ses ateliers:

> "Nous avons parlé d'une instruction publiée à Dijon. Cet ouvrage vient de servir de base à un cours gratuit en 8 leçons, ouvert le 13 août chez M. Lenoir, […] et fait par M. Artur, professeur de mathématiques. […] Il existe sur ces règles trois instructions différentes; une 1re, par M. Collardeau, élève de l'école polytechnique, prix 2 f. une 2^{e}, par M. Mouzin, 1re édition, prix 1f. 25c., Dijon; une 3^{e}, par le même, 2^{e} édition: prix 2 f."

Quelques années plus tard, en 1827, Artur publie également un manuel d'instructions; peut-être est-ce le produit de ses cours chez Lenoir?

Le premier manuel publié est celui de *Collardeau*, en 1820. En effet, Artur l'indique dans sa préface: "Monsieur Collardeau, élève de l'école polytechnique, a publié en 1820, la première instruction française sur cet instrument, en prenant pour modèle l'instruction anglaise que lui avait remise M. Hachette, à son retour d'Angleterre." La filiation anglaise est bien présente… L'édition que nous avons pu consulter est de 1833. L'auteur, (Charles Félix Collardeau du Heaulme ou Duhaume, 1796-1869) polytechnicien de la promotion de 1815, est celui dont nous parle Francœur dans son article sur la règle à calcul; il a donc travaillé avec Jomard, et chez Lenoir pour se familiariser avec les méthodes de construction. Il a aussi beaucoup travaillé avec Gay-Lussac, auquel il rend hommage au début de son livre, et est devenu fabricant d'instruments de précision au 47 rue du Faubourg Saint Martin à Paris. Il s'est d'ailleurs un moment présenté comme "successeur de Lenoir", mais nous reviendrons sur cette "succession". Son ouvrage sur la règle à calcul est signé "Collardeau". Son manuel a donc été réédité au moins une fois en 1833.



INSTRUCTION
SUR L'USAGE
DE LA RÈGLE A CALCULS
PORTATIVE,
A UNE SEULE COULISSE.

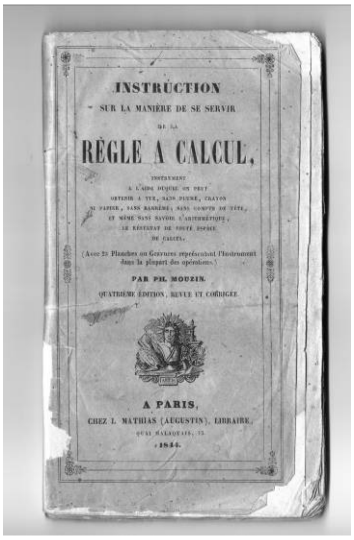
Instrument utile aux Ingénieurs, Marins, Filateurs, Hydrauliciens, Mécaniciens, Maîtres d'Usines, Contre-Maîtres, Ouvriers, et toutes Personnes employant des Ouvriers; Architectes, Arpenteurs, Jaugeurs, Toiseurs; Charpentiers, Entrepreneurs, Maçons, Menuisiers, Peintres; Distillateurs, Chaudronniers, Bouchers, Droguistes, Marchands de Bois, de Métaux, etc.; Commis-Marchands et Demoiselles de Comptoir; Propriétaires, Rentiers, etc., etc., etc.; et enfin à toutes Personnes ayant des Calculs à effectuer, soit qu'elles connaissent ou qu'elles ignorent les Règles de l'Arithmétique.

PAR COLLARDEAU.

LA RÈGLE ET L'INSTRUCTION SE TROUVENT CHEZ L'AUTEUR, A SA FABRIQUE DE BAROMÈTRES, THERMOMÈTRES, MANOMÈTRES, ALCOOMÈTRES, JAUGES, SIPHONS, etc.,

A PARIS,
RUE DU FAUBOURG-SAINT-MARTIN, N° 56.

fig. 7 - Collardeau

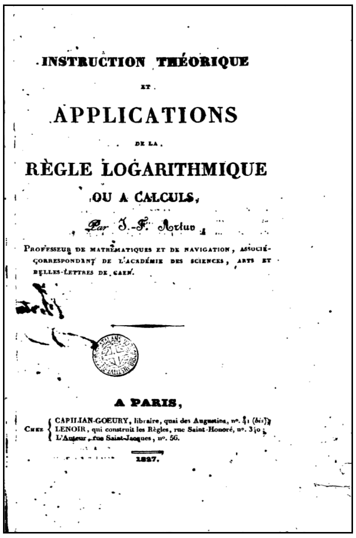


INSTRUCTION
SUR LA MANIÈRE DE SE SERVIR
RÈGLE A CALCUL,

PAR PH. MOUZIN.
QUATRIÈME ÉDITION, REVUE ET CORRIGÉE.

A PARIS,
CHEZ L. MATHIAS (AUGUSTIN), LIBRAIRE,
1844.

fig. 8 - Mouzin



INSTRUCTION THÉORIQUE
ET
APPLICATIONS
DE LA
RÈGLE LOGARITHMIQUE
OU A CALCULS,
Par J.-F. Artur,
PROFESSEUR DE MATHÉMATIQUES ET DE NAVIGATION, ASSOCIÉ-CORRESPONDANT DE L'ACADÉMIE DES SCIENCES, ARTS ET BELLES-LETTRES DE CAEN.

A PARIS,
CHEZ CAPILIAN-GOEURY, libraire, quai des Augustins, n°. 41 (bis);
LENOIR, qui construit les Règles, rue Saint-Honoré, n°. 340;
L'Auteur, rue Saint-Jacques, n°. 56.
1827.

fig. 9 - Artur

Le deuxième cité est *Ph. Mouzin*, dont Jomard dit qu'il est avocat à Dijon et qui se présente aussi comme mathématicien. Son ouvrage aura au moins quatre éditions entre 1824 et 1844, en général à Paris et Dijon.

Enfin, le troisième manuel est de *J.-F. Artur*, celui-là même qui donnait les cours gratuits chez Lenoir. Artur devait connaître Lenoir depuis un certain temps, puisqu'il a publié un manuel d'instructions concernant le cercle répétiteur de Borda, construit par Lenoir. Il se présente comme ″professeur de mathématiques et de navigation, associé correspondant de l'académie des sciences, arts et belles lettres de Caen″. La première édition date de 1827, et il faut remarquer que son livre est publié, entre autres, ″chez Lenoir, qui construit les règles, rue Saint Honoré, n° 340″. Il a connu au moins une autre édition en 1845.

Ces trois livres, assez courts (celui de Collardeau contient 92 pages, celui de Mouzin 122 et celui d'Artur, un peu plus important, 155) sont conçus à peu près sur le même plan. Il s'agit dans tous les cas de présenter un objet assez nouveau, d'en décrire ou d'en vanter les possibilités, et enfin d'expliquer la manière de s'en servir, en partant des cas les plus simples jusqu'aux plus compliqués, accompagnés d'exemples et d'exercices, certains demandant une vraie virtuosité, avec des considérations théoriques plus ou moins importantes, surtout, bien sûr, concernant les logarithmes.

Le titre du livre de Mouzin est complété par les précisions suivantes: ″instrument à l'aide duquel on peut obtenir à vue, sans plume, crayon ni papier, sans barème, sans compte de tête, et même sans savoir l'arithmétique, le résultat de toute espèce de calcul.″ Il s'agit cette fois d'indiquer ce que l'on peut faire avec la règle, plutôt que d'énumérer les différents corps de métiers intéressés.

A cet égard, le titre de l'ouvrage d'Artur est sensiblement différent: ″Instructions théoriques et applications de la règle logarithmique ou à calculs″, sans autre précision sur cette page. On passe donc de ″l'instruction sur l'usage″, ou ″sur la manière de se servir″, à un manuel ″d'instructions théoriques″, où l'usage et l'utilisation deviennent des applications. Au moins au niveau du titre, le manuel d'Artur apparaît donc comme plus ″savant″, plutôt dirigé vers des lecteurs familiers de certaines connaissances mathématiques.

Le vocabulaire utilisé pour décrire la règle à calcul et ses diverses parties n'est évidemment pas encore fixé: la partie coulissante s'appelle coulisse chez les trois auteurs, (Artur utilise aussi réglette), mais le mot ″curseur″, utilisé par Artur, n'a rien à voir avec son acception moderne. De même le mot échelle n'a pas exactement le même sens.

Il faut noter cependant qu'à la fin de son ouvrage, au moins à partit de la troisième édition (1837), Mouzin parle du curseur, au sens moderne du terme, (c'est-à-dire une petite pièce en métal ou en verre, puis en plastique évidemment, permettant de bien aligner et repérer des valeurs sur la règle), sans l'appeler ainsi:

> "On ajoute quelquefois à la règle à calcul une pièce en cuivre qui peut glisser le long de l'instrument. Elle donne le moyen d'établir plus exactement la coïncidence des traits de la ligne supérieure avec ceux des lignes des sinus et tangentes. On peut encore s'en servir pour marquer le point où l'on est arrivé par une première opération, lorsqu'on a besoin d'en faire une seconde pour parvenir au résultat."

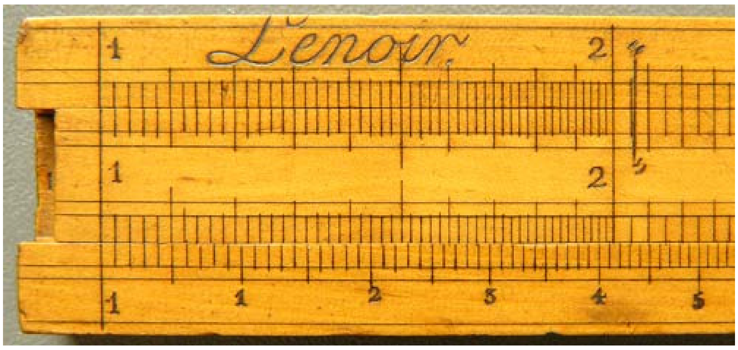
Ainsi le curseur, contrairement à ce qui est souvent écrit, était apparu avant la règle Mannheim de 1851.

Nous pouvons noter que les manuels de Mouzin et d'Artur ont connu plusieurs éditions, et qu'ils ont été publiés pendant près de vingt ans, ce qui laisse à penser que la règle à calcul commence alors à faire son chemin en France.

Deux exemples de règles à calcul fabriquées par Lenoir

Voici à titre d'exemples deux règles fabriquées par Lenoir. Elles portent toutes deux sa signature. Une de leurs principales caractéristiques communes est la présence de deux unités de longueur: cm et mm d'une part, et pouces (de Paris) et lignes (1 pouce = 12 lignes) d'autre part. Cela permet de les dater des années 1825-1830, car ensuite on ne trouve plus les anciennes unités de longueur.

La première (collection. *E Pommel*) mesure 26 cm. La seconde (collection *M. Thomas*) mesure 36 cm. Elles sont toutes deux en bois (sans doute du buis). Leur principale différence est le recto. (voir les photos)



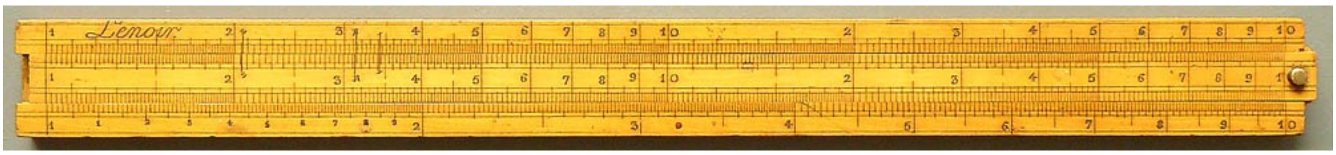


fig. 10 - Règle Lenoir de 26 cm (Coll. E. Pommel)

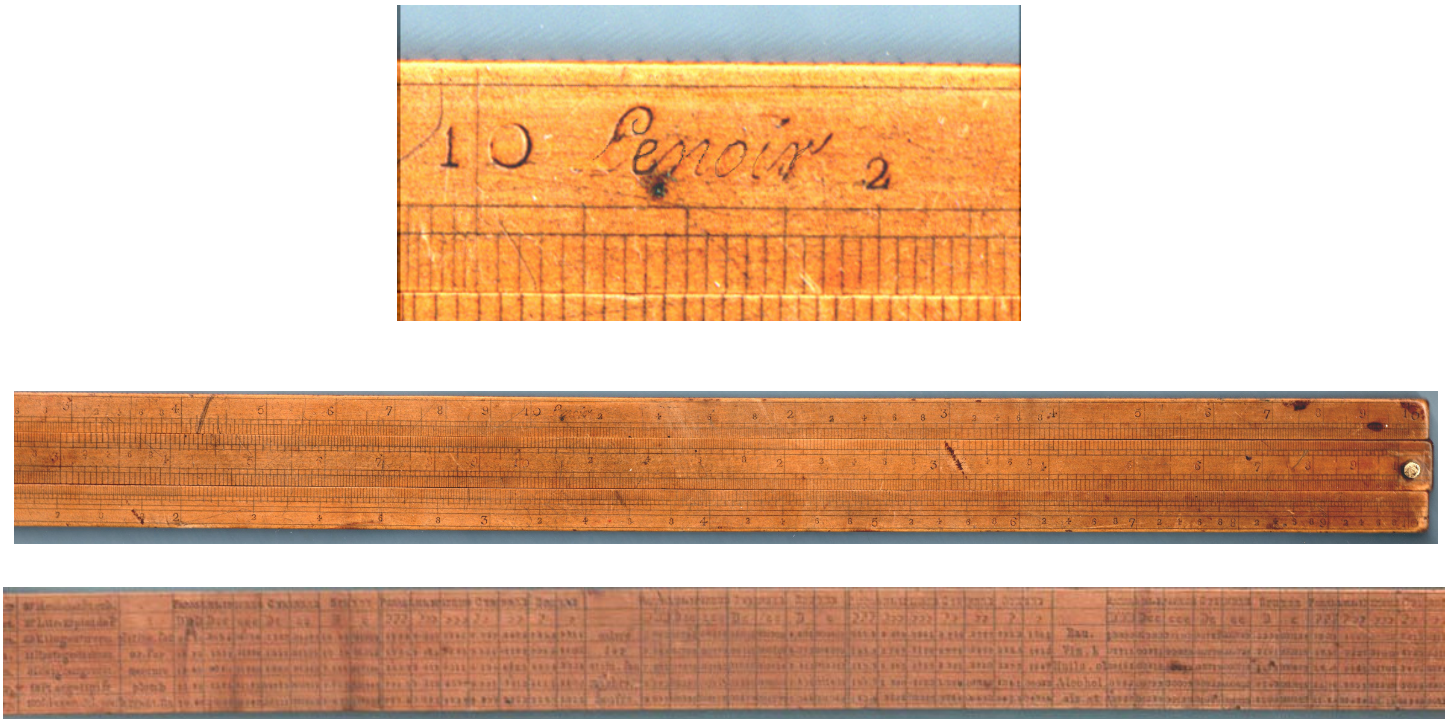


fig. 11 - Règle Lenoir de 36 cm (Coll. M. Thomas)

On peut dire que, vers les années 1830, les principaux éléments en France sont en place pour qu'une réelle diffusion puisse commencer: quelques fabricants sont prêts, les modèles de règle sont au point, les prix abordables, les manuels d'instructions existent, des articles paraissent dans des revues, des dictionnaires: le monde savant sait que cet instrument existe et qu'il répond à un besoin. Nous sommes encore bien loin cependant d'une diffusion massive.

Les successeurs de Lenoir

Etienne Lenoir est mort en 1832; son fils Paul-Etienne était décédé en 1827. Un de ses employés, nommé *Mabire*, a pris sa suite à la même adresse: 14 rue Cassette à Paris. Mais celui qui se révélera être vraiment le successeur de Lenoir, en ce qui concerne les règles à calcul, est *Gravet*. Qui est-il? Nous n'avons guère de renseignements sur Monsieur Gravet. C'est un fabricant d'instruments scientifiques, peut-être un "lunetier"; est-il un "élève" de Lenoir, travaillait-il dans son atelier? En tout cas il est déjà bien connu en 1844, puisqu'il reçoit une médaille de bronze du jury central sur les produits de l'industrie française, section "instruments de précision" pour un niveau à réflexion. Le rapport du jury cite également une boussole, mais surtout une phrase porte un éclairage particulièrement intéressant sur notre sujet: "Ses règles à calculer sont tellement en faveur aujourd'hui, que nous croyons pouvoir nous dispenser d'en faire ici l'éloge". Son adresse est la même que celle de Mabire, et donc de Lenoir: 14, rue Cassette. On trouve également, sur un petit livre d'instruction de 1843: "Se vend chez GRAVET, successeur de LENOIR, fabricant d'instrument de mathématiques et de règles à calcul." Par quelles péripéties cette "succession" est-elle passée? En tout cas Gravet semble l'avoir emporté, puisqu'il vend bientôt ses règles sous le nom de GRAVET LENOIR 14, R. CASSETTE PARIS, et que le nom de Mabire n'apparaît plus dans les publications.

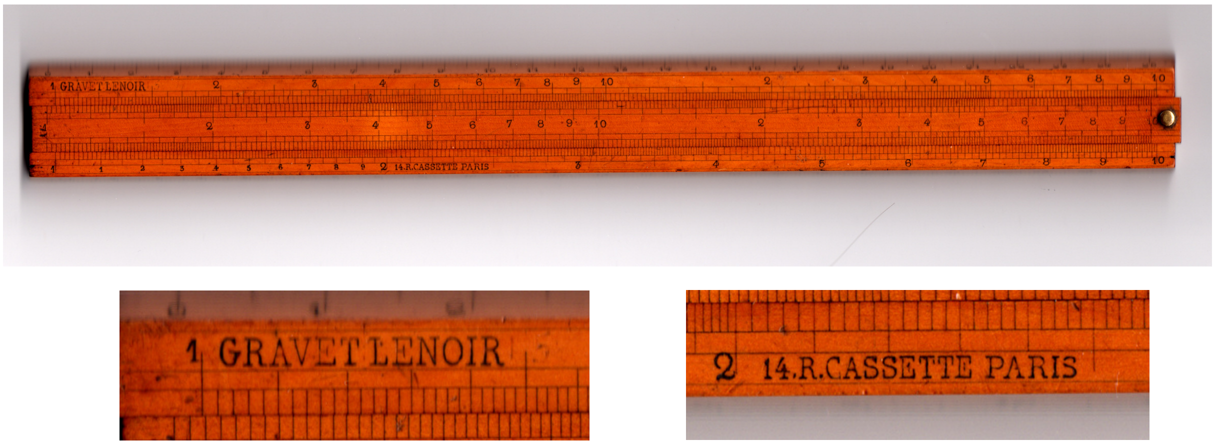


fig. 12 - *Une règle à calcul Gravet-Lenoir (collection M. Thomas)*
Les détails montrent le nom et l'adresse.

Les règles fabriquées par Gravet sont du même type que celles de Lenoir, et de fabrication très soignée. Plus tard la marque prendre le nom de Tavernier-Gravet et fabriquera des règles à calcul de qualité exceptionnelle, mais cela sort du cadre de cette communication.

La diffusion

Les militaires

Nul doute que, parmi les utilisateurs, on trouve des militaires. Une indication nous est donnée par la *Revue militaire belge* de 1841, dans laquelle nous trouvons une "Instruction, à l'usage des officiers et des sous-officiers de toutes les armes, sur la manière de se servir de la règle à calcul, avec des applications aux différentes branches de l'art militaire".

La règle à calcul trouve donc de fervents zélateurs dans l'armée belge! Il ajoute encore, dans un bref historique: "L'emploi de la règle à calcul ne prit d'abord [en France] que fort peu d'extension; aujourd'hui elle commence à être mieux appréciée et à se répandre davantage chez nos voisins. En Belgique elle est à peine connue." Ce passage nous montre bien que ce n'est que vers les années 1840 que la règle à calcul commence à se diffuser d'une manière importante en France.

L'utilisation dans les "grandes écoles"

Quelques esprits curieux, civils ou militaires, n'auraient sans doute pas suffi à donner une impulsion rapide à la diffusion de la règle à calcul. Cependant, dès 1829, la règle à calcul fait partie du matériel demandé à l'inscription à l'Ecole centrale des Arts et Manufactures, école privée qui vient d'être créée.

En 1853, P.M.N. Benoît publie un manuel d'instructions: "La règle à calcul expliquée" où nous pouvons lire, dans l'introduction:

> "Tous ces efforts seraient restés probablement longtemps infructueux, tant on est encore aujourd'hui indifférent en France, pour les améliorations dont le résultat ne peut se traduire immédiatement par un bénéfice matériel, si le Gouvernement n'avait pas sagement imposé, dans ses *Programmes d'admission aux écoles des services publics,* la connaissance et le maniement de la règle à calcul, instrument que M. *Collardeau* et M. *Gravet*, successeur de *Lenoir*, continuent à construire avec une précision remarquable."

Nous voyons que c'est donc en 1852 que la connaissance du maniement de la règle à calcul est rendue obligatoire pour l'entrée dans les "grandes écoles" publiques, ce qui entraîne bien sûr la nécessité pour les candidats d'en apprendre le maniement et donc de s'en procurer une. Il va sans dire que c'est essentiellement cette décision gouvernementale qui a provoqué la généralisation rapide de l'usage de la règle à calcul en France.

Toujours à cette même époque, Giraudet publie un petit fascicule de 24 pages, "Notice sur l'emploi de la règle à calcul destinée aux candidats à l'École Polytechnique et à l'École militaire de Saint-Cyr", certainement à mettre en lien avec la décision gouvernementale citée ci-dessus.

Conclusion

fig. 13 - Amédée Mannheim

Amédée Mannheim (1831-1906) est le personnage charnière qui a fait vraiment entrer la règle à calcul dans l'ère moderne. Polytechnicien (1848), il fait son école d'application dans l'artillerie à Metz, et c'est là que, jeune sous-lieutenant, il a l'idée en 1851 de l'amélioration de la règle à calcul. Mannheim modifie la disposition des échelles sur la règle, et la munit systématiquement d'un curseur pour reporter les valeurs d'une échelle à une autre. Cette amélioration permet de ne répéter que deux fois la même échelle, ce qui libère de la place sur la règle pour en mettre d'autres et facilite considérablement son maniement. Sa publication porte le titre: "*Règle à calculs modifiée par M. Mannheim*". Elle est signée: "Metz, décembre 1851. A. Mannheim, ancien élève de l'Ecole Polytechnique, Sous-lieutenant Elève d'artillerie" (il avait donc vingt ans). Elle consiste simplement en un petit livret de quatre pages.

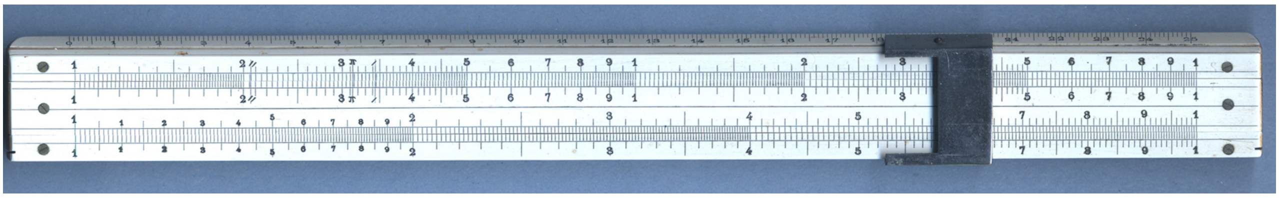


fig. 14 - Règle modèle Mannheim (1918) (collection M. Thomas)

A partir de cette époque, nous pouvons considérer que la règle à calcul entre, en France et dans le monde entier, dans sa période moderne qui durera plus d'un siècle encore...

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INTRODUCTION OF SLIDE RULES IN FRANCE[2]

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Resume
Slide rules have truly appeared in France in the early 19th century. Those few earlier references to logarithmic tools that can be found relate to Gunter rules, especially in naval text books. Starting in 1815, Jomard presents the slide rule and ask Lenoir to manufacture it. The first French slide rules are sold in 1821, with the first manuals following soon. Later, Gravet-Lenoir and Tavernier-Gravet take over the manufacture. In 1851, Mannheim invents the new scale set that bears his name and the next year, mastering of slide rules is a required subject in the technical high schools. This forms the true start of the modern slide rule. The major players in this process of awareness in France will be presented in this paper.

Introduction

Denis Henrion, deceased in 1640, is one of the persons who introduced logarithms in France, in his *Traité des Logarithmes*, published in 1626. That same year, he publishes the *Logacanon*, in which he describes how a logarithmic instrument could be constructed, modelled after the Gunter rule.

An extract from this work (*fig. 1*) shows on top the scales of the logarithms, tangents and sines, the instrument also shows other scales, those for a proportional divider, as well as a complete graphical computing system.

Contrary to the United Kingdom, before the 19th century, no mention is made in France of manufacturers of measuring instruments who produce slide rules on a regular basis. The only

[2] English translation by Ronald van Riet of Thomas' article on "L'introduction des Règles à Calcul en France", page 21

known logarithmic instruments are all based on the model of Henrion, and thus to all intents and purposes Gunter's rules, the lone ruler for one-and-a-half century. These rules were often called "English rules".

Special mention needs to be made of *Joseph Sauveur* (1653 - 1716), who at the end of the 17th century publishes the "*Eléments de géométrie*", re-issued in 1753 in a corrected and extended form by Leblond and titled "*Géométrie élémentaire et pratique*". This work includes the paper "*De la règle logarithmique*" (On the Logarithmic Rule). Sauveur states that "this rule is useful for calculations in which an error of 0.1 or 0.2 percent can be ignored". *<fig. 2 Sauveur's rule>*

Sauveur adds very little to Henrion. He indicates other uses, for example "if the currencies had a fixed exchange rate, one could add a monetary line". In 1700, he instructs Sevin and Le Bas to construct a rule according to this principle. This brass rule, very well built, is on display at the CNAM museum in Paris.

References to logarithmic instruments can also be found in hydrographic textbooks, especially by *Pierre Bouguer* (1698-1758). In 1753 he publishes at the request of the Ministry of the Navy, a "*Nouveau traité de navigation, contenant la théorie et la pratique du pilotage*" (New discussion of navigation, including the practice and theory of piloting), a reference book in all nautical schools. In this textbook, he presents two ways to calculate: the mariner's quadrant and the use of logarithms and logarithmic scales. He also states that he had the intention to construct a circular slide rule, but this doesn't seem to have materialized. *<fig. 3 The logarithmic scales by Bouguer.>*

Lenoir's first slide rules.

Only in the 19th century will the slide rule truly be introduced in France and will it be manufactured in series.Not without problems: the role played by a few men, supported by the "Society for the Encouragement of the National Industry", is essential in this period. Let's introduce the prime actors.

Edme-François Jomard

Edme-François Jomard (1777-1862, *fig. 4*), an early and brilliant student, enters the Polytechnic School as the first of his year (1794). A few years later, he takes part in the expedition to Egypt as a geographic engineer. In 1814, he was sent to England for issues related to Egyptian antiquities: he stays there until the final collapse of Napoleon's Empire. During this stay he gets interested in the slide rule and its use and brings a few samples back home. He then manages to get others interested as we shall see. Jomard continues as a brilliant geographer and, as a known scientist and networker "*avant la lettre*", he produces an impressive correspondence, becomes a member of the Institute and other scientific societies, all the time fighting for a generalized elementary education.

Étienne and Paul-Étienne Lenoir

Étienne Lenoir (1744-1832, *fig. 5*) is, in the period that we are interested in, already one of the best known French artists in the manufacture of scientific instruments. He owns a specialized workshop in Paris for the construction of precision instruments, in this period at 340 Rue St. Honoré. In particular, he already uses dividing machines to very accurately engrave the graduations and which he improves on continually. He continues to work practically until his death.

His son Paul-Étienne (1776-1827), just like Jomard, takes part in the expedition to Egypt. It is not known if they have actually met. Later he works with his father in their workshop. The Lenoirs have, as the first in France, manufactured slide rules to be sold in numbers.

"La Société d'Encouragement pour l'Industrie Nationale" (SEIN)

The Society for the Encouragement of the National Industry was founded on 1 November 1801 under instigation of Chaptal, its first president. Its goal is to put science at the disposal of industry and to arouse interest in technological innovation and its awareness. In this period catching up technologically with England is also an issue. Between 1815 and 1820 and under auspices of SEIN, Jomard will produce a number of publications that we will discuss below. SEIN still exists today.

Jomard's publications within SEIN

Jomard is admitted to SEIN as of 1 January 1815 and his first publication, written within the section of Mechanical Arts, is published in August 1815 in the Bulletin of the SEIN. He describes the slide rule:

> "which is a type of machine, today brought to a high level of perfection. It is a way to perform all calculations without pen, pencil or paper […], and without knowledge of arithmetic. […] They can serve scientists, engineers, merchants, workers, almost anyone. […] It is therefore desirable that its use will become very popular, and that its price will put it at everybody's disposal, but without losing its great accuracy, without which the instrument is of no use. In London, a rule of a foot long costs today about 5 shillings. I believe we could have it manufactured here for 4 or 5 francs."

The slide rule is thus perceived and presented by Jomard as a simple instrument, of general use, accessible to many. It is to be used in everybody's hands and used in everyday life. He has already made contacts to have the slide rules manufactured: the divisions of the logarithmic scales need to be calculated and performed by an able workshop, since the precision of a slide rule obviously depends on the quality of the scales.

> "Preparations are made in Paris to manufacture slide rules, adjusted to French measurements and that, without being longer, will have twice the precision of English rules of one foot long. I have entrusted Mr. *Lenoir*, experienced engineer, with this job. I am indebted to Mr. *Corabœuf*, captain in the Royal Geographers' Corps, for all calculations required for a perfect construction of the slide rule."

This publication presents a tremendous boost to the introduction of slide rules in France. From this moment on, and with support by SEIN, and especially from *Francœur*, of the committee for Mechanical Arts, a real interest develops for this instrument.

<fig. 6 Soho type slide rule (Plate from Jomard's publication)>

The production process and its problems

It takes until 1820 for Lenoir to produce the first prototype of his slide rules. This is what Jomard says in a SEIN publication on 7 February 1821: "The claims we made then [in 1815], are now realized. The first of these rules was registered last year, constructed in copper and with great care; the rules for general use are made of wood". We are dealing here with a registration, undoubtedly to protect intellectual rights, of a type of copper slide rule, which, however, is not the more common rule. But this extract gives very detailed information: in France, at the end of 1820, in the workshop of Lenoir in Paris, the first Soho type slide rule was produced, the first really general purpose slide rule. This model is made of copper, as shown, and is 36 cm long [about 14 inches, note of the translator]. Five years have passed between Jomard's first publication and the manufacture of a slide rule (albeit a prototype), according to his specifications.

Francœur gives us valuable indications of the problems and difficulties that Lenoir encountered:

> "Mr. *Jomard* […] did not hesitate to acknowledge that it was not enough to describe a good instrument to be built by some and used by others. He confided the experienced engineer Mr. *Lenoir*, to construct the scales according to his data. The operation was very slow, because of difficulties in the work needed to produce in large numbers and at low price. […] Mr. *Lenoir*, who understood well that this invention could not be widely distributed without them being priced affordably, with all the care characteristic of all his products, has developed a machine that marks the divisions on eight rules at the same time, and he will soon be able to add to this number."
>
> "Mr. *Collardeau*, graduate of the Polytechnique, aware that the rules, with the dimensions of Mr. *Jomard*, were too long to be easily portable, and had their divisions too close together to be easily used by the common people, had them made at a length of 26 cm [about 10 inches, translator's note]. This young man, entering a career in mathematical instruments, enters the workshop of Mr. *Lenoir* as an apprentice, where he is now charged

> with dividing the rules. These rules do not have the same precision as those of Mr. *Jomard*, but they are more portable, and would in many cases be preferred. Their finish is better than that of the best English rules, to which they have been carefully compared."

Their prices are 10 francs for the Jomard model and 5 francs for the Collardeau type, meaning they are reasonably priced. We find a clear intent of all actors to come up with a slide rule that is affordable. The commercialisation starts in the first quarter of 1821. Lenoir has also manufactured a number of more luxurious models, certainly a lot more expensive, because a model exists in the CNAM museum in Paris bearing his signature that is 36 cm long, made of ivory and is shown in a padded box…

The first slide rule manuals

In 1824, the Bulletin of Mathematic Science gives an overview of manuals that have been published. This same notice mentions that Lenoir has organized free courses in his workshop:

> "We have mentioned a manual published in Dijon. This has served as the basis for a free course of 8 lessons, started on 13 August at Lenoir, […] and given by Mr. Artur, mathematics teacher. […] For these rules, three different manuals exist: the first by M. Collardeau, student of the Polytechnique, price 2 francs, a second by Mr. Mouzin, first edition, price 1.25 francs, Dijon; a third one, by the same author, second edition, price 2 francs."

A few years later, in 1827, Mr. Artur also publishes a manual, perhaps the product of his courses at Lenoir?

The first manual to be published is the one by *Collardeau* (*fig. 7*), in 1820. Actually, Artur mentions in his foreword: "Mister Collardeau, student of the Polytechnique, has published in 1820 the first manual for this instrument, taking an English manual as an example given to him by Mr. Hachette upon his return from England." The English link is well visible… The edition that we have been able to consult is from 1833. The author (Charles Félix Collardeau du Heaulme or Duhaume, 1796-1869), 1815 graduate of the Polytechnique, is the same one mentioned by Francoeur in his publication on slide rules; he has therefore worked with Jomard and with Lenoir to become familiar with the construction methods. He has also worked a lot with with Gay-Lussac, whom he mentions in the beginning of his book, and he has become a precision instrument maker in Paris. For a brief moment he is described as "successor to Lenoir", but the issue of this succession will be dealt with later. His work on the slide rule is signed "Collardeau". His manual must therefore have been edited at least once in 1833.

The second we mentioned is *Ph. Mouzin*, of whom Jomard mentions that he was a lawyer in Dijon and who introduces himself also as a mathematician. His work will have at least four editions between 1824 and 1844, in general in Paris and Dijon.

The third manual finally, is from *J.-F. Artur*, the same one who gave the free courses at Lenoir. Artur must have known Lenoir for a certain time, because he has produced a manual for the Borda disk, made by Lenoir. He introduces himself as "teacher of mathematics and navigation, associate of the Academy of Science, Arts and Literature in Caen". The first edition is dated 1827, and it is noteworthy that his book is published, amongst other places, "at Lenoir, who constructs the rules, 340 rue Saint Honoré". It has known at least one other edition in 1845.

These three books, rather short (that of Collardeau has 92 pages, the one by Mouzin 122 and the one by Artur 155) are set up more or less along the same lines. In each case, they present a relatively new instrument, describe or praise its possibilities and finally explain how to use it, starting from the simple cases to very complex ones, accompanied by examples and exercises, some of which require a high level of expertise. Each additionally presents more or less elaborate theoretical coverage of logarithms.

The book by Mouzin is complemented by the following additions: "instrument with the use of which one can obtain visually, without pen, pencil or paper, without tables, without calculating by heart, and even without knowledge of mathematics, the result of all sorts of calculations." In this case, he describes more what one can do with the slide rule than which areas of application it applies to.

In this respect, the title of the book by Artur has a different approach: "Theoretical Instructions and Applications of the Logarithmic Rule or Slide Rule", without any further detail on this page. We have now moved from "Instructions in Use" or "how to use" to a manual "Theoretic Instructions", where the use has become the application. At least in the title the book by Artur appears more "scientific", more oriented to readers familiar with mathematics.

The wordings used to describe the slide rule and its various parts is obviously not yet crystallized: the slide is called "coulisse" ["runner"] by all three (Artur also uses the word "réglette" ["little rule", the current term], but the word "cursor", used by Artur, has nothing to do with the current meaning. Similarly, the word "échelle" ["scale"] doesn't quite have the same meaning. It is nevertheless noteworthy that at the end of his work, at least starting with the third edition (1837), Mourzin mentions a cursor, in the modern sense (that is, a small metal or glass piece, later made of plastic, allowing to better align and read off values on the rule), without giving it this name:

> "Sometimes a copper piece is added to the slide rule that can slide along the instrument. It serves to more exactly align the tick marks of the upper line with those of the sine and tangent. One can even use it to mark a result of one operation that is to be used in a second operation to arrive at the result."

Therefore, contrary to what is usually written, the cursor appeared well before the Mannheim slide rule in 1851.

The manuals by Mouzin and Artur have seen several editions, and they have been published during almost twenty years, which seems to indicate that the slide rule has begun to find its way around France.

Two examples of slide rules manufactured by Lenoir

We present examples of two slide rules manufactured by Lenoir. Both carry his signature. One of the main characteristics us that they show two units of length: centimeters and millimeters on the one hand, and *pouces de Paris* [French inches] and *lignes* [not to be translated, 1 pouce = 12 lignes] on the other hand. This fact dates these slide rules to the 1825-1830 timeframe, because 1830 saw the demise of the old units.

The first one (collection *E. Pommel*) is 26 cm long. The second one (collection *M. Thomas*) is 36 cm long. Both are made of boxwood. The major difference is in the reverse (see photographs).

<fig. 10 Lenoir slide rule of 26 cm> *<fig. 11 Lenoir slide rule of 36 cm>*

One can say that by 1830 the major elements are in place in France for a real widespread use to begin: manufacturers are ready, the slide rule models have been defined, the prices are affordable, instruction manuals exist, articles appear in magazines: the scientific world knows that the instrument exists and that it answers to a certain need. It is still far from a massive use.

The successors to Lenoir

Étienne Lenoir dies in 1832; his son Paul-Étienne had died in 1827. One of his employees, named *Mabire*, takes hold of the workshop at the address 14 rue Cassette in Paris. But it is *Gravet* who really succeeds Lenoir as far as slide rules are concerned. Who is he? We know hardly anything about Monsieur Gravet. Is he a manufacturer of scientific instruments, perhaps spectacles? Is he a pupil of Lenoir? Did he work in Lenoir's workshop? In any case, he was well known in 1844, when he receives a bronze medal from a jury in a contest for precision instruments for a mirror level. The jury report also mentions a compass, but one line is especially interesting for our discussion: "his slide rules are so much favored today that we believe they don't need our praise here. His address is the same as that of Mabire, and therefore Lenoir: 14 rue Cassettte. One can also find in a booklet of 1843: "sold by Gravet, successor to Lenoir, manufacturer of scientific instruments and slide rules". How did this "succession" come about? Gravet seems to have gotten away with it, because he soon sells his slide rules under the name of GRAVET LENOIR and mentioning the address 14, R. CASSTTE PARIS (*fig. 14)* and the name of Marbire doesn't appear anywhere anymore.

The slide rules manufactured by Gravet are of the same type as those of Lenoir, and very well constructed. Later, the brand bears the name of Tavernier-Gravet and manufactures very high quality slide rules but that falls outside the scope of the current paper.

Dissemination

Military

Without doubt, the military was amongst the users. We find an indication in the Belgian Military Revue of 1841, in which we find an "Instruction for the use by officers and NCOs of all branches on how to use the slide rule, applied to different branches of the military."

The slide rule thus finds favor with the Belgian army! It is added that "The use of the slide rule is not widespread [in France]; today it begins to be more appreciated by our neighbors. In Belgium it is still hardly known." This extract shows that only by 1840 is the slide rule achieving widespread use in France.

Usage by the major schools

A few enlightened minds, civil or military, would not have been sufficient to give a major boost to the dissemination of slide rules. Still, from 1829, the slide rule is part of the equipment required on entry at the Central School for Arts and Manufacture, a private school that has just been created.

In 1853 P.M.N. Benoît publishes a manual "The slide rule explained"; the introduction states:

> "All these efforts would probably have taken a long time, in view of the current indifference in France, for improvements that don't translate into immediate material benefit, had the Government not wisely imposed, in its Program for the Entry into the Public Services Schools, knowledge of and experience in the slide rule, which Mr. *Collardeau* and Mr. *Gravet*, successor to Lenoir, continue to manufacture with a remarkable precision."

We see that by 1852 knowing how to handle a slide rule had become mandatory to enter the major public schools, which leads of course to all candidates to learn to master and procure one. This decision by the government was therefore responsible for the quick uptake of the slide rule in France. Still in this same period, *Giraudet* publishes a small booklet of 24 pages, "Instructions for the use of the slide rule for the candidates of the *École Polytechnique* and the *École Militaire* of Saint-Cyr", clearly in line with the government decision mentioned above.

Final remarks

Amedée *Mannheim* (1931-1906, *fig. 13*) is the key person to truly embed the slide rule in the modern era. Graduate of the Polytechnique (1848), he studies artillery in Metz and there in 1851, as a young second lieutenant he develops an improved slide rule. Mannheim changes the layout of the scales and provides it with a cursor to transfer the values from one scale to another. This improvement results in each scale appearing a maximum of two times, freeing up the slide to include other scales and thus greatly improving its usefulness. His publication is entitled "Slide rule modified by Mr. Mannheim". It is signed Metz, December 1851, A. Mannheim, graduate of the Polytechnique, second lieutenant (in training) of the artillery (he is only 23 years old). It is a simple booklet of four pages.

<fig. 14, Mannheim type slide rule>

From then on, we can consider the slide rule to have entered its modern period in France as well as in the rest of the world, which is to last more than a century.

LE MULTIPLICATEUR BARIT[1]

Une Application Française des Batons de Neper

Gonzalo Martin

Né à Madrid (Espagne), s'installe en France en 1966; depuis 1970 jusqu'à sa retraite en 2003 travaille dans le domaine des Télécommunications. Collectionneur de machines à calculer depuis déjà 15 ans, il s'intéresse aussi aux règles à calcul, spécialement à la marque Graphoplex dont il possède plus de 90 exemplaires ; sa collection est exposée depuis 2 ans sur le site web qu'il a créé: www.photocalcul.com. Il participe activement au forum (en espagnol) du site www.reglasdecalculo.com

Il est aussi membre de l'ANCMECA (Association Nationale des Collectionneurs de Machines à Ecrire et à Calculer Mécaniques) http://calcollect.free.fr/

Résumé de la présentation au IM2010

Depuis l'invention des Bâtons de Neper plusieurs appareils basés dans cette technique ont été inventés afin d'améliorer leur manipulation. Un court exposé d'instruments de ce type est inclus.

Autour des années 1900 beaucoup d'instruments utilisant les réglettes de Neper sont apparus en France, le multiplicateur *Barit* est un parmi ceux qui nous sont parvenus; un calculateur unique car aucun autre exemplaire n'est connu ni référencé; ses caractéristiques et son fonctionnement sont expliqués en détail.

Introduction

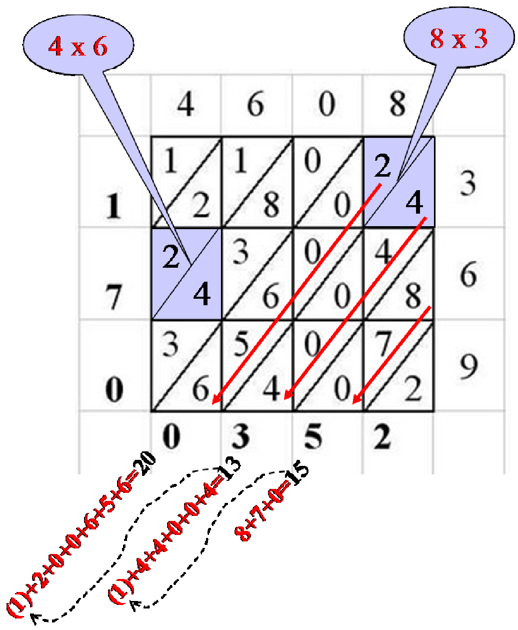
Au XVII siècle, les progrès de l'astronomie, de la navigation et du commerce impliquent des besoins en calcul qui s'accroissent, il devient nécessaire de simplifier les procédés opératoires pour les opérations arithmétiques.

John Napier (1550-1617), connu comme Neper en France, invente les logarithmes en 1614…, les calculs sont simplifiés.., les multiplications/divisions deviennent des additions/soustractions, les risques d'erreur s'amoindrissent…

En 1617 Neper publie son livre 'Rabdologie' où il décrit comment effectuer les opérations arithmétiques en utilisant des 'bones' (bâtons) sur lesquels sont gravés les tables de Pythagore, cet instrument sera utilisé jusqu'au XIX siècle.

La base de la multiplication avec les bâtons est la méthode 'per gelosia' ou 'méthode arabe de multiplication' qui était utilisée en ce moment-là.

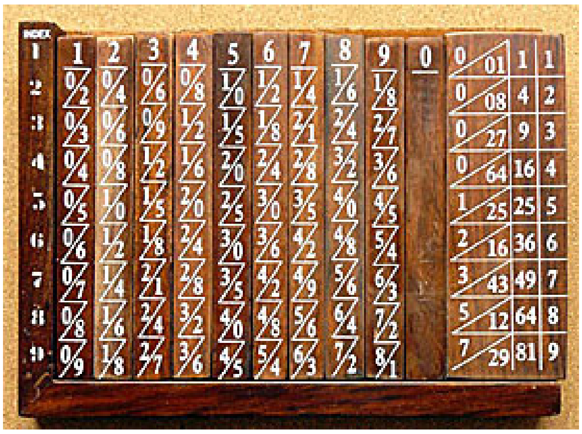
Cette méthode consiste à placer horizontalement le multiplicande et verticalement le multiplicateur et à écrire dans l'intersection ligne/colonne le produit des deux chiffres concernés. Ensuite on additionne les chiffres par bandes obliques, dans le cas ou il y a une retenue elle sera reportée sur la bande à gauche.

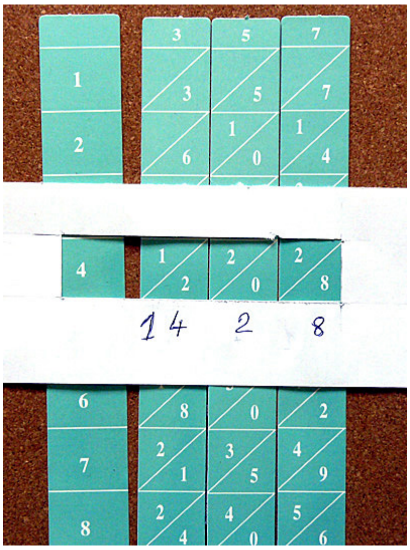


[1] An English translation of the text follows this article, on page 45

Le principal inconvénient de ce système est l'obligation de connaître la table de multiplication ; par contre avec les bâtons de Neper il est suffisant de connaître les tables d'addition.

Les Bâtons de Neper





Les Bâtons de Neper sont constitués de bâtons de section carrée, avec sur chaque face une table de Pythagore différente. Chaque bâton est divisé en 9 cases, la case supérieure porte un nombre (de 0 à 9), les autres cases sont divisées en deux par un trait diagonal. Chaque face du bâton porte donc un nombre sur la première case et les multiples de ce nombre sur les autres cases, le trait diagonal sépare les dizaines des unités ; par exemple le bâton 5 portera les nombres 05, 10, 15,….. 40, 45.

Un plateau avec un rebord gravé de 9 cases (numérotés de 1 à 9) permet de placer les bâtons comportant les chiffres composant le multiplicande.

Exemple: pour multiplier 357 par 4, nous plaçons cote à cote les bâtons '3' '5' '7' sur le plateau, le résultat de la multiplication par 4 sera lue en face du chiffre 4 au bord du plateau, on commence par la droite et on additionne les chiffres qui sont dans les mêmes bandes diagonales, soit: 8 pour les unités, 2+0 = 2 pour les dizaines, 2+2 = 4 pour les centaines et 1 pour les milliers. Nous rajouterions les retenues si nécessaire. Le résultat est 1428.

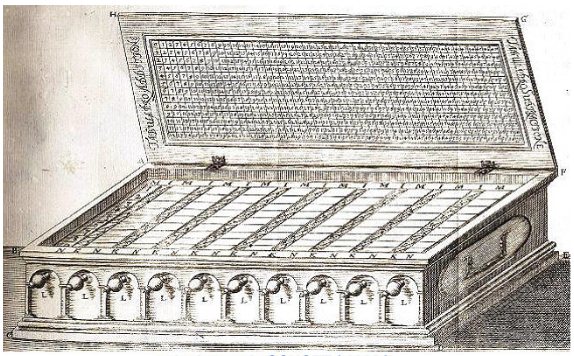
Maintenant pour multiplier par un nombre à plusieurs chiffres on effectuera les produits partiels qu'on additionnera par la suite.

Exemple 357 x 54: On effectue d'abord la multiplication par 4 et après par 5, on pose l'addition en tenant compte de la valeur relative: x4 et x50.

Evolution des Bâtons de Neper (XVII et XVIII siècles)

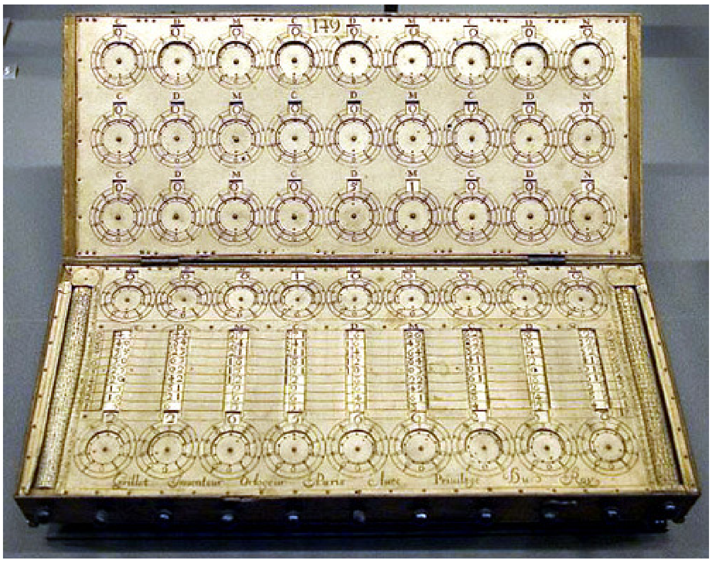
Des variantes apparaissent rapidement, nous citerons à titre d'exemple:

- ***Le calculateur de Schott (1668)*:** Des cylindres parallèles divisés en 10 bandes numérotés 0 à 9 remplacent les bâtons de Neper. Il suffit de tourner les cylindres pour afficher le multiplicande.

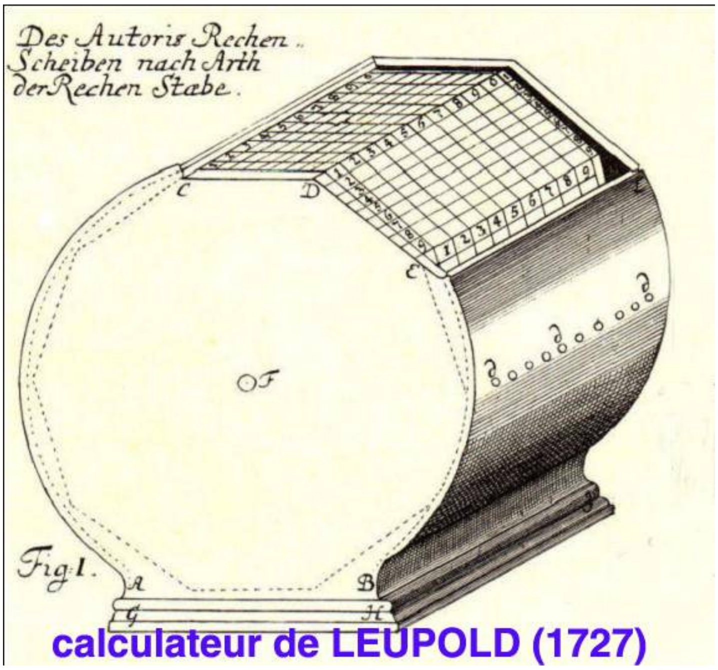


calculateur de SCHOTT (1668)

- ***La machine à cylindres népériennes de Grillet*** (1678): Le dispositif de Schott est repris par Grillet, il ajoute des cadrans permettant les additions.



- ***Le calculateur de Leupold*** (1727): Constitué par des disques décagones contigus mobiles les uns para rapport aux autres, les bâtons de Neper sont gravés sur l'arête du disque.



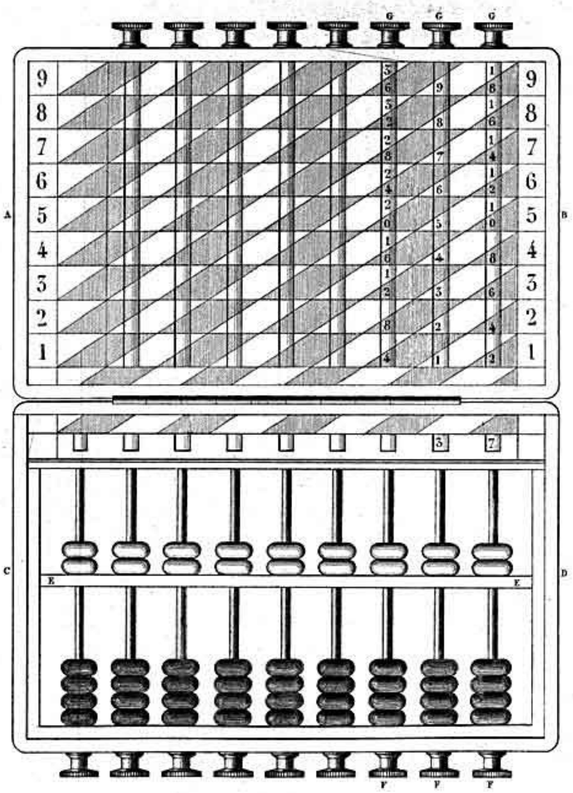
Les Bâtons de Neper en France 1800 - 19..

Divers dispositifs sont inventés au long de ces années, la tendance étant à la portabilité et à la légèreté de l'appareil. Toutes ces instruments montraient les résultats partiels des additions à l'aide de fenêtres ou lucarnes.

Quelques exemples sont montrés à la suite, consultables pour la plupart dans la revue 'La Nature'.

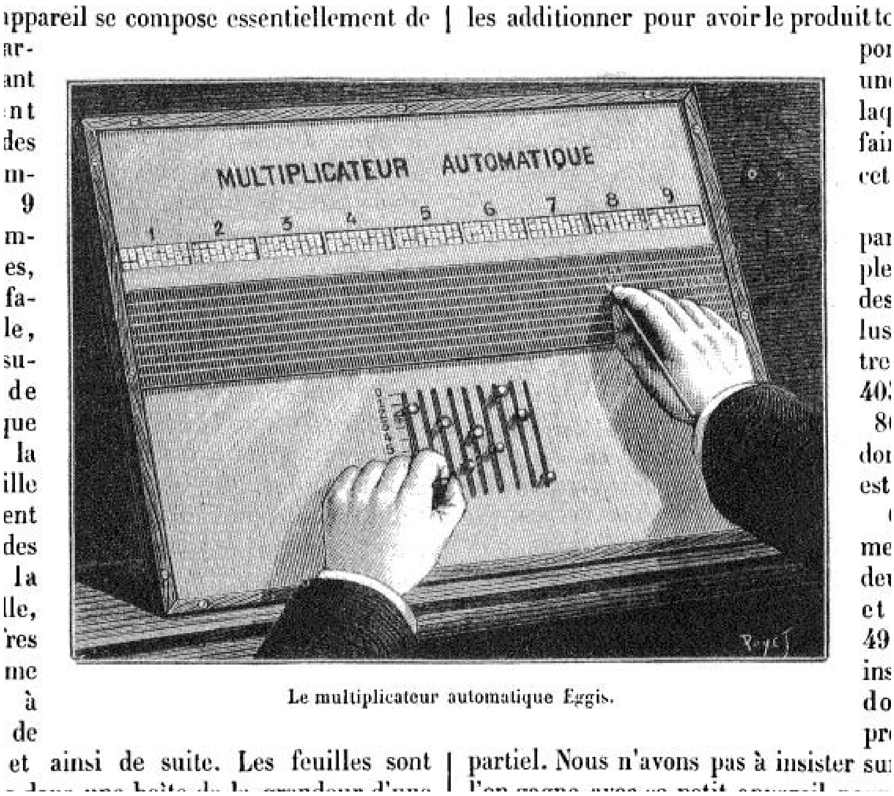
- ***Abaque portatif de M. Michel Rous*** (1869): Appareil groupant dans un coffret un abaque et un multiplicateur constitué de 8 cylindres, lesquels portent les nombres des bâtons de Neper.
Bulletin de la Société d'Encouragement pour l'Industrie Nationale 1869, 68e année, 2e série tome16, page 137 http://cnum.cnam.fr/CGI/fpage.cgi?BSPI.68/143/100/806/69/734

Fig 5.



voir photo INRIA: http://interstices.info/encart.jsp?id=c_15272&encart=10&size=800,700

- ***Le multiplicateur automatique de M.Eggis*** (1886): Composé de 9 feuilles superposées, chaque feuille porte le produit de 9 x 9 nombres.
Les résultats partiels sont lus dans 9 fenêtres horizontales.
La Nature, deuxième semestre, 1886, page 323
http://cnum.cnam.fr/CGI/fpage.cgi?4KY28.27/327/100/432/0/0


ppareil se compose essentiellement de | les additionner pour avoir le produit to

Le multiplicateur automatique Eggis.
et ainsi de suite. Les feuilles sont | partiel. Nous n'avons pas à insister su

- ***L'automultiplicateur de M. Eggis*** (1892): Dans cet appareil tous les multiples des nombres de 0 à 9 sont inscrits à la suite sur des bandelettes, une ligne verticale sépare les dizaines des unités.

La bandelette peut être déplacée verticalement grâce à une fenêtre qui montre les repères de 1 à 9. Lorqu'on déplace la bandelette, par exemple sur le 3, tous les produits par 2, 3, 4… apparaîtront dans les 8 fenêtres correspondantes situées verticalement.

La Nature, premier semestre, 1892, page 381

http://cnum.cnam.fr/CGI/fpage.cgi?4KY28.38/385/100/536/0/0

LA NATURE.

NOUVEAU MULTIPLICATEUR AUTOMATIQUE

stinés à faciliter la mul- | l'aiguille successivement d
qui en dérivent sont de | et 7, dans les trois bande

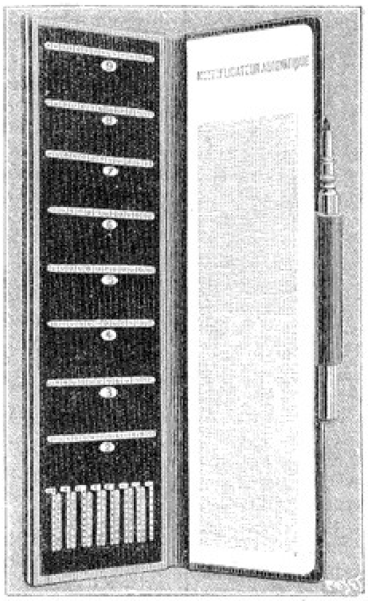


Fig. 1. — Multiplicateur automatique de M. Eggis.

correspond au bas de la | d y revenir. Nous renv

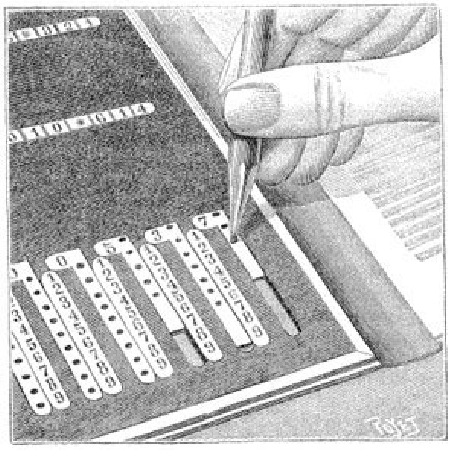


Fig. 2. — Mode d'emploi du multiplicateur.

- ***Le multiplicateur de Léon Bollée*** (1895): Le multiplicande est composé de 6 cylindres portant les bâtons de Neper ; un petit écran mobile permet de poser le multiplicateur et lire les résultats partiels. Bulletin de la Société d'Encouragement pour l'Industrie Nationale 1895, 94e année, 4e série tome10, page 986 http://cnum.cnam.fr/CGI/fpage.cgi?BSPI.94/991/100/1437/617/773

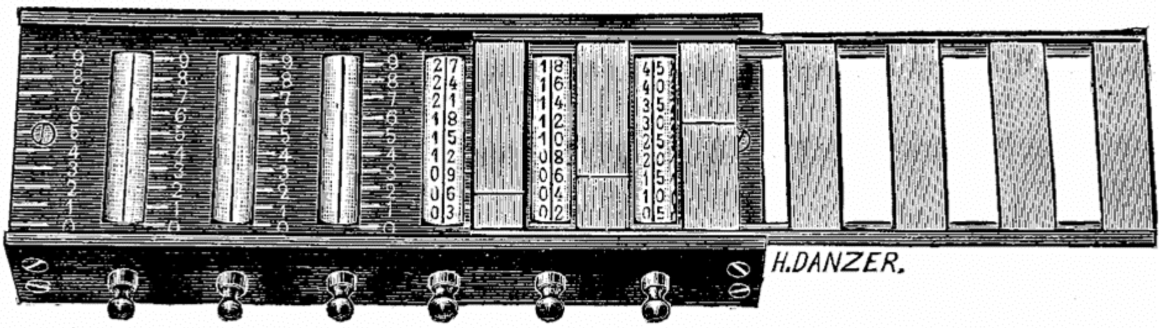


Fig. 2. — Petit appareil multiplicateur. **Léon Bollée (1895)**

- *La Multi* (1920): Le multiplicande est composé de 7 cylindres parallèles portant les réglettes de Neper, les dizaines sont représentées séparées des unités et rapprochées des unités du cylindre contigu afin de faciliter les additions partielles.

Un chariot mobile contenant 9 rangées de 5 fenêtres, fermées par des volets, permet de constituer le multiplicateur par l'ouverture des volets correspondants.
La Nature, Juillet 1920, page 30.

La " MULTI " (1920)
photo Science Museum

multiplier comme entiers et la place de la virgule | chiffre des unités du produit des centaines du

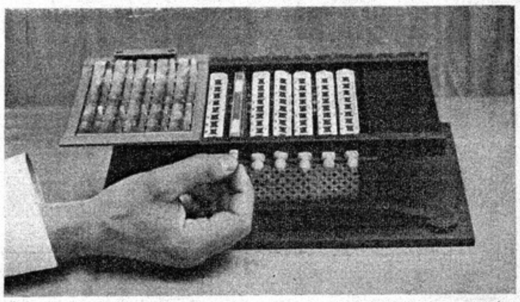


Fig. 2. — Manœuvre des axes de la « Multi ».
Chacun d'eux supporte des tables de Pythagore enroulées sur des cylindres parallèles.

détermine ultérieurement. dans le produit | multiplicande par les unités du multiplicateur

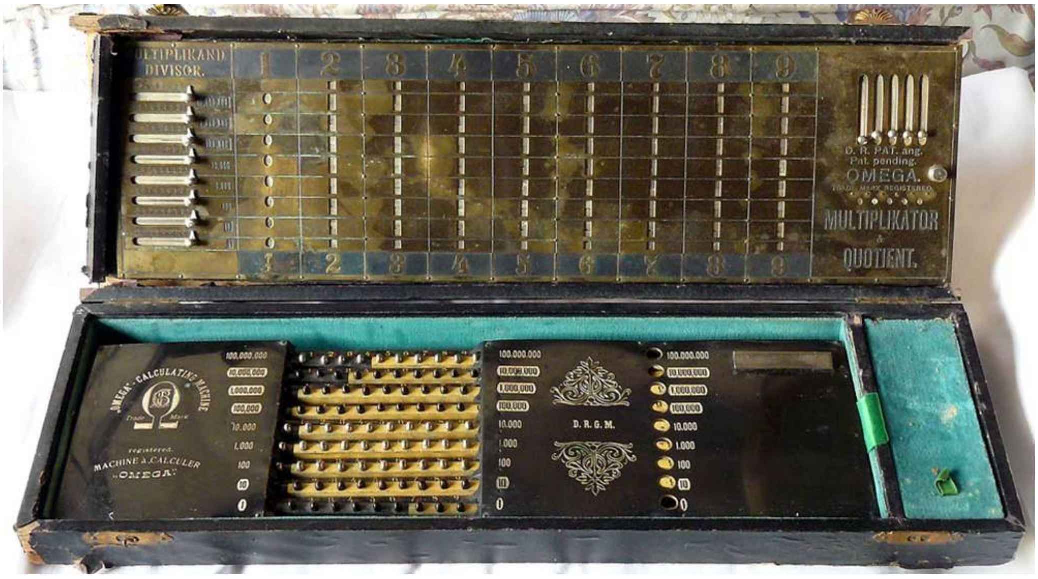
- ***La Machine Omega*** (1903): Cette machine, d'origine américaine, est un bon exemple des appareils existants à cette époque basés dans les bâtons de Neper.

Elle est constituée:

- dans sa partie inférieur, d'un addition-neur de type Locke Adder pour les additions et soustractions

- dans sa partie supérieur, d'un multipli-cateur / diviseur Népérien.

Les leviers situés à gauche de la machine servent à inscrire le multiplicande, les résultats partiels de la multiplication sont lus dans les lucarnes situées à la verticale de chaque chiffre multiplicateur. http://www.rechnerlexikon.de/artikel/Bamberger_Omega



Conclusion

Ces multiplicateurs à base de Bâtons de Neper avaient quand même l'inconvénient de ne pas donner directement le résultat, il fallait passer par des additions partielles avec des erreurs possibles.

Les réglettes de Genaille (1885), qui donnent par simple lecture le résultat de la multiplication, ainsi que les tables toutes prêtes des multiplications et enfin l'utilisation de plus en plus répandue des règles à calcul ont certainement donné le coup de grâce à ces appareils.

Le multiplicateur Barit (Calculateur Mécanique)

Cette machine est référencée seulement dans un catalogue de A. Brieux de 1984, elle n'apparaît sur aucun catalogue ni revue de l'époque; la recherche sur Internet ne donne aucun résultat. Le catalogue Brieux indique que c'est une machine de 1901 basée sur les bâtons de Neper; l'exemplaire en ma possession m'est parvenu dans une vente Ebay.

L'appareil se présente comme un livre: lorsqu'il est ouvert nous avons l'appareil lui-même à droite et le mode d'emploi imprimé à gauche.

L'étude de son fonctionnement permet de constater la ressemblance avec l'automultiplicateur de M. Eggis (présence du multiplicande et de réglettes de Neper) et avec la Multi (présence du multiplicateur avec ses volets). Le multiplicateur Barit est simplifié en portant seulement les multiplicateurs 1-2-4-7, en effet les multiplicateurs 3-5-8-9 sont composés par addition 3=1+2, 5=1+4, etc.

Principe de fonctionnement

8 réglettes de Neper permettent d'indiquer le multiplicande de 1 à 99999999; le résultat de sa multiplication par les nombres 1, 2, 4, 7 apparaît automatiquement dans les fenêtres du corps de l'appareil. Lorsqu'on initialise la multiplication ces fenêtres sont cachées par les volets fermés de la plaque mobile.

On va inscrire le multiplicateur en soulevant les volets de la plaque mobile de cette façon:

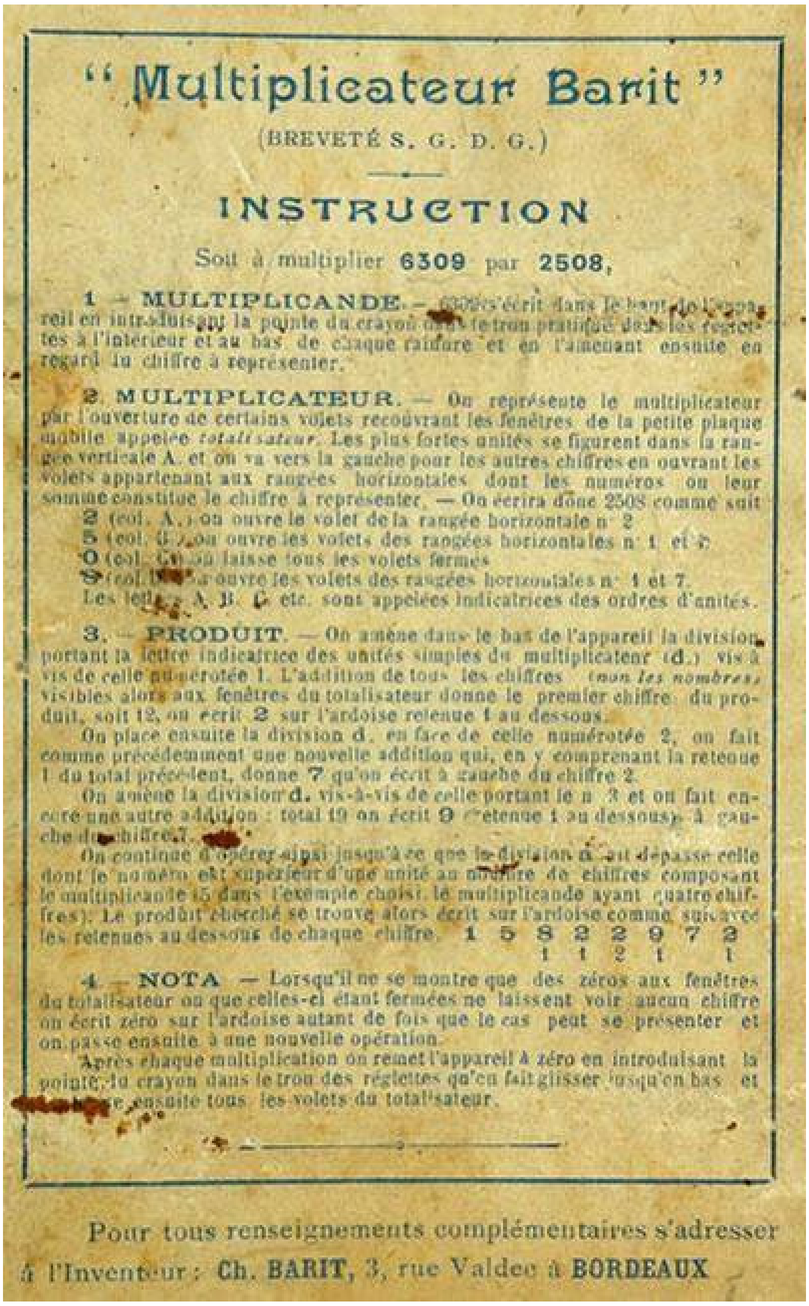
- Le chiffre de plus haut rang sera inscrit sur la rangée la plus à gauche (rangée A) et on va vers la droite pour les autres chiffres, ainsi 128 s'écrira:

1 sur la rangée **A**, **2** sur la rangée **B** et **8** sur la rangée **C**.

- Les chiffres 1, 2, 4, 7 s'écrivent en soulevant les volets correspondants.

- Les chiffres différents de 1, 2, 4, 7 s'écrivent en ouvrant les volets dont la somme constitue le chiffre à représenter, ainsi pour 8 on ouvre les volets 1 et 7.

On va successivement faire coïncider la colonne des unités du multiplicateur avec les colonnes du multiplicande dans l'ordre: unité, dizaine, centaine,... et ceci en déplaçant la plaque mobile de droite à gauche. Dans chaque position nous ferons la somme des chiffres qui apparaissent dans les fenêtres non cachées par les volets du multiplicateur et en ajoutant les retenues si nécessaire. Ces instructions sont mieux détaillées dans la notice livrée avec la machine.



“ Multiplicateur Barit ”

(BREVETÉ S. G. D. G.)

INSTRUCTION

Soit à multiplier **6309** par **2508**,

1 – **MULTIPLICANDE.** – 6309 s'écrit dans le haut de l'appareil en introduisant la pointe du crayon dans le trou pratiqué dans les réglettes à l'intérieur et au bas de chaque rainure et en l'amenant ensuite en regard du chiffre à représenter.

2. **MULTIPLICATEUR.** — On représente le multiplicateur par l'ouverture de certains volets recouvrant les fenêtres de la petite plaque mobile appelée *totalisateur*. Les plus fortes unités se figurent dans la rangée verticale A. et on va vers la gauche pour les autres chiffres en ouvrant les volets appartenant aux rangées horizontales dont les numéros ou leur somme constitue le chiffre à représenter. — On écrira donc 2508 comme suit

2 (col. A.) on ouvre le volet de la rangée horizontale n° 2

5 (col. B.) on ouvre les volets des rangées horizontales n° 1 et 4

0 (col. C.) on laisse tous les volets fermés

8 (col. D.) on ouvre les volets des rangées horizontales n° 1 et 7.

Les lettres A. B. C. etc. sont appelées indicatrices des ordres d'unités.

3. – **PRODUIT.** — On amène dans le bas de l'appareil la division portant la lettre indicatrice des unités simples du multiplicateur (**d.**) vis à vis de celle numérotée 1. L'addition de tous les chiffres *(non les nombres)* visibles alors aux fenêtres du totalisateur donne le premier chiffre du produit, soit 12, on *écrit* **2** sur l'ardoise retenue **1** au dessous.

On place ensuite la division **d.** en face de celle numérotée 2, on fait comme précédemment une nouvelle addition qui, en y comprenant la retenue 1 du total précédent, donne **7** qu'on écrit à gauche du chiffre 2.

On amène la division **d.** vis-à-vis de celle portant le n° 3 et on fait encore une autre addition : total 19 on écrit **9** (retenue 1 au dessous) à gauche du chiffre 7.

On continue d'opérer ainsi jusqu'à ce que la division d. ait dépassé celle dont le numéro est supérieur d'une unité au nombre de chiffres composant le multiplicande (5 dans l'exemple choisi, le multiplicande ayant quatre chiffres). Le produit cherché se trouve alors écrit sur l'ardoise comme suit avec les retenues au dessous de chaque chiffre. **1 5 8 2 2 9 7 2**

1 1 2 1 1

4 – **NOTA** — Lorsqu'il ne se montre que des zéros aux fenêtres du totalisateur ou que celles-ci étant fermées ne laissent voir aucun chiffre on écrit zéro sur l'ardoise autant de fois que le cas peut se présenter et on passe ensuite à une nouvelle opération.

Après chaque multiplication on remet l'appareil à zéro en introduisant la pointe du crayon dans le trou des réglettes qu'on fait glisser jusqu'en bas et [illegible] ensuite tous les volets du totalisateur.

Pour tous renseignements complémentaires s'adresser à l'Inventeur : **Ch. BARIT**, 3, rue Valdec à **BORDEAUX**

Bibliographie

- site Internet de Stephan Weiss http://www.mechrech.info/
- Le calcul simplifié par les procèdes….. Maurice d'Ocagne 1928
- Histoire des instruments et machines à calculer Jean Marguin1994
- Revue « La Nature » consultable dans http://cnum.cnam.fr/

Multiplicateur Barit
(BREVETE S. G. D. G.)

INSTRUCTION

Soit à multiplier 6309 par 2508

1 – MULTIPLICANDE – 6309 s'écrit dans le haut de l'appareil en introduisant la pointe du crayon dans le trou pratiqué dans les réglettes à l'intérieur et au bas de chaque rainure et en l'amenant ensuite en regard du chiffre à représenter.

2 – MULTIPLICATEUR – On représente le multiplicateur par l'ouverture de certains volets recouvrant les fenêtres de la petite plaque mobile appelée *totalisateur*. Les plus fortes unités se figurent dans la rangée verticale A et on va vers la gauche pour les autres chiffres en ouvrant les volets appartenant aux rangées horizontales dont les numéros ou leur somme constitue le chiffre à représenter.-
On écrira donc 2508 comme suit:
2 (col. A) on ouvre le volet de la rangée horizontale n° 2
5 (col. B) on ouvre les volets des rangées horizontales n° 1 et 4
0 (col. C) on laisse tous les volets fermés
8 (col. D) on ouvre le volets des rangées horizontales n° 1 et 7
Les lettres A, B, C etc. sont appelées indicatrices des ordres d'unités.

3 – PRODUIT – On amène dans le bas de l'appareil la division portant la lettre indicatrice des unités simples du multiplicateur (**d**) vis-à-vis de celle numérotée **1**. L'addition de tous les chiffres (*non les nombres*) visibles alors aux fenêtres du totalisateur donne le premier chiffre du produit, soit 12, on écrit ***2*** sur l'ardoise retenue *1* au dessous.

On place ensuite la division **d** en face de celle numérotée **2**, on fait comme précédemment une nouvelle addition qui, en y comprenant la retenue 1 du total précèdent, donne ***7*** qu'on écrit à gauche du chiffre ***2***.

On amène la division **d** vis-à-vis de celle portant le n° **3** et on fait encore une autre addition: total 19 on écrit ***9*** (retenue *1* au dessous) à gauche du chiffre **7**.

On continue d'opérer ainsi jusqu'à ce que la division **a** ait dépassé celle dont le numéro est supérieur d'une unité au nombre de chiffres composant le multiplicande (5 dans l'exemple choisi, le multiplicande ayant quatre chiffres). Le produit cherché se trouve alors écrit sur l'ardoise comme suit avec les retenues au dessous de chaque chiffre. ***1 5 8 2 2 9 7 2***
1 1 2 1 1

4 – NOTA – Lorsqu'il ne se montre que des zéros aux fenêtres du totalisateur ou que celles-ci étant fermées ne laissent voir aucun chiffre on écrit zéro sur l'ardoise autant de fois que le cas peut se présenter et on passe ensuite à une nouvelle opération.

Apres chaque multiplication on remet l'appareil à zéro en introduisant le pointe du crayon dans le trou des réglettes qu'on fait glisser jusqu'en bas et on ferme ensuite tous les volets du totalisateur.

A French Application of Napier's Bones: The Barit Multiplier[2]

Gonzalo Martin

Born in Madrid (Spain), he has lived in France since 1966 and has spent his professional life in telecommunications until his retirement in 2003. He has been collecting slide rules for 15 years

[2] English translation by Ronald van Riet of Martin's article on "le Multiplicateur Barit", page 37

and specializes in Graphoplex, of which he has more than 90 examples, his collection is available on line at www.photocalcul.com. He is an active member of the Spanish slide rule forum www.reglasdecalculo.com. He is a member of the French National Association of Collectors of Writing and Calculating Machines.

Overview of the Paper

Since the invention of Napier's Bones, several instruments based on this technique have been invented to improve their manipulation. An overview of some examples of this type of instrument is given.

Around 1900 several instruments using Napier's Bones appeared in France, the Barit multiplier is one that has survived, probably unique, no other example is known to exist. This multiplier will be described in more detail.

Introduction

John Napier (1550-1617), in France usually called **Neper**, invents logarithms in 1614, allowing simpler calculations, multiplications/divisions become additions/subtractions with resulting lower margins for error.

In 1617 Napier publishes his book "Rabdologie" in which he describes how to calculate using bones (sticks) on which multiplication tables are inscribed; this type of instrument was used until the 19th century. The method was based on lattice multiplication. The figure shows how to multiply 4608 * 369: the multiplicand is placed horizontally and the multiplier vertically. One then adds the numbers in diagonal lines from right to left with carry over to arrive at the result horizontally. Normal multiplication requires knowledge of the multiplication tables, with the bones, one just needs to perform additions.

Napier's Bones are square section sticks with each face showing a different multiplication table. Each bone is divided in 9 sections, the top one containing the numbers 0 … 9, all other sections being diagonally divided to include the multiplication table for the number on top. Normally, Napier's Bones are used in a board with the left margin showing the numbers 1 … 9 as the multipliers, the multiplicand being constructed by choosing the correct bones in the proper order. For example, to multiply 357 by 4, take the bones numbered 3, 5 and 7 and align them left to right, the on the fourth row perform the calculation to arrive at the result of 1428 (from right to left 8, then 2+0=2, 2+2 =4, finally 1),again using carry over when necessary. Using multipliers of multiple positions, take each of the single digits of the multipliers and add them like regular long hand multiplications.

Evolution of Napier's Bones in the 17th and 18th century

Quickly, variants appeared, of which we will briefly mention a few examples:

Schott Calculator (1668): parallel cylinders divided in 10 bands numbered 0 … 9 replacing the bones. Turning the cylinders sets the multiplicand.

Grillet's cylindrical Napier machine (1678): Expanding on Schott's calculator, with addiators to ease the addition of partial results.

Leupold's Calculator (1727): The multiplication tables of Napier's Bones are engraved on the sides of ten-sided drums.

Napier's Bones in France from 1800 – 1930

Various devices are invented over the years, with a tendency to make them lighter and more easily portable. All these instruments use some form of window to present the partial results. Some examples are shown, the majority from the magazine "Nature".

Portable calculator of Mr. Michel Rous (1869): An abacus and a Napier's bone type multiplier consisting of 8 cylinders on a single case.

Eggis' 1st Automatic Multiplier (1886): A fairly large, flat instrument consisting of 9 superimposed sheets, each sheet imprinted with the 81 single products. The partial results are visible through 9 horizontal windows.

Eggis' 2nd Automatic Multiplier (1892): A vertically oriented instrument working with bands on which all multiplications of the numbers 0 … 9 are inscribed with the tens and units divided by a vertical line. The bands can be moved vertically (not unlike a standard addiator) and all multiplications by 2, 3, 4, … (in fact, all possible partial results) are shown through 8 horizontal windows arranged vertically.

Léon Bollée's Multiplier (1895): The multiplicand is formed by 6 cylinders inscribed with Napier's Bones, a small moveable screen sets the multiplier and allows reading the partial results.

The "Multi" (1920): The multiplicand consists of 7 parallel cylinders inscribed like Napier' Bones. The tens are represented separate from the units and close to the next cylinder to ease the addition in the partial results. A sliding carriage with 9 rows of 5 windows, closed by shutters, is used to set the multiplier by opening the corresponding shutters.

The Omega Machine (1903): This originally American instrument is a good example of the instruments of this period based on Napier's Bones.
It consists of:
At the bottom, an addiator for additions and subtractions
On the top, a multiplier/divider using Napier's Bones
The levers at the right are used to set the multiplier, the partial multiplication results are read in the windows below each of the numbers of the multiplicand.

Conclusion

These multipliers based on Napier's Bones all had the characteristic that they only show partial results which then have to be added together for the final result.

The rules of Genaille (1885), where the multiplication result can be directly read, as well as ready reckoners and finally the slide rule have given this type of instrument the death blow.

The Barit Multiplier

The only reference to this instrument is a catalog by A. Brieux of 1984, there is no known description in contemporary publications nor is anything to be found on the internet. The Brieux catalog states that it dates from 1901 and is based on Napier's Bones; the example shown is the only one known and was recently purchased on eBay.

It opens like a book, when opened the left shows the instructions for use while the instrument itself is on the right. It has features similar to Eggis' 1st multiplier and the Multi. It is a simplified instrument with only multipliers 1, 2, 4 and 7, the other numbers can be formed by adding partial results like 3=1+2, 5=1+4 etc.

Principle of Use

8 Napier's Bones allow multiplicands f 1 to 99999999 to be set, the results of multiplying by 1, 2, 4 and 7 appears automatically through windows. When setting up the multiplication, all windows are closed initially. The multiplication is performed by opening shutters as follows:

The most significant number is set on the left, lower order numbers to the right, so 128 is set as 1 in column A, 2 in column B and 8 in column C. The numbers 1, 2, 4 and 7 are set directly, other numbers are set by combining, e.g. 8 is set by opening shutters 1 and 7.

Sliding the windowed part over the base with the multiplicand starting with the units and moving left successively, write down the sum of the numbers appearing in the open windows using carry over where necessary.

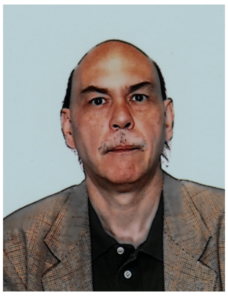
The instructions given on the instrument {and translated on the CDROM] are a much more detailed version of these abbreviated instructions.

Contribution à la reconstitution de l'histoire de GRAPHOPLEX[1]

un grand fabricant français de règles à calcul, ses procédés, sa production

Daniel TOUSSAINT

01/11/1947
toussaint@linealis.org
site: http://linealis.org



C'est vers 1990 que j'ai commencé à collecter et rassembler des règles, instruments de calcul et de dessin, livres et documentations à ce domaine. Mais c'est seulement à partir de 2005, ou j'ai eu plus de temps libre pour me consacrer à mes hobbies, que j'ai réellement mis en forme ma collection et inventorié mes trouvailles. C'est finalement en janvier 2007, donnant suite à une idée que j'avais depuis quelques temps que j'ai créé mon site internet, linealis.org . J'y ai ajouté par la suite une liste de diffusion francophone.

Introduction

Reconstituer l'histoire de Graphoplex n'est pas chose facile, ce grand fabricant français de règle à calcul de la seconde partie du vingtième siècle n'a laissé ni archives ni historiographie en disparaissant. Son nom prestigieux est utilisé maintenant par un fabricant et vendeur de matériel de bureau et de dessin de haut de gamme mais sans relation aucune avec les produits originaux de Graphoplex.

J'ai mené des recherches dans deux directions, d'une part retrouver les procédés de fabrication et les solutions techniques utilisées par ce fabricant et d'autre part reconstituer le catalogue des différents modèles de règles commercialisées à l'usage du public ou fabriquées pour répondre à une demande spécifique. Le catalogue établi en 1994/1995 par Herman van Herwijnen et le « Dutch Circle of Slide Rule Collectors » a constitué une base précieuse, j'ai par la suite retrouvé de nombreuses autres règles produites par Graphoplex, plusieurs collectionneurs français m'ont communiqué des informations pertinentes sur les règles qui figuraient dans leur collection, je les remercie pour leurs contributions précieuses qui ont permis la rédaction de ce document.

Plusieurs solutions sont possibles pour effectuer la gravure des échelles d'une règle. La plus ancienne est la gravure mécanique, c'est par exemple le cas des règles Tavernier-Gravet. Bien d'autres solutions sont possibles, la solution choisie par les inventeurs, à l'origine de Graphoplex, est innovante. Un autre point est la fabrication de l'ensemble de la règle, règles monobloc ou les échelles sont gravées ou imprimées sur la règle, en une seule pièce ou de rapporter des échelles gravées ou imprimées sur des plaquettes de matière plastique sur des bâtis standard, cette solution, longtemps utilisée par Graphoplex, permet – au prix d'une fabrication plus complexe – de produire à partir d'un bâti standard, une grande variété de modèles.

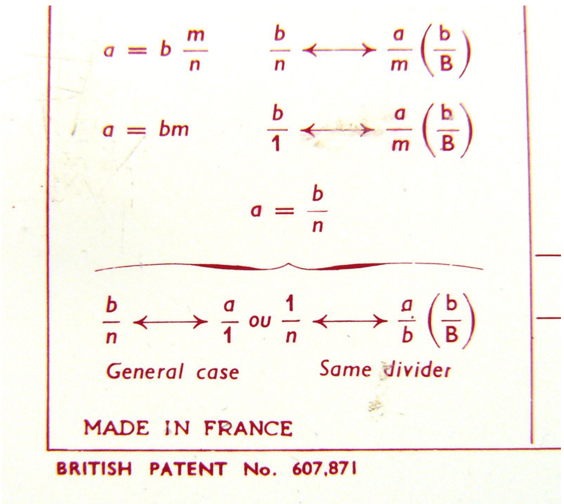
Historique

Une minutieuse enquête a permis de retrouver quelques points de repère dans l'histoire de Graphoplex.

Une origine longtemps passée inaperçue.

Les premières règles Graphoplex vendues en France, comportaient parfois au verso, des tables aide-mémoire avec de nombreuses formules utiles, tout comme bien d'autres règles de toutes origines. Dans la plupart des cas il n'y avait aucune mention de brevet, quelques 640 portaient la mention « N° 640 . ELECTRIC LOG-LOG (marque déposée) ». Cela ne permettait toujours pas de progresser.

[1] An English translation of the text follows this article, on page 62



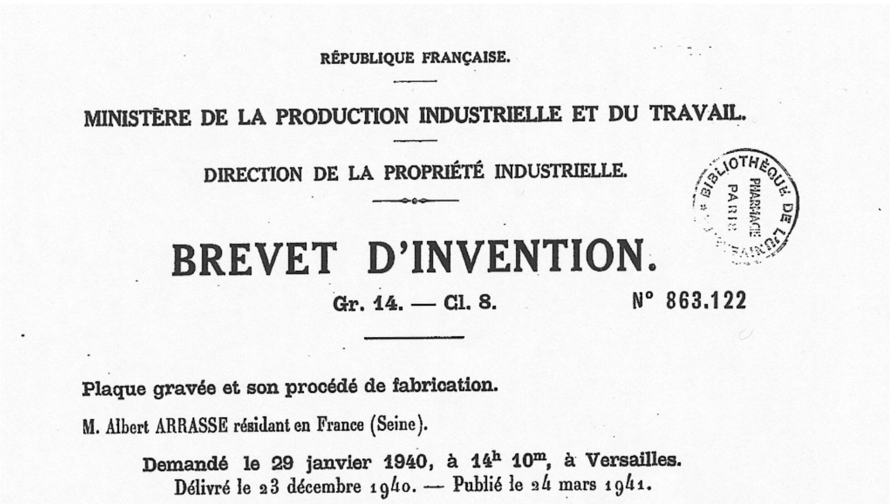
Vue partielle de l'aide mémoire figurant au dos d'une 640 destinée au marché britannique (collection & photo Gonzalo MARTIN)

Jusqu'au jour, ou un collectionneur et ami, Monsieur Gonzalo MARTIN, m'a communiqué des photographies d'une 640 destinée à être vendue en Grande Bretagne, et qui comportait un aide-mémoire rédigé en anglais avec la mention qui a servie de point de départ « MADE IN FRANCE – BRITISH PATENT N° 607 871 ».

Cette information m'a permis d'obtenir copie de ce brevet et de retrouver aussi le brevet français qui était à son origine. A noter que le brevet anglais fait référence, alors que le brevet français est muet à ce sujet, à un brevet antérieur N° 426 866 dont je parlerai plus tard.

Le brevet français N° 863 122, déposé le 29 janvier 1940 par monsieur Albert ARRASSE, concerne la photogravure des matières plastiques, de préférence le polyméthacrylate de méthyle, par le procédé dit « à la gomme bichromatée » et la gravure à proprement parlé par l'acide phénique avec inclusion du colorant dans le mordant. C'est le détail essentiel, le colorant est inclus dans la matière même de la règle, et devient quasiment inaltérable.

Ce brevet, déposé par Albert Arrasse en son nom propre, pendant la seconde guerre mondiale était indétectable et aurait pu n'être jamais découvert.



RÉPUBLIQUE FRANÇAISE.

MINISTÈRE DE LA PRODUCTION INDUSTRIELLE ET DU TRAVAIL.

DIRECTION DE LA PROPRIÉTÉ INDUSTRIELLE.

BREVET D'INVENTION.

Gr. 14. — Cl. 8. N° 863.122

Plaque gravée et son procédé de fabrication.

M. Albert ARRASSE résidant en France (Seine).

Demandé le 29 janvier 1940, à 14h 10m, à Versailles.
Délivré le 23 décembre 1940. — Publié le 24 mars 1941.

Une brochure imprimée par Hardy date de 1949, des fiches de contrôle insérées dans certains étuis sont datées de 1950, certaines notices, imprimées par M. Pattegay à Luxeuil, datent de 1951, ces informations permettent d'affirmer que les premières ventes ont eu lieu en 1949 au plus tard.

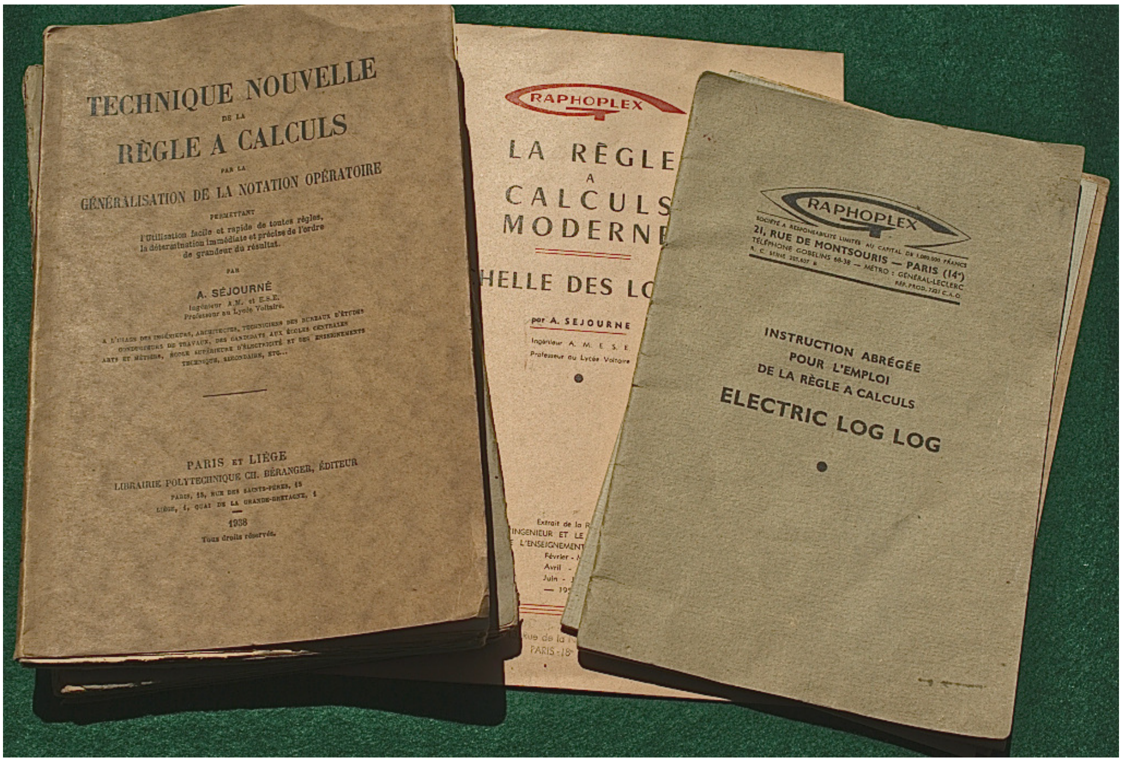
La conception des échelles et les règles Log-Log

André Séjourné, ingénieur A.M. Et E.S.E., Professeur au Lycée Voltaire (classe préparatoire aux A.M.) est devenu Conseil (la dénomination de sa fonction n'est pas exactement connue) de la société Graphoplex à partir de 1948-1949. Il est l'auteur d'un livre sur les règles modernes : « Technique Nouvelle de la règle à calcul par la généralisation de la notation opératoire » publié en 1938 par la Librairie Polytechnique CH. Béranger et réédité en 1947, par le même éditeur dans une édition revue et augmentée.

Il est aussi l'auteur de « La règle à calcul moderne – L'échelle des Log-log », série d'articles publiés dans la revue « L'ingénieur et le technicien de l'enseignement technique » entre février et juillet 1952 et ensuite rassemblé en une brochure (12 pages) éditée par PYC Éditions.

Il est également l'auteur de plusieurs brochures non signées, publiées directement par Graphoplex, sous le titre « Instructions abrégée pour l'emploi de la règle à calculs ELECTRIC LOG LOG ». L'édition la plus ancienne en ma possession a été imprimée par Hardy en 1949 de 32 pages et renvoie à l'ouvrage de Séjourné « pour renseignements complémentaires ».

L'autre édition, datée de Janvier 1953 et considérablement allégée – 16 pages, réimprimée à plusieurs reprises par Hardy (au moins en 1955 et 1957, selon les exemplaires que j'ai pu retrouver), fait doublement référence à l'ouvrage de Séjourné et à la brochure éditée par PYC Éditions.



Les livres de André Séjourné et les premières brochures Graphoplex

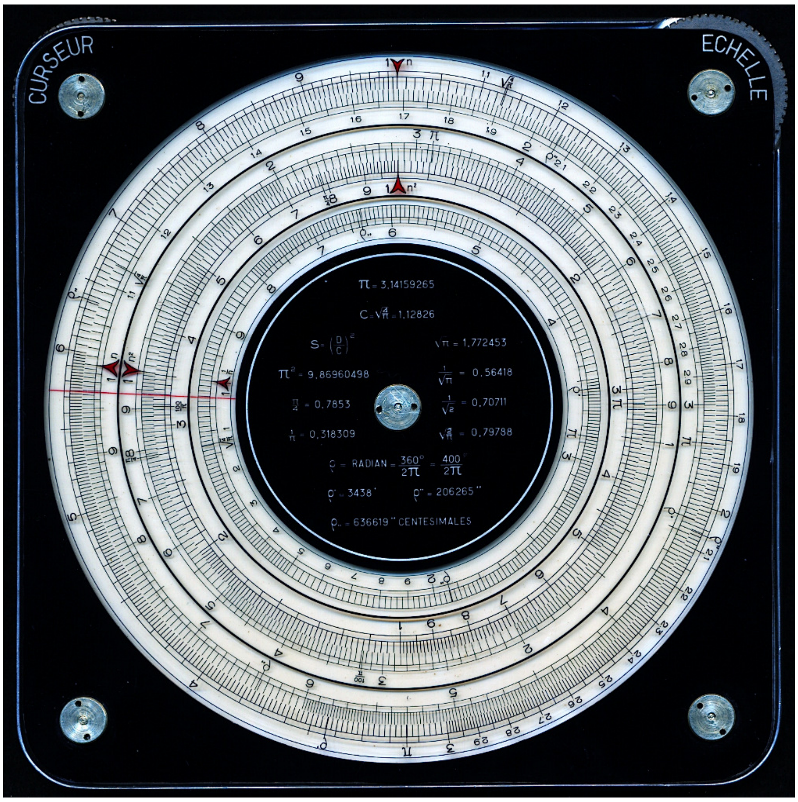
Je ne veux pas reprendre ici le catalogue des règles Graphoplex, qui sera joint en annexe avec le CD-Rom, mais plutôt montrer leur évolution.

Souvent il n'y a pas de date précise, de nombreux modèles ont existé simultanément, mais l'évolution de la fabrication peut quand même donner des indications précieuses pour déterminer une chronologie.

Certains détails m'ont été donnés par d'anciens collaborateurs de Graphoplex lors d'entretiens téléphoniques, la fiabilité de ces informations est celle de leur mémoire, il ne subsiste aucun document écrit, les équipements techniques ont été revendus ou mis à la casse.

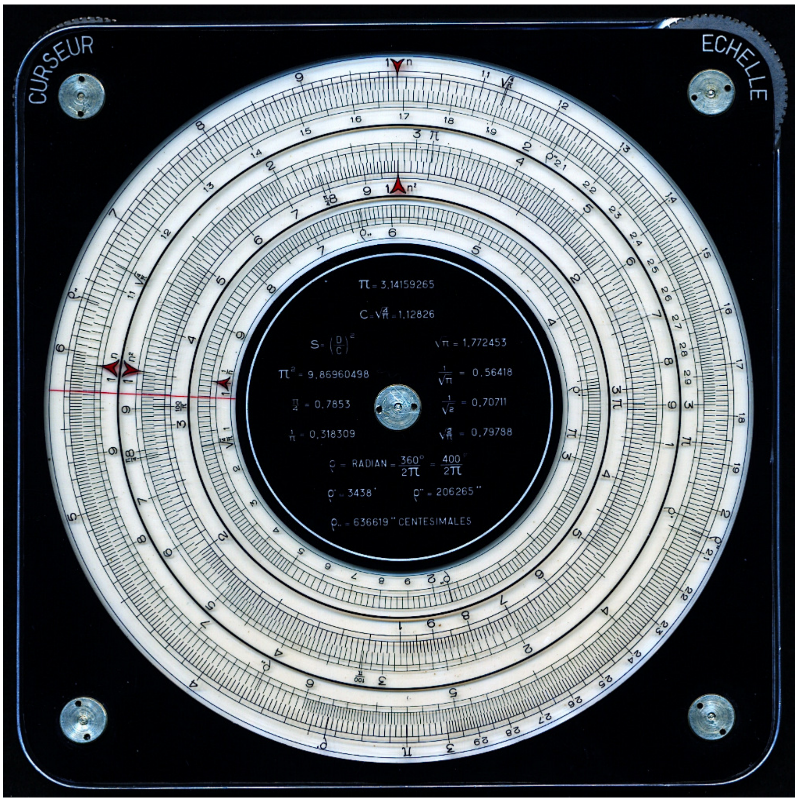
Le procédé de photogravure

Je vais décrire le plus précisément possible la méthode employée par Graphoplex car elle constitue une des originalité de ces règles, d'autres fabricants ont aussi utilisé la photogravure, mais l'inclusion du colorant dans la solution d'attaque (mordant) a permis d'obtenir une gravure inaltérable (ou presque) lié à une grande finesse de gravure, le plus bel exemple en est le calculateur circulaire ROPLEX:



ROPLEX (recto)

Ce cercle à calcul se démarque de la production Graphoplex, il est double face, fabriqué en Plexiglas transparent, aluminium et acier, il mesure 13 x 13 cm. Le logo est argent sur fond noir. Je ne connais pas sa date de fabrication précise, mais sa notice a été imprimée en 1960 par Hardy.



ROPLEX (verso)

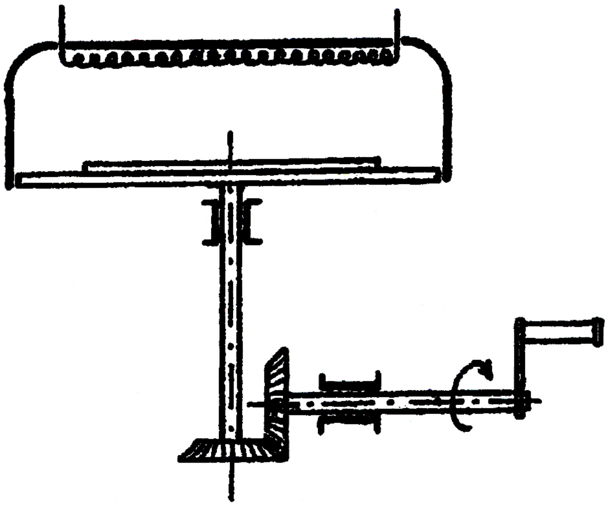
Basé sur une méthode classique, connue depuis les origines de la photographie, le procédé dit « à la gomme bichromatée » est connu depuis le milieu du dix neuvième siècle, il a été souvent appliqué à la photographie au début du siècle suivant. Une autre de ses applications est la photogravure des matières plastiques. Le brevet déposé par Albert ARASSE décrit parfaitement l'application de cette méthode à la gravure du polymétacrylate de méthyle (en abrégé PMMA) plus connu sous ses dénominations commerciale telles que Altuglas, Lucryl ou Plexiglas), il faut noter que les premières notices Graphoplex des années 1950 revendiquaient le fait que les règles étaient en « méthacrylate de méthyle », synonyme à l'époque de haute qualité.

Décrivons rapidement le procédé:

Le procédé ne permettait que la photogravure sur une surface plane, en une seule couleur, la gravure en plusieurs couleurs nécessitait de refaire le cycle de manipulation.

Les échelles étaient dessinées fortement agrandies, manuellement et probablement à l'aide d'un coordinatographe rectangulaire. Elles étaient ensuite reproduites à l'aide d'une chambre photographique de grand format BOUZARD, semblable à celles utilisées chez les imprimeurs et réduites à leur dimensions définitives sur un film à haut contraste AGFA (très probablement Gevalith Ortho, qui à été utilisé au moins pendant quelques années). Les échelles pouvaient être reproduites plusieurs fois sur un même film. Le cliché obtenu était un négatif (dessin noir sur fond transparent).

Les plaques de Polyméthacrylate de méthyle étaient enduites d'une fine couche de gélatine bichromatée (la formule est donnée dans le brevet), puis séchées sur une tournette spéciale. Après exposition dans un châssis photographique, à travers le film, par une source lumineuse actinique intense (lampe à arc nu, au xénon, à vapeurs de mercure), les ébauches étaient dépouillée dans un bain révélateur, la couche de gomme bichromatée, durcie lors de l'exposition était insoluble sauf aux emplacements des échelles, protégées de la lumière.



TOURNETTE pour l'enduction de gomme bichromatée (d'après le brevet)

Une technique proche est utilisée encore aujourd'hui pour la production des circuits imprimés utilisés en électronique.

Les zones non protégées étaient ensuite attaquées par une solution de phénol dans laquelle était dissout le colorant qui imprégnait ainsi les zones non protégées.

Les colorants utilisés par Graphoplex avaient été produits par les établissements LEROY, rue de Paris à Montreuil, ce sont toujours les mêmes colorants (probablement des colorants à l'aniline) qui ont été utilisés, notamment le colorant rouge bordeaux, spécifique des règles Graphoplex. Les établissements LEROY n'existent plus, et les archives techniques n'ont pas été conservées.

Après essuyage (avec une solution alcoolique) pour enlever l'excès de colorant, les ébauches sont placées dans un bain de durcissement à base de formaldéhyde, la gomme bichromatée est ensuite éliminée par rinçage prolongé à l'eau froide. Les ébauches sont ensuite polies. S'il était nécessaire d'utiliser plusieurs couleurs, l'ensemble du cycle de photogravure devait être recommencé.

Les premières règles étaient monochromes noires, par la suite le logo à été photogravé en rouge, c'est seulement par la suite, lorsque tous les difficultés relatives au repérage précis nécessité par des impressions multiples, que les échelles ont été réalisées en plusieurs couleurs (jusqu'à 5 sur une des faces de la règle radiologique (rouge, bleu, jaune-orange, vert et noir).

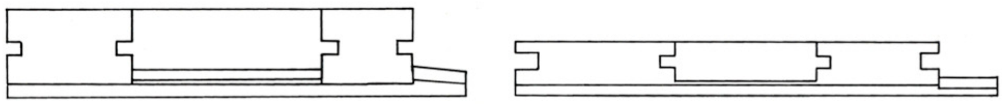
Ensuite les plaquettes comportant les échelles étaient découpées puis assemblées par collage sur les ébauches de bâti et de réglette découpés dans des profilés extrudés puis finis par fraisage. Une des faces pouvait-être photogravée directement.

Les règles étaient encore assemblées à partir de plusieurs éléments comme les règles plus anciennes en bois plaqué.

Evolution de la fabrication

Lorsque par la suite, des matières plastiques moins « nobles » mais plus économiques telles que le polycarbonate (en abrégé PC) connu aussi sous des noms tels que Lexan ou Makrolon, ou le polychlorure de vinyle (en abrégé PVC), dans ces deux cas, le phénol était remplacé par de la méthyl éthyl cétone. Cette recherche de rentabilité a conduit aussi à une réduction de qualité, notamment au niveau de la gravure (diffusion superficielle du colorant dans le PVC).

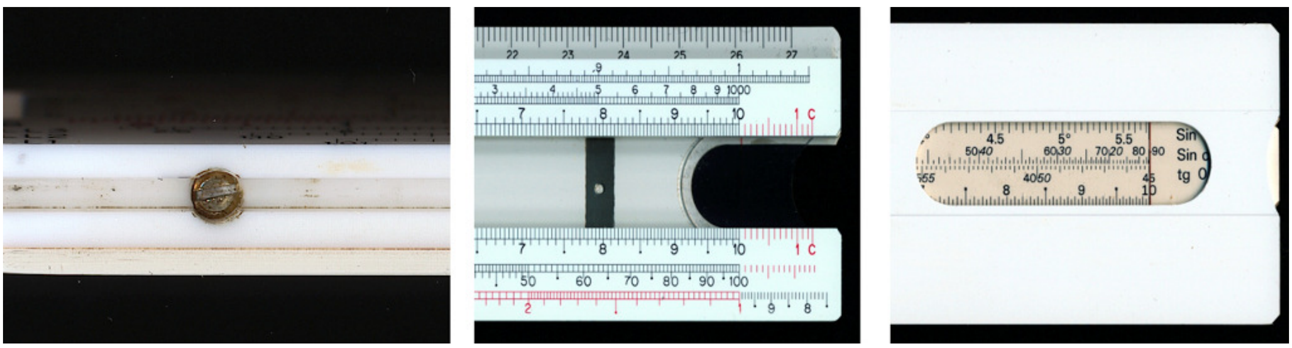
C'est à partir de la réalisation des règles double face (série des 69x) que la fabrication a pu être simplifiée, les règles ont été fabriquées d'un seul tenant, comme c'est généralement le cas des règles en matière plastiques, les ébauches étaient directement impressionnées. Quelques autres modèles telles que les 621, 641 ainsi que les dernières versions d'autres modèles (620, 640) ont bénéficié de cette évolution, elles se reconnaissent à un détail, l'échelle centimétrique, est beaucoup moins inclinée, c'est la seule échelle qui est rapportée.



Evolution de la 640 (à la même échelle)
à gauche 640 en PPMA vers 1950 *à droite 640 en PVC vers 1970*

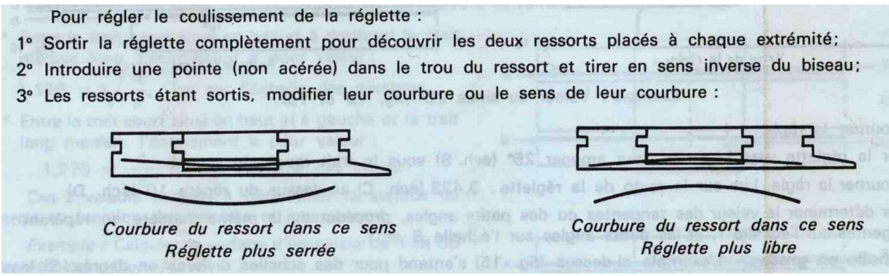
Les premières règles Graphoplex ont été réalisées en PMMA, c'est la revendication de qualité mentionnée dans les notices des années 1950. Cette matière plastique, naturellement transparente est colorée en blanc par ajout d'une petite quantité de pigment blanc, ce qui lui confère un aspect laiteux, le réglage du coulissement était souvent réalisé par deux vis disposées latéralement. Cette disposition est peu fréquente, je ne l'ai vu aussi que sur quelques règles BRL (par exemple une D26 Darmstadt).
Ces premières règles ne comportaient pas de référence.

Le réglage du coulissement par des lames métalliques est ensuite intervenu, finalement, un profil particulier a permis ce réglage par simple déformation, cette disposition implique une fenêtre fermée pour la lecture des échelles du verso de la réglette.



Évolution du réglage du coulissement.

1. réglage du coulissement par vis
2. réglage du coulissement par lame
3. réglage du coulissement par déformation


Pour régler le coulissement de la réglette :

1° Sortir la réglette complètement pour découvrir les deux ressorts placés à chaque extrémité;

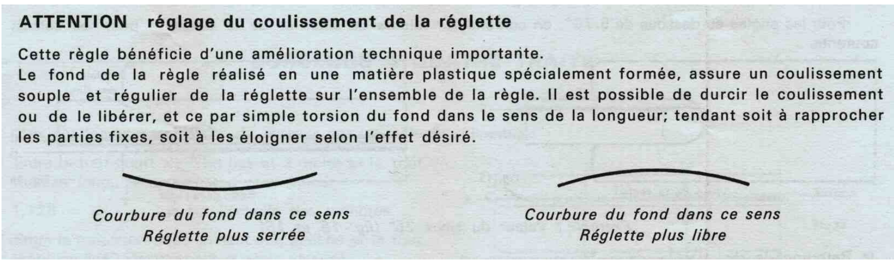
2° Introduire une pointe (non acérée) dans le trou du ressort et tirer en sens inverse du biseau;

3° Les ressorts étant sortis, modifier leur courbure ou le sens de leur courbure :

Courbure du ressort dans ce sens
Réglette plus serrée

Courbure du ressort dans ce sens
Réglette plus libre

mode 2 la majorité des règles simple-face


ATTENTION réglage du coulissement de la réglette

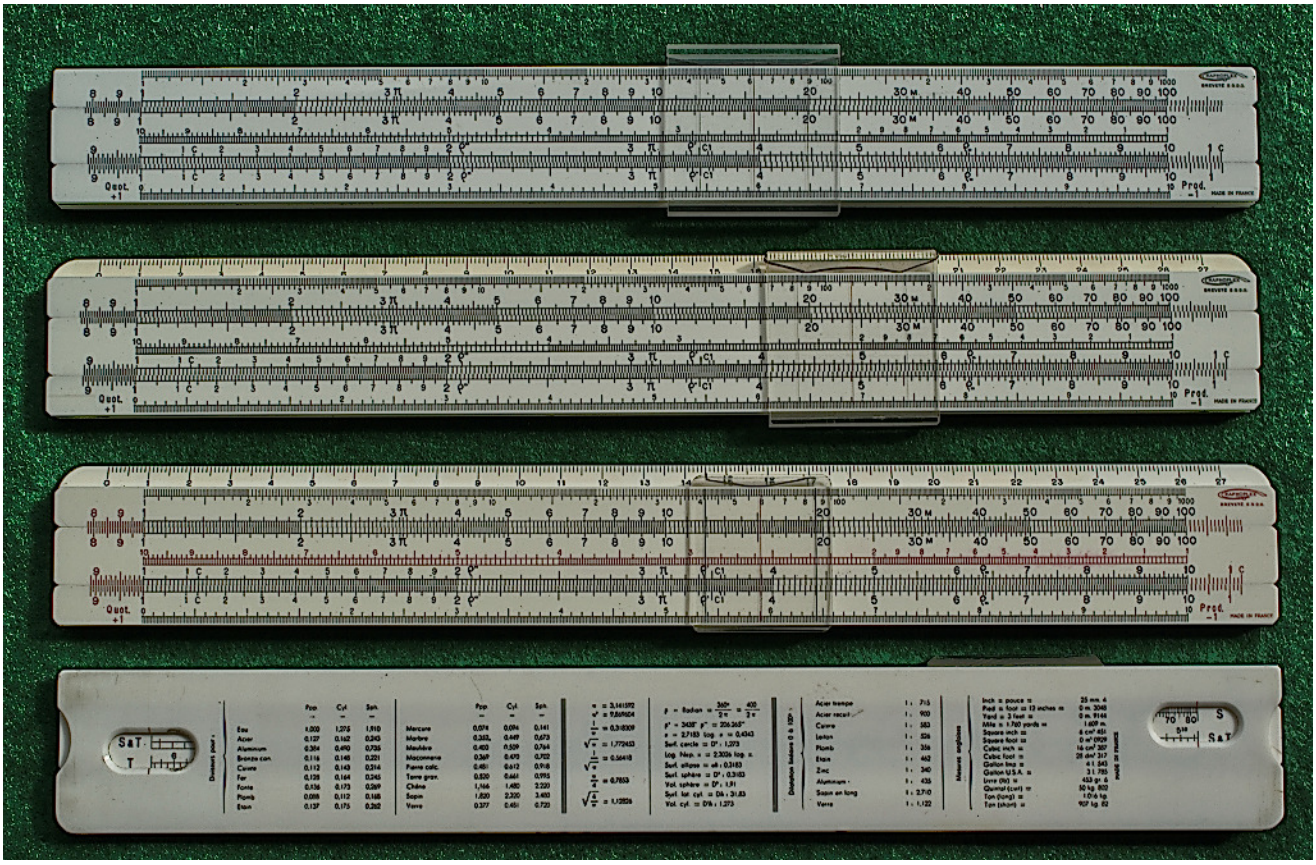
Cette règle bénéficie d'une amélioration technique importante.
Le fond de la règle réalisé en une matière plastique spécialement formée, assure un coulissement souple et régulier de la réglette sur l'ensemble de la règle. Il est possible de durcir le coulissement ou de le libérer, et ce par simple torsion du fond dans le sens de la longueur; tendant soit à rapprocher les parties fixes, soit à les éloigner selon l'effet désiré.

Courbure du fond dans ce sens
Réglette plus serrée

Courbure du fond dans ce sens
Réglette plus libre

mode 3 dernières 620 et 640, 612, 615, 643, 6250, 6245 621 et 641

Les modes 2 et 3 sont documentés dans les notices livrées avec les différents modèles de règle.



Trois règles Graphoplex primitives en PPMA (vers 1949 /1950), sans référence, elles sont semblables à la 620 qui va apparaître un peu plus tard. Il ne faut pas les confondre avec la 610, règle scolaire simplifiée qui est référencée et plus tardive.

1. Gravure monochrome noire sans biseau, logo noir creux, curseur modèle 1, aucun réglage du coulissement.
2. Gravure monochrome noire avec biseau, logo noir creux, curseur modèle 1, réglage du coulissement par vis.
3. Gravure bichrome rouge et noire, logo rouge creux, curseur modèle 2, réglage du coulissement par vis.
4. Verso, identique pour les trois.

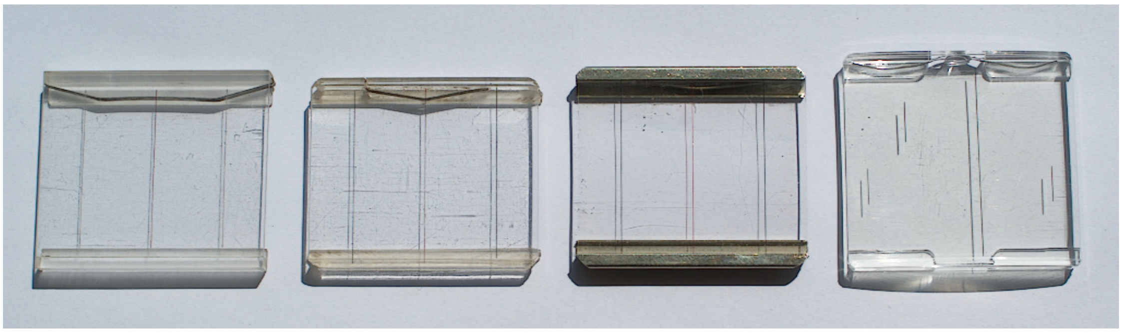
Les premières règles étaient photogravées en noir, avec un logo creux, le logo rouge creux est ensuite apparu, puis les logos ont été photogravés en plein.

La difficulté était d'obtenir un repérage parfait lors des expositions successives nécessité par la photogravure, le problème à été résolu assez rapidement et les règles bichromes rouge et noir ont été fabriquées.

Quelques logos utilisés par Graphoplex

Les curseurs

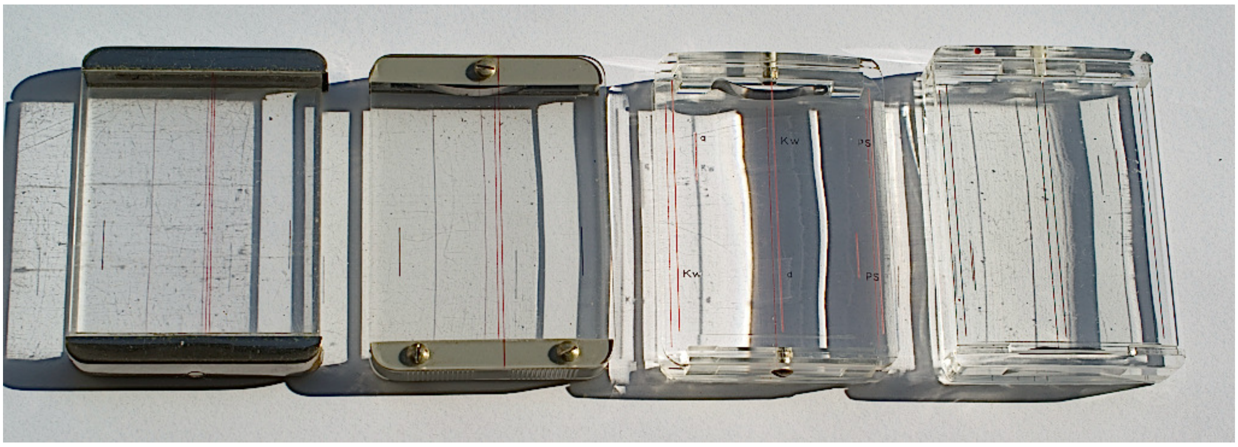
Un autre aspect des premières Graphoplex est l'évolution du curseur. Un premier curseur en plexiglas collé a fait une brève apparition, il a été rapidement remplacé par un curseur thermoformé. Ensuite les curseurs constitués par des glissières en métal chromé et une plaquette plane de plexiglas sont longtemps utilisés et finalement remplacés par des curseurs moulés, faisant loupe.



4 curseurs pour règles simple face, du plus ancien au plus récent.

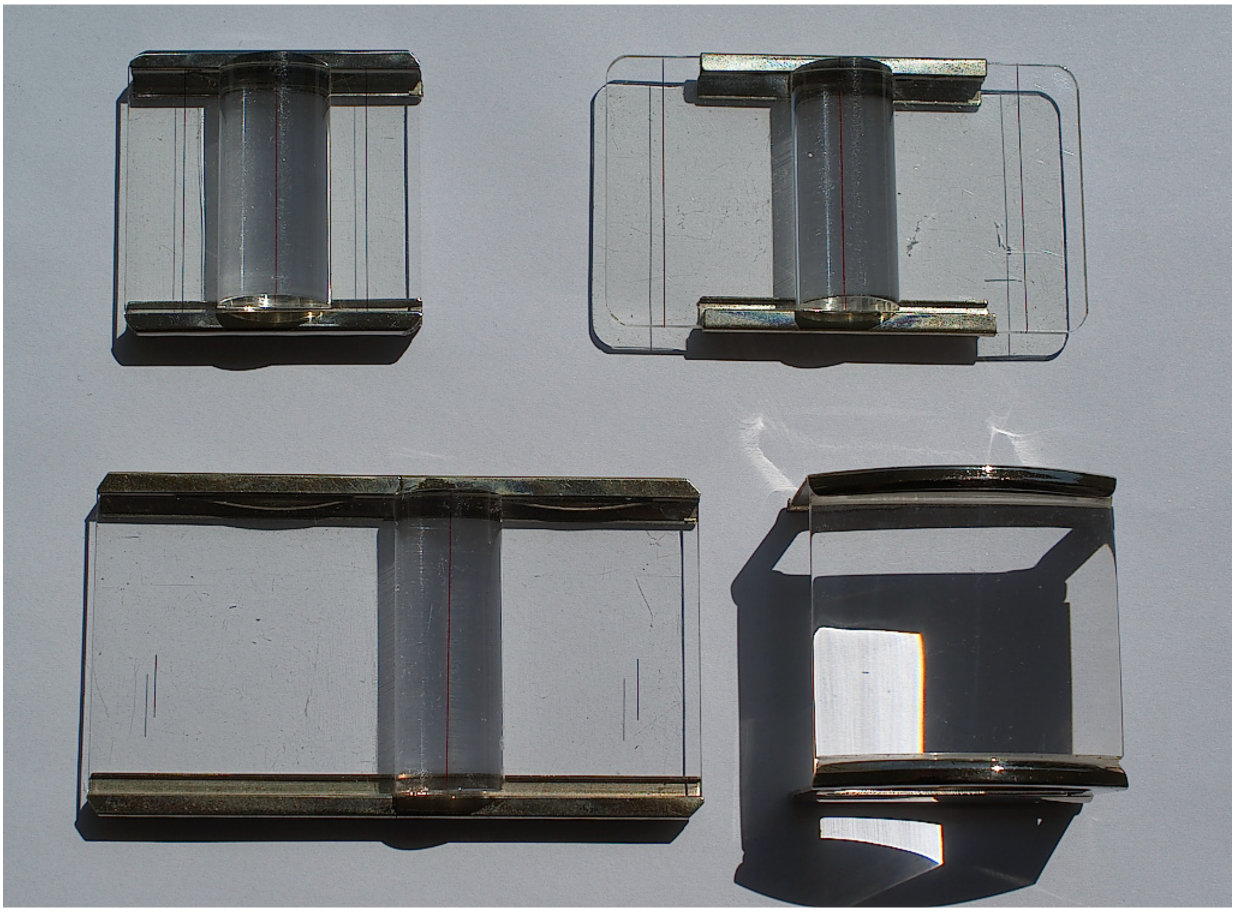
Les curseurs des règles double-face ont aussi évolué, les premiers, munis d'embouts métalliques ont eut une existence éphémère (5), ils ont été remplacés par un curseur comportant des entretoises en PVC gris (6) puis rapidement par un curseur en plexiglas moulé, non réglable (7), finalement le curseur, dont les deux faces pouvaient être ajusté par un excentrique en nylon est apparu (8).

Sa description en serait fastidieuse, le brevet joint sur le CD-Rom de l'IM 2010 le décrit bien.



4 curseurs de 690 et 690a, la première ne porte pas encore de référence, le quatrième est celui de la 690a, la 690 présente de nombreuses variantes.

Des curseurs spéciaux avec loupe hémicylindrique, ou des loupes clipsables sur un curseur standard ont été vendus en accessoires.



Respectivement, curseurs loupe pour règles 620, 6250, 6245 et 620
clipsable sur un curseur standard à glissières métalliques

L'évolution des étuis est moins intéressante, d'une part parce que il n'est pas certain que l'étui soit avec certitude celui qui contenait la règle à l'origine, les règles vendues sur les brocantes ou sur internet peuvent faire l'objet d'une reconstitution, dans une moindre part cela peur aussi arriver pour les curseurs.

Les premiers étuis étaient en carton noir avec un logo argent ou or, très rarement vert grainé avec un logo or pour quelques règles spéciales (FLEXIMAX Standard, système G. Potzsch), des étuis en carton bordeaux ont suivis, puis les étuis en carton toilé marron sont devenus les plus usuels. Des étuis en simili-cuir étaient proposés en option. Les étuis en matière plastique sont aussi très fréquent. Des étuis en cuir véritable ont été fournis avec les règles de poche ainsi qu'avec des règles destinées à l'armée française (quelques étuis en cuir bleu pour les règles avion).

La dernière règle fabriquée par Graphoplex est une règle électro, la règle à calcul pour réseaux B.T. Modèle 35.11.416 datée de 1992, la technologie de fabrication a changé, il s'agit d'une règle souple sérigraphiée sur Astralon (comme les curseurs techniques). L'acte de dissolution-radiation de Graphoplex a été signé en décembre 1991 et publié début 1992.

Il n'est pas possible de décrire toutes les modèles de règles à calcul fabriquées par Graphoplex lors de cette présentation, j'ai tenté de donner quelques informations sur les origines de cette marque prestigieuse. Le catalogue, recensant environ 180 modèles de règles fabriquées par Graphoplex est joint sur le CD-Rom de l'IM 2010, si vous avez des informations nouvelles, ou si vous connaissez d'autres règles qui n'y figurent pas, toutes vos informations sont les bienvenues.

Les catalogues

Les catalogues constituent un outil précieux pour dater les règles, Graphoplex en à édité plusieurs qui étaient destinés aux revendeurs, malheureusement il n'en subsiste que peu d'exemplaires, ils étaient jetés quand une nouvelle édition était distribuée et ont été rarement conservés quand les règles à calcul ont cessées d'être d'un usage courant.

Les quelques éditions que j'ai pu voir permettent de donner quelques points de repère pour les règles proposées à la vente, ces catalogues ne donnent pas d'informations sur les règles spéciales fabriquées sur commande, il ne s'agit que des règles proposées au grand public. Les références sont données comme figurant sur les catalogues. Il faut remarquer que les références ne précisent pas en général les évolutions des règles telles que 690 vers 690a par exemple.

Édition vers 1970 (non datée – l'adresse indiquée est celle de la rue Paul Fort)

Le système de classement est celui adopté par Graphoplex dans le catalogue, seules les règles à calcul sont citées à l'exclusion de tout autre matériel de dessin.

Règles à calcul de poche:

Système Rietz: 612, 615

Système Électric Log-Log: 643

Système Électro: 650
Système Néperlog (duplex): 692b

Règles à calcul de bureau:
Système Rietz: 620, 6250
Système Électric Log-Log: 640, 6245
Système commercial: 645
Système Darmstadt: 647
Système Géomètre 630
Système Rolinéa (Beghin): 660
Système Statos-Béton: 680
Système Gaz de France: GR/25

Règles à calcul double face
Systéme Néperlog: 690
Système Néperlog-Hyperbolic: 691
Système Radian-Log: 695
Système Décilog: 699
Système Électronicien 698

Règles à calcul scolaires:
Système C.A.P. Rietz: 1600
Système Pédago-Math: 610
Système Techni-Math: 1694
Système C.A.P. Log-Log: 1614
Système Technilog (Duplex): 694

Règle spéciale pour imprimeur et publicistes:
Typomètre-Lignomètre 604

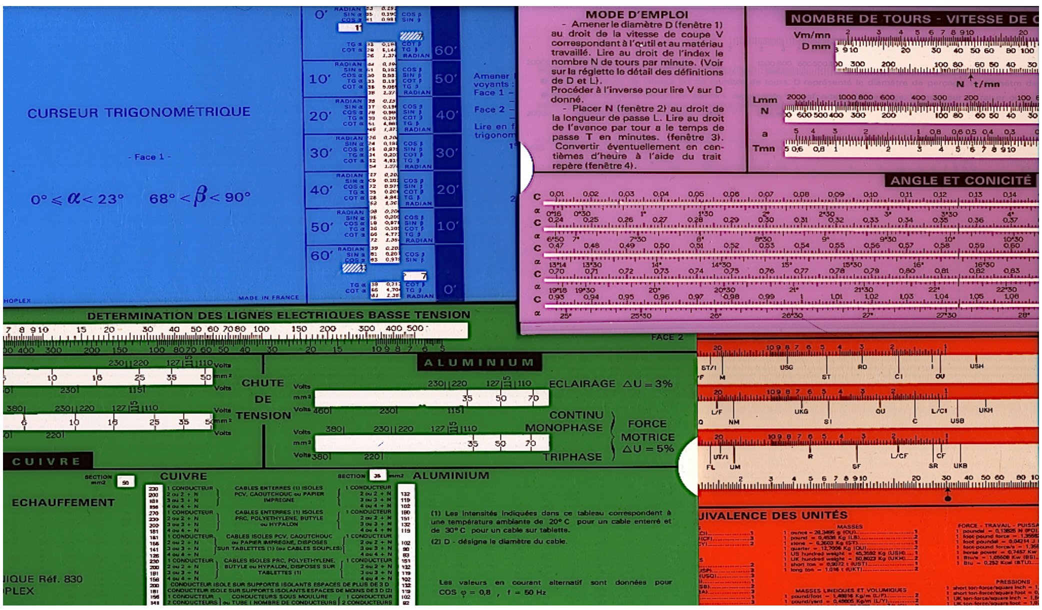
Règle à calcul pour démonstrations: règle fonctionnelle de 1,30 m reprenant les échelles de la 1694.

Règle de projection « pour diascope » reprenant les échelles de la 690a

Un tableau des échelles figurant sur les différents système sera joint en annexe sur le CD Rom.

Édition 1975

Un tarif non illustré mentionne les nouveaux modèles de règles type S (621 et 611), les règles 612, 650, 643, 692, 1621, 615, 620, 640, 647, 630, 660, 680, 645, 1694, 690, 691, 695,698,699, 610,1600, 1614, 694, 6250, 6245 et les curseurs techniques 800, 810, 811, 812, 820, 830, 840, 850 qui seront décrits plus loin.



Édition 1978

Le système de classement est celui adopté par Graphoplex dans le catalogue, seules les règles à calcul sont citées à l'exclusion de tout autre matériel de dessin. L'espace consacré au matériel de dessin devient prépondérant, le déclin des règles à calcul est évident.

Curseurs techniques sérigraphiés sur astralon souple:
800: Trigonométrique
810: Poutrelles
811: Cornières
812: Produits sidérurgiques courants
820: Conversions
830: Électricité
840: Tolérances
850: Visserie
861: Construction métalliques (flexion)
862: Constructions métalliques (flambage)
880: Poids et prix des tôles
890: Transmissions de puissance
Règles spéciales pour imprimeurs:
Typomètre-lignomètre 604
Règles à calcul
Système Rietz S: 621
Système Rietz: 612, 615, 620, 6250
Système Log-Log S: 641
Système Électric Log-Log: 643, 640, 6245
Système Darmstadt: 647
Système commercial: 645
Scolaires
Système C.A.P. Rietz: 1600
Système C.A.P. Log-Log: 1614
Règles à calcul double face
Système Néperlog: 692, 690
Système Néperlog-Hyperbolic: 691
Système Électronicien: 698
Système Technilog (Duplex): 694
Règles à calcul
Système Géomètre: 630
Système Électro: 650
Système Rolinéa (Beghin): 660
Système Statos-Béton: 680
Règle à calcul pour démonstrations:
Règle fonctionnelle de 1,30 m reprenant les échelles de la 1694
Règle fonctionnelle de 1,30 m reprenant les échelles de la 621
Règle de projection « pour diascope » reprenant les échelles de la 690a

Édition de 1980

La liste des règles proposées est identique à celle du catalogue de 1978.

Quelques repères

Les fondateurs de Graphoplex, leurs noms apparaissent sur de nombreux documents tels que des brevets :

Albert ARRASSE, Didier ERNOTTE, Jean-François MATTEI, Michel, VILLARD

D'autres noms ont été évoqués, aucun document ne le confirme.
Graphoplex a changé à plusieurs reprises de localisation, voici les adresses connues:

Vers 1950: 21 rue de Montsouris, Paris 14
Vers 1970: 21 rue Paul Fort, Paris 14
Vers 1975: La société déménage à Monts (en Touraine), un bureau commercial subsiste rue Paul Fort jusqu'aux années 1980.

Bibliographie

Sur les règles à calcul (en relation ou citant les règles Graphoplex)

André Séjourné
Technique nouvelle de la règle à calcul par la généralisation de la notation opératoire
Éditions Charles Béranger
Première édition 1938 – 158 pages
Deuxième édition 1947 – 210 pages

Instruction abrégée pour l'emploi de la règle à calculs Electric Log-Log
Brochure Éditions Graphoplex 1949 – 32 pages – non signé

Instruction abrégée pour l'emploi de la règle à calculs Electric Log-Log
Brochure Édition Graphoplex 1953 – 20 pages – non signé, réimprimé en 1955 et 1957 au moins, renvoi à la brochure L 'échelle des Log-Log

La règle à calculs moderne – L'échelle des Log-Log
Brochure Éditions PYC 1952 – 16 pages, logo Graphoplex en couverture

Ch. Guilbert
Votre règle à calcul
Éditions Radio 1961 – 72 pages (couverture rouge)
Éditions Radio 1969 – 80 pages (couverture verte)

Fred Klinger
Mais oui, vous savez utiliser la règle à calcul
Éditions du Jour 1963 – 240 pages (plusieurs réimpressions identiques)

Paul Berché & Edouard Jouanneau
Apprenez à vous servir de la règle à calcul
Librairie Parisienne de la Radio neuvième édition 1962 – 119 pages, c'est seulement à partir de cette édition que les auteurs citent les règles Graphoplex.

Edouard Jouanneau
Pratique de la règle à calcul
Librairie Parisienne de la Radio 1971 – 240 pages

André Robichon
La règle à calculs
Éditions Foucher – deuxième édition 1969 – 184 pages

R. Dudin
La règle à calcul
Éditions Dunod – quatrième édition 1964 – 212 pages

Brevets

Seuls les brevets relatifs aux règles, à la photogravure ou à des procédés de fabrication figurent dans les documents joins sur le CD-Rom. Graphoplex a aussi déposé de nombreux brevets relatifs à des stylos à encre de chine pour le dessin ou des stylos pour tables traçantes.

Liste des brevets joins:

Antériorités revendiquées dans le brevet anglais d'Albert Arrasse

- BE398086A
- FR759442A
- GB426866A

Photogravure (Brevets déposés par Albert Arrasse)

- FR863122A
- GB607871A

Curseurs

- FR2061568A1

Fabrication

- FR2442144A1
- CH627133A5

Sur les matières plastiques et leur histoire

J. Jousset
Matières plastiques tomes 1, 2 & 3
Éditions Dunod 1968, 304 + 216 + 240 pages

J.P. Trotignon, J. Verdu, A. Dobraczynski & M. Piperaud
Précis Matières plastiques
Éditions AFNOR–Nathan 1996 – 232 pages

Documents joins sur le CD Rom IM 2010

Première notice vers 1950
Brevets Graphoplex
Tableau des échelles établi par Graphoplex
Catalogue des règles Graphoplex

Graphoplex: History[2]

Around 1990 Daniel Toussaint started to collect slide rules, drawing instruments and related documentation. From 2005 this got a big boost resulting in 2007 in the internet site linealis.org with mailing list in French.

Introduction

The history of Graphoplex is difficult to reconstruct since no archives have survived. The name is now used by a manufacturer of office and drawing equipment without any link to the original Graphoplex products.

My research has been in two areas: the manufacturing processes and reconstructing the catalog of general and special slide rules. Herman van Herwijnen's catalog has been a useful source, as have contributions from several French collectors.

Graphoplex has pioneered a way of engraving which was different from the classical mechanical engraving as used by Tavernier-Gravet for example. Another innovation was the construction of the slide rule where Graphoplex chose – at the expense of a more complex manufacturing process – to use a standard base onto which separately manufactured scales were attached, giving rise to a large variety of models.

History

The early Graphoplex slide rules sometimes had quick reference paper strips on the back, like many other early slide rules had. Most of the time, no patent was mentioned, some 640s mentioned "No. 640 Electric Log-Log (registered trademark)" which doesn't help much.

Then, one day, Gonzalo Martin sent pictures of a 640 destined for sale to the UK with a quick reference card in English mentioning "Made in France – British Patent No. 607 871".

This patent allowed finding the original French patent. The British patent also referred to an earlier patent No. 426 866 which we will discuss later. The French patent doesn't mention this original patent.

<fig. Excerpt from the quick reference card of the British 640>

The French patent No 863 122, applied for on 29 January 1940 by Albert Arrasse , deals with photo etching of plastic materials (called PPMA), where the coloring agent is directly introduced in the etching chemicals. This is an essential detail, as the colors become an integral part of the slide rule. This patent, applied for by Arrasse as an individual, might easily have gone unnoticed.

A brochure printed in 1949, control lists dated 1950 that were inserted in slide rules cases, notes printed in 1951 all indicate that the slide rules were first commercialized in 1949 or even later.

Scales and the log-log slide rules

A teacher named André Séjourné became consultant to Graphoplex from 1948-149, his exact responsibilities are not known. He had written a book on modern slide rules "New Techniques of the Slide Rule by a generalization of the operating notation", published in 1938 and reissued in 1947 in a revised and extended edition.

[2] English translation by Ronald van Riet of Toussaint's article on Graphoplex History, page 48

He had also written "The Modern Slide Rule – The Log-Log Scale", a series of articles between February and July 1952 and later issued as a 12 page brochure.

He had written several unsigned brochures, published by Graphoplex, called "Abbreviated Instructions for the Use of Log-Log Slide Rules", the oldest edition of 32 pages was printed in 1949 and refers to the work by Séjourné for additional information. The 1953 was much shorter at 16 pages and was reprinted in 1955 and 1957, with references to both Séjourné and the above-mentioned 1952 brochure.

<fig. The books by Séjourné and the first brochures from Graphoplex>

Rather than copying the complete Graphoplex catalog – which is included on the additional material CDROM – we will try to show their evolution, partly given to me by former employees of Graphoplex, who worked from memory, making correct timing impossible. Various models co-existed, but the evolution of the manufacturing can still be roughly determined.

The Photo Etching Process

We will try to describe as accurately as possible the photo etching process since this is specific to Graphoplex. Other manufacturers have also used photo etching, but the inclusion of the color in the etching chemicals was unique to Graphoplex and made for an almost inalterable etching of high definition, best demonstrated in the circular slide rule Roplex.

This circular slide rule (see figures) is double-sided, made of transparent Plexiglas, aluminum and steel and measures 13 x 13 cm. The imprinting on the outside is silver on black. The exact date of manufacture is not known, but the notice was printed in 1960.

The photo etching process itself was well known since the middle of the 19^{th} century and had been used in photography before being applied to plastic by the patent of Arasse. The PPMA plastic used was better known under commercial names like Plexiglas. In the early notices from Graphoplex, it was called by its official chemical name which was then seen as a synonym for quality.

Short Description of the Process

The process was only useful for flat surfaces and could only work with a single color at a time, etching multiple colors meant as many process steps. The scales were drawn at a large scale, probably manually using a pantograph. They were then reproduced photographically on high definition photographic film (Agfa Gevalith Ortho was used at least for several years). The scales could be reproduced several times on the same film, in negative: black on a transparent film.

The Plexiglas plates were covered by a gel (the formula is given in the patent), then dried using a special turning table <*see figure*>. After exposure by a very bright light (xenon or mercury vapor), the exposed parts had become hardened, whereas the covered parts could be washed away to expose the base material. A similar process is still used today to etch electronic circuit boards.

The unexposed places were then treated with a phenol solution in which the coloring agent was introduced. The colours used by Graphoplex were produced by Leroy in Montreuil and were probably aniline based. The same colors were used throughout, the burgundy red being specific to Graphoplex. Leroy doesn't exist anymore, no archives have survived.

After cleaning using an alcohol solution to remove the excess coloring, the blanks were placed in a bath of formaldehyde for hardening, following which the photographic gel was removed by prolonged washing in cold water, finally they were polished. When more than one color was necessary, these steps were repeated.

The first rules were etched in black only, later the logo was etched in red, only much later, when the problems of alignment had been resolved, were multi color scales introduced (with a maximum of five on a radiologic slide rule with red, blue, orange, green and black). Finally the blanks with the scales were cut and glued on the bodies and slides, cut from extruded and milled profiles. One of the faces could be photo etched directly.

The slide rules were still assembled from multiple parts like the older boxwood rules.

How the Manufacturing Process Evolved

Later on, more economic plastics were used, such as polycarbonates (commercially known as Makrolon) or PVC. In these cases, phenol as an etching agent was replaced by methyl ethyl ketone. This economization resulted in a lower quality, especially in the etching, where in PVC rules the colors could sweat <note of the translator: as demonstrated by a 6250 of which photos will be included on the additional material CDROM>.

Starting with the duplex rules (69X series), the manufacturing process was simplified, the slide rules were made in a single block, like most plastic slide rules, and the etchings were directly applied. Some other models like the 621 and 641 as well as late versions of the 620 and 640, have benefited from this evolution, they can be identified by much a less slanted centimeter scale.

<fig. Evolution of the 640 (same scale): left PPMA from1950, right PVC from 1970>

The first Graphoplex rules were made of PPMA, as is indicated by the included notice from the 1950s. This naturally transparent plastic was colored white by the addition of white pigments, giving it a milky look. The sliding could be adjusted by lateral screws, which is an unusual arrangement, only seen in some BRL slide rules (like the D26 Darmstadt). These early slide rules show no reference number.

Metal strips were later used to adjust the sliding, followed by a a special profile of the slide rule that could be deformed, and which resulted in a window in the gutter of the slide rule to read the reverse of the slide.

Fig: evolution of the sliding adjustment: by screws; by metal strip; by deformation>.

<fig. type 2: most of the simplex rules>

<fig. type 3: late 620 and 640, 612, 615, 643, 6250, 6245, 621 and 641>

Types 2 and 3 were described on the notices delivered with the slide rules.

<fig.>

Three early Graphoplex slide rules made of PPMA (1949/1950), without reference number. They look just like a 620 which would appear slightly later in time and not to be confused with the 610, a simple student slide rule which was produced later in spite of the lower reference number.

1. Monochrome black etching without bevel, black outline logo, cursor type 1, no sliding adjustment.
2. Monochrome black etching with bevel, black outline logo, cursor type 1, sliding adjustment by screws.
3. Bicolor black and red etching with bevel, red outline logo, cursor type 2, sliding adjustment by screws.
4. Reverse, identical for all three.

The first rules were photo etched in black with outline logo, then the red outline logo appeared, followed by the filled logo.

<fig. Some of the logos used by Graphoplex>

Cursors

The first type of cursor of glued Plexiglas was used only briefly, it was quickly followed by a thermally formed cursor, then appeared a cursor with metal gliders and a flat Plexiglas pane and finally replaced by a molded magnifying cursor.

<fig. 4 cursors for simplex slide rules, from old to new>

There were also different types of cursors for duplex rules, the first type, with metal ends, was short-lived, they were replaced by a cursor with grey PVC spacers, quickly followed by a molded plexiglas cursor, the final type of cursor could be adjusted by an eccentric nylon screw. It was described extensively; the patent on the CDROM describes it well.

<fig. 4 cursors of the 690 and 690a, the first one still without reference, the fourth is from the 690a, *the 690 has many variations>*

Special cursors with semi cylindrical magnifiers, or magnifiers that could be clipped onto the standard cursor, were available as accessories.

<fig. magnifier cursors for the 620, 6250, 6245 and 620 that could be clipped onto the standard cursor with metal gliders>

The evolution of the cases is less interesting, partly because it is difficult to prove that a certain slide rule was originally sold with a certain case.

The first cases were in black cardboard with a silver logo, or rarely cloudy green with gold logo, or for some special rules (Fleximax Standard, system G. Potzsch) burgundy red cardboard, then brown padded cardboard cases were the most used. Fake leather cases could be ordered as an option. Plastic cases were also very common. Pocket slide rules were delivered with genuine leather cases, also slide rules for the French Army were delivered in leather cases, some blue for the French Air Force.

The last slide rule manufactured by Graphoplex was the B.T. 35.11.416 of 1992, for low voltage electrical networks. The construction had changed to astralon, as used for slide charts.

The dissolution act of Graphoplex was signed in December 1991 and published early 1992. Within the context of this paper it is not possible to describe all models of slide rules made by Graphoplex, we have tried to give background information on the origins of this quality brand. The catalog containing about 180 models of slide rules made by Graphoplex is included on the CDROM. Additional information on slide rules that are not included is very welcome.

Catalogues

The catalogues provide a useful means to date slide rules. Graphoplex has issued several versions to its distributors, however only few have survived since they were usually discarded when a new edition came out, especially when a certain type of slide rule was no longer commercially attractive.

Those few catalogues that are known give some indications for general purpose slide rules, but they give no information on special rules. The references will be given as they appear in the catalogues. They often do not discriminate between subtypes like the 690 or 690a. Only slide rules will be mentioned. *<fig. issue about 1970, address given as rue Paul Fort>*

An overview of the scales used in the different systems is included on the CDROM.

1975 edition: a simple price list shows the new type S slide rules (621 and 611), slide rules 612, … , 6245 and slide charts 800, … , 850 that will be described later.

1978 edition: only the slide rules are mentioned, although the drawing equipment takes up considerably more space now. The 800 series are again slide charts made of astralon.

1980 edition: identical to the 1978 edition.

Some key data

The founders of Graphoplex, their names appear in numerous documents and patents:

Albert ARRASSE, Didier ERNOTTE, Jean-François MATTEI, Michel VILLARD

Other names have been mentioned, but these have not been confirmed in any document.

Graphoplex has been located at different addresses:

1950: 21 rue de Montsouris, Paris

1970: 21 rue Paul Fort, Paris

1975: moving to Monts, a sales office remains in rue Paul Fort in Paris until the 1980s.

Bibliography

Patents

Only the patents relating to slide rules, the photo etching process or the manufacturing process are included on the CDROM. Graphoplex has also issued numerous patents on drawing pens or pencils.

Documents on plastics

Documents on the CDROM

ADULTES ET RÈGLES À CALCUL[1]

une Expérience Paradoxale ou un Défi à notre 21ième Siècle?

Raymond CADENAS-GURDIEL

Raymond CADENAS-GURDIEL, après des études de Philologie et Linguistique aux Universités de Madrid (Espagne) et Liège (Belgique), complète sa carrière dans cette dernière université par une formation en Economie & Gestion. Avant de retourné en Espagne en 1991, il obtient un Grade en Électromécanique, (B.Sc) en Belgique. Son activité professionnelle a surtout été orientée vers la gestion commerciale et d'exportation pendant plus de 20 ans. Ce qui lui a permis de voyager de part le monde. A partir de 2005, R. CADENAS-GUDIEL accepte le poste de Professeur Titulaire en Automatisation et Automatismes Electromécaniques à Madrid. Il est l'auteur de divers livres dans cette spécialité. De plus, R. CADENAS-GURDIEL est Administrateur-Adjoint du site espagnol arc.reglasdecalculo.org

Introduction

L'aventure de l'être humain est un conte dans lequel s'entremêlent des anecdotes le plus souvent contradictoires. Ainsi, l'Histoire est, en fait, une réalité qui, sans cesse, revient à son point de départ, mais après chaque retour une nouvelle appréhension de cette réalité semble avoir évincé la réalité antérieure.

Depuis la révolution intellectuelle des années 60 et 70 du XXième siècle, notre société a pris conscience de l'importance que notre passé représente pour nous. Cette révolution intellectuelle a mis l'accent sur l'aspect social, psychologique et anthropologique comme facteurs intrinsèques à chaque individu qui forme notre société civilisée. C'est d'ailleurs ce trait de civilisation qui nous a fait prendre conscience de l'importance de notre passé, sans lequel nous ne serions ce que nous sommes.

Une réaction face à tout ce qui ne semble pas être sain, naturel et instinctif a suscité à chacun de nous de laisser de côté, dans la mesure du possible, tout ce qui pourrait être l'indice d'une dégradation de notre intégrité. Ainsi, mangeons sain tel que le faisaient nos grands-parents, respirons sain dans des contextes éloignés des agglomérations urbaines contaminantes, et même, pensons sainement en développant notre cerveau.

C'est d'ailleurs, dans ce contexte qu'une des plus curieuses paradoxes de notre savoir est surgie: le retour de la règle à calcul. En effet, c'est un paradoxe qui semble bien confirmer, voire même ratifier cette insolite affirmation: l'intérêt pour ce que notre propre société a voulu mettre dans un musée de souvenirs. Sans les multiples règles de calcul nous ne serions pas où nous sommes actuellement.

Je vais me permettre de vous faire bénéficier d'une expérience qui pourrait sembler, à première vue, un conte de fées, pour ne pas parler d'un rêve, d'un retour à notre jeunesse. Qui au XXIième siècle pourrait s'imaginer que plusieurs de nos voisins, de nos amis, de nos concitoyens aient voulu refaire vivre ce que d'autres ont voulu mettre en silence?

Cette expérience commence, comme pour beaucoup d'entre vous, dans les pensées d'un jeune adolescent de la libération spirituelle des années 70, à qui son professeur de Mathématiques lui présente sa première règle à calcul. Depuis lors, il n'a cessé de considérer, tout d'abord cette première règle à calcul, et en suite les diverses règles qu'il a, petit à petit, acquises sur plus de trois décennies, comme une merveille du savoir mathématique.

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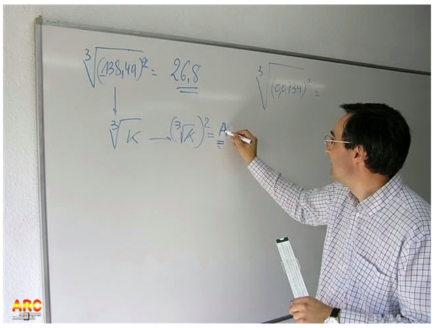
[1] An English translation of the text follows this article, on page 72

C'est avec cette conviction, une fois qu'il décide d'orienter sa carrière professionnelle vers



l'enseignement, il y a de cela peu d'années, qu'il se propose, comme fait instantané et naturel, d'utiliser une de ces règles lors de ses classes de cours. Car, il se convînt à lui même, que quelque révolution électronique que ce soit, elle est, sans aucun doute, un tremplin vers l'aisance individuelle, et pourrait se convertir aussi en une paralysie mentale due à la Loi du Moindre Effort. C'est pourquoi, comme tâche, en tant d'enseignant, est de prêcher par l'exemple.

Cette introduction, n'est, en réalité, que le contexte avec lequel cet adolescent, aujourd'hui une personne adulte, se sent ravi et comblé de satisfaction quand il peut apprécier comme un groupe d'étudiants s'intéressent à nouveau pour ce qui fut le symbole du génie des nombres.

Les Bases de l'Experience

Cette même curiosité que j'éprouvais à l'époque du collège, l'éprouvent aujourd'hui beaucoup de personnes. Sans forcer, ni contraindre, chaque groupe s'est débrouillé pour trouver une ou plusieurs règles à calcul, dans le but que je leur explique comment l'utiliser. Et au fur et à mesure qu'ils apprennent à l'utiliser, plus grand est encore leur intérêt et leur motivation. Pourquoi cela? Permettez-moi que je puisse vous en présenter les argumentations.

Voyons quel est le profil des étudiants qui assistent à mes séances de classe. Il s'agit d'adultes entre 20 et 55 ans, bien que les 3/4 ont un âge compris entre les 30 et 50 ans, qui, soit pour des raisons professionnelles ou personnelles veulent approfondir leur formation de base ou veulent obtenir une certification professionnelle qu'ils n'ont pas pu ou voulu obtenir lors de leur jeunesse. Contraints para la situation économique, ils mettent tous leurs efforts et ressources personnelles dans une formation professionnelle technique continue et pour l'emploi de type long allant d'une à deux années, en fonction de l'expérience professionnelle acquise auparavant. D'ailleurs les cours que je peux leur donner ont une durée de près de 3 mois, le plus court d'entre eux, et de 10 mois, le plus long d'entre eux.

Il s'agit, donc, d'un ensemble de personnes intégré par plusieurs sous-groupes de catégories sociales, académiques et professionnelles diverses:

De 20 à 25 ans: ces étudiants viennent de terminer une formation technique, et leur soucis est soit d'approfondir la matière étudiée, soit de compléter celle-ci par une formation supplémentaire. Leur niveau de formation est, dans la plupart des cas, assez superficielle, avec une base mathématique et scientifique souvent défaillante.

De 25 à 30 ans: ces étudiants ont déjà acquis une expérience professionnelle de quelques années, mais, soit ils sont conscients qu'il leur manque certaines connaissances. Leur formation technique semble être, pour la plupart, une réalité de hier et un doute pour demain. Ce sont des étudiants qui montrent un grand intérêt pour les matières expliquées.

De 30 à 45 ans: ces étudiants représentent la portion plus importante du groupe. Peu d'entre eux décident par motivation propre de reprendre des cours en combinaison avec leur travail et leur famille, si ce n'est qu'ils se trouvent, la plus part d'entre eux, dans une situation économique défavorable en tant de demandeurs d'emploi.

Beaucoup d'entre eux ne peuvent justifier aucune formation technique officielle. Suivre une formation pour l'emploi est leur seule possibilité de pouvoir se réincorporer dans le marché du travail.

De 45 à 50 ans: ces étudiants représentent le collectif le plus pénalisé par la situation économique. Beaucoup ne possèdent pas de formation technique, et ceux qui en ont une sont hors jeu en ce qui concerne leurs connaissances. Une formation urgente ou un recyclage aussi urgent représente un ballon d'oxygène, auquel ils s'accrochent fermement. Ce sont les étudiants les plus persévérants, qui savent l'importance *d'achever leur propre formation*.

De 50 à 55 ans: ces étudiants sont le revers des premiers jeunes. Ils possèdent une très bonne expérience, mais la société actuelle préfère les mettre dans une voie de garage et laisser place à de plus jeunes. Leur intérêt dans une formation pour l'emploi représente pour eux la possibilité de montrer qu'ils peuvent encore être actifs.

Parmi ces différents groupes assistant aussi des professionnels avec une formation universitaire de premier niveau. Certains sont même ingénieurs, et savent apprécier une formation de qualité.

Cet aperçu permet de tracer le trait général et commun à tous ces étudiants: besoin de formation et de savoir profond et pratique. Il n'est pas question de s'aventurer dans les considérations qui pourraient représenter une perte de temps pour eux. Il n'est pas question de s'attarder sur des bagatelles et des histories à dormir debout. Il est urgent d'acquérir le plus de savoir et de connaissance en un délai le plus court possible.

Une Curiosité sans Revers

Dans ce contexte d'agressivité sociale, économique et professionnelle, comment songer à qu'une règle à multiples graduations soit de quelque intérêt? Et bien, là est la curiosité même. Tous les étudiants, quelque soit leur âge, leur niveau social et même leur formation portent et manifestent un intérêt surprenant sur cet engin. Le fait de voir la personne qui doit les guider dans leur apprentissage, comment elle utilise sa propre règle et ce qu'elle est capable de réaliser avec cet engin, surprend et intrigue l'audience de la classe.

Plus de calculatrices, plus d'électronique. Ils viennent de réaliser que leurs habilités mentales de calculs et de raisonnements se sont amincis petit à petit dû à la commodité de la haute technologie. Après quelques mois, ils reconnaissent qu'ils ont récupéré une dose importante de leur initiative mentale. De même que celui qui, après plusieurs années de vie active et mouvementée, retourne dans son village à la campagne. Là, il semble revivre à nouveau. Ses poumons dévorent l'oxygène des près, comme s'il récupérait une perte de respiration. Un même sentiment s'empare de ces nouveaux élèves, quand ils commencent à comprendre la technique de calcul des différentes échelles graduées. Ils comprennent quel est le lien étroit entre la règle à calcul et leur propre cerveau. Et là, pourrait être le mystère – si mystère y a – de cette Renaissance de notre vieille règle à calcul. Cela expliquerait certainement pourquoi ils manifestent un fervent intérêt pour notre règle:

- Cet engin est écologique, ne consomme pas d'énergie.
- Cet engin ne contamine pas.
- Cet engin est sain et maintient une activité mentale active et saine. Il favorise le maintien des neurones. Et ce n'est point peu de chose.
- C'est original, et cela suffit pour se démarquer des autres.

Certains élèves, peu, il est vrai, savent ce qu'est une règle à calcul, mais ne l'on jamais utilisée ou s'il l'on fait, cela remonte à toute une éternité. Imaginez la sensation de redécouvrir quelque chose qui fait partie de leur jeunesse. Ils se sentent à nouveau rajeuni. Tout un compliment pour eux.
Comme nous pouvons le comprendre, la règle à calcul est à juste titre comparée à ce que je vous ai présenté comme la Renaissance du sain, du naturel, du passé. C'est le retour à la Mini-Cooper mais au XXIième siècle. Pourquoi ne pas vouloir ou prétendre à ce qu'elle ait sa place dans cette société qui apprécie le passé?

Une Méthodologie pour l'Apprentissage

Voyons maintenant, quelle méthodologie nous avons jugée plus adéquate. Il convient de différencier les cours de courte durée de ceux de plus longue durée. En deux mois, il n'est pas pensable de prétendre expliquer tout sur l'utilité d'une règle à calcul. D'ailleurs sur une période plus longue, l'exhaustivité demeure également une utopie. Néanmoins, une base solide propre à chaque niveau reste l'objectif recherché.

Lors de cours de courte durée, nous avons opté pour une règle élémentaire: l'ARISTO JUNIOR 0901 ou la FABER-CASTELL MENTOR 52/80. Grâce à l'aide et le support apportés para Mr. Jorge FABREGAS, le titulaire du site espagnol «arc-regalsdecalculo.org» et des ses membres historiques, sans lesquels cette aventure n'aurait pas pu démarrer, nous avons essayé de trouver un même lot de règles pour le 12 à 15 élèves qui suivent les types de cours que je présente. Mais, dû à l'importance du groupe d'étudiants, parfois 2 groupes simultanément, nous avons dû nous résilier à combiner les deux modèles utilisés. De toute façon, l'utilité de l'un ou de l'autre modèle est arbitraire, puisque tous deux prétendent au même objectif: initier l'étudiant à l'utilisation de la règle à calcul.

Vous vous demanderez, sans doute, quelle a été la programmation de ce module introductif. Sur une période approximative de 8 semaines, l'itinéraire formative a été le suivant:

Semaine Nº 1:

- Introduction à l'histoire de la règle à calcul et aux différentes échelles élémentaires.
- Concept de nombres génériques et d'exposants de base ou rangs (Axiome d'Archimède).
- Lecture et précision de la lecture sur une et, puis, sur plusieurs échelles.

Semaines Nº 2 et 3:

Echelles C et D:

- Multiplication de 2 facteurs, d'abord sans rangs, puis avec rangs.
- Multiplication de plusieurs facteurs ou multiplication en cascade.
- Division de 2 termes, d'abord sans rang, puis avec rangs.
- Division de plusieurs termes ou division en cascade.
- Opération mixtes de multiplications et de divisions, d'abord avec 3 termes, puis avec divers termes.

Echelles CI, C et D:

- Inverse d'un nombre et calcul de son rang, d'abord sur l'échelle CI, puis avec les échelles C et D.
- Multiplication de 2 et de plusieurs facteurs avec les échelles C et CI.
- Division de 2 et de plusieurs termes avec les échelles C et CI.
- Opérations mixtes de multiplications et de divisions avec les échelles C, D et CI.

Semaine Nº 4:
- Calcul de proportionnalité directes et inverses (fonctions linéaires).
- Règles de Trois simples directes et inverses.
- Règles de Trois composées.

Semaines Nº 5 et 6:
- Concept de carré d'un nombre avec les échelles C et CI, puis avec les échelles A (et B).
- Concept de carré d'un nombre avec les échelles A (et B).
- Concept d'extrapolation d'une racine carrée d'une valeur donnée. Approximation d'une racine
- carrée d'un nombre au moyen des échelles C et CI.
- Opérations mixtes avec des carrés de nombres et des racines carrées (Echelles C, D, A (et B)).
- Résolution d'équations du second degré à une inconnue (Echelles C et CI).

Semaine Nº 7:
- Concept de cube d'un nombre sur l'échelles K.
- Concept de racine cubique avec l'aide de l'échelle K.
- Opérations mixtes avec des cubes et des carrés de nombres ainsi que racines cubiques et carrées (Echelles C, D, A (et B) et K).

Semaine Nº 8 (optionnelle):
- Concept d'échelles décalées (CF, DF et CIF).
- Opérations avec les échelles décalées.
- Calcul d'intérêts avec les échelles décalées.
- Traits spécifiques du curseur et leurs applications pratiques.
- Révision générale.

Pour les cours de longue durée, une période allant jusqu'à 6 mois a été programmée. Nous avons, tout d'abord, utilisé une règle à calcul élémentaire différente. Ainsi, nous avons préféré la règle ARISTO SCHOLAR 0903, qui est une règle assez facile de localiser en quantités suffisantes. Les deux premiers mois ont été programmés conformément au modèle antérieur, sans, pour autant, parler des échelles décalées.

Une fois, cette période terminée, la suite de l'apprentissage se complique légèrement, car peu d'étudiants savent ou ne se souviennent plus des concepts mathématiques plus spécifiques. C'est pourquoi, nous nous sentons obligés d'introduire ces concepts avant d'initier son apprentissage sur la règle à calcul. Mais, cette parenthèse théorique et pratique est hautement appréciée par chaque étudiant. Compte tenu de ce petit commentaire, la programmation de cette seconde partie pourrait être résumée de la façon suivante:

Semaines Nº 9, 10 et 11:
- Introduction au calcul logarithmique.
- Calculs logarithmiques avec des tables décimales simplifiées.
- Calculs logarithmiques sur la règle à calcul (Echelle L).

Semaines Nº 12, 13, 14, 15 et 16:
- Introduction Trigonométrie Plane.
- Calculs trigonométriques avec des tables décimales simplifiées.
- Calculs trigonométriques sur la règle à calcul (Echelle S, ST, T).
- Applications mathématiques et techniques de la Trigonométrie Plane.
- Résolutions de triangles.

Lorsque l'apprentissage des diverses échelles de la règle élémentaire a été accompli, nous avons dû recourir à une règle plus complète à double face. Nous avons préféré les modèles suivantes: ARISTO STUDIO 0968, FABER-CASTELL D-STAB 52/82 et 152/82. Pendant les deux autres moins restants à l'apprentissage, la programmation, avec ces nouvelles règles, a été la suivante:

Semaines Nº 17:
- Introduction à l'échelle pythagoricienne (Echelle P).
- Calculs appliqués avec l'échelle P.

Semaines Nº 18, 19, 20 et 21:

- Introduction aux logarithmes et exposants de bases quelconques.
- Calculs de logarithmes et exposants de bases quelconques avec les échelles LL.
- Calculs pratiques de logarithmes et exposants de bases quelconques avec les échelles LL.

Semaines Nº 22 et 23:

- Concept d'échelles décalées (CF, DF et CIF).
- Opérations avec les échelles décalées. Calculs d'intérêts avec les échelles décalées.

Semaine Nº 24:

- Révision générale.

Lors des premières semaines, nous avons pris l'initiative de vérifier tous nos calculs et nos opérations mathématiques au moyen de calculatrices avec une double finalité. Tout d'abord, s'assurer que nos calculs étaient corrects. L'étudiant est sceptique au début, mais il se résigne à accepter l'efficacité de la règle à calcul, lorsqu'il a pu vérifier de ses propres yeux les résultats obtenus. De plus, il prend conscience de la rapidité avec laquelle il obtient les résultats. La calculatrice n'est pas toujours aussi rapide qu'il le pensait. Et, en suite, connaître son degré d'approximation, c'est-à-dire, l'erreur commise sur les calculs effectués. Et là, il se convînt lui-même des mérites de son nouvel engin.

Après les premières sessions d'exercices, l'erreur moyenne commise ne dépasse pas 0,5 %. Ce qui est un grand exploit, compte tenu du temps dédié en classe à l'apprentissage de l'utilisation de la règle à calcul. Car le temps employé par jour est de 20 à 25 minutes sur une période de cours de 5 à 6 heures par jour.

En Guise de Conclusion

Tout ceci confirme que notre société n'a pas pu mettre en voie de garage la légendaire règle à calcul. Subsiste-t-il encore un moindre intérêt pour cette relique du passé? La réponse ne peut qu'être qu'affirmative. Donnons-lui encore une chance, et nous nous étonnerons de voir comment elle revit au seing même de cette société hautement électronique. Ce qui nous manque, c'est justement la liberté de ne pas dépendre continuellement de ces merveilles de l'électronique appliquée, car la première réalité à en subir les conséquences est notre cerveau, qui devient de plus en plus paresseux. Si nous ne calculons plus mentalement, et on nous apprend à utiliser une calculatrice ou un ordinateur, si nous lisons de moins en moins, car il est préférable de regarder des programmes, instructifs ou non, au lieu de lire des livres sur ces mêmes sujets, que deviendront nos aptitudes intellectuelles, et je me permets de citer les valeurs statistiques du désastre éducatif dans certains pays européens, comme, par exemple, l'Espagne, où l'étudiant ne s'y retrouve plus dans ses comptes ni dans ses écrits.

Notre société a-t-elle besoin de reconsidérer certaines valeurs traditionnelle afin de se réaffirmer? Suffit-il de penser chacun seulement à son corps et son apparence extérieure comme critères appellatifs et expressifs de sa personnalité face à la société? C'est à discuter. Que devient de Juvénal et de sa maxime « Mens sana in corpore sano » (Un esprit sain dans un corps sain) (Satires, X, 356)? L'expérience, dont je vous parle, plaide pour une re-vitalité de l'esprit et de l'intellect de l'individu. Anecdote, certes, telle est cette expérience, mais aussi un défi à ce XXIième siècle qui promet d'être riche en technologies de pointes.

Mais, l'être humain saura réellement définir sa place dans cette jungle du progrès? La règle à calcul est toute disposée à l'aider à se faire un chemin dans cette impressionnante jungle.

ADULTS AND SLIDE RULES[2]

Raymond Cadenas-Gurdiel, graduate from the universities of Madrid (ES) and Liège (BE) is currently professor of automation in Madrid and has written several books. He is responsible for the Spanish site arc.reglasdecalculo.org on slide rules.

Introduction

Using a slide rule is a good mental exercise which is why this has been incorporated in courses for adults.

Base Experience

The students are adults aged between 20 and 55 years, 75 % are older than 30, who want to get a better general education or obtain some diploma which they had not managed to do when they were younger. They follow a one to two year technical study, depending on previous experience. Courses last from 3 to 10 months.

The group can be subdivided in several age groups:

20-25 years: these students have just completed a technical study and want to either deepen or widen their knowledge. The base education is often rather limited mathematically and scientifically.
25-30 years: these students have several years of working experience and realize they lack in certain areas. Their technical study is often outdated. These students are highly motivated.
30-45 years: the largest group. They are often forced by the economic climate and the demands of their jobs. Many have not followed any formal technical study. Following courses is their only option to get a new job.
45-50 years: the group affected most by the economic climate. Many have no technical schooling and those who have, have forgotten most. These are the most persistent students, knowing only too well how important a formal study is.
50-55 years: the inverse of the first group: lots of experience but still they are replaced by younger colleagues. Completing the study enables them to prove that they can still be active.

Amongst these groups some university trained people are present. We can deduce a common denominator in these groups: the need of education and a of deep and practically oriented knowledge. They waste no time in acquiring this knowledge in the shortest possible time.

Simply Being Curious

In this aggressive social context, why would slide rules be of any interest? Throughout the subgroups, all students show a surprising interest in slide rules; they are intrigued by what they can be used for. Students realize how their mental calculating has been eroded bit by bit by electronic calculators. After a few months, they realize that they have recuperated an important part of their mental abilities, similar to elder people who return to the village where they spent their childhood. They almost feel reborn.

A similar feeling comes when the students start to understand how to use the different scales and how the link to their brain is forged. And here is the secret of the Renaissance of our good old slide rule:

[2] English summary by Ronald van Riet of Cadenas' article on "Adultes et régles à calcul", page 66

- Slide rules are environmentally friendly: they use no electrical power
- Slide rules do not contaminate the environment
- Slide rules are healthy: they keep the brain fit which is no small feat
- Slide rules are original and that makes them stand out.
- Some students are familiar with slide rules, but if they have used them at all, it was a long time ago. Rediscovering this part of their youth gives them a bit of their youth back.

Teaching Method
Different methods are used for short and for long-term courses. In two months one cannot explain all there is to know about slide rules. Even in longer courses, one cannot teach everything. The objective is to give a solid base tailored to each level.

For the short term courses, we have selected elementary slide rules: Aristo Junior 0901 or Faber-Castell Mentor 52/80. Thanks to the Spanish slide rule collectors, we have been able to get enough slide rules for the 12 – 15 students that take part in the courses. Sometimes we have two groups simultaneously and we are forced to use the slide rules in a mix. Using either of the slide rules is not essential to teach the basic use of slide rules.

Curriculum for the 8 week course:

Week 1:
- history of the slide rule and of the basic scales
- numbers and exponents
- reading the scales

Weeks 2 and 3:
- C and D scales:
- Multiplying two numbers
- Multi stage multiplication
- Dividing two numbers
- Multistage division
- Mixed multiplication / division
- CI, C and D scales:
- Inverse of a number
- Multiplication using CI and C scales
- Division using CI and C scales
- Mixed multiplication and division using C, D and CI scales

Week 4:
- Proportions

Week 5 and 6:
- Squares using C and CI scales, then A and B scales
- Square roots using A and B scales
- Extrapolating square roots from a given value or average using C and D scales
- Mixed squares and square roots using C, D, A and B scales
- Solving second degree equations with one unknown using scales C and CI

Week 7:
- Cubes using K scale
- Cube roots using K scale
- Mixed squares and cubes and square and cube roots using C, D, A, B and K scales

Week 8 (optional):
- Folded scales CF, DF and CIF scales
- Operations using folded scales
- Interest calculations using folded scales
- Use of additional cursor lines
- General review

For the longer courses, a curriculum of up to 6 months has been prepared. We start with a different slide rule, the Aristo Scholar 0903, easily obtainable in quantities. The first two months are similar to the curriculum mentioned above, without the folded scales.

Then the course becomes a bit more difficult, since most students don't know or remember enough mathematics, so we introduce some mathematical concepts before proceeding, resulting in the following curriculum:

Week 9 - 11:

- Introduction to logarithms
- Logarithmic calculations using simplified tables
- Logarithmic calculations on the slide rule using the L scale

Week 12 – 16:

- Introduction to plane trigonometry
- Trigonometric calculations using simplified tables
- Trigonometric calculations on the slide rule using the S, ST and T scales
- Mathematical applications and techniques in plane trigonometry
- Solving triangles

For the remainder we are using duplex slide rules, viz. Aristo Studio 0968 and Faber-Castell D-Stab 52/82 and 152/82. The remainder of the curriculum now becomes:

Week 17:

- Introduction to the P scale
- Calculating using the P scale

Week 18 – 21:

- Introduction to logarithms with different bases
- Logarithmic calculations using LL scales
- Practical calculations using LL scales

Week 22-23:

- Introduction to folded scales (CF, DF and CIF)
- Operations using folded scales
- Interest calculations using folded scales

Week 24:

- General review

During the first weeks, we check the results of the calculations with electronic calculators, not just to check whether these are correct, but to let the initially sceptic student verify the results themselves. Additionally, he gets to appreciate how fast results are obtained, electronic calculators not always being as fast as they are perceived to be. They thus accept the usability of their new tool.

After the first few exercises, the average error is consistently below 0.5 %, an important result given the limited time spent on teaching how to use slide rules, 20 to 25 minutes per day out of a total of 5 or 6 hours of study per day.

Conclusion

The results show that there is still a definitive interest in slide rules in this high-tech world. We need to free ourselves of the ubiquitous electronic gadgets. If we abolish mental calculations, stop reading because multimedia content is so much easier to absorb, what will become of our intellectual capabilities?

SLIDE RULE WRISTWATCHES

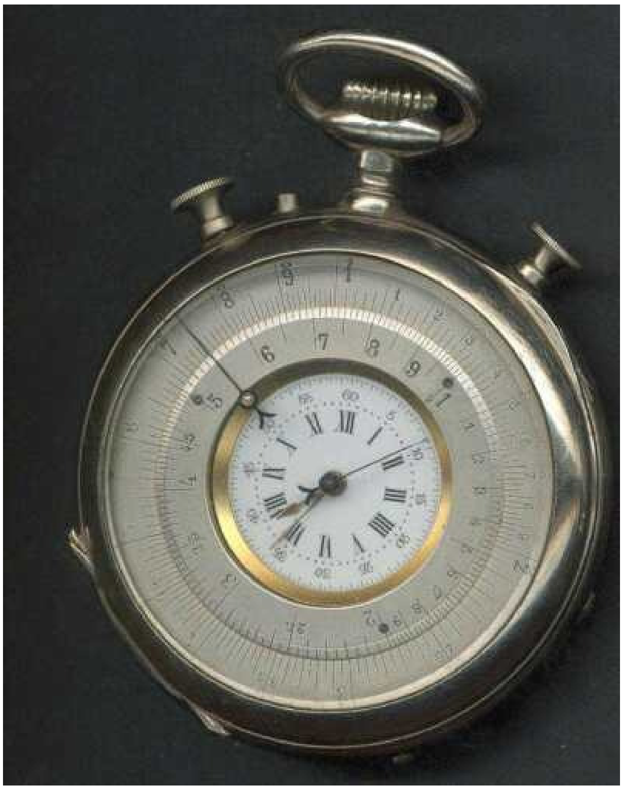
Robert Adams

Robert graduated with a Electro-Technology Diploma from the SA Institute of Technology in 1970, using a slide rule (Thornton P221) and with a Engineering Degree in 1979 using a electronic calculator (HP25). He is currently the Principal Strategist for ElectraNet, an electricity transmission company. He started collecting slide rules approximately 10 years ago and has currently approx. 400 rules in the collection. A main focus of the collection is "Electro" slide rules and rules that have hyperbolic functions. Robert currently resides in Enfield, South Australia.

Introduction

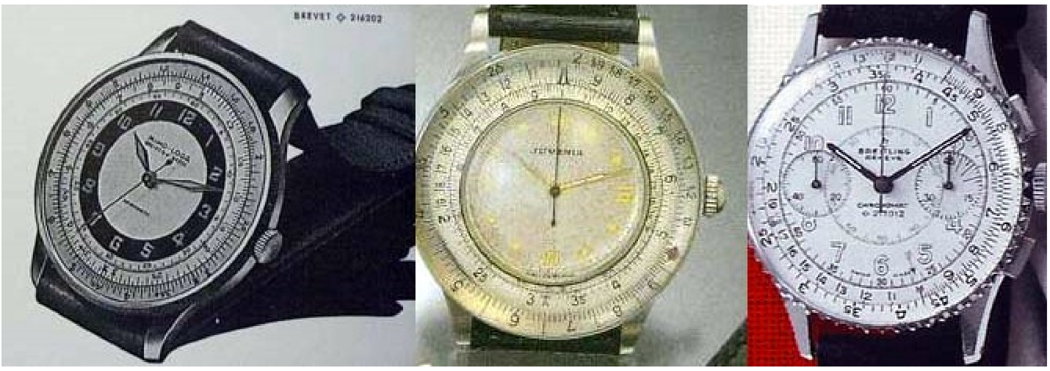
A slide rule watch can be defined as any watch which combines the normal chronological functions with a calculating device that uses logarithmic scales. A small number of watches have only one logarithmic scale that rotates around a fixed time scale or have only one logarithmic scale for decoration, I do not consider these to be slide rule watches.

The first slide rule watch was probably a pocket watch designed by Meyrat & Perdrizet in France near the turn of the 19th century.



The slide rule wristwatch has a relatively recent origin, appearing from 1940 onwards. There is some dispute about who manufactured the first slide rule wristwatch, but it was certainly a Swiss firm. The first three slide rule wristwatches came from the firms MIMO, Juvenia and Breitling. The Mimo-Loga was possibly the first, with its patent application appearing on July 27, 1940, some weeks before Breitling's patent for the Chronomat which was submitted on August 26, 1940. The Juvenia Arithmo is usually dated around 1945 when it became commercially available.

The images of the Mimo-Loga, Juvenia and the Breitling below are taken from Art Simon's Slide Rule watch site.



However In 1952, Breitling also introduced a pilot's wristwatch with an integrated circular slide rule that incorporated scales specialized for flight calculations: the Navitimer. This watch which was referred to by Breitling as a "navigation computer", featured airspeed, rate/time of climb/descent, flight time, distance, and fuel consumption functions, as well as kilometre–nautical mile and gallon–litre fuel amount conversion functions. This watch, available in larger commercial quantities, came to epitomise the slide rule watch.

With few exceptions no other watch manufacturers introduced slide rule models until the 1960's. This may be attributed to the fact that Swiss patents have a term of 20 years, and so after the 1940 patents expired, other watch manufacturers felt free to incorporate logarithmic scales on their products.

The Japanese (Seiko and Citizen) introduced models around the 70's. And now even budget brands such as Casio have introduced slide rule models.

Types

Slide rule wristwatches can be broadly categorized into two classes based upon their scale types and the number of scales included. The categories are described as follows.

- Calculating Watches
- Aviator (or Navigator) Watches

Calculating watches

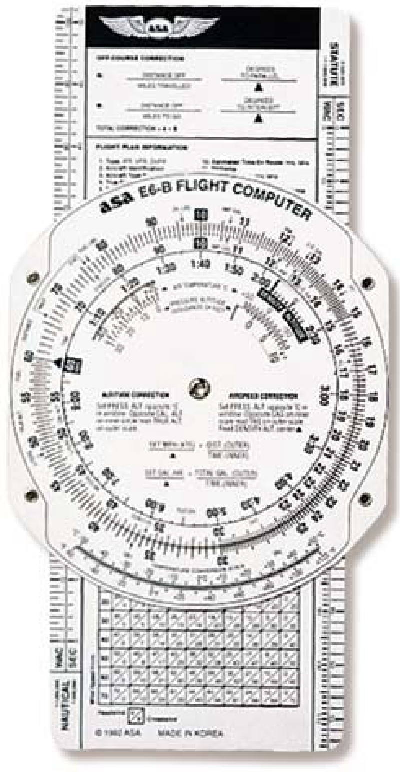
These wristwatches usually have only two scales usually a C and D scale arranged in similar fashion to the Mimo-Loga patent. (Note: in this paper I will refer to the C scale as being the outer most scale on the watch). Examples of this genre are:

The Girard – Perregaux

The Ventura Loga

Aviator watches

An aviator or navigator slide rule wristwatch by definition should assist the navigator in calculations required by their profession. To do this the slide rule wristwatch needed to emulate the main functions of the E6-B computer, the pilot's manual calculating device.



An E6-B Flight Computer

The Breitling Navitimer was the first to do this by combining the C and D scales on a rotating Bezel and inner face and with a direct 9-hour speed scale on the clock face in a similar layout to the E6-B. This arrangement enabled pilots to calculate airspeed, rate/time of climb or descent, flight time, distance, and fuel consumption functions, as well as kilometre–nautical mile and gallon–litre fuel amount conversion functions.

Examples of this type are:

Breitling Navitimer with 9-hour speed scale.
(Note: not all Navitimers have this scale)

The Pulsar
(probably 100 times cheaper than the Breitling!)

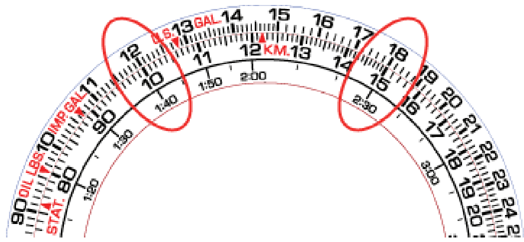
Use

The uses of the slide rule scales on a slide rule wristwatch are as per the normal methods used on any circular slide rule and any instructions for a circular slide rule would be able to be used for the slide rule watch. To illustrate the general calculations and aviation calculations I have condensed instructions from the Casio Watch Company. The full and unabridged instructions can be found on their website http://world.casio.com/. The examples use an aviator watch which has a outer and inner logarithmic scale and also a inner time scale. In these explanations I will use the terms inner and outer to refer to the logarithmic scales and the term inner (time scale) to refer to the time scale.

Math Calculations

Multiplication

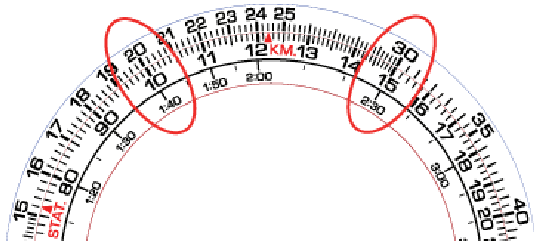
Example 12 x 15



Align 12 on the outer scale with 10 on the inner scale. Then, 15 on the inner scale corresponds to 18 on the outer scale, taking into account the position of the decimal point to obtain the answer of 180.

Division

Example 300 / 15



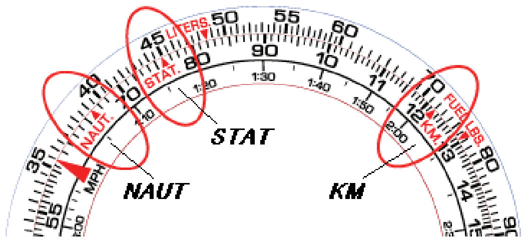
Align 30 on the outer scale with 15 on the inner scale. Then, 10 on the inner scale corresponds to 20 on the outer scale, taking into account the position of the decimal point to obtain 20.

With other methods ratios and square roots can be obtained.

Conversions

Distance

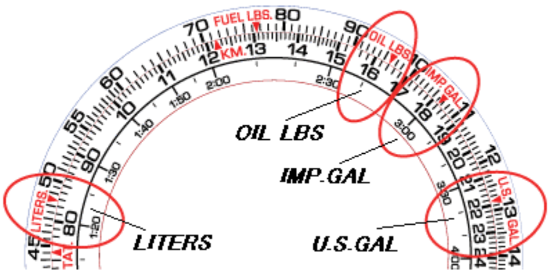
Example: Convert 45 miles into nautical miles and kilometres



Align 45 on the outer scale with STAT on the inner scale. Then, NAUT on the inner scale corresponds to about 39 nautical miles on the outer scale, and KM on the inner scale corresponds to about 72 km on the outer scale

Weight

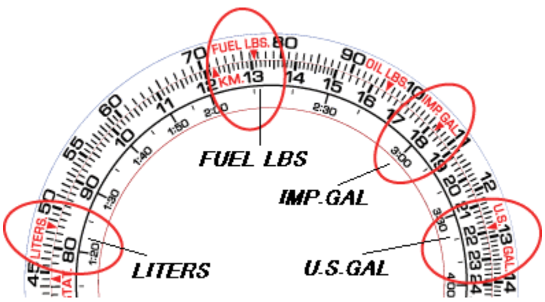
Example: Convert 16.4 oil lbs. into U.S. gallons and IMP gallons and litres.



Align 16.4 on the inner scale with OIL LBS on the outer scale. Then, U.S. GAL on the outer scale corresponds to about 2.2 U.S. gallons on the inner scale, and IMP. GAL on the outer scale corresponds to about 1.8 IMP gallons on the inner scale, and LITERS on the outer scale corresponds to about 8.3 litres on the inner scale

Volume

Example: Convert 13.1 fuel lbs. into U.S. gallons and IMP. gallons and litres.

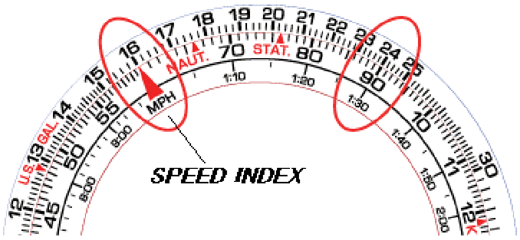


Align 13.1 on the inner scale with FUEL LBS on the outer scale. Then, U.S. GAL on the outer scale corresponds to about 2.2 U.S. gallons on the inner scale, and IMP. GAL on the outer scale corresponds to about 1.8 IMP. gallons on the inner scale, and LITERS on the outer scale corresponds to about 8.3 litres on the inner scale

Aviation

Travel Time required

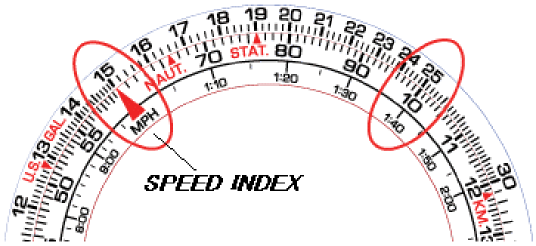
Example: Obtain the time required for the flight of an aircraft at 160 knots for 240 nautical miles



Align 16 on the outer scale with the speed index (in this case the MPH line) on the inner scale. Then, 24 on the outer scale corresponds to "1:30" on the inner scale (time scale). Thus, the time required for the flight is 1 hours and 30 minutes. Note this only works for the same dimensions i.e. in this case knots and nautical miles. It would not give the correct answer for 160 kilometres per hour and 240 nautical miles without conversion of one of the units.

Speed to distance

Example: Obtain the knots (air speed) for 250 nautical miles with a flight time of 1 hour and 40 minutes



Align 25 on the outer scale with "1:40" on the inner scale (time scale).Then; the speed index on the inner scale corresponds to 15 on the outer scale. Thus, the air speed for the flight is 150 knots. Again consistent units are required.

Scales

Nearly all current slide rule wristwatches use a same scale layout with the two C and D scales running left to right. The other scales from the standard slide rule which are used for roots, trigonometry, logarithms or other mathematical operations are rarely seen on wristwatches. There are, however some notable exceptions.

The CI Scale

This is the inverse of the C scale. Invariably positioned as the outermost scale it increases in magnitude in an anticlockwise manner. It normally replaced the C scale on the watch as can be seen in the following image.

The Breitling for Bentley

Only the Juvenia Arithmo, early Breitling manual-wind Chronomat, the current Breitling for Bentley models and a Chinese replica of the Breitling for Bentley have this scale arrangement. Although you can still perform the usual multiplication and division, the reason for this inverse scale is a little difficult to establish, it is really only convenient if multiplication by reciprocals (i.e. division) is your usual calculation.

Trigonometric Scales

Very rarely have trigonometric scales been included on slide rule watches. The only example that I have seen is the magnificent Seiko 6138-7000,

Seiko 6138 - 7000

Scale designations

The images above show that the outermost scale is an inverse sine scale (SI). The scale provides the answer to 1/sin(x) which would be of advantage in any calculation involving the law of sines. It is interesting to note that the scale also has the converse to the sine scale i.e. the cosine scale indicated in orange, which would also allow the calculation of problems involving 1/cos (x). This watch is also unique for another reason which will be elaborated in a later section.

Index Mark

The index mark is placed at the 12 o'clock position usually on the inner scale. In the majority of the aviator and other slide rule wristwatches the value on the D scale (the normally fixed scale) at the index position is 60. In other cases the slide rule watches mimic a normal circular slide rule and the value at the index position is 10 or 1.

Examples

Index Mark = 60

Index Mark = 10

Index Mark = 60

Index Mark = 10

The reason for the placement of the index mark in these cases seems to be arbitrary. In most cases Aviator type watches tend to have the index mark at 60. Where as most calculator wristwatches tend to have the mark at 10. Although this convention is not consistently applied.

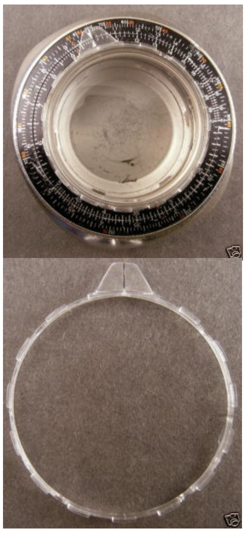
Gauge Marks

Many wristwatches, particularly the Aviator type, include gauge marks for many of the calculations. Most calculations involve a fixed relationship and are used for the conversion of one quantity to another e.g. nautical mile to kilometres or litres to gallons. As such the placement of the gauge marks could have been arbitrarily distributed along the scale. I.e. taking the statute mile to kilometre gauge marks for example, as long as the relationship of approximately 1 to 1.61 is maintained between the marks, any values could be used. But nearly all watches conformed to the gauge mark values contained in the following table.

Category	**Gauge Mark**	**Value**
Distance	Nautical Mile	660 or 327
	Statute Mile	760 or 380
	Kilometre	1222 or 611
Fuel	Litres	485
	Fuel Lbs	766
	Oil Lbs	960
	Imperial Gallon	1065
	US Gallon	1280
Mathematical	Pi	3.14
	Seconds	360
	Lbs	3630
	Kgm	1623
	Feet	1430
	Metres	4360

Cursors

Cursors on slide rule wristwatches are indeed rare; the only real example would again be the unique and magnificent Seiko 6138-7000.



Cursor Parts

Cursors are indeed a rare inclusion for a number of reasons. Not least is the fact that normally only two scales are usually involved and therefore an index mark is all that is required. Another reason could be that the implementation of a cursor on a watch means that a protuberance would be required and this would be prone to catching on pockets, garment edges etc.

Another form of cursor is that used in the Mondia illustrated below. The Mondia had two movable scales and had an engraved red hairline on the watch class. This provided a "cursor" function.

The Mondia

Accuracy

Sufficient accuracy and precision was and is the difficulty faced by all small length slide rules and slide rule wristwatches being some of the shortest length scales suffered the most from problems with accuracy and precision.

The "accuracy" of a calculation system is the degree of proximity of the calculated result to its actual value. The "precision" of a calculation is the degree to which repeated calculations show the same results.

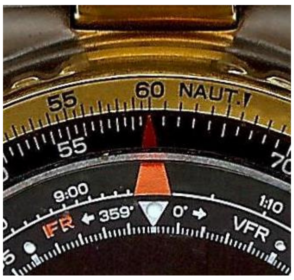
As the scales on a slide rule wristwatch are concentric the repeatability of the calculation would normally be guaranteed if there is no flex in the mounting of the scale rings. The placement of the scales had a direct bearing on the readability of the scales and hence the repeatability (precision) of the calculation. This is best demonstrated by the following images

Placement of the scales as close as possible to each other made reading straightforward

Whereas placement of the scales in this example makes accurate reading of the result difficult to repeat.

In most linear slide rules, even, the cheapest rule had scales that "tick" marks that aligned along the entire scale. The early and high end slide rule wristwatches, such as the Juvenia and Breitling also showed the same manufacturing accuracy. But some modern slide rule wristwatches demonstrate somewhat shoddy manufacturing techniques and the alignment of the tick marks can be so far out of alignment that errors in calculation can easily approach 10%.

Citizen Wingman

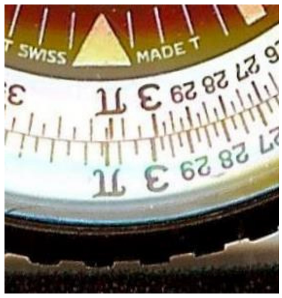


Index aligned

Tick Mark at 30 aligned

GE Ollech and Wjas

Index aligned



Tick mark at 30 out of alignment. 30 on the inner scale aligns with 29.8 on the outer scale

Evolution

As electronics drove to ever decreasing sizes it was inevitable that calculators could be produced in the size aspect of wristwatches. There are many examples of "4 function" calculators produced in wrist watch form but very few in scientific styles. Perhaps the most complicated watch is the Casio CFX-200 shown in the following image.

Like the HP35 to the slide rule this would seem to be the death knell for the slide rule wristwatches. But no, the Casio CFX-200 has been and gone and the slide rule wristwatch is more prevalent than ever. Why? I would like to think that the slide rule, has at last found a position in the modern world, but alas I think it is a reflection of fashion or mode for the retro feel.

Acknowledgements

Firstly I would like to thank Art Simon for allowing me to use many of the images from his excellent Slide Rule watch site. http://sliderulewatches.googlepages.com/history.html. The use of these images greatly assisted me in the preparation of this paper. And I relied upon his site for the introductory historical information.

Secondly, I would also like to thank David Rance for again editing this paper and his many suggestions that significantly improved it.

THE EASY SLIDE RULE

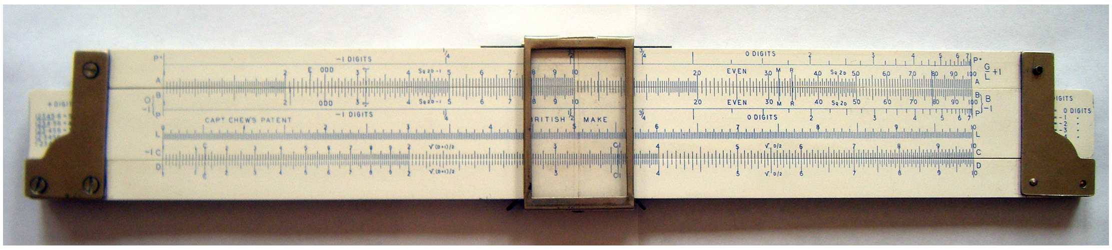
Robert Adams[1]

Introduction

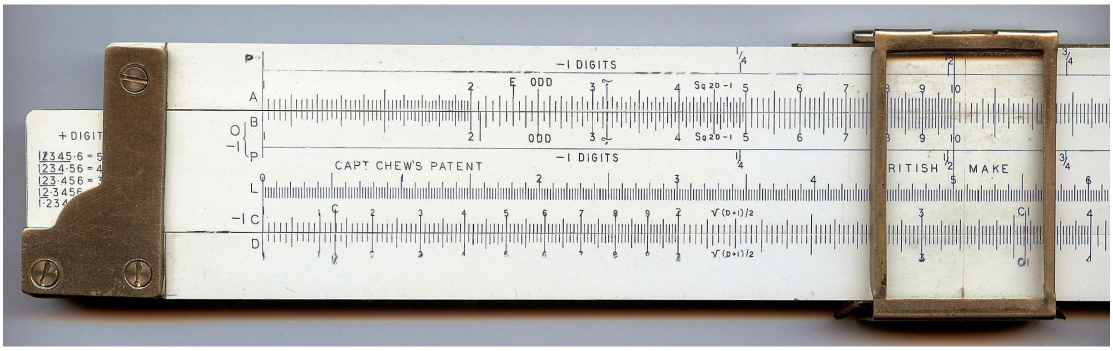
It appeared one day on the UK eBay site, with out of focus photos and a fairly unremarkable description of the actual slide rule. What drew me to the advert was the unusual end braces. I thought maybe this is something different to the norm so threw in a perfunctory bid and lo and behold it was successful. It was only after I had received it I that I knew there was some thing far more interesting about the rule than just end braces!

Slide Rule

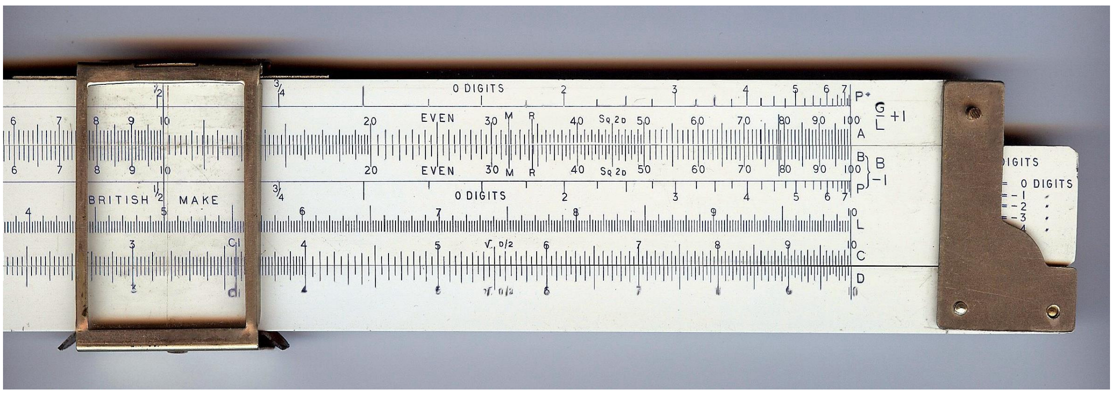
At this point a few images will explain in far better terms than I can write, about the unusual features of the rule. Hopefully they are better than the original eBay advert!



Easy Slide Rule Front



Easy Slide Rule Front LHS



Easy Slide Rule Front RHS

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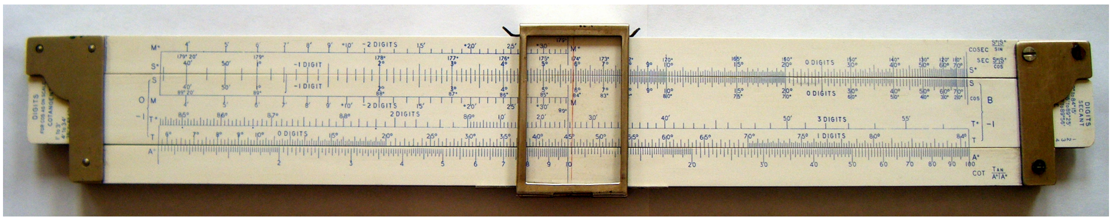
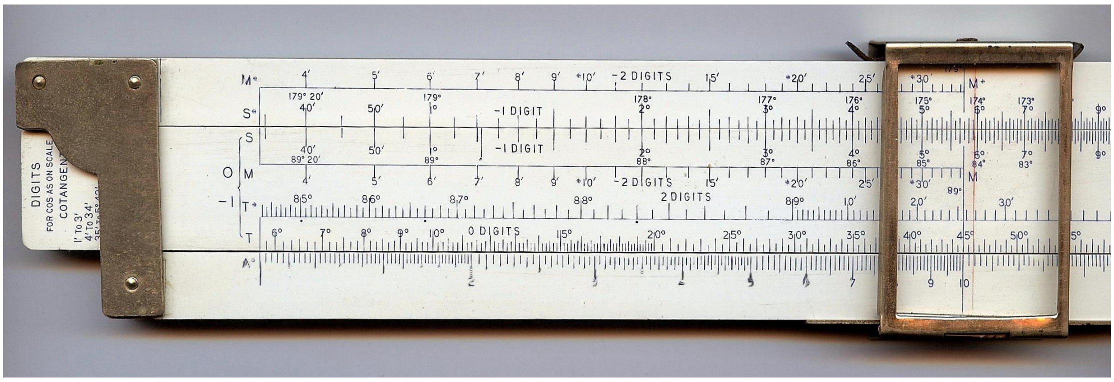
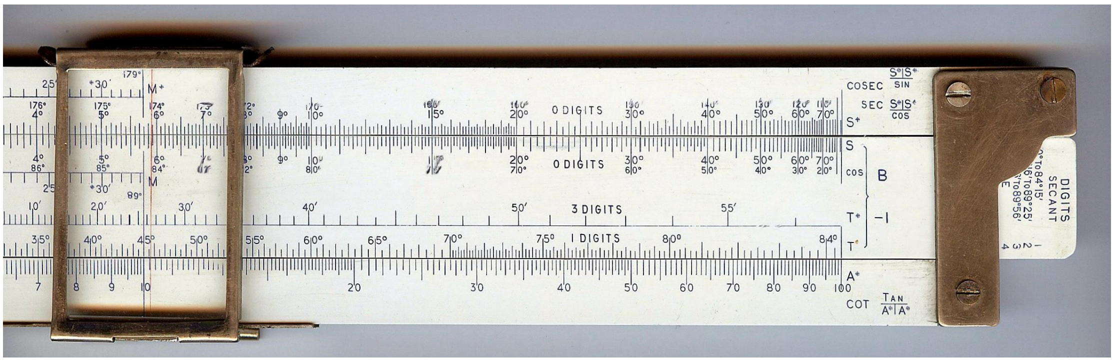
[1] See page 75 for biography and picture of Robert Adams



Easy Slide Rule Back



Easy Slide Rule Back LHS



Easy Slide Rule Back RHS

Technical Specification

The rule, as can be seen from the images, is an open frame duplex rule of physical dimensions of 338 X 46 X 7 mm, made from a wood that resembles rosewood. The slide contains a groove along each edge and this fits a tongue on each of the stator bars. This tongue is actually an insert of a darker coloured wood.

The scale markings are on white celluloid material that is glued to the wooden stator and slide pieces. The scale markings are incised into the celluloid material. The markings are consistently uniform across all scales so I believe them to be engine divided.

The cursor is metal framed of novel design (detailed later in the paper) and is made of glass. Not readily apparent from the images is that the cursor has on the top edge a large flat piece of metal that extends approximately one half inch (12.7mm) either side of the cursor. I assume from the later detail this is to hold the cursor in a perpendicular fashion at all positions. The front indicating line on the cursor although faded is a red line; the indicating line on the reverse side is also red.

Included Scales

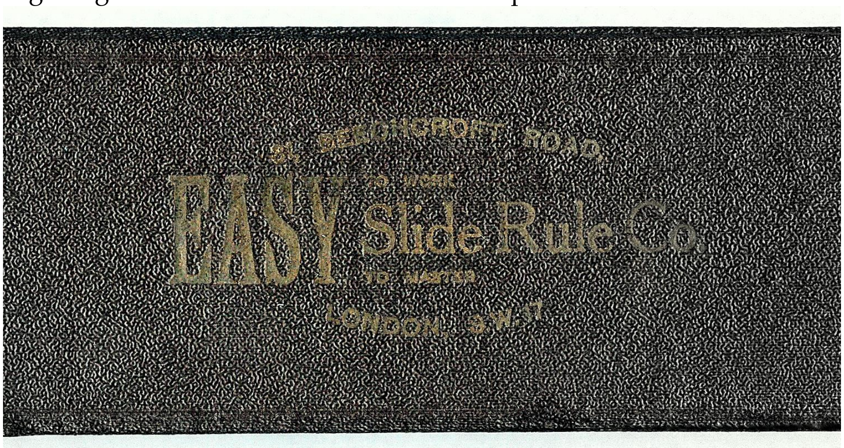
Examining the images, the rule contains a number of familiar scales such as on the front side an A, B, L, C and D scales. But the front also contains a P and P* line or scale that is marked from 0^+ (I presume) to 7^+ and indications of -1digits and 0 digits. There is also the words ODD and EVEN attached to these "scales".

There are a number of gauge marks on the scales, some usual ones such as M and R on the A and B scales. One mark (M) equates to the value of 1/Pi at 3183, and another (R) which equates to the number of minutes in one radian at 3437. There are marks at 4.5 and 45 on the A and B scales notated as Sq 2D-1 and Sq 2D respectively. Similarly on the C and D scales there are two notated marks at 2.2 and 5.5 called √(D+1)/2 and √D/2. There are also curious markings (which can be explained later) at the end of a number of scales on the front, e.g. G/L +1 and B-1 on the LHS of the front.

Equally, the back of the rule has such normal scales such as the A and T scale (albeit in the position normally used for C and D), there are some unusual scales such as dual sine scales marked S and S*. Two minute scales marked M and M* plus a T* scale that seems to be a reversed T scale. The top sine scale marked S* has an overlying scale marked from 90^o to 179^o 20', the bottom sine scale (S) also has an additional scale attached to it in an underlying fashion; this one is marked in the cosine scale.

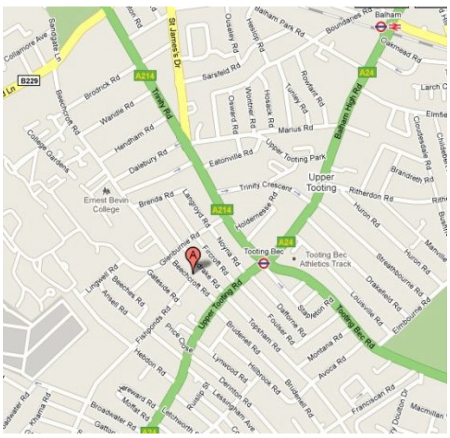
Who made it?

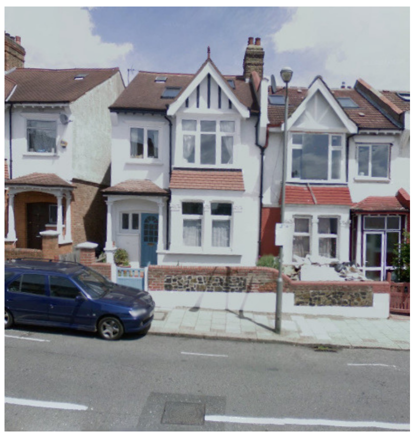
The following image is a scan of the actual box it is kept in.



Although it is not that legible in the image, the manufacturers' name is shown as the EASY Slide Rule Co. and the motto of the rule are EASY to Work, plus EASY to Master. Both of these assertions I will leave it to the reader to make up their mind on their validity!

The additional writing on the box is hard to read accurately, but I think it lists the company's address as 34 Beechcroft Road, London SW 17. The following map indicates that the address is now in the suburb Wandsworth.





34 Beechcroft Road, London

So as the front of the rule says (refer to the first and second images) it is a "British Make" and seemingly from somewhere in South West London.

Something Rare

Was it something rare? Well, I had not seen anything like it and all the usual sources, Peter Hopp's book, Rod Lovett's Web site, Herman's Catalogue did not mention it at all. The rule itself mentioned a Capt Chew's Patent, but a quick search of patent references and the slide rule patent CD I had purchased across the internet failed to turn up any mention of the slide rule.

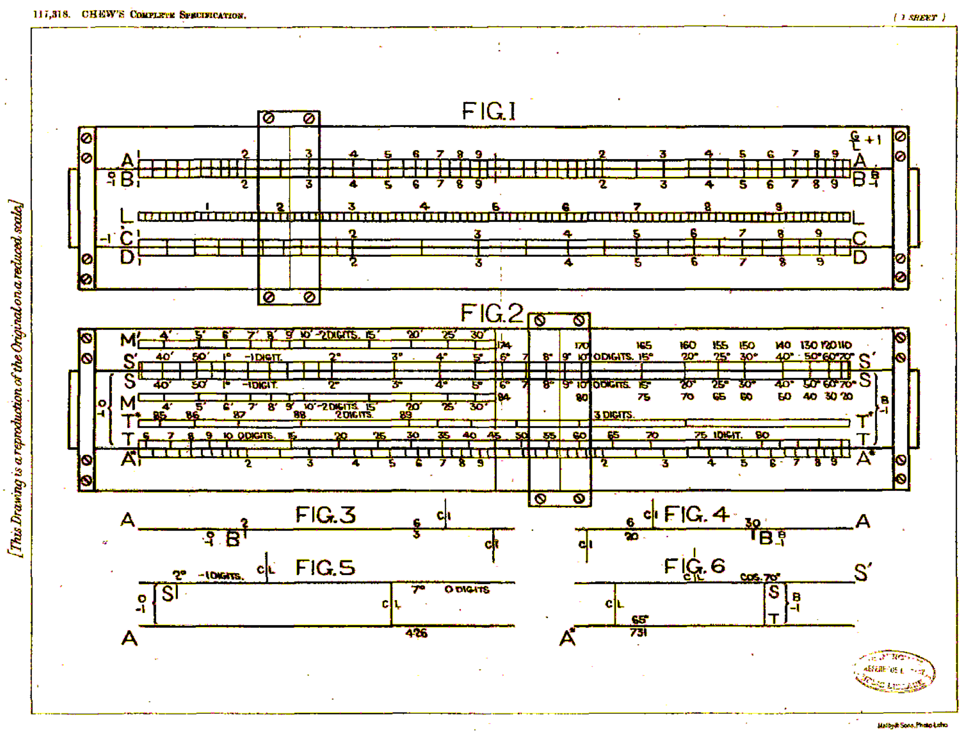
So I thought maybe this is a rare rule, being an Australian so far away from the main slide rule collecting activity and not being able to obtain many of the ultra rare rules, the excitement mounted. Further research indeed identified that a British patent was granted (number 117318) for "Slide Rule" to a Captain A.C. Chew on July 1918. A little more information on Captain A.C. Chew is contained in Appendix A (which is included in the CD version of this paper).

Main Patent

The main patent concerning this slide rule and implied on the rule itself, is the British Patent 117318 titled "Slide Rule". The provisional and full patent specifications are presented in the appendices B and C (which are included in the CD version of this paper).

It is interesting to note that there is a reference to three tangent scales in the provisional specification; this was not evident either in the later complete specification or on the production rule that followed. Whether this was a mistake or the design continued to evolve between the times of the provisional specification to the complete specification is not known.

The diagrams submitted with the patents clearly show that the production rule faithfully, in the most part, followed the design indicated in the patent.



A number of differences can be noted in the production model to that described in the patent specification.

1. The matching scale designators are consistently marked with a star e.g. M and M* instead of the superscript 1.

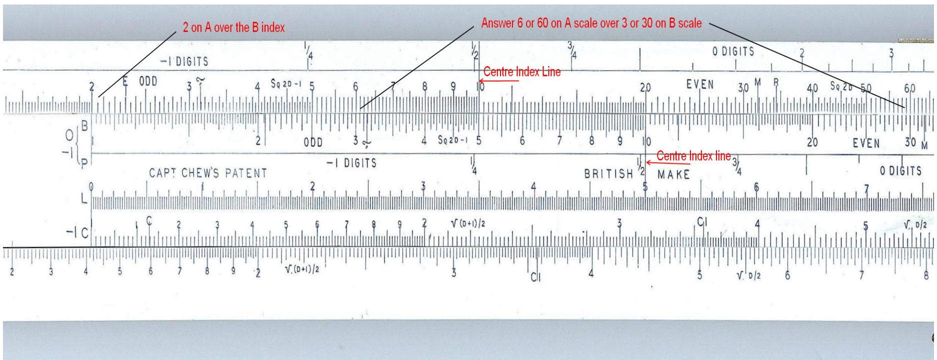
2. End braces have grown.
3. Cursor is of improved construction (refer associated patent in the appendix).
4. The addition of the mysterious P and P* scales.
5. Additional gauge marks and other notation.

Function

How did the rule function? The best way to understand this is by way of illustration. The basic slide rule functions of multiplication, division, squares and square roots are as performed on any conventional slide rule. However the inclusion of the "O-1" and the "B-1" aids the determination of the number of significant figures, for example

2 X 30 = 60

Set the left index to 2 on A over 3 on B and read 6 on A

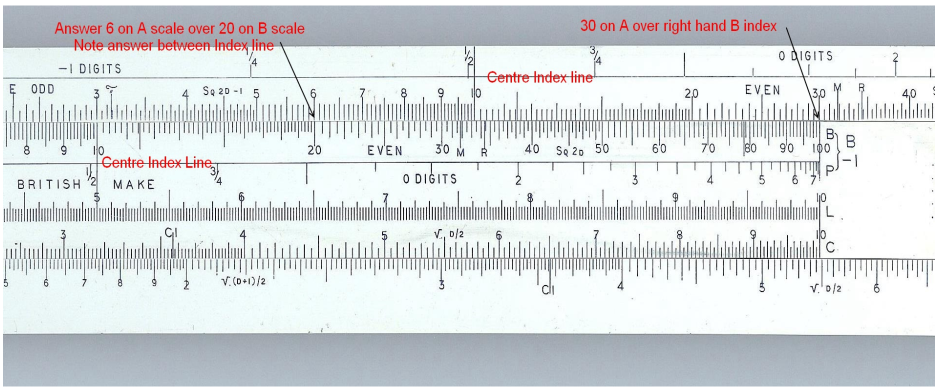


The number of digits in the number 2 is 1 and the number of digits in the number 30 is 2. Add these together and we have 3 digits.
Looking at the rule face the left index of B is being used therefore the product falls on A outside the centre indices so 1 is deducted from the digit addition result i.e. O (outside) -1. Therefore the number of digits in the answer is 3 -1 = 2, thus the answer is 60.
Note even if we had set the calculation with the left index on 2 and used 30 on B to provide the answer 60 on the A scale we still would have obtained the number of digits as 2 as even this answer is outside of the centre indices.

Note: it is assumed that the answer obtained on the slide rule calculation is between 0 and 1 e.g. in the above calculation the answer is 0.6 and moving the answer decimal point by 2 gives 60. This is consistent throughout the calculations that follow.

30 X 20 = 60

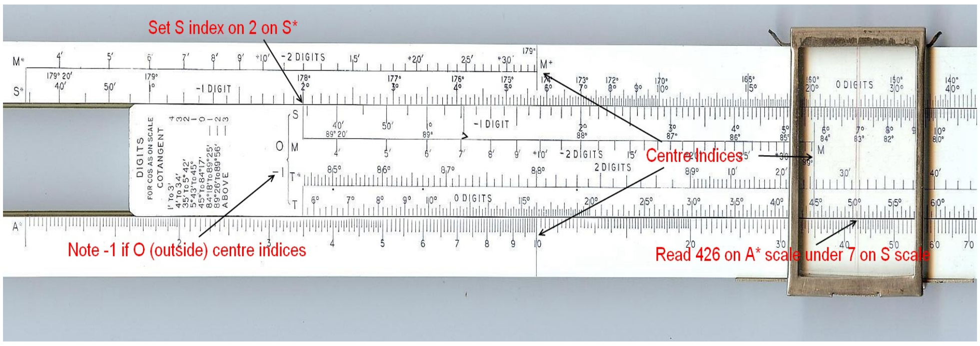
Set the right index of B to 30 on A and over 20 on the B scale read 6 on the A scale.



This time the sum of the number of digits in the problem is 2 + 2 =4. However as we have used the right hand index of the B scale we need to modify the result by the B (between) -1. That is if the answer lay between the centre indices then we need to deduct 1 from the digit addition result. Thus the number of digits that the answer needs to be shifted from the decimal point should be 4 - 1 = 3. Therefore the answer is 600.

Sin 2° X Sin 7°

Set the left index of S to 2° on S* then under 7° on S read off 426 on A*.

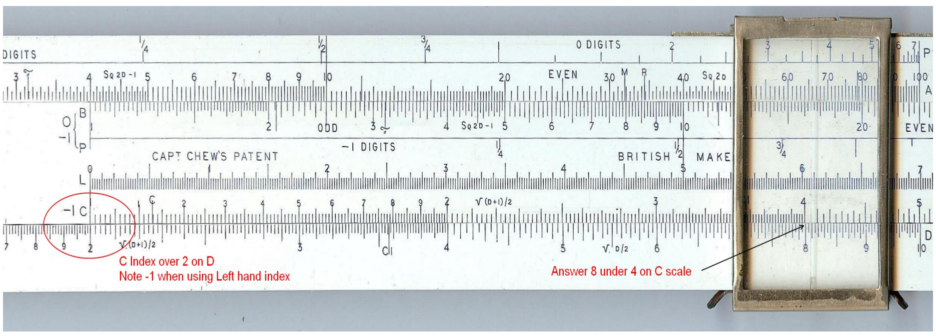


In this calculation the number of digits in sin 2° is -1 and the number of digits in sin 7° is 0. (Note the number of digits is given on the rule face). The sum of the number of digits is -1, and because the left hand index is used and the result lies outside the centre indices and additional digit must be subtracted from the result. Thus the result needs to be shifted from the decimal point by 2 digits therefore the answer is 0.00426. *Again note that the answer indicated on the rule is 0.426 thus shifting 2 places provides us with the actual answer of 0.00426.*

20 X 400 = 8000

In this example the scales C and D are used. Referring to the images of the rule in the introduction you should note that in using the C left hand index a digit must be subtracted from the result. (Note some conventional rules used this method).

The example requires that the left index of C is set to 2 on D and the answer 8 on D is read under 4 on C.



Again the sum of the digits 20 having 2 and 400 having 3 is 5. As the left hand index of C is used one digit must be subtracted from this result. Therefore the number of digits the result needs to be shifted from the decimal point is 4, thus the answer is 8000.

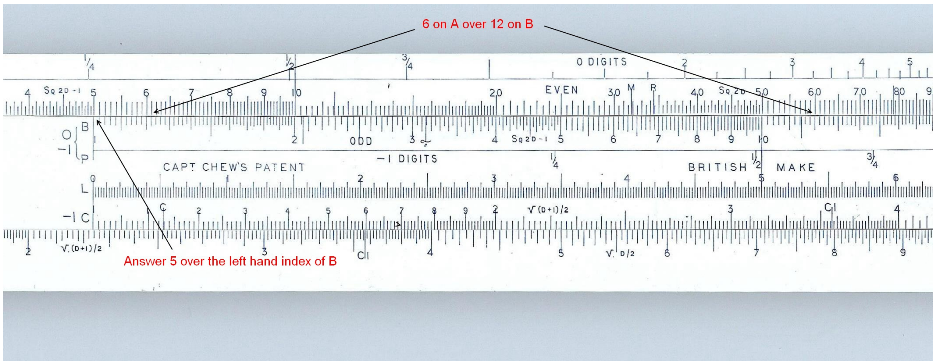
Use of the G/L + 1 system.

This system is normally used in division problems. Refer to the complete specification wording concerning this process. It noted that where the significant figure in the dividend is greater than

the significant figure in the divisor, one (1) must be added to the sum of the digits in the dividend MINUS the sum of the digits in the divisor.
For example

$$\frac{0.06}{0.0012}$$

Set 6 on the A scale over 12 on the B scale and read the answer 5 on the A scale over the left hand index of B.



Now the number of digits in the dividend is -1 and the number of digits in the divisor is -2. The number of digits in the dividend <u>minus</u> the number of digits in the divisor is

-1 – (-2) = 1

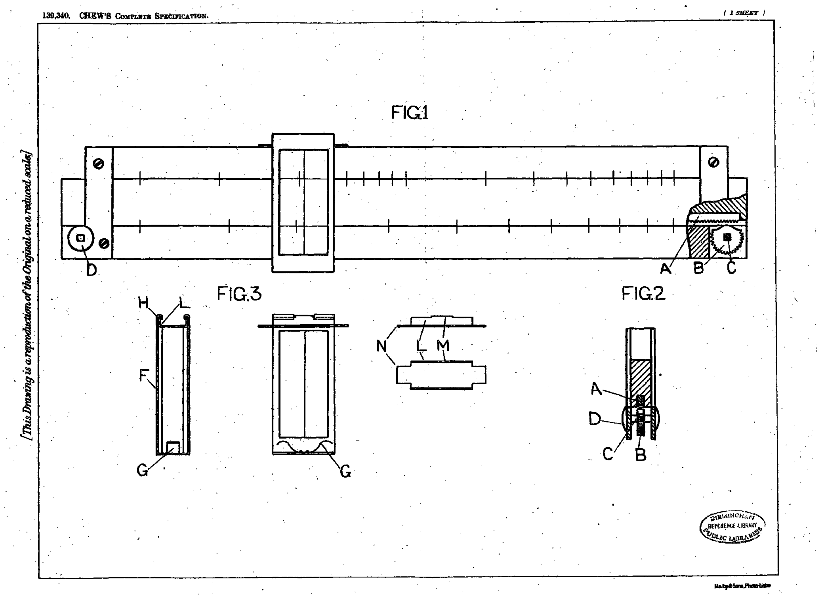
Now as the significant figure in the dividend (6) is greater than the significant figure in the divisor (1), a digit must be added to the calculation above. Therefore the answer must be shifted from the decimal point by +2, thus the answer is 50.

A further complex example using nearly all these methods of decimal keeping is presented in appendix E (which is included in the CD version of this paper).

Further Innovations

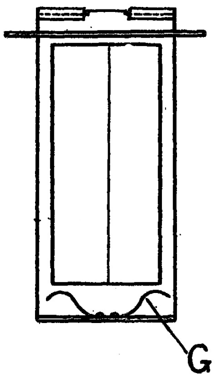
An associated patent (also a British Patent) was applied for in 1919 and granted as British Patent 139340 on March 4 1920 for "Improvements in or connected with Slide Rules". Again this is presented in the appendix D (which is included in the CD version of this paper).

The following diagram presents the main innovations of this associated patent, namely the flat extended edge piece at the top of the cursor and the ratchet system for fine adjustment.



Cursor

The patent 139340 described an improvement in cursor design which also made its appearance in production on the EASY Slide Rule. The design was supposed to prevent any cross movement of the frame and also allow the cursor index line to travel perpendicular to the scales at all times.

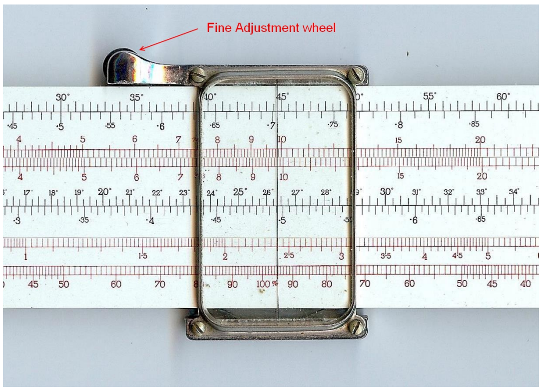


The Cursor

As can be seen from the image the "locking plate" edges extend for some distance outside the edge of the frame. The frame being 1 ¼ inches wide and the locking plate 2 ³/₈ inches long.

Rack and Pinion Fine adjustment.

From the description in the patent it can be seen how the fine adjustment of the slide can be accomplished. It was interesting to note that the pinions could be kept out of play until required and then used to gear with the rack to finely adjust the slide. I have not seen this method used on any existing slide rule. The closest to this idea was a cursor fine adjustment feature implemented on some of the White and Gillespie rules from Australia as can be seen in the following image.



White and Gillespie 432 with fine adjustment cursor

From the patent description the method employed by the design seemed to be overly complicated requiring a precision rack and pinion system to be included into the rule itself and it is no surprise that this innovation did not appear on the production rule.

Conclusions

There are many questions left unanswered at the present time,

- What are the P scales and how are they used?
- Was this a rule with military applications?
- The patent cited the purpose of the rule was "... in solving problems in plane and spherical trigonometry" is this correct?
- A full patent was applied for and granted …why?
- How many of these rules where produced?

- The construction of the rule was sophisticated, who produced it and when was the rule manufactured?

I can guess at a few answers to these questions but I cannot answer in the definitive for each. For example;

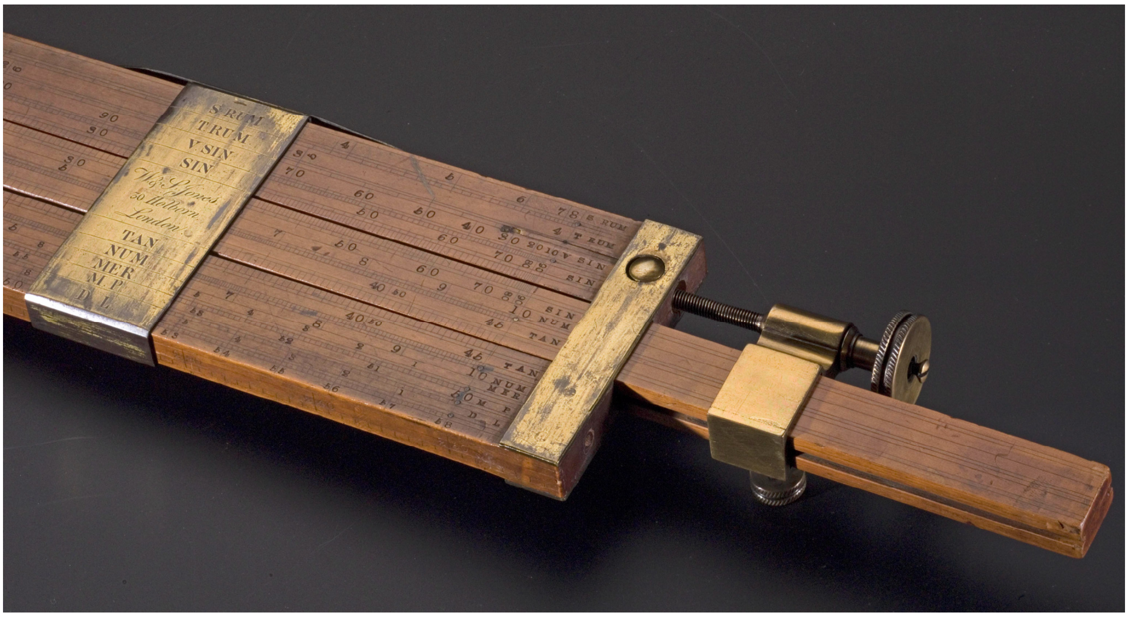
- The P scales seem to be integral to the rule functions but I have no clue as to their purpose, even the patent applications do not mention them.
- There are no military marks (e.g. upwardly pointing arrows) on the rule, suggesting that the military had no interest in the rule.
- The inclusion of dual sine and tangent scales would have aided trig calculations and therefore would have been helpful in plane and spherical trigonometry, even the “minute “ scales could have aided more accurate calculations
- Yes a full patent was applied for when it was normal to just opt for a provisional application. This suggests that Mr Chew thought this system was worthy and could have been financially rewarding.
- The construction and design of the rule was substantial and of an engineering quality that was first class. I find it hard to believe that the production run was sufficiently small as to not have a number of these rules in the hands of collectors but this does not seem to be the case.
- When was the rule made? At least we know the rule was produced after 1919 the year of the patent application for the cursor design and I assume it was produced before the start of the Second World War. Therefore the range of possible dates would be from 1920 to 1940.

Note by the Editor

The rack and pinion mechanism to adjust the slide’s position of the EASY slide rule, as described in above paper on page 91 & 92, did have a predecessor as it turns out.

In 1788, a book was published by W. Mountaine describing the Sliding Gunter designed by J. Robertson, see articles in the *Journal of the Oughtred Society*, Vol. 8:2 in 1999 (p. 7) and Vol. 16:1 in 2007 (p. 12 and front cover). That slide rule had a fine adjustment of the slide which was more precise by its screw arrangement, although less user-friendly because it had to be locked or unlocked by a second screw.

The attached picture by the *National Museums of Scotland* shows the specimen in their collection (object nr. T.1978.94), one of the seven known surviving Robertson rules.



WHAT IS NEW IN THE WORLD OF TIE-CLIP SLIDE RULES ?!?

Dieter von Jezierski

From 1952 to 1991 Dieter von Jezierski worked in the marketing division of A.W. Faber-Castell. In 1956 he became Group Product Manager in charge of all the Faber-Castell Technical Drawing products. He was responsible for all development and marketing.

Dieter was also instrumental in redeveloping the company's slide rule business – e.g. the Novo-Duplex, the Duplex and the Mathema models. In 1991 he retired from the company.

Earlier publications and achievements

In 1997 Dieter published in German the book *"Rechenschieber - eine Dokumentation"*, which is still highly regarded. For those preferring to read English, an expanded version of the book was later translated by Rodger Shepherd and published as: *"Slide Rules - A Journey Through Three Centuries"*. Dieter is an Honorary member of the UKSRC and in 1997 was awarded the Oughtred Society Award for: *"for writing the first modern book on slide rules, for his substantial role in the organization of the International Meeting IM 1997 in Stein, and for sharing his wide expertise acquired as collector and as former employee at Faber-Castell in numerous research publications and communications"*.

Tie-clip slide rules

The most important models of his collection of "mini slide rules" were first depicted and described in an article, *"Slide Rule Tie Bars"*, published in Vol. 16, No. 1 of the Journal of the Oughtred Society in 2007.

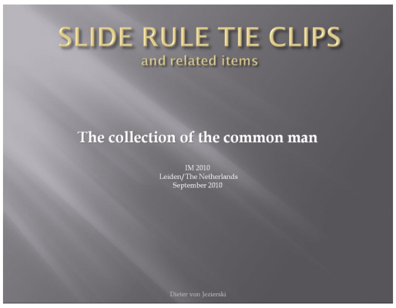
Then came the idea to present all the models in full colour on a "big screen" for the participants of the IM 2010 being held in Leiden, The Netherlands. Disappointingly the information gathering for the presentation was largely unsuccessful, at least about tie-clip slide rule production at the Attleboro, Massachusetts founded company

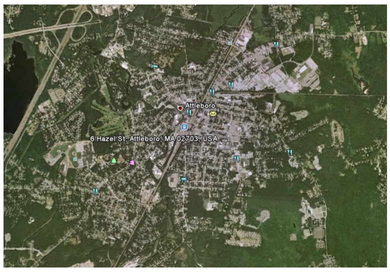
SWANK INC http://www.swankinc.com/
and http://www.answers.com/topic/swank-inc

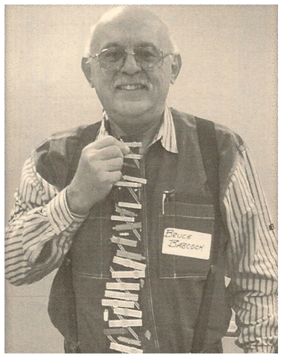
Even the extensive company website reveals nothing about slide rules as tie-clips.

Presentation outline

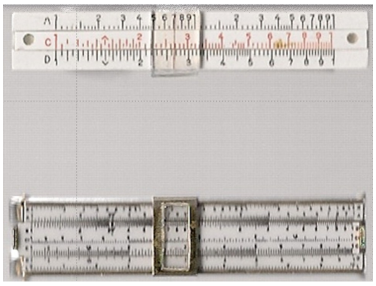
The next pages show a "thumbnail" outline of the presentation illustrating in colour all the various types of tie-clip slide rules.





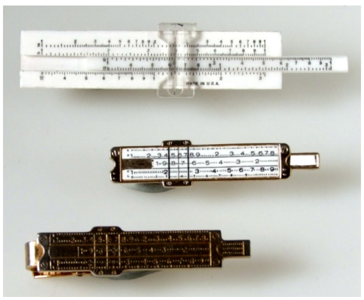


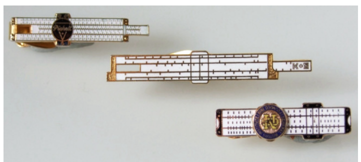
Title and credits	**SWANK INC, Attleboro**	**Bruce Babcock**



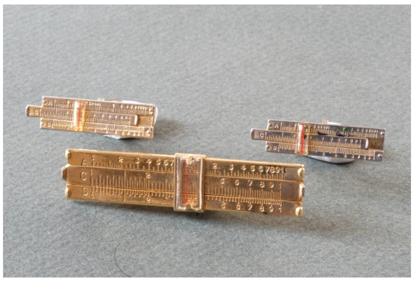
The two SWANK´s	**Model A: Grand Prix**	**World's Greatest Engineer**

Model A: Swinging Clip	**Faber-Castell version**	**The "Authentic" model**





Money clip	**"No name" models**	**Pickett Logo, K&E, GM**



Gold-plated brass

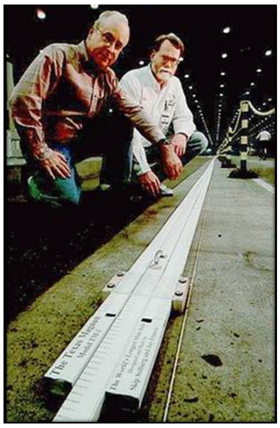
Circular slide rules

Key-ring circular Flight Computer

T-Squares

The Texas Magnum

This world's longest slide rule is constructed in sections for ease of construction, assembly, storage & transportation. It assembles to form a single rigid unit - scale length is 350.529 feet.

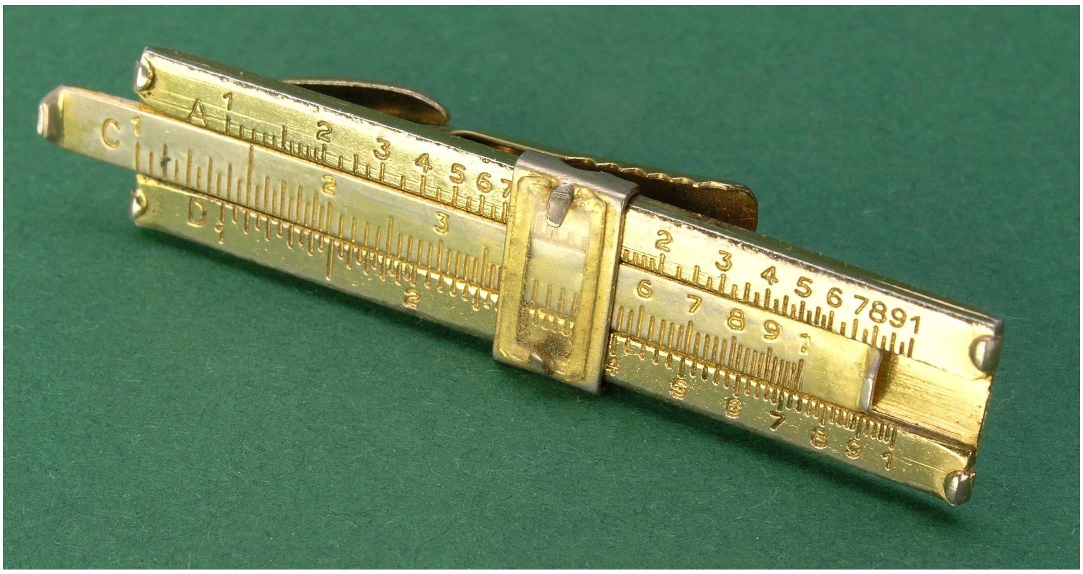


The Texas Magnum

ꕥ

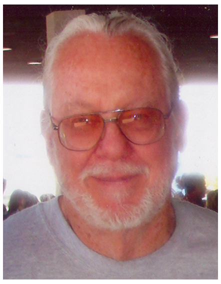
Note by the Editor

Many of the tie-clip slide rules are so small (5 cm) that it is difficult to see details. Therefore a 2½ times magnified picture of a "Vernon" brass-plated tie-clip is added to give a better view. The slide and cursor of this worn specimen are still moving, but the red hairline –originally applied to the outside of the plastic window- has mostly gone.



FABER-CASTELL 50 CM SLIDE RULES
The Collectors Holy Grail

Richard Smith Hughes



Richard graduated, in 1960, from the University of Nevada with a B. S. degree in Electrical Engineering. He spent his carrier designing receivers and signal processing circuitry for Anti Radiation Missiles (ARM) and published numerous journal articles and four books. After retirement, in 1998, he spent considerable time researching and publishing the Textual Evolution of Ancient Egyptian Middle Kingdom Coffins. He became interested in slide rules in 2005 and has published articles on various designs and applications. Recently he has begun in-depth research on the early history of Quantum Physics.

Summary

Fifty-centimeter slide rules are the "Holy Grail" of many collections. They were produced in smaller numbers than their 25 cm brothers, and are becoming increasingly difficult to find. This article will briefly present the 50 cm slide rules produced by Faber-Castell from 1893 until 1975. Several slide rules from my collection will be discussed; both the good and the questionable. This paper would not have been possible without *Peter Holland's* excellent book [1].

The 50 cm Family

Faber-Castell produced ten 50 cm slide rules from 1893 until the end of slide rule production in 1975. Table 1 lists the various models, with their model number evolution given in Table 2. The various scale sets, from Peter Holland's book [1] are given in Table 3. They are all difficult to find, with the System *Pickworth*, *Columbus*, *Mathematiker* and *Log Log* being quite rare.

Just who would have purchased them? Probably anyone who needed the added accuracy and who could afford the price; they cost slightly more than twice their 25 cm brothers. Table 4 gives some idea on the added accuracy. As expected the accuracy decreases at the high end of the scale, 9 to 10, for both models. We can, with a little practice, obtain three-figure accuracy, from 9 to 10, for the 50 cm 4/54 verses two plus estimate of the third for the 25 cm 1/54. Is this accuracy worth the extra (times 2) cost? As an Electronic Engineer the answer is no, however they obviously had a following. It should also be mentioned that to use 50 cm slide rules one needs an uncluttered desk; they do take up considerable space, especially when doing calculations.

Slide Rule Discussion

I am fortunate to have six models in my collection. They are listed, in the order of manufacturing date, in table 5. The scale designation may differ from those given in Table 3; several are of **a later date** and one was intended for the English market. The Rietz and Darmstadt are well known and understood and don't really need any discussion. The other four do deserve some discussion.

Columbus (System Rohrberg), 342

Since this slide rule is made of Ebony it dates to 1926/1927 [1]. It is an early Disponent (business) slide rule. Table 6 shows a scan, and a brief introduction of its uses.

Disponent, 4/22

This is a well-known slide rule in the 25 cm size, 1/22, and is an excellent business "calculator". A scan of the 4/22 and some of the equations it helps solve is given in Table 7. A strong point for the 4/22 are the 19 conversion gauge marks at the top. Panagiotis Venetsianos lists these, and all other gauge marks in his monograph [2]. Note the tension screws on the front side; these will be a problem on the next slide rule, the Tachymetric/Stadia 4/38.

Tachymetric/Stadia, 4/38

Tachymetric/Stadia slide rules are used to calculate the horizontal distance and vertical height in Stadia land surveying, and the 50 cm 4/38 does give better accuracy than the 25 cm 1/38. Table 8 gives a scan and, for those interested, an introduction on its basic operation. The tension screws pose a problem. Note their interference with the tg scale; just try to find Tan 14.3^{o}.

Elektro, 4/98

Elektro slide rules were designed to aid Electrical Engineers in calculating the weight, resistance (which is temperature dependent) and Voltage drop (also temperature dependent) for power lines; knowing the total length and wire size it is possible to find the total wire weight, resistance, and, knowing the current, the voltage drop. The designer must know what wire size to use, and must consult a handbook for its diameter before using the slide rule. The U. S. wire gauge tables also include, for a given wire size, the weight in pounds per 1,000 feet and the resistance, at a reference temperature (often 68 ^{0}F in the United States), in Ohms per 1,000 feet. Knowing the total line length, in feet, it isn't rocket science to calculate the weight and resistance, at the reference temperature! What is the resistance, and knowing the current the voltage drop, at another temperature? The following equation is a reasonable approximation,

$R_{T2} = R_{TI}[1 + 0.00222(T_2 \text{ in } {}^{0}F - T_1 \text{ in } {}^{0}F)]$.

$V_{T2} = IR_{T2}$

A temperature difference of 90 ^{0}F gives $R_{T2} = 1.2R_{TI}$, or a 20% increase. The real world is temperature sensitive and several slide rule manufactures include a temperature scale to find R_{T2} as a function of temperature. The 25 cm 1/98 Elektros for the English market have a temperature scale, figure 1. The European 4/98 does not have this scale, and without a temperature scale the slide rule is severely limited. A scan and operation overview of the 4/98 is given in Table 9.

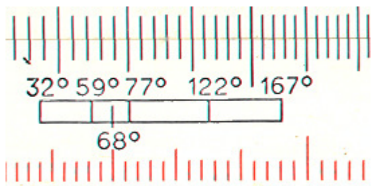


Figure 1 - 1/98 English Market Temperature Scale
(Reference temperature = 68 ^{0}F)

Conclusions

Well there you have it. Would any of these "Holy Grail" slide rules have served you in days long gone? Obviously only you can answer that, however whatever your answer they certainly are an important part of any collection.

Acknowledgments

I am grateful to Dieter von Jezierski for his help, suggestions and comments on all things Faber-Castell. Thanks Dieter!

Table 1
Faber/Faber-Castell 50 cm Slide Rule Types and Dates
(Data from Peter Holland's book [1])

Type	Year																
	< 1890	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	< 1975
Normal-Trig	**>------------------------------1893 - 1943-------------------------------------<**																
System Pickworth			**1913 >-----< 1915**														
Columbus System Rohrberg (Business)						**>----------1923 – 1942--------<**											
Rietz						**>--1924 – 1975-------------------------------------<**											
Elektro (Electrical Engineering)						**>---------------------------------------1924 – 1973-----------------------------------<**											
Mathematiker						**1929 >-----------------< 1939**											
Log Log (Engineers)								**1939 >--< 1942**									
Darmstadt									**>--------------------1940 – 1976 --------------------------------<**								
Disponent (Business)										**>--------------1946 – 1973------------------<**							
Tachymetric (Stadia Surveying)													**>----1959 – 1973----<**				

Table 2
Type/Model Numbers
(Data from Peter Holland's book [1])

Type	Model Numbers
Normal-Trig (1893 – 1943)	380, 380N, 370, 4/60/380, 4/60, 44/60
System Pickworth (1913 – 1915)	384
Columbus (1923 – 1942)	342, 342N, 3/42/342, 3/42
Rietz (1924 – 1975)	385, 385N, 4/87/385, 4/87, 44/87, 4/87m
Elektro (1924 – 1973)	388, 388N, 4/98/388, 44/98, 4/98
Mathematiker (1929 – 1939)	382, 3/92/382
Log-Log (1939 – 1942)	4/92
Darmstadt (1940 – 1976)	44/54, 4/54
Disponent (1946 – 1973)	4/22, 44/22
Tachymetric (1959 – 1973)	4/38
Note: some 44/xx made with laminated wood without the brass inserts (approximately 1940 – 1955)	

Table 3
Faber/Faber-Castell 50 cm Scales
(Data from Peter Holland's book [1])

Type	Scales	Comments
Normal-Trig	A // B, C // D // S, L, T //	
Pickworth	A // B, C // D // S, L, T //	
Columbus	Val // Div, ValMult, ValMult, Div // Val Currency conversion, EP/VP See text for discussion	Business (Early Disponent)
Rietz	K, A // B, CI, C // D, L // S, ST, T) //	Updated Normal-Trig
Elektro	LL2, A // B, CI, C // D, LL3, K // S, L, T // Special Elektro scales in the well See text for discussion	Electrical Engineering
Mathematiker	LL1, A // B, CI, C, // D, LL2, K //S, L, T //	
Log-Log	LL2, A // B, CI, C // D, LL3, K // S, L, T //	Elektro without special scales
Darmstadt	K, A // B, CI, C // D, P, S, T, Lg // LL1, LL2, LL3 //	P scale $\sqrt{(1 - x^2)}$ 360° and 400^g versions

Disponent	KZ // T, Val (p%), E (T) // V (Z), L
	English Currency conversion
	// LL1, LL2, %, C //
	See text for discussion
		Business
		Numerous conversion gauge marks referenced to DF.

Tachymetric	L, A // B, CI, C // D, P, Sin, Tg // Special Tachymetric scales // See text for discussion	Stadia surveying 360° and 400^g versions

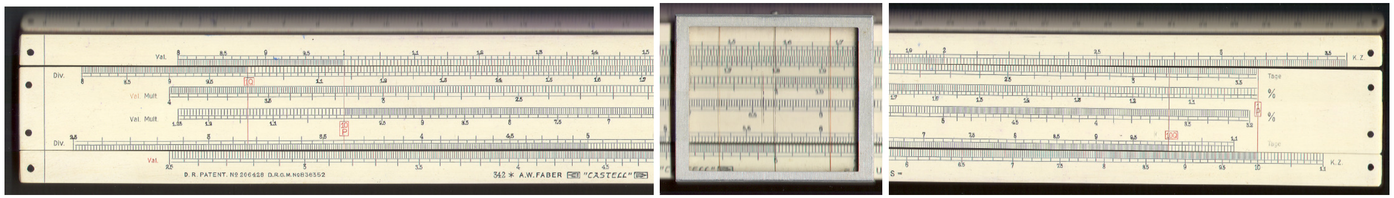
Table 4
50/25 cm Slide Rule Accuracy
C/D scales

Slide Rule	Interval					
	1 to 2		3 to 4		9 to 10	
	Exact	Estimate	Exact	Estimate	Exact	Estimate
4/54 (50 cm)	X.xx	0.000 to 0.005 0.005 to 0.01	X.xx	0.000 to 0.001	X.x	0.00 to 0.02[2]
1/54 (25 cm)	X.xx	0.00 to 0.01	X.x	0.00 to 0.02[1]	X.x	0.0 to 0.05 0.05 to 0.1
[1] With practice the 1/54 has 3 figure accuracy from 3 to 4						
[2] With practice the 4/54 has 3 figure accuracy from 9 to 10						

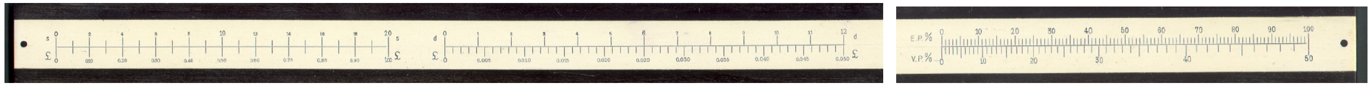
Table 5
Faber-Castell 50 cm Slide Rule Scales
From My Collection

Model Number	Type	Date	Top Edge	Body//Slide//Body	Bottom Edge	Comments & Market
342	Columbus (Business)	1925/29 (Ebony)	37 cm ruler	Val (K.Z.) // Div. (Tague),Val. Mult (%),Val. Mult (%),, Div. (Tague) // Val.(K.Z.) // English currency conversion, E.P.%/V.P.% // See text for discussion	-	Three, two section scales = 50cm. European
4/22	Disponent (Business)	5/47	50 cm ruler	KZ // T, Val (p%), E (T) // V (Z), L // L1, L2, %, C // See text for discussion	d/£ currency conversion s/£currency conversion	19 conver-sion gauge marks [2]. European
4/87	Rietz	7/59	20 inch ruler	K, A // B, CI, C // D, L // Sin, Sin/Tg, Tg //	50 cm ruler	Trig scales referenced to C. English
4/38	Tachy-metric (Stadia)	7/59	50 cm ruler	L, A // B, CI, C // D, P ($\sqrt{(1-x^2)}$ // special Stadia scales // See text for discussion	Sin,Tg	360^o Trig scales referenced to D. European
4/98	Elektro (Electrical Engineer-ing)	7/63	50 cm ruler	LL2,A(Amp)//B(length/diam^2),CI,C//D,LL3 // S,L,T // special scales in well See text for discussion	K	Trig scales referenced to B. No tempera-ture scale. European
4/54	Darmstadt	10/71	50 cm ruler Lg x	K, A // B, CI, C // D, P ($\sqrt{(1-x^2)}$ // LL1, LL2, LL3 //	S, T	Trig scales referenced to D. 360^o European

Table 6
Faber-Castell Columbus (System Rohrberg) 342
European Market (1925/1929, Ebony)



Front



Reverse Slide

Scales

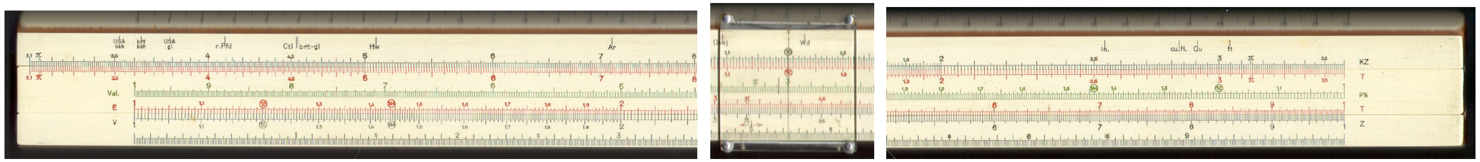
Val (K.Z.) // Div. (Tague), Val. Mult (%), Val. Mult (%), Div. (Tague) // Val. (K.Z.) // English currency conversion, E.P.%/V.P.% //
Val. (K.Z.) = Principal/Cost and Interest
Div. (Tage) = Current Interest (Days)
Val. Mult (%) = Interest rate (%)
Note: These scales are two continuous sections with a total scale length of 50cm.

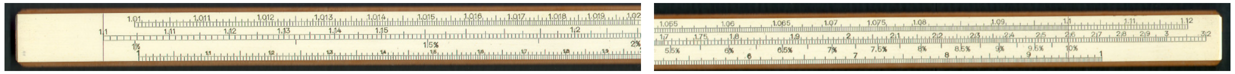
Equation Solved

(Translation of the Instructions for the Columbus, IJzebrand Schuitema [3])
Interest = (Principal)(Interest Rate (%))(Days/360)

E.P.% and V.P.% Scales
Price Increase (%) = {[Price Decrease (%)]/[100 - Price Decrease (%)]}100:
Price Decrease (%) on V.P.% scale, read Price Increase (%) on the E.P.% scale.
Reverse procedure to find the Price Decrease.

Table 7
Faber-Castell Disponent/Business 4/22
European Market (5/47)


Front; Note special gauge marks at the top (referenced to the DF scale)


Reverse Slide


Bottom Front Edge (Currency Conversion)

Scales

KZ // T, Val (p%), E (T) // V (Z), L (not labeled)
// L1,L2,%,C //

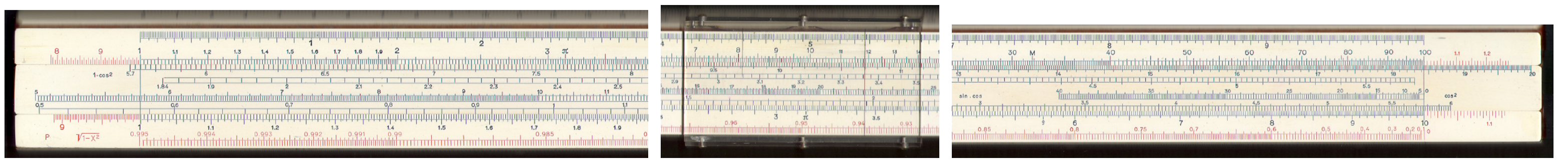
19 special gauge marks above the top scale [2]

KZ = Principal and Interest (DF scale folded at 360 days
T = Days (CF scale folded at 360 days)
Val (p%) = Percent rate (CI scale)
E (T) = Days (C scale)
V (Z) = Interest (D scale)

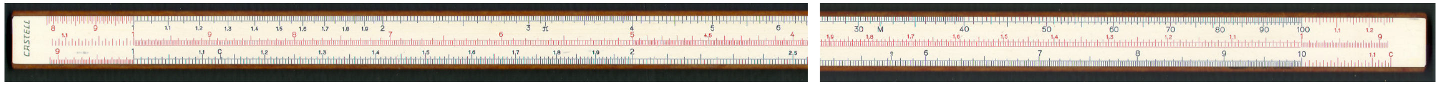
Equations Solved

Interest paid = (principal)(% interest)(days); Selling price = cost / [1 – profit (%)/100]; Profit (%) = 100(1- cost/selling price)
Interest on Investment = (principal)(Interest (%))(days); Future value = (present value)(1 + interest rate (%)$^{-days}$
Present value = (future value)(1 + interest rate (%))^{days}; Rate of return = [(future value/present value)$^{1/days}$ – 1]

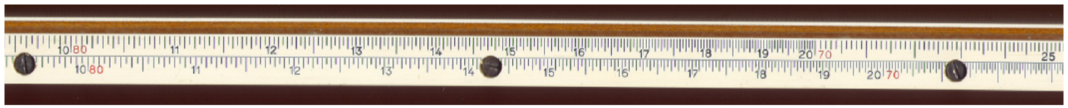
Table 8
Faber-Castell Tachymetric/Stadia 4/38 (360°)
European Market (1/59)



Front



Reverse Slide



Bottom Front Edge
Note tension screw interference on the Tg (lower) scale

Tachymetric/Stadia Scales
$\cos^2$: $1 - \cos^2$: sin.cos

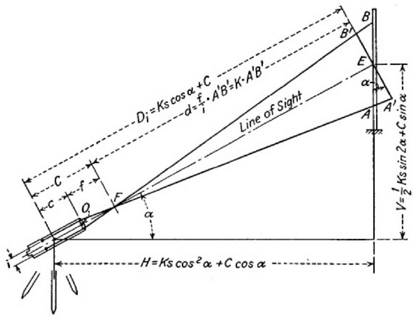
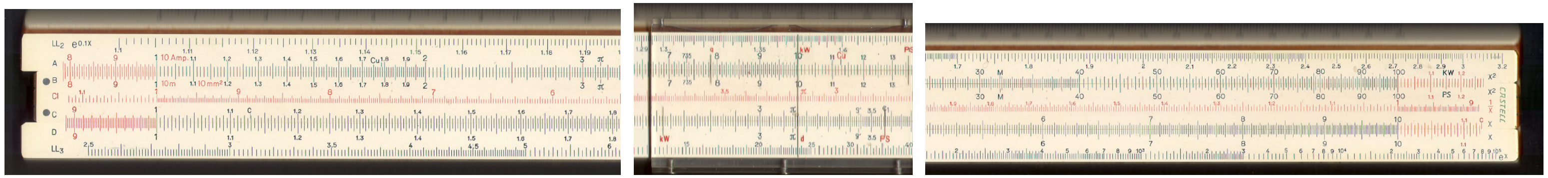
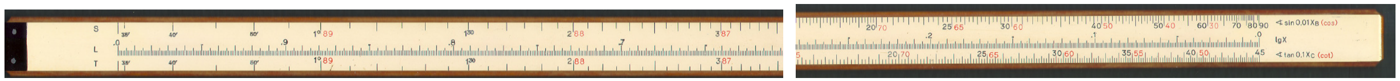
<table>
<tr><td rowspan="3">Tachymetric/Stadia Method

K = f/i = 100 for US transits
S = Stadia rod reading = B - A</td><td colspan="2">Horizontal Distance H</td><td rowspan="2">Vertical Height V</td></tr>
<tr><td>α > 10°</td><td>α < 10°</td></tr>
<tr><td>H =100S(cos²α)</td><td>H =100S - ΔH
ΔH =100S(1 - cos²α)</td><td>V =100S(sinαcosα)</td></tr>
<tr><td></td><td colspan="3">U. S. Transits use Degree-Minutes-Seconds. To use the slide rule, we must first convert from D-M-S to decimal degrees:
XX.xxx ° = XX° + (1/60)[(mm Minutes) + (ss Seconds)/60]°
Example; 35° 47' 12" = 35° + (1/60)[47' + (12"/60)]° = 35.787°</td></tr>
</table>

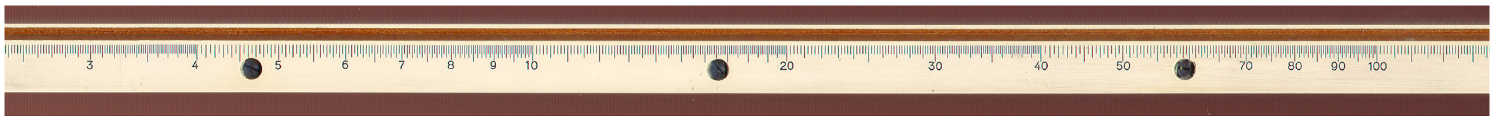
Table 9
Faber-Castell Elektro 4/98
European Market (4/63)



Front (No Temperature Scale)



Reverse Slide



Bottom Front Edge (K Scale)

Scales

LL3, A (Amp) // B (Length, Area), CI, C // D, LL3, K
// S, L, T //
Well: Motor and Generator/Dynamo Efficiency and Voltage drop

Equations Solved

Motor Efficiency =73.6(HP_{out})/(P_{in}(kW): Generator/Dynamo Efficiency = 136(P_{out}(kW) /(HP_{in})
Weight, W =(γ, specific gravity for Copper)(L, the wire length in meters)(π(d, wire diameter in mm)^2/4) kg (temperature independent)
Resistance, R (at 15 °C) =(ρ, resitivity of Copper at 15 ^{0}C) (L, the wire length in meters)(π(d, wire diameter in mm)^2/4) Ohms
Voltage drop at 15 ^{0}C = I(R at 15 ^{0}C) Volts
The resistance is temperature dependent
$R_{T2} \approx R_{T1}[1 + 4E^{-3}[T_2\ (^oC) - T_1\ (^oC)]$
For T_2 - T_1 = 50 °C, R_{T2} = 1.2 R_{T1} (20% increase). Without a Temperature scale, the 4/98 is severely limited! See text.

References

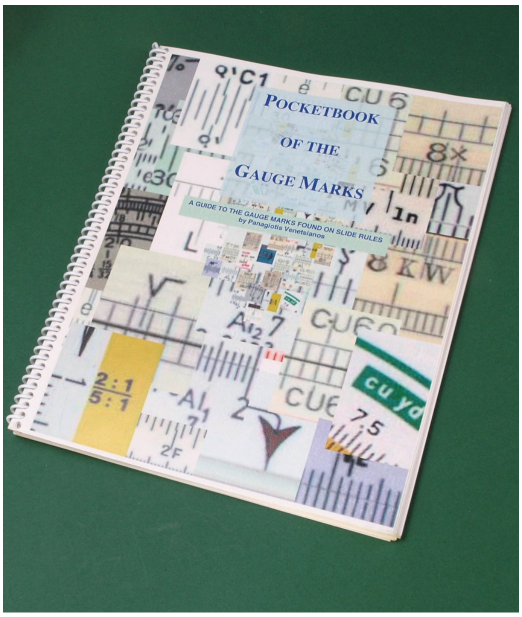
[1] Peter Holland, A. W. Faber-Castell Slide Rules; Models, Types, Scale,s 2009 This is an important work, with German and English text. It is a must have for anyone remotely interested in Faber-Castell slide rules

[2] Panagiotis Venetsianos, Pocketbook Of The Gauge Marks, The Oughtred Society, 2006. Another must have for the user/collector

[3] IJzebrand Schuitema, Translation of the Instructions for the Columbus, Journal of the Oughtred Society Vol. 4, No 1, March 1995

Note by the Editor

The literature references [1] and [2], rightfully recommended above, can be recognized with the help of the following pictures.



FINANCIAL INTEREST CALCULATIONS WITH LOGA DISCS AND DRUMS[1]

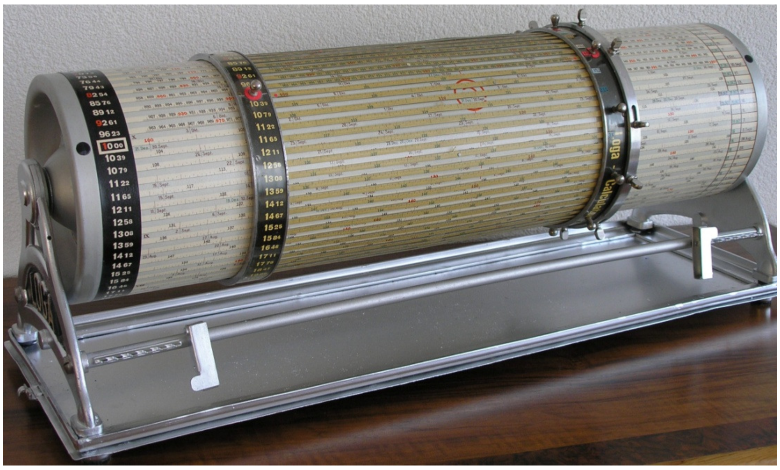
Nico E. Smallenburg

Nico Smallenburg studied chemistry and physics in Utrecht and Delft. He worked about 15 years at laboratories from the PTT, the Railroads, and the environmental laboratories of the RIVM and the DCMR. After that he has worked until now at the Dutch Province Gelderland in the field of external safety. Because his father was the Dutch importer of the Swiss LOGA-Calculators, Nico is collecting these calculators as remembrance.

In this presentation he will give you practical information how to use these calculators and calculating discs in the field of finance.

Introduction

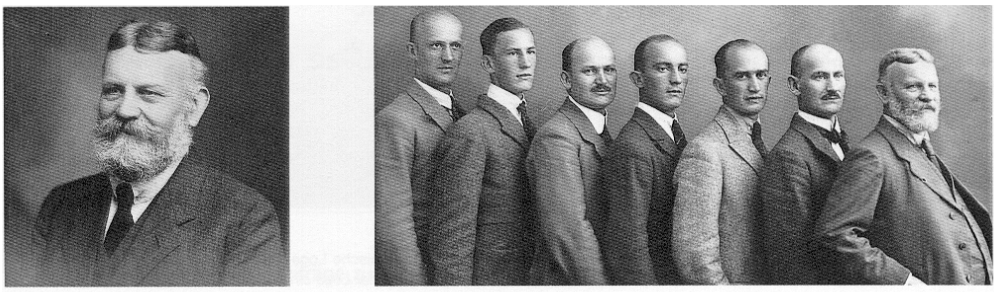
Financial crises are of all times. So are financial calculations of all times. The firm LOGA in Uster, Switzerland, had developed a line of LOGA calculators especially for financial calculations: the calculating discs LOGA 30RZ and 75RZ, but also the drums of type 15mE and 15mZ had in common the special interest scale Z (*Zins* = Interest).



*The **LOGA 15mZ** Calculator on the floor plate of the transport box*

The foundation of the firm LOGA

The founder of the firm LOGA and the producer of the LOGA calculating machines was Heinrich Daemen-Schmid. Heinrich Daemen was born 1856 in Prussia.



Heinrich Daemen-Schmid and his six sons

[1] Translated from Dutch and adapted by Otto van Poelje; see also full original paper on the IM2010 CD

In 1896 he emigrated as a merchant specialising in textiles to Switzerland and established himself in Zürich. By 1888 Heinrich had already built his first model of the cylindrical calculating drum. In 1889 he started developing and producing calculating drums and other calculators based on the same working principle. Between 1910 and 1920 he started the production of slide rules. Later, after 1935, circular slide rules were developed.

In 1903 the firm moved to Zürich-Oerlikon. Here Heinrich established an engineering works annexe and an engraving department. By 1911 he had moved the firm to Uster, a small village approximately 15 km east of Zürich. Here the firm remained until it went into bankruptcy in 1979. The old company name "Heinrich Daemen-Schmid" was changed in 1915 to "LOGA". This new name had already appeared on all the cylindrical calculation drums and slide rules since 1903.

From Zürich-Oerlikon and later from Uster, the LOGA calculators were dispatched all over the world. The company production consisted of cylindrical calculation drums, slide rules and circular slide rules.

The factory in Uster, near Zürich, Switzerland

The cylindrical calculation drums formed the most important part of the production in the 1930's. After 1935, the production of circular slide rules increased. Cylindrical calculating drums were produced until the 1970's. Approximately 30,000 calculating drums were produced and used world-wide. They were used mainly for financial calculations.

The Dutch representation of LOGA

On August 4 in 1937, Nicolas J.W. Smallenburg, from Aarau, Switzerland, established Holland, in the village of Wassenaar a firm to represent the firm LOGA and to import their products. A number of large firms, such as Johan Enschede printers, AKZO, Shell and Unilever but especially major banks, for example AMRO, were substantial customers.

LOGA was promoted regularly at various business fairs and exhibitions. A dedicated "LOGA stand" was designed to give demonstrations of calculation applications of LOGA drums and discs and of the high

N.J.W. Smallenburg demonstrates the LOGA 75E and a LOGA drum calculator in the Kurhaus in Scheveningen, near the Hague, 1964 precision these instruments could achieve.

When my father visited a major firm, a representative from the calculations department was often invited to join the meeting. This expert would carry an electromechanical calculating machine into the room. A calculating example would be presented to be solved on both the LOGA and the electromechanical device. The LOGA drums and discs had the advantage that after setting parameters, the result could be read almost instantaneously. Most often my father won these kind of contests, resulting in another sale of a LOGA product.

In this article I want to discuss the theory, and especially the practical methods by which various financial calculations could be executed with the LOGA calculators.

Financial Calculations with LOGA Discs – see CD

The IM2010 Proceedings will focus on financial calculations with specialized LOGA drums. Financial calculations with specialized LOGA discs are described in the original full paper which can be found on the IM2010 CD which accompanies the paper Proceedings.

Financial Calculations with LOGA Calculating Drums

General Description

The LOGA calculating drum – like any slide rule – uses logarithmic scales to execute multiplications and divisions. The precision of slide rules is determined by the resolution of the scale divisions. If a scale is longer, then finer divisions can be used to read more digits of a scale value. The LOGA drum calculator splits a one-decade logarithmic scale of, for example, 15 meter into 60 scales of 25 cm. These scales are printed on longitudinal strips along the surface of the drum. The cylinder or drum is called in the Dutch language a "*wals*" (abbreviated as "W"). If the drum is considered to contain the "fixed scale" (D-scale) of a slide rule, then the scales (C-scale) of the "slide" are affixed onto an enclosing cylinder with open slits between the 60 scale strips, in such a way that any scale strip of the enclosing cylinder can be moved against any scale strip of the drum by sliding and turning the cylindrical slide. The drum W itself is fitted in a bearing on the base frame and can also turn, so that any scale strip can be put into view by the user. The cylindrical slide (abbreviated as "S") contains 60 scale parts of 25 cm each, but the drum has 60 scale parts of 50 cm each half overlapping to allow space for the lateral movement of the cylindrical slide. If a value on the slide can not be aligned with a number on the left half of the drum, it is possible to do so on the right half.

To make it easier to find scale values, markings indicate in 4 decimals the start and end value of each horizontal strip of the logarithmic scale on the left and right sides of the drum. Values along the scale are named in three decimals, but the division ticks indicate four decimals, in the lower range (from 1000) even with a subdivision for each half of a 4th decimal.

Use of the LOGA calculator in the foreign exchange market

The foreign exchange market requires the fastest communication means, at the time telex and telephone. Exchange rates in different countries worldwide need to be available almost instantaneously, to be acted on with maximum speed. For that reason the LOGA calculator was a standard attribute in the arbiter's telephone booth.

Arbiter with LOGA drum in telephone booth

Practice has shown that specific LOGA features are amazingly helpful for arbitraging foreign currencies. Lack of calculating speed will never impede the trader with a LOGA calculator in his booth. Needing less time in calculating, he has more time to prepare his trading decisions. These LOGA features will be illustrated by the following examples using the German Mark as base currency.

Buy and Sell arbitrage by telephone

Note: the buy and sell rates of the Berlin bank office are already available before the phone call.

For fast working, it is advised to mark the actual currency rates with colored tabs on the scales of the cylindrical slide. When the bank Office in Zürich calls, it will take only a second to place the black tab of the Swiss Franc against the red "*100*" division on the drum, mid-position; a look at the right-side "100" will then immediately give the currency rate in Zürich.

At a next call from Amsterdam, the arbitrageur will place the green tab of the Dutch Gulden against the red "*100*" division on the drum.

If the Amsterdam caller wants to deal in Swiss Francs, our arbitrageur turns the black tab up front and he can make decisions based on the value against that black tab. Because he has the overview of all known rates and ratios, he can judge immediately how far his counterpart can go in closing a deal and how far he himself can go.

Example:

Zürich	*black*	London	*red*
Amsterdam	*green*	Copenhagen	*white*
Paris	*dark blue*	Stockholm	*brown*
Brussel	*yellow*	New York	*light blue*

Example values

Berlin Rate	Buy	Sell	Berlin Rate	Buy	Sell
Zürich	3796.20	3803.80	London	804.15	805.85
Paris	1513.45	1516.55	Copenhagen	3796.20	3803.80
Brussel	1473.50	1476.50	Stockholm	4695.30	4705.70
Amsterdam	6993.00	7007.00	New York	204.79	205.21

Buying and selling own currency

Note: Buying and selling rates of the German bank office are known before the phone call, and marked with the tabs on the cylindrical slide.

Solution:

When the call arrives from Zürich, the arbitrageur immediately places the left black tab of the Swiss Franc against the red "*100*" division on the drum, mid-position, and then turns the 100 at the right side of the slide into view, because around that position the rate in Zürich at the German bank office can be read on the drum. If the arbitrageur reads against the 100 on the slide the value 2.634, and from Zürich the message is given that the buying rate is 2.70, the this means selling in Zürich is interesting. If the arbitrageur then sets the selling rate 3803.80 and he reads against the 100 on the right side of the slide the value 2.629 (while Zürich said 2.75) then buying in Zürich is clearly not interesting.

In other words, selling is only interesting if the buying rate is to the right of the rate at the own office. Buying is only interesting if the communicated selling rate is left of the rate at the own office.

Set-up scheme: buy				Set-up scheme: sell			
W	*100*	2.634	(2.70)	W	*100*	2.629	(2.75)
S	3796.20	**100**		S	3803.80	**100**	
			Buying rate Zürich				Selling rate Zürich

Buying and selling foreign currency

One calculates the buy- and sell rates of foreign currencies in Zürich by two slide settings: if one sets the buy rate of the own office for Zürich at 3796.20 against the red circled *100* in mid-position of the drum, and then looks on the drum for the buy rate given by Zürich. All tabbed buy rates of the own office to the right of this position are interesting for selling, while the others are not.

Set-up scheme:

City		Paris		Brussel			Amsterdam	London	
W	*100*	39.625		38.50			184.25	21.18	
S	3796.20	1504.25	(1513.45)	1461.50	(1473.50)	(6993.00)	6994.50	804.03	(804.15)

Buying rates	Zürich	Berlin	Selling in Zürich interesting?
Paris	1504.25	1513.45	nee
Brussel	1461.50	1473.50	nee
Amsterdam	6994.50	6993.00	ja
London	804.03	804.15	nee

Set-up scheme:

City		Paris		Brussel			Amsterdam		London
W	*100*	39.68		38.55			184.40		21.25
S	3803.80	1509.35	(1516.55)	1466.40	(1476.50)	(7007.00)	7014.00	(805.85)	808.30

Selling rates	Zürich	Berlin	Buying in Zürich interesting?
Paris	1509.35	1516.55	ja
Brussel	1466.40	1476.50	ja
Amsterdam	7014.00	7007.00	nee
London	808.30	805.85	nee

The LOGA-calculator for money exchange

How many Swiss Francs do I get for 5000 dollar?

Note: the buying rate for dollars at the German bank office is 182.30 Marken. The selling rate for Swiss Francs is 3548.50.

Solution: Set the dollar rate (182.30) on the slide against the Swiss Francs rate (3548.50) on the drum, and read against the amount of dollars (5000.00) on the drum, the result (25687.00) on the slide.

Set-up scheme:

W	3548.50	5000.00
S	182.30	25678.00

Also in departments for stockholders, saving accounts, calculations or statistics, the LOGA calculator is used, a useful tool thanks to time gained and errors prevented. With the LOGA calculator a user manual and other accessories are available.

Financial Interest Calculations with LOGA-Calculators

Interest calculations with the LOGA drum type 15mE
How much interest is generated by Fr. 28647 during 142 days?
The calculation needed is: 286.47 X 142 = 40679
The result is rounded off (up or down) at the last digit before the decimal point.

Set-up scheme:

W	142	40612 + 67	= **40679**
S	100	286 + 0.47	= 286.47

In reality two settings have to be done.

First:	142 X 286	= 40612
Second:	142 X 0.47	= 67
Totaal:	142 X 286.47	= 40679

Some detailed examples of interest calculations follow below.
Interest percentage P = 3%, time t = 142 days, Capital K = Fr 30786
Interest Z = (K/100 X t) / D (D = 360/3 = 120)
Z = 307.86 X 142 / 120 = 364.30

For a capital that is ten times as big, Fr 307855, a precise interest calculation can be done with the 2-step method, see next set-up scheme.

2-step set-up scheme:

W	142	364.30	3642.....	3550.00 + 92.95 =	3642.95
S	120	307.86	3078.55 =	3000.00 + 78.55	

Interest calculations with interest-numbers (N)

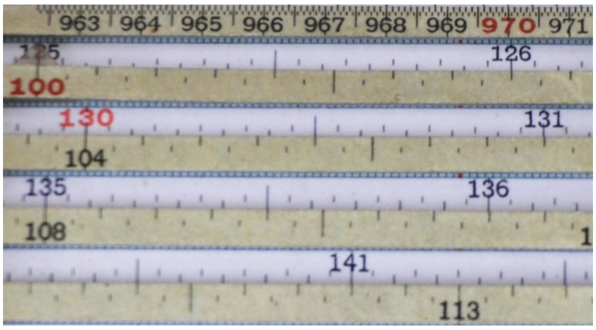
The interest calculations with the **LOGA 15mE** drum calculator use in general the interest-numbers (although this step can also be left out).

Interest-numbers are used by financial LOGA calculators to rearrange the general interest formula into a simple division of two new units: N (Interest Number) and D (Interest Divisor).

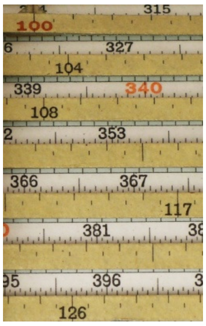
If: **Z** = interest sum (Zins in German), **K** = capital, **t** = nr. of days, **p** = interest percentage, **D** = interest divisor = 360/**p** and **N** = interest-number (Zinsnummer in German) = 1% * **K** * **t**, then the rearranged interest formula is:

Interest **Z** = 1 % * capital * percentage * days / 360, or **Z** = 1% * **K** * **t** / **D** = **N** / **D**

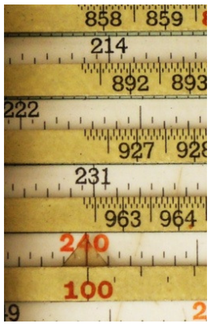
Put the index (100) of the slide against the number of days during which interest is generated. Find the present value of the capital amount on the slide's scale. Read the interest-number at the corresponding position of the drum scale. In the set-up scheme three calculations are included for 125 days, 240 days and 314 days respectively, each with different capital amounts.



Interest-number: 125 days, cap. 1132



240 days, c. 8925



314 days, c. 1264

Determining the interest-numbers N (bold)

Set-up scheme:

W	125 (**t**)	**1415**(**N**)	W	240 (**t**)	**21420** (**N**)	W	314 (**t**)	**3969** (**N**)
S	100	1132 (cap)	S	100	8925 (cap)	S	100	1264 (cap)

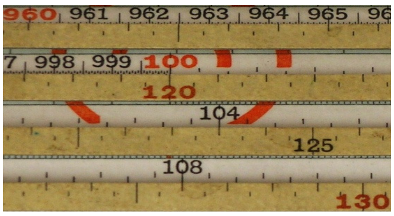
First example of interest calculations with interest-numbers

Example: p = 3 %, so D = 120. Then if N = 129.774 so Z = 129.744/120 = 1081.45

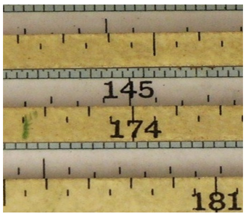
Set-up scheme:

W	3(**p**)	100	1080.00(**Z1**)	+ 1.45(**Z2**)	Z tot. = 1081.45 (Z1+ Z2)	-> **Ztot./12** = 90.12	Z tot. + Ztot./12 = 1171.57
S	360(**t**)	120(**D**)	129600(**N1**)	+ 174(**N2**)	N total = 129744 (**N1 + N2**)	0.25% higher percentage	when p = 3.25%

The closest divisible value **N1** is 129600.



Setting D=120, interest=1080



Interest Z2

Interest Z/12

The remainder of the interest-number **N2** = 174 contributes a correction **Z2** = 1.45 .

If **p** had been 3 ¼ %, then the amount of interest (at 3 %) should have been increased with 1/12 of the interest 1081.45, and this can be done in above example with the same settings. The higher interest would then be the sum 1081.45 + 90.12 = 1171.57 .

Second example of interest calculations with interest-numbers

Interest percentage **p** = 3%, time **t** = 142 days, capital **K** = Fr 30.786

Interest: **Z** =((**K**/100)***t**)/ **D** (**D** = 360/3 = 120)

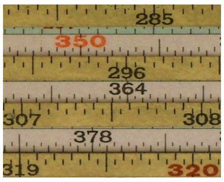
Z = 307.86 * 142/120 = 364.30

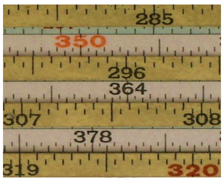
For the ten times as big capital Fr 307.855 a precise interest calculation can be done with the 2-step method using the set-up scheme below.

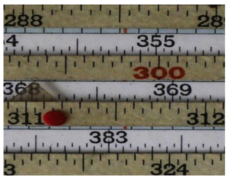
Set-up scheme:

W	142	364.30	3642.…	3550.00 + 92.95 =	total interest 3642.95
S	120	307.30	3078.55 =	3000.00 + 78.55	

capital 30786 *approximate capital 3078..* *capital 300000* *capital 7855*







interest 364.30 *approximate interest 3642..* *interest 3550.00* *interest 92.95*

Interest calculations with the LOGA drum type 15mZ

This type of calculator is specialised for interest calculations. Especially the different method of calculations and the differences in the number of settings needed, will be illustrated by some typical financial

To calculate interest (*Zinsen* in German) the banking community in the world uses different ways of day counts. According to the German method a financial year consists of 360 days and a month always counts 30 days. The French method also assumes a financial year of 360 but every month contains the real number of days. The English method uses a 365-day year and the real number of days for every month. This means that interest calculations result in slightly different results in the various countries.

For example, a capital of 100 000 euro, and interest percentage of 5 % generates from February 15 to March 15 an interest of 416.67 euro by the German method, 388.88 euro by the French method and 383.56 euro by the English method.

The date scale on the drum of the LOGA Zins Calculator has the layout of the German method, so all days of the year include for example February 30 and December 30, but December 31 is left out. In the specific design of the LOGA 15mZ, this scale is also logarithmic ordered, and the numeric distance between two days is 1111 (in comparison with the numerical drum scale). For instance the position of date 12 September is under 120 on the numeric drum scale, while the position of 11 September is under 121.111 on the numeric drum scale. The date scale is in reciprocal order printed on the drum. The end or start of the year is located near the left side of the drum or near the middle of the drum below the numeric scale under 400. (360 days X 1.111 = 400).

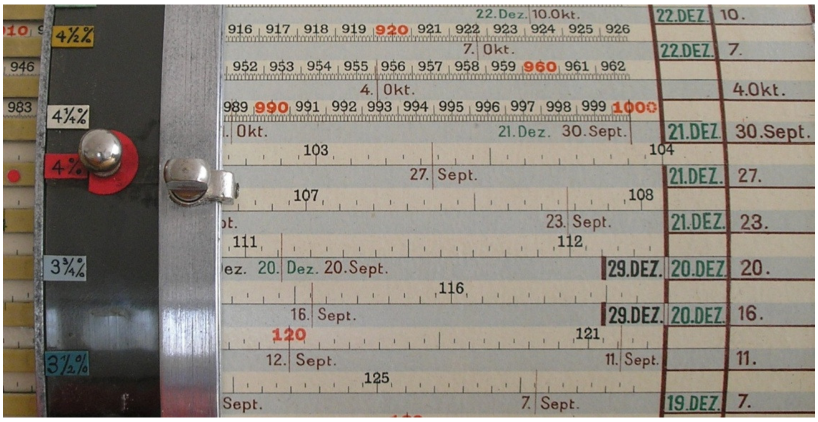
On the slide's scale several interest percentages are marked with different colors. On that scale also the calculated divisors D = 360 / (interest percentage) are marked with the corresponding colors. Because the date scale on the drum starts under 400, they used a correction factor of 1111. The same correction must be made on the divisors D on the slide's scale, to ensure correct interest calculations.

These divisors D are therefore different (corrected with factor 1111) from the LOGA 75 RZ or 30 RZ discs. For instance the divisor D is with an interest percentage of 4 % on the disc 360 / 4 = 90 while this divisor on the LOGA 15mZ = 100, or with an interest percentage of 5 % divisor D = 360 /5 = 72 on the disc and 72 X 1.111 = 80 on the LOGA 15mZ.

The LOGA 15mZ drum is able to calculate interests directly, without intermediate calculations. One only needs to set the drum once a day to the current day, to allow direct interest calculations of any capital amount, until any other day in the year.

The interest is calculated by the determination of the division of 1% of a certain capital K multiplied with the time during the money is in deposit, and the divisor D is 360/interest percentage. **Z** =((**K**/100)***t**)/ **D**

By putting the marked D-number under the date from which the capital gets interest, you can read above the capital K on the slide scale the interest on the drum scale.



Detail of the scales on the LOGA 15mZ

Interest calculation from a given date

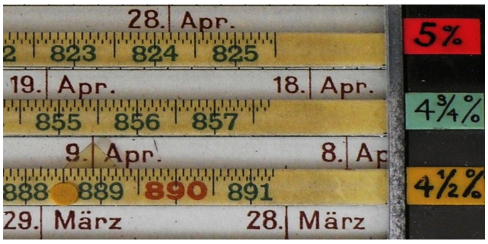
Method for the LOGA 15mZ drum, to calculate interests from a certain date.

a. Place the mark on the slide, determined by the interest percentage (at the yellow dot) against the starting date.

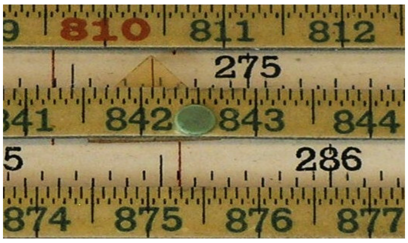
b. Fix the slide with the brake onto the drum, and turn the slide one scale up.

c. Find the capital value on the slide, and read the interest on the drum against that value.

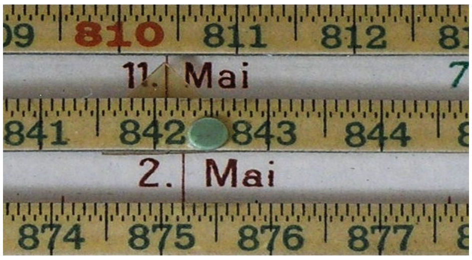
Some examples for an interest rate of 4½% and 4¾%.



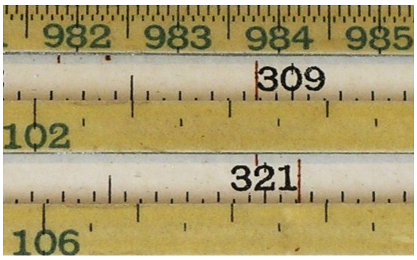
April 9 is date of interest calculation



Interest 285.65 of capital 8755



May 11 is the date for interest calculation



Interest 321.35 of capital 10635

Interest calculations with changes in interest percentage during the year

A second possibility of this specialised drum is to calculate changes in interest when the interest percentage is changed from a certain date. The method is as follows:

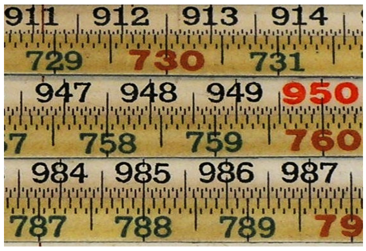
a. Place the divisor for the percentage difference (800 for ½ % difference) against the date from which the percentage is changed.

b. Fix the slide with the brake onto the drum, and turn the slide one scale up.

c. Find the capital value on the slide, and read the interest on the drum against that value.

The divisors for some percentage changes are for 1/8%: 3200, for ¼%: 1600, for ¾%: 533.33 .

Divisor ½ % = 800 at the from-date



Calculated interest for capital 7880

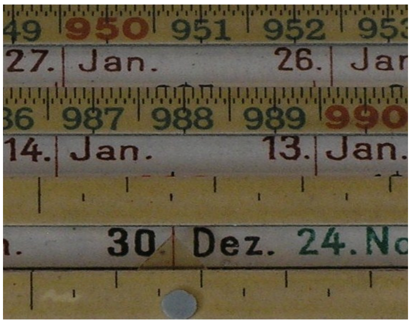
Interest calculation during a running year

Method to calculate the annual interest of a capital value at fixed interest percentage.

a. Place the mark on the slide, determined by the interest percentage (at the blue-grey dot) against the end date of the year.

b. Fix the slide with the brake onto the drum, and turn the slide one scale up.

c. Find the capital value on the slide, and read the interest on the drum against that value.



Closing date year deposit 30 Dec

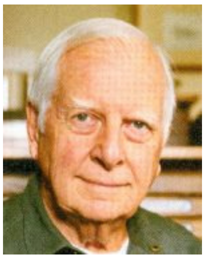
Yearly interest above cap 1656

Conclusion

- Interest calculations with the LOGA drum 15mE require just as many settings as with the disc 75RZ (which is discussed in the full paper 0n the IM2010 CD).
- Precision of the drum 15mE (~ 4 decimals) is higher than of the disc 75RZ (~ 3 decimals) – due to the difference in scale lengths.
- Results for one interest rate and different capital values can be read on the 15mE drum with only one setting. Interest values are calculated with the so-called interest-numbers which depend on the combination of interest rate and duration. First the interest-number has to be calculated; then interest amount can be read for any capital value. Interest-numbers can also be retrieved from tables.
- By splitting interest calculations in two steps, one for the major part of the capital and one for the remaining lower decimals, an even higher precision can be reached.
- Interest calculations on the specialized LOGA 15mZ require the least amount of settings and have the highest precision. This calculator also allows interests to be read directly for different capital values, after only one setting for the duration days.
- Therefore the 15mZ calculator is the best LOGA calculator for this kind of financial calculations.

DESCRIPTION AND USE OF THE SLIDING GUNTER IN NAVIGATION

Thomas Wyman



The Dutch have a long and proud sea-faring tradition which is reflected in many ways. For roughly a century, from 1570 to 1670, mapmakers in the Low Countries produced some of the greatest maps in the world. The centers of production, at first in Antwerp and Duisburg, soon shifted to Amsterdam. The Dutch maps and sea charts of this period have never been surpassed for their magnificence of presentation, richness of decoration and accuracy based on information available at the time. Names of the near-legendary map-makers of the period include: Abraham Ortelius (1527-1598), Gerard Mercator (1512-1600), Jodocus Hondius (1563-1611) and his son Henry Hondius, Willem Janszoon Blaeu (1571-1638) and his two sons, Joan and Cornelis, and finally Jan Janson (1596-1664).

The Dutch proved to be powerful allies of the English in promoting the concept that California was an island off the western coast of the New World. This was a cartographic misconception that prevailed for over 100 years – from 1620 until well after 1701 when Father Eusebio Francisco Kino, a Jesuit priest from Spain showed conclusively that California was no island.

The first page of an atlas produced by mapmaker Johannes Jansonius in 1620 reflects the Dutch awareness of marine-related activities. Looking closely we see a group of mariners with all manner of globes, sea charts and atlases, a cross staff, an astrolabe, dividers, a compass box and hour glass all set before an imposing sea scene as background. Incidentally, the bookseller who was offering this rare maritime atlas with 40 double-page charts was asking £70,000!

Another reflection of the keen interest of the Dutch in things maritime can be found in their 18th and 19th century ceramic tiles or *tegels* where remarkably detailed ship scenes are depicted on individual tiles and on museum-quality tile tableaus. The attention that artists gave to the detail of ship design and ship rigging shown on Dutch *tegels* reflects a knowledge and awareness that one would expect mariners to possess but not expect tile painters to understand and appreciate.

Shown here is a ship panel of 12 Delft tiles produced in 1800. The attention to the detail of ship design and rigging reflects an artist with a remarkable understanding of his marine subject.

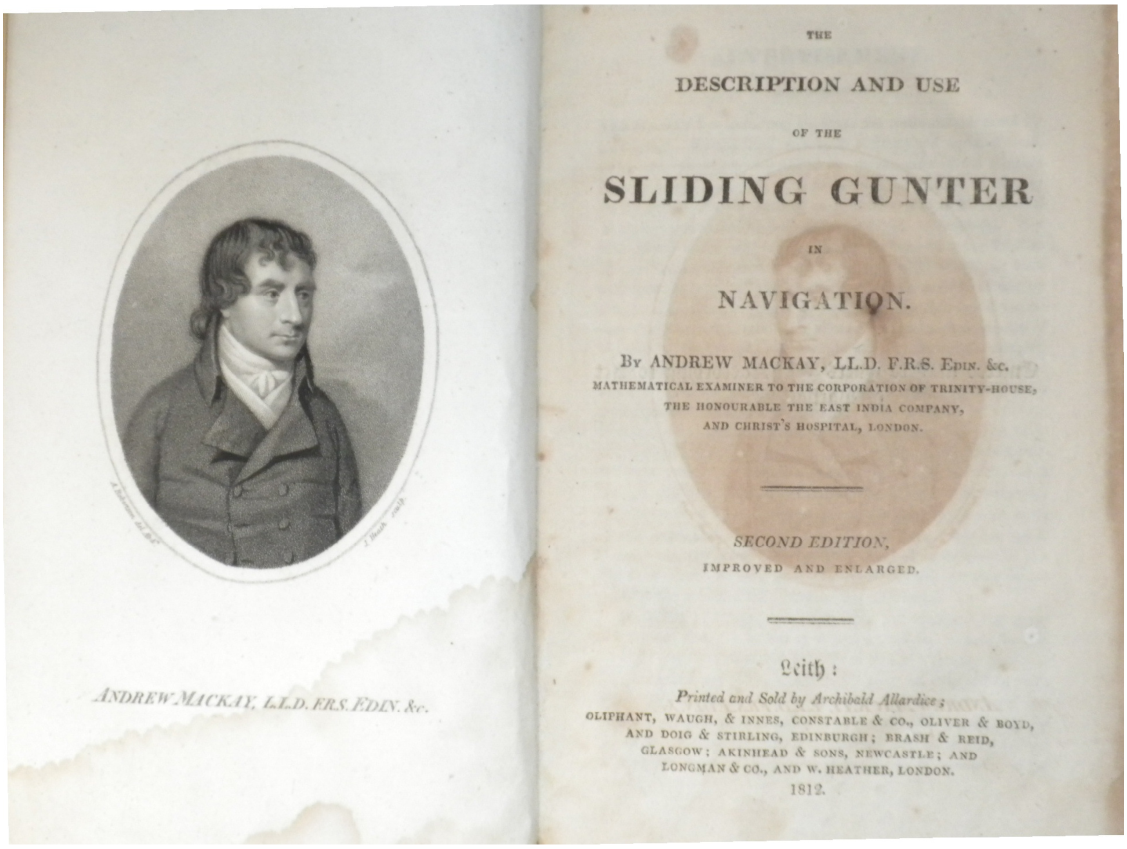
With the long-time maritime tradition of The Netherlands, it is most appropriate that this paper on sliding Gunters, be presented at IM 1010 which our Dutch friends are hosting.

A sliding Gunter that was available to mariners is shown in a foldout and described in Andrew Mackay's 2nd edition of *The Description and Use of the Sliding Gunter in Navigation.* The 2nd edition of Mackay's book, published posthumously in 1812, substantially altered and improved the 1st edition.[i] The lead-in "Advertisement" contained in the book offers some generalized comments on the Sliding Gunter:

> This is an instrument which has been used frequently at sea, but has been very little noticed of late by writers on navigation…Above fifty years ago, the Sliding Rule, was employed very generally at sea; and if it be less so at present, we can account for it in no other way, but from the difficulty of finding

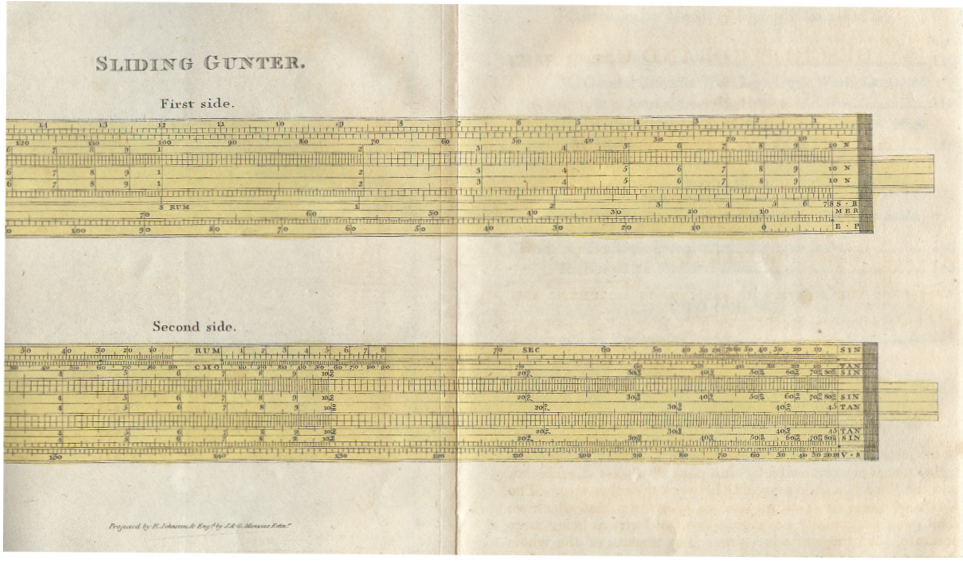
> a treatise that contains directions and examples sufficiently plain and extensive to guide the mariner in his use of it. This defect being so completely supplied by the present work, may we not reasonably expect, that the use of the Sliding Gunter will revive, and the method of performing the practical operations of navigation by it will again become general.

The 1st edition of Mackay's book appeared ten years earlier in 1802 and indeed may have served to encourage mariners to use the sliding Gunter. However, judging from the foregoing comments that appeared in the 2nd edition, the use of the Sliding Gunter had declined, and there is no evidence that it found wider application as a navigational instrument following the appearance of the 2nd edition in 1812. The reasons for this lack of interest in slide rules designed for use in marine navigation may never be known for certain, but we can make several observations as to why this appears to be the case.



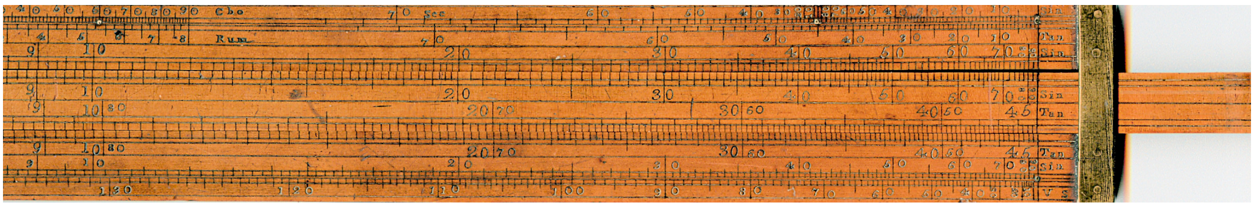
Andrew Mackay and his 2nd edition of The Description and Use of the Sliding Gunter in Navigation published posthumously in 1812.

However, first we should understand how the sliding Gunter was meant to be used. After a few preliminary comments Mackay goes on to describe the instrument saying, "*The length of the rule is either one, or two feet; that which we shall more particularly describe, is two feet long, as being more accurate, than those of less size.*" In the first 18 pages the author instructs the reader on the use of the rule in solving basic arithmetic and trigonometric problems. The remaining 150 pages are devoted to the use of the Gunter Rule in solving a wide variety of navigational problems as well as providing specific instructions on maintaining a ship's log.



Pictured here is the sliding Gunter as shown in the foldout of Mackay's book and described in the text. The foldout includes a small note "Projected by E Johnston & Eng^{d} by J. & G. Menzies Edin."

The author's 24-inch boxwood sliding Gunter is unmarked but identical to that pictured above. A navigational slide rule nearly the same as that shown above was produced by Isaac Bradford at 136 Minories, Tower Hill, London -- his address from 1802 to 1822. If a reader of Mackay's book wanted to obtain a sliding Gunter, this was very likely the maker he would have consulted.



A 24x1.9-inch sliding Gunter made of boxwood identical to the one shown in the foldout in Mackay's book. Maker is not known but was probably Isaac Bradford at 136 Minories, London.

Mackay's book is a most comprehensive work written for mariners and offers numerous examples and explanations for using the sliding Gunter to solve a range of navigational problems. For example, the following direct quotes offer examples of calculations that could be performed using this instrument:

- Given the Latitude and Longitude of two Places, to find the course and distance between them. Example: Required the course and distance from Flamborough-head, latitude 54° 11' N. and longitude 0° 19' E. to the Naze of Norway, in latitude 57° 56' N and longitude 7° 15' E? (p.39)
- Given the Course and Distance sailed from a known place, to find the Latitude and Longitude of the Place come to. Example: A ship from Cape Clear, in latitude 51° 18' N. and longitude 11° 15' W. sailed S. E. ¼ S, 120 miles: Required the latitude and longitude come to? (p.49-50)
- Given the Latitude of two Places, and the Distance between them, to find the Course, and Difference of Longitude. Example: A ship from St. Alban's Head, in latitude 50° 37' N. and longitude 2° 13' W, sailed 171 miles upon a direct course between the S. and W. and by observation is in latitude 48° 28' N.: Required the course steered, and longitude come to? (p.54)

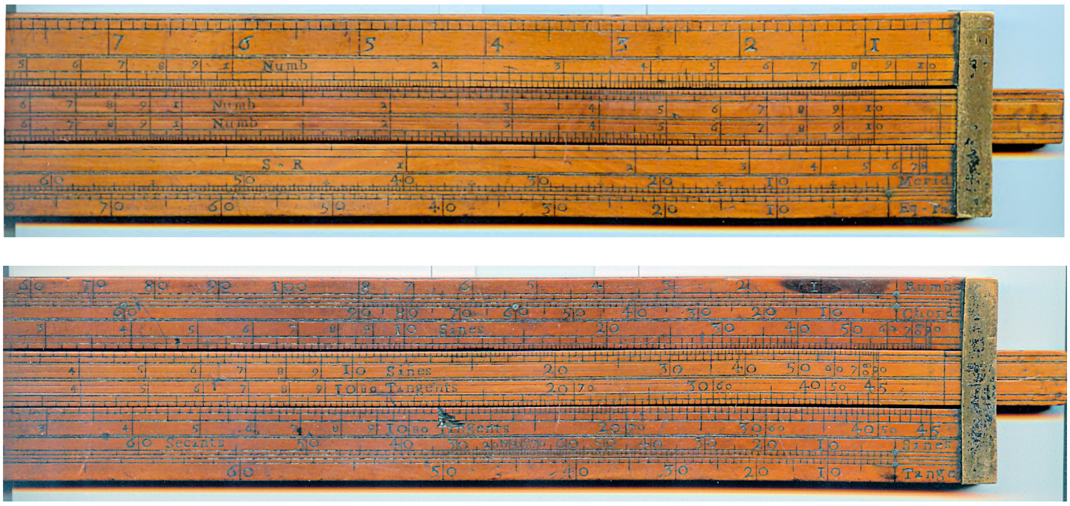
- Windward Sailing is the method of gaining an intended port, by the shortest and most direct method possible, when the wind is in a direction unfavourable to the course the ship ought to steer for that port. Example: A ship is bound to a port 26 miles directly to the windward, the wind being N. E. which it is intended to reach on two boards, the first being the larboard tack; and the ship can ly within 6 points of the wind: Required the course and distance on each tack? (p.64)
- Current sailing by the Sliding Gunter. The computations, in the two preceding chapters, have been performed upon the assumption that the water has no motion. This may, no doubt answer tolerably well in those places where the tides are regular; as then, the effect of the flood will nearly counterbalance that of the ebb. But in places where there is a constant current, or setting of the sea, towards the same point, an allowance must be made of the ship's place, arising therefrom. And the method of resolving those problems in sailing, in which, the effect of a current or heave of the sea, is taken into consideration, is called "Current Sailing." Example: A ship sailed S. W. by S. at the rate of 7 knots an hour: Required the course, and distance made good in 24 hours? Example: A ship bound from Dover to Calais, lying S. E. by E. ½ E. distant 21 miles, and the flood tide setting N. E. ½ E. 2½ miles an hour: Required the course she must steer, and the distance to be run by the log, at 6 knots an hour, to reach her port? (p.66-68)

These examples are sufficient to suggest the versatility of the sliding Gunter. Indeed, the role of a ship's master and his navigator in assuring safe and direct passage from one port to another was not trivial. Ships were primitive and the navigational equipment of the period was rudimentary but still very practical.

The truth is, however, it seems unlikely that calculations such as those quoted above were performed routinely. More likely, mariners seldom strayed from waters with which they were familiar with the result that over time they developed an "experience factor" or an intimate knowledge of the waters they plied. Mariners learned the courses to be sailed, the set of the sea and could assess prevailing wind and weather conditions as they set out and once underway would make adjustments accordingly depending on what weather conditions developed. This knowledge was passed from generation to generation as young mariners learned the ways of the sea from seasoned sailors. Mariners were never troubled by electronic communications and mid-course destination changes from shore management so that once at sea a ship's destination remained unchanged.

Thus, while the sliding Gunter was an ingenious instrument applicable in solving many navigational problems, in reality, such problems seldom arose in the routine voyages of the day. The "old salt" with his experience and knowledge of the waters he sailed had little need for a sliding Gunter and probably would not have been able to use it if, indeed, he had one. Given that traditional ways of the sea change slowly, one can imagine that such instruments may even have been held in some disdain by seasoned mariners as a "gadget" that reflected the user's callowness and inexperience.

As noted earlier, the "Advertisement" to Andrew Mackay's 1812 edition comments on the sliding Gunter saying, "*This is an instrument which has been used frequently at sea, but has been very little noticed of late by writers on navigation. Above fifty years ago, the Sliding Rule, was employed very generally at sea….*" Representative of those earlier slide rules designed for navigators is a 12-inch boxwood and brass slide rule that was produced by John Cook. It has the appearance of an 18th century rule with small somewhat cramped numbering and lettering. I have been unable to learn anything about the maker.

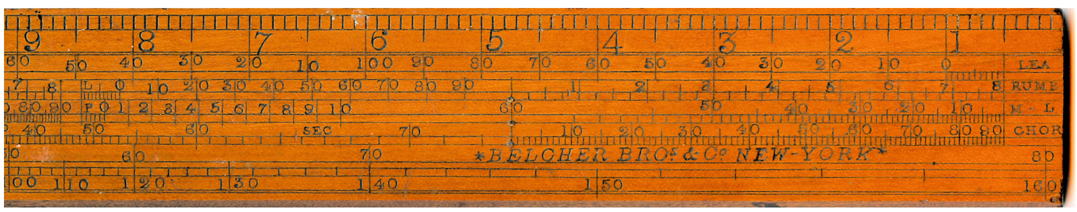


A boxwood and brass 12-inch sliding Gunter produced by John Cook. Circa 1760.

The scales of this navigational rule by John Cook are as follows:
The scales on the first side from top to bottom is 12-inch scale and two cycle log scale ("Numb") adjacent to the slide. There are two 2-cycle log scales (each marked "Numb") on the slide, with "S.R." and "Merid" scales and an arithmetic "Eq. P." scale on the lower edge of the first face. On the reverse side from top to bottom there is a "Rhumb" scale, "Chord" scale, "Sines" scale adjacent to the slide. The slide has scales marked "Sines" and "Tangents." The lower body of the slide rule has "Tangents," "Sines" and "Tangent" scales.

This is an interesting example of a sliding Gunter. Overall, it does not appear to be an instrument that would be particularly easy to use and the darkening of the patina over time would make it more difficult to read, especially where light was poor.

I do not intend these remarks of the comparative rarity of the sliding Gunter to apply to the simpler one piece Gunter rule which found much wider acceptance in the maritime community than did the sliding Gunter. Those seeking more information on the Gunter rule should refer to two most comprehensive papers written by Otto van Poelje that appeared in the *Journal of the Oughtred Society* in 2004 and 2005.[ii] One may speculate as to the reasons why the Gunter rule proved so much more enduring than the sliding Gunter. However, those reasons must include the rule's basic simplicity combined with its versatility and the fact that calculations were readily made using mechanical dividers -- instruments that every navigator had at hand and used regularly.



Right hand portion of a 24-inch Gunter rule by Belcher Brothers & Co., New York. Circa 1855.

An earlier volume, *Epitome of the Art of Navigation or, a Short, Easy, and Methodical Way to become a Competent Navigator* published in 1762, mentions *en passant* the Gunter scale in several places as an aid in solving certain calculations. This leaves a researcher today with the impression that the Gunter rule was not a particularly important item in the navigator's kit of instruments.[iii]

In his *The Art of Navigation in England in Elizabethan and Early Stuart Times,* D. W. Waters offers an interesting perspective on the importance of mathematical training as applied to navigation in the first half of the 17th century:

> [W]hat was most necessary was for a man to have a good grasp of the principles of the sciences of geometry, trigonometry, and astronomy, and the ability to add, subtract, multiply, and divide simple figures accurately. In fact, by then navigation had developed far towards becoming a mathematical science. This is reflected in the manuals of navigation compiled after this date. All treat their subjects from the mathematical aspect.
> This does not mean to say that by 1631 all masters were mathematicians and all practiced scientific navigation. Indeed many were poor mathematicians and even worse navigators. They had no standard qualifying examination to pass under the auspices of Trinity House, and in consequence many inherited and transmitted a deep distrust of "ciphers." But the successful navigators were far more numerous than is commonly averred; the growth of English commerce and colonization in the early seventeenth century and the success of naval operations in the mid-century wars with the Dutch alike vouch for this.[iv]

The very fact that there are comparatively few books that appear to have survived which describe the use of the sliding Gunter in solving navigational problems suggests that there were not that many written in the first place. This also reflects the comparatively thin market and limited use of the instrument among navigators. From this evidence one is led to conclude that it was a specialized application of the slide rule that never found wide acceptance among mariners.

With respect to navigation in the Elizabethan and early Stuart times (mid-1600s to early 1700s) Waters also observed:

> Just as today, so then the coaster practiced a simpler form of navigation than the deep sea trader. Much of the trade was still coastal. It follows that much of the navigation was coastal, and much of it pilotage. But to argue from this, as is often done, that the navigational knowledge of the period was rudimentary, and the practice unskillful, is to deny the evidence of the published books on the subject, of the exquisite accuracy of the surviving instruments, and above all, the meticulous entries of many a master mariner's journal.[v]

Nathaniel Bowditch's well respected *The New American Practical Navigator: Being an Epitome of Navigation* was first published in 1802. This writer's copy, a well-worn 17th edition that appeared in 1847, has short chapters on both the "Gunter's Scale' and "Sliding Rule." Thus, these instruments evidently were considered at least marginally useful in navigation during the early 1800s. On the other hand, in 1846 Edward Hazen wrote of the instruments employed by navigators but did not mention the Gunter rule or the sliding Gunter:

> The instruments now employed in navigation, are the mariner's compass, the azimuth compass, the quadrant, the sextant, the chronometer, the half minute glass, the log, and the sounding line. In addition to these, the general navigator needs accurate maps and charts, lists of the latitude and longitude of every part of the world, the time of high water at every port, and a book of navigation, containing tables, to aid him in performing various calculations with facility; and, with a view to calculate the longitude by observation, he should be furnished with the nautical almanac, containing the places and declinations of the fixed stars and planets…[vi]

The fact that Bowditch only briefly refers to the sliding Gunter and Hazen makes no reference to it strongly supports the conclusion that by the mid-19th century the slide rule was never more than of peripheral importance as a navigational instrument. The sliding Gunter may have found a receptive market among some mariners earlier when it first appeared but fell into disuse as they discovered that they seldom if ever used the instrument or really needed it. Thus, we must conclude from available information that unlike technicians and engineers, who relied heavily on their slide rules during their working years, few mariners ever developed the same dependence and affection for the sliding Gunter designed for navigation. This esteem for slide rules among land-based technicians and engineers and general disdain among sea-going types of the sliding Gunter persisted over the years into the 20th century. Thus, we are left to conclude that the navigational slide rule never found an enduring role aboard ship.

AFTER THOUGHT: With tongue in cheek the author reports that he served in the U.S. Navy aboard the aircraft carrier *USS Lexington CV 16* as a quartermaster, owned a Star Class sailing boat and spent over 30 years in the management of seagoing tanker operations for a major oil company and never once during that time encountered a sliding Gunter.

[i] Andrew Mackay, *The Description and Use of the Sliding Gunter in Navigation,* 2nd ed., Leith, 1812.
[ii] Otto van Poelje, "Gunter Rules in Navigation," Journal of the Oughtred Society,Vol. 13, No. 1, The Oughtred Society 2004, p 11-22 and "The Navigation Scale, Improved by B. Donn," ," Journal of the Oughtred Society, Vol. 14, No. 2, The Oughtred Society 2005, p 36-32. In addition, a comprehensive description of sliding Gunters can be found in the article by Otto van Poelje, "The Sliding Gunter – Versions for Navigation at Sea" JOS, Vol. 16, No. 1, 2007, pp 12-18. Mr. van Poelje's article served as the genesis for this paper which builds on it to offer an assessment of the significance of the sliding Gunter in marine navigation.
[iii] James Atkinson Sr. *Epitome of the Art of Navigation or, a Short, Easy, and Methodical Way to become a Competent Navigator,* London, 1762. See for example pp 105, 106 and 108
[iv] D. W. Waters, The Art of Navigation in England in Elizabethan and early Stuart Times, Yale University Press, 1958. p 498
[v] Ibid. pp 498-499.
[vi] Edward Hazen, *Popular Technology or, Professions and Trade,* Vol. 1, Harper and Brothers, New York, 1846. p 183.

Note by the Editor

The above article by Tom Wyman on the Sliding Gunter, sobering but true, opens with the insularity issue of California in old maps. This "*cartographic misconception*" originated from an incorrect report by Fray Ascension from a Spanish expedition led by Sebastian Vizcaíno in 1602-1603, claiming that California had been found to be an island.

From Dutch perspective the following happened. In 1615 the Dutch privateer Joris van Spilbergen captured a Spanish ship that carried charts showing California as an island. This map eventually came into the hands of the Dutch mapmaker Hessel Gerritz (of the hydrographic office of the VOC - Dutch East India Company) who included it as new information on his 1622 map of the Pacific, not on the main map but only in a small cartouche of the Western Hemisphere.

Since that year most Dutch mapmakers copied the Californian error until the early 1700s with some exceptions, for example Blaeu's *Atlas Maior* did not contain the error: its chart of America was based on an earlier 1617 version.

It is remarkable in the attached California map by Johannes Vingboons, 1639, how detailed the mid and southern parts were, while the unknown Northern part still contained the error.

GIRTANNER'S LOGARITHMICAL TABLES
of 1794
for Simplifying Commercial Calculations

Werner H. Rudowski

Werner H. Rudowski studied Process Engineering and discovered his interest in the great variety of slide rules when he designed – as a young engineer – a slide rule for air-cooled Heat Exchangers. He has collected slide rules since the early 1970s, mostly as a *hunter*. But only after his retirement did he start to study them in more detail and to write articles for various publications. His special interests are early slide rules, mainly old English ones, and searching for early German slide rules or logarithmic calculation devices. Besides slide rules Werner collects abaci from Europe, Russia, China and Japan, as well as *Rechenpfennige* (counters or jetons).

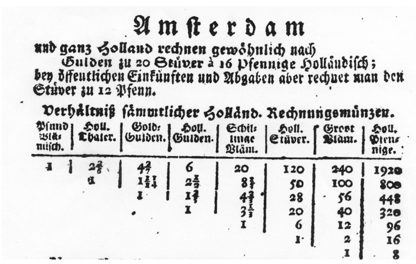
Foreword

The many different logarithmic tables in this book were developed for merchants and bankers in German speaking states at the end of the 18th century. These tables look very strange to us nowadays. To understand them it is necessary to know a little bit about the monetary systems of that time and the customs in financial affairs, which were different at the trading places in Europe. Therefore the first chapters of this article explain currencies, money and coins used in that time and how business was done between various states and market places with different currencies. Unfortunately, Girtanner did not explain the background, he just gave instructions on how to use the tables. Only with the help of other books of the 18th / 19th century – listed under *Literature* – was it possible to decode the secret in Girtanner's tables.

The chaotic money system in Central-European minor states and trading centers at the end of the 18th century

In the 18th century and also still in the 19th century there was no common system for measures, weights and currency. Each one of the many small states and bigger cities had their own measures and money. And even at one place the units for lengths, volumes, weights, and money for our understanding were very confusing. Additionally comparisons were even more difficult, as in many cases the same name for a unit was used at various places – for example *Gulden* – but with different values. Similar to today, the value of coins changed in rather short periods, to say it more exactly, the value became less.

There were thick handbooks where merchants at that time could find explanations and tables for comparison of the great variety of measures and currency. Only a few examples from Nelkenbrecher's book of 1798 [7] give an impression: *Rechnungsmünzen* (accounting money, not necessarily actual coins) of the cities of Amsterdam, Augsburg and Zurich (Fig. 1a, b, c).



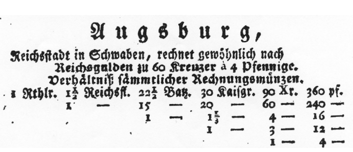
Amsterdam

und ganz Holland rechnen gewöhnlich nach
Gulden zu 20 Stüver à 16 Pfennige Holländisch;
bey öffentlichen Einkünften und Abgaben aber rechnet man den Stüver zu 12 Pfenn.

Verhältniß sämmtlicher Holländ. Rechnungsmünzen.

Pfund Vlämisch.	Holl. Thaler.	Gold-Gulden.	Holl. Gulden.	Schillinge Vläm.	Holl. Stüver.	Groot Vläm.	Holl. Pfennige.
1	2 2/5	4 2/7	6	20	120	240	1920
	1	1 11/14	2 1/2	8 1/3	50	100	800
		1	1 2/5	4 2/3	28	56	448
			1	3 1/3	20	40	320
				1	6	12	96
					1	2	16
						1	8

Figure 1a

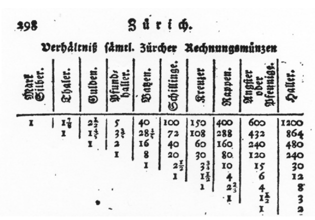


Augsburg,

Reichsstadt in Schwaben, rechnet gewöhnlich nach
Reichsgulden zu 60 Kreuzer à 4 Pfennige.
Verhältniß sämmtlicher Rechnungsmünzen.

1 Rthlr.	1 1/2 Reichsfl.	22 1/2 Batz.	30 Kaisgr.	90 Xr.	360 pf.
	1 —	15 —	20 —	60 —	240 —
		1 —	1 1/3 —	4 —	16 —
			1 —	3 —	12 —
				1 —	4 —

Figure 1b



498 Zürich.

Verhältniß sämtl. Zürcher Rechnungsmünzen

Mark Silber.	Thaler.	Gulden.	Pfundhaller.	Batzen.	Schillinge.	Kreuzer	Rappen.	Angster oder Pfennige.	Haller.
1	1 7/8	2 1/2	5	40	100	150	400	600	1200
	1	1 4/5	3 3/5	28 4/5	72	108	288	432	864
		1	2	16	40	60	160	240	480
			1	8	20	30	80	120	240
				1	2 1/2	3 3/4	10	15	30
					1	1 1/2	4	6	12
						1	2 2/3	4	8
							1	1 1/2	3
								1	2

Figure 1c

Some abbreviations for Augsburg need to be explained:

Rthlr. = *Reichsthaler*
Reichsfl. = *Reichsgulden*
Batz = *Batzen*
Kaisgr. = *Kaisergroschen*
Xr = *Kreuzer*
pf = *Pfennig*

As mentioned before *Rechnungsmünzen* were not identical with actual minted coins. For example, Augsburg used:

- *Ducaten* and *Goldgulden*
- two-, one- and half *Gulden* (fl) in Silver (courent)
- coins for 1, 3, 6, 12 and 24 *Kreuzer*

In Zurich according to the *National- Münzsystem* were minted:

- In gold: **-** one (=5 fl), half and quarter *Ducaten*
- In silver: - one, half and quarter *Thaler* (1 *Thaler* = 2 local *Gulden)*
  - *Vierbätzler* at 10 *Schilling* each, *Zweibätzler, Batzen* and half *Batzen* at 4 and 2 *Kreuzer*
  - One and half *Schilling*
  - Coins for 12 and 6 *Haller*, for *Rappen* and *Angster*

Several professional organizations preferred certain money. For example, corn-merchants in Amsterdam mainly calculated in *Goldgulden* (= 28 *Stüver*); wine, beans and peas were charged in *Pfund* (= 20 *Schilling* = 240 *Pfennig*), in the exchange business *Thaler* at 50 *Stüver* or 16 *Pfennig/ Stüver* commonly were used. But the confusion was even worse.
One calculated for example in:

- Banco-*Geld* (Bco): This was the "Best of the Country"
- *Courant-Geld* (courant = circulating) was used in daily life and trade. It was worth less than Banco-*Geld*. The difference – the Agio – was about 3 to 5 percent.
- *Edict-mäßiges Geld*: This was the money fixed, minted and circulated by the sovereign. It corresponded mainly with the *Courant-Geld*.
- *Giro- or Wechselgeld*: in Augsburg it was always 27 percent better than *Courant-Geld*, i.e. 100 *Rthlr Giro* corresponded with 127 *Rthlr. Courant*. In Zürich *Wechselgeld* was worth about 14 % more than *Courant-Geld*. According to Flügel [3] one *Louis d'Or* was worth 7 *Gulden Wechselgeld* and 7*fl* 45 *Kr*. (later 8 *fl*) *Courant-Geld*.

Comparison of currency – absolutely necessary for trade and banking

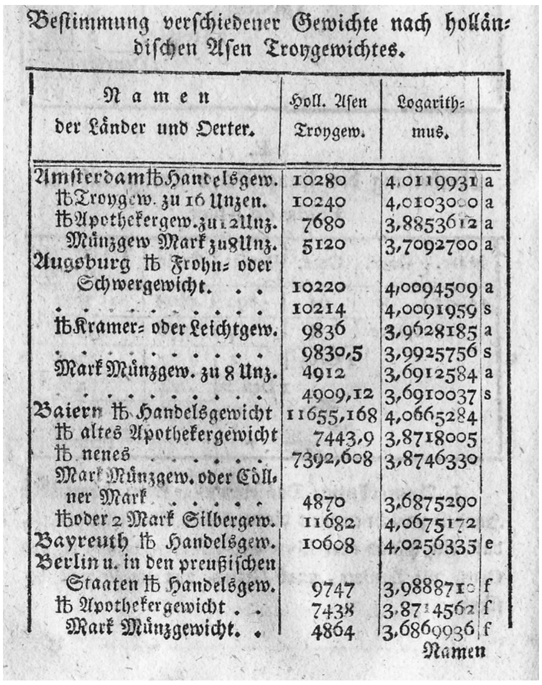
Probably the most known and accepted method for comparison of the many currencies in central Europe was the *Cöllnermark Münzgewicht* (Weight of one Cologne mark). It was defined as 4864 *Aasen* Dutch *Troy* weight. The name *Troy* was derived from the French town Troyes in the Champagne – area, in former times an important market place. The Dutch *Troy* weight for a long time was used to compare weights. The smallest unit was the *Aß* (or *Aas)* representing 0.047445231 gr in the metric system [2], in another source [6] it was 0.048047355 gr. From the latter source Figure 2 has been taken, giving the weights common in several states and cities in Dutch *Asen-Troygewicht* and additionally the logarithm belonging to it.

Münzfuß (money basis) was the rule given by the sovereign which dictated how much each coin had to weigh *(nach Schrot und Korn).* The total weight of a coin was called *Schrot* and the precious metal contained therein *Korn*. Unfortunately, the *Münzfuß* in Germany changed very often. After the 7-year-war (1756-1763) most of the German sovereigns had decided to introduce the ***Conventionsfuß***: The *Kölner Mark fein Silber* should be minted to 20 *Gulden* (Guilders) or 13⅓ *Reichsthaler*. Therefore the *Conventionsfuß* also was called ***Zwanzig-Gulden-Fuß.***

According to this new *Conventionsfuß* the *Kölnische Mark fein Gold* had to be minted to 283 7/71 *Flor* (Guilders) and *Ducaten* at 4 1/6 *Flor* each. That resulted in 67 *Ducaten* minted from 23 2/3 carat gold with a pure gold content of 71½ Dutch *Aasen* (appr. 3.4 gr) [2]. With the gold price of today a *Ducat* would be worth approximately 80 euro.
Comparison of 283 7/71 Guilders in Gold and 20 Guilders in silver minted from one *Kölner Markgewicht* gives a relation of the worth of gold to silver of 14.15:1. Today it is about 65:1.

Later, in some countries the ***24-Guldenfuß*** was again introduced, i.e. out of 1 *Kölner Mark fein Silber* 24 *Gulden* or 16 *Reichsthaler* were minted. In 1798 the municipal council of Cologne fixed a ***Fünf und Zwanzig Guldenfuß*** (25 Gulden-Basis) as the only standard rate for calculations and comparisons. Thus the *Conventionsthaler* got the value of 2½ *Gulden* or 1 2/3 *Reichsthaler* and was known as *Conventionsthaler courant.* Compared with the previous 20 *Guldenfuß* the value of the new *Reichsthaler* became the value 0.8.

The Amsterdam-*Gulden* corresponded with 24 3/8 coins minted from 1 *Cöllner Mark fein Silber* and therefore had a value of 0.54702 *Reichsthaler* according to the *Conventionsthalerfuß Courent* (*25- Guldenfuß*). Figures 3a, b are taken from Nelkenbrecher's book of 1798 [7]. This extensive table allows comparing all different currencies, also when based on a different *Guldenfuß*. The Gulden of Cologne acc. to the *24-Guldenfuß* thus had a value of 0.5555 *Reichsthaler* (*Rthlr*) per piece, the English pound a value of 6.27460 per piece. Additionally, there also existed tables for comparison of currencies of different places as shown for example in figures 4a, b, taken from the same book [7]. In this case the currencies of different places are given acc. *to Conventionsthaler Courent* in *Reichsthale*r and *Groschen* and in *Prussian Reichsthaler* and *Kreuzer* and additionally in *Reichsgulden* (*Rfl*) and *Kreuzer* according to the *24-Guldenfuß*.

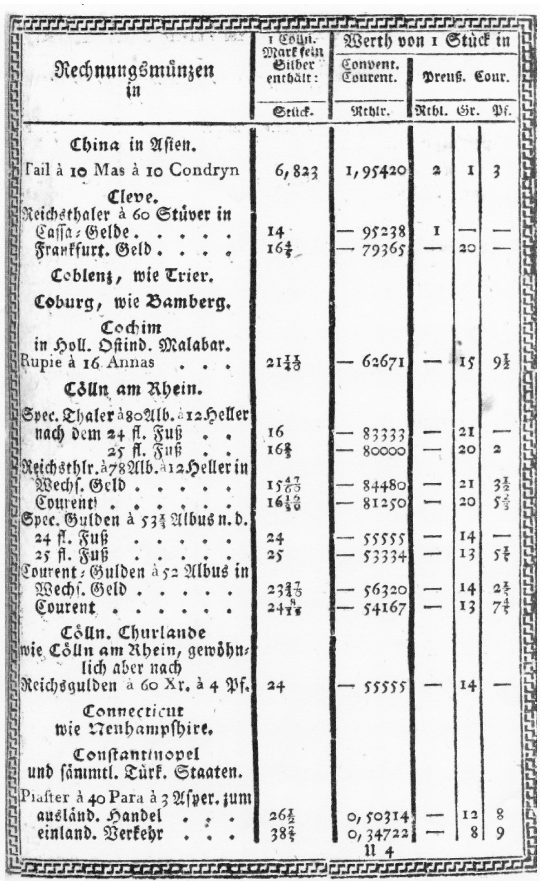


Bestimmung verschiedener Gewichte nach holländischen Asen Troygewichtes.

Namen der Länder und Oerter.	Holl. Asen Troygew.	Logarithmus.	
Amsterdam ℔ Handelsgew.	10280	4,0119931	a
℔ Troygew. zu 16 Unzen.	10240	4,0103000	a
℔ Apothekergew. zu 12 Unz.	7680	3,8853612	a
Münzgew Mark zu 8 Unz.	5120	3,7092700	a
Augsburg ℔ Frohn- oder Schwergewicht. . .	10220	4,0094509	a
. . . .	10214	4,0091959	s
℔ Kramer- oder Leichtgew.	9836	3,9628185	a
. . . .	9830,5	3,9925756	s
Mark Münzgew. zu 8 Unz.	4912	3,6912584	a
. . . .	4909,12	3,6910037	s
Baiern ℔ Handelsgewicht	11655,168	4,0665284	
℔ altes Apothekergewicht	7443,9	3,8718005	
℔ neues	7392,608	3,8746330	
Mark Münzgew. oder Cöllner Mark	4870	3,6875290	
℔ oder 2 Mark Silbergew.	11682	4,0675172	
Bayreuth ℔ Handelsgew.	10608	4,0256335	e
Berlin u. in den preußischen Staaten ℔ Handelsgew.	9747	3,9888710	f
℔ Apothekergewicht . .	7438	3,8714562	f
Mark Münzgewicht. .	4864	3,6869936	f

Namen

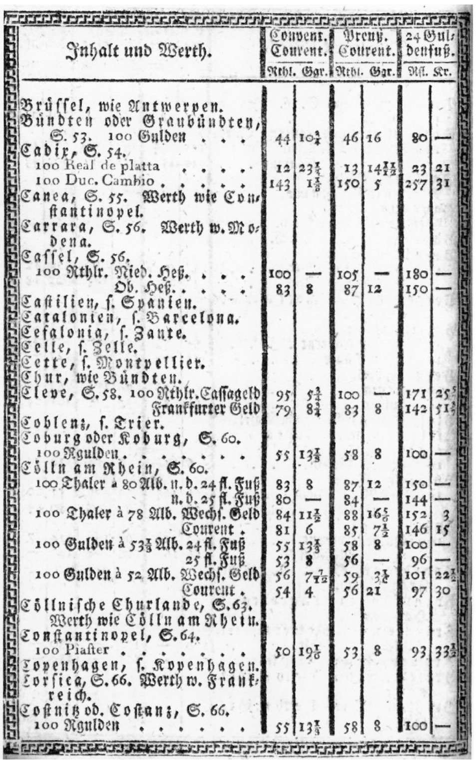
Figure 2



Rechnungsmünzen in	1 Cölln. Mark fein Silber enthält: Stück.	Werth von 1 Stück in Convent. Courent. Rthlr.	Preuß. Cour. Rthl.	Gr.	Pf.
China in Asien.					
Tail à 10 Mas à 10 Condryn	6,823	1,95420	2	1	3
Cleve.					
Reichsthaler à 60 Stüver in					
Cassa-Gelde	14	— 95238	1	—	—
Frankfurt. Geld	16 4/5	— 79365	—	20	—
Coblenz, wie Trier.					
Coburg, wie Bamberg.					
Cochim in Holl. Ostind. Malabar.					
Rupie à 16 Annas . . .	21 11/40	— 62671	—	15	9 1/2
Cölln am Rhein.					
Spec. Thaler à 80 Alb. à 12 Heller					
nach dem 24 fl. Fuß . .	16	— 83333	—	21	—
25 fl. Fuß . .	16 2/3	— 80000	—	20	2
Reichsthlr. à 78 Alb. à 12 Heller in					
Wechs. Geld	15 47/60	— 84480	—	21	3 1/2
Courent	16 13/20	— 81250	—	20	5 2/3
Spec. Gulden à 53 1/3 Albus n. d.					
24 fl. Fuß	24	— 55555	—	14	—
25 fl. Fuß	25	— 53334	—	13	5 1/7
Courent-Gulden à 52 Albus in					
Wechs. Geld	23 27/40	— 56320	—	14	2 1/5
Courent	24 8/13	— 54167	—	13	7 4/5
Cölln. Churlande wie Cölln am Rhein, gewöhnlich aber nach					
Reichsgulden à 60 Xr. à 4 Pf.	24	— 55555	—	14	—
Connecticut wie Neuhampshire.					
Constantinopel und sämmtl. Türk. Staaten.					
Piaster à 40 Para à 3 Asper. zum					
ausländ. Handel . . .	26 1/2	0, 50314	—	12	8
einland. Verkehr . . .	38 2/5	0, 34722	—	8	9

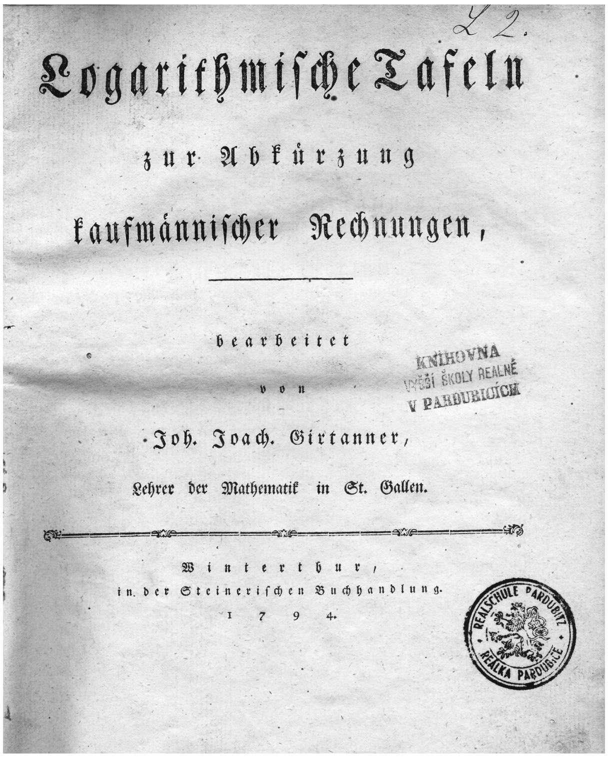
U 4

Figure 3b (Figure 3a only on CD)



Inhalt und Werth.	Convent. Courent. Rthl.	Convent. Courent. Ggr.	Preuß. Courent. Rthl.	Preuß. Courent. Ggr.	24 Guldenfuß. Rfl.	24 Guldenfuß. Kr.
Brüssel, wie Antwerpen.						
Bündten oder Graubündten, S. 53. 100 Gulden . . .	44	10 3/4	46	16	80	—
Cadix, S. 54.						
100 Real de platta	12	23 1/4	13	14 11/12	23	21
100 Duc. Cambio	143	1 1/8	150	5	257	31
Canea, S. 55. Werth wie Constantinopel.						
Carrara, S. 56. Werth w. Modena.						
Cassel, S. 56.						
100 Rthlr. Nied. Heß. . . .	100	—	105	—	180	—
Ob. Heß.	83	8	87	12	150	—
Castilien, s. Spanien.						
Catalonien, s. Barcelona.						
Cefalonia, s. Zante.						
Celle, s. Zelle.						
Cette, s. Montpellier.						
Chur, wie Bündten.						
Cleve, S. 58. 100 Rthlr. Cassageld	95	5 3/4	100	—	171	25 5/[illegible]
Frankfurter Geld	79	8 3/4	83	8	142	51 3/7
Coblenz, s. Trier.						
Coburg oder Koburg, S. 60.						
100 Rgulden.	55	13 1/3	58	8	100	—
Cölln am Rhein, S. 60.						
100 Thaler à 80 Alb. n. d. 24 fl. Fuß	83	8	87	12	150	—
n. d. 25 fl. Fuß	80	—	84	—	144	—
100 Thaler à 78 Alb. Wechs. Geld	84	11 1/2	88	16 5/6	152	3
Courent .	81	6	85	7 1/2	146	15
100 Gulden à 53 1/3 Alb. 24 fl. Fuß	55	13 1/3	58	8	100	—
25 fl. Fuß	53	8	56	—	96	—
100 Gulden à 52 Alb. Wechs. Geld	56	7 7/12	59	3 1/6	101	22 1/2
Courent .	54	4	56	21	97	30
Cöllnische Churlande, S. 63. Werth wie Cölln am Rhein.						
Constantinopel, S. 64.						
100 Piaster	50	19 1/6	53	8	93	33 1/2
Copenhagen, s. Kopenhagen.						
Corsica, S. 66. Werth w. Frankreich.						
Costnitz od. Costanz, S. 66.						
100 Rgulden	55	13 1/3	58	8	100	—

Figure 4b (Figures 4a & 5 on CD only)



Logarithmische Tafeln

zur Abkürzung

kaufmännischer Rechnungen,

bearbeitet

von

Joh. Joach. Girtanner,

Lehrer der Mathematik in St. Gallen.

Winterthur,

in der Steinerischen Buchhandlung.

1794.

Figure 6

Just as chaotic: Weights and Measures

At the end of the 18th century measures and weights were still very, very complicated. Each of the German *Kleinstaaten* (mini-states) and trading places had their own system. Even if they used the same word, for example *Fuß* (foot) the absolute values differed remarkable. The same applied to weights and to dry and liquid measures. It was common to compare lengths with the help of *Pariser Linien* which were 12 in one Parisian inch (= 2.25583 mm for one *Linie*). For weights one used Dutch *Aasen* as already explained above.

After 1800 more and more the new metric system was used for comparisons and conversions. But in daily life the old and familiar local, non-decimal units were still used.

Who was able to oversee the chaos and to calculate therein? Correctly?

Could one imagine how many tremendous mistakes occurred when converting measures, weights and currencies? Only a few were able to oversee the complicated systems and many a man not so versed might have been cheated.

In that time many mathematicians and teachers had written books on mathematics. Quite often they included comprehensive chapters on measures, weights and money. Some of these books have been a valuable source for this article. It is also remarkable that there were quite a lot of tables for the conversion of fractions and non-decimal subdivisions of measures and coins into decimal fractions. Fig. 5 for example gives decimal fractions of *Reichsthaler* for *Groschen* and *Pfennige*. Often one finds hints to use logarithms for calculations.

Girtanner's Logarithmical Tables for Simplifying (shortening) Commercial Calculations [1]

In 1794 the Swiss teacher of mathematics Johann Joachim Girtanner from St. Gallen decided to recommend logarithms to bankers and merchants for their time-consuming daily work. As said in the foregoing paragraph 200 years ago this was indeed a complicated task. Girtanner dedicated his book, of which the title page in shown as Fig. 6, to four most honorable gentlemen. These were merchants, teachers and bankers who had obviously given their opinion on his work.

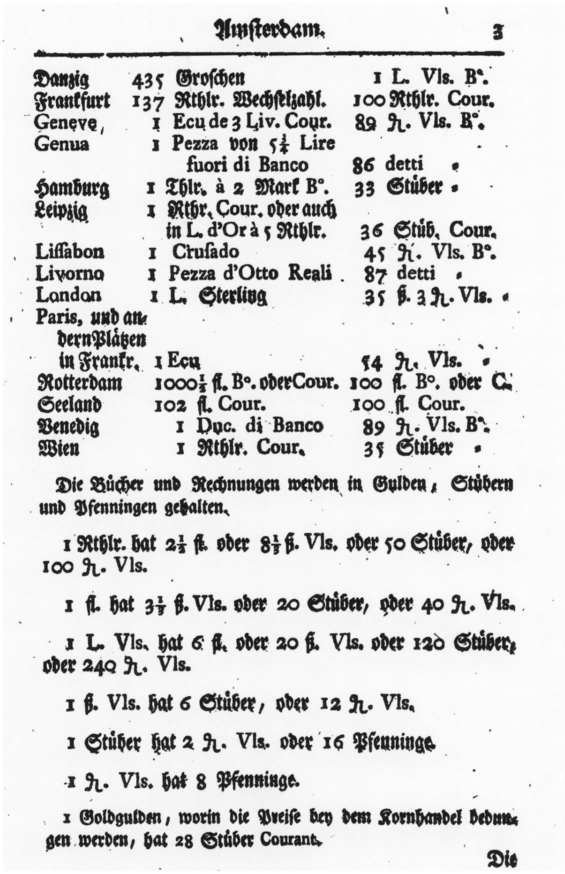
This book with dimensions of 245 x 210 (mm) consists of 250 pages and is divided into 10 paragraphs and several comprehensive tables. The introduction is followed by two general paragraphs on logarithms and their use. The next three chapters deal with exchange and arbitration business, which will be dealt with later in detail. In the 7th chapter (in the book by error entitled *VI'er Abschnitt*) the use of logarithmic tables for currencies of that time is explained. Finally Girtanner gives instructions for the use of his tables of interests, *Procento* and *Pari-Verwandlungs-Tafeln*.

Arbitration and Exchange Business

In the 18th century (and later) most of financial transactions were done by bills of exchange. Many authors had written about rates of exchange and customs at the different trading centers. Probably the most common and accepted book was *Georg Thomas Flügel's Courszettel*…. [3]. Fig. 7 (on CD only) shows the title page of the 7th edition of 1785. Even long after his death many more editions were printed, updated and extended by other authors. Fig. 8a (CD only), valid for Amsterdam, gives an impression of the information contained in this book. Girtanner mentioned the name *Flügel* and it seems that he had taken the data in his book from Flügel.

From Fig. 8b we see that for example one had to pay 35 Flemish shilling and 3 Groot for one pound Sterling (London) in Amsterdam. As at the time, knowledge about the meaning of abbreviations and signs used in banking business was little understood, Flügel in later editions explained them in the introduction.

Unfortunately, Girtanner did not include such explanations with his table. Instead he emphasized that he did this because all readers who will use the tables would be merchants, and all other readers first had to learn the fundamental principles. And he adds, that for such persons still not having the necessary knowledge even the most extensive instructions would be too short. Instead of understandable explanations Girtanner listed a great number of mostly similar examples common in the exchange business and arbitration. The latter means: to take advantage of the rate of exchange for bills of exchange, bonds or money at different trading place.


Amsterdam. 3

Danzig	435 Groschen	1 L. Vls. B°.
Frankfurt	137 Rthlr. Wechselzahl.	100 Rthlr. Cour.
Geneve,	1 Ecu de 3 Liv. Cour.	89 gr. Vls. B°.
Genua	1 Pezza von 5¾ Lire fuori di Banco	86 detti
Hamburg	1 Thlr. à 2 Mark B°.	33 Stüber
Leipzig	1 Rthr. Cour. oder auch in L. d'Or à 5 Rthlr.	36 Stüb. Cour.
Lissabon	1 Crusado	45 gr. Vls. B°.
Livorno	1 Pezza d'Otto Reali	87 detti
London	1 L. Sterling	35 ß. 3 gr. Vls.
Paris, und andern Plätzen in Frankr.	1 Ecu	54 gr. Vls.
Rotterdam	1000½ fl. B°. oder Cour.	100 fl. B°. oder C.
Seeland	102 fl. Cour.	100 fl. Cour.
Venedig	1 Duc. di Banco	89 gr. Vls. B°.
Wien	1 Rthlr. Cour.	35 Stüber

Die Bücher und Rechnungen werden in Gulden, Stübern und Pfenningen gehalten.

1 Rthlr. hat 2½ fl. oder 8⅓ ß. Vls. oder 50 Stüber, oder 100 gr. Vls.

1 fl. hat 3⅓ ß. Vls. oder 20 Stüber, oder 40 gr. Vls.

1 L. Vls. hat 6 fl. oder 20 ß. Vls. oder 120 Stüber, oder 240 gr. Vls.

1 ß. Vls. hat 6 Stüber, oder 12 gr. Vls.

1 Stüber hat 2 gr. Vls. oder 16 Pfenninge.

1 gr. Vls. hat 8 Pfenninge.

1 Goldgulden, worin die Preise bey dem Kornhandel bedungen werden, hat 28 Stüber Courant.

Die

Figure 8b

The first most simple example in Girtanner's book is shown in Fig. 9. As emphasized he did not *trouble* readers with explanations. The problem is: A merchant or banker in Zurich sells *Londnerbriefe* (i.e. English pounds Sterling) in Amsterdam for an exchange rate of 35 Flemish *Shilling* and 7 *Groot* and receives in Zurich 100 *Thaler* for 87 ¾ Flemish *Reichsthaler*. The question is: How many *Gulden* does he get in Zurich for 1 pound Sterling?

According to Girtanner one has now to look in the tables for the relevant *Hülfszahlen* (supporting numbers) in order to find the *Londnercours* in Zurich. Table IV (London in Amsterdam) gives the *Hülfszahl* 851 (Fig. 10a), and in Table IX (Fig. 10b) we find 4444. The sum of both is 5295 (printing errors corrected). With this new *Hülfszahl* one can read off in Tab. V (London in Zurich) the exchange rate with a bit above 10 *Gulden* (Fig. 10c).

§. 53.

Es sey dieses das erklärende Beyspiel, für die erste Klasse: Gesetzt, ich würde (als Kaufmann oder Banquier von Zürich) Londnerbriefe nach Amsterdam übermachen, wo sie à 35 = 7. negotirt würden, — und das Product derselben, auf diesen letztern Platz, à 87¾ in Bco entnehmen — so ist die Frage: Wie viel mein London rendirt habe? Unter dieser Vorstellung mögen alle Operationen der ersten Klasse enthalten seyn.

§. 54.

Es ist klar, daß bey diesem Geschäfte, London, Amsterdam und Zürich mit einander zu thun haben. Man braucht also, um die gesuchte Antwort zu erhalten — nur die Tabellen aufzuschlagen — die die Aufschriften: London in Amsterdam — und Amsterdam in Zürich haben — und die in dem Beyspiele angegebene Course in denselben aufsuchen — so erhält man durch die Addition ihrer Hülfszahlen in der Tabelle die die Aufschrift: London in Zürich führt, was man zu wissen verlangte. Nun ist

London in Amsterdam, 35 = 7. — und die Hülfszahl = 851 } addirt
und Amsterdam Bco in Zürich, 87¾ — ———— = 4441 (4)

5295 ~~2592~~ diese Hülfszahl oder dieser Logarithmus zeigt, daß der Londnercours in Zürich just auf fl. 10 — kommt.

Wen

Figure 9

Tab. IV.
London in Amsterdam.

	32	33	34	35	36	37	38	39	40
Den.	532	131	258	636	1003	1360	1707	2046	2375
1	498	98	290	667	1033	1389	1736	2073	2403
2	464	65	322	698	1063	1418	1764	2101	2430
3	430	33	353	728	1093	1447	1793	2130	2457
4	397	*	385	759	1123	1477	1821	2156	2484
5	363	33	417	790	1153	1506	1849	2184	2510
6	330	65	448	820	1182	1535	1877	2212	2537
7	296	97	480	851	1212	1563	1906	2239	2564
8	263	130	511	882	1242	1592	1934	2266	2591
9	230	162	542	912	1271	1621	1962	2294	2617
10	197	194	573	942	1301	1650	1990	2321	2644
11	164	226	605	973	1330	1679	2018	2348	2671

Figure 10a

Tab. IX.
Amsterdm. in Bco in Zürich.

	83	84	85	86	87	88	89	90	91	92	93
	5168	5012	4857	4705	4554	4406	4258	4113	3969	3826	3686
⅛	5148	4992	4838	4685	4536	4388	4240	4095	3951	3809	3669
¼	5128	4973	4819	4666	4517	4370	4222	4077	3933	3791	3651
⅜	5109	4954	4800	4646	4499	4351	4204	4059	3915	3774	3634
½	5090	4934	4781	4627	4480	4333	4186	4042	3898	3756	3617
⅝	5070	4915	4762	4608	4462	4316	4169	4024	3880	3738	3600
¾	5051	4896	4742	4589	4444	4298	4151	4005	3862	3721	3581
⅞	5031	4877	4723	4570	4425	4276	4133	3987	3845	3703	3564

Figure 10b

Tab. V.
London in { Augsburg, Botzen, Nürnberg, Wien, Zürich

fl.	kr.		fl.	kr.		fl.	kr.		fl.	kr.		fl.	kr.		fl.	kr.	
8	30	3165	8	50	3666	9	10	4149	9	30	4614	9	50	5064	10	10	5498
	31	3191		51	3691		11	4173		31	4637		51	5086		11	5520
	32	3216		52	3716		12	4196		32	4660		52	5108		12	5541
	33	3242		53	3740		13	4220		33	4683		53	5130		13	5562
	34	3267		54	3764		14	4243		34	4706		54	5151		14	5583
	35	329[illegible]		55	3789		15	4267		35	4728		55	5174		15	5604
	36	3318		56	3813		16	4290		36	4751		56	5196		16	5626
	37	3343		57	3837		17	4314		37	4773		57	5217		17	5647
	38	3368		58	3862		18	4337		38	4796		58	5239		18	5668
	39	3393		59	3886		19	4361		39	4819		59	5261		19	5689
	40	3418	9	—	3910		20	4384		40	4841	10	—	5283		20	5710
	41	3443		1	3934		21	4407		41	4863		1	5304		21	5731
	42	3468		2	3958		22	4430		42	4886		2	5326		22	5752
	43	3493		3	3982		23	4453		43	4908		3	5348		23	5773
	44	3518		4	4006		24	4477		44	4931		4	5369		24	5794
	45	3543		5	4030		25	4500		45	4953		5	5391		25	5815
	46	3568		6	4054		26	4523		46	4975		6	5412		26	5835
	47	3593		7	4078		27	4546		47	4997		7	5434		27	5856
	48	3617		8	4102		28	4569		48	5020		8	5454		28	5877
	49	3642		9	4125		29	4592		49	5042		9	5477		29	5897

Figure 10c

If one tries to check this example one will face some problems.
First trial:

$$x = 35\ ^{7}/_{12}\ \text{x}\ 87\ ^{3}/_{4} : 100 = 31.22 \neq 10\ \text{fl}$$

Second trial with the currencies behind the numbers:

$$x = \frac{\text{35sh vls, 7gr} \quad \text{x} \quad \text{1.8 fl Wechselgeld}}{\text{1 £} \quad \text{x} \quad 87\ ^{3}/_{4}\ \text{gr}} = 8.759\ \text{fl} \neq 10\ \text{fl}$$

Third trial, remembering that *Wechselgeld* is worth more than *Courant-Geld.* In Zurich *Wechselgeld* had the value 7 in one *Louis d'Or* and *Courant-Geld* 8 in one *Louis d'Or.*

$$x = \frac{\text{427 Groot} \ \text{x} \ \text{1.8 fl} \ \text{x} \ 8/7}{\text{1 £} \quad \text{x} \quad \text{87.75 Groot}} = 10.01\ \text{fl}$$

Thus Girtanner's tables include not only exchange rates but also the currency relations and customs at the trading places.

As we see Girtanner reduces the multiplication of exchange rates to addition.
But are his *Hülfszahlen* logarithms? If we look in Tab. IV (Fig. 10 a, London in Amsterdam) for log 1 = 0 we find a star (*) representing "0" at 33 ⅓. For example the relation 40 : 33 ⅓ = 1.2 would give a logarithm of 0.07918. But Girtanner gives 2375; i.e. he had multiplied the decimal logarithm by 30,000. This way he did not need to use decimal fractions. Another reason might be that he wanted to make a secret about his numbers.

Hülfszahlen below 0 are not marked with a minus sign, instead Girtanner instructs his readers to subtract numbers placed left/ before *. All his Hülfszahlen are calculated the way described above. His reference, i.e. log 1 = 0, marked with the *, Girtanner had chosen rather voluntary. Obviously he had tried to use "round" numbers like 100, 60 or 33⅓ for the most important trading places. And they should be located inside the scope of the table if possible. But if exchange rates of two different places are multiplied with each other, then the reference mark (*) for the third place necessarily is fixed and may be outside the scope of the table. Probably Girtanner had tinkered for a long time to calculate the 30 tables. This may also explain that by and far not all trading places are covered by his tables, and especially how only a few of all possible combinations were considered. But why did he not choose all reference points close to the usual exchange rates? It can be demonstrated that in this case all reference points would be inside the tables.

The many other examples in the book are in general not much different from the first. Girtanner introduced three classes of problems which may occur in the business of merchants or bankers, but actually only four or five trading places are involved instead of three in the example above. From our point of view the excessive number of examples are confusing and only add to the confusion rather than helping to understand the idea behind the tables.

Logarithmical Tables for Merchants of the 18th Century

People in German-speaking Switzerland and in many, especially South German, trading centers mostly calculated with the *Gulden* each having 60 *Kreuzer.* In Switzerland 1 *Kreuzer* had 2 ⅔ *Rappen* or 4 *Angster* = *Pfennige*, or 8 *Haller.* In Augsburg one calculated with 4 *Pfennige* for one *Kreuzer*. For multiplication of quantities of goods and values one either had to convert the non-decimal currency into decimal fractions (Fig. 5, on CD only) and then find the logarithm, or one used tables of logarithms for the common money system. The first way was the most common one. But Girtanner tried to avoid this intermediate step and calculated his *Logarithmische Tafeln.*
First we find the ***Haupt-oder allgemeine Tabelle A*** (main or general table A) designed for *Gulden* and *Kreuzer (*Fig. 11). On 162 pages of logarithms for 1 to 20,000 *Gulden* can be found, but not for *Kreuzer* below one *Gulden*. Up to 200 *Gulden* logarithms are tabulated for intermediate values of 1 to 59 *Kreuzer*, thereafter up to 2492 for groups of 6 *Kreuzer* and finally for *Gulden* only.

Logarithmische Tabellen.

Haupt = oder allgemeine Tabelle. A.

N.	60tel	Logarith.	N.	60tel	Logar.	N.	60tel	Logar.	N.	60tel	Logar.	N.	60tel	Logar.	N.	60tel	Logar.
1	—	0/00000	2	—	0/30103	3	—	0/47712	4	—	0/60206	5	—	0/69897	6	—	0/77815
	1	00718		1	30463		1	47952		1	60386		1	70031		1	77935
	2	01424		2	30820		2	48192		2	60566		2	70185		2	78055
	3	02119		3	31175		3	48430		3	60745		3	70329		3	78175
	4	02803		4	31527		4	48666		4	60923		4	70472		4	78295
	5	03476		5	31876		5	48902		5	61101		5	70614		5	78414
	6	04139		6	32222		6	49136		6	61278		6	70757		6	78533
	7	04792		7	32565		7	49369		7	61454		7	70898		7	78651
	8	05435		8	32906		8	49600		8	61630		8	71040		8	78769
	9	06069		9	33243		9	49831		9	61804		9	71180		9	78887
	10	06694		10	33579		10	50060		10	61979		10	71321		10	79005
	11	07310		11	33912		11	50288		11	62152		11	71461		11	79122
	12	07918		12	34242		12	50515		12	62325		12	71600		12	79239
	13	08517		13	34570		13	50740		13	62497		13	71739		13	79355
	14	09108		14	34895		14	50965		14	62668		14	71877		14	79472
	15	09691		15	35218		15	51188		15	62839		15	72016		15	79588
	16	10266		16	35538		16	51410		16	63009		16	72153		16	79703
	17	10834		17	35857		17	51631		17	63178		17	72290		17	79819
	18	11394		18	36172		18	51851		18	63346		18	72427		18	79934
	19	11947		19	36486		19	52070		19	63514		19	72564		19	80048
	20	1[illegible]494		20	36797		20	52288		20	63682		20	72700		20	80163
	21	130[illegible]		21	37106		21	52504		21	63849		21	72835		21	80277
	22	13566		22	37413		22	52720		22	64015		22	72970		22	80391
	23	14092		23	37718		23	52934		23	64180		23	73105		23	80504
	24	14612		24	38021		24	53148		24	64345		24	73219		24	80618
	25	15126		25	38321		25	53360		25	64509		25	73373		25	80731
	26	15634		26	38620		26	53571		26	64673		26	73506		26	80843
	27	16136		27	38916		27	53782		27	64836		27	73639		27	80956
	28	16633		28	39211		28	53991		28	64998		28	73772		28	81068
	29	17124		29	39503		29	54199		29	65160		29	73904		29	81179
	30	17609		30	39794		30	54406		30	65321		30	74036		30	81291
	31	18089		31	40082		31	54613		31	65481		31	74167		31	81402
	32	18563		32	40369		32	54818		32	65641		32	74298		32	81513
	33	19033		33	40654		33	55022		33	65801		33	74429		33	81624
	34	19497		34	40937		34	55226		34	65960		34	74559		34	81734
	35	19957		35	41218		35	55428		35	66118		35	74689		35	81844
	36	20412		36	41497		36	55630		36	66275		36	74818		36	81954
	37	20862		37	41774		37	55830		37	66432		37	74947		37	82064
	38	21307		38	42050		38	56030		38	66589		38	75076		38	82173
	39	21748		39	42324		39	56229		39	66745		39	75204		39	82282
	40	22185		40	42597		40	56427		40	66900		40	75332		40	82391
	41	22617		41	42867		41	56624		41	67055		41	75460		41	82499
	42	23045		42	43136		42	56820		42	67209		42	75587		42	82607
	43	23468		43	43403		43	57015		43	67363		43	75714		43	82715
	44	23888		44	43669		44	57209		44	67516		44	75840		44	82823
	45	24303		45	43933		45	57403		45	67669		45	75966		45	82930
	46	24715		46	44195		46	57595		46	67821		46	76092		46	83037
				46½	44326												
	47	25123		47	44456		47	57787		47	67973		47	76217		47	83144
	48	25537		48	44715		48	57978		48	68124		48	76342		48	83251
	49	25927		49	44973		49	58168		49	68274		49	76467		49	83357
	50	26324		50	45229		50	58397		50	68424		50	76591		50	83463
	51	26717		51	45484		51	58546		51	68574		51	76715		51	83569
	52	27106		52	45737		52	58733		52	68723		52	76839		52	83674
	53	27492		53	45989		53	58920		53	68871		53	76962		53	83780
	54	27875		54	46239		54	59106		54	69019		54	77085		54	83885
	55	28254		55	46488		55	59291		55	69167		55	77207		55	83989
	56	28630		56	46636		56	59476		56	69314		56	77330		56	84094
	57	29003		57	46982		57	59659		57	69460		57	77451		57	84198
	58	29373		58	47227		58	59842		58	69606		58	77573		58	84302
	59	29779		59	47470		59	60024		59	69752		59	77694		59	84406

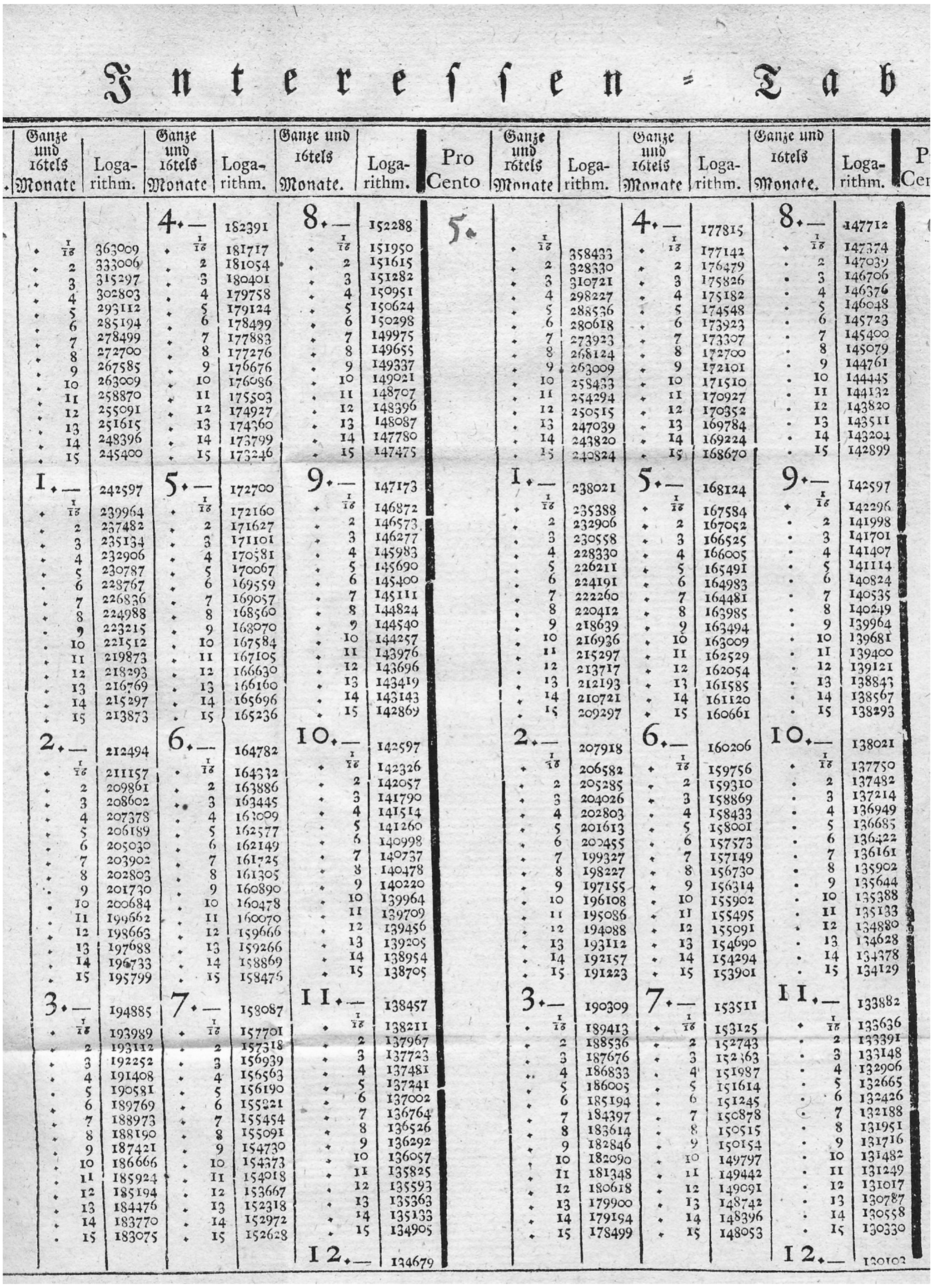
N. 7.

Figure 11

Besides the mantissa also the characteristics are given, because the non-decimal fractions (60 *Kreuzer* per *Gulden*) do not allow reducing the figures to only one decade. This of course explains why, despite of 162 pages, the 5-digit-mantissa partly have large interval steps.

In his instructions Girtanner gave a great number of examples without solutions as readers would then be “under-challenged”. Below are a few examples:

1. One wants to know how many *Reichsthaler*, according to the 24 *Guldenfuß*, are 849½ *Laubthaler* each worth fl 2 - 46 kr.
2. How much are 139 ¾ *Ellen* (ell or yard), if one *Elle* costs fl2 - 47kr? Or: how much is 1 *Elle* if 447 ¾ cost fl 72 - 27 kr? (Here we have division).
3. How much are 197 lb, 7s, 11 D Sterling at fl 11- 51kr in St. Gallen?
4. A merchant wants to pack 1000 pieces each 14 Zoll (inches) long, 9 Zoll wide and 1 Zoll thick into a chest with same length, width and height. In this case Girtanner gives detailed explanations.
5. How much do I get for 400 fl in 10 years with annual interest of 5 percent?



Interessen = Tab

Ganze und 16tels Monate	Logarithm.	Ganze und 16tels Monate	Logarithm.	Ganze und 16tels Monate.	Logarithm.	Pro Cento	Ganze und 16tels Monate	Logarithm.	Ganze und 16tels Monate	Logarithm.	Ganze und 16tels Monate.	Logarithm.	P Cen
		4. —	182391	8. —	152288	5.			4. —	177815	8. —	147712	
. 1/16	363009	. 1/16	181717	. 1/16	151950		. 1/16	358433	. 1/16	177142	. 1/16	147374	
. 2	333006	. 2	181054	. 2	151615		. 2	328330	. 2	176479	. 2	147039	
. 3	315297	. 3	180401	. 3	151282		. 3	310721	. 3	175826	. 3	146706	
. 4	302803	. 4	179758	. 4	150951		. 4	298227	. 4	175182	. 4	146376	
. 5	293112	. 5	179124	. 5	150624		. 5	288536	. 5	174548	. 5	146048	
. 6	285194	. 6	178499	. 6	150298		. 6	280618	. 6	173923	. 6	145723	
. 7	278499	. 7	177883	. 7	149975		. 7	273923	. 7	173307	. 7	145400	
. 8	272700	. 8	177276	. 8	149655		. 8	268124	. 8	172700	. 8	145079	
. 9	267585	. 9	176676	. 9	149337		. 9	263009	. 9	172101	. 9	144761	
. 10	263009	. 10	176086	. 10	149021		. 10	258433	. 10	171510	. 10	144445	
. 11	258870	. 11	175503	. 11	148707		. 11	254294	. 11	170927	. 11	144132	
. 12	255091	. 12	174927	. 12	148396		. 12	250515	. 12	170352	. 12	143820	
. 13	251615	. 13	174360	. 13	148087		. 13	247039	. 13	169784	. 13	143511	
. 14	248396	. 14	173799	. 14	147780		. 14	243820	. 14	169224	. 14	143204	
. 15	245400	. 15	173246	. 15	147475		. 15	240824	. 15	168670	. 15	142899	
1. —	242597	5. —	172700	9. —	147173		1. —	238021	5. —	168124	9. —	142597	
. 1/16	239964	. 1/16	172160	. 1/16	146872		. 1/16	235388	. 1/16	167584	. 1/16	142296	
. 2	237482	. 2	171627	. 2	146573		. 2	232906	. 2	167052	. 2	141998	
. 3	235134	. 3	171101	. 3	146277		. 3	230558	. 3	166525	. 3	141701	
. 4	232906	. 4	170581	. 4	145983		. 4	228330	. 4	166005	. 4	141407	
. 5	230787	. 5	170067	. 5	145690		. 5	226211	. 5	165491	. 5	141114	
. 6	228767	. 6	169559	. 6	145400		. 6	224191	. 6	164983	. 6	140824	
. 7	226836	. 7	169057	. 7	145111		. 7	222260	. 7	164481	. 7	140535	
. 8	224988	. 8	168560	. 8	144824		. 8	220412	. 8	163985	. 8	140249	
. 9	223215	. 9	168070	. 9	144540		. 9	218639	. 9	163494	. 9	139964	
. 10	221512	. 10	167584	. 10	144257		. 10	216936	. 10	163009	. 10	139681	
. 11	219873	. 11	167105	. 11	143976		. 11	215297	. 11	162529	. 11	139400	
. 12	218293	. 12	166630	. 12	143696		. 12	213717	. 12	162054	. 12	139121	
. 13	216769	. 13	166160	. 13	143419		. 13	212193	. 13	161585	. 13	138843	
. 14	215297	. 14	165696	. 14	143143		. 14	210721	. 14	161120	. 14	138567	
. 15	213873	. 15	165236	. 15	142869		. 15	209297	. 15	160661	. 15	138293	
2. —	212494	6. —	164782	10. —	142597		2. —	207918	6. —	160206	10. —	138021	
. 1/16	211157	. 1/16	164332	. 1/16	142326		. 1/16	206582	. 1/16	159756	. 1/16	137750	
. 2	209861	. 2	163886	. 2	142057		. 2	205285	. 2	159310	. 2	137482	
. 3	208602	. 3	163445	. 3	141790		. 3	204026	. 3	158869	. 3	137214	
. 4	207378	. 4	163009	. 4	141514		. 4	202803	. 4	158433	. 4	136949	
. 5	206189	. 5	162577	. 5	141260		. 5	201613	. 5	158001	. 5	136685	
. 6	205030	. 6	162149	. 6	140998		. 6	200455	. 6	157573	. 6	136422	
. 7	203902	. 7	161725	. 7	140737		. 7	199327	. 7	157149	. 7	136161	
. 8	202803	. 8	161305	. 8	140478		. 8	198227	. 8	156730	. 8	135902	
. 9	201730	. 9	160890	. 9	140220		. 9	197155	. 9	156314	. 9	135644	
. 10	200684	. 10	160478	. 10	139964		. 10	196108	. 10	155902	. 10	135388	
. 11	199662	. 11	160070	. 11	139709		. 11	195086	. 11	155495	. 11	135133	
. 12	198663	. 12	159666	. 12	139456		. 12	194088	. 12	155091	. 12	134880	
. 13	197688	. 13	159266	. 13	139205		. 13	193112	. 13	154690	. 13	134628	
. 14	196733	. 14	158869	. 14	138954		. 14	192157	. 14	154294	. 14	134378	
. 15	195799	. 15	158475	. 15	138705		. 15	191223	. 15	153901	. 15	134129	
3. —	194885	7. —	158087	11. —	138457		3. —	190309	7. —	153511	11. —	133882	
. 1/16	193989	. 1/16	157701	. 1/16	138211		. 1/16	189413	. 1/16	153125	. 1/16	133636	
. 2	193112	. 2	157318	. 2	137967		. 2	188536	. 2	152743	. 2	133391	
. 3	192252	. 3	156939	. 3	137723		. 3	187676	. 3	152363	. 3	133148	
. 4	191408	. 4	156563	. 4	137481		. 4	186833	. 4	151987	. 4	132906	
. 5	190581	. 5	156190	. 5	137241		. 5	186005	. 5	151614	. 5	132665	
. 6	189769	. 6	155821	. 6	137002		. 6	185194	. 6	151245	. 6	132426	
. 7	188973	. 7	155454	. 7	136764		. 7	184397	. 7	150878	. 7	132188	
. 8	188190	. 8	155091	. 8	136526		. 8	183614	. 8	150515	. 8	131951	
. 9	187421	. 9	154730	. 9	136292		. 9	182846	. 9	150154	. 9	131716	
. 10	186666	. 10	154373	. 10	136057		. 10	182090	. 10	149797	. 10	131482	
. 11	185924	. 11	154018	. 11	135825		. 11	181348	. 11	149442	. 11	131249	
. 12	185194	. 12	153667	. 12	135593		. 12	180618	. 12	149091	. 12	131017	
. 13	184476	. 13	152318	. 13	135363		. 13	179900	. 13	148742	. 13	130787	
. 14	183770	. 14	152972	. 14	135133		. 14	179194	. 14	148396	. 14	130558	
. 15	183075	. 15	152628	. 15	134905		. 15	178499	. 15	148053	. 15	130330	
				12. —	134679						12. —	130102	

Figure 12

Fig. 12 shows only part of the ***Interessen-Tabelle B***. This table contains logarithms for 4, 4 ½, 5, 6 and 6 ½ percent annual interest rates. Girtanner again avoids minus-signs for the fractions 0.04 etc. But his numbers are the logarithms of the reciprocals multiplied by 100. Therefore the reversed logarithms have to be subtracted and the result gives the correct interest. As a further aid Girtanner had calculated the reversed logarithms for months and 1/16 of a month which saved one multiplication step. With the help of ***Tabelle C*** (Fig. 13, on CD only) one could find the period in months and 1/16 of a month between two dates.

If one wanted to calculate interest for days Tab. B had to be used. For example the logarithm for 6 ½ percent can be found at 6 fl-30Kr = 0.81291 and the logarithm for 287 days at 287 Gulden = 2.45788. But one always had to subtract 4.56229. No explanation is given but obvious: It is the logarithm of 365 days (= 2.56229) plus 2 for the logarithm of 100 resulting from percent.

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Pro Cento = Tabelle, D.

Diese Tafel ist bis 100 subtractiv, über 100 aber wird sie additiv.

	50	51	52	53	54	55	56	57	58	59	60
	30103	29243	28400	27573	26761	25964	25181	24413	23657	22915	22185
1/8	29995	29137	28295	27470	26660	25865	25084	24317	23564	22823	22095
1/4	29887	29031	28191	27368	26560	25767	24988	24222	23470	22731	22004
3/8	29779	28925	28088	27266	26460	25669	24891	24128	23377	22640	21914
1/2	29671	28819	27984	27165	26360	25571	24795	24033	23284	22548	21824
5/8	29564	28714	27881	27063	26261	25473	24699	23939	23192	22457	21735
3/4	29456	28609	27778	26962	26162	25376	24603	23845	23099	22366	21645
7/8	29350	28504	27675	26861	26063	25278	24508	23751	23007	22275	21556

	61	62	63	64	65	66	67	68	69	70	71
	21467	20761	20066	19382	18709	18046	17393	16749	16115	15490	14874
1/8	21378	20673	19980	19297	18625	17963	17312	16669	16037	15413	14798
1/4	21289	20586	19894	19213	18542	17881	17231	16589	15958	15335	14722
3/8	21201	20499	19808	19128	18459	17800	17150	16510	15880	15258	14645
1/2	21113	20412	19723	19044	18376	17718	17070	16431	15802	15181	14569
5/8	21024	20325	19637	18960	18293	17636	16989	16352	15723	15104	14494
3/4	20936	20239	19552	18876	18210	17555	16909	16273	15646	15027	14418
7/8	20849	20152	19467	18792	18128	17474	16829	16194	15568	14951	14324

Figure 14

The ***Pro-Cento – Tabelle, D*** (Fig. 14) contains logarithms for 0.5 (50 %) up to 2.14875 (214 7/8 %). To avoid negative logarithms Girtanner had given the logarithms of the reciprocal value for percentages from 50 % to 100 %. Therefore these logarithms have to be subtracted. As usual in this book the logarithms are multiplied, in this case by 100,000. Thus they can be used together with the main table A. According to Girtanner instruction table D is thought to be used for conversions of sums (?), currencies, weights, yards and other measures.

The last chapter of the book with several ***Reductions-Tabellen*** that should help with conversions, in case of ***Tabelle E*** (Fig. 15) for French *Livre* into *Reichsgulden* according to the 20, 22 or 24 *Guldenfuß* or the reverse. It is presumed that the reader knows that for example with the *24-Gulden-Fuß* there are 11 *Gulden* in one *Cöllner Mark fein.* The logarithm 033882 means 0.33882 and stands for the relation 2.18182 between *Reichsgulden* and *Livres*. In the supplement another ***Reductions-Tabelle N*** gives the relationship for conversion of French *Livres tournois* into English, Dutch, Portuguese, Milanese, Genoese, Venetian, Turinian and Russian money and vice versa.

Tab. E.

	Logarithmen.		
NLd'or à 24. L. t. oder à fl. 11.	— 033882	wird gebraucht, wenn Livr. tourn. in fl.	zu verwandeln sind.
	+ 033882	— — — — — — fl. in Livr. tourn.	
— — — — — à fl. 10.	— 038021	— — — — — — Livres in fl.	
	+ 038021	— — — — — — fl. in Livres	
— — — — — à fl. 9 1/5.	— 041643	— — — — — — Livr. in fl.	
	+ 041643	— — — — — — fl. in Livr.	

Figure 15

If in addition to the official exchange rates also losses or agio had to be considered, the ***Reductions-Tabelle F*** (Fig. 16, on CD only) had to be taken into account. This table considers besides the exchange rate losses for 0 to 40 %. Example: Exchange rate 2.18182 : 0.6 = 3.63637 (loss = 40%). Log 3.63637 = 0.56067. The table gives 56067. ***Tafeln G*** and ***H*** are ***Verwandlungs-Tabellen*** (Conversion tables) for French Livres into several Suisse currencies with *Procento-Verlust* (loss in percent).

Verwandlungs-Tabelle I (Fig. 17, on CD only) allows conversions of Genève's *Livres* into *Gulden* of Zurich and vice versa. There are logarithms for different rates of exchange. The usage is explained in the instructions.

Insider know-how is also required for ***Verwandlungs-Tabelle K*** (Fig. 18, on CD only). This table had to be used for different currencies, for which in Amsterdam *Stüber* or *Groot* had to be paid, but the result was required in *Gulden Banco*. One has to remember that 1 Dutch *Gulden* had 20 *Stüver* or 40 *Flemish Groot*. The table is valid for 60 to 97 7/8 *Groote.* The numbers are the logarithms of exchange rate divided by 40 (*Groote* per *Gulden*) multiplied by 100,000. If payment was in *Stüver* then the exchange rate had to be doubled (1 *Stüver = 2 Groot*).

Non-less complicated and not specified is ***Tabelle L*** (Fig. 19, on CD only). Logarithms of this table consider the subdivision of 1 *Gulden* = 60 *Kreuzer* and the reverse of the exchange rate. Example by Girtanner:

How much are 861 ¾ pound, if one pound costs 52 Kr, 7 hl?

Log of 861 ¾ = 293538 (Tab. A)

Log 60 : 52 ⁷/₈ = - 005490

288048

Again, in Tab. A we find 759 ⁴/₁₀ as the answer.

Finally, the last ***Tabelle M*** gives logarithms of exchange rates between different Suisse trading places. There are 13!

These tables are placed at the end of the description, not as part of the table-section.

How practical were Girtanner's Tables?

Without doubt the complicated non-decimal measure and monetary systems of the late 18th century were a great problem for merchants and bankers. Suitable logarithmic tables therefore could have been a great help for all tasks connected with multiplication. But probably most merchants of that time at least had the same problems with logarithms as people in the second half of the 20th century. Therefore Girtanner had tried to make their use as simple as possible. But from a modern-day viewpoint his tables have enormous disadvantages:

- The tables presuppose great knowledge of the customs in financial affairs of the time.
- Instructions are mainly schematic without giving explanations for real understanding.
- Logarithms have only four or five digits. Girtanner at several occasions stressed out that this results in sufficient accuracy for merchants.
- The 30 tables for arbitration and exchange business consider only a fraction of the trading centres in the 18th century and even less of the possible combinations. Thus they are only useful in a few cases.
- In many cases only the currency in the German-speaking Suisse and South Germany, i.e. *Gulden = 60 Kreuzer* was considered.

These disadvantages were partly already criticized when Girtanner's book was published. The *ALLG. LITERATUR-ZEITUNG* [8] of 1794 contains a review. The introduction chapter on logarithms was characterized as a *deterrent, unprepared, mysterious fragment*. Also the instructions for the tables were *sketched hastily.* Too many examples were mentioned without the necessary discussion and development. Although the intention and effort of the author in general were *praiseworthy, the manner however, only to dictate what has to be added or subtracted... is very unsatisfying and educational bad*. Especially it was criticized that the main table contains only 5-digits logarithms (without interpolation), which would not be sufficient for many commercial calculations. Other authors and Vega's tables were more recommendable. But, nevertheless, the courage of the author to support the use of logarithms was appreciated.

From this review we also know the price of Girtanner's book: *3 Rthlr, 16 Groschen.* Today this would be more than 200 euro.

Life and Work of Johann Joachim Girtanner [9]

He was born on 23rd May 1745 in the Swiss town of St. Gallen. His father was the tailor Joachim Girtanner. After the early death of his parents he grew up and was educated in the orphanage of St. Gallen. Due to his talents in calligraphy and arithmetic and also because of his pedagogical abilities he became tutor in Haldenstein in 1767. But he became ill and in 1776 went back to St. Gallen. As an excellent mathematician and pedagogue he taught mathematics and calligraphy at the grammar-school. In 1778 he married Magdalena Hiller, daughter of the tin founder Abraham

Hiller. Girtanner became *Erziehungsrat* (educational council) of the Suisse canton in 1799. Shortly after his promotion, during a meeting, he suddenly died on 20th Feb. 1800 in St. Gallen.
Besides his *Logarithmische Tafeln* of 1794, described here in detail, Girtanner published *Lehren der Rechenkunst* (2 parts in 1790 / 1791) and *Untersuchungen über Cardan's und Bombelli's Regeln* (1796, St. Gallen). The subtitle explains the content: Short methods to solve cubical and bi-quadratic equations.

Johann Joachim Girtanner had dedicated his book besides others to "Herrn Casper Girtanner, Commercien-Rath und Banquier in St. Gallen" and to "Herrn Daniel Girtanner". The latter was also banker in St. Gallen and founder and director of the literary society. Both were also mayors of St. Gallen (1798 and 1795). The name Girtanner was well known in St. Gallen for centuries. There were merchants, scientists and physicians with this name. Whether Johann Joachim was related to the two gentlemen mentioned above is not yet known.

Was Girtanner a Plagiarist?

Girtanner was not the first to introduce logarithmical tables for bankers and traders. 22 years earlier, in 1772, Aaron Kalman Cohen [10] published his *Allgemeine Logarithmische Geld- und Wechsel-Arbitrage Tabellen* (Fig. 20, on CD only). Compared to Girtanner, Cohen gave a detailed description of his tables including definitions of terms used in the trading business of the day. He already used the word *Hülfszahlen* for his logarithms. Which is the mantissa multiplied by 10,000 to have rounded figures without decimal fractions. Girtanner confused his readers by multiplying by 30,000. The main part of the book (192 pages) consists of 190 examples for the many different tasks of a tradesman or banker at the end of the 18th century. Cohen described the problems and gave the solution with his *Hülfszahlen*. They are depicted in 41 tables. Tab. XIII for example (Fig. 21, on CD only) contains *Hülfszahlen* for the exchange rate *London auf Amsterdam*. It is very similar to Girtanner's Tab. IV (Fig. 10a). Cohen used as reference a rate of 25 *Flemish Shilling* for 1 £. The logarithm of the relation 32 to 25 is given as *Hülfszahl* multiplied by 10,000; lg 32:25 = 0.1072.

Another example for *Amsterdam auf Hamburg* (Fig. 22, on CD only) shows a conversion rate anchor point which is located inside the table at 33 $^5/_{16}$. The black line indicates when a *Hülfszahl* had to be added or subtracted.

If one compares Girtanner's book with that of Cohen one comes to the conclusion that Girtanner had to have known about Cohen's book because the example problems and the tables are very, very similar. But nowhere does Girtanner mention Cohen. His book is poorly explained and in many cases confusing.

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LOGARITHMS - MINI AND MORE

Klaus Kühn

Klaus Kühn studied chemistry at the University of Cologne. For almost 20 years he has been with the pharmaceutical industry. 10 years ago he founded the Institute of Applied Simulation (www.IASim.de) and helps to visualize, analyze, and optimize processes within the healthcare business, mainly hospitals, by means of simulation.

Klaus started to collect slide rules in 1981 and has switched his major interest to logarithms 7 years ago. He is now also collecting Tables of Logarithms and has created a documentation catalogue of presently more than 2200 Logarithmic Tables (see www.rechnerlexikon.de - Logarithmentafeln). He is involved in organisational activities of the RST, and is member of The Oughtred Society, the Dutch Kring, as well as of the UKSRC.

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Summary

Tables of Logarithms are in use for almost 400 years. Their content did not change very much during that period. But in some aspects the tables differ obviously: number of decimals, arrangement, and format. Not necessarily those criteria were depending of each other. In this presentation, the reader will become acquainted with single decimal logarithms as well as with those of 137 decimals. And the reader will get some impressions of how "mini" tables of logarithms compare to those of "more" pages or of larger formats. Interestingly in the second half of the 18th century many "new" tables were published all over Europe, indicating the start of a new scientific era.

Introduction

Everything is already said about the history of logarithms in all major languages. Due to language barriers some aspects have not been looked at from all perspectives. For me French is such a barrier (and I am aware of important French contributions within the field of logarithms), so I can focus my considerations just on German and English presentations.

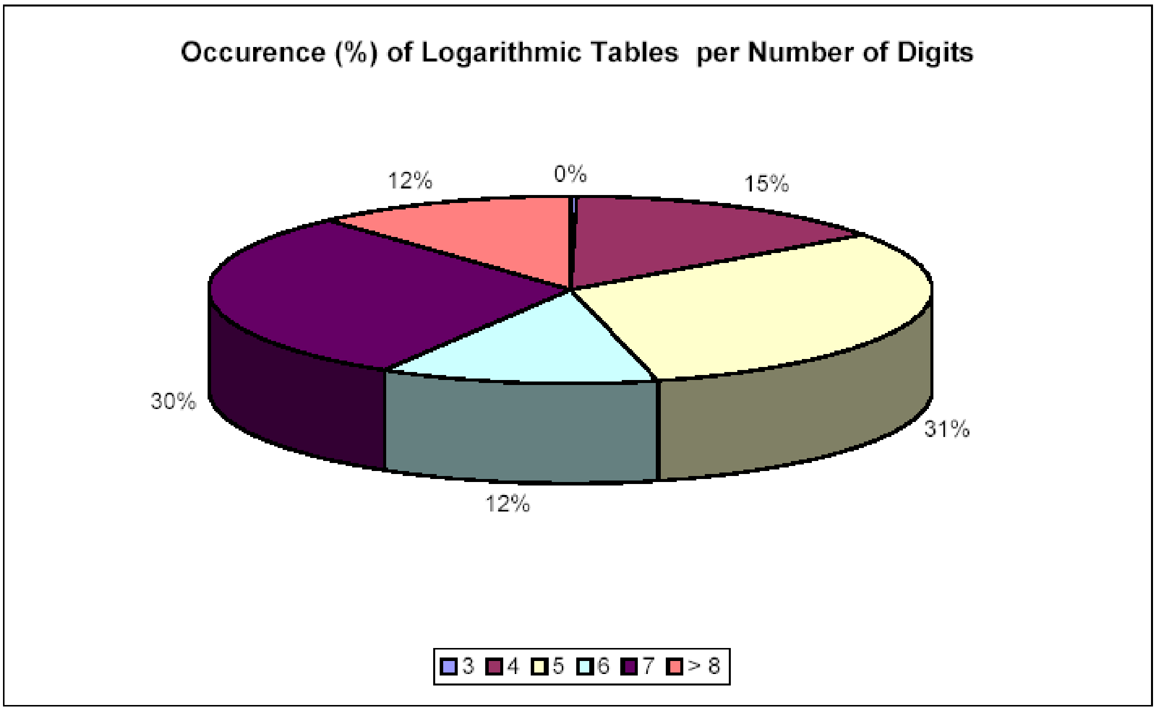
Long before 1614 scientists have worked with some kind of "logarithms" - Archimedes, Babylonians, Chuquet, Stifel [i].

The publication of a direct combination of an arithmetic row with a geometric one

arithmetic	-3	-2	-1	0	1	2	3	4	5	6
geometric	1/8	1/4	1/2	1	2	4	8	16	32	64

by Michael Stifel in 1544 [ii] might have given the final impuls for John Napier and Jost Bürgi to calculate a whole set of logarithms and publish those in their tables in 1614 resp. in 1620.

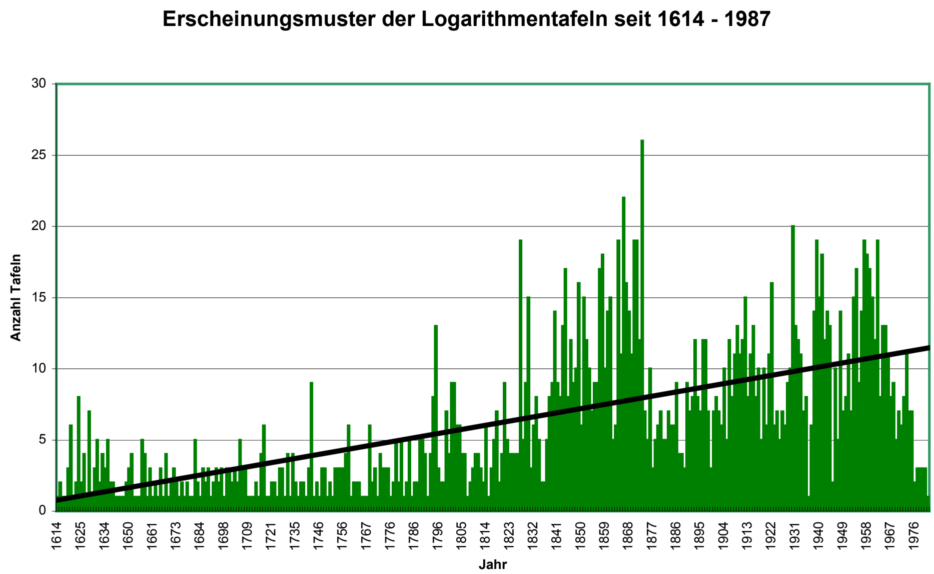
Principally, those two rows above are a logarithmic table with single digits. The numbers of digits in the first tables, though, were more than 1, it were tables with 7 digits in the "Mirifici" and 8 digits in the "Progress Tabulen". Later on tables with even more digits were published but the main portion of the logarithmic tables were those with 4 (15%), 5 (31%), 6 (12%), and 7 (30%) digits/decimals [from iii]. Another 12% of the tables were with 8 or more digits.



Those tables were published in many different arrangements, formats, and qualities. John Napier published his "*Mirifici Logarithmorum Canonis Desriptio*" in a handsome format of 7.5 x 5.5 inches (190.5 mm x 139.7 mm). Jost Bürgis "*Arithmetische und Geometrische Progress Tabulen sambt gründlichem unterricht wie solche nützlich in allerley Rechnungen zu gebrauchen und verstanden werden soll* " seem to be a little bit larger: 7.25 x 6 inches (184.1 mm x 152.4 mm).

And after that time, a never ending discussion started - mainly in the introduction - which format is the best for which use, resulting in plenty of different Logarithmic Tables - as I can tell from having seen at least 300 different tables. And it is some kind of fun - as it is with slide rules - to contemplate what was the driver for the author´s choice.

A publication pattern of some 2000 documented logarithmic tables from 1614 to 1987 (for more than 350 years of usage) looks like the figure below [from 3]:



Logarithms with mini decimals

Preferred numbers (Normzahlen - NZ; Renard series; nombres normaux) have been the topic of some articles in the recent past [iv, v] . Tuffentsammer and Schumacher [vi] - both engineers - considered preferred numbers as "single digit logarithmic tables of the engineer". Why?

Charles Renard, the inventor of the NZ, took advantage of the similarity of expressing the value 1000 in 2 different ways: 2^{10} and 10^{3}. 10 duplications of 2 lead to almost the same value as 3 ten-folds of 10, since taking certain roots of both basis′ one ends up with an almost similar value:

$$\sqrt[3]{2} = 2^{\frac{1}{3}} = 1.2599 \approx 1.26 \quad \text{and} \quad \sqrt[10]{10} = 10^{\frac{1}{10}} = 10^{0.1} = 1.2589 \approx 1.26$$

So if you double 1 for 10 times you get:

X	1			2			4			8	
			16			32			64		
		128			256			512			1024
Adding $\log_{10} 2 = 0.3$ leads to											
Log X	0			0,3			0,6			0,9	
			1,2			1,5			1,8		
		2,1			2,4			2,7			3,0

Since log 2 = 0.3 is not the exact value we have to round the x-values:

X	1			2			4			8	
			16			31,5			63		
		125			250			500			1000

Dividing the second row by 10 and the third one by 100 gives:

NZ	1	1,25	1,6	2	2,5	3,15	4	5	6,3	8	10

which is the R10 series of the preferred numbers and leads with Log NZ to

NZ	1	1,25	1,6	2	2,5	3,15	4	5	6,3	8	10
Log NZ	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1

a logarithmic table with single digits. The authors recommended to their readers to acquaint themselves with this table since it is also helpful for rough calculations.

E.g.: 1,6 x 2,5 = 4 which is the value in the row above 0,6, the sum of 0,2 and 0,4.

Or: 1,8 x 125 = 225 => 0,25 + 2,1 = 2,35 => the mantissa ,35 stands for 2,25 and the characteristic 2 stands for 100 = log 2 ; so 2,35 stands for 225.

This last example demonstrates that this table not only works or the R10 values but also for those interpolated values between. It is a single digit (mini) logarithmic table which helps to reduce multiplication to addition.

Logarithms with more decimals

As shown in the above diagram only 12% of the documented logarithmic tables have 8 and more digits/decimals. So we have tables with 10 digits, e.g.[vii, viii], tables with 48 digits, e.g. [ix], with 61 digits, e.g. [x], with 102 digits, e.g. [xi], and with 137 and even more digits.

Horace Scudder Uhler has published in 1942 in New Haven, Connecticut "*Original Tables to 137 Decimal Places of Natural Logarithms for Factors of the Form 1±n•10^{-p}, Enhanced by Auxilliary Tables of Logarithms of Small Integers*". I understand those tables as being computing aids for logarithms with a large number of digits. For what purpose those kind of logarithms are required is beyond my knowledge and is not explicitly mentioned in the introduction. The graphic below shows Table 4 of those "Original Tables" from Uhler:

TABLE 4

```
log_e10 = 2.30258 50929 94045 68401 79914 54684 36420 76011 01488 62877 29760 33327 90096 75726 09677
            35248 02359 97205 08959 82983 41967 78404 22862 48633 40952 54650 82806 75666 62873 69098
            78168 94829 07208 32555 46808 43799 89482 62331 98528 39350 53089 65377 73262 88461 63366
            22228 76982 19886 74654 36674 74404 24327 43651 55048 93431 49393 91479 61940 44002 22105
            10171 41748 00368 80840 12647D

log_10e = 0.43429 44819 03251 82765 11289 18916 60508 22943 97005 80366 65661 14453 78316 58646 49208
            87077 47292 24949 33843 17483 18706 10674 47663 03733 64167 92871 58963 90656 92210 64662
            81226 58521 27086 56867 03295 93370 86965 88266 88331 16360 77384 90514 28443 48666 76864
            65860 85135 56148 21234 87653 43543 43573 17253 83562 22813 95603 04864 66523 66095 53937
            73561 76323 43191 67109 91412N

log_e11 = 2.39789 52727 98370 54406 19435 77965 12929 98217 06853 93741 71752 18567 70913 05736 23913
            23671 30750 54708 00263 47914 14715 72588 81379 98522 25556 91585 95787 39535 53023 908

log_e13 = 2.56494 93574 61536 73605 34874 41565 31860 48052 67944 76020 71164 19045 51066 34646 67324
            41017 93995 74663 44048 94887 69258 19209 27627 21631 53215 44919 86587 01382 52681 170N

log_e17 = 2.83321 33440 56216 08024 95346 17873 12653 55882 03012 58574 47872 97237 73788 22925 75800
            93128 09120 94868 03750 29475 18348 26204 71870 57291 39759 28419 46738 36429 97545 657P

log_e19 = 2.94443 89791 66440 46000 90274 31887 85353 72373 79261 29912 88185 37960 23640 92927 02064
            19728 87141 58383 81573 98957 97040 63322 07501 36349 02195 37906 81320 61126 46333 285P

log_e23 = 3.13549 42159 29149 69080 67528 31810 19611 84423 80314 84043 57419 98635 37748 29932 45984
            79829 81984 01092 15299 48143 54197 21357 13301 36895 85872 86350 36337 80457 54969 580N

log_e29 = 3.36729 58299 86474 02718 32720 32361 91160 54945 12913 92274 40789 21670 35164 27807 81137
            85233 32933 67114 81785 64226 45999 58472 51668 34726 55830 33111 79184 60754 32745 770n
```

Here we see that the Modulus M=log$_e$10 and 1/M=log$_{10}$e have even been calculated for 325 digits ! The other logarithms are for prime numbers and are continued up to log$_e$113 for 148 digits. Both series with more than the 137 digits as announced in the book´s title. In table 1 the natural logarithms of 1 to 10 are calculated for 137 digits together with the natural logarithms of 10^{20} to 10^{110} in steps of 10^{10}. So in total, with table 2 (negative logarithms for nonets), table 3 (positive logarithms for nonets), tables 5 and 6 (skeleton formulations) the whole book fills (only) 120 pages. With certain computation methods [xii] it is possible to obtain all natural and common logarithms for all numbers with at least 137 decimals with those logarithms from H.S. Uhler.

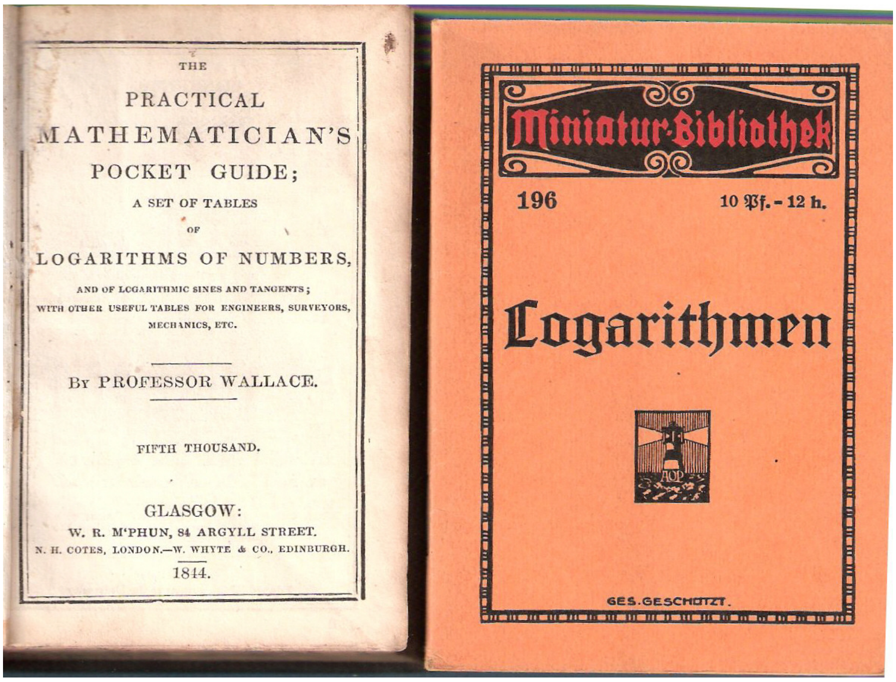
There is no other TABLE like that known to me which contains logarithms of so many numbers. According to Henderson [xiii] there are some tables with e.g. 272 digits but only for the numbers 2, 3, 5, 7, and 10 from Adams [xiv], who did use those logarithms to calculate Euler´s constant.

Logarithmic tables in mini format

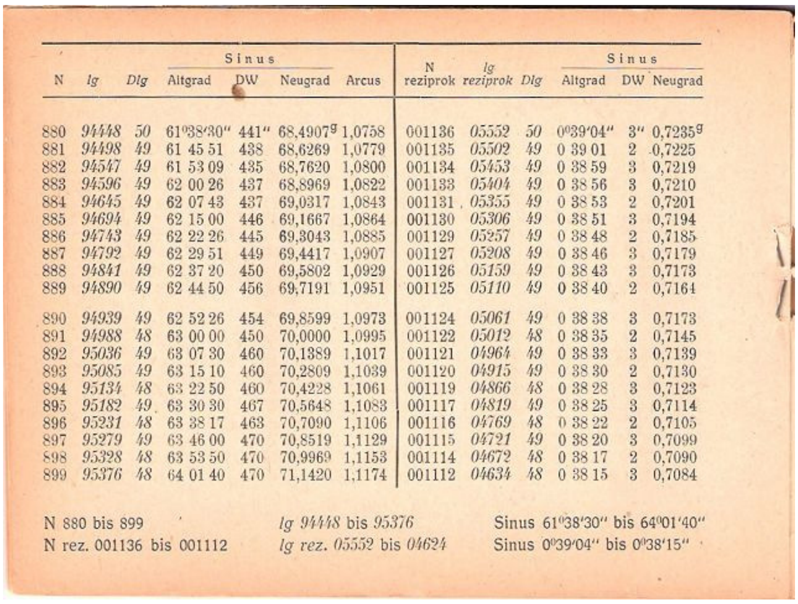
Driven by another idea of keeping the format of logarithmic tables handsome, some authors edited tables of small formats less than octavo, 8°. Those smaller formats required smaller prints of figures, thus are harder to read. Nevertheless, some of those tables in pocket format with 5 decimals were pretty successful and have been published for several editions [xv,xvi]. The smallest logarithmic tables

I am aware of, do not have an author mentioned and were published in the "*Miniatur Bibliothek*" by Albert Otto Paul, Verlag für Kunst und Wissenschaft, Leipzig around 1900. Their cost were 10 Pfennig, and the portrait format was 110 mm x 73 mm. 39 pages of this small booklet edition # 196 were dealing with logarithms, 8 of those contained a 4digit logarithmic table for 10 to 999, another 4 pages a 5digit table for numbers from 100 to 1299, the rest was theory and examples of logarithmic calculations. An additional 16 pages were ads for other books of the "Miniatur Bibliothek". In later (unknown) years the format was a little bit enlarged to 121 mm x 80 mm. The content remained exactly the same.

In the same format as this last one we find "*The Practical Mathematician´s Pocket Guide; a Set of Tables of Logarithms of Numbers, and of Logarithmic Sines and Tangents, with other useful tables for Engineers, Surveyors, Mechanics, etc*." [xvii]. This pocket guide with its 149 pages is a "real" logarithmic table with even 6 decimals. Although the arrangement of the figures looks crowded, the figures are readable, whereas the text with explanations is small and harder to read.



Around 1949 Karl F. Körner has published a "*Fünfstellige Logarithmen-Tafel mit Winkelfunktionen und Arcuswerten*" in an unusual landscape format 150 mm x 103 mm [xviii]. Also the arrangement of those tables was pretty unusual and focussed mainly on natural trigonometric data as can be seen in the graphic below:



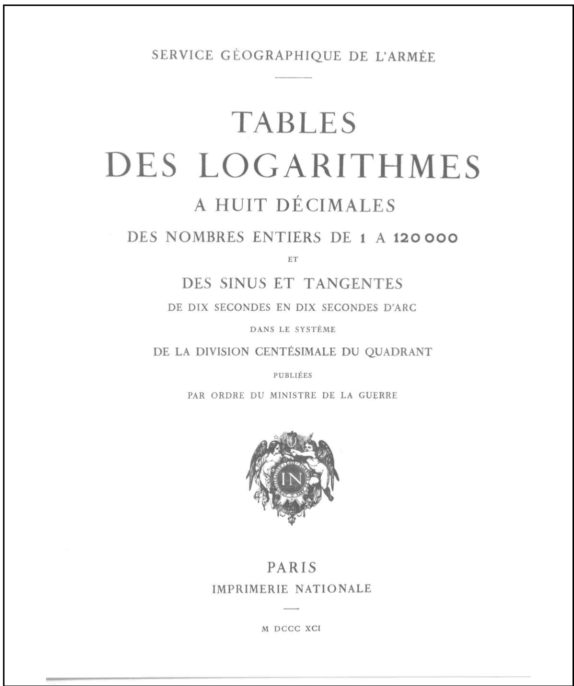
			Sinus							Sinus		
N	*lg*	*Dlg*	Altgrad	DW	Neugrad	Arcus	N reziprok	*lg reziprok*	*Dlg*	Altgrad	DW	Neugrad
880	94448	50	61°38'30"	441"	68,4907^g	1,0758	001136	05552	50	0°39'04"	3"	0,7235^g
881	94498	49	61 45 51	438	68,6269	1,0779	001135	05502	49	0 39 01	2	0,7225
882	94547	49	61 53 09	435	68,7620	1,0800	001134	05453	49	0 38 59	3	0,7219
883	94596	49	62 00 26	437	68,8969	1,0822	001133	05404	49	0 38 56	3	0,7210
884	94645	49	62 07 43	437	69,0317	1,0843	001131	05355	49	0 38 53	2	0,7201
885	94694	49	62 15 00	446	69,1667	1,0864	001130	05306	49	0 38 51	3	0,7194
886	94743	49	62 22 26	445	69,3043	1,0885	001129	05257	49	0 38 48	2	0,7185
887	94792	49	62 29 51	449	69,4417	1,0907	001127	05208	49	0 38 46	3	0,7179
888	94841	49	62 37 20	450	69,5802	1,0929	001126	05159	49	0 38 43	3	0,7173
889	94890	49	62 44 50	456	69,7191	1,0951	001125	05110	49	0 38 40	2	0,7164
890	94939	49	62 52 26	454	69,8599	1,0973	001124	05061	49	0 38 38	3	0,7173
891	94988	48	63 00 00	450	70,0000	1,0995	001122	05012	48	0 38 35	2	0,7145
892	95036	49	63 07 30	460	70,1389	1,1017	001121	04964	49	0 38 33	3	0,7139
893	95085	49	63 15 10	460	70,2809	1,1039	001120	04915	49	0 38 30	2	0,7130
894	95134	48	63 22 50	460	70,4228	1,1061	001119	04866	48	0 38 28	3	0,7123
895	95182	49	63 30 30	467	70,5648	1,1083	001117	04819	49	0 38 25	3	0,7114
896	95231	48	63 38 17	463	70,7090	1,1106	001116	04769	48	0 38 22	2	0,7105
897	95279	49	63 46 00	470	70,8519	1,1129	001115	04721	49	0 38 20	3	0,7099
898	95328	48	63 53 50	470	70,9969	1,1153	001114	04672	48	0 38 17	2	0,7090
899	95376	48	64 01 40	470	71,1420	1,1174	001112	04634	48	0 38 15	3	0,7084

N 880 bis 899   *lg* 94448 bis 95376   Sinus 61°38'30" bis 64°01'40"
N rez. 001136 bis 001112   *lg rez.* 05552 bis 04624   Sinus 0°39'04" bis 0°38'15"

Logarithmic tables in maxi format

At the end of the 18th century one of the most ambitious projects for calculating logarithms was started by Gaspar Riche de Prony (1755 - 1839), a French mathematician and engineer. Being involved in the "Bureau de Cadastre" and later with the "Bureau des Longitudes" his idea was to publish the most accurate logarithms with 14 decimals. The calculations have been performed by re-educated 60 - 80 hairdressers, who at that time had lost their jobs and who in 1794 produced 700 results per day [xix]. De Prony has had the figures calculated by two different procedures in order to compare at the end the results for correctness. This way both routes generated 19 volumes in folio format each. Unfortunately those volumes never were published because the cost would have been much too high, making those tables probably unsellable.

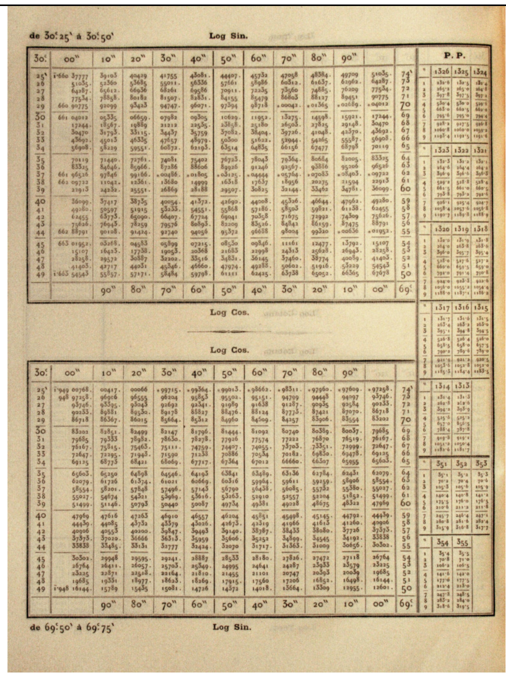
The originals are now stored in some Paris´ libraries. But the calculations were not in vain since an abbreviated form of de Prony´s tables were published as 8 digit logarithms by the "Service Geographique de l`Armee" in 1891 in folio without mentioning the originator in the title. This edition was the first 8digit table after 1658 [13, page 143].


SERVICE GÉOGRAPHIQUE DE L'ARMÉE

TABLES
DES LOGARITHMES
A HUIT DÉCIMALES
DES NOMBRES ENTIERS DE 1 A 120 000
ET
DES SINUS ET TANGENTES
DE DIX SECONDES EN DIX SECONDES D'ARC
DANS LE SYSTÈME
DE LA DIVISION CENTÉSIMALE DU QUADRANT
PUBLIÉES
PAR ORDRE DU MINISTRE DE LA GUERRE

PARIS
IMPRIMERIE NATIONALE

M DCCC XCI



Since the figures were printed larger in this volume, that folio format (363 mm x 284 mm) with its 240 pages (Table I: logarithms of numbers) + 600 pages (Table II: centesimal logarithms of sines and tangents) looks much more majestic than Vega´s Thesaurus (330 mm x 210 mm) and its 648 pages.

Later the "Service Geographique de l`Armee" has published an even smaller - easier to use - version with 5 digits: "*Nouvelles Tables de Logarithmes a cinq decimales por les lignes trigonometriques*", 1914 - 1939; 208 pages with a blue paper table for the sexagesimal trigonometric logarithms.

In the 1950s the successor of those tables was probably the newly edited version of "*Nouvelles Tables de Logarithmes*" in a small format of 110 mm x 224 mm by Bouvart, C. & Ratinet, A., published by Hachette, Paris - the last known version of that 5 digit table appeared in 1978.

Another very impressive 7digit table was published by Michael Taylor in 1792: "*Tables of Logarithms of all numbers from 1 to 101000; and of the sines and tangents to every second of the quadrant*." With a preface by Nevil Maskelyne, Astronomer Royal, who completed the tables after Taylor´s death, 530 pages in folio printed by Christopher Buckton, London and sold by Francis Wingrave, successor to Mr. Nourde.

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ENIGMA, BOMBY, LORENZ, COLOSSUS

Jerry McCarthy

Jerry McCarthy's day job is to write software, in areas such as cryptography and the internationalisation arena, for a global computing company.

Summary

During the 1930's and up to 1945, German Armed Forces used a variety of coding systems to encrypt their messages, and amongst the most well-known of these would be the Enigma and the Lorenz SZ42 (Schlüsselzusatz - Encryption Attachment). Notwithstanding the complexity of these systems, it proved to be possible, using the technology of the time, to decode the messages. This presentation will attempt to explain some of the workings of these encryption systems, and devices developed for decoding, in particular the Polish "Bomba" (plural: "Bomby") which led the to the British, and later, American, "Bombes", and then the Colossus. Additionally, some processes more appropriate to today's technology will be described.

Introduction

A simple method of encipherment is the Caesar Cipher (generally attributed to Julius Caesar, 100 BCE – 44 BCE) .

Starting with a simple message:

`"a very important message which must be kept secret"` *,

and treating each letter as a number between A=1 and Z=26, we can add some number (modulo 26) between 1 and 25 to get a replacement letter. For example, by adding a fixed value (the "key") of 5 we can get an encryption process, using the algorithm:

for character-number = 1…n, <crypto-text> = <plain-text> + "key".

which can also be described as a "permutation", which looks like:

ABCDEFGHIJKLMNOPQRSTUVWXYZ
FGHIJKLMNOPQRSTUVWXYZABCDE

resulting in a message like this:

F AJWD NRUTWYFSY RJXXFLJ BMNHM RZXY GJ PJUY XJHWJY[1]

It is next traditional to remove spaces (to remove information about word lengths and division), and then rewrite the text into short fixed-length blocks (to make handling the message easier) like this:

FAJWD NRUTW YFSYR JXXFL JBMNH MRZXY GJPJU YXJHW JY

[1] This document follows the convention that plain-text is written in lower case, and cipher-text is written in UPPER CASE

Decrypting this message is not hard if the process used to encrypt it in the first place is understood; it is possible to derive an answer using a so-called "crypto-text" brute force attack in a maximum of only 25 attempts, by subtracting 1, then 2, then 3, etc., from the letters in crypto-text.

Slightly more mathematically, we can rearrange all the letters in the cipher-text in alphabetical order like this:

A B D FFF G HH JJJJJJJ L MM NN P RRR S T UU WWW XXXX YYYYY Z

and immediately see that there is a predominance of the letter "J", followed by, in second place, the letter "Y". Given that distribution of letters in English is generally something like "E(1) T(2) I(3) O(4) N(5) A(6) S(7) H(8)", we can guess that "J" represents "e" and "Y" represents "t"; Given that ("J" - "e") = ("Y" - "t") = 5 we have determined the shift (the "key") used to create the message in the first place. This is a highly valuable method of analysis known as "*frequency analysis*".

Let us now consider the use of a variable key; let us assume that it starts at the value of 5, as above, and is incremented for each letter encrypted - i.e., the first letter is encrypted with 6, the second with 7, and so on. So, the key is still 5, and the algorithm for applying it is

for character-number = 1…n, <crypto-text> = <plain-text> + "key" + character-number.

The encrypted result is then:

GCMAI TYCCG JRFMG ZOPYF EXJLG MSBAC LPWRD IIVUK YO

Rearranging the crypto-text alphabetically gives:

AA B CCCC D E FF GGGG III JJ K LL MMM OO PP RR S T U VW X YYY Z

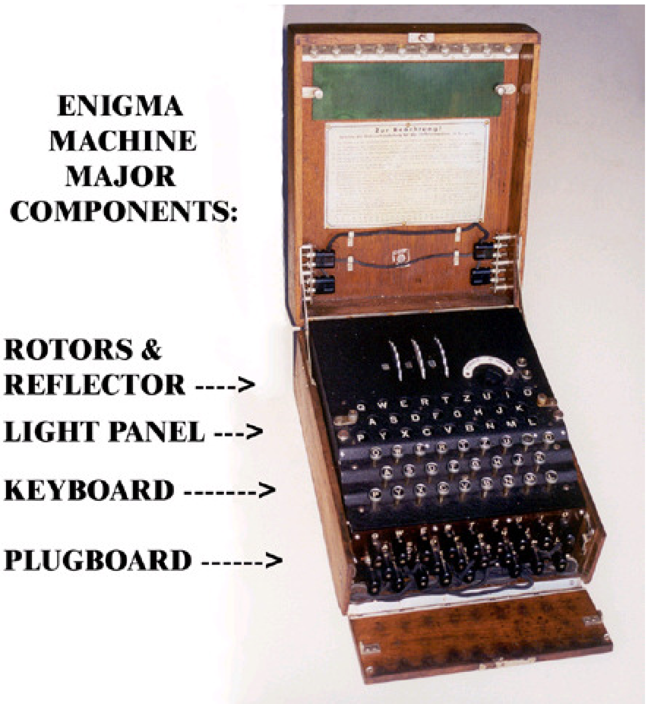
Based on the frequency analysis approach used previously, you might think that either "C" or "G" is an encrypt for "e"; however, you'd be wrong! Lining up the original message and the encryption thereof, it can be seen that "e" is variously encrypted as "M", "Z", "E", "P", "R", "V" and "Y", so, not much help is gained using that methodology!

```
G CMAI TYCCGJRFM GZOPYFE XJLGM SBAC LP WRDI IVUKYO
a very important message which must be kept secret
```

That said, if a reasonable amount of the plain-text message is known, then it would be quite easy to derive the algorithm used, using a so-called "plain-text" attack, and then determine the remainder of the message. On the other hand, if the algorithm is known, but no part of the plain-text is known, it is still quite easy to break the message using a crypto-text attack in the same number of attempts (25) as in the case above.

The next logical step is then to replace each letter in the plain-text with a crypto-text letter generated by a less obvious algorithm, and this is the basis of an Enigma Machine.

The Enigma Machine – brief description



Copyright (c) 2006: Prof. Tom Perera Ph. D. Reproduced with his permission from **[13]**

It is perhaps worth making the point here that The Enigma Machine is not a single, specific machine, but rather there is a family of several different types of encryption machine, each with different features and different strengths. The one I will be describing here is a typical version, with three rotors (W*alzen*) and fitted with a plug-board (***Steckerbrett***). These three rotors are selectable from a group of eight (typically numbered in Roman from "I" to "VIII"), and can each be set into one of 26 start positions (***Grundstellung***) (typically denoted from "A" to "Z". Additionally, each rotor can have a ring-setting (***Ringstellung***) established within it; again, this has one of 26 possibilities (typically numbered straightforwardly from "1" to "26") for each rotor. The use of this ring-setting and also of the plug-board will be expanded upon later.

Finally, there are three stationary reflectors (***Umkehrwalzen or UKW***) (coded as "A", "B" and "C") of which one can be selected; the selected UKW can be fitted in exactly one position, and does not rotate.

The Enigma Machine – Encryption

Above, I showed a trivial permutation, in which each letter is encrypted to a new letter, where <new letter> = <old letter> + 5 (*modulo 26*):

```
ABCDEFGHIJKLMNOPQRSTUVWXYZ
FGHIJKLMNOPQRSTUVWXYZABCDE
```

In the case of an Enigma Machine, a less ordered permutation is used; for example:

```
ABCDEFGHIJKLMNOPQRSTUVWXYZ
EKMFLGDQVZNTOWYHXUSPAIBRCJ
```

To be more specific, three different rotors bearing three different permutations, of which the one above is one example, are used sequentially, followed by a reflection process, followed by the three permutations as just mentioned in reverse. For each character which is encrypted, one, two or three of the rotors is/are rotated one step, thereby "shifting" at least one of the permutations. For example, the above permutation, after one step, becomes:

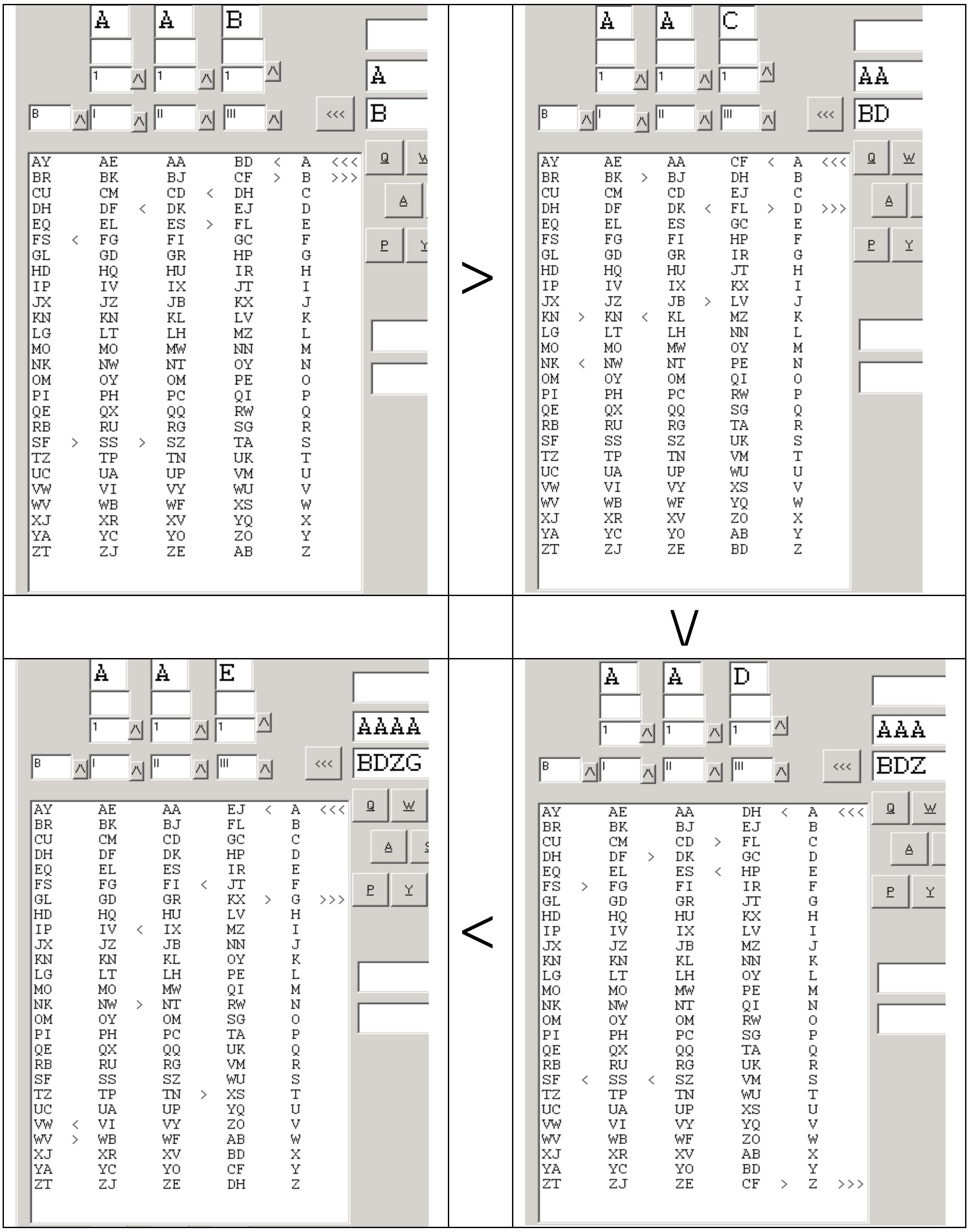
ABCDEFGHIJKLMNOPQRSTUVWXYZ
KMFLGDQVZNTOWYHXUSPAIBRCJE

Then, after another step, we have:

ABCDEFGHIJKLMNOPQRSTUVWXYZ
MFLGDQVZNTOWYHXUSPAIBRCJEK

This means that each time the same plain-text letter is encrypted, the resultant crypto-text letter will result from a different path through the series of permutations.

Below are shown four screen shots from the author's own Enigma simulation software.



In these four screen shots, the plain-text "aaaa" is input. Each picture in order shows the resulting path through the rotors. The order in which the pictures are to be studied is clockwise from top left.

Before the first plain-text "a" was encrypted, the rotors were installed in the left-to-right order: "I", "II" and "III"; they were set with ring-settings of "1" and start-positions of "A", and the reflector coded "B" has been inserted. The plain-text letter "a" was then entered; before anything else happens, the right-most rotor advances one step, that is, from its start-position of "A" to its next position, "B". The encryption route can now be followed by following the chevrons ("<" and ">" characters) starting from the right, and the result of encrypting plain-text "a" can be seen to be "B".

Before each of the next three plain-text letters "a" are encrypted, the right-most rotor steps on by one step, resulting in four different paths through the rotors, and resulting in, in this case, four different encryptions of the letter "a". At a given point in the right-most rotor's rotation, a single step of the middle rotor is triggered, and at a given point in the middle rotor's rotation, a single step of the left-most rotor is triggered. This means that, after a maximum of 26 steps of the right-most rotor, there will be a single step of the middle rotor, and after a maximum of 26 steps of the middle rotor, there will be a single step of the left-most rotor. The exact point at which a given rotor triggers a step of the rotor to its left is determined by the ring-setting (***Ringstellung***) of the given rotor.

Note: there is a quirk in this process such that the middle rotor may step twice under certain circumstances, and simulators and decoders must take this into account for satisfactory performance! [1]

The Enigma Machine – Daily setting

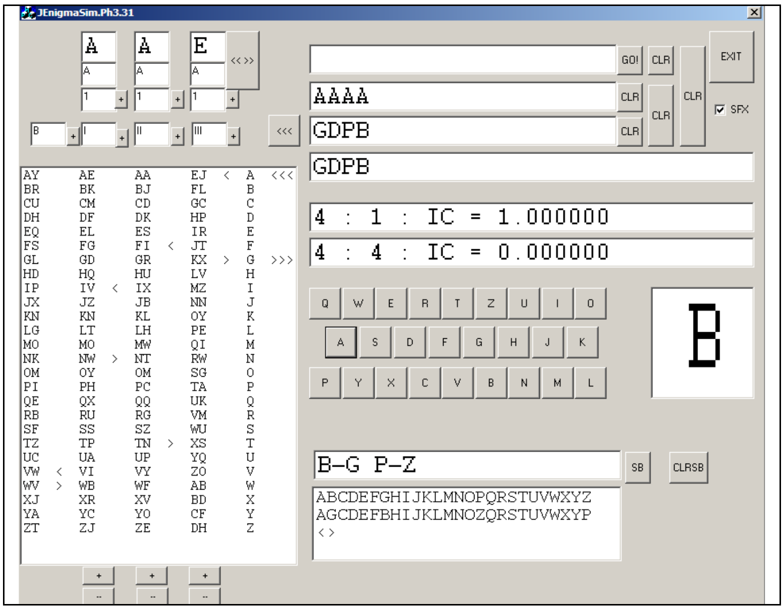
All machines in a given network have to be set to the same settings, and these settings were published to the users of the machine in that network. Below is a sub-section for dates around this meeting, generated using a Codebook Generator simulation by Dirk Rijmenants **[2].**

GEHEIM! SONDER-MASCHINENSCHLUSSEL: IM2010 LEIDEN SEPTEMBER 2010

Tag	UKW	Walzenlage	Ringstellung	Steckerverbindungen	Kenngruppen
19	B	V I III	14 07 11	AE BK CQ DF JN LS PY RZ UW VX	PPH HGW FKD NJZ
18	C	II IV I	19 15 16	BG DV EP IU JX LN OT QW RS YZ	VCI VFY FDO MCG
17	C	I II III	07 20 18	BU CO FJ GM HP KS LW NY QX RZ	UQX KCX MUD SSL
16	B	I IV III	22 13 14	AK CF DG ER HL IZ JM NW PY TU	BOF AVM DLB IGI

These settings show, in order, the date, which reflector is to be used, which rotors are to be used, the order in which they are to be used, and the internal settings of each of the rotors. Also shown are the plug connections (***Steckerverbindungen***), which are used to define the connections of the plug-board (***Steckerbrett***). The plug-board is interposed between the keyboard and the rotor mechanism as keystrokes enter the rotor mechanism, and then again between the rotor mechanism and the indicators. Given that there are 26 letters in the character set being used, a maximum of 13 such cables can be used; generally 10 were used.

In the example below, with B connected to G, and P connected to Z, all occurrences of B are converted to G, and *vice versa*, and all occurrences of P are converted to Z, and *vice versa*; this conversion applies not only to letters typed, but also to letters output from the machine.



The Enigma Machine – Decryption

The Enigma machine is fully reversible, in that, if the same start position is set, with the same rotors and reflector in place, then typing the cipher-text into the machine results in the original plain-text being generated. This means that once it is known which rotors are in use, what their settings are, in which order they are installed, and which reflector is in use, it is possible to derive the original plain-text from the cipher-text.

Two methodologies exist, and will be further explained:

1) Known plain-text attack.
2) Cipher-text attack.

Known plain-text attack

This is an approach to be taken when you know, or can guess at, some of the plain-text represented by a cipher-text. If you have some of the plain-text, and can determine how that plain-text and cipher-text are related, then it may be possible to derive the day's key for the machine in question, and subsequently decrypt all the cipher-texts from the machine in question while it is using the same settings. Effectively all of the work at Bletchley Park ("BP") was based on known (or "guessed") plain-text attacks.

To take an example: the crypto text message is:

"OPCURLVMMAXXTZEBTYDBOXHGCQWXP"

and it is suspected that this contains, somewhere, the plain-text:

"nothing special to report".

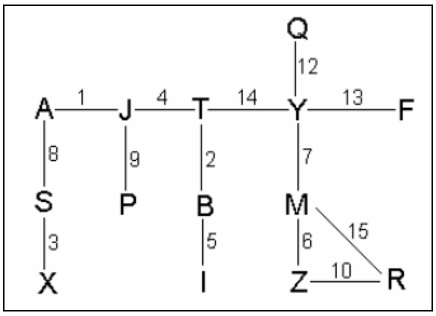
It is possible to line up the crypto text and the plain-text and determine the possibilities for a contradiction between the two texts. This works on an interesting flaw in the Enigma system, which is that no letter can ever encrypt to itself, no matter what the rotor settings or plug-board settings might be. In the following picture, all places where the suspected plain-text messages line up with the crypto-text message such that one or more letters in the plain-text is/are the same as the letter in the same position in the crypto-text, is marked, and can be discounted as possibilities.

In BP terminology, these are referred to as “*crashes*”. The process of sliding the plain-text and crypto-text alongside each other is referred to as ***“crib dragging”.***

In the next figure, crashing lines are marked with an **“x”**, and crashing letters are underlined.

```
OPCURLVMMAXXTZEBTYDBOXHGCQWXPEFONUPBDIHWDFG
nothingspecialtoreport
 nothingspecialtoreport
  nothingspecialtoreport                     ---   X
   nothingspecialtoreport
    nothingspecialtoreport
     nothingspecialtoreport                  ---   X
      nothingspecialtoreport
       nothingspecialtoreport
        nothingspecialtoreport
         nothingspecialtoreport
          nothingspecialtoreport
           nothingspecialtoreport
            nothingspecialtoreport           ---   X
             nothingspecialtoreport
              nothingspecialtoreport         ---   X
               nothingspecialtoreport
                nothingspecialtoreport       ---   X
                 nothingspecialtoreport
                  nothingspecialtoreport
                   nothingspecialtoreport    ---   X
                    nothingspecialtoreport   ---   X
                     nothingspecialtoreport
```

The next stage is to try to work back from the non-crashing pairs of lines, and this is where some “magic” comes in; this “magic” often appears in documentation originating from, or concerning, BP, and takes the form of an interesting-looking diagram, such as this (from **[7]**):



Somehow, out of this “magic” diagram comes the solution of the original text – not just of the crib section, but of the whole message. So, just how does this work?

Firstly, let us step back a little, to around October 1938. At that time, the daily keying information included an initial key setting of three letters.

An early method of preparing the Enigma machine for sending a message was for the operator to use the initial key setting to encrypt a second, randomly determined, group of three letters, twice, and then send the result of so doing followed by the message itself, encrypted by the second group of three letters. So for example, given a daily key setting of “LEI”, and considering a randomly selected second group of letters, such as “DEN”, the result of encrypting the latter, twice, by the former, could be “YGWZOO”; “LDN” would then be used as the settings for encrypting the rest of the message; e.g., “the quick brown fox” -> “AVQMV DEOYA LSKQW U”. The transmitted message would include that crypto-text message preceded by the twice-encrypted key, “YGWZOO”.

In Poland, work was in progress to decrypt the Enigma messages, and, having guessed that the six letters represented the same three letters encrypted twice, Polish cryptographers were then able to determine the rotor wirings. Of particular value was the case, which was known for reasons which are lost in obscurity as “samica” (=”female”) where the first and fourth, or the second and fifth, or the third and sixth of the encrypted key were the same, as this meant that, given that the plain-text was also the same in the those positions, it was possible to determine the morphology of the encryption machine.

The Polish cryptographers, in particular Henryk Zygalski (1908 - 1978), Marian Rejewski (1905 - 1980), and Jerzy Różycki (1909 - 1942) then created two methodologies to automate the process of determining the keys used. For further reading on this subject please see, for Zygalski sheets, **[3]** and for "Bomba Kryptologiczna" (cryptologic bombe), **[4]**. On the subject of the Zygalski sheets, however, the available Wikipedia entry seems somewhat cryptic; the most important part of the explanation reads *"**When the sheets were superposed and moved in the proper sequence and the proper manner with respect to each other, in accordance with a strictly defined program, the number of visible apertures gradually decreased. And, if a sufficient quantity of data was available, there finally remained a single aperture, probably corresponding to the right case, that is, to the solution.*** **[12]"** This author has not yet determined what the "strictly defined program" might be, but plans to do some further research in this area!

Unfortunately, these processes quite quickly became unusable as a change to the key encryption process was introduced which no longer included the same three characters encrypted twice.

Alan Turing (1912 - 1954) then generalised the design of the Polish bomba to cover the whole message and any proposed crib. In the same way as the Polish Bomba was used on the possible patterns inherent in encrypting the same three characters twice with the same key, the Turing bombe design could relate the morphology of the inner wiring of the Enigma system to the layout of the encrypted message and the proposed equivalent plain-text.

So, developing the ***crib-dragging*** example shown above, let's select one of the non-*crashing* pairs, and rewrite it with some numbering:

```
00000000011111
12345678901234
nothingspecial
MMAXXTZEBTYDBO
```

Now, let's begin at the beginning, and see that at the first position of the Enigma, the "n" is connected to the "M", so this is represented diagrammatically as:

```
N – 1 – M
```

Next, we see that "o" is connected to "M", so we can add to the diagram like this:

```
N – 1 – M – 2 – O
```

Note that, as mentioned above, the Enigma is fully reversible; in the second column, for example, at that position of the Enigma, "o" encrypts to "M", but also "m" encrypts to "O". *In the graphing process which we have now started to work with, all letters, whether plain or encrypted, are represented in UPPER CASE*. We can now see, at position 6, that "n" is connected to "T"; therefore, at this time, we can extend our picture to the left to get:

```
A – 3 – T – 6 – N – 1 – M – 2 – O
```

Now, at position 3, "t" is connected to "A", and also "T" is connected to "e" at position 10, thereby introducing a fork in the diagram:

```
A – 3 – T – 6 – N – 1 – M – 2 – O
        |
        – 10 – E
```

The process continues until all of the characters are graphed in this fashion. Particularly valuable cases arise when a loop of letters can be found, in that loops occur infrequently and when they do occur, they tend to indicate, quite strongly, particular positions of the rotors of the Enigma machine.

The author of this paper is making available some software (source included) which can be used to execute some of this graphing, and which also provides input to a Bombe Simulator, written by Jean-François Bouchaudy, which can be downloaded from [5]. The important thing to realise here is that the Bombe (the originals used in Poland and BP, and any simulator) does not provide a decrypt of the message. The Bombe provides a "guess" at the key settings that were used during the encryption of a particular message; these key settings can then be used to attempt to decrypt the rest of the messages that were sent on the same day, on the same network, using the same key settings.

Some software written by the author assists with the visualisation of the chains and loops which can be found in a parallelised pair of plain- and cipher-texts:

```
L n O b M a N f T j E h S
P i B m A c T f N a M b O n L
A c T f N a M b O n L
H d X e I l D
S h E j T c A m B i P
G g Z
C k Y
```

This can then be visualised more diagrammatically as:

```
P – 9 – B – 13 – A – 3 – T – 6 – N – 1 – M – 2 – O – 14 – L
                         |
                          – 10 – E – 8 – S

C – 11 – Y                                          G – 7 – Z

H – 4 – X – 5 – I – 12 – D
```

Running M. J-F Bouchaudy's Bombe Simulator **[5]** with this menu results in, for the six attempted wheel orders (all combinations of wheels I, II and III), no fewer than 59 possible solutions for the keys. The solutions file accompanies this presentation as **results2.txt.**
Having 59 possible solutions for a crib would be considered a very poor result back in the days of BP, as attempting to run 59 or so different solutions would have taken a very long time indeed. In these days of Pentium (or better) processors, however… The correct solution which that software gave was:

STOP menu0.2.cri4 I II III AAH N:N AA BB EE LL MM NN OO PP SS TT

which shows, in order, the wheel order (I II III), the *Grundstellung*, (AAH) and the *Steckerverbindung* (in effect, none). Now the crib (**"MMAXXTZEBTYDBO**") started 7 characters into the crypto-text; to decrypt the full crypto-text requires backing off the *Grundstellung* by 7 places (from AAH to AAA), before decryption of the whole crypto-text can be carried out thus:

B I II III AAA 1 1 1 : THEREISNOTHINGSPECIALTOREPORT

Cipher-text attack

This approach is applicable when you have no idea what a piece of cipher-text represents, although you might have some idea of some of the settings. Basically, what is required is to "brute-force" a solution using all of the known settings, and rotating through all the unknown settings. It involves a process similar to the frequency analysis shown above, but uses an overview method to determine if a given result is likely to be valid. As noted above, English, along with other languages, uses some letters more than others, resulting in a "lumpy" distribution. Crypto-text generated by an Enigma, however, tends to be much more even, and faulty decryptions also tend to be more even than plain-text. It is therefore possible to perform an analysis on the "lumpiness" of a piece of text to see if it is likely to be a valid plain-text. The algorithm used is called the "Index of Coincidence" ("IC") **[6]** and it looks like this:

<u>Index of Coincidence</u>

$$\frac{\sum(f_i * (f_i - 1))}{N(N-1)}$$

where *i* is in the range 1 to 26 and represents the number of unique letters in the sample, f*i* is the number of occurrences of the *i*th letter of the alphabet in the sample, and N is the total count of the letters in the sample.

As a demonstration, a version of the text from the first paragraph of this document was used as a plain-text. Using a *Grundstellung* of "**JMC**" and these other settings:

```
|UKW| Walzenlage|Ringstellung|      Steckerverbindungen                 |
-------------------------------------------------------------------------
| C | V  IV  II | 11  9  23   | A-T B-G D-V E-W F-R H-N I-Q J-X K-Z L-U |
```

The resultant crypto-text is:

```
FPKTC CJZNG VQNHG LJCJM CKHLN PEXNT VDVQW QNEUP KAYHK FVSQE TFHKD
BUELY RYFPC GUWKY CJHFZ EDGTT PXWBP RAWDG AKSAN EQYDJ EIISI VSXND
RJHHQ
```

From the point of view of this test case, to decrypt this crypto-text, we can then rotate around all possible key settings, or, to save time from the point of view of this presentation, we can assume that we know some of the settings, such as the UKW, the wheel order and the plug-board settings. Given a fixed *Ringstellung* of 1, 1, 1 and rotating through all possible *Grundstellungen* from AAA to ZZZ via AAB, AAC,..ABA, ABB, etc., it is possible to gain a partial solution, using the IC, relatively quickly. An analysis of the IC of all possible solutions in that range gives, as the top 25 values of the IC, the following:

<u>0.054920</u>, 0.050801, 0.049428, 0.049275, 0.049123, 0.048970, 0.048818, 0.048513, 0.048360, 0.048055, 0.047902, 0.047750, 0.047597, 0.047445, 0.047292, 0.047140, 0.046987, 0.046834, 0.046682, 0.046529, 0.046377, 0.046224, 0.046072, 0.045919, 0.045767.

The first value is a clear leader, so, going to the log of the decryptions, it is then possible to see a resultant, albeit partial, decryption as:

```
C V IV II ZFG 1 1 1 A-T B-G D-V E-W F-R H-N I-Q J-X K-Z L-U:
TMRRYMCCARTHYSDAYJOBISTOUOMQESOFTWAREINAREASUCHASCIPQYOGRAPHY
ANDTHEINTERNATIANIFATIONAREAFORAGLOBALCOMWRRHFPPNSWZJS
```

The complete file of results can be found accompanying this paper as **TestFile.2.stats.txt.**

By inserting judiciously placed separators, it is possible to divide the imperfect plain-text into blocks of 26, and it can then be seen that it is the last four characters of each block of 26 which is incorrect; in other words there is a cycle of 26 characters containing 22 correct characters and four incorrect characters:

```
tm/rrymccarthysdayjobistouomq/esoftwareinareasuchascipqy/ographyandthein
ternatianif/ationareaforaglobalcomwrrh/fppnswzjs
```

This can generally be taken to mean that, during the decryption process, turnovers of the middle rotor and possibly the left rotor have taken place; those turnovers are out of step with the turnovers of the encryption process, and therefore certain parts of the encrypted text have been incorrectly decrypted.

Given the fact of four incorrect characters per 22 correct characters, it would then be possible to proceed further, moving through 4 *Ringstellungen* on the right-most rotor, to get a better result in a sequence like this:

```
C V IV II ZFF 1 1 26 A-T B-G D-V E-W F-R H-N I-Q J-X K-Z L-U:
TMRRYMCCARTHYSDAYJOBISTOWOMQESOFTWAREINAREASUCHASCRPQYOGRAPHY
ANDTHEINTERNATIONIFATIONAREAFORAGLOBALCOMPGRHFPPNSWZJS

C V IV II ZEE 1 1 25 A-T B-G D-V E-W F-R H-N I-Q J-X K-Z L-U:
TMRRYMCCARTHYSDAYJOBISTOWRMQESOFTWAREINAREASUCHASCRYQYOGRAPHY
ANDTHEINTERNATIONIFATIONAREAFORAGLOBALCOMPUHHFPPNSWZJS

C V IV II ZED 1 1 24 A-T B-G D-V E-W F-R H-N I-Q J-X K-Z L-U:
JMRRYMCCARTHYSDAYJOBISTOWRIQESOFTWAREINAREASUCHASCRYPYOGRAPHY
ANDTHEINTERNATIONIFATIONAREAFORAGLOBALCOMPUTHFPPNSWZJS

C V IV II ZEC 1 1 23 A-T B-G D-V E-W F-R H-N I-Q J-X K-Z L-U:
JERRYMCCARTHYSDAYJOBISTOWRITESOFTWAREINAREASUCHASCRYPTOGRAPHY
ANDTHEINTERNATIONISATIONAREAFORAGLOBALCOMPUTINPPNSWZJS
```

The last one is now almost perfect, except that there remains some corruption in the last few characters; as this is at some repetition frequency greater than 26 characters, it can be assumed to be caused by the middle rotor triggering a rotation of the left-most rotor. By modifying the *Ringstellung* of the middle rotor by one place only, we get the final decryption, which incidentally, as a result of the corrections described above, has an even higher IC (***0.060564***):

```
C V IV II ZDC 1 26 23 A-T B-G D-V E-W F-R H-N I-Q J-X K-Z L-U:
JERRYMCCARTHYSDAYJOBISTOWRITESOFTWAREINAREASUCHASCRYPTOGRAPHY
ANDTHEINTERNATIONISATIONAREAFORAGLOBALCOMPUTINGCOMPANY
```

Bigram/Trigram analyses

Bigram/Trigram analyses are further statistical methodologies for computer determination as to whether a text is likely to be a good decryption of a cipher text. This is particularly useful when it is necessary to determine plug-board settings. Basically, this methodology rotates through all possible plug-board settings, starting with the first cable; the resultant text is then analysed to determine whether its bigram and trigram counts improve for a given plug-board setting; the best possible plug-board single cable setting is then retained, and a further cable tested. Suitable demonstration software is available at **[11]**; this software can be used to analyse typical text for a given language, and the results of these analyses can then be used to automate the testing of decryptions. The software has been run on a version of this paper, and full analyses are supplied as the files **bi_prezi.2.txt** and **tri_prezi.2.txt,** but this table shows the first dozen bigrams and trigrams for this document. The values are typical for English, although the Trigrams list does show the unusual combinations "ryp" and "cry"; these derive from this paper's subject matter, of course!

Bigrams		Trigrams	
th	75028	the	71070
he	72226	ing	61059
in	71048	and	57875
er	70210	ion	57536
te	68522	tio	57005
re	67430	ter	57005
es	67038	int	56540
en	66312	her	56444
ti	66204	ryp	55850
et	66131	cry	55539

Running the analysis software, with no advance information, (that is, no knowledge of any of the settings), but using the bigram/trigram analysis data from this paper, on the same crypto-text used above:

```
FPKTC CJZNG VQNHG LJCJM CKHLN PEXNT VDVQW QNEUP KAYHK FVSQE TFHKD
BUELY RYFPC GUWKY CJHFZ EDGTT PXWBP RAWDG AKSAN EQYDJ EIISI VSXND
RJHHQ
```

Results are in the files supplied as **decyrpto.txt** and **decyrpto.2.txt**, of which the best final entries are:

```
Date: 2010-04-21 12:26:19
Score: 3574702   UKW: C   W/O: 542
Stecker: ATBGDVEWFRHNIQJXKZLU
Rings: AGV   Message key: YJB
jearymccarthysdayjobistowritvsoftwareinareasuchascrypttgraphyandthe
internationisationareaforaglobalcomputijgcompany

Date: 2010-04-21 14:47:10
Score: 3831763   UKW: C   W/O: 542
Stecker: ATBGDVEWFRHNIQJXKZLU
Rings: AFW   Message key: YIC
ntnrymccarthysdayjobistowritesoftwareinareasuchascryptographyandthe
internationisationareaforaglobalcomputingcompany
```

The first of these shows a single character error at 26 character intervals, indicating an error of one place of the right-most rotor. The second is correct throughout, except for the first four characters, indicating an error in the setting of the middle rotor.

Lorenz, Colossus

Space in this paper does not permit a full treatment of this area; therefore this section will be restricted to a brief description of how this system differs from the Enigma / Bombe system. A future paper and lecture may well cover these subjects for this forum.

The Enigma system is basically an alphabetic replacement system: given an input letter, an output letter is generated, where the output letter is dependent upon the input letter.
In contrast, the Lorenz SZ42 (Schlüsselzusatz (Encryption Attachment)) system worked by a process similar to a Vernam cypher, in which the characters to be encrypted are processed as a sequence of 5-bit teleprinter characters, and the encryption is carried out using a second tape of 5-bit characters. The encrypting tape was moved once for each character on the data tape, and the resulting character was produced by an exclusive-or process combining the character to be encrypted with the character from the encrypting tape. In the Lorenz system, the encrypting tape was replaced by a system of wheels, somewhat similar to those of Enigma, but of which the movement was less regular. Much more about this system, and Colossus' role in decrypting it, can be read at **[8].**

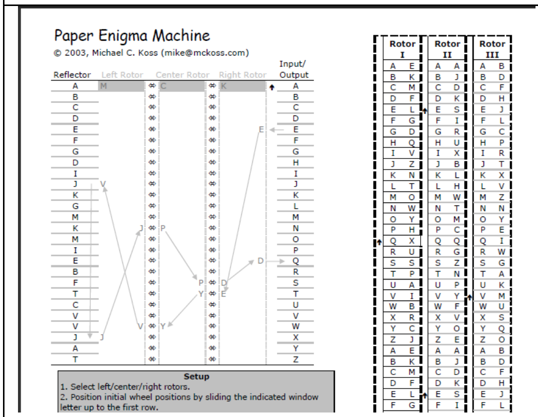
Slide Rule Appendix

Slide rule connection?

As this forum is, at least in origin, a slide rule interest group, I thought I should include some slide rule connected topics.

For the linear slide rule enthusiast, there is downloadable from **[9]** a paper enigma with three slides, which can be cut and put together to form a simulated three-rotor enigma, albeit with no ring-settings or plug-board. For those whose tastes veer more in the direction of the cylindrical slide rule, the Imperial War Museum in London sells a pair of cylindrical enigma-type simulators; these lack the ring-settings, the plug-board *and* the reflector.

From [9]



From [10]

References

[1] David Hamer, "Enigma: Actions Involved in the 'Double-Stepping' of the Middle Rotor", *Cryptologia*, 21(1), January 1997, pp. 47–50, Online version http://www.eclipse.net/~dhamer/downloads/rotorpdf.zip

[2] http://users.telenet.be/d.rijmenants/en/codebook.htm

[3] http://en.wikipedia.org/wiki/Zygalski_sheets
http://pl.wikipedia.org/wiki/Henryk_Zygalski

[4] http://en.wikipedia.org/wiki/Bomba_(cryptography)

[5] http://users.telenet.be/d.rijmenants/bp12.zip

[6] http://en.wikipedia.org/wiki/Index_of_coincidence

[7] Frank Carter, "From Bombe 'stops' to Enigma keys", http://www.bletchleypark.org.uk/content/bombestops.pdf

[8] http://www.tnmoc.org/colossus-rebuild.aspx

[9] http://mckoss.com/Crypto/Enigma.htm

[10] The Imperial War Museum, London (product available via Amazon.co.uk) http://www.iwm.org.uk/upload/package/10/enigma/index.htm

[11] http://www.bytereef.org/enigma-suite.html

[12] Marian Rejewski, "The Mathematical Solution of the Enigma Cipher," Appendix E to Władysław Kozaczuk, *Enigma*, 1984, p. 289.

[13] http://www.w1tp.com/enigma Museum

DIFFERENCE ENGINES IN THE 20th CENTURY

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Introduction

Related to difference engines and their inventors first of all the names Babbage, Scheutz, Wiberg or Grant come in mind. During the 19th century the named men built machines of that type or at least made some attempts. Their history and success or failure has been often documented and is well known. With the end of 19th century the history of difference engines didn't come to an end. During the next century two innovative new difference engines were built and used for calculating logarithmic tables. In scientific papers they are incidentally named and if, only little information is given. This article will throw some more lights on these difference engines of 20th century.
Our first question is what is a difference engine and what is it used for?

What is a difference engine?

A difference engine is a historical, mechanical special-purpose calculating machine designed to tabulate polynomial functions. Our next question is how does it work and what is it good for? This question can be answered best with an example. Assuming we have to tabulate the function $f(x) = x^2 + 2x - 7$

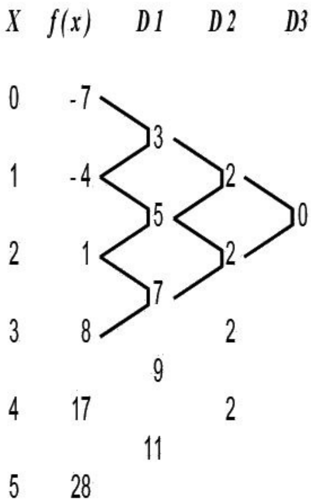


Figure 1 - function $f(x) = x^2 + 2x - 7$ and its differences

First we calculate some function values *f(x)*, then the first differences *D1* between successive values and finally the second differences *D2* between the first differences which become constant (fig. 1). With a polynomial of order n ($f(x) = x^n + ...$) the differences *Dn* become constant and all differences of higher order are therefore zero. By inspection of fig. 1 it is obvious that all following values of *f()* can easily be calculated only by additions. With our example *D2* = 2 added to *D1* = 7 gives *D1* = 9 and that sum added to the last function value *f(3)* = 8 gives the new value *f(4)* = 17 and so on. All additions may be done with mechanical adders that store the intermediate results and they should be done by machine to avoid errors, because a possible error runs through all calculations that follow. Of course the calculus of finite differences provides not only extrapolation starting from a given value as shown above, but also interpolation between two values and many more algorithms and possibilities that cannot be explained here.

A difference engine is adapted to this algorithm shown above, it is build of serial connected adders that store and transfer intermediate results. Such a serial machine should not be mixed up with a double and parallel working machine used especially in geodesy.

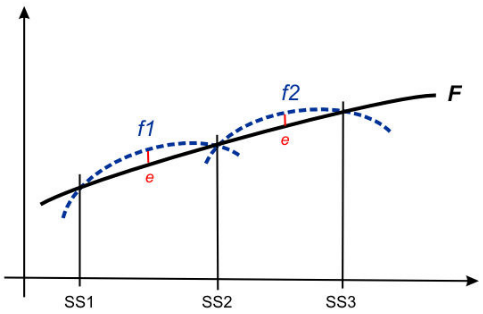


Figure 2 - Approximation of a function

Logarithmic, trigonometric and some other functions cannot be expressed by polynomial functions, but fortunately they can be approximated. To approximate the function *F* in fig. 2 we select so called supporting points SS on it, calculated with great accuracy or taken from other tables, and choose the coefficients of the polynomials *f1*, *f2*... thus that they lead through the selected points. Care has to be taken of the maximum errors *e*.

Since logarithmic and trigonometric functions can be approximated by polynomials, such a difference engine is more general than it appears at first. A historical remark: Gaspard de Prony used the methods of differences when he organized calculations for the *Tables du Cadastre* like producing goods in a factory at the end of the 18th century and later Babbage thought of them.

The first difference engine we meet in the 20th century is that of Christel Hamann in Berlin who at that time has been well known for his desk calculators *Gauss* and *Euklid*.

Christel Hamann

Shortly before 1900 the astronomers Julius Bauschinger and Jean Peters decided to calculate new logarithmic and trigonometrical tables with eight figures to meet the constant increasing requirements for greater accuracy in astronomy and geodesy. First discussions between Julius Bauschinger and the mathematician Heinrich Bruns took place in 1904. Bruns acted as a consultant for all problems related to calculation of the tables. Both decided not to recalculate again all values but to use the method of interpolation between known values with second differences. In the first years they thought of using a Burroughs adding machine. Later, in spring 1908 when the first calculations started in preparation for the mechanical interpolations, Hamann was asked to design and build a machine for the aimed purpose. Only one year later Hamann delivered his unnamed difference engine that surpassed all expectations. As far as we know the machine was used only for one complete run. The first table, derived from the results, was published in 1910 [1, 5:#197.0].

Next we will have a closer look to the construction of the machine.

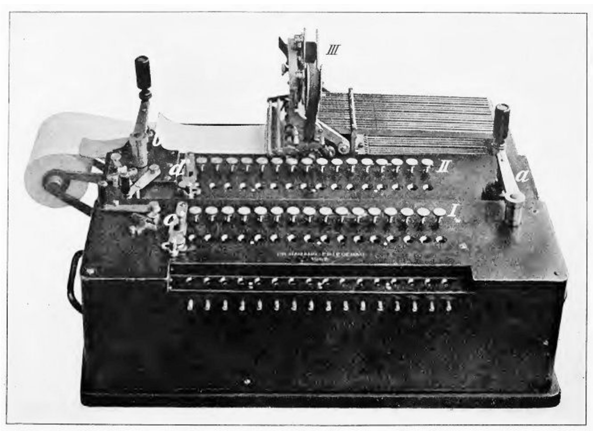
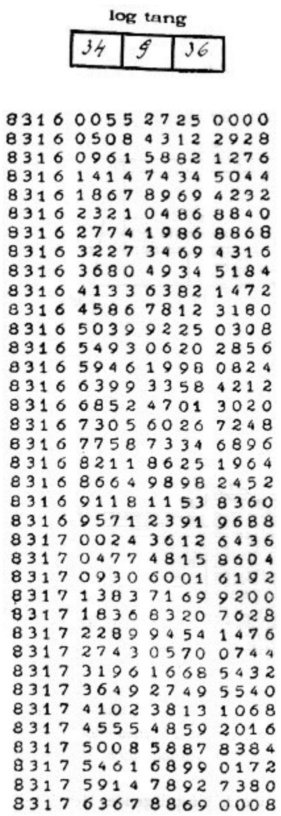


Figure 3 - Hamann's difference engine

The machine (fig. 3) must have been a large and heavy one, I reconstructed a weight of about 40 to 50 kilograms. It is divided into three parts: in the first adder placed next to the user the second difference is added to the first difference. With the second adder in the middle part this sum is added to the intermediate result and the third section, a printer, prints the result onto a strip of paper. All differences and the result can be set, operated and printed with sixteen places. Each of the two adders is driven by its own handle. With use of the printing device errors in copying from result register to first script are avoided.

The construction of the machine and the way the logarithms were calculated are described in the foreword of the first volume in the first German edition. In the English edition the description of the machine is missing.

All printed strips which the machine produced were given to Astronomisches Rechen-Institut in Berlin. The papers are lost, only a copy of a single stripe survived (fig. 4). It shows the interpolation between log tan 34° 9' 36'' and log tan 34° 10' 12''. The function values should be read as 9.831... – 10. The ten is omitted and the decimal fraction is regarded as an integer number.


log tang

34 | 9 | 36

8316	0055	2725	0000
8316	0508	4312	2928
8316	0961	5882	1276
8316	1414	7434	5044
8316	1867	8969	4232
8316	2321	0486	8840
8316	2774	1986	8868
8316	3227	3469	4316
8316	3680	4934	5184
8316	4133	6382	1472
8316	4586	7812	3180
8316	5039	9225	0308
8316	5493	0620	2856
8316	5946	1998	0824
8316	6399	3358	4212
8316	6852	4701	3020
8316	7305	6026	7248
8316	7758	7334	6896
8316	8211	8625	1964
8316	8664	9898	2452
8316	9118	1153	8360
8316	9571	2391	9688
8317	0024	3612	6436
8317	0477	4815	8604
8317	0930	6001	6192
8317	1383	7169	9200
8317	1836	8320	7628
8317	2289	9454	1476
8317	2743	0570	0744
8317	3196	1668	5432
8317	3649	2749	5540
8317	4102	3813	1068
8317	4555	4859	2016
8317	5008	5887	8384
8317	5461	6899	0172
8317	5914	7892	7380
8317	6367	8869	0008

Figure 4 - Copy of a printed stripe from Hamann's machine

The two main points log tan 34° 9' 36'' (first line) and log tan 34° 10' 12″ (last line) are either calculated with high precision or taken from Briggs-Gellibrand *Trigonometria Britannica* (1633 and later). Logarithms for numbers they took from Briggs' *Arithmetica Logarithmica* (1624 and later) and other works. If either the original value or the result of calculations with differences is incorrect the next supporting points will not meet close together.

In the preserved example the used starting point is
log tan 34°09'36'' = 9,8316 0055 2725 – 10
with the differences
d1 = 0,0000 0453 1587 2928
and
d2 = -0,0000 0000 0017 4580

It is reported that a trained human computer could do the input to the machine and the whole interpolation in five minutes.

Now we should do some own calculations: we interpolate nine values between log 169500 and log 169510. The values log 169500, log 169510 and log 169520 we take from a table with high precision. For the large intervals between 169500, 169510 and 169520 we get the differences

```
log 169500 = 5.2291 6970 2539
                D11 = 0.0000 2562 1338
log 169510 = 5.2291 9532 3877
                D2  =-0.0000 0000 1512
                D12 = 0.0000 2561 9826
log 169520 = 5.2292 2094 3703
```

For the nine values between 169500 and 169510 we have to use the differences
d2 = 0.01*D2 + ... = -0.0000 0000 0015 1200
d1 = 0.1*D1 – 0.045*D2 + ... = 0.0000 0256 2201 8400

The red numbers are set to the machine as starting points. Next we start a virtual machine and the output looks like this

2291 7226 4740 8400 ≡ log 169501
2291 7482 6927 5600 ≡ log 169502
2291 7738 9099 1600
2291 7995 1255 6400
2291 8251 3397 0000
2291 8507 5523 2400
2291 8763 7634 3600
2291 9019 9730 3600
2291 9276 1811 2400
2291 9532 3877 0000 ≡ log 169510

and this is how the appropriate row looks like in the table, rounded to eight places:

N.	0	1	2	3	4	5	6	7	8	9	d.
16950	229 16970	17226	17483	17739	17995	18251	18508	18764	19020	19276	256
51	19532	19789	20045	20301	20557	20813	21070	21326	21582	21838	256
52	22094	22351	22607	22863	23119	23375	23631	23888	24144	24400	256
53	24656	24912	25169	25425	25681	25937	26193	26449	26706	26962	256

For every interval, new differences must be calculated and they differ from interval to interval. That is why in the first year when the engine was build, about four human computers did nothing else but calculate differences for the later use with the machine. Since the supporting points have been either recalculated with high precision or taken from Briggs' table or at least compared with Briggs we can say from another point of view Briggs' tables have been enlarged by Bauschinger and Peters, not replaced.

Ten years later Peters used the printed output of Hamann's machine again and produced ten figures tables [7, 5:#199.3]. Why he published the new tables is described best with the words of *Encyclopaedia Britannica*, edition 1911. Under the heading 'Mathematical Tables' the dictionary writes : '*A copy of Vlacq's Arithmetica logarithmica (1628 or 1631), with the errors in numbers, logarithms, and differences corrected, is still the best table for a calculator who has to perform work requiring ten-figure logarithms of numbers, but the book is not easy to procure, and Vega's Thesaurus has the advantage of having log sines, &c., in the same volume.*'

Hamann's machine is regarded to be lost since the Twenties of last century, even the construction drawings could not be found. Only a picture of the machine, shown in fig. 3, the only one we have, and the above shown copy of a small printed sheet of paper survived.

Logarithms with eight places in 1910, with ten places in 1920 – no effort seemed to be sufficient. The next, the last and highest step in table making during the 20th century followed soon.

Alexander John Thompson

During the Twenties of the last century Alexander John Thompson, at that time member of staff in the General Register Office in London, decided to calculate a twenty figures logarithmic table [9]. Between 1924 und 1952, with a longer break during World War II, parts of the table appeared as nine booklets in Pearson's series *Tracts for Computers* [first part 5:#199.4]. In 1911 Karl Pearson (1857 – 1936) founded the world's first University Statistics Department at University College London and established the discipline of mathematical statistics. Origin and purpose of this table are described best with the words of the publisher Cambridge University Press in a summary of the book: *'This work of Dr Thompson's is an attempt to commemorate in a worthy manner the first great table of common logarithms, which was computed by Henry Briggs and published in London in 1624. It brings together the series of nine separate parts, issued between 1924 and 1952 from University College, London, in Karl Pearson's Tracts for Computers series. The main table, which consists of the common logarithms to twenty decimals, of numbers up to 100,000, is accompanied by differences of even order. It is likely to be used chiefly in the computation of other mathematical tables, and will facilitate the work of the large calculating machines now being developed. For these purposes values of 15 to 20 figures are often required. The table is preceded by a very full introduction which describes methods of interpolation and the mode of construction, and provides some useful auxiliary tables.'*

The intended commemoration is explicitly expressed in the addendum to the whole title …Issued by the Department of Statistics, University College, London, to commemorate the Tercentenary of Henry Briggs' publication of the *Arithmetica Logarithmica*, 1624.

Thompson not only commemorates Briggs' first big table three hundred years ago, he also lifts himself to the level of Briggs. When the reader opens the book he finds two title pages side by side. On the left side Briggs' old title page from 1624 is placed and on the right side one sees Thompson's title page in modern letters. Furthermore for his work Thompson composed the Latin name *Logarithmetica Britannica*, derived from the titles of Briggs' tables *Arithmetica Logarithmica* and *Trigonometria Britannica* with the adjective logarithmic here changed to a noun. With respect to his extensive work – twenty figures logarithms for the numbers 10.000 (1) 100.000 – in my opinion he had some rights to do so.

When he started neither new industrial manufactured nor historic difference engines weren't available, so after having worked for a short time with a single calculating machine of type Odhner he decided to build one by himself. Assistance he got from the agent for Triumphator calculating machines in England, whom he thanked for his help in the introduction to his work. This expression of thanks is the only source for us to know that he used Triumphator calculating machines, produced by Triumphator Rechenmaschinenfabrik GmbH in Leipzig, Germany. The only known picture of the composed machine is shown in the introduction to the table (fig. 5).

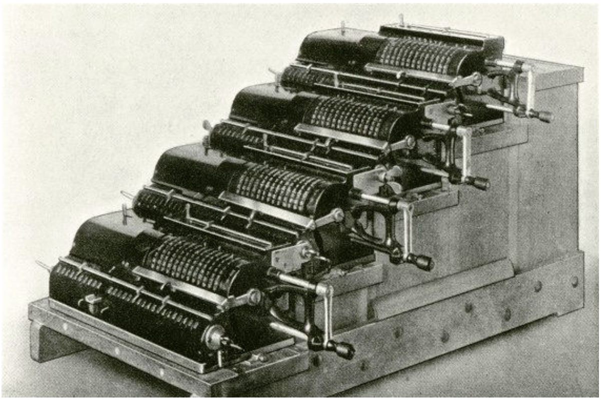


Figure 5 - Thompson's difference engine

Four single machines are arranged on a stepped wooden base. The fifth highest step may lead to the assumption that he thought of a fifth machine. Results are transferred downstairs from a result register to the upper part of the input register of the next lower machine. That is why the single machines are arranged one behind the other and in increasing height. Thompson didn't call his machine a difference engine, he named it with the oppositional expression *integrating and differencing machine* with respect to the fact that the original meaning of to integrate is to sum up and that the machine is used for calculation with differences. In Thompson's opinion his machine is the only one with its peculiar design – and he is right to think so – and therefore he doesn't intend to explain all technical details and procedures how to work with it. If however we follow his explanations more details not mentioned by him can be reconstructed.

If we denote with D1..D4 the differences and their orders and with M4 the highest, with M3 the next lower machine and so on, a calculation with four differences runs as follows:

D4 is set in the input device of M4,
D3 is set in the result register of M4,
D2 is set in the result register of M3,
D1 is set in the result register of M2,
the last function value is set in the result register of M1.

Next we

add D4 to D3 in M4 and transfer D3 to input device of M3,
add D3 to D2 in M3 and transfer D2 to the input device of M2,
add D2 to D1 in M2 and transfer D1 to the input device of M1,
and finally
add D1 in M1 to the last function value.

When Thompson had finished his work in the following decades nobody knew what had happened with his machine. In 2007 I had luck finding Thompson's machine in the cellar of a Statistical Department in London and I asked a friend of mine. a photographer in London, to take some pictures. The machine has retired but is still alive and sometimes is used to demonstrate to the students how logarithms were calculated by grandfather in former times.

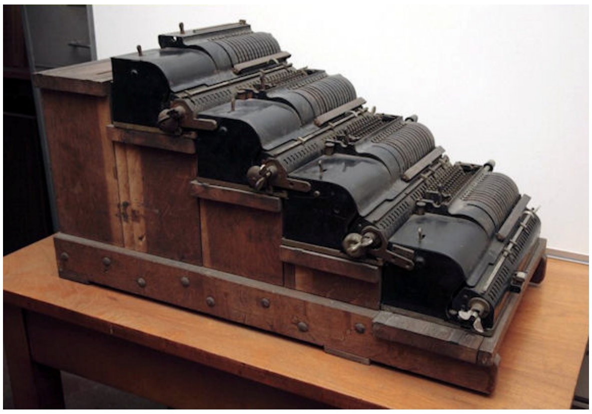


Figure 6.1 - Thompson's difference engine, left side

The photographs I got allow a closer look to the machine.

Fig. 6.1 displays the left side of the machine, fig. 6.2 the transfer unit from the result device of the upper machine to the input device in the lower machine. The result units are locked with a plate, otherwise the transfer mechanism wouldn't work.

Fig. 6.3 shows an input device with thirteen levers. The lettering *Triumphator* on the left side is cut by the zeroing mechanism. This detail is a second indication that they used Triumphator machines with a nine places input and enlarged them to thirteen places. The result device holds eighteen places, but with a fixed result device it only can be used up to thirteen places plus a possible carry.

Figure 6.2 - Thompson's difference engine, the transfer mechanism

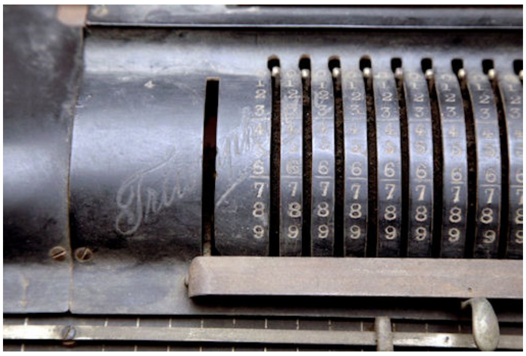


Figure 6.3 - Thompson's difference engine, the input device

To calculate logarithms with twenty figures one needs at least twenty-three or twenty-four figures to avoid errors in rounding. A question arises: how to calculate twenty-three figures with a machine with thirteen input levers? The answer astonishes: Thompson calculated twice, an example will demonstrate how he proceeded.

Assuming based on known values and a difference he has to calculate a new logarithm like in

log(N+1) = –log(N–1) + 2log(N) + d2log(N)

for N = 15455 with

A = log(N–1) = 18904 09079 09009 92819 (actually 4,18904...)

B = log(N) = 18906 90093 99323 73840

C = d2log(N) = –00000 00018 18219 42567

In the first run he works with the ten figures on the right side of all summands, in the second run he processes the left figures in the same summands included the carry from the first run. The following record summarized the whole process.

		2nd run R2	1st run R1
A	–	1890409079	– 0900992819
B	+	1890690093	+ 9932373840
B	+	1890690093	+ 9932373840
C	–	0000000018	– 1821942567
		↰1	
sum		**1890971090**	**17141812294**

We get log15456 = 18909 71090 71418 12294 (actually 4,189097...)

In this example I use twenty figure numbers because I don't know the values with twenty-three or twenty-four figures he really used.

Actually not all logarithms were calculated with differences, abbreviations can save labour. So if log 80.000 to log 100.000 are already known, log 40.000 to log 50.000 may simply derived with the expression log N = log 2N – log 2. On the other side very much effort was necessary to control and minimize possible errors. For that purpose Thompson calculated and used differences up to 10th order.

In a short time it is impossible to explain here all algorithms, formulas or abbreviations Thompson used to calculate differences and logarithm – his original description includes 54 large folio pages – but the two used examples will be enough to demonstrate what a difficult and hard task Thompson undertook. He even bought a monotype keyboard, typed the final results on punched tape for auto-print and compared the results by himself.

N, 15400—15500

N	log N	δ^2 —	δ^4 —
15450	18892 84837 60853 44725+	18 19396 45715+	4573
51	95 65925 26398 56608	9160 95944	72
52	18898 46994 72782 72546	8925 50744	71
53	18901 28046 00241 37741	8690 10116	70
54	04 09079 09009 92819	8454 74057	68
55	06 90093 99323 73840	8219 42567	67
56	09 71090 71418 12294	7984 15644	66
57	12 52069 25528 35105-	7748 93287	65-
58	15 33029 61889 64628	7513 75495-	64
59	18 13971 80737 18657	7278 62267	63

Figure 7 - Small part of Logarithmetica Britannica

Figure 7 shows a small section of *Logarithmetica* with the columns numbers N, logarithms logN, and second and forth differences d^2 and d^4.

Since Thompson based his calculations on Briggs' *Arithmetica*, his work gives an extensive table of errors found there. Another source he used for supporting points is Sharp, 1717 [8, 5:#65.0], who gives logarithms of numbers 1 to 99 with sixty-three figures and of prime numbers 101 to 1097.

Thompson's *Logarithmetica* is an extensive work, placed on the level of Briggs and, when it was finished, some years later followed by desk and pocket calculators, not to speak of electronic calculators, which made it finally useless.

His difference engine remained to be the last machine built for the specific methods of calculations with differences. At the end of the Twenties the commercial market offered machines for more general purposes and that could be used as difference engines too. In relation to commercial machines Leslie John Comrie (1839 – 1950) should be mentioned.

Leslie John Comrie

Being an astronomer and mathematician and member of the Nautical Almanac Office he soon became an expert in all aspects of calculating tables and therefore tested various types of machines [4.1 – 4.5 in a selection]. He neither invented nor built a difference engine, but he investigasted and demonstrated how to use commercial machines for the special purposes of table making.

At the same time when Thompson started his work and built his own machine, Comrie published an article on how to use Brunsviga Dupla for calculations with second differences [4.1]. The Dupla, manufactured by Brunsviga-Maschinenwerke in Braunschweig, Germany, between 1927 and 1930, is not a difference engine, it is a single calculating machine, but with peculiar properties. With it you can add a number from input device to one of the two result registers and transfer the content of both result registers back to the input levers.

Some years later he used a Hollerith (later IBM) accounting equipment for tabulating. For a National accounting machine and a Burroughs Class 2 machine that followed he developed algorithms for calculations with differences too [4.4].

It was Comrie's valuable contribution to show that cheap commercial accounting machines could be used as difference engines and thus he revolutionised the art of table making until the new technology modern computers came into use.

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Sources

Fig. 3: [1] foreword
Fig. 5 & 7: [9]
Fig. 6.1 – 6.3: Photos Dominik Gigler, © Department of Statistical Science, University College, London, with kind permission
All other figures by the author

THE PLANIMETER OF J. GIERER
Invented by Misunderstanding

Stefan Drechsler

Stefan Drechsler graduated from the RWTH Aachen with a major in communication engineering.

As a software engineer in research and development he worked on topics as diverse as room acoustics, numerical simulation of electric and magnetic fields, wave propagation, field-strength prognosis for broadcasters and degaussing of ships.

As a collector of calculation devices he is especially interested in analog computing mechanisms such as planimeters, nomograms etc.

Preface

In the middle of the 19th century, land surveying and cadastral mapping was introduced in most European countries. Fiscal laws required size and value of land areas to be determined authoritatively as a basis for tax equity. All real estate had to be recorded and its extent, value and ownership documented. The need for precise calculation of area especially for taxation purposes led to the appearance of various measuring devices, and a variety of planimeters was invented.

In 1853, the German professor of geodesy, Carl Maximilian von Bauernfeind, published the first general overview of the state of the art of planimetry in which he described the many different devices and their functional principles. At that time, the devices in use ranged from gadgets as simple as harp planimeters, which give only an approximate value of the area, to "real" planimeters that determine the area precisely by tracing a pointer around its perimeter.

Johann Andreas Gierer, a drawing teacher from the Franconian town Fürth, was fascinated by Bauernfeind's article, especially by a device called "Ringmesser" (circle gauge). Since this planimeter was only rudimentarily described by Bauernfeind, Gierer decided to re-invent it. The fruit of his inventive talent was not a simple approximating instrument like the Ringmesser, but a real integrating planimeter incorporating a unique functional principle.

Early Planimeters

The bestiary of planimeters can roughly be divided into two classes: non-integrating planimeters and integrating planimeters.

The first class, non-integrating planimeters, determine the area in question either by decomposing it into parts whose area can easily be calculated (e. g. triangles), or by approximating the area with a number of small calculable "finite elements" and adding up their sizes. The simplest (but inexact) method to approximate the area of an irregularly shaped figure is to cover it with a grid of equal-sized rectangles and to count them. The same result can be achieved more easily by dividing the figure into stripes of equal width and adding up their lengths. This is the principle of the various forms of harp planimeters.

On the other hand an integrating planimeter determines the area exactly via integral calculus. The first integrating planimeter was invented in 1814 by the Bavarian land surveyor Johann Martin Hermann. Hermann created a multiplying gear by combining a recording wheel with a spinning cone. A carriage, in which the cone is mounted, moves along the x-axis and causes the cone to rotate. The recording wheel can be moved parallel to the y-axis thus rotating the faster the nearer it is to the cones base. The recorded value is proportional to the distance covered along the x-axis, as well as to the position of the wheel on the cone, which is the y-value of the function traced by a cursor steering the wheel.

About 10 years later, the Italian mathematician and Professor Tito Gonella, in ignorance of Hermann's ideas, re-invented the cone-wheel mechanism. What is more, he realised that the working of the mechanism did not depend on the opening angle of the cone. It could be done as well with an angle as wide as 180°, leading to the replacement of the cone by a disc and the invention of the disc-wheel integrating mechanism.

The cone-wheel-mechanism experienced its third re-invention in 1827 by the Swiss inventor Johannes Oppikofer, and its fourth re-invention by John Sang in 1851.

Bauernfeind's article

The German geodesist Carl Maximilian von Bauernfeind (28.11.1818 - 3.8.1894) can be regarded as one of the founders of geodesy as a modern science. In his article "*Die Planimeter von Ernst, Wetli und Hansen, welche den Flächeninhalt ebener Figuren durch das Umfahren des Umfangs angeben*", Bauernfeind describes the state of the art of planimetry as far as it is known to him. In particular, the planimeters of Hermann and Gonella were not yet known to Bauernfeind in 1853 when the article was published. The article specifies the various forms of non-integrating and integrating planimeters and presents the underlying mathematical theory.

Bauernfeind limits himself to short notes concerning non-integrating planimeters, such as the method of counting squares using graph paper, or the Oldendorp planimeter, which measures stripes. One of the described non-integrating planimeters is the so called "*Westfeld'sche Ringmesser*", Westfeld's circle gauge. On the 47 pages of Bauernfeind's article only a few lines mention this Ringmesser, and there is only one sentence about its functional principle. But since a description of the Ringmesser had already been published in 1826, Bauernfeind preferred to direct the reader's attention to the newer, integrating planimeters.

The Planimeters of Ernst, Wetli and Hansen

As the title implies, the major part of Bauernfeinds article treats the planimeters of Ernst, Wetli and Hansen. Because these planimeters make use of two independent movements orthogonal to each other, their type is also called orthogonal planimeter.

Heinrich Rudolf Ernst came in contact with Oppikofers planimeter in Switzerland, where he was charged with finishing its construction in 1828 after the death of the original instrument maker [Fisc2002]. Later, in 1835 in Paris, he constructed his own planimeter (Fig. 1), which was based on the same principle, the cone-wheel-mechanism.

In 1849, Caspar Wetli from Switzerland designed a coordinate planimeter which used a disc-wheel-gear to calculate the area. This is the first occurence of the disc-wheel-mechanism after Gonellas planimeter from 1823, which was obviously unknown to Wetli. Nevertheless, in his article Bauernfeind points out the fact that the basic principle of Wetlis planimeter is the same as that of Ernst's, and he regards Wetli's device not as an independent invention but an improvement of the Ernst type.

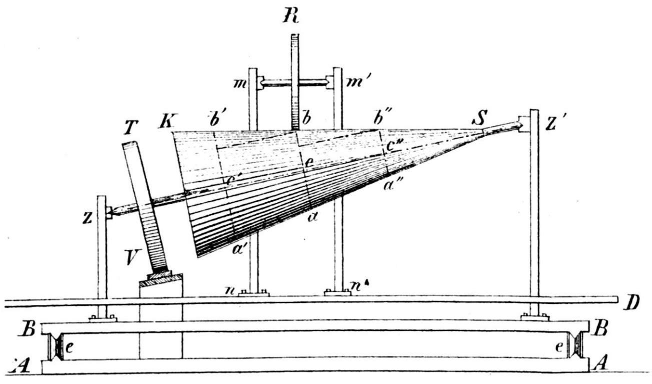


Fig. 1 - The Ernst planimeter [Baue1853]

The third orthogonal planimeter that Bauernfeind mentions in the title of his article and gives an in-depth treatment to, was constructed in 1851 by the German astronomer Peter Andreas Hansen. Hansen's planimeter (Fig. 2), is based on Wetli's disc-wheel-mechanism with several practical improvements.

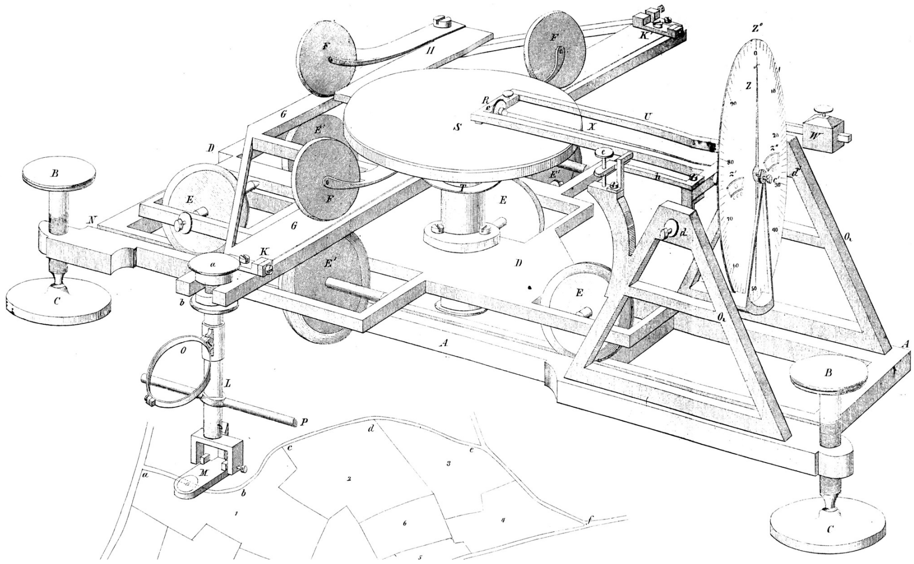


Fig. 2 - The Hansen planimeter [Baue1853]

How does the Orthogonal Coordinate Planimeter work?

The most basic recipe for measuring an area is: Take a small rectangle with a known area and count how many of those rectangles fit into the region of which you want to know the area. That is what you do when estimating the area with the use of graph paper. This type of non-integrating planimeter works according to the formula:

$$A = \sum_i \Delta x \Delta y$$

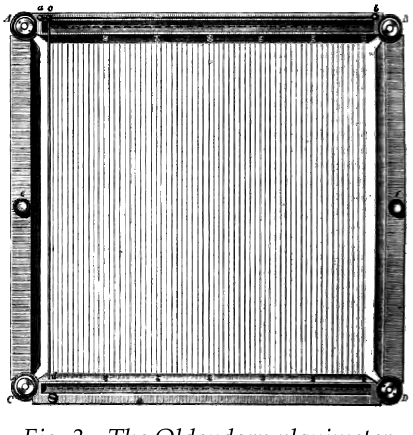


Fig. 3 - The Oldendorp planimeter measures an area by summing up the lengths of parallel stripes [Hunä1864]

Of course this is only an approximation, but you can get a better result by decreasing the size of the rectangles. The best result, i. e. an exact measurement of the area, will be achieved when the size of the rectangles becomes infinitely small:

$$A = \int \mathrm{d}x \, \mathrm{d}y$$

There is no obvious way to handle infinitely small areas in practice, and even counting small rectangles is too much work. To speed things up, you can use a trick. Arrange all the small rectangles in parallel rows. Instead of counting the small rectangles of a single row, you can measure the length of this stripe. One of this type of stripe planimeters, the Oldendorp planimeter, was also mentioned by Bauernfeind.

The Oldendorp planimeter is a tool for dividing an area into stripes. The lengths of these stripes can be added with a pair of compasses, according to the formula:

$$A = \sum_i y_i \Delta x$$

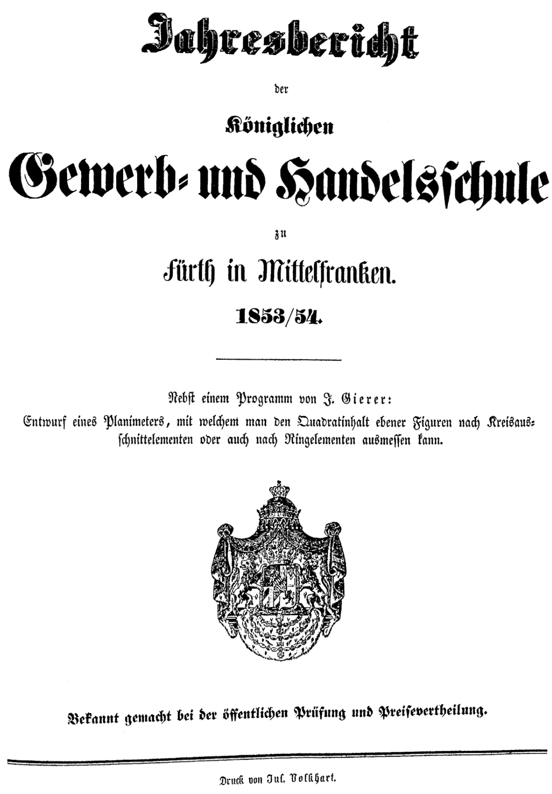
Again, this is an approximation. To obtain the exact area, the width of the stripes must be made infinitely small:

$$A = \int y \, \mathrm{d}x$$

A mechanism working according to this formula will have to measure the lengths of the stripes, multiply them by the infinitesimally small width and to sum them up. There is a quite common device that determines the sum of infinitesimal magnitudes. We all know the mileage-counter in a car, which counts the distance covered of a wheel on a surface. For measuring areas instead of mileages we need to connect the "mileage"-counter with the measurement of the stripe lengths in a manner that the counter counts faster, when the stripe is longer. That means we need a "car" with a "mileage"-counter and a continuous gear box. As the continuous gear box one can use a cone-wheel-mechanism or a disc-wheel mechanism. The latter is just a very obtuse cone, so in theory both are the same.

The Ernst planimeter with its cone-wheel-mechanism and the Hansen planimeter with its disc-wheel-mechanism are both based on the same theory.

Bauernfeind's planimeter article was not the first, but it was one of the more important and widespread articles read by many people. One of them was Johann Andreas Gierer.


Jahresbericht
der
Königlichen
Gewerb- und Handelsschule
zu
Fürth in Mittelfranken.
1853/54.

Nebst einem Programm von J. Gierer:
Entwurf eines Planimeters, mit welchem man den Quadratinhalt ebener Figuren nach Kreisausschnittelementen oder auch nach Ringelementen ausmessen kann.

Bekannt gemacht bei der öffentlichen Prüfung und Preisevertheilung.

Druck von Jul. Volkhart.

Fig. 4 - Gierer's publication on his planimeter [Gier1824]

Johann Andreas Gierer

Not much is known about the life of Johann Andreas Gierer (15.6.1798 - 2.5.1864). He was a teacher for draftsmanship at the "Gewerb- und Handelsschule", the vocational school, in Fürth, a town next to Nürnberg in the kingdom of Bavaria. This school was founded in 1833, and first used rooms in the inn "Zum Roten Roß", but moved later to another building. Gierer was one of their first teachers. The area around Fürth and Nürnberg was at that time an booming industrial region. In 1835, Germany's first railway was built to connect both towns. It was a time when drawing was very close to both drafting and painting. Consequently, Gierer tought both freehand drawing and technical drawing. [Vett1856] [Vett1864] [Fron1887] [Schw1968]

Gierer's Intention

Gierer was a member of the "Polytechnischer Verein für das Königreich Bayern", the Polytechnical Society for the Kingdom of Bavaria. He was a regular reader of the "Kunst- und Gewerbeblatt", the journal of that society. It was the issues of March and April 1853 of this journal where Bauernfeind first published his article [Bau1853]. Through this article Gierer was introduced to planimeters, mainly orthogonal integrating planimeters. He became curious about variants of these planimeters, especially about Westfeld's Ringmesser. Gierer had an idea:

"… [Westfelds Ringmesser] gab, da ich diese Beschreibung nicht besitze, Veranlassung zu untersuchen, ob es mir nicht möglich wäre, einen Planimeter zu entwerfen, der (…) nach Elementen von Ringstücken oder Kreisausschnitten mißt." ([Westfelds Ringmesser], since I do not have its description, induced me

to examine, if it where not possible, to design a planimeter, which measures using elements of rings or sectors of a circle.) [Gier1854]

Gierer tried to reconstruct the Ringmesser of Westfeld on this sparse information about that device *"it is based on something circular"*, but retaining the assumption, that it had the same purpose as an orthogonal integrating planimeter, which is described in detail in that article.

Instead of using rectangular elements $\Delta x \Delta y$, Gierer intended to use ring elements $\Delta r \Delta b$, where Δr is the difference of the inner and outer radius of a ring, and Δb is the length of the arc of this ring element. In polar coordinates, we prefer to use angles instead of arc lengths for the small area element:

$$A = \sum_i \Delta r \, r_i \, \Delta\varphi$$

Or, for an exact rather than an approximate solution:

$$A = \int r \, \mathrm{d}r \, \mathrm{d}\varphi$$

As in the case to stripes instead of rectangles, we can save a lot of work by summing up sectors instead of ring elements. We have to keep in mind that a sector with a very small angle is more like a triangle than a rectangle. Therefore we need a factor of ½ in the following formula:

$$A = \sum_i \frac{1}{2} r_i^2 \, \Delta\varphi$$

Thereby, we gain as exact formula:

$$A = \frac{1}{2} \int r^2 \mathrm{d}\varphi$$

That is what Gierer intended to use as the underlying theory for his planimeter. Instead of the length of a stripe, he measures the radius. Since the radius is a length, too, this is not difficult to do. Again, Gierer uses a cone-wheel-"milage"-counter to add up these infinitesimally small magnitudes. But there is an r^2 in the formula. That means Gierer had to invent a mechanism to square a magnitude.

The Squaring Mechanism

As described above, Gierer needed a mechanism with a radius as input and another length as output, the square of the input. Being a draftsman, Gierer started by drawing the input magnitude on the right side and the corresponding output magnitude on the left side as shown in fig. 5. A mechanism consisting of only two linkages is very simple, and that is what Gierer used: two linkages. He used one end of the first linkage as input and one end of the other linkage as output. The other ends of the both linkages were connected to each other with a hinge. If this mechanism is to give a defined output for a defined input, the connection point cannot be just anywhere but must move along a defined curve. With the known input and output, Gierer was able to fix the position of the intermediate connection by drawing the linkages for some input and output values. (In fact, Gierer drew only the endpoints of the linkages but in fig. 5 the linkages are shown.)

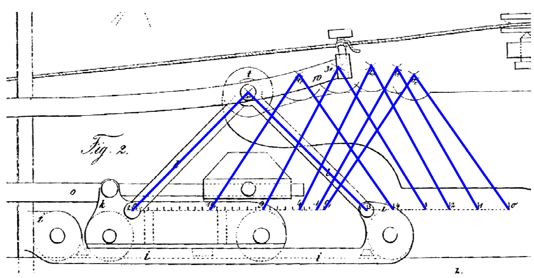


Fig. 5 - The linkage mechanism for squaring a length and its construction [Gier1854]

The required curve for the intermediade linkage connection point was interpolated by drawing a continuous line through the constructed points. To force the hinge to move along this curve, Gierer used an additional roll whose axis coincided with the hinge axis. That means that the center of the roll moves along the curve. That is achieved by rolling the roll along a path different from the curve but dependent on it.

The Blueprint

Gierer published an article on his findings in 1854. It included a drawing consisting two parts: a side view (Fig. 6) and a top view (Fig. 7) [Gier1854].

The planimeter consists of a base ring, on which three rollers revolve around the rings centre. These rollers support the framework and allow the whole device to turn. The cone of the cone-wheel-mechanism is mounted coaxially to one of these rollers, so the cone will rotate when the framework turns.

On the framework two carts can glide radially along two rails. These two carts are connected by the squaring mechanism. For the input magnitude a rod is fixed to the first cart and bears a cursor and a magnifying glass.

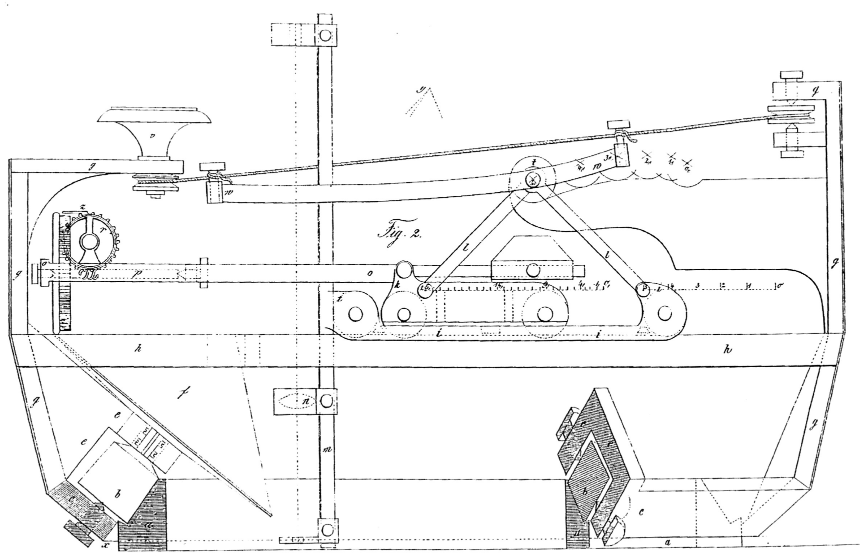


Fig. 6 - Side view of the Gierer planimeter [Gier1854]

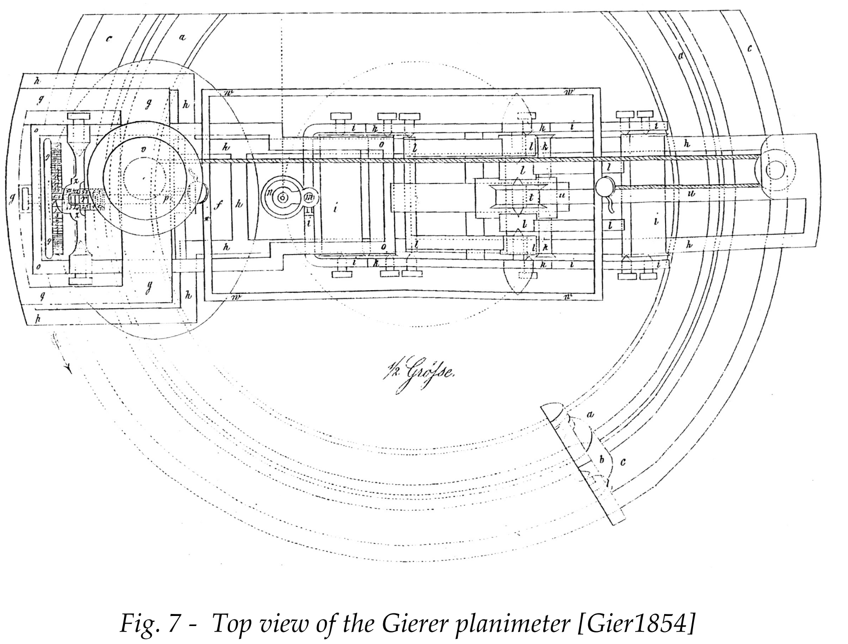


Fig. 7 - Top view of the Gierer planimeter [Gier1854]

When the device is used, the border of an area is traced with the cursor. Following the cursor, the framework turns around and the cart glides back and forth according to the radial distance. The two linkages of the squaring mechanism cause the second cart to move in a radial direction proportionally to the square of the radial distance. This movement is transferred to the wheel of the cone-wheel-mechanism (Fig. 9). This wheel is divided into one hundred sections. Each turn of the wheel is counted with a worm gear, and a second wheel that is divided into twenty five sections.

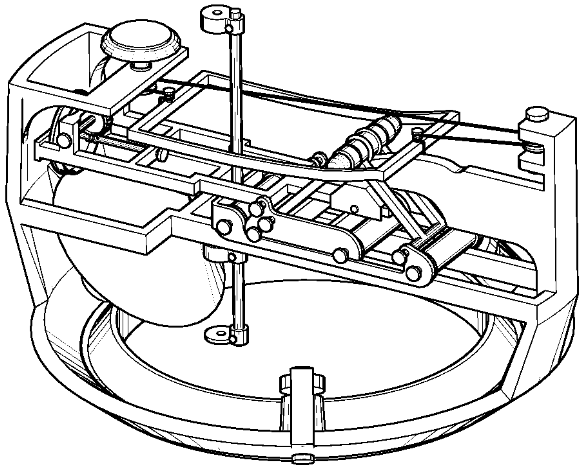


Fig. 8 - Perspective view of the Gierer planimeter

Gierer's design does not propose to move the cursor directly. The cursor is moved by the framework in a circumferential direction. In radial direction the cursor and the carts are shifted by moving the hinge of the squaring mechanism. For this purpose there is a second smaller frame connected to the hinge, that can be handled with a wire by turning a knob fixed to the framework (Fig. 10). The path for the hinge of the squaring mechanism is also a part of the framework.

Gierer's planimeter

When measuring the area of a region, the planimeter (Fig. 8) is placed upon the map with the region under the planimeter. All the movements of the planimeter are controlled with the knob on the framework. By turning and moving the knob, the cursor is placed at a starting point at the border of the region. The operator has to note the reading of the counter mechanism. Using only knob operations, the boundary of the area is traced with the cursor until the starting point is reached again. Here the reading of the counter is noted again. The difference of the two readings is the area of the region.

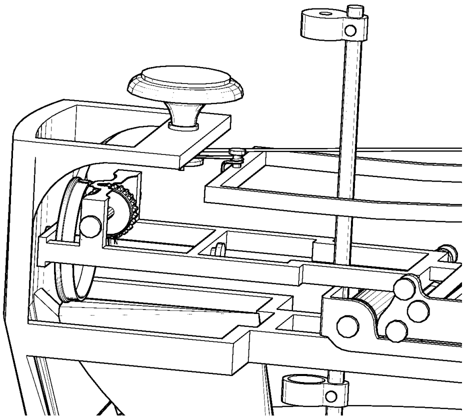


Fig. 9 - The cone-disc-mechanism of the Gierer planimeter

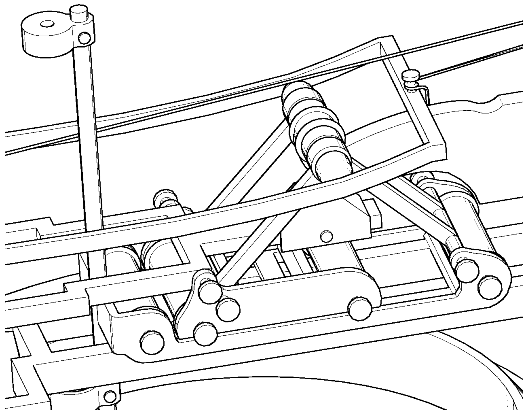


Fig. 10 - The squaring mechanism of the Gierer planimeter

Misunderstanding as the mother of invention

We have seen what Gierer did to reconstruct Westfeld's Ringmesser without having access to Westfeld's description. Now let us take a closer look at that description. In 1826, Westfeld published a few pages [West1826] describing the device shown in fig. 11. It looks quite similar to a pair of compasses, but instead of a spike there is a "mileage"-counter.

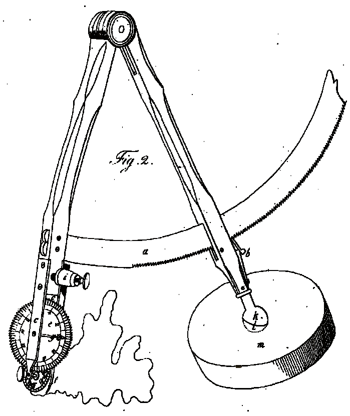


Fig. 11 - Westfeld's Ringmesser [West1826]

The counter measures the arc length tangential direction and not in the radius direction. That means that it measures the arc length of a section of a ring.

Westfeld did not use small ring elements $\Delta r\ r\ \Delta\varphi$, but the formula:

$$A = \sum_i r\varphi_i \Delta r$$

where $r\ \varphi_{\mathrm{i}}$ is the arc length of the ring sections. Westfeld did not even use infinitesimally thin rings according to the formula:

$$A = \int r\ \varphi\ \mathrm{d}r$$

So Westfeld's Ringmesser is only capable of obtainig approximate values for the area. Evidently, Gierer used a completely different approach from Westfeld's for measuring the area a region. Instead of re-inventing the Ringmesser, Gierer invented an entirely new device with a much more complicate mechanism.

Should we blame Gierer for misunderstanding what Bauernfeind wrote about Westfeld? Definitely not. Other readers also misunderstood the available sparse information but did not come up with an original solution:

Baxandall for example, for the catalogue of the collections in the London science museum, writes: "About 1856 a planimeter of the polar type, in which the recording wheel, kept in the required position by means of a guiding curve, rolled on the paper, was designed by Gierer of Fürth."[Baxa1975] "About 1856" probably refers to an article which was published by Jacob Amsler in that year [Amsl1856A].

Amsler decribes the Gierer planimeter correctly, but together with two other devices from Decher and Bouniakovsky. So the recording wheel rolling on the paper mentioned by Baxandall is from Decher or Bouniakovsky but not a feature of Gierers planimeter.

In 1911, Willers describes Westfeld's Ringmesser correctly, but claims that Gierer's planimeter uses the same principle [Will1911], which is wrong. However it is exactly what Gierer claimed to have done.

To complicate things further: Gierer's "polar coordinate planimeter" is not to be confused with the "polar planimeter" that came into use a few years later.

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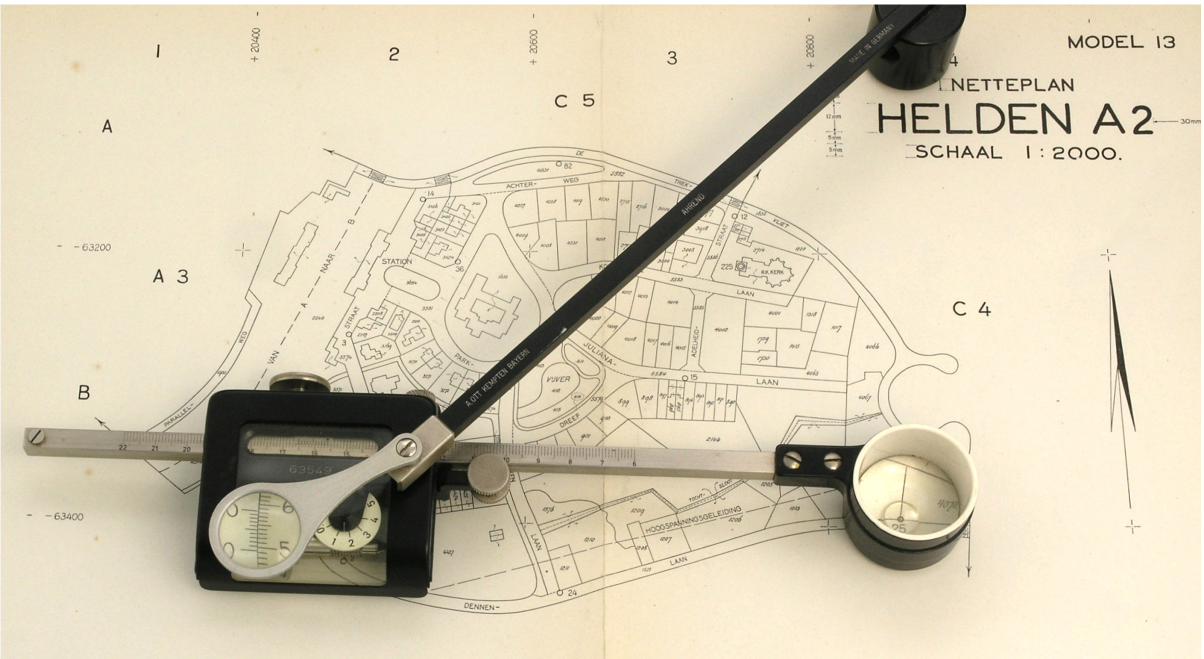
Note by the Editor

The last paragraph in the Gierer paper above mentions the more familiar polar planimeter that became popular in cadastral organizations world-wide. It was invented by Amsler in 1854.

The picture below shows the set-up of the polar planimeter after having run the contours of plot nr 4070 on a cadastral map, resulting in a reading of 1493. This planimeter was produced by A. Ott in Kempten Bayern since the 1940s, and was marketed in the Netherlands by Ahrend.



COMPUTING LINKAGES

Andries de Man

Andries de Man studied applied physics at the Eindhoven University of Technology and spent 10 years on computational chemistry in the Netherlands, Germany and the USA. Currently he is developing e-learning and web applications for the Leiden University Medical Center.

As a collector, he is mainly interested in mechanical calculators and planimeters. After maintaining a website on "Original Documents on the History of Calculators", he is now co-editor of the online "Rechnerlexikon".

Summary

Analog calculating machines usually contain lots of gears (differentials), cams, ball-and-disc integrators and rack-and-pinions. But would it be possible to construct such calculating machines only using hinged rods? In the first instance, one would think only linear functions could be represented by such a mechanism but that is not true.
This presentation describes "computing linkages" and the work of Antonin Svoboda on their systematic development.

Introduction

Analog calculating machines can immediately present the results of a calculation on a continuous scale, in contrast to digital calculators that perform the calculation step by step, and present them in a "rounded-off" fashion. Unlike slide rules, some analog calculating machines can be integrated in a mechanical sensor-actuator system, so there is no need for a human hand to set up the calculation and read the result. Most mechanical analog calculating machines contain gears, cams and cam followers, rack and pinions, and ball-and-disk integrators. Some of them contain mechanisms purely consisting of linked rods, which we will call bar-linkage-mechanisms. Bar-linkage mechanisms can be used as "stand alone" calculators as well. Pure bar linkages mechanisms are only built from solid bodies that are hinged to each other or to a fixed base. In practical applications, these mechanisms also contain tracks or curved slots along which a pivot of a bar can slide.

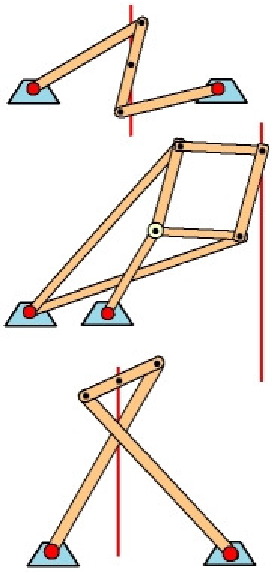


Figure 1 – Linear movement mechanisms of Watt, Peaucellier and Chebyshev

Bar-linkage mechanisms have attracted the attention of mathematicians and engineers for centuries, mainly for their kinematic properties. People like James Watt, Charles-Nicolas Peaucellier and Pafnuty Chebyshev designed linkages for linear movements (figure 1). Watt's and Chebyshev's mechanisms approximate a straight line, but Peaucellier's mechanism gives an exact straight line segment. Bar linkages have also been designed to draw a variety of curves, including ellipses.

The advantages of bar-linkage computers relative to "geared" computers are [1]:

- Bar-linkages require less space
- Bar-linkages have less friction
- Bar-linkages have small inertia
- Bar-linkages have a stable performance
- It is possible to approximate some complicated functions with a simple bar linkage
- Bar-linkages are easy to combine into complex systems
- Bar-linkages are cheap

Disadvantages are:

- Bar-linkages usually have a structural error
- Not all mathematical functions can be represented by bar-linkages
- Complexity of bar-linkages increases with increasing accuracy
- Bar-linkages are difficult to design
- The travel of the bar-linkage mechanism is limited, which affects its use as part of an automated system. Mechanical errors, like backlash and elasticity, should be reduced by careful construction

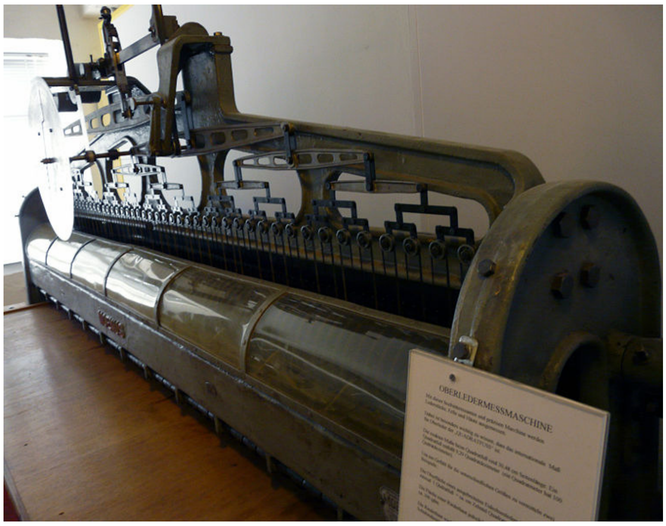


Figure 2 – Leather measuring machine [2]

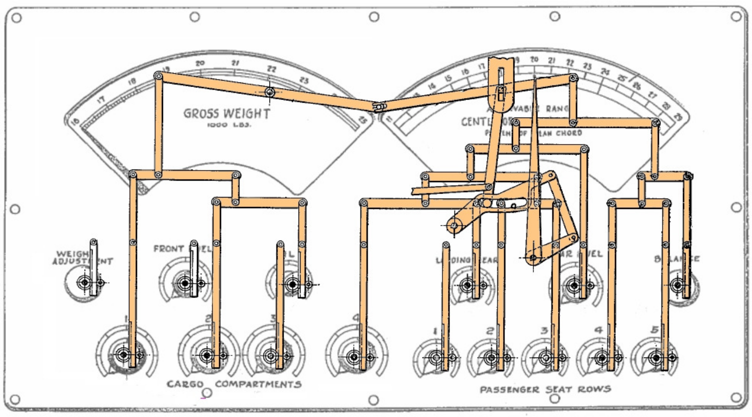


Figure 3 – The center-of-mass section of Imm's balance computer

Adding

A bar-linkage mechanism can be used as an adder, for instance by a construction similar to the pole attachments used for a team of horses. This mechanism has been applied in a machine for measuring the surface area of leather (figure 2).

Adding, multiplying and dividing

In a balance computer patented by L.W. Imm [3] a large number of bar linkages is used to add the weights of loads in different compartments of an aircraft, and to calculate the combined center of mass. The weights are represented by sliding bars that are set through a rack and pinion by turning a knob (figure 3). This briefcase-size device was made by the Librascope Company for a.o. the Lockheed PV-1, Douglas DC-3 and Lockheed "14". Imm also developed a bar-linkage computer for aircraft power vs. fuel consumption [4].

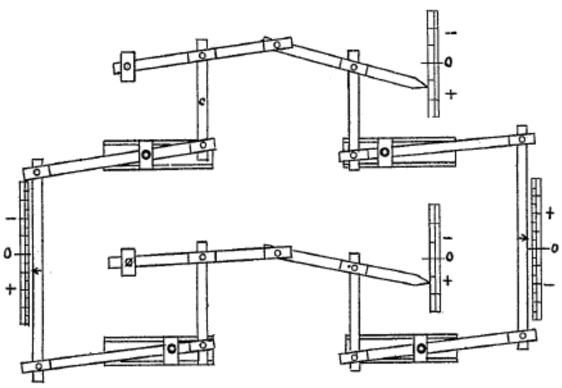


Figure 4 – Spilker's linear equation solver

A standalone bar-linkage mechanism to solve linear equations was patented [5] by Arnold Spilker. The mechanism shown in figure 4 solves two linear equations in 2 unknowns

$\alpha_{11} \cdot x_1 + \alpha_{12} \cdot x_1 = \beta_1$

$\alpha_{21} \cdot x_2 + \alpha_{22} \cdot x_2 = \beta_2$

but can be easily extended for a larger number of equations and unknowns.

The coefficients α_{ij} of these equations are set by adjusting the position of the "central" pivot of a bar, thus dividing the bar in two sections. After the pivots are fixed on the bars, the pivots can move on a horizontal slide. The mechanism has to be adjusted for each new set of α_{ij}'s and it would be difficult to incorporate it in an automated system which varies α_{ij}'s.

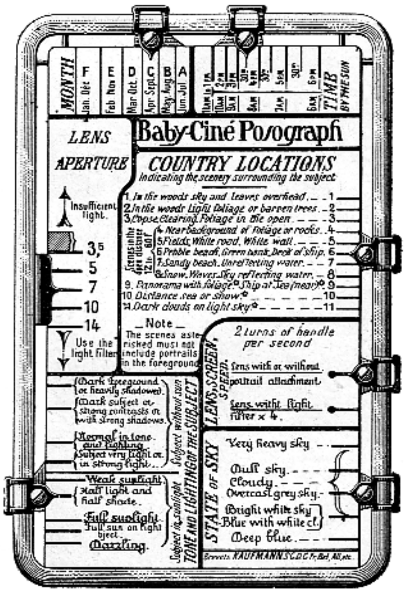


Figure 5 – The Posograph

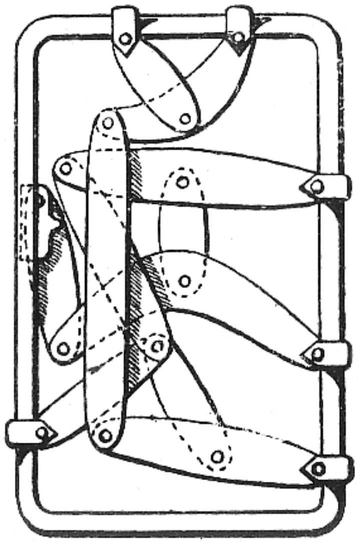


Figure 6 – The Posograph mechanism

Nomograms

If we allow the result scales of the computer to be non-linear, a bar-linkage can mechanise a nomogram. A pretty example is the Posograph (figure 5) patented [6] by Auguste-Robert Kaufmann in 1922. This device represents a relation between 6 inputs and 1 output variable, and was made in different versions for photo-graphic and cinematographic calculations. Its mechanism,

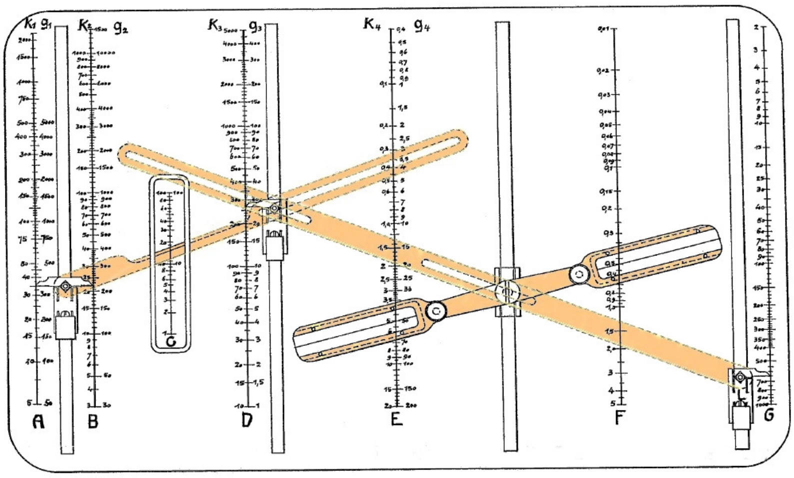


Figure 7 – Bloch's Schnellrechner

which was proudly displayed in its instruction book, is shown in figure 6. Note that most of the scales are categorical. The physics behind them is non-linear.

The Bloch Schnellrechner (figure 7), which also mechanises a nomogram with non-linear scales [7], is strictly speaking not a bar-linkage calculator because it uses rods provided with slots in which the connecting pins slide, instead of fixed hinges.

Consul, the Educated Monkey (figure 8), and similar educational toys, are pure linkages. The central slotted bar is not mathematically necessary [8]. For simplicity, the monkey has discrete "scales", but the result could be represented by a grid-like graph if we discard the "square number" option at the far right.

Figure 8 – Consul, the Educated Monkey

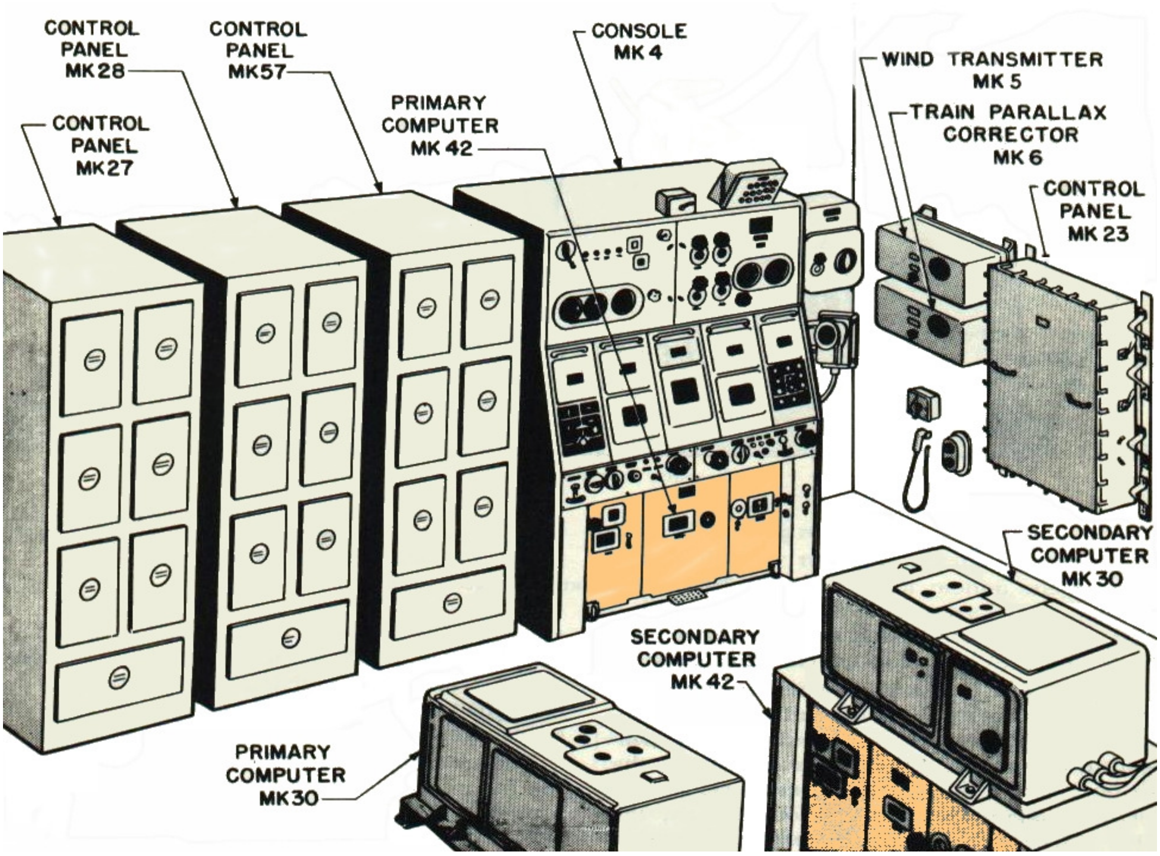


Figure 9 – Mark 56 fire control system with two Mark 42 ballistics computers [14]

Antonin Svoboda

During the Second World War, Antonin Svoboda developed methods for designing bar linkage computers, which were published after the war in the ultimate book on linkage calculators: "Computing mechanisms and linkages".

Svoboda was born on October 14, 1907 in Prague [9]. He earned a degree in electrical engineering from the Czech Institute of Technology in 1931, and a PhD in 1936. During his service in the Czech army the following two years, he helped to design an analog anti-aircraft gun fire control system [10] based on a differential analyser [9]. At the beginning of the Second World War he moved to Paris with his colleague Vladimir Vand [11] and worked for SAGEM (Société d'Application General d'Electricité Mécanique). Later, in 1941, he went to the USA, at first working for the ABAX Corporation in New York, designing an anti-aircraft control for the 40 mm Bofors gun [10,12]. In 1943 he started working at the Radiation Laboratory of the Massachusetts Institute of Technology. The Radiation Laboratory was established in 1940 to develop radar systems. By the end of the war, it had 3900 employees [13]. Svoboda was again involved in the

Figure 10 – Svoboda and the ballistics-computer [9]

development of gun fire control systems, and contributed to the Mark 42 ballistics computer of the Mark 56 anti-aircraft defence system [10]. The Mark 56 consisted of a radar set and a huge amount of electronic and electromechanical controlling and computing units, among which two Mark 42 ballistics computers, to allow for two types of guns to be aimed at the same target. The Mark 42 had five mechanical inputs, one by hand (initial velocity) and the others by servo's. The results, projectile time of flight, super-elevation, drift, range rate, and fuse time, were converted into electrical analog form by rotating potentiometers. The primary ballistics unit weighed 290 kg, the secondary one 250 kg [14,15]. The unit was produced by the Librascope Company. When the British adapted the Mark 56 for their own MRS 3 system, they replaced the Mark 42 computer by a "geared" electro-mechanical one [15].

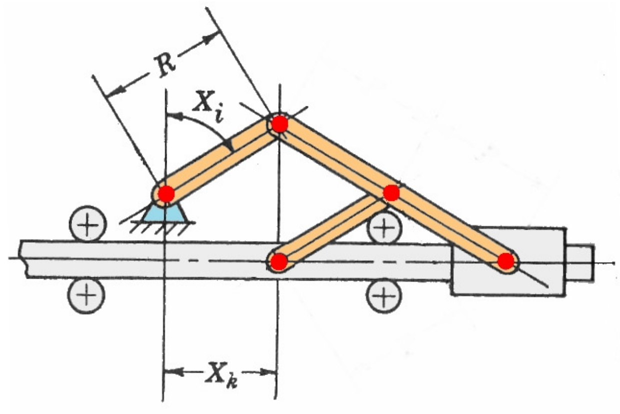


Figure 11 – Ideal harmonic transformer

After the war the Radiation Laboratory closed but some of the scientists were invited to contribute a volume to the "M.I.T. Radiation Laboratory Series". Most books dealt with electronics, but the Svoboda's contribution was purely mechanical: "Computing mechanisms and linkages". In 1946 he returned to Czechoslovakia and worked on relay computers. He went back to the USA in 1964 and became professor of computer sciences at the University of California in Los Angeles. Svoboda died on May 18, 1980.

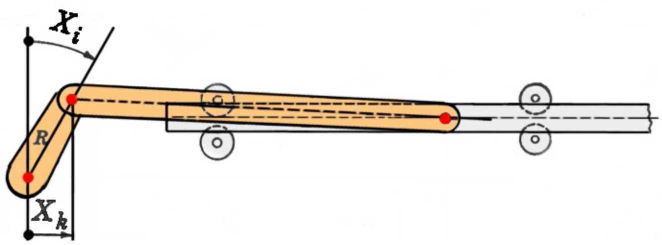


Figure 12 – Non-ideal harmonic transformer

Function generators

In his book, Svoboda describes various kinds of elementary bar-linkages:

The ideal harmonic transformer has as input an angle X_i and as output a displacement X_k, with $X_k = R \sin X_i$ (figure 11).

The non-ideal harmonic transformer has as input an angle X_i and as output a displacement X_k, with $X_k = R \sin X_i + E(X_i)$, where $E(X_i)$ is a deviation from the harmonic transformation (figure 12). It is this deviation which can be used to make the harmonic transformer approximate another function in a limited domain, for instance $X_k = R \tan X_i$ for $0° < X_i < 50°$. Svoboda gives extensive tables to help fitting a harmonic transformer to the desired function. Note that in the ideal harmonic transformer (figure 11), a half-Peaucellier movement is used to achieve a pure parallel motion, an "infinite bar", linked to the rotating bar whereas in the non-ideal harmonic transformer (figure 12) a short bar links the rotating bar to the slider.

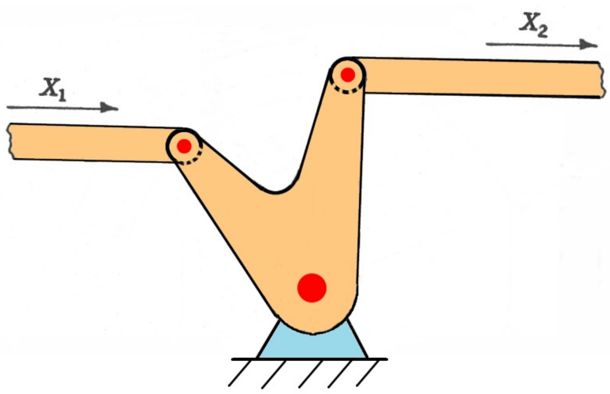


Figure 13 – Ideal double harmonic transformer

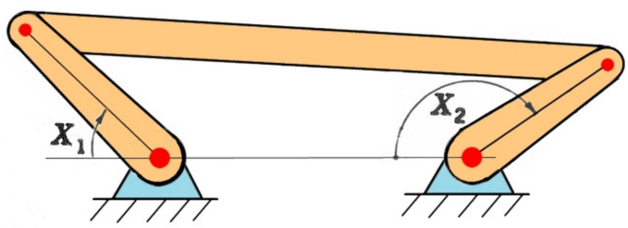


Figure 14 – Three-bar linkage

Having different kinds of input and output (angle vs. displacement) can complicate the integration of this mechanism into a complex calculator. The solution is to add another linkage.

The double harmonic transformer (figure 13) transforms a displacement into another displacement. Again, one can distinguish ideal and non-ideal harmonic transformers. For the design of such a transformer, the tables for the single harmonic are used in combination with graphs to find matching pairs of transformers for a given function. The design process is iterative, and convergence is not guaranteed.

A three-bar linkage (figure 14) has an angular input and output. Svoboda presents two methods to design such linkages: a nomographic one, using a single nomogram for all purposes, and a geometrical one, using two charts that have to be drawn from scratch for each problem.

Using a double three-bar linkage, Svoboda was able to make a logarithm-generator with evenly spaced input and output scales (figure 15) for $1 \le X_i \le 50$ with a maximum error of 0.003 [16].

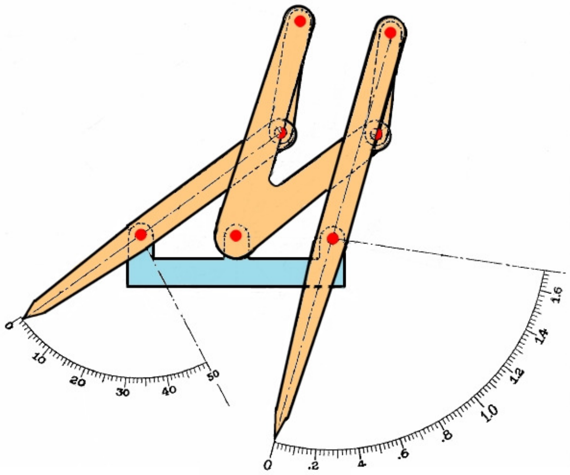


Figure 15 – Double 3-bar linkage for log(x)

Bar linkages with two inputs

A common example of a bar linkage with two inputs is the multiplier. Pure bar linkage mechanisms cannot perform exact multiplications with two variable multiplicands, but Svoboda presents a multiplier that is pretty accurate and can handle positive and negative multiplicands (figure 16). In his design method, Svoboda starts with a contour-graph of the output vs. the inputs. Then he performs a geometrical transformation that approximates the two-dimensional contours by a single output scale. Usually, the resulting input and output scales are curved. Another transformation, mapping the two input scales upon each other, could result in the grid of the Educated Monkey.

As an example of another two-input bar linkage Svoboda discusses the step-by-step design of a simple ballistics computer that calculates gun elevation from ground range and relative altitude of the target without aerodynamic corrections.

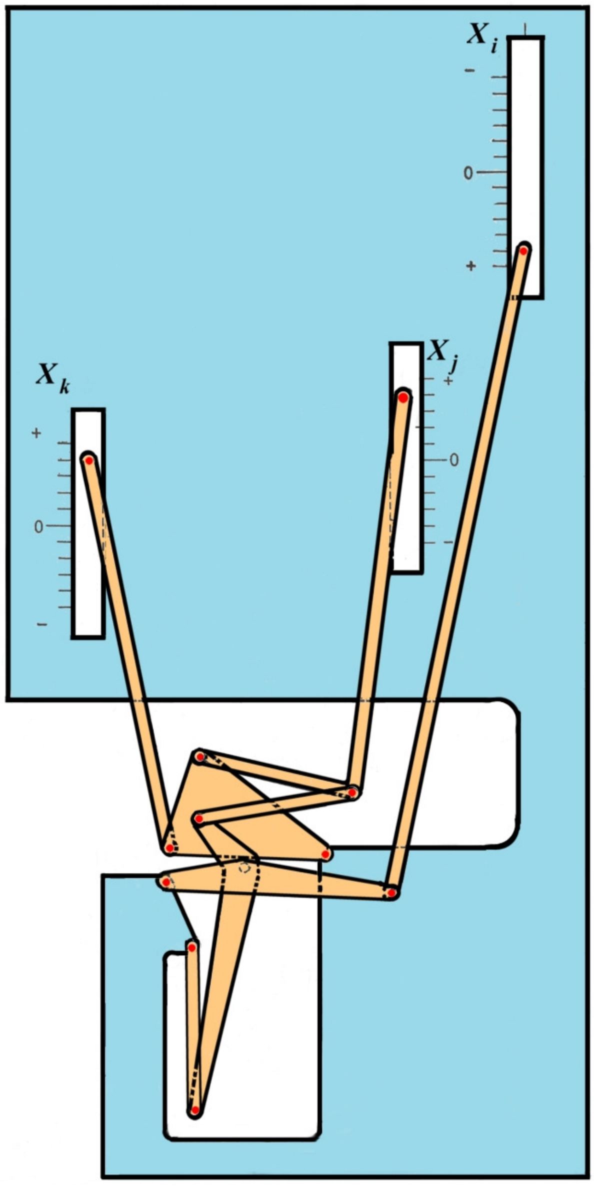


Figure 16 – Multiplier: $X_i = X_j \times X_k$

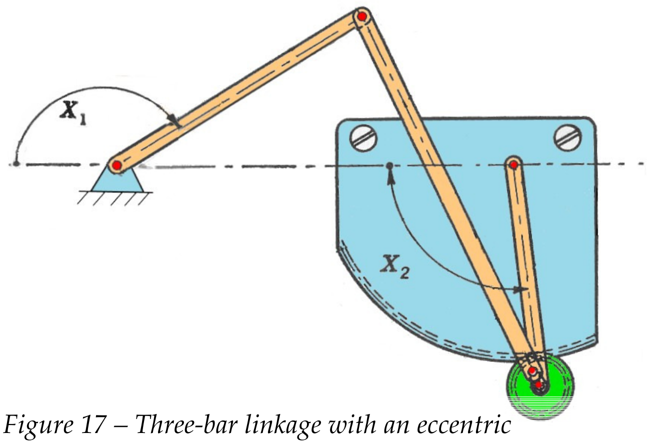


Figure 17 – Three-bar linkage with an eccentric

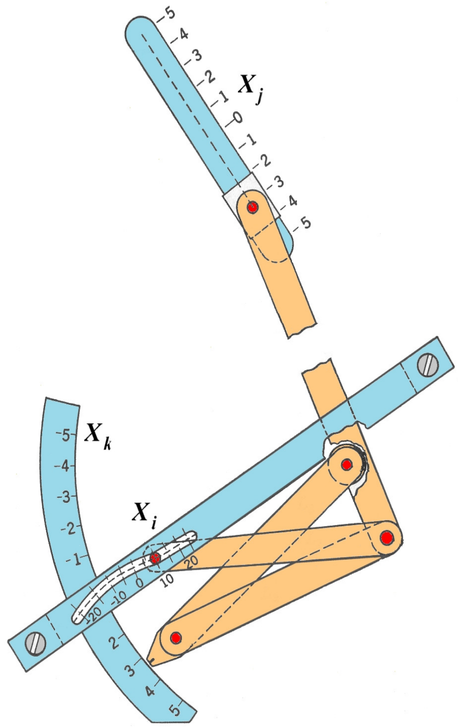


Figure 18 – Multiplier with curved scale

Tweaking

There are several methods to improve bar linkages by adding new types of constructions.

One of them is replacing hinges by eccentric hinges (figure 17), which is typically done for the output link to minimize the structural error. Another method is the use of slots in which pivot slide. Figure 18 shows a multiplier in which the output scale is curved. This is an obvious disadvantage, as is the fact that one input scale is a line segment and the other a circle segment. By adding transformer linkages to the inputs and outputs one can get a calculator with linear scales, like the multiplier previously shown in figure 16.

Fire control computers

The use of bar-linkages in complex calculators took off during the First World War and continued during the interbellum [17]. These calculators were part of gun fire control systems, especially for naval and anti-aircraft guns. Mechanical gun fire computers were still used in the 1970's [17].

An early example is a torpedo director patented in 1893 by Walter Gordon Wilson [18] (figure 19). Wilson is well known as the designer of early British tanks [19]. In 1918 he patented [20] a far more complicated fire control computer which combines a cam follower with bar linkages (figure 20). The cam follower and the upper linkages are used to calculate gun elevation from observed range and angle of sight. The three "square" linkages in the lower right part of the computer were used to calculate corrections for muzzle velocity, wind and air density. These corrections were added to the estimated elevation using the vertical bars at the far right. Linkages can also be found in the Vickers Predictor [17,21] and in the artillery calculator of Kurt Pannke [22], (figure 21).

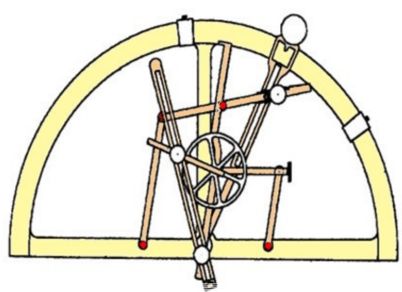


Figure 19 – Wilson's torpedo director

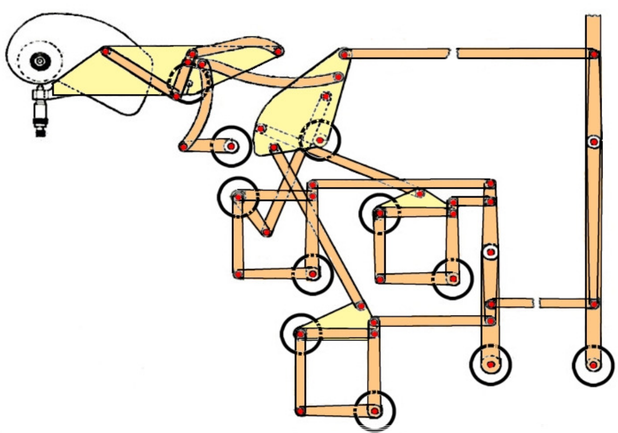


Figure 20 – Wilson's fire control calculator

Other Applications

Although mechanical analog computers were mainly used for military purposes [17], there were some civilian uses.

A bar linkage has been designed for measuring electrical resistance. It divides the measured voltage and current values [23]. A bar linkage has been proposed for the geometric summation of measured real and reactive electrical power to get apparent electrical power [24]. Bar linkages can be found in a protractor-like device to evaluate synchronous alternating current motors [25]. A differential flow meter with computing linkages has been produced by the Hagan Corp. of Pittsburgh [26] (figure 22).

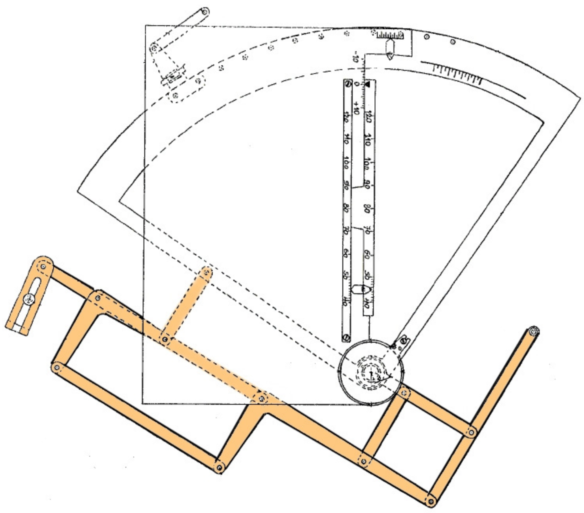


Figure 21 – Pannke's fire control calculator

Final remarks

Kinematic linkage design has a long history and still receives much attention, for instance in robotics. The design of *computing* linkages, however, once part of a "basic text and reference book" for the US Navy [27], is now a forgotten art.

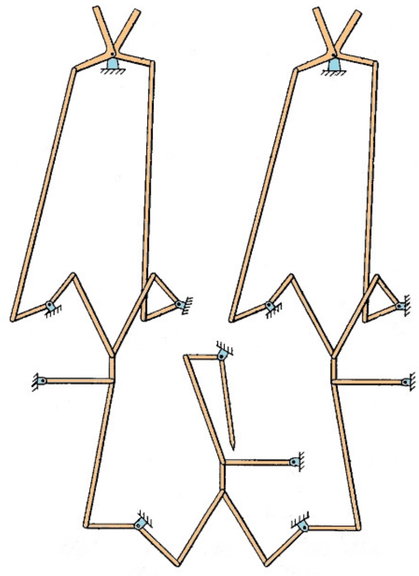


Figure 22 – Hagan flow calculator [26]

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[1] Antonin Svoboda, "Computing Mechanisms and Linkages", Dover Publications, New York, 1965; originally published as: M.I.T. Radiation Laboratory Series Volume 27 (1946).

[2] Picture: German Shoe-Museum Hauenstein, see also Robert W. Strout , "Machine for measuring the area of surfaces ", US Patent 738580, Sep. 8, 1903 (assigned to the Vaughn Machine Company)

[3] L.W. Imm, "Balance Computer", US Patent 2179822, Nov. 14, 1939; US Patent 2373566, Apr 10, 1945 (assigned to Librascope Inc.); E. Churchill, "Automatic Brains", *Popular Aviation*, Feb 1940.

[4] L.W. Imm, "Power Computer", US Patent 2394180, Feb 5, 1946; "Dress Rehearsals for Danger Aloft", *Popular Mechanics*, Aug. 1940.

[5] Arnold Spilker, "Vorrichtung zum Auflösen linearer Gleichungen", German Patent 415286, Jun 17, 1925. The better known equation solver by Josef Nowak consisted of gears.

[6] Auguste-Robert Kaufmann, "Appareil indiquant le temps de pose pour l'obtention de clichés photographiques", French Patent 542107, Aug. 5, 1922.

[7] Georg Bloch, "Rechentafel", German Patent 347926, Jan. 27, 1922; Georg Bloch, "Rechentafel nach Patent 347926 mit in Schlitzen beweglichen Schiebern", German Patent 361708, Oct. 18, 1922.

[8] William Robertson, "Toy", US Patent US1188490, June 27, 1916 and "Calculating device", US Patent 1286112, Nov. 26, 1918 (assigned to the Educational Novelty Company, Dayton).

[9] "Antonin Svoboda", IEEE Global History Network, http://www.ieeeghn.org/wiki/index.php/Antonin_Svoboda (accessed May 22, 2010).

[10] Antonín Svoboda, OH 35. Oral history interview by Robina Mapstone, Nov. 15, 1979. Charles Babbage Institute, University of Minnesota, Minneapolis.

[11] Vladimir Vand went to Glasgow, became an expert in crystallographic calculations, and worked a.o. with Francis Crick.

[12] The Swedish Bofors 40 mm guns could also be equipped with English Kerrision Predictors, American Sperry and even the Dutch (well... German) Hazemeyer fire control units.

[13] Wesley W. Stout, "The great detective", Chrysler Corp, Detroit, 1946, p.66.

[14] "Naval Ordnance and Gunnery, Volume 2, Fire Control", NavPers 10798-A, U. S. Government Printing Office, 1958, Chapter 26.

[15] Norman Friedman, "The Naval Institute guide to world naval weapons systems", 1997-1998", page 59 and 350.

[16] Antonín Svoboda, "Mechanism for use in computing apparatus", US Patent 2340350, Feb. 1, 1944.

[17] Allan G. Bromley, "British mechanical gunnery computers of world war II", manuscript, Jan. 1984.

[18] Walter Gordon Wilson, "Improvements in Directors for 'Whitehead' Torpedoes and the like", British Patent 17656/1893, Nov. 11, 1893.

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[20] Walter Gordon Wilson, "Improved means for computing the elevation or deflection of guns and the setting of fuses", British Patent 113136, Feb. 7, 1918.

[21] Percy Willis Gray, "Improvements in or relating to apparatus for use in the fire control of anti-aircraft guns", British Patent 236250, July 3, 1925 (assigned to Vickers Ltd.).

[22] Kurt Pannke, "Dělostřelecké počitadlo denních vlivů" [artillery calculator], Czech Patent 24349, Feb. 25, 1928. It is unclear if this is part of the 50 kg T4 device mentioned in *The Field Artillery Journal*, Nov-Dec 1931. At the end of the First World War, Pannke designed an "Artillerie-Plan-Rechenmaschine" for Mercedes Büromaschinen- und Waffen-Werke. In the 1950's Pannke manufactured a Fourier analyzer, especially for crystallography (W. Hoppe, K. Pannke, 1956 *Z. Krist*. **107** p.451).

[23] "Elektrisches Messgerät zur Anzeige des Quotienten aus zwei elektrischen Grössen, insbesondere Quotientenrelais für den Schutz von elektrischen Leitungen", Swiss Patent 144893, May 16, 1931 (assigned to Siemens-Schuckertwerke AG, Berlin).

[24] Wilhelm Stäblein, "Einrichtung zur geometrischen Summierung von Meßgrössen, insbesondere zum Zwecke der Fernmessung von Scheinleistungen", German Patent 566565, Dec. 19, 1932 (assigned to Allgemeine Elektricitäts-Gesellschaft, Berlin).

[25] Vladimir Karapetoff, "Calculator", US Patent 1648733, Nov. 8, 1927 (assigned to General Electric).

[26] Otto B. Vetter, "Calculating linkage", US Patent 2527282, Oct. 24, 1950 (assigned to Hagan Corp.); Canadian department of Trade and Commerce, "Approval of pressure and temperature compensated recording ring balance flow meters model 3000, 3001, 3002, 3003, 3004", Ottawa, 1960 http://www.ic.gc.ca/pics/lm/gas/sga/0185.pdf

[27] "Basic Fire Control Mechanisms", Ordnance Pamphlet 1140, 1944 (section 7).

SEVENTEEN SPECIMENS "ONE OF A KIND"
also known as "One-Off's"

Nr. 1: ET ULTRA WASHINGTON Concrete Calculator
ONE-OFF becomes a MORE-OFF

by Chris Hakkaart

At the IM 2008 I presented a steel concrete calculator as a ONE-OFF because such a device was at that time not earlier found. Although it was clear that more could have been produced, no information was available. There was only one look alike known, a comparable front, but without the characteristic steel box owned by John Vossepoel. Some months afterwards, John Hunt sent me a reaction. He had found a similar steel box with a Spanish set of guidelines from 1936, used in South America. Translation took some efforts, but finally it was done by Jose Fernandez. After the Spanish text had been formatted to Word, it became readable. A comparison of the 3 machines has been made.

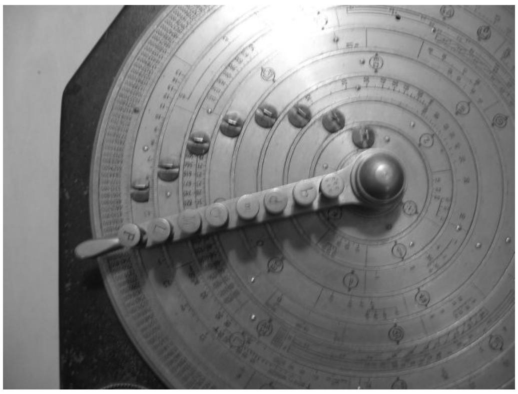
Owners:	Chris Hakkaart	type G	steel box
	John Hunt	type G36	steel box
	John Vossepoel	type H39N	flat

Main differences between G and G36 is the use of colours for concrete (black) and steel data (blue). Obvious the G36 is of a later date.

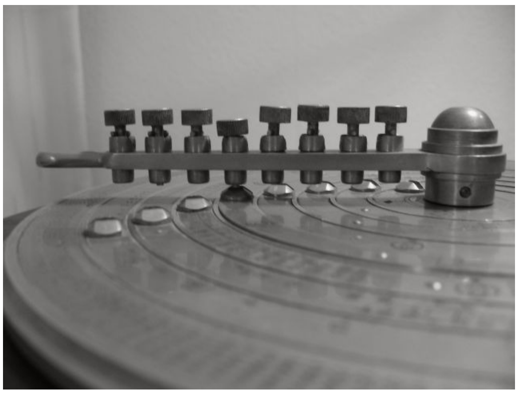
Pictures:

Type G

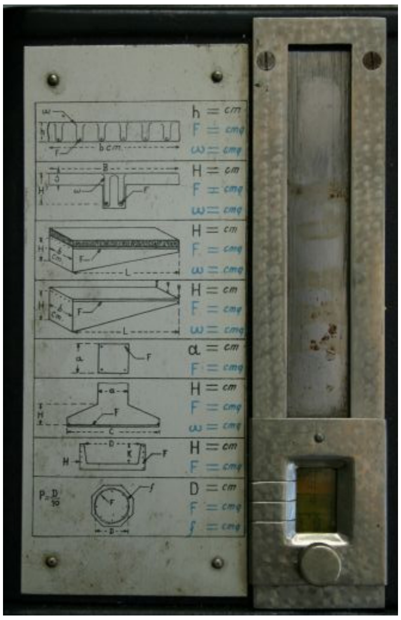
Type G36



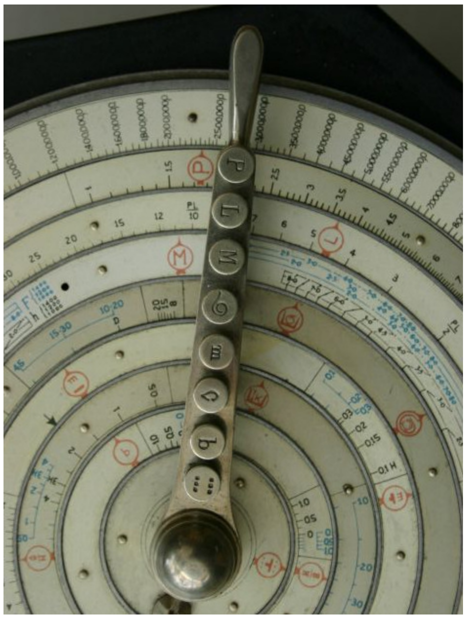
Detail of front scales Type G



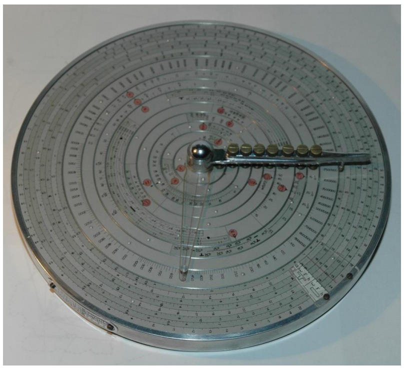
Detail of arm type G



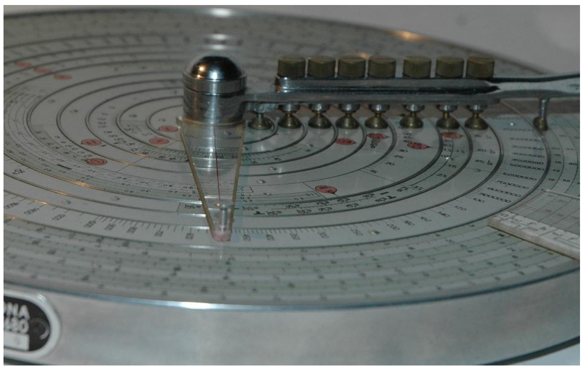
Detail of top slide with window type G36



Detail of front with coloured marks type G36



Disk of the H39N



Detail of front of the H39N

Purpose of the Slide Rule

The purpose of this item is to execute Reinforced Concrete calculations. It has a different layout than the more conventional concrete slide rules. Several gauges have to be used to perform the calculation.

Additional information:

On the IM2010 CD more detailed information is available about:

- comparison between the three Washington's
- A table with a comparison of the scales
- A Spanish set of documents from J. Hunt
- A translation of these documents by J. Fernandez

Nr. 2: Thacher Reproduction

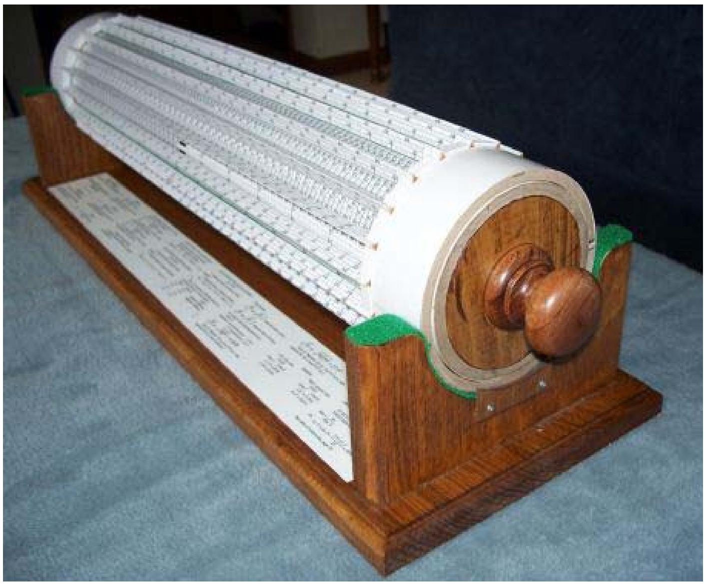
Owner: Rod Lovett

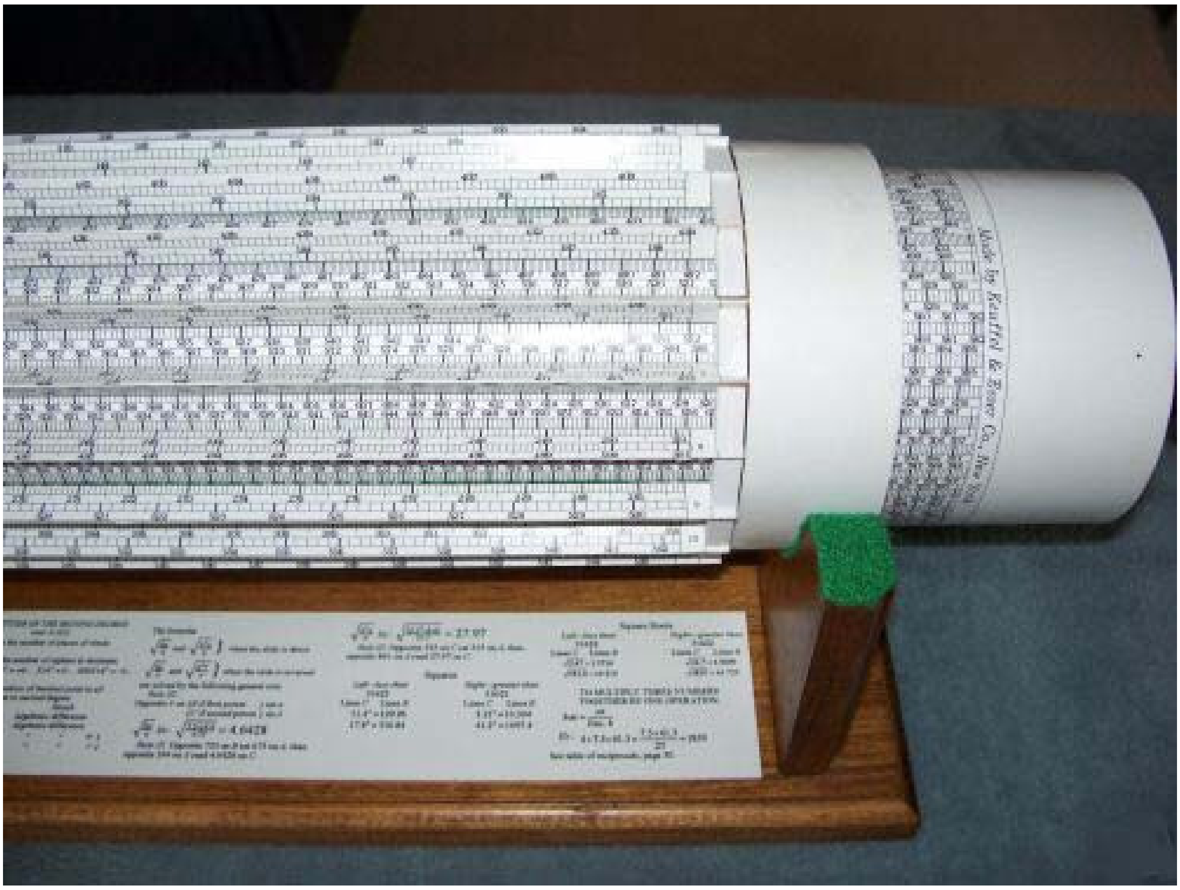
Purpose:
General purpose calculating drum for multiplication, division, squares, and square roots.

Dimensions:
Overall length of rule: 22 ½ inches
Length of scales: 18 inches
Effective length of scales: 30 feet
Outer Cylinder: 6 inches diameter
Inner Cylinder: 4 inches diameter

Material:
Plastic and cardboard on a mahogany base with varnished photo-quality paper scales.

Pictures:





Layout and scales:
20 Axial Rib Segments (B and C scales)
Rotating Inner Cylinder (the A scale)

Designer:
David White (U.S.A.), 2007

Nr. 3: Wall Chart "Dekadische Logarithmen"

Owner:
Before IM2010: Otto E van Poelje
Since IM2010: Klaus Kühn

Purpose of the Wall Chart:

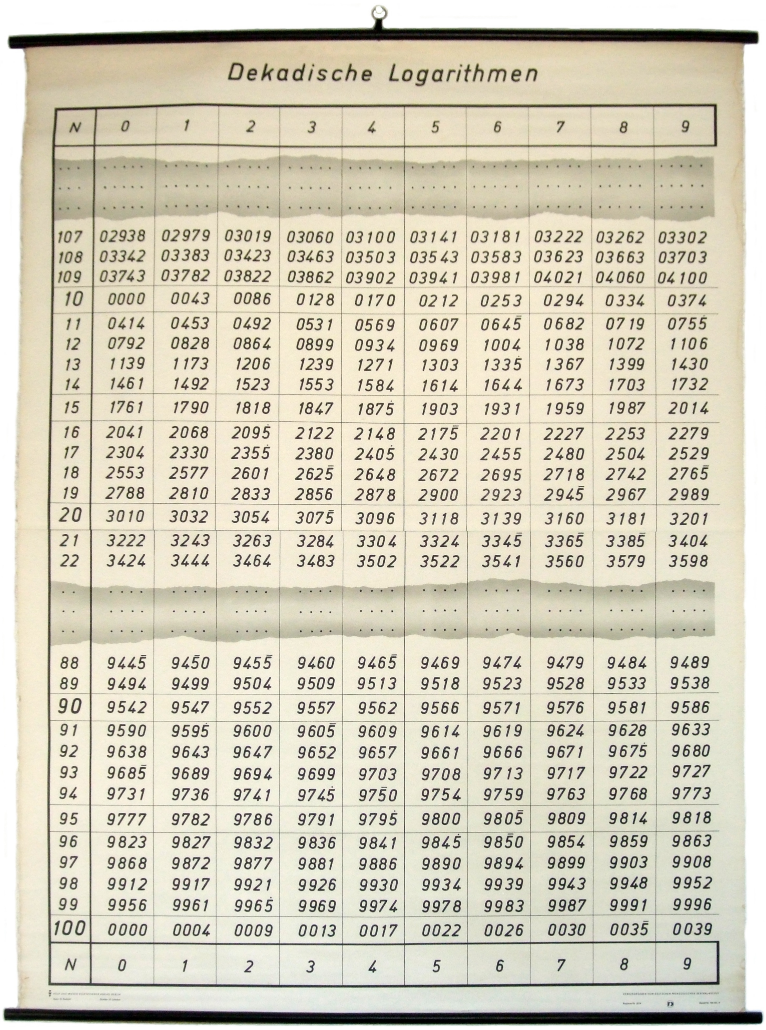
The purpose of this item is to teach in math classes the nature and the use of logarithmic tables. It has been designed and manufactured in the former East German Democratic Republic (DDR).

Dimensions :
- **Chart:** 117 x 157 cm
- **Staves:** 122 cm, ∅ 2 cm

Material:

Paper on linen, suspended between two wooden staves

Picture:


Dekadische Logarithmen

N	0	1	2	3	4	5	6	7	8	9
...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
107	02938	02979	03019	03060	03100	03141	03181	03222	03262	03302
108	03342	03383	03423	03463	03503	03543	03583	03623	03663	03703
109	03743	03782	03822	03862	03902	03941	03981	04021	04060	04100
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
..	....	....	....	....	....	....	....	....	....	....
..	....	....	....	....	....	....	....	....	....	....
..	....	....	....	....	....	....	....	....	....	....
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996
100	0000	0004	0009	0013	0017	0022	0026	0030	0035	0039
N	0	1	2	3	4	5	6	7	8	9

Layout:
- The chart looks like a regular page from a book of logarithmic tables; it probably was the counterpart of an existing schoolbook.
  It may be considered a prime example of the IM2010's *Mini & More* theme, because a log-table with a "Mini" range has been printed on a page with a size of "More" centimetres than any existing log-table book could possibly occupy.
- The main range is top-down from 100 to 1009 with the last digit on the horizontal row.
- The blank space between 229 and 880 is clearly inserted to keep the table in one page, but it reminds one of the "hole" from 20000 to 90000 in Briggs' *Arithmetica Logarithmica*, 1624.
- The first three lines with the range 1070 to 1099 are remarkable, and would have been used to show the need for higher precision in the range just over 10 where the differences are so large that interpolation is less precise. This follows the design of many regular log-table books where the range does not end at 1000…, but at 1100… or even 1200…

Remarks:
- The last digits “5” have rounding-off marks: a superscript “-“ if the 5 has been rounded off upwards, and a “.” for downwards.
- Just like in regular tables, only the mantissa (the part of the logarithm *after* the decimal point) is shown: the handling of the characteristic, or index (the part of the logarithm *before* the decimal point) would have been explained without help from the wall chart.
- This crowded chart has no room to display tables with Proportional Parts (PP) to calculate intermediate values by interpolation; regular tables normally show these in some blank space on the page.

Designer:

Publisher:

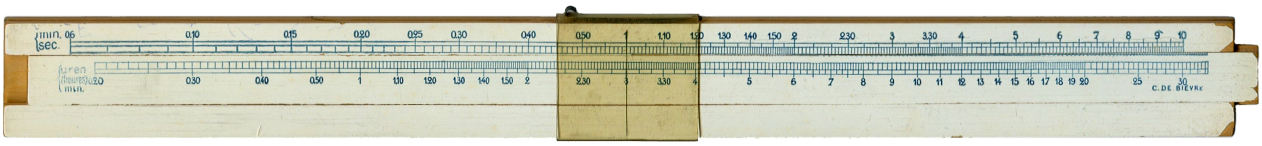
Acknowledgment:

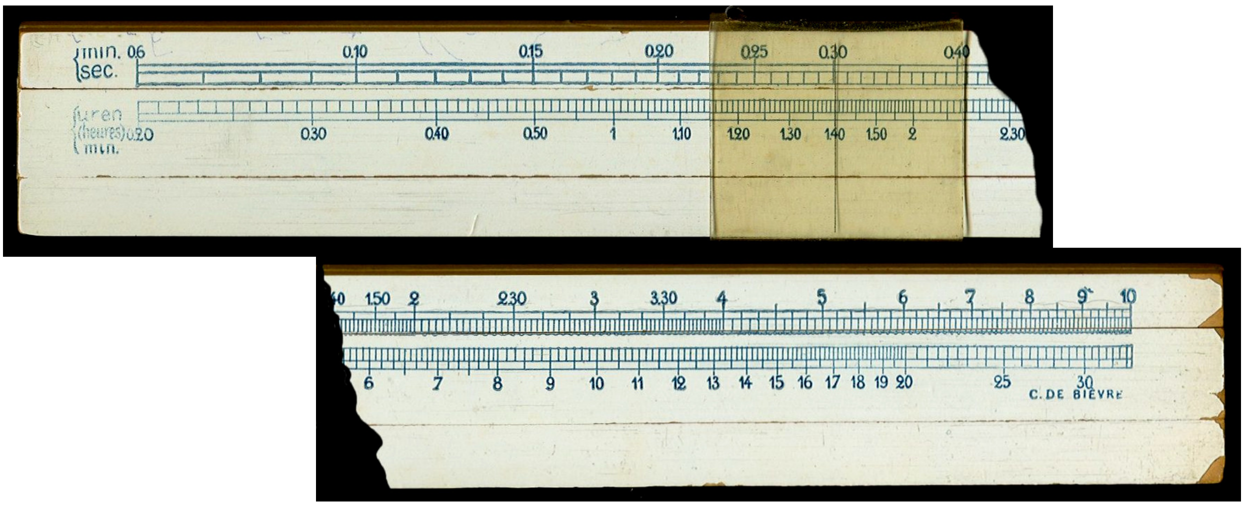
Thanks to Peter Holland for exploring the East German origin of the wall chart table. His contacts with some collector/teacher friends, who have lived and worked in the DDR, did not turn up any memories of learning or teaching by this wall chart.

Nr. 4: Sexagesimal Slide Rule (Hr-Min-Sec) by C. de Bièvre

Owner: Otto E van Poelje

Pictures:





Purpose of the Slide Rule:

This logarithmic "sexagesimal" slide rule is used to multiply or divide numbers in the hours/minutes/seconds notation HH.MM or MM.SS. At first sight this looks useless, but the real value is in multiplication and division of HH.MM.SS values by *integer* values!

For example: if a factory production cycle is timed with a chronometer to take 20 minutes, then 13 cycles will take 13 x 20 = 260 minutes, or 4 hours and 20 minutes. The first picture (of the complete slide rule) shows the A : B alignment 0.20 : 1 to agree with 4 $^{20}/_{60}$: 13.

Dimensions:

- Overall length 275 x 26 mm
- Length of scales: 249 mm (it really is 1 mm smaller than the usual 25 cm: maybe shrunk, maybe on purpose?)

Material:

- Body and slide made of pear tree wood.
- Scales printed on thin white plate, somewhat chipped off at the right side.
- Cursor made of celluloid.

Layout and scales:

There are only two scales:

- "min-sec" scale on the body above the slide (where a regular slide rule has the A-scale)
- "uren-(heures)-min" on the upper side of the slide (where a regular slide rule has the B-scale)

Looking closely at the two scales, it becomes clear that these are really A- and B-scales, with the following observations:

1. The A-scale has on the right half, as usual, the integer numbers 1 … 10. The fractions between these integers however don't have decimal divisions, but sexagesimal: the resolution is $^{1}/_{60}$ between 1 and 2, $^{2}/_{60}$ between 2 and 4, and $^{5}/_{60}$ between 4 and 10.
2. The B-scale is identical to the A-scale, but is folded: shifted over a value 3 to the left. The upper limit of the "hours" scale is 33 – a maximum which would be severely limiting when used for degrees, in angular measures.
3. The dual language -Dutch and French- in the scale names indicates a Belgian origin.

Designer:

The name "C. de Bièvre" is printed on the right side of the slide. There may have been many people with that name in Belgium, but as of now there appears to be a concentration (6) in Brasschaat. Looking on Google, one finds a "bon ingenieur" C. de Bièvre around Antwerpen.

He was involved in (amateur?) astronomy organisations (1940s), and wrote books on the history of mathematics, e.g. on *Descartes et Pascal* (1955). Such a person may very well have been the designer of the sexagesimal slide rule as it also relates to astronomical measures (degrees, hours etc). If this is true then the rule can be dated to the 1940s – 1950s. However, this is pure conjecture. The manufacturer of the sexagesimal rule is unknown.

Remarks:

Regular slide rules did not offer the possibility to calculate in sexagesimal numbers. The only use of HMS values was in the goniometrical scales. Originally the angle arguments were given in degrees and minutes (seconds didn't figure in a slide rule's precision range), or in the purely decimal 400^g (grads) system of European surveyors. Only later in the 20^{th} century a decimal 360° degree notation was introduced, but slide rules used either HMS or decimal ("*decitrig*" on K&E).

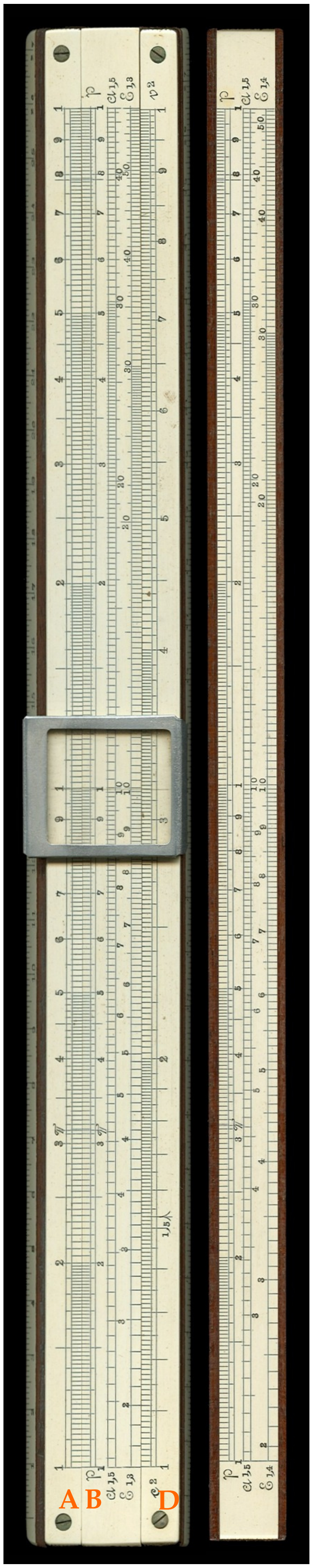
On many scientific electronic calculators calculations with hours (or degrees likewise), minutes and seconds are available. Most Hewlett Packard calculators with advanced scientific functions had at least a conversion function between decimal hours (degrees) and the 3-level sexagesimal notation HH.MMSS. Some models even had special operators for HMS-encoded values, but those were exclusively the add and subtract functions. Even the famous HP-01 digital LED wristwatch in 1977 could add and subtract HMS times (and dates too).

Multiplication and division however have never been offered as functions for HMS values on calculators. In this respect the "de Bièvre" rule was special; each scale has only 2 levels (HM or MS), but the intention was to apply the A-scale for MS and the B-scale for HM.

Still the designer appears to have missed the opportunity to include H-HMS conversions and mixed H-HMS calculations on his slide rule, which would have been easy by adding the mirror images of his sexagesimal A- and B-scales to the lower half of the rule, but then divided decimally.

Nr. 5: Mystery Slide Rule with "Broken Powers" by D&P (1906)

Owner: Otto E van Poelje **Pictures:**



Purpose of the Slide Rule:
Unknown mystery, see the reasoning on the scales.

WHO CAN TELL MORE ABOUT THIS RULE'S USAGE ???

The unique aspects of this mystery rule's application are:

- formulae with $\sqrt[1,5]{B}$ or other broken powers, with $0.1 \leq B \leq 10.0$
- parameters with names: p $a_{1,5}$ $e_{1,4}$ $e_{1,3}$ and c^2
- gauge mark with upward pointing arrow at $\boldsymbol{c}^2 = 153$

Dimensions:

Overall length: 279 x 25 (32) mm
Length of scales: 250 mm

Material:
Body and slide made of mahogany.
Scales and lettering stamped on white celluloid.

Layout and scales:

The slide rule has the regular Mannheim A, B and D-scales. On the slide however very different scales are placed which are related to exponentiation with broken powers 1.5, 1.4 and 1.3

The abbreviations of the scales are irregular too. The A scale has no caption at all. The layout in Herman van Herwijnen's general scale notation is:

$[A] = p \quad a_{1,5} \quad e_{1,3} = c^2$ on the front of body and slide

$= p \quad a_{1,5} \quad e_{1,4} =$ on the back of the slide

The p–scale is equivalent to the unnamed A-scale, so it actually is a regular B-scale. The c^2-scale is a one-decadic scale, so it actually is a regular D-scale. All other scales with indexes 1,5 and

1,4 and 1,3 are also logarithmic - which can be checked by the fact that proportions (such as 2:3 or 3:4) have equal lengths at different positions within each scale.

Karl Kleine gave the hint that the indexes "1,5" and "1,4" and "1,3" indicate the "broken" power of the root which transforms a value on the two-decadic B-scale (p) to the corresponding value on one of the mystery scales with that index: in the German language a *comma* is used for the *decimal point*.

It turns out that the relations are:

$a_{1,5} = \sqrt[1,5]{B}$ (for example check B = 0.3, $a_{1,5}$ = 0.448; B = 3, $a_{1,5}$ = 2.08)

$e_{1,4} = \sqrt[1,4]{B}$ (for example check B = 0.3, $a_{1,4}$ = 0.423; B = 3, $a_{1,4}$ = 2.19)

$e_{1,3} = \sqrt[1,3]{B}$ (for example check B = 0.3, $a_{1,3}$ = 0.396; B = 3, $a_{1,3}$ = 2.33)

and even for the bottom D-scale (c^2) it is clearly valid:

c^2=D= $\sqrt[2]{A}$

Note that a different position of the decimal point in B gives a different result in the broken power formula. This is caused by the root part of the power fraction: for $a_{1,5}$ this is 3, therefore three different results exist depending on the decimal point position of the B-value.

For $e_{1,4}$ there are 7 different results (14/10 = 7/5), and for $e_{1,3}$ even thirteen!

The conclusion is that on the left decade of the B-scale the broken power results are only correct for 0.1 ≤ B ≤ 1.0, and on the right half for 1.0 ≤ B ≤ 10.0 .

On the bottom scale a gauge mark is stamped with an upward pointing arrow at c^2 = 153; this value is exact as it does not have a separate division tick. Value 153 does occur in Pano's "*Pocket-book of the Gauge Marks*", as statute mile conversion, but it is not clear in what way this value can be used here as such. It may have had a completely different use.

Designer:

Unknown. It was custom in the last century to give a designer's name (Mannheim, Rietz etc.) to a slide rule design and often that name was imprinted on each rule, but not so for this one.

Manufacturer:

The following text is imprinted in the middle of the well, behind the slide:

"DENNERT&PAPE ALTONA D.R.P. №.126499"

The patent number is referring to the "spring loaded stator" invention of D & P in 1901, and has nothing to do with the rule's application.

The blind figures "06" are stamped in the well at the left, so the production year was 1906. The build and construction have the regular appearance of early 20th century D & P slide rules. Also the screws, to attach the scales to the body, were used for D & P slide rules at the time.

Remarks:

There is a possible connection with gauging and ullaging of convex casks for wine or beer. Many mathematicians in the past centuries have worked out formulae to describe their forms in the best way possible. In English excise practices a number of rotation-symmetric forms have been defined: spheroid (variety of the first kind), parabolic (second kind), double-conical etc.

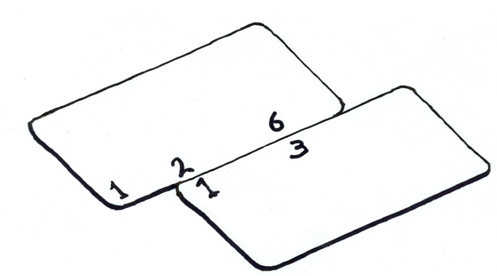
A Dutch mathematician (Hendrik de Hartog, 1815) has reasoned that any convexity of a cask is limited "in extremis" by a straight line y=x (a cylindrical barrel) and a parabolic curve $y=x^2$ as maximum convexity. His reasoning therefore was that a regular convex cask could be described by a "bastard" parabola $y=x^p$, where p is between 1 and 2. From his experiments with existing barrels he concluded that $y= x^{5/3}$ would give the best fit. This exponent (1.67) is somewhat greater than the ones on the D&P mystery rule.

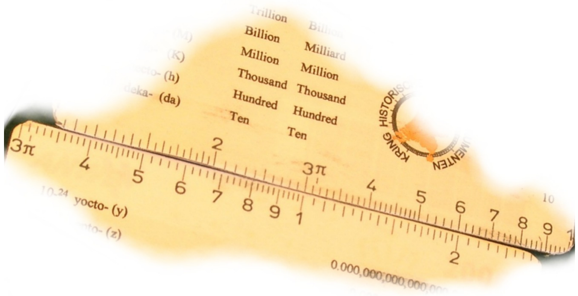
Could this theory have been used by D&P to create their slide rule?

Nr. 6: Mini Calculating Cards

Owner: Otto E van Poelje

Picture:





Purpose:

Over the last years a number of articles have been written about *calculating rods*.
For example the Lambert-Brander rods were described by Karl Kleine [1], and Werner Rudowski has published about other calculating rods [2], with more to come.
Logarithmic scales on calculating rods are freely gliding along each other, moved and held together by hand, not by frame or braces as in a slide rule. This means that the maker does not have to worry about construction of moving parts, and tension or friction between slide and body; the only requirements lie in the quality of the scales and the straightness of the rods.

Design considerations:

The idea behind the calculating cards is based on the assumptions that really portable sliding rods should be small enough to fit in a wallet while the precision does not require more than 2 decimal positions. What better medium for such mini rods than the common ***Credit Card***?

Dimensions (Standard credit card):
Height: 85.6 mm, Width: 54 mm, Thickness: 0.76 mm

Material (Standard credit card):
PVC body (2 plates for front and back), offset-printed on each side, laminated for protection

Layout and scales:

When 2 credit cards are used as rods, different scales could be used on upper and lower edge, and on front and back. For simplicity’s sake however the same one-decadic log-scales are used on both upper and lower edge. The scale length is limited to card length minus the two rounding spaces at the corners, so about 80 mm (this is even less than de 100 mm C-/D-scales on the Aristo Puck or the Sun-Hemmi mini-slide rules). The almost 50 mm blank space between upper and lower scale can be used for printing useful data, as was common practice on the old slide rule back-sides.

Manufacturer:

Alas, only one cardboard prototype has been constructed by printing and gluing, and this specimen has been destroyed by accident, see picture above.
It is not known if or when this project will proceed.

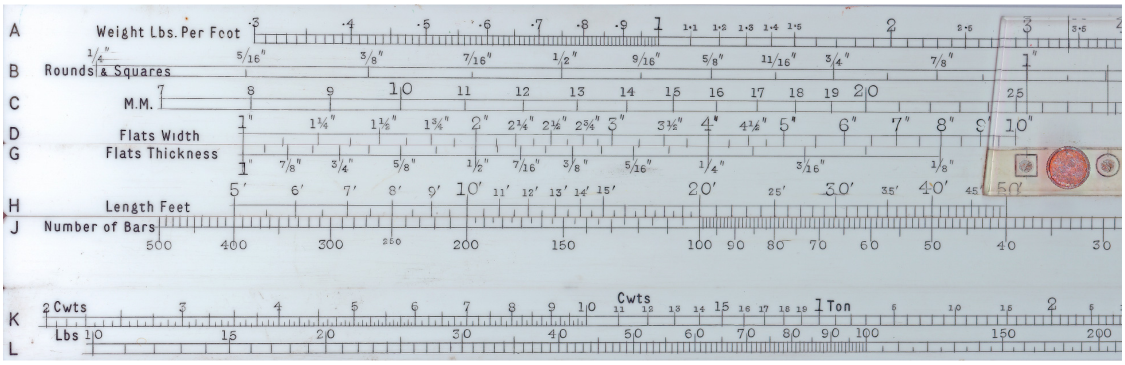
References:

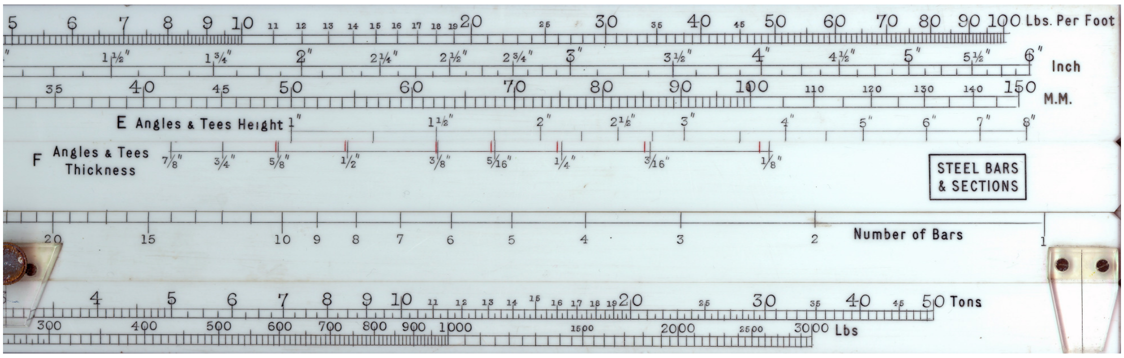
[1] Karl Kleine, “Die Lambert-Branderschen Rechenstäbe”, IM2006, Greifswald, p. 13 - 22
[2] Werner Rudowski, “Calculating Rods”, *Slide Rule Gazette*, Issue 8, 2007, p. 1 – 9

Nr. 7: Desktop Poly-Slide Rule for Steel Bars & Sections

Owner: David G Rance

Pictures (left and right-hand ends only)**:**





Purpose of the Slide Rule:

This rule was designed for the bygone age when imperial-based calculations were prevalent in the steel trade. That is a bygone since 1980 for all countries except the United States of America, the Union of Myanmar (Burma) and the Republic of Liberia – three countries that still have to go metric.

Being based on logarithmic scales, slide rules were not suited to calculations involving fractions, imperial units or non-decimal currencies. The first slide rule (incorporating a mixture of special scales and gauge marks) specifically designed for Merchants working in fractions, imperial units or non-decimal currencies only came onto the market in 1913 - the Nestler "System Kaufman" model 40. Many manufacturers just settled for a conversion table glued or printed on the backs of their slide rules.

An extra peculiarity to steel bars and sections, and hence reflected in this slide rule, is their end-on profile. For example, a steel bar of a particular grade and length with a square profile weighs more than the same bar but with a round profile.

Dimensions:

- **Base:** 58 cm x 8 cm x 1 cm
- **Slides:** both 58 cm x 1.1 cm x 0.6 cm
- **Cursors:** all 3 plastic - 1 large with a brass knob and 3 hairlines in a fixed position on the top slide and 2 small (1 with a brass knob) with a single hairline both in a fixed position on the bottom slide

Material:

- **Stock:** plastic **"**Astralon-like**"** extremely thick high-quality white PVC
- **Slides:** two identically sized plastic "Astralon-like" high-quality white PVC tongue-and-grooved and mounted one above the other
- **Cursors:** (i) one large plastic fixed off-centre on the top slide
  (ii) two small plastic fixed – one fixed off-centre and the other fixed at the right-hand end of the bottom slide
- **Finishing**: the printing (in black) is a form of screen printing straight onto the PVC stock and slides

Simplex layout and scales:

A solid frame rule - unexpectedly all eleven scales (**A–L**) are logarithmic and more surprisingly all but two of them are based on imperial units for length or mass.

- **Stock above the slides:**
  - **A** 0.3-100 **Weight Lbs. Per Foot** logarithmic scale
  - **B** ¼″-6″ **Rounds & Squares** logarithmic scale
  - **C** 7-150 **M.M.** logarithmic scale
  - **D** 1″-10″ **Flats Width** logarithmic scale
  - **E** 1″-8″ **Angles & Tees Height** logarithmic scale
- **Top slide:**
  - **G** 1″-⅛″ **Flats Thickness** logarithmic scale
  - **F** ⅞″-⅛-" **Angles & Tees Thickness** logarithmic scale
  - **H** 5′-50′ **Length Feet** logarithmic scale.
- **Bottom slide:**
  - **J** 500-1 **Number of Bars** logarithmic scale
- **Stock below the slides:**
  - **K** 0.1-50 **Tons** logarithmic scale
  - **L** 10-3000 **Lbs** logarithmic scale

Designer:

Nothing is known - although with ***nine*** imperial-based logarithmic scales for length and mass it was clearly a major, and possibly unrivalled, design feat.

Manufacturer:

Unknown - although there are certain similarities to the high-quality Mark IV/V Pilot Balloon slide rules made in the 1950's/1960's by UK manufacturer Blundell Harling. However, there is not a shred of evidence it was made by them. **Can anyone identify the maker?**

The first country to convert from imperial to metric was France in 1799. Over the next two centuries most other countries followed but it is still not universal – e.g. the U.S.A. has still to go metric. So without knowing the manufacturer and/or the country it was marketed in, the year of manufacture is sadly indeterminate. But given the use of PVC as its base material, it most probably dates from somewhere between 1950 and1980.

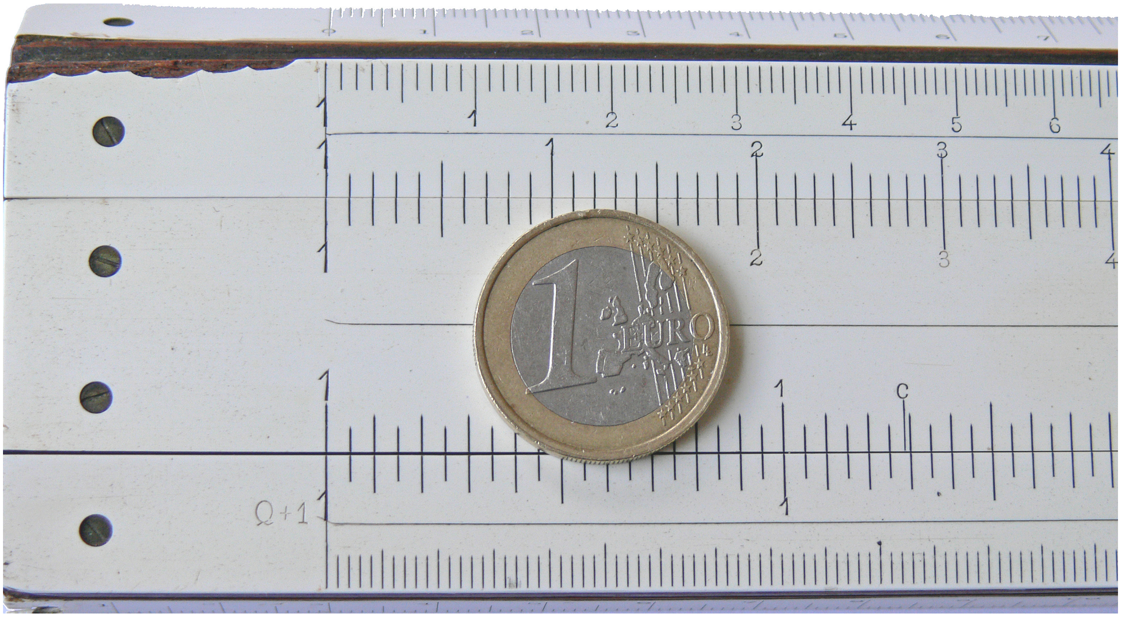
Final remarks:

It is not known if a user manual ever existed. So I have no real idea of how the scales are supposed to interact or what calculations the slide rule can carry out – does anyone have any ideas?

Nr. 8: MAXI Desktop Slide Rule

Owner: David G Rance

Picture (left-hand end only – 1 Euro coin included for size comparison)**:**



Purpose of the Slide Rule:

At first glance this MAXI rule looks a bit of an anomaly – surely too big to be a Desktop rule but too small to be a Demonstration rule. So what is it? Most of the main manufactures traditionally made, at most, two types of "oversized" linear slide rules:

- 40/50/60cm Desktop slide rules
- 1-2m Demonstration rules

For most manufacturers large Demonstration rules were not part of their standard product range or even considered "special commissions". Instead they were usually a crudely made "blown up" versions of a popular standard model. They were sometimes used for advertising but more often for teaching *"How to use a slide rule"* sessions. Clearly the primary role of a Demonstration rule was to show how various calculations could be performed on a slide rule. As such, the accuracy of the rule was secondary to legibility. Indeed most of the early Demonstration rules were notoriously inaccurate – made from a cheap(er) wood such as pine or poplar and brightly painted. Certainly none of the scales on a Demonstration rule would have been etched or incised by a "dividing engine". Instead most of the company branded Demonstration rules were inevitably hand-made by a local or in-house carpenter.

In contrast, most of the leading commercial slide rule manufactures had one or more linear Desktop slide rules in their product range. Such models were 40cm, or more commonly 50cm, long and were engineered to the same degree of accuracy as their other linear slide rules – i.e. the pocket 10-15cm or the standard 25-30cm rules. Desktop models were twice or three times the price of a 30cm rule – a price justified by claims that they were more accurate than a standard 30cm linear rule. But this claim is largely unfounded as most of the chosen Desktop scale layouts were just enlarged/stretched versions of a 30 cm rule. A few did use the extra long stock to increase the number of divisions or tick marks. But the main advantage of such larger sized Desktop models would have undoubtedly been visual – i.e. with any Desktop linear rule, it was easier to set more accurately the values for the any calculation and read off more precisely the calculated answer shown by the cursor hair-line(s).

For the majority of the manufacturers their output of Desktop rules was less than 5% of their total production – for some, it was as little as just 1%. But only one commercial manufacturer was capable of scaling up their production of linear slide rules to cater for stocks longer than 60cm. The "dividing engines" designed and built for the renowned German manufacturer **Nestler** could produce a 100cm Desktop slide rule. Like others, Nestler did have 100/150/200cm Demonstration rules. But they were the only manufacturer to have four 100cm Desktop models (the 2c, 19a, 24b and 24 R/1), made to the same exacting production methods as all their other precision linear slide rules, in their product range. For all the other manufacturers, anything longer than 50cm, or 60cm at most, could not have been manufactured on the production machines they had on the shop floor.

Dimensions:

- **Stock:** 106 cm (D scale 100cm) x 6 cm x 1.6 cm.
- **Slide:** 106 cm x 2.8 cm x 0.6 cm
- **Cursor:** sadly missing

Material:

- **Stock:** mahogany base with celluloid veneers secured with 8 German sliver screws (2 either end of the front face of the stock and 1 at either end of each the two edge scales).
- **Slide:** mahogany with celluloid veneers secured with 8 German sliver screws (2 at either end of the front and back of the slide).
- **Cursor**: sadly missing but would have been a closed frame metal and glass type, possibly with 3 hair-lines.
- **Finishing**: all the scale divisions, gauge marks, etc highlighted in black ink.

Simplex layout and scales:

A solid frame classic "System Rietz":

- **cm / K A / B C / D L | cm // S T**

The top bevelled edge cm scale runs from 0 -100.

The A / B scales runs from 1 -100 and C / D scales from 1 -10. However, the number of divisions is identical with the equivalent Nestler 50 cm Desktop rule – i.e. sadly the 100cm scale does not have double the number of scale divisions as the equivalent 50cm Desktop rule (see **Picture**).
The bottom straight edge cm scale runs from 0 – 106.
This layout and arrangement of scales conforms to the 100cm Desktop slide rule **- model 24b**

Designer and date:

The scale layout must obviously be attributed to the German engineer Max Rietz (1872-1956). But the style of the company name, **ALBERT NESTLER LAHR ^{I}/B**, found in the well of the stock, and in particular the way "^{I}/B" in "LAHR ^{I}/B" (Lahr in Baden) is inscribed superscripted, shows that this was one of the earliest 100cm Desktop slide rules ever made by Nestler and dates from a short 4-year period: **1908 - 1911**.

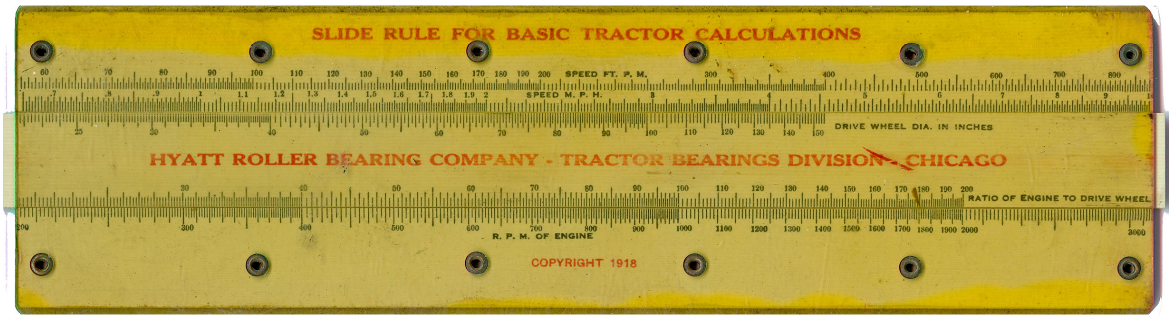
Final remarks:

Besides the example shown, only two other Nestler 100cm Desktop rules are known still to exist. One is owned by the Nestler family and the other is part of the collection of Hans-Peter Schaub. The model numbers of the other two are unknown.
If anyone ever happens to come across an unbelievably big and wide cursor, please keep my "MAXI" Desktop slide rule in mind!

Nr. 9: Slide Rule For Basic Tractor Calculations

Owner: David G Rance

Pictures (front and back)**:**



Purpose of the Slide Rule:

Speciality slide rules were made for many trades and professions. But perhaps because of a strong "hands-on" element, agricultural slide rules are singularly uncommon. A couple of rare examples for animal husbandry do spring to mind: (i) the cattle-breeding and pig-breeding rules from ARISTO and UTO respectfully and (ii) rules based on Richmond's milk scale for the dairy industry. However, for land husbandry, apart from Forestry lumber rules, none existed.

Well, I was wrong, or at least, I think I was. Being always intrigued by slide rules with unusual or "whacky" scales, a 2009 eBay® offering of a "*Slide Rule for Basic Tractor Calculations*" caught my eye. For a given a size and type of tractor engine the rule calculates (?) the force on the bearing(s) when a tractor is driving and powering one of the many agricultural tractor attachments. For example, when using a tractor to plough or drill-seed a large acreage of farming land. The company name on the rule, *Hyatt Roller Bearing Company* of Chicago U.S.A., no longer exists – they were acquired by car manufacturing giant General Motors some time shortly after GM was formed in 1908.

Dimensions:

- **Base:** 210 mm x 56 mm x 4 mm.
- **Slide:** 260 mm x 17 mm x 1.5 mm
- **Cursor:** none or missing (probably not needed)

Material and construction:

The type of construction is best described as a hybrid between a slide rule and a slide chart. To avoid having any "tongue-and-groove" construction for the slide, the unknown maker choose to encapsulated three strips of white plastic with two translucent (possibly aged yellow with age) plastic sheets front and back. Six metal pop-rivets along the top and the bottom of the "stock" make sure everything stays in place and enables the middle strip to act as a conventional slide.

- **Base:** plastic **"**Astralon-like**"** white PVC strips and translucent (yellowed) plastic sheets
- **Slide:** plastic **"**Astralon-like**"** white PVC strip
- **Cursor**: "missing" or not needed.
- **Finishing**: the printing (in black and red) is a form of screen printing onto each of the PVC plastic strips.

Duplex layout and scales:

Unexpectedly all the scales are, at least in part, logarithmic and even more surprisingly, many of them are based on imperial units.

- **Front of "stock" above the slide:**
  - 10-119 **AREA OF PISTON – SQ.IN** logarithmic scale
  - 2.9-12.3 **BORE OF CYL.** and 156 - 1850 **CU. IN DISPLACEMENT** logarithmic scales
- **Front of the Slide:**
  - 12-1 **No. OF CYLINDERS** scale and 3-19 **STROKE OF ENGINE** logarithmic scales
  - 154-24 **DIA. OF DRIVE WHEELL IN INCHES** and 156-15.5 **RATIO OF ENGINE TO DRIVE WHEEL** logarithmic scales
  - a blind-stamped "F" top and bottom of the right- hand end
- **Front of "stock" below the slide:**
  - 1000-15800 **RIM PULL (NO FRICTION)** and 860-11200 **TORQUE POUND INCHES** logarithmic scales
- **Back of "stock" above the slide:**
  - 55-880 **SPEED FT. P.M.** logarithmic scale
  - 6.5-10 **SPEED M.P.H.** logarithmic scale
- **Back of the Slide:**
  - 2-55 **DRIVE WHELL DIA. IN INCHES** logarithmic scale
  - 20.2-200 **RATIO OF ENGINE TO DRIVE WHEEL** logarithmic scale
- **Back of "stock" below the slide:**
  - 200-3160 **R.P.M.** logarithmic scale

Designer:

Apart from "**COPYRIGHT 1918**" printed on the front and back of the rule – nothing is known.

Manufacturer:

Unknown - although showing certain construction similarities to slide rules made by UK manufacturer Blundell Harling, retired Technical Director, Peter Soole, says it was not made by them. **Can anyone identify the maker?**

Given the take-over of the company by GM and the copyright year "**1918**", the year of manufacture is probably around 1920's.

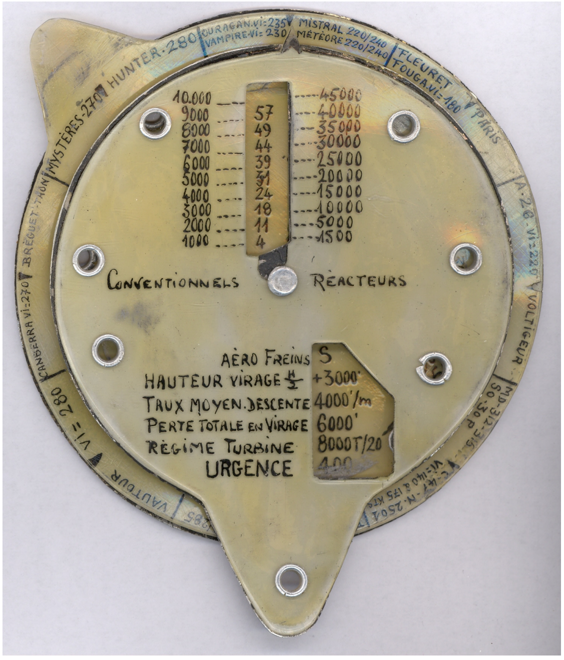
Final remarks:

It is not known if a user manual or an instruction leaflet ever existed. So I have no real idea of how the scales are supposed to interact or what calculations the slide rule can carry out – **does anyone have any ideas?**

Nr. 10: French Aircraft Performance Computer

Owner: Ronald van Riet

Picture:



Purpose of the Slide Rule:

This slide rule shows the most important performance characteristics of various French and other aircraft at a glance.

Dimensions:

- **Base disk:** 12 cm diameter
- **Top disk:** 10.3 cm diameter

Material:

- **Base:** aluminum, celluloid covered
- **Top disk:** aluminum, celluloid covered

Layout and scales:

The base disk has eight sectors each dedicated to one or more types of aircraft. When positioning the top disk to point at one of these sectors, important flight parameters are shown through windows in the upper disk.

The data given is different for piston or jet types (e.g. the operating altitudes for jet aircraft are much higher).

Aircraft types include well known types as the (British) Hawker Hunter or Gloster Meteor, (American) A-26 and C-47, but also French aircraft like Dassault Flamant and Ouragan and even aircraft that never were developed beyond the prototype stage like the Breguet Taon.

Designer:

Unknown, French.

Manufacturer:

Hand crafted.

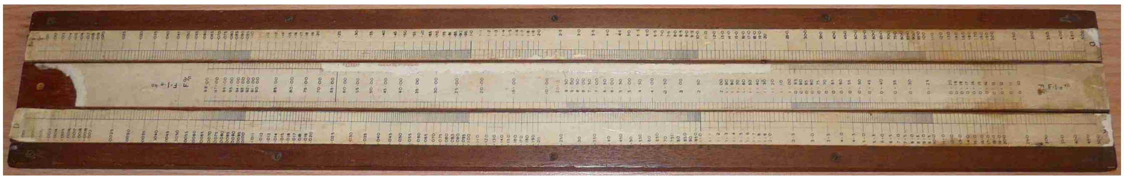
Remarks:

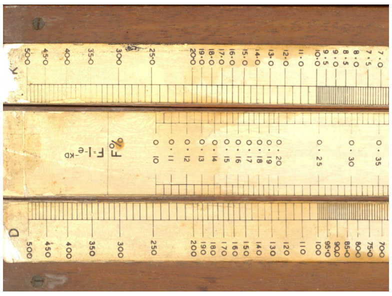
From the aircraft types included, the computer can be dated to about 1958. One could argue if this is a slide rule or not, but the similarity of use to other aircraft performance computers made me decide to classify it as a slide rule.

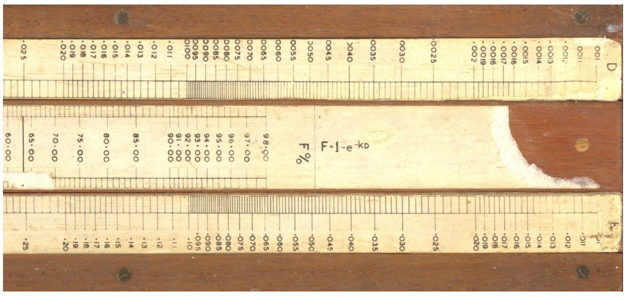
Nr. 11: 61 cm Negative-Exponential Slide Rule

Owner: Ronald van Riet

Pictures:







Purpose of the Slide Rule:

The only clue as to the purpose of the slide rule would be a formula printed on the slide rule: $F = 1 - e^{-KD}$, but what this formula relates to, I have no idea.

Dimensions:

- **Base:** 61 x 9.2 x 1.2 cm
- **Slides:** 2, each 1.9 cm wide
- **Cursor:** none, presumably not meant to be used with a cursor.

Material:

- **Base:** Mahogany
- **Stators :** Mahogany, screwed on the base
- **Slides:** Mahogany
- **Scales:** Paper, manually printed.

Layout and scales:

- **Base:** labeled F %
  range 0.10 – 98.00
  gauge mark type of line at about 63.25
- **Slides:** each labeled D on one end and K on the other.
  range 0.010 – 500 (from K to D)
  range 0.0010 – 50.0 (from D to K)

Designer, Manufacturer:

Unknown, slide rule was purchased in the United Kingdom.

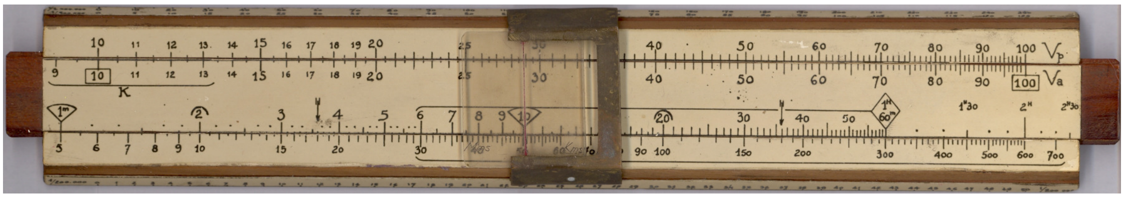
Remarks:

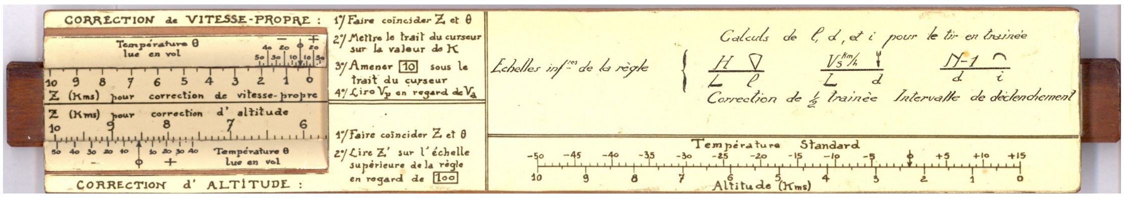
The name *Fred Burniston* is handwritten on the reverse.

Nr. 12: Normandie-Niemen Flight Computer

Owner: Ronald van Riet

Pictures:





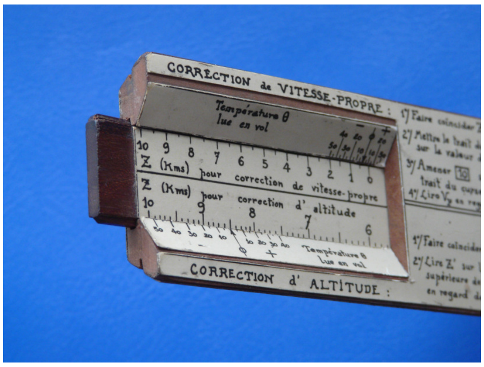
Purpose of the Slide Rule:

This slide rule is a French adaptation of the Soviet .NL-series flight computer.

Dimensions and materials:

- **Base:** wood, 28 x 5 cm with paper scales glued on
- **Slide:** wood, 30 x 2.3 cm with paper scales glued on
- **Cursor:** brass 3 cm wide, glass 3.3 cm wide

Layout and scales:



Instructions are given on the back in French. An instruction sheet (also in French) of two 25 cm square pages in a contemporary blue print comes with the slide rule.

The reverse contains a heavily bevelled window to enable calculating true air speed and true altitude (see picture)

Front scales:

- Top: two logarithmic scales graduated 10 – 100 for calculation of true speed and true altitude in cooperation with scales on the reverse
- Bottom: on the body a logarithmic scale graduated from 5 to 700 for combined use of speed and distance in T/S/D calculations.
  On the slide rule a logarithmic scale graduated from 1 m to 2 h 30 for use as a time scale in T/S/D calculations.
  Gauge marks at 3.6 and 36 to facilitate h/m/s calculations.
- Bevels: top: scale factors 1: 1,000,000 and 1:500,000, bottom: 1: 200,000

Note: even though the printed instructions mention a tangent scale (which was normally available on NL type flight computers), this scale does not appear on the present flight computer.

Cursor: one line in the middle, the left and right edges of the glass window serve as gauge marks to convert between nautical miles and kilometres (or knots and km/h).

Back scales:
- Top: Temperature and altitude scales for the calculation of true air speed, in cooperation with the top scales on the front
- Bottom: Temperature and altitude scales for the calculation of true altitude, in cooperation with the bottom scales on the front

Designer:
Unknown, about 1944

Manufacturer:
Hand crafted, probably by a Frenchman in the Soviet Union.

Remarks:
During WWII, the Free French led by Charles de Gaulle were distrusted by the western allies because of the armistice the French had concluded with the Germans and the continued fight by the official French army, navy and air force against the allies.

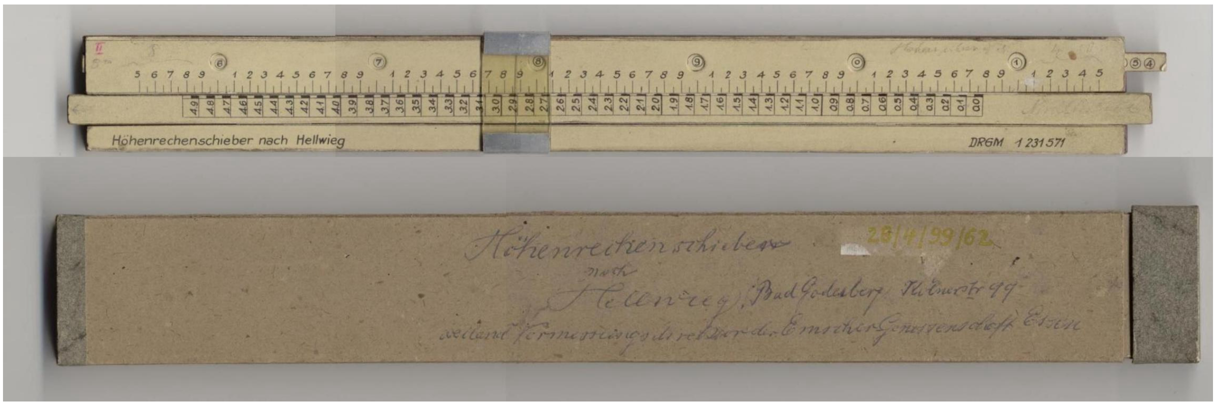
The situation of the Soviets was so bad, that they welcomed the offer by the Free French to send personnel for an air force squadron to the Soviet Union, where they were provided with some of the best Soviet fighter aircraft. This squadron, called Normandie, fought in some of the heaviest battles on the eastern front and claimed many victories; the honorary title Niemen was added by Stalin for its participation in the Battle of the Neman (or Niemen) River (http://en.wikipedia.org/wiki/Normandie-Niemen).

While in the Soviet Union, the French pilots became acquainted with the Soviet flight computers of the NL series and this flight computer is a French version with adaptations of the basic NL-4 as used by the Soviets.

Nr. 13: Hellwieg's Höhenrechenschieber

Owner: John Vossepoel

Pictures:



"Höhenrechenschieber nach Hellwieg"

Detail of the upper tongue showing the number sequencing.

Purpose of the Slide Rule:

German linear slide rule used in land surveying for calculating elevations. In contrast to the Dennert & Pape Höhenrechenschieber D&P MHR1 or MHR2 cylindrical slide rule used for navigation by German U-boats during WW2, this similarly named slide rule was designed for use in land surveying to calculate elevations by adding and subtracting the level readings from the surveying rods.

Dimensions:

The slide rule measures 324x36x13mm.

Material:

Somewhat crude in appearance - paper mounted on plywood, featuring a simply made cursor, linear scales on 2 tongues - leads one to believe that Hellwieg's Höhenrechenschieber is most likely a prototype of sorts.

Layout and Scales:

The upper slide with 7 groups of numbers facilitates the operating range in elevation/height. The bottom slide with numbers from 0.0 to 4.9 represents the full length of the surveying rod (i.e. 5-meter rod).

Designer:

The cardboard box containing the slide rule displays the following handwritten text: "*Höhenrechenschieber nach Hellwieg, Bad Godesberg Kölnerstr 99 Weiland Vermessungsdirektor der Emscher-Genossenschaft Essen*". In other words, Hellwieg was formerly the surveying director of the Emscher water management association in Essen. The Emschergenossenschaft was established on 14 December 1899 as the first water management association in Germany. An quick internet search produced the following info on the maker Hans Hellwieg: born on 1 August 1874, place of residence: Waiblingen, occupation: Oberlandmesser i.R. (English: senior surveyor, retired).

In the cap of the cardboard box there is a (14.5x9.5mm) folded piece of paper in stating: "Geschenk von Herr Hellwieg am Bauschule am 5.3.1955", a gift to a (unspecified) school of architecture and civil engineering. There is a designation 28/4/99/61 written on the box and on the slide rule, the meaning of which is unclear, but probably just an inventory number.

On the slide rule, there is a 1930s patent number DRGM 1231571. A patent search on Espacenet produced no information or document, the number may therefore be provisional designation. However, we were able to find a fully documented "Nivellierlatte" DRGM 1607459 dated 12 February 1950 by Hans Hellwieg.

Nr. 14: Steinhäuser's Suggestion for a Slide Rule in 1807

Owner: Stephan Weiss

This One-Off is not an actual slide rule, but the finding of a slide rule description that is remarkable in its splendid isolation.

The history of slide rules in Germany in the first half of the 19th century is well documented, for example by W. H. Rudowski [4]. Besides the rules named in this article I found a paper by J.G. Steinhäuser that documents the isolated new invention of a simple sliding rule which will be described here. Steinhäuser's paper [1, p. 33 – 45] is titled (in translation): *Description of a new very simple calculating machine by Prof. Steinhäuser, with which not only the four species of calculation, but also all proportions, roots and trigonometrical calculations can be performed very fast and secure with four places.*

This description has been abridged repeatedly in contemporary encyclopaedias in 1809 [2, Kap. XVII, p. 566 – 568] or in 1812 [3, heading *Rechenmaschine*] and in some others. It is striking to note that in none of those copies this instrument is compared with slide rules existing at the time.

Purpose:

Steinhäuser argues as follows: for the usage of existing calculating aids the user must have knowledge in calculating. The easiest aid with which one can do roots and trigonometric calculations is the logarithmic table. Many people fear the table because of so much numbers inside, its use should be made easier and more comfortable. In his opinion a precision of 4 figures suffices in most cases.

Numbers can be expressed by the length of lines. So he thinks of two scales, about one meter in length, the first equally divided and marked with positive numbers 1 to 10000 and the other below with their mantissas. Both lines are better to be overlooked than a table. A pointer can be used as link between the two. With other words: he thinks of a small logarithmic table of one dimension placed on a rod or similar device. Operations could be done as usual by reading and writing.

In the next step Steinhäuser asks for and finally finds a way to omit the intermediate step of reading the logarithms. He invents the so called logarithmic scale. The readers are surely familiar with such a transformation from table to scale, but for the author two hundred years ago it seems to have been an unique new innovation, because he writes (in translation) "*I hope to have served that purpose the following way*". With theses words his article is evidently not an explanation but describes an invention.

Dimensions and Material:

He suggests to build three identically equal rules, made of pear tree wood, 110 centimeter long and one Zoll (about 2.5 centimeter) in square.

Layout & Scales:

The first side bears a diagonal scale, probably 100 centimeter long as in the former suggestion, divided up to 1000 parts.

The second side bears the same scale, marked with numbers in a distance from the origin 1 which equals their logarithms. When we follow Steinhäuser's instructions this logarithmic scale is divided 1 – 10 – 100 – 1000. The third side bears an identical scale with values of logarithms for trigonometrical functions. By sliding the rules side by side it is possible to multiply, divide, to do proportions or with help of the scale on the first side to calculate roots or powers and all that by adding or subtracting lines and, as intended, without knowing the logarithms themselves. Examples of usage are added in the original article.

Inventor:

Johann Gottfried Steinhäuser was born 1768 in Plauen and died 1825 in Halle, both cities now located in Germany. In 1805 he became Professor for Mathematics in Wittenberg and 1816

Professor for Science of Mining in Halle. He made investigations about terrestrial magnetism and tried to explain magnetic deviations with a magnet that rotates within the hollow earth.

Picture of source text, from [2]:

5. Steinhäuser beschreibt eine neue ganz einfache Rechenmaschine.

Der Hr. Prof. Steinhäuser hat in einer der Wittenberger Provincial-Societät übergebenen Abhandlung, die in dem Ersten Beitrag zum vorläufigen ökonomischen Schwanengesang des Hrn. Commissions-Rathes J. Riem. 8. Leipzig 1807. S. 33 bis 45. mitgetheilt wird, eine Beschreibung einer neuen, ganz einfachen Rechenmaschine, wodurch nicht allein die vier Species der Rechnung, sondern alle Verhältnisse, Wurzel und trigonometrische Rechnungen sehr geschwind und sicher auf 4 Decimalstellen ausgeführt werden können, gegeben, worin nach vorläufigen Erörterungen des Erleichterungsmittels der logarithmischen Tafeln, bei der Rechenkunst diesen Zweck folgendermaßen erreicht zu haben glaubt. Auf drei Stäben von Birnbaumholz, deren jeder 11 Decimeter lang ist, und 1 Zoll ins Gevierte enthält, ist auf jedem eine gleichartige Scala angebracht, nach welcher, wie bei dem verjüngten Maaßstabe, jedes Dezimetres in 100 Millimeter durch Transversalen abgetheilt ist, zwischen denen man noch die Dezimillimeter nach dem Augenmaaße abschätzen kann. Man sieht sehr leicht ein, daß man nach solchen gleichförmigen Maaßstäben, deren Theile im o geraden Verhältnisse der Längen stehen, Zahlen zu einander addiren, oder von einander abziehen könne, wenn man z. B. 3. 4 Längen zusammen setzt, oder eine Länge von der andern hinweg nimmt. Um aber mit diesen Stäben auch multipliciren, dividiren, Wurzeln ausziehen zu können, hat er angenommen, diese Längen, des in Millimeter abgetheilten Maaßstabes, wären die Logarithmen natürlicher Zahlen. Auf einer zweiten Seite dieser Stäbe hat er also eine Scala für die natürlichen Zahlen in der Maßen entworfen, daß bei dem Anfange der logarithmischen Theilung des Stabes, wo die Zahl 0 auf solche steht, auf dieser letztern Theilung, die natürliche Zahl 1 steht; ferner entspricht die Zahl des gleichförmig getheilten Maaßstabes 30102 die Zahl 2, nach dem Maaßstabe natürlicher Zahlen. Die umständlicheren Beweiße und Zahlsätze muß man in dem Aufsatze wahrnehmen.

Remarks:

It is evident that Steinhäuser explains the principles of a slide rule. Based on his own words and since he does not mention the already existing slide rules at all we must assume he doesn't know them and describes his own original invention. At the end of his article the inventor promises to publish pictures of the scales in the future. Until now I haven't found them, maybe he got troubles in dividing the scales, maybe someone told him that the slide rule has been already invented...

Steinhäuser's ideas had had no influence on the further development of slide rules. They may be regarded as a singular event of little or even no importance, but they are a small part in the answer to the question how well known were slide rules in Germany before the second half of the 19th century.

References:

[1] Riem, Johannes (Karl Richard), *Ökonomischer Schwanengesang*, Leipzig, 1807

[2] *Almanach der Fortschritte, neuesten Erfindungen und Entdeckungen...*, 13. Jg., Erfurt 1809

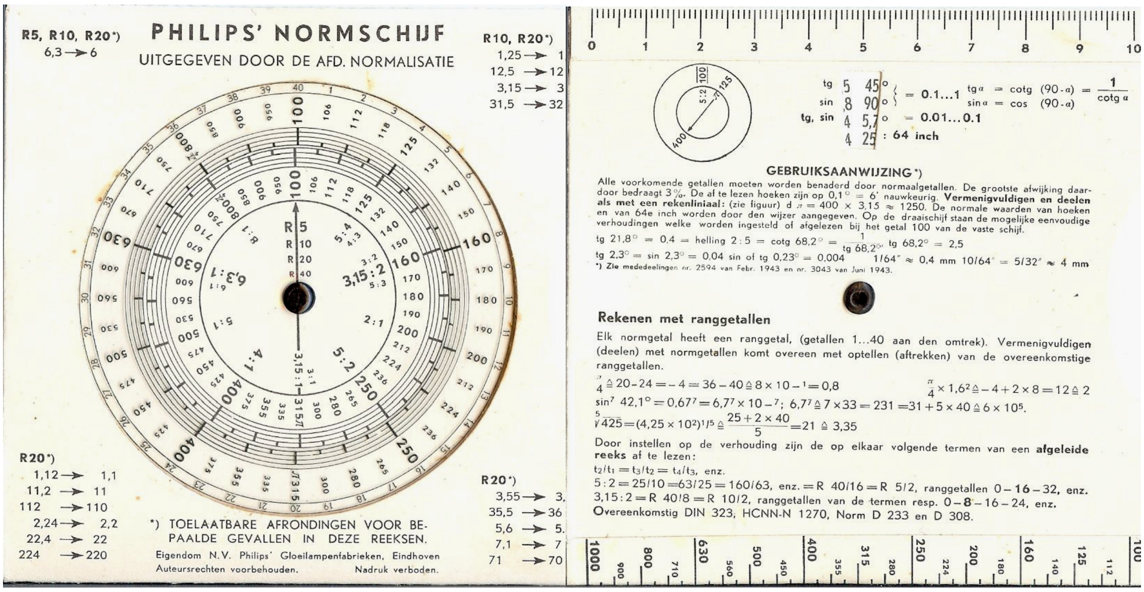
[3] Krünitz's *Ökonomisch-technologische Encyklopädie*, Berlin 1812

[4] Rudowski, Werner H., "How Well Known Were Slide Rules in Germany, Austria and Switzerland Before the Second Half of the 19th Century?", *Journal of the Oughtred Society*, 15:2, 2006

Nr. 15: Philips' Normschijf

Owner: Thomas van der Zijden

Pictures:



Purpose of the Slide Rule:

This is a standard disk for multiplication and division, but instead of using the normal C and D scales it uses scales of Renard preferred numbers of the series R40, R20, R10 and R5. Multiplication of Renard numbers gives by definition a Renard number as a result.

Dimensions:

- Carton frame, holding the disk : 107 x 105 mm
- Inner disk diameter: 60 mm
- Outer disk diameter: 80 mm
- No cursor

Material:

- Frame and disks: carton
- Metal center pin
- Disks protected with a plastic foil

Layout and scales:

- **Inner disk:**
  - One scale with the different Renard series. The different numbers are printed in different font sizes. R5 is the biggest, followed by R10, R20 and R40.
  - In the center the different number font sizes are explained.
  - Some values (such as Pi) are marked, with the corresponding preferred number printed next to it (3,15 in this case).
- **Outer disk:**
  - An identical size containing the R-numbers.
  - An outer scale ranging from 1 to 40, indicating the n-th element of the R40 serie.

- **Frame:**
  - Top title "PHILIPS' NORMSCHIJF UITGEGEVEN DOOR DE AFD. NORMALISATIE"
  - Different permitted round numbers, e.g. "R5, R10, R20*) 6,3-> 6"
  - "*) TOELAATBARE AFRONDINGEN VOOR BEPAALDE GEVALLEN IN DEZE REEKSEN. Eigendom N.V. Philips' Gloeilampenfabriek Eindhoven. Auteursrechten voorbehouden. Nadruk verboden."
- **Back**
  - Complete instructions
  - A cut-out window for tg, sin, "tg, sin" and the x/64 inch scale
  - Cm. scale and a linear R-scale

Designer:
According to the manual "E. Oosterling", with assistance of my grandfather J.A.M. van der Zijden

Manufacturer:
Philips ("N.V. PHILIPS' GLOEILAMPENFABRIEKEN TE EINDHOVEN")

Remarks:
Full manual available "NORMALE GETALLEN", which is, according to the booklet, part of "NORMALISATIE" bulletins, being "NORMALISATIE NR. 2, MAART 1944"

While the booklet and the disk seem to be intended to be distributed amongst Philips employees, this booklet may well be a pilot booklet, with the accompanying slide disk being a prototype. It is dated March 1944 and as my grandfather recalled it, there were other priorities in those days than to learn Philips engineers how to apply German DIN standards.

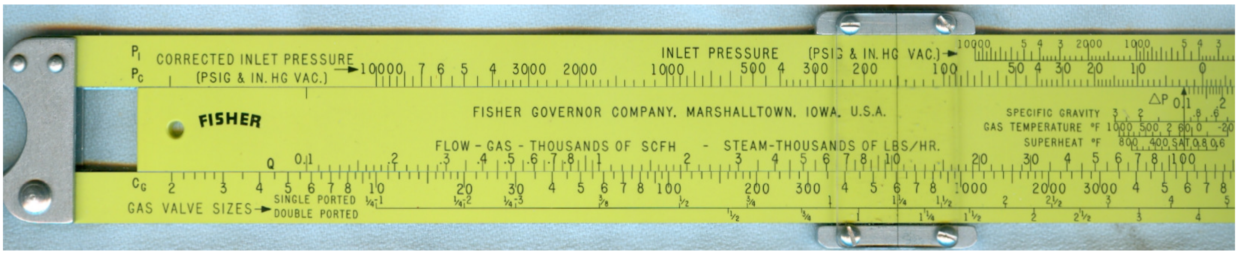
The slide disk was, according to the booklet, intended as a gimmick to stimulate the use of "normale getallen" in the daily work of Philips engineers. "Normale getallen" (preferred numbers) are a way to standardize component sizes. Renard split the distance from 1 to 10 in equal parts (5, 10, 20 or 40 pieces), which actually mean, that a series was created with $\sqrt[x]{10}$ being its constant factor of multiplication. R5 has therefore 5 elements, each being multiplied by $\sqrt[5]{10} \approx$ 1.6. The R5 series is 1.6, 2.5, 4, 6.3

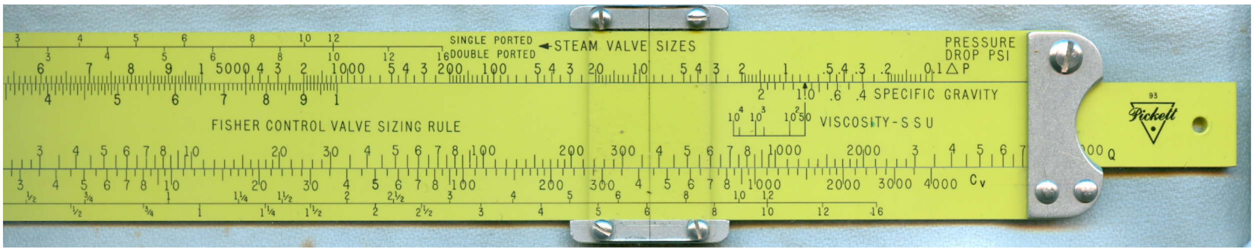
A multiplication of preferred numbers yields a preferred number. The manual describes this as an advantage: if for voltage and amperage preferred numbers are chosen, resistance and power will also be preferred numbers.

Nr. 16: A Special Purpose Pickett Slide Rule

Owner: Tom Wyman

Pictures:





General:

This yellow-faced aluminum is identified as a "Fisher Control Valve Sizing Rule." Measuring 12-inches overall with a copyright date of 1954, it was produced by Pickett for the Fisher Governor Company in Marshalltown, Iowa. It is not a unique product in the sense of being the only one ever produced, but certainly, the slide rule must have had a very limited, low volume production run given its highly specialized purpose.

Purpose of the Slide Rule:

The slide rule was designed for sizing and selecting Fisher-made gas and liquid valves.

Layout and scales:

The scales include a 5-inch slide rule with "C" and "D" scales for normal calculations. In addition there are three, 5-cycle log scales for gas and liquid flow. Operating factors used in valve sizing calculations include:

Pressure
Temperature
Specific gravity
Viscosity
Flow rate

Comment: Other than a small, cryptic "93" above the Pickett logo and "94" above the Fisher logo, there is no other identification number, suggesting this was a special-run slide rule that Pickett produced solely for the Fisher Governor Company. This is not a cheaply made slide rule and was probably designed primarily for in-house use by Fisher technicians rather than as a give-away to customers. The trim all-leather case is inscribed "Fisher Governor Company, Northern Columbia Process Equipment, Ltd., Vancouver." This particular specimen included two plastic cards providing valve size coefficients for use in making calculations involving liquids, air or gas, and steam.

I would be interested in any information others may have on this instrument.

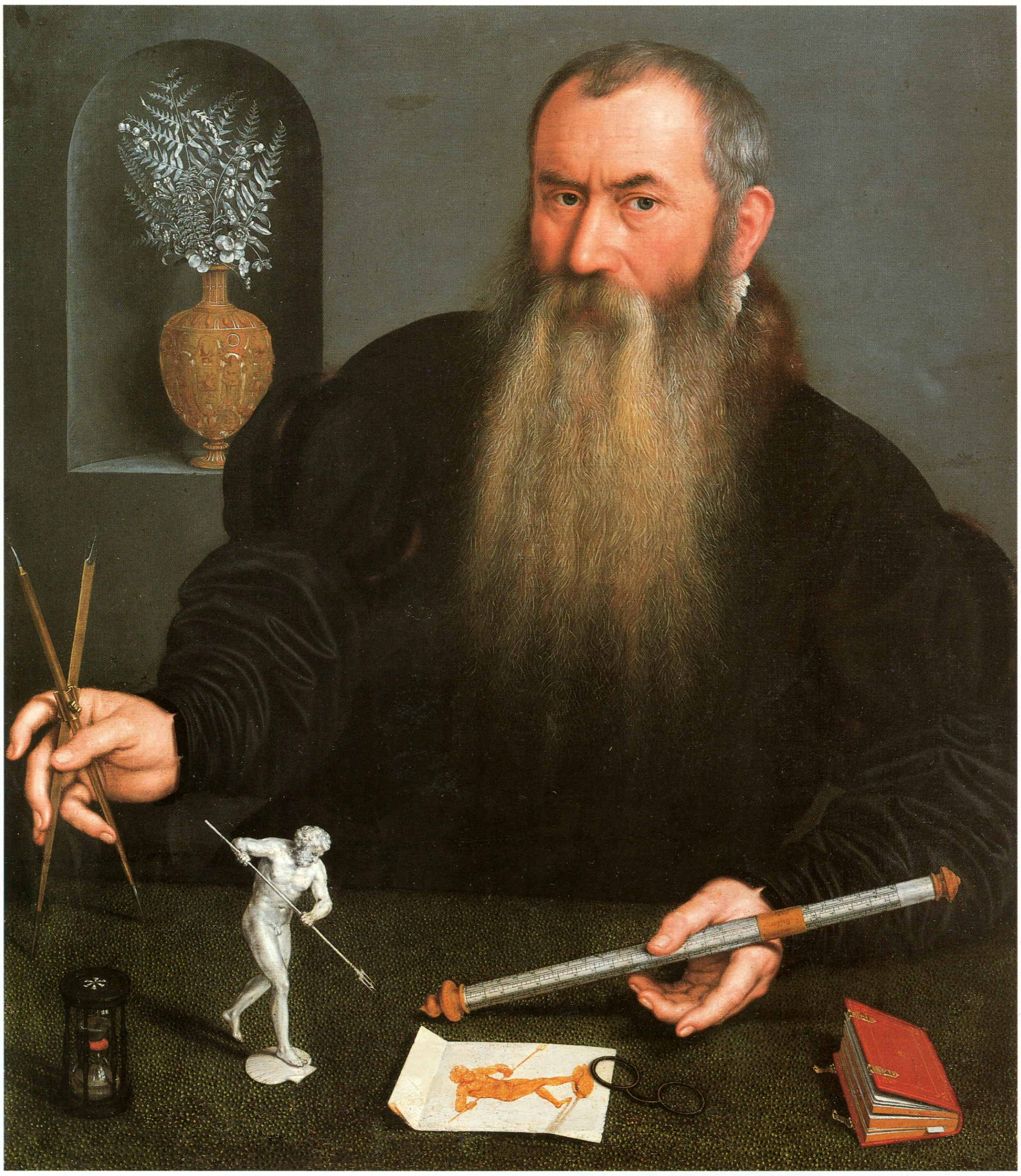
Nr. 17: Wenzel Jamnitzer's Calculating Cylinder

Note by the Editor:
Picture found in *Museumschatten*, SDU Den Haag, 1990, p. 118.

Owner: Musée d'art et d'histoire, Genève, Inv. 1825-23, Photo by J.-M. Yersin.

Description:
Painting "*Portrait de l'orfèvre Wenzel Jamnitzer*" by Nicolas de Neufchâtel of the Austrian-born goldsmith and instrument maker Wenzel Jamnitzer (1508 – 1586), working on a perspective drawing of a figurine. In his hands he holds an early version of reduction compasses and a calculating cylinder. The calculator, from before the age of logarithms, has axial scales with linear divisions (readable numbers from 1 upwards) and a sliding cursor with text (unreadable). Assumedly these tools were used to measure and reduce the proportional dimensions of the object to be drawn. See also E. Zinner, *Astronomische Instrumente des 11. – 18. Jahrhunderts*, 1956, p. 394.

Picture:



Nicolas Neufchâtel (ca. 1527-ca. 1590), Portret van Wenzel Jamnitzer, ca. 1562/63.
Doek, 92 x 79 cm., Musée d'Art et d'Histoire, Genève.