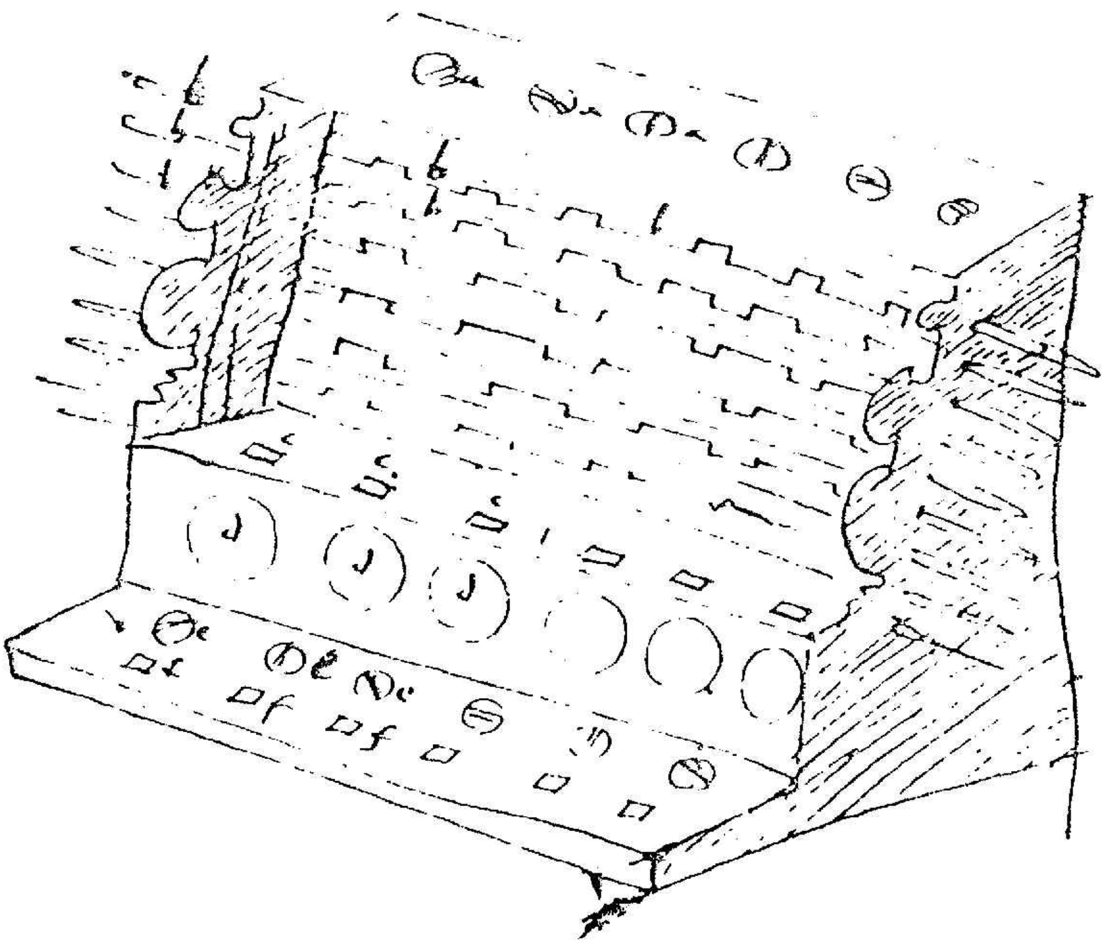


TECHNIQUES AND MACHINES IN THE HISTORY OF COMPUTING

Preface by Bernhard Korte

In a time in which computers and robots are increasingly influencing if not forming many technical, scientific, social and even personal domains of life, it seems fitting to cast a glance at the historical roots and sources of the development in order to place the spirits one has conjured up and now cannot get rid of, in the right historical context. The history of computing is in my opinion not only a relevant part of the history of technology but also a notable part of cultural history with all its positive and negative sides. This exhibition „Techniques and Machines in the History of Computing" with its in part unique exhibits from the Braunschweigisches Landesmuseum of Art and History and from the Institut für Operations Research der Universität Bonn presents an excellent opportunity to gain insight into this field.

One will observe with some interest that many of the exhibits are connected with famous mathematicians such as Pascal, Leibniz, Schickard, Kepler and others. With an eye on the current scientific policy discussions it is worth pointing out that these famous scientists did not consider it beneath their dignity to deal with cogwheels, shafts, tolerances, and nuts and bolts, and in fact spent a fair portion of their time in this way.

This exhibition was made possible by the enthusiastic interest of the members of the Institut für Operations Research der Universität Bonn and of the Sonderforschungsbereich 21 which is funded by the Deutsche Forschungsgemeinschaft, in particular Michael Jünger, MS and Gerhard Reinelt, Dipl. Inform., who have not only arranged the exhibition but have delved into the historical sources of computing with great historical and mathematical interest. To them I extend my particular thanks and appreciation. My thanks also go to Rolf Paland of the Braunschweigisches Landesmuseum for making the unique collection of computing devices available to us and supporting us with his extensive knowledge.

A modified version of this exhibition was presented from the 12. to 29. November 1981 in the Wissenschaftszentrum Bonn by the Deutsche Forschungsgemeinschaft and found great general interest. It was thus decided to present the exhibition again on the occasion of the XI. International Symposium on Mathematical Programming from the 23. to 27. August 1982 in the festive hall of the University. It will, I think, be particularly interesting for the participants of this symposium to learn something about the „Techniques and Machines in the History of Computing".

I would like to close with a quotation of Blaise Pascal (1623-1662) who at the age of 21 constructed one of the first mechanical computers, and which in my opinion is as relevant today as it was in the 17th century:

What the computer accomplishes
comes closer to human thinking
than anything that animals can
achieve; but it can do nothing
which could induce us to say
that it possesses a free will
akin to ours.

Introduction

The beginnings of the history of machine aided computation can only be treated satisfactorily in the general context of man's ability to count, introduce the abstract notion of „number" and calculate with these abstract quantities. Only the giant step from the distinction of „one", „two", and „many" to numbers in today's sense made calculations and the development of calculating aids possible. The oldest known numerals were used about 5000 years ago in Egypt and Mesopotamia. By putting together and taking away pebbles in the sand (later the Romans called them „calculi") additions and subtractions could be carried out. But yet another abstraction, namely the introduction of the digit value system, was necessary for the development of the abacus which is still in use today. In the first millenium A.D. the Romans brought the abacus to the middle European countries.

Not until the 17. century with its significant progress in philosophy, mathematics and mechanics did the development of more powerful mechanical computing machines take place which could handle the more complicated tasks of the time.

From then on the development continued rapidly. It took only 350 years from the machine of the mathematician Wilhelm Schickard, whose one and only model was destroyed by fire shortly after completion, to today's electronic computers built worldwide in the millions. These are 350 years of great inventive activities with all their successes and disappointments. The exhibition is an attempt to demonstrate the development of the mechanical computing machine by showing their outer, and partly inner, construction in significant examples. Some graphics and opened models illustrate the „inner life" of the machines. The technical details and the complicated interaction of frequently more than a thousand parts can be gleaned only after a thorough study.

The first section of the exhibition is dedicated to the abaci of the antique world. The following sections show the milestones of the historical development of the mechanical computing machine. These are connected with the names Napier, Riese, Schikkard, Pascal, Leibniz, Hahn, Müller, and Thomas.

The historical survey ends with a collection of computing devices of the Braunschweig firm Brunsviga-Maschinen-Werke resp. Grimme, Natalis u. Co. from the period 1892 to 1946. The punched-cards technique introduced shortly before that time by Hermann Hollerith (1860-1929) as well as the program controlled computer already initiated by Charles Babbage (1791-1871) and the gigantic consequences of their ideas in the explosive development towards today's computers was intentionally omitted in order to stay within the limited historical framework of this exhibition. The major part of the exhibited objects is on loan from the Braunschweigisches Landesmuseum and the others are from the collection „Geschichte des maschinellen Rechnens" of the Institute for Operations Research of the University of Bonn.

Special thanks are due to the Braunschweigisches Landesmuseum for making most of the exhibited objects available to the XI. International Symposium of Mathematical Programming.

Bonn, August 1982

Michael Jünger
Gerhard Reinelt

Section 1. Antique Abaci

The only computing aid of the antique world was the abacus. The name stems from the Greek word „abakion", meaning „circular plate" on which counters were moved.

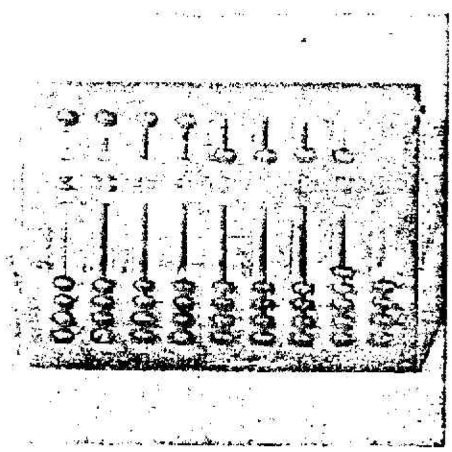
The Roman abacus was used from the third century B.C. to the fifth century A.D. and experienced a revival between the tenth and twelfth centuries through a book whose author later became Pope Silvester II (ca. 945-1003). In spite of their widespread use only few examples have survived, and reports about their application are even sparser. Furthermore the subdivision and digit-assignment varies on all known pieces. The abacus shown here has two counting grooves for the ounce and the 1/2, 1/3 and 1/4 ounce. The Roman figures for 1, 10, 100,..., 1000000 start from the third position. In each position the numerals from 0 to 9 can be represented. The upper bead stands for the value 5 and is moved down when applicable, the four lower beads have value 1 each and are moved up. Thus for example 9 is represented by 5+4x1. It is remarkable that the Greeks and Romans used the decimal system.

The Japanese Soroban is - even in today's form - a certain counterpart of the Roman abacus, although direct connections are not known. We only know that it was imported from China in the 7. century. The exhibited example was made in the 19. century.

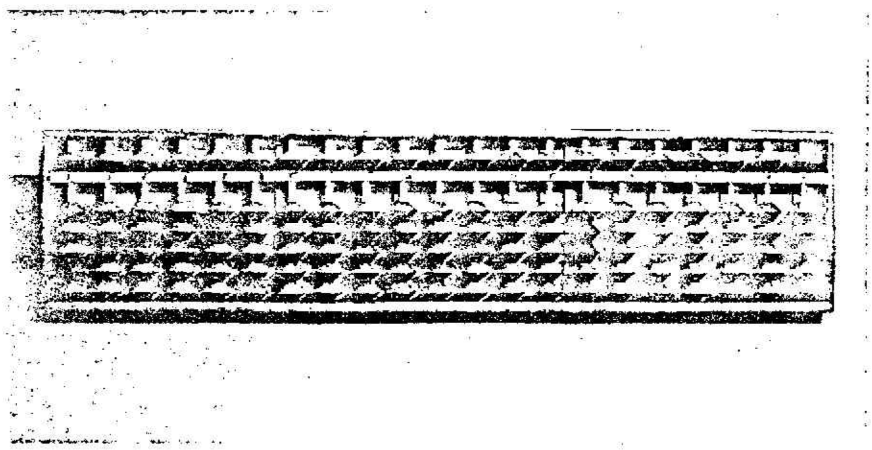
The Chinese Suanpan is considered to be one of the oldest computing devices in the world. Its original form with loose stones was already in use during the 11. century B.C.. The Chinese also used the decimal system. The construction is similar to that of the Roman abacus with two additional beads on each rod, one in the upper (value 5) and one in the lower section (value 1). Thus the carry-over from lower to upper compartment or from one rod to the next did not have to be performed immediately and could be delayed until convenient. However, the instructions state that these additional beads should be used as seldom as possible. The exhibited example was made in the 19. century.

The Russian Stschoty differs from the abaci described above in having ten beads for each decade. Of course this made the usage easier. The two columns with 4 beads are for 1/4 rubels.

Abaci are used to this day in Eastern Asia and Russia by merchants who apply them not only for addition and subtraction but also use them as an aid in multiplication and division.



Roman Abacus
L 12cm, W 9cm, H 0.5cm
Original: Cabent des Medailles, Bibliotheque Nationale, Paris



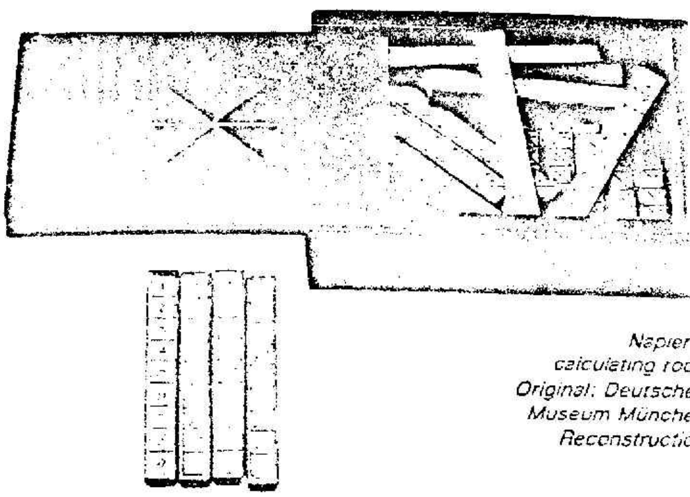
Japanese Abacus
SOROBAN
L 35cm, W 8.4cm, H 2.4cm

Section 2. Napier's calculating rods

John Napier of Merchiston (1550-1617), a Scottish lord, introduced the logarithm and is also known as the inventor of the decimal point. As an aid for the numerous calculations he had to perform, he invented the so-called Napier's calculating rods (or Napier's bones) for multiplication and division. The rods are assembled in such a way that the multiplicand appears in the upper row and its multiples from 2 to 9 in the following rows. Of course, the carry-overs have to be taken care of by the user.

Being a very simple computing aid, Napier's calculating rods were still in use in our century. The Theutometer, manufactured in 1914 in Württemberg, illustrates this. The reference to Egypt is purely a commercial gag.

Lord Napier of Merchiston (1550-1617)



Napier's calculating rods
Original: Deutsches Museum München
Reconstruction

Section 3. The reckoning table in the late middle ages

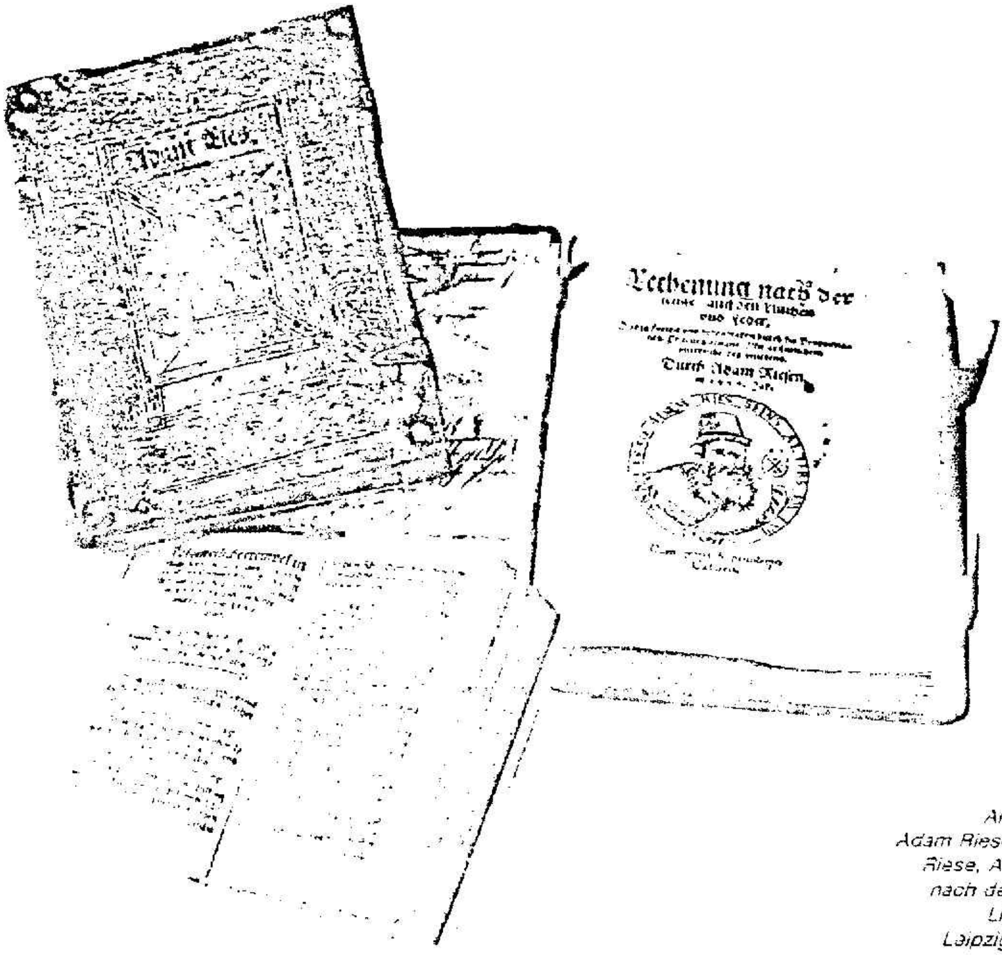
Having found its way to Europe about 1000 A.D., the art of calculating by arranging coins on lines became increasingly popular, especially among merchants.

Two pictures dating from 1491 and 1531 give an impression of such medieval reckoning tables.

In the allegorical representation of Arithmetic in the Margarita Philosophica by Gregor Reisch (1503) we see the written art of reckoning depicted alongside the reckoning board.

Section 4. Arithmetic book by Adam Riese

Adam Riese was born about 1492 in Staffelstein (Franken) and died in 1559 in Annaberg. He was one of the first to give a description of the four fundamental operations of arithmetic using numerous examples from everyday life, and after 1518 published many arithmetic books. His portrait is depicted on the frontispiece of the exhibited book.



Arithmetic book by Adam Riese (ca. 1492-1559) Riese, Adam: Rechenung nach der Lenge auff den Linihen und Feder. Leipzig, A.Benvalt 1650 196 p.

Section 5. Arithmetic books from 1661 to 1790

Swiss arithmetic book of 1661

The author H.H. Strübi „Ordinarium Schul- und Rechenmeister" at the German School in Zürich presents an introduction to the four fundamental operations of arithmetic as well as interest calculations and weight and coin tables.

Strübi, H.H.: Arithmetica: Ein new künstlich Rechenbuch. Bern: G. Sonnleitner 1661. 196 p.

Italian arithmetic book of 1685

The book contains numerous calculation problems illustrated by examples for practical applications. For example, a wood engraving shows a baker weighing out pieces of dough for Brötchen (rolls).

Libro d'abaco. Mailand: G. Rolla 1685. 160 p., H 15.2 cm. W 11.0 cm

Textbook on the mathematical sciences by Benjamin Hederich (1675-1784)

The book contains introductions to and problems in arithmetic, geometry, military and civilian architecture, astronomy and gnomonics (the science of sun and moon dials).

Hederich, M. Benjamin: Anleitung zu den führnehmsten Mathematischen Wissenschaften. Wittenberg u. Zerbst. S.G. Zimmermann 1754, 456 p.

Textbook on the mathematical sciences by Christian Wolff (1679-1754)

Christian Wolff was a professor of mathematics in Halle, where he also gave philosophical lectures. In the exhibited book he gives introductions to arithmetic, geometry, trigonometry, mechanics, optics, astronomy and algebra.

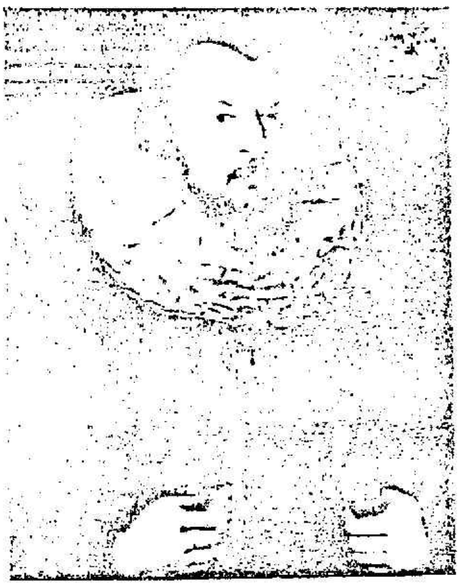
Wolff, Christian: Auszug aus den Anfangsgründen aller Mathematischen Wissenschaften zu bequemem Gebrauche der Anfänger. Halle: Rengerische Buchhandlung 1772, 764 p.

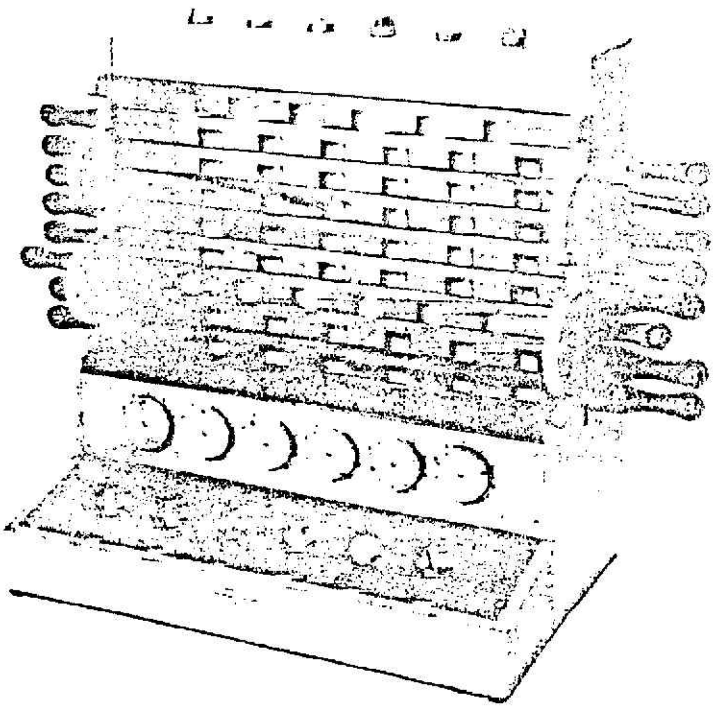
Arithmetic book for merchants (1790)

The many different sorts of coins and the various weights and measures which were valid simultaneously in Germany up to the middle of the 19. century led to the creation of conversion tables for merchants.

Steffens, J.H.: Rechnungsspiegel dessen man sich im Handel und Wandel mit leichter Mühe bedienen und darin den Preis der Dinge, die man kaufen oder verkaufen will, gleich ersehen kann. Quedlinburg : F.J. Ernst 1790, 192 p., H 17,2 cm, W 7,8 cm

Wilhelm Schickard (1592-1635)





Calculating machine by Wilhelm Schickard L 55cm, W 35cm, H 58cm Reconstruction: Institut für Schwingungsforschung, Tübingen

Section 6. The calculating machine of Wilhelm Schickard

Wilhelm Schickard was born on April 22, 1592, in Herrenberg. He attended the local Latin grammar school, then the royal seminary in Bebenhausen and afterwards the monastery school and the ecclesiastic foundation in Tübingen. Already in 1611 he became magister and soon after repetitor, and was known for his exceptional pedagogic abilities. In 1617 he met Kepler for the first time. Kepler recognized his remarkable talents and thought very highly of his mechanical inventiveness and ability as a draughtsman and engraver. He encouraged the young man to continue his mathematical studies. In 1619 Schickard was appointed to a professorship in Hebrew, Aramaic and other biblical languages in Tübingen. In the years 1623 and 1624 he invented a calculating machine which must be considered as the first of its kind. Unfortunately it was destroyed as early as 1624 by fire. Its existence was not known until the discovery of the correspondence between Schickard and Kepler. Schickard's life was overshadowed by the 30 years war. Twice he had to flee with his family from the advancing troops. In the year 1634 the plague broke out in Tübingen and his whole family died. On October 24, 1635 Schickard also died of the plague.

The rediscovery of the machine must be credited to the historian Dr. Franz Hammer who found a little drawing in Kepler's papers and a further sketch together with a note of instructions for the mechanic, among Schickard's papers. He noticed that both drawings belonged to Schickard's letters to Kepler in the years 1623 and 1624. When Dr. Hammer presented these discoveries to a congress of mathematicians in 1957, one of the audience, the Tübingen professor of philosophy B. Baron v. Freytag Löringhoff, succeeded in reconstructing the mechanical details. The machine was rebuilt according to his instructions and a first model was completed for the city of Tübingen on May 11, 1960.

Addition and subtraction can be carried out by entering the summands from right to left using the big brass wheels. Multiplication and division is performed using Napier's rods, here in the form of vertical cylinders, by uncovering the appropriate row and entering partial results and carry-overs as described above. The multiplicand is stored by means of the small disks.

Schickard's ingenious idea was forgotten during the confusion of the 30 years war and in his obituary it is not even mentioned.

Section 7. The calculating machine of Blaise Pascal

Blaise Pascal was born on June 19, 1623 in Clermont-Ferrand and died on August 19, 1662 in Paris. The talented young scientist made many contributions not only to mathematics and physics, but also to religious philosophy. At the age of 20 years he invented an eight-digit two-species machine for his father, who was a tax collector in the Normandie. The unidirectional machine can perform additions and subtractions using complementary numbers. Numbers are entered by dialling the digits into the eight dials with a rod. By moving the covering strip in the upper part of the machine the appropriate display (addition or subtraction) is revealed and the other covered. The values of the different places correspond to the contemporary French monetary system:

1. place: 12 deniers = 1 sol or sou
2. place: 20 sous = 1 livre
3. place: nombres simples (ones)
4. place: dixaines (tens)
5. place: centaines (hundreds)
6. place: milles (thousands)
7. place: dixaines de milles (ten thousands)
8. place: centaines de milles (hundred thousands)

The carry-over problem is solved by a complicated lever mechanism which utilizes the force of gravity. Evidently it could work only in the horizontal, and since it is relatively unreliable it is sometimes suspected that the machine was never fully operational. Schickard had solved the problem much more satisfactorily using a one-tooth wheel.

Pascal excited considerable admiration for his machine which was sold by the Paris mathematician de Roberval for 100 livres a piece. We do not know whether more than 7 machines were sold. It is only known that more than 50 prototypes were built before a fairly operational machine evolved. Pascal dedicated one of the first models to the chancellor Pierre Seguier, the governor of the Normandie and his father's employer. In his letter of dedication he writes:

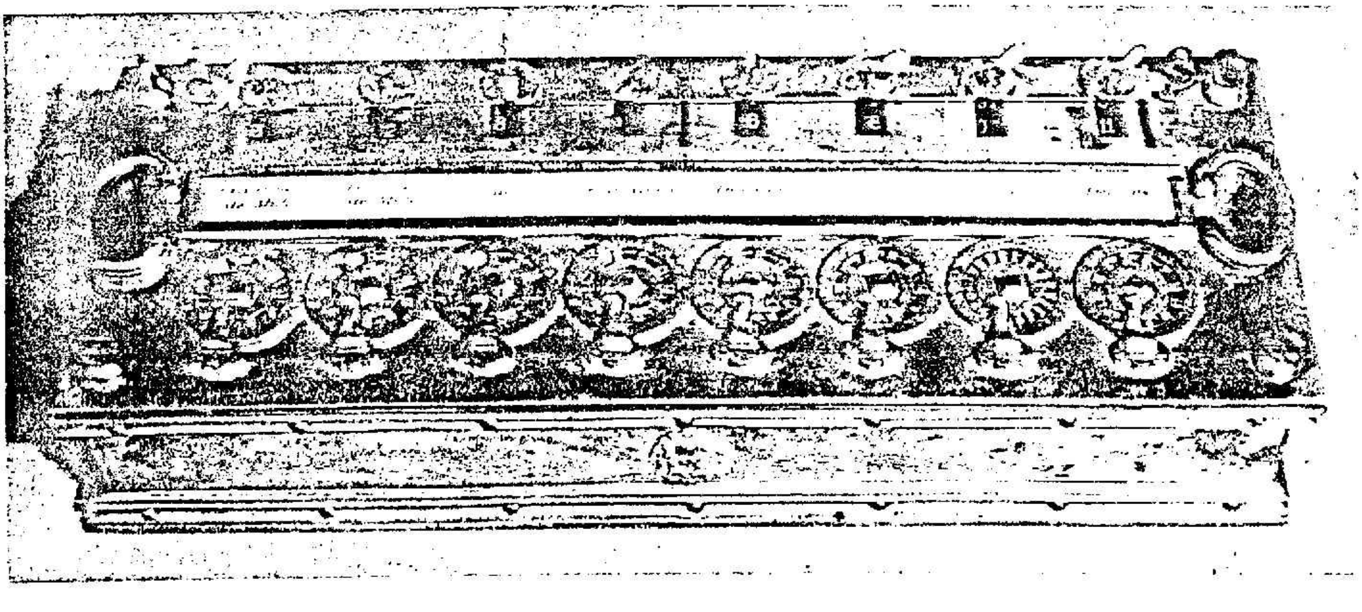
„Les longueurs et les difficultés des moyens ordinaires dont on se sert m'ayant fait penser à quelque secours plus prompt et plus facile, pour me soulager dans les grands calculs où j'ai été occupé depuis quelques années en plusieurs affaires qui dépendent des emplois dont il vous a plu honorer mon père pour le service de sa Majesté en la haute Normandie, j'employai à cette recherche toute la connaissance que mon inclination et le travail de mes premières études m'ont fait acquérir dans les mathématiques; et après une profonde méditation, je reconnus que ce secours n'était pas impossible à trouver. Les lumières de la géométrie, de la physique et de la méchanique m'en fournirent le dessein, et m'assurérent que l'usage en serait infallible si quelque ouvrier pouvait former l'instrument dont j'avais imaginé le modèle." (The tediousness and difficulty of the usual methods gave me the idea of inventing a device to speed up and facilitate the extensive calculations with which I have been occupied for several years in connection with the posts with which my father was honored for the services that he performed in upper Normandy for His Majesty. To this end I applied all the knowledge of mathematics that I have acquired through my first studies and my inclinations, and after deep consideration I realized that it would not be impossible to invent such a device. The foundations of geometry, physics and mechanics provided me with the basis for its design and gave me the assurance that its use would be infallible if only a mechanic could construct it according to my plan.)

In return Seguier obtained for him the privilege of patent in 1647. The king of Sweden also received one of the machines as a present.

In *Machines et inventions, approuvées par L'Academie Royale des sciences, depuis son établissement jusqu'à présent,* edited by M. Gallon, Vol. 4, Paris, the Pascal machine appears as one of the inventions which were presented to the royal academy of science in Paris in the years 1720 to 1726 and subsequently published.

Blaise Pascal
(1623-1662)

Calculating machine
by Blaise Pascal
L 36.2cm. W 13.1cm. H 9.5cm
Original: Conservatoire des
Arts et Metiers, Paris
Reconstruction



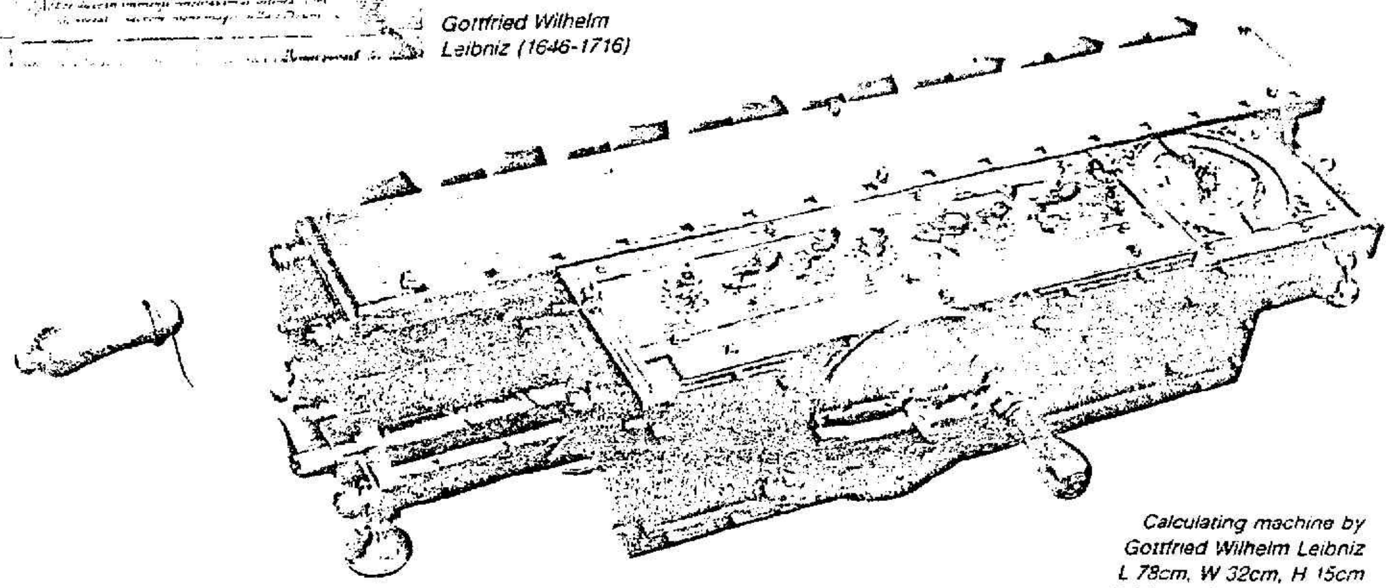
Section 8. The calculating machine of Gottfried Wilhelm Leibniz

The inventions of the philosopher, mathematician and (last of the) universal geniuses Gottfried Wilhelm Leibniz (1646-1716) brought about a major breakthrough in the mechanization of computing. Born in Leipzig, he studied law and philosophy in his hometown and in Jena. In 1667 he became doctor of law in Altdorf. After serving as a counsellor to the elector of Mainz he spent about four years in Paris where he pursued mathematical and scientific studies. In 1676 he was appointed librarian and counsellor in Hannover by Herzog Johann Friedrich von Braunschweig-Lüneburg. He also served the successors of the Duke and simultaneously was librarian at the Herzog-August-Bibliothek in Wolfenbüttel. This universal genius is considered to be the founder of the post-scholastic German philosphy. In addition he has made fundamental contributions to the fields of law, history, linguistics, politics, science and technology, and modern mathematics.

Without knowing of Schickard's and Pascal's machines Leibniz developed a four-species calculating machine. In his letter to Herzog Johann Friedrich von Hannover he wrote: „In Mathematicis und Mechanicis habe ich vermittels artis combinatoriae einige dinge gefunden die in praxi vitae von nicht geringer importanz zu achten, und ernstlich in Arithmeticis eine Machine, so ich eine lebendige Rechenbanck nenne, dieweil dadurch zu wege gebracht wird, daß alle zahlen sich selbst rechnen, addiren, subtrahiren, multipliciren, dividiren...". (I have by means of Combinatoris found certain things in Mathematics and Mechanics which are in daily life of no little importance, and very especially in Arithmetic a machine, which I will call a living reckoning bench, as wherewithal is achieved that all numbers add, substract, multiply and divide themselves ...)

Gottfried Wilhelm Leibniz (1646-1716)

From 1676 to 1694 he employed the Paris mechanic Olivier and then for another ten years Professor Wagner and the mechanic Levin on the machine. After 1715 the mathematician Teuber in Zeitz continued the work. It is not known how many machines were built, but it is assumed that there were three. Two were sent to Helmstedt for repair and are missing since then, the third is in the state library of Niedersachsen. This piece was accidentally discovered in 1893 while the roof of the university of Göttingen was repaired. It was given to the well-known German calculating machine constructor Arthur Burkhardt in Glashütte for restauration. But as several parts were missing the machine remained incomplete and therefore not operational. However, the general concept being clear, the honor of having constructed the first fully mechanical calculating machine for all four fundamental operations in arithmetic must be credited to Leibniz. During his whole lifetime he worked on the construction of this machine and invested the very high amount of 24000 Taler for that purpose.



Calculating machine by Gottfried Wilhelm Leibniz
L 78cm, W 32cm, H 15cm
Original: Niedersächsische Landesbibliothek, Hannover
Reconstruction

The machine was based on the „Staffelwalze" („stepped wheel", a cylinder with nine teeth of increasing width), a principle used 50 years later by Phillip Matthäus Hahn and still a basic part of some of today's mechanical computing machines.

The carry-over is performed in parallel and the machine is bidirectional, i.e. addition and subtraction differ only in the direction of rotation. For the first time multiplication and division are performed via successive additions resp. subtractions.

Finally it should be mentioned that Leibniz already considered the concept of a „Machina arithmeticae dyadicae", i.e. a machine performing arithmetic using dual numbers. which was not realized until the 20. century.The picture in *Miscellanea Berolinensia ad incrementum scientiarum ex scriptis Societati Regiae Scientiarum exhibitis edita cum figuris aeneis et indice materiarum, Berlin: J. Chr. Pape, 1710*, a publication of the Royal Academy of Science containing scientific papers and mechanical inventions must either have been simplified or the few machines that were built differed considerably from each other.

Section 9. The calculating machine o. Philip Matthäus Hahn

Together with Jakob Leupold (1674-1727) and Antonius Braun (1685-1727) Phillip Matthäus Hahn is one of the most important pioneers in the further development of the mechanical calculating machine.

Hahn was born on November 25, 1739 in Scharnhausen near Stuttgart as the son of the local parish priest. Already as a boy he was interested in geometry, astronomy and mechanics. After attending the Latin schools in Eßlingen and Nürtingen he entered the University of Tübingen in 1756 where he graduated as magister. In 1764 he was appointed to a parish in Onstmettingen. in 1770 he moved to Kornwestheim and in 1781 to Echterdingen where he died on May 2, 1790. His contemporaries admired Hahn as an inventive mechanic. They also esteemed him as a venerable priest, but at the same time they found him rather excentric and strange. While dealing with astronomical machines, clocks and hydrostatic scales, he had the idea of building a calculating machine, as he tells in a little paper of 1770, in which he also refers to Leibniz' experiments.

In the absolutist (pre-industrial) time of Hahn there was no real need for labor saving computing machines. Such sophisticated instruments were not meant for the offices of merchants but rather for the art- and miracle chambers of that time. During the baroque era computing machines were often regarded as a constructive mechanical proof for the philosophical world-clock-analogue. The pious priest Hahn, however, had neither economical nor philosophical reasons for his activities, but a theological motivation, as he writes in his diary on August 10, 1773:

„Was Rechnungsmaschine, was Astronomische Uhr, das ist Dreck! Jedoch um Ruhm und Ehre zum Eingang und Ausbreitung des Evangelii zu erlangen, will ich die Last noch weiter tragen". (What's in a reckoning machine, what's in an astronomical clock, they are nothing! But to earn fame and honor in spreading the Gospels I will carry this burden further.)

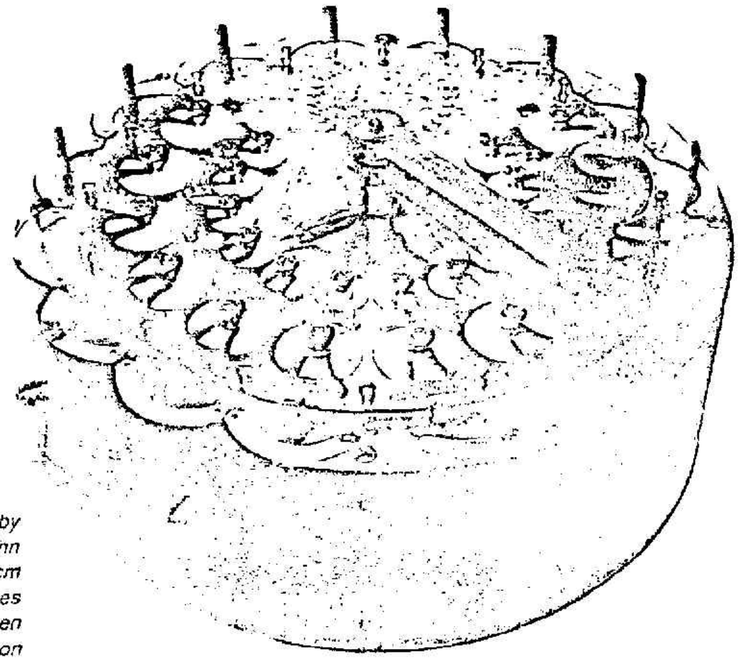
The development of the machine which began in 1770, was satisfactorily completed in 1774 with the help of a „studied, diligent watch maker". In the following years several successively improved machines were built.

The Teutsche Merkur, 1779, pp 137-154, contains a detailed description of the machine and its usage by the inventor.

In the Teutsche Merkur, 1785, pp 86-96, Hahn defends his machine against the assertion of Müller (c.f. Section 10), that it is not sufficiently safe. On the last pages Hahn suggests that Müller must have known more than the outer appearance of his machine before building his own. But he ends with the reconciling words:

„Dies soll ihm aber den Ruhm nicht nehmen, daß er große Fähigkeiten habe, und ich werde auch nicht mit ihm um den Vorzug streiten, weil dieses ihn und mich wenig nützen wird, so lang man nicht solche Talente soweit unterstützt, daß Leute, die dergleichen Gaben haben, ohne ihr eigen Vermögen daran zu setzen, Versuche machen können." (With this I do not however wish to discount the fame of his great talents, and I will not squabble with him about priority, as this would benefit neither him nor me so long as such talents are not supported to the extent that persons endowed with such gifts are able to persue their researches without cost to themselves)

Phillip Matthäus Hahn (1739-1790)



*Calculating machine by Phillip Matthäus Hahn
Ø 31.5cm, H 21.5cm
Original: Deutsches Museum, München
Reconstruction*

Section 10. The calculating machine of Johann Helfreich Müller

Johann Helfreich Müller (1746-1830) was engineer and architect in Darmstadt. In 1783 he built a calculating machine which was very similar to that of Hahn. In his „Beschreibung einer neu erfundenen Rechenmaschine, nach ihrer Gestalt, ihrem Gebrauch und Nutzen",(Description of a newly invented calculating machine, its appearance, its usage and its advantages) he writes:

„Da ich nun vermutete, daß der erwähnte Herr Hahn nach seiner beinahe siebenjährigen Arbeit und vielen unvollkommenen Versuchen den einfachsten und sichersten Weg gefunden haben würde: So durchging ich nochmal die in dem Teutschen Merkur eingerückte Beschreibung von der äußeren Gestalt und Behandlung seiner Maschine, in der Hoffnung, daß vielleicht eine von meinen Ideen mit dem Äußern jener Maschine übereintreffen würde. Meine Hoffnung wurde erfüllt und ich arbeitete nun diese Idee glücklich aus." (As I could assume that the Herr Hahn mentioned earlier had, after nearly seven years' work and numerous unsuccessful attempts, found the simplest and surest solution: thus I once again examined the description given in the Teutsche Merkur of the outer appearance and usage of his machine, in the hope that one of my ideas would be in agreement with the exterior of that machine. My hopes were fulfilled and I was fortunately able to realize my ideas.)

*Calculating machine by Johann Helfreich Müller
(1746-1830)
Ø 32cm, H 15cm
Original: Landesmuseum Darmstadt
Reconstruction*

Hahn, however, asserted that Müller must have known more than the outer appearance of his machine, and a priority struggle ensued which however was fought only in the papers and not in court, there being no patent laws at that time (c.f. Section 9). Even if Müller really knew more about the Hahn machine than its description in the Teutsche Merkur, we still have to acknowledge his improvements and his ingenuity as a mechanic. The exhibited single parts and the open section show the inner construction and provoke admiration for the highly developed precision mechanics of that time.

Section 11. The calculating machine of Charles Xavier Thomas

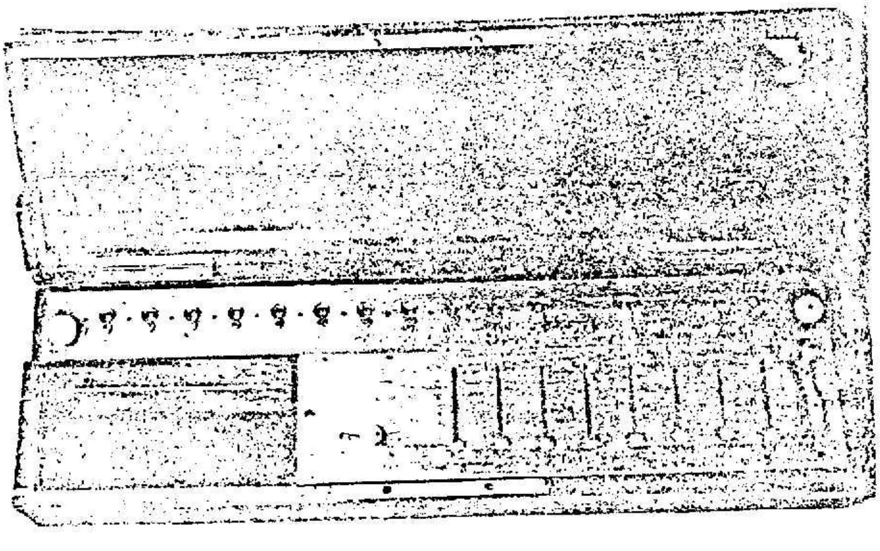
Charles Xavier Thomas (1785-1870) of Colmar in Alsace was the founder and director of two Paris insurance companies. In 1820 he applied for a patent for his newly constructed calculating machine, called Arithmomètre, and in 1821 he submitted it to the Société d'Encouragement pour l'Industrie Nationale in Paris for appraisal.

The machine uses the stepped wheel of Leibniz but unlike the Leibniz machine it is unidirectional having a switch for addition/multiplication and subtraction/division.

The Thomas Arithmomètre was the first calculating machine made in large numbers for general sale. In the following years about 1500 continuously improved machines were built and were on sale until the beginning of our century. Before the foundation of Arthur Burkhardt's firm in 1878 the Thomas factory was the only one in the calculator business. In the *Bulletin de la Société d'Encouragement pour l'Industrie Nationale (1879), pp 393-425,* a detailed description of the Thomas machine was published. The picture gives a good impression of the inner construction.

Charles Xavier Thomas (1785-1870)

Calculating machine by Charles Xavier Thomas L 57cm, W 17cm, H 9.5cm



Section 12. Adding machines

Besides the calculating machines for the four fundamental operations of arithmetic shown so far, there have since a long time also been special purpose devices for addition and subtraction only. Especially in the field of commercial arithmetic they were in widespread use. We show three early examples.

The adding and subtracting device of Christian Ludwig Gersten was invented in 1722. Gersten was professor of mathematics in Gießen. The original of the machine in Darmstadt was destroyed in the second world war and the reconstruction shown is the only existing piece.

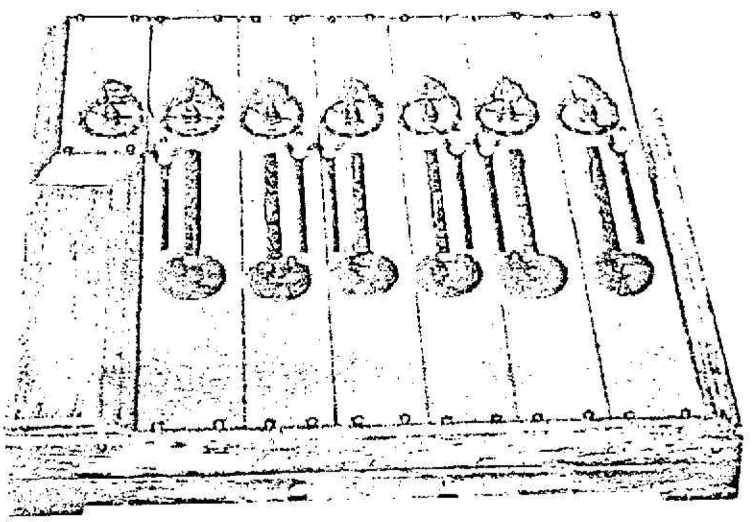
Adding machine GERSTEN (1722), reconstruction, original destroyed in the second world war, L 37,2 cm, W 37 cm, H 7 cm

The adding and subtracting device of Israel Abraham Staffel is believed to be constructed in Staffel's hometown Warsaw. It is one of the rare eastern European pieces

Adding machine STAFFEL (1845), L 25 cm, W 25 cm, H 6 cm

The comptometer of Dorr E. Felt, invented in 1885 in Chicago , was the beginning of the development of key driven adding machines. As the keys may be pressed simultaneously this was a fast way to perform additions. By moving the hand one place to the left or right while retaining the fingers in the same position relative to each other multiplications could also be performed. For training the necessary manual skill there were special comptometer schools.

Adding machine COMPTOMETER (1887), L 35,5 cm, W 20,3 cm, H 12,5 cm



Adding machine by Christian Ludwig Gersten 1722 L 37.2cm, W 37cm, H 7cm Original destroyed in World War II Reconstruction

Section 13. Three calculating machines from the years 1880 to 1905

In the twenties the construction of calculating machines had spread all over the world. About 50 firms worked in this difficult field of precision mechanics with more or less success. The three exhibited machines have been chosen to point out early examples of different types.

Arthur Burkhardt of Glashütte was the first in Germany to manufacture a Thomas-type machine for large scale commercial distribution. The Burkhardt Arithmometer was built in continuously improved versions from 1878 to 1929. The exhibited machine is an early piece having serial number 324.

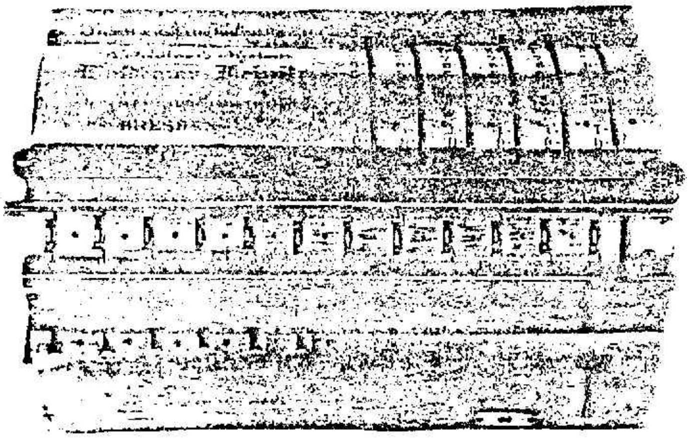
Calculating machine BURKHARDT (1880), L 59 cm, W 19,8 cm, H 10,2 cm

A different major principle, the wheel with a variable number of teeth, was used in the construction of the Monopol Simplex by Waldemar Heinitz of Dresden. Its unique feature is the handle on the left hand side which allowed the right handed operator to write down the results while computing.

Calculating machine MONOPOL-SIMPLEX (1894), L 29 cm, W 17,5 cm, H 12,5 cm

The Gauss machine made in Berlin by the Mercedes Bureaumaschinenwerke was developed by the successful German calculating machine constructor Christel Hamann in 1905. Instead of using a Leibniz stepped wheel for each place, we here have a single circular plate with nine concentric arcs containing one to nine teeth. Clearly this arrangement was only useful for circular machines.

Calculating machine GAUSS (1905), diameter 14 cm, H 10 cm



Calculating machine
MONOPOL-SIMPLEX
1894
L 29cm, W 17.5cm, H 12.5cm

Section 14. Brunsviga-Calculators

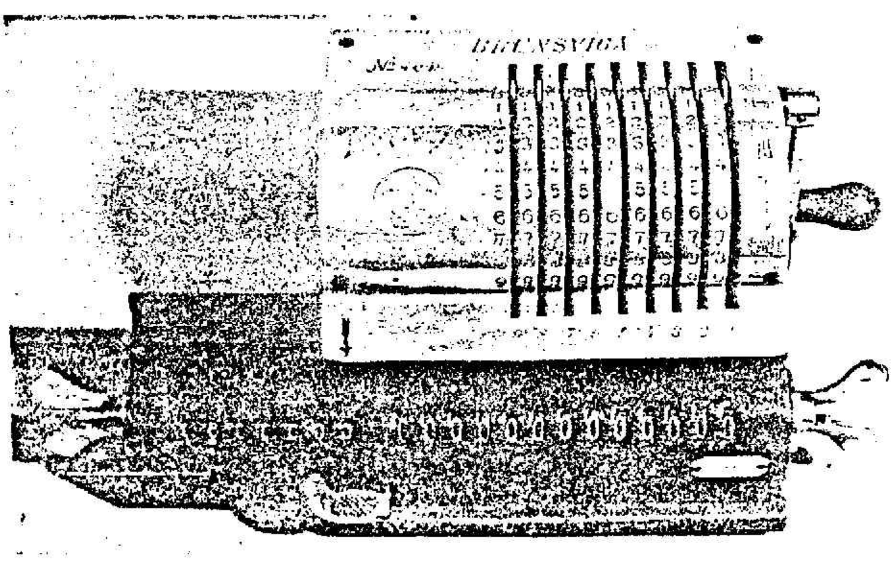
After Arthur Burkhardt in Glashütte, the firm Grimme, Natalis & Co. started the second series of large scale calculator manufacture. Having acquired the German patent of Willgodt Theophil Odhner for the wheel with a variable number of teeth, they were able to build more compact and commercially very successful calculating machines with the brand name BRUNSVIGA. The production started in 1892 and the machines underwent continuous technical improvement under the guidance of the technical director Franz Trinks, a very inventive engineer. Trinks was also the founder of the calculating machine museum in Braunschweig, now in the Braunschweigisches Landesmuseum, the permanent home of most of the exhibited pieces.

Calculating machine BRUNSVIGA B (1892), L 29 cm, W 15,5 cm, H 12 cm

Calculating machine BRUNSVIGA M 24 (1924), L 23 cm, W 13,5 cm, H 12

Calculating machine BRUNSVIGA 13 Z (1932), L 29 cm, W 23 cm, H 16 cm

Calculating machine BRUNSVIGA 13 ZK (1946), demonstration model, L 29 cm, W 23 cm, H 16,5 cm



Calculating machine
BRUNSVIGA B
1892
L 29cm, W 15.5cm, H 12cm