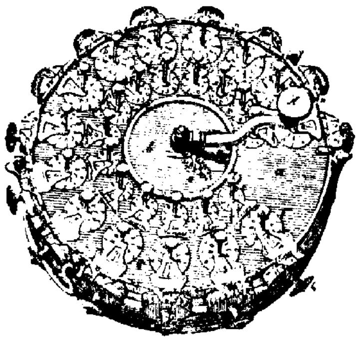


Figure 25
Müller's machine.

Auch (1790)

Jacob Auch, one of Hahn's coliaborators, constructed a machine that can be seen in the Physical Institute of the Technische Hochschule in Karlsruhe. It was rectangular in form and is reported to have been suitable for adding, multiplying, subtracting, and dividing (figure *26).*

Steffens (1790)

This is another German calculating machine which is unknown in practice.[36]

Reichold (1792)

The parson Reichold of Dottenheim in Aischgrund engaged, just like his colleague Hahn of Kornwestheim, in the manufacture of wooden clocks. He also made, among other things, a calculating machine for addition, subtraction, multiplication, and division. However, this machine did not offer any particular advantage over earlier machines. If Parson Reichold had not died early, he would undoubtedly have made a significant contribution to the development of calculating machines.

36. Martin often uses the phrase unknown *in practice*. The editors are unsure if this implies *not* known *to be extant* or simply *never became of any practical importance*, however the editors know of extant machines that Martin referred to in this way. and thus the latter phrase may be the best translation.

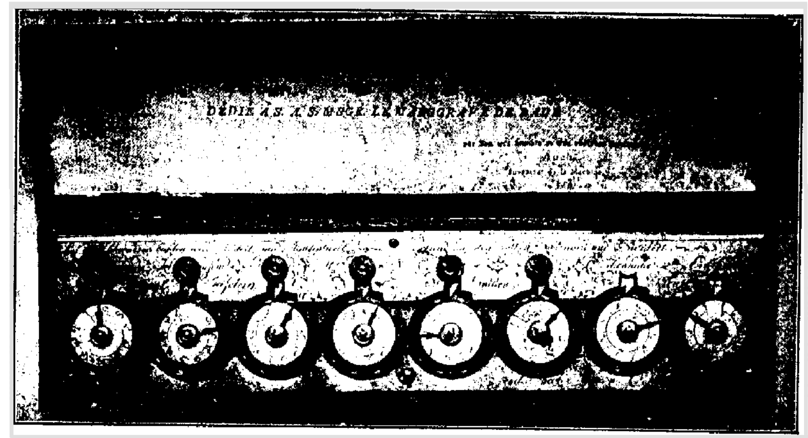


Figure 26
(Source: Engelmann, Phil. Matthäus Hahn)

Stern (1814)

The clockmaker Abraham Stern of Warsaw constructed a machine in which it was only necessary to set up the amount to be manipulated and then to start a clockwork mechanism. In 1817 he made a second machine that served mainly for extracting square roots. Later he consolidated the two machines into one, but it never had any real influence on further developments.

Thomas (1820)

In 1821 Charles Xavier Thomas of Colmar (1785–1870) (founder and manager of the Compagnie d'Assurance Le Phénix, 33, rue de l'Echiquier, and the Compagnie d'Assurance Le Soleil, 13, rue du Helder, both in Paris) submitted, to the Société d'Encouragement pour L'Industrie Nationale in Paris a calculating machine he had constructed, which he called an arithmometer. Thomas is usually thought of as the founder of the calculating machine industry because Parson Hahn's efforts probably did not yet amount to an industry since he and his collaborators manufactured only a relatively limited number of their calculating machines. Thomas devoted himself to this branch of industry up to the time of his death, and he raised this industry, over a period of several decades, to a rather high level. In fact, up to the time when

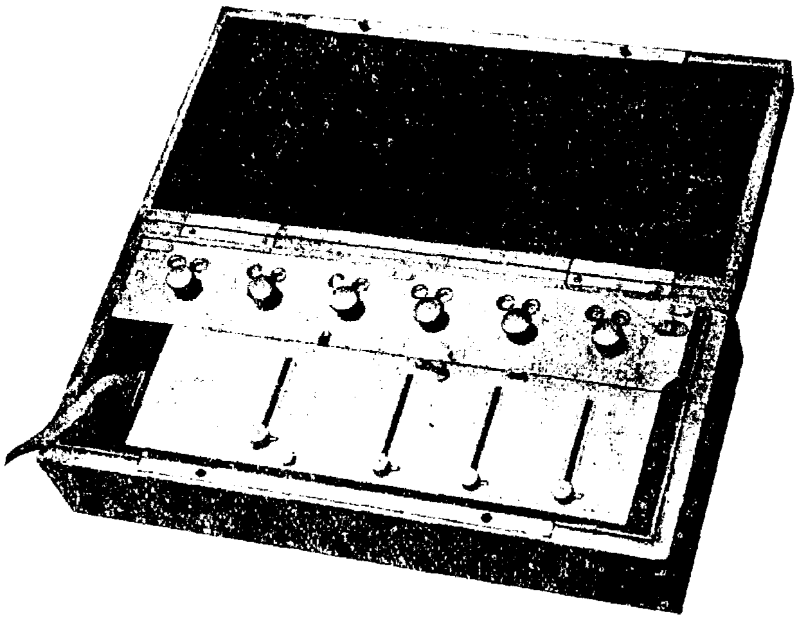


Figure 27
The oldest Thomas machine.

the calculating machine industry was introduced into Germany by Arthur Burkhardt (1878), the Thomas workshop was the only firm in this line and supplied the whole world with its products. We know, for instance, that the Thomas workshop completed five hundred machines from 1821 to 1865, three hundred machines from 1865 to 1870, four hundred machines from 1871 to 1875, and three hundred machines from 1876 to 1878. Approximately 30 percent of these machines were six-place machines, 60 percent were eight-place machines, and 10 percent were ten-place machines. Out of one hundred completed machines, sixty went abroad and only forty remained in France. The cost of a sixteen-place machine was five hundred francs, which at the time was generally regarded as too expensive to permit a larger turnover.[37]

The Machine of 1820 This machine, Thomas' first model, had only three setting slides and consequently it had **only** three stepped drums, but it had six places in the result mechanism. A fourth setting slot is provided to the left of

37. **The *sixteen-place machine* presumably is one that showed sixteen places in the result. These machines allowed eight-place entries.**

the other three, which is likewise provided with the scale 1 to **9** and with a slide bearing the inscription *multiplicateur*. Below this slide, in the interior of the machine, is a drum with a silk ribbon attached to and wrapped around it. The other end of the ribbon sticks out of the machine on the left hand side. To the left of the ribbon drum, also in the interior of the machine, there is another drum with nine steps and a spring attached between the drum and the machine casing. The two drums are connected by gears. The spring causes the ribbon drum to rewind; that is to say, the force of the spring automatically wraps the ribbon back on the ribbon drum after it has been pulled out during calculation. The three stepped drums are connected with one another and with the ribbon shaft by means of gears. When the ribbon is pulled, the ribbon shaft rotates, which, in turn, causes rotation of the three stepped drums. When a value has previously been set on the stepped drums by means of the slides (and if the slide of the multiplier device has been set to 1 on the scale), rotation of the drum will transmit that value into the result mechanism. Thus the **pull** on the ribbon takes the place of the turn of the crank employed in today's machines.

How does multiplication occur on such a machine? Recall that there is a multiplication slide that may be shifted along a scale marked 1 to **9**. This slide acts upon the previously mentioned drum with nine steps in such a manner that if the slide has been set to 3 and the ribbon is then pulled. the ribbon drum can make exactly three revolutions. This rotates the three stepped drums exactly three times around their axes since the ribbon drum is connected with the stepped drums through gears, and thus the amount registered on the respective three places is transmitted three times in succession onto the result mechanism. Since the carriage may, if lifted, be moved horizontally, the machine permits multiplication of multidigit values.

The carriage possesses six double windows. A numeral disk, situated below two associated windows, contains two sets of digits—a black set on the outer edge of the disk and a red set on the inner edge. The black digits appear in the left window and the red ones in the right window; the black ones show the results of addition and multiplication and the red ones the results of subtraction and division. In order to avoid confusion, a perforated draw band is provided that exposes the left windows during addition and multiplication and the right ones during subtraction and division.

Subtraction occurs in the same way as addition except that the larger item may be set up directly with the aid of rotating knobs placed below the windows. The subtraction windows are opened, the amount to be subtracted is

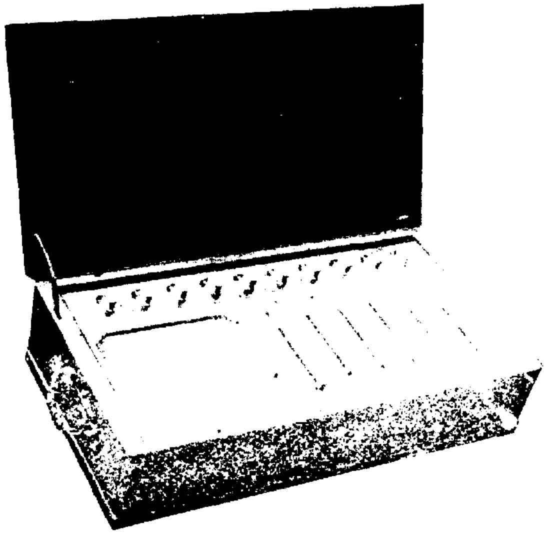


Figure 28
The machine of 1848

set on the setting slides, the multiplication knob is set to I, then the draw ribbon is pulled out. Division occurs in the same manner except that the carriage is displaced from place to place in the same way as with multiplication.

The Machine of 1848 This machine has five slide slots and the previously mentioned multiplication slide. It has ten places in the result mechanism with only one window each because transition from addition-multiplication to subtraction-division is affected by a lever. In place of the complicated ribbon mechanism, a crank is provided in the front part of the machine. The individual stepped drums have only nine teeth instead of eighteen.

The Machine of 1858 The main improvement **in** this version **of** the Thomas machine is the second counting mechanism without a tens-carry (revolution counting mechanism). The uses to which this can be put have been described in the general description of stepped drum machines in the Introduction. The machine was also provided with one zero-setting device that acted on all the windows of the result mechanism and another for all the windows of the revolution-counting mechanism. Previously, all the numeral disks had to be set *to* zero individually **by** turning knobs placed below the individual windows. The zero-setting device is in the form of a rotating knob that is turned to the right until all the windows of the respective numeral mechanisms show zero. The zero-setting device of the result mechanism is mounted **on** the right side **of** the upper surface of the carriage, whereas the zero-setting mechanism of the revolution-counting register is arranged at the left.

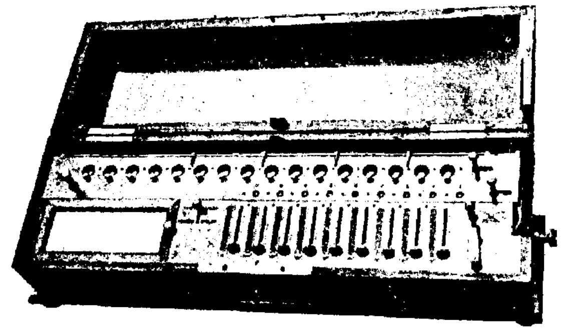


Figure *29*
Present day model

The Machine of 1878 In this model the setting slides were provided with small springs, which, when the slide has been set to a certain digit, cause the slide to slip into a notch opposite that digit so that an accidental movement of the setting knob during operation of the crank **is** avoided. The tens-carry mechanism was materially improved. Means were provided to prevent overthrow.'' Of course, Thomas never manufactured the machines himself, rather he contracted out this aspect **of** the business. In the 1870s, **A.** M. Hoart was engaged in their manufacture in the house of the Insurance Company Soleil, 13 rue du Helder. Later the manufacture was transferred to L. Payen, then to L. Payen's successors, 16 rue de La Tour des Dames. Today Aph. Darras, 123 Blvd. St. Michel, Paris manufactures the arithmometer in France with 12, **16,** and 20 places in the result mechanism. Figure 29 shows a machine of the present manufacturer. One of the older original Thomas machines can be found in the Deutsches Museum in Munich.

38. Overthrow is the result of turning the crank with enough force that the momentum applied to the mechanism causes it to rotate past its normal stopping point and, *as* a consequence, produce incorrect results.

Tyrell (1830)

In many instances the literature contains only meager information about many of the details of the construction of different machines. These machines were of no influence in the further development of the calculating machine art, but we would like to mention them nevertheless for the sake of completeness. To this class of little-known instruments belongs the adding machine patented to the Englishman John Tyrell on 13 November 1830, which F. M. Feldhaus mentions in his *Technik der Vorzeit*.[39]

Samuel Downing (1833)

In 1829, after new imperial weights and measures were introduced in England, Downing constructed new slide rules as calculating aids for the new system. In the production of these instruments he used a composite plane for preparing the edges and the slides. He later invented a calculating machine about which there is some meager information in the English technical periodicals of his time. His calculating machine, which was intended to be competitive with the calculating machine designed by Babbage, was patented in England in 1833 and has been described in several places. No drawings are in existence.

Daniel Kohler (1835)

With regard to this inventor's adding machine, a contemporary report states that it (like all the other calculating machines that had been produced to this time) might, at best, find a place in the model collection of scientific societies.

J. S. Holland (1835)

According to a patent application. J. S. Holland of Three-Colt Street in Limehouse, London, invented a calculating machine capable of addition, subtraction, multiplication, and division, and also of solving problems of the rule of three, of powers, roots, and additional calculating problems. His machine was reported to have been so simple that it was not nearly as liable to malfunction

39. *Technical Science of the Past*, published in Leipzig and Berlin by W. Engelman, 1914.

as other models and would not cost any more than an ordinary clock. It was stated that any skilled mechanic would be capable of making it. Yet nothing was ever heard about this calculating machine again.

Barnet (1842)

The next English patent taken out for a calculating machine was that of Barnet. No further information is available.

Roth (1841)

Dr. Didier Roth. 21, boulevard des Capucines, Paris, designed an adding and subtracting machine with a stylus setting mechanism — similar to Pascal's machine but materially improved. Unlike Pascal's machine, Roth's is almost entirely flat. Here the result digits (0 to 9) appear twice on horizontal gears and are covered by a plate with semicircular slots so that one can see only the individual teeth of the gears. The addition digits are marked on the cover plate just above the setting slots. Setting of a value occurs by inserting the stylus next to the digit to be set up and pulling the setting gear to the left until the stylus reaches the end of the slot, whereupon the respective number appears in the window below. Unlike Pascal's tens-carry, the tens-carry in the Roth machine is a gradual one and consequently carries through to the last place. This is especially important in Roth's machine because of the zero-setting mechanism. Resetting is done by pulling a knob at the left of the machine that sets all gears to 9. In order to obtain zero setting, which is necessary for a new setting of the next value, 1 is added in the first place from the right, which sets all windows to 0. The individual digit gears are provided with locks so that no overthrow can occur. Later the machine was somewhat improved by providing red subtraction digits within the setting slots, whose setting result was shown in separate red subtraction windows so that the machine could be conveniently employed for subtraction as well. The machine was supplied with eight digit places, but neither in France nor in other countries did it gain any importance. Manufacture was discontinued a long time ago. An example of Dr. Roth's machine may be found in the Calculating Machine Museum of the firm Grimme, Natalis and Company of Braunschweig.[40]

40. Now in the Braunschweigisches Landesmuseum, Braunschweig, Germany

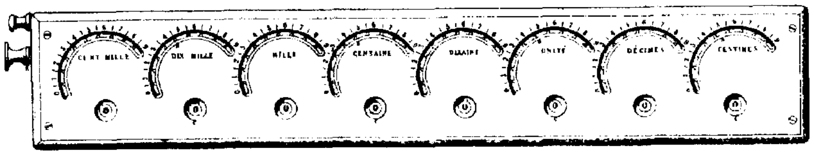


Figure 30

Dr. Roth also designed a machine that externally resembles Hahn's machine and possesses gears with a variable number of teeth. Setting up an amount upon the external numeral dials of the machine releases the corresponding teeth that carry out multiplication when the crank is rotated. The result may be read from the window of the inner circle. This machine, like his simpler adding machine. was of no importance, but two models of it may be found in the Conservatoire des Arts at Métiers in Paris.

Marston (1842)

No details are known about this machine that was patented in England.

Wertheimber (1845)

This English patent represents another attempt in calculating machine design to employ the pinwheel, which is the gear with a variable number of teeth. However, the idea was not actually implemented at the time. Baldwin was the first to revive this invention, and he actually used it in a machine for the first time (see Baldwin, 1875).

Staffel (1845)

This is a seven-place adding machine made by J. A. Staffel, a Pole. The machine is flat and has setting slides and windows below the slide slots. A zero-setting device is provided at the right side of the machine. Like Roth's earlier adding machine. it never gained any importance. An example may be found in the Calculating Machine Museum of the firm Grimme, Natalis and Company in Braunschweig.[41]

41. Now in the Braunschweigisches Landesmuseum, Braunschweig, Germany

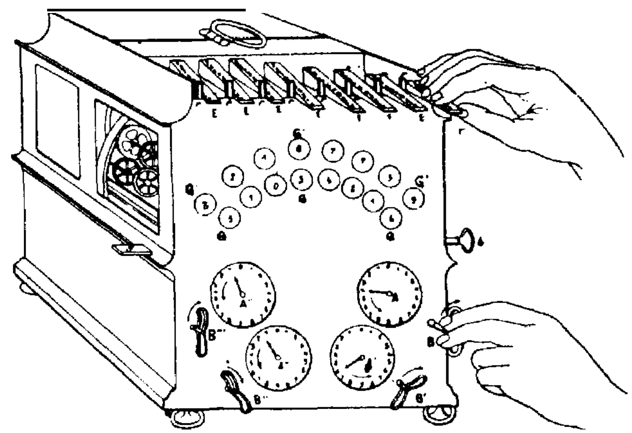


Figure 31

Arithmaurel (1849)

This device was made by Maurel and Jayet. The machine is especially well suited for multiplication and division but is also capable of performing additions and subtractions. The operation is very simple. The whole setting mechanism and the result windows are shown in figure 31.

For multiplication the larger amount is set up with the aid of the eight setting bars, which can be seen on the top edge of the machine. These are pulled out (forward) as required until the digit to be set up is positioned next to an indicator. Multiplication is carried out by means of the four keys shown on the front face of the machine. Each key has an indicator dial associated with it. There is no carriage shift. The first dial at the right performs unit multiplication, the one positioned below performs tens multiplication, the one situated at the lower left performs hundreds multiplication. and the last one performs thousands multiplication. As soon as one of the key-driven dials has been shifted to a certain number, the result may be read from the lowest set of windows. The machine allows multiplication of eight-digit values by four-digit values. The upper row of result windows serves to maintain a sum during continued multiplication. This is undoubtedly a rather interesting machine, yet it did not find introduction into practice because it is fairly complicated and may easily get out of adjustment. An example of the machine may be

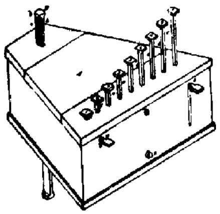


Figure 32
Parmelee.

found in the Conservatoire des Arts et Métiers, Paris. Two more examples are in the hands of private French owners.

Parmelee (1850)

The Parmelee machine is the first adding machine with keyboard (key-driven) setting. It must be admitted, however, that it was rather primitive and never went beyond the experimental stage.[42] It has nine keys, 1 to 9, which are mounted upon a progressively ascending key lever. At the other end of the machine there is a graduated bar marked with successive digits, and the front side is provided with teeth. Upon depression of a key, a lever (mounted on a shaft) with a pawl at the end engages the teeth of the bar and lifts it by as many units as are represented by the marking of the key. Another pawl is arranged to maintain the raised bar in its set position until subsequent depressions of a key raise it further. It is evident from this description that only as many digits could be added with this machine as were provided on the bar—to accumulate a sum of up to one hundred, the bar would have to be almost a meter long.

Schilt (1851)

This adding machine, with keyboard setting, was displayed in London in 1851. Details are lacking.[43]

42. The editors believe that it never even reached the experimental stage. All illustrations of Parmelee's machine appear to be simple copies of the illustration used in his patent application.
43. The Schilt machine is now in the National Museum of American History. Smithsonian Institution, Washington D.C.

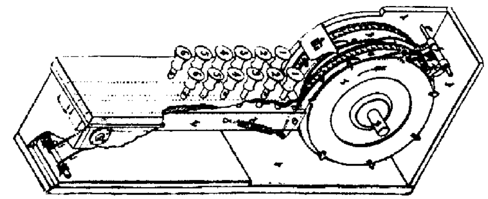


Figure 33

Hill (1857)

Hill's machine, as illustrated in figure 33, shows considerably more similarity with our modern keyboard adding machines than either Parmelee's or Schilt's device, yet it never advanced beyond the experimental stage. The model illustrated may be found in the National Museum in Washington.[44] The individual digit wheels have the digits 0 to 9 inscribed around them seven times. These digit wheels are moved by a gear which, in turn, is driven around by the action of depressing a key on the keyboard. There are no overthrow locks. The tens-carry mechanism is similar to that of Pascal's machine.

Arzberger (1866)

This is an adding machine with only two keys for the digits 1 and 3. This machine was only intended for the addition of individual columns.

Samostchoty (1867)

This machine was designed by Bouniakovsky. It is an adding machine of the same type as Pascal's.

Webb (1868)

Designed by C. H. Webb, it consists of two rotatable circular disks, one for the numbers up to a hundred, the other one for thousands. The apparatus has automatic tens-carry.

44. Now the National Museum of American History. Smithsonian Institution. Washington D.C.

Chapin (1870)

A nine-key machine for adding single columns of numbers. The machine never went beyond the experimental stage.

Robjohn (1872)

A nine-key adding machine with three result windows. On the exterior it resembles the Gab-Ka machine, and likewise. serves for the addition of columns of single-digit numbers.

Barbour (1872)

This machine deserves attention because it represents the first attempt to design a calculating machine that prints. It was an eight-place machine. The setting of a value occurred by withdrawing a slide, whose interior portion was provided with sets of one to nine teeth. The exterior portion of the slide was inscribed with digits corresponding to the number of teeth that were engaged inside the machine. In a way, these sets of one to nine teeth form a kind of multiplication mechanism such as we will find much later in Boilee's machine, in the Millionaire machine, and similar devices. To the right of the setting slides there is a scale inscribed with the digits 0 to 9, above which a lever may be moved.

If a number or amount has been set up with the aid of the slides and one wishes to multiply, the lever is moved to that digit of the scale which is to be the multiplier. This establishes a connection between the calculating mechanisms and the teeth on the slides and turns the result wheels an amount pro-

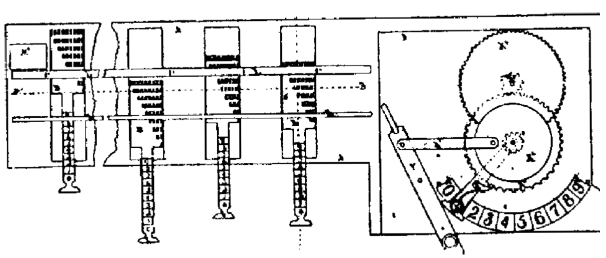


Figure 34

portional to the number of teeth currently engaged. Each place requires two result wheels, each of which contains an additive and subtractive circle of digits, one for viewing through the result window and the other for the printing mechanism. Only sums and subtotals can be printed. A piece of paper is placed upon a lid, the lid is hinged so that it may be raised, the printing wheels inked, and the lid is pressed down to provide the impression. The design of the machine was later improved by Ramon Verea, but only a few examples were built. In the United States it is regarded as the first complete machine of this type. It could perhaps be regarded as a forerunner of Bollée's design.

Beiringer and Hebatanz (1873)

This is a keyboard adding machine with clock mechanism drive. Details are lacking.

The Original Odhner (1874)

There is a difference between the Original Odhner and the Odhner machine. The ***Original Odhner*** was made by Willgodt T. Odhner of St. Petersburg, or his present legal successor. The term Odhner machine covers all those machines that have the same design as the Original Odhner; in other words, which are imitations of the same although they were originally manufactured on the basis of purchased patents. Several years ago the factory in St. Petersburg wrote the following about Odhner himself:

> Swedish by birth, and related to his great countryman John Ericson—the famous builder of the first modern steamboat—he left his home in Varmland at the age of twelve and went to Stockholm. originally with the intention of becoming a merchant. Even at that time his mind was set on technical matters and soon he recognized his true calling. He thus left the counter and entered a machine factory where he worked for several years gaining practical experience. He also prepared himself, by diligent study, for entry into the technical college. Having completed a three-year course, he obtained employment in the St. Petersburg plant of the Swedish industrial tycoon Nobel (the founder of the well-known Nobel prize),[45] but was later appointed to manage the Imperial Russian Workshops. Here he distinguished himself by the invention of a series of important improvements in such a way that, after only three years of service, he was honored by bestowal of the great golden medal.

45. In fact. the factory was owned by Ludvig Nobel, Alfred's brother. Ernst Martin obviously misunderstood the original reference to "the Nobel family."

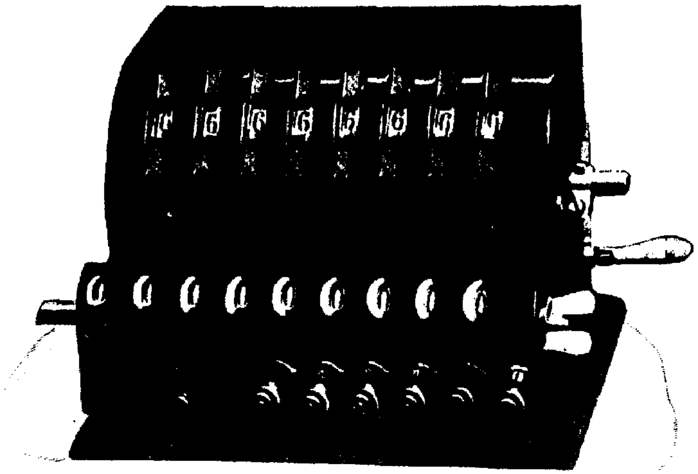


Figure 35
The model of 1874. handmade by the inventor himself

Odhner died on 15 September 1905. The invention of his calculating machine dates back to the year 1874. and our figure 35 shows the machine as it appeared at that time (which was already rather similar to the later Original Odhner machine). The setting wheels were shifted by small setting levers. which are scarcely visible in figure 35, in such a way that the digits to be set appeared in the upper row of windows. The lower row of windows belongs to the result mechanism of the carriage that was cleared, that is, was set to zero, by means of the winged screw. In this model the revolution counter mechanism has the form of six small cylindrical buttons with window openings on their surfaces. Zero setting of these revolution cylinders occurs by turning them to the right. Figure 36, which represents an 1876 model, shows the two characteristic arrows (which we find in all Odhner machines) near the crank that indicate the rotational directions for addition/multiplication and subtractionldivision. This model is of better workmanship and the German patent specification 7393, of 1878, is based on these two models (the German Patent Office did not commence functioning until 1877). The patent specification was not issued in the name of Odhner but in the name of Koenigsberger and *Co.* **of** St. Petersburg. because Odhner himself engaged in the manufacture **of** the machine in Petersburg and for this reason ceded the German manufacturing rights to the above mentioned company. This company, however, did not go into production and later sold their rights to Grimme, Natalis and

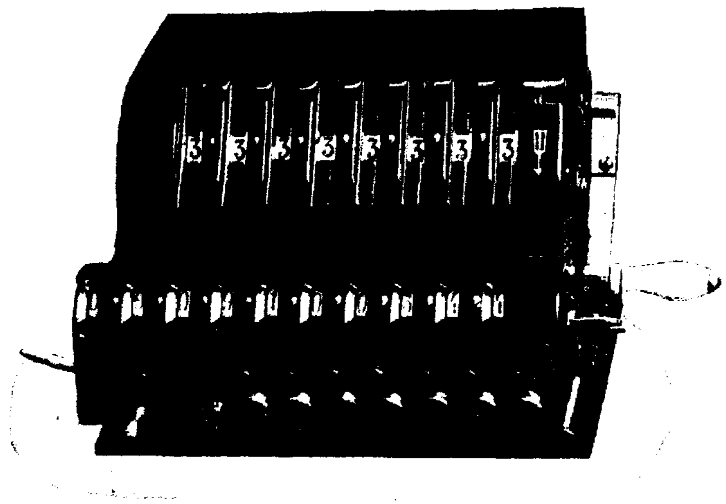


Figure 36

Co. of Braunschweig. who have very successfully distributed the machine, under the name of Brunsviga, all over the globe. The large-scale manufacture of the Original Odhner did not commence until 1886 when the W. T. Odhner factory, St. Petersburg. Tarakanoffski Per. No. 4, was specially built for this purpose. The machine had some distribution in Russia and sold well in the Nordic countries. At different times the firm kept representatives in England. the Netherlands. Belgium, France, and Italy, whereas the Original Odhner could not be marketed in Germany for a long time on account of the patents that had been sold. After these patents had expired, however, the Odhner firm took up selling the machine in Germany and Austria, .but was not able to compete, with any considerable success, with the well-established Brunsviga.

The machine illustrated in figure 36 became best known in Germany. It is the same in both exterior appearance and interior mechanism as the Odhner machine described in the Introduction under the heading The Pinwheel Machine. lt was manufactured in three sizes; namely, (1) thirteen places in the result mechanism, (2) fifteen places in the result mechanism, and (3) eighteen places in the result mechanism.

Machines (1) and (2) have eight places and (3) has ten places in the revolution counter mechanism. Several models appeared on the market under names such as VKD, G. HK, or VK. with almost no differences from one model to the next. For instance. the **VK** model possessed two extra keys, the

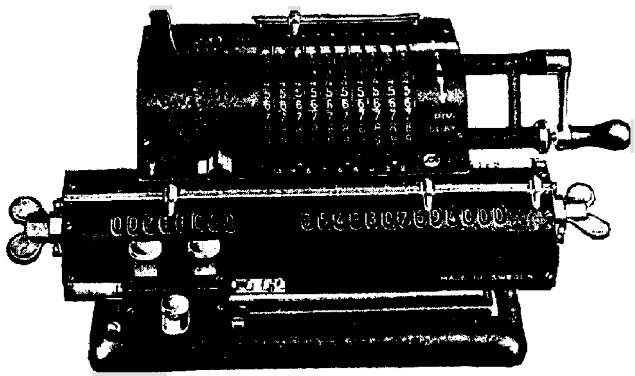


Figure 37
Model 8.

right one moving the carriage stepwise to the right, and the left one moving the carriage stepwisc to the left, with a lever mounted beneath the keys permitting one **to** movc the carriage in both directions.

During the late revolution the factory in St. Petersburg became the property of the state, the equipment was moved **to** Moscow, and soon the manufacture was entirely discontinued. However, Odhner's legal successors, namely his two sons Alexander and George Odhner and his nephew, Valentine Odhner, went to Sweden where they founded the Aktiebolaget Original Odhner in Göteborg and resumed the manufacture **of** the Original Odhner machine. Today they manufacture the following models:

Model 7: 20 by 15 cm. weight 4.5 kg, ten setting levers, thirteen places in the result mechanism, eight places in the revolution counter.

Model 6: identical with model 7 but possesses an improved zero-setting device.

Model **8:** has the same size and capacity **of** model 7, but possesses tens-carry in the revolution counter register, hence operates without red digits. The tens-carry neither increases weight nor volume of the machines.

Model 14: shows special setting control windows.

Model 19: has ten setting levers. nineteen places in the result mechanism, ten places in the revolution counter. It weighs 5.5 kg, and its dimensions arc 25 by 15 cm. It is especially suited for banks, insurance companies, and the like.

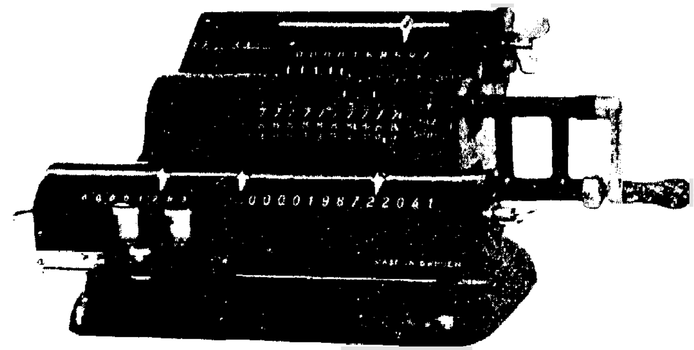


Figure 38
Model 14.

Model **9:** a small machine with only five setting levers, nine places in the result mechanism, and five places in the revolution counter. **It** weighs 3.8 kg, and its dimensions are only 18 by 13 cm. This **small** model is adequate for a large number of small calculating problems that were previously computed with paper and pencil because of the relatively high cost of calculating machines. In order to render the machine as cheap as possible, the automatic carriage shift and various locking devices were omitted.

All of the newer machines possess a lever that permits automatic resetting of the input levers to zero. Recently the Odhner factory paid particular attention to the production of machines for the complicated English currency and brought out no fewer than six models for this purpose:

Model A: a machine for multiplication or division **of** amounts in English currency **by** an amount in decimal currency (for instance f16.1 1.7 × 36.5 = £605.2.9½). This model has ten setting levers, seven places in the pound column **of** the result mechanism, and five places in the pound column of the revolution counter.

Model B: a machine for converting an amount in pounds at a particular rate into decimal currency and vice versa (for instance £945,126.19.11½ at a rate of $3.7675 equals $3,572,065.46). It has ten setting levers, ten places in the result mechanism, six places for pounds in the revolution counter.

Model C: a multiplication machine for English currency in cases in which the price is expressed in pounds or shillings or pence, but not in **two** or three of these units.

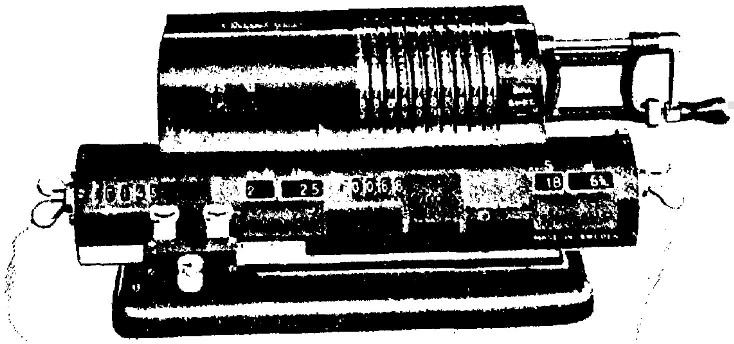


Figure 39
Model G.

Model F: a machine in which the revolution counter and also the result mechanism may be used for pounds. shillings, and pence or for decimal currency as desired. Therefore, this machine is a combination of the regular decimal machine and of models A and B. It is provided with movable decimal indicators for the setting levers and for the revolution counter and is therefore more suitable for a plurality of different calculation problems and is especially suited for calculating problems of different types and sizes. The machine has ten setting levers. the same number of windows in the result mechanism, and eleven windows in the revolution counter. It can, for instance, perform operations such as £6,217,293.12.5 at a rate of $3.899375 = £24,243,559.31.[46]

Model *G:* a machine that combines the advantages of the regular decimal machine with those of machine model C and is also suitable for carrying out multiplications in which the quantity is given in tons, hundred weights, and pounds and the price in pounds, shillings, or in pence. It has ten places in the setting mechanism. four places for pounds in the result mechanism, and four places for tons, etc. in the revolution counter (for instance, 145 tons, 2 hundred weight, 25 pounds at 9½ shillings = £68.18.6¼).

Model H: is a special machine for computing the interest in English currency. It has the advantages of a regular decimal machine and. with a few small exceptions, also of models A and B. This machine is particularly intended for banks and insurance companies; it has ten setting levers. four pound places

46. Sic—the result should obviously have been expressed in dollars

in the result mechanism, and seven pound places in the revolution counter mechanism. The type of problem it does best is, for instance, £365,806 at 4% for 21 days (84) yields an interest of £841.17.1¼.

The Original Odhner is also sold under the name Arithmos, and in England it is sometimes sold with the label "Lusid," which was meant to represent "£ u s i d" or "£, sh. d".

Manufacturer: Aktiebolaget Original Odhner, Goteborg.

Baldwin (1875)

As previously mentioned, the wheel with a variable number of teeth seems *to* have been known to Leibniz. Later we find such a wheel in the model of Poleni's machine and also in the device by **Dr. Roth** that may be found in the Conservatoire des Arts et Métiers in Paris. However, these were all experimental machines. Baldwin was the first to employ this device in practice. We are indebted to L. Leland Locke, a well-known American calculating machine expert, for the photograph of a document according to which Frank Stephen Baldwin and William E. Harvey swore on 28 September 1872, before a notary public in St. Louis, that they believed to the best of their knowledge and conscience to be jointly the first inventors of the "improved calculating machine according to the following specification."

The specification is a patent application received at the patent office in Washington on 5 October 1872, which contains exact details and drawings of Baldwin's machine, specifically of the model that appeared on the market in 1875 that included the gear with the variable number of teeth. Under the date of 8 September 1873, an improvement on the first model was added to the patent.

Since Odhner's efforts date back only to 1874, the year he made his first model, it seems now definitely proved that Baldwin was the first to employ, in practice, the gear with the variable number of teeth in a calculating machine. It may be assumed that Odhner reinvented this device at a later date. In any case we have no proof whatsoever that Odhner imitated the Baldwin machine, which, as is widely known, the Americans often claim. Figure 43 shows Baldwin's setting wheel (Odhner's setting wheel, for comparison, was illustrated earlier in figure 6).

Apparently Harvey played only a subordinate part. Baldwin being the actual inventor. He was born on 10 April 1838 in New Hartford. During his

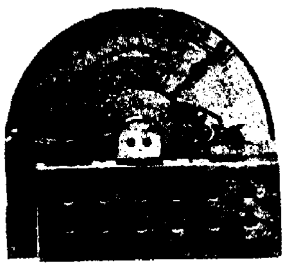


Figure 40

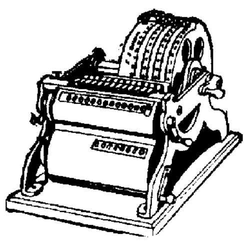


Figure 41

youth he created various inventions that, however, had nothing to do with the calculating machine industry; thus they will not be described here. About 1870 he saw the first stepped drum machine and it caught his interest. He decided to build a machine with only one cylinder instead of nine drums. The resulting model may be found in the patent office in Washington (figure 41).[47] In order to build this model, he employed William Seward Burroughs, later to be the designer of the adding machine capable of printing the result and which bears his name. It is known that Burroughs did not start working on his own machine until 1880. Baldwin had meanwhile moved to Philadelphia where he made a small machine that performed additions only (figure 40), which he called an arithmometer. This arithmometer was patented by him on 2X July 1874. Meanwhile, the first ten copies of the initial Baldwin calculator had been completed, so that Baldwin was in a position to enter into an agreement with the Reliance Machine Works in Philadelphia, according to which this firm was to undertake the manufacture while Baldwin was to take over the sales. The connection with this company, however, did not prove profit-

47. The model is now in the National Museum of American History. Smithsonian Institution. Washington D.C.

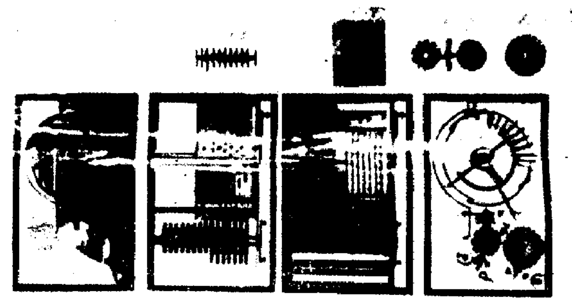


Figure 42

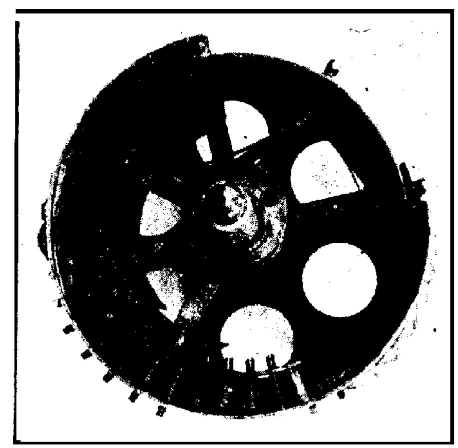


Figure 43

able. and Baldwin therefore returned to St. Louis in 1876 and manufactured the machines himself. As may be seen from figure 41, Baldwin's invention had a great similarity with the Odhner machine, quite apart from the pinwheel mechanism: setting slots, setting levers, the result mechanism disposed underneath, the revolution counting mechanism at the very bottom, the crank at the right side that rotated forward and backward, the zero-setting cranks for the two counting mechanisms — all these are details found in the Odhner as well. It should be mentioned that Baldwin manufactured the machine shown in figure 41 with a printing device, but this model remained unknown in practice.

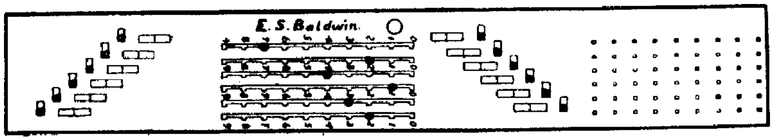


Figure 44

Figure 45

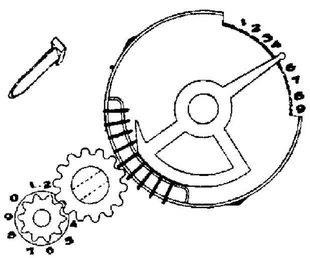


Figure 46

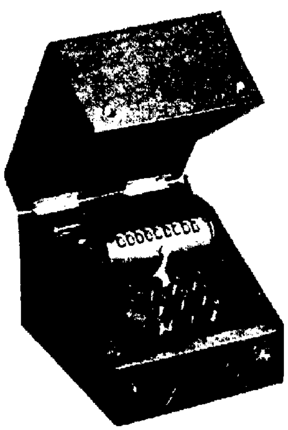


Figure 47

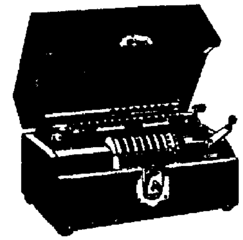


Figure 48

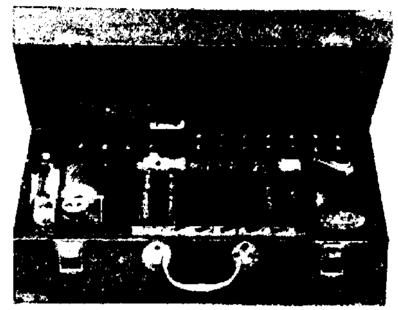


Figure 49

In 1900 a calculating machine was patented by Baldwin with which multiplication and division could be carried out by a single lever pull per digit place. However, the machine remained unknown.

In 1902 there appeared an improved model of the Calculator (figure 48) and a number of these machines are still in use today. In 1905 a ten-key adding machine appeared (figure 47), and in 1908 the Baldwin Recording Calculator, which is illustrated in figure 49. This machine is the forerunner of the Monroe machine of today (see the Monroe reference in this volume).

Figure **42** shows details from the patent application of 1872; figures 44, 45, and 46 are construction drawings of the same model. These **four** figures originate from **Mr.** Leland Locke in Brooklyn.

Carroll (1876)

This is a single-row adding machine with key setting.

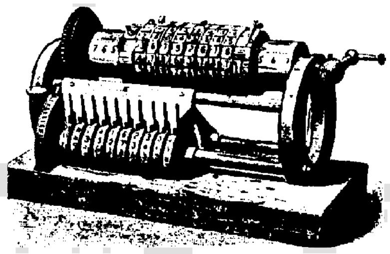


Figure 50

Grant (1877)

This machine was constructed by George B. Grant as early as 1870, but was not publicized until 1877. Additional publications concerning this machine are likely to appear in Brooklyn in the near future.

An upper cylinder is turned by means of a crank and drives a small shaft mounted underneath. A slide on the cylinder, which may be set in eight different positions, carries eight digit rings that may be set for eight or fewer decimal places. With each turn of the crank, the numbers set up in the rings are added to the value set in the ten numeral wheels of the lower shaft.

The multiplication process is best explained with the aid of an example. In order to multiply 347 by 492, the upper rings are set to 3, 4, and 7. The cylinder is turned twice in order to multiply by the units digit (2) of the multiplier; the slide is shifted by one notch so that each ring now moves to the next higher numeral wheel and nine rotations are made, which multiplies 347 by 90 and simultaneously adds the product to the previously computed product. An additional shift of the slide and four revolutions complete the operation and show the result $170{,}724 = 347 \times 2 + 347 \times 90 + 347 \times 400$ in the numeral wheels. Half a reverse revolution of the crank clears the result and sets all rings to zero. thus readying them for the next calculation.

Division is carried out in the opposite way from multiplication. The dividend is set on the wheels, the divisor on the rings, and the quotient appears on the upper numeral wheels. The machine illustrated in figure 50 operates with eight place values or less and shows the result in full, unless it yields more than ten places. The size of the machine is 33 cm by 12 cm by 18 cm. It has only eighty operating mechanical parts, and none of them is either small

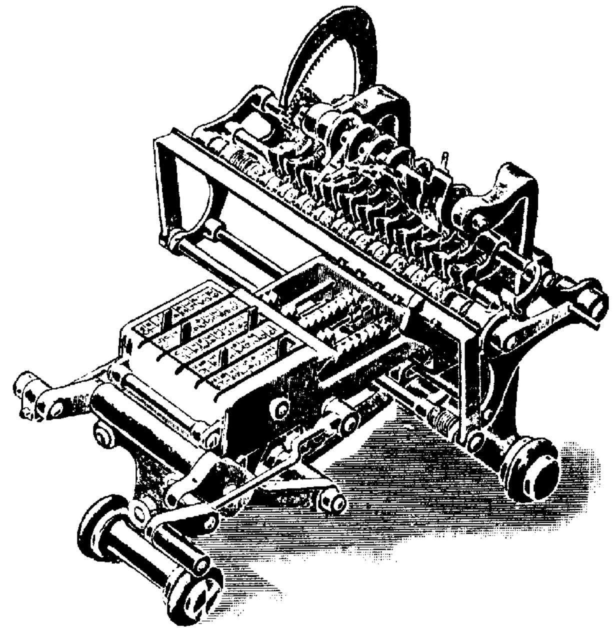


Figure 51

or fragile. It seems that the machine was never put into mass production. Until recently it was unknown even to the American experts. The description originates from Scientific *American*.

The machine illustrated in figure 51 also originates from the same inventor, In front there are five setting slots with setting levers protruding from them; each slot has two rows of additive and subtractive setting numbers printed adjacent to it. Movement of the setting lever forward or backward moves the racks visible in the drawing. When the crank is turned, the whole carriage is moved forward, and the setting racks mesh with the gears and move them, together with the appropriate numeral wheels. When the carriage is returned, the connection between racks and gears is broken and a successive tens-carry takes place. Zero setting also occurs by rotation of the crank. The machine was suited for all four types of calculation and was later designed to print as well, but it never gained any importance in practice.

Burkhardt's Arithmometer (1878)

In 1876 C. Dietzschold. an engineer in the town of Glashutte, set out to build a multiplication machine. He encountered difficulties, however, and asked for help from one of his schoolmates, Arthur Burkhardt, another engineer who was then serving his time in the army. Burkhardt came to Glashutte in 1878, shortly after Dietzschold had supplied one of his machines to the Royal Prussian Statistical Office. The statistical office found that the machine did not operate to their full satisfaction. A year later Burkhardt replaced this machine with two others constructed according to the stepped drum system (Thomas-Colmar) and thus laid the foundation for the calculating machine industry in Germany. Soon afterward Professor Dr. Reuleaux confirmed that Burkhardt's product excelled the French one in many ways. A number of machines were produced for government authorities, insurance companies, and the like, but the demand for such machines was still so insignificant that Burkhardt had to turn to the manufacture of other articles and, in fact, had to leave Glashutte for Braunschweig (during which time he was active in an entirely different line). He later returned to Glashutte and again devoted his time to the manufacture of calculating machines, which were becoming popular in commercial firms, manufacturing enterprises, and banks. Burkhardt is generally regarded as the founder of the calculating machine industry in Germany, and in the course of years he managed to keep improving his product so that, even today, it is still very popular and meets with increasing sales. Burkhardt died on 21 July 1918.

The following four models are no longer produced but will be mentioned so that the record will be complete:

Model H: It came in a wooden chest, had six setting rows, twelve places in the result mechanism, and seven places in the revolution counter (it was **also** available with 10 × 20 × 11 places). In this model the setting slides could be returned to their initial position by means of handle E. In order to facilitate reading the values that have been entered, the slides are provided with small cover plates that show the entered digit but cover the preceding and succeeding digits. *S* marks the lever for reversing from addition to subtraction. The two rows of windows are cleared by clearing-levers A and B. The machine is provided with decimal point indicators.

Model D (of 1909): **A** machine having two result mechanisms (the use of these was described in the Stepped Drum Machine section of the Introduc-

Figure 52
Burkhardt's original machine

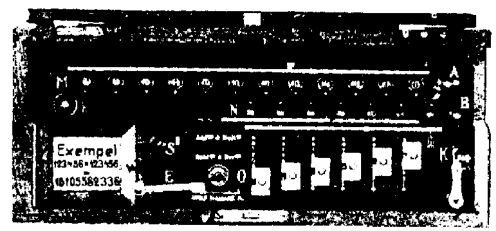


Figure 53
Model H.

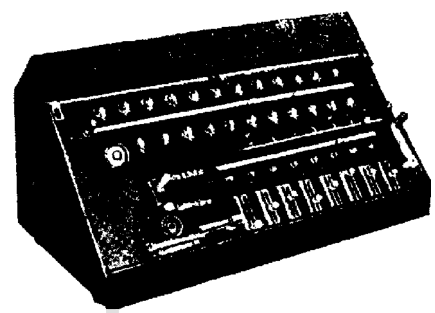


Figure 54
Model D.

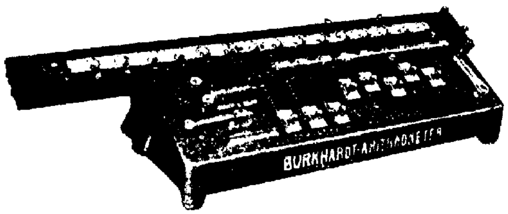
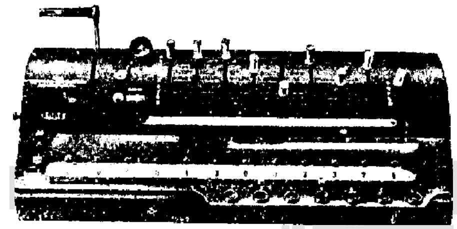


Figure 55
Model *G*.

tion). The three rows of windows have instantaneous resetting devices, as do the setting slides. The reversing mechanism is a double one because of the two result areas: the upper result mechanism can be disconnected. The machine comes in an enameled aluminum casing with a protective wooden chest. It was furnished with eight setting rows, twelve places in the result mechanism. and seven places in the revolution counter.

Model G: This was supplied in a black enameled casting with handles and a protective wooden chest. The two rows of numerals had uniformly colored backgrounds tor the figures, which allowed more convenient reading. Resilient setting slides were employed, as in model D, and also slide cover plates as in model **H**. Two keys took the place of the reversing lever, and a device for locking the crank in the normal position was provided. Smooth tens-carry was achieved in this model. Model ***G*** had eight setting rows, sixteen places in the result mechanism, and nine places in the revolution counter. This model was provided with a decimal point indicator and, in fact, all models so far described were equipped with setting knobs below the windows for entering the dividend or for correcting (rounding off) the results.

Model K (1913): **A** design by Max Klaczko of Riga (who now resides at Goethe **Str.** 76 in Charlottenburg). who became famous because of his earlier typewriter designs. This model combines the convenient setting device and the Comprehensive view **of** the pinwheel machine. with the dependable smooth mechanism of the stepped drum system. The machine also possesses a number of advantages **of** its own. **All** operational digits are positioned in front and above one another, offering a comprehensive view. The rows of digits possess uniformly colored backgrounds and thus permit convenient reading. The setting levers. whose handles are arranged into colored groups, engage easily and securely at the desired figures and thus make the machine especially suitable for addition. To facilitate checking, the entered digits ap-



g *56*
del K

pear in a straight line. An easily operable, and reliable, clearing device is provided for the setting mechanism. The drive mechanism acts through a conveniently arranged traction lever that, for the purpose of addition, is equipped with an item counter that has a complete tens-carry and zero-setting mechanism. Reversing occurs by means of two keys that indicate in a window, for checking purposes, the type of calculation for which the machine is set. A hand bar with seven key buttons is provided for moving the carriage, which permits automatic movement of the carriage so that the hand may remain at a fixed location. The machine has nine setting places, twelve places in the result mechanism, and seven in the revolution counter. This model is also built into a casting and is furnished with a protective wooden chest.

Model C: Essentially identical to model G, but the setting plate is provided with resilient setting slides and checking digits arranged in a straight line so that they can easily be read. This model was furnished in the following sizes:

Setting mechanism	Result mechanism	Revolution counter	Weight
8 places	13 places	7 places	*6.5* kg
8 places	16 places	9 places	7.2 kg
10 places	20 places	I I places	7.65 **kg**

Model E: At the present time it is mainly model E that is being supplied. The characteristic feature **of** this model is the setting mechanism. Numbers are entered in a convenient manner by levers that are movable in a straight line and may be set quickly and quietly with utmost reliability. Above the setting levers is the setting control mechanism. This offers a fully comprehensive view because it cannot be covered up during operation of the machine. The setting mechanism is sealed in a way that prevents dust from entering the

Figure 57
Model E.

machine, Another innovation is the instantaneous zero-setting of the setting mechanism by depression of a key. A quick, light pressure upon the key is sufficient to return all digits of the setting mechanism to zero. The machine is built into a black-enameled aluminum casing. It has convenient handles at both sides, and a protective metal casing is furnished with each machine. The instantaneous clearing device for the two calculating mechanisms may be found at the right side of the carriage. The instantaneous clearing of the result mechanism may be operated to simultaneously deal with two different calculation operations, so that a double result mechanism is not necessary. Reversing occurs through the setting of two keys, and a lock is provided for the crank in its normal position. The tens-carry in the result mechanism is designed to act smoothly and automatically. Model E is supplied in the following sizes:

Setting mechanism	Result mechanism	Revolution counter	Weight
10 places	13 places	7 places	7.2 kg
10 places	16 places	9 places	8.5 kg
10 places	20 places	11 places	9.9 kg

Arthur Burkhardt's Erste Glashiitter Rechenmaschinenfabrik in Glashutte merged, in 1920, with the Glashutter Rechenmaschinenfabrik, Saxonia, also in Glashutte, so that nowadays the Saxonia machine is manufactured by the same firm. The name of the new firm is Vereinigte Glashiitter Rechenmaschinenfabriken Tachometer und feinmechanische Werkstatt, Glashiitte i. Sa. The abbreviated mailing address is Vereinigte Werke, Glashutte, Sachsen.

Borland and Hoffman (1878)

A single-row adding machine with key setting.

Leiner (1878)

An adding machine with rack drive.

Smith (1881)

A single-place adding machine with key setting.

Berndt (1881)

An adding machine with eleven keys, ten of which serve for setting up the digits, For addition the machine is first set to zero, which lowers the eleventh key to the bottom.[48] The first digit from the right is pushed (to enter the units digit), and this action raises the eleventh key by a small increment; then the second (tens) digit is set, which again raises the eleventh key, and so on. The eleventh key is raised ever higher as more digits are entered. After the total value has been set, the eleventh key is pressed down to add the set value to the result mechanism. The second and subsequent amounts are added in the same manner. The machine is not provided with zero setting, and the individual numeral drums must be successively adjusted to zero by depression of the corresponding digits. The designer is O. Berndt of Nienburg. The machine never acquired any importance.

Tschebicheff (1882)

This is a combined adding, subtracting, multiplying, and dividing machine designed by the Russian mathematician Tschebicheff.[49] Only one example of the machine was built, in Paris, and it may be found in the Conservatoire des Arts et Métiers. The machine does not use any springs.

The Adding Machine: A shaft carries ten drums, each of which have three sets of the digits 0 to 9 printed on their circumferences. Each drum is provided with a drive gear, whose teeth project beyond the circumference of the drum.

48. The original German said "Key I," which we presume was a misprint for "Key II."
49. A different description, together with several more photographs, can be found in an appendix to *Le Calcul Simplifié: Graphical and Mechanical Methods for Simplifying Calculation*, Volume II in this Charles Babhage Institute Reprint Series for the History of Computing.

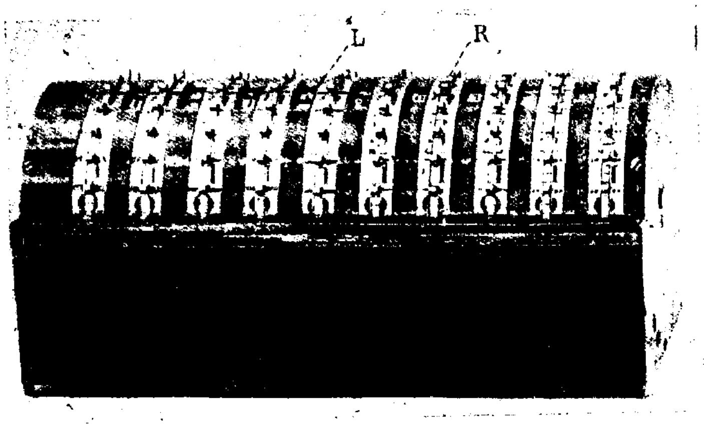


Figure 58
Tschebicheff's machine.

The gear and drum are mounted on the same shaft. The characteristic feature of this machine is a gradual tens-carry, a part of which is placed between each of the individual digits on the drum circumference, as can be seen from figure 59.

The windows are rather large because not only must they show their respective digits but also up to nine-tenths of the preceding or succeeding digits. The shaft, together with drive gears and numeral drums, is arranged within a housing (figure 58) with slots along its carefully made surface. The teeth of the drive gears may move in these slots. The setting digits 0 to 9 are adjacent to, and between, the slots. The windows are approximately midway along each slot. Adding occurs by taking the tooth of the setting wheel (which is next to the digit to be added) and moving it down until it reaches a stop, whereupon the number entered will show in the window. Subtracting occurs by shifting the tooth from zero up opposite the digit to be subtracted.

Zero Setting: A button on the left side of the machine is depressed. then the first of the adding gears is turned until it engages with a stop, then the second from the right. and so on.

Multiplication: If the machine is to be used for multiplication. it must he partly shifted into a separate multiplication mechanism. The multiplication machine, with the adding machine inserted, is shown in figure 60. The multiplicand is set with the aid of small slides, not visible in figure 60, in the longitudinal slots at the right side of the machine. These slots are provided with notches on their lower edges. Every place. that is. units, tens. hundreds.

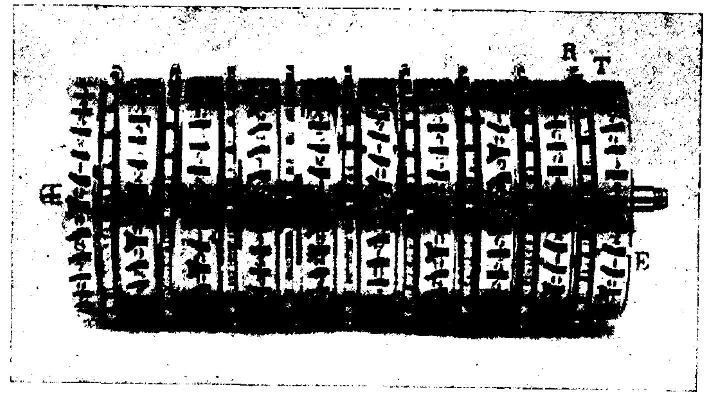


Figure 59

and so on. requires one such slot. The multiplier is entered into the counting mechanism with the aid of the eight levers farther to the left. These may be moved back and forth in the slots adjacent to the marked digits after a lever. mounted below these setting slots. has been shifted completely to the right. Alter setting up the niultiplicr. the lever must be moved back completely to the left. The crank of the machine is then turned until all the setting buttons on the right setting mechanism have returned to their initial positions.

Division: This occurs in a similar manner to multiplication, but the complement of the dividend has to be set into the adding machine, and then the adding machine is connected with the multiplying machine. The divisor is set in the right setting mechanism, the setting ievers of the counting mechanism are set to 9. and the lever mounted underneath is shifted to the left, after which rotation of the crank may commence.

Hammenstede (1882)

In 1882 Edward Hammenstede of Cologne received German patent number 20443 on a Schnelladdicrmaschine[50] with two rows of keys arranged in the following way:

6	7	8	9	
1	2	3	4	5

A numeral drum was at the heart of the mechanism for doing the arithmetic.

50. Speed-Adding Machine.

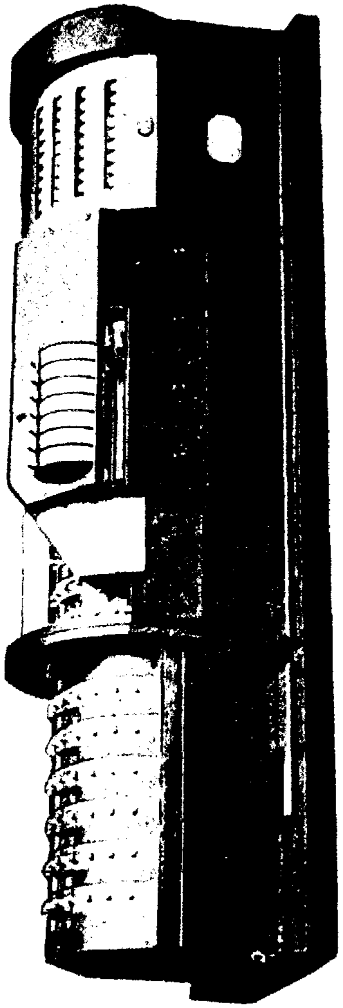


Figure 60

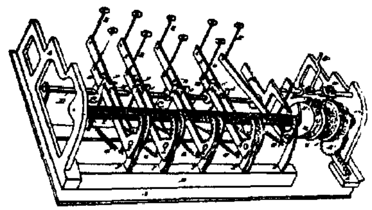


Figure 61
Bouchet.

Layton (1883)

From 1883 to 1886 Layton's Arithmometer was manufactured and sold by Charles and Edwin Layton on Farrington Road in London. This was the first English stepped drum machine. Later Tate, a sales agent for the machine, improved it. It was sold under the name Tate from 1907 until 1914. At the present time manufacture has been discontinued.

Bouchet (1883)

The machine, illustrated in figure 61, was made and sold in America but never gained importance. It is a nine-key adding machine for single-column calculations: the keys are arranged in two rows: 1 to 6 and 6 to 9. The ends of the key levers are bent upward and carry from one to nine teeth, depending on their values. Upon depression of a key, these teeth engage a grooved rod. extending over the total length of the machine, and turn the rod an amount proportional to the number of teeth on the end of the key being pressed. The same action also turns a counting wheel mounted on the rod. A tens-carry mechanism carries the tens to a second and third counting wheel so that columns of figures may be added up to a total of 999.

Spalding (1884)

This is a single-column adding machine with nine slides, situated in one row, for setting up the individual digits. Instead of the customary counting gears, this machine has mounted on its surface two numeral dials, each with a pointer. The large dial on the left (figure 62) is for the numbers 1 to 99; the

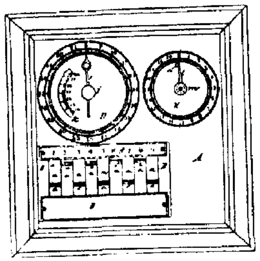


Figure 62

right and smaller one for the hundreds. of which it may register up to 19. The individual setting slides therefore act upon the large dial moving its pointer an amount depending on the value entered. When the sum exceeds 99, a hundred is automatically transferred to the smaller dial on the right. The machine was never put into production and remained unknown in practice.

Stark (1884)

This is a single-column adding machine with keys 1 to 9 in a row. As far as we know, it was never put into production.

Azevedo (1884)

This machine—a nine-key. single-column adding machine with ten places in the result mechanism was designed hy Ant Jul. Rodrigo D'Azevedo. Coutinho, in Povoa de Lanhoso.

Bagge (1884)

This was only a primitive device. of the type called addition control machine. created by O. J. Bagge of Christianssund. It never went beyond the experimental stage.

Pottin (1885)

This construction actually was part of a cash register, but it is mentioned here because for the first time we find a key-setting mechanism in which addition

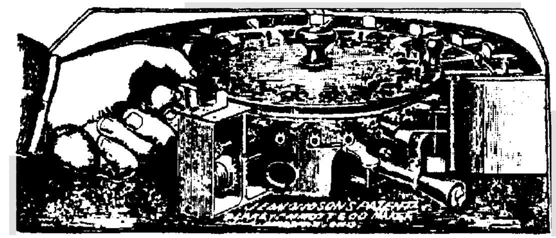


Figure 63
Edmondson.

and printing are not accomplished directly by the setting mechanism but by a special lever pull." as will later be seen in many of the full-keyboard and ten-key adding machines capable of printing.

Swem (1885)

A single-column key adding machine that remained unknown in practice

Edmondson (1885)

In this machine the multiplicand and divisor are set with the aid of the slides shown in figure 63. The result mechanism and revolution counter are situated upon a circular disc in the center. This arrangement has the advantage that a division that does not end without remainder may be continued for any selected number of places. whereas the stepped drum machine or the pinwheel machine only permit division to be carried on over a limited number of places. The machine is provided with a zero-setting device with which some, or all. of the windows may be set to zero. The machine was manufactured by Blakey, Emmot, and Company in Halifax, but has long since disappeared.

Comptometer (1885)

Dorr E. Felt was employed as a mechanic in Chicago in 1884 when he was twenty-two years old. He spent his free time on experiments making a calculating machine. In 1885 his first machine, which admittedly was rather

51. That is to say, the machine has keys, but is not key driven

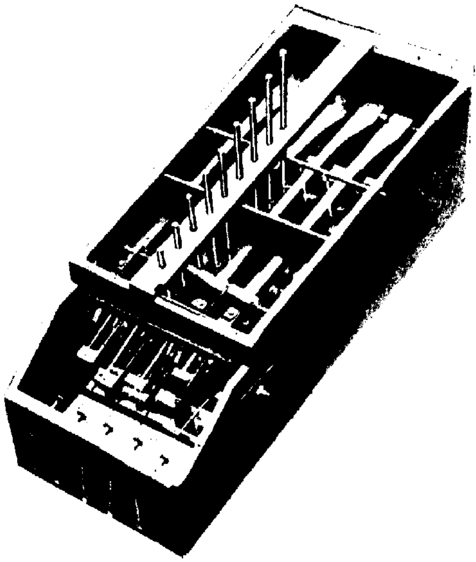


Figure *64*

primitive, was completed. It is illustrated in figure 64, and since it was built into an old macaroni box. it received the name *macaroni box model.* This model is still in existence today.[52]

This wooden model was improved, and in the fall of 1886 the first machine with a metal mechanism in a wooden housing was completed. By September 1887 the first eight machines were completed, and one of them (figure 65) went to Washington where it was employed in a government office until 1909. Today it may be found in the National Museum in Washington.[53] The other seven machines were also placed and gave full satisfaction.[54] In November 1887 the firm Felt and Tarrant was founded. It was registered in January 1889. and since that time the firm has been manufacturing Cornptometer calculating machines under the personal management of the inventor.

Although the machine of today follows the principles of the original machine, many major and minor improvements have been provided in the decades this machine has been in use. The first important improvement was the introduction of the so-called multiplex keys, which permit simultaneous depression of keys in several different columns—the earlier models permitted only successive depression of the keys. This innovation is based upon a device that does not perform the tens-carry from a lower to a higher order immediately but delays it until such time as the movement of the higher place result wheel is finished.

52. It is currently in the National Museum of American History. Smithsonian Institution, Washington D.C.
53. Now the National Museum of American History, Smithsonian Institution, Washington D.C.
54. It is not entirely clear if Felt sold his first machines or gave them away in exchange for recommendations.

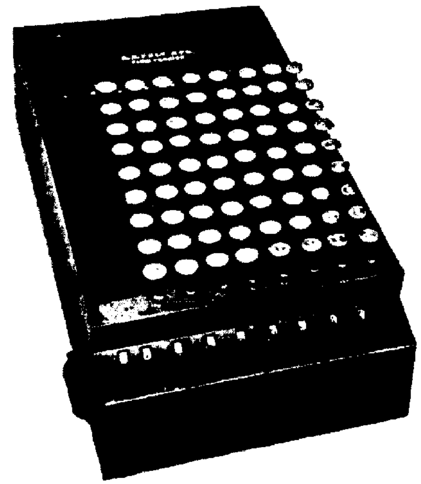


Figure *65*

After the multiple-key mechanism came the so-called controlled keys. This mechanism prevents entry of a wrong number if the key has not been fully dcprcssed. It is a known fact that most of the errors occurring during mechanical calculation are not due to the machine but to improper operation. It is readily understandable that a machine operator may make errors if we stop to think that he carries out between 50,000 and 200,000 keystrokes daily.

Another important improvement in the latest model is the triple-clear signal. which eliminates the danger of the machine not being set to zero before a new operation is begun. Since two or three thousand zero settings are needed a day, such a safety device is certainly indicated. If an operator should forget to perform the zero setting before a new operation is commenced, three different signals will remind him of this fact. As soon as a new calculation operation commences, a bell sounds. If only half-zeros appear in the windows, and if during the first depression the finger feels a certain resistance, it means that the machine has previously been set to zero.

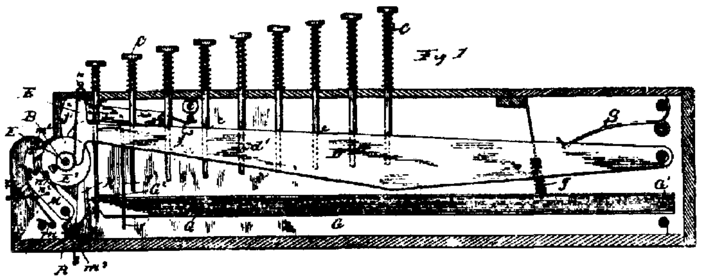


Figure 66

The Comptometer belongs to the class of true calculating machines because not only addition and subtraction but also multiplication and division may conveniently be carried out (the actual keyboard adding machines are less suited for multiplication and division, as is well known). The Comptometer excels adding machines proper as regards speed. After a value has been depressed in an adding machine, a crank must be pulled or a motor key depressed; then the amount entered is transmitted to the calculating mechanism and the keys are released for setting up the next amount. In the Comptometer, however, the operator merely has to depress the key (or, if possible, several of them at the same time), and the result may be read from the windows below the keyboard. The crank, which can be seen at the right side of the machine, serves merely for zero setting of the counting mechanism. The right hand remains above the keys and the left one serves for checking and for turning over pages.

Multiplication: For example, to multiply 1364 x 57, the index finger of the left hand is placed over the 50 key and the index finger of the right hand is placed over the 7 key and both are pressed down as often as the rightmost place of the multiplicand requires (4). Now both fingers are moved one column to the left and are depressed as often as the second place of the multiplicand requires (6). The procedure is continued, the index fingers are moved to the next columns to the left, the respective two keys are depressed three times and finally, after an additional lateral displacement, once. The result of the problem may now be read in the windows. In this manner four-digit values may be multiplied (two keys for each hand). In the case of larger values it is advantageous to break the numbers apart and to carry out the multiplication in two stages.

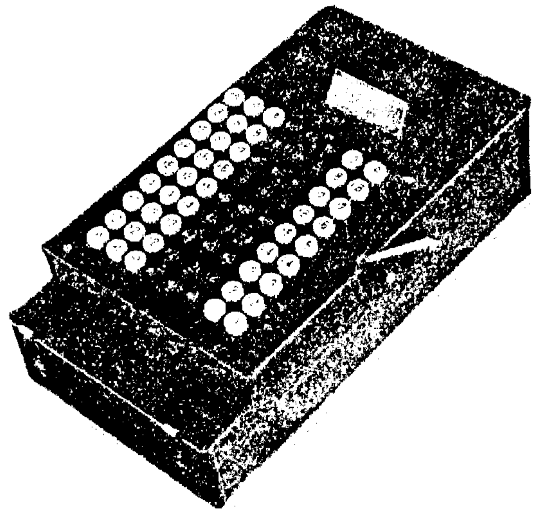


Figure 67
Model A—the first machine with a metal case

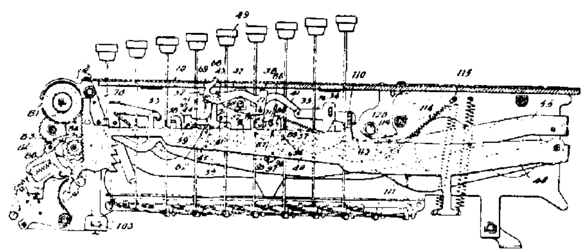


Figure 68
Cross section of the present model

Division: For example, to divide 63542 / 77, the dividend is entered by depressing the appropriate keys on the left side of the keyboard. The divisor cannot be deducted from the first two digits of the dividend. Therefore, the comma is placed above the respective first three digits of the result mechanism, then the two first fingers of the right hand are placed above the keys 76 (77 − 1) ending with the comma at the right, and the keys are pressed down while keeping the eye on the respective three result windows. The two keys are to be depressed as often as the dividend allows. When 77 can no longer

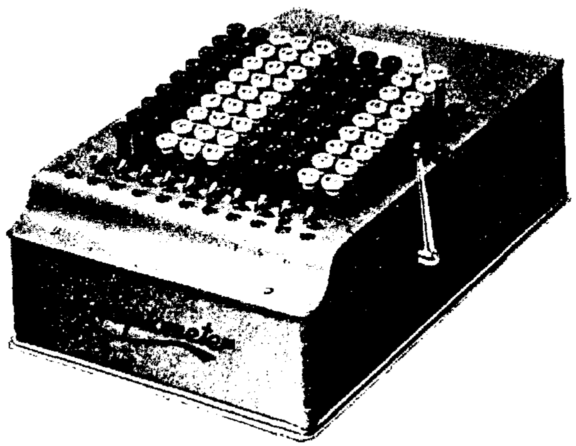


Figure 69
Model H, presently on the market.

be deducted from the amount appearing in the result window, the two fingers are moved one place to the right, and the respective keys are depressed as often as the dividend allows, and so on. Eventually the result appears in the windows at the left, and at the right side is the undivided remainder.

The Comptometer has always been available with eight, ten, and twelve places. Every one of these models has one additional place in the result mechanism. From 1887 to 1903 the machine was supplied in a wooden case. Spiral springs surrounded the shafts of the keys. In the following three years the Comptometer was provided with key coverings of a composite substance.” In these machines it was already possible to depress several keys at the same time. Since 1913, longer keys have been employed. The machine was equipped with a release key situated at the top right, to be depressed if one of the keys had not been completely depressed; such a partial depression is an error and locks the other columns of the keyboard. The present model has been on the market since 1920 and is equipped with the previously mentioned triple-clear signal.

55. Martin indicates that, from 1904 to 1906, Comptometers were sold with *gläsernem* key covers. This adjective means glassy or crystalline. In fact. chemical analysis indicates that the keys from this period are neither glass nor ceramic but a composite of a resin and a filler. We thank Nikki Horton of the National Museum of American History, Smithsonian Institution, for this information.

Number of decimal places	Weight	Dimensions	Price
8	8 kg	37 × 20 × 14½ cm	$300.00
10	9 kg	37 × 24 × 14% cm	350.00
12	11 kg	37 × 28 × 14½ cm	400.00

Machines for fractions and for English currency are also available. The Comptometer is well established in all European countries that are of any importance for the calculating machine trade. Approximately 10,000 Comptometer operators are trained annually in special Comptometer schools. The Comptometer is manufactured by Felt and Tarrant Manufacturing Company, 1713 to 1735 North Paulina Street, Chicago.

Duschanek (1886)

Duschanek’s device is a stepped drum machine with three rows of windows. One row is for the setting mechanism, one for the result mechanism, and the last for the revolution counter. All three window rows are arranged in a straight line, and they are set to zero by a single rotation of a crank. Subtraction occurs by rotation of the crank in the opposite direction. The machine did not develop beyond the experimental stage. The designer was Carl Duschanek of Freiburg in Baden. An example of the machine can be found in the calculating machine museum of the firm Grimme, Natalis and Company in Braunschweig.[56]

Summa (1886)

Designer: Max Mayer of Munich. Manufacturer: M. Barthelmes of Munich.

The first patent for this machine was filed as early as 1881. The Summa is

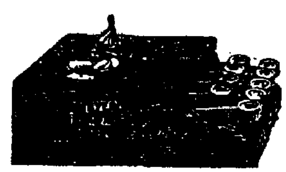


Figure 70

56. Now in the Braunschweigisches Landesmuseum, Braunschweig, Germany

a single-column adding machine in which the keys are arranged in two rows. Like all nine-key adding machines, it had only a very small distribution.

Lindholm (1886)

This is a single-column adding machine of American origin. It remained without any importance.

Selling (1886)

Professor Dr. E. Selling of Wurzburg designed a calculating machine in which the tiresome turning of the crank, and also the jerky tens-carry. was successfully avoided hy employment of the device known as the Nuremberg shears (also known as a stork bill).

The machine consists of two separate mechanisms that are brought into joint action during the operation. The two parts are:

1. The Nuremberg shears with toothed racks and keyboard for setting the multiplicand.
2. The gears and numeral wheels. all mounted upon a common shaft and adapted to receive the longitudinal movement of the racks and convert it into a rotating movement. The numeral wheels are connected with one another by so-called planetary gears for the purpose of tens-carry. Thus a malfunction due to spring obstructions is rendered impossible.

The actual calculating occurs by opening and closing the Nuremberg shears by means

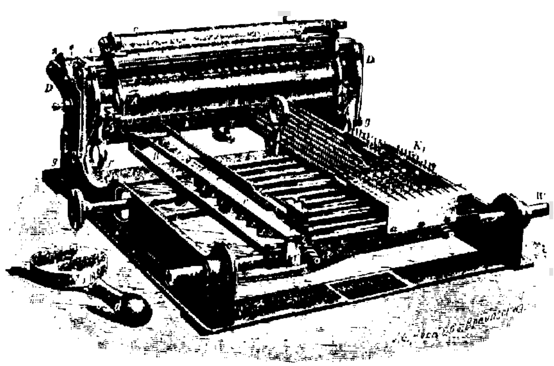


Figure 71

of a hand ring, the magnitude of such movement being determined by the multiplier. (This quotation is from a communication from the former designer Max Ott of Würzburg.)

Dr. Selling later constructed a larger machine that was electrically driven and was equipped with a printing mechanism. It was made by H. Wetzer in Pfonten. One sample of each of the two machines can be found in the Deutsches Museum in Munich. Neither of these machines assumed much importance and their manufacture has been discontinued.

Mahn (1887)

An adding machine with keys was patented to Rudolf Mahn in Leipzig-Reudnitz under German patent 41,725 of 1887. In the finished model, the adding of either single-digit or multidigit items occurred by depression of individual keys marked with the required digits. These keys were arranged in rows, side by side and beneath one another. Racks, connected with the keys, turned the numeral dials in such a way that the total amount appeared directly in the windows. In carryovers from one decimal place to another, the next higher dial was turned by one-tenth of its calibration with the aid of intermediate gears.

Büttner (1888)

Designer: Otto Buttner, Kaulbachstr. 18, Dresden, Sales agency: Wilhelm Brückner, Dresden.

In appearance the machine resembles the contemporary stepped drum machines. The *Unweisung zum Gebrauch der Biittnerschen Rechenmaschine* mention the following advantages over other stepped drum machines:[57] "The carriage is tilted slightly forward affording the operator a better view; the digits in the setting mechanism appear side by side in a straight line so that any setup value may be read directly from them; the crank can be turned backwards."

The notched wheels protruding from the slots at the left of the setting windows may be turned in both directions over an arc of about a quarter revolution. If a setting window reads 0, one turns the wheel upward until the desired figure appears in the window. Similarly, values may also be set directly into

57. *Instructions for the use of Büttner's Calculating Machine*

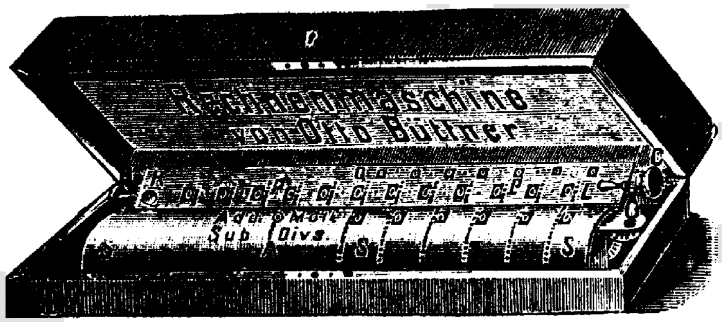


Figure 72

the result mechanism but not in the revolution counter. The latter has a tens-carry and exhibits red and white numerals.

Mounted between the marks ***Add*** - Mult there is the reversing button. Button ***K*** serves for lifting and moving the carriage from side to side. *B* and *C* are zero-setting buttons for the two counting mechanisms. The machine was supplied with six, eight, and ten places in the setting mechanism, with twelve, sixteen, and twenty places in the result mechanism, and seven, nine, and eleven places in the revolution counter. The manufacture has long since been discontinued,

Bahmann (1888)

A key adding machine in which the result is indicated by a pointer in a manner similar to gas meters.

Ludlum (1888)

Ludlum's design, shown in the drawing in figure 73, is the first ten-key adding machine capable of printing. The keys are arranged in one row. The design exhibited a number of defects so that the machine never appeared on the market.

Bollee (1888)

All calculating machines described so far have implemented multiplication by continued addition and division by continued subtraction. Leon Bollée, born

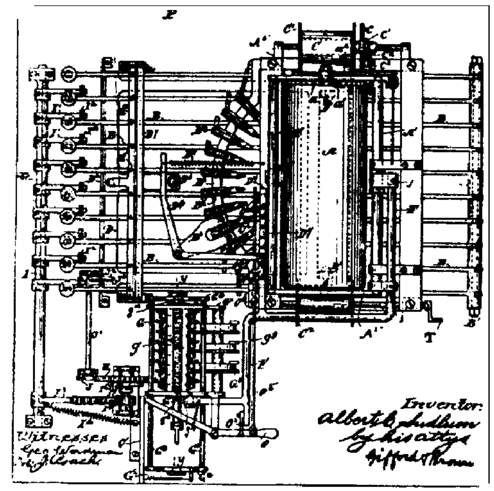


Figure 73

I April 1870, constructed in the course of three months (from February until April 1888) a calculating machine in which the multiplication table was mechanically represented for the first time. In other words, he created the multiplication body that we find today in the Millionaire machine, in the Moon-Hopkins machine, and in the Kuhrt machine, although the various manufacturers designed it in slightly different forms. Bollée's father had a factory for constructing steam tramways and later turned to the manufacture of automobiles. At the age of thirteen his son obtained a patent on an unsinkable water bicycle that was used by the Englishman Rigby to cross the channel. Before starting with the large calculating machine described here, he had made several smaller ones that were also capable of practical use but were never put into manufactured production. There are only three examples in existence of the large machine: the first one has only three places and does not work satisfactorily, while the two others of 1889 and 1892 each have twenty places in the result mechanism and in the revolution counter." One of these latter machines is owned by the widow; the other and older one may be found in the Conservatoire des Arts et Métiers in Paris. Bollee did not exploit his invention. He gave his main attention to the automobile industry to which he made considerable contributions. Later, after the Wright brothers in Amer-

58. Another example. which Martin seemingly did not know about, is in the National Museum of American History, Smithsonian Institution. It is larger than those he describes, being 12 × 22 × 22 rather than 10 × 20 × 20. It is made to the design of 1892.

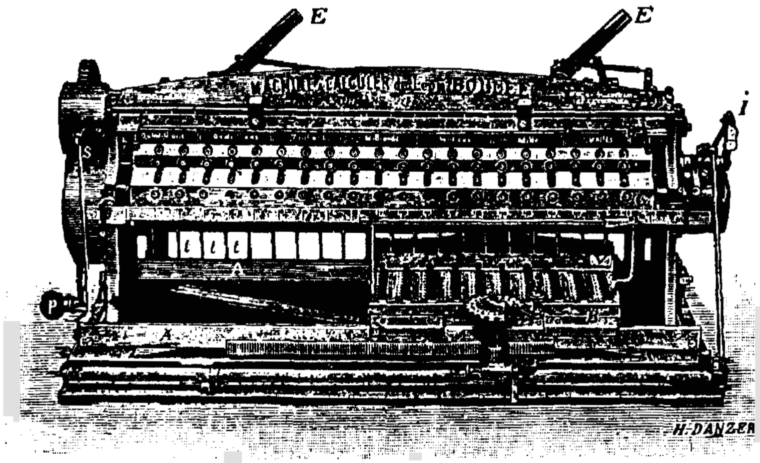


Figure 74

ica had started their attempts to fly, he invited the inventors to France and placed his two large factories in Le Mans at the disposal of Wilbur Wright in 1908 and supported him to a very considerable extent. As a result of his other interests, the plan to manufacture calculating machines fell completely into oblivion. Bollée died on 16 December 1913. His machine is especially remarkable because the designer was not yet eighteen years old when he built the machine and knew no details of other calculating machines except his own earlier constructions.

Figure 74 shows a full front view of the machine. Figure 75 shows the same machine from the back. Figure 76 shows the machine resting on its back. Figure 77 shows the setting mechanism with the multiplication crank. a multiplication, or times table, body, and an upper and lower numeral wheel placed in front of it. It also shows the ten multiplication bodies side by side in the rear of the setting mechanism.

The machine has ten setting rows with setting slides that may be shifted along the digits 0 to 9. Displacement of a setting slide moves the multiplication body connected to it. The multiplication body may best be compared with a brush. In the multiplication body the individual digits are represented by little pegs that vary in length according to the individual digit values. Thus. for instance, the digit 1 is expressed by a peg of unit length, the digit 2 by another of length two. and so on. Multiplication of single-digit numbers sometimes gives two-digit results, for example 2 × 6 is represented by two

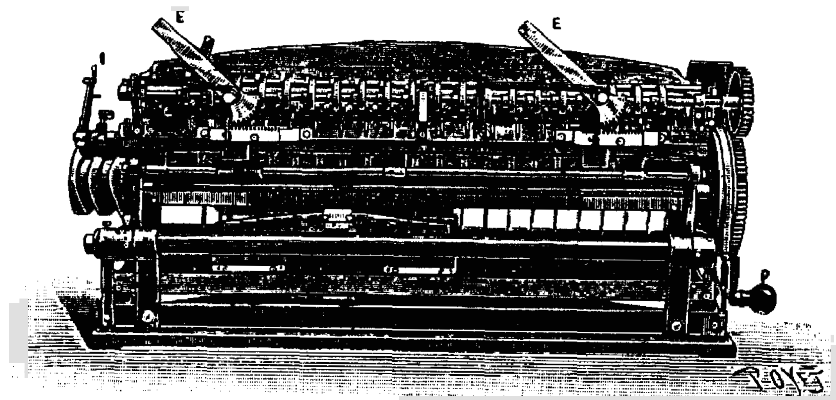


Figure 75

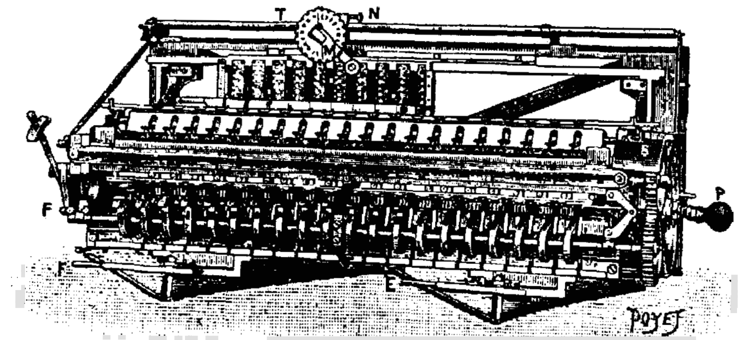


Figure 76

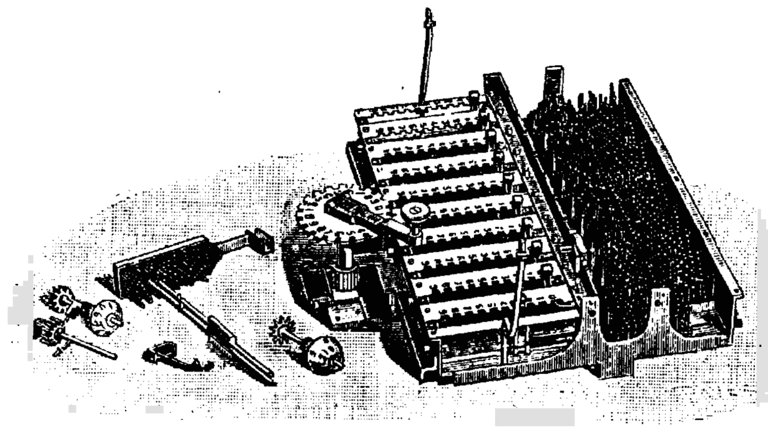


Figure 77

pegs, one of length two, the other of length one; **7** × **7** by one peg of length nine, and the other of length four; **9** × 9 by one peg of length one, and the other of length eight; etc.

The whole setting mechanism, together with the multiplication bodies, may be moved along the whole machine by means of the multiplication crank. This crank revolves around a circular scale with the digits 0 to 9 engraved twice around the circumference. The main crank is positioned on the left side of the machine and is denoted by P. The lever *I* on the right side is used for setting the machine to plus and minus; the two levers E set the two counting mechanisms to zero. The result appears in the upper windows, and the revolution counter numbers appear in the lower windows. The machine is primarily intended as a multiplication machine, but it may also be used for addition, division, and subtraction.

The little bars, *t*, form the connection between the multiplication bodies and the two numeral mechanisms. As may be seen from the illustration, each digit place of the machine has such a bar, but behind each of them are two similar bars that cannot be seen in the illustrations. **1** will now briefly describe the function of these 20 × 3 connection bars.

Let us assume 3 is to be multiplied by 27. We enter the amount **27** by means of the setting slides, as has been explained before, and turn the multiplication crank to 3. As a result of this action, a multiplication mechanism is moved so that the number seven is set on the calculating slide. a peg of length one is below the middle bar, and a peg of the length two is below the back bar—corresponding to the two digits of the product 21 resulting from 3 × 7. On the second setting slide, a peg of length six is below the middle bar corresponding to the product of 3 × 2. Movement of the main crank P lifts the setting mechanism and pushes it against the multiplication bodies. thus transferring the product to the result mechanism. It is not my intention to delve further into the mechanical details in this book.

If, for instance, a larger value is entered with the setting slides (the setting mechanism of the machine has ten places) and is to be multiplied by a multidigit value, for instance **429,** the multiplication crank is set to 4, then the main crank *P* is rotated: thereafter, the multiplication crank is set to 2, the main crank is again turned once, then the multiplication crank is shifted to **9,** and the main crank P is again turned. The upper windows show the result and the lower windows show the multiplier.

So far we have described the function of the middle and back connection bars. The front one transmits the number of revolutions to the lower counting mechanism by means of a tab stop *V,* which is positioned above the setting slide in notches provided for that purpose. This tab stop has steps corresponding to the digits I to 9. For instance, if the multiplication crank was set **to** 3, that is, multiplication was performed with 3 as the multiplier, then step 3 of the tab stop acts upon the front connection bar during upward movement of the whole setting mechanism and also acts on the multiplication bodies because of the rotation of main crank P. This lifts the front bar three places, which in turn advances the respective revolution counter wheel by three digits.

Addition: Addition occurs in the same way as multiplication. The first amount is entered with the aid of the setup slides, the multiplication crank is turned to 1, the main crank P is turned once. and the amount set appears in the upper counting mechanism. Any number of additional items may be added in the same manner.

Subtraction: The larger amount is entered. The multiplication crank is turned to 1, the main crank *P* is turned, and the minuend appears in the result mechanism. Then the machine is set to minus, the subtrahend is entered by means of the setting slides, the multiplication crank is turned to 1, the main crank *P* is turned once, and the remainder may be read from the result mechanism.

Division: Division is carried out in a similar manner.

It would, of course, require going into too many mechanical movements to describe the machine in detail. Here, it is only intended to give an idea of its method of operation, which is certainly not simple. To demonstrate this, it might be mentioned that a single rotation of the main crank *P* performs no fewer than nine different operations in very quick succession, only one of which is the lateral displacement of the setting mechanism. Moreover, the machine consists of more than three thousand parts.

Our description is based upon the machine of 1892, which is the one shown in the illustrations. The earlier machine (1889) differs only very slightly from the machine described here.

Although Bollée's machine was never put into mass production, the model shows an entirely new way of carrying out multiplication and division. It is faster than the methods used in the stepped drum and pinwheel machines. The imitations of Bollée's multiplication body are proof of its practicability.