Main Text

This part of the book is a description of the calculating machines produced since **1642** in chronological sequence.

Pascal (1642)

In 1918 an unknown author wrote an article about Pascal's machine in the Bureau *Industrie* (number *5)* in Berlin under the title "275 *Jahre Addiermachine*."[10]

The inventor Blaise Pascal was born at Clairmont in the Auvergne on June 19, **1623.** His father, Etienne Pascal, was the first president of the court in that city. His mother's name was Antoinette. and she came from a wealthy family by the name of Begon. Blaise had an older sister who died and two younger sisters, one of whom played a significant part in his life: Gilberte, born in **1620,** and Jacqueline, born in **1625.** In **1626,** his mother passed away and five years later the father moved with his motherless children to Paris, so as to let them have an adequate scientific education.

Especially with Blaise, this move bore outstanding fruit. At the age of eleven, he delivered a thesis about the beginning and discontinuation of sound. In this thesis, he investigated such questions as why a key if struck with a knife produces a sound, and why this sound ends immediately when the key is touched with the hand. He later discovered and proved on his own initiative the fact that the sum of the angles of a triangle equals two right angles. His father feared that the child's education in foreign languages might suffer because of his great interest in mathematical and physical problems. He therefore told his friends, who regularly met with him for the purpose of learned discussions, that in the future they would refrain from discussing mathematical and physical problems in the presence of his son. However Blake, although thus

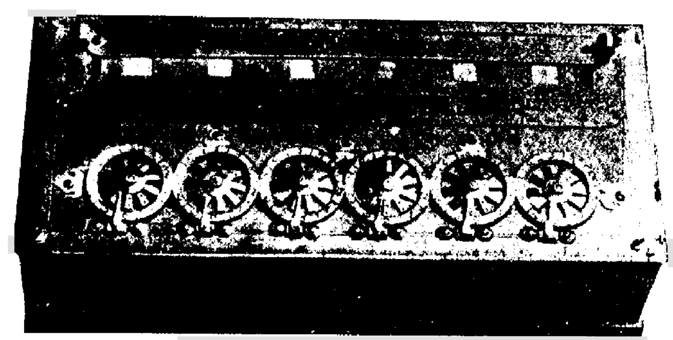

Figure 14
Older six-place machine

10. "275 Years of Adding Machines"

excluded, no longer required outside stimulation to promote his studies. On the floor of his lonely room, where his father had sent him to get on with his study of languages, he drew all sorts of geometrical figures, the proper names of which he often did not even know, and discovered for himself all those fundamental rules that are nowadays the subject of early mathematical education. After his father surprised him in this activity, he was accepted as a full-fledged member in the private circle of the older scientists. There he diligently continued to study, so that at the age of sixteen he was in a position to deliver a thesis on conic sections, which was recognized as having scientific merit.

In **1638,** the municipality of Paris partly discontinued payments of its debt from municipal bonds. This led to great unrest among the owners of the bonds. The elder Pascal was thought to be one of the main ringleaders of the malcontents. Although the charges were untrue, they were not unlikely, because when moving his family to Paris, he had invested a large part of his fortune in such municipal obligations. **A** warrant for the arrest of Etienne Pascal was issued, and only timely flight saved him from imprisonment in the Bastille.

On 3 April **1639** a private theater performance took place before Cardinal Richelieu. *L'Amour Tyrannique*, a tragicomedy by Scudern, was directed by the Duchesse d'Aiguillon who had chosen Jacqueline Pascal for the main part. After the performance, during which the Duchesse presented the fifteen-year old Blaise Pascal to the cardinal as a "great mathematician," Jacqueline submitted to the cardinal a petition on her father's behalf. written in verse. Richelieu was charmed with the small actress and replied, "Write your father that he may return in perfect safety." When Pascal returned, the cardinal received him very graciously and made him superintendent in Rouen **(1641).** where his main task was to collect taxes. It was necessary to go into some detail regarding the history and origin of his father's office, because it seems that it was his father's office alone that was the cause of the son inventing the adding machine that bears his name. Its purpose was obviously to facilitate his father's managerial tasks.

Even today, quite a few of Pascal's machines are still in existence. We are, therefore, well informed about the details of its construction. The first written description of this machine may be found in Diderot's *Encyclopaedie*, dated 1751. Pascal's invention **was** an eight-place adding machine in which the lowest place (derniers) could accommodate twelve units, the second lowest place (sols) twenty units. and the remaining six places ten units each. The first two places were intended for the two lowest denominations of small coinage then in use. The remaining six places were designed to keep track of from one to hundreds ***of*** thousands of full pieces of gold. Depending on the place value ***of*** the amount to be added, the individual wheels were to be moved by as many tooth positions **as** corresponded to the value of the digit concerned. This turned the numeral disks in the interior and caused the resultant sum to appear in the window. According to today's view, the principle, whose discovery **was** unquestionably Pascal's achievement, was not properly carried through. Nevertheless, his invention must be regarded as the basis of innumerable adding machine systems of a later date.

Undoubtedly it will be of interest to give **a** more detailed description of this remarkable machine. The machine to be described is the oldest model in existence—the model the designer dedicated to the Chancellor Seguier.

The machine is 36 cm long, 13 cm wide, **8** cm high; thus it is the size of a shoe box and may easily be carried under the arm. The surface is metal. There are eight windows and visible through them are the result digits. In front of the windows are the eight setting mechanisms. These have the form of a wheel, the spokes of which turn around the axle but whose rim is attached to the surface of the box and is inscribed with the setting digits. The first wheel from the right has twelve spokes, the second wheel has twenty, and each of the remaining wheels has ten spokes—the first serves for adding the *derniers*, the second for the ***sols,*** the additional ones are **for** the ***livres*** (at that time the system of English currency was still in use in France). **If** the machine is to be used for purposes other than the addition of the national currency, only the third. fourth, and subsequent setting wheels are used. Machines were also constructed in which the setting wheels for the derniers and **sols** were missing, so that they only possessed six setting wheels for the livres.

Addition **is** very easy. After any value that may still remain from a preceding operation has been eliminated from the windows by setting the digits to zero (by rotating the individual digit wheels), entering the amount to be added may begin. For example, to set the value f3.15.7, a calculating stylus (or finger) is introduced **into** the space between the spokes next to the digit 7, in the last place from the left, and the wheel is rotated until the stylus strikes against the fixed stop mounted at the lower edge. This transmits the value **of** *7d* into the first window from the right. Next, one begins the setting of the **sols** in the space between the spokes next to the digit 15 of the second setting wheel from the right. This setting wheel is rotated around to the stop that transmits the digit 15 into the corresponding (second) window. Finally, the value *3* (livres) is entered in the third wheel from the right in the same way. In this manner, any selected additional amounts may be added to the result wheels, the conversions (12*d* = 1 sol, **20 sol** = **£1**) being carried out by the tens-carry mechanism without any need for the operator to concern himself about the matter. In this connection it must be pointed out, however, that the tens-carry is not complete but **is** limited to a few places. The black digits **that** appear in the windows are printed on small rollers or drums at the end of the gear train connecting them to the setting wheels.

Pascal's machine is also suited for subtraction. The drums just described not only possess black additive digits but they also have a second row with red subtractive digits. When it is desired to change from addition to subtraction, the black additive digits are covered up by a cover slide extending over the whole length of the machine, as shown in figure 14, which exposes the red subtractive digits and permits the machine to be used in exactly the same way for subtraction as for addition; thus it is unnecessary to enter subtractions in the opposite direction."

Even multiplication is possible, but in multiplication the two first positions from the right—that is, the derniers and sols—must be ignored. If an amount is to be multiplied by 52, it is entered twice in succession, commencing with the third wheel from the right. The hand is moved one position to the left, and, starting with this position, the amount is entered five times in succession; the correct product should now appear in the windows. It must be admitted that this form of multiplication is rather complicated. Actually the machine is not a calculating machine but an adding machine: in fact all similar machines with stylus setting mechanisms should be called adding machines rather than calculating machines because in such machines multiplication takes place in the same somewhat complicated way.

In about 1647 Pascal heard that a clockmaker in Rouen was copying his machine. He attempted to prevent the clockmaker from doing so by sending one of his own machines to Chancellor Seguier, petitioning him for protection of his invention. This machine is still in existence and is currently the property of a partner of a well-known French shipping company (Chargeures Reunis, in Bordeaux). It bears the following dedication.

Illustrissimo et integerrimo Francioe cancellario, D. D. Petro Seguier, Blasius Pascal, patricius arvernus inventor D. D. D. Pascal.[12]

M. Fortunat Strowski of the Sorbonne reports in the *Revue Dactylographique* of 1908 (p. 243), that more than fifty models of the Pascal machine are still in existence. He also reports that they are

tous differents, les uns composés de verges ou de lamines droites, d'autres de courbes, d'autres avec chaines, les uns avec des rouages concentriques, d'autres avec des excentriques, les uns mouvant en ligne droite, d'autres circulairement, les uns en cônes, d'autres en cylindres, et d'autres tout différents, de ceux-la, soit pour la matière, snit pour la figure, soit par le mouvement. L'ivoire, le bois, le fer, le cuivre, seuls ou combinés, furent essayés.[13]

11. In fact it is impossible to rotate the mechanism in the opposite direction because of the way Pascal implemented the carry mechanism. Subtraction was performed using complementary digits hy methods described later in this work.
12. To the most illustrious and honorable Chancellor of France, Pierre Seguier, Blaise Pascal, a nobleman of Auvergnc, gives this as a gift. Pascal.

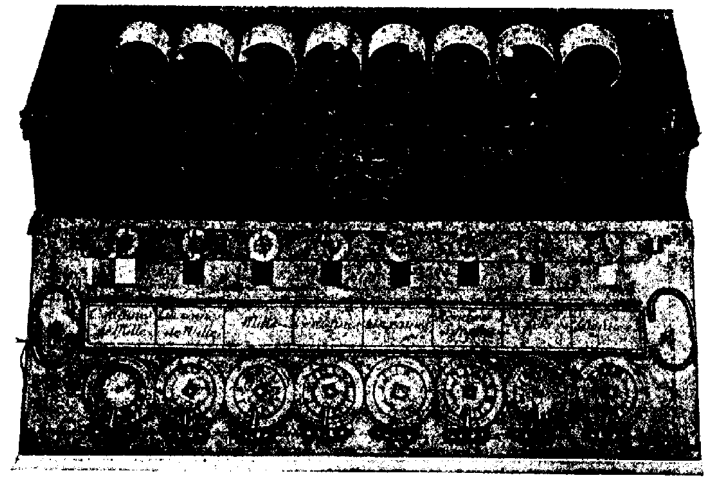

Figure 15

Pascal also sent an example to Queen Christina of Sweden. Two machines are reported to be in Clermont-Ferrand; another example (from 1652) may be seen in the Conservatoire des Arts et Métiers of Paris. It bears the following dedication on the inside of the casing:

Celeberrimae scientiarum academieae Parisiensi instrumentum hoc arithmeticum a, D. Blasio Pascal inventum et probatum offerebat nepos ejus ex matre, anno MDCCXI. Perier, presbyter, Canonicus Ecclesiae Claromontensis.[14]

Figure 15 shows an eight-place machine with the lid removed and set in front of the machine proper. Figure 16 shows the interior of a ten-place machine that can be found in the Mathematical-Physical Salon in Dresden. Replicas of Pascal's machine may be found in the calculating machine museum

13. ". . . all different, some are made of rods or of straight plates, others curved, yet others use chains, some with concentric wheels and others with eccentric wheels. some move along straight lines, some in circles, others in cones, yet others in cylinders and yet others completely different from these, be it in material, configuration, or movement. Ivory, wood, iron, copper, or combinations were all tried."
14. To the celebrated Paris Academy of Sciences: this arithmetic machine, invented and constructed by Blaise Pascal, is offered by Perier, priest and canon of the church in Clairmont and grandson on his mother's side, 1711.

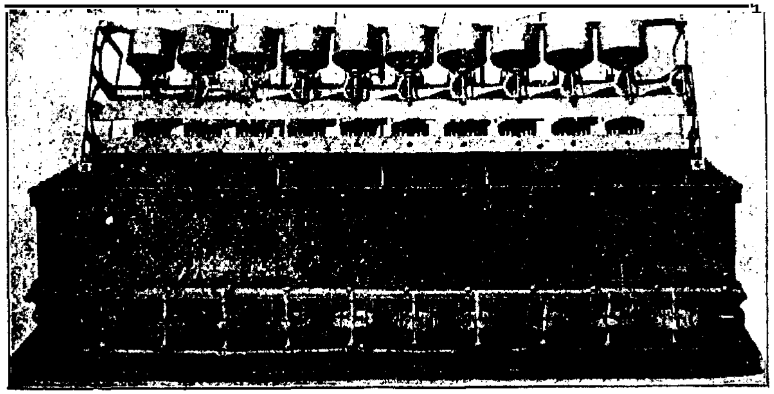

Figure 16
(Source: Engelmann. Phil. Matthäus-Hahn)

of Grimme,[15] Natalis and Company, and also in the Deutsches Museum in Munich.

Sam Morland (1666)

Morland constructed an adding machine that can at best be regarded as an improvement of Pascal's machine,[16] and also a multiplication machine based upon the principle of Napier's calculating rods.[17]

Leibniz (1672–1712)

Indignum enim est excellentium virorum horas servili calculandi labore perire, qui machina adhibita vilissimo cuique secure transcribi posset.[18]
—Leibniz

In 1672 the famous mathematician and philosopher Gottfried Wilhelm Leibniz began to occupy himself with the design and construction of a machine

15. Now in the Braunschweigisches Landesmuseum. Braunschweig. Germany.
16. This machine did not incorporate a proper carry mechanism—all carries were recorded on separate dials and the user then had to manually add the contents of these dials to the next digit. It is. thus. difficult to see how it could be classed as an improvement on Pascal's machine.
17. More commonly known as Napier's bones.
18. It is beneath the dignity of excellent men to waste their time in calculation when any peasant could do the work just as accurately with the aid of a machine.

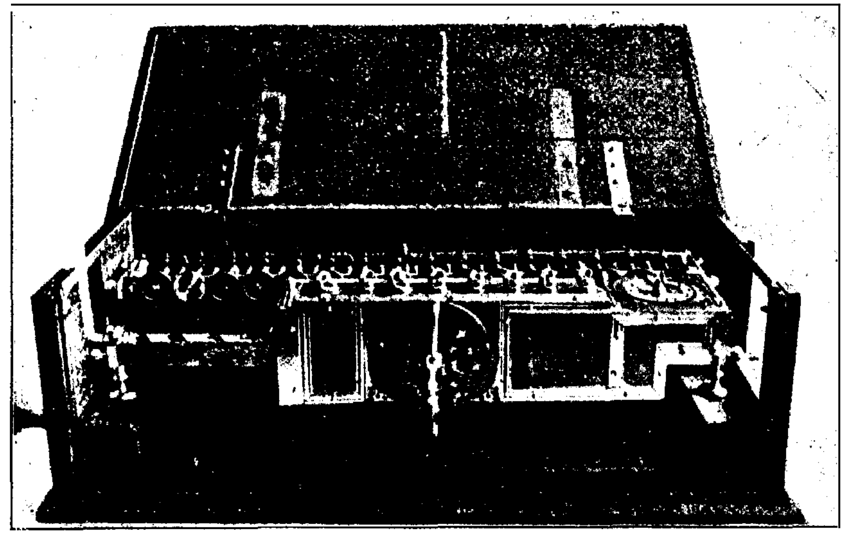

Figure 17
Machine in its case.

for the four fundamental operations of arithmetic. Thinking he would find more competent help in Paris,[19] he moved there and employed the mechanic, Olivier, from 1676 until 1694. For ten more years Professor Wagner and the mechanic Levin in Helmstedt worked on the machine and, after 1715, the mathematician Teuber in Leipzig did the same. It is not known how many machines were completed, but it may be assumed that there were three; two were once sent to Helmstedt to be repaired and since then nothing has ever been heard of them. The third is the one shown in our figures. This one is now in the Kaestner Museum in Hanover, but it is not in usable condition. Neverthcless. it still clearly shows the method of operation.

The mechanism is 67 cm long, 27 cm wide, and 17 cm high and is housed in an oak case. It was this machine that first used the stepped drum mechanism upon which, as is generally known, Hahn's machine, the Thomas machine. and the numerous imitations of same are based. Inside are two rows of stepped drums, one in the setting mechanism and the other one in the calculating mechanism. The calculating mechanism (with its sixteen places) was stationary, but the eight-place setting mechanism may be shifted along

19. In fact. Lcibniz had at the time a diplomatic posting that required his presence in Paris.

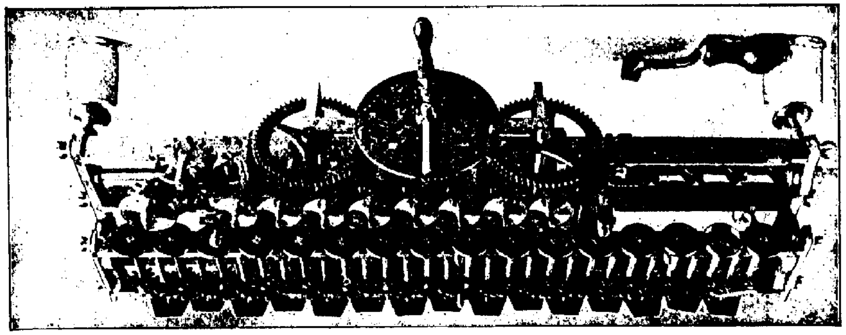

Figure 18
Complete machine, without its case

the individual places of the calculating mechanism with the aid of a crank. The transmission of the amount set up into the calculation mechanism likewise occurs by rotation of a crank. Subtraction and division are carried out by similar rotations of the numeral wheels with the exception that all readings must be taken from the red subtractive digits rather than the normal black additive digits. The machine also possesses a tens-carry and a zero setting device.

The setting mechanism consists primarily of eight numeral dials bearing the numbers 0 to 9 and having pointers by means of which the multiplicand is set up. To the right of the small setting dial there is a large dial consisting of two wide rings and a central plate—the central plate and outer ring arc inscribed with digits. while the inner ring is colored black and is perforated with ten holes. A crank is located in the center. if one wishes to multiply a number on the setting mechanism by 742. a stylus is inserted into hole 2 of the black ring and the crank is turned; this turns the black ring until the stylus strikes against a stationary stop between the 0 and 9 positions. The result of the multiplication by 2 may then be seen in the windows. The next step requires that the setting mechanism be shifted by one place, the stylus inserted into hole 4, and the crank turned, whereupon the multiplication by 42 is completed and may be read from the windows. Again the setting mechanism is shifted by one place, the multiplication by 7 is carried out in the same manner, and now the final result of the multiplication by 742 appears in the windows.

Division is done by setting the dividend in the result windows and the divisor on the set-up dials, whereupon a turn of the crank is performed and the quotient may then be read from the central plate of the large dial.

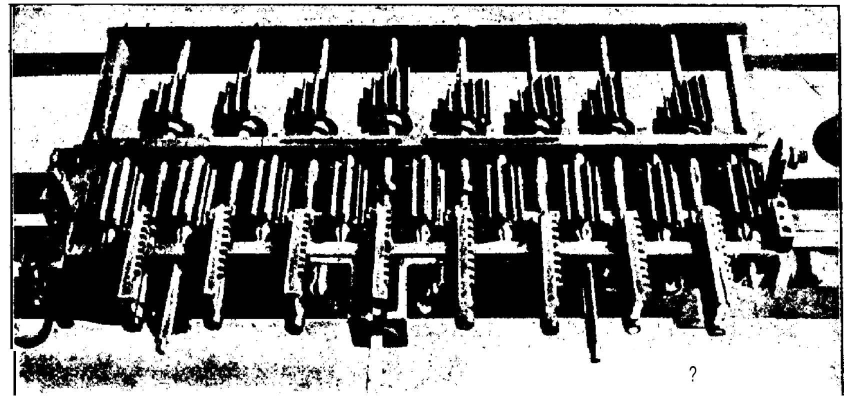

Figure 19
Setting mechanism and stepped drums

The machine had been lying for 250 years in an attic at the University of Göttingen until it was found when the roof was repaired. In 1893 it was sent to Arthur Burkhardt in Glashutte (Burkhardt is well known as the senior designer of calculating machines in Germany) to be put into operable condition. However, parts of the machine were missing. When the machine was returned, the following notes were made:

> All material parts of the Leibniz calculating machine are in operable condition. With the aid of a crank, the eight stepped drums may be rotated to the left and to the right. At the same time the quotient moves correctly. The stepped drums can be shifted axially. but some of them are too short, so that when the control drums are completely shifted from 0 to 9, the gears driving the drums, which are arranged upon the same shaft, become disengaged. The control mechanism may be moved to all positions by the screw spindle. The digit carriage operates correctly in part. Certain parts engage completely. The tens-carry from one element to the adjacent one is correct. We do not question Mr. Burkhardt's conclusion that, the way the machine is arranged, tens-carry to two, or more than two, adjacent elements was not possible. Under this assumption, the machine would not have been able to perform multidigit calculations entirely mechanically. Mr. Burkhardt's treatment of the machine is nevertheless valuable because it brought proof that the Leibniz machine possesses all the fundamentals for the manufacture of a usable machine.

A detailed report by Burkhardt describing his repair work on the machine may be found in the *Zeitschrift Fur Vermessengswesen*, **1897,** p. ***392.***

Leibniz concerned himself with the task of constructing a calculating machine over his whole lifetime, and he sacrificed for this purpose 24,000 talers, which was a very large sum of money at the time. The written testament always mentions an operating machine, which might be an additional proof that the existing machine was not the only one built. Professor Mehmke is of the opinion that one of the Leibniz machines was based on a wheel with a variable number of teeth,[20] a device that was to be employed much later by Baldwin and Odhner. (In 1673 Leibniz submitted the plan of his calculating machine to the Royal Society in London and somewhat later he submitted the completed machine to the Academie des Sciences in Paris.)

As long as no properly functioning model of the Leibniz machine can be produced, or at least no real proof of a properly functioning Leibniz calculating machine can be found, it seems that Hahn deserves the credit for having designed the first practically usable machine for the four fundamental operations of arithmetic.

Grillet (1678)

This is an adding machine similar to Pascal's machine.[21] It has three rows of seven dials, the rows lying below one another. Numbers are set on the dial by turning them with a stylus. The machine possesses no control mechanism, thus it has no need of any device, such as a crank, wheel, or band. to power it. It is described in the *Journal des Scavans*, (1678).

Poleni (1709)

In 1709 Poleni, a mathematician and professor in Padua, published a description of a calculating machine he invented. It is described, complete with diagrams, in Poleni's book, *Miscellanea,* 1709, p. 27,[22] and also by Leupold in his book, *Theatrum Arithmetico-Geometricum*.[23] The machine is made of wood and is rather large, but is reported to have a gear with a variable number of teeth. Weights were employed instead of springs. The machine was later destroyed by Poleni himself.

20. See the note concerning this point in the introduction. under the heading "The Pinwheel Machine."
21. René Grillet's machine had no carry mechanism and was simply a set of dials that could be rotated to record numbers and the results of mental arithmetic operations.
22. Poleni. Giovanni. marchese. 1709. *Miscellanea*. Venice.
23. Leupold. Jacob. 1727. *Theatrum Arithmetico-Geometricum*. Leipzig.

Figure 20
Poleni's machine

Lepine (1725)

This is an adding machine without keys, essentially a simplified version of Pascal's machine.

Leupold (1727)

In the *Theatrum Arithmetico-Geometricum*,[24] Jacob Leupold published the drawing of a calculating machine shown in figure 21. but it was never constructed.

24. Leupold, Jacob. 1727. *Theatrum Arithmetico-Geometricum*. Leipzig.

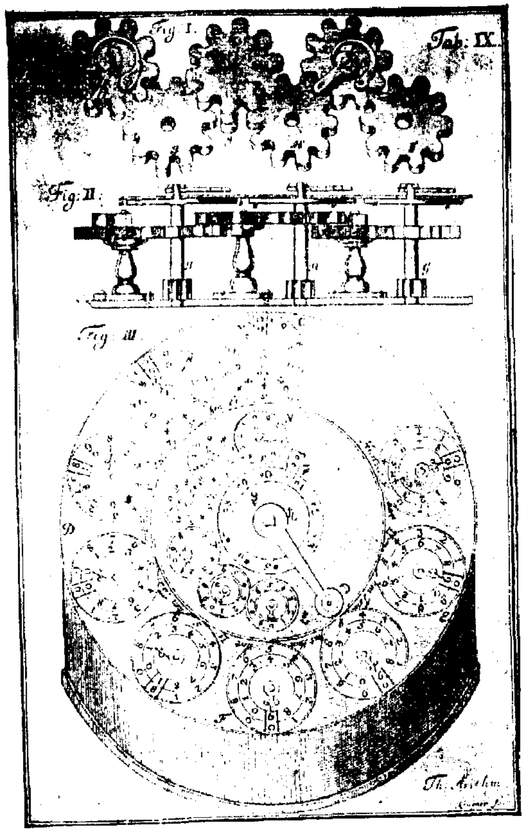

Figure 21
Machine of Leupold. (Source: Engelmann, Pfarrer Phil. Matthäus-Hahn)

Poetius (1728)

In his *Anleitung zur Arithmetischen Wissenschaft*,[25] published in 1728, Johann Michael Poetius provided ideas for a calculating machine, but it seems they were never acted upon to produce a working example.

25. Martin does not give the title of the main work; it is usually cataloged under Poeli. *Introduction to the Science of Arithmetic*. J. Mich. 1728. *Anl. z.b. arithmet. Bissensch.* Halle, Fritsch.

Hillerin de Boistissandau (1730)

This is an adding machine, without key setting, similar in type to that produced by Pascal. The friction generated during the use of this machine was so great that it could not be used in practice. The inventor attempted to improve it twice, but without success.

Gersten (1735)

In 1735, C. L. Gersten, mathematics professor in Giessen, submitted to the Royal Society in London an adding and subtracting machine with setting slides that had six places in the setting mechanism and seven places in the result mechanism and that also had a tens-carry mechanism. A model of the machine can be found in the Calculating Machine Museum of the firm Grimme, Natalis and Company in Braunschweig.[26,27]

Pereire (1750)

Jacob Isaac Pereire constructed a machine having a number of small boxwood drums, all of which rotated around a common shaft. Each drum had the digits 0 to 9 written around the circumference three times. This small machine was housed in a box, the surface of which had slots for each of its numeral wheels. The wheels could be set into motion by manipulating them through the slots with the aid of a pointer or stylus.

Hahn (1774)

The Parson Phillip Matthaeus Hahn was born on 25 November 1739, at Scharnhausen. He was not only a parson but an eminent clockmaker and maker of astronomical instruments as well. He also undertook, from 1770 in Kornwestheim and from 1781 in Echterdingen, the manufacture of calculating machines. According to the present status of research in calculating machines, he was the first to design a truly usable calculating machine for all four arithmetic operations and to manufacture a number of models, several of which have been preserved and are still in usable condition. Although he knew that

26. We believe that, in this case, *model* should be interpreted as *replica*.
27. Now in the Braunschweigisches Landesmuseum, Braunschweig, Germany.

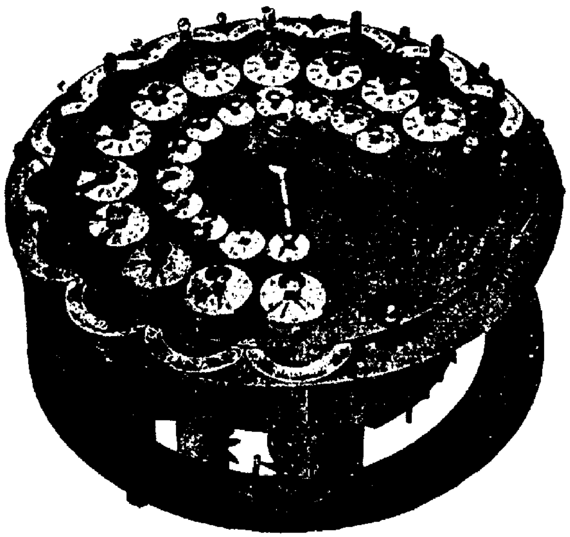

Figure 22

Leibniz had occupied himself with the problem for forty years and had sacrificed a fortune for it without producing a machine capable of solving large problems, Hahn was not deterred from considering the matter in detail.

In his experiments he used the stepped drum, which Leibniz had used before. It is not known whether Hahn reinvented the stepped drum or simply borrowed the concept from Leibniz. He arranged the stepped drums in a circle so that on the outside his machine is similar to the one designed by Leupold.

Max Engelman's book ***Leben und Wirten des württembergischen Pfarrers und Feinmechanikers Phillipp Matthäus Hahn*** gives, on page **4,** detailed information on the history of the development of his machine.[28] The first machine was demonstrated in **1774**, but it is possible that a usable model existed as early as **1773.**

The machine illustrated in figure **22** is the property of the Duke of Urach. In 1882 it was repaired by Arthur Burkhardt, who is well known as the founder of the German calculating machine industry. Figure **22** shows the complete machine out of its case. Figure **23** shows the frame, the stepped drums, and the drive gears. Figure **24** shows the movable carriage and the indicator mechanism with the crank.

28. *The Life and Activities of the fine Mechanic Phillip Matthaus Hahn of Wurtemberg.* This volume appears to be extremely rare.

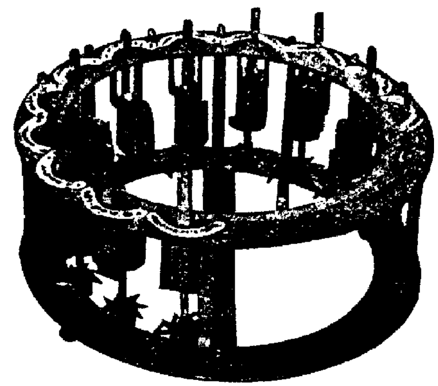

Figure 23

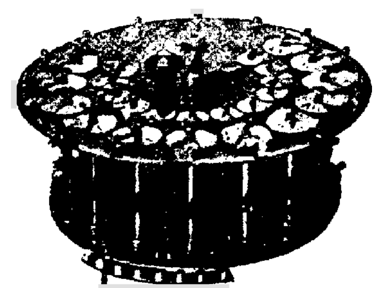

Figure 24

The method of operation of the machine is explained in detail in Hahn's ***Beschreibung*** des ***rechten Gebrauchs der Rechenmaschine,***[29] (Cod. Math. **4** No. 55, State Library in Stuttgart).[30]

The calculating machine has twelve numeral rods inserted around its outer rim. and inward has twelve large enamel plates. on each of which there is a row of black and a row of red digits. Further toward the center are twelve small enamel plates on which the digits 1 to 0 are written. To begin adding, one sets the indicators on the black numbers on the large numeral plates. Each indicator has a window or opening so that the digits may he seen through it. Since adding and multiplying are done with the black numbers on the enamel plates, just above the indicator and the engraved numbers

29. *A Description of the Proper Use of the Calculating Machine.*
30. The following is a translation of a quaint German text of 200 years ago. and frequently the sentences seem mutilated or in the wrong order. The editors have made only minor attempts to correct the worst of these problems.

the letters *A* and *M* are indicated. In the same way, the letters *S* and *D* are above the remaining numbers.

For addition the intermediate, larger, numeral plates are all set at zero if I wish only to add with units or tens. because here the sum is to appear." The digits will appear below the openings of the numeral plates. In connection herewith it should be noted that addition and multiplication take place with the aid of the black digits, and subtraction and division take place with the aid of the red digits. In order to give an easy example. let us assume that I wish to add **12, 8,** and **15.** For this purpose I withdraw the numeral rods so that the unit rod shows **2** at the bottom near the rim and the tens rod shows 1. Then I turn the crank around once, and 12 appears in the windows of the intermediate numeral disks which formerly showed zero. Now I set the unit rod to 8, turn around once. and **20** will appear in the openings; then I set the unit rod to 5, the tens rod to 1, turn around, and *35* will appear in those windows, and so on. No matter how large the number and how long the column of digits to be added, all will add into one sum. When adding larger numbers the procedure is:

1. One row, for instance **34,562. is** set into the larger numeral plates in black digits below the openings.

2. The other number given, for instance 23,541, is set up at the outermost rim by withdrawing the numeral rods. so that on the unit rod the lowest digit is 1, on the rod of the tens the lowest digit is **4,** on the rod of hundreds it is 5, and *so* on until the second number given is completely expressed.

3. Then the crank is lifted a little, until its point of rest is passed, and is turned around until it strikes against a stop; then the sum 58,103 appears in the openings.

Subtracting occurs in the same way. The larger number given, for instance **58,103,** is set in red digits underneath the openings of the larger numeral plates; the smaller value, for instance 34,562, is set below in the numeral rods. **As** in addition, units are always to be beneath units, tens are to be beneath tens; then the crank is released and is turned once around, and as a result **23.541** will appear in red digits below the openings.

Multiplication is carried out in the following manner:

1. One of the given values. for instance 3,235, is set below on the numeral rods.[32]

2. The larger and smaller numeral plates are set at black zeros below the openings.

3. The crank is turned around as often as the first digit of the other given number, that is. if the multiplier be **432,** until the digit 2 appears in the first upper opening of the small numeral disks.

4. **Now I** move the multiplier one place ahead. This happens if I release the steel latch on the outer rim and advance the inner disk with the numeral plates by one gap as provided on the outer rim of the disk until the latch engages again or until the indicator in the center of the surface points to the second small upper numeral plate; (then I turn the crank) until the second digit **of** the multiplier, which in the present case is 3, appears in the opening. Since in the present case the multiplier consists of three digits, I once more move the inner disk by one gap in the exterior rim until the indicator in the center points to the third numeral plate, then I turn around the crank until (in this case) the digit **4** appears in the third opening of the third numeral plate. Now the numbers have been multiplied and the product **1,397,520** appears in the lower windows of the larger numeral plates in black digits.

31. Hahn appears to he describing the larger numeral plates as intermediate between the numeral rods and the smaller plates closer to the center.

32. Hahn refers to setting numbers on the stepped drums with his rods as *setting below*.

Division occurs as follows:

1. The dividend. for instance 1,397,520, is set in the red digits upon the larger lower numeral plates beneath the windows, that is, in the present case 0 appears upon the units tablet. 2 appears upon the tens tablet, and so on, in red digits.

2. Zeros are set below the small numeral plates.

3. The divisor is set below with the numeral rods, for example, **3235.**

4. Now the inner disk with the plates is moved **just** like in multiplication in such a manner that the value **3235** is positioned below the value **13975,** and because **1397** is smaller than **3235,** I had **to** move the divisor one place further in order that the dividend be larger than the divisor, in the same manner in which it is customary to position the values in ordinary division.

5. Now I turn the crank until the value positioned above the divisor becomes, for the first time, smaller than the divisor, for which reason it is necessary to check every time that the crank has been turned around whether the upper value is not yet smaller than the value placed underneath—which in the present instance will be the case during the fourth turn of the crank. Now **1035** will appear above the divisor instead of 13975.

6. Therefore I shift the disk with the dividend by one place with the result that my divisor now appears below the value **10352.** Now again I turn the crank until this value becomes smaller, which will be the case during the third time, and **647** will remain as the diminished value from which the divisor **3235** can no longer be subtracted. For this reason, I again move one place ahead so that the divisor will be positioned below the value **6470.** If I now turn the crank until this value is smaller than the divisor, this will occur during the second time. Then there will be only red zeros in the windows as a sign that there is no remainder, unless a fraction has remained, which would show. Now the openings of the upper numeral tablets will show the values sought, namely the quotient **432.** If something had been left over and the divisor had not gone into the dividend without remainder, then the remaining value would have been the upper part of the fraction above the line and the divisor would have been the lower part of the fraction below the line.

The rule of three and other calculations, such as calculation of fractions, and square root. and cubic root extractions, may all be performed on the calculating machine because they may all be carried out through multiplication and division; all one has to know is how to position properly. If the correctness of the result is doubted, the problem should be attempted in the opposite form of calculation. For instance, if one has multiplied, then divide this number so one has proof of the correctness of the calculation.

It is strange that the published literature has not mentioned the similarity of the main parts of the Thomas machine with Hahn's machine much earlier than this, We conceded to the Frenchman the invention of the calculating machine, although Thomas merely produced Hahn's machine in a partly modified form and exploited it commercially, whereas the manufacture of Hahn's machine was discontinued soon after the death of Hahn (2 May 1790) and his collaborators. At the occasion of the Exhibition of Scientific Apparatus in South Kensington Museum in 1876,[33] the original machine. illustrated in figure 22, was demonstrated and the exhibition catalogue contained the following statement on the subject:"

> The model on display shows all the details of arrangement of the Thomas calculating machine which is now in use. with the difference that in the Thomas machine the digits are arranged in a straight line, whereas they are arranged in a circle in Hahn's machine. Most likely a model was the pattern for the Thomas calculating machine. The machine operates perfectly well up to values having twelve digits.

In his rather interesting publication, ***Die Sogenannte Thomassche Rechenmaschine***,[35] Professor F. Reuleaux criticized this opinion as inaccurate and going too far. However, the Thomas machine has several main characteristics in common with the older machine: the stepped drums already used by Leibniz, although with twice the number of teeth as Hahn's, an automatically operating tens-carry mechanism that acts through all places, a shiftable carriage. and finally the employment of black additive and red subtractive digits on circular numeral disks. Since Engelmann's book tells us that Hahn was continuously in contact with the city of Colmar, by maintaining correspondence and business relations with a parson Günther who lived in Colmar. it is entirely possible that this connection drew Thomas' attention to Hahn's machine and Thomas used Hahn's machine as prototype and created his well-known arithmometer by using it as the basic model.

Whether Thomas used Hahn's machine as a pattern or not is of lesser importance. It is more important that the view, originally prevalent, that Hahn's machine was not operative has been thoroughly disproved

33. See *Handbook of Scientific Apparatus*. London: HMSO, 1876.
34. This is a translation from Ernst Martin's German and not a quotation from the original English version.
35. *The So-Called Thomas Calculating Machine*, published in Leipzig by A. Felix. 1892

1. by the detailed description of the operation of the machine as reprinted above,
2. by the above mentioned opinion of the London Exhibition, and
3. by the fact that there are still machines in existence, which can demonstrate at any moment that Hahn's machine was capable of performing the four basic operations of arithmetic in a thoroughly reliable manner.

Hence, Thomas was by no means the builder of the first usable calculating machine that permitted performance of not only addition and subtraction but also of multiplication and division; it is Phillip Matthaeus Hahn who deserves the credit.

It has not been established how many copies of this machine were produced. According to Engelmann there are four in Stuttgart, there is one in the Deutsches Museum in Munich (which also has two copies by his brother-in-law, Johann Christopher Schuster), one is owned by the Duke of Urach, one is in the Technische Hochschule in Charlottenburg (likewise by Schuster). Since Hahn's two sons in Stuttgart and his brother-in-law Schuster in Uffenheim and Ansbach manufactured calculating machines after Hahn's death (Schuster, in fact, up to 1820), it is likely that an appreciable quantity were produced having various numbers of decimal places.

Mahon (1775)

Lord Mahon, Earl of Stanhope, designed two machines, one for addition and subtraction and the other one for multiplication and division. His constructions are also reported to exhibit the drums with teeth of uneven length (stepped drums), which were employed by Leibniz and Hahn.

Miiller (1783)

Johan Helfreich Muller, a captain in the engineers and county surveyor, designed a calculating machine, which he had built by a clockmaker from Giessen. It is very similar to Hahn's machine, but Hahn's setting rods, which were adjustable in height and had to be handled very carefully, were replaced by rotatable disks that bore the digits 0 to 9. The machine also had a signal bell. In later years Hahn's brother-in-law Schuster manufactured calculating machines embodying Müller's improvements. One of them may be found in the Deutsches Museum in Munich, and a Muller machine may be found in the museum in Darmstadt.

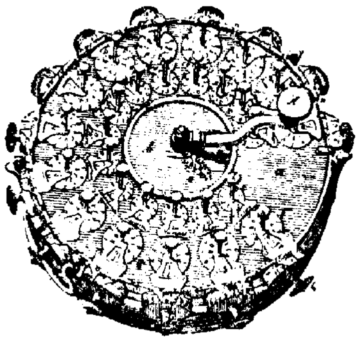

Figure 25
Müller's machine.

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.

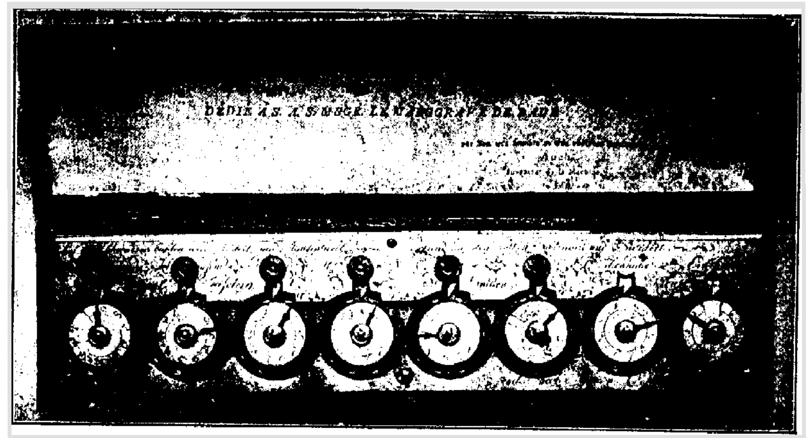

Figure 26
(Source: Engelmann, Phil. Matthäus Hahn)

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