Israel Abraham Staffel: Lost Book Is Found

Timo Leipälä[1], Valery V. Shilov[2](✉), and Sergey A. Silantiev[2]

[1] University of Turku, Turku, Finland
timo.leipala@saunalahti.fi
[2] National Research University Higher School of Economics, Moscow, Russia
{vshilov, ssilaniev}@hse.ru

Abstract. This article is devoted to the rediscovery of a document by Israel Abraham Staffel (1814–1885), a prolific Polish inventor. It is a handwritten book in Russian and Polish that provides detailed information about one of the most famous of Staffel's inventions, a 13-digit arithmometer, honored at the Great London Exhibition in 1851. The brief biography of Staffel, born into a Jewish family of meagre means who became famous in his time as an inventor, and a description of his developments are presented. Particular attention is paid to his mechanical calculating machines. In the Appendix, an English translation of the handwritten book by Staffel appears for the first time. Typical mechanical calculating machines by the end of the nineteenth century were based on Leibniz's stepped drums. Staffel's arithmometer was based on pinwheels. The content of the discovered book allows us to raise the question of the influence of Staffel's invention on the arithmometer's design. The paper, which also clarifies and complements certain facts about his life, activity and inventions, demonstrates the need for further archival research to confirm the currently accepted history of innovation.

Keywords: Calculating machines · Great London Exhibition · Israel Abraham Staffel · Pinwheel arithmometers · Stepped drum

1 Introduction

In the diaries of the famous British financier, banker, and philanthropist Sir Moses Montefiore the opening of the London exhibition, held on 1 May 1851 was described:

> Sir Moses and Lady Montefiore went to the opening of the Exhibition. The building was already full on their arrival, but Lady Montefiore secured a good seat. The Queen and the Prince entered at twelve. The procession was a splendid one, and the Palace presented a magnificent scene. The ceremony passed off extremely well, without the slightest hitch, to the great delight of spectators. Sir Moses' attention was drawn to the Russian Division of the Exhibition, where an apparatus was exhibited for ascertaining the value of gold and silver coins and other metals without the use of fire or chemical analysis, also to a calculating machine for simple and compound addition, subtraction, multiplication, division, and extraction of square and cubic roots, both invented by Israel Abraham Staffel of Warsaw. Being most anxious to befriend so clever a young man, he at once invited him to his house, and after impressing upon him the necessity of raising and maintaining the standard of education in Russia and Poland among his co-religionists, made him a handsome present. [27, p. 24]

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It seems that the name and works of Israel Abraham Staffel (Fig. 1), this "clever young man" – Polish inventor and one of the pioneers of mechanical computing in Eastern Europe, are not forgotten. Indeed, his inventions are mentioned quite often in modern publications on the history of mechanical calculating machines. However, usually it is only brief mentions. His biography is still known in only the most general terms, and the descriptions of his machines are very brief and sometimes contradictory.

Fig. 1. Israel Abraham Staffel [13].

In this paper, we want to give an overview of contemporary sources and modern scholarship on the life and inventions of Staffel, to clarify and supplement some of the facts and judgments, and introduce a unique historical document, a manuscript book, written by Staffel in 1845, which was considered lost. This document, which also clarifies and complements information about his main invention, demonstrates the need for further archival research to confirm the currently accepted history of innovation.

2 Literature Review

Staffel's activity attracted the attention of contemporary Polish newspapers and magazines several times. Usually, this was due to the successful demonstration of his machines at various industrial exhibitions. Probably the first and, to our knowledge, only publication was Staffel's own article *O nowej maszynie rachunkowej z* *wykazaniem potrzeby mechanicznej pomocy do odbywania rachunków* [1], which appears to be unavailable. Judging by the title, Staffel proved the necessity of using mechanical machines to facilitate calculations and, perhaps, briefly described his first developments. Three more notes [2–4] were also published on the eve of the Warsaw Exhibition of 1845, where his arithmometer was demonstrated.

Several publications in English [5, 6] are associated with the London Exhibition of 1851. The Report of the exhibition jury adjoins them [7]. These publications are extremely important, because in them we find the description of one of Staffel's machines and its external appearance. Furthermore, it contains the English translation of the Report of the commission of the Academy of Sciences in St. Petersburg, which had studied this machine several years earlier. Later publications in Polish [8–12] also contain some additional information about Staffel's calculating machines. An obituary [13] is very important because it provides the main information we know today about the Staffel's biography.

Contemporary sources also include publications in London newspaper *The Jewish Chronicle* [14–18], containing information about Staffel's time in London in 1851. Strangely enough, modern authors do not even mention this trip. Therefore, most of what we know about Staffel comes from newspaper sources.

However, modern publications devoted to Staffel personally are not numerous. First of all, we should mention here the paper *From the History of Computing Devices (Based on the Archives of the USSR Academy of Sciences*) [19], which for the first time after a long break drew the attention of researchers to the inventions of Staffel in the field of computing technology. In this paper, several Russian translations of documents originally written in French related to Staffel's contacts with the Academy of Sciences in St. Petersburg were published. Very important is the work *Mechanik warszawski Abraham Izrael Staffel (1814–1885) i jego wynalazki* [20], the most detailed of those devoted to Staffel. Several review articles in German [21] and Polish [22, 23] consider Staffel's inventions among a number of works of other Polish inventors of the nineteenth century. Finally, there is the only one review paper about Staffel in Russian [24].

Thus, we see that among the sources there are no memories of contemporaries and Staffel's own works. So, the rediscovery of the document that we give in Appendix – Staffel's handwritten book – has a unique significance for the history of computing.

3 Brief Biography and Inventions

Israel Abraham Staffel was born in 1814 in Warsaw, the capital of Poland (on 1815 the Kingdom of Poland became the part of Russian Empire) to a poor Jewish family. He received his primary education in Cheder, a traditional Jewish elementary school teaching the basics of Judaism and Hebrew language. After his graduation the boy was sent to serve as an apprentice to a watchmaker. At the age of 19, Staffel got a license and opened his own watch workshop in Warsaw. Although Staffel was a conscientious and talented watchmaker, the workshop did not provide him great profit and prosperity. He always was interested in the design of mechanical calculating machines, measuring instruments and other devices.

Many of his developments were presented at national and international exhibitions, in particular, at the Great London Exhibition, and were awarded medals and monetary prizes. Besides calculating machines, among his inventions were a precious metal alloy assaying device on the basis of the Archimedes principle, ventilators, an anemometer, an automatic taximeter for cabs which was controlled automatically (it started during the getting on of passengers and stopped after their getting off), a device to prevent forging signatures, and a two-color printing press. The latter was used to print the first Polish postage stamps in 1860 and later for printing banknotes [20].

Staffel died in poverty in 1885 at the age of 70, spending all his savings on his inventions. The anonymous author of his obituary [13] wrote that Staffel was very modest; glory and recognition did not interest him. So, his death remained almost unnoticed, and few of his contemporaries guessed that the work of the man who died would gain worldwide fame.

4 Staffel's Calculating Machines

Before presenting the first of his machines to the public at the Warsaw Exhibition in 1845, Staffel had been working hard on them for more than ten years. In total, Staffel designed four different types of calculating machines. Unfortunately, we know very little about them.

The exemplar of his earliest machine is stored in the Museum of Technology in Warsaw (Fig. 2).

Fig. 2. Staffel's adder of 1842 (property of Muzeum Techniki in Warsaw, Poland).

It is held in a walnut box and has the inscription in Polish: *Arithmetical Machine Invented and Constructed by Izrael Abraham Staffel, the Watch-Maker in Warsaw, A. D. 1842*. The mechanism consists of gear wheels and allows adding and subtracting. The results of these operations (numbers to a maximum of seven digits) appear in the window. To perform these operations, one must pull forward pins in appropriate fields of the values of digits of the added numbers during adding and pull backward digits of subtrahend while subtracting. Another specific feature of this calculating machine is the ability to mutually convert zloty and ruble currencies. On the both sides of the field that displays the results of main operations, Staffel placed adequate conversion values. One side is designated for conversion from zloty into ruble currency, and the other one from ruble into zloty currency.

The most famous of his machines, a 13-digit arithmometer, was also demonstrated for the first time at the Warsaw Exhibition in 1845. A year later, it aroused great interest in the Russian Academy of Sciences and then made a sensation at the London Exhibition in 1851. We will not specially mention these events, which are described in detail in the literature [19–24]. Let us recall only that the magazine *Scientific American* named Staffel's arithmometer "the most extraordinary calculating machine, we ever heard of" [6]; that means, at the time of his invention, it was probably the best calculating machine in the world.

The only one known until recently drawing which shows the external appearance of this arithmometer (Fig. 3) was published repeatedly (see, for example, [5, 9, 20, 21]). But its internal construction has not been known.

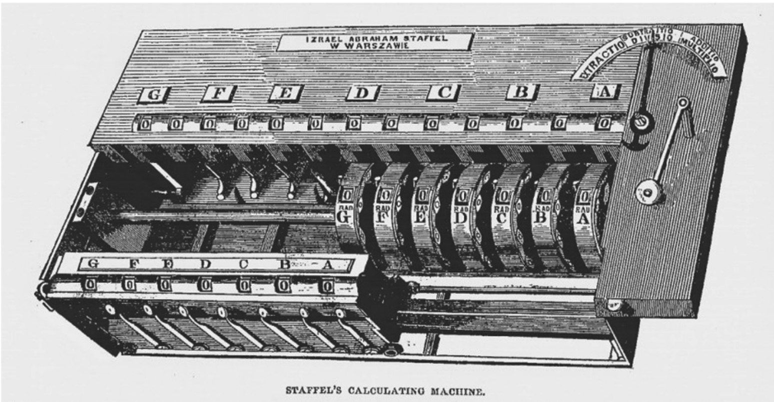


Fig. 3. Staffel's arithmometer [9].

In 1876, Staffel handed over his 13-digit arithmometer to the Physical Cabinet of the Russian Academy of Sciences in St. Petersburg [19, p. 586], but its current placement is unknown.

At the London Exhibition Staffel also presented another machine. It is only known that it performed adding and subtracting fractions with denominators 10, 12, and 15 [7]. This machine is not preserved.

Finally, around 1858, Staffel designed another seven-digit adding machine without the function of mutual converting of zloty into ruble currency (Fig. 4).

Fig. 4. Staffel's adding machine of 1858 [11].

This machine was presented and awarded at the exhibition in Warsaw in 1858. It is possible that Staffel also presented it at other exhibitions, in particular in Moscow in 1882 (see the next section). The only known exemplar of this machine was owned by the famous German firm Grimme, Natalis & Co, which was established in 1871 and produced arithmometers under the brand name "Brunsviga" from 1892 on. Staffel's machine constituted a part of the firm's rich exhibition of historical calculating machines [25]. In 1959, the firm was absorbed by Olympia Werke AG (part of the AEG group), and production of arithmometers came to an end in the late 1960s. The said collection was then delivered to the State Museum in Brunswick and now Staffel's adding machine is stored there.

We have no information about how many copies of these calculating machines Staffel made. We know that "mechanical schoty" were produced in Staffel's workshop (see Sect. 5 below). Most likely, their number (as well as other Staffel's machines) was small. In general, in the Russian Empire until the end of the 19th century the demand for calculating machines, including those designed by Russian inventors, was not very significant. This is due, among other things, to the wide utilization of *Russian schoty* in this country – a simple, cheap and reliable device for calculations [35].

Thus, till now from all Staffel's calculating machines only one exemplar each of the 1842 and the 1858 adders are preserved.

5 Supplements and Corrections

As we have already pointed out, there is very little information about the life of Staffel. Nevertheless, we can add some new facts to his biography.

It is known that he was born and spent his entire life in Warsaw. His workshop was first located on Marshalkovskaya str., 1379, and then his whole life Staffel worked in a workshop at Grzhibovskaya str., 982. However, no data is available in the literature on the volume and assortment of his workshop's production. We were able to find the following entry in the Index of the All-Russian Industrial and Art Exhibition of 1882, in which Staffel took part:

> Staffel Israel. Warsaw, Grzhibovskaya str., 982
> Mechanical schoty; ventilating apparatus; anemometer (wind meter); room ventilator.
> Workshop, since 1835; 2 workers; annual production up to 3,000 rubles; purchase of material in Russia and abroad; marketing in Russia" [26, p. 64].

Thus, we see which of his inventions Staffel presented at this exhibition. The list of exhibits awarded with bronze medals in the section "Educational and scientific equipment" contains the line: "Staffel, Israel, in Warsaw – for ventilators and anemometers" [26, p. 352]. Probably, this was one of the last exhibitions in which Staffel participated, and one of the last awards he received. It is interesting that the Index mentions "mechanical schoty." It can be assumed that this was the 1858 adder.

We have already mentioned that authors of the works about Staffel do not note his personal presence in London during the Exhibition of 1851. At the same time, this visit is fixed in a number of sources, as Sir Montefiore's Diary, quoted above (unfortunately, this book does not contain information whether Staffel visited Sir Moses or not).

We found interesting information about Staffel also in the London newspaper *The Jewish Chronicle*, noted above. His name is cited on its pages five times. In the issue of 18 July 1851 the article from *Illustrated London News* [5] was reprinted. In one of the following issues, the newspaper describes a visit the members of the Royal family to the Russian court of the London Exhibition:

> On Friday morning last, about nine o'clock, Her Majesty and His Royal Highness Prince Albert, accompanied by Princess Alice, paid a visit to the Great Exhibition. In passing through The Russian court, the royal visitors stopped for several minutes, and inspected Mr. Staffel's calculating machine (of which an illustration and full particulars appeared in our last number). Mr. Staffel, be desire of Prince Albert, worked sums in addition, subtraction, and multiplication, with which His Royal Highness expressed his gratification; and, addressing the Princess Alice, said, "Notice, this is a self-calculating machine." His Royal Highness then addressed a few remarks to Mr. Staffel on the pleasure he had experienced with respect to the calculating machine, and also of Mr. Staffel's ingenious machine for proving the value of gold and silver, and the royal party then passed on to other portions of this wonderful building. [15]

The issue of August 1 states that the inventions of Staffel caused interest in the Governor of the Bank of England, who expressed a desire to test in action the arithmometer and machine for testing the precious metals:

> Mr. Staffel's Calculating Machine. – On Friday last, the Governor of the Bank of England, accompanied by another gentleman of establishment, attended the Great Exhibition, by appointment, to inspect the above work of art, as also Mr. Staffel's machine for testing the precious metals. After some time in testing the machines, the Governor desired that they might be brought to the Bank at the close of the Exhibition, for the purpose of their relative proficiency being more fully proved. [16]

We do not know if such tests were ever conducted. Here it can be noted that the mechanization of calculating operations at the Bank of that time was clearly no less urgent problem than coin testing.

In the issue of October 24, Staffel's name is mentioned among the names of other Jewish inventors awarded at the exhibition [17]. Finally, in the issue of November 21, we find a note in which the author expresses his satisfaction that the work of a talented inventor has received a monetary reward:

> Liberality of the Prince Albert. – It must be a source of great delight to our brethren, to be made acquainted with the munificent liberality of the royal consort of our beloved Queen towards a humble mechanic of the house of Israel. The liberality of his Royal Highness has been exercised in the case of J. A. Staffel, of Warsaw, the inventor of the calculating machine, etc., which was exhibited in the Russian department of the Crystal Palace, who has received from his Royal Highness a cheque for 20 *l*. as an acknowledgement of his Royal Highness's appreciation of Mr. Staffel's ingenious invention.
> Since writing the above, we are glad to hear that Baron L. Rothschild, M. P., also presented our scientific brother with a cheque for 10 *l*. as a due acknowledgment of Jewish talent. [18]

Unfortunately, the information published about Staffel and his inventions is not always free of errors. For example, there is a statement that he was awarded the highest scientific prize of Russian Empire, the Demidov prize: "Staffel was awarded a Demidov prize amounting to 1,500 rubles" [23, p. 60]. The same mistake is repeated in [28]. In fact, the commission of the Russian Academy of Sciences considered Staffel's machine worthy of the Demidov prize, but on formal grounds he was recommended to put forward his work for the prize next year. They stated on the possibility of awarding the Demidov Prize to I. Staffel in the minutes of the meeting of Physical and Mathematical Branch, November 6, 1846 St. Petersburg:

> The rescript dated October 24, No. 9570 was announced, in which the Mr. Minister of Education informs the Conference that due to the very favorable response of the Academy about the arithmetic machine of Mr. Staffel, which from the mechanical point of view deserves special attention and in practical application has the advantage over Slonimsky's machine, His Excellency considered the invention could be worthy of the Demidov Prize.
> It was decided to reply that Slonimsky's machine was awarded a prize for the principle on which it was designed and which reveals a new property of numbers proven by Slonimsky and not known so far. Whereas, Staffel's machine is distinguished only by a cleverly constructed mechanism. The latter, moreover, is so complex that, even under the most favorable conditions, its high cost will always prevent its practical use. Nevertheless, if Staffel wants to join the applicants for the nearest Demidov competition, it will be enough for him to submit his machine with a printed description, and the Academy will resolve the matter with all fairness and impartiality" [19, p. 572–573].

Even though, that never happened. Thus, Staffel did not receive the Demidov prize (3,000 rubles). He was paid 1,500 rubles from the budget of Kingdom of Poland according to an order of the Emperor.

The shortness and fragmentariness of information about calculating machines built by Staffel leads to the fact that researchers do not always correctly interpret it. For example, in the book of Ernst Martin, Staffel's arithmometer is not even mentioned; as well, the adder of 1858 is dated 1845 [29]. Incorrect information that Staffel submitted to the Russian Academy of Sciences his adder of 1842 is given also in [28]. In fact, to both the Academy and the London Exhibition Staffel presented the same machine, namely his famous 13-digit arithmometer.

6 Staffel's Innovation

As it was said above, the only work published by Staffel and known to authors is a newspaper article [1]. Unfortunately, the text remained inaccessible to us, but probably it provided some explanation of his invention. At the same time, it is known from a report (written in French) of Russian academicians Victor Bunyakovsky and Boris Jacobi that, when presenting his machine to the Academy of Sciences, Staffel accompanied it with a handwritten description in Russian and Polish (English translation of this report is given in [5], and its Russian translation in [19]). However, this handwritten description was considered lost until recently. Thus, all information known about Staffel's machine was reduced to its description [5, 19], and a published drawing [5, 9, 14].

However, a few years ago, one of the authors of the present article purchased a hand-written book in antique store.

This document is undoubtedly a description of the machine that Staffel submitted to the Russian Academy of Sciences in 1846 along with the machine itself. Its value lies not exclusively in the fact that this is the only full description of how to work with a calculating machine, but also that the drawings attached (Figs. 5 and 6) make it possible to understand its construction.

Due to this finding we for the first time got an opportunity to see the inner construction of Staffel's arithmometer that made it possible to substantiate the assumption about the influence of its design on the construction of other arithmometers of the XIX and XX centuries.

Gottfried Leibniz's Stepped Reckoner, the first arithmometer that survived to our time, had the so-called stepped drum as the main unit. The stepped drum is a cylinder on the lateral surface of which there are nine steps of different length parallel to the generatrix. Stepped drums were the basis for the design of many arithmometers in eighteenth, nineteenth, and twentieth centuries: Philipp Matthäus Hahn's calculator (1774), the first commercially available arithmometer patented in 1820 in France by Charles-Xavier Thomas de Colmar and its improved versions (Arthur Burkhardt, 1879; Samuel Tate, 1903, and others).

However, arithmometers with a different construction, in which the main unit is a wheel with variable number of teeth, or pinwheel, became widespread only at the end of the nineteenth century. It is all the more surprising that apparently already Leibniz initially intended to use pinwheel. In 1685 Leibniz wrote a manuscript describing his machine, *Machina arithmetica in qua non aditio tantum et subtractio sed et multiplicatio nullo, divisio vero paene nullo animi labore peragantur*. Its design was based on wheels with variable number of teeth, not on stepped drums [30]. Even earlier, Leibniz's manuscript contained the image of pinwheel (Fig. 7).

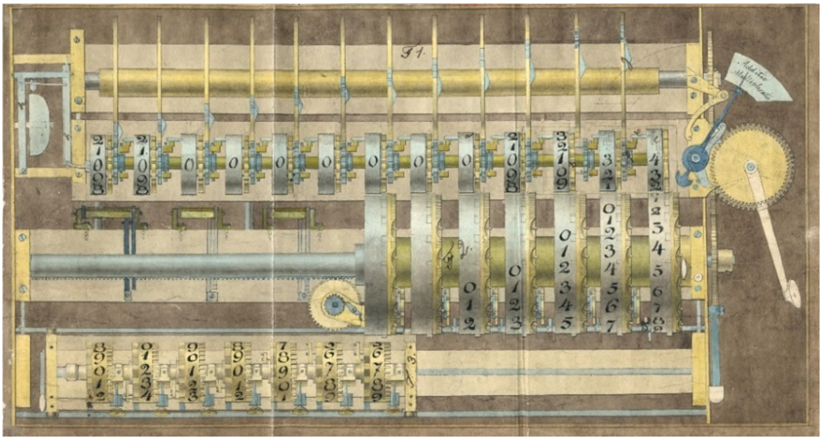


Fig. 5. Drawing from Staffel's handwritten book.

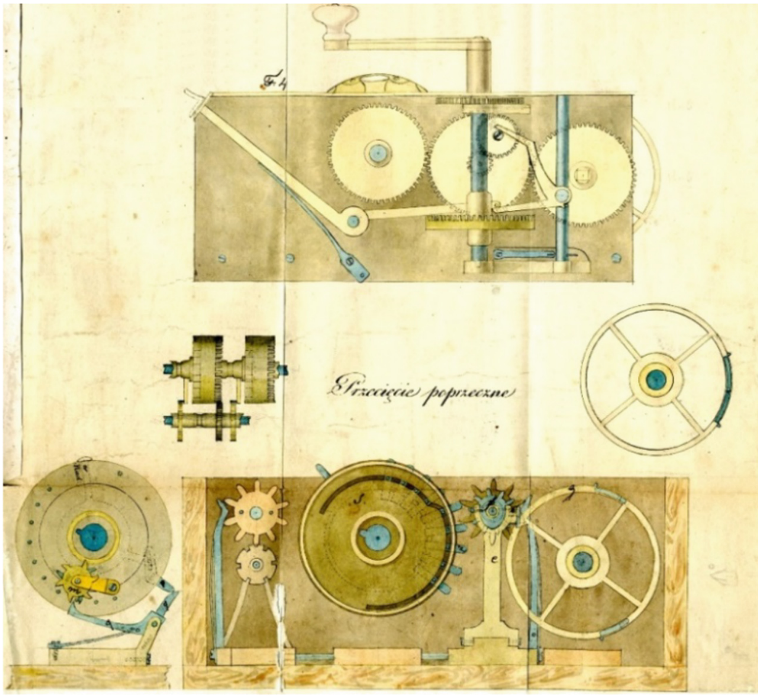


Fig. 6. Drawing from Staffel's handwritten book.

This idea of Leibniz was hardly known to other inventors, and in the next two centuries it was repeatedly rediscovered. Already in 1709 Giovanni Poleni in his arithmometer [31] used the mechanism of teeth erecting, the original version of

Fig. 7. Pinwheel (G. Leibnitz, c.1673) (from [30]).

pinwheels (see the right-hand side of Fig. 8, borrowed from Jacob Leupold's book [32]). A few years later, the Austrian mechanic Anton Braun, who was undoubtedly familiar with the Leupold's book, manufactured arithmometer also based on the use of pinwheels. The well-known inventor Dorr Felt wrote that the pinwheels were the basis for the construction of Charles Stanhope's arithmometer built in 1775 [33, p. 15].

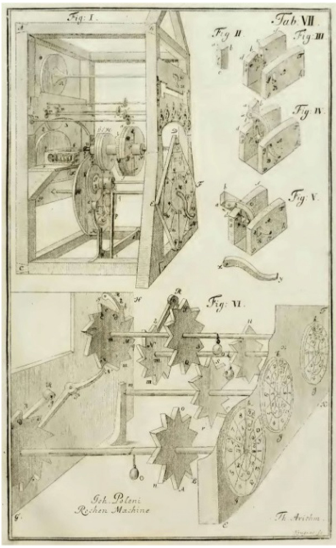


Fig. 8. Mechanism of teeth erecting (G. Poleni, 1709) (from [32])

On November 24, 1842, an emigrant from Austro-Hungarian Empire Didier Roth, who lived in Paris, received a patent on an arithmometer using pinwheels (Addition 3, No. 14535, Fig. 9, left). Then, his device was also patented in England by David Isaac Wertheimber (patent No. 9616, July 23, 1843). Soon afterward, Staffel's arithmometer appeared, in which we also see a similar unit (Fig. 9, right). Here we may note that the

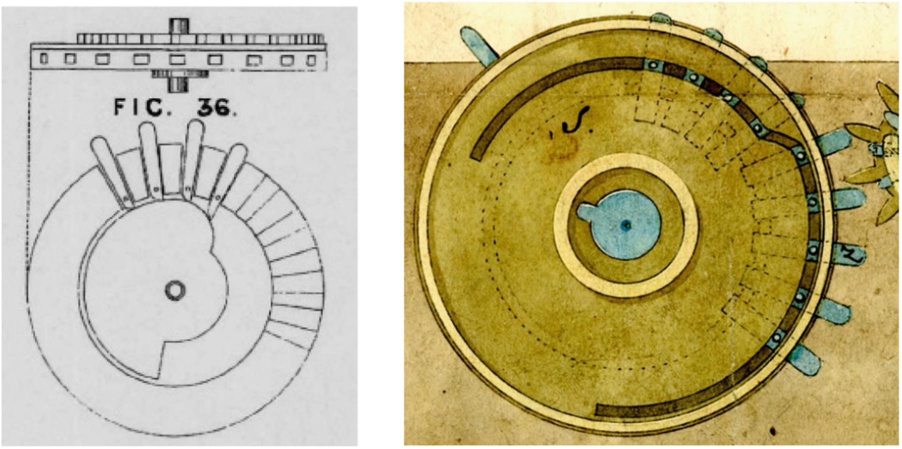


Fig. 9. Pinwheel (D. Roth, 1842, and I. Staffel, 1845).

acquaintance of Staffel with Roth patents seems extremely unlikely: the French patent was a manuscript, and the English one was published only in 1856.

However, arithmometers, based on pinwheels, began to receive wide application only from the end of the nineteenth century. On February 2, 1875 patent No. 159244 was received by the American Frank Baldwin. The pinwheel from this patent is shown in Fig. 10.

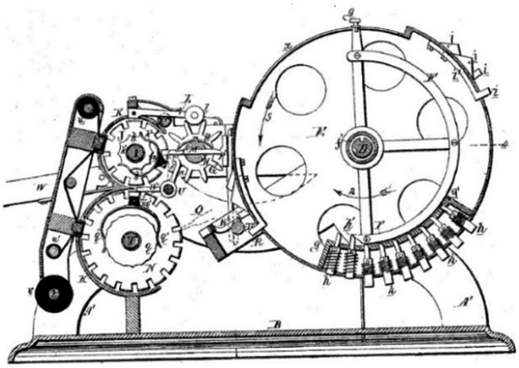


Fig. 10. Pinwheel (F. Baldwin, 1875).

A few years later, on 31 December 1879, the Russian *privilegia* (patent) No. 2329 on the arithmometer, invented by the Swedish engineer Willgodt Odhner (who lived in St. Petersburg), was given to the trading house "Königsberger & Co." The variant of pinwheel from this patent is presented in Fig. 11. Earlier, U.S. patent No. 209416 and German patent No. 7393 were granted. It is particular the design of

Odhner became the basis of most of the arithmometers produced under various trademarks throughout the world for a hundred years.

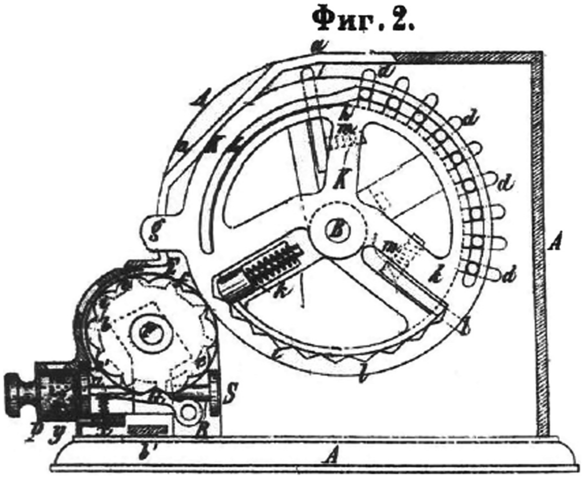


Fig. 11. Pinwheel (W. Odhner, 1878).

In a 1919 interview, Baldwin said,

> One of my 1875 models found its way to Europe, falling into the hands of a Mr. Odhner, a Sweden. He took out patents in all European countries on a machine that did not vary in any important particular from mine, and several large manufacturing companies in Europe took it up. [34]

The question of whether Odhner was acquainted with Baldwin's arithmometer is still open, although most likely Odhner have been unaware of it. But with Didier Roth's construction he could be familiar. However, one question is extremely interesting: could Odhner or Baldwin have known about the construction of Staffel's machine? Although Staffel's arithmometer was well known at the time, its drawings were never published, so Baldwin could not be familiar with the internal arrangement. At the same time, since Staffel's arithmometer in February 1876 was transferred to the Physics Department of the Academy of Sciences in St. Petersburg and became "accessible to those wishing to study it" [19, p. 586], it is possible that Odhner got acquainted with this device. Though the prototype of Odhner's first arithmometer was already finished at that time, he may have seen and studied the handwritten description of Staffel's machine before. This description (the translation of which we present in the Appendix) was available in St. Petersburg in 1846. Subsequently it was lost, but perhaps in the early 1870s it was still available.

However, regardless of whether or not Staffel's work influenced the design of the probably most commonly used arithmometers, he managed not only to offer, but also to realize, a calculating machine that received the highest appreciation of his contemporaries.

7 Conclusion

We hope the new materials presented in this paper will be an impetus to further study of the inventions of Israel Abraham Staffel and help to determine more accurately their place in the history of mechanical computing devices. We also hope that new documents related to the life and work of this remarkable inventor, who in 1851 was called the designer of the best calculating machine of all times, will be found in the archives of Poland, Russia, and England.

Appendix

The handwritten Staffel's book has 71 Russian and 57 Polish unnumbered pages plus 3 color drawings. Its cover of green color has a title in Russian, *New Calculating Machine* (Fig. 12).

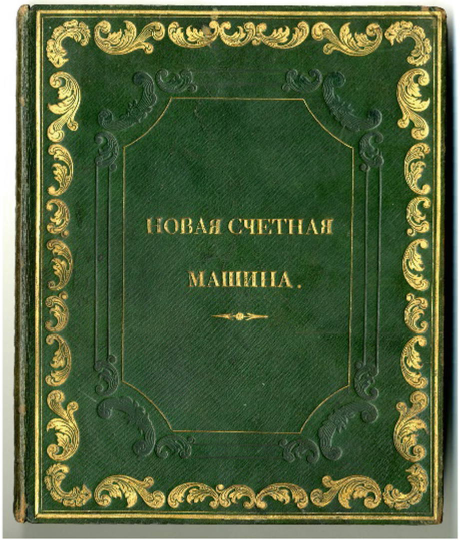


Fig. 12. Cover of Staffel's handwritten book.

The book has 71 Russian and 57 Polish unnumbered pages plus 3 color drawings. Both Russian and Polish texts are preceded by title pages (Fig. 13), on which it is written, respectively in Russian and Polish, "New Calculating Machine (Aritmetica Instrumentalis). Invented and designed I. A. Staffel. Warsaw. 1845."

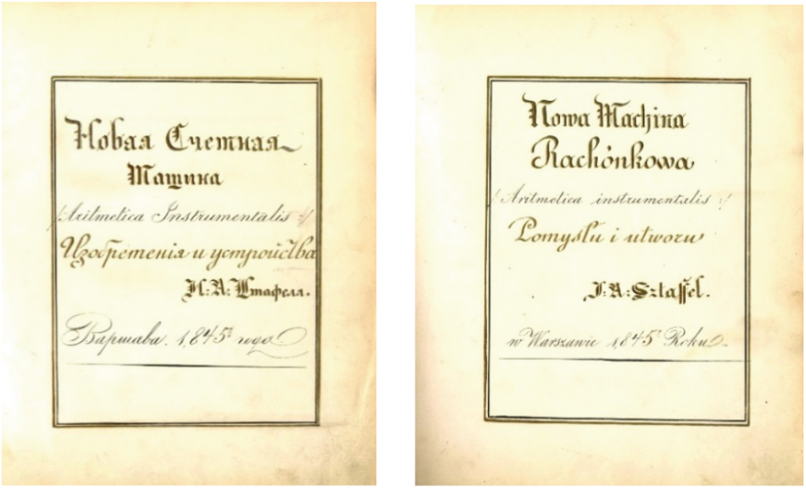


Fig. 13. Title pages of Staffel's handwritten book in Russian and Polish.

The text is written neatly, in a large legible handwriting (Figs. 14 and 15), but the Russian part contains many errors and slips of the pen. It seems the Russian language was not native for the writer, who was most likely not Staffel himself, but a professional copyist. The language of the document contains many obsolete even that time expressions and words. Sometimes it is even difficult to understand the author and we tried to interpret the text in modern English.

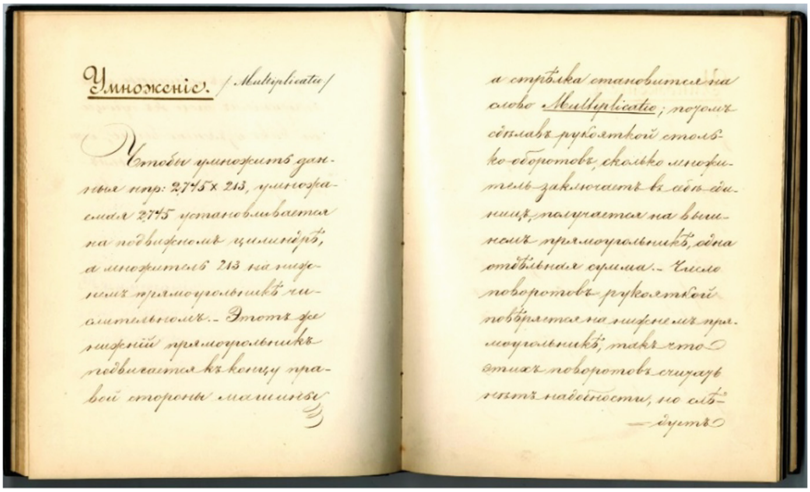
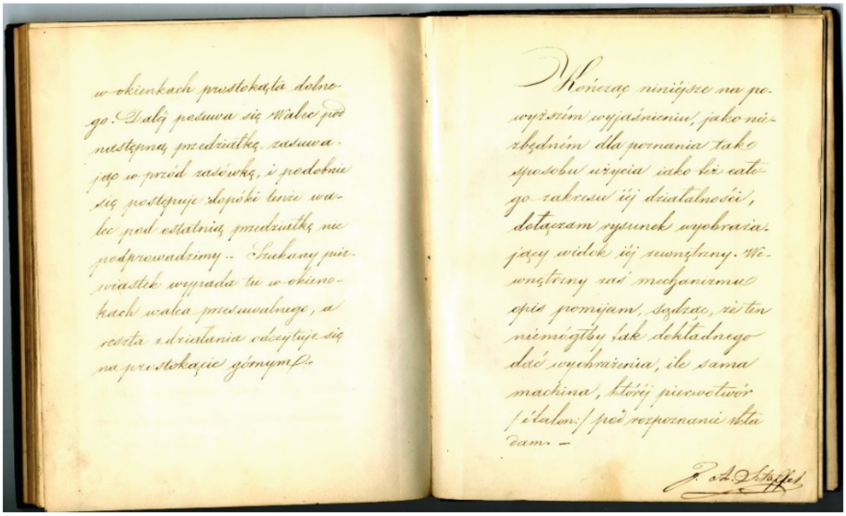


Fig. 14. Pages of Staffel's handwritten book in Russian.


w okienkach prostokąta dolne-
go. Dalej posuwa się Walec pod
następną przedziałkę, zasuwa-
jąc w przód zasówkę, i podobnie
się postępuje dopóki tenże wa-
lec pod ostatnią przedziałkę nie
podprowadzimy. – Szukany pie-
rwiastek wypada tu w okieno-
kach walca przesuwalnego, a
reszta z działania odczytuje się
na prostokącie górnym. –

Kończąc niniejsze na po-
wyższem wyjaśnieniu, jako nie-
zbędnem dla poznania tako
sposobu użycia jako też całe-
go zakresu iej działalności,
dołączam rysunek wyobraża-
jący widok iej zewnętrzny. We-
wnętrzny zaś mechanizmu
opis pomijam, sądząc, że ten
niemógłby tak dokładnego
dać wyobrażenia, ile sama
machina, której pierwotwór
/ etalon: / pod rozpoznanie skła-
dam. –

Fig. 15. Pages of Staffel's handwritten book in Polish with his autograph.

The translation of the Russian text is presented below. The number in curly brackets refers to the page number and after it is the text of the page.

New Calculating Machine
/ Aritmetica Instrumentalis /

Invented and designed

I. A. Staffel

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{1} There is no doubt that mathematics is the most important field of human knowledge which also got the most extensive application. People of every profession use mathematics {2}, beginning with an experienced Astronomer who calculates the distances and turns of countless celestial bodies moving in an immeasurable space to the last countryman who cultivates the land.

Without calculations and without estimations, it would be difficult to work {3} for governments, farmers, artisans, traders, and workers of other industries. Therefore, arithmetic is the basis and soul of all knowledge and it alone is able to estimate all the benefits. However, complex calculations made in the mind take a long time and are very fatiguing.

We know from experience that often even simple addition, subtraction, multiplication, and division, especially of multi-digit numbers, requires mental effort and attention because a mistake in one figure often destroys the entire result. During calculation, arithmetic doubts, thinking, repetition, and rewriting are testing one action by another, but meanwhile the error that has appeared during verification could {6} stipulate the error of the main action. And what are the means for reducing this work, this mental strain? Of course, in subtraction we could replace one rule by another, in multiplication searching for a quotient is possible, in division – skipping digits of the dividend {7} or finally using logarithms. All this, however, is nothing more than the tedious check of the mental action by an equal mental action. These actions do not bring a real effective facilitation, but on the contrary, they take a person in one difficult job to another even more difficult.

{8} As for addition, there are no reductions in this case and no verification by other rules, except for a repetition of the action. So, this kind of calculation is the most dubious. Therefore, in commercial operations where significant {9} amounts are considered, or when there is a lack of time, usually two or three accountants produce the same action simultaneously.

Due to this burdensome intellectual labor, the vital necessity itself has long pointed out various means, in order to shorten the actions [10] of this kind. Among them there are certain tables known at Chancelleries and offices which facilitate calculations to a certain extent. Already among ancient Greeks, Pythagoras, the creative genius of Geometry, understanding the need to eliminate difficulties in counting, compiled a well-known multiplication table {11}, which facilitates addition. According to his example, various other calculation tables were invented later and applied to the four main rules. Those tables, however, are either very small or too large. Some do not fit to their purpose and others {12} are so inconvenient and insufficient due to their vastness that it is not possible to find the desired results conveniently and with the required speed. Scientists of different epochs and times, concerned about the public benefit and bearing in mind that all methods of training young people {13} to calculations are inseparable from mathematical principles, tried to replace them[1] with a simple mechanism in order to eliminate, or at least reduce in some way, the labor associated with written and mental counting.

Among such scientists we can mention on the first place such renowned persons as: Leibniz, Hahn, Babbazh[2], Miller (see footnote 2), and Stern, who applied significant efforts and spent large sums in the invention of machines[3] for mechanical counting.

Here I will keep silence about the inventors of different tables and {15} devices with mobile rollers because they also do not give all the desired final results, and therefore do not meet the requirements of effective mechanical calculation. Equally, I am far from a detailed investigation of machines invented by my venerable predecessors. I shall mention {16} them only to such extent as it is necessary for characterization of my own machine.

Although their devices did not achieve the desired perfection, they all do not lose their quality, though along with some shortcomings such as mechanisms {17} consisting of numerous rings, springs, and watch chains, moved by several handles. For

[1] The tables. [Present author's note].

[2] So is written by Staffel. [Present author's note].

[3] Leibniz 24,000 [thalers]; Babbazh 17,000 [pounds sterling]; Stern 10,000 [thalers]: and others had got appropriate expenses. [Staffel's note].

this reason, they are quite prone to breaking, tearing and any other damage that is difficult to repair. This requires great attention and caution during operation, and to work with them demands {18} studying the rules, perhaps more concerning the mechanism itself, than it is necessary for ordinary calculations. Meanwhile, only one mistake in operation destroys all labor and causes the necessity to start again; the work slows down and the machine could be damaged. At last, the obtained intermediate results {19} are often not yet completed and one needs to use a pen or chalk in order to get the final result.

Yet in my young years I felt an irresistible {20} passion for calculus and. experiencing great mental efforts in this branch of the sciences, I wanted to free myself from burdensome counting by some extraordinary means in order to be able to dedicate my mind and time to other useful sciences. This thought, once settled in my mind. {21} had grown further to the point that I finally stopped thinking only about my personal purpose. All my aspirations I turned to the general liberation of people devoted to this science from the difficult implementation of arithmetic operations. Then the time came that {22} gave me the opportunity to get acquainted with the already existing machines, devices, and counting tables, and in the intricate complexities of their Mechanism and construction I managed to find the reasons of their shortcomings.

Having in mind completely different ideas, I avoided {23} this paved road, choosing a new direction, inventing a completely new method for mechanism.

I had been working for about 10 years on the construction of a new calculating machine while being a watchmaker, and I directed all my efforts {24} to use in it the most simplified and highly perfect mechanism. However, there is nothing more difficult than to simplify and, together with that, improve such a great thing.

Success happily was achieved due to such intense work and numerous costs {25}. I reached my deliberate goal and a machine I invented was completely built.

It represents a rectangular parallelogram of length 18, width 9, height 4″, equipped with three cylinders of special purpose. Its advantages are as follows:

1. It consists of {26} 13-digit numbers reaching billions (see footnote 2).
2. With the help of a single handle, four main rules are produced, that is addition, subtraction, multiplication and division, and also extraction of square roots with fractions in accordance with the direction of the arrow placed on the screen. All this is very rapid {27} and without the use of a pen or chalk. The purpose of the arrow is that it facilitates the resolution of all tasks like the triple rule and others, composed from the above-mentioned arithmetic rules, by moving it from one word to another.
3. In all cases {28} where a subtrahend is bigger than a minuend, a multiplier is bigger than the sum that can be installed on the machine, or a divisor is bigger than dividend, the ringing of a small bell is heard, so all arithmetic operations can be performed on this machine even without light.
4. The mechanism of this machine is quite simple and does not require {29} mental strain for using it. It does not break down even during excessive handling and could be used for the construction of another calculating machine, more accessible for public use, although it may differ in value, type and number of digits.
5. Construction of this machine is understandable for anyone who just wants to use it, so one can learn it in half an hour and perform calculations without any difficulty. In

short, it is the first, as I know, hitherto nonexistent machine of this kind, convenient, perfect and simple.

This machine is really Automatic and similar to a practical *rakhmistr*,[4] who solves {31} tasks according to the rules of theory in a rapid and correct manner. From this point of view, it unquestionably provides a great service to the chancellery, offices, bankers, commercial houses, architects, geometers, and anyone who needs to perform calculations in a rapid and correct {32} manner. It can also be placed at home libraries and successfully used at other premises designated for mental exercises.

{33} **Description of Machine and its external appearance.**

The machine has the form of a rectangular parallelogram, length of 18 inches, width of 9 inches and a height of 3½ inches without a handle.

Looking from above it is visible:

a: two rectangles connected with each other at an angle.

One so-called numeral is located along the machine, having {34} on the surface thirteen openings, in which digits from 0 to 9 can be installed. Above these openings from the left to the right there are letters A, B, C, etc., but only over every second of them. These letters are needed for extracting square roots.

Another is lying in transverse to the machine direction, on which a handle is placed of 3 inches length {35} and 1–3/4 inch height, as well as the clapon[5] that fixes the turning of handle, and the arrow with the scale adjoining to it with the inscriptions of arithmetic rules. This handle is drawn from the right hand to the left when the arrow is placed on the words Additio and Multip, and from the left to the right when placed on the words Substractio, Divisio or Extractio.

{36} ***b***: The cylinder lying horizontally, 6½ inches, made up of seven permanently connected circles, about 31/4 inches in cross section. These circles are designated by letters [**A**, **B**, **C**], etc. from right hand to left. Each circle has an opening on its surface under which it is possible to enter the digits from 0 to 9 by using balls mounted {37} on its toothed circumference. So, the cylinder, made up of seven separate circles, is fixed on the horizontal axis, with which it rotates together when the handle (mentioned in point ***a***) is actuated. In addition, it can be moved along the same axis and fixed as needed with the help of a clapon.

c: Lower rectangle, {38} similar to the same upper or numeral, with the only difference that it has only seven openings, under which figures can be brought, moved by the help of lateral toothed heads. This part of Machine is movable and, just as the cylinder [*mentioned in point* ***b***] can be fixed as needed.

{39} **How to use Machine**

Addition. /Additio/

Wanting to add the numbers, for example 5372 + 3845, you must first point the arrow on the word Additio. Then (assuming that there are zeros in the openings of

[4] Treasurer, cashier, counter in Polish. [present author's note].

[5] Staffel uses the word *clapon* (*клапон*) in Russian text. There is no such word in the Russian language. Probably Staffel meant *stopper* or *detent* [present author's note].

upper numeral rectangle), set the first number 5372 on the movable cylinder, and, after stopping the handle by pressing the clapon make one turn from the right hand to the left.

As a consequence, the digits (5372), set on the movable cylinder, go into the openings of upper rectangle. On the same movable cylinder another number 3845 is set and another turn of the handle is made. Then {41} in the openings of upper rectangle appears the number 9217, which is the sum of two given numbers 5372 + 3845 = 9217 which we alternately set on the movable cylinder. In the same way, we do for getting sums of other three, four, etc. {42} numbers.

Notes on the following Arithmetic Rules

1st Note. The same method of transferring the first of sums for addition from the cylinder to upper rectangle is used for subtraction and division, since the upper rectangle {43} has its application in subtraction and division as well as. For on this upper rectangle, it is necessary to set the sum more than the other in the case of subtraction, and divisible in the case of division, when producing these arithmetic operations.

2nd Note. As the movable cylinder is made up of seven separate circles only, then {44} the sum consisting of seven digits can directly be transferred to the upper rectangle. But, if there were a need to transfer the sum of eight, nine or more digits, then by transferring the first seven digits, it is necessary to move cylinder to the other end of the machine and set the digits eight, nine and eight on the eighth, ninth {45} or following openings of the upper rectangle etc. Then, making one turn with a handle, transfer these digits to the corresponding openings, which will make up with the seven previous digits the sum that we want to transfer to the upper rectangle.

{46} **Subtraction** /Substractio/

If you want to subtract amounts, e.g., 6428–5879, you must first transfer to the upper rectangle the larger number 6428 in the way described in addition. Then, set on the movable cylinder the subtrahend or smaller number 5879. Put the arrow on the word Substractio, {47} take off the handle brake, and make one turn from the left hand to the right. Then the number 549, appearing in the openings of the upper rectangle, is the result.

1st Note. If suddenly the machine user mistakenly transferred to the upper rectangle the lesser number {48} and from it wanted to subtract a larger number, than as a caution from this arithmetic improbability he would hear the sound of the bell placed inside the machine. Such an error could be conveniently corrected by moving the arrow to the word Additio and making one turn to the opposite side.

2nd Note. If it is necessary {49} to clear the openings of the upper rectangle from the digits on it and replace them by zeros, this is done evenly by subtraction. For, if you put on the movable cylinder the same numbers that are visible in the openings of the upper rectangle and, furthermore, point the {50} arrow at the word Substractio and make one turnover with the handle then the zeros appear in the upper rectangle, because the difference of two numbers is equal to zero (327 − 327 = 0).

3rd Note. If the number of the upper rectangle consists of more than seven digits, then by moving the cylinder to {51} the other end of the machine and repeating the same process as explained above, the remaining digits are also zeroed out.

{52} **Multiplication** /Multiplicatio/

To multiply the numbers, e.g. 2745×213, the multiplicand 2745 is set on the movable cylinder, and the multiplier 213 on the lower numeral rectangle. The same lower rectangle moves to the end of the right side of the machine {53} and the arrow point on the word Multiplicatio. Then making by the handle as many revolutions as the multiplier encloses the units one separate number is obtained on the upper rectangle. The number of handle turns is verified on the lower rectangle, so there is no need to count these turns. But it is necessary {54} only to pay attention to the corresponding opening of the lower rectangle, in which the numbers with each revolution are reduced by one unit and rotate until the zero appears in that opening. Then, the cylinder moves to the next digit of the multiplier and the handle rotates until {55} the zero appears in the opening of the lower rectangle, and so on.

After such a transition with the cylinder through all the multiplier digits, although not according to their arithmetic order, but only so that all the multiplier digits be reduced to zero, the sought number 584685 {56} appears on the upper numeral rectangle.

All reductions obtained by multiplying on paper could also be produced on this Machine.

{57} **Division**. /Divisio/

To produce the division, you need to transfer the dividend to the upper rectangle according to the method described in addition. Set the divisor on the movable cylinder, on the lower rectangle set the zeros. Move this rectangle to the right side {58} of the machine, and point the arrow on the word Divisio. After this, the movable cylinder is placed under the dividend, so that part of it from the left hand to the right is greater or at least equal to the divisor. Then the handle rotates until the number of the dividend, decreasing with each rotation {59}, becomes less than the number of the divisor. However, there is no need to observe this, because if you make more turns, the sound of the bell will immediately warn about that, and the error can be corrected by turning the handle to the opposite side.

{60} After that, the cylinder moves one digit further and the process continues in the same way to the last digit of the dividend. The result appears in the openings of the lower rectangle, and the remainder of the division, or fraction, appears on the upper rectangle.

General note.

Knowing the rules of the theory, {61} it is convenient to solve on the same machine all other tasks, arising from the four above described operations, such as: Arithmetic proportions, rule of three, etc., moving the arrow from one word to another as needed.

{62} **Extracting the Square Root** /Radix/

At the very beginning of the machine description and, in particular, in the paragraph under letter ***a*** about the numeral rectangle, it has already been said that there are letters **A**, **B**, **C**, etc., above the openings over each second of them {63} from the left to the right, needed for extracting the square roots.

Two such openings, denoted by one letter, will be called pairs, when extracting the square roots proceeding, however, according to the following:

If you want to extract the square root of any number, you need to set it on the upper rectangle {64} and set the zeros on the movable cylinder and the lower rectangle, except for the first opening from the right hand of this rectangle. Then point the arrow on the word Extractio, rotate the handle so that fixing clapon falls into its place. Move {65} the movable cylinder to the highest pair of the given number so that the letter of the cylinder corresponds to the letter of the given pair. In the same way, the lower rectangle is placed. Then the latch located next to the word Radicis moves to it, and the handle is turned until the number on the upper rectangle {66} becomes lesser or at least equal to the number in the openings of lower rectangle. After that, the cylinder moves to the next pair (sliding before the latch) and process continues in the same way with all the following pairs.

The sought root appears {67} in the openings of the movable cylinder, and the remainder is on the upper rectangle.

{68} Finishing the present description by above written explanation, necessary to learn how to use the machine and the whole range of its actions, I attach a drawing depicting the machine external appearance. As for its internal construction, I believe that the description could not give such a detailed its understanding as the machine itself, as the original exemplar (étalon), which I present.

I. A. Staffel

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