J. H. Müller's ..... Description of His Newly Invented Calculating Machine, Its Form, Its Use, and Its Utility

Klipstein, Ph. E.

Frankfurt and Mainz, 1786

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J. H. Müller's,

Princely Hesse-Darmstadt Engineering Captain and Correspondent of the Royal Academy of Sciences at Göttingen,

Description

of his newly invented

Calculating Machine,

its form, its use, and its utility.

Published

and accompanied with a preface

by

Ph. E. Klipstein,

Princely Hesse-Darmstadt Chamber Councillor and Honorary Member of the Society of Natural Science Friends in Berlin.

With one copper plate.

Frankfurt and Mainz 1786, at Varrentrapp Son and Wenner.

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Preface.

This splendid invention has so far become known only through a few periodical writings and learned journals. What was still lacking was a treatise that would contain as complete an explanation as possible not only of the exterior of the machine and its use, but also of its reliability and speed — in short, of the advantages it provides.

My most esteemed friend, Mr. Müller, has drafted such a treatise and entrusted me with presenting it to the public.

So important an invention as this, which surely among the other inventions of our [[UNCLEAR: times]]

IV

will do Germany particular honor, would have deserved that a scholar of the mathematical class had taken care of this edition.

In the meantime, no one else would have been able to confirm as reliably as I that Captain Müller was the inventor, and that the cited tests of speed and accuracy were carried out with all caution and impartiality; for I had the good fortune to observe, as it were, the very germination of the first idea for this invention in my friend, and from then on, during the realization of the ideal, to observe all progress; under whose own co-supervision those important experiments were undertaken.

I could present my testimony on this matter, conclude with that, and leave it to the kind reader, after reading the following treatise, to consider for themselves what great and publicly beneficial consequences may be expected from this invention, once it is one day rewarded — and then the machine is manufactured in large numbers and

and will be used; but the concern that a large portion of readers might regard it more from the standpoint of artistry and rarity than of utility — a prejudice that can do exceptionally great harm to such inventions useful to mankind, because it suppresses, or at least hinders, the spread of their use — this concern moves me to present my expectations and feelings. If, with my preliminary remarks leading into the treatise, I could have some effect against such preconceived opinions, my purpose would be fulfilled.

I believe that one is by far not yet in a position to foresee all the useful consequences of the perfected calculating machine, even in the field of finance alone. They are too important, have too much influence on a great variety of subjects, which in turn give rise to many other consequences, for anything entirely complete to be said about them at this time. Who could, at the time of the invention of the art of printing, have known and described all its consequences? And [[UNCLEAR: sind doch]] yet

XI

yet — the invention of the calculating machine belongs precisely to this class of inventions, to the class of those which promote the happiness of the human race through facilitated enlightenment, whereby not only much contemplation that wears out body and soul is spared, but whereby one can also easily form clear concepts of a multitude of objects and relationships, the greater part of which would otherwise either have remained entirely hidden, or would have become clear only to a few with great effort and incalculable loss of time.

It is an invention whereby the possible skill in the practice of the art of calculating is brought closer to the skill in the art of reading and writing — whereby one can find the result of given digits and numbers with a somewhat similar speed and reliability, just as through the latter one can find the result of given letters and words, especially in large divisions and multiplications. Through it, the man of strong

VII

strong judgment — from whom the patience and memory that reliable calculation demands can so seldom be expected — will gain more inclination for works that require considerable and correct calculations. He will deliver incomparably better work than many of the most precise and best calculators, who either are endowed by nature with lesser judgment, or have worn it out too much through the sustained exertion of their mental faculties.

Rulers will be able to have proposals submitted to them, insofar as they are based on calculations (and that will always be a large part), examined by means of this machine under their own eyes by impartial, indeed depending on the circumstances of the subject of the proposal, entirely unknowledgeable people.

Businessmen will work their way through the greatest calculations as if at play. Cameralists will be able to verify their own and others' plans with regard to the calculations themselves, or at least in their presence, easily and reliably

VIII

readily examine, and have examined. They will investigate the accounts of important administrations, through most questions whose resolution is useful to them, with far greater ease than at present.

They need only ensure reliable initial records, reasonable divisions, and well-organized controls. All remaining effort in finding noteworthy rates and ratios will be exceedingly facilitated for them by the machine.

Every experienced and thorough cameralist will know how extremely important and necessary for good management it is to calculate the ongoing value of various products of seigneurial estates, mines, manufactures, factories, and other establishments, as well as the value of manifold requirements, accurately and repeatedly, both in whole and in detail. Whoever fails to recognize or despises the benefit of this effort must be either weak-minded, or a lover of illusions and darkness. The upright man of insight, however, knows how to value it, knows thereby stupidity

IX

ness and deceit. How greatly must such a person rejoice over a tool that helps facilitate this noble occupation for him. He can now devote thought and effort more undisturbedly to the collection of materials, etc., need not entrust himself to too many assistants, and can thus quietly obtain the most useful overview.

The usefulness for progression calculations, and with what extraordinary speed such tables can be produced by means of this machine, Herr Hauptmann has himself explained in the treatise. I refer to that, and only wish to mention here additionally how useful the same could become to a man who trades in manifold articles and also sells them in small quantities, while purchasing once or several times a year at various prices — and in this way often turns over a considerable capital. With little effort, such a person can from time to time calculate a number of tables for himself, or have them calculated at quite insignificant cost, from which he instantly

ly sees how he can quote every article at the smallest price, and so forth. He thereby avoids a great many errors that harm him or others, and in both cases are detrimental to his business. Moreover, he can also verify his accounts with it. How easily he thereby avoids losses of 100 guilders and more.

The preparation and verification of probability tables concerning future likely grain prices, e.g. according to Unger's instructions — the calculations for tontines, widows' societies, orphan, poor, and sick care institutions, pawnshops — debt amortization tables for bankruptcies or agreements with creditors over certain years and annual payment sums — partnership accounts, where often considerable sums must be divided into very small parts with the utmost precision — calculations in coinage, and more of the like, must all be able to be [[UNCLEAR: carried out]] considerably more easily and reliably with the help of this machine.

Finally, this must thereby greatly facilitate the wider dissemination of the best method of presentation in accounting: the improved double-entry bookkeeping [1] in general, and the so necessary and important work of balancing, calculating profit and loss. As is well known, for complete accounts, in order to obtain an overview of the whole and its parts, it is necessary that all goods in kind be valued in money, especially when calculating the remainder from one quarter or year to the next, and where one wishes to ascertain loss and profit — that is, one must know the actual cost value. In this regard, there are often very large multiplications and divisions, whose reliable calculation makes the precise closing of accounts, and thereby the internal verification of accounts, more difficult.

In short, the consequences of this invention are certainly of the most widespread utility.

Would the famous Herr von Leibniz, along with an expenditure of more than 24,000

[1] See my treatise on the method of accounting. Leipzig, 1781.

24,000 Thaler, sacrificed nearly his entire life, so many of his spare hours, to the contemplation of this invention [1]; if the great consequences thereof had not encouraged him to do so?

Muller was so fortunate as to find what Leibniz had sought. The consciousness of having accomplished such a thing is beyond all reward, and invaluable.

Every day that meanwhile passes; while this now existing, still unique machine remains merely the property of its inventor — while its internal mechanism remains unknown to others — every one of these days is a loss for the human race.

The patron who takes it upon himself to shorten this time will be thanked even by the latest posterity.

P. E. Klipstein.

[1] Ludovici, Outline of a History of Leibnizian Philosophy, I, p. 69; II, pp. 237 and 238.

[[UNCLEAR: moren mA laa]]

Foreword

The very great futile effort which many scholars, even a Leibniz, had long since devoted to inventing a machine with which one could calculate quickly, easily, and without thinking, was well enough known to me, and my confidence in my own abilities so little exaggerated, that it would never have occurred to me to attempt whether I might achieve what had been unattainable for such profoundly thinking famous scholars. Had I even wished to dwell on such a thought for a few moments, the description of the similar machine invented by Pastor Hahn, which I had seen some years before the invention of mine

of my calculating machine in the German Merkur from May 1779, instead of encouraging me, would have deterred me even further; for from this I could have assumed such a predecessor who would give this machine all the perfection required for its general usefulness, and consequently would render my effort and thought devoted to it superfluous.

However, I arrived at it by a very easy path — without many years of reflection and without manifold experiments, more by chance than by intention.

Certain tables that I had to calculate gave me the idea of devising, and if possible developing, a machine that would serve solely for addition, in order to be able to calculate those tables more conveniently, more reliably, and more quickly.

This machine was designed on paper in a short time. But then I first became aware that one could also subtract with it, if one simply wrote the digits on the outer number wheels in reverse. Since multiplication and division can, as is well known, be regarded as repeated additions and subtractions, I ventured to go further, and — I very soon found the possibility of the four common

ordinary types of calculation not only with common numbers, but also with the most common named numbers and fractions. But then I had to completely redesign the original plan of the addition machine. In the process, so many different ideas went through my mind that in the end I did not know which one to choose and develop, or which would be easiest to put into practice.

Since I then supposed that the aforementioned Mr. Hahn, after nearly seven years of work and many imperfect attempts, would have found the simplest and most reliable method, I once again went through his description of the external form and operation of his machine, which had been published in the Deutscher Merkur, in the hope that perhaps one of my ideas would correspond with the exterior of that machine. My hope was fulfilled, and I now successfully developed this idea.

This is all that I have to thank the invention of Mr. Hahn for, namely: that without his description I might first have worked in vain on many another idea before arriving at the most suitable one; for the internal construction

can be produced in quite various, though not equally good and not equally easy or convenient to put into practice, ways, and each produces a different external form [*].

With the entire invention I had thus, alongside my other main occupations, spent only a quarter of a year, and also prepared the drawings, then handed it over to a clockmaker for execution. In the meantime, however, many difficulties were raised for me from that side, and I would have nearly given up the matter on that account, if I had not soon through reliable

infor-

mation

[*] Mr. Hahn is therefore very much mistaken when he believes, in the German Mercury of June 1785, that the description of his machine prompted me to make a similar invention, or that I derived more from it than he could have drawn from Leupold's description of the inner construction of various machines designed by Leupold and others, and of the external form of Leibniz's machine. Had I had this book at the time, I would perhaps not have needed as much time as Hahn's description required merely to form a correct idea of the external form and operation of his machine. But more on this in a counter-statement to appear shortly.

reports that the Hahn [[UNCLEAR: machine]] does not always calculate correctly *), and would have been encouraged by the advantage that my machine already had over the Hahn machine, namely that one can calculate with denominate numbers and various fractions just as quickly as with ordinary numbers, without having to first reduce them to ordinary numbers, whereas with the former, the denominate numbers and fractions must first be converted into ordinary ones before one can enter them into the machine.

That report, that the Hahn machine often errs, led me to more careful reflection; and indeed — I found that my machine, despite the most diligent crafting of its inner parts, was likewise

[[UNCLEAR: liable]]

*) Mr. Hahn admittedly does not wish to concede this in the German Merkur from June of this year. I do not blame him for it either, but merely wish to offer the following for consideration. If he was confident in the infallibility of his machine, why did he not submit it to any academy for examination, since, as he himself states in the German Merkur, May 1779, His Imperial Majesty, during His passage through Stuttgart at that time, is said to have repeatedly advised him to do so?

would have been lacking in the same way, had I not known how to improve it in time.

Since I finally found my constant supervision necessary during the construction of the machine, I was obliged to set up my own workshop and to take on journeyman clockmakers, through which it was completed without difficulty.

I then went to Göttingen in June 1784, showed it there to the members of the mathematical class of the Royal Society of Sciences, including its internal construction, and in an extraordinary assembly of the Society, in the presence of many other scholars and students, demonstrated its operations. Regarding the applause received thereafter, I refer to the Göttingen Scholarly Notices, 120th issue, 1784.

Shape and Movement of the External Parts

The external shape of the machine is best seen from the copper plate, fig. 1. The housing is made of gilded brass, 10 Paris inches in diameter, and nearly 3 inches tall. Including the number discs and knobs attached to the outside, it measures 12 inches in diameter, and up to the knob of the centrally located crank, 5½ inches in height.

On the upper horizontal plate, or the cover a, there are two rows of enameled number discs arranged in two circles, 14 in each row. The smaller discs e are inscribed with the 10 digits 0, 1, 2 ... 9. The outer, larger discs f show these digits twice, in black on the larger circumference and in red on the smaller circumference *). The former serve for addition and multiplication, the latter for subtraction and division. Each disc rotates around its own center; the

[[UNCLEAR: entire]]

*) Because in the figure all digits are black, in the following the black digits on the discs f will be called the outer digits, and the red ones the inner digits.

the entire plate a can also be rotated with all these discs around the center point of the machine.

At the upper edge of the immovable side wall there are likewise 14 discs g, which are inscribed on their wide enameled rim with the digits 0 — 9, except for the first 6 on the right, on which, besides those digits, 10 and Tx also appear for use with named numbers.

Each number disc of all 3 rows can be turned by means of the knobs h, until the digits required for the intended calculation appear within the perforated pieces i attached to the casing, as through windows *). One can turn the discs forward and backward at will. So that one can bring a desired digit into the window by the shortest movement.

The outermost number discs g located on the side wall can only be turned by means of the knobs h. The two inner rows e and f, however, are turned both by means of the knobs and also by the gear mechanism of the

*) These pieces i on the discs e and f also serve as clamps, or to hold the axis of the discs in their position.

the machine is moved, and through the latter the digits belonging to the completed calculation are brought into the windows.

Just as several digits standing next to each other represent a number, so too, for example, in the first figure the outer digits on the first 4 number discs (at the bottom right in the windows) show the number 3145; and since each row has 14 discs, it is clear that this machine can represent any number up to nearly 100 trillion. For convenience in use, the value of each digit is also marked according to its position, whether they are tens, hundreds, thousands, etc., as can be seen in the figure.

The middle part of the upper plate b, together with the pointer e located on it, is immovable. This pointer indicates the smaller number discs e, which serve only for multiplication and division.

The aforementioned rotation of the upper plate a, together with all the discs e and f attached to it, occurs only during multiplication and division, namely by means of the knob m, which is attached to it and fitted with a joint. This knob must always rest in one of the notches n located in the upper edge of the side wall, and can be lifted from one notch to another as required.

In

External Appearance.

In the center of the surface there is a crank k, which can only be turned to the right; and because it must always stand still at a certain position when one sets the digits given for the intended calculation into the windows, or slides plate a forward, a raised bump has been placed at d on the immovable piece b, on which the crank must rest, which for this reason has a joint at 1, so that it can be lifted over d before turning. q are 2 handles for carrying the machine conveniently. They can be detached from it.

The machine has also been provided with such a well-secured case that it can be transported without danger on a wagon, as far as one wishes.

In the lid of this case, 15 number discs are additionally stored, which serve for the calculation of the most commonly named numbers, and can be placed on the machine in place of others. Because for the lesser values of the named numbers rarely more than 6 digits are required, between the third and fourth number disc on the plate at o there is a protruding pin, whereby, when it is turned by means of a key according to the letter a engraved nearby, the clamps of the 6 number discs along with these can be detached so that one can remove all of them, or

Usage, II

at will take some of them out, and instead of them insert other discs suitable for the intended named numbers. p are small ivory tablets on which the usual symbols of the intended named numbers are written with pencil, as one usually writes them above such things.

[[UNCLEAR: decorative separator]]

Use of the Machine:

[[UNCLEAR: Addition]]

If only 2 numbers are to be added, one sets one given number, e.g. 2516, on the discs d by means of the outer digits, and the other, 624, on the discs e properly beneath the previous number; namely the ones under the ones, tens under the tens, and so forth. The remaining digits standing beside them in these two rows, which are not required for these numbers, one sets to zeros; if one now turns the crank once around, the one given number on f transforms into the sum — 3145, as the first figure shows. *)

Continued

*) If on the discs f instead of the given number nothing but zeros had been set, then after one

Use.

If more than 2 numbers are to be added, e.g., to those 2 numbers a third, 1802, one first adds, as before, the first 2 numbers, leaves the sum 3145 standing on f, sets the third number 1802 on g, and turns the crank once more: then the sum of all 3 numbers, namely 4947, will appear on f. In a similar manner, the addition of further numbers is continued.

Subtraction.

The larger given number, e.g. 7483, is set on the discs f by means of the inner (on the machine, red-colored) digits; the smaller number 629 is placed properly beneath it on the discs g, with the remaining digits set to zero; then, after one turn of the crank, the larger given number, consisting of red digits, on f will have been transformed into the remainder 6854. Fig. I [*]

Mul-

after one turn of the crank the lower number 629 will have appeared on f; for naturally the sum of 629 and zeros cannot be more than 629.

[*] In the first figure, beside the number 6854, to the left, nothing but nines are shown; these should indeed, in the previous addition, appear in the inner circles above the zeros of the outer circles, but here they should have been zeros.

Multiplication

If one of the given numbers consists of only a single digit. For example, 629 is to be multiplied by 5. One sets the largest number 629 on the discs g. The discs e and the outer digits of the discs f are set to zero. If one now turns the crank around in a circle so many times until the number 5 appears on the first small disc to the right e, where the pointer c indicates (which happens after five turns of the crank), then instead of the zeros previously set on the discs, the product 3145 will appear in the outermost digits *). Fig. [+

If the smaller number consists of more than one digit, for example in the previous example instead of 5 it is 35, then one proceeds first with the [[UNCLEAR: 5]] as before, leaves all

digits

To save several figures, the example has been arranged so that it also fits other types of calculation.

*) The machine has thus added the number 629 five times onto the discs f. Upon the first turn of the crank, this number itself took the place of the zero (see note p. 11), and was afterwards added to it four more times, and the smaller dial e has been advanced by one as many times as the crank was turned, or as the addition was performed.

[[UNCLEAR: 34]] Usage.

digits stand, and one pushes or turns the entire plate a by means of the knob m so that the pointer c points to the next following disk e. Now one turns the crank around as many times until the number 3 appears on this disk. Then on the disks f the product of 629 times 35, namely 22015, will appear in the outer digits *), Fig. 2.

Like-

*) From this it will be clear that one must not turn the crank as many times as the smaller number contains units, but only as often as the digits of the smaller number, each considered individually, contain units. Thus in this example not 35 times, but only 5 and 3, that is 8 times. Strictly speaking, to the product first obtained from 629 times 5, the larger number has been added three more times, but shifted one place further to the left, which position gives this added sum a tenfold value, or yields the number 629 multiplied by 10.

It is more advantageous to set the larger factor on the disks g than the smaller one, or in the case that both given numbers contain nearly or exactly the same number of digits, to turn the number whose digits taken together contain the fewest units onto the disks e by means of shifting the plate and the crank. For if in the above example one had set 35 on g and wanted to turn out 629 on e, the crank would have to be turned 17 times, consequently requiring more time.

The

Usage. 15

One proceeds in the same manner if the smaller factor has still more digits.

[[UNCLEAR: Division]]

The dividend, e.g. 1643, is set up by means of the inner digits f, the divisor 64 on the discs g, both in the positions corresponding to their value; on the small discs e and on the remaining ones next to the previous numbers, zeros are placed. Now the plate a is turned by means of the knob m so that the highest digit of the divisor comes under the highest digit of the dividend; should this digit, however, be smaller than the former, as is the case in this example, then the next following digit is shifted over the former, as one does in the ordinary method of division *), namely

It is, however, immaterial whether one first turns out the 5 on the 1st or units disc or first the 3 on the 2nd or tens disc e.

Figures 2 to 5 are likewise intended to represent the machine; only as much of it has been drawn here as is sufficient for the explanation of the examples.

*) Some have objected to this: does one not still need to know how to calculate? As soon as one knows that one is to divide and understands the above sufficient instructions, one need not know how to calculate further. However, in order to use the machine to any advantage at all,

16 Usage,

namely thus: Then the crank is turned around so many times until the first digits of the dividend become smaller than the digits of the divisor standing beneath them. In the present example, this will have occurred after two turns of the crank, and consequently the first digit of the quotient, 2, will appear on the small discs e, Fig. 3. If now the entire remaining dividend had become smaller than the entire divisor, then the division would be finished, and the number still standing on the discs f would be the remainder. But if this is still larger than the divisor, as in this example the number 363 is larger than 64, Fig. 3, then one moves the plate a by means of the knob m one position further to the left, or as far forward until the highest digit of the divisor has a larger number above it, and turns the crank again so many times until the upper digits become smaller than the lower ones: thus finally the quotient 25 will appear on the discs e, and in the place of the dividend the remainder of 43, Fig. 4, or in case it divides evenly, zeros will appear in the latter place.

[[UNCLEAR: It]] must be said that to use this, one must certainly understand arithmetic; for otherwise one does not even know which type of calculation to employ in order to find what is sought.

Use. 17

It is understood that if the remaining number of the dividend had still been greater than the divisor, one would have had to repeat the shifting of the plate and turning of the crank in the aforementioned manner several times *).

Calculation with named numbers and fractions, as well as duodecimal and sexagesimal numbers.

Because the procedure here is the same as with the calculation of common numbers **), I will only present the following

*) From the foregoing it will now be comprehensible that here too the crank does not need to be turned as many times as the whole quotient contains units, but only as many times as the digits thereof contain individually, thus in the example not 25 but 7 times. In essence, the procedure corresponds to multiplication, except that there one adds, but here one subtracts.

If one wishes to verify the division by multiplication, one sets the remainder, if there is one, such as 43 above, from the inner digits into the outer ones of the discs f, leaves the divisor 64 standing on g, and sets zeros on e. Furthermore, one turns the quotient 25 as the now smaller factor onto e by means of the crank and plate, and the [[UNCLEAR: dividend]] will appear again on the outside of f.

**) Something of this has already been [[UNCLEAR: mentioned]] above on p. 6; as is well known, named numbers are either calculated piecemeal, or everything in units. Of the smallest

[2]

in Use.

following example: 158 Reichsthaler 217 Kreuzer are to be added to 33 Reichsthaler 762 Kreuzer. So I write on the second, third, and fourth ivory tablets the usual symbols of this currency course, Rthlr. and Kr., Fig. 5; then I take on the right the first disc [[UNCLEAR: b]] from the side wall and the first and third disc, or the ones and hundreds, from the plate a, in the manner somewhat described on p. 10. Since 1 Rthlr. contains 90 Kr., no digit higher than 8 may appear in the highest place of the Kreuzer; I therefore take from the number discs located in the lid of the case the one on which only the digits 0 to 8 appear—then

manner reduced, and afterward treated as ordinary numbers. Both can equally be performed on a machine set up merely for ordinary numbers, only with more effort. On my machine one needs neither the one nor the other; rather, one sets the named numbers on the machine just as they are, as will become clear from the following example. This does, to be sure, have various exceptions, but where these are addressed in what follows, that ordinary method of calculation still applies in all cases. One can thus actually say: the calculation with named numbers has some limitation only with regard to the greater advantages offered by this machine through the direct entry of named numbers.

Use. 19

then take out the two discs marked with fractions, and place them in the proper location on the machine *); then I set one of the given numbers, e.g., 158 Reichsthalers [[UNCLEAR: 21¾]] Kreuzer, into the outer digits e, and the other, 33 Reichsthalers [[UNCLEAR: 7■]] Kreuzer, on g properly beneath one another; turn the crank once, and the sum of 192 Reichsthalers [[UNCLEAR: ¾]] Kreuzer will appear in f.

The addition and subtraction of named numbers in this very convenient manner has no limitation **). The

*) The more detailed manipulations, how the removal and insertion is done, and for which barely a few minutes are required, can be better described at the machine itself, or through the more detailed explanation appended to it. Inserting other number discs would not be worthwhile for the sake of a single example; but it would be worthwhile when several calculations are to be performed. Should one also need to calculate with common numbers in the meantime, the named number discs can always remain in place, since there are still enough common number discs on the machine beside them.

**) The main matter would now be described; at least after this, a person skilled in arithmetic can also manage with what follows. However difficult and tedious the procedure may perhaps seem to some based on this description, it is in fact not so in practice when it is demonstrated on the machine itself. One would have to be a person entirely devoid of understanding,

20 Usage.

Multiplication, however, in which the named numbers and fractions are to be set on g, the remaining rows on zeros, and where the common number to be multiplied with the named number must be turned out on e, works well enough when the common number consists of only one digit, but not when it consists of several digits; for in that case the plate a must not be shifted. One therefore cannot multiply by any large number, unless one wished to turn the crank as many times as the number contains units. If, for example, the number were 55, the crank would have to be turned 55 times.

The division of named numbers and fractions, both among themselves and with common numbers, can also be performed without breaking them down into the smallest units, by inserting the previously described number discs; this, however, can likewise only be done with numbers where one is not contained in the other very many times, and indeed for the same reason mentioned with multiplication.

Moreover, further restrictions arise with division, and in that case several rules would be [[UNCLEAR: needed]]

insofar as he only understands the numbers, even if he would not want to grasp the whole matter in a single hour; but to impress the method of procedure upon the memory, only somewhat more practice is required.

rules necessary, which however a thorough calculator will find on his own. Yet they can also, upon request, be described in a special supplement to the machine. Where multiplication and division do not apply, the named numbers must be reduced to their smallest value and then processed on the machine just as with common numbers.

The present machine and the accompanying named number discs are set up for those currency exchange rates which are common in most English, French, Russian, Italian, Swiss, and various German trading cities as well as other cities; furthermore for various weights, grain and liquid measures, rod, foot, and ell measures, hours, degrees, and their smaller subdivisions, etc.

Since some rods contain 12 feet, a foot 12 inches, an inch 12 lines, an hour 60 minutes, a minute 60 seconds, etc., it follows that duodecimal and sexagesimal calculation also takes place [*].

[*] It is evident from this that machines could be manufactured for any number system, thus also, for example, one for Leibniz's Arithmetica Dyadica.

22 Usage.

The fraction discs contain only such small fractions as can be brought under the denominator 12, as they usually occur in monetary calculations. Other small fractions which are not found among these, e.g. 1/7, 1/9, can easily be noted and calculated separately.

Can not all possible named numbers and fractions be applied without reduction, then? No, and this will never be achievable. However, upon request a machine can be manufactured for other arbitrary named numbers.

That one can have all possible decimal fractions on the machine is obvious in any case. But any large fraction, if a small imprecision does not matter, can be converted into a decimal fraction. Furthermore, the numerator and denominator must, as usual, be calculated separately; and since this is accomplished more easily and quickly on the machine with large numbers than through ordinary calculation, one need not fear large fractions either, as often tends to happen in cases where a small discrepancy is initially disregarded, but in the end considerable errors arise.

Other Compound Types of Calculation.

Since in the rules of three, rules of five, root extractions, and progressions, one or more of the four

Use.

[[UNCLEAR: ...the four]] simple types of calculation can be applied: it is already clear in itself that those calculations too can be performed by means of the machine. Some things, however, still deserve special mention.

The Rule of Three for common numbers can be carried out without recourse to a pen; for, since the product of the second and third terms appears in the outermost digits of the discs, this can immediately be transferred to the inner digits of these discs in order to divide it by the first term.

For arithmetic progressions in common as well as denominate numbers and fractions, the machine provides exceedingly great advantage. I need not say how this is accomplished through mere addition or subtraction by means of the machine. I only wish to note that, since the first term and the common difference of the terms need only be set once on the machine, each subsequent term can be found merely by a single repeated turn of the crank; consequently, one needs to do nothing more than turn with one hand and copy down with the other *); yet here is an example of this. Suppose [[UNCLEAR: 1]] pound costs [[UNCLEAR: 4]]

[[UNCLEAR: tiv,]]

*) It could easily be arranged for greater convenience that the crank could be turned with the foot.

24 Usage

Livres 12, Sous 37, Deniers [1]. If I want to have a table up to 100 Pfund in order to immediately know from it the value of any given number of Pfund, I set the appropriately designated number discs on the machine, enter the above number both into the outer digits of the discs f, as well as onto the disc g. On the first small disc e I set 1, which signifies 1 Pfund.

If I now turn the crank once, I obtain on f the value of — Livres, Sous, Deniers.

[[UNCLEAR: 2b. nh — 9 4 +]] after the second turn [[UNCLEAR: 19 11M A 2, 16 108]]

after the third [[UNCLEAR: aB di veg ggg]]

and so forth [[UNCLEAR: SI das 490 dde Lili X E]] [[UNCLEAR: O! Be EAA OSZE SG e mida]] [[UNCLEAR: 7b — — 12 6 i M]]

And so on, whereby the number of Pfund can also be checked each time on the small discs e for greater certainty. In the use of the machine thus far, I have found that one, with

[1] A Livre has 20 Sous, a Sous has 12 Deniers.

Use. 25

progressions can also, by means of the aforementioned number discs, apply larger fractions, indeed almost any desired fraction, and has discovered several other advantages, which would be too lengthy to describe here in full, and which will naturally present themselves to anyone skilled in calculation [[UNCLEAR: upon use]] [*].

Of

[*] I subsequently had a special number disc made for insertion into series f, for the following purpose: When the first term, and perhaps also the difference, of an arithmetic series contains a decimal fraction of many digits or places (which, to be sure, must not be abbreviated when computing the following terms, in order to obtain them as precisely as possible, but of which for practical application only the hundredths, for example, are needed — so that the thousandths and subsequent smaller values can be omitted in the transcription — in which case, however, one would like, in order not to err by more than half a hundredth, to round up by one hundredth whenever the thousandths place contains 5 or more units, or when the following places still contain more than half a hundredth): one inserts that disc into the thousandths place. The machine will then correctly compute the entire decimal fraction with all its digits through all the terms, and will only carry one unit into the hundredths place when the thousandths place contains 5 or more units, but will not do so when the digit [[UNCLEAR: is below 5,]] 4 or

[[UNCLEAR: Gebrauch]] Usage.

A very advantageous extraction of roots of very large numbers will be dealt with separately in the following.

Calculation with larger numbers than the machine can contain.

Because this machine has only 14 number wheels in a row *), according to the above instructions one can only produce a number as large as 100 trillion, but it is also possible, through a minor trick and still with considerable advantage, to calculate a far larger number than the machine can hold at once. One need only divide the number into two or more parts, calculate each part separately, and properly combine the resulting partial numbers together—

* 4 or a smaller one stands in the place of the thousands. I know well that one can also accomplish this in copying the numbers without particular difficulty, but not easily without error.

*) According to my design, a machine can be manufactured with as many number wheels as one desires. If I am put in a position to be able to manufacture several such machines, I will have one made that contains a couple more places. Even larger numbers seldom occur, so it would not be worth the expense to add more classes.

combine. Even this can be obtained without special addition; one need only copy down the parts of the product or quotient. The manner in which this must be done a calculator can find out for himself *).

[[UNCLEAR: §. 74]]

On the Reliability of the Machine.

Two main questions still remain to be answered:

1) Does the machine not err, or can one not easily make a mistake oneself?

2) Does it also bring so much advantage that it is worthwhile to acquire such a machine?

Both—

*) I once calculated, as a test, a product consisting of 50 digits far more conveniently and quickly than it can be done with the pen. By this means, among other things, root extractions in pure equations in higher mathematics can be carried out very advantageously when one seeks the root by approximation. (See Kästner's Anal. finit. [[UNCLEAR: §. 22r.]] XXIX.) Thus, much larger logarithms than those contained in the common tables can also be found with little effort and great accuracy, and so forth.

28 Safety. 4

Both of these I can confidently answer with Yes. The following will confirm it.

When during addition or multiplication the sum or the product inadvertently becomes larger than the machine can display.

When during subtraction the number which one wishes to subtract from the other is larger than [[UNCLEAR: it]] is, or which amounts to the same thing: when the smaller number from L is set upward into the row f.

When in division, during the repeated turning of the crank, the numbers of the dividend are not always checked to see whether they have become smaller than the divisor, and consequently the crank is turned around more often than it should be; or when the divisor, in cases where it should have been advanced two or more places, is only moved by one.

All these errors are indicated by the sound of a small bell located inside the machine. In subtraction and division, the calculation must then be set and cranked out again from the beginning *).

At

*) In division it is the same case as in subtraction, namely that through an error the machine is expected to subtract a larger number from a smaller one. It does indeed attempt to count beyond zero,

Security. 29

For addition and multiplication, this is not necessary; for when one calculates with large numbers, one will always consider beforehand whether the machine can accommodate them. However, this cannot always be determined in advance down to a single digit without some effort; thus, if one believes that the resulting sum or product will at most not exceed 15 digits, one can continue calculating regardless after the bell strikes — one need only note the number of bell strikes and place this number in the fifteenth position.

Inside the machine, in the lower, immovable part of the housing, there are toothed wheels that engage with the number discs, but not until the crank is turned. For if they were connected while the crank was at rest, one would

[[UNCLEAR: lehnet]] rejects it, and for this reason turns all the zeros in the row into nines, so that the error is indicated not merely by the bell strike, but also by the nines appearing in the empty positions. The eye, however, can sometimes be deceived. The little bell thus saves the attention that one would otherwise often have to devote to the empty positions as well. Sums or products that exceed the capacity of the machine cannot in any case be detected by the eye, but only by the little bell alone.

Reliability. one cannot turn the number discs by hand at will. Now, if the digits were not placed exactly in the middle of the windows, the teeth of the wheels would not properly engage with one another, or would even press and push against each other to the detriment of the machine. On my machine, however, one does not need to place the digits so precisely in the middle of the windows for this reason; for as soon as one sets the crank in motion, the digits are automatically positioned so precisely by a special mechanism [*] before the wheels engage that the teeth necessarily mesh correctly.

Because after the completed rotation of the crank, the number discs must again come out of connection with the aforementioned wheels, and consequently with very rapid movement of the crank the wheels must also necessarily turn rapidly, and these in turn must turn the number discs rapidly: it could easily happen that the discs, at the end, when they are released by the wheels, would be driven further by one or more digits than they should be, by virtue of their acquired rapid momentum. I have therefore devised an additional mechanism suited to this purpose,

useful

[*] Not by mere springs. These are also present, but can occasionally cause jarring, because they must not be too strong.

Safety. [[UNCLEAR: BL]]

arrangement has been made, by which this is also prevented even during the fastest operation.

But since an overly rapid rotation, or so to speak a wrenching around of the crank, could damage the machine in other respects, provision has also been made for this. 5 revolutions of the crank can take place in 4 seconds, and even 2 revolutions in one second without any concern, although the latter would greatly fatigue the hand during sustained work. But it is absolutely impossible to turn it any faster; for as soon as one attempts to do so, the crank stops and cannot be moved further unless it is first turned back as far as possible. Thus merely a warning that one must not turn it faster.

From the description on p. 10, it is evident that the crank must always stand at its resting point, namely at the elevation d, when one sets the given digits or turns the plate a by means of the knob m. If the crank were accidentally moved to a position other than the resting point, the dials would be immovable and thus could not be set for the intended calculation; nor could the plate a be advanced without damaging the machine. Provision has therefore been made so that it remains immovable, or cannot be moved from its position in any way, until one has corrected the position of the crank.

Would

32 Security.

If the aforementioned knob were not exactly set into one of the gaps n, then without one noticing it (especially if the distance from the gap is small), either a harmful jamming or a false calculation could arise, because the discs f would then not stand directly over the engaging wheels. I have, however, made a device so that the crank can only be moved from its resting position and turned when the aforementioned knob is seated in a gap. *)

Now [[UNCLEAR: pe]]

*) I have never seen Hahn's machine myself, but according to the description of all those who have seen it and its operation with some attention, these devices, partly for warning, partly for self-correction, are not installed. It could also otherwise not possibly calculate so erroneously. Only if one pays exact attention to everything, places the digit very carefully in the center of the windows, and turns the crank approximately as slowly as if one wanted to observe the movement of each digit, should it still calculate fairly correctly. But what time and patience does this require? Mr. Hahn often excuses himself by blaming poor workers. The first four digits of my machine were also initially, when I did not yet have the workers under my constant supervision, as poorly made as possible; nevertheless, when I had them cobbled together for some testing purposes, they did not make a single error in calculation.

Reliability, 33

Now I am aware of no further error that could arise other than this: if one does not place the numbers given for the preceding calculation in the correct rows, or does not properly place them beneath one another. For example, 37 under 29 [[UNCLEAR: Gb]] for addition, thus: 4, or because one uses other digits [[UNCLEAR: in]] calculating, only on account of the many alterations made to them and their short durability, one 1) later confused them with new ones.

That one cannot calculate with the aforementioned numbers on that machine nearly as conveniently or as quickly as on mine can already be proven from the Reverend's own description.

Beyond all of this, that machine has the inconvenience that instead of number discs, upright little rods are found at the edge, which must be pulled out of the housing up to the desired digit among the sideways-pushed figures. It is therefore not possible to view the digits of several rods at once. They also hinder the convenient turning of the upper plate, and in the process the rods can easily be displaced. The remaining number discs can only be turned one way, which is likewise inconvenient.

Mr. Hahn must therefore not yet know my machine well enough, nor have himself read the reports about it that have been published here and there, because otherwise it would hardly have occurred to him to dispute its advantages over his own in the German Mercury, June 1785.

digits than were given, e.g., for 296, one enters the number 206 or 269; however, the former case would be far too obvious, and for these errors absolutely no machine is possible that could correct or indicate them. For how could a machine calculate the numbers one has in mind if they were not actually given to it? How could it produce the sum 333 from 296 and 37 if it were given 296 and 370, or 206 and 37, to add? Here, therefore, attentiveness is required. Should such an error happen to occur, it can always be found in the end through simple verification.

One should only consider here that when calculating with a pen, one can make not only these very same errors, but also infinitely many other mistakes besides.

There remains yet one more circumstance to consider, namely that something in the machine could break, despite great care having been taken for its durability, and it could thus calculate incorrectly without one immediately noticing. Who would not think here that one would indeed not notice such a thing at that very moment, but would soon become aware of it, if one only occasionally performs a verification — not with the pen — but by means of the machine itself, e.g., verifying a division by multiplication.

The

Advantages, 38

What is broken can also easily be repaired by a mediocre worker, because there is almost no piece in the machine that does not have several more perfectly identical pieces beside it; for one can say: the entire machine contains 14 smaller machines within itself, which are all completely identical to one another, and also stand in the same connection among themselves.

Advantages which the machine grants over ordinary calculation.

The benefit which the use of the machine can provide to anyone who has many and extensive calculations to perform will already be fairly clear from the foregoing. The clearest proof, however, is surely if I present here an excerpt from the trials which, alongside a seconds clock, with the same calculation examples, were partly actually conducted and partly subsequently verified by me using the machine, and by one of the most skilled calculators, Mr. Accounting Auditor Mezler, with the pen, under the kind supervision of Privy Councillors Klipstein and Heumann, in the presence of several members of the Princely Revenue Chamber and Accounting Audit Office in Darmstadt.

[[UNCLEAR: y C4 Wor]]

Advantages

For now, however, I must still note the following: Because even the most practiced calculator must repeat every example, or at least verify it once, if he wishes to be convinced of its correctness; the time for verification would likewise have to be taken into account, which, however, was not necessary with the machine on account of its [[UNCLEAR: infallibility]].

Section 6

In the following table, the average time has been taken from many equally large examples, because individually they do not all require the same amount of time. For if, for example, the multiplier is 1322, one will finish much faster with the machine than if it is 6987. In the former case the crank is turned only eight times, but in the latter 30 times, see p. 14, note.

It goes without saying that the setting of the given digits on the machine and the copying down of the resulting numbers must also be taken into account.

The small amount of time required for entering the said numbers, amounting to approximately only 25 minutes for 8 discs, has not been noted in the table; on the other hand, neither has the time that the calculator spent sharpening and dipping the writing pen.

Because

Advantages. [[UNCLEAR: ELA]]

Because the human calculator could not well maintain the same speed throughout, the time he spent did not always turn out exactly proportional to the size of the examples. By means of the machine, one could already work more uniformly.

During the experiments I found that setting up the given numbers takes much and almost always most of the time. This prompted me to think of a means by which the numbers could be set up even more conveniently and quickly; it succeeded.

I constructed a model of it *), and made with it, under the aforementioned supervision, further experiments, to which the last column of the following table refers.

The writing down of the given numbers for calculation with the pen is consistently under the allotted time; but because in the addition of several numbers the calculator often already has the numbers written down before him in proper order: this case too has been tested and marked in the table with an asterisk.

The named numbers given in the table were in each case Reichsthalers and Kreuzers.

Addi-

*) With this arrangement, the numbers can even be set, calculated, and found in the dark of night, and thus all the more reliably during the day.

Addition.

2 common numbers, each having 3 digits each with 7 digits each with 14 digits

2 named numbers with 2 to 6 digits, for example [[UNCLEAR: 1044 rth. 60 fr.]] 36— 66—

10 common numbers, each with 2 to 4 digits

These without writing down the given numbers

40 common numbers, each with 12 digits

Without writing out

20 named numbers, each with 2 to 4 digits

Without writing down

Advantages. A practiced calculator completes the task in

with writing and calculating | verification | total Min. Sec. | Min. Sec. | Min. Sec. — 11 | — 2 | — 13 — 4 | — 57 | — 29 [[UNCLEAR: — 7]] | [[UNCLEAR: — 15]] | [[UNCLEAR: — 9]] — 20 | — 5 | — 25 1 41 | — 33 | 2 14 — 33 | — 33 | 1 6 4 26 | 1 15 | 5 41 1 21 | 1 15 | 2 36 1 42 | — 26 | 2 8

— 35 | — 26 | 1 [[UNCLEAR: 1]]

By means of the machine, the following is required

the current one | the improved one Min. Sec. | Min. — 18 | [[UNCLEAR: —]] — 38 | [[UNCLEAR: —]] 1 16 | [[UNCLEAR: —]]

[[UNCLEAR: —]] | [[UNCLEAR: —]] 44 | [[UNCLEAR: —]] 44 | [[UNCLEAR: —]] 42 | [[UNCLEAR: —]] 42 | [[UNCLEAR: —]]

16 named numbers with 1 to 5 digits and some small fractions, e.g.

8 rthl. 75 gfr. 2 28 — 40 — 276 — 26 — [[UNCLEAR: 565]] — 38 — 3 [[UNCLEAR: %]] 7 2 — 30 — Without [[UNCLEAR: N TE AU]] 7 — 45 — writing — 15 [[UNCLEAR: I]] — down, however 120 — — — [[UNCLEAR: y ad! 7 Visas!]] [[UNCLEAR: i — — 241i]] [[UNCLEAR: daa =]]

Subtraction.

2 common numbers, each with [[UNCLEAR: Z]] digits with 7 digits — with 14 digits each

2 named numbers with 4 to 6 digits, e.g.

705 rthl. 9 gfr. 326 — 56 —

Multiplication of common numbers, one [[UNCLEAR: z]] the other 2 digits

—

Advantages.

A practiced calculator brings to

— with writing and calculating | verification | total — 2 min. 10 sec. | 1 min. 34 sec. | 2 min. 44 sec. — 1 min. 53 sec. | 1 min. 34 sec. | 1 min. 27 sec. — [[UNCLEAR: 1 min. 13 sec.]] | — 3 sec. | — 16 sec. — 1 min. 30 sec. | — 6 sec. | — 36 sec. — 1 min. 48 sec. | — 9 sec. | — 57 sec. — 1 min. 27 sec. | — 8 sec. | — 35 sec. — 1 min. 13 sec. | — 4 sec. | — 17 sec.

By means of the machine are required

the improved | the current min. | sec. | min. | sec.

[[UNCLEAR: 14]] | 1 min. 57 sec. [[UNCLEAR: 17]] 1 min. 30 sec. | [[UNCLEAR: 1 min. 3 sec. 13]] [[UNCLEAR: 15]] |

[[UNCLEAR: toi]]

30

— /

35 / 1 min. 30 sec.

[[UNCLEAR: Eine]]

One 7-digit number, the other 1 digit

One 5-digit number, the other 2 digits

One 5-digit number, the other 4 digits

One [[UNCLEAR: 5]]-digit number, the other 4 digits

One [[UNCLEAR: 7]]-digit number, the other 5 digits

One 7-digit number, the other 6 digits

e.g. 2,288,515 multiplied by 635,382

One 8-digit number, the other 7 digits

Said numbers with up to 6 digits, the multiplier however 1 digit

Likewise with 4 to 5 digits, the multiplier 2 low digits, e.g. 128 Reichstaler 26 Kreuzer multiplied by 23 [[UNCLEAR: 4]]

Advantages.

A practiced calculator requires | By means of the machine, the following is required

in total | with writing and calculating | with verification | of the current [machine] | of the improved [machine]

M | S | M | S | M | S

[[UNCLEAR: 2]] | 29 | [[UNCLEAR: 1]] | [[UNCLEAR: 27]] | [[UNCLEAR: 1]] | [[UNCLEAR: —]]

[[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]]

45 | 58 | [[UNCLEAR: 41]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]]

20 | 51 | 29 | [[UNCLEAR: —]] | 24 | [[UNCLEAR: —]]

[[UNCLEAR: —]] | 46 | [[UNCLEAR: —]] | [[UNCLEAR: 4]] | [[UNCLEAR: 1]] | [[UNCLEAR: 51]]

[[UNCLEAR: 1/27]] | [[UNCLEAR: 1]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]]

[[UNCLEAR: 1/28]] | [[UNCLEAR: 1/17]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]]

[[UNCLEAR: 1/46]] | [[UNCLEAR: 1/32]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]]

multiplied

[[UNCLEAR: —]] | 40 | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]]

49 | [[UNCLEAR: —]] | 44 | [[UNCLEAR: —]] | [[UNCLEAR: —]] | [[UNCLEAR: —]]

Advantages, 41

A practiced calculator takes || By means of the machine are required

[[UNCLEAR: column headers for timing data appear to be: "with the division" | "sum and verification" || "with the division" | "counter-check" | "sum" | [[UNCLEAR: remaining column headers garbled]]]]

of common numbers.

Dividend 3, Divisor 2 digits — 4[[UNCLEAR: '—l34|—129]] Dividend 3, Divisor 1 digit — [[UNCLEAR: |—|16 —| 4|—|20||—|35|—|3x]] Dividend 5, Divisor 4 digits — 42 [[UNCLEAR: |—j18| 1|—||—l46|—{38]] Dividend 5, Divisor 2 digits — 44 [[UNCLEAR: |—|16| 1|—|| 1]] Dividend [[UNCLEAR: $→8]] Divisor 5 digits — 1/35 [[UNCLEAR: |— 54| 2|29|| 110] t|—]] Dividend 11, Divisor 6 digits — 2/10 [[UNCLEAR: 1/22| 3/32|| 1/36] 1|23]] Dividend 14, Divisor [[UNCLEAR: $→8]] digits — 7/9 [[UNCLEAR: 1—6/25|13/44|| 1/59] 1/46]] Dividend 14, Divisor 6 digits —

For example: 26933479833168 divided by 517245 — 4/40 [[UNCLEAR: 2/48 7/28|| 2/11] 1/53]]

Named numbers with common ones of 3 to 6 digits —

Named with named, each with 3 to 5 digits — 1/20 [[UNCLEAR: |—|40] 2|—||—|51|— 46]]

[[UNCLEAR: right-side column entirely garbled — contains fragments: VI, 158|— 5ST, and other unreadable symbols]]

[[UNCLEAR: partial text at bottom: Arith-]]

Arithmetic Progressions in common numbers. 20 increasing terms, the first with 6, the difference 4 digits. Likewise decreasing, 20 terms, the first with 2 and the difference with 1 digit, both with decimal fractions of 8 digits. Example: First term 26.83055121, Difference 3.24290973, of which, however, only one digit of the decimal fraction, namely the tenths, has been written down for use. (See p. 25, note.)

Increasing — Decreasing

In named numbers. 20 increasing terms, the 1st term and the difference.

Advantages.

A practiced calculator requires:

By means of the machine are required:

In total | With the verification | With writing and calculating | The present [[UNCLEAR: machine]] | The improved [[UNCLEAR: machine]]

3 | 3 4 | 5

5 hr. 38 min. | 36 min. 46 min.

10 hr. 16 min.

Each 2 Reichstaler 46 Kreuzer.

46 hr. 15 min.

[[UNCLEAR: Minutes]]

56 min. 5 hr. 35 min. | 8 min.

[[UNCLEAR: 1 hr.]]

58 min.

20 min.

48 min.

50 min. 12 min.

45 min. Likewise

Advantages. 43

A practiced calculator produces: | By means of the machine are required with writing & checking | Total || the current | the improved M. | S. | M. | S. || M. | S. | M. | S.

Just as many, each Calc. 108 582 kr. increas- [[UNCLEAR: 2|16|5]] — |1|18| 3|33|1| 1|53| 1|15|09 ing

20 numbers, the first term 632 Reichsthaler 84½ kr. the dif- ference 25 Reichsthaler 47½ kr. decreas- [[UNCLEAR: 16|5|15|2|18|3|42]] ing

[[UNCLEAR: 7|13|5]] — [[UNCLEAR: z|]] 6

Note. Based on this, anyone else can now test themselves and compare their speed with the machine. Only in multiplication and division must either the average from many examples be taken, or one must calculate with digits of medium size, so that each pair of digits of the smaller multiplicator or of the quotient taken together contain no more than 9 units. See p. 35.

From these experiments it now appears that, while with small examples the calculator finishes with the pen in somewhat shorter time than by means of the machine, with larger numbers the machine is far ahead. I also did not have the intention of inventing it for small calculations, which one can in any case perform with little effort, nearly in one's head, or without a pen.

When

44 Advantages.

When the time of all calculated examples (of which the previous table is only an excerpt), from the smallest to the largest, the number of which consisted of 103 examples, is added together, the time spent by the human calculator is:

4 hours 32 minutes 49 seconds; but by means of the machine,

2 hours 50 minutes 23 seconds.

This does not yet include the additional time that the former still needs in order to perform the second verification where the first does not match: for he always left it at the first attempt, even though it did not always agree.

Undoubtedly he would also have spent even longer on each example if he had been required to calculate them all without interruption, or without recovering during the intervening time that elapsed each time, among other things, in order to record the time found and to wait until the clock hand had returned to the first second for the following example. The speed by means of the machine, however, would not have diminished even without such interruptions.

Whoever occasionally has to perform large, continuous calculations requiring many days will know how much sustained calculating fatigues,

tires, and how dull one's thinking becomes after a few days, so that one not only commits more errors in the calculations themselves, but also sometimes loses all track of the context after completing an example, and does not know where one left off, and occasionally falls into unnecessary complications. None of this is to be feared when using the machine. And since by means of it one can persevere far longer without fatigue, the loss of time can be amply compensated even in those cases where the machine is somewhat slower than the pen.

One can stop in the middle of an example and resume at another time, provided that nothing is disturbed on the machine in the meantime.

I venture, on account of all these circumstances, to assert that someone who has many and extensive calculations to perform can accomplish more with the machine in two days than another person can in a week. Experience has already confirmed this for me.

In addition to the above trials, I also had some carried out by another person who was indeed skilled but not very practiced at calculating, and who formerly instructed young people in arithmetic, and found that he, while in the addition and subtraction of two ordinary numbers

and was somewhat faster at the multiplication and division of very small numbers; in all other cases, however, and even in the addition of multiple numbers, when they were already properly written one below the other before him, he was far slower than the machine.

With regard to larger numbers than the machine can deliver at once, I only made an attempt myself with a multiplication example whose product consisted of 50 digits, and produced it on the machine quite comfortably in 38 minutes. I had no desire to verify it by pen, but believe that at least 2 hours would be required for this.

Now it will become fully clear, if I even only consider the progressions, of which an example is given above on p. 24, what advantages the machine alone brings in the preparation of various useful tables for fiscal administrators, engineers, architects, accounting offices, auditors, treasury officials, merchants, tax assessors, surveyors, etc., for tables whose preparation one has hitherto shunned on account of the effort involved, and whose absence nevertheless takes up a great deal of time, which must gradually be spent on calculating individual cases.

Advantages. 47

Durability can be promised of this machine, even with the heaviest use, as reliably as of a good clock. Not only because everything is made partly of wrought brass and partly of steel, but also because I have had it given such a simple and reliable design that it came down solely to diligent workmanship.

It can therefore also be easily reproduced, and of course all the better if a craftsman already knows how to work with it. If it should find general approval, many would soon apply themselves to it, and although it would not be as inexpensive as, say, an ordinary repeating clock, it could nonetheless be made so affordable through advantages I have already devised, and even more so through factory-style production, that any man of moderate means who does much calculating would gladly acquire one.

But even apart from this, it is already worthwhile to acquire it for use in accounting offices, large commercial counting houses, at universities for the mathematics department, and by several persons jointly.

Newer

[[UNCLEAR: SIC]]

Newer Invention of Other, Even More Capable Calculating Machines, Also an Arithmetic Printing Machine.

Should some acceptable buyer and patron of this useful invention soon come forward, I shall not delay in making the inner construction of this machine known in the clearest manner, as well as having other calculating machines manufactured that achieve even more than the present one; and among other things also deliver entire series of numbers that progress in compound arithmetic proportion, each number by merely 2 to 3 turns of the crank (thus far faster than the present machine).

But because copying many numbers that grow into large tables not only takes up much time, but can itself become prone to errors, I have devised that the machine, when one desires it, prints the resulting numbers together with the necessary natural sequential numbers and intermediate lines onto paper placed beneath, without one needing to set type or to ink it with printer's balls, since all of this must be accomplished by the machine. If therefore only once

[[UNCLEAR: Dere]]

Newer Invention, 49

once the first number along with the corresponding difference numbers (whether common or named) have been set on the number wheels and the necessary printer's ink has been placed into a certain vessel in the machine, and the printing paper has been laid in the appropriate frame: the worker has nothing further to do than to continuously turn the crank, and to turn the paper over once a page or the entire sheet has been fully printed, or in the latter case to replace it with a new one, for which the crank, which then locks in place, gives him a signal.

The advantage here is particularly this: that one receives the numbers calculated by the machine and coming out one after another, printed entirely correctly, in incomparably shorter time than copying by hand would require.

Thus, according to a preliminary estimate, an arithmetic series of 60 numbers, common or named (such as, for example, some appear on p. 25), each number having many or few digits, can be calculated and put to paper by a mere common day-laborer in one minute—that is, in approximately one-twentieth of the time otherwise required for this, and at one-sixtieth of the cost.

Thus, for example, entirely correct cube tables from the roots 1 to 100,000 could be delivered in approximately 10 days, even if only 8 hours were worked per day.

D [[UNCLEAR: tet]]

would be. One would admittedly receive only a single copy in that time, but in those cases where only a few copies are needed, the work could still be repeated with advantage; for at least 10 copies could be delivered correctly printed *) in the same time as is required for a single and perhaps erroneous handwritten copy.

This much I dare to bindingly promise upon request; but I hope perhaps to bring it to the point that, by means of the machine, with not much more effort, any desired number of copies can be delivered just as correctly.

After the completion of the above-described and constructed machine, I intended to also have one or several smaller ones made solely for addition and subtraction; but since with these, according to the very simple design I intended to give them, one could conveniently add, but no progressions could be produced with advantage, I have thus far refrained from doing so.

*) Which no printer is capable of: for at most he can only vouch for one correct copy.

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