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von S. Weiss, Sep. 2009

ART. XXIV.—*A New Calculating Machine;* by GEORGE B. GRANT.

"SINCE the dawn of mathematical science in Europe, the attempt to construct a machine, capable of satisfactorily performing arithmetical operations, has occupied the attention of a great number of ingenious men, several of whom have been among the most celebrated of their time for originality of genius and for the large contribution which they have made to the progress of science."*

Leaving out of mention the Greek abacus and the Chinese schwan-pan of ancient times, the first recorded attack on this difficult problem was made in the tenth century by Gerbert, Chancellor of France and afterward Pope under the title of Sylvester II. He is credited with the introduction into Europe of the arabic numerals, and endeavored to construct a mechanism to facilitate their use. But of his results we have no published account.

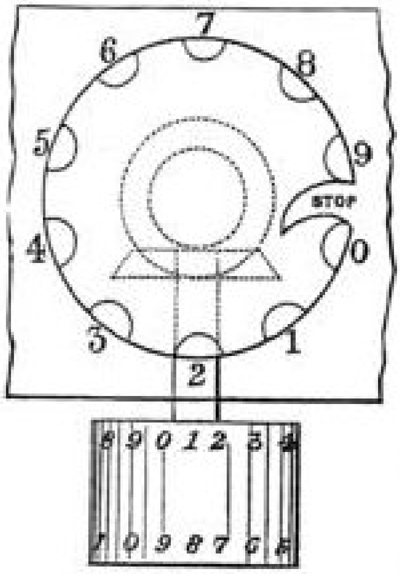
The first successful device was the invention of John Napier, celebrated for his invention of logarithms. His "rhabdology," or as they are better known, "Napier's bones," can hardly be classed as mechanism, and they are too well known to need description here.

The first actual machine of which we have detailed information was the invention of no less a man than Blaise Pascal, the distinguished philosopher of France, who in 1645 published an account of his "arithmetical machine," on the invention of which he had spent several years.

* President Barnard of Columbia College, in the U. S. Reports of the Exposition of 1867. "The Industrial Arts and Exact Sciences." Harper & Brothers. New York. 1867.

The diagram, fig. 1, will illustrate Pascal's design sufficiently for the purposes of this article. A horizontal wheel having ten teeth turns in an opening in the fixed upper plate of the machine, and about the opening are the ten numerals. A pencil placed between the teeth at any number and brought round to the stop will turn the wheel through that number of teeth and record it on the large figured cylinder. The cylinder is provided with two rows of figures complementary to each other, so that the result is addition or subtraction, according as we read by one row or the other. Carriage was accomplished by mechanism on the shaft of the cylinder, which forced the next cylinder forward one figure whenever its own passed from 9 to 0.

1.



PASCAL'S MACHINE.

Pascal's machine was not a success, for though correct in theory it was so complicated, delicate, uncertain, and limited in its operations, that it was practically useless. But the principles of its action, particularly the toothed wheel, fixed figured arc and stop, and the complementary rows of figures, have appeared in most subsequent machines, and have been patented many times as new both in this country and in Europe.

Without giving a complete history of the subject, I can mention the names of Roger Bacon, Leibnitz—the inventor of the Infinitesimal Calculus, Diderot, Gersten, and Sir Samuel Morland, as among those who have paid particular attention to this subject.

The next attempt resulted in a substantial success, and by a man otherwise entirely unknown. Charles Xavier Thomas de Colmar patented in 1822 his "arithmometer," a machine that not only solved the long tried problem, but solved it practically, and which is now in use in large numbers for actual work. The able description, in the United States Reports above referred to, of this machine and of the subject in general, is so accessible to the public, that a detailed account is unnecessary here

Colmar's invention has been directly or indirectly adopted by every inventor who has successfully appeared in public since his time. The principle of his invention is shown by the diagram fig. 2, in which a recording wheel is in gear with a driving wheel having a variable number of teeth, and the number added to the recording wheel at each turn of the driver will depend on the number of teeth exposed. Colmar varied his number by placing nine rows of teeth side by side,

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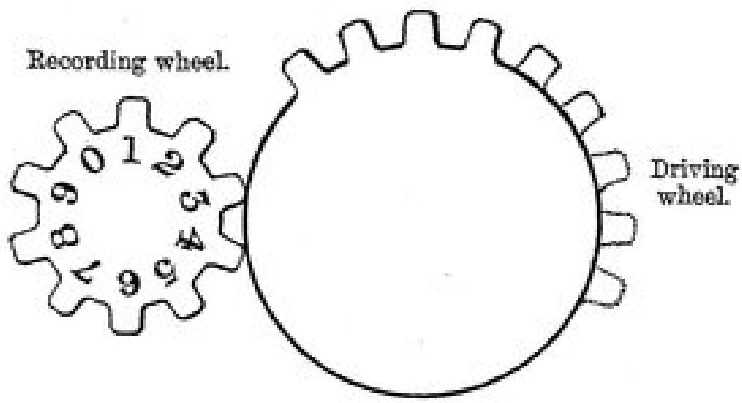


COLMAR'S PRINCIPLE.

having from one to nine teeth each, and made the recording wheel movable, to be placed to gear with either row at pleasure. Other inventors, as Staffel of Russia, have made the teeth separately removable, so that those not wanted could be put out of gear. Another has hung the driver on a movable axis and provided means for meshing the two wheels at the proper place for the desired number of teeth to act. Still another spreads Colmar's nine rows of teeth out on a plane, and moves the recording wheel over them.

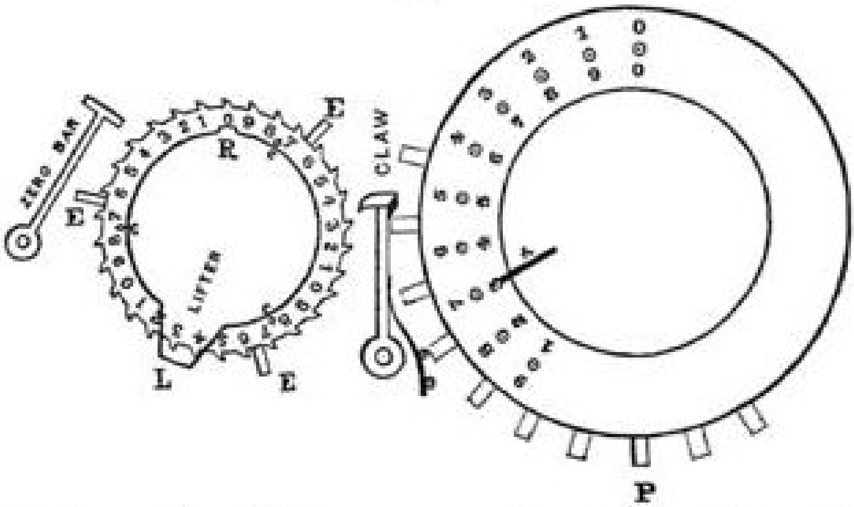
Calculating machines by the score may be found in the patent records of the United States, England and France. Colmar's idea has been twisted into every conceivable position, but no improvement has been made on the disposition originally adopted by him. And his machine is the only one now in use, to any mentionable extent.

Colmar's machine, as the first solution of an old and well studied problem, and as a specimen of the mechanism of his day, certainly deserves the highest praise. But it is undenied that it is in a high degree complicated, a mass of small cog wheels and delicate mechanism, which require close adjustments, and which easily get out of order, requiring the greatest care in handling and the best skill in repairing. The needs of the present time require, and the state of the art at this day admits of, a better design, one that is simpler and of more substantial construction, easier to put in order and easier to keep in order, and better suited for the use of those but little accustomed to machinery. And as such we will introduce the subject of this paper.

The New Machine.—In the diagram fig. 3 all framing and unessential parts are omitted, and the positions so arranged as to show the principle of action most clearly.

Two parallel cylinders are geared to turn together. One cylinder is larger than the other, but the gears are equal, so that one turn of the handle on the larger revolves both once. The larger cylinder slides laterally on its arbor, and can be placed opposite any part of the smaller at pleasure.

3.



On the small cylinder are a number of recording wheels, more or less according to the capacity desired. Each is provided with thirty teeth, and a numeral is stamped at each tooth. A fixed point, R, is chosen as the reading point, and the number shown at any time at that point is the reading of the wheel.

On the large cylinder are a number of driving wheels, each having an adding pin, P, which can be fixed in ten different positions by the pin at *r*.

On a bar between the cylinders is a row of fixed spring claws, one for each recording wheel. If the claw be pushed slightly to one side, it will drop off its catching pin on to the wheel and hold it.

As the handle is turned, the recording wheel revolves with its cylinder, but when the adding pin strikes and lets down the claw, it will be held still till the lifter L is reached, by which the claw is returned to its pin and the wheel allowed to pass on. It has, by being held, been carried over a number of teeth from its original reading, more or less according to the position of the adding pin on its cylinder. If the adding pin is placed at its zero position, it will come to the claw simultaneously with the lifter, and the wheel will not be affected. But if it be placed at 7 for example, it will reach the claw seven teeth in advance of the lifter, and the number seven will be added to the wheel.

The action between each wheel claw and adding pin is the same, and it is plain that the number represented by the setting of the adding pins will be transferred to the recording wheels at each turn of the handle. If now the larger cylinder be set up one space, each pin will act on the next wheel above and ten times the number set up will be added.

The carriers for effecting the carriage of the tens are placed, one for each wheel, between it and the next one higher, each one being a tooth in advance of the preceding one. It is a simple lever fixed on the cylinder behind the lifter, L. As the wheel passes from 9 to 0, a stud *c* upon it will strike the carrier and throw it over slightly. When over, it is in the path of the next claw above, and will throw it off so as to add one to its wheel before reaching a second lifter.

The machine as above described is complete and ready for work, all that is essential being the recording wheels, adding pins, claws, lifters, and carriers. But for the sake of convenience and efficiency, various attachments might be added. As for instance, a ratchet and click to prevent backward motion of the handle, a counter to register the turns of the handle, and for some purposes a printing apparatus, to record the results of the work.

Eraser.—A valuable attachment always found on an efficient calculating machine is an apparatus by which a result may be erased and all the wheels brought to zero at once. This erasure is required before each operation, and to do it by hand, one wheel at a time would be tedious and inaccurate.

Projecting from the wheel is the erasing pin, E, and fixed on the side of the frame is the zero bar. This bar is common to all the wheels, and is ordinarily up out of the way of the pins, but when pressed down will be in their path. If then the cylinder be turned backward, each pin will stop when it reaches the bar, and all the wheels will be brought to zero simultaneously.

The process by this machine is always an addition, never a subtraction. But subtraction of any number is accomplished by setting it up by the inner row of figures on the adding wheel, they being so arranged that the complement of the number set up will be used.

The size of the machine varies with its capacity. The recording wheels are $1\frac{1}{4}$ inches and the adding wheels $2\frac{1}{2}$ inches in diameter, and the distance from wheel to wheel is three-eighths of an inch. A ten-wheel machine would occupy a box $6\times6\times4$ inches in dimensions.

The compound action of the claw being thrown from its pin, catching on the wheel, carrying it along a definite distance, rising and catching again, may be considered complicated and delicate. But the fact is it is very reliable: a poorly made apparatus has been worked at the rate of 10,000 operations per minute with perfect accuracy. The object of having one cylinder nearly three times the size of the other is to secure this accuracy. The angular motions are equal, but the actual speed of the pin is nearly twice that of the wheel, ensuring that the claw shall strike the right tooth every time, even if the parts are not precisely in their proper places.

Operation.—Multiplication is accomplished by the principle of successive addition of the multiplicand to itself, first used mechanically by Colmar, and in fact the only practical and reliable principle yet proposed. Since the invention of Napier's bones, many have tried to give them a more mechanical shape, and to use them in automatic machinery. But though it has been done in several ways, the result has always been too complicated, clumsy and costly, to compete with the theoretically more roundabout, but practically simpler and shorter method borrowed by Colmar from the mental process.

For an example let us multiply 657 by 325. The adding pins are first set to the number 657 and the recording wheels brought to zero by the bar, after which five turns of the handle will transfer it five times on to the wheels and 5×657, or 3,285, will appear. Then set the cylinder up one space, and two turns will multiply 657 by 2 and add ten times the product, or 13,140, to the 3,285 previously shown. Another shift of the pins and three turns will complete the operation and show the final product 213,525 in plain figures. This result can be obtained in ten seconds, allowing one-half a second for each turn and each figure set up, and one second for erasing and for each shift of the cylinder.

The larger the numbers used the greater the proportional gain over mental labor; for the machine will add ten figures to ten as quick as one to one, while mentally it would take ten times as long. But the greatest advantage of the mechanical method is not in the time saved, but in the superior ease and accuracy with which the work is done.

Reduction of Star Places.—If the result ab of any multiplication is not erased, the result of the next cd will be $ab+cd$, and if either c or d are set up negatively the result is $ab-cd$. By an attachment, this machine is peculiarly adapted to work the quantity $Aa+Bb+Cc+Dd+$ &c. for star reductions, where the same values of ABCD or of $abcd$ are used for a large number of operations. Four or more fixed quantities, ABCD, etc., can be set up once for all, and either one be quickly brought to act at pleasure to the exclusion of the others, it not being necessary to set it up figure by figure. With this attachment, reductions to apparent place may be made at the rate of two per minute, whereas it usually takes from three to five minutes for each operation.

Addition and subtraction are of course worked directly, but in common with all machines yet contrived, it offers small advantages over the common method, except in regard to ease of execution. For large work of four or more places it would be found useful, but to ordinary accounts no machine has yet been profitably or extensively applied.

For division two different processes may be employed. One, the old tentative process used by Colmar, is nothing but the usual mental method put into mechanical shape. The other is an improvement on the first, by which it is rendered automatic and entirely independent of mental labor. It is peculiar to this machine, and presents the first solution of the problem of mechanical division.

By the tentative method we first set up our dividend 213525 on the wheels by hand, or better, by transferring it from the pins. We then set the pins to our divisor 0657, by means of the inner or negative rows of figures, taking care to leave one zero in advance of it. Then place it up opposite the 135 of the dividend, and turn the handle, stopping at every turn to observe the dividend. It will continually decrease, and when you perceive that it is less than the divisor, you must stop and set the pins down one place before proceeding to the next figure. In the above case, the dividend after three turns will read 16425, and that being less than 65700 the first quotient figure is 3. The wheels will then read 00003016425, the quotient figure being recorded automatically by the machine on the upper wheels left vacant by the retreating dividend.

To explain the automatic method we need to follow the process of continual subtraction a little more closely.

213525	
9999343	−1
147825	
9999343	−2
82125	
9999343	−3
16425	
9999343	−4
999950725	
657	+1
16425	

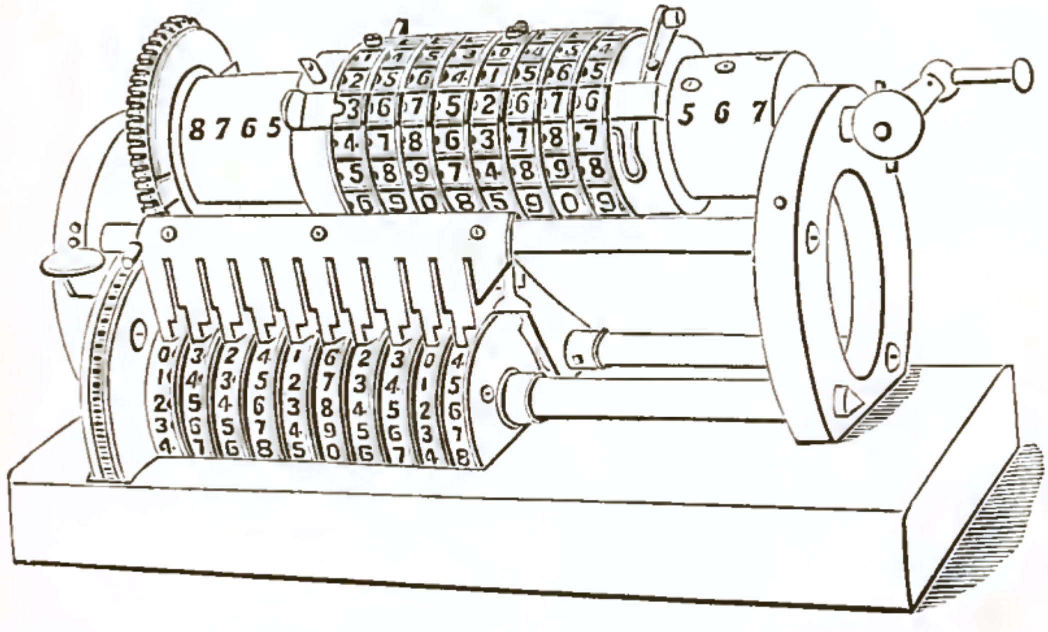
As 9999343, the complement of our divisor 657, is added, the divisor decreases, and after three divisions is reduced to 16425, a number less than 65700, requiring us by the old method to stop and set down for the next figure. And it is necessary to watch for this point, for mechanism to determine that 16425 is less than 65700 has never yet been contrived, and it is doubtful if a simple apparatus could be devised for that purpose.

But it may be observed that if 65700 is subtracted from 16425 once more, that a negative number would result. And where, as on this machine, a negative number is expressed by its complement, its mechanical perception is an easy matter, since for such a case the upper wheels all read nine. A snap, which will indicate when the last wheel stops on nine, will answer our purpose, and warn us that a mistake of one turn has been made. Having made a mistake, we must correct it by adding our divisor once, and bring the dividend back to a positive number, ready to set down for the remaining figures.

The problem of the calculating machine is an exceedingly difficult one, as anyone acquainted with the immense labors of Pascal, Leibnitz, Babbage and Scheutz will acknowledge. Pascal speaks of his invention as "a work of some years." Leibnitz, at the height of his fame, devoted four years to this object, and failed; Babbage worked from 1822 to 1842 on his Difference Engine to no purpose; and Scheutz was from 1834 to 1854 bringing his machine to the partially successful condition it is now in. The machine described above for the first time is the result of nearly four years of study and labor.

Cambridge, Mass., July 15, 1874.

600.



Das Bild ist entnommen aus: Appletons' cyclopaedia of applied mechanics: a dictionary of mechanical engineering and the mechanical arts. Vol. 1, 1880, S. 287