THE HISTORY OF MODERN CALCULATING MACHINES, AN AMERICAN CONTRIBUTION.

By L. LELAND LOCKE.

During the past two decades the calculating machine has been developed and commercialized to such an extent that it may be said to rival logarithms in importance as a labor-saving device. Coming as the climax of three centuries of somewhat unproductive experimentation, its perfecting lacks the picturesqueness which belongs to the invention of logarithms. Just how soon the latter device will be remembered only as a curiosity in the development of mathematics it is difficult to predict. Certain it is that the calculating machine has not attracted the attention of the mathematician to the extent it deserves, witness the complete absence of literature on the subject in American technical journals and an almost equal void in foreign publications.

The available information concerning such machines is chiefly to be found in patents, descriptive articles on the mechanical features of particular machines, catalogs of collections and exhibitions, advertising material (sometimes with historical notes of more or less value), and a few general treatises. Moreover, these various elements, with diverse and often competing aims, have produced an ambiguous terminology which is a source of dissatisfaction to the careful reader. Inaccuracies in statement, once made, have been repeated, and incorrect dating, particularly where priority is involved, has become a serious fault. The first of the following notes is merely suggestive in the matter of nomenclature in laying a foundation for the second note, which is a compilation of facts bearing on one of the more important questions of priority.

1. **Terminology.** Mathematics is a science which has slowly evolved with the culture of the race and from the needs of everyday life, the concepts and terms being the result of a long-continued process of refinement. The designing of calculating machines is an art which has been derived from the science itself and it has the disadvantage of possessing a terminology appropriated from and based on that of mathematics, this terminology occasionally being none too well defined. It is but natural that the inventor should choose the most high-sounding phrases to describe his work, a practice scarcely so serious in its effects as the very prevalent tendency of some manufacturers to endeavor to make a machine which is designed for a particular purpose function in every conceivable situation. The term "calculating machine" is often applied to a mechanism which has no mechanical capacity for carrying out the four processes of addition, subtraction, multiplication, and division. Such machines were primarily designed for one or more of these four fundamental operations, the remaining processes being worked out by means of applied formulas. For example, any adding machine may be used for calculations involving subtraction, multiplication, and division, as it is possible to work out all of these through the medium

of addition, with pencil and paper as well as with a machine. In order to be mathematically correct, however, the name *Calculating Machine* should be reserved for such machines as have the mechanical capacity for working out each of the four operations by a direct mathematical method.

No serious attempt has yet been made to standardize this terminology although Lenz [1] has given a brief statement of the practice used in the German Patent Office. For the purpose of the next note the following convenient terminology is suggested.

Machine. Consider a decimal scale, where nine units have been registered in any order. If, when the tenth unit is registered in this order, provision is made automatically to carry one to the next higher order, this mechanical feature may be said to transform the device into a *machine.* The Japanese soroban is probably the most versatile calculating device ever created but lacks the one feature essential to classify it as a machine.

Counting Machine. A machine designed to receive entries in the units' or ones' order only, the register in the higher orders being the accumulations from the carry, may be called a *counting machine.* Such a machine is exemplified in any one of the various types of meters.

Adding Machine. A machine designed to receive entries in all orders, successively or simultaneously, may be called an *adding machine.*

Calculating Machine. Two additional features will be deemed necessary to produce a calculating machine: (1) a carriage by which the numeral wheels or registering dials and the selector mechanism may have their relative positions shifted; (2) provision for the performance of subtraction directly. By "directly" is meant that the number to be subtracted is entered on the set-up and combined with the number recorded in the machine, either by a reversal of the numeral wheels or by mechanically produced over-addition. In subtraction by over-addition the difference between the subtrahend and the next higher power of ten is added to the minuend. The 1 from the carry is taken care of by inserting a succession of 9's or by providing a cut-off for the carry at the proper point. In an article on "Calculating Machine Mathematics" in *The Mathematics Teacher,* XV, 7, the use of the word *supplement* was suggested for the difference between a number and infinity, infinity being here defined as a power of ten which will carry the 1 off the machine. An earlier use of the word in a similar sense by Barr in certain British patents has since been noted.

For descriptive purposes the parts of the common calculating machine, with their functions, may be named as follows:

Set-up Mechanism. The device by which a given number is entered on the machine will be designated the *set-up mechanism.* The older form of set-up was usually a slide, either a straight line or an arc of a circle. This form is now being rapidly replaced by the keyboard. The set-up mechanism is sometimes called the *installing mechanism,* a somewhat more desirable term.

Selector Mechanism. The mechanism which selects the proper mechanical

[1] K. Lenz: *Die Rechenmaschinen und das Maschinenrechnen,* Leipzig, 1915, p. 22.

movements to correspond to the number set up is designated as the *selector* or *differential mechanism.* It may well be called the brains of the machine, the design of which determines one of the commoner classifications of machines. The Leibniz-Thomas stepped cylinder is shown in fig. 2 and the Baldwin cam-operated radial pins in fig. 3. Among other types may be mentioned the rack-and-pinion of the Millionaire and Mercedes machines, the mechanical Pythagorean table of the Bollée and the Millionaire, and the squirrel cage or lantern wheel of the Monroe.

Registering Mechanism. The set of circular or cylindrical dials or numeral wheels upon which results are usually recorded is called the *registering mechanism.*

Carry Mechanism. The function of the carry mechanism is fully implied in the term.

Control Mechanism. All devices for the prevention of inaccurate operation, mechanical or human, such as checks for overrotation, locking devices and stops, will be included under the term *control mechanism.*

Erasing Mechanism. The various types of devices used to return the numeral dials to the zero position are known as *erasing* or *zero-setting mechanisms.*

2. A new classification of calculating machines. The classifications heretofore used have been either on a basis of function, as adding, listing, multiplying, dividing, etc., or of the employment of essential mechanical elements, as the stepped cylinder, cam-operated radial pins, mechanical Pythagorean table, etc. The new classification is based on the sequence of operations as follows:

Type I. Monophase machines,
Type II. Non-reversible cycle machines,
Type III. Reversible cycle machines.

In type I the carry action occurs simultaneously with the digital selection or registration. Such machines may be unidirectional or reversible, the latter type not having been developed commercially. In type II the digital registration and the carrying of tens occur in cyclic order. The cycle is divided into two parts, the first part serving for digital registration, and the second part for the carrying of the tens from the lower to the higher numeral wheels. Obviously this cyclic action is not reversible and in order to reverse from positive to negative numeral

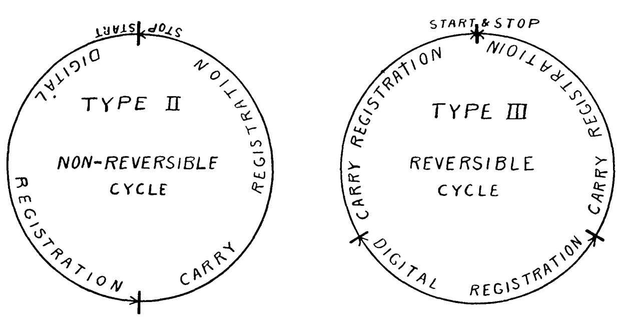

FIG. 1.

wheel registrations, special reversing mechanism must be installed which will not reverse the cycle. Such mechanism may be manually or automatically controlled. In type III the digital registration and the carrying of the tens occur in reversible cyclic order. The zone of digital registration is located midway in the cycle, with a carrying zone provided on each side. The carry action will therefore function after the digital registration in either direction of operation. In this type no special reversing mechanism is required, merely a reversal of direction of the driving shaft which operates the machine. Figure 1 shows the two latter types in diagrammatic form.

3. The Baldwin-Odhner priority claims. To Pascal belongs the honor of having conceived and constructed the first calculating machine of which certain models and a description have been preserved. Of more than fifty models constructed by Pascal, several are extant, the oldest of date 1642. Following the classification above, this would be called an adding machine. However it is interesting to note Pascal's genius in discovering the process of subtraction by overaddition, very similar to the method commonly employed with keydrive machines. Of the many attempts following the work of Pascal, only those in direct sequence in the development of the commercial calculating machine of today will be mentioned. The first of these was the multiplying machine of Leibniz, who designed the stepped cylinder as a selector mechanism, which became the distinctive feature of one of the two great classes of commercial calculating machines.

The next real advance was due to Thomas de Colmar, who utilized the stepped cylinder of Leibniz in a machine built in 1820, although it is said that he was not familiar with the work of the latter. The Thomas invention is the prototype of practically all commercial machines built before 1875, and of a goodly share of those developed since that time. In fig. 2, A is the stepped cylinder, on the

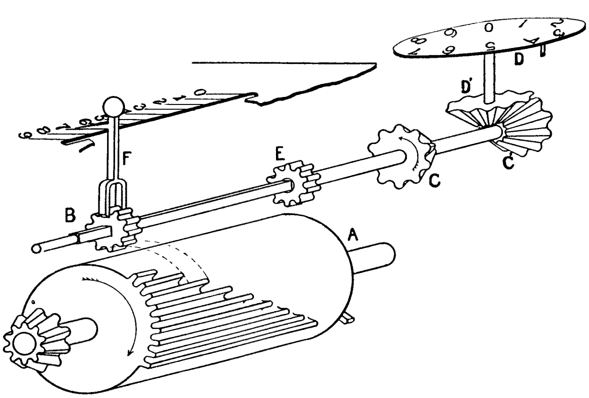

FIG. 2.

surface of which are nine cogs of length varying from one to nine units. This cylinder always rotates in one direction as indicated by the arrow. On the shaft above and parallel to the cylinder a pinion B slides to a position indicated by a scale on the edge of the groove in the upper plate. When the pointer on handle F indicates 7, the pinion will engage with the seven longest cogs on the cylinder and miss the eighth.

The motion is transmitted by the shaft to the pair of bevel gears C and C'. The dial D with a bevel gear D' on the lower end of its shaft is mounted on a carriage. By means of a slide lever this bevel gear may be placed in mesh with either C or C' at will, one of which rotates it forwardly for addition, the other rotating it reversely for subtraction. Thus the Thomas machine is transformed by a lever shift from an adding and multiplying machine into one adapted to subtraction and division.

Frank Stephen Baldwin, on September 8, 1873, applied for and on February 2, 1875, was granted a patent on the first[1] practical calculating machine which at all times had the capacity to add, subtract, multiply, and divide with no resetting of the mechanism and with no form of conversion for any of the processes. It is the purpose of this note to describe the machine briefly and to submit evidence as to the validity of the two qualifying adjectives, *first* and *practical*, the former of which has frequently by implication been denied.

Description. In the Baldwin machine the stepped cylinders of Leibniz and Thomas are replaced by a single cylinder. The selector mechanism is a series of sets of nine radially placed pins, one set for each decimal order and located in planes at right angles to the axis of the cylinder. By means of a rotatable cam these pins may be made at will to project beyond the surface of the cylinder as shown in fig. 3. In this figure the handle which operates the cam is located

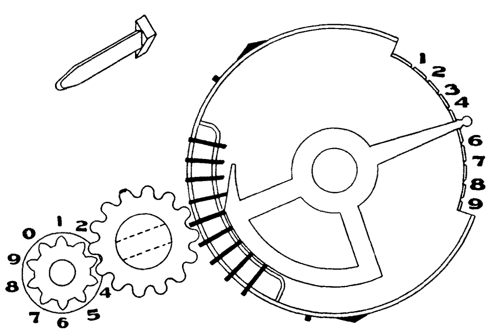

FIG. 3.

at 5, corresponding to which five of the pins project beyond the surface and thus engage cogs of the intermediate pinion, which in turn is in mesh with the recording or numeral dials. The five pins are said to be active and the four which do not

[1] Possibly the nearest approach to such a machine was that of Stanhope (1777), which did not pass the experimental stage. This invention was based on certain mechanical principles inherently weak which would seem to preclude its development into a practical machine without radical changes in design.

project are inactive. This set of active and inactive pins[1] controlled by a rotatable cam in the plane of the pins is the "active and inactive pin principle," which is the distinctive feature of the second great type of calculating machine.

A second feature of the Baldwin machine is the "wedge" shown in figure 3, which passes through a slot (indicated by dotted lines) in the shaft of the intermediate gear. When the numeral wheel passes from 9 to 0 or from 0 to 9 a stud or post on the dial pushes the slide through the shaft toward the large cylinder as shown in figure 4. The bevel edge on the larger end of the wedge throws a

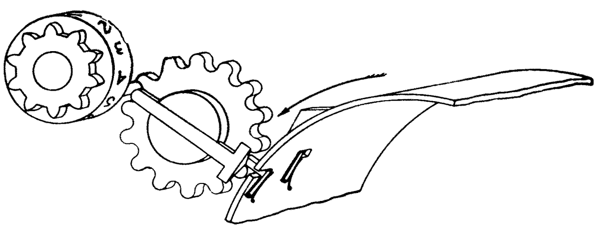

FIG. 4.

finger on the surface of the cylinder into the path of the pinion which operates the next numeral wheel and 1 is carried to that wheel. The large cylinder or set-up barrel may be moved to the right or left to bring the pins opposite any order of the dials or numeral wheels, which are mounted in the frame of the machine.

Chronology. On October 5, 1872, Mr. Baldwin filed with the United States Patent Office a caveat, attested on September 28, 1872, containing complete drawings and description of this machine. On September 8, 1873, application was filed for a patent which was granted on February 2, 1875, as U. S. No. 159244. A complete model of the machine was submitted with the application, and is now in the possession of the Smithsonian Institution. The design of this machine was therefore, by documentary evidence, completed before September 28, 1872.

Practicability. Of the first ten machines built, eight were sold as follows: Pennsylvania R.R., Philadelphia, (1); Fairman Rogers, Philadelphia, (1); State Insurance Department, Albany, (1); Insurance Companies, New York, (3); War Department, Washington, (1); Interior Department, Washington, (1).

All of the above were sold before 1876. The pertinent question here is, were these machines in the experimental stage, or were they calculating machines. This question is fully answered in the one letter which space allows.

[1] The cam operated radial pin was utilized in a machine designed by Roth in 1841. The disposition of the parts and general design in no way resemble the work of Baldwin. This machine was never developed commercially and was unknown to Baldwin and probably to Odhner, so that it may safely be said to have had no influence in the development of this type of machine.

The works of inventors whose machines were not developed to a commercial stage are milestones in the pathway of progress and should not be subject to disparagement. However a distinction must be made between those inventions which terminated in a blind alley and those which led to the development of commercial machines.

Philadelphia, August 8, 1874.

F. S. Baldwin, Esq.
Dear Sir:

I have used for the last four months one of your large machines daily in this department and have no hesitation in saying it performs its work rapidly and reliably, and for the purpose used does the work of at least three men, with a certainty of correctness, and greater rapidity. For Railroad Companies, calculating mileages and tonnages, it is, I consider, invaluable.

Yours respectfully,
G. M. Taylor,
P.R.R. Co.

The writer has recently dismantled and reassembled one of these machines built fifty years ago and found with some slight adjustment necessary from wear that the machine functioned perfectly.

The Odhner Machine. Willgodt Theophile Odhner, a Swede, filed application on July 13, 1878, and was granted U. S. Patent No. 209416 on October 29, 1878, on a machine very similar in design to the Baldwin machine and embodying the two distinctive features of Mr. Baldwin's invention, the cam operated radial pins and the sliding wedge carrying mechanism. Odhner interchanged the Baldwin static and moving parts, placing the numeral wheels in the carriage and the selector mechanism in the frame as in the Thomas machine. Otherwise the disposition of parts and operation are very similar to those of the Baldwin machine. Odhner's other patents were dated as follows: Germany, November 19, 1878, No. 7393; Russia, applied for February 14, 1879, granted December 31, 1879 (O.S.). No. 2329 (No. 148 of 1879).

Priority. The earliest documentary [1] evidence for the Odhner machine available to the writer is the date of the application for the U. S. Patent, July 13, 1878. Baldwin's caveat shows a completed design on September 28, 1872.

Independence. External evidence. Is it possible that these two machines, externally similar in construction and operation and based on a combination of the same two essential mechanisms, should be invented independently? Consider the internal evidence. Preceding Odhner's claims in U. S. Patent 209416, occurs the following statement: "I do not claim, broadly, setting the teeth of the counting-wheels by means of an adjustable cam or cam-wheel, nor the use of a slide for causing the lateral movement of tenth-carrying teeth, nor the combination of a toothed counting and recording wheel." No other machine than Baldwin's had these essential features. It is of more than passing interest to note that this allowance of credit does not appear in foreign patents granted to Odhner.

It is not the purpose of this note to attempt an evaluation of Mr. Baldwin's first calculating machine, nor of his subsequent work, but rather to establish the validity of the statement that this machine is the direct and lineal prototype of all machines of that class which have erroneously been attributed to Odhner,

[1] Johannes Meyer, Pappenheim, Bavaria, has an Odhner illustration which has been in his possession since about 1904, and which bears the inscription, "Hand made model of the inventor in 1874." If this date be accepted at its face value, it definitely places the early Odhner model, leaving Mr. Baldwin with a margin of two years.

that Mr. Baldwin shall receive the credit which has been so long and so persistently withheld and which is his just due.

Thomas de Colmar was the inventor of the first practical non-reversible cycle calculator. Frank Stephen Baldwin was the inventor of the first practical reversible cycle calculator. Probably 90 per cent. of all calculators which have achieved commercial success since 1875 must be classed as direct successors of the Baldwin patent.

THE THEOREM ON THE MOMENT OF MOMENTUM.

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1. Introduction. In volume XXI of the MONTHLY, Professor Huntington [1] pointed out the inadequacy, and in some cases also the erroneousness, of the treatments of the theorem on the moment of momentum in the current elementary texts in mechanics. He then gave a correct and admirably simple treatment of the theorem in the case of uniplanar motion of a rigid body, on the assumption that a rigid body may be regarded as a system of a finite number of particles rigidly connected.

In conducting courses during the last four years, I found that not only were the elementary texts unsatisfactory with regard to this theorem, but that many of the classical books on mechanics were also. For this reason, and also because, in the interests of simplicity, Professor Huntington restricted himself in point of generality, I venture to offer the presentation which I have developed in my lectures. I do this under no misapprehensions as to the likelihood of novelty in method or results, but because the theorem is so important that it is high time that correct presentations of it became current.

2. Statement of the Theorem. We shall first consider a system of n particles, which may be free, or subject to constraints. The hypotheses of the theorem are Newton's second law, and his third law extended as indicated below. These laws, of course, postulate the existence of absolute motion. They may be stated as follows:

II. *The product of the vector acceleration of a particle by its mass is proportional to the resultant of the forces acting on the particle.*

III. *The forces exerted by two particles on each other are equal in magnitude, and opposite in sense.* We assume further that they are *directed along the line joining the particles.*

Forces satisfying this extended third law we call *internal forces.* All others we call *external.*

By the *momentum* of a particle, we mean the product of its vector velocity by its mass. The velocity may be either the absolute velocity, or the velocity relative to some specified moving point. By the *moment* of a vector $\boldsymbol{v}$, passing

[1] E. V. Huntington, "The Theorem of Rotation in Elementary Mechanics," this MONTHLY (*1914*, 315–320).