Frank Stephen Baldwin, Founder of Mechanical Arithmetic

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THE science of mathematics is based fundamentally upon arithmetic. Arithmetic is built upon the basis of the "four rules," addition, subtraction, multiplication and division. By applying these four rules, all of the most advanced scientific and commercial calculations may be worked out.

To our grandfathers, machine calculations were practically unknown. Tedious hours of brain-fagging toil was the price they paid to carry on their barter and trade, and to develop our modern mathematical science. Today tireless machines have greatly increased the individual's capacity for such work, and contributed to make life easier and pleasanter for all of us. What can be said of the future? Will our grandchildren be virtually free from mental effort in solving the great bulk of the world's calculations? Will their machines have far greater speed and be broader in scope than the machines of today? Will they be more automatic in their action? The inevitable answer is "Yes."

The present achievements are one of the world's greatest marks of progress, to be compared with the locomotive, the telephone, the wireless, and numerous others. The history of this achievement provides most interesting reading. In the last November issue of "Topics" one of the most complete and most readable of short articles written on the subject was contributed by Mr. J. D. Clark. The title of his article was "The Evolution of the Calculating Machine." There are some points which were referred to in Mr. Clark's article upon which more may advantageously be offered, in particular the great contribution of Mr. Frank Stephen Baldwin to the development of modern calculating machine art.

The development of the processes of calculation may be divided into three distinct periods, the first of which is the objective period, in which all of the operations were performed by a direct manipulation of objects, such as pebbles, beads and jetons. The second stage begins with the introduction into Europe of our present numeral system, the Hindu-Arabic, which occurred in the two centuries following 1000 A. D. The advantages of this system as a means for calculating easily place it in the front rank of the great factors which have made for the development of commerce and science. The third phase is that of machine reckoning, which in turn may be divided into three periods, the vision, realization and commercialization. To Pascal, the illustrious French physicist and mathematician, belongs the honor of having conceived and constructed the first calculating machine of which the description and models have been preserved. The stepped reckoner of Leibnitz was destined to become the mechanical device upon which the first practical machine, that of Thomas de Colmar, was to be built, and which determined the form of all machines which were developed to the practical stage until the 1875 Baldwin was constructed. With Thomas began the period of realization. He devised a practical machine which would perform the four fundamental processes of arithmetic without error, fulfilling the dream of Pascal, Leibnitz and a host of others.

The inventive genius of Frank Stephen Baldwin displayed itself early. Two trivial circumstances served to turn that great creative ability into the field of mechanical calculation, a field in which he was destined to carve his name high among the immortals, Pascal, Leibnitz and Thomas. In 1869, as manager of Peck's Planing Mills in St. Louis, Mr. Baldwin invented a lumber measure which measured and recorded four different kinds of lumber. Work upon this device, coupled with the fact that he was called upon to repair one of the few Thomas machines then in use in this country, called his attention to the possibility of improvements in calculating machines. On September 8, 1873, Mr. Baldwin applied for, and on February 2, 1875, was granted, letters patent on a machine for which he was awarded the John Scott medal by the Franklin Institute of Philadelphia, and the machine, which was a direct means of rapidly commercializing the art of mechanical calculation. That this effect should be reflected in Europe rather than in America is one of the interesting pages of the history of the art.

Before attempting an evaluation of Mr. Baldwin's accomplishment, a brief survey of the difficulties to be overcome will be given. What was Pascal's vision? What is the single essential step from objective manipulation to machine reckoning? What would transform the Japanese soroban, the most versatile reckoning device ever produced, into a calculating machine? When the number of units in any one order exceeds nine, the number of tens must be recorded in the next higher order. When means is provided to automatically take care of the carry, the device may be said to have become a machine. In the Pascal machine this carry mechanism was a one-step ratchet, resulting in a machine differing in no essential from the modern counting machine, such as the cyclometer, except that provision was made to register *separately* in all of the orders. It is a long step from Pascal to Thomas.

The design of a machine in which numbers may be registered in two or more orders simultaneously, introduces several difficulties. In addition, the carry must be a progressive process from right to left. Thus if 1 is added to 999999. the carry runs successively through the orders from the lowest to the highest. In subtraction the carry (or borrow as it is sometimes called) must in theory be reversed. Provision must be made to properly register tens, carry over values and digital values without confusion, as in adding

$$\begin{array}{r} 88888 \\ 44444 \\ \hline 22222 \\ 11111 \\ \hline 133332 \end{array}$$

the digits 4 must be added to the digits 8. making 12, that is, 2 and 10 to carry, and this registration must be accurately made at great speed. Locking mechanism must stop the action with great precision, checking any tendency to overthrow. These are some of the great problems for the designer.

Thomas surmounted these difficulties by placing the actuating gears on approximately one-half of the circumference of the stepped drums, retarding each successive drum the value of one tooth, and following the last tooth by a carrying finger, so that the dial received its actuation from the number registered first, immediately followed by the carry. This produced what is termed retarded carry. The portion of the drum covered by the gears determined the capacity of the machine in the number of orders possible in one cycle.

The Thomas machine is of the convertible type. It is a machine built fundamentally to perform two of the four rules of arithmetic, addition and multiplication, and convertible by the throwing of a lever into a subtracting and dividing machine. It has at no time the universal capacity for the four rules. When set for negative calculations, subtraction and division, it cannot add or multiply; when set for positive calculations, it cannot subtract or divide.

In three short years. Frank Stephen Baldwin, then a young mechanic, solved the problem by inventing and later selling for extended service, the first practical calculating machine which at all times had the capacity to add. subtract, multiply or divide, with no resetting of the mechanism, and with no conversion of any sort for the various processes. In other words, you may install any number in the Baldwin machine, and add, subtract, multiply or divide that number by merely turning the operating crank forward or backward the required number of turns. In its mathematical concept, this was a marked advance over the convertible type of machine. In practical operation, the versatility of the Baldwin principle has effected a great saving, as the science of calculation has been largely reduced to a system of short cuts, wherein positive and negative calculations arc intermingled. This system of short cuts is based largely on the idea that to multiply by 98, for example, it is easier to multiply by 100 and subtract twice.

Leibnitz had labored for over twenty years in attempting to realize the dream of

Pascal, but had encountered mechanical difficulties which he could not overcome. Thomas had brought to the problem the mechanical skill which Leibnitz lacked and the centenary of his success was fittingly celebrated in Paris in 1920.

Mr. Baldwin's machine, which was invented in the years 1870 to 1873 and was patented in 1875. was the basis for rapid and successful commercial development in Europe, and subsequently in America. The construction of the 1875 model in itself is an achievement which easily places Mr. Baldwin in the foremost rank of inventors. A single cylinder or drum was substituted for the several stepped cylinders of the Thomas machine, an arrangement which permits of the vertical placing of the recording dials, thus bringing the numerals side by side, and at the same time placing the bevel gears of Thomas by spur gears, a mechanical advantage. Corresponding to each numeral order there is on the surface of the drum a set of nine radially placed pins. Any number of the nine pins may be made to project beyond the surface, at the will of the operator, by means of a rotatable cam. and when thus projecting they engage gear teeth which operate the dials. This principle of active and inactive teeth set by a cam was used by Roth in a model of a disk machine in 1841, but was unknown to Baldwin and probably to Odhner. who utilized the same idea. Between the drum and the dials is a shaft carrying the intermediate gearing. Passing through this shaft is a short sliding bar which is moved toward the drum by a stud on the dial as the dial passes from 9 to 0. When in this position the other end of the bar which carries a double bevel throws a projecting pin on the surface of the drum into the path of the gear in the next higher order and moves it forward or backward one tooth, according to the direction of rotation of the drum. The bar is restored by a cam following the pin on the drum. The problem of delaying the carry and making it progressive in either direction is solved by the arrangement of the elements on the surface of the drum. The drum is divided into four parts, one sector and its opposite being taken up with the set-up. The carrying fingers and cams for addition are arranged spirally in one direction for addition in one sector and in the opposite direction for subtraction in the fourth sector. The drum progresses from one order to the next by means of a spiral thread on its carrying shaft. The number of rotations forward and backward is recorded on a set of dials by an eccentrically operated finger. A number is set on the drum, a single turn of the crank in one direction adds, while a turn in the other direction subtracts. The machine is a single machine performing all four operations with no presetting.

In 1878, Willgodt Theophile Odhner, a Swedish engineer, took out patents in the United States and in the principal European countries on a machine embodying the principal operating features of Mr. Baldwin’s machine. The most outstanding difference between the two machines is that Odhner chose for the moving element the Thomas carriage rather than the Baldwin drum. While it is within the bounds of possibility that these two machines were invented independently, in his United States patent, dated October 29, 1878, Mr. Odhner precedes his statement of claims with these words: “I do not claim, broadly, setting the teeth of 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.” As the first two of these items in conjunction are the operative features upon which the Baldwin was constructed and are not known to have been used in any preceding machine, one inference seems justifiable. The Baldwin 1875 model is the prototype of those machines built on Odhner patents, and to Mr. Baldwin belongs an honor long withheld.

Each one of the three periods into which the development of calculating machines may be divided, therefore, has its beginning marked by some great invention, the period of vision beginning with Pascal and Leibnitz, the period of realization dating from Thomas de Colmar, and the period of commercialization founded upon the invention of Baldwin.

Space will not permit of an account of Mr. Baldwin’s subsequent inventions in the field of calculators. For fifty years he has continued with his inventions, and has produced and sold calculating machines of many different types. The present embodiment of his life’s effort is to be found in the well-known Monroe calculating machine, developed jointly by Mr. Monroe and Mr. Baldwin. This machine is constructed on the fundamental idea of Baldwin’s ‘‘four rules” machine of 1875.

In recent years many very ingenious and useful machines have been developed. Some of them print a list. Others are combined with typewriting mechanism. Wonderful calculators have been developed which operate fundamentally on the principle of addition. What of the future? Will the machines of the future be broader in their scope? Will the Baldwin principle of the “four rules” in one machine, with no presetting or conversion required to determine the nature of the operation, prevail, or will some new achievement take its place? Up to the present, from the standpoint of pure mathematical conception, Mr. Baldwin’s invention bids strongly for a foremost position as a mechanical embodiment of the “four rules” of arithmetic in a unitary mechanism.

The years have been kind to “Dad” Baldwin, as he is affectionately known by his associates. On April 10, last, he celebrated his 84th birthday. It is given to few to exceed the alloted threescore and ten, and to still fewer to be accorded the merited honor and to reap the financial success around the eightieth milestone.

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