

*The ELECTRICAL TABULATING MACHINE.*

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WHILE engaged in work in the tenth census, that of 1880, my attention was called by Dr. Billings to the need of some mechanical device for facilitating the compilation of population and similar statistics. This led me to a consideration of the problems involved. I found, for example, that while we had collected the information regarding the conjugal condition of our 50,000,000 inhabitants, we were unable to compile this information even in its simplest form, so that, until the census of 1890, we never even knew the proportion of our population that was single, married, and widowed. Again, while we classed our population as native white, foreign white, and coloured, this was extremely unsatisfactory. For example, of what significance is it to know the number of children under 5 years of age who were native born? To have divided the native born into those of native parentage and those of foreign parentage, would have been practically impossible with the methods of 1880.

To obtain the population classified according to age, sex, and birthplace of mother could not have been considered. Again, it was apparent that if we wished to consider the progress of the negro in regard to illiteracy, we should know the number of illiterates at each age-period. In vital statistics much could be done in combining race, age, conjugal condition, occupation, and cause of death. Almost in every direction could be seen the need for combined or correlated statistics.

These were the considerations which prompted me to take up this problem, the result of which studies, after years of experimental work, are embodied in the apparatus or system which I will now briefly describe.

It must not be considered that this system is still in an experimental stage. Over 100,000,000 punched cards have been counted several times over on these machines, and this has afforded ample opportunity to test its capabilities.

I am glad to be able to say here to-day that in my struggle to secure the adoption of this system in the United States, I often had recourse, with great advantages, to references to and quotations from, the works of your Dr. Farr.

This system of electrical tabulation may perhaps most readily be described as the mechanical equivalent of the well-known

method of compiling statistics by means of individual cards, upon which the characteristics are indicated by writing. As it would be difficult to construct a machine to read such written cards, I prepare cards by punching holes in them, the relative positions of such holes describing the individual. In the United States Census we used cards of  $3\frac{1}{4}$  inches by  $6\frac{1}{8}$  inches, the surface of which was divided into 288 imaginary spaces  $\frac{1}{4}$  inch square. To each of these spaces some particular value or meaning is assigned; a hole in one place meaning a white person, in another a black. Here a hole means a certain age-group, there it gives the exact year in that group. A combination of two holes in another part of the card indicates the occupation of the particular individual. In this way we not only recorded the answers to the twenty-six inquiries of the population schedule, but we also recorded the particular State, county, city, and enumeration-district in which the given person resided. Besides this, a number was stamped on the card, so that by these means any one of the 62,000,000 cards could be readily identified and compared with the original return.

This punching of the card, so far as the individual record is concerned, was done by means of the keyboard punch. The combination of holes representing the enumeration-district (over 40,000 in all), being the same for all the cards of a given district, was most readily punched by means of the gang punch. The punches being set for the given combinations, five or six cards were punched at one operation, the cost of this part of the work being thus relatively insignificant.

Having thus prepared a punched transcript for each individual, we are ready to tabulate them on the electrical machine. This consists primarily of a press or circuit-closing device, the upper and movable portion of which is provided with projecting spring-actuated needles, or points corresponding in number and relative position to the holes which may possibly be punched in the record card. The lower or fixed plate consists of a piece of hard rubber provided with a corresponding number of cups partially filled with mercury, which through suitable wires are connected with the binding posts of the switch board. If a punched card is placed in this bed, and the handle depressed, wherever there is a hole in the card the needle will dip down into the mercury, while at all other points the needles will be pressed back.

In connection with this so-called press counters are used. A counter consists of an electro-magnet, so arranged that each time a circuit is closed through it the armature is actuated so as to register 1. These counters can readily be re set to zero, and will count to 9,999.

If now we imagine such a counter connected to each mercury

cup, it is evident that if all the cards are successively placed in the press, the counters will ultimately give the total number of times any given hole occurred in the cards; or, in other words, a total showing the frequency of the different holes or items.

In practice, however, it is not sufficient to know simply the number of males and females, but we must know, for example, how many males there are at each age-period, as well as how many females at each age-period; or, in other words, we must count age and sex in combination. By a simple use of the well-known electrical relay we can secure this or any other possible combination. It must not be understood that only two items can be combined; in this way any number of items can be combined. We are only limited by the number of counters and relays.

As it would require 800 counters to compile a table of 800 columns, I have recourse to the use of a sorting box. This is simply a box divided into compartments (usually 24), placed by the side of the operator. The lids of these compartments are controlled by electro-magnets operated in exactly the same manner as the electro-magnets of the counters. If these magnets are connected to the mercury cups corresponding to age-groups, for example, and the cards are successively placed in the press, for each card a lid is automatically opened, according to the age of the individual represented by the given card. Each card having been deposited in the compartment opened by it, we have all our cards sorted according to twenty age-groups. If now each of these groups be passed through the machine provided with fifty counters, we obtain a result equivalent to a table of 800 columns.

It must also be noted that these two operations of sorting and counting can be conducted simultaneously, or either one independently of the other.

To show what can be done with such a machine, permit me to call your attention to the first handling of the punched cards of the United States Census. Here we obtained for each of the divisions of the population, *i.e.*, native with native parents, native with foreign parents, foreign white, and coloured, a classification according to sex, and the following age-periods: less than 1 year, 1 to 4, 5 to 9, 10 to 17, 18 to 20, 21 to 44, 45 and over. At the same time we obtained a classification as to homes and farms, whether hired, owned free, or owned mortgaged. For the foreign, in addition to the above, whether a citizen or alien, and whether the person could speak English. For the coloured, a distinction as to Black, Mulatto, Quadroon, Octoroon, Chinese, Japanese, and Indian. This information it must be remembered was obtained for each enumeration district.

I will not weary you with the details of the various operations further than to call your attention to some few points.

We, I believe, pay about 35,000,000*l.* annually in pensions. How long this will continue is of course an interesting question. In case of any further legislation relating to pensions, we will know how many survivors of the late war there are at each age-period, also as regards the age of widows of soldiers. In other words, we now have some data upon which to base our calculations.

For certain classes of occupation, as many as ten distinct and different items were tabulated at one operation of the machine. Thus, for example, we now know the number in each occupation who were born in England, and who had mothers born in England.

It is of the greatest interest to know whether such a machine is accurate. Liability to error is of course always present, but with a properly arranged plan the possibility of an error going undetected is narrowed down to the one operation of punching. If the punched cards are verified, the subsequent operations can be fully checked by mechanical means. Even some of the errors of punching are detected by the electrical machine. If, for example, you forgot to punch whether the given foreign born person is an alien or citizen, the machine will not operate. Again, as this question is applicable only to males over 21 years of age, the machine takes all this into consideration, and does not refuse to count a female or a male under 21 even if citizenship is not punched. Only such errors of punching as are consistent will pass through the machine. I mean, for example, if a card is punched citizen when it should have been alien.

Naturally, in handling over 180 tons of cards as we did in the United States, there is apt to be some confusion. A few carpenters may get among the blacksmiths, or a few Bostonians may get mixed with the New Yorkers. These machines, however, were so connected that if while counting the blacksmiths of New York a carpenter should by accident come into the machine, it would not count. Likewise, if a Boston card came into the press it would be rejected.

Without the slightest delay such an electrical counting machine will read or test before tabulating whether the given person was white, native born, native father, native mother, male, blacksmith, and resident of new York City. If it agree in all these particulars, it would tabulate the person under from six to ten different items, whereas if the description did not tally, or any one of the required facts were not punched, the card would be rejected. An inspection of the card would then show the cause, and if due to an omission, this was supplied by reference to the original schedule.

Thus it is believed that the liability to error is much less, take it all in all, than with the old system of tallying, of ticking, or even the method of sorting and counting the original individual cards, as practised in Germany.

This system also possesses one advantage to which I would like to call your attention. In the case of current work the punched card may contain a pretty elaborate transcript which can be used for compiling the simpler monthly and annual tables, while at the end of say five or ten years there will be accumulated the cards, which will then be ready for an exhaustive tabulation. This would be true in case of registration of births, deaths, and marriages insurance experience, and many similar kinds of statistical work.

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*Discussion on MR. PORTER'S and DR. HOLLERITH'S Papers.*

DR. W. OGLE congratulated Mr. Porter on having brought the gigantic task of the American census to a successful issue. He sympathised with him in his remarks on the reception often given to census results by the public. Those who found the figures tally with their expectations were given to cry out that a census was of little use, for they knew all about it beforehand; while those who found that the figures did not support their theories, attacked the census methods, and sometimes did not hesitate to accuse the census-takers of writing with an animus, and misrepresenting the facts.

He had no intention of comparing the results of the American and English enumerations; that would be an interesting but formidable undertaking. He would simply note that many of the phenomena presented by the population were the same in both countries. Such were the decreasing birth-rate, the decline in the rate of increase, and the migration of the rural population into the towns. These phenomena presented themselves both in America and in England, and indeed in other countries, and the explanation must therefore be sought not in conditions peculiar to ourselves, but in conditions shared by us with foreign States.

The American census differed enormously from the English census in its scope. Our own was limited to the enumeration of the people and houses, with some simple particulars concerning them, such as their age, sex, and occupation. But this was a comparatively insignificant part of the American census, which branched out into multitudinous inquiries, doubtlessly of high interest, but scarcely, as it seemed to him, coming properly under the designation of census work. For example, in the census report of 1881 there was, if he remembered rightly, a whole volume devoted to the habits and natural history of fishes, the