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PUNCHED-CARD EQUIPMENT

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'Punch-card equipment is becoming more and more a convenient and useful tool of the actuary. For this reason, the study of this equipment and its flexibility should and will occupy a larger place in the training of actuarial students in the future.'

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I. INTRODUCTION

The actuary employed in life office work is very closely concerned with the methods by which the valuation and other records of a life office are built up. It is surprising, therefore, that there are very few references in the pages of the *Journal* of the Institute to the use of punched-card equipment for life office work. The use of the equipment for calculations of interest to the actuary, such as the construction of tables, has also been largely ignored. Actuaries employed in work outside life offices so often rely on punched-card equipment for their statistical data that the authors feel that no apology is needed to either class of actuary for presenting a paper on the subject. Punched-card equipment has received much more attention in the *Transactions of the Actuarial Society of America*, most recent volumes containing a paper or note on its application.

The present paper is divided into two main parts. The first half includes a short history of punched cards and gives a brief description of the equipment now available and the operations which can be performed. The second half is devoted to the application of the equipment to life assurance work. This is divided into three parts, office records, the production of forms, and calculations. Future developments are considered in a short section at the end of the paper.

Space will not permit a discussion of other systems of office records (such as Adrema and Addressograph) despite their advantages in certain circumstances.

It is not proposed to give detailed accounts of office systems but to indicate on general lines how the machines can be adapted to life assurance work. In attempting this, the authors have found themselves in something of a quandary. The most complex and certainly the most interesting aspects of the subject lie in the adaptation of specified machinery to particular tasks, and those actuaries who are familiar with the use of punched-card equipment may feel that by omitting a discussion of such questions the authors have dealt with the subject in too elementary a manner. On the other hand, they have had in mind that many members of the Institute, in particular the students, will not be familiar with punched-card installations and that for them a general outline will, in the first instance, be more helpful than a discussion of points of detail. They have therefore confined themselves to dealing with the matter on broad lines, but they hope that this will not preclude the more detailed aspects from being raised during the discussion of the paper.

II. HISTORICAL

The use of perforated cards to control mechanical operations dates back at least to the introduction of the Jacquard loom. Although bearing the name of a French inventor, Joseph Marie Jacquard, born in 1752, the principles of the loom were of earlier origin and represented the work of several men over a long period. As early as 1725 perforated strips of paper were used in the 'Bouchon' loom and perforated cards were introduced with the 'Falcon' loom of 1728. Jacquard looms are still used, though modified and improved with time, but the essential principle is unaltered—the weaving of a pattern is controlled by a series of cards in which holes are cut to represent a particular pattern.

The first application of perforated cards in connexion with arithmetical calculations is attributed to Charles Babbage. When work was suspended in 1833 on his 'difference engine', Babbage devoted his energies to the construction of an 'analytical engine', the purpose of which was to evaluate any mathematical formula. The various operations were controlled by punched cards of the Jacquard type, but the scheme proved to be too ambitious and the machine was unfinished when Babbage died in 1871.

The first use of hand-written cards for statistical work is now attributed to A. G. Finlaison who used this method for the *Report on the Sickness and Mortality in Friendly Societies*, 1846–50, dated 1 August 1853 (see Lidstone's note in *J.I.A.* Vol. LXXII, p. 229).

As with so many other advances, punched-card equipment started from the amalgamation of two ideas which had previously been used in different fields. The combination of the idea of hand-written cards for statistical work and the idea of perforated cards used with machinery was a great step forward.

Punched cards were first used in this sense in the United States of America, and arose out of the need for mechanical assistance in extracting the results of a census. Herman Hollerith who had been engaged on the 1880 Census developed an idea put forward by J. S. Billings, and, after experimenting with perforated strips of paper, adopted the principle of a perforated card as a basis of a mechanical method of tabulation. The first machines were available for use in connexion with the 1890 Census.

Even before that census, however, the new machines were used in the compilation of mortality statistics of Baltimore and other cities, and were soon afterwards employed in the Austrian, Canadian and other censuses of the same period. Although the need for a more rapid compilation of the results of the 1890 U.S. Census was the main reason for the development of the mechanical method, the latter was immediately used over a wide range of governmental and municipal statistical work in several countries.

In these early machines, cards of a standard size and shape were used and a meaning assigned to each possible position of a hole in the card. The position had no numerical value apart from the code employed (that is, the numbers 1, 2, 3, etc., were not represented in each column and the fields did not cover a group of columns) but otherwise the card was broadly of the same nature as that in use today. The first tabulator was a clock-face type—each card was placed individually by hand on to a sensing mechanism and electrical contact through the holes caused the appropriate dials to advance one unit.

The success of the punched-card method led to the formation by Dr Hollerith of the first Tabulating Machine Company in 1896, and the use of the machinery was extended to the commercial field in 1899, the first of such users

being U.S. railway companies in connexion with the auditing of freight receipts. Improvements in machines soon led to the production of tabulators that would accumulate totals and permit automatic feeding of the cards, a process greatly facilitated by the introduction of the 'columnar' card. The first elementary automatic sorter was built in 1900, naturally following the use of the 'columnar' card.

Many commercial firms built machines for their own use and many inventors were associated with the development of punched-card machinery. At this point it is appropriate to mention the work of John Kinsey Gore, who was actuary to a large U.S. insurance office and whose death occurred as recently as 1943. He was concerned with industrial policies of which very large numbers were in force, and during the early 1890's the volume of work threatened to outgrow the manual system then used. At the same time the preparation of new punched-card files appeared to involve a prohibitive amount of work.

Gore constructed inexpensive machines designed to work on the existing manual cards which were themselves punched. His multiple-die punch provided automatic feeding and ejection of cards and in many respects anticipated the modern automatic punch, while his sorting machines operated on an unique principle in that at one sensing operation not merely one card but all cards of a particular characteristic were selected at once. In favourable circumstances, therefore, the sorting speed was comparatively great, and it is recorded that on one occasion 200,000 cards were so sorted on one of these early machines in 8 hours. Nothing corresponding to a tabulator was necessary, owing to the nature of the industrial insurance policy records, and counting was effected with a commercial friction card-counting machine. Gore's simple machines were used continuously for 35 years and provide a fine example of the early use of punched cards in life assurance work.

Development in machines and in methods was very rapid in the early years of the present century and two of the best-known names in punched-card machine research developed their ideas round about 1910. J. Royden Peirce produced a printing punch so that the card was interpreted in the punching operation; his tabulator was very complicated but anticipated many of the features that are general to-day. Some of these tabulators were used by U.S. insurance companies but the field was then limited and ultimately the Peirce Accounting Machine Company was absorbed by the successor to Hollerith's original company. Many of Peirce's ideas are used in the machines of the present company—International Business Machines Corporation—and in particular the present standard alpha-numerical tabulator of that company is generally known as the 'Peirce' tabulator.

The other leading inventor of this period was James Powers, who was, prior to the taking of the 1910 U.S. Census, required to improve the existing punched-card machinery for the purpose of that Census. An improved punching machine with the principle of simultaneous perforation was introduced, and this machine was developed into the 'Powers' automatic key-punch which with other machines was placed on the market in 1913. The tabulator for the first time printed totals instead of merely indicating them on registers; up to this time punched-card machines had been used only for strictly 'statistical' work but now their use was extended to 'accounting' work. Soon the printing of totals was effected entirely automatically and within 10 years the tabulator, as used for numerical work only, had developed into the general form in which it is known today.

The next stage was the printing of alphabetical data from combinations of holes in the cards. All the early development of punched-card machinery had taken place in the United States but this extension originated in Great Britain with Charles Foster of the Accounting and Tabulating Machine Corporation of Great Britain (now Powers Accounting Machines Ltd.). An alphabetical printing tabulator was first used in 1920 and inaugurated a period of great development in 'accounting' work; with the introduction of the summary punch and the use of auxiliary machines such as the interpreter, the reproducer, the interpolator or collator, and finally the multiplier, we have the wide range of machinery available today.

III. DESCRIPTION OF EQUIPMENT

Many companies have manufactured punched-card equipment and there has been a history of keen rivalries, amalgamations, the expenditure of large sums on research and the jealous possession of patents. In the English-speaking world this process has led to the formation of two competing groups; every development of the one has been followed by a corresponding development on the part of the other, but, owing to the ownership of patent rights, the mechanical system of operation varies between them, and the machines of each group respectively possess distinct advantages in different circumstances.

Distribution is usually effected, especially in countries other than that of manufacture, through subsidiary or associated distributing companies, but actual manufacture on a large scale is at present limited to five manufacturing companies. In alphabetical order of the name by which the product is normally known these are:

'Bull': Compagnie des Machines Bull (France).
'Hollerith': The British Tabulating Machine Co. Ltd. (Great Britain).
'I.B.M.' (Formerly known as 'Hollerith'): International Business Machines Corp. (U.S.A.).
'Powers': Powers Accounting Machines Ltd. (Great Britain).
'Remington-Rand' (Formerly and still widely known as 'Powers'): Remington-Rand Inc. (U.S.A.).

Of these, 'Hollerith' and 'I.B.M.' are closely associated in one group and 'Powers' and 'Remington-Rand' in another group; in each case the association involves the joint use of patents and division of territory. Within either of these two groups it can be stated that the fundamental principles of operation of the machines of the two companies are the same, but development in the two English-speaking countries has been along different lines and in general corresponding machines, and particularly tabulators, are not interchangeable, partly owing to the different currency systems. At least in the case of 'Hollerith' and 'I.B.M.', however, the present tendency is towards the adoption of common machine designs.

We shall confine our description of the equipment to that of the two firms which manufacture in Great Britain—'Hollerith' and 'Powers'. The descriptions must of necessity be brief and many interesting points have had to be ignored. Both firms are still developing their equipment and fresh facilities become available from time to time.

Cards

The cards are of stout manilla paper approximately ·007 in. thick. The various sizes available are as follows.

Make	Size of card (ins.)	No. of columns	No. of positions in each column
Powers	$2 \times 2\frac{3}{4}$	21	11
Powers	$2 \times 4\frac{11}{16}$	36	11
Powers	$3\frac{1}{4} \times 7\frac{3}{8}$	45*	12
Powers	$3\frac{1}{4} \times 7\frac{3}{8}$	65	12
Hollerith	$3\frac{1}{4} \times 3\frac{1}{16}$	38	12
Hollerith	$3\frac{1}{4} \times 7\frac{3}{8}$	45*	12
Hollerith	$3\frac{1}{4} \times 7\frac{3}{8}$	80	12

* No longer in production

One corner of each card is cut so as to ensure that it is filed the right way round. Coloured cards, or cards with the top edge coloured, are available so that cards used for different purposes can be readily distinguished. One column is normally required for each digit in a number or each letter in a name. When two or more columns are used in conjunction to represent a group of numbers, such as a policy number, or a group of letters, such as a name, the group of columns is called a field. Tabulating equipment may limit the extent to which columns may be used for letters.

Although the main use of a punched card is as a record in a form which can be sorted and tabulated readily, a card, wholly or partially punched, can be used as a notice to an agent or policyholder or as a form on which future or altered information can be written and returned to head office. In both these applications it is usual to 'interpret' part of the card (see under *Interpreter*).

When there is a large amount of information to record, two or more cards may be required for each policy. This is likely to be the case when addresses are recorded.

Use of the twelve punching positions in a column

Ten of the twelve punching positions in each column are normally numbered 0–9, the remaining two positions, which are at the top of the card, being marked X and Y (or A and B). The use to which the positions may be put depends on the equipment available for handling the cards. In the simplest application the positions 0–9 represent the numbers 0–9 and the X and Y positions are ignored. This is suitable for handling numbers. In the simplest type of tabulator each type-bar prints a number 0–9 corresponding to whichever of the positions 0–9 is punched. Pence can be recorded by using the whole range of twelve positions instead of the ten positions 0–9, provided the tabulating equipment is designed to print and cast in the duodenary instead of the denary scale. Two columns can be used for shillings or the ten shillings may be recorded in the X or Y position at the top of the shilling column. As in the case of pence the tabulator must be designed to correspond with this special application.

If one position only is punched in each column, it is not possible to represent a letter of the alphabet in a single column, but by using double punching the

recording and tabulating of letters can be achieved. 'Powers' originally introduced alphabetical tabulating, by dividing the column into two sections, the first section consisting of the top position only and the second section consisting of the remaining 11 positions. If not more than one hole is punched in each section, we have $2 \times 12 = 24$ combinations. The combination of no punched hole in each section cannot be used as it is the same as an unpunched column. Hence 23 combinations were available for printing 26 letters, and composite characters had to be used for three pairs (I and J, U and V, and X and Z or O and Q). This arrangement has been superseded by the alpha-numerical system used by both 'Powers' and 'Hollerith', which divides the column into sections of 2 and 10 positions respectively. This gives $3 \times 11 - 1 = 32$ useful combinations, which is sufficient to print 10 numerical and 26 alphabetical characters if 4 combined symbols are used such as O and 0, I and 1, G and 6, and S and 8.

Further development is possible by making other subdivisions of the positions or by using triple punching. An interesting development is the division of the card, or part of it, into halves, each half having six positions to a column; numbers and letters can be tabulated and the capacity of the card doubled. This development is limited to 'Powers' and the punching of letters in the 6-hole columns is not yet available in this country.

The top positions can be used to enable numbers greater than 9 to be dealt with in one column by a system known as over-punching. This system has been developed chiefly by 'Powers'. The X, Y and 0 positions are treated as the digits 1, 2, 3 in the tens position and the tabulator is designed to deal with them in this way. Thus numbers up to 39 are dealt with in one column, the tabulator automatically printing 0 if no hole is punched in the column. Moreover, if the top positions in adjacent columns to the right are not required for use in those columns, they can be treated as further digits in the tens position of the first column. Thus, by using the top positions of one adjacent column, numbers up to 69 can be dealt with in one column, while, if two adjacent top positions are used, numbers up to 99 can be similarly dealt with. Again, if three consecutive columns and the top positions of three adjacent columns are available, numbers up to 99,999 can be recorded.

'Hollerith' have recently introduced a method of over-punching which enables 0–99 to be punched in any column. This method is known as Ducol and increases the recording capacity of the card to 160 columns for numbers on the denary scale. Two letters or two numbers in the duodenary scale such as months and pence cannot be punched in one column. With this method, if the number 27 is to be recorded in a column, both the 2 and the 7 positions are punched, an over-punch position being used to distinguish between 27 and 72 and to indicate the repetition of one figure such as 22. A special punch carries out the over-punching without the operator depressing the X and Y keys.

Another method of doubling the capacity of a card is to make use of the spaces between the rows by shifting the card half a space upwards and re-punching. Specially designed equipment is necessary.

Information other than numbers and letters can be recorded on punched cards by means of coding. Thus, the mode of payment of premiums could be recorded by using 0 for yearly, 1 for half-yearly, 2 for quarterly, etc.

Punches

In order to make the holes in the cards, punches are used. The machines produced for 'Hollerith' and 'Powers' are not dissimilar. The simplest punch is a hand-punch with a keyboard of 15 keys, 12 for the twelve punching positions in the column, one for spacing, one for release and one for skipping. More advanced models are power-driven with automatic feeding of cards, and 'Hollerith' have a machine with an alpha-numerical keyboard just like a typewriter. 'Hollerith' also have an automatic duplicating punch for reproducing information on a number of cards from a master card. 'Powers' automatic key punch includes this feature and also provision for slightly offsetting the punching for automatic verification (see below). In the Powers automatic punch the card is completely visible and the whole information is set up in the machine before punching, the entire card being punched in one operation. This enables corrections to be made by the operator without the necessity of rejecting a card and starting afresh.

The holes in the 'Powers' cards are round and in the 'Hollerith' small vertical slots.

Verifiers

Verifiers are used to check the information punched on cards. Generally they are similar to punches except that when a key is depressed a hole is not cut but the existing hole or holes are sensed. If a hole has been incorrectly punched, or no hole has been punched where there should be one, the machine stops. The 'Powers' automatic verifier, however, is of different type. In its application the key-punch is used a second time to punch the card, slightly offset, so that the effect of repeating the punching is to elongate the holes where the original punching is correct and to leave ordinary round holes where errors have occurred. On passing the cards through the automatic verifier, the latter indicates errors by inserting a coloured card behind each incorrect card.

Sensing

Before referring to other types of equipment, reference must be made to the main difference between the two makes. In the 'Powers' equipment the sensing, that is the method of picking up the information from the card, is mechanical by means of pins which feel for the holes while the card is held stationary. In the 'Hollerith' equipment the sensing is by electrical contact by sensing brushes which the card passes over so that each position of the column is sensed in turn.

Reproducer

A reproducer transfers information punched on one card to one or more other cards. The information transferred may be the whole or part of that on the original card and if desired it may be reproduced in different fields. A great deal of work in the preparation of a set of cards can often be saved by 'gang-punching' the same information on a number of cards by means of a reproducing punch. With 'Hollerith' equipment gang-punching can be done from interspersed master cards. This enables a master card containing values of x and $f(x)$ to be used to transfer $f(x)$ to sets of detail cards punched only with x.

Interpreter

An interpreter prints on the card itself all or part of the information which is punched on the card. The information can be printed only in a horizontal line across the card, either at the top or in certain other selected positions. This facility is useful if a punched card is used for a notice to an agent or as a record card, etc. An interpreted card can be used for a bonus notice or renewal notice but the tabulator is sometimes considered more suitable for preparing notices to the public.

Sorter

A sorter divides the cards into twelve packs according to the position of the hole in the particular column on which the machine is operating. A thirteenth pack is made of those cards without any hole punched in the column being sorted. Sorting can be carried out on one column at a time only; hence if a group of unsorted cards needs to be arranged in policy number order and there are a maximum of six figures in the policy number the cards must be passed through the sorter six times. Where double punching is used, as in alpha-numerical, the cards must pass through the sorter twice for each column.

A number of ingenious devices are available to enable special jobs to be handled easily. For instance, where a record card is followed by an address card relating to the same case, it can be arranged for the second card to follow the first automatically. Again it is possible to sort, on one run, for cards with certain characteristics affecting a limited number of columns, e.g. sums assured over £500 or occupation designated by a particular code number.

Tabulator

The function of the tabulator is either to list card by card the information punched on the cards and to print totals of various fields or to tabulate and print totals only. Tabulators are fitted with controls so that sub-totals may be taken according to some chosen designation, the tabulator automatically printing the sub-total each time the designated information punched in the card changes. Negative as well as positive figures can be dealt with by means of indications punched in the card. The 'Hollerith Rolling Total' tabulator transfers, either positively or negatively, accumulated totals from one adding counter to another.

The tabulator head is fitted with a number of type-bars (or sectors) which may be numerical, alpha-numerical or specially arranged for the particular installation. As the cards pass through the tabulator each column is connected with one or more of these bars. In 'Hollerith' equipment this is done by means of an electrical plug-board, similar in principle to a telephone switch-board. This board can be plugged at will so as to connect the card with the tabulator head in any way desired. Two or more interchangeable boards are supplied with each machine allowing the operator to plug for the next job whilst the machine is working. Where routine jobs recur interchangeable boards with fixed wiring can be used. In 'Powers' equipment the connexion is made by means of a mechanical 'connexion box'. This consists of a box containing a number of metal rods, one for each hole in the card. These rods are motivated by the sensing-pins which pass through the holes in the card and cause the rods to operate the appropriate type-bar in the tabulator head. In the simplest case each rod passes vertically through the box so that the

information appears on the tabulation paper in precisely the same order as it is punched in the cards. However, great ingenuity is used in constructing boxes in which the rods cross the box at an angle, so that the order of the information is transposed. Over-punching referred to earlier is necessarily limited by the ability to construct connexion boxes by which the information in the over-punched positions can be connected to suitable type-bars. Separate boxes may be required for different card forms, but one box in the tabulator can be easily replaced by another.

The number of type-bars is, of course, greater than the number of columns in the card because, when double punching is used, each column may require more than one bar and also because the tabulator is required to print totals which contain more digits than the individual items. The total number of bars is divided into groups or units, each one of which totals separately without carrying over into the adjacent unit. Not all the units would normally be fitted with adding and subtracting devices, some being used only for printing purposes. The total number of type-bars is limited by the size of the tabulator and there may be other limitations such as a limit on the number of alpha-numerical type-bars.

As well as listing and totalling the information punched on cards, tabulators may be used in conjunction with special stationery for printing, from punched cards, various forms such as policies, premium notices and receipts, bonus notices, etc.

Summary card punch

A summary card punch may be coupled to a tabulator at will, in order to punch on a card the result of adding or subtracting figures recorded on a group of punched cards, together with any designating information that may be common to the group. The 'Hollerith' model can be used also for gang-punching or reproducing.

Collator and interpolator

The 'Hollerith' collating machine and the 'Powers' interpolator perform almost identical tasks. They can be used in order to handle automatically a variety of tasks in which two packs of cards are required to be checked, compared, interleaved or separated according to whether there is agreement or disagreement between the designations punched on the cards.

The 'Hollerith' equipment operates on any columns in the card, up to 16 in all, and the 'Powers' equipment on up to 10 consecutive columns. The columns need not be in the same position on the two packs.

The essential feature of the equipment is a comparator unit which simultaneously senses one card from each pack and indicates whether the readings agree or disagree and which is the higher. Subject to the setting of controls, the two cards are fed simultaneously if they agree, or in sequence if they disagree. They can be delivered into the same or separate receiving boxes in the case of agreement, and cards which disagree can be deflected into separate boxes if required.

Typical uses of the machines are as follow.

(*a*) Two packs of cards both in policy number order can be merged. Either pack may be incomplete and may have duplicates.

(*b*) Two packs of cards both in policy number order may be checked against each other, cards in both (or any one) pack which have no corresponding card in the other pack being turned out.

(*c*) All cards with a certain hole or set of holes punched can be sorted from a pack of cards.

(*d*) On the 'Hollerith' collator it is possible to check that a single pack is arranged correctly in numerical order, and tabbed cards can be inserted automatically to indicate errors.

Mark-sensing and spot-punching

Mark-sensing is peculiar to the 'Hollerith' equipment. Information can be recorded by placing on a card pencil marks in places specially indicated. Since graphite conducts electricity, sensing brushes passing over a mark will pass a small current which, when amplified, will operate the equipment and punch a hole in any desired column on the card. Thus the work and possible errors of punching information on to cards by hand is avoided and cards completed by unskilled clerks and agents can be fed straight to the punched-card equipment. The capacity of a card for marking is limited, as each pencil mark occupies the width of three normal columns, though the back of the card can be used for marked information also. However, the portion of the card used for marking is available for ordinary punching so that the full 80 columns can be ultimately punched.

The 'Powers' spot-punch has been designed to fulfil a function similar to that performed by mark-sensing. In place of marking the cards with pencil, they are punched with a special pocket punch which can be used by untrained operators. To avoid off-punching, the centre of each hole is indicated on the card by a small pin-hole; the punch is fitted with a pilot pin and so constructed that a hole can be punched only when the pilot pin has passed through the pin-hole in the card. Each column occupies the width of two normal columns, but the cards can be dealt with on standard sorters and tabulators. The amount of information which can be conveniently recorded on a card is small but, of course, further information can be punched on the same card by the normal punches.

Cross-adding punch

'Powers' cross-adding punch enables information contained in 2, 3 or 4 fields of one card to be added or subtracted and the result punched in another field. If desired the machine will print the details of the calculation. Calculations such as $A \pm B \pm C \pm D$ can be performed and the equipment is particularly useful for dealing with bonus records. The machine contains the elements of the multiplying punch which in the case of both 'Hollerith' and 'Powers' can be used for cross-adding as indicated below.

'Hollerith's' rolling total tabulator performs somewhat similar functions to the cross-adding punch.

Multiplying punch

The multiplying punch will carry out various calculations on a card. Thus, a number punched in one field on the card can be multiplied by a number punched in a second field and the result punched into a third field. In the 'Hollerith' model the multipliers can be taken from master cards sorted in ahead of classified groups of detail cards. More complicated calculations such as $(a \times b)+(c \times d)$ and $(a-b) \times c+d$ ('Powers') and $(a \times b)+c+d+e$ ('Hollerith') can also be carried out. The 'Powers' model will operate direct on pounds, shillings and pence and decimals of a penny and also on fractions.

One 'Hollerith' model will operate on the scale of ten only while another will operate on shillings and decimals of a shilling or on pence and decimals of a penny. The capacity of the 'Powers' model for a simple multiplication is

$$12345{\cdot}123 \times £1234.\ 19s.\ 11{\cdot}9999d.,$$

but the answer is limited to six figures in pounds together with shillings, pence and decimals as in the multiplicand. The 'Hollerith' capacity is eight digits by eight digits.

'Hollerith' have developed a new type of multiplier which works on a system of electrical relays. This method is much faster than the systems used in the punches referred to above. As the machine is still in an experimental stage its digital capacity cannot be stated.

Another 'Hollerith' machine, also in an experimental stage, is a multiplier which, by making full use of electronic methods, calculates a product almost instantaneously.

Speeds

One of the most important features of punched-card equipment is the speed with which records and statistics can be handled. The speeds with which the various operations can be carried out depend upon the type of equipment, the model and the information being dealt with. The following table gives some idea of the speeds obtained on 65 and 80 column card machines.

Operation	Speed
Punching	Up to 120 per hour
Reproducing	About 100 per minute
Interpreting	About 75 per minute
Sorting	About 500 per minute
Tabulating	About 100 per minute
Collating and interpolating (one feed)	About 200 per minute
Multiplying	The speed varies according to the size of the multiplier and the make of equipment. A rough average figure is 20 per minute.

The above speeds are given as a guide only. Punching speeds depend largely upon the number of columns being punched and the amount, if any, of over-punching required. In tabulating, additional time must be allowed if an appreciable amount of sub-totalling and totalling is required and, with all machines, allowance must be made for starting and stopping and for loading the machines with cards and paper, where necessary. For these and other reasons effective machine speeds are generally lower than those given above.

IV. OFFICE RECORDS

(i) *General considerations*

Life assurance business, consisting as it does of a large number of contracts of a permanent or semi-permanent nature which may be subdivided into a comparatively few simple classes, is particularly suitable for mechanization. The large amount of numerical work involved makes punched-card machinery most appropriate for the work.

Life assurance offices differ one from another in many ways. Size, type of business, agency system, will all vary and a system of records which is best for one office may not be particularly suitable for another. The authors do not believe there is any ideal system and do not propose to attempt even the description of a typical system; rather they will consider the various records which are common to most offices and indicate some special points which arise in planning a mechanized system. To produce a really satisfactory system, office records must be considered as a whole and any particular detail must be viewed in relation to the whole. It is most important to acquire the facility of grasping readily a complete system and of appreciating the interrelationships of the parts of the system and the checks they can impose one upon another.

The facility of appreciating the complete system is of special importance in planning the layout of the tabulators and the design of the cards, particularly in the case of a small office where the size of the installation is limited and one tabulator may be required to perform a number of different functions. The best arrangement for one purpose may be quite unsuited to another, and it is a problem of some complexity to determine which arrangement will give satisfactory results for all purposes. It may be mentioned that it has been found possible to design a tabulator which will handle both ordinary and industrial records and valuation data, including the preparation of ordinary renewal and bonus notices and industrial policies. It is, of course, necessary to use a number of different connexion boxes or plug-boards.

(ii) (*a*) *Ordinary branch in-force and renewal records*

In considering any system of office records it is necessary to decide what is to be the ultimate record concerning a policy. The proposal papers could constitute such a record but they are bulky to handle and hence the practice of having a policy register giving the details of policies has become normal in ordinary life assurance work. Some offices make the policy register the ultimate record on all matters concerning the policy, alterations such as bonus allotted and surrendered being shown in the policy register, but not on the proposal papers. Other offices, while making the policy register the ultimate record on most matters concerning the policy, have a different ultimate record on certain matters, e.g. bonus.

A matter for consideration is whether it is desirable to substitute a punched card for the policy register. The answer to this question lies in the extent to which the policy register is the principal record. In cases of dispute it is sometimes necessary to produce the record of the policy in court. A policy register is particularly suitable for production but a punched card is most unsuitable. A written or typed policy register is almost invariably used for ordinary assurances and a punched card in addition would not be justified unless it could be used for other purposes. Such a card could be used to print the policy register initially, to print details of the policy for the purpose of surrender value, loan, non-forfeiture and similar calculations, and so to save the work of hand extraction from the policy register. One disadvantage of this scheme is that many details of the policy would have to be expressed in code, which is not entirely satisfactory for a policy register.

In order to collect premiums satisfactorily it is necessary to issue each month a renewal notice in respect of each policy due for renewal in the month and at the same time lists of renewal premiums due must be prepared which

can be marked off as the premiums are received. Lists of premiums on each agency or district may be required as well, depending upon the agency system.

To avoid having to discuss the problem in too general terms it will be assumed for the present that the record of the addresses of the policyholders is not centralized, renewal notices being dispatched to the agents who either deliver the notices by hand or post the notices in envelopes addressed from the records in their possession.

From a set of renewal cards renewal lists can be printed on the tabulator. The tabulator will also print the renewal notices and by using interleaved carbon paper the receipt can be produced at the same time. A cheaper but slower process is to arrange for the tabulator to print consecutively the notice and the receipt from each card. Alternatively, the renewal notice may be produced in the form of a punched card with an interpretation of the information it contains printed across the face of the card. The card would be reproduced from the original renewal card, two cards being reproduced consecutively if a receipt is also required. This is a very economical method of producing renewal notices, but in some cases it may be a disadvantage that the receipt and renewal notice are not attached to each other.

If the number of policies is small the renewal cards can be kept in any convenient order and the cards required for each month's renewal lists sorted out. If the number of policies is large it will be found necessary to keep the cards in some order which simplifies the work of extracting each month's renewals. Thus the cards may be divided first according to mode of payment, yearly, half-yearly, etc., and then according to month of renewal. Thus all the policies with premiums payable yearly and due January will be kept together. This will involve twelve subdivisions of the yearly policies, six of the half-yearly, three of the quarterly, etc. Within these groups the cards may be kept in policy number order or may be further subdivided according to the grouping required for the agency renewal lists.

If the record of the addresses of policyholders were centralized, the addresses could still be omitted from renewal notices, which could be inserted in addressed envelopes prepared from Adrema, Addressograph or similar equipment. In most office systems with a centralized record of addresses, however, it is necessary to print the address on the renewal notice, which is then dispatched to the agent. In this case three courses are open.

(*a*) Punched-card machinery may be used throughout, the name and address being printed from cards. This will normally involve the use of more than one card per policy. An interpreted card cannot be used for renewal notices in this case.

(*b*) Punched-card machinery may be used for the renewal lists, and plates (Adrema, Addressograph, etc.) used for the renewal notices, the cards and plates being kept in the same order for cross-checking.

(*c*) Plates may be used for both the renewal notices and the renewal lists.

The use of punched cards for at least the renewal lists greatly assists in the problem of ensuring that the valuation data and the renewal lists agree, thus providing a satisfactory check on both the renewal collection and the valuation data.

The determination of the number of sets of cards which should be used is a problem which always occurs in devising a system of punched-card records.

At first sight it might be thought that the sets of cards should be kept to a minimum and in fact that one set of in-force cards should suffice. This is not necessarily so. Once a card has been punched for a new case, cards duplicating some or all of the information punched on the first card can be produced so readily on the reproducer that the greater flexibility which results from more than one set has distinct importance. By omitting some items space can be left for inserting additional information, such as net premium, not required on the original cards. Where sets of cards are required for temporary purposes, such as new business analysis, a second set is normally advantageous, but where an in-force bureau has to be set up the advantages of flexibility must be set against the extra work of carrying out the movement which is appreciable on a large bureau.

(ii) (*b*) *Industrial branch in-force records*

For industrial business, records of premium payments are not kept at head office, but are obtained, when required, from the premium receipt book or the agent's collecting book. There is no question of sending renewal notices and the problem is therefore confined, in essence, to maintaining records of the business in force from which can be obtained details of any given policy when required, the data for valuation, and any additional information that may be necessary for other purposes.

The large number of policies involved makes a handwritten policy register impracticable and if a policy register were maintained it would usually be compiled from punched-card tabulations. Alternatively, a file of punched cards can itself be used as the head office record. The ultimate record is, of course, the proposal papers but in most cases it is convenient to reduce to a minimum the occasions when these need be referred to. In some cases proposal cards are used and these cards can be filed in a suitable order and used as a substitute for the punched cards. There is at least one large industrial office which still employs this method, but in view of the very large number of policies involved the use of punched cards is becoming increasingly common and has definite advantages.

The best system to follow will, of course, depend on the organization of the office and no general rules can be laid down. In any case, however, it seems that a card should be punched initially from the proposal papers giving the fullest possible information concerning the policy.

In both industrial and ordinary assurance records, it is usual, as soon as the initial card has been punched for a new case, to make a copy of it by means of a reproducer, so that the first card can be filed in the in-force set and the duplicate can be used for such purposes as the monthly or quarterly tabulations of movement. If further cards were required for any purpose, they could be obtained by reproduction from the duplicate card. This procedure ensures that the in-force set of cards is always complete and up to date. The duplicate and any further cards which may be prepared are normally destroyed once they have served their original purpose.

(iii) (*a*) *Ordinary branch valuation records*

Since the earliest times cards have been used to compile valuation data. Before the days of punched-card equipment this often involved a great deal of work as is evidenced by the following extract from the valuation report of one office:

In obtaining the particulars from the cards, every operation has been checked, and this has involved the necessity of passing each of the cards through the hands of sixteen persons, and the calculations, which occupy more than eight thousand sheets, have all been twice checked.

Punched-card equipment has done much to simplify the work of a life office valuation. An ordinary branch valuation card will normally record the policy number, sum assured, table, term, valuation grouping, the office and net premiums, outstanding instalments and any valuation constants required such as $P \times N$ or Z. The office premium on the valuation card will be the total yearly premium and will therefore differ from the premium on the renewal card when premiums are payable more frequently than yearly.

The in-force for each valuation can be obtained by tabulating all the cards in force at the date of valuation but the more common procedure is to use a continuous method of classification. By this means the valuation records at one valuation are brought forward to the next valuation by a tabulation of the movement only. A tabulation according to valuation groups is made in respect of all movements 'on' and 'off' the in-force. Summary cards are punched for each valuation group in respect of all on and off movement for each quarter of a year or other suitable period. These cards would contain a punched indication of their sign (plus or minus) and by passing them through the tabulator with the summary cards of the in-force at the end of the previous year, the new in-force is automatically obtained.

If a continuous method of classification is employed it is not essential to keep the valuation cards in valuation grouping. It is possible therefore to combine the valuation and renewal cards in one card.* Such a combination, although attractive from many aspects, suffers from grave disadvantages if it is desired to change the valuation basis or to carry out any special investigations. On the whole it would seem better to employ two sets of cards, one for renewal work and one for valuation, particularly as so much of the information required for valuation is inapplicable to renewal work and vice versa.

Whether working from summary cards for large groups or in-force cards for small groups the tabulator can be used to print the valuation schedules direct and, except when Lidstone's Z method is used, the factors can be entered automatically from cards at the same time.

With punched-card equipment a change of valuation basis is not such a formidable task as it was in the days of handwritten cards.

Punched-card equipment is particularly useful if the *n*-point method of valuation is employed.

(iii) (*b*) *Industrial branch valuation records*

It is not customary to punch net premiums and other valuation constants into the card for an individual policy. This practice originated in the days when handwritten cards were used and to do so would have been a very laborious task. Today, with the use of punched-card equipment, the practical objections are less strong and it would be quite feasible to punch net premiums, etc., into the individual cards, particularly where a separate card, reproduced from the record card, is used for valuation purposes. The cards for the new business could be sorted periodically into table, age at entry, and weekly or monthly premiums, and the valuation constants (normally only the net premium) gang-

* See *Application of the Powers System to Ordinary Branch Work*, by W. E. H. Hickox, *J.S.S.* Vol. III, p. 303.

punched into each subgroup. The exit cards could be treated similarly where they did not already contain the necessary particulars. However, in view of the large number of policies involved, it is questionable whether this procedure is worth while, particularly in view of the difficulties involved in a change of basis. In general it would seem preferable to defer the insertion of the valuation constants until a later stage, or to keep the data so subdivided that they can be obtained from factor cards.

The most common procedure is to group the business under each table by year of entry and age at entry. It is not practicable to sort the whole of the in-force in this way at each valuation and a continuous system of classification is essential. For the new business and revivals, cards are punched and sorted into table, year and age groups. Either the record card itself or a card reproduced from it can be used. For the exits no card need be punched as the record cards themselves can be extracted from the files and sorted into the same groups. Using the summary card punch a summary card of 'ons' and 'offs' can be obtained for each year and age, and, by passing these through the tabulator with the summary cards for the previous year's in-force, the new in-force is obtained. This procedure can be carried out either once a year or more frequently. There is much to be said for doing it quarterly or even monthly, thereby reducing the amount of machine work to be done at the peak period at the end of the year. Moreover, these totals can be reconciled with figures obtained from other sources, so that any errors can be rectified during the year.

In the foregoing remarks it has been assumed that the sum assured is punched in the card. In the unit method of valuation, using a year of entry grouping, this is not always done, the sum assured being dealt with in the same way as other valuation constants. Where punched cards are used, however, there should in general be no difficulty in punching the sum assured. There are obvious advantages in doing so, and it saves one set of calculations in the valuation.

The year and age grouping gives both the age at entry, on which depend the valuation constants, and the attained age for the valuation factors. The next step is the insertion of the valuation constants. This will normally be done by hand on tabulations of the summary cards for each sub-group, but it could be done on a multiplying punch. This is discussed later.

It is a common practice to value the business for each year of entry separately. Where this is done the calculation of the net premiums, etc., is made at the same time as the calculation of the present values. Factor cards are prepared in advance showing for each year of assurance the amount and value of the various items per unit policy. The factor-card figures are then multiplied by the number of units in each group to obtain the valuation figures. This method has certain advantages but seems rather laborious. It is not recommended when the staff available is small.

Another procedure is to insert the constants in the year and age tabulations and then punch fresh summary cards including these constants and also the attained age (or year of birth). These cards can then be sorted into attained ages and retabulated, thus providing the data for a normal attained age valuation as in the ordinary branch.

The treatment of bonuses may present some difficulty, depending on the form in which they are granted. Where, however, the accrued bonus depends on duration only it can be treated as an additional valuation constant and inserted on the year and age tabulations.

(iv) *Mortality investigations, etc.*

Although the use of one card for both valuation and renewal records is not advisable it is unnecessary to keep a separate set of cards for each aspect of life assurance records. For example, the records required for the continuous mortality investigation can be obtained from the valuation cards. Initially an in-force must be set up but it can be kept up to date by a continuous classification method, providing each valuation card contains the necessary information for correct grouping in the continuous mortality investigation and a special punched position to indicate that the case is included in the investigation.

After the movement cards have been used for the continuous valuation tabulation they can be re-sorted and tabulated for the mortality investigation.

(v) *Accountancy*

Punched-card machinery can be used for many accountancy tabulations and calculations not peculiar to life office work such as shareholders' records, dividend payments, staff records, and 'pay-as-you-earn' income tax. These uses have received detailed attention in other places and space does not permit their discussion here.

It is necessary, however, to avoid the error of introducing punched cards in addition to existing accountancy methods merely to obtain more analyses than are possible under a manual system. Economic and effective use of punched cards for accounting involves the setting up of a card at the earliest possible stage and the abandoning of many of the usual concepts of columnar accounting.

(vi) *Mark-sensing*

It is, perhaps, appropriate here to consider to what extent mark-sensing can be used for building up the various records that have been discussed.

When the information on the cards is obtained from internal sources, the choice between mark-sensing and direct punching depends mainly on the staff available. Direct punching is probably somewhat quicker, but it requires skilled operators. Marking the cards by pencil can be done by relatively unskilled staff and may be an advantage where skilled operators are scarce.

Where, however, the information is obtained from external sources, e.g. on schedules compiled by the agents, mark-sensing may be helpful. For instance, an industrial office wishing to repunch its in-force cards from the agents' records could supply the agents with blank cards to be marked and returned to head office. The most satisfactory results would probably be obtained where information is required at regular intervals from the same individual, so that he becomes used to marking the cards properly.

(vii) *Controls*

It is not possible in this paper to give any detailed consideration to the controls which should be introduced in a punched-card system. These controls may be limited to ensuring that no cards are lost, but more systematic controls providing a check on number of policies, sums assured, premiums, etc., can be employed. In particular a premium control can be used to provide the basis of a premium accounting system. Starting from a pack of cards (possibly renewal receipts on interpreted cards) representing the renewals due in a particular month, a tabulation of these cards provides the debit for the month. As each premium is received the card for the policy is withdrawn and a check of the debit for the month less premiums received against the total of the premiums on the cards still in the pack is always available.

V. PRODUCTION OF FORMS

(i) *General considerations*

An enormous number of forms, notices, etc., are written or printed each year in connexion with assurance business. The following may be mentioned—acceptance form, policy form, policy register, proposal papers facing sheet, renewal notice, renewal receipt, lapse notice, bonus notice, maturity notification, claim papers facing sheet, renewal lists, commission lists, agency record card. Careful consideration should be given to the possibility of mechanizing each of these items and to the best method to be employed.

Punched-card equipment can be used for printing many of the various forms, and in considering its use for this purpose an important objective should be to employ a card which has already been punched for another purpose. It is the punching of the cards that takes most time and if a card has to be specially punched much of the advantage of using punched cards may be lost. It should be borne in mind that not all the information punched into a card need be printed if it is not required.

No mention need be made here of the printing of renewal lists and renewal notices, as the printing of these from the renewal cards has been discussed in the preceding section.

(ii) *Policy forms*

The printing of policies from punched cards is likely to become increasingly popular in this country. At present it is confined mainly to industrial branch policies. This is probably because it is not possible to use paper of the weight and texture normally employed for ordinary branch policies and because all the particulars usually given in an ordinary policy cannot be punched into one card. If several cards have to be used it ceases to be an economical proposition. In addition, ordinary branch policies do not lend themselves to easy standardization of form.

In the industrial branch, however, paper of adequate strength and durability can be used and all the particulars can be obtained from one card. The speed with which policies can be printed on the tabulator makes it a very attractive method when very large numbers are involved.

The ideal arrangement is to print the policy from the record card. This avoids the necessity of punching a special card and automatically ensures that the records and valuation data agree with the policies issued. The record card will normally contain all the information required except the address and the relationship of the proposer to the life assured. It is generally possible to get the names of both the proposer and the life assured on the record card. The relationship can be punched into the card and printed on the policy in the form of a numerical code, the key to which is incorporated in the body of the policy. The procedure is complicated if the address is included in the policy as this must be typed in or printed from a second punched card. The inclusion of the address serves little purpose and its omission is likely to become customary as this method of printing policy forms becomes more popular.

Continuous feed stationery would be employed, the individual forms being separated by perforations. A machine is available for separating them after they have passed through the tabulator, and at the same time cutting off the sprocket holes by which the paper is fed into the tabulator.

A difficulty at present arises in connexion with the stamping of the policies. Somerset House will not accept continuous stationery for stamping if the width exceeds 14in. This is unfortunate because it rather cramps the policy on account of the lengthy extracts from the Industrial Assurance Acts which have to be printed on industrial branch policies. If larger forms are used, they must be stamped separately. This means either stamping them after they are printed, which is not generally convenient, or feeding them individually into the tabulator, which greatly slows up the process.

The suggestion has been made that the Stamp Acts should be revised to allow industrial policies to be issued without being individually stamped, the stamp duty being paid in bulk.

If pre-stamped continuous stationery is used, it is necessary to have a separate pack for each stamp value, or at any rate for the more popular denominations. This means that the cards must be sorted into stamp denominations before passing them through the tabulator. To simplify this sorting, a single figure code can be punched into the card to denote the stamp value required.

(iii) *Industrial branch policy registers and collecting books*

The cards which are used to print the policies can be immediately passed through the tabulator again to provide a printed list of policies issued, probably in district and policy number order. These lists may be used to build up a policy register and if printed in duplicate (using interleaved paper) a copy can also be sent to the district office to form the basis of a district office policy register.

Punched cards could also be used to print the agents' collecting books. To do this, it is necessary to group the cards relating to a particular agent's debit in walking order, so that all cards for the same address are brought together. The cards must be punched initially direct from the agent's collecting book. An address card is punched, followed by a detail card for each policy. The cards are then passed through the tabulator and printed on suitably prepared forms so that the address appears at the top, followed by a list of the policies. As each address card enters the tabulator, it skips to the next form. The forms are then used as a loose-leaf collecting book. A total of the weekly premium for each address is also printed, but where more than one owner is involved this may need to be split to enable arrears to be correctly apportioned.

An in-force file of cards must be maintained in the order in which they are printed, movement being carried out throughout the year so that new collecting book pages can be printed at the end of the year. To facilitate this, it seems necessary to code the addresses so that the appropriate code can be punched on each card. This would be practicable only in a block agency system.

It is doubtful whether the method is economical for an office which already maintains an in-force file of cards in some other order, and its application is probably limited to offices which are setting up a file for the first time.

(iv) *Bonus certificates*

The preparation of bonus certificates issued in connexion with ordinary life assurances would be a major undertaking for a large office unless some mechanical means were employed.

Punched-card machinery is particularly suited to the preparation of these certificates. Details of the systems vary but most systems have a bonus card

for each with-profits policy which has punched on it the name, policy number, sum assured and bonus to date. Other information such as year of entry, table, agency, etc., will be punched on the card as required for (i) determining the rate of bonus, and (ii) distributing the bonus certificates. When a declaration of bonus is made the bonus cards are sorted according to sum assured and any other factor which affects the rate of bonus. The new bonus is gang-punched on to the bonus cards and the total bonus inserted by a cross-adding punch or by summary punching with a rolling total tabulator. Bonus certificates can be obtained from the bonus cards in the form of an interpreted card or by means of a tabulator. It will normally be possible to include more than one declaration on the same bonus card and when all the columns have been used a new set can be prepared by a reproducer. Alternatively, a fresh bonus card may be prepared for each declaration, the old card being used as the bonus certificate by interpreting the information on it. Before it is despatched it is reproduced with the total bonus figure transposed into the existing bonus field. The reproduced card is then ready for the insertion of the next declaration of new bonus, the procedure already described being repeated.

(v) *Notices to agency staff*

Interpreted cards are particularly suited for policyholder's record card, notification of policy maturing, notification of industrial policy becoming a free policy and similar notices to agency staff.

VI. CALCULATIONS

(i) *General considerations*

Life offices in this country have not as yet used punched-card equipment at all extensively for actuarial calculations. It seems clear, however, that there will be a steady increase in this application. There is an extensive literature on the use of punched-card equipment for general calculations. In this paper the authors can do little more than refer to the more obvious applications and give some references to papers which deal with actuarial calculations. *The Multiplying Punch in a Life Office* by M. Lander, *J.S.S.* (1948) Vol. VII, p. 189, gives examples of some uses of the equipment for such calculations.

(ii) *Bonus calculations*

The use of punched-card machinery for the calculation of the bonus standing to the credit of a policy after a valuation has already been referred to in the previous section of this paper. This is of course a very simple calculation.

(iii) *Valuation calculations*

A multiplying punch can be used for the calculations involved in valuing policies in groups. It saves time if the valuation factors can be punched on a set of cards prior to the valuation and hence the fixed maturity age method of valuing endowment assurances is particularly appropriate. The actual calculations involved in a valuation are a small part of the total work and it will normally be found as economical to carry out the work on electrical calculating machines.

However, where a multiplying punch is already available it might be found worth while to use it for some of the preliminary calculations, particularly for industrial branch business where the number of such calculations is large. Reference has previously been made to the possibility of using it for calculating net premiums. The summary cards of the in-force by year of entry and age at entry could be sorted into table and age at entry only. The net premium per unit policy (say per 1*d.* weekly premium) could then be gang-punched into the cards. The cards would next be passed through the multiplying punch, which would multiply the unit net premium by the total number of units (say total weekly premium) and punch the product into the cards. They would then be ready for sorting into attained ages. Other valuation constants could be similarly treated.

(iv) *Construction of tables*

It is in the field of construction of tables that the calculating side of punched-card equipment can be most useful to the actuary. Space does not allow us to set out a description of the procedure to be adopted, but we would refer those interested to the following American papers:

Use of Punched-Card Equipment in Calculating Group Annuity Rates, by M. D. Miller and R. P. Coates, *The Record* (June 1941), Vol. XXX, p. 58.

Use of Punch-Card Equipment in Computation and Listing of Premiums and Reserves under Joint and Last Survivorship Immediate Annuities, by E. A. Abbott, *T.A.S.A.* (1939), Vol. XL, p. 13.

Use of Punched-Card Equipment for the Calculation of Policy Values and Guarantees, by R. T. Wiseman, *T.A.S.A.* (1943), Vol. XLIV, p. 326.

Remarks by J. J. Finelli in the discussion on *Rates for Participating Policies*, by H. R. Bassford, *T.A.S.A.* (1943), Vol. XLIV, p. 129.

Reference can also be made to the review of *Valuation Tables on the Oriental Mortality Experience*, O(25–35), by C. D. Sharp, *J.I.A.* Vol. LXXII, p. 292.

The main objective in using punched cards should be to reduce the number of machine operations to a minimum, and this offers great scope for the use of ingenuity in planning the operations. In general, multiplications such as

$$v^x \times l_x = D_x$$

will be done on the multiplying punch, and additions on the tabulator. Continuous additions (e.g. $N_x = \Sigma D_x$) are made by taking a sub-total after each card. The use of the interpolator or collator for linking up two sets of cards (e.g. a factor card and a data card) should not be overlooked.

Tables can be printed by a photographic process direct from a tabulation of the punched cards, thus saving all typesetting and checking.

(v) *Mortality investigations*

Punched-card equipment can be used with advantage in calculating the expected deaths in a mortality investigation.*

(vi) *Calculations without a multiplying punch*

It must not be thought that it is impossible to use punched-card equipment for calculations when no multiplying punch is available. A method known as

* See *Some New Uses for Modern Punched Card Equipment*, by C. E. West, *T.A.S.A.* (1934), Vol. XXXV, p. 265.

progressive digiting makes multiplications possible when a tabulator only is available. Those interested are referred to:

Mechanical Multiplications by Use of Tabulating Machines, by W. A. Milliman, *T.A.S.A.* (1934), Vol. xxxv, p. 253.

Industrial Assurance. Valuations and Valuation Machinery, by R. J. Fagg and G. A. Hosking, *Transactions of the Tenth International Congress of Actuaries* (1934) Vol. v, p. 301.

The Application of some Commercial Calculating Machines to certain Statistical Calculations, by H. O. Hartley, Supplement to *J.R.S.S.* (1946), Vol. viii, p. 154.

(vii) *Punched-card libraries*

Sets of punched cards may replace printed volumes of tables as values can be extracted from such sets automatically without risk of error. As an example, mention may be made of a set of industrial branch free policy tables which is kept in this form by one office.

VII. FUTURE DEVELOPMENTS

Over the last decade there has been tremendous development in the use of electronic devices for all kinds of calculations. The war has yielded big advances in electronics due to large research and development programmes for radar display equipment and gunnery predictors. There has also been a greatly increased need for differential analysers and other calculating machines. It may now be said that provided the necessary money and research capacity are available a machine can be developed to carry out practically any calculation problem which can be specified. Admiral the Viscount Mountbatten in a presidential address to the British Institution of Radio Engineers in 1946 drew attention to these developments. He mentioned the electronic brain which will receive information about the situation of the machinery under its control and provide an *intelligent* link between that information and the action necessary to keep the machinery in general conformity with the overall directions given to it by man. He also referred to a machine which could be made to play a rather mediocre game of chess!

These developments are in the field of calculating machines and not punched-card machinery. The use of punched cards in the I.B.M. Automatic Sequence Controlled Calculator and in E.N.I.A.C. is purely incidental, punched cards being used to feed data into or record the results of the machines. A brief appreciation of the recent and prospective developments in this class of calculating machine is given in *Calculating Machines* by D. R. Hartree, Cambridge University Press, 1947.

Modern electronic equipment is a most fascinating subject and it is interesting to speculate to what extent it will become the handmaid of the future actuary. A paper by E. C. Berkley, *T.A.S.A.* Vol. xlviii, p. 36, gives a brief description of the more important electronic calculating machines which have been constructed in the United States of America and speculates on the use of such machines in the future for life office work. He envisages a machine which will carry out the work at present done by punched-card and similar equipment in the office as well as all the calculation work for valuations, quotations, etc. Such speculation is probably rather fanciful at the moment, though development is taking place so rapidly that it would be unwise to be dogmatic about future possibilities. Electronic equipment is of proved worth for complex

problems in calculation, including the storage of reference tables, but it may not be generally realized that it is capable of being used for the storage of factual information in the same way as a policy register or a bureau of punched cards. There are, however, many practical problems to be solved before the equipment can be made to release such stored information in a form which can be used satisfactorily for office records or for producing renewal notices and all the other forms required for life assurance work. The figure of £20,000 to £50,000 mentioned by Berkley for such a machine includes no allowance for the cost of development, but it does indicate that the price may be comparable with that of an average punched-card installation. It seems likely, therefore, that life offices, or groups of offices, will purchase electronic machines which will do the work of graduation and construction of tables, and possibly the calculation of surrender values and the annual valuation calculations.

The search still goes on for a really satisfactory solution of the problem of combining the advantages of the present punched-card systems with those of the printing plate, the former so convenient for sorting and tabulating, the latter so convenient for printing renewal notices including the full address of the assured. The magic word 'electronics' does not yet bring us very much nearer to the solution of this problem, but electronics will no doubt help to solve it and pave the way for further advances.

VIII. CONCLUSION

In conclusion it is perhaps fitting to quote from some remarks on punched-card equipment made by Sir Joseph Burn in the Presidential Address for the year 1927: '...this class of machinery is most dangerous in the hands of non-experts, but is capable of boundless advantages in the hands of the skilled mathematician who is used to seeking the quickest methods of obtaining practical results, as is most certainly the case with the best actuaries.'

There are doubtless a number of important omissions in this paper, and where the authors have expressed opinions many will disagree with them. But if they have succeeded in giving a bird's-eye view of the present uses of punched-card equipment in the life assurance industry, they have achieved their purpose. Anyone interested in a particular aspect will need to study it in far greater detail than has been possible here. He will find, however, as the authors have done, that a wealth of advice and experience will be readily placed at his disposal both by the manufacturers of the equipment and by other users of it.

The authors are indebted to several members of the staffs of the two firms manufacturing the equipment for their helpful comments and suggestions.

ABSTRACT OF THE DISCUSSION

Mr N. E. Coe, in introducing the paper, expressed Mr Hedley's regret at being unable to travel the rather considerable distance necessary if he were to be present that evening.

There were many omissions in the paper. It would have needed a book to cover all the ground. There was, however, one point to which the authors' attention had been drawn and to which he wished to refer. That was the question of accuracy. The authors did not (as the paper might seem to suggest) believe that errors could not occur in the use of this equipment, but the means of detecting errors and ensuring accuracy depended so much on the particular system in use that it was almost impossible to make any general statement on the matter. The errors were of different types. In the first place, there were errors in the sources from which the data were obtained. They would arise under any system and were probably outside the scope of the paper. Errors could also arise in the punching of the cards. They were largely dealt with by the verifiers described in the paper; but errors could occur even when verifiers were used, and it was perhaps worth mentioning that where a document such as a policy or a renewal notice was prepared from the card, that did in fact provide a further check, because it might be hoped that, if wrong, it would be returned for correction.

Then there was the question of cards being mislaid or not punched at all. That was not so easy a matter to deal with as might be felt at first sight, because where a completely mechanized system was in use almost all the figures required would be obtained from the cards which had been punched, and therefore, if a card or a group of cards was omitted, it was not always easy to detect the fact. The ideal, of course, would be to check the card totals against some total obtained independently of the cards; but to do that might require a departure from 100% mechanization, and that was not always convenient or desirable. He thought that all that could be said was what in fact was said in the paper on the subject of controls, that they should be inserted wherever possible; but he felt that such controls should be obtained from the system in use. Unless it was absolutely essential to do so, it was not economic to introduce processes purely for the purpose of obtaining control figures.

The question of accuracy was in essence a question of the time and money to be spent on the system. It was rather like a convergent series; the sum to infinity might represent 100% accuracy, but the more terms were taken, the slower the approach to that 100% accuracy became. He thought it could be said that it was possible to rely on a very high degree of accuracy from these machines, and that it was probably good enough to use reasonable safeguards to ensure that errors were not of a major kind. A point to bear in mind was that the machines had no sense of discrimination, and, if they were going to make a mistake, they would make it as cheerfully in the millions as in the units.

In conclusion, he would like publicly to thank members of the staffs of Hollerith and Powers for their valuable assistance in preparing the paper, and also to thank various actuarial colleagues for helpful criticism at different stages of its preparation.

Mr Max Lander, in opening the discussion, said that there were still some people who seemed to think that there was something a little improper about the use of punched-card machinery. For his own part, he was frankly an advocate of these machines, and for that fact he made no apology at all. He had been very pleased to hear that a paper on the subject was to be read before the Institute, because it was a very long time since anything on punched-card machines had appeared in the *Journal*, and the present paper was the first solely on the subject of punched-card equipment to be presented to the Institute.

If, after reading the paper, he was to a certain extent disappointed, the reason for that was that he had hoped that the authors would seize the opportunity to indicate possible lines of future development to a much greater extent than they had. The relative space which they had devoted to the history and development of the equipment and to a

description of it and of some of its applications in actuarial work, as compared with the small section on the possible future uses of the machines, was so great as to render the paper largely a record of what had happened in the past. That aspect of the subject was interesting, but, in his opinion, what was needed was a bold departure from present well-established lines of action which would fire the imagination and result in advances, both administratively and technically.

He wished to consider some of the details of the paper, but before doing so he would like to make the general comment that the authors had assumed that the readers of the paper knew nothing whatever about punched-card machines. That assumption was underlined in the introduction, in which the authors expressed commendable concern that students should be able to follow them without trouble. Such concern should always be in the minds of those who wrote papers, in particular for the Students' Society. Whether some of the statements in the paper were justified when discussion before the Institute itself was in view might be questioned, particularly as the reader was supposed to understand references to E.N.I.A.C. and the Automatic Sequence Controlled Calculator.

There was a number of references to many excellent American papers on punched-card machinery. That emphasized the lack of British work, at any rate in actuarial literature, to which Mr Coe had referred, though, on a broader view of punched-card and other methods of computation, such British names as those of Prof. Hartree and Dr Comrie were pre-eminent throughout the world.

About half the paper was devoted to a short historical note followed by a description of the machines. That description largely comprised matters of fact, and it might be thought that there was not much room for differences of opinion. It was important, however, and it was not quite as easy as might be thought, to get those fundamental facts correct. There was a good deal of difficulty in defining a fact precisely when using words only, and it was not always easy when using mathematical symbolism; but as perforce those facts had to be expressed in words, care was necessary that the correct ideas might be conveyed.

When it was desired to compare the merits or demerits of the two rival sets of machines produced in this country, the facts were comparatively nebulous, and it was therefore all the more important to be very careful about conveying the right shade of meaning. Some time ago he had had occasion to make a detailed analysis of the two types of machine, the 'Powers machines' *vis-à-vis* the 'Hollerith', from the point of view of an actuary, and on a certain number of points he found himself at variance with the conclusions reached by the authors.

On p. 251 there was a description of the over-punching system. It was very important, in his view, to read that in connexion with what was said in the section on the *Tabulator* where it was explained that the prolific use of over-punching on the 'Powers' card caused difficulties in the connexion box, which to a certain extent militated against the advantages claimed for the device. He mentioned that because it was important when assessing the relative card capacity of the 'Hollerith' card compared with the 'Powers'.

In passing, he would make a minor criticism of the coding example at the bottom of p. 251. He thought that it was an unfortunate one. A much more practical code to use was m where the premiums were payable m times a year.

In the section on *Punches* the authors said 'The machines produced for "Hollerith" and "Powers" are not dissimilar'. It was true, of course, that the objects for which the machines were built were the same, but in his view the machines were dissimilar and, in fact, the greatest dissimilarity between the two systems was to be found in the automatic punches. He thought that it was worth mentioning that the 'I.B.M.' punch in America (the American version of the British 'Hollerith') was very different from the punch obtainable from the British Tabulating Machine Company, and in his view it was considerably superior. It was much more like the 'Powers' automatic key punch, and it was a pity that it was not available in Britain; it was to be hoped that it would be one day.

With regard to the reproducer, there should be a reference to the fact that the 'Hollerith' machine contained a checking circuit which did not exist in the 'Powers'

machine. The check compared the newly reproduced card with the card from which it was reproduced, and if there were any errors in the newly punched card—i.e. if it did not agree with the original one—the machine stopped, and those errors were automatically indicated. It could be argued that the 'Powers' machine was perhaps more robust mechanically than the 'Hollerith' because it depended on direct mechanical action and probably did not need such a checking circuit. On the other hand, the checking circuit was of considerable value in itself because, apart from acting as a check on cards which had just been punched, it could be used for comparing existing cards which had previously been punched.

In the same section of the paper, the authors referred to the 'Hollerith' method of ganging from interspersed master cards. An additional feature was obtainable known as selective reproduction. It was difficult to explain in words without having a machine for demonstration. Where on the cards there were a number of different fields in which information might change, but not always on the same field, a new set of skeleton cards could be punched containing the new changed information only, and by interleaving those with the old cards containing all the information—i.e. the rest of it which had not changed plus the information which was now incorrect—the selective reproduction would yield a new card which contained the new information where there had been a change together with all the old information where there had been no change. That was a very convenient arrangement. The machine automatically picked out the field (wherever it happened to be) where the information had changed, and put it on the new card together with all the old information.

With regard to the interpreters, he felt that the 'Powers' machine was somewhat superior to the 'Hollerith' because it was rather more flexible with regard to the place of the printed information on the cards.

He wished to comment in passing on the use of the term 'sub-total'. It was used on p. 253, and in the section on p. 256 dealing with the construction of tables. It was generally taken to mean an accumulative total, a total such as was formed when in the calculation of N_x from D_x, and not a complete total. In the section on the *Tabulator* it was stated that, where control was exercised, sub-totals were taken; that was misleading. The authors meant that totals of groups or classes were taken, which totals then built up again from zero, after the exercise of the control.

On the question of the summary card punch, there was an essential difference between the two rival machines. The 'Powers' summary card was a large affair which ran on a pair of rails and could be used only for summary card punching, whereas the 'Hollerith' machine was merely an ordinary reproducer with an additional circuit, connected to the tabulator by an 80-core cable which took the information across. The depression of a suitable switch enabled that reproducer (which could be used at other times for its normal purpose) to be used as a summary card punch.

In the section on *Mark-sensing and spot-punching*, the authors stated, quite correctly, that the portion of the card used for marking was available for ordinary punching, so that the full 80 columns could ultimately be punched. It was important to realize the exact implications of that statement. Owing to the fact that the mark occupied the width of three columns, the maximum number of columns that could be mark-sensed on a card was 27 on each side, a total of 54. If, therefore, it was desired to use the full card, the remaining 26 columns had to be punched by ordinary methods.

The development of mark-sensing was in its early stages, at least in Great Britain, and, if there should be an application where it was important to mark-sense the whole card, it would seem that that might be possible by insisting on a higher standard of marking, and by arranging the circuit of the machine to pick up the mark from two column-widths instead of three, so as to get the complete 80 columns by means of the front and back of the card, mark-sensing the whole of them. There would be a rather higher chance, of course, of picking up errors. So far as he knew, such a machine had not been produced, but he saw no reason why it should not be, if the need were great enough. In his opinion, which might be contradicted by other users (he would be glad to know whether it was), spot-punching was not comparable with mark-sensing, and was in fact considerably inferior to it.

It might be mentioned that multiplying punches could deal in certain cases with negative signs as well as positive. Although that was a small point, it was important. For working in sterling with multiplying punches the 'Hollerith' machine was very limited indeed, the 'Powers' machine being considerably better.

The remainder of the paper, except for the last page or so, was concerned with a description of what had been done in the past, and what might be done in the future to some extent, through mechanization in life office practice, and he would leave it to those who were more intimately concerned with life office business than he was to comment on that in detail.

On p. 258 the authors referred to the printing of addresses. There was a punched-card method, known as stencil collating, which had been developed in the United States to a considerable extent during the war 1939–45, when it was used, he believed, to produce pay-checks for the dependants of men in the American Army. It was worked by the use of a specially thick punched card, having the thickness of three ordinary cards stuck together, which on its left-hand side had the ordinary columns in which holes could be punched, using a punch in which the feed had been adjusted to take those specially thick cards. The right-hand three or four inches of the card contained an ordinary Japanese tissue stencil on which information could be cut in the normal way. Those cards were fed into a special collator in which the stencilled information could be printed in normal fashion. The system had the great advantage of combining stencilled information with the control and speed of the punched card. He believed that there had been one or two attempts to do that in Great Britain, but they had not been very successful. Whether that was the ideal solution of the problem he did not know, but he thought that it was one which was worth investigation.

It was very tempting to embroider the electronic machinery theme which appeared in the last section of the paper. It was a fascinating subject. Those who had listened to Dr D. H. Sadler the previous week at the Students' Society were open-mouthed at the description of the latest electronic calculator. However, though he hesitated to cross swords with Lord Mountbatten, he deprecated the use of the word 'intelligence' in connexion with those machines. He was in good company there, as Dr Comrie had also deprecated the use of the word 'intelligence' in a similar context. The essential feature, he believed, of any of the machines that had yet been built or planned was that both numbers and orders were fed into the machine but that what came out were always numbers. Until a machine could be produced which would replace human judgment to some extent, he thought that the use of the words 'brains' and 'intelligence' was out of place.

He was in entire agreement with the authors' assertion that there were tremendous possibilities for using punched-card machines in actuarial work and life office practice, and personally he thought that it was a very good thing that the whole question had been discussed at a meeting of the Institute. In the small section on *Accountancy* the authors said 'Economic and effective use of punched cards for accounting involves the setting up of a card at the earliest possible stage and the abandoning of many of the usual concepts of columnar accounting'. That was fundamental not only in connexion with accounting but from a general point of view, and he thought that its importance could not be over-emphasized. He would like to see a paper or a series of papers devoted to building up punched-card systems for actuarial work and life office practice taking into account both the capabilities of all the machines available on the market and those of such new machines, including electronic machines, as might be developed later. The authors had not attempted to cover such a wide field, and had limited themselves to laying the foundations. It was for others to erect a building on those foundations for the advantage and use of all. Lest anyone should think that that was, perhaps, not work for actuaries as such, he would conclude by stating his conviction that it was a task which would be accomplished successfully only by combining actuarial judgment in its widest sense with a detailed knowledge of the machines.

Mr F. H. Spratling, referring to the section on *Accountancy*, agreed that it was not possible for the authors to deal comprehensively with punched-card techniques in

a short paper; but, whilst it was true that those techniques were first seriously developed for census work, and were applied in this country to industrial life assurance at an early stage, he thought that perhaps the main stimulus for subsequent development had come from accountancy. In his view, many developments had taken place which would never have occurred if the machines had been applied merely to census and life office work. All sorts of accounting jobs were being done by punched-card methods, for example, ledger posting, costing, stores control and stores accounting, invoicing, pay-rolls, including income tax deductions under the 'Pay-as-you-earn' system, and so on. Punched cards had been stamped with postage stamps and sent through the post without envelopes; they had also been used as cheques, being passed through the banks in the ordinary way. Many of those developments would not have been required in the life office field alone.

In a large organization, it was interesting, and often important, to decide whether a particular job should or should not be undertaken by punched-card methods. There were other excellent and versatile mechanized systems each of which, properly applied, reduced clerical costs. It was not his intention to discuss the alternatives in any detail, but it was relevant to ask what were the qualities which made a piece of work call for consideration of punched-card methods. He thought that there were three. First, volume was important. It was not economic to introduce punched-card methods for a small job. Secondly, was it of value to be able to rearrange the same basic data frequently for the purposes in view? Thirdly, would it be useful to preserve the basic data in a form in which it could be dealt with easily long after it had been created? He thought that if any one of those features was present there was a *prima facie* case for consideration of punched-card methods.

There was another problem which large organizations had to face from time to time. They might have a punched-card installation, doing a particular piece of work. If another demand arose which could be effectively dealt with by punched-card methods, the question was whether the second job should be superimposed on the existing installation, the installation being appropriately enlarged, or whether an entirely separate set of machines should be installed for the second job. In the former case, experience showed that all kinds of problems of phasing of work, machine loadings and priorities were apt to arise. He thought that provided the job itself was sufficiently large to justify a separate installation, the motto should be 'One installation, one job'. Superficially, that might seem extravagant but, in the long run, it was probably more economical and efficient.

He held the question of controls to be one of outstanding importance in the successful operation of a punched-card installation. Effective control must be of two kinds. First, it was necessary to control the data flowing into the machine room for completeness and accuracy, and secondly, once the data were in the machine room, the machine processes must be controlled for accuracy. It was easy to say that everything must be done twice, but, usually, that would be absurd. It was often more effective to introduce a control which would cross-check a result already obtained by some entirely independent process. An effective system of controls must not merely detect errors, but must detect them as soon as possible after they had been made, so that too much time should not be wasted on inaccurate material. It was a question of when, where and what controls should be included in the machine routine. He thought that the subject merited research. As an example, he would take the apparently simple question of checking the punching operation. What was the best method? Was it by interpreting and calling back with the original data, or by automatic verification, or by tabulating unchecked cards and calling back the tabulation with the original data, or was it by some other method? Members of the Institute might usefully direct their attention to problems of that kind.

He wished to mention one factor which, he thought, the manufacturers of the machines should keep in mind in the interest of users, namely stability of card capacity. When a decision was taken to introduce a punched-card system, it was usually a long-term decision. As time went on the nature of the work often changed in detail, and additional machines had to be installed. In that event, the installation would eventually

comprise machines of several different vintages. If subsequently a major change of system had to be made, some degree of capital waste would generally be involved. Stability of card capacity over a long period would minimize that sort of waste. He did not think it would involve sterility in technical development which, in the past, had usually proceeded independently of card capacity.

Mr R. L. Michaelson expressed his gratitude to the authors for presenting a paper on a subject which he found of great interest and which had had, he thought, less attention from the actuarial profession than it deserved. Personally, he had no doubt that punched-card technique in general would benefit from the close study of actuaries, and that offices in particular would benefit by way of economies if their actuaries examined their own punched-card installations. They would undoubtedly find means of improving their methods and of increasing the scope of the mechanized work.

He could add a little to the history which the authors had given. The earliest installations in Great Britain that he had been able to trace were all about the year 1904, and were in Woolwich Arsenal, Vickers, and the Lancashire and Yorkshire Railway. The cards had 37 columns, and the machines were hand-driven. Some of those machines could be seen at the Science Museum. The first installation to attract public attention was, he thought, that used for the 1911 Census.

He had been interested to read on p. 248 of the work of John Kinsey Gore. The name was new to him, and he had been unable to find any details of Gore's methods. The idea of sorting, not one card at a time, but all the cards, was sensational. The natural inference was that Gore used profile notching rather than punched holes as they were known today; the idea had been preserved in the Paramount system, where notches were nicked in the edges of the card. It would be most interesting if the authors could give some further information on Gore's work.

Mr Lander had referred to over-punching, which was a perfectly workable and a much-used artifice to increase card capacity. He thought that the authors, however, had given the wrong emphasis to it. It should undoubtedly be regarded as a device to be used only if the full card capacity was inadequate to do the job in any other way. He said that because there was a price to be paid for it, as might be expected. In that instance the price was a slight increase in the complexity of the punching. If over-punching was confined to one column that was not an important matter, but if it involved many adjacent columns the unfortunate punch operator had to recall the over-punching code and punch the information in the right place.

On p. 251, the authors gave an excellent example of how not to code. It would be possible to devote a whole paper to coding, but one obvious principle was to make the code as easy as possible to code and decode. For that reason he suggested using 1 for yearly, 2 for half-yearly, 4 for quarterly, and probably 9 for monthly. Then only the last figure had to be remembered. The rule should be to make it as easy as possible to memorize the code.

There were four main types of punched-card jobs for which mark-sensing and spot-punching were suitable. The first was where the cards were created at dispersed points and machined centrally. An example was the authors' suggestion on p. 262 that mark-sensing should be used where the information was obtained from schedules compiled by agents. The fundamental assumption was that insufficient cards were created at any dispersed point to enable a full-time punch operator to be employed.

The second was where large numbers of punched cards were required for a special non-recurring job. It was often difficult to provide the necessary staff of trained punch operators for a short time, and it might be easier to gather together from the whole of an office's resources clerks who could learn to mark the cards by pencil or to use the spot-punch after a few minutes' coaching. Of course, it was not always easy to get such a body of clerks together.

The third was where most of the information on a document had to be coded before it could be punched. The recording of a code number could be telescoped into the punching operation, thus eliminating further hand-punching and not greatly reducing the speed of the coding clerks.

The fourth was where further information had to be added to an existing file of cards. In such work it was usually necessary to write the additional information on each card before it was punched. Mark-sensing and spot-punching were obviously economic in those circumstances.

With regard to the table of speeds on p. 256, he thought that the speeds obtainable in practice depended on many variables, amongst which were the number of columns to be punched, the layout of the documents, the skill of the operators, the general punch-room conditions, and, by no means least important, the payment of bonuses to punch operators. The Organization and Methods Division of the Treasury, who were no mean exponents of the punched-card art, gave the following speeds as having been actually attained in practice: for 80-columns punched, 120 cards per hour; for 55-columns punched, 165 cards per hour; for 20-columns punched, 700 cards per hour. *Machines and Appliances in Government Offices*, H.M. Stationery Office, 5*s*., from which he quoted the punch speeds, contained excellent descriptions and photographs of the machines and a description of a punched-card job. It dealt with all office machinery, and not merely with punched cards, and it was worthy of study by all who were concerned with office organization.

He would like to end, as he had begun, with a plea that intelligence such as an actuary could bring to bear on a punched-card project would benefit all concerned. It would avoid the deadlock which sometimes arose, as, for example, in the case of a successful business man who suddenly decided that his office methods were out-of-date. He examined most carefully all forms of modern office appliances, and decided on punched-card equipment. He wrote to the manufacturers of the equipment and said 'I shall be glad if you will instal three tabulators, two sorters and a reproducer, but I do not want any of the cards with the silly little holes'.

Mr H. F. Fisher referred to the 'Powers' system of inter-stage punching which was dealt with in the penultimate paragraph on p. 251. The method there was to cause the card to be lowered slightly so that a further hole could be punched between the normal columns. That enabled the card to be used to double its normal capacity, but he felt that the authors should have pointed out that it was not possible to verify such cards by the 'Powers' system of verification, and that to some extent limited the application of the method.

The question arose whether a job performed by that system of inter-stage punching was capable of independent check. There was the accounts job where the figures of the accounts might be obtained from other sources, and then the system might be an excellent one; but if the figures which were being used were, say, valuation data, he felt that the inter-stage method might not be suitable, in view of the fact that verification was not possible.

It was mentioned that specially designed equipment was necessary, and that, of course, was true; special punches were required, and a specially built tabulator; but if the designation on the normal punching and inter-stage punching was the same, and it was only intended to sort on that particular designation—for instance, on an accounts job if the designation was by district and by week, and the same designation applied to both stages of punching—an ordinary sorter could be used. A further point was that on that type of card it was not possible to use gang-punching, which was a considerable help in punching information quickly.

He thought that the suggestion with regard to mark-sensing and spot-punching was excellent, but he would question the issue of cards to be mark-sensed by agents in order to repunch the business in force of the office, as suggested by the authors. Experience of the work of agents did not lead one to suppose that mark-sensing at a distance just for one operation would lead to a great deal of accuracy. He felt that mark-sensing could be applied, as Mr Michaelson said, to smaller and more isolated jobs, but where it was a question of punching in-force cards for an industrial valuation there was enough work for proper punching by skilled operators.

Mr E. Jones said he imagined that in the last sentence in the section on the *Sorter* the authors were referring to the group-selection device which could be incorporated

in the machine. In the case of 'Hollerith', that could be operated on any number of columns up to eight situated anywhere on the card, and made it possible to select at one run all cards punched with a certain combination of code numbers in those particular columns. For example, all cards with date of birth 18. vi. 07, say, could be picked out in one operation. Whilst this device would make it possible to select on one run all cards with sums assured of exactly £500, it would not extract those with sums assured of all varying amounts over £500; the latter would be an operation for the collator.

He felt that in discussing the problem of the number of sets of cards to be used the authors had not dealt adequately with the main difficulty which arose in maintaining a duplicate file of in-force cards, namely the doubling of the hand-pulling work in respect of exits and other off-movements. Fortunately, the collator could be employed to deal with this problem. One method would be to hand-pull cards for off-movements from File 1 only and, when they had accumulated sufficiently, to sort them into the same sequence as that in which the File 2 cards were stored. The pack of off-cards would then be fed into the collator together with the whole of File 2 with the result that the counterparts of the former were removed from the second in-force file mechanically.

The method could, in suitable circumstances, be extended to obviate all hand-pulling. A skeleton card would be punched in respect of each off-movement to incorporate policy number and any other particulars (e.g. month of renewal) necessary to sort those cards into the same sequence as the in-force file. The off-cards would then be extracted by means of the collator.

He shared Mr Lander's disappointment at the extremely brief section on the use of the machines for calculations, and felt that the paper was thoroughly unbalanced. If, as indicated in the introduction, it was considered necessary to pay particular attention to the needs of students, why was not the paper presented in another place? It was, of course, easy to make such criticisms and he would be the first to admit how difficult it was to give a comprehensive account of punched-card equipment and its use without running to book length. However, he felt that discussion of the machines in general terms did not lead very far and that much more would be learnt by the detailed study of one type of installation.

Amongst the subjects referred to briefly in the section on calculations he saw no reference to one particularly interesting application, the use of punched-card equipment for differencing. Using cards punched with the successive values of argument and function the 'Hollerith' senior rolling total tabulator would calculate and print differences of all orders up to and including the fifth. For second differences, printing only x and $\Delta^2 u_x$, the speed would be about 1500 cards per hour. It was fascinating to watch the differences coming out of the machine. He thought that some indication of the methods by which that was accomplished would have been of value to actuaries.

Mr R. E. Beard wished to make one or two general comments which arose from his experience in using punched-card machines. The solution of the kind of problem arising in their use was to him rather like the solution of a problem in mathematics; the better the operator's equipment and the wider his knowledge of techniques, the tidier would his solution become. The remarks on p. 257 on the importance of taking an over-all view of any particular problem could not be over-emphasized.

During the war he had been associated with a computing firm, one of whose members had a reputation for ability with 'Hollerith' machines in particular. It was perhaps significant to note that he was a mathematics graduate who had specialized in the theory of functions, probably the purest piece of pure mathematics that there could be; yet he could apply himself to any problem and think of it in terms of the machines. That was what had to be done in any particular application; it was necessary to look at any particular piece of routine and recognize its mechanical analogue.

He did not intend to detail the advantages and disadvantages of different types of machine, but proposed to sketch briefly an installation which was being developed in connexion with the general branch. To his mind, it gave an indication of the form that some future installations might take. The first problem was to decide where the information was to be picked up. A consideration of the particular policies which had

to be issued showed that in a substantial proportion of the cases more information would be required than could be conveniently carried on a single punched card, and it was decided to pick up after the preparation and checking of the policy. A main file card was therefore prepared carrying the necessary information, and containing the name of the insured, the policy number, the agency, the premium and a few other matters. To avoid too many complications he proposed to discuss the procedure on renewal rather than in new cases. The cards were maintained in agency order in month of renewal, and the organization was such that the renewals were issued to the agents who maintained records of the addresses. The advantage of that was that the minimum amount of information was required to be carried on the card.

When the renewals for a particular month were to be issued, the cards were taken from the main file and a control total established by tabulation. If necessary, that could of course be checked with the previous year's figures, and involved quite a simple operation. The cards were then passed through a reproducer for the production of a debit card which was subsequently interpreted. For the production of renewal notices and receipts, the master cards were passed through a special interpreter which printed the information on to cards which were unpunched, but were the same size as the normal 'Hollerith' or 'Powers' card. The advantage of that machine was that the tabulator which was usually employed for preparing renewal papers, and which was the most expensive unit, was freed for the more important accounting and statistical work, and the rate of production could be appreciably stepped up as compared with the paper feed. A disadvantage of the method was that the notices and receipts were separated, but that was not a serious drawback and could be minimized in various ways.

The debit card, renewal notice and renewal receipt, so prepared, were sent to the agent who sent the renewal notice to the client and returned the debit card with the account on which the premium was remitted. Provision was made on the debit card for any further information required from the agent, such as the reason for lapse or non-collection, so saving correspondence.

After the renewals had been issued, the master cards were placed to one side as a current outstanding file. When the debit cards were received from the agents they could be handled mechanically for establishing premium payment controls and used with the collator to pick out their corresponding master cards from the outstanding file. The paid master cards could then be filed away for next renewal and the lapses put into a 'dead' file. The paid debit cards could then be used for statistical and record purposes, and after that sorted into a convenient order for use as a reference file for paid cases. By that means it was possible to cut out a vast amount of manual posting, ticking and checking and other details, which work was put on to the machines. The fact that a physical record of any particular case accompanied the accounting work meant that the simple process of comparison could be substituted in many operations for more complex purposes.

A subsidiary advantage of the scheme was that the renewal card machine could be used to establish cards for card indexes with the result that in a large organization it was possible to produce and maintain card indexes, a useful feature in branch office as well as in head office routine.

The system might perhaps be summarized as being a close approach to the desideratum expressed on the last page of the paper, in which the renewals and accounts were linked absolutely.

With regard to future developments, the subject of electronic machines was a popular one, and there was a good deal of loose talk on the subject, but it was perhaps of interest to note that only a year ago the Actuarial Society of America and the Life Office Management Association both appointed committees to investigate and explore the possibilities of making use of such machines. Of course, most of the machines were in America, and the Americans had more facilities in that respect. The authors rightly remarked that it was wise not to be dogmatic in comments about the future, but a little critical examination would, he thought, be very valuable in helping to maintain a balanced view of the position.

In 1938, when he was considering the construction of a differential analyser, he made

some attempts to devise an electronic machine to perform the same functions, but was unable to do so for various reasons, and therefore decided to adopt a mechanical method of dealing with the problem. The principles of applying that type of machine to actuarial calculation were outlined in his paper submitted to the Institute in 1941 (*J.I.A.* Vol. LXXI, p. 193). It might be remembered that the principle of application of the differential analyser was to feed μ_x into the machine and to calculate from it the actuarial function required. There would be no difficulty, however, in devising a machine in which a number of parameters to calculate μ_x were set up and fed automatically into the machine. As a matter of fact, therefore, the problem of quotations had been solved at least ten years previously by mechanical methods, since it was merely necessary to set up a differential analyser and press the button for the desired result.

Since then, electronic machines had been devised and development had followed two main lines. One comprised the so-called analogue machines, and the other the digital machines, of which the E.N.I.A.C. was perhaps the best-known example. Along different lines a small electronic differential analyser was built by Dr J. M. Jackson during the war and had been described in a publication of the Admiralty Computing Service. That machine had certain advantages; it was compact, cheap and fairly simple to operate, and he thought that a development of that type of machine would have some future in actuarial work. By appropriate design of the units they could be connected up to solve any quotation problem such as was described by the authors. He thought that research on this type of machine had virtually ceased, so that it was not possible to tell whether it had a future, but it seemed to him a development well worth pursuing.

On the question of using the special advantages of the modern electronic computer for other actuarial problems, it was clear that such machines could be used in the preparation of tables, which would probably always be the mode of dealing with day-to-day problems, and, as their accuracy could be carried far beyond that necessary for actuarial purposes, the objections raised to the use of the differential analyser were absent. However, it was pertinent to ask what the future of actuarial tables was. Actuaries' knowledge of mortality and of their own needs seemed to be such that a few well-chosen hypothetical tables would serve all practical needs, and once those were tabulated no other major requirement would arise. Moreover, he could not see the benefit of a machine capable of doing a multiplication in a fraction of a second in connexion with a graduation problem. Relative to the other aspects, the arithmetic of graduation was a minor point.

The question of valuation might also be considered. A valuation could be made by resisting electronic machines, as for example the machine built by the Bell Telephone Laboratories, by feeding the valuation data, presumably from punched tapes, and by having the valuation factors on punched tapes in the machine, and the machine would do the rest. That would certainly be using only a tiny fraction of the capacity of the machine. He would like to ask, however, whether the arithmetic of valuation was a problem of really practical importance.

To his mind, the use of modern, large-scale electronic machines for life office work or actuarial research was a subject about which there was no need to worry for a considerable time to come. Whilst in America during the war, he had been able, through the kindness of Dr Bush and Prof. Caldwell, to see the so-called 'new differential analyser' built at the Massachusetts Institute of Technology. To see that machine in operation, with its hundreds or rather thousands of valves and its selectors and relays, would strike fear into the heart of a Company manager asked to approve the installation of an electronic policy register!

There was one other point to which he wished to refer, namely that raised by a previous speaker on the use of punched-card machines for calculation. That subject had been dealt with extensively elsewhere, but he would like to call attention to Dr Comrie's warning that, before deciding to use a punched-card installation for any computing problem, it was desirable to have a look at the other machines available, because it was quite probable that the work could be done more quickly and more easily on a small machine. Thus, for differencing work it might be found quicker to put

the data directly into a National machine rather than to punch cards and put them through the 'Hollerith'. That was another example of the way in which it was desirable to think functionally all round a problem before deciding what to do.

Mr W. Desborough (a visitor), while admitting that the paper might be disappointing to some people, because the subject could not be comprehensively dealt with in 23 pages, or even in 230, considered that the authors were wise in not going into any greater detail, because much of that detail was controversial from the point of view of the machines and technique of application.

He would like to record the opinion that actuaries had always been in the van of progress in their appreciation and adoption of the punched-card art. In the early days, assurance companies were amongst the largest users, and provided more users than other companies. That position, however, had been reversed, owing to the greater appreciation of the possibilities of applying the machines to accounting functions, and assurance companies were in a minority as users of the machines. That arose particularly from the fact that, by and large, assurance companies had not yet adopted the methods mentioned in Parts IV–VI of the paper. It was only recently that one or two companies in England had used punched cards for purposes other than the actuarial and statistical work of an assurance company.

He had often wondered why that was so, because the machines, the machine functions and the technique for this work had been available for some years. He could only assume that it arose in part from apathy on the part of the companies, and from the enormous number of cases that were involved. It might also arise in part from the very definite departmentalization which existed in assurance companies as between the actuarial, accounting, book-keeping, recording, and policy functions of the company.

There were other reasons, of course; the application of punched cards to the book-keeping, accounting and recording functions of the companies required very careful investigation and a consideration of the differences in organization and methods which would result. Office organization and methods were not an exact science in quite the same way as actuarial and statistical work; the former involved special considerations.

As was shown in the paper, he thought that it was abundantly clear that the development of punched-card machines, as with all office machinery, had been evolutionary rather than revolutionary. There were always people who looked for something new, and they came to exhibitions and so on and wanted something new and revolutionary. That was unlikely, he thought, to be found. He said this lest any of those who read the paper, when they came to Part VII, should be inclined to procrastinate, and should wish to put off their further consideration of punched-card equipment until such time as electronics and so on had come along. He did not think that electronics was likely to affect the general principles of punched-card technique. The speed of electronics, in calculating work in particular, was likely to be phenomenal; but a motor-car which was capable of doing 300 m.p.h. on the road was of little or no commercial value unless and until there were roads capable of taking traffic which could achieve that speed. In the same way, a calculating mechanism which could perform 100,000 calculations per hour was of little use until ways and means were found of recording the answers in a usable form at that speed.

It was a fact that electronic multiplication and calculation would be of great value in scientific computing, but scientific computing was entirely different from the ordinary computing or calculations which commercial firms had to do, and commercial firms would, he believed, always form 99% of the users of punched-card and other office machines.

There had been several important contributions to the discussion that evening, and he would like to emphasize in particular what Mr Coe had said on the subject of accuracy. One thing which had not been stressed, however, was that, with punched cards, accuracy was more easily achievable than with any other system. Mr Coe rightly emphasized that accuracy depended particularly upon controls, and upon time and cost. Obviously controls were easier with punched cards, and the time and cost spent in chasing errors or reconciling totals were less.

He had been surprised to hear the reference by Mr Spratling to the necessity for stability in the size of punched cards. The size of punched cards had never altered since the machines were introduced, and all four companies today adopted the same size of card. Possibly what Mr Spratling had in mind was the question of card capacity. Card capacity had changed, and was likely to change in the future, owing largely to actuaries and accountants, who continually demanded more and more columns on a card. Not many years ago it was generally thought that 45 columns were adequate for any punched card, but today one of the companies had 130 columns, and some people said that that was not enough. The card size, however, had remained unchanged, and he thought would remain standardized by all the companies; he could not imagine any one of the companies who manufactured punched-card equipment changing the size of the standard card, at any rate for ten years or so.

Mr Michaelson had referred to over-punching. Over-punching was simply a method of getting out of a column more values than the single value of that column. All companies today used over-punching according to the ability of their machines; it was not a mere artifice but a means of getting the full value out of a card.

He hoped that all actuaries would read the paper, and that all those in insurance companies would read particularly Parts IV–VI.

Mr E. M. Foster (a visitor) said that, within the limited scope of the paper, the authors had confined themselves to dealing with matters on broad lines, and had covered a great deal of ground, covering it very clearly. He wished to refer, however, to some points of detail, the first of which was on p. 250, where it was explained that one corner of each card was cut to ensure that it was filed in the right way, the right way round. That was true, but its primary function was to ensure that all the cards went through the machine in one way. On the next page, where the authors referred to the 'Powers' system of over-punching, they said that it affected the design of the tabulator. In fact it did not do so; the only part of the mechanism affected was what was known as the connexion box, so that, so far as tabulator design was concerned, there were no special difficulties associated with over-punching. The authors went on to say that the tabulator automatically printed 0 if no hole was punched in the column. That was true provided that there was a significant figure to its left.

In the section on the *Sorter*, it might be explained that when sorting on a 6-figure number it was in fact not necessary to go through the sorting of all the cards on those numbers. Some method was wanted of expressing that there was a reducing factor of the number of cards that went through the machine.

In the next paragraph, the authors gave an instance of making one range of cards follow another. That was not the use of a device; it was the application of a technique. There was no device needed to achieve that result. He would not refer to the example of extracting a group of cards for the sum assured of £500 or over, beyond suggesting that the word 'sort' should be 'select'.

On the following page the authors said 'The total number of bars is divided into groups or units, each one of which totals separately without carrying over into the adjacent unit'. By and large that was true, and it was undesirable to go into too much detail, but it was possible on one of the machines to bridge those units.

Mr T. B. Boss said that the importance of the subject under discussion required no emphasis, but he thought that the advent of centralized administration, together with nationalized industries and perhaps planned economy, raised the question whether the existing punched-card machines were adequate for the tasks expected of them. He did not wish to go into that question, but whereas the time taken to punch, say, 10,000 cards was not alarming, if it was multiplied by 10 or 100 rather large figures were obtained.

Various remarks had been made on the question of students, and on whether certain subject-matter should or should not be included in the paper. On that, he would only like to say that the number of examples of punched-card work fully written up which were suitable for study by students and which were available for study in Great

Britain was so small that he thought it was essential that something should be done about it.

In that connexion, he would plead for an extension of the bibliography on the subject. The admirable description by Comrie, published in 1933, of punched-card machines was, he was afraid, out of print, but he believed that there was a copy in the Institute library. Furthermore, one of the best examples so far set out in print of card work was the description by the same author of his work on the extension of Brown's tables. He did not suggest that that should be read too lightly by anyone who was not familiar with punched-card technique, but it was a very notable contribution.

It was pertinent to the question (which he did not propose to answer) of what in fact had been done in Great Britain with regard to the exploitation to the full of punched cards. To answer that question properly might well require its subdivision into different types of activity for which punched cards were used, but he would be bold enough to mention two things, rather by way of promoting discussion and thought. He believed that since about 1925, and perhaps a little before then, there had been a great and important development of the simpler uses of punched cards, for what he would term, for the sake of brevity, purposes of analysis. It centred chiefly in the recording of a large amount of data on the cards, extensive sorting, and the production of lists or group totals and the like, in which the fundamental point was that the punched card was used not only as a record card but as a working tool, and its value and usefulness were not changed by its being moved into a different place. He believed that that was done with considerable enthusiasm and initiative by many people.

The stage having been reached, however, he felt that the further development of punched cards, for what he would call more specialized technical purposes, was a story on which, generally speaking, the British had not very much on which to congratulate themselves. In particular, he was thinking of the uses of punched cards for the purposes of calculation, which involved extensive copying, selection and comparison, multiplication, and in fact the carrying out of a series of operations the principal element of which was that most hand operations had been cut out. Many people might not agree with his second expression of opinion. He was not very concerned with attempting to prove his case; he believed that the evidence was overwhelming, though it might not be in everybody's possession.

No doubt he would be asked into which of the two categories he fitted the use made by insurance companies of punched cards. He thought that he would subdivide that, and include among the simpler operations, for instance, the maintenance of records and the production of renewal notices, while in the second group he would include the actuarial work on life valuation and the construction of mortality tables and tables of surrender values. It was to be noted that there was almost no work recorded in Britain on these matters.

To mention one small piece of history by way of illustration, he thought that it would be a fair statement to say that in the five years or so preceding the outbreak of war in 1939, when all the principal machines now available existed in hardly less efficient form than today, there was no group or body of people in Britain from the universities, the Civil Service, the research associations and the industrial groups who considered it worth while to devote systematically, even on a part-time basis, a certain amount of time and money for research into punched-card technique, apart from what the manufacturers themselves were doing; and they had in most cases a sufficiently difficult problem, with rapid addition and subtraction and the mixture of twelfths and twentieths and tenths.

On the outbreak of war, one government department was considering the installation of 'Hollerith' machines for the purposes of calculation. It was not, however, until 1944 that such an installation was actually set up by the Ministry of Aircraft Production, while in 1945 a second installation was set up in the National Physical Laboratory, with which he himself was associated. That was not a very happy record of effort, particularly when it was remembered that a book was published in the U.S.A. in 1935 called *Punched-card Methods in Colleges and Universities*, by the Columbia University Press, which mentioned a number of activities, some elementary and some serious, many of which, he believed, had not as yet been duplicated in Great Britain.

With regard to the details of the paper, there was one general question which he would like to raise about the machines. The authors, and some of those who had taken part in the discussion, had made various interesting comparisons between individual machines, but, possibly deliberately, no one had touched on the rather more difficult question of the relative merits of a group of 'Hollerith' machines as compared with a group of 'Powers' machines. A general comparison was quite out of the question in the time available, and he did not wish the few words which he would say on particular points to be interpreted as a general statement covering either set of machines; but for the benefit of those using one type of machine who were not closely aware of the details of the other, he thought it should be stated that the very much greater flexibility (under the control of an operator) of a group of 'Hollerith' machines was an important factor in regard to the ease of carrying out calculations of the type referred to towards the end of the paper.

Other things being equal, it would be expected that there would be a price to pay for that, and one small price which was worth mentioning was that it made much heavier demands on operators. He did not wish to suggest that certain calculations could easily be carried out by the same staff that would be capable of producing, say, renewal notices. The references to American journals in the paper related, he thought, entirely to work on 'Hollerith' machines, and that was a point which should be mentioned.

He would like to emphasize the importance of summary-punching. That was one of the principal means of avoiding one of the chief difficulties of most calculations, the handling and transfer of figures by hand, and he did not think that it could be over-emphasized. Like most mechanical processes it could be weak and break down, but generally speaking it was a feature of the utmost importance.

On the question of controls and check totals, his experience was that a check total, quite apart from any other process of checking involved, was essential.

Mr S. F. Isaac remarked, in closing the discussion, that it was apparent from the size of the audience and from the length of the discussion that the subject of punched-card equipment was of considerable interest to actuaries. It was a subject which had received very little attention from the Institute in the past, and the authors were to be congratulated on producing a valuable contribution at an opportune moment. He hoped that they would not be unduly distressed by criticisms of the elementary nature of their paper. In his opinion, the first paper on any subject should be elementary. His own remarks would of necessity be extremely elementary, because they were based on only a limited experience, an experience of life office work, using one particular type of machine.

He thought that in the largest life offices today punched-card equipment was almost indispensable, but it was probably also true that in the smallest offices the use of the equipment was not an economic proposition. He happened to know that there were present that evening one or two actuaries of offices of medium size who would like some guidance as to the point at which it became an economic proposition to instal punched-card equipment, and he wondered whether it was too much to ask the authors to offer some guidance on that question. It was very difficult to give an answer, and the answer must depend very largely on the character of an office's business and on the purpose for which the machines would be used—whether solely for statistical purposes or for, say, the renewal work.

He thought that perhaps a very brief indication of what happened in his own office might be of some interest. Punched cards were used to compile the valuation statistics but not for valuation calculations. A duplicate set of cards was used to analyse new business because the numerous analyses which were made would otherwise hold up the valuation work. Separate bonus cards served for three triennial periods and from these the bonus notices were printed. The valuation cards were used to compile the mortality statistics and the necessary lists of forthcoming maturities, etc. The cards were not used for renewal purposes except in connexion with certain large staff schemes. He did not consider punched cards satisfactory as the ultimate record of an office but preferred a bound policy book for that purpose.

At present his company had about 80,000 policies in force in the life department. The punched-card system was installed 22 years ago, when the number in force was about 35,000 only. An increase in efficiency was apparent from the outset and there could be no doubt that today efficiency was considerably increased. He would, however, hesitate to claim any very substantial economy either of staff or of expense.

He believed that punched-card equipment would be of advantage to all but the smallest offices. The benefits, both to the office and to the staff, were numerous. The drudgery of routine work, such as sorting and casting, was to a large extent eliminated. The risks of human error were minimized. Routine work was speeded up when saving of time was most important. The results were presented in a neat and uniform fashion. Changes of valuation basis were greatly facilitated by the ease with which the cards could be thrown into any desired order, such, for example, as age at entry, subdivided according to sum assured.

Reference had been made to mechanical errors. His experience was that these were relatively few, and that when they did take place they were usually of such an outrageous character that they were apparent without very much delay or inconvenience.

No doubt those who were contemplating installing punched-card equipment would be concerned about the question of staff. For a small and simple installation consisting of one punch, one sorter and one tabulator, a staff of two would be essential and a staff of three, and perhaps four, would be preferable. In considering the economics of the matter allowance had to be made for the fact that, in addition to the operators, there must be staff to prepare the data for the operators, to control the work and check the results. That raised the question of the type of labour which should be employed. Sir Joseph Burn, in his Presidential Address in 1927, which was referred to in the paper, said 'Operators can become experts after a short apprenticeship, although quite ignorant of the nature of the data with which they are dealing'. That was undoubtedly true, and in a large installation which was continually in use it was probably inevitable that the work of the operators should be almost entirely mechanical, and that they should be ignorant of the real nature of the work which they were performing. He thought, however, that in the case of the small installation the position was different and that the office of moderate size with an installation such as he had indicated would find that, except during a short period of the year, its operators were employed in operating the machines for only a relatively small portion of their time. It was desirable, therefore, to recruit staff capable of work of a different nature.

In his office the machine operators were used to write the new business books from which the new cards were punched. These books were compiled from the proposal papers and contained very full information regarding the policy, including the necessary valuation constants. The operators performed that work and work of a similar nature very well and appreciated the variety and interest thereby provided. Their work was, of course, checked by an experienced actuarial clerk.

He thought that prospective users might like some guidance as to the probable life-time of the machines. He did not know of any sickness or mortality experience of punched-card machines and he wondered whether the authors were prepared to hazard a guess. The answer must, of course, depend on the extent to which the machines were used, but his opinion was that the lifetime might be 10 to 15 years. If, at the end of that time, the machines were discarded it would probably be not because they had deteriorated but because new developments and improvements had rendered them obsolescent.

Turning to the later part of the paper, he was impressed by the possibilities which the multiplying punch afforded, but confessed that he had no experience of it. He was also not in a position to comment on the use of punched-card equipment for the calculation and the production of tables. In 1927, E. W. Phillips, in a paper submitted to the Institute, said with reference to punched-card equipment, 'When a new tool becomes available through the imaginative genius of the inventor, it is not unusual to find that at first the less imaginative members of the community do not attempt to use the new tool to accomplish more than was previously possible by other methods. whereas the real merit of the new tool is that it renders available information which it

would not have been economic, or perhaps even possible, to obtain before'. From what he had said about the limited use of machines in his own office and his own limited knowledge of the subject it was obvious that he had to rank himself among the less imaginative members of the community. In that capacity, however, he felt entitled to issue a warning to the over-imaginative that they should at all costs avoid the risk of collecting and analysing data without a very clear idea as to the purpose for which they would be used, an error into which it was easy to fall.

The potentialities of electronic equipment were indeed fascinating and no doubt eventually the use of equipment of that type would solve many problems. He felt, however, that if carried too far it might create others. One of the more imaginative members of the actuarial profession might care to consider what the possible ultimate effects might be and, in particular, what would be the effects on recruitment and training for the actuarial profession. Would the mathematical ability of actuarial students decline when they used mathematical machines, as he was quite sure that their arithmetical ability had declined with the increasing use of calculating machines? What was going to be the effect on the scope of the profession generally? It was a great comfort to him to hear from Mr Lander and from Mr Beard that the day was far distant when almost the whole of the work would be done by the machines and when the actuary would only be required in order to play a mediocre game of chess with a machine which had otherwise not enough to do!

The President (Mr A. H. Rowell), in proposing a vote of thanks, said that there had been a very good discussion, and he hoped that the practical exponents of the technique described would feel that the paper was a first step towards filling a gap in the pages of the *Journal* on the subject. Those practical exponents had urged on other occasions that, in fairness to students, the subject ought to find fuller recognition in the course of reading, though not pre-eminently adapted for examination purposes. Personally, he felt that there was a great deal more in the whole matter than met the eye, and the most important thing at the start was that it should meet the eye; and so it was a good idea that actuarial students, at any rate in London, should have opportunities of seeing actual installations at work and of satisfying their curiosity on the spot.

The discussion that evening had convinced him of what he had previously suspected, namely that if this subject were admitted to the Institute's already adequately burdened examination syllabus it would be very easy to begin, but very difficult to know where to stop. One of the valuable tasks which the authors had achieved had been to lay a foundation, upon which further papers might be constructed, on lines which had been indicated in the course of the discussion.

Mr L. H. Longley-Cook, in reply, said that the authors had given careful thought to the amount of space which they should devote to the various aspects of the subject. They felt that it was most important, in that first paper on the subject, to deal with simple matters, to describe the equipment and the various technical expressions, so that readers of the *Journal* would be able to understand that and the subsequent papers, which they hoped would be submitted on the subject, without having to purchase some booklet such as the admirable one to which Mr Michaelson had referred. They offered no apology, therefore, for the fact that they went rather slowly at first and then, towards the end of the paper, gathered speed and made only brief references to future developments.

The opener and other speakers had gone into great detail about minor features of the various pieces of the equipment and their uses, but he was very disappointed that there had been so few comments on the valuation of life assurances by means of punched-card equipment. Valuation methods had shown almost no change as a result of the introduction of this equipment. Personally he thought that there was a very good case for reconsidering the methods adopted for valuation in the light of punched-card equipment.

Mr Isaac asked what was the smallest office in which it was advisable to introduce punched-card equipment. From Mr Isaac's own remarks it was clear that the equipment could certainly be used with advantage in any medium-sized office.

In considering a medium-sized office another question arose. Was the continuous method of building up the valuation data really the best? There was much to be said for tabulating the data each year from the cards, which, if the office were not too large, could be sorted into any order at each valuation. In addition, if the fixed maturity age method of valuation were used for endowment assurances no net premiums need be punched on the cards, thus avoiding any difficulties on a change of basis. Summary cards could be punched for each original term and curtate duration, net premiums added and the whole valuation carried out very simply.

It might be thought that the actuary should not concern himself with the subject of punched-card equipment and office records, but the proper organization of office records was essential to the efficient and economic running of a life office, and a full understanding of such an organization was not possible unless punched-card equipment was appreciated. That equipment was a most useful tool in the hands of the actuary, and a good workman should know his tools well.

Mr C. D. Sharp writes: An appreciable part of the past volumes of the *Journal* has been devoted to neat and ingenious methods of reducing the mass of tabulations and calculations involved in life office work, and solutions have been evolved for our standard problems which have become so much a part of our accepted practice that it is now very nearly heresy for anyone to suggest that they are obsolete. With the present-day forms of punched-card tabulation and calculation the justification for many of these ingenious but indirect methods has very largely disappeared, and, for instance, in the valuation of the whole-life limited payment form of policy it is simpler and quicker to make a double tabulation first by 'office year of birth' and then by 'year of premium cessation' and 'office year of birth', to insert the appropriate valuation factors and, by continuous multiplication, to put in the group values of the sum assured and of the premiums, than to use Lidstone or Karup. Although the principles of life office valuation may remain unchanged, a modern valuation technique would start with the advantages and limitations of the machines now at our disposal, and then make the rest of the valuation methods and machinery conform, whereas at the moment the machines are often introduced to carry out more effectively work which has hitherto been done by hand.

As a statement of the general position the present paper is a very useful one, but it would be of great value to the practising actuary if members of the Institute who were using punched-card systems were accustomed, and able, to record in the *Journal* applications of the system which were outside the conventional life office method. The authors express in their opening remarks some surprise at the absence of references in the *Journal* to the use of punched-card equipment; this absence appears to be at least partly due to the shortage of space during the war years, as details of the application of the machines and cards to the calculation of life office tables were found to be unacceptable.

The paper has one most interesting omission; nowhere is reference made to the degree of accuracy which can be expected from the machines. Those unfamiliar with the subject may be tempted to conclude that results will be completely accurate, whereas in practice machine errors can and do occur. In the preparation of sets of tables it is of course essential to see that the results are completely accurate, but in life office valuation, in mortality investigations, in the analysis of lapse experiences and in similar work, it becomes a very nice question whether anything more than group checking is really justified. It will be noticed that the authors suggest that the valuation data should be obtained by the continuous method, but it is doubtful whether if this is to be done the punched card will justify its existence, for the individual group movement will be too small. It is probably better to record the group totals direct after an appropriate sorting, and to use the overall movement figures for numbers of policies, for sums assured and for office premiums as a check on the accuracy of the results. Incidentally if a fixed age is to be used for the valuation of endowment assurances it is probably not worth introducing the net premiums into the cards, as they can readily be obtained by a double tabulation of the sum assured by 'Year of Maturity' and 'Year of Assurance';

this arrangement will, however, not be satisfactory if it is wished to limit the individual net premiums to a certain percentage of the office premiums.

In recent years it has become more and more the practice to insert in bonus notices the cash value which the company is prepared to pay if the bonus is surrendered. A typical bonus notice will give new bonus, existing bonus, cash value of new bonus and the total bonus if the new bonus is not cashed. To prepare and insert these figures in the individual notices would be a major operation if it had to be carried out manually, but by using the punched cards and the multiplying punch the calculations become easy, while by the use of continuous stationery and the tabulator the notices themselves are very quickly prepared.

The introduction of calculating machines and of punched-card equipment has very largely eliminated the drudgery from life office valuation and similar work, and this is of the greatest importance at a time when the supply of cheap clerical labour is being limited by changing economic conditions. At the same time the most economical use of these expensive tools becomes of paramount importance, and as they are the natural province of the actuary it seems essential that the Institute should take early steps to see that its graduates are well trained in their use.

Mr Longley-Cook subsequently wrote as follows: Mr Lander and Mr Jones have both criticized the scope of the paper. Mr Lander wanted more space devoted to future developments. He will find a whole paper devoted to this subject in a recent volume of the Transactions of the Actuarial Society of America (E. C. Berkley, *T.A.S.A.* Vol. XLVIII, p. 36) but the remarks of Mr Beard and Mr Desborough suggest that the authors were wise in restricting this section of the paper severely. In this section it was clearly impracticable to give detailed descriptions and the authors feel they owe no apology to Mr Lander for failing to give a detailed description of E.N.I.A.C. which was mentioned only in order to make the point that it had no real connexion with punched-card equipment. A reference to a ready source of information on this and similar equipment was included in the paper. Mr Jones considered the paper thoroughly unbalanced and wanted more space devoted to the use of the equipment for calculation. The authors had in mind that a large majority of the members of the Institute were interested in the application of the equipment to life office work, where the equipment was very rarely used for calculation. For anyone engaged entirely on statistical work there are a number of useful papers and books on punched-card equipment already available. The balance of interest in this paper is intentionally very different. While I agree with Mr Jones that it is fascinating to watch a machine producing second differences at the rate of 1500 per hour, it must be very rare for differences to be required in actuarial work at such a speed or in such a quantity to make the use of punched cards desirable. The authors gave very careful consideration to the scope of the paper and the amount of detail included in individual sections. Despite the criticisms referred to above they still feel they made the right choice in providing a broad foundation on which others could build and in doing little more than indicating fascinating fields which require fuller exploration.

Mr Lander and some other contributors to the discussion spoke at length on the relative merits of the equipments of the two firms manufacturing in this country. The authors had studiously avoided comparisons as much as possible as they involve the consideration of many points of detail of the exact task under discussion and the very careful weighing of the various advantages and disadvantages. Except for a few special techniques, which are not normally required in life office work, it may be said that the two equipments will perform almost identical functions although, owing to fundamental differences in design, the details of the procedure may be very different. The authors have, therefore, concentrated on the similarities in the two equipments except where differences are so marked as to make comment inevitable. A full consideration of the points raised would take up a large amount of space and would not be of sufficient general interest to justify its inclusion in this discussion.

Both Mr Lander and Mr Michaelson criticized the example of the coding given at the bottom of p. 251. The authors regret they chose an example which was open to criticism. They suggested the use of 0 for yearly, 1 for half-yearly, 2 for quarterly and 3 for

monthly. This code is not self-evident but it has the advantage that it leaves the rest of the column available for punching some other information, such as mode of exit, if, as is not unusual in life office work, every space on the card is precious. This course is more likely to be adopted with 'Powers' than 'Hollerith' equipment as the former is more adapted to using one column for two different pieces of information. Self-evident codes are most attractive but they so often break down, as in this example where Mr Michaelson suggests 9 to represent monthly payments.

In the description of the sorter on p. 253 the authors had said that, with the help of ingenious devices, it was possible to sort on one run for policies with sums assured over £500. Mr Jones has denied this and said it was only possible to sort for sums assured of *exactly* £500. The authors have since checked their statement with the two manufacturers. Both firms state that with a suitable attachment this sort can be done in one run.

Mr Michaelson asked for further details of Mr Gore's unusual sorting machine. The description on p. 248 is not quite accurate. The machine did not select at one sensing operation all cards of a particular characteristic as was there stated, but it selected all cards of a particular characteristic *which happened to be together*. The sorter lowered packs of cards in turn on ten blocks on which pins could be pre-set to correspond to any chosen punching positions. All those cards at the bottom of the pack which had holes punched corresponding to the pins were allowed to fall and the pack was then passed on to the next block. The ten blocks were arranged in a circle and ten packs were rotated above them. Four sorters of this nature, one above the other, were incorporated in one machine.

Mr Fisher asked if verifying and gang-punching were possible with 'Powers' interstage punching. There are some limitations to the use of the method of 'oval hole' verification, the actual limitations varying from case to case. Mechanical verification by use of the hand verifier is, however, fully available. Ordinary gang-punching is available but there are again some limitations on the facility (normally afforded by the Universal Automatic Key Punch) of gang-punching concurrently with manual punching.

Mr Lander has criticized the use of the word intelligent with reference to electronic 'brains'. There has been much discussion in the scientific press on this point and opinions appear to be about equally divided. As in all these discussions the argument turns on the exact definition of 'intelligence' and 'brain'.

The authors would like to thank the contributors to the discussion who have added to the value of the paper by giving more details of the equipment and examples of its application.