JIA 81 (1955) 0203-0260

INSTITUTE OF ACTUARIES

ORDINARY LIFE OFFICE ORGANIZATION USING A LARGE-SCALE ELECTRONIC COMPUTER

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[Submitted to the Institute, 28 March 1955]

INTRODUCTION

IN a paper on *Large-scale Electronic Digital Computing Machines* read before the Institute in 1953 (*J.I.A.* 79, 274) R. L. Michaelson drew the attention of actuaries to the possibilities which existed in a life office for the use of a large-scale electronic digital computer (referred to hereafter as a 'computer'). Both the paper itself and the discussion which followed emphasized the need for a detailed investigation of the problems involved from the points of view of the life office and the manufacturer.

2. The author of this paper has been privileged to undertake, in close co-operation with a large manufacturer of computers in this country, a detailed investigation of possible life-office organization based on a computer. This paper sets down some of the results of this investigation with particular reference to life offices transacting ordinary as distinct from industrial life assurance.

3. The present organization of each life office has developed, and is still developing, as the result of long experience and increased mechanization, and is generally considered both reliable and economic. It is therefore only natural to consider whether a computer can be incorporated effectively within the existing framework of organization, i.e. with the present departmental divisions and policy records. Consideration will therefore be given to the possible uses of a computer in the various departments.

(*a*) *Underwriting*. It is doubtful whether a computer can be usefully employed in the underwriting department. Even if a numerical system of underwriting is employed, as in North America, the major work is still the coding of each relevant favourable and unfavourable feature, and it might well take a longer time to code this information and feed it into the computer than it would take a human underwriter to deal effectively with the case. Apart from this the computer program would be exceedingly complicated.

(*b*) *Policy preparation*. This is essentially a printing and not a computation problem. If, however, policies are at present tabulated from punched cards they could equally well be printed by a computer from the same records, although this would in itself be less economic as a computer is a more complex and expensive machine than a punched-card tabulator.

(*c*) *Renewals*. This again is a printing and not a computation problem, and therefore unlikely in itself to be an economic task for a computer. The use of a computer may, however, lead to minor savings as follows:

(i) agency commission may be calculated by the computer, thus avoiding the calculation of commission by clerks as at present;
(ii) similarly, gross and net interest on policy loans may be calculated by the computer;

(iii) agents' monthly lists could be prepared from the same records as those used in the preparation of renewal notices and receipts, by making the computer select the items required for printing.

(*d*) *Accounts.* At this stage it is difficult to visualize how a computer may be employed economically in this field as little computation is required.

(*e*) *Special quotation.* Quotations for new business, surrender and paid-up policy values, and policy conversions are so varied (except perhaps for pension and assurance scheme quotations and surrender values) that it will probably be uneconomic to program and use a computer for this work. In addition, the results may be required at short notice for which further reason a computer may not be suitable.

(*f*) *Policy valuation.* The main work of a valuation is the maintenance of the policy records and not the computation involved. A computer could certainly be used to complete the valuation once the valuation punched cards had been sorted into their valuation classes and grouped by age and unexpired term; alternatively, the computer could carry out the sorting and value the policies by groups or could value each policy individually from first principles. In any event the use of a computer could probably obviate the need to calculate valuation functions such as net premiums and Z factors. The valuation might be completed in under two weeks by any method, but this would lead to little or no reduction in time, staff, desk calculating machines or punched-card equipment, all of which are normally required throughout the year for other purposes.

(*g*) *Bonus distribution.* While this involves a small amount of computation it is again mainly a matter of printing. Under the reversionary bonus system computation is of such a straightforward nature that it can be carried out economically by clerks or by punched-card machines.

(*h*) *Premium tables.* The construction of premium tables is a comparatively simple operation on a desk calculator and, unless very extensive tables are required at frequent intervals, it is unlikely that a computer will prove an economical machine for the purpose.

(*i*) *Staff salaries.* Several computers are already programmed to carry out salary and wage calculations, including P.A.Y.E. deductions, but life-office pay systems do not generally include the complicated piece-work systems found in other industries and which form the principal economic justification for the use of computers for this type of work.

(*j*) *Pension and assurance schemes.* This type of business, involving as it does much routine computation on the data of large numbers of persons who fall within a restricted number of classes, clearly offers great scope for computer techniques. While pension and assurance schemes are normally considered as part of 'ordinary life assurance', they may, from an organization point of view, be considered as a completely separate class; moreover, in the majority of life offices, this class of business is smaller than that composed of individual policies. The more general approach therefore appears to be to investigate the possible uses of a computer in connexion with individual policies and to leave a consideration of pension and assurance schemes to a subsequent investigation. I am confident that such an investigation will form the subject-matter of future papers to the Institute, and I propose therefore to omit from the remainder of this paper any reference to pension and assurance schemes.

4. As the cost of a computer for life-office purposes (*vide* Part 3) may be as high as £100,000 or as low as £25,000, including both the means of reading

in data and printing out results, and as no precedents exist to suggest over what period of years the cost should be amortized, it is difficult to translate a purchase price into a level annual charge. Some approximation must, however, be made, and I think it is clear that unless a saving in the order of £5000 to £15000 per annum is realized, the purchase of a computer cannot be justified. Even if this amount covers the annual charges for amortization, maintenance and staffing a still further saving must be realized to justify a life office changing its present system to a completely new one.

5. It seems unlikely that the application of a computer on the lines discussed in paragraph 3 will lead to savings on the scale shown to be necessary in the preceding paragraph. This, however, does not mean that further investigation is unnecessary; it only serves to emphasize that one cannot reasonably expect to apply new techniques such as computers directly to an organization which has been developed to suit other techniques, such as sorting by the use of manuscript or punched cards. Computers are in no way a development of punched-card machinery; they are based on quite different techniques, and any investigation into their respective merits should not be restricted in any way, for example, by making computer techniques apply to a record system developed for use with punched cards.

6. The whole question of life-office organization must therefore be reviewed from first principles and new methods of operation deduced. It seems probable that the new techniques will require changes in the existing organization and policy records and an open mind must be kept on these matters. The efficiency and cost of the new methods, including the cost of the computer, must be compared with the known efficiency and cost of the present methods before we can answer the question 'Is there any future for computers in life-office organization?'.

PART 1. POLICY RECORDS

7. In the early days of life assurance, policy records consisted only of (*a*) case papers including the proposal form, medical report and correspondence relating to the policy, (*b*) copy policy and (*c*) policy register. These records proved adequate for those features which, in their broadest sense, are the essentials of life-office administration, namely:

(i) the collection of premiums,
(ii) the valuation of liabilities,
(iii) the distribution of surplus,
(iv) the payment of claims.

8. With the growth of life assurance, and the introduction of card indexes and mechanization, the original policy records were increased by the addition of separate renewals records, valuation records and bonus records. Each new development, such as the typewriter, the addressograph, and punched-card equipment, while being itself a revolutionary step forward, has merely served to speed up a system designed many years ago, and still basically unchanged.

9. The electronic computer must be regarded as much more than another means of speeding up existing methods. Our present organization and methods must be reviewed from first principles and, if necessary, completely altered so that full advantage can be taken of the electronic processes now available. All

ideas based on punched cards, for example, must be forgotten, as punched cards are themselves a development of grouping and sorting; in our new approach to life-office organization we have yet to see whether or not it will be necessary to employ grouping and sorting. The logical approach is to cast our thoughts back to the earliest days of life assurance and deduce the administrative system which might have developed if electronic computers had then been available.

10. The basic policy records are the proposal, on which the policy is issued, the policy itself and its copy; these records show the intentions of the contracting parties and may be regarded as the records of legal significance. It is not easy to see how either the proposal or the copy policy can be used as a main record for interpretation by the computer in carrying out the administrative procedures mentioned in paragraph 7; the proposal is generally handwritten and may well contain a number of corrections and alterations, and even if questions can be drafted so that a simple yes/no, or digital answer, is given, neither it nor the copy policy contains in the one document the full information which would be required. It would be possible for the policy typist to type any required additional information on to the copy policy only, but, in view of the large variety of policies issued at present, and the many different policy conditions used, it is doubtful if the data could be transferred automatically and economically in all cases into a form suitable for use by a computer. A machine is at present being developed by the National Bureau of Standards in Washington to convert typescript by a photo-electric scanning process into a form acceptable to a computer, and the author has witnessed an impressive laboratory demonstration of such a machine; however, even should a machine of this nature be marketed in a few years' time it is difficult to visualize its application to ordinary life assurance for the purposes at present under consideration.

11. It is, therefore, necessary to add a further policy record in a form readily acceptable to the computer to carry out the procedures mentioned above. If this one new record can be used to fill the place of some or all of existing renewals records, valuation records, bonus records and policy registers, it is clear that a substantial saving in head-office expenses can be obtained; if, in addition, the computer can arrange to print the policy and copy policy from the data in the new record there will be a further saving in head-office expenses. If a suitable all-embracing record of this type can be found there will certainly be a considerable reduction in the number of staff at present engaged in record maintenance, and, if the computer is able to replace some existing punched-card equipment as well, then there is a distinct possibility of a saving in expenses of over £15,000 per annum by many life offices.

12. The basic policy records suggested for the new organization are thus: (*a*) the case papers and (*b*) a policy register in a form acceptable to a computer. It will be noticed that these records are a reversion to the policy records of over 100 years ago as set out in paragraph 7.

13. It is a practical matter, as will be seen later, for the computer to print the policy and copy policy from the data in the new-style policy register, at least for the major classes of policy; the remaining policies could be typed as at present. The copy policy forms a most important record, and it is suggested that it be kept at the branch office as its policy record; the branch would also

be sent a copy of each policy endorsement, thus reducing to a minimum the manuscript alteration of branch-office policy records. The up-to-date copy policy would be readily available if required by head office.

14. It is probable that any new-style policy register of the type suggested will only be able to record current data—it will not form a complete historical record. However, it can readily be arranged that a printed copy of the policy register is obtained automatically for the policies concerned when details of a new policy are first entered and also after each alteration. The printed copies may be filed with the case papers to give a full policy history in legible form while reducing manuscript entries to a minimum. An alternative method would be to keep the historical record on punched cards as in the American Consolidated Functions approach (see paragraph 94), but to my mind the limited capacity of a punched card, the extra time and storage space required and the increase in the number of policy records are valid objections to this method. A further complete historical record is available at the branch in the form of the copy policy.

15. It is anticipated therefore that day-to-day head-office enquiries will be dealt with by reference to the case papers, which assume a more important place, perhaps, than at present. It is probable that more control over extraction and filing of case papers will be necessary. If case papers are filed in a storeroom under the permanent charge of one or more storekeepers, who are the only persons allowed to extract or file papers and who keep a record of where extracted case papers may be found, and if the case papers are brought to the person requiring them by a storeroom messenger, the speed of access will be high and the chance of loss low. For a large life office the use of an internal teleprinter type system for requesting case papers would avoid the delays which might arise if a telephone system were used.

16. At present policy registers are kept in the life department itself, and actuaries are accustomed to an access time of about a minute. The policy register for use with a computer would probably have to be kept near it, and in any event would probably not be in a legible form. A change from a system of immediate access to a typed or manuscript register to one of slower access to case papers is, however, a small change compared to the major changes envisaged in this paper and would have the advantage of saving valuable floor space. As practically all head-office inquiries come from the agents and policyholders in letter form, either direct or via a branch office, the need for immediate access to the policy data is small; those few urgent inquiries which are received by telephone may, under the new system, take slightly longer to answer, but if a method such as that suggested in the preceding paragraph is used the delay will be of very short duration. If, however, the case papers are not available for any reason it must be possible to obtain a copy of the new-style policy register in a matter of minutes, and this point must be borne in mind when designing a new system.

17. Before discussing in more detail the medium on which the policy register will be recorded and its form, it will be helpful to examine the type of operation which the author expects from the computer, and its approximate speed of operation. Let us then consider two major operations: first, the printing of renewal notices and receipts, details of both the premium and loan interest due being included on the same form, along with summaries for agents, branches and head office, and secondly, the valuation of all policies.

18. (*a*) First, each month the whole-policy register will be fed into the computer which determines whether or not each policy is due for renewal. If it is due for renewal, a renewal notice and receipt are printed along with the required summaries for agent and branch. In the policy register, if all policies through the same agency are kept together, and all agencies under the same branch are kept together, no sorting is required. If the policy is not due for renewal the computer takes no action except to pass on to the next policy. It will be necessary to carry out the whole monthly renewals procedure for all policies in less than two weeks for this method to be attractive. It is realized that this is no faster than existing methods, but speed is not the end in itself.

(*b*) Secondly, each year the whole policy register will again be fed into the computer which values each policy from first principles by a formula based on the valuation class of the policy, and prints out the results in the form required by the Assurance Companies Acts. For large policy portfolios individual policy valuation may be impracticable, and a method of group valuation using a computer may be required. It will be an advantage if a complete valuation on one basis can be done in less than a week, but here again mere speed is not the end in itself, and the speeding up of the valuation is unlikely to lead to much reduction in cost over present methods. It is apparent that pre-sorting of policies is unnecessary. The valuation and renewal aspects are only selected as examples of the type of large-scale operation for which a computer may be of assistance; it is fully appreciated that a computer could be used for many additional purposes.

19. The preceding paragraphs show that from a purely functional viewpoint the computer acts in exactly the same way as does a human clerk. The computer, or electronic clerk, on being given a policy register, examines each policy in turn, carrying out whatever procedures are required in respect of it. The electronic clerk is fully briefed as to what he has to do (by the computer's program of instructions) and can, if necessary, repeat each operation or calculation by a different method and/or on a separate occasion to obtain a check on his results. The electronic clerk has available scrap paper (the computer's fast working store) for writing down the intermediate steps in his calculations, ledgers (the computer's backing store, e.g. a magnetic drum) for recording items of a more lasting nature such as running totals, a calculating machine (the computer's arithmetic unit) for mathematical work, and pen and ink (the computer's printing units) with which to write out documents for submission to management and the public. Apart, therefore, from the very high speed at which the computer operates I submit that it should be regarded merely as a trained clerk, and I hope that this conception will help to dispel much of the mystery surrounding the word computer.

20. Appendix A shows the items which might be recorded in a unified policy register of the type envisaged. In the normal case many of the items would not be required, but provision must be made for eventualities.

21. The actual storage medium for the new-style policy register must now be considered. At present there are three known media which can now be used, namely, punched (teleprinter) tape, punched cards and magnetic tape. The use of photographic storage on cinematograph film is a possibility, and, in view of the small space required for the details of each policy, an attractive one, but the system is not yet developed to the stage at which it would repay a detailed investigation by actuaries; no further mention will therefore be made

of this storage medium except to say that no difficulties should be envisaged should developments in the next 10 years or so call for a transfer of data from one medium to another. As actuaries are in general unfamiliar with the properties of magnetic tape, the following brief non-technical description of it, and of some check systems which may be applied to it, will be of interest.

22. Magnetic tape may be likened to cinematograph film which, instead of recording pictures records elementary magnets of either north-south or south-north polarity. By dusting the tape with iron filings the outlines of the elementary magnets are clearly visible. Many different types of magnetic tape are in existence, and each computer manufacturer appears to produce tape which differs from that of his competitors; the tapes range in width from about a quarter of an inch to three inches, carrying (in addition generally to a synchronizing pulse channel) from one to thirty data channels respectively; the density of pulses along the tape is generally one hundred to the inch but may be significantly more. In the majority of American data-processing systems the tape width is about half an inch, which is wide enough to record one character (i.e. letter or decimal digit) in binary form across the tape and so give a total of at least one hundred characters in one inch of tape. Magnetic tape can normally be passed through a reading or writing station at a rate of 100 inches per second, so that data can be read from tape into a computer at the rate of at least 10,000 characters per second. The rate at which data can be written on to magnetic tape by a computer is the same rate at which it can be read from tape by the computer.

23. Before magnetic tape is released by the manufacturer it has to pass stringent reliability tests to ensure that the surface is perfect; any flaws found are isolated in such a way that these portions of the tape cannot be written on. A record on magnetic tape can be regarded as permanent unless it is deliberately altered. Random errors may sometimes be produced, for example, by dust on the tape or if the surface of the tape becomes chipped, but these errors may be both prevented and detected automatically.

24. Thus the tape may be made double the normal width and a system of duplicate recording used in which each character is recorded twice across the tape so that a stray dust particle cannot obscure both characters. Alternatively, a 'parity check' system can be used; in this system an extra check digit appears alongside the character digits, the extra digit being a 0 or 1, so that the total number of 1's in the character plus check digits is an odd number; the fact that the number of 1's is odd is checked automatically each time a quantity is moved or operated on in the computer and by this means random alteration of an odd number of binary digits may generally be noted immediately. This type of parity check is known as a latitudinal one, and it is possible to add a longitudinal parity check as well; the latter is based on extra check digits at the end of the data for each policy, the digit at the end of each data track being such that the total number of 1's in the track plus check digit is an odd number. If both a latitudinal and a longitudinal parity check are used then any error in a single binary digit can generally be located immediately and automatically. A third type of automatic check system is known as the check sum system; in this system it is arranged that when the policy data is first recorded on the main policy record tape the character values of all items in the policy record are summed and this check sum is recorded at the end of the policy data; each time the policy data is fed into the computer the sum is formed of the character

values of all items in the policy record, and this sum is compared by the computer with the check sum recorded on the tape at the end of the policy data.

25. It can generally be arranged that the first time a check fails the tape is automatically reversed and the process repeated; if the check fails again the computer can print out the reference number of the policy concerned, and possibly the item in which the error has occurred, for future attention and then proceed to process the next policy. The check sum facility may involve no extra hardware in the computer system; duplicate recording requires some extra hardware in the reading and writing stations and a wider tape, and parity checks require much additional hardware throughout the computer and are thus the most expensive. The following illustrations show how duplicate recording and latitudinal parity checks are effected:

Synchronization track — Data tracks

↓	*A* ↓	*D*	*B* ↓	*E*	*C* ↓	*A*	*D* ↓	*B*	*E* ↓	*C*
1	1	0	0	1	1	1	0	0	1	1
1	0	0	1	1	1	0	0	1	1	1
1	1	1	1	0	1	1	1	1	0	1

Duplicate recording

Data tracks — Parity check track

A	*B*	*C*	*D*	*E*	↓
1	0	1	0	1	0
0	1	1	0	1	0
1	1	1	1	0	1

Latitudinal parity check

26. It is possible to combine the very high speed at which data can be recorded on magnetic tape by a computer with the check sum facility if a true copy of a record on magnetic tape is required. One way in which this could be done is for the original tape to be fed through a reading station into the computer which copies the data from the original tape and writes it on to the copy tape through a writing station; after passing through the reading and writing station respectively the data on the original tape and the data on the copy tape are compared within the computer by means of a suitable program of instructions; if the comparison check fails both tapes are reversed and the copying process is repeated. Successive failure would indicate that the attention of the operator or the mechanic was required. This is only one of several methods which are available for obtaining an exact tape copy of an original tape.

27. This ease of reproduction combined with normal computer facilities provides an automatic way of altering policy records. A tape containing details of policy alterations, including the alteration date, previously arranged in the same order as the policies appear in the main record tape can be fed in at the same time as the main policy record tape and the program designed so that the output tape will contain exact copies of unaltered policies and corrected versions of altered policies, including the date of last alteration, all followed by recalculated check sums; the output data would then be compared by the computer with the original policy record, and if neither the last alteration dates nor the check sums agreed (showing that an alteration had been made) the computer could be programmed to produce a printed record of the revised policy data together with such other numerical or accounting checks as are required. As magnetic tapes are capable of re-use many thousands of times it is clear that as a record storage medium the cost is likely to be very low.

28. A comparison of the three types of main record storage medium may now be made. For purposes of comparison a policy portfolio of 100,000 policies will be considered, and it is assumed that a complete unified policy record of 500 characters per policy will be used.

The comparison is, however, not quite so straightforward as the table on the next page suggests. Data in binary form is generally stored as words of about eight characters, each word (or group of words) being associated with the address of the storage location within the computer to which the word(s) will be routed when input; the space taken up by the address characters can be regarded as wastage of the storage medium, and this wastage may be as high as 20% of the total. Alternatively, the data may be recorded on the storage medium in a predetermined order, equivalent to the fields used at present on punched cards, in which case although addresses of storage locations are not required a certain amount of wastage again occurs due to blank spaces having to be left where the data items are zero. Where data is stored on punched cards there is additional wastage, on all cards other than the first relating to a policy, for the recording of indicative information, such as the branch, agency and policy numbers. The extent of the wastage depends on the data to be recorded and the skill of those responsible for the arrangement of the data in the storage medium, but it will generally be found that wastage is less on tape than it is on punched cards.

29. It is apparent that on their present input speeds neither punched tape nor punched cards will be a satisfactory record storage medium for the type of system visualized, particularly as the majority of offices likely to be interested in computer possibilities, in the first instance, will have more than 100,000 policies. If the estimated future speeds are obtained, however, both storage media would appear to be usable though the speed of input of magnetic tape is still considerably better. The comparatively slow speeds of punching new tape or cards is only disadvantageous if the system to be followed requires the punching of large quantities of data. The principal difficulties with both punched tape and cards under the proposed system is the fact that no simple automatic means exists for maintaining the main policy record; it is clearly uneconomic to use a reproductive method such as that suggested for use with a magnetic tape file, since it is not possible to replace information on paper tape or punched cards by new and more up-to-date information. While this difficulty appears to be economically insurmountable as regards punched tape it is quite possible with punched cards to maintain the existing manual filing system with the usual chance of errors arising from the human element involved.

30. If the main policy record is kept on punched cards and the file is kept up to date by the manual system used at present, the new organization procedure resolves itself into the substitution of a unified record for the present two or three separate records without, however, achieving any further extensive mechanization; the effective reduction in staff will be small and a certain amount of punched-card equipment must be retained for punching new data and for punching, sorting and listing alterations, etc. The possibility of a substantial saving in operating costs to pay for the computer is small.

31. The deduction to be drawn from the preceding paragraphs is not that punched tape and punched cards are unsuitable for life-office use with a

Comparison of types of record storage medium—see §28

Data for 100,000 policies—500 characters per policy	Punched paper tape	Punched cards (80 col.—decimal punched)	Punched cards (12 rows of 80 cols.—binary punched)	Magnetic tape
(1) Approximate volume of main policy record	347 × 1200 ft. spools or 30 cu.ft.	313 × 2000 card trays or 115 cu.ft.	130 × 2000 card trays or 48 cu.ft.	35 × 1200 ft. spools or 3 cu.ft.
(2) Approximate cost of the storage medium for the quantity in (1) above	£65	£470	£195	£160
(3) Value of storage medium after use	Scrap	Scrap	Scrap	As new
(4) Speed of input of storage medium to the computer	(*a*) 20 in. per sec. (*b*) 100 in. per sec.	150 cards per min. 900 cards per min.	150 cards per min. 900 cards per min.	— 100 in. per sec.
(5) Speed of input to the computer in characters per sec.	(*a*) 200 (*b*) 1000	200 1200	480 2880	— 10,000
(6) Approximate speed of input to the computer in policies per sec.	(*a*) 0·40 (*b*) 2·00	0·40 2·40	0·96 5·76	— 20·00
(7) Time in hours for reading in the data of 100,000 policies	(*a*) 69·4 (*b*) 13·9	69·4 11·6	28·9 4·8	— 1·4
(8) Computer output speed	(*a*) 15 characters per sec. (*b*) 50 characters per sec.	100 cards per min. 450 cards per min.	100 cards per min. 450 cards per min.	— 10,000 characters per sec.

Notes. (1) The magnetic tape records characters across the tape as shown in the diagrams in paragraph 25.
(2) Speeds and times assume that the storage medium passes into and out of the computer at the maximum physical speeds.
(3) Speeds and times marked (*a*) are currently available in Great Britain; those marked (*b*) are obtainable now or will be available shortly in North America.

computer, but rather that the unified policy record system as outlined does not lend itself to these types of record storage media.

32. Magnetic tape, however, appears to satisfy all requirements as regards speeds of input and output, is relatively inexpensive, takes up very little space, and is readily adaptable to the automatic alteration of policy records. It is important at this stage to dispel some doubts which are sometimes cast by actuaries and other company executives on the reliability of magnetic tape as compared with punched cards as a basic policy record. Although several firms in Great Britain have produced magnetic tape units they have as yet no long-term experience of them for record storage purposes such as we are considering; the general opinion in North America, where a considerable experience is available, is that although magnetic tape storage has not yet been perfected, a magnetic tape/computer is, in its present state, more reliable than a punched-card/human-element system, and magnetic tape should be considered the standard storage medium of the immediate future. The position is similar to that which existed when punched cards were first introduced except that today there is a natural reluctance on the part of companies with a large investment in punched-card machinery and punched cards to admit the advent of the new medium. In North America the punched-card manufacturers are in the lead in producing magnetic tape computer systems, and it seems improbable that punched-card manufacturers in this country will neglect this new storage medium. The experience of those North American life offices which have carried out extensive tests of magnetic tape is that it is well suited to the storage of policy data. It is sometimes suggested that basic records may be kept on magnetic tape only if a duplicate record in a readily processable form, such as punched cards, is also kept. I would, however, suggest that, if magnetic tape proves so unreliable as to necessitate the maintenance of a duplicate record in this form, then magnetic tape should not be used at all. I, myself, trust that magnetic tape will in due course come to be generally accepted as a reliable record storage medium and, on this assumption, a duplicate record in printed form is clearly of much greater use than a punched-card one.

33. It is now proposed to consider a major modification of the suggested policy record system and to examine its effect on the suitability of the different record storage media. The modification involves the deletion from the unified policy record of all data which is not actually required for computation purposes; thus all items marked with an * in Appendix A would be deleted, and by this means the average number of characters per policy would be reduced to about 200 (including address symbols) in place of 500. This modification will reduce the time of data input to two-fifths of that shown in the table on the previous page, while retaining the essential features of the unified policy record; for example, the names and addresses of the assured and life assured may initially be recorded for new policies, but unless required for renewal purposes may readily be deleted from the main record after the policy has been prepared. So long as at least two other records of all relevant data are kept there is little need to maintain a further copy of the data on the main policy record if it is never required for processing. The objections to the use of punched paper tape still appear to be valid and, while the objections to the use of punched cards are not so strong as in the system originally proposed, they are still, to my mind, sufficiently strong to suggest that if one is restricted to

the use of punched cards for the basic record medium then this system may not be the most economic one.

34. While the systems described are therefore capable of using a main policy record on punched tape, punched cards or magnetic tape, the systems seem to be especially suited to magnetic tape, and it is assumed for the remainder of this paper that the main policy record will in practice be kept on magnetic tape.

35. The fact that data may be fed into a computer by way of punched tape, punched cards or magnetic tape is a useful feature. Present policy records are in most cases kept on punched cards, and by feeding them into the computer the appropriate items may be transcribed on to the new storage medium. The data concerning new policies and alterations can be introduced by any method, and this makes possible further economies in the cost of head-office administration. Data may be recorded initially on punched or magnetic tape by a 'tape typewriter' which, in addition to producing a normal typescript copy (with carbon copies if required), will record the typed data on the tape; this means that data for new policies, alterations and exits can all be recorded on tape by means of typewriters kept in those sections of the life department which currently deal with new policies, alterations or exits; in addition, the typescript copy can in many cases serve as an original accounting entry for recording, for example, claim payments. Case papers need no longer be passed from section to section to enable all bookkeeping entries to be made and policy records to be altered; indeed, opportunities may arise for the tapes to be produced at the branch offices and mailed to or reproduced by teleprinter at the head office for processing by the computer.

36. If data for new and altered policies are presented in random number order it may be more economic to punch the data initially on to punched cards and to sort these before feeding them into the computer. Whether this method proves more economical than recording the data directly on punched or magnetic tape and letting the computer itself carry out the sorting depends on the quantity of data, the amount of sorting required, the value of the typescript record, the operational speed of the computer for sorting work and the amount of spare computer time available. A computer equipped with magnetic tape input/output can be a fast sorting machine; the complete number is operated on at the one time, and not only one column as is the case with punched-card sorters, and if spare computer time is available it may not be economic to introduce a punched card system and sorter merely for this part of the procedure.

37. In the case of new policies or major alterations to an existing policy, it would be necessary for the new data to be recorded on, say, punched or magnetic tape by means of a tape typewriter for subsequent incorporation in the main policy record. It should be noticed that for alterations, apart from the policy reference number, i.e. branch, policy and agency numbers, it is only necessary to type those items which are actually being altered. For example, if the policy term is extended and the sum assured is increased, no other amendment being made, it would only be necessary to record on the alterations tape the reference number of the policy, the new sum assured, maturity date, last premium date and the date of alteration.

38. In the early stage where cases are being sorted by the computer into reference number order, only small batches of policies can be operated on at

the same time; the maximum economic number in any batch would depend on the extent of the computer's internal storage capacity. It is during this sorting process that the data would be converted into binary form if the main policy record is kept in that form. The collation of several tapes in which data is arranged in reference number order into one combined tape is a very speedy process. The amount of processing which can be done at each stage will depend largely on the number of magnetic tape input/output units in the computer system.

39. The idea of copying the whole policy register at frequent intervals is a novel one. The fact that a complete copy of the magnetic tape policy register is available, in a comparatively up-to-date form, is valuable in itself in case any damage, accidental or otherwise, is caused to the main policy record. The interval at which the policy record would be rewritten and brought up-to-date need not be fixed within narrow limits; once a week may be quite satisfactory; but a longer interval may elapse at the time when the valuation is being done or when the monthly renewals program is being carried out. The interval will also depend upon what data is recorded on the tape and whether or not the tape records are referred to when dealing with everyday policy inquiries. At least one company has seriously considered whether or not any useful purpose is served by keeping the proposal form, medical report and other correspondence. I have no wish to raise this matter now except to say that if a company does not now retain sets of case papers of this nature it may not wish to restart the practice and in this event may be prepared to accept, as policy records, the copy policy and the magnetic tape record. If so, it is essential that the tape record is kept right up-to-date and complete in every detail, and that the time required to obtain a printed copy of any required policy record is short. Alternatively, if data of a purely record nature is recorded on the case papers or on another file and only data actually required for processing is recorded on the tape, then it seems logical to file a printed copy of the magnetic tape record and to use this copy for everyday inquiries. In this event, it would probably not be necessary to keep the tape record up-to-date more frequently than once a month, and a rapid access time to the tape record is of less importance.

40. A large part of this paper has been devoted to the subject of policy records, but no apology is offered for this as the new life-office organization using a computer depends wholly on the number and type of policy records kept and the storage medium chosen. The present multiplicity of policy records necessitates a heavy cost of record maintenance without the certainty that all records are correct at any moment of time. If present policy records can be replaced by one record, and punched-card techniques forgotten, it is clear that a substantial saving in record maintenance staff, punched-card machinery and office rental will result.

PART 2. MONTHLY RENEWALS, POLICY VALUATION AND RECORD PRINTING USING A COMPUTER

41. In order to test that the theories developed in Part I work in practice it was clearly necessary to carry out some demonstrations based on conditions likely to be met in a life office. Such demonstrations serve two purposes: first, they prove whether or not the theoretical approach is sound; and

secondly, assuming that the demonstrations prove satisfactory, they assist computer manufacturers in the drafting of specifications for a computer if one should be designed specially for life-office work.

42. The computer most readily available for demonstration purposes was the Ferranti Mark 1 Digital Computer installed at Manchester University. The main features of this machine as they affected the demonstrations are as follows:

(*a*) The computer can output data through all or any of three channels, namely:

- (i) A Ferranti High Speed Parallel Printer, i.e. a built-in line by line printer which prints up to 64 characters in any of 92 positions in each line (28 positions must be pre-set by the computer operator as blank spaces) at a maximum rate of 150 lines a minute. The computer is able to operate on the data of one policy while it is printing out a line of characters computed from the data of the previous policy.
- (ii) A built-in teleprinter which operates at a maximum rate of seven characters a second.
- (iii) Punched teleprinter tape on which data can be punched at a maximum rate of fifteen characters a second.

(*b*) Input to the computer is by means of punched teleprinter tape at a maximum rate of 200 characters a second. Each character is read in individually from the tape and the maximum speed can only be achieved provided that not more than five or six instructions are carried out on each character before the next character is read in.

(*c*) The computer operates in the binary code, thus entailing some decimal/binary conversion during input and some binary/decimal conversion during output. All conversions are done by the computer.

43. It was decided, after a full consideration of the purposes of the demonstrations and the facilities offered by the available computer, to carry out three demonstrations. These were as follows:

(*a*) A monthly renewals demonstration involving

- (i) The printing of branch and agents' monthly renewal lists.
- (ii) The printing of a list of policies due for automatic alteration or other attention (but excluding automatic terminations).

(*b*) A policy-valuation demonstration involving the individual valuation of policies from the commutation column factors N_x, M_x, v^x, etc., and the printing of the results in the form of the 4th Schedule to the Board of Trade returns.

(*c*) The printing of the punched-tape policy record for use as a legible policy record.

44. The data used were the records of all the 344 policies (excluding group pension and assurance policies) issued by a British life office in a week chosen at random in 1952. Some ten different classes of policy are covered, but to increase the value of the demonstration the following adjustments were made:

(*a*) Loans were effected on twelve policies, interest being assumed payable either annually or half-yearly.

(*b*) Five policies were placed under non-forfeiture on one of two bases as follows:

Basis 0: the policy is maintained in force for one year from the date of the unpaid premium and is then made paid up or surrendered.

Basis 1: the policy is maintained in force as a temporary assurance for the full sum assured from the date of the unpaid premium until the surrender value is exhausted.

(*c*) The policies were divided into four branches and sixty-five agencies.

(*d*) Eighteen policies were marked for reference to the life department at various future dates.

45. To get the most information out of the demonstrations it was necessary not merely to ascertain the average time taken per policy in each demonstration, but to deduce the time taken per policy for each major class of policy and each major section of the routine. The required times were obtained either by summing the individual instruction times of the routine under consideration or by timing a number of complete runs of the data. Where results were obtained by both methods the results agreed closely.

Production of main policy record in binary form

46. The single policy record used for the demonstrations is shown in Appendix B. As the computer operates in a binary scale it was decided to keep the main policy record in binary form. The procedure by which the manuscript data was converted into a record in binary form on punched tape is as follows:

(*a*) The decimal data on each single policy record was recorded twice on punched paper tape by means of a teleprinter. The first punching of the policy data was fed in to the computer which, depending on the introductory letter (H, V and X), carried out the following procedures:

H: the life assured's name and policy reference numbers were stored in binary coded decimal form in storage locations determined by the number associated with the letter H.

V: £ *s*. *d*. amounts were converted into binary pence and stored in locations determined by the number associated with the letter V.

X: Dates, percentages and miscellaneous codes. The sections terminating with a W or M, each containing a number from 0 to 31, were separately converted into binary form. Each section terminating with a Y contains a number with a range of 1024 values; this number could alternately be used to represent an integer, a percentage up to say 10·23%, or, after reduction by 1800, a calendar year between 1800 and 2823; this quantity was in any event converted into binary form. The three sections were stored together in a location determined by the number associated with the letter X.

(*b*) A very much more complex storage form could have been adopted, but by expressing all the data in one of the three above forms the program for the conversion of the data into binary form was comparatively straightforward.

(*c*) When all the data for one policy had been read in and converted, the total character values in all the policy-data storage locations were summed and the resulting 'check sum' was recorded at the end of the policy data.

(*d*) The data, including the check sum, were then written on to the magnetic drum.

(*e*) The repeat punching of the policy data was then fed into the computer and the same operations as described above were repeated up to paragraph (*c*). The data, including the check sum, were then compared with the data on the drum.

(*f*) If the comparison in (*e*) fails the tape stops and is then reversed and fed in again by the operator; if the comparison fails twice the policy reference number is recorded by the computer operator for later inspection.

(*g*) If the comparison succeeds, the policy data in binary form (as described in subparagraph (*a*) above) is punched out item by item, including the check sum, on to what is called the binary tape, each item being preceded by the two-character address of its storage location. If there is no significant data in a storage location, nothing is punched out in respect of it, so that blank space on the binary tape is kept to a minimum.

(*h*) The binary tape is now read into the computer and checked against the original policy data still recorded on the magnetic drum. If the comparison fails the binary tape is reversed and fed in again by the operator; if the comparison fails twice the policy reference is recorded by the operator for investigation later and the comparison of policies proceeds.

(*i*) If the comparison succeeds it is reasonably certain that the binary tape is a true representation of the original policy data (further checks are available in practice, e.g. the printing of the data on the binary tape in alpha-numerical form for visual comparison with the original data).

47. The various stages in the preparation of the checked binary tape were timed and the following results were obtained:

(*a*) Average number of characters per policy, including H, V, X, L, Z, P and W M Y characters in the decimal data originally punched 165 characters.

(*b*) Average time per policy taken to read in the duplicated decimal data (i.e. 330 characters) 1·65 sec.

(*c*) Average computation time per policy to convert the duplicated decimal data into binary form, produce the check sums and compare the two sets of binary data 5·6 sec.

(*d*) Average number of characters per policy, including address locations, on the binary tape 156 characters.

(*e*) Average time per policy for the computer to punch out the binary tape 10·0 sec.

(*f*) Average time per policy to read in the binary data 1·3 sec.

(*g*) Average computation time per policy to compare the data read in on the binary tape with the data on the drum 0·1 sec.

The total average time per policy for the preparation of the checked binary tape is thus 18·65 sec. made up of 12·95 sec. input/output time and 5·70 sec. computation time.

48. In practice, if a computer working in the binary code were used by a life office, this preparation of a binary tape would only arise (apart from the conversion of existing policy data) in respect of new policies and major policy alterations. The data of a policy on the binary tape might be used on the average over a hundred times for renewals and valuation purposes before the policy is deleted from the tape; thus the time taken initially to convert the policy data into binary form is equivalent to only a very small addition to the average computation time per policy per passage through the computer.

Monthly renewals

49. As the work involved in preparing the necessary instructions for feeding into a computer is not generally known to actuaries, the approach to this demonstration is set out in some detail. The methods described may be taken as typical of those normally adopted in work of this nature.

50. First, it is necessary to determine the output required from the computer. In this case it was decided to print for each policy under which a premium and/or loan interest payment falls due the following data:

Agent's monthly list

Collection code	Life assured's name	Policy number	Date of renewal	Premium due	Agency commission	Loan interest gross	Loan interest net

The collection code number 0 or 8 indicates whether the renewal notice is to be enclosed with the agent's monthly list (Code 0) or is to be sent, if required at all, direct to the policyholder (Code 8). The data would be printed in list form by the line-by-line printer. Policies would be shown in numerical order within each agency, and the list for each agency would be followed by the branch number, the agency number, and the month of renewal. Totals at the end of each agent's list would be shown separately for (*a*) amounts to be paid through the agency and (*b*) amounts to be paid direct to the life office. Where a loan interest payment is involved the renewal notice would be sent direct to the policyholder and the premium and loan interest would be included in the '(*b*)' totals. This code system can be extended to cater for Bankers Order and other special collection systems.

51. In practice, by use of a multiple input system, it would be possible to feed in a tape carrying the name and address of each agency at the same time as the policy data is fed in, so that the agent's name and address can be printed on his monthly list; alternatively, the agent's name and address could be recorded on the main policy record tape either immediately before or immediately after the policies through his agency. In addition, the lists would be printed on pre-printed continuous stationery, using a paper-throw facility, and one or more carbon copies taken; the top copy from which all loan interest details had been detached would be sent to the agent, along with the appropriate renewal notices and receipts, and the carbon copies kept for branch and head office use.

52. At the moment when the computer prints an entry in the agent's monthly list, it is apparent that the computer holds within itself all the data required for the preparation of the renewal notice and receipt with the exception of the name and address of the person to whom they are to be sent. It would be quite a practicable matter to record this name and address as part of the policy record and to program the computer to produce the data necessary for the printing of the renewal notice and receipt. Alternatively, to obtain a complete check on the operation of the computer the notices and receipts could be obtained by a separate processing of all the policy data, provided that sufficient time were available for this.

53. As the second part of the monthly renewals demonstration it was decided to print on the teleprinter the policy number of each policy due for automatic alteration or other attention. Each entry would contain a code number or code letters to show why the policy appears in the list, e.g. N.F. to indicate that the policy required attention by the department dealing with non-forfeitures. In practice a form of output such as this from the computer could be used to print the policy numbers of policies maturing, terminating or vesting in the month under consideration or for any subsequent month(s), but these cases were not considered in this demonstration.

54. Secondly, the form of input to the computer must be considered to ensure that sufficient basic data is available on which the computer can operate to provide the desired output. For these demonstrations the policy record shown in Appendix B was adequate, the record being on punched tape in binary coded form following the procedure detailed in paragraph 46.

55. Thirdly, a flow diagram as shown in Appendix D is prepared showing the various stages in the processing of each policy. Great care is required at this stage to ensure that the development of the flow diagram is logical and that all possible contingencies are covered. Each stage in the flow diagram is then broken down into its most elementary steps; thus stages 4 and 5 which are concerned with non-forfeiture, are broken down as shown in Appendix D.

56. An experienced programmer can readily convert elementary steps of this nature into the code applicable to the computer being used, but I do not consider that an actuary needs to concern himself with the details of the coding system unless he is directly connected with the computer department.

57. The times deduced from several runs of the monthly renewals demonstrations are as follows:

	Seconds
(*a*) Average time per policy to read in the policy data and apply the check sum test	1·30
(*b*) Average computation time per policy to determine that the policy is not renewable	·009
(*c*) Average computation time per policy to determine that the policy is renewable, calculate the items for entry in the agent's monthly list, add these items to the agency running totals, convert them to decimal form and arrange to print them	1·50
(*d*) Average computations time per agency to add the agency totals to the branch running totals, convert the agency totals to decimal form and arrange to print them	
(i) two-line totals for codes 0 and 8	4·00
(ii) one-line total for either code 0 or 8	2·00
(*e*) Average computation time per agency to add the agency totals to the branch running totals	
(i) two-line totals for codes 0 and 8	0·30
(ii) one-line total for either code 0 or 8	0·15
(*f*) Average computation time per branch to convert the branch totals to decimal form and arrange to print them (two-line totals for codes 0 and 8)	3·90
(*g*) Computation time to convert an amount less than £1 m. from binary pence into decimal form and arrange to print	0·35
(*h*) Average computation time to convert the data for printing one entry in the automatic alterations list into decimal form and arrange to print it	2·25

58. It is possible from the times in the preceding paragraph to estimate the total computation time required in practice for the preparation of agents' monthly lists and renewal notices and receipts taking into account the agency structure of the office. For purposes of example the following assumptions are made:

(*a*) Total policy portfolio—500,000.
(*b*) Number of policies renewable in a month—100,000.
(*c*) The policy distribution by agencies is as follows:

(i) one policy per agent for 60,000 agencies (60,000 policies).
(ii) two or more policies per agent in the same collection, class 0 or 8 for 10,000 agencies (25,000 policies).
(iii) two or more policies per agent, one or more in each collection class for 5000 agencies (15,000 policies).

(*d*) Agency totals are printed only if there are two or more policies through the agency, and separate totals for collection classes 0 and 8 are only printed if the agency contains policies in both classes.
(*e*) Collection is made through 150 branches.
(*f*) 250 policies are listed in the automatic alterations list.
(*g*) 10% of renewable policies carry loans, these policies being distributed among agencies in the same ratio as all renewable policies are distributed.
(*h*) If no loans are recorded in the agency, the loan interest totals are not printed thus saving the binary/decimal conversion time for these amounts.

59. The total computation time for preparation of the agent's monthly lists is thus as follows:

	Hours
400,000 non-renewable policies (at ·009 sec. per policy)	1·0
100,000 renewable policies (at 1·5 sec. per policy)	41·7
60,000 one-line agency totals to branch totals (at ·15 sec. per agency)	2·5
10,000 one-line agency totals (at 1·46 sec. per agency)	4·1
5,000 two-line agency totals (at 2·92 sec. per agency)	4·1
150 branch totals (at 3·90 sec. per branch)	·2
	53·6

To this, however, must be added the time required to convert the agents' names and addresses to a form suitable for printing; for 75,000 agencies I estimate that this will take a further 8·6 hr. approximately, but no practical test was made to confirm this.

60. Assuming that the data for printing the renewal notices and receipts is to be obtained at the same time as the data for printing the agents' monthly lists, then the only additional computation involved is as follows:

(*a*) the conversion of the name and address of the addressee to a form suitable for printing,
(*b*) the computation of the net total amount to be paid on renewal, and
(*c*) the necessary rearrangement of the data for printing.

For the 100,000 addresses involved in (*a*) I estimate a computation time requirement of 11·4 hr. The time for (*b*) and (*c*) above will be much shorter and is unlikely to exceed 2 hr.

61. The total estimated computation time, therefore, for the production of agents' monthly lists, renewal notices and receipts using a computer operating at the same speed as the one used in the demonstrations is some 75·6 hr. The input/output time is still to be added, but this subject is discussed later.

Policy valuation

62. It was decided to carry out a net premium valuation on two separate bases of mortality and interest, net premiums wherever practicable being calculated by the computer. The procedure followed was similar to that followed in the monthly renewals demonstrations. The form of output was first determined and this is shown in Appendix E. The policy record used was the same binary coded record as was used for the monthly renewals demonstrations. A flow diagram was again drawn up setting out the logical sequence to be followed during the valuation process and this is shown, with particular reference to an endowment assurance, in Appendix F.

63. A prospective method of valuation is used as the policy record is not an historical one, and so, if the policy has ever been altered, no details of the policy prior to its alteration are available to the computer. In cases such as children's deferred assurances before vesting, where the reserve may be expressed as an accumulation of the premiums paid, it would be possible to use an accumulative method of valuation and to bring the reserve up to date either during the monthly renewals program or following payment of the premium. In general, however, the system lends itself to a prospective valuation method. A net premium method was used in the demonstration as this is the one in general use; it had been hoped to carry out a gross premium valuation as well, but this was not possible in the time available, although it would have saved the complication of computing the net premiums.

64. The valuation bases, formulae and methods used were chosen more to prove the efficiency or otherwise of the computer in carrying out an individual policy valuation than for any particular merits which they may have in themselves. The valuation was carried out on two bases, namely, Basis A, (A 24/29 Ultimate Light at 2%) and Basis B (A 24/29 Ultimate Normal at $2\frac{1}{4}$%); the valuation formulae used are shown in Appendix G. Some of the features of the valuation of interest to actuaries are as follows:

(*a*) If in Appendix B the item 'valuation net premium' is zero, the net premium is calculated by the computer in accordance with the formula shown in column 3 of Appendix G; if the item is 1*d*., a quantity chosen arbitrarily as being readily distinguishable from the 'zero' case already mentioned and any net premium likely to be found in practice, the net premium is taken to be 90% of the office yearly premium; if the item exceeds 1*d*. it is itself the net premium.

(*b*) Cases accepted subject to an increase in age are valued at the rated-up age, the number of years rating being shown in the item 'Extra premium or debt-Term'.

(*c*) In the case of a policy subject to a level extra premium and including either a family income or a decreasing temporary assurance benefit, and while the extra premium is payable and the benefit is in force, the total extra reserve is arbitrarily divided—one-third to extra premium reserve and two-thirds to the reserve held for the basic policy.

(*d*) p_a is a percentage addition to the value of the sum assured plus bonuses for policies including an annuity option. In the demonstration p_a has a range of four values from 0 to 10 depending on the item 'Annuity or annuity option—Mortality and interest code'. p_a could as easily have depended on the year of issue of the policy.

(*e*) p_b is a percentage addition to the value of the sum assured for policies on the lives of or for the benefit of children and carrying a continuation option at the vesting date. In the demonstration p_b has a range of four values from 0 to 20, depending on the item 'Annuity or annuity option—Mortality and interest code'. Again p_b could have depended on the year of issue of the policy.

(*f*) The mortality and interest functions used in the valuation were as follows:

(i) Values of N_x and M_x for integral ages. The N_x values were scaled down so that the maximum value was less than 10^6 and the M_x values were similarly scaled.

(ii) v^x for integral values of x up to 25.

(iii) Four values each of p_a and p_b.

(iv) $d=(1-v)$.

65. The times deduced from several runs of the valuation demonstration are as follows:

	Seconds
(*a*) Average time per policy to read in the policy data and apply the check sum test	1·30
(*b*) Average computation time per policy for valuation on two bases	1·6
(*c*) Average computation time per policy for valuation on one basis only	·9
(*d*) Average computation time per policy for the items in the 'General' section, i.e. items (2)–(13) in Appendix F	·2
(*e*) Time taken to print out the results	45·0

In view of the special interest in valuation work the valuation times are shown in greater detail, with particular reference to an endowment assurance, in the next paragraph.

66. The item numbers shown in this paragraph coincide with those in Appendix F.

	Seconds
General:	
Item 2. Test if policy is still in force	·007
Item 3. Test if currency is sterling	·005
Item 4. Isolation of packed items	·055
Items 5–6. Determine that future premiums are payable and find the office yearly premium exclusive of extras—minimum time	·030
Items 7, 9, 11 and 13. Determine that the policy has no extra premium, income benefit or decreasing temporary assurance benefit	·015
Class-Endowment assurance:	
Items 21 and 22. Test whether the net premium is to be computed and compute net premium—minimum time	·115
Item 23. Compute $2(N_x - N_{x+2})^{-1} = D^{-1}_{x+\frac{1}{2}}$	·085
Item 24. Compute annuity factor ($D^{-1}_{x+\frac{1}{2}}$ being available) and value premiums	·025
Item 25. Compute assurance factor ($D^{-1}_{x+\frac{1}{2}}$ being available) and value sum assured and bonus	·030
Item 26. Add policy totals to class running totals	·150
Items 32 and 33. Test for reassurance, compute and add to reassurance totals	·210

The balance of the computation time per policy not accounted for in the preceding items is mainly taken up in reading down routines and commutation columns from the magnetic drum to the fast working stores.

Record printing

67. The last part of the demonstration consisted of printing out from the binary coded policy records the details of certain policies intimated to the computer by feeding into it on punched tape a list of the selected policies. The times deduced from this demonstration are as follows:

	Seconds
(*a*) Average time per policy to read in the binary data and apply the check sum test	1·30
(*b*) Average computation time per policy to determine that the data of the policy is not to be printed	·005
(*c*) Average computation time per policy to determine that the data of the policy is to be printed, to convert the data to decimal form and arrange to print	9·00
(*d*) Computation time to convert a quantity in the form *aWbMcY* from binary to decimal form and arrange to print	0·30
(*e*) Computation time to arrange to print the life assureds name (maximum fifteen letters and spaces)	0·15
(*f*) Computation time to arrange to print the policy number (six figures)	·05

68. From experience gained during the programming of the demonstrations it is evident that the times deduced could in some cases be reduced significantly. Thus the storage of the periodical premiums in binary coded decimal as well as in true binary form would save the binary/decimal conversion time whenever the periodical premium has to be printed. In the valuation procedure the use of a table of D_x^{-1} or $D_{x+\frac{1}{2}}^{-1}$ would reduce the use of the reciprocal routine, and the assumption that 'family income benefits' and 'decreasing temporary assurance benefits' are mutually exclusive would further reduce the valuation time. Time savings would also result from a rearrangement of the items in the policy record.

69. The results of the demonstrations show that a computer can be programmed to operate on a single basic policy record as follows:

(*a*) to provide all the information required on policy renewal,
(*b*) to carry out a complete net premium policy valuation, and
(*c*) to print a copy of the record itself.

It is a small step from here to deduce that from the same policy record a computer can be programmed to carry out the following procedures:

(*d*) a gross premium valuation (including a more accurate estimate of the allowance for future expenses than is available at present),

(*e*) a list of the reserves held against each policy, or a list of surrender values if these can be deduced from the policy reserves or computed by a different method. This might be of assistance in reducing the work of calculating surrender values or in providing a check on individually calculated values,

(*f*) the calculation of the reversionary bonus to be allocated to each policy and the valuation of the bonus,

(*g*) the printing of bonus notices,

(*h*) the amendment of the policy record to show the new total bonus attaching,

(*i*) the provision of statistics of policies in force,

(*j*) the provision of statistics for mortality investigations. More detailed investigation of the effects of different impairments may well become practicable,

and, provided certain additional data was available for new policies,

(*k*) print the majority of policies and compute the stamp duty.

It is, I submit, evident that a computer could be used, with a suitably designed single policy record, to carry out most if not all of the functions of life-office administration which involve functions of basic data.

PART 3. LIFE OFFICE COMPUTER SPECIFICATIONS

70. When the principal North American computer manufacturers drew up specifications for their general purpose commercial computer systems they took into account the requirements, *inter alia*, of certain life offices, each of which had portfolios of many millions of policies. Computer cost thus became of relatively minor importance, although it should be noted that a life office with about 600,000 policies has recently justified an expenditure of about $1 m. for the purchase of a computer system. The law and practice of life assurance in North America results, in general, in a much greater amount of routine head-office administration than is required in this country, and I think it is clear that few, if any, life offices here with portfolios of 600,000 policies could afford computer systems costing $1 m. or over.

71. There has been, indeed, a widely held belief in this country that, for many years to come, only the very largest life offices will be able to justify the cost of computer systems, but this belief is quite unfounded. A computer system has already been announced in this country for about £25,000 containing a comparatively slow-speed binary coded drum computer together with the means of reading in data from punched cards, punching out data on punched cards and printing data on a line-by-line printer. This system naturally differs in many respects from those referred to in the preceding paragraph which *inter alia* operate at higher speeds, have certain built-in checks and a greater number of high-speed input/output stations. It will be appreciated that each new facility will, in general,

(*a*) increase the cost of the system, and

(*b*) increase the overall speed of operation.

72. Computer manufacturers cannot be expected to produce computers 'tailor made' to the individual requirements of every life office, and it is necessary for manufacturers to determine the size of the offices whose needs they wish to meet. In this connexion, while it is reasonable to expect a very large life office to use several comparatively inexpensive, slow-speed computer systems, it is a much more complex matter for smaller offices to arrange to share a comparatively expensive, high-speed computer system. My own feeling is that manufacturers should in the first place look to satisfying the large field of offices with portfolios of under 500,000 policies, although I do not expect unanimity of opinion on the number selected. Larger offices could work extra shifts, use more than one system or obtain a system specially designed for a much larger volume of work.

73. Besides knowing the size of portfolio on which the computer system will operate, the manufacturer requires to know whether the computer system will be operational on a one-, two- or three-shift basis; this introduces a complication which assumes a greater importance if the system is rented. Several North American life offices have based their plans on a two-shift system in view of their large policy portfolios and the fact that they have already purchased, or are proposing to purchase, rather than rent, their computer systems. Personally, I should like the computer proper to be able to carry out the major administrative procedures for 500,000 policies on the assumption that it will be employed on a single-shift basis and can be relied upon to be fully operational for at least 32 hr. per week (i.e. approximately 85% of the normal working week).

74. While the times deduced from the demonstrations in Part 2 of this paper are based on a very small and limited experience and are in any event only approximate ones, they can be used to obtain estimates of the times which would be required in practice to carry out the main life-office administrative procedures. For illustrative purposes the following assumptions are made and apply throughout the remainder of the paper:

(*a*) The policy portfolio numbers 500,000.
(*b*) The average number of characters per policy in the binary main record is 200.
(*c*) The main record is kept on magnetic tape, the data of 10,000 policies being kept on each spool.
(*d*) The magnetic tape input/output units operate at speeds of 10,000 characters per second and the tape stop and start times are 5 msec. each.
(*e*) 7,200 amendments to the main record (new business, alterations and exits) arise each fortnight.
(*f*) The average number of alpha-numerical characters per amendment is 165.
(*g*) Amendments are punched twice on paper tape for input to the computer.
(*h*) The computer can sort 7,200 items into reference number order in 2 hr.

Maintenance of magnetic tape main record

75. If the procedure set out in Appendix C is adopted the following times result:

	Input/ output hours	Computation hours
(*a*) Production of the checked binary amendment tape for 7,200 amendments	3·4	11·4
(*b*) Sorting amendment tape into reference number order	·1	2·0
(*c*) Input of main record tapes	4·2	
(*d*) Input of amendments tape	·1	
(*e*) Computation time (say 9 sec. per amended policy and 5 msec. per unaffected policy)		18·7
(*f*) Output of main record tapes	4·2	
(*g*) Output of accounting and record printing tapes	·1	
	12·1	32·1

76. The comparison by the computer of the main record tapes before and after alteration so as to select the policies whose data is to be printed acts as an additional check upon the procedure set out in Appendix C (vide paragraph 26), and the additional time required for this is as follows:

	Input/ output hours	Computation hours
(*a*) input of main record tapes	4·2	
(*b*) input of main record tapes (after alteration)	4·2	
(*c*) computation time—8 msec. per policy		1·1
	8·4	1·1

The approximate total time required for the whole procedure is thus 21 hr. for input/output and 33 hr. for computations. The time required to print the records of 7,200 policies at the rate of one policy every 5 sec. is 10 hr.

Monthly renewals

77. It has already been deduced that 75·6 hr. computation time would be required for the monthly renewals procedure. The input/output time would be as follows:

	Hours
(*a*) Input of main record tapes	4·2
(*b*) Output of tape for printing agents' lists	·7
(*c*) Output of tape for printing notices and receipts	1·6
(*d*) Output of tape for printing alterations list	·1
	6·6

78. Assuming that notices and receipts are printed side by side and that each contains eight lines of type, including the name and address of the addressee, and assuming that the agents lists show the name and address of the agent, then approximately one million lines of type are involved. In addition, time will be required for the paper throw facility to jump from one preprinted form to the next. At the maximum printer speed currently available in this country of 150 lines per minute the printing with paper throw would require about 120 hr.

Valuation on two bases

79. The input/output time for the valuation procedure would be as follows:

	Hours
(*a*) Input of main record tapes	4·2
(*b*) Output of tape for printing 4th Schedule	·1

Some 222 hr. computation would be required and the printing time is negligible.

80. The approximate times in hours taken to complete three of the main life-offices administrative procedures are summarized in the following table:

	Input/output hours	Computation hours from the demonstrations	Estimated computation hours allowing for program improvements (vide para 68)	Estimated input/output plus computation hours	Printing hours
(a) Maintenance of magnetic tape main record	21	33	30	51	10
(b) Monthly renewals	7	76	66	73	120
(c) Valuation on two bases	5	222	200	205	1

I have little doubt that further experience in this work will enable these times to be still further reduced, but the extent of such further reductions can only be a matter of conjecture at this stage. Thus even with the use of high-speed magnetic tape input/output units the times shown are much too long to allow the use in practice of a computer system operating at the speed of the one used in the demonstrations. Consideration will therefore be given to the principal components of a computer system assuming that one were to be designed especially for life-office work within the framework suggested in this paper.

Input/output

81. While an input/output speed of 10,000 characters a second seems capable of achievement in this country in the next year or two, I doubt whether any further significant increase in speed can be looked for, in that time. If, however, a speed of 10,000 characters a second is not achieved, then some reduction in input/output time will undoubtedly be advantageous. Some ways of reducing input/output time are mentioned in the following paragraphs.

82. Where the computation time per policy is less than the data input time (e.g. 20 msec. if the policy record contains 200 characters) which may be the case, for example, for each non-renewable policy in the monthly renewals procedure, then it may be possible to design the policy record and the program for the procedure so as to avoid the necessity for the tape to stop and restart between policies.

83. It is also possible to arrange for the data of one policy to be read in while the computer is operating on the data of the preceding policy; in this way it is possible to save up to the full input time (e.g. 20 msec) for each policy where the computation time per policy exceeds this amount. It is also possible to have a similar facility to reduce the output time.

84. Even though it is possible by a combination of the above methods to effect substantial reductions in the total input/output time it does not follow that the reductions are economically desirable. For example, if an overall

reduction in the input/output plus computation time for the monthly renewals procedure of about 50% is required, it may be more economic to reduce the computation time by two-thirds and leave the input/output time unaltered.

85. Appendix C shows how six tape units could be used at the same time during the record maintenance procedure while the monthly renewals procedure would require five to seven units depending on whether or not the addresses of the agents and the addresses of the notices are kept on the main policy record tapes or on separate tapes. Any magnetic tape system designed for life-office work should be able to handle up to ten units, although many offices might require fewer.

Computer

86. It is evident from the figures in paragraph 80 that a substantial reduction in computation time will be necessary. If a computer were being designed especially for life-office work an increase in computer operational speed as compared with that of the demonstration computer might be achieved by any of the following ways:

(*a*) Faster transfer from the magnetic drum to the operational stores or the replacement of the drum by a new medium.
(*b*) An increase in the amount of rapid-access storage (to reduce the need for transfers from the drum or other backing store).
(*c*) A new form of rapid access storage medium.
(*d*) A higher speed of operation in the arithmetic unit.
(*e*) A decimal or alpha-numerical system of operation.
(*f*) Duplication of hardware so that calculations may be carried out twice and the results compared to save the time lost in programming checks, or improved reliability so that programmed checks are unnecessary.
(*g*) An increase in the number of instructions.

87. It is for the manufacturer to determine which combination of these methods will be the most efficient in ensuring the optimum balance between cost, speed and reliability. In this connexion it is heartening to note that some comparatively inexpensive computers are now coming on to the market capable of carrying out certain scientific computations in less time than that taken by the demonstration machine; if a reduction in computation time of two-thirds can be achieved for life-office procedures, and I am convinced that it can be, then the input/output and computation times for the three procedures mentioned in paragraph 80 will be as follows:

	Input/ output (unaltered hours)	Computation hours	Total hours
(*a*) Maintenance of magnetic tape main record	21	10	31
(*b*) Monthly renewals	7	22	29
(*c*) Valuation on two bases	5	67	72

I suggest that if a thoroughly reliable computer system is available which can operate within these time limits then no further reductions in time need be looked for by the majority of British life offices.

Printer

88. A printer operating directly from magnetic tape (quite independent of the computer) is required. A printing speed of 150 lines a minute is probably adequate, though a speed of up to 200 or 250 lines a minute may be advantageous if the machine cost increases at a lower rate than the speed. A paper throw facility is also required. On the basis of the table in paragraph 80 the monthly renewals printing time of 120 hr. for a portfolio of 500,000 policies would be reduced by the use of three printers operating at 200 lines a minute to 30 hr. which would be satisfactory. As mechanical items such as printers are generally the weak links in computer systems I suggest that at least two printers are necessary, and for this reason comparatively slow inexpensive machines have advantages over faster more costly ones. To save printing and computation time renewal notices and receipts should be printed side by side and a line of at least 120 characters will be useful.

89. The need to preset spaces on most current printers is a device to economize in printing time and so is useful, but it is a serious drawback to the obtaining of a neat lay-out and hinders the rapid change from one form of printing output to another. The difficulty may be solved by having a character in each position but with the facility to preset spaces where required.

Overall reliability

90. Little has been said on this subject in this paper, although it is clearly of the greatest importance. Computers in North America are earning a great reputation for complete accuracy in the computations carried out, and it is hoped that British manufacturers will be able to prove by exhaustive tests that the present worries of actuaries on the point can be set at rest.

Cost

91. Having set out certain computer specifications in the broadest sense it is now necessary to consider the question of cost. The approach suggested in paragraph 6 cannot be made unless the cost of the computer system is known, and it is clearly not practicable for manufacturers to quote even approximate costs at this stage. My personal view, and this may in no way represent the view of any computer manufacturer, is that a complete system on the lines suggested should be obtained at a cost lying somewhere between £50,000 and £100,000. I hope that this rough estimate will suffice at this stage to stimulate investigation by a number of life offices on the lines set out in paragraph 6.

92. These specifications all assume that the modified system outlined in Part 1 and demonstrated in Part 2 of the paper is to be followed; if any major amendments are made to this system the specifications may not be suitable. Thus, if a premium accounting method is to be used, whereby during the monthly renewals program a premium-due file, on magnetic tape or punched cards, is prepared showing the policy number of each renewable policy and the premium due under it, and, as each premium is paid the details of the payment are entered on magnetic tape or a punched card for checking against the corresponding item in the premium-due file, then a higher speed of operation from the computer will be required in view of the extra work which it will have to do. If magnetic tape is used time will be required for sorting the items

on the payments tape and then comparing it with the premium-due file; if cards are used time is required for punching them, as well as the extra staff to carry out the checking process. It is only by formulating our proposed office procedures and making these known to computer manufacturers that life offices will be able to influence the design of computer systems.

PART 4. GENERAL

93. There is now so much printed information regarding computers and computer applications and so many different makes of computer are on the market, or promised in the near future, that many actuaries find the wealth of information rather confusing. I shall therefore conclude this paper by discussing a few questions of a general nature in connexion with computer systems which will, I hope, clarify the position.

(*a*) *Magnetic tape.* Magnetic tape is frequently directly compared with punched cards as a policy-data storage medium and is thus generally found wanting. I submit that the correct comparison is between a magnetic tape/computer system and the present punched-card/human-element system, and on this basis the magnetic tape/computer system is generally held to be the more reliable.

(*b*) *Decimal operation.* Whether the computer operates in a binary, octal, decimal or any other scale, information is in all cases input and output in decimal and alphabetical form, and apart from the actual programmer no one need concern himself with the scale in which the computer operates. The important point is to ensure that the optimum relationship is obtained between reliability, speed and economy in the solution of life-office problems.

(*c*) *Speed of operation.* This must be examined in relation to the whole computer system and the whole life-office problem. A computer addition time of 1 msec. and a multiplication time of 2 msec. tell us little about the overall speed of operation. It is necessary to program demonstration problems in order to deduce the full operation time.

(*d*) *Fast printing.* Much talk is heard of the need for fast printing units, and many firms in North America are engaged in producing printers operating at speeds of about 600, 900 or more lines per minute. I doubt whether many life offices could keep such fast printers fully employed. Electric typewriters controlled by magnetic tape may sound slow, but a number of such machines operating on a 24 hr. basis are comparatively inexpensive, require little attention and the breakdown of one machine will cause little inconvenience. Some ten or twelve typewriters may give the same output as one line printer of the type used in the demonstrations.

(*e*) *Programming.* Many actuaries appear to be unduly worried about the programming problem. The main work is not the translation of basic steps into code form but the complete analysis of office procedures into basic steps. This latter part of the work may well take up to two years and, this being so, an early start on the general approach to be taken is to be recommended.

(*f*) *Size of computer system.* The modern tendency is to construct the system in sections, each section being of wardrobe size or less. The whole installation will certainly take up only a small portion of the space now occupied by punched-card equipment. Special air-conditioning plant is necessary for most large computers at present, but here again new techniques (e.g. transistors) may be expected to reduce or obviate the need for this.

(*g*) *Maintenance staff*. A staff of at least two technicians per shift is fairly standard for most large computer systems. New techniques may again be expected to lead to greater reliability and simpler servicing and so to a reduction in the number of maintenance staff required. The eventual position probably depends on the method of computer construction adopted and on what servicing facilities, if any, manufacturers are prepared to offer in the main centres of operation.

(*h*) *Operating staff*. It is probable that two or even three operators will be required in the day-time while one operator may be sufficient on night shifts where work of a routine nature would probably be run.

(*i*) *Depreciation*. Computers have few moving parts, and physical depreciation of components is unlikely to be a serious problem. With good maintenance a computer system should be as efficient after 5 or 10 years as it is at date of purchase.

(*j*) *Obsolescence*. It is sometimes suggested that prospective purchasers should wait until computer techniques settle down before purchasing a computer system or that the question of obsolescence be avoided by renting a system instead of buying it. If an office is satisfied that the purchase of a computer and a change in office procedure is fully justified now there seems little to be gained by deferring the purchase; if new techniques or machines become available in a few years time a further investigation can be made as to the possible advantages of changing on to the latest system.

94. This paper would not be complete without some reference to the systems of operation proposed by those North American life offices which have investigated computer techniques: the two chief ones are the Consolidated Functions system and the Combined Operations system. Brief details of these systems are given in the following paragraphs.

95. (*a*) The Consolidated Functions system is based on the use of three separate records for each policy namely:

- (i) a premium billing file containing the data necessary for printing renewal notices, receipts, agent's accounts, etc.,
- (ii) a calculations file containing the data necessary for calculating policy reserves, dividends etc., and
- (iii) a policy history file containing the history of the policy, including premium payment and loan details, which is brought up to date automatically from files (i) and (ii) on policy renewal dates.

(*b*) The system takes its name from the consolidation of all existing policy records (generally ten or more for many North American offices) into the three files mentioned, and the consolidation of many jobs formerly done separately by different departments into a small number of complete file processing jobs. The ability to cross-check between files gives a very complete audit control.

(*c*) One office has already installed a large magnetic tape computer system and is considering using it to carry out the Consolidated Functions system of life-office administration. The calculations file is on magnetic tape and the other two files are on punched cards, but I understand that, if magnetic tape proves as reliable as is anticipated, the premium billing file will eventually be transferred on to magnetic tape. At the time of writing the computer is giving excellent service in a local application within the Actuarial Department as well as being used to develop new programs.

96. (*a*) The Combined Operations system is based on the use of one record for each policy to contain all data which is required for premium billing and accounting and for the calculation of policy reserves, dividends, etc. This system also takes its name from the combination of many existing policy records into one record and the carrying out, at each processing of data, of many operations now performed separately by different departments.

(*b*) One office which hopes to put a Combined Operations system into use shortly is proposing to maintain the main policy record on magnetic tape and to make a printed copy of the policy data on the tape every month; the printed copies can be filed as historical records, but other historical records, which are completed in manuscript at present, will probably be continued in this form. It is of interest to note that the office in question is proposing to hire a punched-card-to-magnetic-tape converter for a period of about one year to transfer existing policy records on to magnetic tape and that no use will be found for punched cards thereafter.

(*c*) Another office which proposes to use the Combined Operations system will also keep the main policy file on magnetic tape. In this office also, while punched cards have their uses at present as the entry medium of new data and in the premium collection and accounting system, changes are under consideration whereby the use of punched cards for these purposes may become unnecessary.

97. The method demonstrated by the author is essentially a combined operations one but it differs in many ways from those mentioned in the preceding paragraphs. The renewals system depends on the agency system in force, and one American office which has a completely centralized premium collection system maintains its main policy record in 'day of renewal' order (the policy reference is of the form '18·1234567' where the premium falls due on the 18th of the month and the policy serial number is 1234567); premium billing can thus be done on a daily rather than a monthly basis, which is of material assistance in maintaining an even flow of work. Another major difference arises from the different bonus distribution systems in force; under the North American 'contribution' method of calculating bonuses it is found convenient to bring the policy reserve up to date at the policy anniversary and compute the policy dividend at this time; the reversionary bonus system seems to be well suited to a year-end computer valuation. There are, in addition, many minor differences but I do not think it necessary to expand on these at present.

98. The challenge of computers presents actuaries with an excellent opportunity to review their present life-office administration from top to bottom, and whether or not an office decides to adopt a computer system, the investigation into current methods will itself be well worth while. In addition, it presents actuaries with a new tool for valuation and other actuarial calculations, and actuarial methods will clearly have to be adapted to the new techniques or new methods deduced. I certainly consider that a close investigation, undertaken with a completely open mind, of computer techniques will lead actuaries to look forward eagerly to the appearance on the market of reliable commercial computer systems.

99. In conclusion, I would like to thank Ferranti Ltd. for practical encouragement which made these demonstrations possible and Mrs A. L. Clarke and Mr H. Cotton, B.Sc., for carrying out the necessary programming.

APPENDIX A

POLICY RECORD

1. Policy reference
   (*a*) Branch number
   (*b*) Agency number
   (*c*) Policy number

2. Life assured
   (*a*) Name
   *(*b*) Address
   (*c*) Sex
   (*d*) Date of birth
   (*e*) Whether age is admitted
   (*f*) Repeat of (*a*) to (*e*) for joint-life policies

3. Underwriting
   (*a*) Class of acceptance
   (*b*) Medical or non-medical
   (*c*) Extra premium or debt details
   (*d*) Code number of disability if accepted on special terms

4. Benefits
   (*a*) Currency
   (*b*) With or without profits
   (*c*) Date risk commenced
   (*d*) Sum assured or annuity
   (*e*) Maturity, vesting or expiring date
   (*f*) Repeat of (*d*) and (*e*) for multiple benefit policies
   (*g*) Attaching bonus
   (*h*) Annuity details: term certain, payable in advance or arrears, frequency, final proportion or not, rate of annuity option, mortality and interest basis
   (*i*) Family-income benefits: amount per annum, expiry date, method of payment, sum assured deferred, interest on sum assured deferred

5. Reassurance
   (*a*) Amount reassured
   (*b*) Class of reassurance
   *(*c*) Offices with which reassured and proportion ceded to each

6. Premiums
   (*a*) Annual renewal date
   (*b*) Frequency
   (*c*) Frequency loading

6. Premiums (*continued*)
   (*d*) Periodic premium
   (*e*) Date payable from
   (*f*) Date payable up to and including
   (*g*) Repeat of (*d*) to (*f*) up to four times for known variations of premium

7. Commission
   (*a*) Class
   (*b*) Initial rate
   (*c*) Initial amount
   (*d*) Renewal rate
   (*e*) Name of agent
   (*f*) Address of agent

8. Loan
   (*a*) Amount
   (*b*) Date of last alteration
   (*c*) Interest rate
   (*d*) Interest frequency

9. Non-forfeiture
   (*a*) Class
   (*b*) Date effective

10. Automatic alteration
   (*a*) Reason
   (*b*) Date

11. Address for notices
   (*a*) Name
   (*b*) Address

12. The assured
   *(*a*) Name
   *(*b*) Address

13. Policy printing
   *(*a*) Form number
   *(*b*) Reference numbers of special conditions

14. Notices
   * Number and brief details of all notices affecting the policy

15. Valuation
   Valuation functions

* See paragraph 33.

POLICY RECORD

Life Assured	Policy Reference: Branch No.	Policy Reference: Agency No.	Policy Reference: Policy No.
1H	2H	3H	4H

Annual Renewal Date	Premium Freq. / Premium Freq. % Loading	Commission Code / % Renewal Commission	Valuation Class / % S.A. Reass'd	Date of Birth	Date Risk Commenced
1X W M	2X W Y	3X W Y	4X W Y	5X W M Y	6X W M Y
Ren'l thro' Agent or direct / Sex / N-F Code	N.P. or P. / Non-Med. or Med. / U/write Class	Cur-rency / Reass'ce Code / Disabil-ity Code	Extra Premium or Debt' Term / % / %	Refer to Life Dept. Code / Date	Under N.F. From
7X W M Y	8X W M Y	9X W M Y	10X W M Y	11X W M Y	12X W M Y
AGENCY COMMISSION On First Premium	AGENCY COMMISSION On first Combined Init & Renew. Premium	Spare	Loan Amount	Loan Int. Freq. / Int. Rate %	Loan Date of Last Loan
1V L Z P	2V L Z P		3V L Z P	13X W Y	14X W M Y

BENEFITS

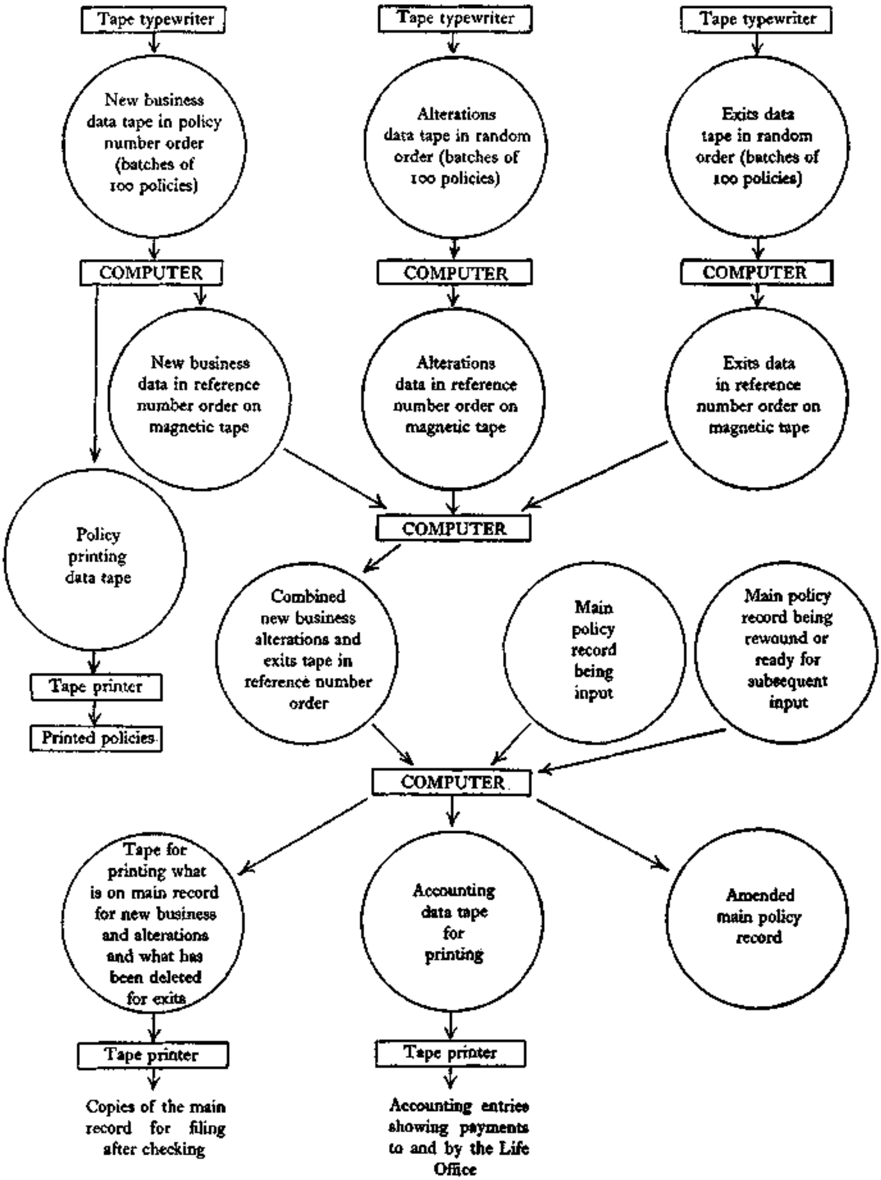
SUM ASSURED OR ANNUITY (1) Amount	SUM ASSURED OR ANNUITY (1) Mat'y, Exp'y or Vesting Date	Income Benefit Amount p.a.	Income Benefit Expiry Date	Income Benefit Payment Code / Int. on S.A. Deferred	Income Benefit Sum Assured Deferred
4V L Z P	15X W M Y	5V L Z P	16X W M Y	17X W Y	6V L Z P
SUM ASSURED OR ANNUITY (2) Amount	SUM ASSURED OR ANNUITY (2) Mat'y. Exp'y or Vesting Date	Annuity or Annuity Option: Term Certain / Life T'after / Adv. or Arrears	Annuity or Annuity Option: Freq. / Final Pp'n. / Mort. & Int. Code	Attaching Bonus	Spare
7V L Z P	18X W M Y	19X W M Y	20X W M Y	8V L Z P	

PREMIUMS

Periodic Amount	Payable From	Payable up to and including	Extra (incl. I.B. & D.T.A.) in Amount	Net Premium (A)	Net Premium (B)
9V L Z P	21X M Y	22X M Y	10V L Z P	11V L Z P	12V L Z P
13V L Z P	23X M Y	24X M Y	14V L Z P		
15V L Z P	25X M Y	26X M Y	16V L Z P		
17V L Z P	27X M Y	28X M Y	18V L Z P		

APPENDIX C

MAINTENANCE OF MAIN POLICY RECORDS ON MAGNETIC TAPE



APPENDIX D

Monthly Renewals—Flow Diagram

1. Print initial headings.
2. Read in policy data and test check sum.
3. Determine if policy is renewable.

(Yes) (No)

4. Test if policy is under non-forfeiture.

(No) (Yes)

7. Test if policy is to be referred to the life department.
5. Test if action is required now or not.

(Yes) (Yes) (No) (No)

6. Output data for automatic alterations list.
8. Output data for automatic alterations list.
9. Find premium due
10. Compute agency commission.

(None found)

11. Test for loan → 12. Compute interest.

(None) (loan)

13. Test if collection is through agent or direct.
14. Add renewal amounts to correct totals depending on 13.
15. Print policy data in agents monthly list.
16. Test for end of agency and end of branch printing the appropriate totals and headings.

Notes

(*a*) The flow for single-premium policies side-tracks the premium and commission sections, and if there is no loan or loan interest due proceeds direct to item 16.

(*b*) The fact that premiums are 'paid up', other than single-premium cases, is established in item 9, and for these paid-up policies if there is no loan or loan interest due, the flow proceeds direct to item 16.

(*c*) Each stage in the flow diagram is broken down into its most elementary steps; thus stages 4 and 5 are broken-down as follows:

Item 4. Test whether or not there is an entry in the computer store containing the item 'Under N.F. From Date'.

(Storage location blank) (Storage location not blank)

Not under N.F. *Proceed to item 7*

Isolate the item 'N.F. Code'

Test whether this item equals 0 or 1

(N.F. Class 0) (N.F. Class 1)

Add 1 year to the date in the item 'Under N.F. From Date' and retain the sum in the computer's arithmetic unit

Place the 'Refer to Life Department—Date' in the computer's arithmetic unit

Test the equality of the item in the computer's arithmetic unit with the 'Month and Year of Renewal'

(The Same) (Different)

Print on the teleprinter the Policy Reference and the code letters 'N.F.' and then *proceed to the next policy*

No action required—*proceed to the next policy*

FOURTH SCHEDULE

VAL ON BASIS A AT 31 DEC 1954	PARTICULARS				VALUATION			
	NO OF POLS	SA AND BONUS	OFFICE YLY PM	NET YLY PM	SA AND BONUS	OFFICE YLY PM	NET YLY PM	NET LIAB
WITH PROFITS								
WHOLE LIFE	3	20946*	211	97	2567	3181	2071	495
ENDOWMENT ASS	55	63676*	2351	1755	28118	30672	23025	5093
EXTRAS			54		107			107
TOTALS P	58	84622	2615	1852	30792	33853	25096	5696
NON PROFITS								
WHOLE LIFE	4	15745*	244	186	5967	4024	3556	2411
ENDOWMENT ASS	26	78733*	1494	1136	18123	15473	13900	4223
DOUBLE END								
PURE END								
LEVEL TEMPORARY	4	37000	156		312			312
DECREASING TEMP	5	10827	48		314			314
FIXED TERM	1	131	6	5	102	82	74	28
C D A	4	1108	50	45	860	705	635	225
EXTRAS			13		124			124
TOTALS NP	44	143544	2011	1372	25801	20284	18164	7638
TOTAL ASSURANCES	102	228165	4627	3224	56594	54137	43260	13333
REASSURANCES								
NET TOTAL ASSCES	102	228165	4627	3224	56594	54137	43260	13333

VAL ON BASIS B AT 31 DEC 1954	NO OF POLS	SA AND BONUS	OFFICE YLY PM	NET YLY PM	SA AND BONUS	OFFICE YLY PM	NET YLY PM	NET LIAB
WITH PROFITS								
WHOLE LIFE	3	20946*	211	98	2437	3010	1972	465
ENDOWMENT ASS	55	63676*	2351	1739	27018	29688	22043	4975
EXTRAS			54		107			107
TOTALS P	58	84622	2615	1837	29563	32698	24015	5548
NON PROFITS								
WHOLE LIFE	4	15745*	244	185	5764	3791	3328	2436
ENDOWMENT ASS	26	78733*	1494	1135	17473	14998	13458	4015
DOUBLE END								
PURE END								
LEVEL TEMPORARY	4	37000	156		312			312
DECREASING TEMP	5	10827	48		314			314
FIXED TERM	1	131	6	5	91	79	71	20
C D A	4	1108	50	45	773	675	607	166
EXTRAS			13		124			124
TOTALS NP	44	143544	2011	1371	24851	19543	17464	7386
TOTAL ASSURANCES	102	228165	4627	3207	54413	52240	41479	12934
REASSURANCES								
NET TOTAL ASSCES	102	228165	4627	3207	54413	52240	41479	12934

* The major part of these items is the commuted value of Income Benefits, the premiums for which appear in the 'Office Yearly Premium' column.

APPENDIX G

Net Premium Valuation Formulae

Calendar year of:	Birth	Entry	Valuation	Last premium	Maturity or expiry
Assumed age:	0	y	x	$(x+t)$	$(x+n)$
Duration:		< r years >	< t years >	< $(n-t)$ years >	

(1) Valuation class	(2) Sum assured and bonus	(3) Net yearly premium (when computed)	(4) Value of sum assured and bonus	(5) Premiums valuation factor
Whole life	SA + bonus	$M_y(N_y-N_{x+t+1})^{-1}$ (SA) but limited to 90 % of (OYP)	$(M_x+M_{x+1})(N_x-N_{x+2})^{-1}$ (SA + bonus)	$2(N_{x+1}-N_{x+t+1})(N_x-N_{x+2})^{-1}$
Paid-up loadings	—	—	$2(N_{x+1})(N_x-N_{x+2})^{-1}(K)$ for paid up policies $2(N_{x+t+1})(N_x-N_{x+2})^{-1}(K)$ for policies with limited future premiums where $(K)=(\mathrm{SA})/100$ if with profits and SA/200 if without profits	—
Endowment assurance	SA + bonus	$\{(N_y-N_{y+1})(N_y-N_{x+n})^{-1}-d\}$ (SA) but limited to 90 % of (OYP)	$2\{\frac{1}{2}[M_x+M_{x+1}]-M_{x+n}+N_{x+n}-N_{x+n+1}\}$ $(N_x-N_{x+2})^{-1}(1+p_a)$ (SA + bonus)	$2(N_{x+1}-N_{x+t+1})(N_x-N_{x+2})^{-1}$
Income benefits	$(n-1)$ (income benefit per annum less interest on SA deferred)	—	(SEP), (TEYP) or 2 (EYP)	—
Extra premiums	—	—	(SEP), (TEYP) or 2 (EYP)	—
Level temporary	SA	—	(SP), (TYP) or 2 (OYP)	—
Decreasing temporary	(SA′) $(n-1)(n+r)^{-1}$	—	$\{(n-1)(n+r)^{-1}$ (SEP)$\}$, (TEYP) or 2 (EYP)	—
Fixed term	SA	90 % of (OYP)	$v^{n-\frac{1}{2}}(1+p_b)$ (SA)	$2(N_{x+1}-N_{x+t+1})(N_x-N_{x+2})^{-1}$
C.D.A.	SA	90 % of (OYP)	$v^{n-\frac{1}{2}}(1+p_b)$ (SA)	$v^{\frac{1}{2}}\sum_{n=1}^{x+t} v^n$
PE (with returns)	SA	90 % of (OYP)	$v^{n-\frac{1}{2}}(1+p_a)$ (SA)	$v^{\frac{1}{2}}\sum_{n=1}^{x+t} v^n$
Double endowment	(SA + SA′)	90 % of (OYP)	[(SA) $\{\frac{1}{2}(M_x+M_{x+1})-M_{x+n}+N_{x+n}-N_{x+n+1}\}$ + (SA′) $(N_{x+n}-N_{x+n+1})$] $2(N_x-N_{x+2})^{-1}(1+p_a)$	$2(N_{x+1}-N_{x+t+1})(N_x-N_{x+2})^{-1}$

Notes. (i) SA is the principal sum assured, SA′ is the subsidiary sum assured.

(ii) (OYP) is the office yearly premium exclusive of extras where premiums are still in force.
(TOYP) is equivalent to (OYP) where premiums have terminated.
(SP) is the office single premium exclusive of extras.

(iii) (EYP) is the extra yearly premium where the extra is still in force.
(TEYP) is equivalent to (EYP) where the extra premiums have terminated.
(SEP) is the single extra premium.

(iv) p_a is an increase in the assurance value for policies with annuity options and depends on the option basis.

(v) p_b is an increase in the assurance value for policies with a continuation option at vesting date and depends on the option basis.

APPENDIX F

Flow Diagram for Net Premium Valuation

INPUT 1. Input policy data and test check sum.

GENERAL 2. Test if policy is still in force—(No)

(Yes)

3. Test if currency is sterling—(No)

(Yes)

4. Isolate W, M and Y coded items required for later use (e.g. separate 'valuation class' and '% reassured' into individual storage locations).

5. Determine whether premiums are
   0—Single
   1—Terminated periodical premiums
   or
   2—Continuous future premiums
   3—Limited future premiums

7. Test for extra premium

(No) (Yes)

6. Find office yearly premium exclusive of extras.

9. Test for I.B.

(No) (Yes)

8. Value extra premiums and adjust if there is I.B. or D.T.A. as well.

10. Value I.B. and adjust if there is an extra premium as well.

11. Test for D.T.A.—(Yes)

(No)

12. Value D.T.A. and adjust if there is an extra premium as well.

13. Enter appropriate valuation class routine.

E.g. *Endowment Assurance.*

CLASS 14. Add sum assured and bonus to policy totals.

15. Test for maturity age under 70.

(Yes) (No)

*17. Read down valuation tables for ages under 70.

*16. Enter routine similar to 17 onwards but reading down tables for ages 70 and over where required.

18. Test for annuity option.

(No) (Yes)

20. Compute x and $x+n$.

19. Increase valuation sum assured by appropriate amount.

21. Test whether net premium is to be computed.

(Yes) (No)

22. Compute net premium.

23. Compute $D^{-1}{}_{x+\frac{1}{2}}$.

24. Compute annuity factor if there are future premiums.

25. Compute assurance factor.

26. Value (sum assured plus bonus) and test that the value is less than the (sum assured plus bonus).

27. Value office yearly premiums if there are future premiums.

28. Value net yearly premiums if there are future premiums.

29. Test for negative values.

(No) (Yes)

30. Adjust value of net premiums accordingly.

31. Add policy totals to running totals.

32. Test for reassurance—(Yes)—33. Compute and add to reassurance totals.

(No)

34. Arrange to repeat 15 onwards on basis B or go on to the next policy.

* The storage of the computer used in the demonstration is such that it is convenient to divide the commutation columns into two sections.

ABSTRACT OF THE DISCUSSION

Mr A. C. Baker in introducing his paper said that, in his opinion, the subject of electronic computers was of immediate importance to the profession. It was not one that could safely be set on one side to answer itself in the next five, ten or fifteen years. The techniques involved had reached the stage where manufacturers were able to take a keen interest in the requirements of commercial establishments. In fact, they were taking orders for machines incorporating punched-card and magnetic-tape input/output channels. In other words, all the techniques that had been produced could be provided in the near future for those people who knew what they wanted and asked for it.

The challenge, therefore, appeared to lie with the prospective users: first, to examine the capabilities of computing techniques; secondly, to see how they could use currently marketed computers to solve their problems; and thirdly, to try to merge the latest electronic techniques with possible changes in their own organizations to see how best the problem in all its aspects could be approached and answered. He had himself, perhaps, concentrated on the third of those approaches, because he felt that computing techniques were something essentially new. They were not a development of punched-card techniques. It was true that punched-card techniques could be used on computers, but he thought it should be placed that way round.

Mr D. J. Leapman, in opening the discussion, pointed out that some two years had elapsed since Michaelson had presented his paper to the Institute in which he described in great detail how a computer actually worked. The precedent of that paper had enabled the author of the paper under discussion to avoid reference to the technical working of a computer save for a description of the new magnetic-tape techniques, and to concentrate on the actual use of the computer from an operational point of view.

The author had not tried to justify the need for a computer in a life office, since quite clearly an investigation by the potential user was required. He had, however, indicated how he considered an investigation by a potential user might proceed and the criteria which might be used to determine whether a computer was an economic proposition. He had propounded the hypothesis that it would shortly be feasible to use a single record to produce almost all the documents required for the policy portfolio side of life office operation. For the purpose of the demonstration described in the paper he actually used punched-paper tape, but his main arguments were based on the future use of magnetic tape. He illustrated how the single record could be used to carry out two detailed routines and also indicated how other information would be obtained as a by-product. He concluded by discussing the improvements in the times which would be achieved when more sophisticated computer techniques were available.

His description of magnetic tape and the facilities which it provided was convincing, and that tape appeared to be almost standard equipment in the United States. Although that stage had not been reached in the United Kingdom, magnetic tape would eventually be regarded as a fast and reliable recording medium.

However, before they discarded the punched cards which had become the main recording means in most large offices, they should consider just what disadvantages and advantages they had.

A punched card, decimal punched, could be interpreted by a human being, albeit slowly; standard equipment existed by which the punched card could be handled easily and rapidly; it could be used for feeding data into a computer but not at the same rate as could be achieved by magnetic tape. If 900 cards per minute could be passed by a card-reader, as was suggested in the paper, it would take some 28 hours to pass through all the cards for 500,000 policies of 200 decimal characters per policy. That, however, presupposed only a single feed. There seemed to be no reason why the number of feeding channels should not be multiplied, with several working in parallel, until the data from cards could be assembled in the computer at a speed compatible with the computer's operating speed.

The chief disadvantage of punched cards in their current use seemed to be that they required human handling for filing purposes. If punched cards could be used to ensure that a particular engine was attached to the appropriate chassis and body at the right spot on the floor of the assembly shop of a motor car manufacturer, was it too much to suppose that similar facilities could be provided for the handling of the cards themselves?

It seemed to him that a decimal-operating computer was desirable. Even if that was not feasible and a binary-working computer had to be used, at least the main register record should be stored in decimal form. Clearly, unless that was done the punched cards were completely useless; but even if magnetic tape was used a system was needed whereby the information from the register could be obtained in a form intelligible to the human being without its having first to be passed through the computer or a small version of it. A record was needed which could merely be put through a printer to obtain the information required and if that facility did not exist the standard of service to policyholders would be severely restricted.

A binary-working computer could be programmed to operate on decimal numbers. Moreover, where discriminations were involved, and a large amount of processing was concerned with discriminations, it was just as efficiently carried out on decimal numbers as it was on pure binary numbers. Consequently, the overall efficiency of a binary computer working on decimal numbers depended essentially on the ratio of discriminations to true calculations.

He had been through the renewals program which the author had outlined, and believed that it contained only two or three true multiplications which would become more complicated if they were applied directly to decimal, rather than binary, numbers. However, the quotients from those multiplications were all likely to remain constant over a considerable period, the most likely cause of change being an alteration in the frequency of premium payments or a change in the standard rate of income tax where loans were concerned. Otherwise, the only calculations were, he thought, binary/decimal conversions.

In §68 of the paper the author referred to the improvements which might be obtained in the speed of operation by a slight sophistication of methods. It would seem that even with a binary computer, it would be preferable to use a decimal record with a redundant binary version of certain items in the policy data. Those binary entries would be used merely for producing agency and branch totals.

If a record were retained in that form, it would seem that a considerable saving in time would be achieved. The conversion of the binary items could easily be obtained during the periodical processing of the main register for alterations.

Obviously, in using a binary computer the main record could only be held in decimal form if a separate valuation record were used. But even if a decimal computer was used, he believed that a separate valuation record in valuation order was preferable. The Board of Trade Fifth Schedule requirements were drawn up in a form which made sorting desirable. Although it was feasible to sort and to obtain the information for the Fifth Schedule from a register maintained in policy number order, it seemed rather a long way round. It would, of course, be foolish to ignore the possibility that in the future the Board of Trade might be satisfied with a copy of the main register each year or at the end of each valuation period.

The valuation record had only to contain information necessary for the valuation or actuarial investigations into mortality, lapses, and so on. Obviously, for maximum speed that information should be stored in the machine code. A valuation record in that form could be easily prepared after the alterations to the main register had been carried out; it would merely require the alterations taped to be re-sorted into valuation order and then applied to the valuation record, the information being converted to the machine code before it was recorded on it. Having the valuation record in valuation order would achieve a considerable saving in time during the valuation. That saving would occur because it would be possible to carry forward the factors determined for one policy and test whether the next policy would require the use of any of those factors again. The author's method of using a register in policy number order meant that a complete set of factors had to be calculated in respect of each policy. Moreover, in most offices a considerable proportion of the business was written under a few tables and having information in valuation order would make possible the preparation of group summaries of those tables and the valuation of the data for the whole of a group, instead of for each policy separately.

The valuation time referred to in the paper, assuming that computer operation was three times the current speed, was about 70 hours, and 70 hours during which no really useful output was effected would seem to be a long time. He would prefer to see the valuation broken up into a series of sections, each self-contained. That was clearly possible if the data were in valuation order, since each of the sections would relate to one or more policy tables. If the data were in policy number order, the only intermediate output that could be obtained would be, for example, the liability under policies administered through the branches in Yorkshire, and that was not normally of great use.

The author outlined a system using only one record and he justified that by pointing out that originally only three records were used within an office. The multiplication of those records had arisen partly by the need for sorting to obtain statistical information for the Fifth Schedule or for actuarial investigations and partly because policies had become a more frequently used form of collateral security. That duplication might appear redundant, but it was not necessarily undesirable *per se*. The criterion was whether the alternative minimum record system produced greater efficiency. Unwillingness to adopt a unified record system did not prevent the use of a computer. For example, the Consolidated Functions approach, which had been suggested by one United States office and which was referred to in the paper, was not a unified record approach.

When a computer system was installed in an office, some reduction in staff per policy would occur. It would therefore be necessary to consider what would occur in the event of a serious breakdown. He was not a believer in the use of central reserves or mutual assistance arrangements, because peak operating conditions in several offices would be likely to coincide. It would seem that the only satisfactory alternative was a system using not one but two or three computers, and in those circumstances there was much to recommend decentralization rather than integration, so that in the event of a breakdown the least important processes could be temporarily suspended.

The system described by the author in his paper was completely automatic and to that extent it was less flexible than a semi-automatic system which blended human ability with automatic methods. A completely automatic system required a very high standard from all those who were concerned with it, and integration on the scale outlined in the paper would involve serious administrative problems, apart from the technological problems discussed in the paper.

He himself believed that scope for progress in the immediate future lay more in an improvement of the manual processes and in making them more automatic, rather than in complete integration of all processes. A certain degree of integration would automatically occur in such improvement, but flexibility would be retained. There were still many jobs in an office where it was more economical and faster to scan a manual register than to use mechanical equipment.

The author had illustrated the practicability of an integrated system. He had produced a considerable quantity of data which would greatly assist those who were interested in computer operations. In doing that, he had provided a basis for further investigation and had assisted them to crystallize their ideas.

Dr J. Engelfriet (a visitor) thought that the author had given a detailed and clear account of a system which he had developed on the main idea of a policy record on magnetic tape. He, himself, had been interested for some years in the subject and had read the paper with great pleasure, though he could not say that he agreed with the author's views in all respects.

He (the speaker) had developed a system which was based on the idea of a policy record on punched cards, whereas the author's sympathy was wholly on the side of magnetic tape. It would therefore be of some use, perhaps, if he were to make a short comparison of the two systems. That would enable him to make clear any special respects in which his own views differed from those of the author.

The main advantage claimed in the paper for magnetic tape was the very small volume of policy record on magnetic tape. No one would disagree with that view. Another point was that the combination of many functions in one policy record could be achieved. It was possible, in the opinion of the author, to do all the necessary jobs concerning premium renewals and the calculations in connexion with interest on loans, agency commission and valuation, and even the preparation of automatic alterations. That was a lot of work. It might not, however, be advisable to try to establish a policy record on punched cards in which all those functions were combined. Two files at least were needed, one for renewals, agency commissions and interest on loans, for instance, and another file for which the punched cards would have to contain the basic data of the policies; other files might then be necessary for valuation purposes and perhaps the preparation of automatic alterations and so on.

That would seem to be a disadvantage for the punched-card system, but that disadvantage should not be exaggerated; for insofar as some data might be necessary on both files, those data could be reproduced, of course, automatically from one punched card into another.

Another aspect was that of the automatic reproduction of the file. The magnetic-tape system might have an advantage in that respect, in that it was possible to reproduce it automatically and in that way to keep it up-to-date. But because it would take too long to feed the tape through the computer every day, the job had to be done, say, once in two weeks; so there would be an advantage in automatic reproduction and a disadvantage in not being able to keep the file up-to-date daily, a disadvantage he would explain when he had dealt with some other aspects of the problem.

So far he had dealt only with the form of the policy record or the form of the files. He next proposed to consider the set of jobs that had to be done in a life office, as the author had done in his paper.

As regards renewals, the calculation of payments for agency commission, and interest on loans, once the data had been punched into cards or had been typed on magnetic tape there was not a great difference between the two systems as regards speed of printing; for the handling of renewals and so on was especially a problem of printing, and the speed of printing was rather independent of the means by which the basic data had been recorded. If it was possible to increase the speed of printing, that could be done as well for a magnetic-tape policy record as for a file containing punched cards.

The same could be said about valuation. It was true that it would not be practicable to make a valuation in the manner described in the paper, by feeding the whole policy record once a year through the computer. That might take too long with punched cards, because the basic policy data might need more than one card, so that it would take too long to feed the whole record through the computer. But it was not necessary, of course, to follow the method described in the paper. It would be possible to use one of the well-known grouping methods. In the Dutch office where he had developed a system of valuation by the aid of a computer, he had chosen a system whereby after each entry or immediately after each alteration of policy three valuation results were calculated on three dates which were the same for all policies; say, 31 December 1954, 1959 and 1964. The results would take about three seconds to obtain on an average for each policy with the computer which that office would be using in the immediate future.

The program was very like that outlined in the paper. It covered practically all the variations of life assurance policies on one life that were current in Holland, so that no preliminary sorting was required. In that way, it was possible to carry out the routine and calculate the three valuations daily. Of course, once in five or ten years new results on new data would have to be calculated. But on the whole, the system had the advantage that the work could be done daily and the main policy record on punched cards could be kept up-to-date daily. That was of some advantage for all other daily work.

In the preparation of automatic alterations, there was also not much difference between the two systems. Once the data had been punched into cards or put on to magnetic tape, notes could be prepared, in which all the necessary information could be printed. Those could be sent to policyholders or agencies. With valuation and automatic alteration, then, both systems could be used.

The author had said that for conversions of existing policies there were too many variations, so that it would be impossible, or almost impossible, to establish a program by means of which that work could be done by the aid of a computer. He differed from that view as, in his opinion, the calculation of paid-up policies, surrender values and all the data necessary with respect to conversions could be done quite well with the aid of a computer. The computer which would be used in the Dutch office, to which he had already referred, could be programmed by the aid of punched cards. Each punched card could contain 48 instructions in elementary steps. The cards could be put through a machine at the speed of 120 cards a minute, so that, for instance, a program containing 3000 elementary steps could be carried through in about half-a-minute.

The essential advantage of a computer was that it could deal with large variations. The program might be very long, but that did not matter because the speed of computing was so high. He felt sure that the program of calculating conversion of one type of single-life policy into another would take much less than 3000 elementary steps.

There was a great difference between a magnetic-tape system and a punched-card system, because the handling of conversions, paid-up policies and surrender values by the aid of a computer could be done only when the policy record was kept up-to-date daily and had a short random access time. As was said in the paper, keeping up-to-date with a magnetic-tape system daily would be practically impossible, and the random access time of the magnetic-tape system was too long for daily work.

It might be said that the daily work on conversions, calculation of paid-up policies, and so on was not important enough to be mechanized, with the possible exception of that part of the work which involved calculations; but it should not be forgotten that when that type of work was done mechanically results were obtained in two forms, namely punched into cards and printed on notes which could be sent to agencies and policyholders. When a policy was surrendered, was made paid-up or was converted into another policy, all the data necessary were available for carrying out the remainder of the work mechanically.

To summarize, as regards volume, combining of functions and keeping up-to-date in an automatic way, the system of magnetic tape beat the system of punched cards. But for all that, the punched-card system offered the office the possibility of mechanizing a part of the daily work of the office which could not be mechanized by the aid of a magnetic-tape system so long as the problem of random access time and the keeping up-to-date of a magnetic-tape system had not been solved.

A decision would have to be made, and the choice between those two systems should be made not on general considerations but on specific considerations. For one life office the decision might be quite different from that of another life office. He could well understand that the author had reached a decision in favour of magnetic tape, but he could not agree with the general statement that in all cases the magnetic-tape system would be preferable.

It was all a matter, in some way, of reasoning, of making up programs and experimenting, because no one had as yet had actual experience of daily office routine. It might be that when after some years that experience was available there would be a clearer insight than then existed. However, he thought and, indeed, hoped, that even then different approaches to the subject would be possible.

Mr R. L. Michaelson said that the author had carefully avoided the two dangers of over-generalization and too much detail. He had given a paper which was easy to read and had certainly advanced their knowledge. He himself was about to become critical of some of the author's assertions, but that merely confirmed that the paper gave something at which to bite.

In the first place, he had to quarrel with the description of the new and old systems as 'magnetic tape/computer' and 'punched-card/human-element'. Those two phrases were used in §§32 and 93 (*a*). The implication was that there was no human element in the magnetic tape/computer system. That was too big a claim. Indeed, it was evident from the description in §46 (*e*) that when a disagreement occurred in the 'check sum', heavy reliance was placed on the correct functioning of the human element. He believed also that paper tape was not reversible automatically. The author would correct him if he was wrong, but if he was right the reliance placed on the human element manipulating a piece of tape was high.

If he had correctly interpreted the author, he had implied that, if he had the kind of machine that he would like to have, he would still put in the alterations on paper tape and not on magnetic tape; that again introduced the human element.

He thought that the best way to express the point was to say that no machines were infallible but they ought to form part of a system which included a routine for accomplishing five things when a machine fault occurred. Those five things were:

(1) to signal the fact that something was wrong as soon after the event as possible;
(2) to locate the error or errors in work already done;
(3) to correct the error or errors;
(4) to check the corrections; and
(5) (but not necessarily last in order of time), to repair the machine.

It was undoubtedly true that the magnetic tape/computer system reduced the human element involved in that process, but it could not be entirely eliminated. A paper/magnetic tape/computer would not reduce it so much. The reduction arose, of course, because the computer did not need so many operators and therefore fewer human mistakes would creep in.

On the topic of error correction, he wondered whether any members with experience of organizing mechanical accounting work would agree that the most likely source of error was the incorrect correction of an error which had been located.

The author did not give a great deal of information about the processes antecedent to presenting the jobs to a computer. In particular, he himself would have liked more detail about the preparation of the jobs with which Appendix C commenced. It would appear from Appendix B and §46, if he was correct in his understanding of the author's meaning, that each piece of data to be punched on the tape had to be preceded by a code letter, such as H, V or X. In some cases, it appeared, other code letters were necessary as well. In addition to that, there was the related problem of including on the alteration tape an indication of what had been altered. For instance, something had presumably to be punched to distinguish between the cases in which the age and the premium were altered and those in which the age and the sum assured were altered. If that extra punching was necessary, the human element in coding and punching was definitely increased for all alterations.

The author had made no claim that in the preparation of punched cards or paper tape he had thrown out the human being. He (the speaker) thought there was no doubt that the man or girl sitting at a key-board, making holes in tape or typing, was the slowest and the most expensive gadget in the whole set-up. It was necessary to take that extra burden into account in judging the author's proposals. He did not think for a moment that the extra burden was so great that it would significantly reduce the attraction of the proposal, but its existence should be recognized.

Still on the subject of the input of paper tape, he would like to ask the author whether the conversion of two decimal tapes to one binary tape as described in §47 was an inherent part of his system, as it seemed to be a lengthy process. The creation of a binary tape ought to be avoided.

The author's times did not appear to include any allowance for errors being signalled or for manhandling the tape or the paper on which the results were printed. For example, in §47 (*b*) and elsewhere he quoted 1·65 seconds to read 330 characters, presumably 330 provided by the theoretical speed of 200 per second. Surely some allowance should be made for error correction, stopping and starting the tape and other things which happened in practice.

He had intended to take part in the discussion regarding the relative advantages of magnetic tape and punched cards; but it would be a pity for so excellent a paper to be judged on that basis, and the only thing he wished to add to what had already been said was that in his table (see §28) the author had suggested that, for a punched-card system to store the information for 100,000 policies with 500 characters per policy, 313 trays of 2000 cards would be needed. That implied that 6¼ cards were being used, but it brought out a disadvantage of punched cards, because there could not be 6¼ cards; the number had to be six or seven. The figure of 313 should have read 350 on the basis of seven cards.

But that again equally emphasized one of the advantages of punched cards: namely that if the data were properly arranged seven cards would not be needed for every policy. The card layout might be so arranged as to average say only three cards per policy. He would not like to say definitely how large a reduction would be made; but, although the general conclusions to be reached from the table would be much the same, he did not think the comparison would be quite so marked.

The author had done a great service to both potential users and manufacturers. With his main theme, he certainly agreed, if he interpreted that as meaning that many life offices could use magnetic tape efficiently. But he did not agree that all life offices would necessarily be large enough to use magnetic tape, and he thought the criterion might be complexity of internal system and not size. Neither would he agree that they should necessarily use a single policy record. But he would certainly agree with the author's emphasis on the need to go back to essentials in developing a scheme. He did that very neatly by going back one hundred years. In the final comparison, there were some factors to take into account which were difficult to assess. They were all in favour of the computer. Some of those factors were reduced overheads; for instance, a computer did not need a canteen nor did it call for pension contributions. Some value should be placed on the earlier and better service to policyholders. There was the difficulty of recruiting staff, which he believed was very real, and there was also the training of the staff.

Mr E. J. W. Dyson was particularly glad that the author had devoted such a large part of the paper to a consideration of office records, for those were fundamental to the problems of employing a computer. There might be disagreement over the particular solution to be recommended, but not over the nature of the problem, for the stage had surely been reached when the management of a life office had to ask themselves, in considering the possibility of installing a computer, not 'Can it do the work?' but rather 'What reorganization of our methods will be necessary to make a computer an economic proposition and are we prepared to face such a reorganization?' That involved a complete and laborious analysis of the current methods of the office, the result of which was likely to be that the methods should be completely redesigned and the office completely reorganized before the requisite savings could be obtained.

Looked at in that way, it became obvious that the smaller the office the more complete the reorganization would have to be. At the same time, the fewer were likely to be the number of qualified staff available for elaborating the details of the organization. That would represent a real problem for the smaller life office. The possibility of a number of offices collaborating in the installation of a computer was one that immediately presented itself for consideration, but he did not think that that prospect was an attractive one, as the details of each office organization were different. It did, however, seem that a number of offices of approximately similar size could usefully collaborate in the design of a basic system suitable for those smaller offices which would only require relatively slight modification in individual cases.

Seen in that way, it would seem that a small rapidly developing office would be well advised to start investigating in some detail the possibilities of a computer in the near future, either alone or in collaboration with other offices. Consideration might then be given to finding out how much business would be likely to make it an attractive proposition and the date when that amount of business was expected to be approached. In view of the amount of work involved in changing, it would be better to make the change too early rather than too late.

There were two practical points to which he would like to refer. The first was control. It was of great importance in installing a system to consider the auditing procedures which would be adopted. After all, even if the computer was capable of finding its own mistakes, it would be operated by fallible mortals. While the computer might be programmed to take care of some errors, it was too much to hope that it would always be able to detect deliberate fraud. For that reason among others he personally was attracted to the Consolidated Functions approach rather than the Combined Operations approach.

Secondly, there was the assignment of policies. The method outlined by the author seemed hardly adequate, as a number of policies were assigned a great many times. The only comprehensive record of assignments for such cases would be on the policy papers, but papers got mislaid from time to time and lost notices of assignment might have serious consequences for the office.

Although the precise moment of time at which a computer should be introduced into an office was a matter of judgment, nevertheless for economic reasons all but the smallest offices would have to instal them in the relatively near future, say the next ten years.

It was not too soon, therefore, to begin seriously thinking about the problems involved, and the paper would give a powerful stimulus to that thought.

Mr T. R. Thompson (a visitor) said that Mr Dyson had rightly stressed the main problem—the reorganization necessary in using a computer. That ought to be the keynote of the whole problem, because it would be most inconvenient to have to reorganize a system which had already been installed. There then arose the dilemma that the equipment currently being developed would soon be out of date. At the same time, it would rightly be felt that the time to start was then and not when the final equipment had been developed.

The author had looked round at the various possibilities immediately available and had rightly considered the virtues of magnetic tape. For that reason, he had sought to develop a system which would use magnetic tape. But had he used magnetic tape in the right way? Various speakers had already brought out that there were alternative methods of organizing the work in which magnetic tape would not play so important a part. It would seem, therefore, that the proper approach was to take the author's idea of going back to fundamentals, to consider how the work of an insurance office could be reorganized in such a way that it would fit in with those fundamentals and to compromise for the time being on the equipment used to carry out the fundamental processes.

He could not hope that evening to go into that in any detail, but he would take one important point, that of the use of magnetic tape for the record. There were obvious advantages in using magnetic tape for feeding the computer but not necessarily in holding information in a permanent form. He thought that magnetic tape could not be recommended for every process but only for the purposes for which it was most suitable.

One argument for magnetic tape was that it could be fed quickly; the computer was an expensive piece of equipment and had to be fed quickly. But there was no similar argument for saying that information had to be taken from records at that speed. There was no reason why the record should not be one which could be read more slowly.

The idea he wanted to suggest was that, whatever equipment was used, it should be equipment that would fit in with the fundamental organization. The important point was to consider reorganization in a form which would not necessarily be ideal but would at least not need changing when new equipment came forward. For that reason, he felt, the paper did not achieve the purpose with which it had set out. It had explored the possibilities but it had not analysed the fundamental processes which had to be carried out for the different purposes. It did not seek to find the equipment which could at that time best be used for the permanent record and for feeding data to the computer. Finally it did not consider the nature of the bridge that had to be established between the record held and the data from it which had to be fed to the computer.

Mr N. D. Hill (a visitor) said that there was a current idea that technical developments were round the corner which would drastically reduce the size and cost of computers. Perhaps he could help to dispel that idea. Developments were, of course, in progress at that moment but it took many years before they could be realized in practical form. It was always possible to wait for better and simpler machines, but it might be necessary to wait for a long time.

Another current idea was that speed was only of secondary importance. Everybody had heard the doctrine that the machines had been developed primarily for scientific purposes, where a small amount of input had to be processed in a very complicated fashion and a small amount of output given to the outside world, and that the contrary was true for business purposes generally and assurance work in particular. That argument was oversimplified and tended to neglect the fact that a good deal of organization was required within the computer. If that organization was not carried out at high speed some interruption or slowing down of the input or output process might ensue.

The question of reliability had not been raised. People might be interested to know that in his experience with a computer having 800 valves there was about one valve failure for every two weeks' operation, corresponding to one hundred hours of operating time. For 800 valves that corresponded to an average life of 80,000 hours, which was far more than the original manufacturers ever expected to obtain, because valves were used by computer designers in a way that helped to conserve their life.

Two points with which he agreed strongly were that magnetic tape should be sufficiently reliable for office records and that high-speed line printers, although attractive, might not be the best form of output. Typewriters fed directly from magnetic tape might constitute a more flexible and possibly cheaper instrument.

The opener's arguments about decimal *versus* binary computers were not clear to him, but he agreed that there was a strong case for keeping records in decimal form which meant in practice some form of binary-coded decimals. The translation from binary-coded decimal form on magnetic tape to the printed form could be achieved without the use of a computer, thereby saving valuable computer time.

Mr C. D. Sharp said he had recently returned from a visit to New York. While there he had the opportunity of watching one of the main electronic computers in action and also of discussing some practical points with the experts who were dealing with electronic problems in one of the big American insurance companies.

Certain conclusions might be of interest to the meeting. Firstly, the American form of magnetic tape had been extensively tested and had been found thoroughly reliable and satisfactory.

Secondly, after extensive trials over the past year it had been discovered that the computer could be used economically for sorting as well as for computing. Naturally in designing the program every effort was made to reduce sorting to a minimum, but it had been found that for many purposes it was advantageous to use the information contained on the magnetic tape to sort the data before it was processed. That information supplemented the point made by the opener.

Thirdly, computers were being used to help to provide their own programs. By building up a bank of standard routines the computer could be instructed to select the appropriate routine and then to produce the program for a particular step. That reduced the demands on the people arranging the programs and enabled them to produce complicated programs in a much shorter time.

Fourthly, it was considered debatable whether the high-speed printer which provided information at 600 lines a minute was economical in practice. The provisional conclusion had been reached that it would probably be better to have two or three slow-speed printers because it was difficult to keep the fast printer in continuous use. Again, if the high-speed printer did break down there could be a serious hiatus in production, whereas the alternative arrangement meant that there would be a machine in reserve.

Fifthly, it had been established that the reliability of electronic equipment was at least as high as that of conventional punched-card equipment.

During his talks in New York he had found that the actuaries of the companies concerned were finding the computer useful in another direction, as the computer had been programmed to provide actuarial functions for alternative mortality and interest bases very quickly. That had particularly interested him because work was being done in England on a set of Indian life tables. For those tables four different mortality curves had been combined with five different rates of interest and a wide range of actuarial functions had been calculated by means of the computer. The possibility of obtaining such information quickly and accurately would, in his opinion, change the attitude of individual actuaries towards standard tables. In due course the actuary would have the choice from tables based upon a family of curves and would not be restricted to a standard curve.

More detailed information regarding the application of a computer to that type of work was contained in the leaflet produced for the Students' Society for their recent visit to one of the punched-card companies. The heading of the leaflet was *The application of electro-mechanical and electronic machines to actuarial practice.*

Finally, he would make a plea that the importance of that new aspect of actuarial work should be recognized by the inclusion in the examination syllabus of a section dealing with mechanization and electronics, so that the attention of the younger members of the Institute would be directed to it.

Mr William Phillips remarked that if he were to lift the receiver off the telephone and dial ACTUARY—assuming, of course, that he did not get the wrong number—he would get not the Institute of Actuaries but Battersea 8279. He did not suppose anyone in the room imagined that the telephone dial knew anything about the difference between A, B and C. Everyone realized that it was simply a variation of impulses; but he thought it did bring home the fact that in coding it was possible to make a machine do pretty well anything.

To his mind, the most valuable part of the author's paper was his insistence that with a new tool, it was necessary to look not only for a new way of doing the job, but also for a new job to do and therefore to go right back and start at the beginning. He remembered when that had to be done on the introduction of loose-leaf ledgers, and later when punched-card systems came along it was an even more important point. It might be a useful idea for anyone who was contemplating installing a computer system to turn back to *J.I.A.* **52**, 453 and read a paper by Kenchington on industrial office organization, where he had something to say about the installation of punched-card machines,—the first application of punched-card machines to life assurance in the United Kingdom, or, so far as he knew, anywhere in the world.

The people who invented punched-card systems thought fit to put extra space along the top for the purpose of containing written information. Sometimes they printed headings. Anyone who wanted could have two extra holes so that the pence could run from 0 to 11; but for enumerations other than money the first ten holes could be used for 0 to 9 and the others for 00 and 10, so as to go from 0 to 19 on the understanding that there would never be less than two holes and never more than two holes in each column, the machine being fixed up in such a way that whenever there were more or less than two holes to a column it stopped automatically. He was interested to see that after thirty years a similar facility was being talked of in regard to electronic computers.

Later it was realized that it was wasteful to use twelve holes in that way, and that it would be much better to go to the scale of notation 6 so as to get a potentiality of 36 units to the column instead of only 20, i.e. from 00 to 55 (0 to 35 in the denary scale).

He mentioned that because he was apprehensive that machines were installed to do the old job in only a slightly new way, instead of the problem being thought out from the beginning, as the author had recommended. In that way rapid progress was far more likely.

Finally, he agreed with those who felt that the policy number should be made to work for its living. It was not necessary for him to say any more about that, because anyone who would turn back to Kenchington's paper would find a recommendation on a policy number which carried with it much additional information.

Mr T. Whitwell thought that the subject of the paper was not capable of expression either in terms of mathematical precision or even in terms of that brand of common sense that applied to most of the Institute's papers. It was a subject which was rapidly growing, continuously changing and changing moreover in certain ways with which the author could hardly be expected to be familiar.

When comparison was made between the use of punched cards and the use of the new techniques employing punched paper or magnetic tape, it was necessary to bear in mind, as the opener had already indicated, that considerable progress could be expected to be taking place in the development of the older techniques under the stimulus of the new ones. To feed punched cards at high rates of speed had become practicable. To take the information recorded at high levels of density from the cards at rates of speed far in excess of the feed rates of the cards themselves, by, say, optical means, was also practicable. It was easy, therefore, to visualize a system whereby a series of punched cards fed through several feeding units in echelon could deliver their information, by such high speed scanning processes, at speeds at least equal to if not indeed exceeding those quoted for magnetic tape.

The question would then resolve itself into what were the other attributes of the media concerned. In the case of cards, they could be read visually with ease and they could easily be changed, one card for another, if alterations were necessary. In the case of magnetic tape, it was difficult to read it visually and it was not easy to make *ad hoc* changes to the information recorded on it. Corrections were particularly difficult to handle but, if substantial changes of a systematic kind were called for, it was many times faster, but not thereby of necessity simpler, to carry them out on magnetic tape than on cards.

If the record were a static one, static for say the lifetime of a policy, the cost of cards became insignificant; but if the record were rapidly changing, say several times a day, the fact that magnetic tape could be used over and over again introduced a cost factor in its favour of no small consequence.

All those factors and many more of a like kind had to be weighed in the final decisions that were made and those final decisions would depend upon local circumstances.

It should be realized that what the new computers did was just what everyone had been doing for years—data processing. The processing might be carried out by means of perforated cards in a conventional manner, or by perforated cards in the newer techniques, or it might perhaps be by means of a series of little black boxes connected together by cables using tapes of various kinds. Incidentally, photographic tape should not be overlooked in that connexion. The potentialities of photographic tape were so high that a great deal of information could be condensed on a photographic record. Means of discriminating in regard to the selection of information from the photographic tape and subsequent electronic storage, handling and re-recording of that information, were such that it was not outside the bounds of practicability to contemplate a master record in the form of a photographic copy of proposal forms containing, automatically impressed therein in coded form, the same data as those recorded on the proposals themselves.

The profession would have to study most closely all those new techniques implied in the system of data processing in its broadest terms. The study groups which the profession was initiating would find the paper, together with the others that had preceded it from 1936 onwards, most stimulating. They would never arrive at a *final solution* because the matters they were dealing with would continue to develop.

Mr W. E. Scott (a visitor) said he would like to refer particularly to the machine side of the problems.

First of all, it was important to approach the problems from as fundamental a point of view as was possible and to look forward to the requirements of the future.

In spite of the excellence of the paper he found fault with § 90 which pointed out that computers in North America were earning a great reputation for complete accuracy and which hoped that British manufacturers would be able to prove by exhaustive tests that the worries of actuaries on the point could be set at rest. That seemed to imply that the machines of British manufacturers were not particularly reliable.

From what he knew of the progress in America and in the United Kingdom, there seemed no reason to suppose that the Americans were in advance in that respect, although there were many more machines in America and many more people working on the subject.

Reliability was an awkward question which people were not ready to define. After all, neither human beings nor punched-card machines nor mechanical machines of various types were completely reliable; but, if a machine produced an answer, it was to be expected that that answer would be correct. Reliability involved also the length of time for which a machine would continue to produce correct answers. There such factors as speed had to be borne in mind. A machine working for one hour that did the work of one thousand people was much more valuable than a machine that worked for eight hours and in that time only did the work of, say, five hundred people. Speed and reliability were therefore inter-related, and that was true also of the engineering design of a machine to a large extent.

From experience to date, he did not think the author need worry about reliability. There was no doubt at all that the machine would be at least as reliable as mechanical machines.

It should also be remembered that the machines worked twenty-four hours a day, so, if the job was not done in the first hour of the day, it could be done later in the same day. Cases arose, particularly in scientific applications, where the machine had to be coupled directly to an apparatus producing information and had to process that information immediately. That meant that if the machine was not working, the data were lost. That did not apply to the kind of work that the author was talking about, except that it was not possible to wait too long before producing the answer.

The question of reliability was also connected with whether the computer was decimal or binary. It was fairly well agreed among designers that a binary machine was likely to be cheaper and more reliable than a machine that worked on a decimal basis.

The argument about punched cards and magnetic tape depended on where the machine was regarded as starting and finishing. He would like to endorse the point made by Mr Thompson that the magnetic tape should be regarded as an internal part of the machine. It should be regarded as input and output internal to the machine, not input and output from human being to machine. If it was regarded as being part of the machine, it did not matter much what was on it. It was not necessary to be very concerned in a punched-card machine as to whether the relays were on or off. What mattered was the information put in initially by the operator as a human being, and the information he got out. That should be in decimal form so that it could be read, understood and checked. If it was desired to read the contents of magnetic tape, it was necessary to have special equipment to do so.

Dr J. M. Bennett (a visitor) remarked that he was engaged in the computer field, and one of the things that had been brought home to him recently was that only a small proportion of the cost of a computer was associated with its arithmetic unit. It was that unit which was concerned with whether the machine operated in binary or decimal or mixed radices—as with pounds, shillings and pence.

In commercial work, where the amount of arithmetic done on individual pieces of information put into the machine was quite small, it was necessary to avoid having a lot of manipulation of information before the processes could be carried out. The opener had made that point very clearly. It was therefore worth spending more money on the arithmetic units, in order to minimize the amount of manipulation involved. It was reasonable that users should ask computer manufacturers for methods which operated on data in forms other than binary.

The basic decision always came down to the question of economics, and in building a machine the cost of quite extensive complications of the arithmetic unit would be comparatively small compared with the cost of the whole machine.

Mr K. A. Usherwood, in closing the discussion, said it was a fact that people in the electronic field, even though only amateurs like himself, tended to speak a special language. He only hoped that the discussion that evening had not gone too far in the direction of technicalities.

Perhaps he might enter a momentary plea there. Their United States friends did not contribute towards clarity. He had never been able to discover why 'consolidated' should mean three records and 'combined' one record.

With regard to specific contributions to the discussion, he was much impressed by Mr Michaelson's reference to the importance of taking into account the type of office concerned. He himself would like to emphasize that and to mention in particular the type of agency system which was under consideration. He for one, from a different field of experience, felt that in the author's sample office the number of agencies would seem to be extremely high. He might perhaps remind members of the original definition of a model office as the sort of office which never had existed and never could.

When, in reading the paper, he had seen the author's keen interest in and support for magnetic tape, he had rubbed his hands together mentally and said, 'Now we shall have some fun from all the people who are attached to punched tape!' That had not proved altogether wrong. If he had read the author aright—and that point had been taken up by Mr Michaelson—he had used paper tape in his experiments because that was all he had. In other words, that was all the machine he was using would take. But he leaned very definitely and strongly towards magnetic tape. Personally, he agreed with the author. Magnetic tape clearly had great advantages; but if any members present had used the other form of magnetic tape that had substantially the same form for sound recording purposes, perhaps they had discovered how far a 1200-foot reel of tape would go when it came off the reel. They would share some of the doubts which he himself felt.

He had been interested in the suggestion that had been made from more than one quarter that magnetic tape might perhaps be regarded as an intermediate medium.

There had been references to reliability, a subject which had been discussed on previous occasions by the Institute and by the Students' Society. He had taken it that the manufacturers would be able to provide the desired reliability or at least give a warning as to the extent to which it was necessary to guard against breakdown and so on. In particular, he imagined no office would commit itself to a single machine which would have to work 168 hours a week in order to get its work done. In other words, there was, with the type of machine in normal use, as there must be, a considerable reserve of time available for servicing and for catching up arrears, if necessary.

He was interested, and had no doubt others were also, in the suggestion that in one form or another high-speed output was going to be—or was—a problem which might be better solved by parallel outputs. The conception was one which caused him a certain amount of difficulty, but Mr Whitwell put his finger on the spot. It was difficult to see how one computer feeding out its results, say, at $10x$ a second was going to feed ten printers each capable of a speed of x a second. Mr Whitwell used the expression 'in echelon' which to those who had had army or similar experience would describe the process.

There had rightly been a great deal of emphasis on organizational problems. The author's paper was, after all, on organization, whereas Mr Michaelson's paper was from a different and earlier angle. It was probably clear to all that the employment or otherwise of a computer in a life office or other type of organization did not involve the executives of the office in understanding in vast detail how the computer worked. What it did involve was a team of people taking the procedure of the office to pieces and putting it together in a different form. It might, of course, be that when they put it together in a different form they had saved so much money that they did not need a computer at all.

There was one fundamental point which came out only in passing, probably because the author and the earlier speakers took it for granted. When, two or more years earlier, most of them began to hear of electronic computers, they were inclined to regard them as, so to speak, all the same sort of beast. But it had become increasingly clear as time had gone on that there were quite broadly two different tasks which digital computers would be, and were being, asked to undertake. That could be put very briefly by suggesting that computers, particularly in the late war period, started in the field where the object was to save the work of ten mathematicians for ten years. The field in which most people were interested was that where they were expected to do in an equally short time the work that would take one hundred clerks a matter of a week or two. In other words, the distribution between data and processing was appreciably different in the insurance field and, indeed, in the business field generally from that in which computers were first envisaged.

On organization, he would like to make a point which occurred to him in reading the paper and which had not, he thought, been substantially made in the discussion. That was the question of saving in the number of staff and consequent reorganization.

His own feeling as he went further into that field—and the paper had made a substantial contribution there—was that staff savings from the employment of computers might easily be over-estimated. That was an argument for and not against the use of computers. He was implying there that there was a large field in which computers would not serve. He thought he was right in saying that nowhere in the paper or in the discussion had there been any reference to what he himself regarded as the thing he wanted to know first about a policy when the records were turned up—namely had the last premium been paid? In those offices which were not in the habit of taking records off their books at one minute after midnight on the first day of the month, it would seem that that was a vital question. It was the sort of question which, so far as he could see, would have to be continually answered by clerical means. Similarly, in an office there were large functions which remained insuperable except by human means. Even in those mechanical days large offices would find on examination that a considerable part of the staff were engaged not in input and output from the machines but in clearing up what were broadly known as enquiries—things that had come up and wanted enquiring into, not necessarily things that had gone wrong in the machine.

He would like to touch on the point, moreover, that while the paper, its predecessor and, he hoped, its successors would do much to testify to the interest of the profession in computers and to stimulate that interest, there was a slightly different angle that had not been mentioned. That was the use of computers on a small scale within at any rate the larger organizations. There was an alternative approach, even if it was not one that manufacturers would be expected to appreciate very much. That was to tuck a computer away in some corner of the organization, such as PAYE or a group in a large organization, with the thought that in a year or two there would have been an immeasurable gain in office experience of its operation. He for one, and no doubt others, felt that practical experience was worth a great deal of theory. That was not said in any sense of depreciating a valuable paper or the discussion; it was merely an alternative suggestion.

The paper and the discussion had shown that there was a wide interest in the subject among members. There was both a challenge to actuaries and a challenge to manufacturers.

The President (Mr J. F. Bunford), in proposing a vote of thanks to the author, remarked on the importance of the discussion. Often their discussions looked back, but that evening they had very definitely looked forward. Mr Baker's was the second paper read to the Institute on the subject of electronic computing in actuarial work, a subject recognized as being one of growing importance and one which had made tremendous strides, even in the past ten years.

The interest shown in the subject by actuaries was evidenced by the large number of members who attended the lectures which were arranged by the Institute for those who were anxious to learn more about it, and also by those who having listened to those lectures wished to proceed further by joining study groups. Members also knew of the interest shown in the subject by the Society of Actuaries and by bodies of actuaries in other countries.

In connexion with the paper, he had turned—as he expected many others had—to the discussion which took place on Mr Michaelson's paper in 1953. Perhaps naturally he had turned particularly to the remarks made at the end of the discussion by the President, Mr Gardner. He noticed especially his plea that in the days ahead, when the physical calculations for premium tables and life office valuation would be done in a matter of hours or minutes, there should still be time for that relaxed consideration of the results and their wider meaning which was so essential to the work and the responsibilities of actuaries. Mr Gardner had hoped, in effect, that the human brain and human judgment would retain mastery of the mechanical brain. At the second discussion, he would like to echo those sentiments.

There remained a pleasant task which was a duty as well as a pleasure, namely to thank Mr Baker, in the name of the Institute, for the preparatory work which he did and for initiating the discussion. There had been, without the slightest doubt, a most interesting and lively discussion, and he hoped Mr Baker felt amply rewarded for all the energy and effort which he had put into the preparation of his paper. He would like also to thank those who had taken part in the discussion and had made the evening such an interesting and important one.

Mr A. C. Baker, in reply, said that the subject was naturally one on which there would be wide differences of opinion, but he had no doubt that opinions would crystallize over the course of the next few years. There was for example the point regarding the need for fast printers. It was left open in the paper whether a battery of slow printers would be used or high-speed ones would be required. He had received a letter from an actuary who was in charge of a high-speed magnetic-tape system in America, and one of the points on which that actuary differed from him was that they would be able to use their high-speed printers, which were 600-line-a-minute printers, fairly fully. His correspondent went on to say they would not even attempt to do premium billing if it were necessary to use electric typewriters such as those employed on their uniprinters.

There were naturally differences of opinion on the use of cards and magnetic tape. He had no doubt that similar differences existed when the use of loose-leaf files and punched cards were discussed some years back. He thought, however, that high speeds of punched-card entry into a machine through several parallel channels would be difficult unless the cards per policy could be restricted to one. Otherwise, it would be difficult to merge the cards from different input units to produce the high speed of input that was desirable.

The only other point to which he wished to refer then was that several speakers had deduced from the times given in the paper and from general reasoning that a binary computer might not be the sort of computer which was necessary for the type of approach he had envisaged. The time taken for binary to decimal and decimal to binary conversions could be a significant portion of the total process time. Even more than that, a binary machine would make the use of a magnetic-tape master file exceedingly difficult if one wanted rapid access to it. If the data could be stored on the tape in decimal and alpha-numerical form, fairly rapid random access could be arranged. If the policy wanted was known, it was only necessary to take the master tape and put it into the printer, and it printed off the details of the one policy that was wanted. It would thus be possible to achieve fairly rapid access to the information on magnetic tape.

The points raised were so numerous that he would prefer to deal with them at a later stage in writing, and he proposed, therefore, to say no more at that stage than to thank those present for their reception of his paper.

Mr H. Prawitz writes as follows:

I have read the paper with the greatest interest but I have not found time to penetrate far enough into it to make any comments of value upon it. May I, nevertheless, utter a few thoughts on the subject?

The paper deals with the question of exploiting electronic computers on the existing level of technical development. I have for the moment nothing to add to this exhaustive and interesting investigation. There is, however, another side of the matter which may be noticed as well. If there is a want of a technical development in a certain direction, and this want is expressed by a sufficiently large range of buyers with extensive purchasing-power, the development wanted will come. I have been concerned with the question of the technical improvements desirable in order to exploit electronic computers in the most extensive way but my thoughts on this subject are yet too vague to be mentioned here. I wish, however, to emphasize the importance of letting the technicians know the direction of technical development which we need.

In Sweden, there exists a computer which can be utilized for various calculations. The life offices are now preparing new technical bases of their premiums and from the moment of their confirmation to their coming into force there will be quite a short time only. Therefore, we are planning to calculate the premiums with the aid of the electronic computer. Some details from a comparison of the costs by electronic calculation and manual calculation may be of interest. The price of using the computer is 240 Sw. kr. (£17) an hour if the customer prepares the code and runs the machine himself, and double that sum, if the coding and the running are to be done by the owner of the computer. For comparison it must be remembered that a manual calculation has to be made by two persons independently, the results have to be compared and corrected, the corrected list has to be typewritten and the typescript has to be compared with the manuscript and corrected. Taking account of these facts we arrive at the conclusion that the electronic computer will make the calculation more cheaply if it takes more than 15 seconds for a person to calculate a premium and write it down. As to whole life and endowment insurances paid over the whole time there will be no, or only a slight, saving by using the electronic computer. If the premium is to be paid over a shorter time, the premium will be calculated cheaper by the computer. In Sweden we use many insurance forms which give rise to complicated premium formulae; for such premiums the use of the electronic computer will be more economical.

We are also investigating a project which, if practicable, will save much work. As you know there exist type-setting-machines which are controlled by a teleprinter-tape without any manual work. The electronic computer I have mentioned can produce the results in two different forms: as a typewritten table or as a punched teleprinter-tape. The code is, however, not the same, but we are investigating whether a translator can be constructed. If this is possible, the tape can be taken directly from the computer and put into the type-setting-machine. This would save not only the manual setting work but also much trouble in reading and correcting the printers' proof.

Mr Hudson J. Stowe, F.S.A. writes as follows:

To those of us in Canada who are studying the use of electronic computers by a life insurance office, it is very gratifying to know that the British actuaries are studying the same subject.

Mr Baker refers in his paper to a large-scale computer and then he proceeds to discuss the cost of a machine.

In Canada we think of a large-scale computer as a machine such as Univac, the I.B.M. 702 or other makes of comparable capacity. In Canada the cost of a Univac would be approximately $1 million while the rental of a 702 would be about $50,000 per month. The figures that the author quotes of £100,000 would compare with the cost of an I.B.M. 650 which would be termed a medium-sized computer.

We in our company feel that the large-scale machine is quite beyond us. We have about 500,000 policies in force and our business is complex but the number of personnel that would have to be replaced to justify the cost would represent a large percentage of our total staff. For this reason the consideration of a machine of this kind has been deferred until our size is bigger or the cost of the machine is less.

We do, however, feel that a machine of the 650 size has a definite place in our plans and with this in mind we have one on order for delivery in 1956.

The valuation in a Canadian company is quite complicated because of the number of countries in which most of us operate. We also do business in many currencies and the returns to the various jurisdictions in which we operate are different. Our valuation has to be done in such a manner that a large number of summaries must be produced to complete these returns.

The method of allotting surplus is on an annual basis and the dividend is the cash payment produced by a percentage of the reserve plus an expense saving that varies with plan and age. This produces a large amount of calculation in comparison with the uniform reversionary bonus system.

In our company we are planning to set up cards which, from two passes through the 650, will produce the following items:

(1) the policy reserve;
(2) expected mortality;
(3) the reserve on Double Indemnity Benefits;
(4) the disability reserves;
(5) the deferred premiums;
(6) the current amount of insurance on the Family Income Plan and reserve;
(7) deficiency reserves for policies with premiums below legal minimum in U.S.A.;
(8) the cash dividend;
(9) the summaries by currency and by country that are required.

This job now requires 17 separate operations to perform and we estimate that over one-half of the rental of the machine will be paid for by sorters and tabulators that we can release.

Another area in which we shall experience a substantial saving will be in the clerical work required in checking reserves and the time that was previously spent in balancing summaries.

Because of the built-in checks in the machine this time will be saved and will be considerable.

We do not anticipate that the machine will be fully occupied by this one job. We shall be able to do our mortgage accounting and all of the special jobs we now do on our 604. The present cost of doing these jobs should more than equal the balance of the rental on the 650.

It is our opinion that once our valuation procedure is working satisfactorily we shall be in a position to mechanize policy loans and perhaps agents' commissions. This will all be done on a gradual basis thereby reducing and spreading the personnel impact.

If each of the policy service operations can be mechanized by itself it should be possible to consolidate them into a combined function and do the premium billing. When we have succeeded to this extent we shall probably have grown to such a size as to justify a large-scale magnetic-tape machine. If our records are on punched cards in such a manner as to permit a combined function on a medium-sized machine with the conversion equipment available, the conversion to a larger machine should be a relatively simple transition.

This paper which has placed at our disposal the results of a study of the Ferranti machine is a welcome addition to our knowledge.

Mr Baker in his written reply, says:

It is only natural that the relative advantages of paper tape, punched cards and magnetic tape should be commented on by numerous speakers. In §31 I suggested that if one retained punched cards as the record storage medium, then a unified policy record system would not necessarily follow; this statement has been confirmed by Mr Engelfriet and others who have shown how punched cards lend themselves to other types of system which are generally of more limited scope than the one envisaged in the paper.

The value of magnetic tape is closely linked with the type of computer with which it is to be used. If one uses a binary computer it may be proper to keep the records on magnetic tape in binary form and to regard the tape files as an internal part of the computer. The tape records in this case have no real entity outside the computer as they cannot be interpreted unless passed through it.

If, however, records are kept in alpha-numeric form on magnetic tape (i.e. there is a one-to-one correspondence between the character representation on the tape and the printed character) then I suggest that the magnetic-tape files have an entity outside the computer. They may indeed be interpreted by feeding direct to a printer and a record of a policy can in this way be printed in about 3 minutes. This type of magnetic-tape record leads naturally to a computer which is able to operate directly on data in alpha-numeric form. A computer of this type is sometimes known as a decimal as distinct from a binary machine; it could I think more properly be called an alpha-numeric computer as it would operate equally well on letters and numbers (e.g. information could if required be sorted into alphabetical as well as numerical order). Mr Hudson Stowe mentions the need for a computer to operate in various currencies and Dr Bennett points out that it is possible economically to arrange for the computer to carry out arithmetic operations in a variety of units as selected by the program. When it is realized that up to about one third of basic policy information consists of dates, another third of amounts in sterling or other currencies and a large part of the balance is alphabetical, it is clear that a computer which can operate arithmetically in a large range of radices selected by program will be of great value to our profession. What is required therefore is not a decimal as distinct from a binary computer but an alpha-numeric mixed radix computer.

I am glad that Mr Scott has given us some idea of the reliability of currently marketed computers; it is however evident that the American trend is to build an increasing number of checking circuits into their commercial computers and it may well be that there will be a tendency to do that in this country.

The opener and others show an inclination towards the maintenance of at least two records. It may be that if a valuation tape is produced each year from the basic tape, the valuation tape containing only those details which are involved in the 4th and 5th Schedules, the need for completely separate valuation records may be avoided with a consequent saving in file maintenance cost. It is worthy of note that a part of the last American Census was carried out on a magnetic-tape computer system at a cost estimated to be some 50% of the cost which would have been incurred if the work had been done with punched cards; census work is a matter of accumulating a very large number of totals from data received in a more or less random order and the number of totals and amount of data involved in the normal 4th and 5th Schedules is on a much smaller scale than that involved in American census work.

When considering the cost of a computer system it should be remembered that not only is there a large development cost to be written off but the cost is also strongly influenced by the supply and demand position. The computer systems at present available in Canada reflect these factors to the full. I certainly consider that a computer system such as is outlined in my paper, including a central alpha-numeric mixed radix computer together with at least four magnetic-tape input/output units and magnetic-tape printer(s) to give a total printing speed of say 300 lines per minute, should be obtained well under the £100,000 figure which I mentioned. At present the possibility of using a decentralized system, or several systems in parallel to eliminate breakdown worries, is rendered impracticable for all but the largest offices for reasons of cost.

I agree with Mr Engelfriet that it is not practicable to keep a large magnetic-tape file up-to-date daily. I doubt however if it is practicable to keep up-to-date on a daily basis the multiple records at present necessary and which he does not propose to reduce in number. By the time the details of an alteration have been passed round the three or more interested sections to alter their records it is probable that at least a week has elapsed; this introduces the further complication that it may not be known exactly which record is up-to-date at any one time.

As Mr Michaelson points out I have assumed a punched paper tape input speed of 200 characters a second without allowing margins; as the input speed available on the latest paper tape readers is 400 characters a second I think that adequate margins may be taken as included. Punched paper tape is an inexpensive medium on which to record new data, particularly where it can be done as a by-product of an otherwise necessary typing operation, but editing difficulties certainly do arise; it is to assist in this editing problem that the new data were typed twice in a manner similar to the punching and verification of punched cards. In the table (see §28) an average of 500 characters per policy was assumed, so that the different media could be considered on a definite basis. In §33 an amendment was proposed to reduce the average number of characters per policy to 200 and on this basis the average number of punched cards per policy would be just over three; by the same reasoning the average space required to store the policy data on magnetic tape would be similarly reduced.

Mr Thompson suggested that magnetic tape is not a suitable medium for holding information in a permanent form. In my proposed system the basic record is in printed form, in fact, a printed copy of the magnetic-tape record; if viewed in this light it is evident that the magnetic-tape record is a processing record only with the advantage however that it does not require to be reproduced from another source before each processing.

The figures for maintenance and operating staff which I gave are those currently considered necessary for large computer installations in America. I agree with Mr Hill that this staff is more than is necessary with most current British computers, but the system which I have described earlier contains several magnetic-tape units and printing machines which are not at present normally associated with computers.

In my closing remarks I mentioned that there may be difficulties in feeding punched cards in echelon unless each card feed represents a different data file or there is only one card per policy. This echelon system can of course be applied with magnetic tapes as well. Economic aspects will, however, arise as the cost of a punched-card input/output unit may be as great as or greater than that of a magnetic-tape input/output unit operating at a significantly higher speed.

In the renewals demonstration, Mr Usherwood considered the number of agencies to be rather too high for an average office. I did feel that the example should show the times which would result from an extreme case rather than an average one, although I have an idea that the number may vary widely from office to office.

I would mention that the output teleprinter tape referred to in §42 (*a*) (iii) can be fed directly to a battery of slower page printers thus providing on the Manchester University computer a fairly economical way of obtaining an intermediate speed printing output. I have no doubt therefore, that Mr Prawitz's requirements in this direction will soon be met.