IBM SELECTIVE SEQUENCE ELECTRONIC CALCULATOR

This machine will assist the scientist in institutions of learning, in government, and in industry to explore the consequences of man's thought to the outermost reaches of time, space, and physical conditions.

Thos J Watson

IBM SELECTIVE SEQUENCE ELECTRONIC CALCULATOR

To help make the efforts of scientists more productive, IBM has produced a new, highly efficient, and more versatile instrument for doing the numerical computations necessary to test their theories and to reconcile them with experimental data. No machine can take the place of the scientist or do creative thinking, but this machine relieves him of burdensome calculations, no matter how complex or involved they may be, thus leaving him more time and energy for creative thinking.

The IBM Selective Sequence Electronic Calculator follows in many respects the pattern of man's mind in performing complex sequences of computations. The machine reads numbers involved in the problem and reads the instructions for its solution. It consults reference tables containing the results of past calculations. The memory element of the machine retains the many intermediate results produced in the machine and recalls them when they are required in the course of the calculation. The calculating element of the machine adds, subtracts, multiplies, and divides the numbers it receives.

By means of a "central nervous system" the program devised by the scientist for the problem in hand automatically directs the sequence of operations, selects the proper numbers from the various memory units or from the reference tables, directs them to the calculating unit, guides the calculating processes, and routes the results back to the proper places in the memory unit. When the desired result is obtained, the program directs the machine to record it.

Because the IBM Selective Sequence Electronic Calculator is a general purpose machine, all fields of physical and social science will benefit from its exceptional versatility and efficiency. It combines for the first time electronic speed, vast memory capacity, and highly flexible and convenient programming (or sequencing) facilities, which provide far greater latitude than has been possible heretofore in manipulating numbers and carrying on mathematical operations. Its flexibility far exceeds that of the IBM Automatic Sequence Controlled Calculator completed in 1944, and its overall productive capacity is far in excess of anything previously achieved. The superior capabilities of this new calculator have been demonstrated in extremely complex test problems.

The high speed of calculation is attained by the use of electronic circuits for computing and control. All the fundamental arithmetical operations that may be called for in the processes of higher mathematics are performed electronically. Additions, subtractions, multiplications, divisions, shifting columnar relationships of numbers, and rounding-off results to the required number of digits are all performed without the use of moving parts.

To make this electronic speed effectively available for the greatly increased complexity of today's scientific problems, it was necessary to provide in the machine facilities hitherto unattained:

(1) Adequate means of getting data and procedure instructions into the machine and of getting results out of it.

(2) A gigantic memory capacity for the storing of huge masses of numerical detail that accumulate in the process of calculation.

(3) A highly flexible means of guiding the flow of numbers throughout the calculation.

The great masses of numerical data and instructions needed for complicated problems are fed into the machine automatically at speeds much greater than ever before. Moreover, facilities are provided for assembling this material automatically from various sources, checking, collating, and arranging it in the most efficient form for the machine. Only by such automatic implementation of calculating programs can a small group of technicians hope to keep the vast resources of the calculator usefully employed in exploring the ever-increasing range of modern science.

Results may be recorded in either or both of two ways at high speed. One is in the form of printed records which are obtained at the rate of 24,000 digits a minute. The scientist can follow the progress of the computation and modify his program in the light of the results as they are derived. This will be of particular advantage because this new calculator will be devoted largely to research problems in which the calculations cannot be completely planned in advance.

Results are recorded also as punched holes for automatic use at a later time, either by the calculator itself or by other devices. For example, during the calculation it is not necessary to decide what results are to be saved or published, or in what form they are to be published; provision is made for later automatic printing from selected machine records without tying up the machine.

The memory capacity provided far exceeds that of any other calculating machine—a total of nearly half a million digits. Indeed, by utilizing punched cards as a supplementary medium of storage, the capacity is made almost limitless. Of equal importance is the machine's ability to make any specific item of this stored information available quickly when it is needed.

Programming facilities have been designed to maintain a smooth, constant flow of traffic with all the proper factors supplied at the right time to keep the arithmetical unit operating at full capacity. This function was made so automatic that only general instructions need be given to carry out comparatively long sequences of operations.

The machine is designed for two distinct modes of operation. One is for general calculations involving a moderate amount of repetition of computing patterns and the other is for long problems of a special nature in which a given pattern is repeated many times. In the former, the ease of preparing instructions is of paramount importance and the machine is accordingly arranged to simplify the process. In the latter case, the effective speed of performing the basic sequence determines the overall efficiency, and the machine can be quickly tailored to permit simultaneous operations over separate channels. IBM Automatic Control Panels permit, in this case, the changing of 40,000 connections in a few minutes.

Technological progress and the accumulated experience of many years in the development of automatic arithmetical equipment have made it possible for IBM to construct this more capable scientists' assistant.

The value of a calculating machine depends not alone upon the excellence of the design as a whole but also upon the faultless performance of its basic components. Long experience in the building of calculating machines has shown the value of actual use as a means of testing and assuring such performance.

In this machine it was possible to incorporate many basic elements which either had been used commercially or had been developed in the IBM Engineering Laboratories. The electronic arithmetical unit was under development before the war and is generally similar to the IBM Electronic Multiplier which has been a part of the regular line of IBM Electric Punched Card Accounting Machines since October, 1946.

The electro-magnetic relays are of the wire contact type developed by the company's engineers for commercial accounting machines. They are the fastest and most compact relays available for such application. The card feeding and printing mechanisms, the card punches, and the control panels are also developments of the IBM Engineering Laboratories, and have been proved in their use on standard machines.

PROGRESS in science and technology is based on the comparison of theory with observation or measurement. In astronomy it is necessary to tie together, by a single mathematical and numerical structure, observations made at widely separated times. In theoretical physics, measurements of pressure, energy, temperature, and the like, made under widely different circumstances, such as those near absolute zero and those in the hot center of a star, must be tied rigorously together. In the design of a new aircraft or rocket it is necessary to apply theories of aerodynamics obtained from measurements made under conditions different from those under which the proposed device will operate. This procedure enables the designer to predict measurements which otherwise can be ascertained only by building the device.

The formulation, clarification, and use of mathematical numerical structures required in many problems involve great labor, and many of the world's greatest scientists have spent entire lifetimes on single structures. With the IBM Selective Sequence Electronic Calculator, solution of one of these lifetime problems can be reduced to a few months, and problems heretofore avoided as being hopeless can be undertaken.

The versatility of this powerful mathematical machine makes it applicable in all fields of physical science both pure and applied, and the social sciences as well; but its advantages may be illustrated for present purposes by a brief description of its operation in a problem of celestial mechanics.

For many centuries calculations in the study of the motions of celestial objects have taxed the facilities of astronomers and mathematicians. Recent improvement in observational techniques calls for more adequate means of performing the tremendous calculations involved.

One method of computing the positions of the moon, sun, or a planet involves the evaluation of a long formula which will give the position at any stated time by substituting in that formula the time for which the position is desired. The new calculator can greatly facilitate both the construction and the use of such formulas.

The IBM Selective Sequence Electronic Calculator reduces to a few minutes the task of evaluating more accurately than ever before the formulas which give the position for a given time. In this brief operation the machine performs about 9,000 multiplications, 10,000 additions and subtractions, and selects and uses more than 1,800 values from trigonometric tables. The lunar formulas are trigonometric series involving about 1,600 terms, each term consisting of a numerical coefficient and the sine or cosine of an angle which is a linear combination of several basic arguments. All the necessary instructions and numerical data are contained in continuous card-stock tapes which may be slipped into the machine in a few minutes.

Similar provision can be made for all major planets so that their positions may be determined very readily for any time in the past or future on the basis of the most accurate theories available.

Increasing the accuracy of existing formulas is an important objective of the projected research program. Billions of multiplications are contemplated in the process.

The paths of the celestial bodies also can be traced from one day to the next by a completely numerical process. The IBM Selective Sequence Electronic Calculator can perform such computations on a scale previously impracticable.

Theoretical physics, including atomic developments with all their crucial implications for human survival, is a field which offers a multitude of mathematical problems the study of which requires calculations of almost inconceivable magnitude and complexity. For example, it is necessary to solve partial differential equations in many dimensions in order to obtain the wave functions of the projectiles used to bombard atomic nuclei, of the products of such bombardment, and of the structural parts of the atoms.

For the very fast electrons now observed in cosmic rays and produced by the new accelerators, more accurate calculations are needed. The slowing down and scattering of fast electrons have been computed in the past with rough wave functions, neglecting the relativistic mass increase.

If more accurate wave functions for the atomic electrons are calculated, nuclear effects observed in atomic and molecular spectra can be analyzed to give better values of nuclear constants, such as the magnetic dipole and electric quadrupole moments.

Many of the computations of atomic physics have been done for a few ionization states of certain atoms. It will now be possible to extend such work greatly, and so to facilitate the work on stellar atmospheres being carried on by astrophysicists. Calculation of still more complicated problems involving several atoms at a time is required to furnish a firm foundation for the chemical physics of combining atoms into molecules.

The solution in any one of these problems of the partial differential equations using a close network of points in many dimensions is a computational procedure of an entirely new order of magnitude. The same is true of the computations required in the solution of equations used in the study of supersonic phenomena. Such computations are made feasible by the speed, capacity, and versatility of the IBM Selective Sequence Electronic Calculator.

In certain commercial and statistical fields there arise calculations wherein complicated sequences of operations must be handled one at a time. These calculations can be performed more efficiently by the IBM Selective Sequence Electronic Calculator than by any standard methods. Typical of these are the more difficult premium and reserve calculations of life insurance as well as graduation problems in mortality studies.

While the problems outlined here come from only a few fields of knowledge, the programs set forth will consume great quantities of human and machine resources. Equally formidable problems arise in almost every field of knowledge, and while each has its own terminology, the mathematical details and the basic scientific process of tying together measurement and theory are the same.

A machine that will trace the path of a planet through space will trace equally well the path of a ray of light through an optical system, or that of a cosmic ray through the earth's atmosphere. Statistical problems whether they arise in education, medicine, agriculture, social science or astronomy follow, in general, a single pattern as far as this machine is concerned. It will carry out the solution of large systems of equations, linear or non-linear, algebraic, differential, or integral. Whether the problems come from pure or applied science, from social or physical science, or from business, the machine is geared to the basic mathematics and not limited by any particular technical terminology.

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3. SEQUENCE RELAYS
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5. RELAY MEMORY
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11. PULSE GENERATOR
12. SEQUENCE INTERLOCKS
13. ELECTRONIC MEMORY
14. CONSOLE
15. PRINTERS
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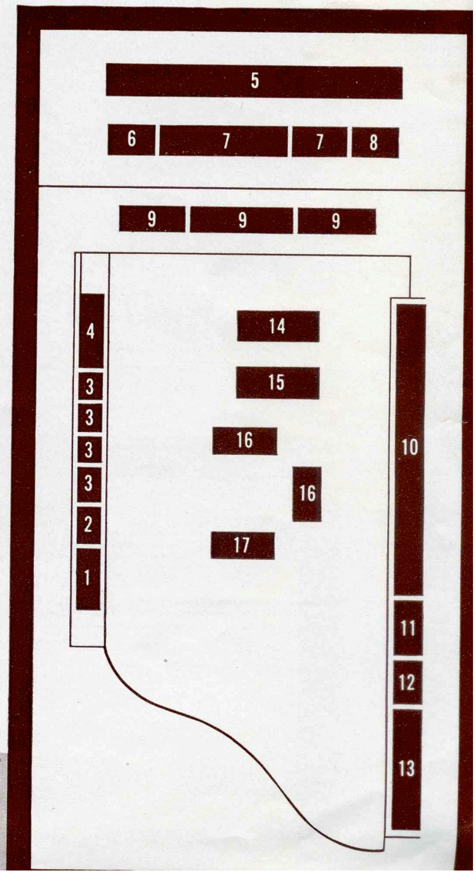
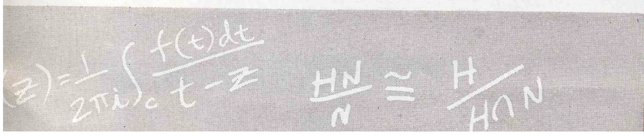
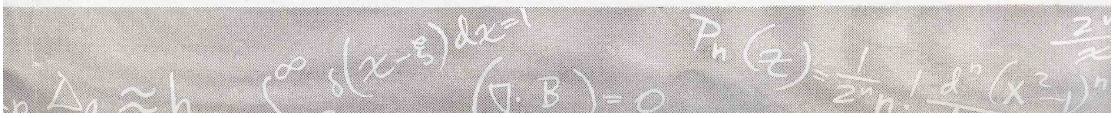
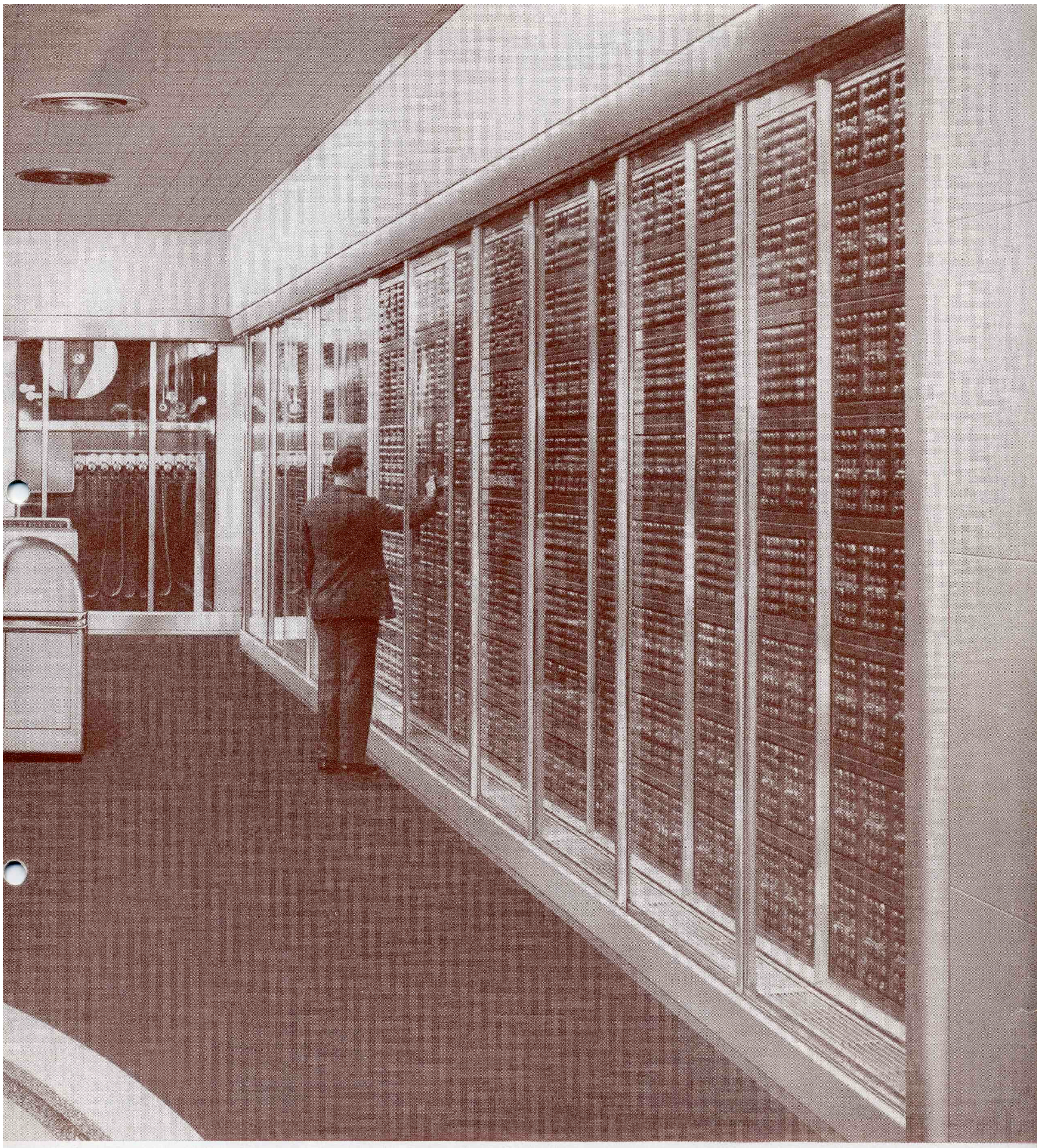




Composite view of the IBM Selective Sequence Electron





alculator. Diagram at left identifies and locates major units.

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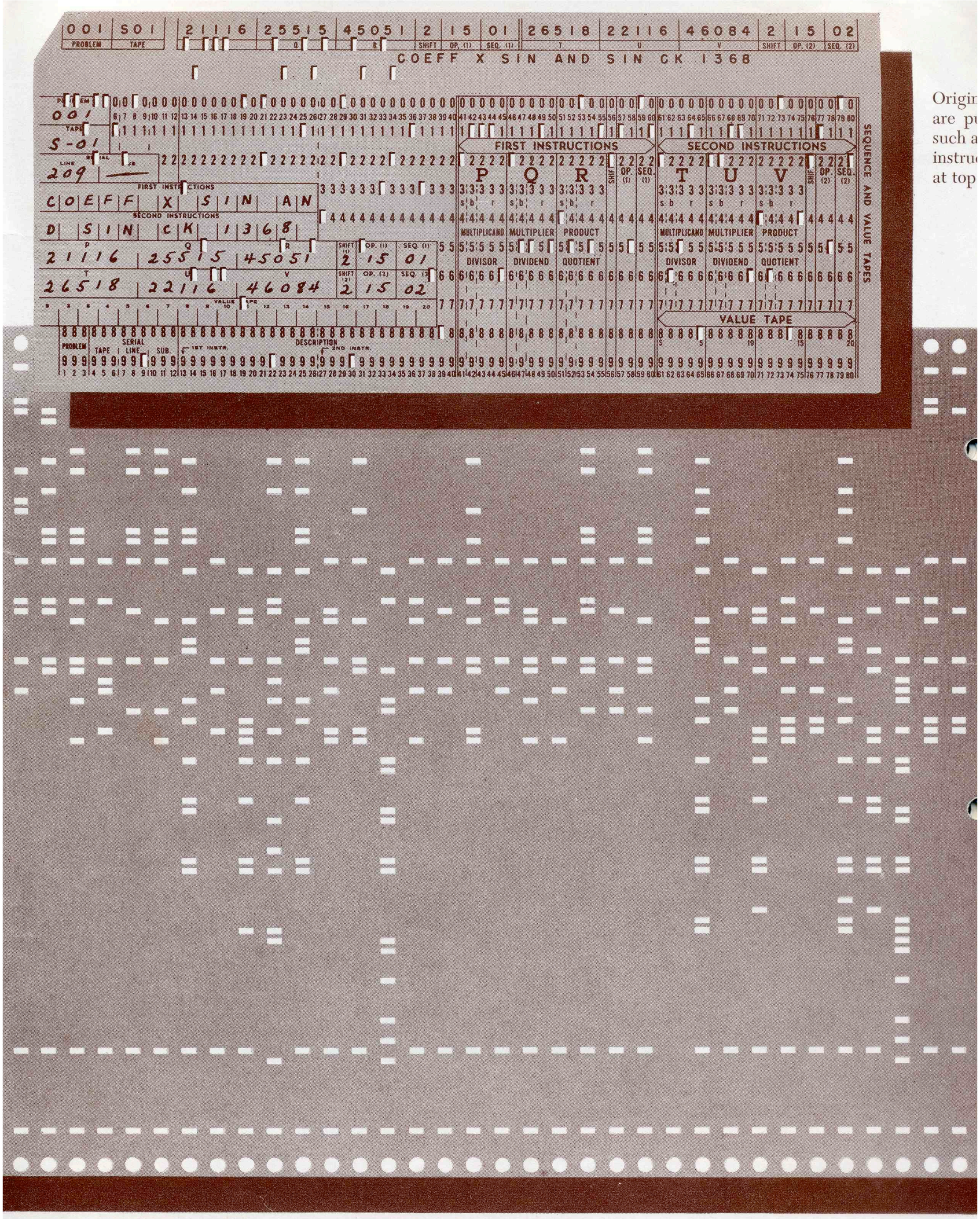

Specimen of the continuous card-stock tape punched in the binary decimal code. This translation from original decimal data in punched cards is produced automatically at high speed.

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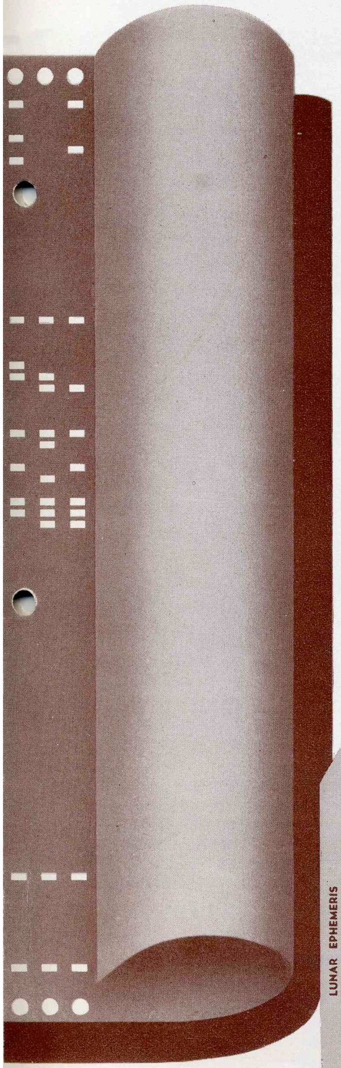
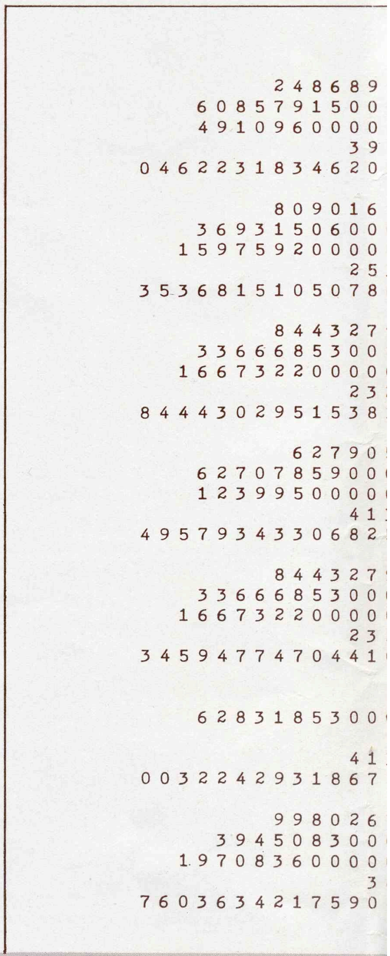
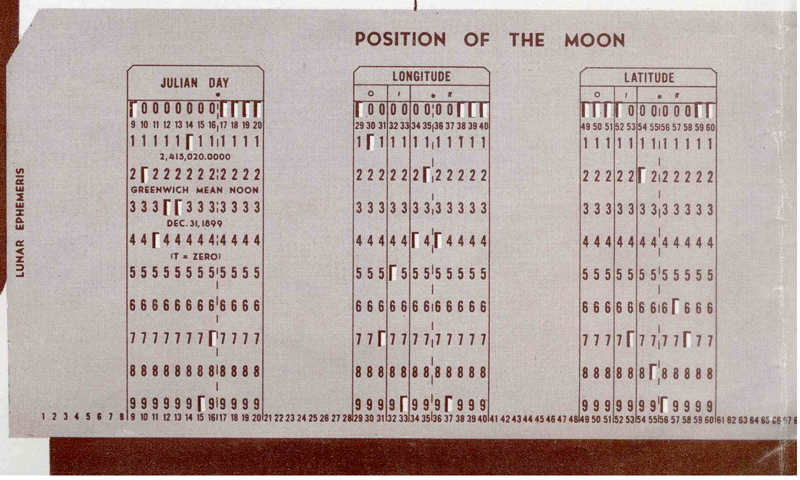
ns. Cards may be interpreted
visual identification.





Results printed in this manner indicate the progress of the calculation.

Problem solutions are recorded also as punched holes in IBM cards which may be further processed on standard IBM Electric Accounting Machines.



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6                 28636312                                          5
0             6053691418293               37673232                  4
0-            5158144847113-          321000081707-                 3
0-                                  247184847113-                   2
5       04                        04                                1

0                 79520535                                          5
0-            3751622522076-              13811638-                 4
0-           15882590027117-          5847192207 6-                 3
1                                     933299728 83                  2
0       35                        35                                1

1-                82908728-                                         5
0             3440096265665               15240642                  4
0            16570220067969           7341096566 5                  3
9-                                  10299993203 1-                  2
0       84                        84                                1

9                 2642756                                           5
0-            6276581869804-              36362957-                 4
0-            1000437864695-           5795969804-                  3
2                                    23951213530 5                  2
1       49                        49                                1

1                 82371879                                          5
0-            3465030945440-              2060912 8-                4
0-           16534940828972-          983456454 40-                 3
9                                    1382791710 28                  2
0       34                        34                                1

                  2025745                                           5
0             6282755505817               20257446                  4
               133298728926-           429794183-                   3
2-                                   133298728926-                  2
0       00                        00                                1

2-                99788075                                          5
0              401670232823                  145976                 4
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2-                                     1414437486-                  2
3       76                        76                                1
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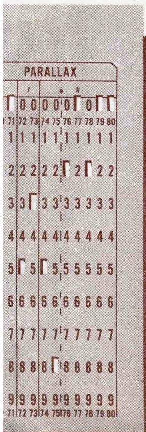

Master copy for publication of results may be prepared directly from cards with an IBM Card-operated Electric Typewriter.

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10	359 28		305 43	194 10		100 17	
20	1 58		308 13	196 41		102 48	
30	4 28	· ·	310 43	199 11	· ·	105 18	· ·
40	6 58		313 14	201 42		107 48	
50	9 28		315 44	204 12		110 19	
13 00	11 58	S19 16	318 15	206 43	N26 17	112 49	S 9 06
10	14 28		320 45	209 14		115 20	
20	16 58		323 15	211 44		117 50	
30	19 28	· ·	325 46	214 15	· ·	120 20	· ·
40	21 58		328 16	216 45		122 51	
50	24 28		330 47	219 16		125 21	

HOW THE IBM SELECTIVE SEQUENCE ELECTRONIC CALCULATOR OPERATES

THE IBM Selective Sequence Electronic Calculator can be explained in simple terms. The basic function of the machine is counting. This operation is performed at very high speed through the use of electronic tube circuits which count rapidly-recurring electronic pulses.

With over a hundred such electronic counting units assembled in proper relation to each other, the four fundamental operations of arithmetic—addition, subtraction, multiplication, and division—are performed silently and at high speed. Groups of counting units are operated simultaneously and repeatedly in performing these basic operations. One combination of units is used as an accumulator which adds or subtracts two 19-digit numbers in less than a thousandth of a second. Another combination multiplies two 14-digit numbers and gives the 28-digit product in a fiftieth of a second. At another command this same unit will divide two 14-digit numbers and give their 14-digit quotient in a thirtieth of a second. The calculator will round numbers to any desired number of digits, shift their columnar relationship, and indicate the algebraic sign of each number.

Just as a large number of counting operations are combined into an arithmetical operation so are these arithmetical operations the building blocks out of which a large numerical structure is assembled. The number of ways in which the four basic arithmetical operations may be combined in a calculation is very great. The machine is designed to use these arithmetical facilities to capacity not on simple problems but upon the most elaborate and complicated structures of science. In order to have the factors flow into and out of the arithmetical unit in an orderly fashion, each in a few thousandths of a second, other facilities of a type not realized heretofore are required.

One may think of the machine as a great traffic system where numbers are vehicles which travel with the speed of light and where collisions and misdirections are not tolerated. In order to keep a continuous flow of numbers going through the arithmetical unit without delaying its operation, it is necessary to have each of the numbers required, of which there may be thousands, available at the proper time.

It should be remembered that for each basic arithmetical operation requiring only a few thousandths of a second, two numbers are required and a new one is generated, and that each of these is only one of thousands that might be involved in the computation.

Some of these factors can be fed into the machine as the calculation progresses, and some of the results may be recorded as derived, but many of them must be held in the machine and remembered for later use. Obviously the facilities for reading data into the machine, for recording, for memory, and for providing adequate operating instructions, must far exceed anything of the past.

Various types of equipment were employed in the construction of the machine, ranging all the way from a vacuum tube circuit to a mechanical printing device. Vacuum tube circuits were used in all computing, storing, switching, and other forms of control where highest speed was required. The general aim was to perform electronically a unit of calculation requiring roughly the time of a complete multiplication, including all the associated reading of instructions, routing and storing of numbers.

TRAFFIC ARTERIES

The data for these elementary computations and the results obtained must flow to and from the arithmetical unit from any one of hundreds of sources throughout the machine, such as the reading and recording units and the great reservoir of stored results. Eight separate channels, each capable of transmitting simultaneously 19 decimal digits, lead to and from the arithmetical unit. Traffic is directed along these channels to and from the other units by means of IBM electromagnetic relays. One of these relays, which is little larger than a conventional vacuum tube, can change twelve independent circuits in a few thousandths of a second. For some special problems it will be desirable to change the whole mode of operation of the machine; this can be done in a few minutes by means of the IBM automatic control panels. About 40,000 pluggable connections on these removable plugboards can be changed in a few minutes.

MEMORY

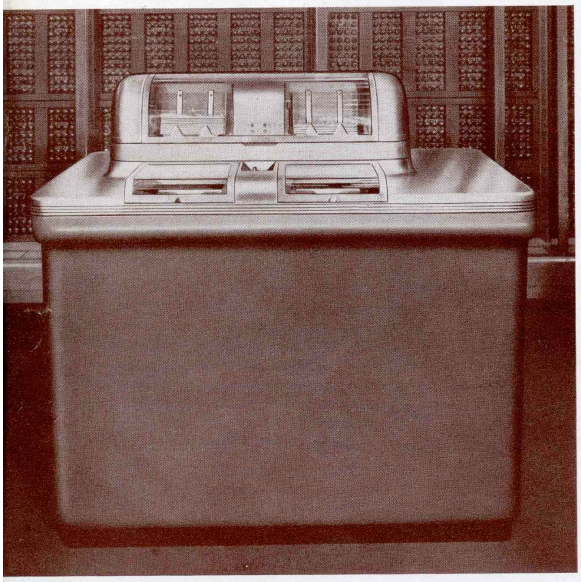
The total internal storage capacity of the machine is over 400,000 digits, i.e. the machine can remember at any one time this many digits and recall them automatically as required. Those which must be recalled most quickly are held in electronic circuits, and the remainder, recoverable as rapidly as they are needed for the calculation, are stored in relays and as holes in continuous card-stock tapes. The electronic memory section includes eight units each with a capacity of 19 digits and algebraic sign. The relay storage unit has provision for 3,000 digits. These can be recalled in any order according to the needs of the problem. In placing numbers in the reference tapes, however, consideration must be given to the order in which they are required.

There are three punched hole memory units, each consisting of a punching unit for continuous card-stock tapes and ten reading stations. These units may be combined in a variety of ways to permit their most efficient use for particular problems. A single line of punching will store 19 digits and an algebraic sign. This punched hole recording is done at the rate of 1,100 lines a minute in each punching unit, or at a combined rate of about 63,000 digits a minute. Reading is done while the tape is at rest and readings of successive lines at the same station are made at the rate of 1,100 lines a minute.

There is, in addition to these units, a group of 36 other reading stations which comprise the table look-up unit. These reading units are connected with a searching mechanism which locates whatever particular information is required for reference. Each of these stations may use a punched tape of 150 numbers and they may be consulted in any order required by the problem. When used as table facilities, they will operate for a selection from as many as six independent tables or as a single table. The table values that may be read out may have a maximum of 38 digits and an algebraic sign.

When a value of a specific table is called for, the machine selects the proper reading station and spins the tape to the correct punched line. The time required for such table reference varies according to the size of the table. To consult an eight-place sine table, for instance, requires on the average about one-sixth of a second. The maximum time for a complete search of a 100,000 digit table is about three seconds.

The searching circuits employed in the IBM



Card readers by which problems and instructions are introduced into the calculator.

Selective Sequence Electronic Calculator differ from those of other calculators in that tables with variable intervals of the argument may be used, thus allowing the use of fewer table values.

Both the punched hole memory unit and the table look-up unit may be used also for giving problem instructions.

Punched card memory provides a reservoir of practically unlimited capacity. Cards in which intermediate results are punched may be processed for later use in connection with the problem at hand and may be retained indefinitely as part of a data library for future computations.

READING AND RECORDING

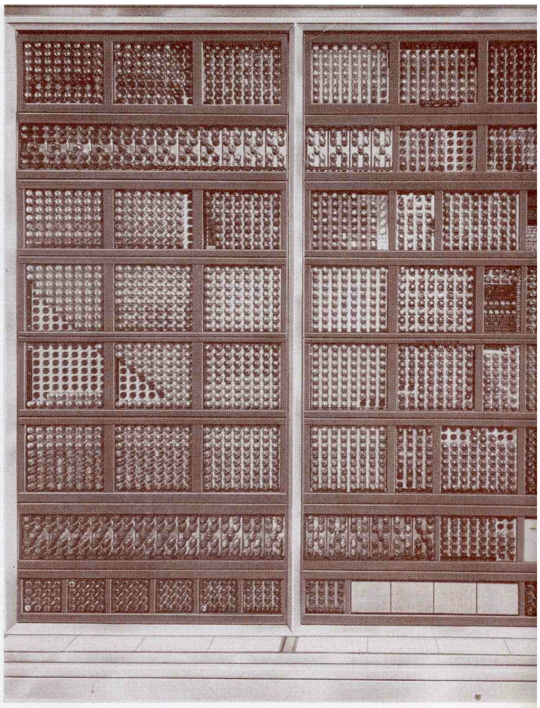
Problem elements and instructions for the calculating procedure are read from holes punched in either standard 80-column IBM cards or continuous card-stock tapes. Reading from standard cards through two card feeding units is performed at the rate of 30,000 digits a minute. From the sixty-six tape-reading units, the reading speed is about 140,000 digits a minute.

The tapes are prepared in either of two ways. One is by the machine itself and the other is by means of an auxiliary tape punch. This punch, which may be operated manually by a keyboard or automatically by punched cards, converts numerical data from their original decimal form into the coded binary form used in this calculator.

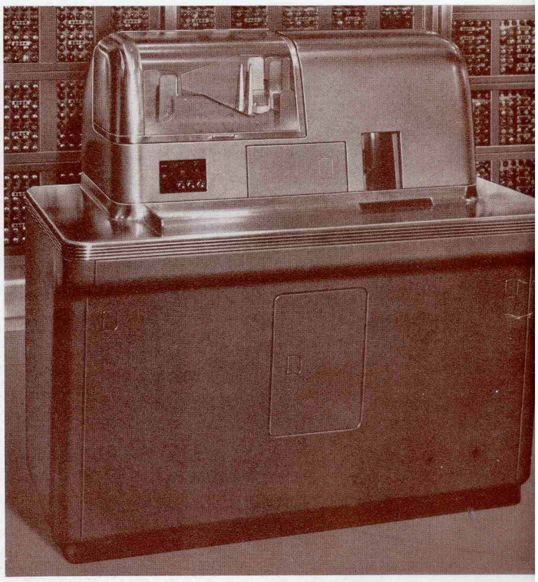
Problem results may be recorded in punched cards or in printed record form, or, if desired, in both forms. The recording speed for cards is about 16,000 digits a minute; for printed records, 24,000 digits a minute.

Inasmuch as the machine is to be utilized principally for research purposes and also because calculation proceeds at such high speed, it is essential that the scientist be able to know at all times what results are being obtained so that modifying instructions may be injected whenever necessary. Provision was made, therefore, for the continuous printing of results throughout the calculation.

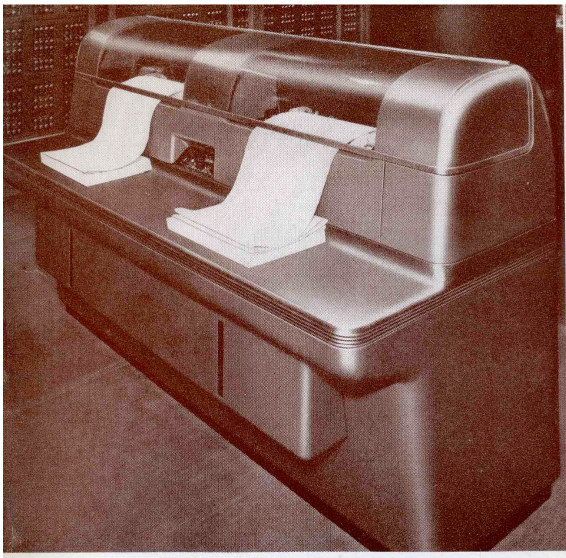
The recording of data in punched cards, however, greatly facilitates later handling when result reports are compiled. The cards can be processed by standard IBM Punched Card Accounting Machines to produce printed final reports or tables.



Section of the electronic arithmetical unit showing typical arrangement of tubes.



One of the two card punches by which results are recorded.



Printers which record intermediate and final results.

Console, or operation indicator and control desk.

PROGRAMMING

In order to keep the traffic flowing smoothly, elaborate control facilities are essential. Because of the speed at which the machine operates, detailed instructions must be supplied in vast quantities and at high speed; yet the person providing instructions wishes to give only general instructions to call into action comparatively long sequences of operations. For this reason sequencing facilities are much more highly developed than those in previous machines.

The basic unit of instruction is a group of commands punched in a line on the tape. These groups are delivered to the machine at the rate of fifty a second. Each group sets in motion a sequence of events controlled by electronic circuits in accordance with the group of commands read from the instruction tape.

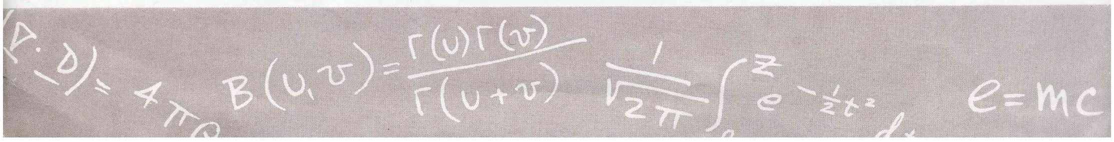
Special electronic circuits may be inserted for performing frequently recurring sequences of operations entirely within the arithmetical unit.

Repetition in the writing of sequences is avoided not only by these electronic cycles but by the use of sub-sequence tapes. Any recurring cycle of operations may be punched in a tape which can be called into operation by a single command. Thus after the fundamental patterns have been established, the master pattern need consist of only a single tape indicating the broadest general instructions.

Because the instructions are set up in numerical form with no distinction between them and the numerical values of the problem, computed modifications of these instructions may be made as the calculation progresses.

Each group of commands carries not only the instructions for locating the factors involved, the operations to be performed, and the destination of the result, but also instructions indicating where the next command may be found.

Since the machine can receive data either from punched cards or from punched tapes which are prepared automatically from cards, it is possible to bring to bear upon the preparation of instructions and initial data the flexible resources of the IBM punched card system. The efficiency of these machines for recording, verifying, rearranging, reproducing, and printing numerical and symbolic data is well known. For the IBM Selective Sequence Electronic Calculator these facilities can be used for assembling the numerical data as well as for preparing and arranging the operating commands.



DEDICATION OF IBM SELECTIVE SEQUENCE ELECTRONIC CALCULATOR MARKS A MILESTONE IN SCIENTIFIC AID

Presentation of the IBM Selective Sequence Electronic Calculator in the company's World Headquarters Building at 590 Madison Avenue, New York, N. Y., was an event of far greater significance than the unveiling of a new machine. It was a dedication not only of the machine to the further advancement of knowledge but also of the scientific and technical groups behind its development. It served to emphasize the social, scientific, and general welfare values of the long continued participation of a large business organization in pure research.

From the beginning of his association with IBM in 1914, Mr. Thomas J. Watson, its president, has maintained that a corporation should take part in the cultural life of the community; the widespread activities of IBM in education, international relations, science, and art are well known. Its participation in many fields of science has been particularly significant. The company has drawn upon the great fund of common scientific knowledge to improve its products; in return it has contributed generously to this common knowledge not only by financial endowment but also by the use of its equipment and of its scientific and technical personnel in such work. There is scarcely a field of knowledge—astronomy, education, physics, geology, chemistry—that has not benefited by this cooperation.

These contributions were made at first through the cooperative efforts of IBM's technical staff with scientists engaged in basic research at various academic institutions. Notable among the many such cooperative projects were the provision of machines for the research work of the Columbia University Statistical Bureau (1928); the first automatic computing installation in the Astronomical Computing Bureau (1934); the Matrix Multiplier for the University of Chicago (1940); the IBM Automatic Sequence Controlled Calculator at Harvard University (1944); the Relay Calculators for the Ballistics Research Laboratories at Aberdeen Proving Grounds (1944); and the Wind Tunnel equipment at the California Institute of Technology (1945).

The Thomas J. Watson Astronomical Computing Bureau, the first automatic computing laboratory, which has been in operation for more than a decade is one of the best examples of scientific cooperation; it is a joint project of the American Astronomical Society, Columbia University, and IBM. The majority of the board of managers is appointed by the Society and calculations are performed for astronomers anywhere.

In order to take a more active part in scientific research, the Department of Pure Science was established within the company in 1945. It was Mr. Watson's thought that a group of scientists engaged in their specialized fields would be able not only to utilize the company's technical resources for effective research but would be able also to make them available to scientists elsewhere. Dr. W. J. Eckert, who organized the laboratory of the Astronomical Bureau and directed its operations until he became Director of the U. S. Nautical Almanac Office in 1940, was chosen to head the new Department of Pure Science.

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DEDICATION OF IBM SELECTIVE SEQUENCE ELECTRONIC CALCULATOR MARKS A MILESTONE IN SCIENTIFIC AID

PRESENTATION of the IBM Selective Sequence Electronic Calculator in the company's World Headquarters Building at 590 Madison Avenue, New York, N. Y., was an event of far greater significance than the unveiling of a new machine. It was a dedication not only of the machine to the further advancement of knowledge but also of the scientific and technical groups behind its development. It served to emphasize the social, scientific, and general welfare values of the long continued participation of a large business organization in pure research.

From the beginning of his association with IBM in 1914, Mr. Thomas J. Watson, its president, has maintained that a corporation should take part in the cultural life of the community; the widespread activities of IBM in education, international relations, science, and art are well known. Its participation in many fields of science has been particularly significant. The company has drawn upon the great fund of common scientific knowledge to improve its products; in return it has contributed generously to this common knowledge not only by financial endowment but also by the use of its equipment and of its scientific and technical personnel in such work. There is scarcely a field of knowledge—astronomy, education, physics, geology, chemistry—that has not benefited by this cooperation.

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In 1945 the Watson Scientific Computing Laboratory was established at Columbia University. This laboratory is operated by the IBM Department of Pure Science and occupies the entire building at 612 West 116th Street, New York, N. Y. The members of the staff conduct researches in their specific fields and cooperate with scientists in other fields. Large projects have been completed in astronomy, physics, crystallography, geology, chemistry, statistics, and optics. The equipment includes calculating machines of all varieties from small experimental devices built in the laboratory to the IBM Relay Calculators whose speed of operation is exceeded only by recently perfected electronic machines. Graduate instruction in the laboratory carries academic credit which may be used in fulfillment of the requirements for advanced degrees at Columbia University and other universities.

In order to extend this program even further, and to solve as many as possible of the problems beyond the reach of existing equipment, Mr. Watson proposed that IBM scientists and engineers design and construct a new calculator that would combine in a single machine the technical advances of IBM's third of a century of calculating machine development. Our scientists and engineers thoroughly explored the possibilities of such a machine, the scientists outlining the nature of the ideal machine and the engineers outlining the possibilities of various devices to accomplish the desired results.

Within a short period of time formulation of a complete plan and the outline of a general pattern of construction had been completed. The calculator began to take definite shape as soon as these plans were submitted to an executive group and the advisory committee. Approval was granted for immediate execution and the actual design and construction work were begun in the IBM Engineering Laboratory at Endicott, N. Y., where one half of the ground floor was extensively altered to house the project and to provide space for a staff of more than sixty specialists.

Every possible facility was made available so that rapid progress could be made. In only eight months, design, manufacture, and assembly were completed and the machine was ready for testing.

In August, 1947, specially designed quarters at 590 Madison Avenue were completed. Disassembling, moving, installing, and testing required another four months and in December the new machine was put into operation. All phases of the development were facilitated by an advisory committee comprised of IBM scientists, engineers, and corporate executives.

Figuring largely in the establishment of specifications were Dr. W. J. Eckert, Director of the Department of Pure Science and of the Watson Scientific Computing Laboratory, and his staff. Dr. Eckert who is well known as a pioneer in the field of automatic computation will serve as director of the research program now being planned for the new machine.

Mr. F. E. Hamilton, IBM Senior Engineer, directed the design, construction, and assembly of the calculator, a post for which he was particularly well qualified by a wealth of experience gained through development work on numerous IBM calculating machine projects, including the IBM Automatic Sequence Controlled Calculator.

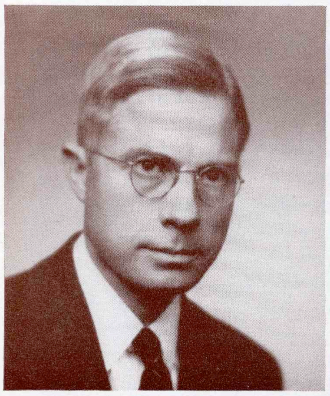
Mr. R. R. Seeber, Jr., Senior Staff Member of the Watson Scientific Computing Laboratory, whose mathematical background and wide experience in large-scale calculation were invaluable in all phases of the project, supervised functional and operating features and served as an effective liaison between engineering and scientific groups.

Some of the most experienced engineering talent available at the laboratory as well as employees recently released from Army and Navy engineering work were assigned to the design of the mechanical and electrical phases. Among these were the Messrs. H. J. Klotz, R. A. Rowley, B. E. Phelps, J. J. Troy, E. S. Hughes, R. W. Prentice, G. E. Mitchell, T. D. Korayne, P. E. Fox, C. S. Jackoski, O. L. Hibbard, and W. D. Mitchell.

Development of the electronic arithmetical unit is the product of several years' work by Messrs. J. W. Bryce, A. H. Dickinson, C. A. Bergfors, R. L. Palmer, and B. E. Phelps. The multi-circuit pluggable relays as well as the control panels were designed and developed by Messrs. C. D. Lake and W. Pfaff. Card feeding and printing mechanisms were developed by Messrs. A. W. Mills and F. J. Furman, and the card punches by Mr. Lake.

Included in the Engineering Laboratory facilities was a complete department devoted to the assem-

IBM SCIENTISTS AND ENGINEERS WHO COLLABORATED
IN PRODUCING THE IBM SELECTIVE SEQUENCE ELECTRONIC CALCULATOR


Dr. W. J. Eckert


R. R. Seeber, Jr.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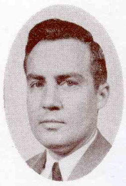
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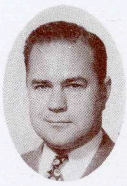
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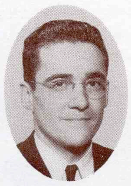
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W. Pfaff


A. W. Mills


F. J. Furman

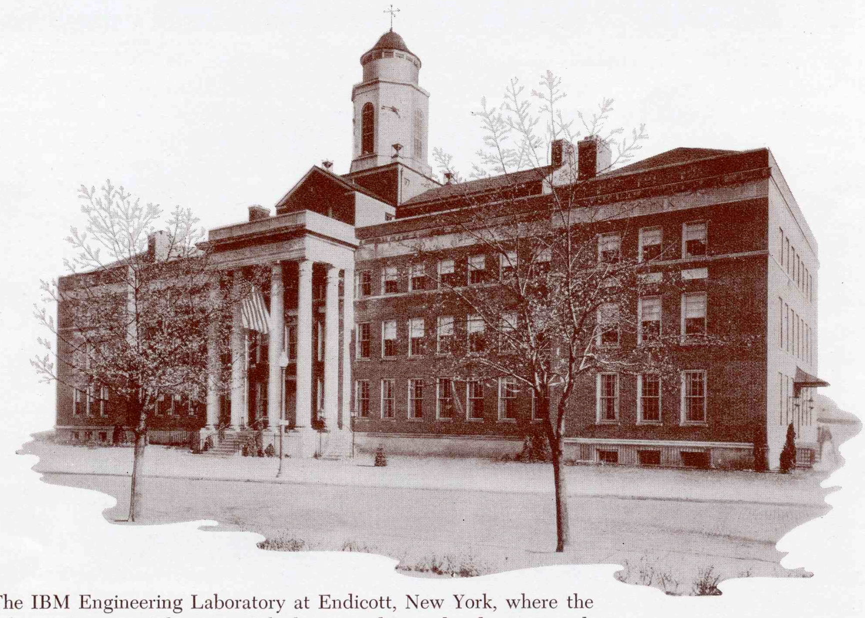
bling and testing of electronic chassis. This department was manned by personnel made up of returned service men experienced in the operation and maintenance of radar equipment.

The technical research department at the Laboratory provided answers to a great many perplexing problems that arose, particularly in connection with the electrical characteristics of tube and relay combinations.

The entire project was effectively expedited by the personnel and facilities of the manufacturing group with their versatile "know how" for the fabrication of parts and electrical assemblies.

With the completion of this machine and the beginning of its program of research another cycle of a familiar pattern of progress has been completed. Science and technology supplied the basic knowledge and technical skill that made it possible to build a powerful new scientific instrument which, in turn, will open the way to vast new accumulations of beneficial information.

In putting into operation the most highly developed scientific tool of its kind, both IBM corporate officials and the scientific group realize the responsibility of applying its capabilities to the best interests of humanity.



The IBM Engineering Laboratory at Endicott, New York, where the Selective Sequence Electronic Calculator was designed and constructed.

HISTORICAL HIGHLIGHTS OF COMPUTING MACHINE DEVELOPMENT

Although mathematics is practically as old as humanity, the technique of calculation has developed slowly. Fingers, toes, and tally-sticks served well as long as the problems at hand did not overtax their capacity. The counting frame, or abacus, was until the Christian era the only instrument man had developed for the purposes of calculation; it is still used extensively in China, Japan, India, and Russia.

The development of arithmetical procedures and systems gave rise in 1617 to an ingenious contrivance of numbering rods known as "Napier's bones," which was used widely throughout the seventeenth century for carrying out large multiplications.

The first real calculating machine employing a mechanical principle did not appear until 1642, when a simple device consisting of geared numbering wheels was invented by Blaise Pascal.

Mathematicians had realized that multiplication is actually a process of repeated addition, and a machine to carry out this principle was first projected in 1671 by Gottfried Wilhelm Leibnitz, though not successfully completed until 1694.

In 1820 Charles Xavier Thomas invented the first calculating machine that was successfully manufactured on a commercial scale. It could perform all four elementary arithmetical operations and during the succeeding several years was extensively improved by inventors in Europe and this country.

During the early years of the nineteenth century several more elaborate calculating machines were proposed. These included the so-called difference engines of which several were constructed. The most ambitious of the proposals, however, was the analytical engine designed by Charles Babbage in 1833 in which several features of his difference engine were to be embodied. This was a calculator intended for the performance of complete computations according to given instructions. The plan, too ambitious for engineering and technical facilities of that time, was unfinished when Babbage died.

The familiar keyboard type of calculating machine originated in the United States at about the middle of the last century and has been developed, chiefly in this country, for many accounting and commercial computing purposes.

Another American development which followed within a few years was the incorporation of a printing device with an adding machine. This accomplishment provided the basis for numerous other developments which have given us today's wide variety of combination computing-listing machines —from single counter adding machines to billing, accounting, and bookkeeping machines.

In 1887 Leon Bollée was successful in producing the first machine capable of performing multiplication by a direct method instead of the method of repeated addition. The principle was further developed in later machines.

To expedite U. S. census compilation work, Herman Hollerith, in 1889, developed the punched card as a means of recording numerical information for automatic computing. At the same time he devised electrically-operated mechanisms which performed adding and counting operations when actuated by punched cards. This method was perfected through a long program of research and development by the International Business Machines Corporation to the point where electromechanical machines could perform a variety of operations, such as reading, adding, printing, sorting, reproducing, multiplying, collating, and summary punching. A progression of refinements and developments has made this currently a most reliable, flexible, and versatile method of calculation not only for commercial but for scientific use as well.

By 1934 electric punched card machines had been perfected to such an extent that they were capable of handling many of the general calculations of science. An automatic computing laboratory was established in and operated by the Thomas J. Watson Astronomical Computing Bureau, a cooperative project of the American Astronomical Society, Columbia University, and IBM. This laboratory has been engaged for thirteen years in the work of astronomical calculations. Since this first application about thirty other laboratories using similar machines and techniques have been established throughout the country for work in many other fields of science.

The first large-scale general-purpose digital calculator was built by IBM for use in science. This machine, known as the IBM Automatic Sequence Controlled Calculator, has the greatest internal storage capacity and most elaborate sequencing or programming facilities of any machine prior to the IBM Selective Sequence Electronic Calculator described in this book.

Up to this time practically all calculating machines utilized the adding wheel as a basic unit. Experiments were under way in an effort to determine if other devices employing electro-mechanical relays or even electronic tubes could be made reliable enough for this function.

Several calculators using relays as the computing units have been built by IBM and other organizations independently.

The electronic tube which can operate with almost unbelievable speed—in the order of a millionth of a second—naturally offers the greatest potential for development. Simple electronic counting devices have been used in physics laboratories since about 1925 and considerable experimentation in their use as computing devices was done before the war. The year 1946 saw the dedication of the first large electronic calculator by the University of Pennsylvania and the marketing of the first commercial electronic computer by IBM. The "Eniac" was built by the University of Pennsylvania for computing trajectories of shells; it has storage for about 200 digits including those in the multiplication and division units, and is controlled by means of pluggable connections.

The IBM Selective Sequence Electronic Calculator marks man's most recent step forward in the search for a machine more nearly capable of meeting the size and scope of the problems at hand. With this machine it is possible for the first time to bring to bear on the vast array of complicated problems of science and technology the full speed and efficiency of electronic calculation.

In building the IBM Selective Sequence Electronic Calculator emphasis has been placed entirely upon giving to science the fullest possible benefit of technical advances to date. Scientific advance, speeded by such assistance, opens the way to further improvements of the tools upon which progress depends. Recognizing the need for a continuing program of improvement, IBM research and development work are unceasing and it is certain that machines of the future will far surpass the present achievement in the field of large-scale calculation.

IBM

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