Research for Industry

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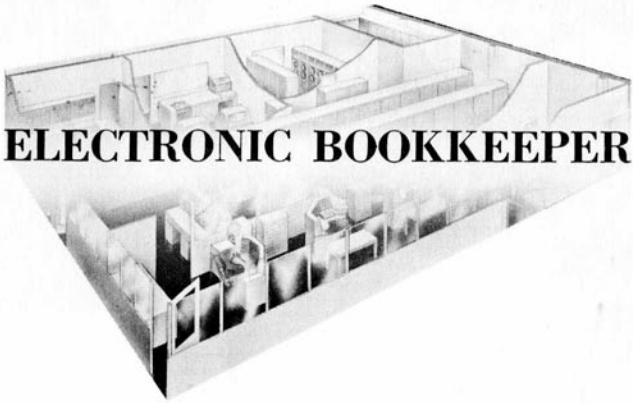
ERMA—



ELECTRONIC BOOKKEEPER

FIVE YEARS of research and development have culminated in a revolutionary electromechanical accounting machine to handle all bookkeeping functions for 32,000 checking accounts. Future production models will serve 50,000 accounts. Designed and constructed in SRI's Computer and Control Systems Laboratories, ERMA (Electronic Recording Machine, Accounting) was developed for the Bank of America.

ERMA credits individual accounts with deposits, debits withdrawals, remembers details of all transactions, maintains correct balances, accepts stop-payments and hold orders, prevents overdrawing of accounts, and sorts checks.

ERMA verifies each accounting step automatically and with lightning speed. Virtually any error is immediately signaled to the operator. Parallel processes ensure accuracy and each step must be correct before the next begins. There is an over-all balancing at the end of each day, plus a monthly recapitulation.

Technically, ERMA stemmed from war-stimulated progress in "electronic brain" computers. Its high degree of bookkeeping efficiency is made possible by a wide range of developments in magnetic recording, machine reading of printed codes, and techniques of mechanical paper handling and high-speed printing.

In addition to the major problem of visualizing the complex system required to handle the bank's accounting system SRI's engineers found an even larger task in making components of the system function together.

In working out the mass of details necessary to do the job, several specialized problems were overcome. Working together, mechanical and electrical engineers in the Control Systems Laboratory devised methods of handling checks of several sizes and weights—even when badly mutilated.

Systems were evolved for reading codes and actual Arabic characters printed in magnetic ink, as well as for development of the ink itself. These make possible the reading of characters with freedom from errors due to poor registration or overprinting.

ERMA includes more than one million

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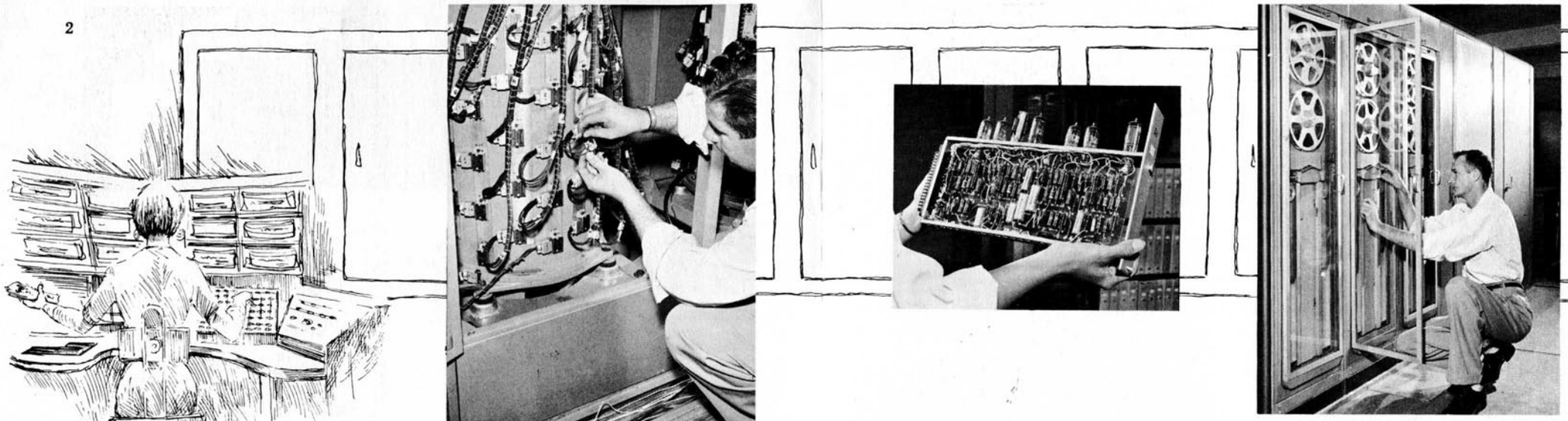


Keys to ERMA's operation are these units. Artist's conception at left shows typical input station with some of ERMA's panel boards in background. Picture at left shows one of the magnetic drums which temporarily stores activity information. In center is one of hundreds of electronic packages which do ERMA's "thinking." Magnetic tapes at right provide permanent storage of account information

feet of wiring, 34,000 diodes, 8,000 vacuum tubes, and it weighs in the neighborhood of 25 tons. It uses 80 kilowatts of electricity broken down into six voltages and generates enough heat to warm three eight-room houses. An air-conditioning system cools it.

The first ERMA machine will be moved to San Jose early in the coming year to handle checking accounts for branches in the San Jose area. The Bank of America needs about 37 ERMAs to serve its branch banks throughout California. The bank's deposit accounts have been growing at a rate of more than 23,000 a month over the past ten years.

ERMA's "Senses"

The input keyboards are the eyes and ears of ERMA. There are five of these, each resembling a large adding machine. The keyboard is the means by which the system receives information. There are keys to represent the account number, branch bank number, and the amount of the check or deposit. ERMA is not embarrassed by any check less than $99,999,999.99.

The keys actuate electrical switches, each of which is connected to five circuits. Four of the circuits establish a code to identify the digit represented by the key —the fifth circuit is for checking purposes. For example, pressing an 8 key closes the first, third, and fourth code circuits; the second circuit remains open. Thus, ERMA recognizes an 8 by circuits 1, 3, and 4 being closed, but 2 open. This can be represented by 1011. Likewise, number 7 is coded by 1010, and so on. The four circuits provide enough on-off combinations to identify all ten digits plus several symbols.

The electronic bookkeeper has five input keyboards—four operators and a supervisor. As the machine handles an average account item in half a second, it can switch itself without apparent delay among all operators. Even if all operators press their item-entry bars at once, one of them might have to pause only about a second if she were entering items as fast as possible, before the keyboard would respond to her next entry.

ERMA has two magnetic drums about the size of small oil drums. These are part of the machine's temporary information "files," capable of servicing a total of 32,000 accounts. The drums are coated with a resin containing tiny particles of iron oxide, the polarity of which can be controlled under the influence of magnetic fields. Each drum is divided into 300 invisible parallel circular tracks about the thickness of a butter knife blade. Each track is divided into sections 0.010 inch long. Under the influence of electromagnets mounted close to the drum surface, the 1,500,000 magnetic cells on each drum are an information storage element for bits (from *bi*nary digi*ts*) in the binary system. Thus, since five bits are used to identify each number, 300,000 separate numbers may be stored on each drum.

ERMA can read! The machine identifies each check by "reading" information printed in magnetic ink on the back of the check. This code is made up of rows of bars with specific spacing, apparent to the human eye, and is similar to the coding described for the input keyboard.

The magnetic ink process allows ERMA to read numbers at the rate of 1,000 characters a second. ERMA is not confused by dirt, ink, or other defacements of the coded number. When the check passes under a magnetizing element in the reader, the tiny iron-oxide particles in the bars line up in a prescribed direction. Then the check passes under a unit with five magnetic reading heads side by side. Because the positions of magnet-ink bars differ, the pattern of voltages at each of the five reading heads differs for each digit. ERMA's electronic circuits are able to distinguish between the resulting unique wave patterns.

ERMA's arithmetic unit is made up of a battery of electronic tubes and related components arranged in pairs capable of performing additions and subtractions on sums as large as $99,999,999.99.

Since the "building blocks" of the arithmetic unit can count only up to two — recognizing only two situations — decimal numbers are represented by specific patterns of binary numbers.

The tubes arranged in pairs are known as "flip-flops." When a potential is applied to a pair by ERMA to "remember" information, one tube becomes conducting, the other nonconducting. Thus, the device essentially stores pieces of information in much the same manner as each

cell on the magnetic drum serves this function.

Detailed Information

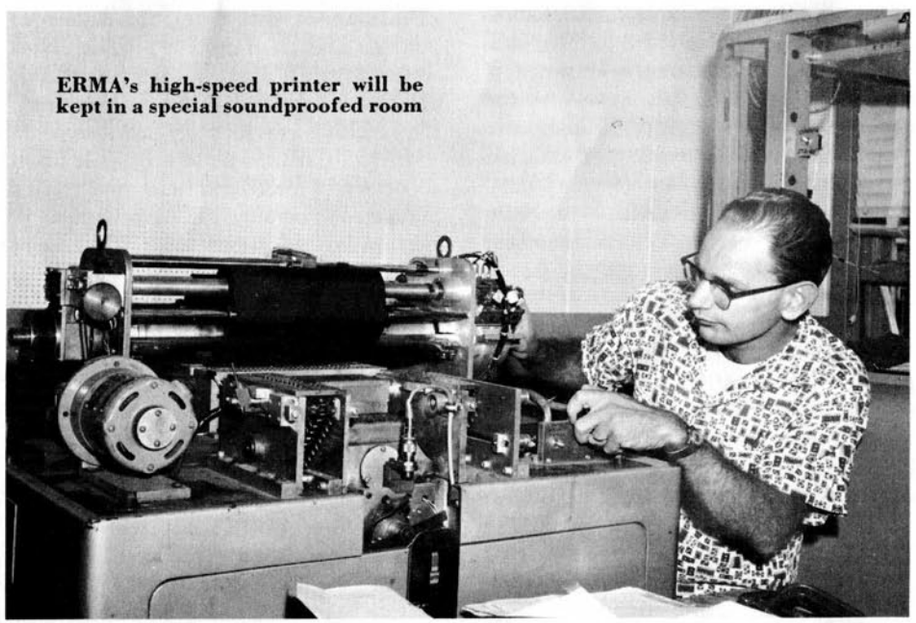
More detailed account information is kept on the machine's main information storage system, on magnetic tapes. Here it is stored in its incoming sequence. Accounts are maintained in numerical order just as they would be in a file cabinet.

Each of ERMA's twelve tape units handles 2,400 feet of ¾″ plastic-backed magnetic tapes, thereby providing space for the detailed record of all transactions over the period of a month.

The tape can be unwound past a set of magnetic heads similar to those used on the drum, for "writing" new information on the tape or "reading" information as it is summoned. The tape stores information on the same binary basis—bits magnetized either N-S or S-N — as on the magnetic drums. There is room on the standard size tape for seven information bits in a row across the tape. Because the tape must also store words or letters identifying transactions, seven bits are required to identify all letters and numerals. Thus each row of bits identifies one character. In this way, information as to account number, name and address, and account activity for a month can be stored in about nine inches of tape for an average checking account. Space on the tape is allocated at the start of each month, based on previous experience with that account. The manner of writing, reading, or erasure of information on the tape is essentially as described for the magnetic drum.

Monthly account statements — with service charges automatically calculated —are prepared from information stored on the tape by a high-speed printer. The printer has a continuous speed of 600 lines a minute—soon to be increased to 900 lines a minute—and needs human aid only when more paper is needed.

The commercially available printing element consists of a cylinder with rows of raised characters across it, each row being as wide as the line of printing on the statement. One row contains a succession of A's, the next B's, and so on around the cylinder for the rest of the alphabet, for numerals and other symbols. The cylinder turns continuously at 1,200 r.p.m., above a row of stationary striking hammers, one for each character in the row. Between the hammers and cylinder is the statement blank and carbon ribbon.



ERMA's high-speed printer will be kept in a special soundproofed room

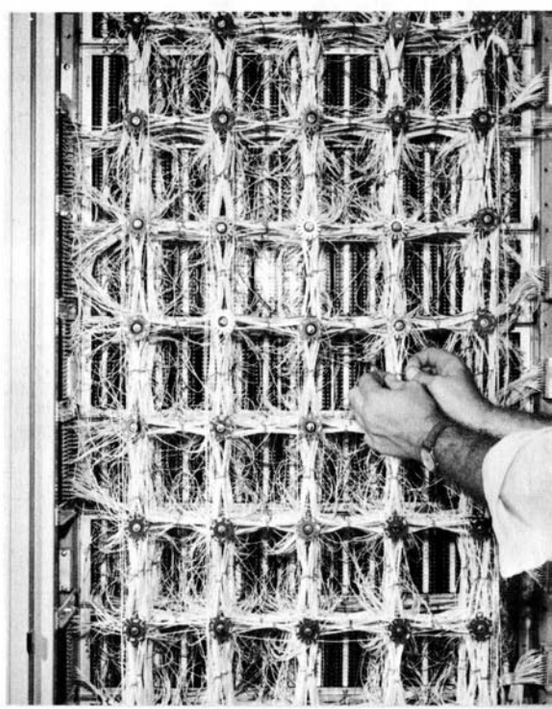
ERMA's service panel with its myriad of indicator lights helps supervisors immediately locate trouble spots in the complex circuitry. From the service desk ERMA can be put through its paces section by section to precisely locate malfunctions and the operation can be stopped at any point in the information processing

Check Sorter

As information from the checks passes through the bookkeeping functions, the paper (deposit slips and checks) is sorted for each individual account by a specially developed automatic sorter which "reads" account identifications and sorts checks at the rate of 10 per second. A stack of a thousand checks about 5 inches high melts down in the input compartment in about a minute and a half. Pneumatic feeding rather than mechanical friction devices accounts for the efficiency maintained at these high speeds — with errors of less than one in 100,000.

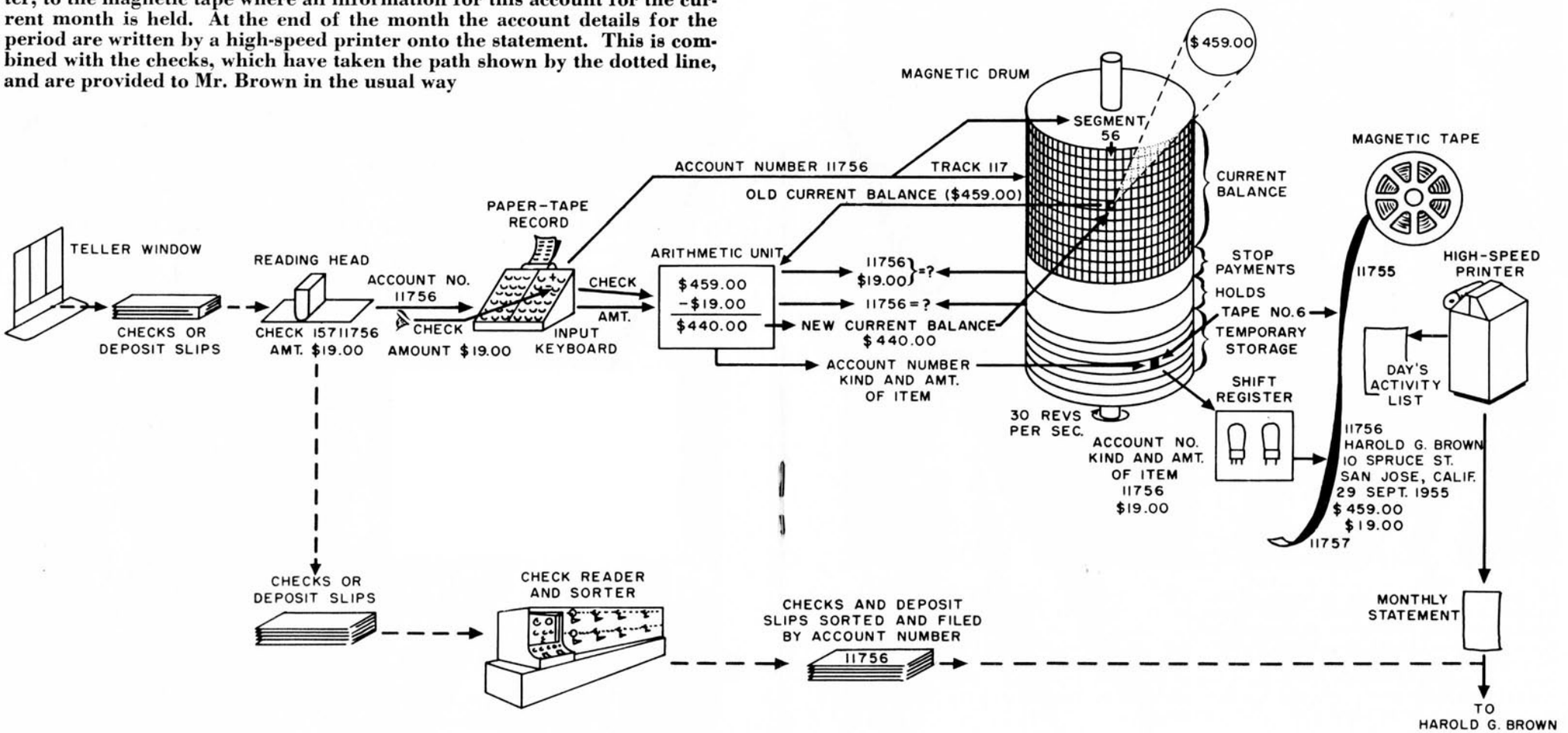
To sort checks, a bundle is placed in the sorter. Top checks are whisked off by a vacuum feeding device and guided to a scanning head set to read the first digit of the account number. This information is momentarily stored on a rotating mechanical memory device. The sorter has 12 compartments (0 through 9 plus two for rejected checks) into which it sorts checks or deposit slips. The checks are sorted through for each digit separately, requiring the sorting of each bundle five times to place them in proper sequence by account number. After sorting, checks are filed, to be later combined with statements for forwarding to customers.

Behind the dozens of panel boards a maze of wires ties together the hundreds of electronic packages which are the senses of ERMA



HOW ERMA FUNCTIONS

Bundles of checks or deposit slips come, by the usual route, to the operators of ERMA. Assume, as a typical case, a check for $19.00 by a Mr. Brown to whose account the bank has assigned number 15711756. To perform the bookkeeping for this check, the machine requires three pieces of information: the amount of the check, which the operator supplies by pressing keys; the fact that it is a check, not a deposit; and the account number, which the machine reads from the code on the back of the check. Having this information, the machine looks up the old current balance for this account, and delivers that sum to the arithmetic unit. It also determines if there is a stop-payment against this check or any holds against funds in this account. If none, the subtraction of the amount of the check is made from the old current balance by the arithmetic unit. If the remainder is plus (a minus sum indicates an overdraft), the new current balance is written on the magnetic drum and the item details are stored in the temporary storage section of the drum. Later these details are transferred, via the shift register, to the magnetic tape where all information for this account for the current month is held. At the end of the month the account details for the period are written by a high-speed printer onto the statement. This is combined with the checks, which have taken the path shown by the dotted line, and are provided to Mr. Brown in the usual way



Dr. Kenneth R. Eldredge, manager of the Control Systems Laboratory, stands by the input station of the automatic check sorter, which "reads" account identification codes magnetically and sorts checks at a rate of 10 per second. The sorter rejects checks which have no magnetic code identification—as in the case of counter checks—and these are then handled manually. The check sorter automatically verifies its own "reading" accuracy by means of built-in checking features of the magnetic code itself and within the machine. The sorter misreads less than one in 10,000 checks and rejects less than one percent due to mutilation of codes or paper

A Typical Account Item

Under the ERMA system each check carries account information in coded bars on the back of the check as shown in insert

HAROLD BROWN writes a check for $19.00 to a merchant; his branch number in the Bank of America system is 167 and his account number is 11756. Thus to ERMA Brown is known as 16711756 and his checks carry this identification in magnetic code.

Eventually, the check arrives at the desk of one of ERMA's five operators via usual banking channels—clearinghouse transfer or directly from one of the branches' own tellers. It is in one of the thick bundles of checks against the many accounts for which the machine is responsible.

The operator of the input keyboard depresses keys to inform ERMA that the $19.00 item is a check rather than a deposit. The machine scans Brown's account number and automatically pulls down the keys on his entire identification number — 16711756 — on the account number section of the keyboard.

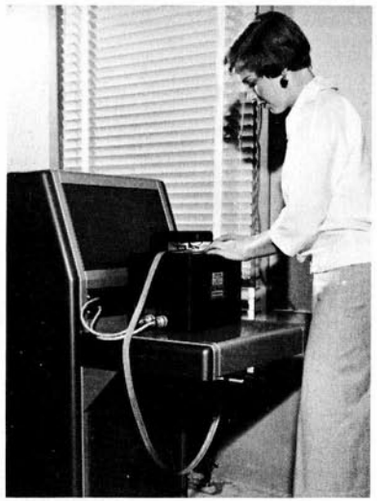
By pressing an entry bar the operator signals ERMA to take over the remaining bookkeeping functions.

In a lightning-fast chain of events the machine collects the amount and information as to whether the item is a check or deposit from the input keyboard and the current balance from the magnetic drum information storage system. These three pieces of information it gives to an arithmetic unit. It also has scanned its drum storage system for two other pertinent bits of information — is there a "stop payment" against this check and are there any "holds" against funds in Brown's account? If "holds" are found, their amounts are subtracted from the current balance, or if a stop-payment is found the operator is notified.

If sufficient funds remain in Brown's account, the arithmetic unit subtracts the $19.00 from the total. Then a new current balance is established and the machine checks its arithmetic in several ways.

The new balance is "written down" on the storage drum, to be held for minutes or perhaps hours until it is convenient for the machine to transfer it automatically to permanent storage on the magnetic tape.

Checks and deposit slips arrive in a random manner but obviously must be "filed" on the tapes in an orderly way. The drum processes information in whatever sequence it arrives and holds it in temporary storage on the drums until it can catch up with its filing on the magnetic tape.



A standard Flexowriter paper tape reader is used in combination with ERMA to transcribe new and changed names and addresses to the permanent files on the magnetic tapes. It can also be used to restore information in the event tapes are damaged.

The reader operates photoelectrically at speeds up to 200 characters a second from tape which has been manually punched by bank personnel. The information passes through a code converter consisting of pairs of vacuum tubes or "flip-flops" and relays en route to the magnetic tapes.

A "reading head" automatically searches the tracks on the magnetic drums looking for the next higher account number for which it has an item to record. That number — assume it is Brown's 11756—and the $19.00 debit are transferred to an intermediate storage register (because the drum operates much faster than the tape) and then to the magnetic tape when the next empty space is found in sequence on the tape.

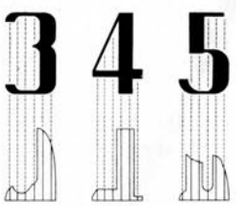
After the item is entered on the tape several cross-checks for accuracy occur. When the machine is satisfied it has made no error, the action proceeds to the next higher account number for which it holds entries.

The bookkeeping on Brown's $19.00 check has now been accomplished and other deposits and withdrawals are entered in like manner throughout the month. At the close of business each month the tapes are connected to high-speed printers which convert the coded information into words and numbers for the conventional monthly statement, including service charges automatically calculated, and current balances altered accordingly.

Harold Brown's checks are machine-sorted, combined with the monthly statement, and returned to him as usual.

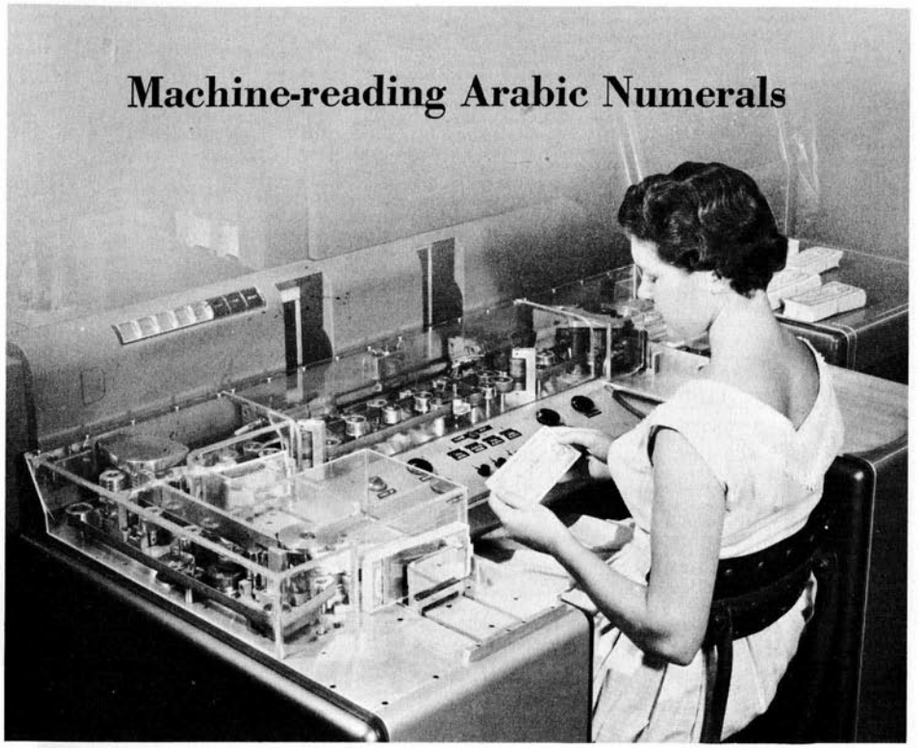
HOW THE CHECK SCANNER "READS" MAGNETICALLY

A magnetic pickup head somewhat similar to that of an ordinary tape recorder enables the traveler's check scanner to identify Arabic numerals by the specific wave forms produced by each numeral.



As each number—printed in magnetic ink—moves laterally across the reading head, the amplitude of the signal will be directly proportional to the amount of magnetic material under the head. Thus, there is a direct relation between the height of each portion of the wave form below and the amount of magnetic ink in the corresponding section of the numeral above.

Machine-reading Arabic Numerals



THE PROTOTYPE ERMA reads binary coded numbers printed on checks and deposit slips. Concurrently with ERMA's development, a project was undertaken to devise a method by which future ERMAs could read printed Arabic numerals directly. This study was carried out using the Bank of America's traveler's check operation which could be isolated from other phases of banking, but providing all the elements required for the development of direct number reading by machine. It is expected this method will be applied to later models of ERMA.

The numbers printed on front of the traveler's checks appear to be ordinary printed numbers. However, this can also be "read" by the scanner with a high degree of accuracy despite disfigurement from overstamping, ink, dirt, fingerprints, or wrinkles. Because the scanner responds only to magnetic ink such obliterations do not confuse it.

The machine also verifies its own reading. Each check is printed with a nine-digit serial number and a tenth number indicating denomination. In addition an eleventh number is provided to make the sum of all eleven digits divisible by nine. A computer element in the scanner makes this addition and division after each reading. If the sum is not divisible by nine the scanner "knows" it has not read the number correctly and the check is diverted into a separate compartment for manual attention.

The prototype scanner reads and verifies eleven-digit numbers at 100 checks a minute, and rejects (checks the machine knows have been read incorrectly) constitute much less than one per cent of the total. This performance—estimated at 50 times better than human accuracy—is being improved.

MACHINES are man-made to aid men and women in the performance of useful work. ERMA is the product of the knowledge, experience, and tenacity of many members of the SRI staff and the Bank of America. It would not be possible to mention all those who contributed to its design and construction over a five-year period, or those whose related research has made ERMA's development possible.

Over-all direction of the project was the responsibility of Thomas H. Morrin, SRI's director of engineering research, and Charles Conroy, assistant vice president of the Bank of America.

Direct responsibility for the technical program lay with Dr. Jerre D. Noe, assistant director of engineering research. Supervision of major portions of the work was divided among Dr. Byron J. Bennett, manager of the Computer Laboratory; Dr. Oliver W. Whitby, technical planning co-ordinator; and Dr. Kenneth R. Eldredge, manager of the Control Systems Laboratory. To these men fell the responsibility for envisioning ERMA as a whole and seeing to it the many separate parts "play together."

For the Computer

Milton B. Adams, Dr. Frank W. Clelland, Jr., Richard W. Melville, and Howard M. Zeidler headed major groups in the development.

Bonnar Cox, Jack Goldberg, and Dr. William H. Kautz were responsible for the detailed logical design.

Roy C. Amara, George A. Barnard III, and Dr. John A. Blickensderfer developed logical design and translated logic into the physical wiring specifications.

C. Bruce Clark was responsible for component selection and quality control.

Other engineers who played an essential part in ERMA's development are: John A. Boysen, Rolfe Folsom, Alfred W. Fuller, Keith Henderson, Robert E. Leo, Maurice Mills, Robert Rowe.

For the Paper Handling and Data-Transcribing Systems

Dr. F. J. Kamphoefner and Paul H. Wendt had direct charge of the electronic and mechanical work.

B. J. O'Connor and A. W. Noon were responsible for the detailed mechanical designs.

Mendole D. Marsh, P. E. Merritt, and C. M. Steele developed the electronic systems for data transcription.

S. E. Graf carried responsibility for the magnetic ink development.

Other essential aspects of the programs were handled by F. C. Bequaert, K. W. Gardiner, T. Hori, A. E. Kaehler, and R. I. Presnell.