ERMA

Electronic Recording Machine, Accounting

STANFORD RESEARCH INSTITUTE

MENLO PARK • CALIFORNIA


WELDON B. GIBSON
ACHIEVEMENT AWARD
The ERMA Project Team, March 21,2001


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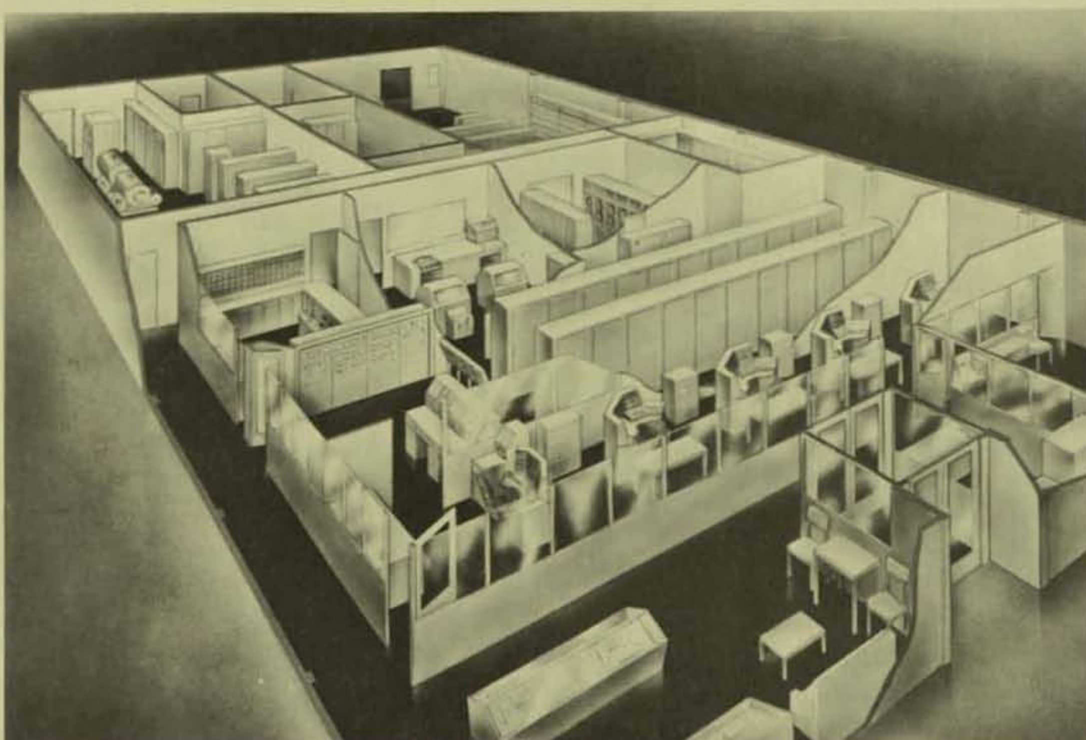
Return to
Fred Kamphoefner

ERMA



Artist's drawing of first proposed ERMA installation.

ERMA

Electronic Recording Machine, Accounting

A MACHINE TO PERFORM THE BOOKKEEPING
OF CHECKING ACCOUNTS, DEVELOPED FOR
THE BANK OF AMERICA BY

STANFORD RESEARCH INSTITUTE

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MACHINE BOOKKEEPING OF CHECKING ACCOUNTS

A machine to perform the necessary accounting for 50,000 commercial checking accounts has been developed for the Bank of America by Stanford Research Institute. In engineering language it is called Electronic Recording Machine, Accounting, which conveniently abbreviates to ERMA.

The prototype has been successfully tested at the Institute's laboratories in Menlo Park, California, and will be installed early in 1956 for operational use by the Bank of America at San Jose, California.

ERMA is a large, data-processing and paper-handling system designed specifically to handle checking-account bookkeeping. From its central position it will perform the accounting for checking accounts of all the branch banks in the San Jose area. The machine enters into individual accounts deposits and checks, remembers details of all transactions, maintains customers' correct balances, accepts stop-payments and hold orders, stops when an item would overdraw an account or when a hold item is presented, and sorts checks.

The electronic bookkeeper physically occupies about 4000 square feet of floor space, and weighs about 25 tons. Its 34,000 diodes, and 8200 vacuum tubes and associated electronic components are housed in two, 40 foot long rows of metal cabinets, six feet high. Sixty kilowatts of power at six d-c voltages are supplied by regulated selenium rectifiers. A 25-ton air-conditioning plant removes the heat from machine's electronic equipment.

The electronic bookkeeper was developed over a period of five years by SRI for the Bank of America. The numerous patents that have arisen from its development will be assigned to the Bank of America. The bank, likewise, will arrange with equipment builders for the construction of production models.

ERMA. . . . *Electronic Recording Machine, Accounting*

Operator at the input console. The amount of deposit or withdrawal is punched on the keyboard, the check or deposit slip is dropped in the automatic reader, then ERMA's work cycle begins.

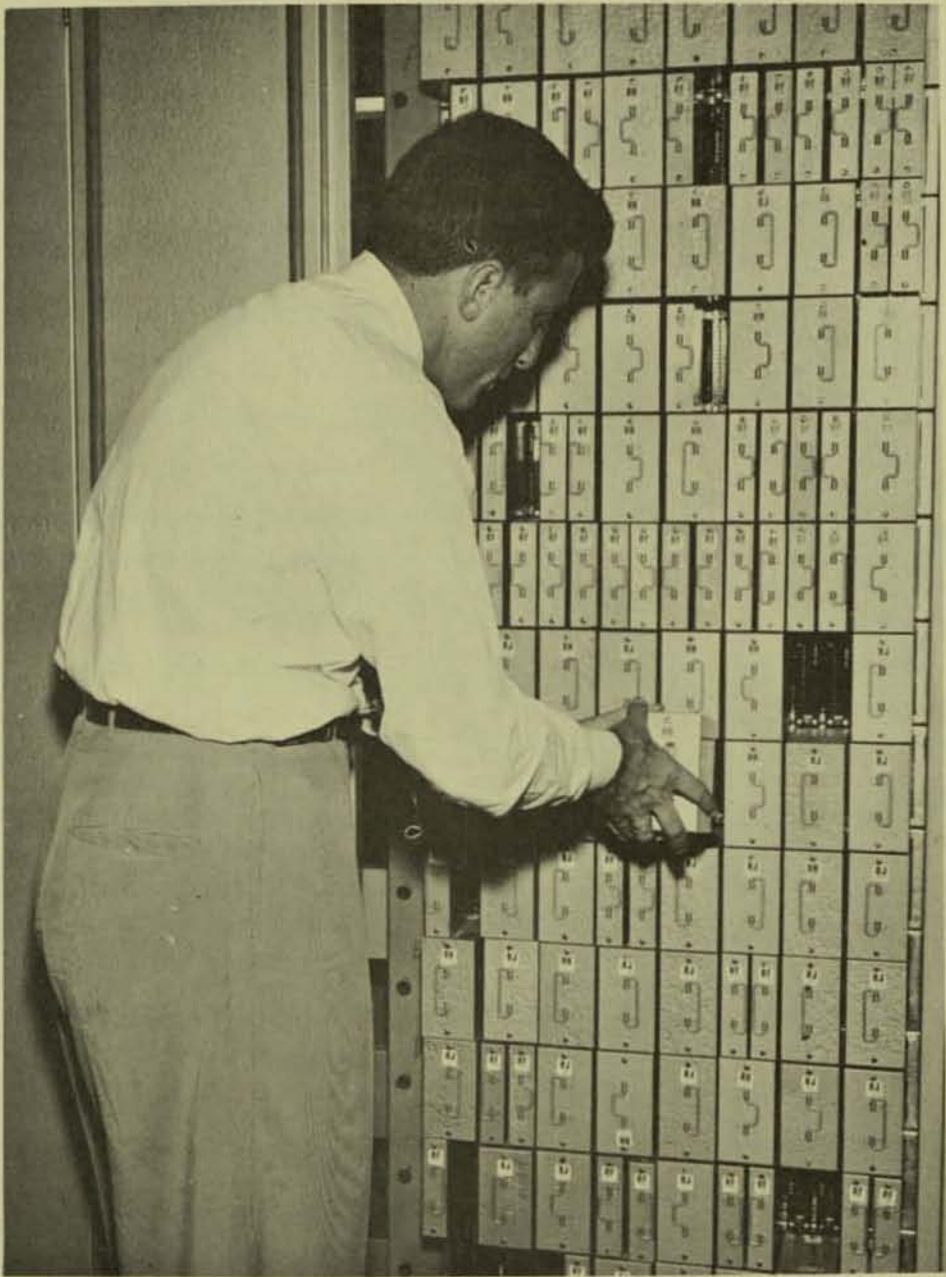
ELECTRONICS AND A BANK ACCOUNT

Consider how the electronic bookkeeping machine keeps track of a typical checking account. Assume it is the account of Harold Brown in the Hester Branch bank of the Bank of America at San Jose. Assume that in the Bank of America system this is branch number 157 and the hypothetical Mr. Brown has been assigned account number 11756 in that branch. Thus Mr. Brown is known to the bookkeeping system of Bank of America – and to ERMA – as 15711756.

Mr. Brown writes a check for, say $19.00 to a neighborhood merchant. Here is where the first but inconspicuous element of difference comes in. Each check of the book supplied to Mr. Brown carries his account number – 15711756. (How this number is put on we'll come to later. Just assume it is in some language intelligible to the electronic computer but not necessarily readable by you or me.) Except for the account number and it is further personalized with Mr. Brown's name and address, the check looks like any other Bank of America check.

The merchant deposits Mr. Brown's check to his own account, which may or may not be the same bank as serves Mr. Brown. In any case the check arrives via usual banking channels, such as clearinghouse transfer or directly from one of the branches' own tellers, to the desk of one of the five operators for ERMA the electronic bookkeeper. It is in one of the thick bundles of checks against the many accounts for which the machine is responsible.

The operator has before her, as do the other four, an array of keys that resembles the keyboard of a large adding machine. One section of the array applies to the branch-bank number and the account number and the other is for the dollars and cents amount of the item. Between the account-number section and the amount section is a single column of keys for various code purposes.



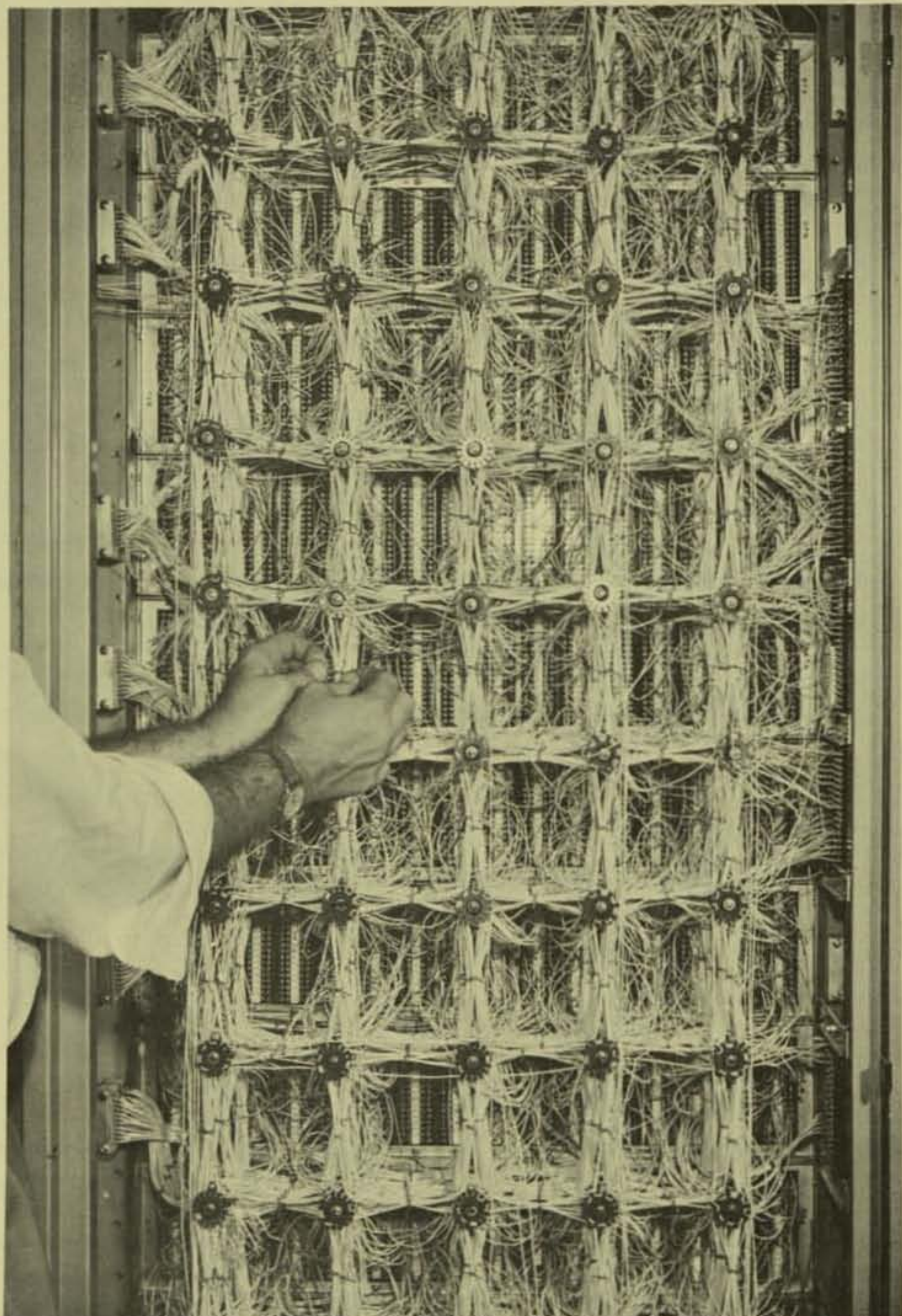
Hundreds of relay units are combined in the construction of ERMA. The units are all of the "plug-in" type and can be replaced with a minimum of difficulty and lost time.

The operator, we'll now assume, picks up from the pile Mr. Brown's check for $19.00. She depresses the keys 19.00 in the amount side and places the check in a slot of the check reader in front of her. The reader then scans the check and reads the account number. It instantly pulls down the keys on the account portion for 15711756. In fact, this is accomplished far faster than the operator can enter the check amount. The operator, if need be, can see the account number the machine has read, although ordinarily there is no reason for her doing so. Or, she can enter the account number by hand if need be. The operator next presses an entry bar at the side of the keyboard. This signals the machine to take over the bookkeeping functions, whereupon it initiates a long but lightning-fast chain of events.

The machine calls for Mr. Brown's current balance from its storage of such information. The machine simultaneously searches for two other pieces of information. Is there a "stop payment" against this check? And, are there any "holds" against funds in Mr. Brown's account? Stop-payment and hold data are stored on the machine's magnetic drum, as are account numbers and current balances, but on a separate section reserved only for that purpose. The machine, in effect, scans the storage drum for a stop-payment signal on a $19.00 check in account 15711756. If such is found, a light flashes before the operator and the machine refuses to take further action on this check. Meanwhile it goes on to the next input position ready for it. If any holds against this account are found, their amounts are transferred to the arithmetic unit and subtracted from the current balance so that the actual funds available are known.

The machine, we'll assume, finds no stop payment on this particular check. It has delivered into the arithmetic unit the amount of this debit and the amount in Mr. Brown's account available for withdrawals, i.e., current balance minus holds.

Next the arithmetic unit makes the subtraction of $19.00 from that amount. If the result of this subtraction is a negative quantity, it indicates that Mr. Brown has overdrawn his account. This unhappy fact is flashed, by signal light, to the operator who refers the matter to the supervisor. The supervisor sends the item to the branch for authorization or rejection of the overdraft. In any case, the machine processes this item no further until directed. It moves on to the next item at the next ready input position.



Many hundreds of thousands of connections and a million feet of wiring are needed to make ERMA function.

Ordinarily the check passes these examinations. The subtraction is completed in the arithmetic unit to establish a new current balance. After the machine checks its arithmetic in several ways, the old current balance for account 15711756 is replaced on the drum by a new one less the $19.00.

Meanwhile the account number and the $19.00 debit item are "written down" in another section of the drum reserved for the temporary storage of this information. It is held there for an appreciable period of time – minutes perhaps, or an hour or so – until convenient for the machine to transfer the information to its detail, account activity file, i.e., magnetic tape. Thereupon, – which is but a small fraction of a second since the start of the operation – the account number and the amount of the item are printed on paper tape in view of the operator.

Checks and deposit slips for different branches and different accounts come to the machine in completely random fashion. The information obviously must finally be stored in an orderly manner. The drum processes the information in whatever sequence it arrives. The drum then holds that processed information (in temporary storage) until it is transferred to the magnetic tape where the details of the transactions to all accounts are held in sequence and in complete detail. Meanwhile, the five operators at the input keyboards continue to feed new check or deposit information into the drum.

Transfer of information about Mr. Brown's withdrawal of $19.00 from the input keyboard to the temporary storage section of the drum is done in a semi-ordered fashion. On the drum are many circular tracks of information. At any one time a track or a group of tracks is assigned to a particular block of account numbers that correspond to those on one of ten magnetic storage tapes. Within that set of tracks the information is stored in random (incoming) order. When information about Mr. Brown's check is sent to temporary storage it is placed on the next empty space on the particular group of tracks assigned to the tape assigned to 15711756.

Essentially instantaneous emptying of the temporary-storage section of the magnetic drum is not necessary. Information is transferred from temporary storage to only one tape at a time.

In a short while it becomes time for the tape containing Mr. Brown's account to be brought up to date by receiving information for its accounts held for it in drum temporary storage. The machine makes the decision when that time arrives. It continually surveys its temporary storage sections, and when one nears filling, it automatically plans for connection to the associated tape at an early opportunity.

The drum rotates 30 times per second (and hence scans all the information held in any particular group of tracks 30 times per second). The tape moves slowly – relatively – at 75 inches per second. Hence some speed-matching device between them is necessary to effect the transfer of information from drum to tape. This device, called the shift register, is an array of electronic tubes that can receive information from the drum at a rapid rate but delivers it slowly to the tape.

After information for one account is transferred from drum temporary storage to the tape via the register, the temporary storage-drum reading head searches the tracks for the next higher account for which it has an item. (Because the drum scans itself 30 times per second this search is accomplished in practically no time at all.)

Assume the next account for which temporary storage has information is that of Mr. Brown. His account number and the $19.00 debit item are transferred to the register and held there while the tape unwinds through the intervening accounts for which no items are available. When the tape reaches account 15711756, that fact is signalled to the register, which readies itself to transfer the item information to the next available empty space on the tape. Physically this is immediately after the most recent entry to Mr. Brown's account. This may have been earlier in the day or on a previous day.

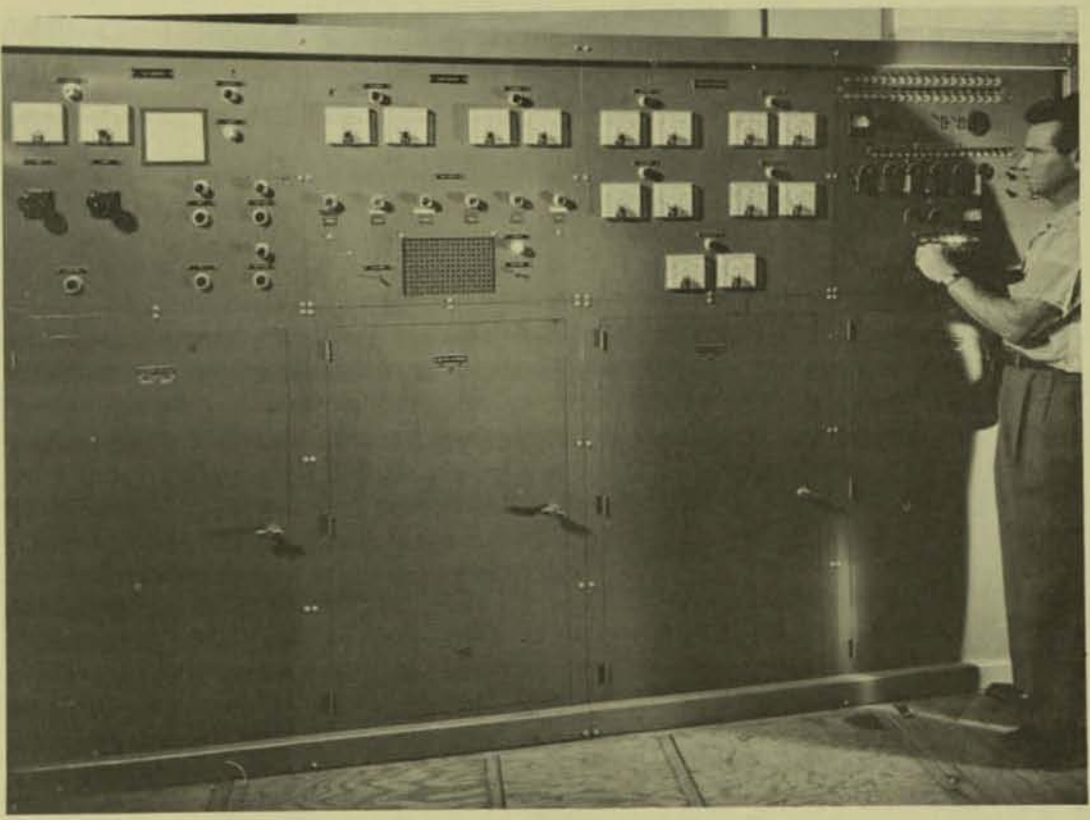
When the item has been entered in the proper place on the tape several cross-checks for accuracy occur. When the machine satisfies itself that it has made no mistake, the transfer-to-tape action proceeds to the next higher account number for which it holds entries. The process continues until the tape reaches its end, at which point the temporary-storage tracks have been wiped clean. The tape automatically rewinds itself to await its next turn for a new round of information.

The bookkeeping for Mr. Brown's $19.00 check has now been accomplished. In like manner other withdrawals and deposits are entered throughout the remaining days of the month. At the end of each day the machine automatically calculates from magnetic tape information Mr. Brown's new current balance. It is checked against that recorded on the magnetic drum and is recorded on the magnetic tape.

At the close of business for the month each tape is removed from the electronic bookkeeper and connected to a high-speed printer. Meanwhile, the machine has calculated the service charge automatically, prints that charge on the statement, and alters its own records on the drum and tape accordingly. The machine figures this charge automatically, applying a formula that includes account activity, balance, and type of account, which the machine ascertains from a code within the account number. Sinultaneously a written record of account activity is printed on paper for the bank's permanent record. When ready to print, the information held for each account in code on the tapes is converted into words and numbers, which it prints on the conventional-appearing monthly statement.

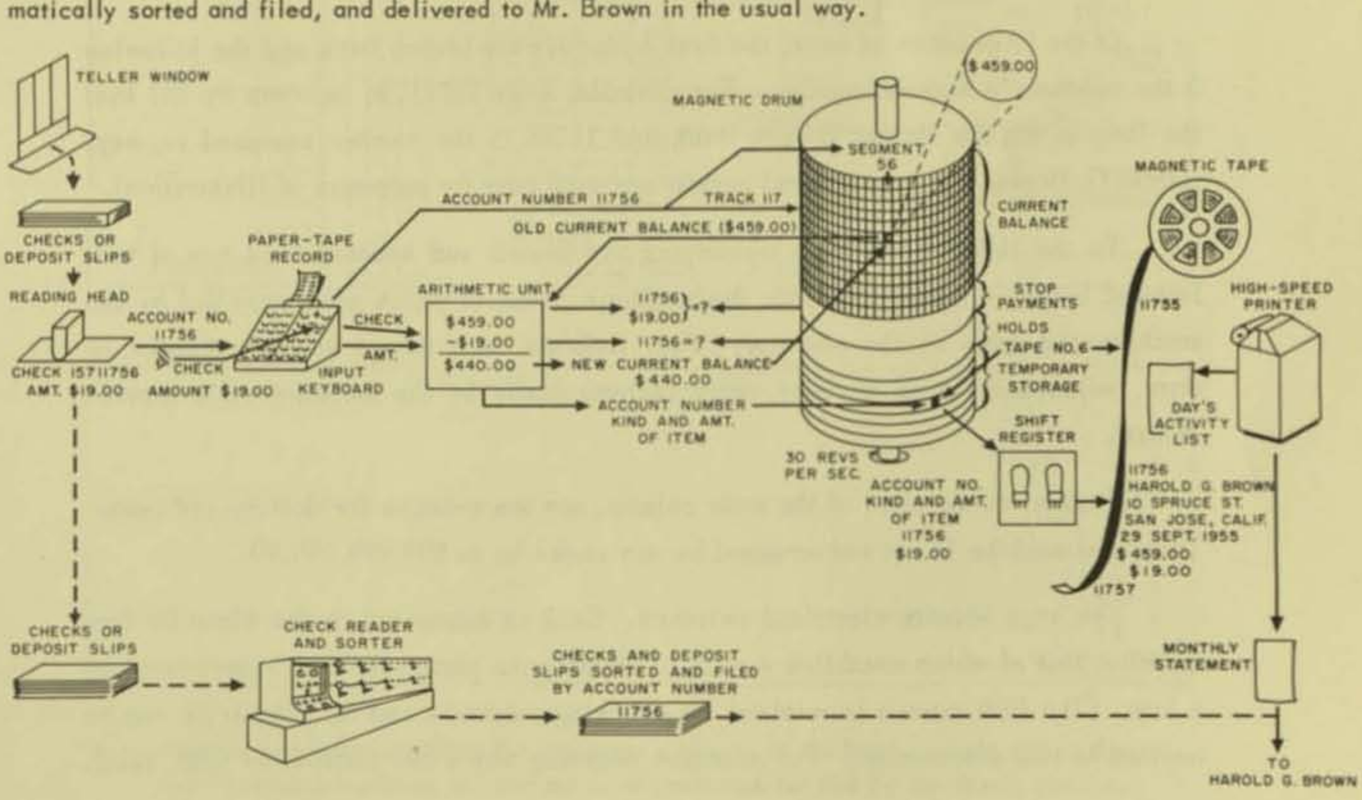
The machine-printed statement is combined with Mr. Brown's checks for the month, which have been sorted by machine and stored in the same order they were processed by the bookkeeping machine. The statement and his checks are delivered to Mr. Brown in the usual way.

When the machine has printed the monthly statement for Mr. Brown it retains (1) on the drum only his account number and current balance and (2) on the tape his account number, name, address, and the current balance. The machine is now ready for next month's activity to Mr. Brown's account, and all others for which it is charged.



Power at seven different voltages is required to keep ERMA in operation. This panel controls the units required to convert 80 kilowatts of alternating current to direct current and to assure freedom from voltage variations.

This chart shows the path of a check or deposit through the electronic bookkeeper. The physical check or deposit slip takes the path of the dotted line; the information from it follows the solid lines. Checks or deposit slips in bundles come, in the usual way, to the operators of ERMA. Assume, as a typical case, a check for $19.00 by a Mr. Brown. The number 157 11756 has been assigned to him, the first three numbers (157) identifying the branch bank with which Mr. Brown does business. To perform the bookkeeping for this check, the machine requires three pieces of information. The amount of the check and the fact that it is a check not a deposit is supplied by the operator who presses the proper keys at her keyboard. The account number is read by the machine from 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 in sequence in space assigned at the beginning of the period to Mr. Brown. At the end of the month the account details for the period are read from the tape by a high-speed printer which writes them onto the statement. This is combined with the checks, which have been automatically sorted and filed, and delivered to Mr. Brown in the usual way.



THE MAIN ELEMENTS OF THE ELECTRONIC BOOKKEEPING MACHINE

INFORMATION INPUT

The input keyboards are the eyes and ears of the electronic bookkeeper (ERMA for electronic recording machine accounting). It is the means by which the machine receives information. In external appearance it is the keyboard of a large adding machine. Its principal array of keys are arranged in 19 columns of nine keys, one for each digit. In addition, there are keys that inform the machine whether the entry to an account is a check or a deposit. An entry bar at the side enables the operator to signal the machine when she is ready for it to process the item.

Of the 19 columns of keys, the first 3 identify the branch bank and the following 5 the customer's account number. For example, keys 15711756 indicate by 157 that the item is for the Hester Branch Bank and 11756 is the number assigned to, say, Harold G. Brown (the hypothetical person assumed here for purposes of illustration).

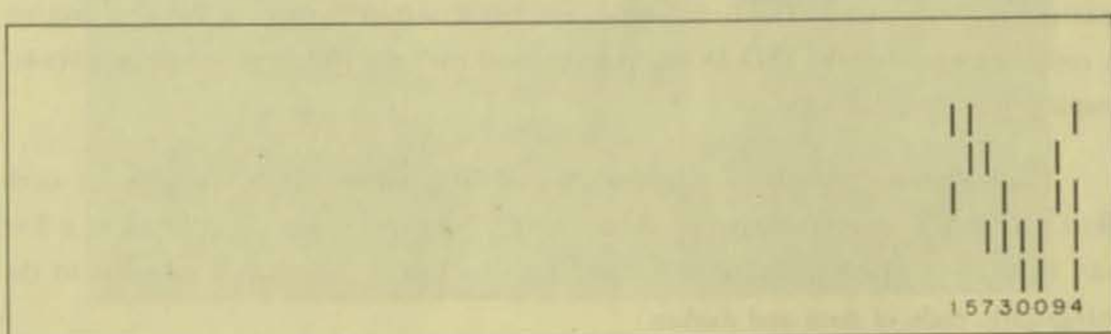
To the right of the keys identifying the branch and account is a row of red, lettered buttons. These are code designations, some of which are controlled by the machine and some by the operator. They indicate such things as correction of an error, adjustment to an account, entry (automatically by the machine) of a service charge.

Finally, at the right of the code column, are ten columns for dollars and cents. Thus, the machine is not embarrassed by any check up to $99,999,999.99.

The keys actuate electrical switches. Each is connected to the wires for five circuits, four of which establish a code to identify the particular digit represented by a key. (The fifth circuit is retained for checking purposes and for simplicity can be omitted in this discussion.) For example, pressing any 8 key closes the first, third, and fourth code circuits connected to it; the second circuit remains open. Thus, the machine recognizes an 8 by circuits 1, 3, and 4 being closed but 2 open. This can be represented by 1011. Likewise the number 7 is coded as 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 keyboard positions (four operators and a supervisor). Because the machine handles the average item in half a second, it can switch itself without apparent delay among all operators as they signal to it. Even if all four operators happen to press their entry bars at once, one of them might have to pause about a second if she were entering items as fast as possible before the keyboard would respond to her next entry.

Each of the five input stations required to keep ERMA busy also have means for printing on paper tape a record of each item entered into the machine, i.e. account



Account numbers printed on the customer's check, on the back in code and on the front in arabic numbers, are printed in magnetic ink for use by the check scanner.

number, amount of item, and whether it is a debit or credit. This same print-out device gives a written answer to any question asked of ERMA, such as, "What is the current balance in Harold Brown's account?" Because the print-out mechanism is operated by depressed keys, each key has a solenoid to pull it down in response to the machine's answers to queries. In other words the keys can be depressed by the fingers of the operator or by solenoids responsive to electronic circuits.

Incorporated into each input station is the account-number reader.

MACHINE READING OF NUMBERS

One of the major technical accomplishments embodied in the electronic banking machine is the ability given it to read numbers automatically from the paper. This development not only plays a large part in the success of the machine but also has enormous implication for other data-handling machines.

This scheme differs from most previous attempts to "train" machines to "read." It does not rely on optical methods such as photocells that distinguish between light and dark or that utilize phosphorescent inks. This machine reads numbers by a magnetic process at the rate of 1000 characters per second. The numbers are printed on the paper in magnetic ink—ink containing particles of iron oxides, about 40 millionths of an inch in size. After the ink has dried, the particles can be aligned like tiny magnets by exposure to a strong magnetic field.

The technique of machine reading of information printed in magnetic ink was undertaken in two steps. The first was to develop a method of reading numbers printed in code in magnetic ink. This is the system used with the prototype electronic bookkeeping machine.

These codes consist of combinations of five narrow black-ink bars for each digit. Thus a 1 is represented by blank, blank, bar, blank, bar (00101) while a 2 is bar, blank, bar, blank, blank (10100), and so on. These codes are analogous to the telegraphic code of dots and dashes.

When a check, with its magnetic-ink coded number on the back, is placed in the check reader to be read it first passes under a magnetizing element. This causes the tiny iron-oxide particles to line up in a prescribed direction. Immediately thereafter the check passes under a reading unit containing five magnetic reading heads side by side. Because the positions of magnet-ink bars differ, the pattern of voltages at the five reading heads differ for each digit. The machine's electronic circuits are designed to distinguish between these unique wave patterns.

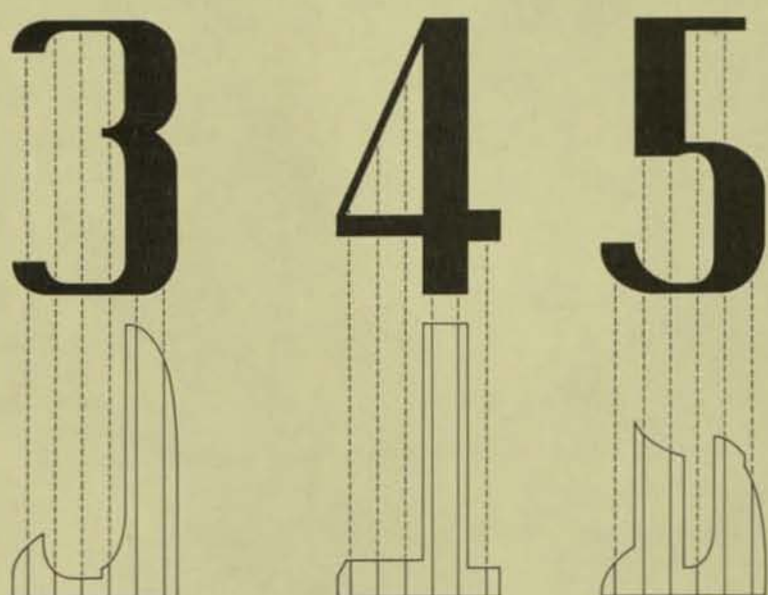
Operator using the Travelers Check number-scanning machine. This machine "reads" arabic numbers on Travelers Checks and punches IBM cards for use in Bank of America accounting systems.

Obviously it would be tremendously advantageous for the machine to read not codes but conventional arabic numerals. Arabic numbers are easier to print, and occupy less space on the check.

The second phase of the development program—direct reading of numerals—has proceeded in parallel and beyond with the code reading. A technique for direct number reading has been developed and successfully tested. It will be incorporated in future electronic bookkeeping machines.

The particular phase of the banking function chosen for the development of machine reading of conventional appearing numerals was the serial number on Travelers Checks. This was done for reason of simplicity. The traveler's check problem could be isolated from other phases of banking, yet it provided all the elements required for the development of direct number reading by machine.

The numbers as printed on the front of Travelers Checks (and eventually as the branch-bank and account number on depositors' checks) are recognizable to the human



Arabic numerals and the wave forms produced by the Travelers Check scanner. As the numbers printed on the Travelers Check pass horizontally beneath the read-head, the head sums up the total magnetic ink covered in a given time interval and produces a proportional electric signal.

eye as ordinary printed numbers. However, the numbers have been designed so that the machine can recognize them with a high degree of accuracy.

The Travelers Check reader has been tested with over 300,000 checks. On many of these the serial number has been purposely disfigured by rubber stamps, ink, dirt, fingermarks, tears, scotch tape, or crumpling, that make optical machine reading impossible. Because this machine responds only to magnetic ink it is not confused by such obliterations. The printing tolerance is large. Numbers can be printed as much as one-half inch above or below their normal position without influencing reading accuracy.

Also, before each check is read it passes through a set of pressure rollers to take out wrinkles. Checks that have been folded or crumpled and crudely smoothed out are readily handled by the machine.

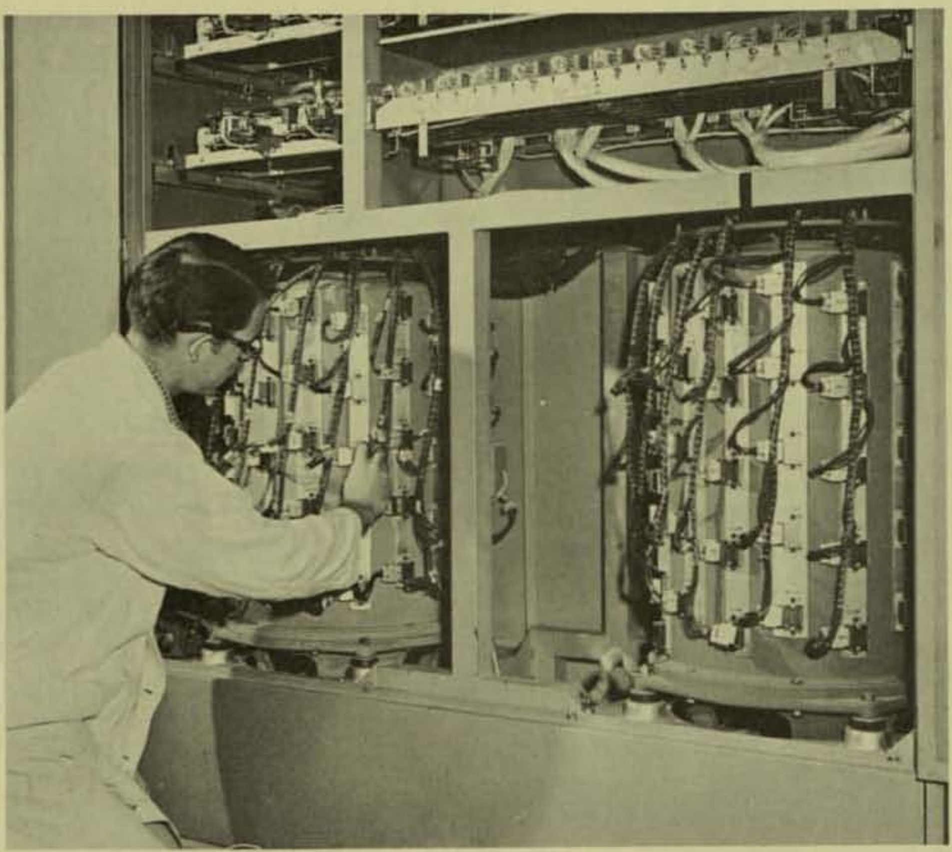
The machine also verifies its own reading accuracy. Each Travelers Check is printed with a nine-digit serial number and a tenth number that indicates check denomination. In addition, an eleventh number is provided. This number, in every case, is chosen such that the sum of all eleven digits is divisible by nine. The check reader makes this summation after each reading. If the sum is not divisible by nine the machine "knows" that it has not read the number correctly, for some reason, such as faulty printing. The check is diverted into a separate compartment for attention by a human operator, or re-run through the machine. These are called rejected checks.

The prototype reader is currently reading (and verifying) the eleven-digit numbers at 100 checks per minute. Rejected checks normally amount to less than one percent of the total number processed. Errors, i.e., checks incorrectly read but passed as correct by the machine are less than one in one hundred thousand, as determined by laboratory tests using machine error-detection techniques. It is expected that even this outstanding performance, which is perhaps 50 times better than human accuracy, will be improved.

THE MAGNETIC DRUM

The magnetic drum is one of the information "files" in the electronic bookkeeping machine. Physically, it is a smooth vertical cylinder of non-magnetic metal 16 inches in diameter and 20 inches high contained in a dust-proof housing. An electric motor drives it at a constant speed of 1800 rpm.

The drum surface is coated with a resin containing millions of tiny particles of iron oxide. Under the influence of fields from electromagnets mounted close to the drum surface, groups of these can be made to act like small permanent magnets of



ERMA's magnetic drums are contained within these vertical cylinders. The drums store current balance, stop-payment and hold information for future use.

controlled polarity. A surge of electric current through the electromagnet in one direction causes the microscopic iron-oxide particles in the tiny area under the electromagnet to align themselves so that their north poles lie in one direction and south poles in the opposite direction. If the current, i.e. field, is impressed in the opposite direction the poles are reversed.

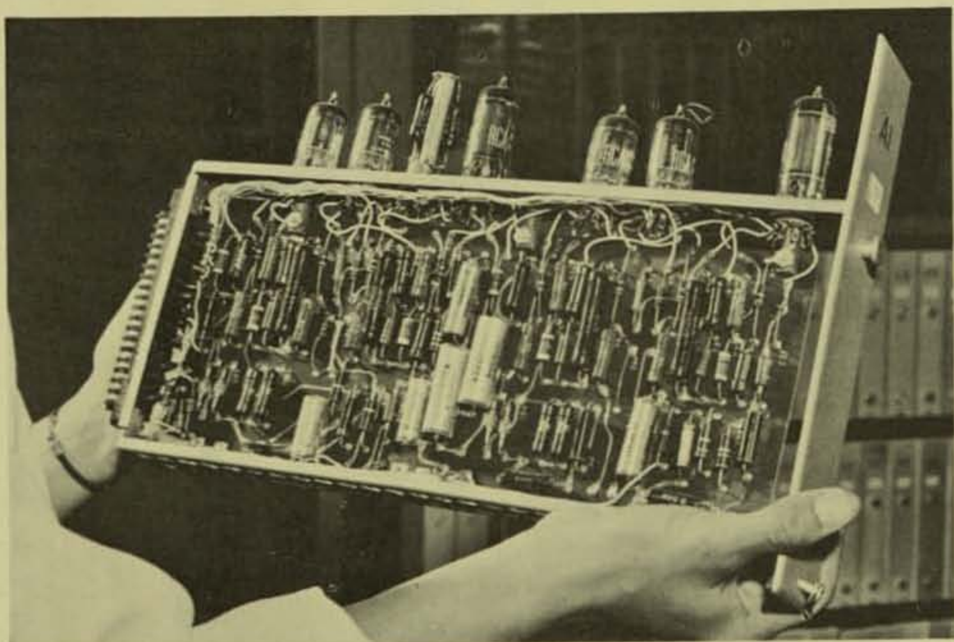
The drum surface with its iron-oxide particles is invisibly divided into 300 parallel, circular tracks, each about 0.040 inch wide. In a lengthwise direction each track is divided — again invisibly — into sections 0.010 inch long. Each little magnetic cell stores what is called a single binary digit or bit of information. Thus the drum surface can be thought of as made up of 1,500,000 separate, but invisible, magnetizable areas. Each of these can be magnetized at will in one direction or the other. The drum thus provides, on the binary system, 1,500,000 information elements.

Four bits are required to store a single digit (a fifth is also reserved for each digit but it serves for checking purposes and can be neglected in understanding the basic principles of the machine). Thus to store an account number such as 11756 the first two sets of four bits on a track are magnetized N-S, S-N, N-S, N-S, (0100), which in machine language means 1. The third set, for the numeral 7 (1010) would be magnetized S-N, N-S, S-N, N-S. Actually, to save bits, which cost money, the information is stored in a way that does not require writing the full account number for each account. The drum is divided in a sort of pigeon-hole or post-office box system in which there are 100 "boxes" in each vertical column (corresponding to 100 spaces around one track) and 300 columns (i.e. drum tracks). Thus, Mr. Brown's account number is filed in the 56th box of the 117th track, without the necessity of having to write on the drum the account number with the current balance. Following the account number on the track the current balance is stored, using the same language of properly polarized four-element magnetic cells.

A set of about 300 elements, one per track, are held close to the rotating drum and spaced evenly around its surface. Each element is used for both reading and writing. These enable the machine to add information into this file, to read its contents, or to empty it when necessary.

Each magnetic head element consists of a coil through which current can be passed. It is wound around a piece of magnetic material containing an air gap spaced a few thousandths of an inch from the rotating tracks. To write a number onto the drum, bursts of current, electronically timed, are passed through the coil. These bursts, by their direction, magnetize the sets of four bits in accordance with the code for the number to be written. The number thus written down remains until it is necessary to change or erase it. Should electric power be turned off no information is lost.

The numbers are read by the same magnetic head elements that write them. Thus each magnetized bit on the drum as it sweeps by the element induces a voltage in the coil. The direction of this voltage is determined by whether the little magnet on the drum is N-S or S-N. Thus the heads can look for a given desired number by searching for the proper combination of bits on the drum. Information, such as current balance, can be read in similar fashion.



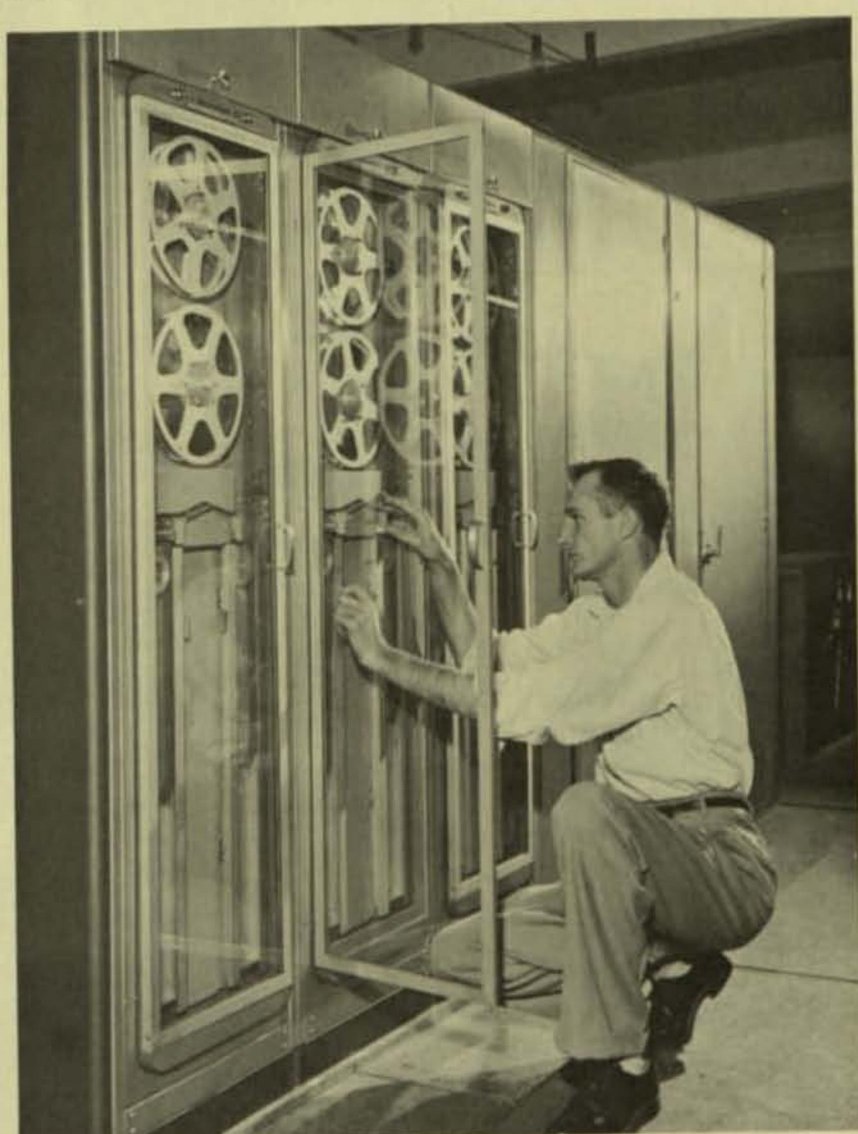
One of the "building blocks" used in the arithmetic unit, capable of performing additions and subtractions on sums as large as $99,999,999.99.

When it is desired to change a number, for example to write a new current balance, it is necessary only to "write over" the old number. The magnetizing forces, applied in the proper coded sequence, are strong enough to overpower the magnetism of any bits that previously were oppositely polarized. Or, a section can be completely "erased" by simply magnetizing all the bits in one section with a common polarity.

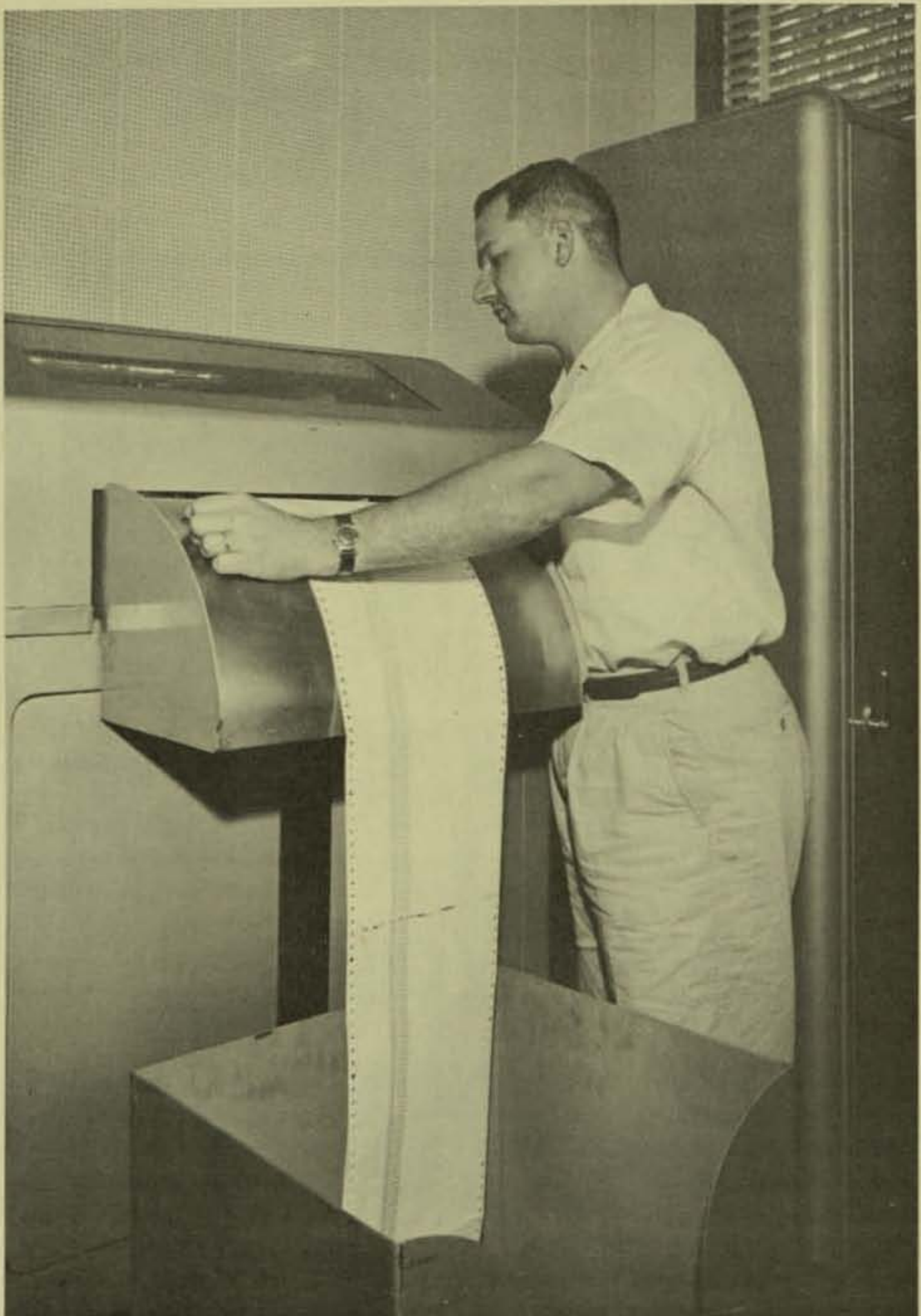
A drum has space for about 300,000 decimal digits. Actually two drums are used, for reasons of practical physical size. This gives a total of approximately 600,000 digits of information. This is adequate for servicing the accounts under ERMA's jurisdiction.

THE ARITHMETIC UNIT

The arithmetic unit is one of the many devices built up from the standard electronic "building blocks." It comprises a battery of electronic tubes and related components capable of performing additions and subtractions on sums as large as $99,999,999.99.



Detailed account activity information is "filed" by ERMA on 10 reels of magnetic tape, each almost half a mile in length. Accounts are kept in numerical order on the tapes which provide storage space for a month's activity.



The high speed printer, used in statement preparation, prints 15 lines per second. The printer can prepare all the statements for ten branch banks in about five working days.

Since the basic building blocks can count only up to two (i.e., they recognize only numbers 0 and 1) the decimal numbers are handled in a coded form such that each decimal number is represented by a unique pattern of binary numbers.

The tubes are arranged in pairs, known as flip-flops, so that when a potential is applied to a pair, one tube becomes conducting, the other non-conducting. The next application of potential causes the conducting tube to become non-conducting, and vice versa. Thus the device has the essential features of a device to store one bit of information, just as each cell on the drum served this function.

THE MAGNETIC TAPE

The second and more detailed information file is kept on magnetic tapes, of which ten are used for storage and two serve auxiliary functions. The entire month's activity for each account is kept together in its incoming sequence, each account being in numerical order, just as in a standard manual file.

The tape itself is the same as conventionally used with data-processing machines. It is a tape 2400 feet long contained on a reel, which provides space for the detail information for several thousand accounts. The tape can be unwound past a set of magnetic heads, similar to those used on the drum, that either write new information on the tape or read information from it as needed. The tape stores information on the same binary basis—bits that are magnetized either N-S or S-N—as on the drum. The tape consists of a plastic backing coated with a film containing iron-oxide particles. The tape of standard size gives room in one row across the tape for seven information bits. Because the tape must store words, i.e. letters, as well as numbers seven bits are required to identify all letters and numerals. The bits in one row across the tape are used for a single letter or numeral. In this way, however, information as to account number, name and address, and account activity for a month can be maintained in about nine inches of tape for an average individual checking account. Space on the tape is allocated at the beginning of every month. The amount of that space in each case is determined by previous experience with that account.

The manner of writing information, reading information, or erasure is essentially as described for the magnetic drum.

HIGH-SPEED PRINTER

Under present banking procedures the entries to monthly account statements are posted daily by hand. This is essential because the volume of work makes doing it all at one time a physical impossibility if it were done manually.

With machine accounting daily posting to the customer's statement sheet is unnecessary. Each statement is printed all at one time on a selected day each month. To make this system possible, however, requires a means of printing information of statement sheets at extremely high speed.

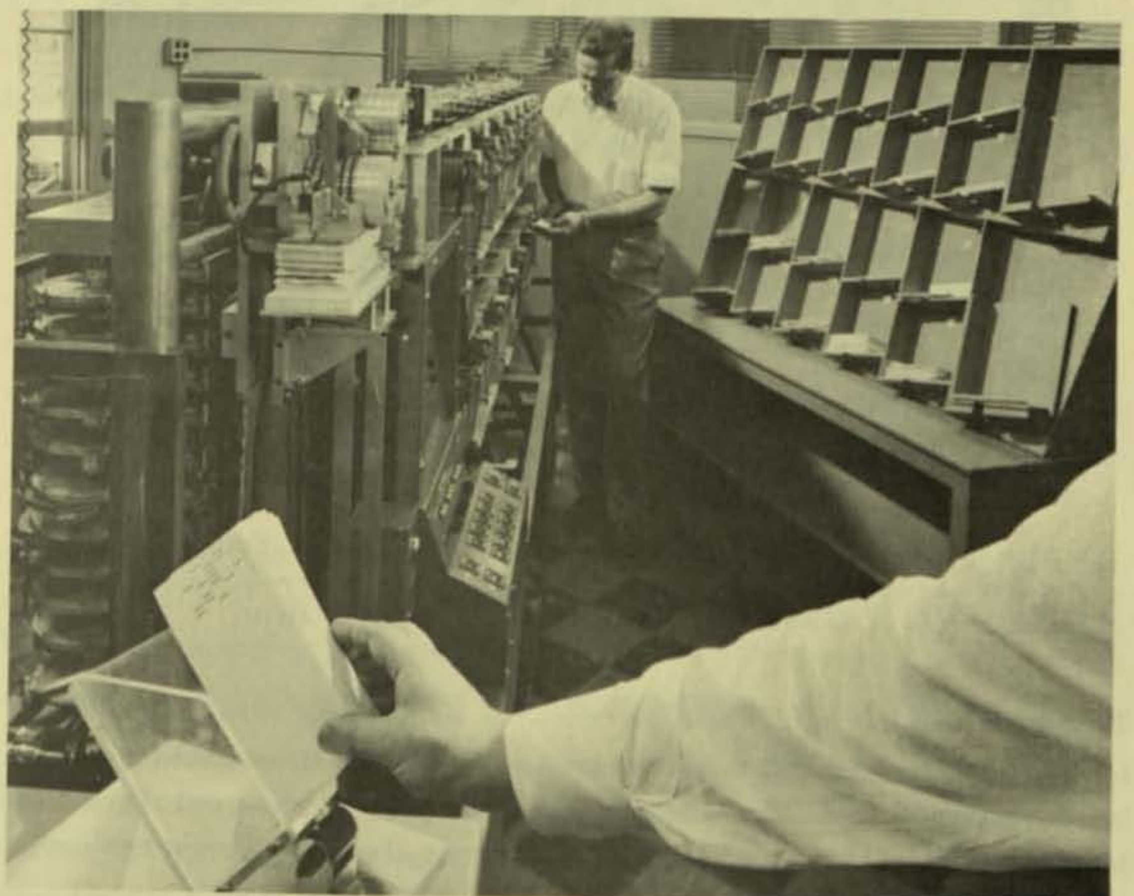
Consider the enormity of the job of statement preparation. For 50,000 accounts and with an average of, say, 25 lines to be printed on each statement (name, address, daily activity, daily balances, service charge, final balance, etc.) that amounts to 1,250,000 lines to be printed.

When the development of the electronic accounting machine was begun the highest speed printer available could manage three lines per second. That seems fast. However, to print 1,250,000 lines at 3 per second—and counting no lost time between statements—would require 120 hours of uninterrupted operation, or five 24-hour days.

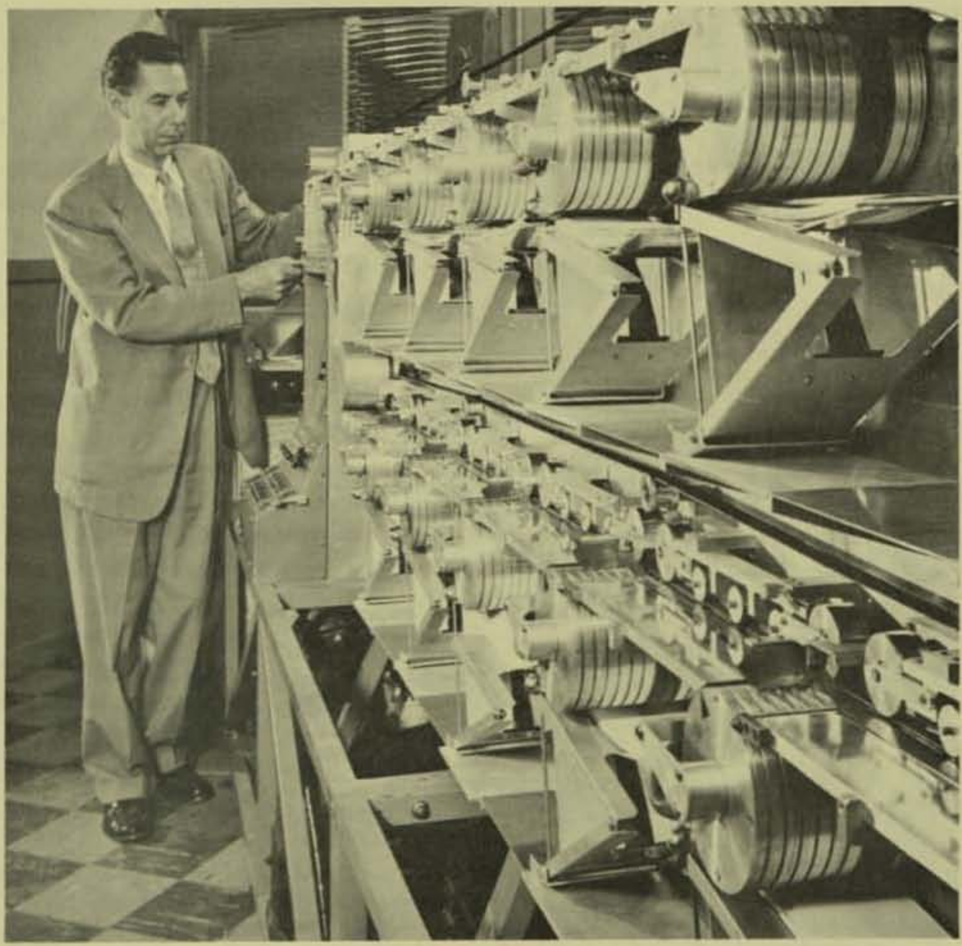
Subsequent developments have fortunately resulted in increasing the printer speed by more than three times—to 10 lines per second—and it is expected this will soon be increased to 15 lines per second. This enables the statement printing for all the accounts handled by the machine to be accomplished in about five normal working days. With the machine serving about 10 branch banks, the statements for all these branches can be turned out during a working week around the month end.

The actual printing element consists of a cylinder with rows of raised characters lengthwise across it. Each row is as wide as the line of printing on the statement. One row contains nothing but a succession of A's, the next, B's, and so on around the cylinder for the remainder of the alphabet, numerals, and other needed symbols. This cylinder rotates continuously at 1200 rpm, above a row of stationary striking hammers, one for each character in the row. Between the hammers and the cylinder is the statement blank and a carbon ribbon.

For printing statements the printer is connected to a magnetic tape where the account detail information is stored. Suppose the statement for the hypothetical Harold Brown is to be printed. As the reading heads at the tape reach the codes spelling out HAROLD BROWN, a blank statement at the printer is synchronized with it. When the line of A's on the cylinder are in a printing position, the coded signals from the tape cause the printing bar to strike the second A in the row of A's. One five hundredth of a second later the B line is in position and the B as the first letter in the surname is printed. There being no C's in the name no hammers strike the paper when the C row sweeps past. Next the D in the given name is printed, and so on.



The electronic check sorter separates the checks by account number and by bank branch so the checks may be returned to the customer with his monthly statement. Automatic sorting is made possible by a special magnetic ink code marking on the back of each check.



Another view of the check sorter which sorts by account number. Each bundle of checks must be passed through the machine five times (once for each digit). The checks travel at the rate of 150 inches per second through the sorter.

Thus in one complete revolution of the drum – one tenth of a second – the whole name is filled in. The paper then indexes to the next line for the street address, which is printed in like manner. Similarly, the remainder of the address, and the account information, including the machine-calculated service charge and current balance, is printed in. The average 25-line statement is completely printed in three seconds.

The monthly statement for Mr. Brown then is assembled with his checks in the order of their presentation which have been sorted by the check sorter and filed for the period. Mr. Brown therefore receives his monthly statement and checks in the usual manner. Except that the statement carries the account number, nothing else distinguishes it to Mr. Brown from others he received before the advent of machine bookkeeping.

THE CHECK SORTER

After all the bookkeeping for a bundle of checks has been completed the checks must be sorted by account number and the checks filed in the same sequence as that in which they are held in the electronic bookkeeper. A machine has been developed to sort them mechanically.

The check sorter has the same ability to read account numbers printed in magnetic ink on the checks as has the input section of the electronic bookkeeping machine. The machine has 12 boxes or output compartments (0 through 9 plus two for rejected checks) into which it sorts the checks or deposit slips.

To sort checks, a bundle is first placed in the sorter. The top check is whisked off by a vacuum feeding device and guided to a scanning head that is manually set to read the first (units) digit of the account number. This information, i.e. whether the unit digit is a 0, 1, 2 or other number, is stored for a fraction of a second on a rotating mechanical memory device. Meanwhile, the check itself is being carried at the rate of 150 inches per second on a belt into the sorting section.

Mr. Brown's account number is 11756. Hence, when the sorter comes to that check, the value of the digit is read as 6 and remembered by the memory mechanism. When the check approaches the number 6 compartment, the memory device causes a gate to open, sidetracking the check into that compartment.

In this manner all checks are sorted according to the units digit. Then the checks from each of the ten compartments are manually collected and run through the machine again, this time sorting for the tens digit. On this next pass, Mr. Brown's check goes into the 5 compartment. By sorting each bundle five times (once for each digit) the checks are placed in sequence by account number—and the items for any one account are in the order of processing by the bookkeeping machine.

ERMA's "Service Station" used to insure the perfect operation of the many delicate circuits in the bookkeeping machine. This maintenance board facilitates the location of troubles within the machine.

ERMA. . . . *Electronic Recording Machine, Accounting*

The outstanding features of this device are not those of its basic principle of operation, which is relatively simple. The requirements of speed and accuracy are so high, however, as to generate engineering problems of a different order of magnitude. Account numbers are read and checks sorted at the rate of 10 per second. A stack of a thousand checks about 5 inches high "melts" down in the input container in about one and a half minutes. To obtain good accuracy at these speeds the paper is controlled pneumatically for both feeding and stacking, not by mechanical friction devices. The machine errors – checks sorted into wrong compartments – run less than 1 in 100,000. Rejects, or checks the machine cannot sort, are below one percent.

Machines are created by people. To conceive, develop, build and test a machine of the size and complexity of ERMA requires the services of many men and women with many skills.

ACKNOWLEDGMENTS

THE TIME AND TALENTS of many persons went into the development of ERMA. While it is not possible to list all of those responsible for ERMA's conception, those with major responsibilities were:

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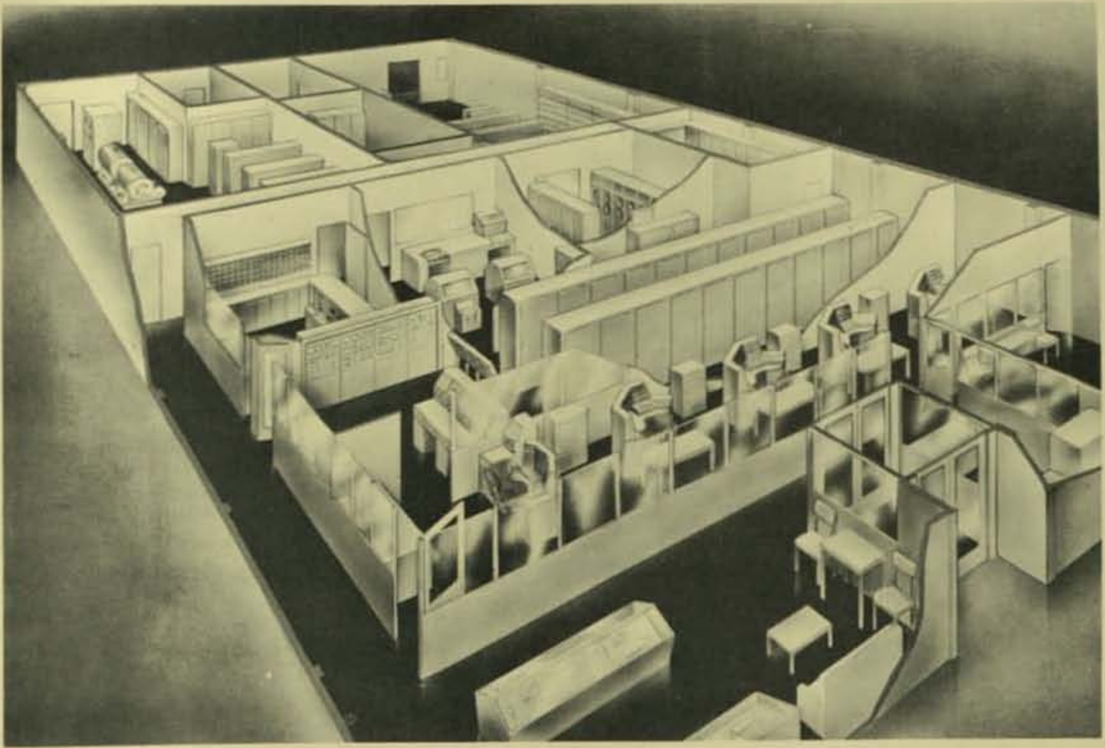
ERMA



Artist's drawing of first proposed ERMA installation.

ERMA

Electronic Recording Machine, Accounting

A MACHINE TO PERFORM THE BOOKKEEPING OF CHECKING ACCOUNTS, DEVELOPED FOR THE BANK OF AMERICA BY

STANFORD RESEARCH INSTITUTE

MENLO PARK • CALIFORNIA

CONTENTS

MACHINE BOOKKEEPING OF CHECKING ACCOUNTS

A machine to perform the necessary accounting for 50,000 commercial checking accounts has been developed for the Bank of America by Stanford Research Institute. In engineering language it is called Electronic Recording Machine, Accounting, which conveniently abbreviates to ERMA.

The prototype has been successfully tested at the Institute's laboratories in Menlo Park, California, and will be installed early in 1956 for operational use by the Bank of America at San Jose, California.

ERMA is a large, data-processing and paper-handling system designed specifically to handle checking-account bookkeeping. From its central position it will perform the accounting for checking accounts of all the branch banks in the San Jose area. The machine enters into individual accounts deposits and checks, remembers details of all transactions, maintains customers' correct balances, accepts stop-payments and hold orders, stops when an item would overdraw an account or when a hold item is presented, and sorts checks.

The electronic bookkeeper physically occupies about 4000 square feet of floor space, and weighs about 25 tons. Its 34,000 diodes, and 8200 vacuum tubes and associated electronic components are housed in two, 40 foot long rows of metal cabinets, six feet high. Sixty kilowatts of power at six d-c voltages are supplied by regulated selenium rectifiers. A 25-ton air-conditioning plant removes the heat from machine's electronic equipment.

The electronic bookkeeper was developed over a period of five years by SRI for the Bank of America. The numerous patents that have arisen from its development will be assigned to the Bank of America. The bank, likewise, will arrange with equipment builders for the construction of production models.

Operator at the input console. The amount of deposit or withdrawal is punched on the keyboard, the check or deposit slip is dropped in the automatic reader, then ERMA's work cycle begins.

ELECTRONICS AND A BANK ACCOUNT

Consider how the electronic bookkeeping machine keeps track of a typical checking account. Assume it is the account of Harold Brown in the Hester Branch bank of the Bank of America at San Jose. Assume that in the Bank of America system this is branch number 157 and the hypothetical Mr. Brown has been assigned account number 11756 in that branch. Thus Mr. Brown is known to the bookkeeping system of Bank of America – and to ERMA – as 15711756.

Mr. Brown writes a check for, say $19.00 to a neighborhood merchant. Here is where the first but inconspicuous element of difference comes in. Each check of the book supplied to Mr. Brown carries his account number – 15711756. (How this number is put on we'll come to later. Just assume it is in some language intelligible to the electronic computer but not necessarily readable by you or me.) Except for the account number and it is further personalized with Mr. Brown's name and address, the check looks like any other Bank of America check.

The merchant deposits Mr. Brown's check to his own account, which may or may not be the same bank as serves Mr. Brown. In any case the check arrives via usual banking channels, such as clearinghouse transfer or directly from one of the branches' own tellers, to the desk of one of the five operators for ERMA the electronic bookkeeper. It is in one of the thick bundles of checks against the many accounts for which the machine is responsible.

The operator has before her, as do the other four, an array of keys that resembles the keyboard of a large adding machine. One section of the array applies to the branch-bank number and the account number and the other is for the dollars and cents amount of the item. Between the account-number section and the amount section is a single column of keys for various code purposes.

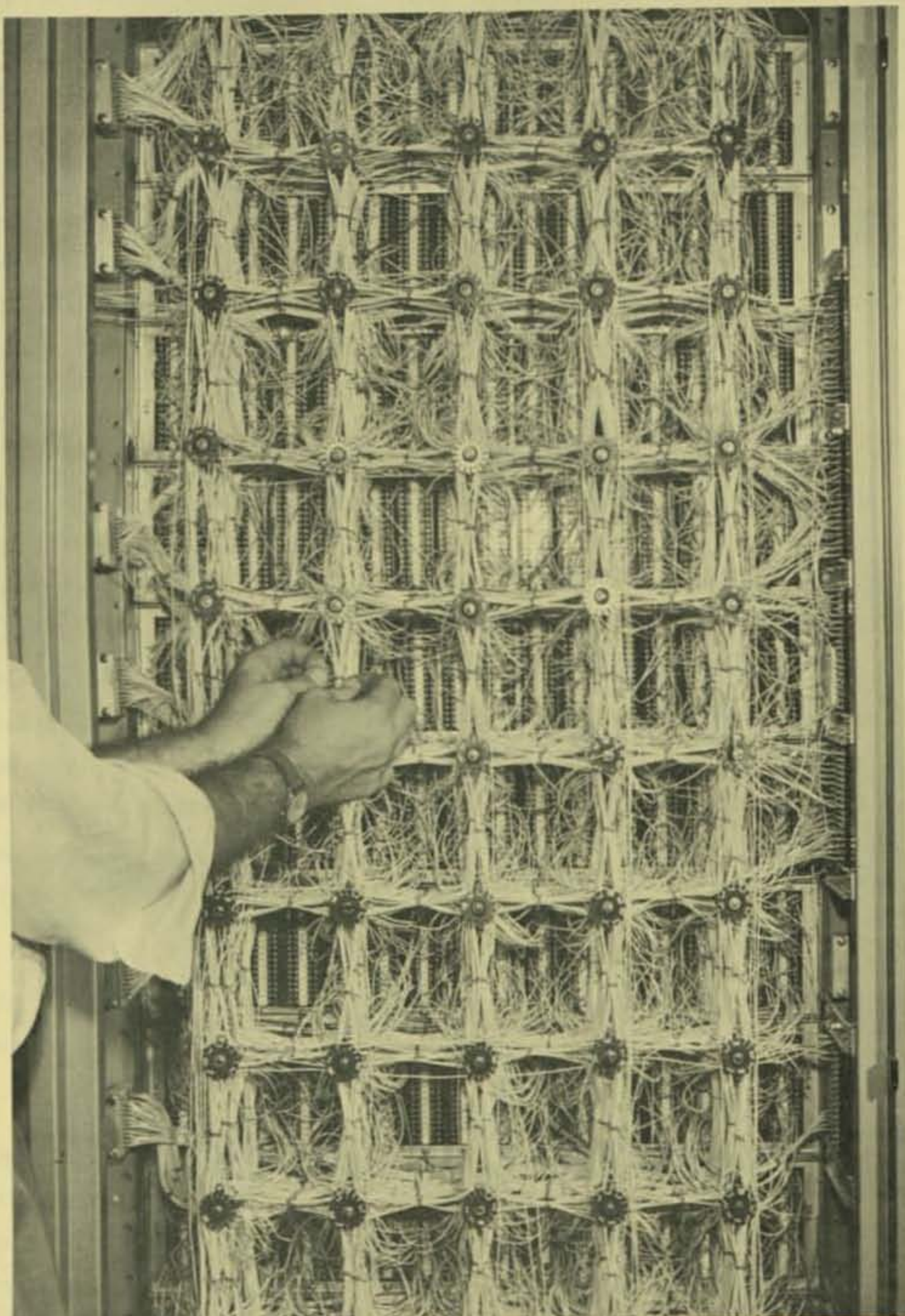
Hundreds of relay units are combined in the construction of ERMA. The units are all of the "plug-in" type and can be replaced with a minimum of difficulty and lost time.

The operator, we'll now assume, picks up from the pile Mr. Brown's check for $19.00. She depresses the keys 19.00 in the amount side and places the check in a slot of the check reader in front of her. The reader then scans the check and reads the account number. It instantly pulls down the keys on the account portion for 15711756. In fact, this is accomplished far faster than the operator can enter the check amount. The operator, if need be, can see the account number the machine has read, although ordinarily there is no reason for her doing so. Or, she can enter the account number by hand if need be. The operator next presses an entry bar at the side of the keyboard. This signals the machine to take over the bookkeeping functions, whereupon it initiates a long but lightning-fast chain of events.

The machine calls for Mr. Brown's current balance from its storage of such information. The machine simultaneously searches for two other pieces of information. Is there a "stop payment" against this check? And, are there any "holds" against funds in Mr. Brown's account? Stop-payment and hold data are stored on the machine's magnetic drum, as are account numbers and current balances, but on a separate section reserved only for that purpose. The machine, in effect, scans the storage drum for a stop-payment signal on a $19.00 check in account 15711756. If such is found, a light flashes before the operator and the machine refuses to take further action on this check. Meanwhile it goes on to the next input position ready for it. If any holds against this account are found, their amounts are transferred to the arithmetic unit and subtracted from the current balance so that the actual funds available are known.

The machine, we'll assume, finds no stop payment on this particular check. It has delivered into the arithmetic unit the amount of this debit and the amount in Mr. Brown's account available for withdrawals, i.e., current balance minus holds.

Next the arithmetic unit makes the subtraction of $19.00 from that amount. If the result of this subtraction is a negative quantity, it indicates that Mr. Brown has overdrawn his account. This unhappy fact is flashed, by signal light, to the operator who refers the matter to the supervisor. The supervisor sends the item to the branch for authorization or rejection of the overdraft. In any case, the machine processes this item no further until directed. It moves on to the next item at the next ready input position.



Many hundreds of thousands of connections and a million feet of wiring are needed to make ERMA function.

Ordinarily the check passes these examinations. The subtraction is completed in the arithmetic unit to establish a new current balance. After the machine checks its arithmetic in several ways, the old current balance for account 15711756 is replaced on the drum by a new one less the $19.00.

Meanwhile the account number and the $19.00 debit item are "written down" in another section of the drum reserved for the temporary storage of this information. It is held there for an appreciable period of time – minutes perhaps, or an hour or so – until convenient for the machine to transfer the information to its detail, account activity file, i.e., magnetic tape. Thereupon, – which is but a small fraction of a second since the start of the operation – the account number and the amount of the item are printed on paper tape in view of the operator.

Checks and deposit slips for different branches and different accounts come to the machine in completely random fashion. The information obviously must finally be stored in an orderly manner. The drum processes the information in whatever sequence it arrives. The drum then holds that processed information (in temporary storage) until it is transferred to the magnetic tape where the details of the transactions to all accounts are held in sequence and in complete detail. Meanwhile, the five operators at the input keyboards continue to feed new check or deposit information into the drum.

Transfer of information about Mr. Brown's withdrawal of $19.00 from the input keyboard to the temporary storage section of the drum is done in a semi-ordered fashion. On the drum are many circular tracks of information. At any one time a track or a group of tracks is assigned to a particular block of account numbers that correspond to those on one of ten magnetic storage tapes. Within that set of tracks the information is stored in random (incoming) order. When information about Mr. Brown's check is sent to temporary storage it is placed on the next empty space on the particular group of tracks assigned to the tape assigned to 15711756.

Essentially instantaneous emptying of the temporary-storage section of the magnetic drum is not necessary. Information is transferred from temporary storage to only one tape at a time.

In a short while it becomes time for the tape containing Mr. Brown's account to be brought up to date by receiving information for its accounts held for it in drum temporary storage. The machine makes the decision when that time arrives. It continually surveys its temporary storage sections, and when one nears filling, it automatically plans for connection to the associated tape at an early opportunity.

The drum rotates 30 times per second (and hence scans all the information held in any particular group of tracks 30 times per second). The tape moves slowly—relatively—at 75 inches per second. Hence some speed-matching device between them is necessary to effect the transfer of information from drum to tape. This device, called the shift register, is an array of electronic tubes that can receive information from the drum at a rapid rate but delivers it slowly to the tape.

After information for one account is transferred from drum temporary storage to the tape via the register, the temporary storage-drum reading head searches the tracks for the next higher account for which it has an item. (Because the drum scans itself 30 times per second this search is accomplished in practically no time at all.)

Assume the next account for which temporary storage has information is that of Mr. Brown. His account number and the $19.00 debit item are transferred to the register and held there while the tape unwinds through the intervening accounts for which no items are available. When the tape reaches account 15711756, that fact is signalled to the register, which readies itself to transfer the item information to the next available empty space on the tape. Physically this is immediately after the most recent entry to Mr. Brown's account. This may have been earlier in the day or on a previous day.

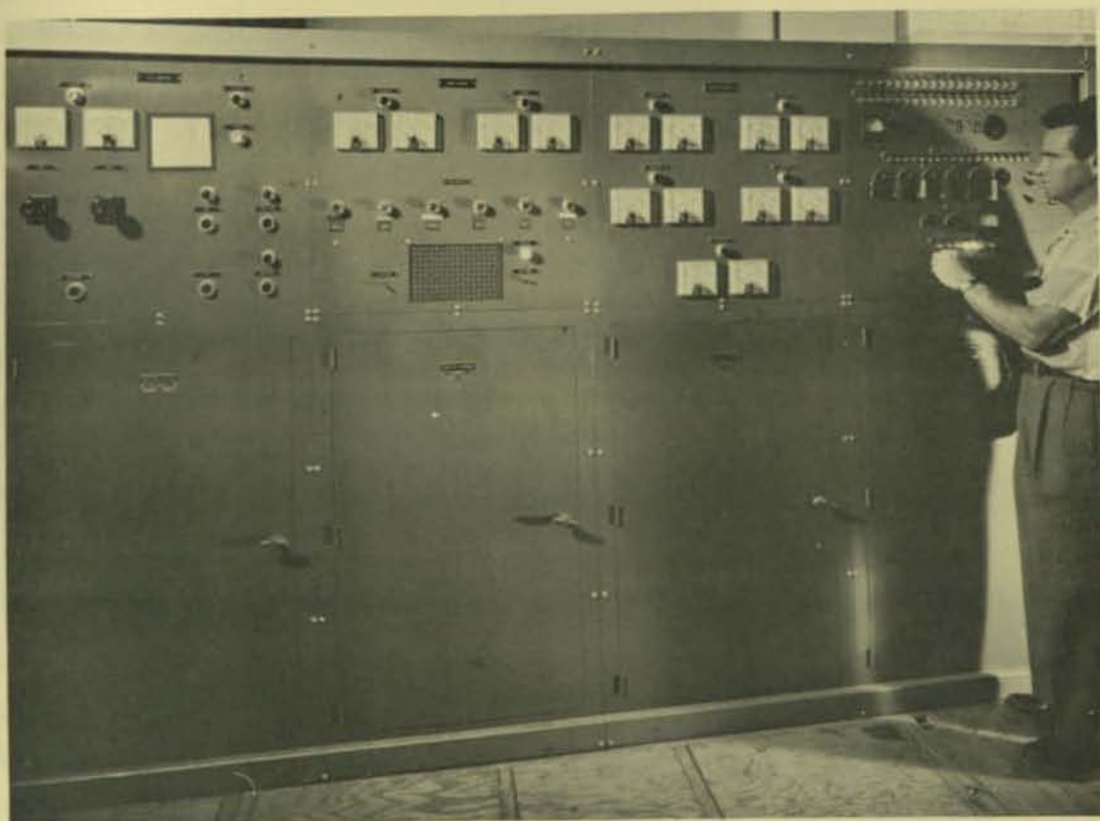
When the item has been entered in the proper place on the tape several cross-checks for accuracy occur. When the machine satisfies itself that it has made no mistake, the transfer-to-tape action proceeds to the next higher account number for which it holds entries. The process continues until the tape reaches its end, at which point the temporary-storage tracks have been wiped clean. The tape automatically rewinds itself to await its next turn for a new round of information.

The bookkeeping for Mr. Brown's $19.00 check has now been accomplished. In like manner other withdrawals and deposits are entered throughout the remaining days of the month. At the end of each day the machine automatically calculates from magnetic tape information Mr. Brown's new current balance. It is checked against that recorded on the magnetic drum and is recorded on the magnetic tape.

At the close of business for the month each tape is removed from the electronic bookkeeper and connected to a high-speed printer. Meanwhile, the machine has calculated the service charge automatically, prints that charge on the statement, and alters its own records on the drum and tape accordingly. The machine figures this charge automatically, applying a formula that includes account activity, balance, and type of account, which the machine ascertains from a code within the account number. Sinultaneously a written record of account activity is printed on paper for the bank's permanent record. When ready to print, the information held for each account in code on the tapes is converted into words and numbers, which it prints on the conventional-appearing monthly statement.

The machine-printed statement is combined with Mr. Brown's checks for the month, which have been sorted by machine and stored in the same order they were processed by the bookkeeping machine. The statement and his checks are delivered to Mr. Brown in the usual way.

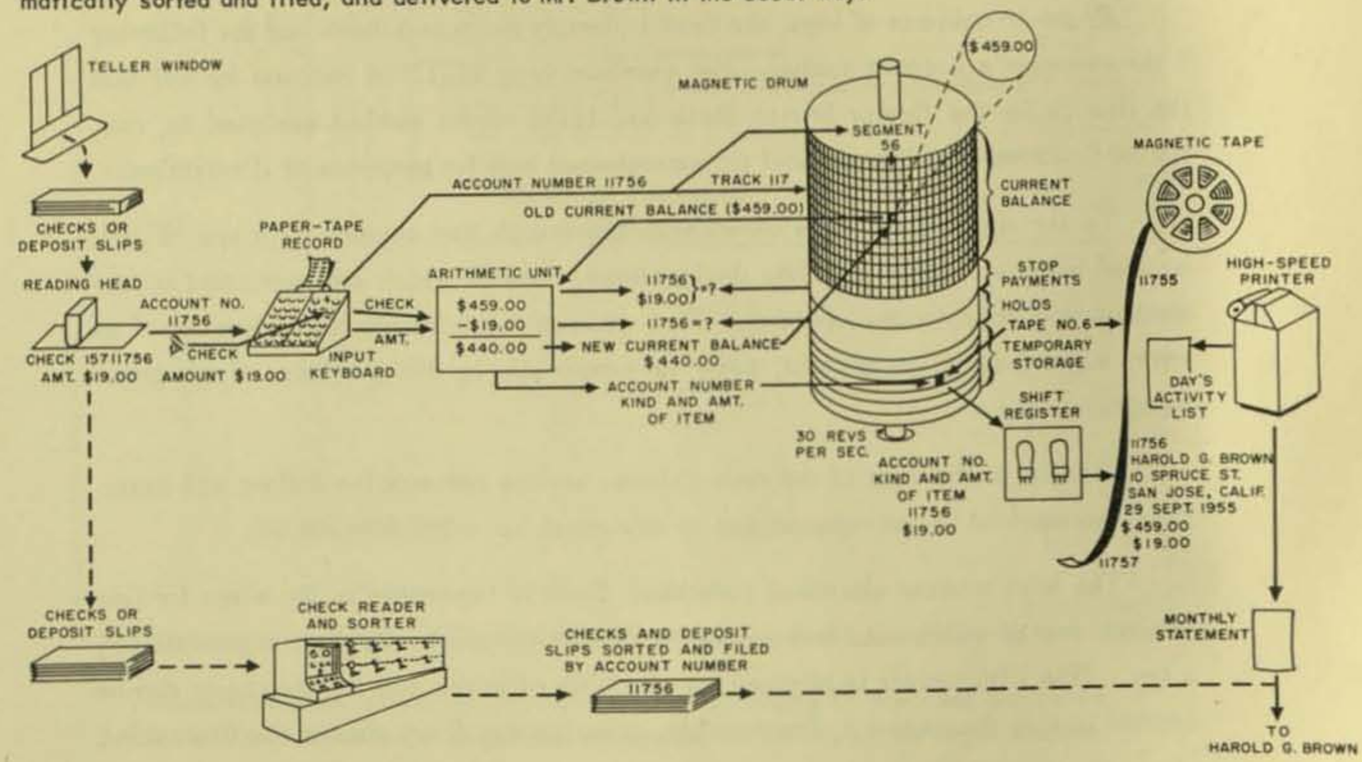
When the machine has printed the monthly statement for Mr. Brown it retains (1) on the drum only his account number and current balance and (2) on the tape his account number, name, address, and the current balance. The machine is now ready for next month's activity to Mr. Brown's account, and all others for which it is charged.



Power at seven different voltages is required to keep ERMA in operation. This panel controls the units required to convert 80 kilowatts of alternating current to direct current and to assure freedom from voltage variations.

ERMA. . . . *Electronic Recording Machine, Accounting*

This chart shows the path of a check or deposit through the electronic bookkeeper. The physical check or deposit slip takes the path of the dotted line; the information from it follows the solid lines. Checks or deposit slips in bundles come, in the usual way, to the operators of ERMA. Assume, as a typical case, a check for \$19.00 by a Mr. Brown. The number 157 11756 has been assigned to him, the first three numbers (157) identifying the branch bank with which Mr. Brown does business. To perform the bookkeeping for this check, the machine requires three pieces of information. The amount of the check and the fact that it is a check not a deposit is supplied by the operator who presses the proper keys at her keyboard. The account number is read by the machine from 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 in sequence in space assigned at the beginning of the period to Mr. Brown. At the end of the month the account details for the period are read from the tape by a high-speed printer which writes them onto the statement. This is combined with the checks, which have been automatically sorted and filed, and delivered to Mr. Brown in the usual way.



THE MAIN ELEMENTS OF THE ELECTRONIC BOOKKEEPING MACHINE

INFORMATION INPUT

The input keyboards are the eyes and ears of the electronic bookkeeper (ERMA for electronic recording machine accounting). It is the means by which the machine receives information. In external appearance it is the keyboard of a large adding machine. Its principal array of keys are arranged in 19 columns of nine keys, one for each digit. In addition, there are keys that inform the machine whether the entry to an account is a check or a deposit. An entry bar at the side enables the operator to signal the machine when she is ready for it to process the item.

Of the 19 columns of keys, the first 3 identify the branch bank and the following 5 the customer's account number. For example, keys 15711756 indicate by 157 that the item is for the Hester Branch Bank and 11756 is the number assigned to, say, Harold G. Brown (the hypothetical person assumed here for purposes of illustration).

To the right of the keys identifying the branch and account is a row of red, lettered buttons. These are code designations, some of which are controlled by the machine and some by the operator. They indicate such things as correction of an error, adjustment to an account, entry (automatically by the machine) of a service charge.

Finally, at the right of the code column, are ten columns for dollars and cents. Thus, the machine is not embarrassed by any check up to $99,999,999.99.

The keys actuate electrical switches. Each is connected to the wires for five circuits, four of which establish a code to identify the particular digit represented by a key. (The fifth circuit is retained for checking purposes and for simplicity can be omitted in this discussion.) For example, pressing any 8 key closes the first, third, and fourth code circuits connected to it; the second circuit remains open. Thus, the machine recognizes an 8 by circuits 1, 3, and 4 being closed but 2 open. This can be represented by 1011. Likewise the number 7 is coded as 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 keyboard positions (four operators and a supervisor). Because the machine handles the average item in half a second, it can switch itself without apparent delay among all operators as they signal to it. Even if all four operators happen to press their entry bars at once, one of them might have to pause about a second if she were entering items as fast as possible before the keyboard would respond to her next entry.

Each of the five input stations required to keep ERMA busy also have means for printing on paper tape a record of each item entered into the machine, i.e. account


No. 1001
19
LESLIE VAN & STORAGE COMPANY
455 Broadway
No. 1001
90-86
1211
PAY TO THE ORDER OF
19
(SPECIMEN)
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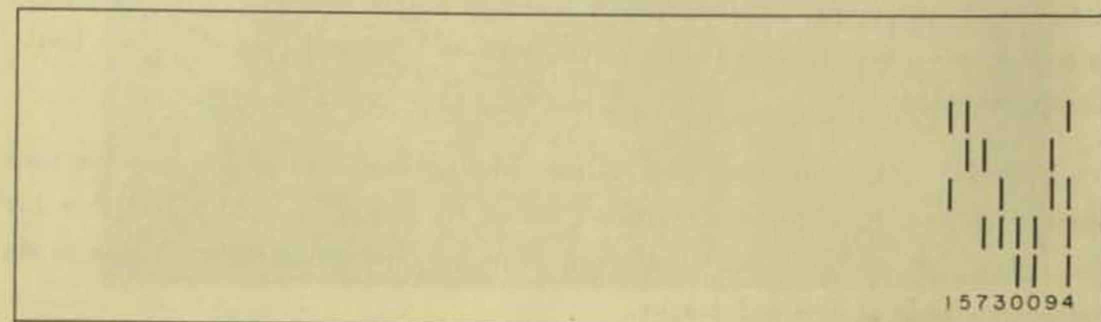
DOLLARS
HESTER BRANCH
Bank of America
SAN JOSE, CALIFORNIA
157 30 094
LESLIE VAN & STORAGE COMPANY



Account numbers printed on the customer's check, on the back in code and on the front in arabic numbers, are printed in magnetic ink for use by the check scanner.

number, amount of item, and whether it is a debit or credit. This same print-out device gives a written answer to any question asked of ERMA, such as, "What is the current balance in Harold Brown's account?" Because the print-out mechanism is operated by depressed keys, each key has a solenoid to pull it down in response to the machine's answers to queries. In other words the keys can be depressed by the fingers of the operator or by solenoids responsive to electronic circuits.

Incorporated into each input station is the account-number reader.

MACHINE READING OF NUMBERS

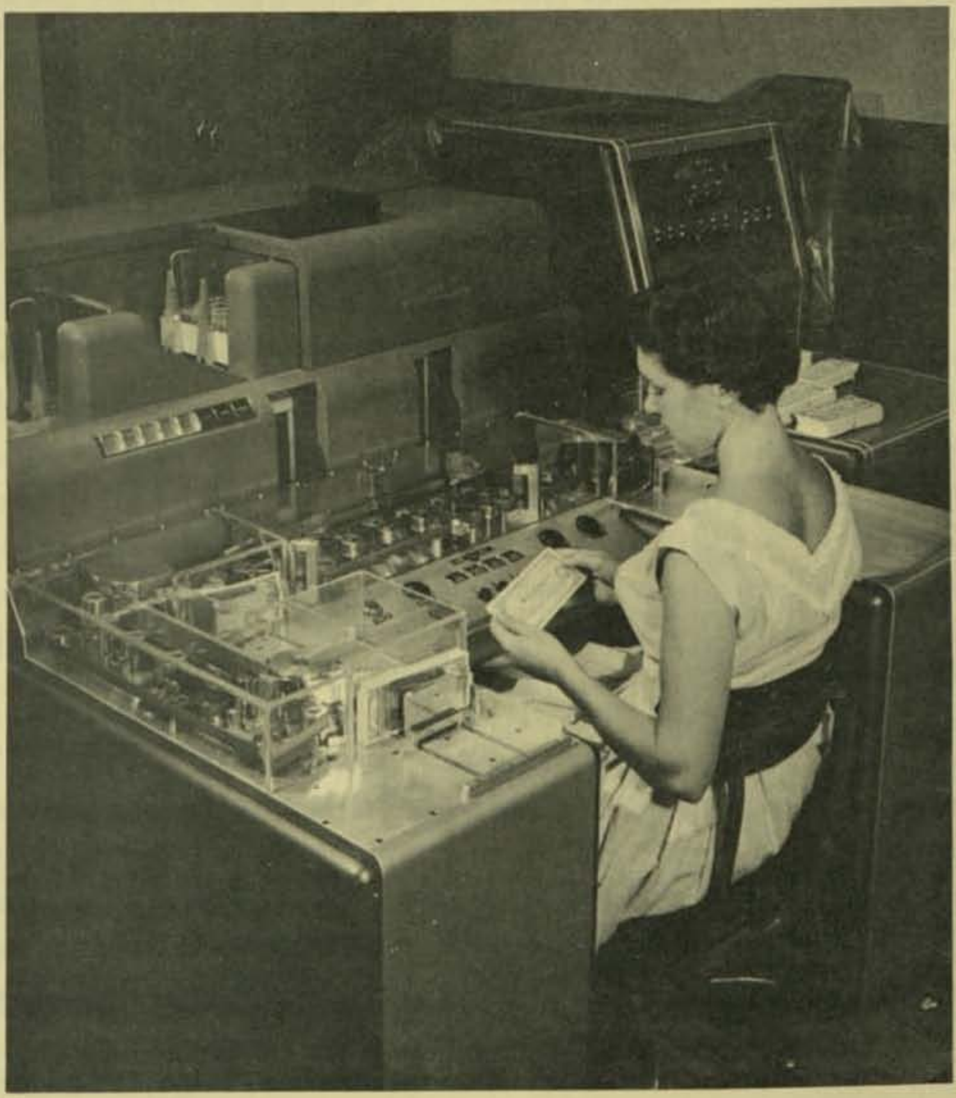
One of the major technical accomplishments embodied in the electronic banking machine is the ability given it to read numbers automatically from the paper. This development not only plays a large part in the success of the machine but also has enormous implication for other data-handling machines.

This scheme differs from most previous attempts to "train" machines to "read." It does not rely on optical methods such as photocells that distinguish between light and dark or that utilize phosphorescent inks. This machine reads numbers by a magnetic process at the rate of 1000 characters per second. The numbers are printed on the paper in magnetic ink – ink containing particles of iron oxides, about 40 millionths of an inch in size. After the ink has dried, the particles can be aligned like tiny magnets by exposure to a strong magnetic field.

The technique of machine reading of information printed in magnetic ink was undertaken in two steps. The first was to develop a method of reading numbers printed in code in magnetic ink. This is the system used with the prototype electronic bookkeeping machine.

These codes consist of combinations of five narrow black-ink bars for each digit. Thus a 1 is represented by blank, blank, bar, blank, bar (00101) while a 2 is bar, blank, bar, blank, blank (10100), and so on. These codes are analogous to the telegraphic code of dots and dashes.

When a check, with its magnetic-ink coded number on the back, is placed in the check reader to be read it first passes under a magnetizing element. This causes the tiny iron-oxide particles to line up in a prescribed direction. Immediately thereafter the check passes under a reading unit containing five magnetic reading heads side by side. Because the positions of magnet-ink bars differ, the pattern of voltages at the five reading heads differ for each digit. The machine's electronic circuits are designed to distinguish between these unique wave patterns.



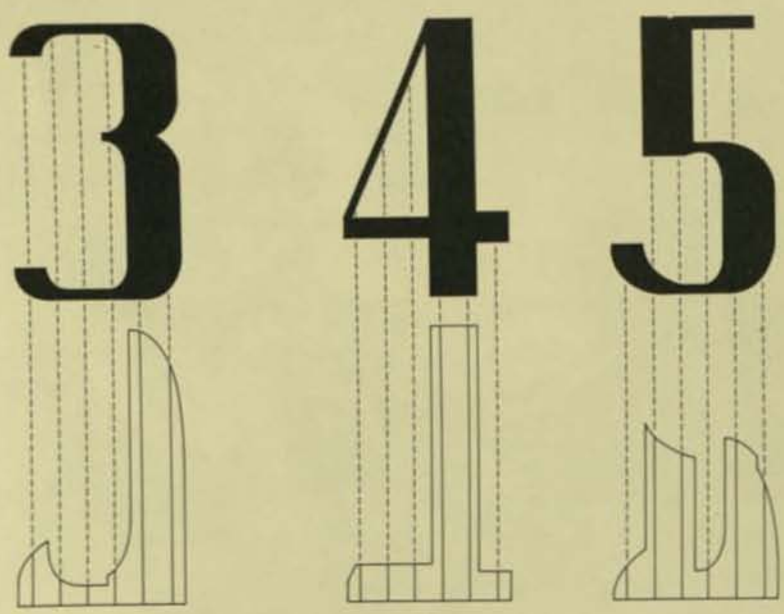
Operator using the Travelers Check number-scanning machine. This machine "reads" arabic numbers on Travelers Checks and punches IBM cards for use in Bank of America accounting systems.

Obviously it would be tremendously advantageous for the machine to read not codes but conventional arabic numerals. Arabic numbers are easier to print, and occupy less space on the check.

The second phase of the development program – direct reading of numerals – has proceeded in parallel and beyond with the code reading. A technique for direct number reading has been developed and successfully tested. It will be incorporated in future electronic bookkeeping machines.

The particular phase of the banking function chosen for the development of machine reading of conventional appearing numerals was the serial number on Travelers Checks. This was done for reason of simplicity. The traveler's check problem could be isolated from other phases of banking, yet it provided all the elements required for the development of direct number reading by machine.

The numbers as printed on the front of Travelers Checks (and eventually as the branch-bank and account number on depositors' checks) are recognizable to the human



Arabic numerals and the wave forms produced by the Travelers Check scanner. As the numbers printed on the Travelers Check pass horizontally beneath the read-head, the head sums up the total magnetic ink covered in a given time interval and produces a proportional electric signal.

eye as ordinary printed numbers. However, the numbers have been designed so that the machine can recognize them with a high degree of accuracy.

The Travelers Check reader has been tested with over 300,000 checks. On many of these the serial number has been purposely disfigured by rubber stamps, ink, dirt, fingermarks, tears, scotch tape, or crumpling, that make optical machine reading impossible. Because this machine responds only to magnetic ink it is not confused by such obliterations. The printing tolerance is large. Numbers can be printed as much as one-half inch above or below their normal position without influencing reading accuracy.

Also, before each check is read it passes through a set of pressure rollers to take out wrinkles. Checks that have been folded or crumpled and crudely smoothed out are readily handled by the machine.

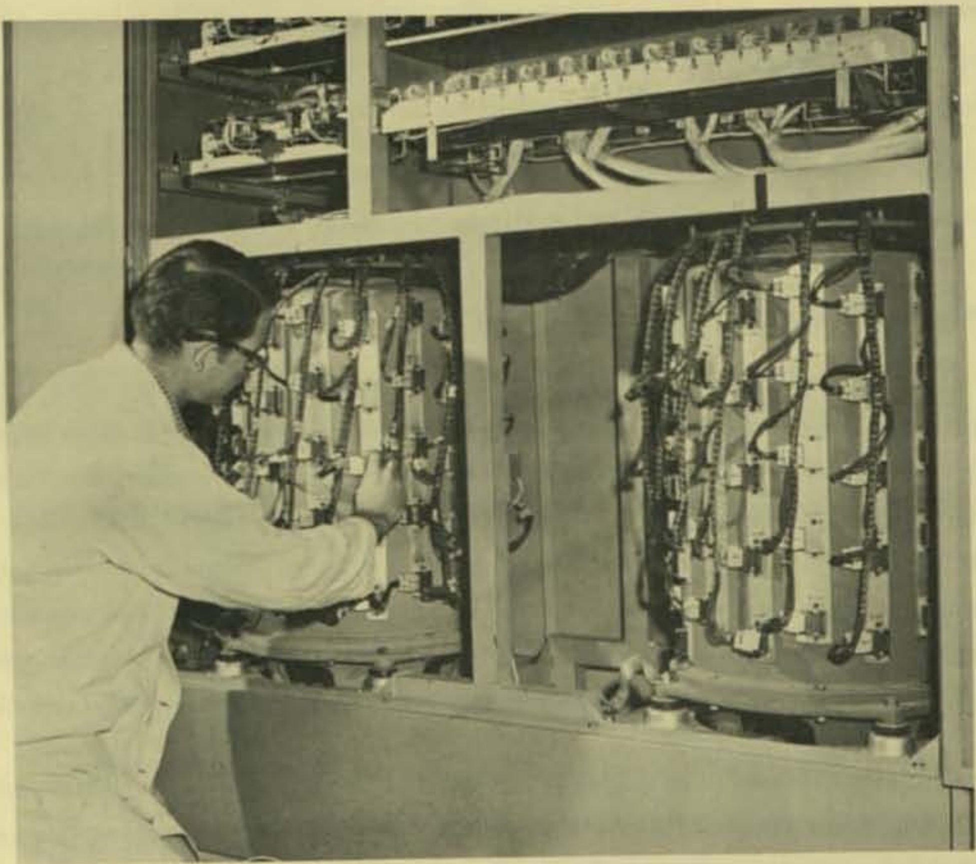
The machine also verifies its own reading accuracy. Each Travelers Check is printed with a nine-digit serial number and a tenth number that indicates check denomination. In addition, an eleventh number is provided. This number, in every case, is chosen such that the sum of all eleven digits is divisible by nine. The check reader makes this summation after each reading. If the sum is not divisible by nine the machine "knows" that it has not read the number correctly, for some reason, such as faulty printing. The check is diverted into a separate compartment for attention by a human operator, or re-run through the machine. These are called rejected checks.

The prototype reader is currently reading (and verifying) the eleven-digit numbers at 100 checks per minute. Rejected checks normally amount to less than one percent of the total number processed. Errors, i.e., checks incorrectly read but passed as correct by the machine are less than one in one hundred thousand, as determined by laboratory tests using machine error-detection techniques. It is expected that even this outstanding performance, which is perhaps 50 times better than human accuracy, will be improved.

THE MAGNETIC DRUM

The magnetic drum is one of the information "files" in the electronic bookkeeping machine. Physically, it is a smooth vertical cylinder of non-magnetic metal 16 inches in diameter and 20 inches high contained in a dust-proof housing. An electric motor drives it at a constant speed of 1800 rpm.

The drum surface is coated with a resin containing millions of tiny particles of iron oxide. Under the influence of fields from electromagnets mounted close to the drum surface, groups of these can be made to act like small permanent magnets of



ERMA's magnetic drums are contained within these vertical cylinders. The drums store current balance, stop-payment and hold information for future use.

controlled polarity. A surge of electric current through the electromagnet in one direction causes the microscopic iron-oxide particles in the tiny area under the electromagnet to align themselves so that their north poles lie in one direction and south poles in the opposite direction. If the current, i.e. field, is impressed in the opposite direction the poles are reversed.

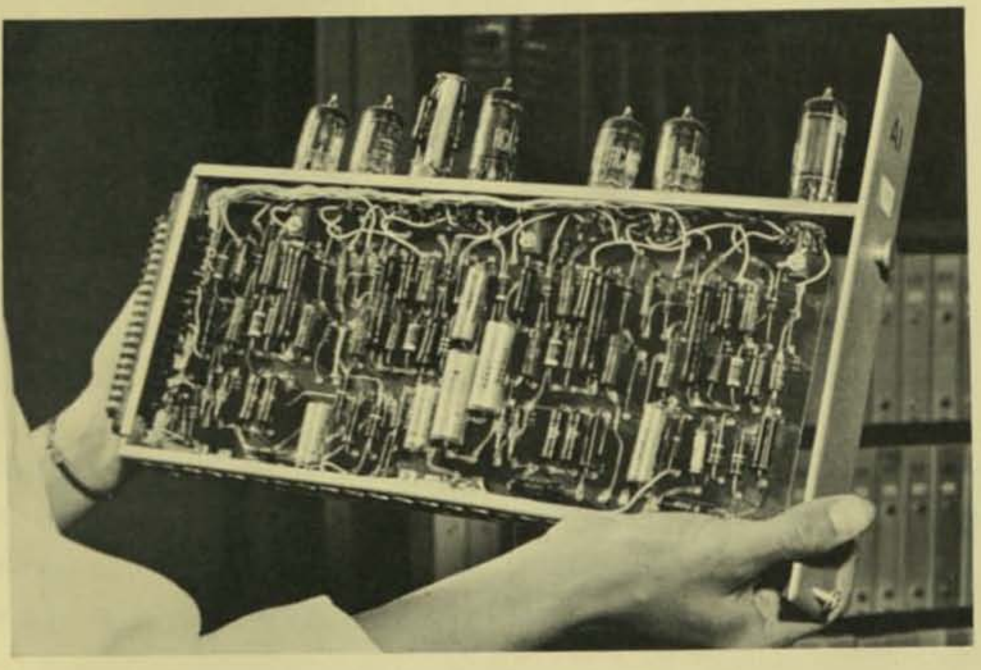
The drum surface with its iron-oxide particles is invisibly divided into 300 parallel, circular tracks, each about 0.040 inch wide. In a lengthwise direction each track is divided – again invisibly – into sections 0.010 inch long. Each little magnetic cell stores what is called a single binary digit or bit of information. Thus the drum surface can be thought of as made up of 1,500,000 separate, but invisible, magnetizable areas. Each of these can be magnetized at will in one direction or the other. The drum thus provides, on the binary system, 1,500,000 information elements.

Four bits are required to store a single digit (a fifth is also reserved for each digit but it serves for checking purposes and can be neglected in understanding the basic principles of the machine). Thus to store an account number such as 11756 the first two sets of four bits on a track are magnetized N-S, S-N, N-S, N-S, (0100), which in machine language means 1. The third set, for the numeral 7 (1010) would be magnetized S-N, N-S, S-N, N-S. Actually, to save bits, which cost money, the information is stored in a way that does not require writing the full account number for each account. The drum is divided in a sort of pigeon-hole or post-office box system in which there are 100 "boxes" in each vertical column (corresponding to 100 spaces around one track) and 300 columns (i.e. drum tracks). Thus, Mr. Brown's account number is filed in the 56th box of the 117th track, without the necessity of having to write on the drum the account number with the current balance. Following the account number on the track the current balance is stored, using the same language of properly polarized four-element magnetic cells.

A set of about 300 elements, one per track, are held close to the rotating drum and spaced evenly around its surface. Each element is used for both reading and writing. These enable the machine to add information into this file, to read its contents, or to empty it when necessary.

Each magnetic head element consists of a coil through which current can be passed. It is wound around a piece of magnetic material containing an air gap spaced a few thousandths of an inch from the rotating tracks. To write a number onto the drum, bursts of current, electronically timed, are passed through the coil. These bursts, by their direction, magnetize the sets of four bits in accordance with the code for the number to be written. The number thus written down remains until it is necessary to change or erase it. Should electric power be turned off no information is lost.

The numbers are read by the same magnetic head elements that write them. Thus each magnetized bit on the drum as it sweeps by the element induces a voltage in the coil. The direction of this voltage is determined by whether the little magnet on the drum is N-S or S-N. Thus the heads can look for a given desired number by searching for the proper combination of bits on the drum. Information, such as current balance, can be read in similar fashion.



One of the "building blocks" used in the arithmetic unit, capable of performing additions and subtractions on sums as large as $99,999,999.99.

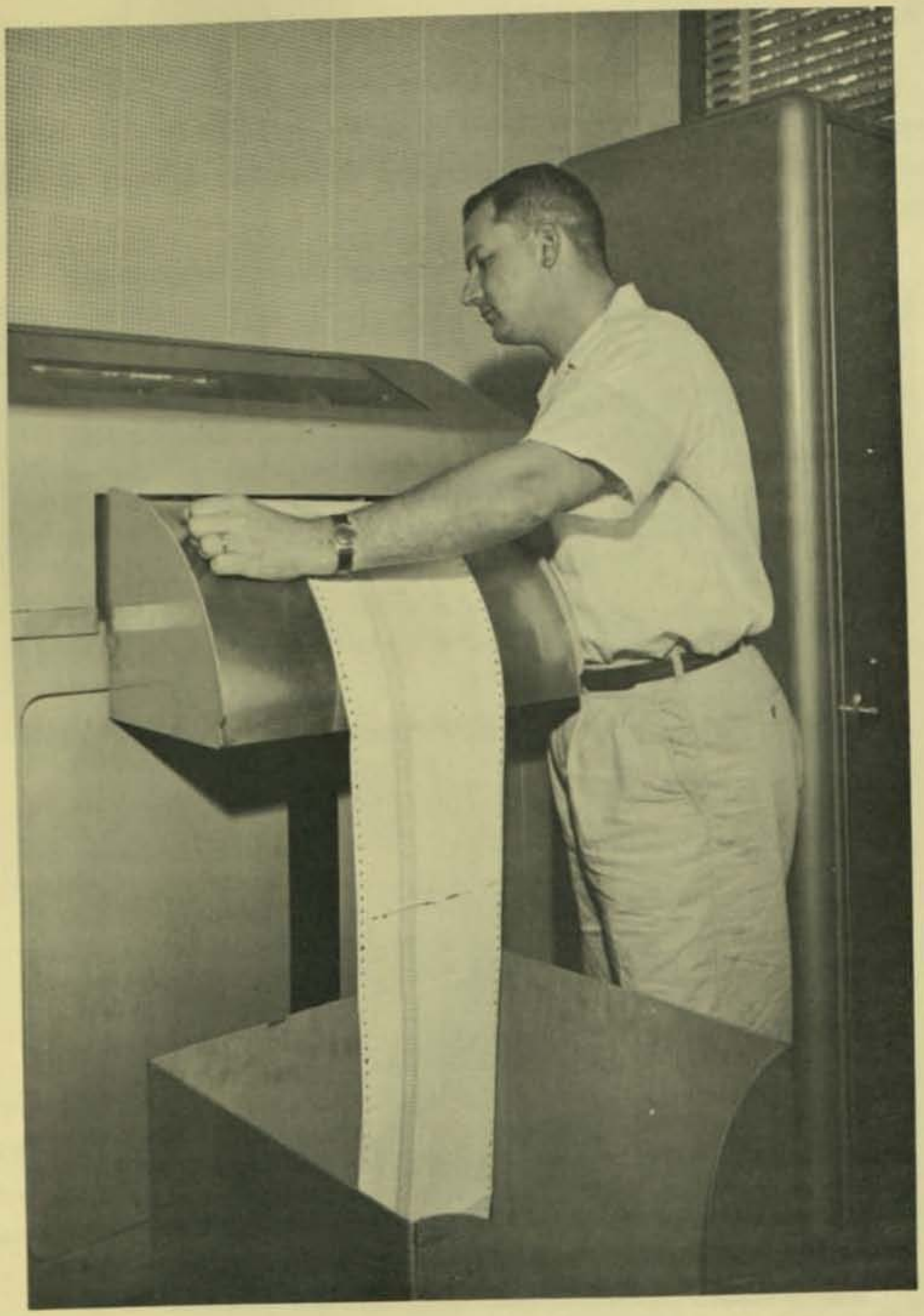
When it is desired to change a number, for example to write a new current balance, it is necessary only to "write over" the old number. The magnetizing forces, applied in the proper coded sequence, are strong enough to overpower the magnetism of any bits that previously were oppositely polarized. Or, a section can be completely "erased" by simply magnetizing all the bits in one section with a common polarity.

A drum has space for about 300,000 decimal digits. Actually two drums are used, for reasons of practical physical size. This gives a total of approximately 600,000 digits of information. This is adequate for servicing the accounts under ERMA's jurisdiction.

THE ARITHMETIC UNIT

The arithmetic unit is one of the many devices built up from the standard electronic "building blocks." It comprises a battery of electronic tubes and related components capable of performing additions and subtractions on sums as large as \$99,999,999.99.

Detailed account activity information is "filed" by ERMA on 10 reels of magnetic tape, each almost half a mile in length. Accounts are kept in numerical order on the tapes which provide storage space for a month's activity.



The high speed printer, used in statement preparation, prints 15 lines per second. The printer can prepare all the statements for ten branch banks in about five working days.

Since the basic building blocks can count only up to two (i.e., they recognize only numbers 0 and 1) the decimal numbers are handled in a coded form such that each decimal number is represented by a unique pattern of binary numbers.

The tubes are arranged in pairs, known as flip-flops, so that when a potential is applied to a pair, one tube becomes conducting, the other non-conducting. The next application of potential causes the conducting tube to become non-conducting, and vice versa. Thus the device has the essential features of a device to store one bit of information, just as each cell on the drum served this function.

THE MAGNETIC TAPE

The second and more detailed information file is kept on magnetic tapes, of which ten are used for storage and two serve auxiliary functions. The entire month's activity for each account is kept together in its incoming sequence, each account being in numerical order, just as in a standard manual file.

The tape itself is the same as conventionally used with data-processing machines. It is a tape 2400 feet long contained on a reel, which provides space for the detail information for several thousand accounts. The tape can be unwound past a set of magnetic heads, similar to those used on the drum, that either write new information on the tape or read information from it as needed. The tape stores information on the same binary basis – bits that are magnetized either N-S or S-N – as on the drum. The tape consists of a plastic backing coated with a film containing iron-oxide particles. The tape of standard size gives room in one row across the tape for seven information bits. Because the tape must store words, i.e. letters, as well as numbers seven bits are required to identify all letters and numerals. The bits in one row across the tape are used for a single letter or numeral. In this way, however, information as to account number, name and address, and account activity for a month can be maintained in about nine inches of tape for an average individual checking account. Space on the tape is allocated at the beginning of every month. The amount of that space in each case is determined by previous experience with that account.

The manner of writing information, reading information, or erasure is essentially as described for the magnetic drum.

HIGH-SPEED PRINTER

Under present banking procedures the entries to monthly account statements are posted daily by hand. This is essential because the volume of work makes doing it all at one time a physical impossibility if it were done manually.

With machine accounting daily posting to the customer's statement sheet is unnecessary. Each statement is printed all at one time on a selected day each month. To make this system possible, however, requires a means of printing information of statement sheets at extremely high speed.

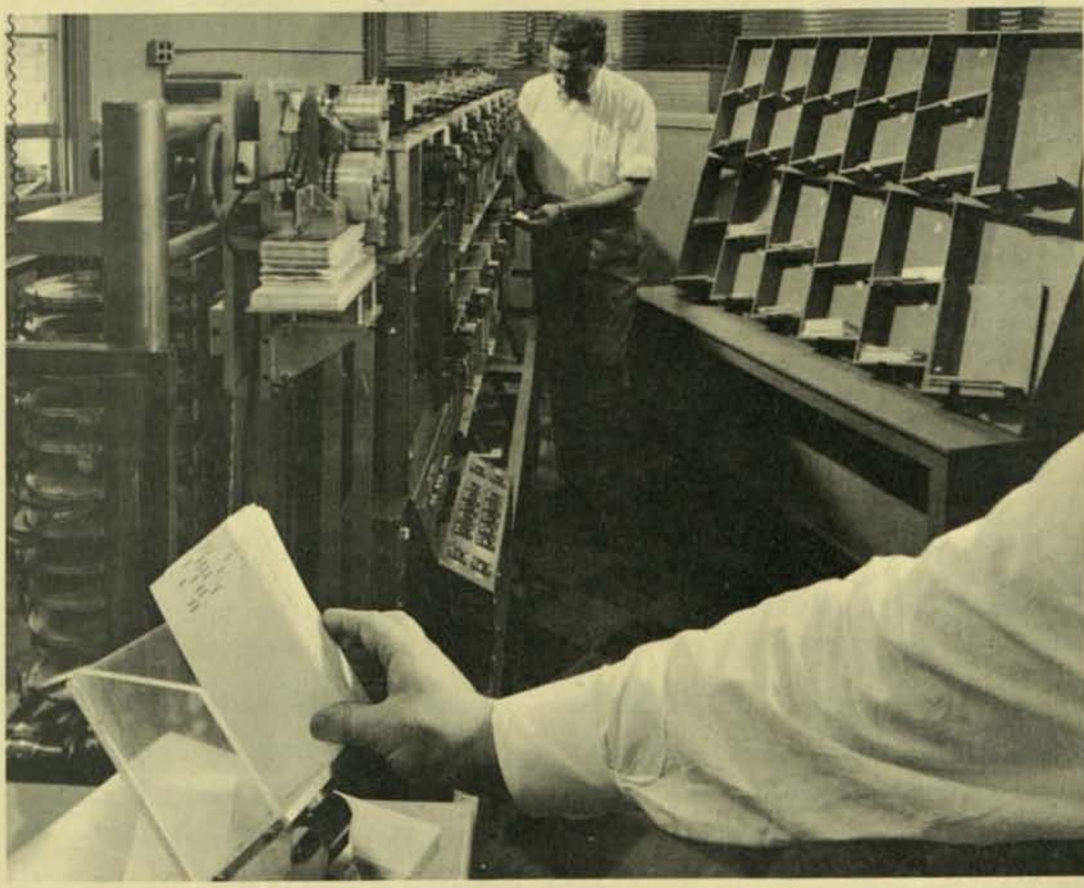
Consider the enormity of the job of statement preparation. For 50,000 accounts and with an average of, say, 25 lines to be printed on each statement (name, address, daily activity, daily balances, service charge, final balance, etc.) that amounts to 1,250,000 lines to be printed.

When the development of the electronic accounting machine was begun the highest speed printer available could manage three lines per second. That seems fast. However, to print 1,250,000 lines at 3 per second – and counting no lost time between statements – would require 120 hours of uninterrupted operation, or five 24-hour days.

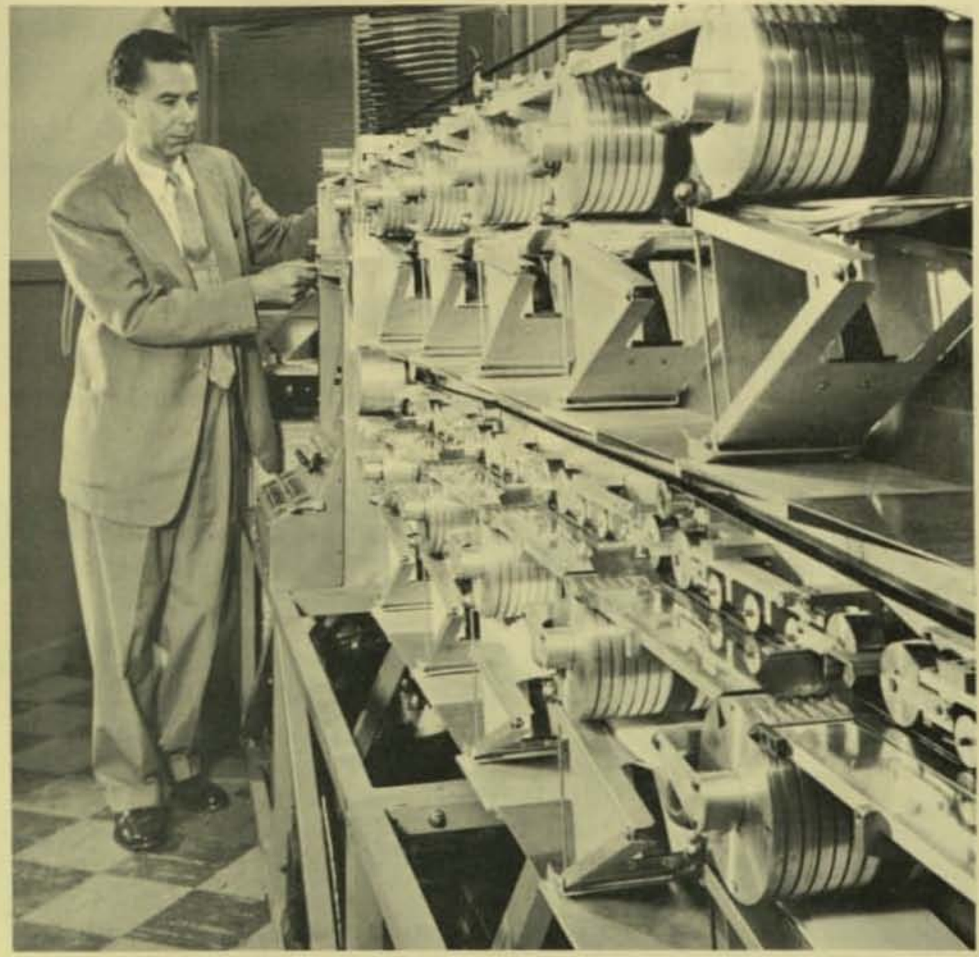
Subsequent developments have fortunately resulted in increasing the printer speed by more than three times – to 10 lines per second – and it is expected this will soon be increased to 15 lines per second. This enables the statement printing for all the accounts handled by the machine to be accomplished in about five normal working days. With the machine serving about 10 branch banks, the statements for all these branches can be turned out during a working week around the month end.

The actual printing element consists of a cylinder with rows of raised characters lengthwise across it. Each row is as wide as the line of printing on the statement. One row contains nothing but a succession of A's, the next, B's, and so on around the cylinder for the remainder of the alphabet, numerals, and other needed symbols. This cylinder rotates continuously at 1200 rpm, above a row of stationary striking hammers, one for each character in the row. Between the hammers and the cylinder is the statement blank and a carbon ribbon.

For printing statements the printer is connected to a magnetic tape where the account detail information is stored. Suppose the statement for the hypothetical Harold Brown is to be printed. As the reading heads at the tape reach the codes spelling out HAROLD BROWN, a blank statement at the printer is synchronized with it. When the line of A's on the cylinder are in a printing position, the coded signals from the tape cause the printing bar to strike the second A in the row of A's. One five hundredth of a second later the B line is in position and the B as the first letter in the surname is printed. There being no C's in the name no hammers strike the paper when the C row sweeps past. Next the D in the given name is printed, and so on.



The electronic check sorter separates the checks by account number and by bank branch so the checks may be returned to the customer with his monthly statement. Automatic sorting is made possible by a special magnetic ink code marking on the back of each check.



Another view of the check sorter which sorts by account number. Each bundle of checks must be passed through the machine five times (once for each digit). The checks travel at the rate of 150 inches per second through the sorter.

Thus in one complete revolution of the drum – one tenth of a second – the whole name is filled in. The paper then indexes to the next line for the street address, which is printed in like manner. Similarly, the remainder of the address, and the account information, including the machine-calculated service charge and current balance, is printed in. The average 25-line statement is completely printed in three seconds.

The monthly statement for Mr. Brown then is assembled with his checks in the order of their presentation which have been sorted by the check sorter and filed for the period. Mr. Brown therefore receives his monthly statement and checks in the usual manner. Except that the statement carries the account number, nothing else distinguishes it to Mr. Brown from others he received before the advent of machine bookkeeping.

THE CHECK SORTER

After all the bookkeeping for a bundle of checks has been completed the checks must be sorted by account number and the checks filed in the same sequence as that in which they are held in the electronic bookkeeper. A machine has been developed to sort them mechanically.

The check sorter has the same ability to read account numbers printed in magnetic ink on the checks as has the input section of the electronic bookkeeping machine. The machine has 12 boxes or output compartments (0 through 9 plus two for rejected checks) into which it sorts the checks or deposit slips.

To sort checks, a bundle is first placed in the sorter. The top check is whisked off by a vacuum feeding device and guided to a scanning head that is manually set to read the first (units) digit of the account number. This information, i.e. whether the unit digit is a 0, 1, 2 or other number, is stored for a fraction of a second on a rotating mechanical memory device. Meanwhile, the check itself is being carried at the rate of 150 inches per second on a belt into the sorting section.

Mr. Brown's account number is 11756. Hence, when the sorter comes to that check, the value of the digit is read as 6 and remembered by the memory mechanism. When the check approaches the number 6 compartment, the memory device causes a gate to open, sidetracking the check into that compartment.

In this manner all checks are sorted according to the units digit. Then the checks from each of the ten compartments are manually collected and run through the machine again, this time sorting for the tens digit. On this next pass, Mr. Brown's check goes into the 5 compartment. By sorting each bundle five times (once for each digit) the checks are placed in sequence by account number—and the items for any one account are in the order of processing by the bookkeeping machine.

ERMA's "Service Station" used to insure the perfect operation of the many delicate circuits in the bookkeeping machine. This maintenance board facilitates the location of troubles within the machine.

ERMA. . . . *Electronic Recording Machine, Accounting*

The outstanding features of this device are not those of its basic principle of operation, which is relatively simple. The requirements of speed and accuracy are so high, however, as to generate engineering problems of a different order of magnitude. Account numbers are read and checks sorted at the rate of 10 per second. A stack of a thousand checks about 5 inches high "melts" down in the input container in about one and a half minutes. To obtain good accuracy at these speeds the paper is controlled pneumatically for both feeding and stacking, not by mechanical friction devices. The machine errors – checks sorted into wrong compartments – run less than 1 in 100,000. Rejects, or checks the machine cannot sort, are below one percent.

Machines are created by people. To conceive, develop, build and test a machine of the size and complexity of ERMA requires the services of many men and women with many skills.

ACKNOWLEDGMENTS

THE TIME AND TALENTS of many persons went into the development of ERMA. While it is not possible to list all of those responsible for ERMA's conception, those with major responsibilities were:

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Research for Industry

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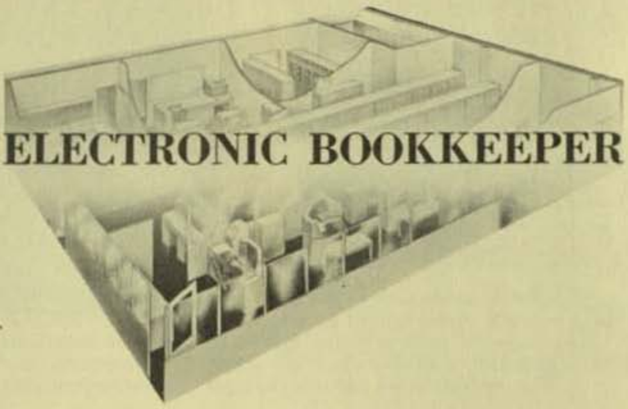
ERMA—



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.

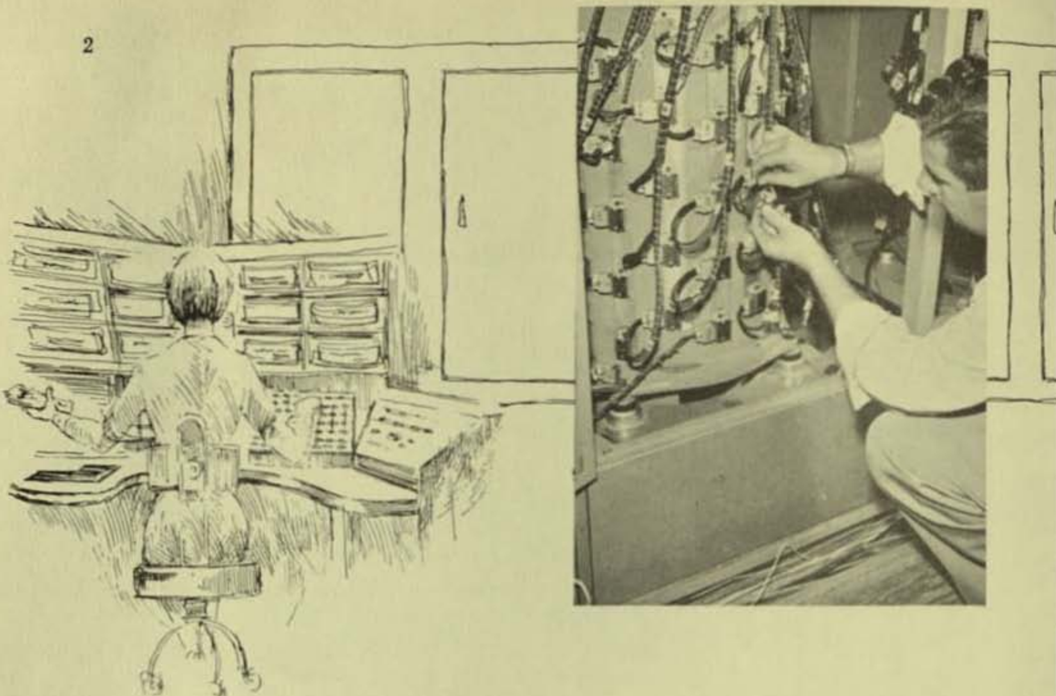
Technically, ERMA stemmed from war-stimulated progress in "electronic brain" computers. Its high degree of bookkeeping efficiency is made possible by a wide range of developments in magnetic recording, machine reading of printed codes, and techniques of mechanical paper handling and high-speed printing.

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



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.

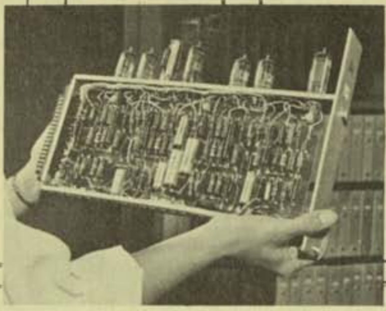
ERMA's "Senses"

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 infor-



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

mation "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

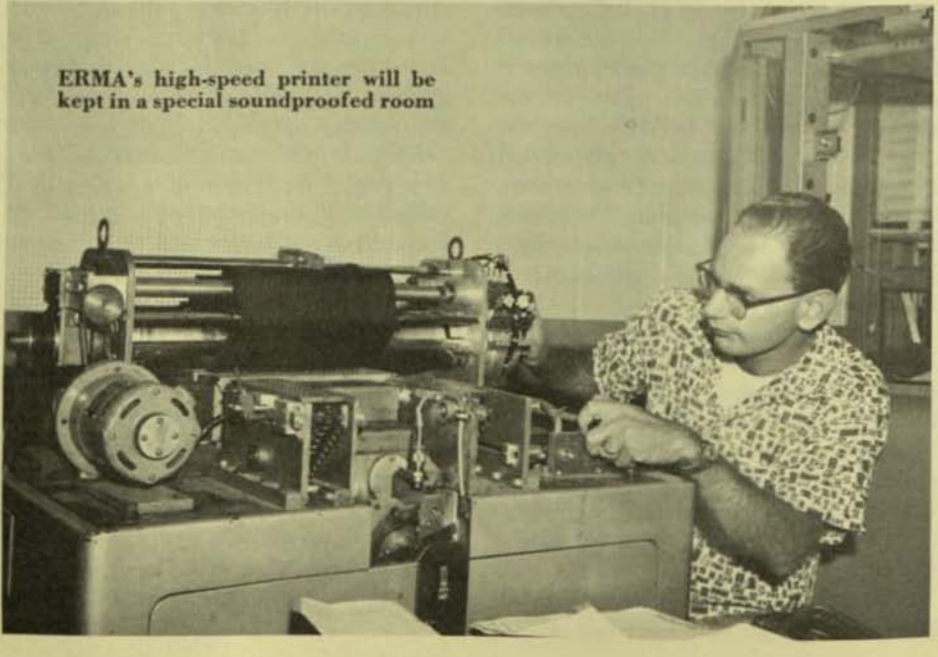
More detailed account information is kept on the machine's main information storage system, on magnetic tapes. Here it is stored in its incoming sequence. Accounts are maintained in numerical order just as they would be in a file cabinet.

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 suc-



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

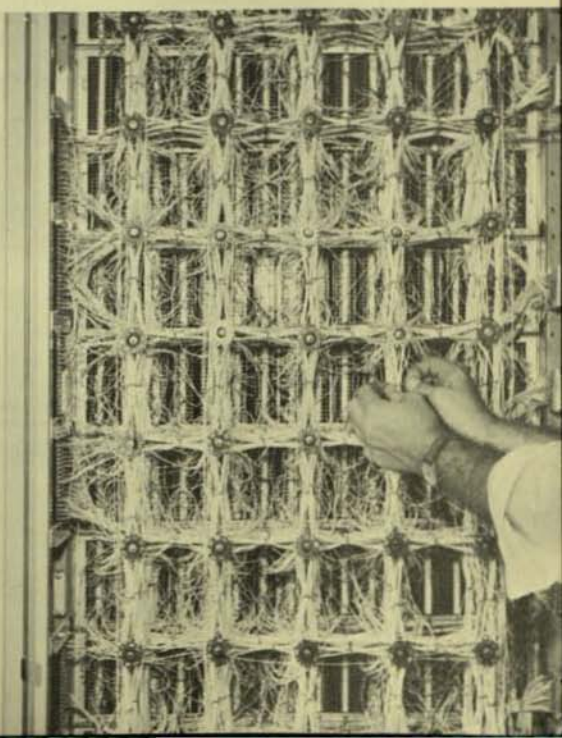
cession of A's, the next B's, and so on around the cylinder for the rest of the alphabet, for numerals and other symbols. The cylinder turns continuously at 1,200 r.p.m., above a row of stationary striking hammers, one for each character in the row. Between the hammers and cylinder is the statement blank and carbon ribbon.

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.

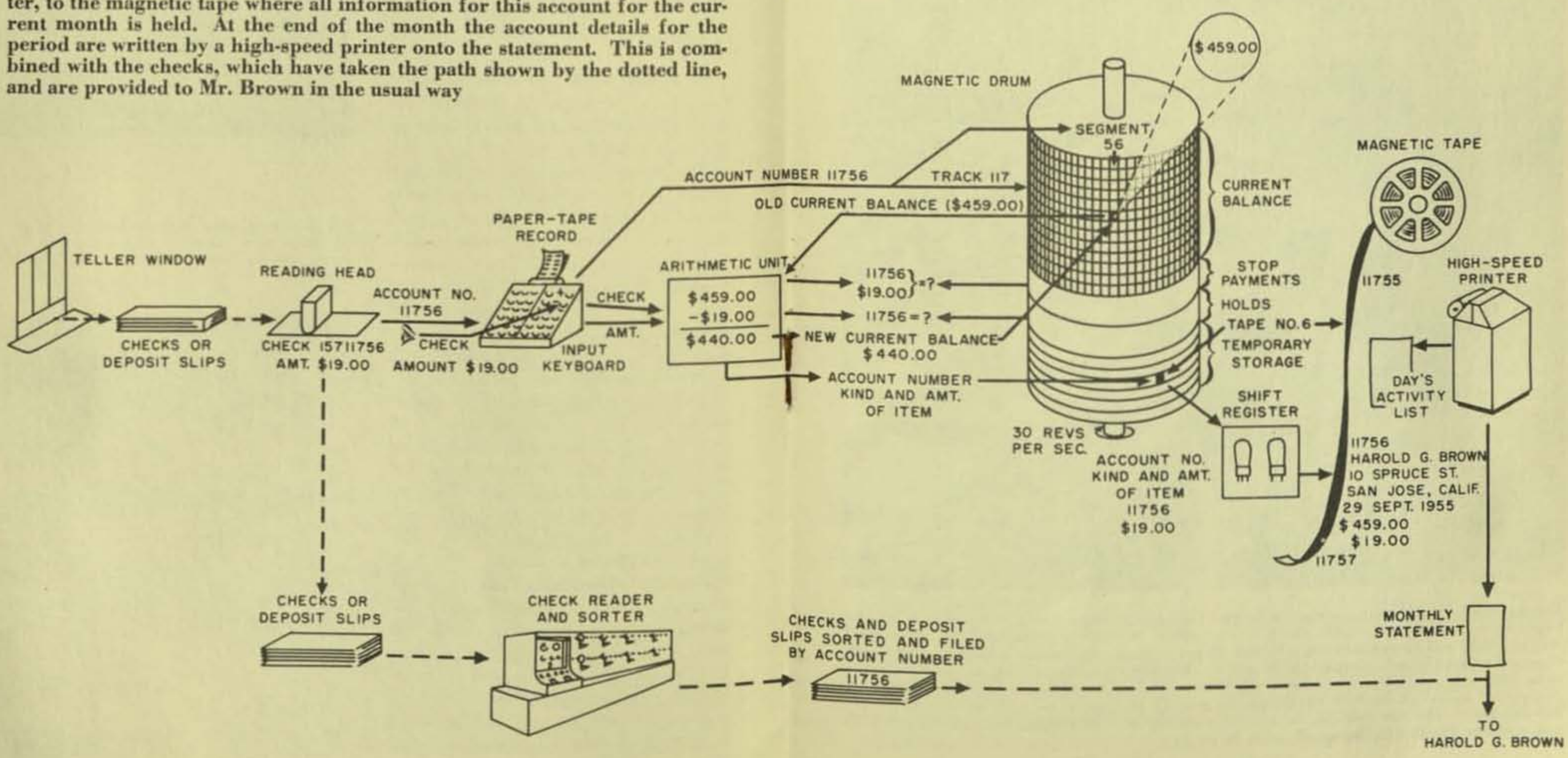
To sort checks, a bundle is placed in the sorter. Top checks are whisked off by a vacuum feeding device and guided to a scanning head set to read the first digit of the account number. This information is momentarily stored on a rotating mechanical memory device. The sorter has 12 compartments (0 through 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.

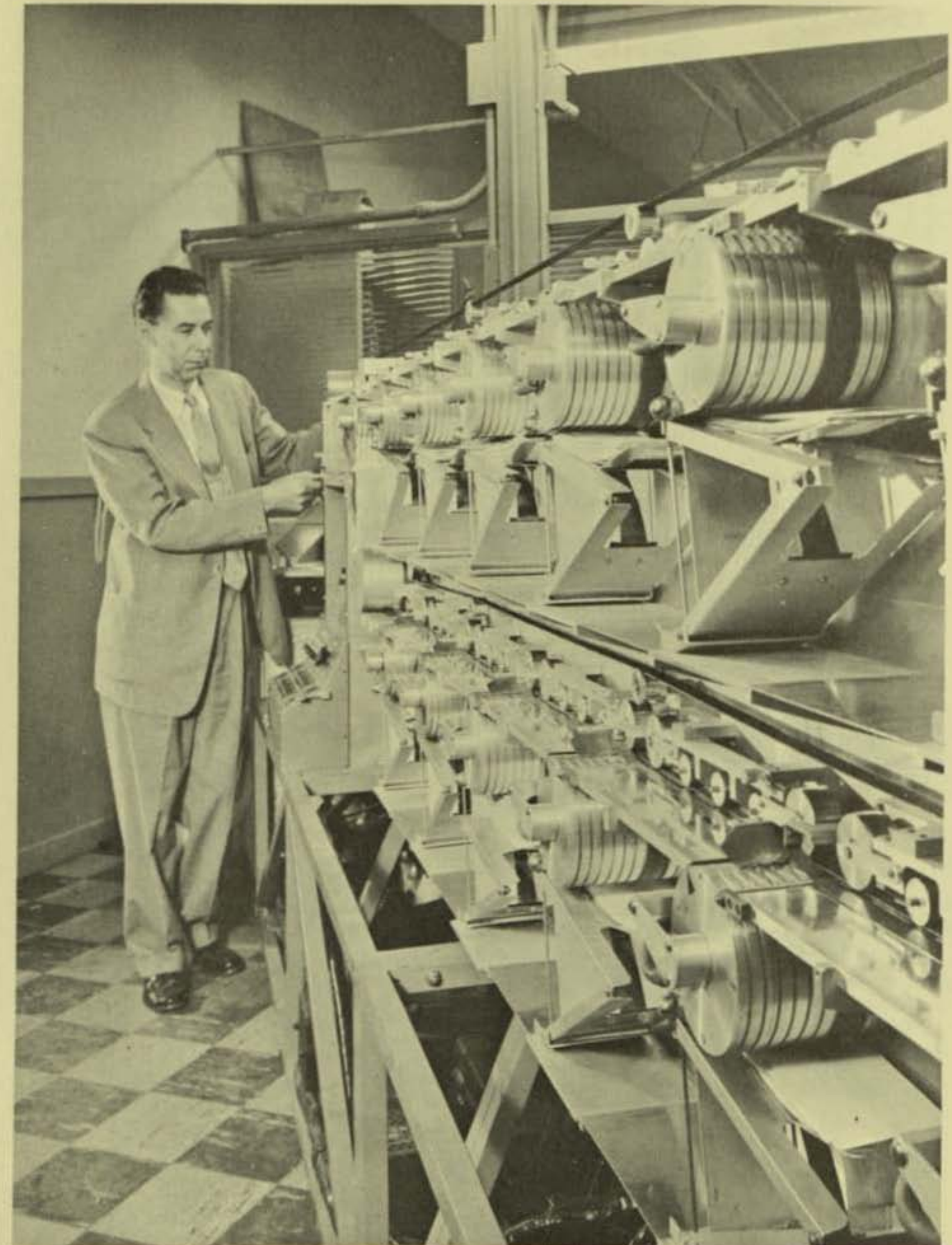
Behind the dozens of panel boards a maze of wires ties together the hundreds of electronic packages which are the senses of ERMA



HOW ERMA FUNCTIONS

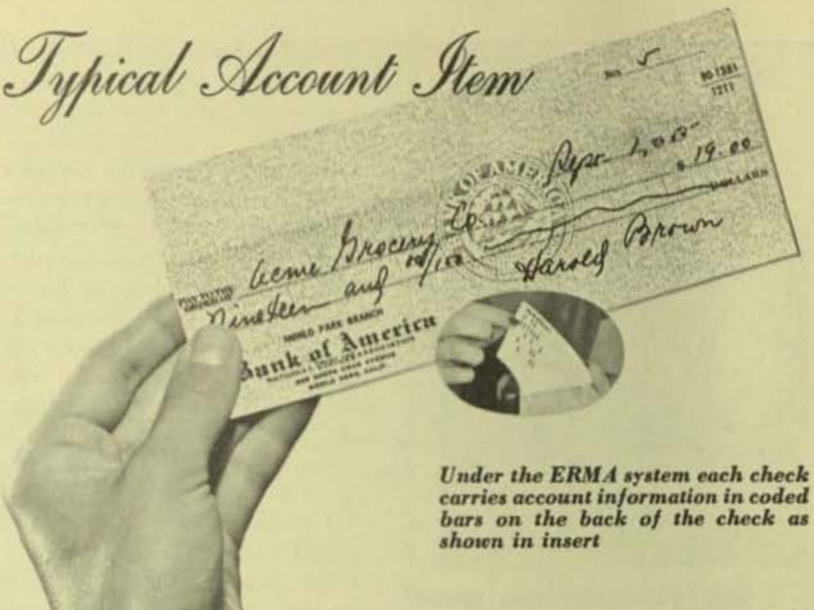
Bundles of checks or deposit slips come, by the usual route, to the operators of ERMA. Assume, as a typical case, a check for $19.00 by a Mr. Brown to whose account the bank has assigned number 15711756. To perform the bookkeeping for this check, the machine requires three pieces of information: the 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.

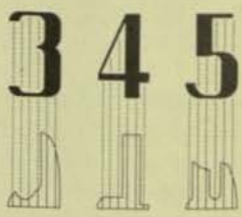
After the item is entered on the tape several cross-checks for accuracy occur. When the machine is satisfied it has made no error, the action proceeds to the next higher account number for which it holds entries.

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.

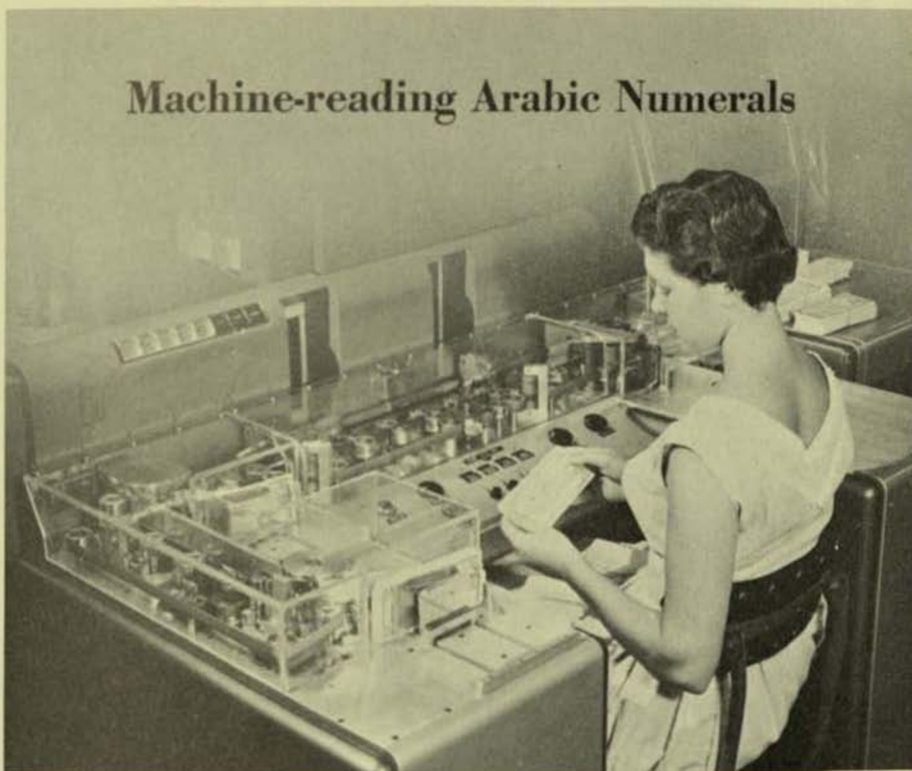
HOW THE CHECK SCANNER "READS" MAGNETICALLY

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.

STANFORD RESEARCH INSTITUTE SRI
MENLO PARK, CALIFORNIA

DIVISION OF ENGINEERING RESEARCH

AUTOMATIC INPUT FOR BUSINESS DATA PROCESSING SYSTEMS*

By

K. R. Eldredge, F. J. Kamphoefner
and P. H. Wendt

ABSTRACT

Computers for business applications are generally input limited and require excessive manpower for data preparation. This can be reduced and gains can be made in speed and reliability if the data forms for the computer and the human being are compatible. Documents must be prepared for manual use in conjunction with many phases of automatic business or technical data handling, and such documents with suitable format arrangements can be fed directly to the computer input with the techniques described. The numbers and symbols on the document are printed in magnetic ink in conventional form and size, and machine reading can be accomplished at rates exceeding 5000 characters per second. The documents themselves have been handled at rates up to 50 per second.

* The work described in this paper was performed under contract for the Bank of America, NTSA, and subsequently continued for the General Electric Company, Industrial Computer Section.

INTRODUCTION

It would be difficult to define the limits of application of computers to the problems encountered in business operations. It can be stated, however, that one of the most important fields of application lies in control of business transactions. Up to a comparatively short time ago such control was achieved largely by manually produced documents, which necessitates a great deal of clerical effort. Lately, the trend to use computers to perform the chores of preparing payrolls, inventories, and gathering statistical data of many types has reduced the cost and man-power required to perform some of these necessary tasks.

One of the difficulties which has seriously limited the application of computers to business problems lies in the fact that information in human language, such as is found on business documents, can not be fed to the computer without translation into the machine language of the computer. Generally, a considerable amount of manual transcription is required to process the data before it can be fed into the computer. This manual work can be reduced and gains can be made in speed and reliability if the data forms for the computer and human being are compatible. The techniques developed at SRI permit the entry of information into a computer directly from business documents in the form of conventional numbers and symbols printed in magnetic ink. Machine reading can be accomplished at rates exceeding 5000 characters per second, and the paper documents themselves have been handled at rates exceeding 50 per second.

Most of the work in these techniques has been aimed at developing a check handling system for banks but the same techniques are readily adaptable to other business applications such as charge tickets, payroll systems, and cost accounting of all types.

Work on the computer input system which has been developed may be conveniently divided into three categories. The first consists of the development of techniques for the reliable machine reading of characters and symbols printed in magnetic ink. The second is the development of a series of magnetic inks suitable for character reading and at the same time compatible with a wide range of printing methods and practices. The third category is in the area of development of electro-mechanical machinery which is capable of reliably handling individual pieces of paper of varying sizes, weights and degrees of mutilation.

STANFORD RESEARCH INSTITUTE CHARACTER READING SYSTEM

In the Stanford Research Institute character reading system the questions relating to magnetic ink printing, to document handling, and to electronic decoding circuitry, are all grouped into a single problem inasmuch as variations arising in any one of the areas affects the other two areas. It is recognized, for instance, that magnetic ink printing has to be adaptable to most of the current techniques for imprinting on paper, but in order to keep the electronics reasonably simple, certain minimal demands are put on printing in order to maintain adequate machine reading quality. On the other hand, the electronics are designed to handle a wide range of registration tolerance in both printing and document handling so that there is a considerable relaxation of these tolerances for the printing and paper handling machinery. In order to further relax the tolerances in both printing and electronics, it was decided to use a degree of styling in the design of the characters such that the wave forms would be more distinct for the machine but which would not prejudice reading by eye. Throughout the whole of this magnetic character reading system, limited compromises have been made which go far to reduce the cost and to increase the reliability of the equipment.

CHARACTER READING

Character reading, properly speaking, begins at the magnetic read head which is in contact with the paper upon which the magnetic characters are printed. The quality of signal derived, in turn, depends on the quality of the printing, but for the purpose of discussing character reading it will be assumed that the signals are adequate.

The magnetic read head used for this type of character reading is conventional in style. The air gap of the read head is positioned at right angles to the line of travel of the paper carrying numbers and in general the numbers are read from right to left. The length of the air gap must be at least equal to the height of the numbers and in addition it has some greater length depending upon how much space is left for registration tolerance. Heads having more than one inch of gap length have been used. Read head inductance is matched to the frequency and impedance requirements for the amplifier input.

In Fig. 1 is shown a simplified block diagram of the electronic reader. The input signals are generated by first passing the magnetic characters through the field of a permanent magnet, such that the polarization is from left to right across the numbers. The output signal from the read head then corresponds, in a first approximation, to the differentiation of the plane area of the number as it passes under the read head. The signals are rather small at this point; in the neighborhood of only 200 microvolts peak. This is occasioned by the fact that the layers of printed ink are quite thin, in the neighborhood of 0.0001" thick, and consequently contain very little magnetic oxide.

The signal has a wave form appropriate to the character involved but up to the present time it has been found that the very high frequencies are less reliable as far as the decode characteristics are concerned, whereas the lower frequencies are much more reliable. During the processes of amplification then, the signals are filtered in such a way that the maximum wave length acceptable from the number is of the order of 1/6th of the width of the number. The amplification is such that the signals have a median peak level in the order of 50 volts. The signals in actuality may be materially greater or materially less than this value. If printing is light the signal level may be only 1/5th that from characters which are printed heavily. Consequently, the whole of the electronic system has been devised to take care of this order of level shift.

The amplified signals are fed into a lumped constant delay line. At a paper speed of 150" per second and with characters printed at eight to the inch, character rate is 1200 characters per second. The delay line would be just longer than one character and consequently have a delay time of approximately 800 microseconds. For 5000 characters per second the delay time is correspondingly shorter or about 190 microseconds. In the presently used equipment, the delay line has essentially zero attenuation and linear phase shift within the band width of the information used. In addition, the delay line is provided with 18 taps along its length. The number 18 provides a 50% safety factor in the number that sample theory predicts is required to completely re-define the wave form within the band width selected.

From the delay line onward, the circuitry is divided into a number of channels equal to that of the number of characters to be decoded. At the head of each channel there is a correlation network from which auto- and cross-correlation voltages are derived for each character as it is sent through the delay line.

Each correlation network is computed on the basis of the expected wave form for its corresponding number, and if the wave form from that number is passed through the delay line, this particular correlation network will have a higher output than any other correlation network at the time that particular wave form is properly stationed within the delay line. All of the remaining correlation networks will have lesser outputs and recognition is premised on the basis of the maximum voltage.

In order to distinguish between the channel carrying the maximum output and those carrying lesser outputs, differential detectors are used. The differential detectors are high gain difference amplifiers in which one side carries the channel voltage and the other side carries a reference voltage. This reference voltage is derived from a diode mixer associated with all channels and which reaches the maximum voltage carried by any channel.

In addition to the character channels, there is an additional timing or character presence channel. This character presence channel is composed of a network which is so disposed that it produces an output at the time when about 1/3 of the character has passed. This output is dependent entirely on the shape of the first portion of the character and is independent of the amplitude of the character. Stray noise and fuzzy edges of the character play little part in affecting the decisions of the character presence circuitry.

The output of the character presence circuitry is appropriately delayed until the character wave form is stationed in the delay line in the design position. The design position is that for which the correlation networks were computed. At that time instant a gate pulse is briefly applied to the differential detector circuitry and the character channel output lines each carry a positive or a negative pulse depending upon the state of the several differential detectors.

In the normal case only one channel is positive and the remainder of the channels are negative. Because the system is based on probability for recognition it is possible that two or more of the channels may become positive during the recognition interval. Such multiple recognition activates reject circuitry.

The use of probability in this system makes it possible to exert a control over the error-reject ratio in the results. In this case errors are spoken of as being faults which the machine does not know it makes; whereas, rejects are faults which the machine recognizes it has made. The distinction between these two is important inasmuch as the unknown fault is carried along with the good material; whereas, the rejected fault can be placed aside for manual intervention. In the discussion of the differential detector circuitry above it was mentioned that the reference line carried the maximum voltage of any of the character channels. Control over the error-reject ratio may be exerted by controlling the fraction of the maximum voltage which is applied to the reference lines of the differential detector circuitry. For instance, if 100% of the value of maximum voltage is supplied to the reference line, then in all cases the most probable number will be accepted. If, however, 90% of the maximum voltage is applied as a reference, then not only will the most probable number be accepted but also any number having 90% or greater probability will also be accepted. This percentage value may be carried to lower values to increase the chances of producing a reject by reason of two or more recognitions from one signal and thus reduce the chances of accepting an error.

The magnetic ink character reading system is secure against most of the common types of defacement. Over-printing, dirt, or writing across the numbers causes no trouble. Embossing caused by ball point pens ordinarily causes no problems nor does wrinkled or sharply creased paper. In the process of reading, close contact with the read head is desirable but a layer of transparent adhesive tape over the numbers causes no trouble. This means that the bulk of torn material can be repaired if necessary. Material printed with magnetic ink is highly durable and thousands of transits across the head cause no impairment of the signal.

MAGNETIC INK PRINTING

Magnetic ink is little different from ordinary printing ink except that it contains pigment which is magnetic in quality. Because the amount of ink transferred to paper in ordinary printing processes is not large, it is desirable to use a material which has a large B-H product. The best materials so far found are those ferrites which are commonly used for magnetic tape. These materials give useful signals even with light printing although considerable care must be used in the mechanical and electronic design in order to minimize circuit and other noises.

Satisfactory inks have been prepared for both letterpress and offset printing, and there is no doubt that suitable inks can be prepared for essentially any other wet printing process. A magnetic transfer tape has also been prepared which has been used successfully on electric typewriters and some types of adding machine mechanisms. No success has so far been achieved with ordinary ribbon type transfer because we seek in this process to transfer an appreciable amount of the solid pigment and not merely a visible amount of a dye.

The several inks developed have each been tailored to transfer to the paper roughly the same amount of magnetic material. Letterpress characteristically transfers more material than does offset printing, and consequently, the offset inks carry more magnetic oxide than do the letterpress inks. Both of these inks are designed to match the magnetic transfer tape so that all three processes give roughly the same signal amplitudes. Another quality has been added to the transfer tape--namely, that of complete transfer. Without complete transfer the ink layer is not uniform and noisy electrical signals are produced, but when transfer is complete or nearly complete they produce uniform and highly reproducible electrical signals.

Engineering standards have not been established for printing and to do so may prove to be difficult. In the work carried out so far, the definition of "good commercial printing" has been adequate to produce machine readable results. Printing that is poor enough to cause a significant increase in reject rate has proven to be discernible to the eye and is generally in the categories of smudgy or gray printing. The most probable fault is expected to be in the region of light printing where the print is definitely gray by comparison to better printing. In tests carried out, the amount of ink transferred has varied by a factor of about five to one for badly over-inked material where such faults as squeeze-out are present, to somewhat under-inked material where blank spaces or grayness begin to appear. The electronic circuitry can handle this range of printing. Material has been obtained from many print shops with a wide range of printing quality and the number of rejects has been very small.

DOCUMENT HANDLING

Basically, the paper handling problem is one of presenting individual documents to a reading device and storing them in an orderly manner after they have been read. A document sorting operation can often be conveniently performed in conjunction with this operation.

It should be kept in mind that the documents from which the information is to be read into the computer in most cases are not in "new" condition. They have been "manhandled" and mutilated to various degrees and are not necessarily of the same size or of the same kind of paper. They may have originated from many different sources and have received all sorts of treatment. It therefore becomes impossible to base the design of the equipment upon the physical characteristics of a specific document type or even on the physical properties of a certain kind or type of paper.

A schematic presentation of the mechanical arrangement of presently used equipment is shown in Fig. 2.

The equipment performs several basic paper handling functions. These consist of (1) separating the first document to be fed from the remainder of the documents in a stack, (2) feeding this document into a transport system and past a magnetic read head, (3) stacking the document in one of several stacking bins.

In Fig. 3 a stack of documents imprinted in magnetic ink with the information to be fed to the computer is placed into the feeder bin. Vacuum nozzles within the rotating feeder drum pull the first check in the stack against the release fingers. This action seals the vacuum nozzles in the feeder drum, stopping air flow in the feeder drum nozzles and preventing additional checks from being picked up. A command from the computer energizes the release finger solenoid. The solenoid retracts the release fingers to a position below the periphery of the feeder drum, permitting the document to be sucked against the rotating drum. Friction between the document and the drum conveys the document into the double belt transport system. Before the entire document has been pulled into the double belt transport system, the release fingers are restored to their initial position outside of the periphery of the feeder drum. As the trailing edge of the document passes into the double belt transport system, the vacuum nozzles in the feeder drum are uncovered and the next document is pulled against the release fingers. The next document is then ready to be fed as soon as the previous one has cleared into the transport system.

It has been found that paper documents have a tendency to stick together because of perforations, bent corners, static electricity, and for numerous other reasons. In order to overcome this tendency, a leading edge vacuum nozzle is incorporated in the feeder. The air flow into this nozzle separates the first document from the second as the first one is pulled against the release fingers.

It should be noted that no large valves or heavy mechanical components need to be actuated in the feeder configuration. The forces which are exerted on the paper, however, are comparatively great. This becomes apparent when one considers that the weight of a commercial document is in the order of one to two grams while the friction force between the feed drum and the paper while it is being accelerated is about two pounds. The mechanism is therefore suitable for high speed operation.

The document is held firmly between two rubber impregnated canvas belts while it travels from the feeder past the magnetizing head and read head to the stacking drum. Rubber rollers hold the document firmly to the magnetizing and read heads to insure reliable signal output from the magnetic ink printed material, even though the paper may be wrinkled or embossed.

While the document travels from the read head to stacking drum (A), the information received by the read head is interpreted by the computer, resulting in a command that the document should be stacked in either stacking drum (A) or (B). This arrangement serves to sort the documents into two categories. The addition of more stacking bins transforms the machine into a sorter which may be used for sorting by decimal or other means.

The stacking drums are essentially hollow cylindrical drums with rows of small holes drilled circumferentially along the axis of the cylinder. Each axial row of holes is interconnected to a vacuum valve. If the computer commands that the document is to be stacked by stacking drum (A), a photodiode in the track senses the presence and location of the document. The diode actuates a solenoid which in turn opens the required vacuum valves of the stacking drum. When the document reaches the stacking drum, it is attached to the drum by the air flowing into the vacuum holes and transported to stack (C). As the document reaches the stripping fingers the vacuum valves are closed and the document is deposited in stack (C). If the paper is to be directed to the other stacking drum (B) it is permitted to continue in its path, and the same stacking procedure is followed when it reaches stacking drum (B).

In some cases it has been found to be advantageous to install a mechanical gate at each stacking drum. Such gates are used to provide a bridge to enable mutilated documents to travel smoothly to subsequent stacking drums. They are not used to deflect the document to a specific drum since this action can be achieved more positively by means of the suction holes of the stacking drum.

An experimental model of the document handling machine has been operated at rates as high as fifty-five per second with a document transport speed of 450 inches per second.

Fig. 4 shows a version of an input machine which is used by the Bank of America to handle and read travelers checks.

A ten-pocket bank check sorter has been in commercial operation since January 1956. All customary sizes and weights of bank checks are handled at the rate of ten per second. In the ordinary day-to-day operation rejects for all causes are less than one per thousand passes.

CONCLUSION

In the system described, character reading, printing, and document handling are strongly interrelated. The system is secure against usual defacement problems and most torn documents can be repaired with ordinary transparent adhesive tape. Printing can be achieved with commercial equipment with little more than ordinary care. Documents can be handled and information can be read with rates and accuracy that are compatible with a large class of computer input requirements.

October 30, 1956

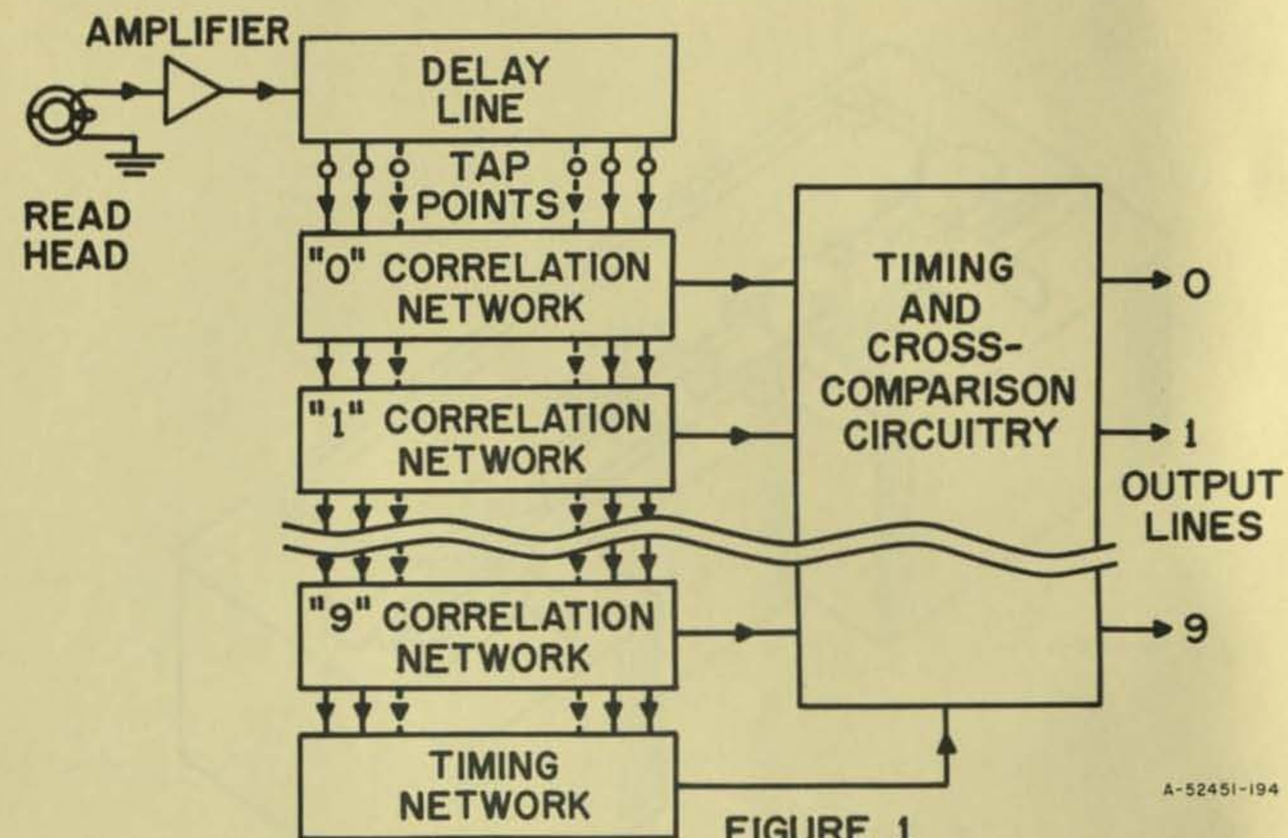


FIGURE 1
SIMPLIFIED BLOCK DIAGRAM
ELECTRONIC READER

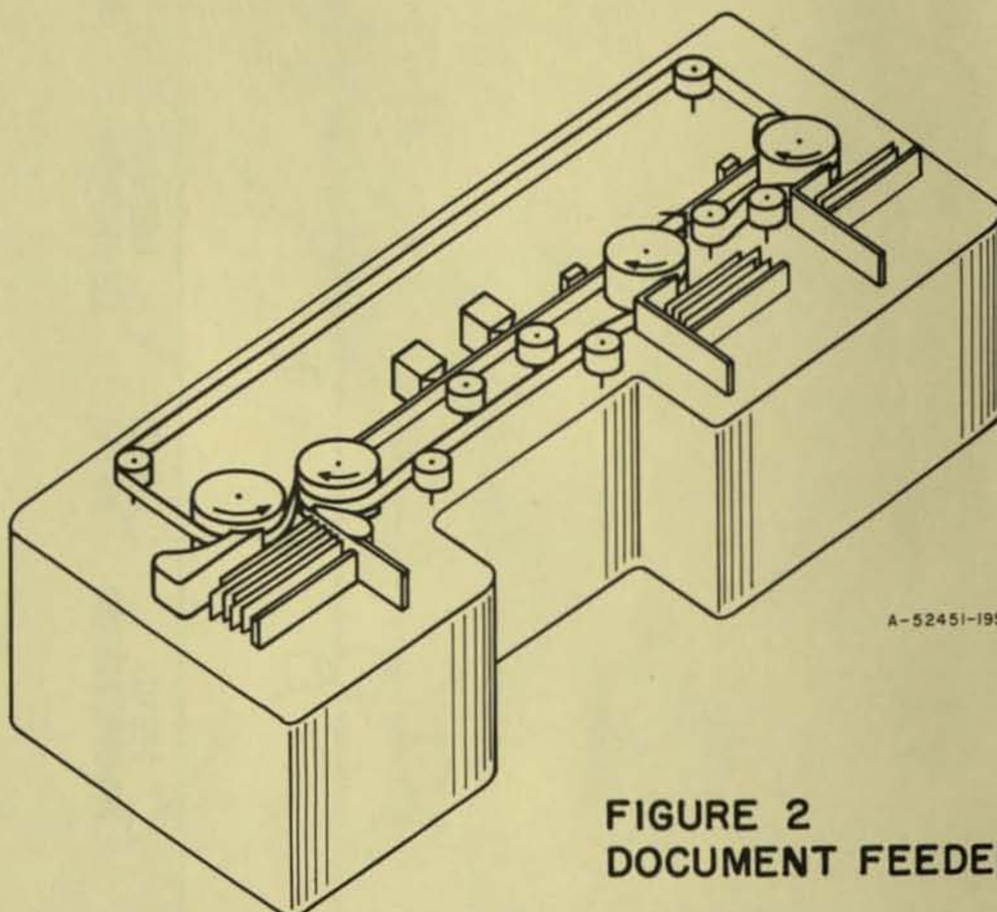


FIGURE 2
DOCUMENT FEEDER

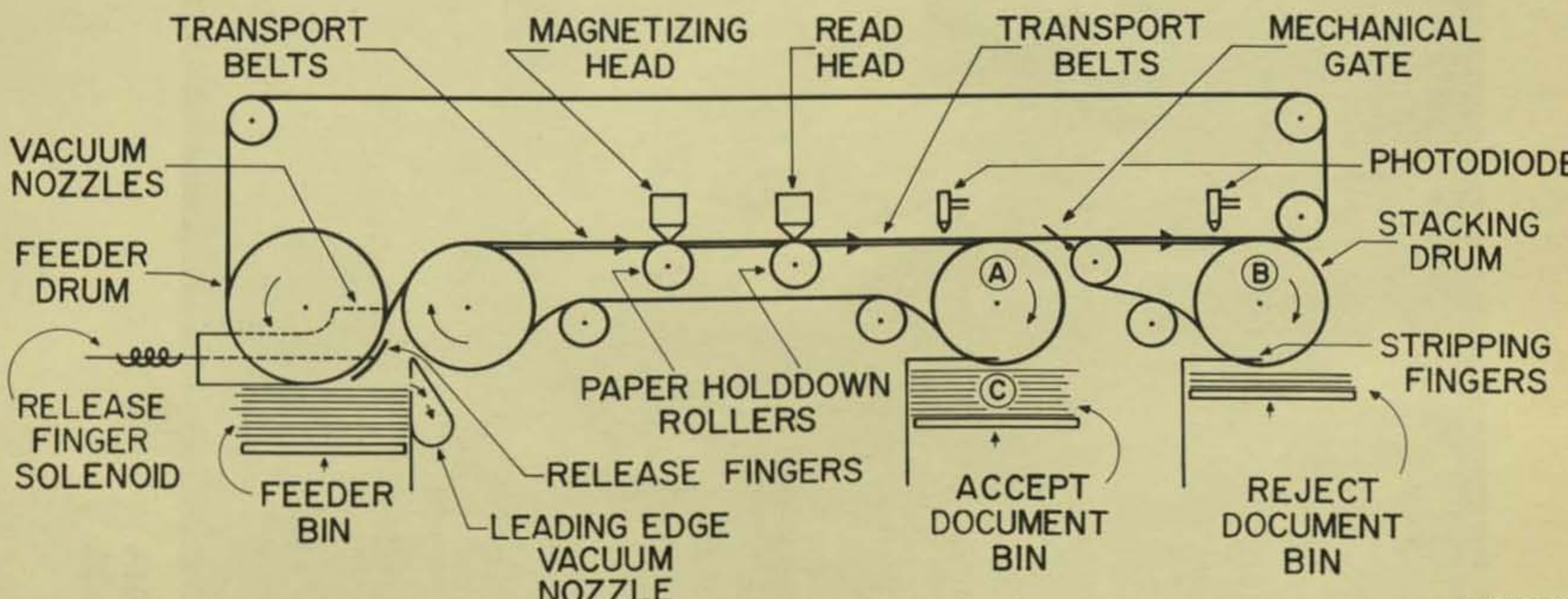


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FIGURE 3
DOCUMENT FEEDER DETAILS

FIGURE 4
DOCUMENT FEEDER

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Chapter 3

Bank of America: Breaking with 500 Years of Tradition

The early 1950s found the banking industry on the brink of a crisis. Check use in the United States had doubled between 1943 and 1952, from four billion to eight billion checks per year, and bankers were projecting continuing increases of one billion checks per year by 1955. Banks were at a standstill, unable to expand, or, in some cases, even to keep pace with the increasing flow of paper.

The immediate culprit was the check clearing process. Each of the 28 million checks written every business day passed through approximately $2\frac{1}{3}$ banks, taking more than two days to be processed. The result was a staggering 69 million checks in process throughout the United States on an average day. Unless deposited at the bank where both accounts were located, a check had to be sorted by hand and individually tallied on an adding machine at least six times during the clearing process.

In a 40-person branch, seven or more people were kept busy sorting, adding, and bundling checks. Most were young female bookkeepers between the ages of 18 and 24. Given the drudgery of the work and the age of the women, who traditionally left the banks upon marrying, turnover was exceedingly high, in some instances 100 percent per year.[1]

Bank of America (called Bank of Italy until 1930) was founded in 1904 as a small San Francisco savings and loan. A single branch, opened in 1909, grew to 24 by the end of 1918 and to 292 by the bank's twenty-fifth anniversary in 1929, at which point Bank of

America employed more than 7,000 people and had more than $1 billion in assets. L. M. Giannini, some of founder A. P. Giannini, took the bank to 495 branches and $2.1 billion in assets by the end of 1941. With World War II, California's population and economy mushroomed, boosting the bank's resources to more than $5 billion. Following the war, Bank of America opened nine overseas offices; by 1946, it was the largest bank in the world.

Former national bank examiner S. Clark Beise, who had come to Bank of America under A. P. Giannini and risen to senior vice president by 1950 (and to president in 1954 to 1964), was acutely aware of the serious problems that faced the nation's banks in general and Bank of America in particular. The bank was managing more than 4.6 million checking, savings, and Timeplan loan accounts, with checking accounts growing at a rate of 23,000 per month. Realizing that growth would be limited not by new business, but by inability to service new accounts adequately, Beise became the first of the bank's senior managers to seek a solution in the automation of check handling. Exhibit 3-1 lists key events in Bank of America's use of IT.

EXHIBIT 3-1 **Development of the Bank of America Dominant Design**

Year	Event	Significance
1920s	Establishes systems analysis department	Competence in systems analysis
1950	SRI hired to analyze potential of IT for check processing	Beise learns of potential of IT; forms joint study team
1951	Beise hires Zipf as IT manager	Forms IT function
1952	SRI to build ERM	Prototype check-processing system
1953	Zipf orders IBM 702	Credit automation initiated
1954	Eldredge invents MICR	Human- and machine-readable type
1955	SRI's ERMA works; Zipf installs 702 and it works	Proves electronic check processing; begins automating credit applications

EXHIBIT 3-1 **Continued**

Year	Event	Significance
1956	GE to build ERMA; initiate loan exceptions	Joint development project; automates credit management
1958–1959	Links branches to headquarters; proofing in ERMA; introduce credit card	Develops electronic infrastructure; enables electronic processing; expands electronic product base
1960–1961	Finishes installing ERMA; installs 7070s; expands credit card to U.S.	Expands branches to small towns; new capacity for new services; national market
1963–1964	Credit card restricted to California; Beise retires; Peterson CEO; Zipf orders new computer	Bank banned from interstate acts; given charge to expand overseas; new generation must reprogram
1966–1968	System failures plague IT; Zipf head of retail bank	Loses confidence of management; S&ER leaderless; loses momentum
1969–1978	Cost-minimization IT era; Zipf retires; IT skills depart	Full generation behind in use of IT; loses momentum; ATMs vetoed
1978–1981	Clausen recognizes problem; works to bring in ATMs	Hires competent IT manager; rebuilding IT infrastructure
1981–1992	Armacost and then Clausen CEO; Clausen empowers a maestro; management becomes involved; establishes evolving IT strategy	Hopper designs new architecture; Simmons builds on Hooper's effort; creates ongoing planning process; strengthens IT competence
1993–present	Rosenberg CEO picks Maestro; continuing IT strategy	Swartz experienced IT manager; expanding in new products

The Searching Phase: 1950–1953

When a promotional meeting at the Emporium department store near Bank of America headquarters ended earlier than expected, Dr. W. B. Gibson of the Menlo Park, California, Stanford Research Institute (SRI), an independent technology research institution at the leading edge of electronics, decided to call on Beise. "I told Beise that this was just a 'shot in the dark,' but that I thought Bank of America should be thinking about electronic applications," Gibson later recalled.[2]

Beise had previously approached several business equipment manufacturers about creating an automated bookkeeping system. Although willing to improve their basic proof machines, none of the manufacturers was interested in investing time or capital to create an entirely new system. Beise acted quickly on Gibson's advice; vice president of operations Frank M. Dana, asked by Beise to follow up and develop a proposal, contacted SRI's director of engineering research, Thomas H. Morrin, and immediately commenced a series of meetings to explore the automation of check processing, account numbering, and paper handling. SRI seemed to Beise to be the perfect solution. As a prominent research and development organization with a strong track record in electronics research, it could establish the possibilities in automated check handling and design a model to test or sell to a manufacturer. Beise formed a close relationship with Morrin, vice president of SRI Engineering and R&D. Working under a charter from L. M. Giannini to solve the banking crisis, he signed a contract, with the understanding that no publicity would be given to the effort. Morrin became his R&D manager. Subsequently, a highly secret feasibility study was initiated. Beise assigned Charles Conroy as systems analyst to work with the SRI team.

Automating Check Processing

When a check was deposited at a bank, two steps had to be accomplished quickly: proofing and bookkeeping. Each afternoon, "on us" checks, meaning checks drawn on the bank that held the account, were sorted by signature and taken to a conventional ledger-card accounting machine whose operator entered the dollar amount on a ledger card and subtracted it from the balance, thereby creating a permanent record for month-end reporting. Daily deposits and withdrawals were subsequently posted to customers' account balances. All other checks were batched into proofed totals and forwarded to other branches and banks. To finish proofing early enough to catch stop payments or overdrafts, most banks were forced to shut their doors to business by 2:00 P.M.[3]

The check was central to SRI's feasibility study. Bank of America, regarding it as an important emotional link to customers, wanted few, if any, changes to the check. One of the first critical choices was between customers' usage habits and system needs with respect to the account filing system. Standard banking practice was to organize customer files alphabetically, which resulted in changing the order of sorting with the addition of each new account, and to identify and verify checks against customers' signatures, which were maintained on index cards at branch offices. SRI engineers suggested that a numerical accounting system would make check processing easier to automate and provide a more reliable means of identifying checks. Conroy worked with them to develop a revised paperwork flow to articulate the potential savings. The proposed change would entail distributing new checkbooks with customer name and account numbers printed on checks and warning customers against loaning bank checks to friends, a common pre-automation practice.

The feasibility study provided an opportunity for engineers and bankers to learn the complexities of each other's businesses. Bank of America vice president Ranaulf Beames stressed to SRI engineers the service-industry/customer-focus character of banking, emphasizing that prompt, reliable banking services engendered customer loyalty. He also underscored the bank's desire that customers be inconvenienced as little as possible and that usage habits be changed only as necessary. Beames discussed with Beise the alternative work flows resulting from printing identification numbers on the checks, and Beise quickly agreed the change was essential. They encouraged SRI to explore the means of electronically identifying the account number, thereby changing a banking tradition established in Venice in 1431.[4]

In late September 1950, Morrin informed Beames that SRI's feasibility study "indicated it was technically possible to build an automatic bookkeeping system for ledger posting and processing of commercial checking accounts" and suggested a three-phase project approach entailing (1) a study of banking procedures external to the machine, (2) logical design, and (3) development, construction, and testing.[5] Because manufacturing ran counter to SRI's mission statement, the last phase was to be carried out by an equipment manufacturer. Beise approved the project under CEO funds and made the fixed investment toward electronic banking. The $15,000 contract (later augmented by $5,000) for SRI's part in the project referred to the system as an electronic recording machine (ERM).

Although the Bank of America was interested in using the proofing process as an input to bookkeeping activities, an April 30, 1951, interim report described the machine as fundamentally a bookkeeping device. Completion of the first two phases of the project found the bank and SRI in agreement that the system would have to perform five basic bookkeeping functions: credit and debit all accounts; maintain a record of all transactions; retain a record of current customer balances to be printed as needed; respond to stop-payment and hold orders on checks; and notify operators of checks that caused accounts to be overdrawn.

SRI subsequently began what was supposed to be its final project for the bank, estimation of optimal account capacity for and cost of constructing the ERM. An initial rough estimate of $750,000, with an additional $15,000 for development of a check reader, was arrived at by comparing it with estimated construction costs incurred by other companies for such large-scale computer projects as the Mark III, UNIVAC, EDVAC, and Whirlwind I. When ERM development was broken down into specifics, the final estimate was $949,000, a figure deemed high by Morrin, who suggested estimating minimum and complete systems. The readjusted figures were $530,000 and $830,000, respectively.

Only Burroughs expressed an interest in building an ERM for the bank, and its proposal to modify an existing system that would deliver less functionality at twice SRI's cost estimate was rejected. Consequently, Beise asked SRI to construct an engineering prototype of the ERM, a decision motivated to some extent by his belief that confidentiality was less at risk with the research firm. Although it had no interest in manufacturing and was ill equipped to build what was to become one of the largest and most complex computer systems yet designed, SRI, on January 28, 1952, contracted to develop, construct, and test a pilot ERM. Beise still planned, once SRI had demonstrated a working prototype, to sell the system design to a manufacturing company.

Phase 3 work on the ERM was to involve completing the logical design of remaining operations; constructing a pilot model; testing the model at a Bank of America branch; and finishing and installing the machine at a local branch. The bank was to pay SRI no more than $850,000 over four years, plus an additional $25,000 to cover subcontracts. (Although expenses were never released, most engineers estimate that the final cost was in excess of $5 million.)

Once SRI had the mandate to develop the system, Morrin and colleagues Jerre Noe and Oliver Whitby — referred to by the few bank employees who knew about the project as the "whiz kids" — began working as technical advisers on the creation of a prototype. Conroy moved to Palo Alto to supervise the project and work with the team. Monthly review meetings with Beise were held at bank headquarters. Design and operation of the ERM were fairly well defined by the fall of 1952. The primary system was to consist of four centrally located, 30,000-account capacity ERMs linked by (in some cases, flying) messenger services to approximately twelve branches. Each ERM was to be operated by ten or twelve bookkeepers and handle both bookkeeping and proofing functions.

SRI had begun in 1952 to develop a system for encoding electronically readable customer, bank, and account information on checks to support automatic proofing. A magnetic ink bar printed on the backs of checks was selected as the best solution to punched-card approaches. Encoding project manager Kenneth Eldredge developed a system to form the magnetic ink into Arabic characters that could be read by humans as well as computers. This magnetic ink character recognition (MICR) system, successfully developed and tested in the summer of 1954 on Bank of America's traveler's check program, proved a superb showcase for advances in machine reading and paper handling; by June 1955, more than 300,000 traveler's checks had been scanned through the system.

SRI launched a wide-ranging technology search for components, visiting companies in the United States and Europe to observe and assess willingness to develop products for the ERM. Meanwhile, SRI engineers had set to work on the logical design of the system. A major design choice was to develop electronic logic using tubes and wired programs, leaving open the possibility of transistorizing the final ERM.

Organizing for Automation

On December 23, 1950, just as SRI had begun work on phase one design of the ERM, Al Zipf, an operations manager in a Southern California branch, received from Bank of America president L. M. Giannini a letter marking the former's fifteen years of service. Zipf, a high school graduate, joined the bank as a night clerk and worked his way up to assistant branch supervisor, along the way securing four patents for inventions and improvements in banking machinery and systems. He responded with a detailed letter encouraging the president to automate bank activities. "If we are willing to take an active part in the engineering development of new machines," he wrote, "I am confident that it is possible and economically practical to accomplish the virtually automatic performance of such tasks as the sorting, listing, and commercial ledger posting of near-standard paper checks." He closed the letter with "my best wishes for Seven Million Dollars, less staff, and more machines."[6] Giannini gave the letter to Beise, who invited Zipf to San Francisco. Impressed by his energy and recommendations, Beise asked Zipf to join the innovation team on a confidential basis to explore alternatives to the SRI approach and instructed that he receive Frank Dana's copies of SRI reports and meeting minutes.

Encouraged by Beise and Dana to evaluate the applicability of current technology to banking, Zipf, on leave at UCLA to study electronic systems during the spring of 1952, began searching for equipment and ideas under the guidance of pioneering computer designer George W. Brown. Zipf visited computer-using manufacturers and firms to observe management and service problems and evaluated the banking potential of more than a dozen suppliers' systems. In a letter to Dana, he observed that there "were enormous opportunities in electronics" and suggested that the bank form a systems and equipment research group. In late 1952, over Morrin's protestations that the ERM could be expanded to support all the bank's data processing, Zipf persuaded Beise and Dana that it was important to begin a computer acquisition appraisal to gain experience with computers for improving bank operations beyond the automation of check handling.

Zipf returned to Bank of America in the summer of 1953 and in October was promoted to assistant vice president with responsibility for managing the newly created Systems and Equipment Research (S&ER) Department. He began with one secretary and a mandate to establish internal systems capability, evaluate suppliers, and pursue potential economic applications of general-purpose computers. Zipf, on the basis of an analysis of two general-purpose computers, the UNIVAC I and IBM 702, decided that IBM could deliver better support and reviewed the latter system's potential with Beise. A tentative order, authorized in October 1953, called for delivery of one IBM 702 to San Francisco in September 1955 and a second to Los Angeles in June 1956. It was contingent on Zipf's providing detailed analyses of costs and benefits with profit objectives by the fall of 1954. The implementation effort was to parallel the ERM project to gain experience in the management and operation of general purpose computers in non-check-processing operations.

Discussion of the Searching Phase

The management team had acquired perspective on the state of electronic technology and the means of applying the technology to banking. They knew it was critical to capture information electronically as soon as possible to take advantage of the speed and economics of electronic processing. In addition, for efficiencies, the more information printed in accessible electronic form, the better. Automating with IT was profitable for certain paper-based systems. Planning is most important prior to designing a system because it is essential to perform a careful analysis of exactly what is desired in the process so as not merely to automate existing procedures but to redesign to improve the entire process. Planning is time consuming and iterative with involvement of systems analyzers and knowledgeable bankers. There are no absolutes, but trade-offs must be made between costs and service requirements. The role of business leadership is to make those trade-offs. In addition, some seemingly obvious processing activities, such as on-line access to memory, are not possible at this point but may be in the future.

The team also gained a broader set of insights into the overall impact of electronic automation. To really gain significant cost reductions, old methods had to change dramatically, not incrementally. There existed no paper-processing standards, and each manufacturer had its own set of codes and designs for the proofing and bookkeeping procedures. The manufacturers intent on incremental inventions in their present systems to maintain and grow market share were unwilling to risk a leap to a totally new system. To obtain such a system, significant capital would have to be invested and the banks would have to change their procedures. The push for that change could come from a knowledgeable banker with persistence and capability. Since he knew it was just as difficult to learn banking as it was to learn systems, Beise decided to lead.

Building IT Competence: 1954–1956

Zipf was faced with three immediate challenges: deciding which tasks to automate, designing and developing programs to automate these tasks, and selecting and training a team. He immediately set about recruiting a group of knowledgeable systems analysts and programmers. An internal personnel announcement of an opportunity for training in computer programming drew thirty-four responses from experienced bank officers. After all were carefully screened, four senior managers were selected to attend, with Zipf, IBM's 702 programming school in Poughkeepsie, New York. There Zipf met and hired the bank's first data-processing "professional," Harry Kahramanian, a graduate of Grace Hopper's UNIVAC program. Hopper, a computer pioneer, had developed the first production-control system for a computer and the elements of a systematic approach to programming computers. When they completed the course, two teams were organized — one in Los Angeles and one in San Francisco — to analyze existing operations and determine where computer automation would be most profitable.

Zipf believed that the computer's greatest potential was for improved management reporting but recognized that the cost of large-scale computing could not be justified on that basis alone. With management reporting as the ultimate objective, he and his team of newly trained programmers searched for areas of bank operations characterized by high-volume, repetitive clerical activities.

In 1954, the American Bankers Association, concerned with the explosive growth of float owing to the cumbersome sorting process, appointed a committee on the mechanization of check handling; Harold A. Randall of the First National Bank of Boston was its chairman. In early 1955, Randall appointed a technical subcommittee of operating managers who were the leaders in using electronic process in their banks. At the time, eleven banks were actively pursuing the use of computers, ranging from the suburban County Trust bank in White Plains, New York, to the Mellon Bank of Pittsburgh.[7] Most were automating loan processing and two were testing punched-card checks.

The committee was chaired by John Kley, leader of the White Plains effort. He selected his committee from innovative IT managers at innovative banks.[8] Zipf, a member of this group, gained access to leading users of IT and the opportunity to be exposed to manufacturers' proposed solutions. The committee met regularly twenty-two times over a three-year period to define a standard that would allow automatic sorting of checks and proofing the sort. At these meetings they heard proposals for the standard from all the major manufacturers, including IBM, NCR, Burroughs, and Addressograph-Multigraph. In July 1956 the subcommittee recom-

mended, with ABA committee approval, that the Bank of America's MICR be the standard for U.S. check processing. One year later it approved the present bottom right-hand corner location, which was consistent with the electronic recording machine (ERM) design. The Bank of America was assured that it was developing the standard check-processing system not only for its customers but for the entire U.S. banking system.

By November 1954 programs for real estate and installment-loan accounting were sufficiently defined to permit evaluation of the functionality and economics of the IBM 702. The program design provided a basis for detailed evaluation of the potential savings from converting existing manual operations to electronic processing. The comparison showed early losses owning to conversion, with a profit beginning in the second year and leveling off at $189,364 in the third year as a result of staff reductions. On Beames's death in the spring of 1953, Howard Leif became controller and assumed responsibility for the ERM project. Beise, Dana, and Leif reviewed the analysis with the management committee and in early December 1954 Zipf confirmed the order for delivery of the first IBM 702 to San Francisco. Each group then proceeded with full-time IBM 702 programming of the system it had analyzed — San Francisco for installment, and Los Angeles for real estate and loan programs. They began to automate operations.

Even without a computer, S&ER had grown to twenty-five people by June 1955. Its two development projects, the SRI ERM and the IBM 702, were at the forefront of computer technology with the first operational large-scale computer applications in banking. The ERM was to be announced and begin servicing the San Jose branch, and the 702 was to be delivered to San Francisco in the fall of 1955. Zipf, having learned during his trips to other companies of the anxieties that introducing a computer could generate, had encouraged the bank in the spring of 1955 to launch a training program to further develop bank employees' understanding of computer systems and mitigate their apprehensions by emphasizing the joint man-machine nature of data processing. The message promulgated to bank employees was that although the IBM 702 (nicknamed BEAST for *B*ankamerica *E*lectronic *A*ccounting *S*ervice *T*ool) was to take over dull work, it would require strong personnel support to function well.

Beise, Leif, and Zipf, growing restless as experimental costs continued to rise, declared the design of the ERM complete in the spring of 1955. They had shifted their goal from building an operational system to building an "as is" prototype for a September 1955 demonstration, with adjustments to be permitted afterward.[9]

Completing construction within the bank's time frame proved challenging; engineers were working in around-the-clock shifts as September neared. When existing paper-handling systems were deemed too unreliable to support proofing, the ERM became exclusively a bookkeeping machine. Checks were to continue to be proofed at branches and sent to the ERM centers. SRI's earlier hope of combining high-speed sorting and bookkeeping into a continuous process also proved unfeasible in the time allotted, relegating the SRI sorter to postprocessing sorting of checks to customers.

When, in the spring of 1955, Beise diverted his team's attention from construction to a grand public announcement, the bank's public relations office, deeming ERM too technical sounding and potentially intimidating to customers, introduced a name change. To the considerable dismay of the engineers, who requested the more scientific-sounding FINAC (for financial accounting), the Marketing Department rechristened the machine to the more appealing ERMA (Electronic Recording Machine Accounting).

Bank of America designated September 22, 1955, ERMA Day. To avoid leaks, the press was bused from San Francisco to SRI's Menlo Park headquarters, the site of the announcement. S. Clark Beise, by then Bank of America president, and Thomas Morrin conducted the presentation. Beise spoke of the great contribution the machine would make to Bank of America and the banking community in general; Morrin emphasized the magnitude of the engineering accomplishment and demonstrated the system. Neither named the firms that had collaborated on the project nor the costs incurred. Bank of America had invited an impressive list of journalists — including the financial editors of newspapers and wire services, California business syndicate writers, and writers from *The New York Times*, *Life*, *Fortune*, *Newsweek*, and *Business Week* — which paid off in a barrage of articles lauding its accomplishment.

The same month that ERMA was announced, the bank's first IBM 702 was installed in a new computer room in San Francisco. The installment loan system was brought up on the San Francisco computer within three weeks, followed in November by the Los Angeles–developed real estate loan program, to which 90,000 loans had been converted. An S&ER implementation audit of the installment and real estate loan operations compared estimated with actual costs to verify the savings and justify to the management committee purchase of a second 702 for Los Angeles. Increased machine

costs were attributed to necessary system modifications and the high labor costs of variable run times. Scheduled five-hour jobs could be stretched to eight hours or more by system errors and to as much as twenty hours when unplanned maintenance was necessary at busy times, yet overall potential savings still produced a planned positive cash flow in the fourth year and a net profit from labor savings in the fifth. Although machine and labor costs were found to have exceeded expectations by $6,373, or 23 percent, Beise, on the basis of analyses that suggested that the loan system would eliminate 200 man-years of clerical activities, approved the second IBM 702 for delivery to Los Angeles in June 1957.

In 1956 Zipf appointed a number of bank managers who relied on the IBM 702 or were interested in automation to an advisory council charged with appraising bank procedures and suggesting automated-processing improvements. Potential plans were reviewed with this council, which also suggested new applications to Zipf. The annual progress summary for 1957 noted forty-three suggestions, a number of which were incorporated into 1957 activities or a 1958 plan. These included such improvements as five new services for Timeplan loans, automated automobile insurance renewal, and discontinuation of delinquent loan notices, for which the new system had eliminated the need by focusing on collection procedures.

Discussion of Building IT Competence Years

Senior and systems management developed a set of habits that gave the bank technological leadership in the use of computers in banking. The members initiated technology scanning of competitors and suppliers and perfected it with experience. They moved quickly to invest in research or early developments, often in parallel, to ensure that their approach stayed at the leading edge and better understand its strengths and weaknesses. They naturally brought these discussions into the management committee and assumed quarterly reviews and full-scale analyses of new technology standard procedures for running a bank. For 1955, this was a unique bank. In this process, they became competent at managing the complexities of computer systems to reduce costs and provide differentiated service.

The bank's senior management had begun to understand the need for changes and the significance of cost savings in automating paper processing with computers. The costs of processing loans had been reduced and accuracy improved by the 702 system, with a base for doubling volume at marginal increases in cost. For a fixed investment, working computer system costs were, up to a point, independent of changes in volume. However, the fixed-cost structures were complex. There were significant up-front costs for training and programming as well as for equipment. Further, the state of development of electronics and programming made precise estimates of functionality difficult. It was essential to set objectives, deadlines, and cost guidelines and trade off among the three. Eventually, however, the deadline had to be adhered to, and functionality was restricted to control cost. The managers learned that at the current state of the technology, computers were not necessarily cheaper than punched cards and were more rigid and costly to maintain.

The bank's management team and system staff gained an understanding of how to design and build computer systems. On the positive side, they learned what applications would reduce operating costs and how to design systems to improve reliability and accuracy. To obtain this benefit, they learned the nitty-gritty essentials of computer-based systems and the importance of redundancy and reliability. They developed a strong sense of the state of the art in electronics and the reasons the current technology was expensive and unreliable. They learned about emerging technologies, the problems these innovations might solve, and those areas which remained significant uncertainties. This perspective, rooted in a pragmatic systems approach of considering cost versus speed and capacity, evolved into an appreciation for the art of the possible, economically as well as technically. The SRI's learning-by-doing development of ERMA had alerted them to the importance of comprehensive planning for a computer center.

The ERMA experience provided the team perspective on all aspects of implementing a computer system and the necessary lead time required to meet deadlines. It was able to plan and construct a fully operational environment that allowed its 702 to roll in and start up quickly, while at least one bank took delivery on a computer before beginning to build the space. The 702 experience convinced the bank management that programming was time consuming and required considerable testing. In addition, it discovered the importance of exchanging information to learn of problems and solutions as it went along. It initiated and practiced a team approach to system development. It learned that programmers had to provide complete documentation and that running and maintaining systems required well-defined operational procedures. Beise and Dana learned the necessity of management analysis. Careful planning was essential to building cost-effective systems. Most important, the team learned the value of knowledgeable, well-trained people who can solve complex problems quickly.

The SRI experiments tempered the management's expectations about the reliability of electronic systems: they failed unexpectedly. The operation was highly dependent on quick, responsive actions by alert individuals. Repairing breakdowns took time and usually required restarting of the entire procedure. Because banks depend on overnight processing for knowledge of their cash positions at the start of the following day, it was essential to finish processing every night. The development of backup procedures and emergency actions was an early concern of the team. Finally, Beise and Zipf concluded that it was equally important to mold the computer systems to their needs, and that existing technology could not completely satisfy those needs. By the fall of 1955 the team consisted of relatively sophisticated computer managers.

At the time, several banks had automated loan processing and two large banks were experimenting with alternative check-processing systems. The Chase Manhattan Bank was working with the MIT Laboratory for Electronics to design and build a system — a computer referred to as Diana, the "Goddess of the Chase." The First National City Bank was collaborating with an International Telephone and Telegraph subsidiary in Antwerp, Belgium. Both projects relied on slave systems, with checks placed into transparent pockets for sorting and with human encoding at the input stage. The subsequent proof process was electronic. A few banks, including the County Trust of White Plains, were experimenting with books of punch-card checks. Following the announcement of ERMA, all shifted to planning for MICR-type processes.[10]

Finally, they had initiated management procedures for dealing with system issues within a small clique of managers. This group knew how to deal with the technology in terms of costs, risks, and rewards. The ERM experience had shown the value of carefully tracking the system-development process and phrasing questions in bank-processing terms. They appreciated the trade-offs between function, access speed, and cost, realizing that the use of computer technology was in constant, rapid change. The 702 implementation had demonstrated the learning required to achieve technical competence in developing and operating a system and gave them the confidence to expand. The traveler's check project confirmed the value of printed information and taking a system point of view.

Expanding IT Competence: 1956–1958

By the fall of 1956, data processing at Bank of America had grown from one IBM 702 in an air-conditioned room in San Francisco to two full-fledged data centers, one in San Francisco and one in Los Angeles, each with an IBM 702 and a thirty-person support staff, plus thirty temporary staff to handle data conversion. The bank's seasoned systems-development and programming staffs had established proven track records and were growing at the rate of 30 percent per year.

The close ties to senior management that resulted when Zipf was promoted to vice president reporting to Dana enabled S&ER to develop a broad research and development program within its charter to "function as an internal consulting group [with] authority to initiate studies and projects in instances where a preliminary evaluation of an application suggests it is justified."[11] For any project it undertook, Systems and Equipment Research had responsibility and authority for economic evaluation of the application, systems design, evaluation and selection of equipment, site preparations (if required), and installation, conversion, and daily operation until a stable routine was established — essentially complete control of the system-development life cycle.

S&ER maintained a list of potential applications that would provide significant payback, and Zipf sequenced these to reduce expensive infrastructure development. An example was the complete rewrite of tape files, which was embedded in a project to convert all credit applications. The high marginal returns covered the investment in infrastructure. Zipf met with Dana regularly to review progress, and both met with Beise to keep him informed. Quarterly, Zipf discussed a portfolio of projects with the operating committee of senior managers; annually, he submitted a proposed budget and longer-term program plan to the management committee for approval. He generally provided a two-year program of work, which always included two or three research projects such as remote input or modification of standard machines.

Manufacturing ERMA

Following the announcement of ERMA, Bank of America faced the task of selecting a qualified manufacturer to build thirty-six of the machines for use throughout California. A bank team outlined four criteria by which to judge prospective manufacturers: technological ability, financial stability, reputation and size, and cost of the proposed system.

The approximately thirty companies that visited Stanford Research Institute to observe the prototype and submit some form of proposal ranged from such predictable contenders as International Business Machines (IBM) and Remington Rand to companies as remote from electronics as General Mills and United Shoe Machinery. By late November the bank had arrived at a short list of four manufacturers, each of which was invited to make a presentation.

Three of the four finalists: IBM, Radio Corporation of America (RCA), and Texas Instruments (TI) were expected contenders. General Electric (GE), a newer entrant, had experience only in military computer systems. The companies' final proposals were submitted to the bank in February 1956. IBM, although a logical choice, was suspect relative to its intentions (a 1971 report suggested that IBM might have been planning to shelve the technology). RCA, although in the final list, also was not considered seriously, leaving TI and GE.

Texas Instruments' plan was to provide the requisite functionality through staged development of a transistorized computer. Payment to Bank of America for patents and rights ranged from $5 to $17 million over six to eight years, in addition to which it was anticipated that the bank would realize $135,000 in annual savings. TI strongly recommended that the automatic input system be developed with SRI.

General Electric, the dark horse in the competition, had no publicized digital computer experience and no organized unit-developing computer systems. GE's proposal encouraged advancing SRI's system and using transistor circuitry wherever possible. The proposal showed how new technology could increase reliability and speed while reducing processing costs, and a work program called for GE engineers to collaborate with SRI engineers on the initial design stage.

SRI engineers overwhelmingly favored Texas Instruments because of its demonstrated technological know-how and interest in extending a number of SRI innovations. The bankers, however, favored General Electric, whose $30 million proposal was considerably lower than any of the others and specified a million-dollar default to be paid to Bank of America if the machine was not produced. Because TI's more costly proposal specified a down payment, the bank was concerned by what it perceived to be the company's shaky financial circumstances. Ultimately, the bankers prevailed, and GE was awarded a $30 million contract to build the thirty-six ERMA computer systems. The contract called for a detailed design proposal by December 31, 1957.

PROPOSALS AND COUNTERPROPOSALS. Once GE recovered from its surprise at being awarded the prestigious contract, Bob Johnson was recruited from its Schenectady electronics laboratory to form and lead a development team. Owing to severe time constraints, Johnson and his team decided to design and develop the hardware logic, assembler language, and control program in three parallel efforts — incredible goals that were nevertheless realized. The team set three objectives: design a reliable computer that could perform necessary functions without strain, given existing capabilities; write assembler programs to perform the necessary banking functions; and develop peripheral hardware to create sorted input tapes. The bank was to design the latter jointly with NCR.

In parallel with the GE effort, Al Zipf and his team, under assistant vice president of systems Reg Carlson, had been making a detailed analysis of check processing in the Los Angeles area, the fastest-growing customer base. Believing that GE needed more systems guidance, in September 1956 the bank gave GE a counterproposal that detailed check-processing activities at the branches and added proofing to the system. The bank believed that paper handling was key to check-proofing operations; simultaneously proofing and sorting checks to their sources in account order and generating a dollar amount control tape would reduce paper processing to a minimum, as checks would have to be sorted to tape only once, after which all processing would be from magnetic tape.

Proofing, which had been in the original, was lost in the final SRI system design. S&ER's proposal restored it, causing a flurry of meetings among the bank, GE, NCR, and SRI. Although GE and NCR were concerned about the extra cost and complexity of adding proofing, all recognized the market value of doing it, and discussions focused on how best, not whether, to implement the function.

The interest and demonstrated flexibility of the vendors led Beise

and his team to conclude that GE would probably fulfill its contract, and Zipf was asked to develop for the bank's board of directors a proposal identifying the costs and benefits of the proposed system (Table 3-1 compares expected cost for the GE ERMA with competing systems of the day).[12] Analysis was favorable due, in part, to recovery of cash from systems depreciation, expected growth in processing activities at relatively constant cost, and projected labor savings from the new system of 51.4 percent direct clerical labor hours, or $46,566 per month, for the Los Angeles branches. The proposal was subsequently approved.

PREPARING FOR ERMA. Planning for the implementation of ERMA began in late 1956 and continued throughout 1957. ERMA systems were to be installed every other month during the first year and every month during the second year. The first system was to be installed in San Jose by December 31, 1959, the thirty-sixth in San Diego County on February 28, 1961. Each would require a trained staff of seventeen and total training time of 221 man-months. With ABA specifications finalized in March 1958, following more than two years of discussion with manufacturers, the bank continued rollout of its standard MICR checks for nearly two million accounts. Over the following five years, Bank of America spent more than $3 million teaching other banks and printers how to print MICR checks and test the quality of printing for character definition and signal strength.

THE FINAL PUSH TO COMPLETION. In the fall of 1958 the GE–Bank of America team hunkered down to develop a working model of ERMA. All components were in the process of being debugged, with connection planned by year end. A working system for December 31 handling of 100 accounts proved that the system could process checks. Zipf accepted the ERMA system from GE as meeting the contract requirements on December 30, 1958. But a contract that spelled out no functions, only the processing of a specified number of checks at a set price, was open to varying interpretations. Zipf and Mel Gienapp, manager of the bank's data operations, recruited a team of thirty seasoned operations managers to be trained as ERMA programmers to serve as backup. Starting on the 702, they switched to the emerging ERMA language. An off-contract compromise on proofing needs, reached in late February, called for GE to expand the core of the main computer hardware to allow the bank to move quickly to automate proofing as the systems were deliv-

TABLE 3-1 **Summary of Financial Elements in Proposals Submitted by Prospective Manufacturers of ERMA**

	Texas Instruments Plan A		Texas Instruments Plan B		General Electric Target Prices		General Electric Ceiling Prices		RCA Alternative A		RCA Alt. B
	Unit Price	Total (36)	Unit Price	Total (36)	Unit Price	Total (36)	Unit Price	Total (36)	Target Prices	Ceiling Prices	Film Prices
Base Price	635,000	22,860,000	685,000	24,660,000	639,000	23,004,000	796,000	28,656,000	29,201,000		25,464,000
Cost of 60 Add'l Sorters	32,500	1,950,000	32,500	1,950,000	30,400	1,824,000	37,900	2,274,000	1,356,000		1,356,000
	667,500	24,810,000	717,500	26,610,000	669,400	24,828,000	833,900	30,930,000	30,557,000		26,820,000
Assume Excise Taxes @ 8%	53,400	1,984,800	57,400	2,128,800	53,552	1,986,240	66,172	2,474,400	2,444,560		2,145,600
Total Equip. Costs	720,900	26,794,800	774,900	28,738,800	722,952	26,814,240	900,612	33,404,400	33,001,560	RCA will not quote ceiling prices for Alt. A	28,965,600
Installation Costs	15,000	540,000	15,000	540,000	61,052	2,197,872	61,052	2,197,872	1,330,000		2,180,000
Gross Cost to Bank, Installed	735,900	27,334,800	789,900	29,278,800	784,004	29,012,112	961,664	35,602,272	34,331,560		31,145,600
Less Tax Savings on Depreciation @ 55.84%	(410,926)	(15,263,752)	(441,080)	(16,349,281)	(437,787)	(16,200,363)	(536,993)	(19,880,308)	(19,170,743)		(17,391,703)
Net Cost After Taxes on Depreciation	324,974	12,071,048	348,820	12,929,519	346,217	12,811,749	424,671	15,721,964	15,160,187		13,753,897
Less: Payments to B of A											
a) Minimum, Guar., after taxes		nil				(2,396,789)		(2,861,273)	(441,600)		(441,600)
Net Cost						10,414,960		12,860,691	14,719,217		13,312,297
b) Maximum, after taxes				(1,779,000)	(200 sales)	(8,000,000)	(50 sales)	(4,600,000)	(662,400)		(662,400)
Net Cost				11,150,519		4,811,749		11,121,964	14,498,417		13,091,497
c) Estimated Probable, after taxes		nil		(1,779,000)	(200 sales)	(5,600,000)	(50 sales)	(4,600,000)	(662,400)		(662,400)
Estimated Net Cost, after all taxes		12,071,048		11,150,519		7,211,749		11,121,964	14,498,417		13,091,497
Credit for cost savings on early deliveries		(1,322,766)		(1,322,766)							
Adjusted base for comparative purposes		10,748,282		9,827,753							
Notes on Financial Arrangements		All prices firm. Under Plan B, we receive $2.5 mill. flat, with 20% down and bal. in insts. @ 3% interest. All patents tfrd. under either Plan. Progress payments required, up to limit of $2.5 mill. outstanding (loss of interest = $100,000 + after taxes).				Using prime costs (excl. G & A and Profit) as a base, 100% of cost reductions from ceiling to target will be refunded to us; below target, we share 50-50. Patents tfrd. GE will expedite completion of Erma 1. No progress payments required.			Under Alt. A (Erma), if actual costs are *below* target, we share 50-50; if *over*, renegotiate. Firm prices will be set when order is half completed. Alt. B (Bizmak) prices are firm. Licensing fee of $1 mil. minimum and $1.5 mil. maximum to be paid us under either plan. *We retain patents.* Progress payments req'd: 75% of insured factory costs; no upper limits.		
Maint. & Parts, per year, after taxes (est. subject to revision downward)		766,927		766,927		1,062,190		1,062,190	724,626		947,497
Space requirements		1000 sq. ft.		same		1,625 sq. ft.		same	2,600 sq. ft.		4,000 sq. ft.
Power requirements		25 KW		same		20–25 KW		same	47 KW		82 KW
Years to pay out through savings of $2,781,345 (after taxes) per year		5.39		5.00		3.36		5.06	6.45		5.83
Date of first delivery		Oct. 1957		same		Oct. 1958		same	Oct. 1958		Apr. 1958
Date of last delivery		Aug. 1960		same		Nov. 1960		same	Nov. 1960		Jan. 1960
Penalties for late deliveries		$10,000 per month per system on first six deliveries				$10,000 per month per system on first six deliveries, up to limit of $200,000			$10,000 per month per system up to limit of $200,000		

(Tax Rates: 55.84% normal, 28.84 Capital Gains)

Source: Bank of America, internal report, 1957. Reprinted with permission from Bank of America.

ered. Bank of America was to provide most of the programming support needed to code the applications.

Organizational Learning during Expansion

The maturing of the bank's organization is evident in its ability to develop two complex system expansions and at the same time continue a research program and provide new services. The need for detailed, long-range planning for a service-oriented computer system was well understood as a prerequisite to guiding implementation and conversion of computer-supported processing. The management committee recognized that human planning was at least as important as preparing for equipment and buildings.

The bank's experience demonstrated the importance of involving key senior management in reviewing future system developments. Senior management was a part of the ongoing process, which could become intense when important decisions were to be made. Planning never stopped. The state of current demand, future demand, and expected alternatives was reviewed at least quarterly. Tracking outside developments was a full-time activity. Senior managers continuously developed a portfolio of computer-based product services to meet and influence customer needs. This had evolved naturally from early reviews of customer needs and was refined with the rollout of the 702 and ERMA. Monthly, senior management monitored exception to plans on the status of equipment and applications of new developments, always considering cumulative savings and new adaptations of existing systems.

Equally important, management developed the complementary assets to nurture and support systems and gained perspective on the lead times required to develop support. Space, training, utility support, and backup procedures all had to be planned, maintained, and factored into the "cost" of the system. Management's acquisition of pragmatic competence led it to appreciate the necessary level of detail, the lead times, and the importance of people to the success of the system. Charles Conroy's early difficulties in securing suitable printing made the team conscious of how broadly a new system affects existing practices. Initially, printing seemed a minor detail, but it proved to be a major problem that had to be solved for the system to work. SRI and bank employees became printing experts and that knowledge became a competitive edge. The success of ERMA was due in no small part to the bank's effort in training independent check printers.

As technology managers they had fashioned an evolving technology strategy. They managed a broad spectrum of external sources while continuing an internal inventive activity that expanded process and product design efforts. They had also acquired an understanding of and skill in developing specialized IT with ERMA. They tracked their competitors, learned new ideas, and confirmed their policies with regard to the importance of investing in people. They formulated a program to expand the scope of applications with the 702 and began to gain experience in general as well as special-purpose systems. They had developed an efficient electronic banking factory and moved to operational dependence on IT.

Establishing the Banking Industry Dominant Design: 1958–1964

In late 1958, Systems and Equipment Research progressed from automating to include exception reporting, trend analysis, and notice of time-dependent actions, a move to informate as they automated. IBM 702 use was expanded to increase management support for loans and mutual funds and add such functions as bond investment, branch clearings reconcilement, accounts receivable, and corporate trust. The trust system was developed to provide timely information on due dates, coupon requirements, and other operational activities of portfolio management, including inventory management and accounting and analytical investment portfolio evaluation. An S&ER program initiated the same year to develop standards, due dates, and cutoff points for exception reporting on overdue loans helped managers identify out-of-control situations by tracking actual results rather than merely identifying exceptions for management analysis. Most loans were being tracked by 1959. S&ER clearly had progressed beyond the automation of existing procedures to utilizing programmed procedures on electronic data to improve customer service and deliver new services to the branches and credit offices.

Meanwhile, an S&ER team working with the bank's credit manager for retail businesses developed a design for a timely exception-reporting system that would build upon the new systems. By the end of 1959, the bank had extended exception reporting to all loans, balances, and payment procedures, and a number of analytic packages supported trust and loan officers in portfolio management. Management of large commercial accounts and automation of the general ledger were untouched. Commercial banking did not seem appropriate for inclusion, as it would yield no cost savings, and in any case, managers continuously reviewed their credit accounts to provide personal service to their clients.

In April 1959, twenty newly trained programmers and three seasoned IBM 702 programmer-managers began working with the GE team to test the production ERMA system. With an August completion date for bringing up the San Jose system and a parallel installation of a second ERMA system under way in Los Angeles, activity became intense. A bank team headed by Tom Russo, a systems manager, had developed a proofing system and set of procedures for implementing the bank's proposed operations, which were tested and implemented in San Jose in the fall. Against all odds, and in the face of Stanford Research Institute's initial skepticism and the stormy start of the Bank of America–GE relationship, GE produced ERMA on time and within budget, a matter of great pride to those working on the project.

ERMA was a far different machine from the computer SRI had constructed three years earlier. The state-of-the-art, programmed computer with automatic check sorting and magnetic character recognition input took advantage of progress in many areas, including transistorization and the latest data-processing techniques. The central processor's command structure and peripheral equipment were especially designed for Bank of America's accounting system.

A 1959 analysis of ERMA's economic impact showed savings increasing at a faster rate than cost, owing partly to a greater than expected volume of processing resulting from higher than projected numbers of customers and increases in check usage. Original estimates were for 1.98 million accounts; by the time the system was implemented, there were 2.3 million. More accurate check processing, coupled with the elimination of 2,332 bookkeepers, helped to reduce float and expand the customer capacity of branches and variety of services.

Opening ceremonies for ERMA, held in 1960 at three different locations connected by closed-circuit television, were hosted with great fanfare by Ronald Reagan of *General Electric's Masterpiece Theater*. With the installation of the last ERMA in June 1961, 13 ERMA centers, employing 32 computers, were servicing 2.3 million checking accounts at 238 branches. Conversion of the bank's 2,382,230 savings accounts was begun on January 11, 1962, and completed on February 23, 1962.

Exploiting an All-Electronic Base

Shifting data processing to an all-electronic base had opened a new set of opportunities. There was no longer a crisis to solve, only economy of scale and experience in providing systems to build upon. Over the next seven years Bank of America, under the leadership of Clark Beise and Al Zipf, expanded the domain of information technology to link to customers, support the introduction of new products and services, and improve management control. IT support became a means to market expansion, not just a way to achieve cost savings, and the availability of up-to-date information fostered more effective control throughout the bank.

Believing that with ERMA he could economically open more branches in smaller communities than had previously been possible, Beise aggressively pushed branch growth, acquiring and converting small banks to branches. Branches grew from 617 in 1957 to 871 in 1964, with a peak addition of 81 in 1961. Bank of America owned 40 percent of the branches in California, which accounted for a 44 percent market share (because its branches could serve more customers). At a board of directors review of ERMA on July 19, 1960, Zipf presented a detailed cost analysis of the 1958 proposal for savings for 1963 with a 1960 analysis based on two years of actual experience. Compared with the former manual system, the cost would have been $15,880,000 versus an expected total of $9,775,000 or a $6 million–plus saving, as shown in Table 3-2.[13]

Since the internal supply of available and interested bankers could not keep up with demand for systems personnel, a new approach was adopted — recruiting from engineering schools and training the beginners for a career in systems. The key ingredient was not the electronic boxes, but capable people who could use the boxes effectively. Zipf, Gienapp, and Herb Swenson of S&ER personnel carefully worked the bank's bureaucratic personnel system to make their job classifications of systems personnel equal to middle-level loan officers or branch managers so as to maintain externally competitive salaries. They developed career paths from operations to programming systems to analyst and eventually to manager. Although the bank's system development organization was growing rapidly, the operations organization provided faster promotions for professionals. Gienapp, the human resource leader of the group, creatively documented the functions of the new jobs in order to substantiate salary levels and job titles competitive with

TABLE 3-2 **Comparison of Net Operating Savings Year 1963[a] Proposal October 1958 vs. Proposal June 1960**

	Proposed Oct. 1958	Current Estimate June 1960	Increase/ decrease	%
Proposed Operating Expenses				
Salaries (Staff Costs)	$2,748,817	$4,072,980	$1,324,163	48%
Rent (inc. Taxes & Upkeep)	158,880	197,232	38,352	24%
Janitor	139,944	208,392	68,448	49%
Telephone	95,040	73,200	−21,840	−23%
Power	259,200	252,600	−6,600	−3%
Stationery & Misc. Supplies				
Stationery	310,401	407,706	97,305	31%
Post Printer & Encoder Ribbons	104,760	93,895	−10,865	−10%
Hi-Speed Printer Ribbons	158,760	168,000	9,240	6%
Flexowriter Tape	2,758	(See Note)		
Magnetic Tape	90,720	86,000	−4,720	−5%
	$667,399	$755,601	$88,202	13%
Check Encoding				
Bank Printing Unit	646,668 (Encoding	523,750	−122,918	−19%
Outside Printers	813,528 Only)	1,027,161	213,633	26%
Maintenance				
Air Conditioning	50,160	50,160	0	0%
Post Printers & Encoders	121,480	153,433	31,953	26%
ERMA (not accelerated)	2,520,920 (1959)	2,460,831 (1959)[b]	−60,089	−2%
Total Proposed Operating Cost	$8,222,036	$9,775,340	$1,553,304	19%
Total Present Manual Cost	$12,715,800 (1963)	$15,880,038 (1963)	$3,164,238	25%
Net Operating Saving	$4,493,764	$6,104,698	$1,610,934	36%
Operating Savings After Taxes	$1,819,974	$2,443,943	$613,969	34%

Note: Flexowriter tape is used in the conversion phase only and should not have been included in operating costs in the 1958 estimates.
[a] 1963 was chosen because in the 1958 proposal this was the first full year of operation at capacity.
[b] Reduced by the agreement of January 15, 1960.
Source: Bank of America, internal report, 1965. Reprinted with permission from Bank of America.

outside employers. However, while individually rewarding the creation of a two-culture environment — fast-track techies and traditional bankers — who required much longer to be promoted — began to isolate systems personnel from other bank employees.

The Credit Card Saga

With S&ER overloaded during the ERMA and IBM 702 projects, Howard Leif, asked by Beise to identify other services that might benefit from the processing potential of the new computer systems, had contracted with Arthur Andersen for an analysis of alternatives.

Among other projects, Arthur Andersen had suggested introducing a credit card. Western Union had issued credit cards as early as 1914 but succumbed to expensive operating costs and credit losses. Since the computer could potentially reduce costs and provide tight credit control, Leif recommended that the bank introduce a credit card; a program was initiated in 1958 under the direction of the assistant controller. Development of system design was subcontracted to an outside supplier, which created a debossed card system (depressed versus raised character). The system was to be tested in Fresno in 1959 and, if successful, gradually rolled out to other branches. The plan was to move city by city, issuing credit cards to the bank's better customers, beginning with the valley cities of Sacramento and Redding and refining the system before taking on the large metropolises.

As Bank of America prepared to enter Sacamento, the First Western Bank of San Francisco announced its intention to issue a credit card statewide. With Beise overseas at the time, Leif and the management committee decided, on the basis of a trial, to preempt the competition by immediately rolling out Bank of America's card statewide, beginning in Los Angeles and San Francisco in early 1960. Expansion continued throughout 1960 and into 1961, but when delinquent account losses for the former year were found to exceed $10 million, Leif halted the expansion and changed management. On taking over the credit card program, Jack Dillon initiated a crash development effort with S&ER that was to employ an embossed card and incorporate a credit tracking system. He subsequently brought in Ken Larkin from corporate lending to manage the revised system, which was subsequently installed throughout the branches to replace the existing credit cards. Statewide reissue was completed in late 1961. A follow-up project revised the IBM 702 system to create invoices and account for payments. The new credit card became a solid product and source of strong earnings.

The market popularity of Bank of America's credit card attracted the attention of banks throughout the country. The bank exchanged its credit card system with Mellon Bank of Pittsburgh for a loan portfolio management system and, after Marine Midland of upstate New York bought the system and three other banks expressed strong interest in it, decided to franchise the product. Larkin actively marketed the credit card service nationally and internationally. But when federal banking authorities threatened to sue for illegal interstate banking, Bank of America decided to divest its out-of-state credit card operations. It subsequently sold its non-

California franchises to the founders of Visa and shifted its emphasis to overseas expansion.

Organizational Adaptation

The introduction of the IBM 702 and ERMA systems occasioned fundamental changes in Bank of America's operations. Traditionally, each branch manager had reported to the president as the personal representative of Mr. A. P. Giannini and his successors. Credit granting and various financing instruments were subject to strong functional control, which had grown with the bank. Central credit staffs in Los Angeles and San Francisco had line responsibility for large statewide and national accounts and functional control of branch credit products such as home and consumer loans and Timeplans. Each branch had a manager, an operations officer, a loan/credit officer, and depending on size, a range of positions focused on such customer areas as retail, small business, and home loans. Branch managers operated fairly independently, occasionally visiting the central office and being visited by specialists. They tended to focus on the banking needs of consumers and small retailers and worked to be identified with the community. Branch managers who routinely exceeded project objectives and expanded market share were given greater autonomy and rewarded with promotion to larger branches.

Clark Beise realized when he launched the automation project with S&ER that the organization would have to decentralize. His first step was to create four functional field staffs — in credit, personnel, operations, and business development — that would exert control over the branches from the center of each region. Field representatives of these staffs served groups of geographically adjacent branches.

The automation effort also shifted roles at the branches. The position most affected was that of Operations officer, traditionally the second in command, with the greatest number of direct reports and responsibility for maintaining fiscal integrity. With expansion of its services into operations and loan procedures, S&ER often met with branch operations officers to assist with developmental activities and training. As automation transformed the branches, Operations lost clerical duties and gained increasing responsibilities related to new systems, staffing requirements, training in standard procedures, and managing support for new products. The latter responsibility drew Operations officers into business development and marketing activities, and its strong link to S&ER made it an important presence in the branch.

The result was a shift from laissez-faire independent branch management of a constant product line with functional staff guidance to an ongoing marketing program orchestrated by S&ER through the introduction of new procedures and products. Gradually, through system-development studies and continual search for new applications, S&ER became the dominant influence in the branches.

As S&ER grew, Al Zipf assumed more control over field operations, first by managing the development and implementation of IBM 702 applications and later in deploying the ERMA program. He assumed formal control of operations in 1959 and extended his authority to personnel and bank operations in 1960. Branch managers then had two bosses — Zipf with his area managers and the president with his regional credit managers. The objective was to make every branch officer a business developer with a focus on customer service. Although it was officially a dramatic change, the bank had been moving in this direction since the introduction of the IBM 702.

A New Hardware Base

Customer and application growth created a capacity problem sooner than anticipated, but rapidly changing technology fortunately made it less expensive to upgrade than to continue with existing capacity. The bank's experience with the IBM 702 installation and observation of other banks' experiences suggested a two-year lead time for planning and installing new equipment. Russell Fenwick, an early programmer who became S&ER's system planner, annually forecasted capacity demand four years out, which was in excess of 15 percent per year. By 1958 applications growth resulted not only from the opening of new branches but also from accelerated growth of applications and management reports. Fenwick's projection showed that the bank could exceed the capacity of the IBM 702s by 1960 instead of the planned 1962–1963 date.

IBM had announced its 7000 family of computers in the summer of 1958. Its initial offering was the 7070, a fully transistorized, core memory machine that was less expensive, significantly more powerful and reliable, took up less floor space, and required less air conditioning than the IBM 702. Moreover, the 7070 was to be easily upgraded to take advantage of rapidly changing transistor technology. In the spring of 1959, S&ER ordered two 7070s for delivery in early

1961. Analysis of costs predicted substantial savings from the 7070s, and 7070 assembly language promised a significant improvement in programmer productivity over the constrained machine language and standard IBM programs of the 702. The management committee approved a proposal that documented the value of buying rather than leasing the systems, at a saving of more than $5 million before taxes, assuming a five-year life expectancy.

New accounting systems for the 7070s, completed in 1960, used an exception-based management reporting procedure for branches, credit cards, and trusts. The San Francisco–based systems group moved into a new building in February 1961; the two machines, installed and tested in March, were running production applications in fewer than ten days. Soon thereafter, most of the other programs were upgraded, and those remaining began to be converted from the 702, a complex task that required subtle system modifications to enable their taking full advantage of the 7070s. Conversion was complete by the end of 1961.

New Markets

The IBM 7070 provided excess computer capacity that Zipf and his team believed could be used to expand services to customers outside the bank to earn real income. S&ER subsequently formed a business service group under Hugh Dougherty, a founding member of S&ER, to provide computer-based services to retail stores and professionals. As Bank of America was already linked to the stores through its credit card, it had an established customer list. It began by offering payroll for stores, doctors, and other professionals. Pricing its services competitively enabled the team to gain market share quickly and break even, with a positive cash flow in the second year. The second step was to expand the product line to include professional billing and freight payments.

In late spring 1962, Zipf discussed with the management committee the need to expand computing capacity, noting that the IBM 7070s could process the existing workload until 1968, but that new applications in planning and development, including personal trust, accrual loans, and business services, would require greater capacity. Technological changes, he pointed out, would allow significantly lower per unit costs while adding capacity, with essentially no conversion expense, since the new 7074 was compatible with the 7070. In December 1962 Zipf recommended and the management committee approved conversion to IBM 7074s.

Expanding the Communications Function

Awareness of the importance of communications as an aspect of information processing had led Zipf and S&ER to assimilate the communications functions and actively begin to manage the cost and form of service. Spurred partially by the need to service a broadly distributed branch banking service, the move quickly led to consideration of how communications might be employed to improve service to customers.

By 1959 Bank of America boasted a complete internal communications service, with a new switchboard in Oakland and an expanded service switchboard in San Francisco. Two years later it had the equivalent of an 800 number dial-in service for customers in the San Francisco area. The bank continued to expand its direct-dial switchboards throughout the state and initiated a program to purchase standard telephone equipment for all branches at quantity discounts. A later study of the feasibility of using private point-to-point microwave links between locations in Fresno led Bank of America to file for a license to become one of the earliest private microwave operators. By 1963 the bank was operating its own telephone service throughout California.

Linking computers over telephone lines had reduced transportation costs and permitted information to be processed in a more timely fashion. The trend generally was to centralize processing and develop electronic means for collecting and distributing information. One important set of technological projects concerned communications between ERMA and the IBM 7070s; S&ER developed a magnetic tape conversion method for transferring information from one system to the other. Building on competence gained from working on the 7070-ERMA link, S&ER was able to select an input or remote processing system on a cost-effective basis and plug it into existing communication systems.

Discussion of the Dominant Design Era

The confidence gained in the expansion period fueled Beise's appetite for new IT products, and as his team expanded into the new technology, he and Zipf found a real leap in productivity owing to the new solid-state reliable system. The team realized enormous cost savings on the operation side, and new storage capacity led to the opening of an entirely new set of products. The team shifted to product expansion and new services in addition to automating and informating old systems. Their visions began to grow to services founded on their existing competencies and customer base. Their payroll and payable services were expanding with the rollout of ERMA. Bank of America was changing from an automate/informate focus to a market–new product service strategy. Its economic scale allowed it to make money at lower costs than small customers could realize independently, in proving its reliability. An entire new market based on existing relationships opened up. S&ER, strongly supported by Beise, expanded rapidly, and the cash flow supported this activity.

Beise, who wanted to grow faster to dominate the market, searched beyond his maestro for new ideas, partly because Zipf was wedded to automating, informating, and then expanding on that electronic base and partly because Zipf's team had a great deal to do. Beise wanted to move to new markets. When the credit card venture was proposed, S&ER was overloaded and Beise recruited an inexperienced team to evaluate and introduce a new IT product without involving the credit organization or S&ER. That team became a classic example of enthusiastic product champions who expect a system to be successful without their taking careful steps to prevent problems. They did not institute a trial, nor did they really want to understand what their market was telling them, namely, that the system was cumbersome to use and card impressions were not readable. They wanted success quickly. The resilience of the existing organization demonstrated the value of competence in systems and the ability of experienced line managers to quickly use the systems to bring the product under control.

The maturing of the organization is evident in its ability to move to an all-electronic base as a means to expand its customer base and product line. In addition, the managers continued to experiment and provide new services. They had clearly mastered the art of detailed long-range planning for a service-oriented computer system. In the entire rollout of ERMA, the most serious glitches were caused by weather-related construction delays. Giving as much attention to human planning as to system development and implementation building is an art several companies ignore today.

A second aspect of planning that is evident is the timing and involvement of key individuals. It was a process that became intense as important decisions had to be made. They never stopped planning. They reviewed the state of demand, future demand, and expected alternatives at least quarterly. Involved staff tracked outside developments and senior managers continuously reviewed the needs of their customers. They did it naturally, as they had started

this process in the beginning and refined it with the installation of the 702 and ERMA to enable the 7070 decision as a normal banking investment.

They combined their technological scanning with constrant reviews of capacity and how bottlenecks might be alleviated with new technologies. When none existed and they saw a real need, they confidently invented a system. Their analysis of technology was always based on capacity and cost: How much per unit of service? was the criterion. At this point they were experienced users of transistor-based assembler-programmed computers. They were clever in organizing the input/output functions to increase throughput. In short, they had learned to adapt existing technology.

Zipf and S&ER had become aware of the importance of communications as an aspect of information processing. Among the first to assimilate the communications functions, they began actively to manage the cost and form of service. This was to some extent due to their real needs of servicing a broadly distributed branch banking service. It quickly led them to consider how they could provide better service to customers.

Strategically, the most important lessons were how to use the systems competitively. The following quotation from Zipf's letter recommending the new focused services documents his insights:

> Bank of America's leadership in pioneering the development and application of electronic processing techniques to internal bank accounting activities today yields a competitive advantage from a standpoint of quality and accuracy in existing deposit account services. However, today's advantage is largely, if not entirely, a question of lead time over competition, for with the passage of time, our competition will achieve the same benefits from the plans they now have under way. It is therefore clear that if we are to maintain our position of leadership and the attendant competitive advantages, we must set out now to establish new variations in service that will enable us to preserve our present margin.[14]

Sustaining an Evolving IT Strategy

The group worked to stay ahead in systems in order to stay ahead in services, not as an end in itself. During this era it gained in competence and understanding of the intricacies of operating a growing complex system. On average, 2 million checks were processed and more than a million customer transactions were handled each day. In addition, it was expanding services and attempting to link new services to old to provide better customer service, making the processing more interrelated. At the end it had the lowest cost in the industry and broadest product line through information technology. The group was secure in the belief that its future lay with new technology.

The group had not made any significant shift in the commercial side of the bank other than in trust, owing partly to the personal nature of corporate banking and partly to the lack of scale economics in its customer-relation activities. It converted loan accounting but did not change the loan negotiating process or strive for innovations. Nor did it try to move overseas with its retail computer competence or work with any affiliate. The leadership and Zipf's competence was focused on California retail banking. This concentration influenced the evolution of computing at the bank.

Clark Beise felt that technology was a force which could be managed to meet market needs. The bank was managing an IT-based strategy through which to support market growth. Evaluating the technological risks as well as the market risks was customary. Beise and Frank Dana reviewed the progress of projects under way and approved new proposals quarterly. For large project proposals, full discussions were held with the management committee. The multiple-year plan, which documented cumulative savings to date, and market progress of new services or products were reviewed annually. Special emphasis was placed on these areas and on significant research projects, such as credit card or microwave communication. Beise presented the business case; Zipf handled the technology costs and risks.

With greater understanding of the potential of systems, S&ER's organizational structures changed to fit the bank's new needs. In the early days an operations group to run the computer and a programming team and analyze and create programs was sufficient. Later a standards and control group, which defined operations and programming standards, was created. Soon thereafter a maintenance group to work on released programs was created.

The 702 conversion had driven home the importance of standards not only for input data but for procedures in creating and maintaining programs, operating systems, and files. The value of moving to a standard system to gain overall economies of system development was demonstrated. As the system-development organization grew, working software development standards evolved. The group

was subsequently split to accommodate different customers' needs, a change accompanied by a commitment to maintain well-trained individuals familiar with those requirements.

The S&ER managers combined technological scanning with a review of capacity and how bottlenecks might be alleviated with new technologies. Real needs, unmet by existing technology, were dealt with by inventing a system. The GE experience had taught them a valuable lesson as to the importance of defining the necessary functions of a system before searching for alternatives. Bank processing was considered to be in its elemental steps of input, memory access/size, processing steps, future processing needs, and maintainability requirements. Technology was analyzed on the criteria of capacity and cost: How much per unit of service? As experienced users of transistor-based assembler language programmed computers, they devised clever solutions to organize the input/output functions to increase throughput. In short, the bank personnel had learned to adapt existing technology to their business needs. They were confident they could make things work, and they did.

Senior management grew more and more confident that its systems expertise was a real competitive advantage that would allow it to stay ahead. Continual reviews were held on system progress, alternatives, and new market opportunities for system use. Considering complex investments in research and development became routine. Management had learned to appraise and evaluate the risks of an R&D decision, for example, the Stanford Research Institute overrun and the occasional mishaps with General Electric and IBM. A tradition had evolved of annually reviewing the three-year technological plan that identified major applications and hardware system changes. Zipf was convinced that technology was an engine of growth. Beise felt that technology was a force which could be managed to meet market needs. They were managing an IT-based strategy to support market growth.

Management worked to stay ahead of the competition in systems, not merely as an end in itself but to stay ahead in banking services. Beise, as president, led the management team and was supported by Dana, his operations chief. Together with Zipf, they were the overall designers of IT systems, continually scanning for new technologies. A common tactic was to invent a new service system, then find someone to develop it for them, sharing the risks, as in the credit card. New product services and processes were designed as extensions to existing systems. System support was expanded throughout the value chain to retail store customers, other banks, and the Federal Reserve.

("Buck") Rodgers of IBM believed that the bank was at least two years ahead of all other banks and even further ahead of most financial service companies.[15] Maintaining the bank's lead required confidence in the system and a well-trained staff. A resilient support system had been developed during the implementation of ERMA. The bank managers comfortably assumed that computers were reliable and never failed to deliver on time. By 1962 an extraordinary competence had evolved to develop new products and operate mainframe computer systems in support of banking activities. The largest distributed private-sector system had been installed economically, and on time. The bank was on the top of the mountain, confident and aggressive in its intensions.

Losing Momentum: 1964–1968

In early 1964 S. Clark Beise became chairman of the board and Rudolf A. Peterson, a former bank employee who had been CEO of a Hawaiian bank and had experience in international banking, became president of Bank of America.[16] With California banking opportunities growing well and further expansion within the United States thwarted (A. P. Giannini's dream of U.S. expansion had been denied by the Congress and the Federal Reserve, and there was considerable pressure to divest Transamerica), Peterson's charge from the board was to expand overseas.

That summer Zipf sent Peterson a plan outlining personnel expansion as an introduction to systems planning. The summary, highlighting recent growth in demands on central office systems, which in 1964, with 114 fewer people, was handling 51 million items, an increase of 1 million since 1962, called for increasing administrative staff by 195, with 90 additional people in Business Services, 74 in Trust, and 31 in Systems and Equipment Research. The rationale was to build programming support for an intregrated branch accounting/management system and further expand Business Service's product line by introducing a professional billing service. In lieu of a strategic discussion with the CEO, Zipf received a note from Peterson, who was traveling abroad, to proceed. Peterson, focusing on overseas expansion, delegated all information technology responsibility to Zipf.

The spring 1964 planning review had convinced S&ER management that business service expansions and increased volume would soon exhaust the capacity of the IBM 7074s. IBM had just announced its 360 series to replace all its prior series, including the 1401, 1074, and 7094 computers, and Burroughs, Remington Rand, and General Electric had recently announced new computer models. Analysis of eight different systems convinced S&ER that the IBM 360, with its operating system COBOL support and massive disk storage capacity, was the only true third-generation system; an IBM 360 could replace a 7074 and increase capacity while reducing costs. S&ER subsequently ordered one and initiated a cost-benefit analysis.

Zipf and his team were eager to convert to a higher-level language such as COBOL. Heralded as the programming language of the future, COBOL held the promise of standardized, machine-independent programming, which would minimize the amount of recoding required in moves to subsequent generations of hardware. S&ER was maintaining more than 400,000 lines of assembly code running 2 million machine instructions and adding approximately 80,000 lines of code per year. S&ER personnel would have to convert all these programs, reformat hundreds of millions of tape records into disc format, and learn new operating techniques. The longer S&ER waited, the greater would be the cost to change, which made moving to COBOL a prime objective.

The first step was to bring up the IBM 7074 data-processing programs. Concurrently, planning could begin for conversion of the ERMA system, which would be more complex, its master account file having grown to twenty-two tape reels and become an operating nightmare for daily posting. Tape failures were causing occasional delays in providing the branches with necessary balance information before opening. Russell Fenwick and his colleagues believed that mass disc storage would eliminate existing cumbersome procedures and improve reliability. Although ERMA would have to continue to rely on card-to-tape data capture and tape-to-printer operation, a parallel tape operation was expected to speed the process. The biggest challenge would be running both systems during the transition.

On November 30, 1964, the management committee approved $3,643,100 for the acquisition of two IBM 360/50s to replace the IBM 7074/1401s. Existing 7074 programs would have to be converted from assembler to COBOL, and 7074 tapes to 360 tape formats. On the basis of its 702 and 7070 conversion experience, the bank decided to subcontract a large part of the effort to reduce the hiring hump and allow development to continue.

Consolidating the Hardware Base

In the spring of 1965, IBM announced the details of its operating system for the 360/65, which with greater disc capacity and more upward growth potential than other 360s promised "more bang for the buck." Four IBM 360/65s could replace all the ERMA processors and provide the same overnight service, as well as acccommodate the 7074 workload and planned expansions during daytime processing, thus supplying a consistent computer architecture and the potential for economy-of-scale operations.

Moreover, the 360/65s promised multitasking (i.e., simultaneous input, printing, and computing), which would reduce elapsed processing time, and supported random-access secondary disc storage, which was much faster than serial-access magnetic tape. Existing bank operations were tape and printing bound, and processing growth was pushing the twelve-hour turnaround window for delivering accurate, up-to-date balances to branches each morning. At more than a million transactions per day, the bank was at the upper limit of a tape-based system. The primary operating appeal of the 360/65 was that it would allow consolidation of all operations into two centers with remote inputs and concentrated operations. This would permit the bank to reduce operations personnel, concentrate support at two sites, and keep running up to a seven-day workweek.

To provide background for the IBM 360 decision, S&ER developed the "Impact of Automation," an economic analysis dated November 8, 1965, and discussed it at a management committee meeting called to review the progress of automation. The analysis, based on the number of employees the bank would have to hire to support its current business at standard manual times for processing tasks, concluded that the existing 2,862 system employees would have to be increased to 4,478. Adjusting for differences in higher system salaries, the annual savings for ERMA would be $4.6 million. Furthermore, actual head count in check processing was decreasing as volume was increasing. Bank of America's profitability continued to rise with expanded service and efficiency enhancements, and processing costs per transaction had fallen by more than 7 percent per year for the past four years. But the bank was approaching a

limit to growth within the existing ERMA system. The new computer promised an opportunity to continue striding foward.

A careful cost analysis of alternative systems of comparable capacity, including utilization of the ERMA for its full operating life versus switching to the IBM 360/65, demonstrated operating expense savings of $12 million from converting ERMA and the 7074s to 360/65s. Growth and dramatic improvements in technology had led Zipf to make this request four years earlier than he had anticipated. The management committee, after some discussion, approved a $14.22 million proposal (considerably less than the $32 million it took to build the GE ERMAs) to replace ERMA with two IBM 360/65s and substitute two more 360/65s for the 360/50s.

Converting ERMA

Zipf and his team planned to begin converting ERMA and IBM 7074 programs to the 360/65s after scheduled delivery in June or July 1966. Check processing was to be done at night, most normal data processing during the day. Existing 7074 procedures were to be tested on the 360/50 over the winter and spring of 1966 and converted to the 360/65s on their arrival in the summer. Conversion was to be completed by December.

The ERMA conversion was to be a massive task. Fenwick estimated that approximately 500 man-years of programming, data conversion, and testing would be required to convert all bank systems to a COBOL-based disc system. Existing systems would not only have to be converted, but also relieved of accumulated patches made over the years and improved to take advantage of disk access. The S&ER staff was to be augmented with IBM system developers and a number of consultant programming groups. In fact, there were to be as many outside as inside staff reprogramming and building new systems during the transition period. The IBM 360/50s were to be installed on delivery and replaced by the 360/65s as soon as the latter became available.

EARLY DISILLUSIONMENTS. The first IBM 360/50 arrived in San Francisco in September 1965, the second in Los Angeles in October. By mid-November it had become apparent that IBM's operating system was not functioning effectively and was highly unstable except in running jobs one at a time. Gloom spread through the S&ER group, but programming continued, one job at a time being debugged with sample data. Conversion plans had to be revised considerably because of the instability of the IBM software. On the basis of conversations with senior IBM executives, S&ER members were convinced that they would be able to begin heavy-duty conversion efforts by summer, and a personnel plan was implemented for training and placement of ERMA workers to be transferred to other jobs later that year.

In January 1966, S&ER informed the management committee of a revised plan that deferred the start of the conversion until August 1966. They warned of the possibility of further delays, citing a faulty operating system and unstable tape and disc drives. S&ER estimated the cost of system failure and lost work at between $70,000 and $100,000. Capacity restrictions soon began to influence operations. Business Services, which had been growing at 15 to 20 percent per year, believing that it could not deliver, stopped soliciting new business and terminated several of the projects it had under way, such as loan flooring, which promised a 200 percent return on investment. Worse, contention surfaced in job scheduling for on-time delivery. Growing demand from both new market services and volume expansion among existing customers exacerbated the problem and delays persisted.

On December 9, 1966, S&ER informed the management committee that the conversion of IBM 360 programs was deferred once again as a result of IBM's continued delay in providing a multitasking operating system. IBM informed the bank that "no other large scale business user . . . approaches [the bank's] level of complexity of multiprogrammed systems."[17] The additional expense of delay, estimated at $364,000, was due to the cost of maintaining parallel systems and a loss of programming effectiveness stemming from operating system failures. Data-processing and ERMA programs were converted to a IBM 360 assembler, with some COBOL routines, using IBM service center 360s and the bank's 360/50s.

By late December 1966, the operating system seemed stable and it was decided to try to convert the mutual fund package, which relied on a massive tape file of the Los Angeles and a smaller file of the San Francisco customer bases. Conversion, scheduled to occur over the New Year's holiday, went as planned in San Francisco. But in Los Angeles, where the entire twenty-reel customer master file had to be updated to finish the conversion, the new high-speed tape systems proved inoperable. Fenwick was called away from a New Year's party at Zipf's home to try to expedite the conversion. After three hours, he called IBM's Buck Rodgers, the company's banking industry executive, who flew a team of IBM tape specialists and system engineers in from Denver to mount a massive change-

over effort, which failed. But at least all then understood the scope of the problem: the size and sophistication of the application was pushing the IBM 360/65 to the limits of its capacity. IBM's hardware support was good, but its lack of strong software had hurt the effort.

END-OF-CONVERSION CRISES. Frustration at the lack of progress and delays in bringing up new systems generated a storm of criticism from members of the management committee in the spring of 1967. Zipf felt compelled to defend his decision to proceed with the IBM 360; on May 10, 1967, he dispatched a letter of explanation to Peterson in which he noted that

> 1966 was the first disappointing year since the group was created in 1954. Disappointing because the delays in converting to the 360 systems did not permit us to achieve the operating economies that had been forecast. Having acknowledged responsibility for what have proven to be unrealistic conversion schedules, I should not like to think my error in judgment will reflect unfavorably upon a competent, dedicated staff who worked ceaselessly in an attempt to achieve the impossible.[18]

On May 25, Zipf reviewed with the management committee a plan that had been prepared in late March, but delayed because of improvements in systems stability and the addition of more core memory. The plan, developed by Fenwick, suggested that S&ER was finally seeing light at the end of the tunnel. The department had regrouped, summarized its progress, and generated a more positive plan with demonstrable results. Morale, which had been terrible, had picked up and the group's "can do" spirit returned.

Although only 35,000 of 400,000 BankAmericard and 504,000 of 2 million Timeplan accounts had been converted by March, the group gained momentum during a stable and productive April; by May it had completed the conversion of BankAmericard, Timeplan, and one of the largest ERMA products. The group had developed new fail-soft procedures and through strenuous efforts with IBM had stabilized the tape subsystems. An additional ray of hope came from the successful start of the demand deposits conversion, the bank's largest ERMA application. With the transformation secure in the spring, Zipf, in a presentation to the management committee, emphasized that not only had other banks followed its leadership to similar systems, but the others' shifts vividly demonstrated the Bank of America economy of scale, as shown in Table 3-3.[19]

However, the delay had entailed serious costs. A staff analysis

TABLE 3-3 Deposit and Loan Volume
Bank of America and Principal Competitors System Comparison

No. of Accounts	Bank of America	Wells Fargo	UCB	Crocker Citizens	Security Pacific
Checking	2,695,000	600,000	350,000	650,000	1,300,000
Savings	3,033,000	650,000	450,000[a]	600,000	673,000
Installment Loans	1,130,000	125,000	300,000	500,000	250,000
Real Estate Loans	263,000	75,000	13,000	25,000[a]	40,000
Total	7,121,000	1,450,000	1,113,000	1,775,000	2,263,000
Equipment	(4) 360-65s	(2) 360-65s	(1) 360-65s	(2) 360-65s	(2) 360-65s
Del'd or on order	(2) 360-30s	(8) 360-30s	(5) 360-30s	(2) 360-50s (2) 360-40s (6) 360-30s	

Source: Memorandum from A. R. Zipf to R. A. Peterson, Samual B. Stewart, F. M. Dana; subject: Computer Systems — Third Generation, Burroughs vs. IBM, May 5, 1967. Reprinted with permission from Bank of America.
[a] Approximations.

suggested that conversion delays for some of the services, such as the flooring program, had had a direct economic impact on profits of $1,471,000 and that delays in developing new products for BankAmericard and providing more automated support for mutual funds and trust had significant negative impacts on earnings. Total impact was estimated to be in the millions of dollars, offset, according to the report, by IBM's contributions, which increased paying all equipment costs, providing professional help valued at $2,700,160, and maintaining an account balance of more than $14 million.[20]

The inescapable conclusion was that the massive conversion effort had failed because of software problems. The report reviewed all the decisions, including the new plan and the cost of the bank of programming and outside help. By May the total direct reprogramming effort was estimated at 167 man-years at a cost of $1.65 million, of which at least 37.4 man-years, valued at $363,834, had been lost — a costly effort.

Discussion of Stagnant Period

The IBM 360 conversion debacle could not have happened at a worse time. Senior management had just shifted from an operations orientation with long experience in systems to a credit orientation with no systems experience or interest. Promotion of key architect

Al Zipf to a wider venue had diluted his influence and diminished reliance on his expertise. Dialogue among senior members of the group about systems development ceased and nothing formal replaced that interchange. System managers, overwhelmed with the conversion, could devote little time or energy to promoting general understanding of what was happening, and the technicians, because the system they had chosen was not working, were constrained in their explanation.

The systems group, which over time had become isolated from the rest of the bank, was nurturing managers from within. It had enjoyed a history of rapid growth and quick promotions; managers in systems were promoted in about half the time and garnered higher salaries than managers in operations, causing resentment in some quarters (for example, Russell Fenwick at thirty-one became Bank of America's youngest vice president ever). Tension between the two cultures continued to grow.

Unfortunately, what the new senior managers believed they had learned was that trying new technology is risky and unnecessary, that the only safe move is to use "tried and true" technology. Moreover, they came to believe that computer suppliers, IBM in particular, were not to be trusted. Senior management reached these conclusions as observers, not as active participants in the events or from hands-on reviews of system development efforts. With no one but Zipf competent or interested, IT development was no longer a senior management topic. IT had become a tough sell, and Zipf, who also had a retail banking agenda, had to select his topics carefully. Ultimately the lessons of the IBM 360 conversion were absorbed only by the technical, not the senior, managers. They moved from a strategic use of IT as their engine of growth to a support IT strategy.

The systems group soon learned the terror of unreliable systems and disgruntled customers. As long as the group was pushing the limits of the technology, any change in the system could and did result in system crashes. Because S&ER took the blame, regardless of the source of the crash, the group became conservative and tested very carefully. Group members became, by some accounts, highly cautious noninnovators.

Lacking senior management support and unable to deliver new services, the systems group quickly lost any remaining support among its active practitioners, who began to use the chain of command to secure priorities rather than work within the system planning process or take leadership from S&ER. The long-term effect of the two-culture environment and conversion debacle was to turn S&ER's once docile customers into aggressive, shortsighted cost savers.

Finally, four years of seven-day workweeks and eighteen-hour days had exacted a toll on the health and morale of the group. The IBM representatives noted that when the conversion was finally complete, the exhausted group received no compliments from users, who had waited impatiently to get on with their work and viewed the job as long overdue. In the wake of the strenuous effort, the systems group faced the development backlog with little enthusiasm. It had learned both the frustration and sadness of failure.

A more fundamental impact on the bank's IT orientation resulted from the lack of shared vision or understanding between Rudolf Peterson and his maestro. Peterson viewed Zipf, whom he trusted implicitly in the dual role of line officer and maestro, as automating retail banking while expanding market share and adding new products. The CEO neither believed it to be his role, nor was he inclined to explore new avenues for IT. Peterson's interest, encouraged by the bank's board, was in expanding commercial banking overseas, a pursuit for which he saw no relevance for IT.

In hindsight, it would have been wiser to experiment with the 360/50 in connection with the delivery of the less time-dependent customer-oriented services. But with the opportunities so great and the risks seemingly so modest, Zipf had boldly struck out. Falling back and regrouping was not considered. No other senior executive had any interest or competence in IT, and IBM's marketing branch was unaware of how far behind schedule development of the multitasking operating system had fallen. Quite simply, both the vendor and the customer had underestimated the complexity of the project.

The Cost-Minimization Era: 1968–1978

Events returned somewhat to normal during 1968. The IBM 360 conversion, despite an enormous backlog of work, was under control, but urgent priorities arising from failures of outmoded systems interrupted other activities. Changeover of the general ledger had to be aborted to deal with a number of operating systems crises, and continued conversion demands delayed almost all requests for support and new products.

Although the S&ER leadership believed that the conversion, because it had resulted in the development of a modern, stable platform as a basis for growth, had been worth the effort, senior management was skeptical. A. W. ("Tom") Clausen, who replaced Peterson as CEO in late 1969, continued to emphasize credit and overseas expansion. Zipf, the only management committee member with operations or computer experience, was promoted to executive vice president in charge of the California bank in the spring of 1970. He was charged with reorganizing retail from a functional to an area structure, and given responsibility for marketing, credit, operations, personnel, and profit of the retail bank. Fenwick became the operational leader of S&ER, reporting to Samuel Stewart, a lawyer in charge of administrative functions. With a backlog of system work, Fenwick and the S&ER team focused inward.

The S&ER management process had changed from an annual three-year planning discussion and follow-up annual budgeting session with quarterly program review with the management committee to an annual budgeting session oriented toward short-term payoffs. Despite a severe backlog and more work than staff, expansion of S&ER was not considered. The new senior management, preoccupied with expanding overseas and managing California retail operations for cash flow, did not perceive any overseas opportunities for IT, and the recent conversion experience had shaken its confidence in technology.

S&ER continued to grow apace with overall volume expansion but lost its leadership role. The early 1970s were devoted to catching up with systems work and improving existing services. S&ER's experience was in large mainframe systems and batch processing; its technicians had little experience with and no means to test on-line processing with database technology. Such an implementation would have required a complete rewrite of existing systems, a task for which they had no enthusiasm. S&ER had slipped behind a full generation of computer software, and its systems effort was not in strategic mode. The group had come to be viewed and managed as a production factory, driven by low cost and timely processing, not product or service innovation. Its broad presence in California and efficient service continued to sustain a growth in retail banking into the 1970s.

Expanding Abroad

By the 1970s Bank of America had eighty-eight overseas branches in eleven countries. With the credit market abroad growing faster than that in the United States, management focused on expanding such markets to gain economy of scale. Overseas system development began in 1968 with a London accounts receivable project that was quickly extended to provide a comprehensive analysis of overall accounting needs.

Development of a new loan-reporting-and-accounting system was led by S&ER's Bruce Foster, an experienced systems developer. The design selected after an extended proposal process called for a central site with distributed minicomputers in the branches. In August consideration was given to means of improving vendor maintenance response to machine failures, which had become common. At the same time, more horsepower was applied to printing, disk storage was expanded, and commitments were made to rapid response. Still the systems failed, so in spring 1975, Alvin Rice, senior vice president of the International Division, demanded a "high noon" review of international support. This resulted in the transfer of international computer support from the central group to Rice's organizations. With international development fragmented in Europe, Asia, and South America, Bank of America's systems groups lacked the coherent image that Citibank and other competitors had fostered. However, electronic banking had not become a force, and Bank of America's markets were growing rapidly owing to the bank's presence and breadth of product line.

Management Succession

In the early 1970s the four systems groups (S&ER, Centralized Operations, Business Services, and Management Science) had reported to Stewart and coordinated with one another, maintaining close ties to Zipf. When Stewart retired in 1973, Zipf assumed responsibility for the computer groups, but being deeply involved in managing the California bank, delegated day-to-day activities to Fenwick. Gradually the systems organizations drifted apart, Business Services creating its own development group. As it became completely independent and forsook technology sharing, Business Services' income growth began to erode and costs increased.

When illness caused Zipf suddenly to retire in 1975, Tom Clausen selected Stan Langsdorf, a former comptroller, to be responsible for all administrative systems, including S&ER. Langsdorf, a relatively passive manager, allowed the three remaining systems groups to continue to coordinate domestic development. In 1975, after receiving permission from the comptroller of the currency, S&ER experimented with ATMs. Fenwick proposed, but the head of branch operations vetoed as too expensive, risky, and counter to the bank's tradition of personal service, a statewide introduction of ATMs.

Bank of America was growing faster overseas than in California, where it had begun to lose market share. Its share further declined as Security Pacific and Wells Fargo rolled out ATMs and other competitors aggressively introduced new loan products. By 1978 Bank of America was being outstripped by all its major competitors and losing market share per branch. This loss was due to a variety of factors, growth of competitors, increased price and product competition, and lag in systems development significant among them. The bank's decentralized, branch-oriented full line of banking emphasized loans as the prime source of income; in IT services the bank lagged considerably behind those of the competition. Senior management in retail banking had a strong bottom-line profit orientation with no in-depth understanding of the economics of systems development. Twenty-six executives had to agree to the acquisition of a significant computer system for the California division; consequently, there had been no major improvements in several years.

Organizational Learning during the Declining Years

The seventies marked a continued shift in Bank of America's strategy from focusing on California to focusing on the international scene and on loans rather than on retail banking. This change was pushed by capable credit managers with no experience or interest in computer technology; stylistically they were delegators rather than hands-on managers. They inherited a split voice for systems: Stewart's pleas for caution and cost control and Zipf's thrust to stay technologically strong.

The ability of Zipf to lead actively was encumbered by his responsibilities in managing the largest retail banking operation in the world in a time of increasing competition and continued population growth. Although he maintained close contact with S&ER, adhering to his retail banking agenda was a severe challenge, and he could spare only modest energies to focus on systems. Further, Stewart's formal authority limited Zipf's influence.

Systems continued to grow to keep pace with the overall volume expansion but lost its new processes leadership role. The early seventies were devoted to catching up on systems and improving existing services. S&ER's experience was in large mainframe systems;

developments in distributed systems were producing innovations in which the group had little practical knowledge. Although it had developed a large, mainframe-based branch support system on the latest IBM equipment, it began to gain experience relatively late in 1972. The system effort was not in a strategic mode — at best it was considered a production factory and managed as one. S&ER was driven by maintaining low cost and timely processing, not innovating products or services. Because it delayed its decision on space, as well as concern for not being first in a computer technology, the bank was a late converter to the IBM 370. This limited its opportunities to move to on-line query and remote processing. Part of the problem was the massive rewrite of existing software that would have been necessary and S&ER's reluctance to undertake that task.

By the end of the era management had lost all its managerial and system competence to effectively guide the development of competitive information systems. The conversion to the 370 absorbed S&ER. Only system managers were concerned with innovative systems. There was a complex set of reviews: any proposal that required investment and new technology generated tension. Hugh Dougherty retired when the environment ceased being fun. Fenwick left, not merely because he did not get the promotion, but also because of the continued hassles the job entailed. They were the last of the old-guard managers, although most of the programming efforts were still run by experienced system managers. In five years the bulk of the innovative talent in the organization in both the systems and management groups had dissipated. Joe Carrera, an effective comptroller, was experienced in solving operational problems but had no familiarity with computers. Having observed the 360 debacle, he wanted to distance himself from the problem.

The fundamental cause of this dramatic loss of technological leadership was lack of concern in maintaining an edge. The new management did not have an understanding and perspective of managing technology. It was composed of credit-oriented bankers when systems had not yet become a powerful force. Leadership must be nurtured to be sustained.

The Long Climb Back: Building Competence

Clausen, who began to recognize the problem in 1978, appointed John Mickel senior vice president in charge of systems.[21] Mickel, the former CEO of Decimus, one of Bank of America's most profitable

subsidiaries, had a strong product-line marketing focus. He was charged with staunching the loss of market share by reviving the competitiveness of the bank's computer systems with newer technology in the branches. With Clausen's sponsorship, Mickel recommended two critical projects that seemed essential to providing a basis for electronic banking: statewide rollout of ATMs and shifting the demand-deposit accounting system for checking to an on-line database system, which would provide easy access to data and support more rapid development of new products and services.[22] Both projects received full funding for a two-year implementation. Mickel recruited teams of experienced systems managers and outside consultants and hired Peter Hill from IBM to provide guidance in developing a distributed system. Twenty-six ATMs tested by the Santa Clara branch were subsequently deployed statewide. In 1981, eighteen months into both projects, Clausen went to the World Bank and Samuel H. Armacost became CEO. Worldwide banking was in a credit crisis and U.S. banking was in the process of deregulation. Bank of America's loan and credit portfolios were mismatched and its decentralized organization was ill prepared to meet demands for rapid response.[23]

Armacost embarked on a reevaluation of Bank of America's systems strategy, recruiting Max Hopper from American Airlines to restore momentum in retail banking — Mickel had left to start a telecommunications business — and forming a senior retail banking advisory committee.[24] Discussions between Armacost and Hopper about how to make the bank a competitive systems user became a daily ritual, and a vision for the future emerged. Hopper recruited Bruce Fadem of IBM Systems to run Retail Banking and Joe Ervin to head Operations and Technology. This team, with Hill, analyzed the bank's need to develop an overall architecture, which was discussed with an expanded advisory committee.

With the help of Hill, Fadem, and Ervin, Hopper initiated the development of a high-capacity, bankwide communications system and centralized policy to create an overall bank view. Recognizing that enormous investments would be required to bring the bank's structure up to competitive standards, he initiated two major system-development projects — BankAmerica Systems Engineering (BASE) and BankAmerica Payments Systems (BAPs) — to provide the essential architecture for the future. As a member of the management committee, Hopper was involved in discussions of why these systems were essential to establish bankwide standards and support the eventual integration of information and payments.

Armacost had recruited Tom Cooper, an early ATM proponent, an experienced computer user, and a cost-oriented banker from Mellon Bank, to the International Division for the worldwide rollout of BAPS. They developed a program to integrate overseas and expand the product line with BAPS. When Bank of America subsequently experienced a series of earnings pressures that made expansion unpopular and cost cutting important, Cooper pressed to reduce system costs and slow the transition, while Hopper believed it was essential to continue. When Armacost sided with Cooper, Hopper returned to American Airlines and was replaced by Lou Mertes of SeaFirst of Seattle, a Bank of America subsidiary.

Armacost and Cooper charged Mertes with controlling systems costs, establishing a business-oriented planning process, and developing a bottom-up planning and budgeting process that would provide an economically sound basis on which the management committee might evaluate systems investments. Mertes emphasized a detailed, analytical economic planning discipline as the core of systems planning and worked to streamline and reduce the size of the systems organization. When he left a year later after a series of system problems, Hill and Fadem became acting managers of information technology.

Clausen, returning to Bank of America in 1986, assumed personal responsibility for restoring the bank's leadership position in IT. His search for a strong IT manager produced Mike Simmons of Fidelity, who subsequently launched an aggressive integration of electronic banking in Credit and Retail worldwide. Dick Griffith, hired by Clausen from the Federal Reserve to manage Wholesale Banking, brought with him Bill Ott, the architect of the Federal Reserve system. With this new team, which possessed more than a hundred years of systems development experience, and the competent technical managers Mickel and Hopper had hired, the systems function regained its intellectual base.

Simmons, charged with demystifying the technology and encouraging users to support expansion, worked with Clausen to better understand users' requirements. Finishing the implementation of BASE and BAPS, they were early marketers of a personal computer-based treasurer's system. Simmons artfully described the impact of IT programs in customer terms and organized a user committee of senior managers that met regularly to review a portfolio of proposed projects and establish priorities.[25] He also rejuvenated Hopper's experiments in future technologies and created a lab to test, among other products, a new smart card. Most important, his team produced reliable, money-making services and products on time and within budget.

Hopper's communications network capitalized on economies of scale by consolidating all systems at the four existing sites into one overseas system in London (for Asia and Europe), all national accounts in San Francisco, and South American accounts in Los Angeles. This network, coupled with a coherent hardware design consolidated around a few vendors and software systems with consistent operating systems, lent Bank of America a modern bank architecture. At Clausen's retirement in 1992, Richard Rosenberg was named CEO. When Simmons subsequently moved on to First Boston to continue rebuilding, Rosenberg hired as his new maestro Marty Stein of Paine Webber, who was later promoted to vice chairman.

Diversion cost it twenty-two years, but Bank of America has regained its leadership position and is building momentum. The next dominant design for information processing in banking, if it is not originated by Bank of America, will quickly be appropriated by the bank.

Discussion of Decline and Regaining Momentum

The gradual demise of Bank of America prowess in IT was masked by its incredible economy of scale and competence in retail banking. The California bank was a classic cash cow as it allowed its technological competence to decline. Had it rolled out ATMs, the bank might have moved into other new technologies. Technological brass rings appear but quickly pass the hesitators. Senior IT line leadership is essential to sustain appraisal of the art of the possible. These investments require an understanding of both the potential and the risks of emerging information-processing innovations. Had the bank been experimenting with minicomputers along with its competitors, management might have understood the future trend in IT architecture and the need for ATMs. Management has to appreciate the market impact of emerging IT innovations within an evolving IT strategy. Few unique innovations cause a strategic shift, but the fast pace of change in the underlying chip continually causes potential services to appear. To judge the innovation effectively requires a shared vision of how the organization could function as well as how to merge new technologies and move the organization. The bank leadership lost the planning process and thereby sowed the seeds of its eventual loss of leadership.

The ensuing saga demonstrates the momentum an IT strategy creates and the ability to obtain short-run profits at the expense of long-term gains. As Richard Vietor has pointed out, IT was a contributing factor to the mismatch of the bank's loan- and interest-generating portfolios. Whether that was a direct result of not continuing improvements in management control is not clear. However, lack of an integrated overseas system hindered the bank in understanding its overall international portfolio and allowed individual managers to pursue different policies. Domestically, the bank not only fell behind but extended an outmoded technology, creating a more costly renovation project.

The Bank of America had lost its apparent technical competence and ability to frame technological investments in business terms acceptable to the line managers. Whether the loss was real or apparent is irrelevant because the IT group could not arrange a productive hearing of the issues and opportunities. A dialogue is essential to maintain the ability to perceive the impact of new technologies on the market and to believe in the economics of the investment. In large part, innovating with IT is a matter of faith created by experience. A key issue is to perceive how an innovation will affect the organization as well as the market. At their peak, Beise and team could review an idea and instantly perceive the impact on their markets and costs, for example, of the credit card. The technological glitch arose from lack of experience in developing and implementing the system and failing to involve S&ER.

The long climb back to competence documents the deep, implicit nature of an IT strategy. Management's attentive curiosity to the art of the possible and willingness to experiment depends upon IT leadership. Information processing typically impacts not only procedures and services but also the management process and organizational structure. The line managers during the decline of IT at the bank realized that they had to rely on IT and wanted to sustain it within their purview. They gradually created a strong control system to maintain the status quo — a typical response, as IT causes change that can threaten roles, the experience base of individuals, and power bases. Creating a vision that includes how the organization could function and the growth potential is a salient facet of IT strategic planning.

The long road back required not only rebuilding technology but also perspective on the competitive value of IT. Clausen saw the need and moved but did not weave the effort into the bank's processes. Armacost, who recruited and empowered Hopper, again, had not embedded IT as a vital element of strategy. When Clausen returned, he realized the full court-press effort required to regain momentum and effectively built upon former efforts to forge an IT-based strategy. The saga documents the ease of slipping and the expense of regaining momentum.

Notes

1. Detail references can be found in A. Weaver Fisher and J. L. McKenney, "The Development of the ERMA Banking System: Lessons from History," *IEEE Annals of the History of Computing*, 15, no. 1 (1993): 44–57.

2. SRI memo, G. B. Gibson to J. Noe, December 6, 1954.

3. A proof machine totaled and sorted by bank, branch, or general category batched checks submitted by tellers. The machine operator checked individual totals against adding machine tapes supplied by the tellers and the total of all sorted checks against the total of all the tapes. Batched checks transferred between sort stations were accompanied by printed tallies of individual amounts and totals until the final sort to customer account. Automating proofing inferred that the operator would enter check amounts and the system would read encoded customer identification information, eliminating subsequent manual activities.

4. Frederic C. Lane, *Andrea Barbarigo, Merchant of Venice, 1418–1449*, Johns Hopkins University Studies in Historical and Political Sciences, Series 62, no. 1 (Baltimore: Johns Hopkins Press, 1944).

5. "A History of the Electronic Recording Machine (ERM)," SRI, Menlo Park, Calif., June 1, 1955.

6. Letter from A. R. Zipf to L. M. Giannini, December 27, 1950.

7. The others were Bank of America, Portland National Bank (Oregon), First Wachovia (Winston-Salem), Fletcher National (Indianapolis), Salt Lake National, First National Bank of Chicago, First of Dallas, Republic National (Texas), Chase Manhattan, and First National City Bank of New York.

8. Other members of the technical subcommittee included Herbert A. Corey of the First National Bank of Boston, which was a leader in the use of proofing machines and had an excellent cost system; C. M. "Mac" Weaver of the First National Bank of Chicago, which used bar-code traveler's checks; and Loren Erickson of the First National City Bank of New York, which was implementing a slave check-processing system. Later, Raymond C. Kolb at Mellon Bank, who had installed one of the first computers in banking, joined the committee; David Hinkel, also of Mellon, replaced Weaver. Edward Shipley, the auditor at the Wachovia Bank and an enthusiastic computer user, joined the committee in the second year.

9. The ERM was designed to automate the bookkeeping details of 50,000 checking accounts. The computer and drum memory were used to determine whether checks exceeded account balances (the memory stored only account numbers and current balances), with proofing and sorting performed on supporting systems. Account numbers, names, addresses, checks by amount and date, and current balances were retained on magnetic tape, from which was printed monthly a record of all account activity, including calculated service charges for each account. The computer, which comprised 8,200 vacuum tubes, 34,000 diodes, 5 input consoles with electronic reading devices, 2 magnetic memory drums, a check sorter, high-speed printer, power control panel, power plant and maintenance board, 24 racks holding 1,500 electrical and 500 relay packages, 12 magnetic tape drives, each able to handle 2,400 foot tape reels, a refrigeration system, and more than one million feet of wire, weighed a hefty 25 tons and occupied 400 square feet.

10. J. L. McKenney, "Developing a Common Machine Language for Banking: The ABA Technical Subcommittee Story," HBS Working Paper 92-061, 1992.

11. Memo from F. Dana to A. R. Zipf, October 27, 1957.

12. Cost justification to GE ERMA, board presentation, November 14, 1956.

13. Summary of board of directors' presentation, July 19, 1960.

14. Letter to S. C. Beise, December 10, 1962.

15. T. P. "Buck" Rodgers, interview with author, March 12, 1992.

16. See J. L. McKenney, and A. Weaver Fisher, "The Growth of Electronic Banking at Bank of America," IEEE *Annals of the History of Computing* 15, no. 3 (1993): 87–93, for reference details.

17. Rodgers, interview.

18. A. R. Zipf, letter to R. A. Peterson, May 10, 1967.

19. A. R. Zipf memorandum to R. A. Peterson, Samuel B. Stewart, and F. M. Dana, May 5, 1967; subject: Computer Systems–Third Generation Burroughs vs. IBM.

20. During the conversion IBM had invested 66 field engineer man-years and 10 tape specialist man-years to make the subsystem operable. At one point an IBM 360 production team had been flown in from Poughkeepsie to "make the system work." After the conversion, IBM accepted the GE equipment as a trade-in, allowing credit for the remaining book value of the ERMAs. A first for IBM, the allowance was kept confidential to avoid starting a trend.

21. McKenney interviews with Clausen, May 17, 1990, October 22, 1992.

22. McKenney interview with Mickel, October 22, 1992.

23. R. L. Vietor and J. M. Lynch, "Bank of America Corp. (A), Case No. 9-390-176" (Boston: Harvard Business School, 1990).

24. McKenney interview with Hopper, October 5, 1992.

25. McKenney interview with Simmons, September 18, 1992.