nearing completion. This machine uses approximately 1,500 ferractors, 9,000 germanium diodes, and several dozen transistors. Only a few vacuum tubes are used in the circuits which generate the carrier essential to the operation of the magnetic amplifier. The information rate of the machine is 660 kilocycles. This was chosen as a conservative figure for the first attempt at a large system.

The basic circuit is the series magnetic amplifier in which the output circuit is fed from a low impedance source. This type of amplifier has the following advantages:

1. Power is distributed from a constant-voltage low-impedance pulse power supply instead of a constant-current high-impedance power supply as heretofore used in magnetic circuits. It is much easier to generate and distribute high frequency pulse power at a low-impedance level than at a high-impedance level.
2. Each amplifier performs the functions of pulse shaping and timing, in addition to power amplification.
3. The zero output signal is easy to handle by straightforward amplitude clipping techniques.
4. The circuits are simple and require a minimum of components.

The analysis of the high frequency operation of magnetic amplifiers includes consideration of all core and circuit tolerances as well as the high frequency properties of magnetic materials and the associated diodes. In order that system reliability be realized a standard minimum output signal from an amplifier with maximum load is assumed. The design is such that the minimum output signal which is obtained under worst operating conditions is sufficiently large to operate the intended circuits in the computer. The zero signal is effectively suppressed by the amplitude clipper referred to in the foregoing. Furthermore, the magnetic cores have the property of integrating the effects of signals applied to them. Therefore, they are not as sensitive to high frequency noise as other types of circuits.

An exhaustive study of the characteristics of all commercial magnetic materials and some specially made in the laboratory showed the superiority of *4-79* molybdenum permalloy for magnetic amplifier applications. The analysis of the gain of magnetic amplifiers shows clearly the detrimental effect of space factor on magnetic amplifier gain. The gain goes down as the ratio of magnetic material cross section to air cross section in the amplifier output winding decreases. A realization of the importance of space factor led to the use of a stainless steel bobbin as a support for the magnetic material and wire. It is possible to fabricate stainless steel with much thinner walls than the ceramics which are customarily used as bobbins for magnetic amplifiers. Difficulty is experienced in machining ceramics to a thickness smaller than 0.015 inch. As this thickness is approached the ceramic loses strength and becomes as fragile as an egg shell. On the other hand, stainless steel can be fabricated into bobbins with walls of thicknesses as small as 0.003 inch. These bobbins have adequate strength if they are handled with care.

A typical design of a core for the computer referred to above has 13 wraps of 1/8-mil *4-79* molybdenum permalloy tape, 1/32 inch wide, wound on a stainless steel bobbin, 0.1 inch diameter. The cores are machine wound and potted in hermetic seal headers. The headers are then mounted on printed circuit boards which also contain associated diodes and resistors. These printed circuit boards are plugged into the computer frame work.

Laboratory experience with the computer has shown the magnetic circuits to be very reliable. In low frequency applications magnetic amplifiers have been unsurpassed in reliability when properly designed and packaged. Now that high speeds have been achieved with magnetic amplifiers, speeds that are comparable to those which can be obtained with any other available method of power amplification, the magnetic amplifier will find wide use in high-speed pulse handling systems.

Purpose and Application of the RCA BIZMAC System

W. K. HALSTEAD J. W. LEAS J. N. MARSHALL E. E. MINETT

THIS presentation before the 1956 Western Joint Computer Conference is the first complete public presentation of the RCA (Radio Corporation of America) BIZMAC system. In November 1955, the system passed acceptance tests and was delivered in December to the Ordnance Tank-Automotive Command (OTAC) of the U. S. Army Ordnance Corps in Detroit, Mich.

This set of papers covers the system philosophy embodied in the equipment. It attempts to set forth the reasoning and planning behind the development of the data-handling equipment.

The RCA BIZMAC system is an accounting system in the broad sense that it aims to mechanize all the functions of record keeping, handling of data, calculation and decision, summarization, and prediction which are the basic functions of industrial paper work. It is a system developed to meet the requirements of such work, and not an attempt to apply an available component to the extent that it can be useful. The measure of its success is cost reduction to its user. By making a machine do routine "mental" work, it will help to free many people from tasks which are dull and repetitious, to be available for more creative and challenging work.

In the Ordnance application, the job to be performed is supply and stock control of tank and automotive parts. It is a task of some magnitude. The system must be able to keep inventory records on 250,000 items. Each item contains data of stock on hand at a number of depots, shipments made, goods received, back orders, stock-leveling action taken, various condition codes signifying such things as whether an item is new, or used, earmarked for overseas shipment, etc., as

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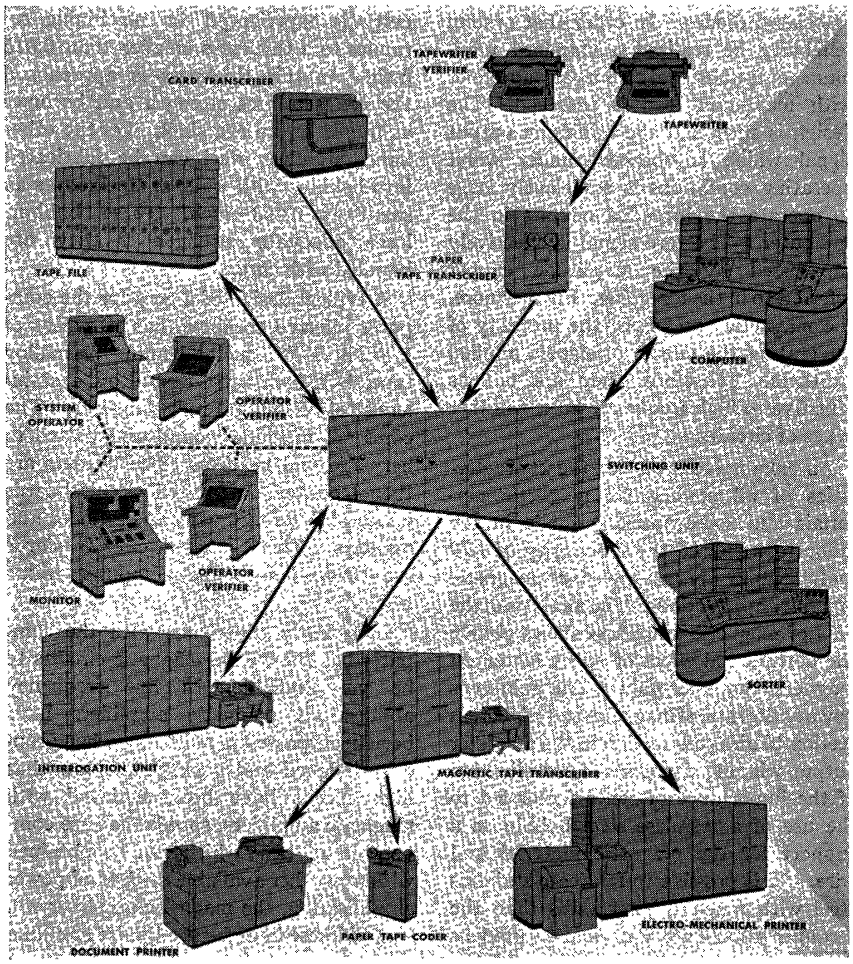

Fig. 1. RCA BIZMAC system

well as the stock number, noun description, and total national inventory. The average number of characters used to describe a stock item is 300, but in some cases runs as high as 1,500. Each day up to 65,000 transactions must be handled, the inventory corrected, the reordering and stock leveling action taken reported, action on special cases indicated, and a daily transaction record printed out. In fact up to 254,000 lines of printing must be put out each day.

A business machine system which employs a serial file is particularly well adapted to cyclic operation. Therefore, routine operations tend to be handled in a cyclic manner. Yet in any business data-processing task there are many times when data must be examined singly without regard to the main procedure which may be in process. In data-processing systems where reference data are contained in some sort of readable form, handling of the look-ups can be accomplished manually with relatively little cost. With the necessity to record data in an invisible form on magnetic tape in order to process them rapidly, the problem of handling look-ups must be faced. Obviously, duplicate files in readable form can be maintained. The cost of keeping such files up to date can soon outweigh their value. If, on the other hand, it is possible to interrogate a magnetic-tape file, the look-ups which must be handled quickly and yet specifically can be accomplished. Without such means, look-ups can only be handled in a batch after accumulation, which, of course, delays actions considerably. To cover the need for rapid random look-up, another special-purpose machine called the interrogation unit was designed. In the Ordnance application this unit will perform some 100 demand look-ups in an 8-hour day.

Now how these new machines and concepts fit into the over-all data-processing system will be examined. This can perhaps be done best by tracing the flow of data as it is processed through the RCA BIZMAC system.

RCA BIZMAC Equipment

In looking at the RCA BIZMAC input equipment, there are two basic types: manual and automatic. Manual input is through what is termed a tapewriter, which is a keyboard device producing punched paper tape and hard copy. A similar machine can be used to verify the input of the first one. This is called a tapewriter-verifier. The operation is similar to key verification of punched cards. Not only does the punched paper-tape output from the tapewriter provide a ready means of verification, but it provides an economic means of transcription from readable data to magnetic tape. This is accomplished through the unit known as the paper-tape transcriber. It can actually transcribe the normal output of about 35 tapewriters. The paper-tape transcriber reads the code punched in the paper tape and directly records it on magnetic tape as the paper tape is punched in the RCA BIZMAC machine language. It transcribes data at 200 characters per second. To save key stroke operations, the intermessage space on the magnetic tape is introduced automatically in the paper-tape transcriber rather than having this put on the paper tape by the tapewriter operator.

Automatic input is handled through the unit called the card transcriber. It reads punched cards at the rate of 400 per minute, and has the ability not only to split columns and add more data prior to recording on magnetic tape, but also permits rearrangements of data before recording on magnetic tape. While this rearrangement can be accomplished by a computer pass, it is less costly to do this at the card transcriber by means of plugboard connections.

The data are recorded in machine language on plastic-based magnetic tape. Each reel of tape is mounted at a tape station, and a pool of such equipment is called the tapefile. This is the reference and working file for the system.

The data are recorded 125 characters to the inch on a 5/8-inch-wide tape, and the tape is run at 80 inches per second giving the rate of data transfer of 10,000 characters per second. It may be of interest to point out that all data are recorded twice on the tape. Read-back of either recording will give satisfactory operation. This is accomplished by having 14 channels across the 5/8 inch width of the tape, thereby recording each of the seven channels twice. No more electronics is required to accomplish this, as the seven pairs of head coils are joined immediately outside the magnetic head. The dupli-

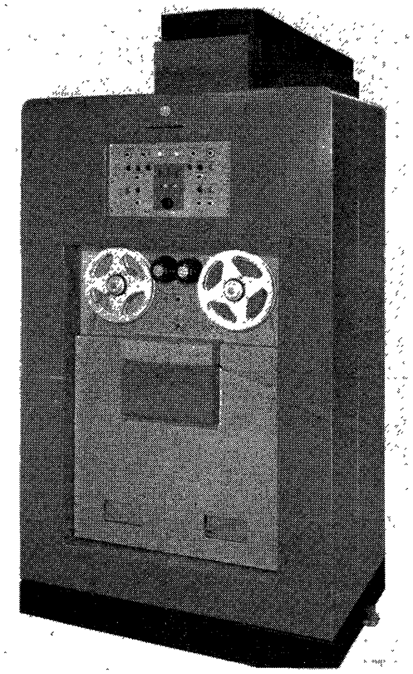

Fig. 2. Paper tape transcriber

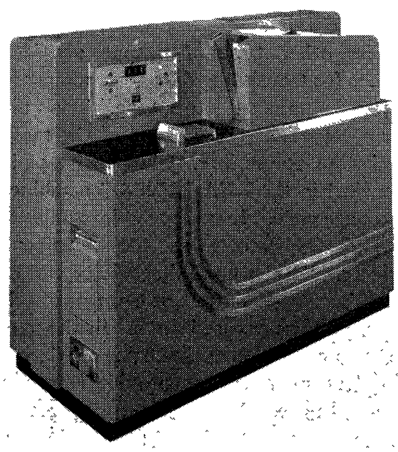

Fig. 3. Card transcriber

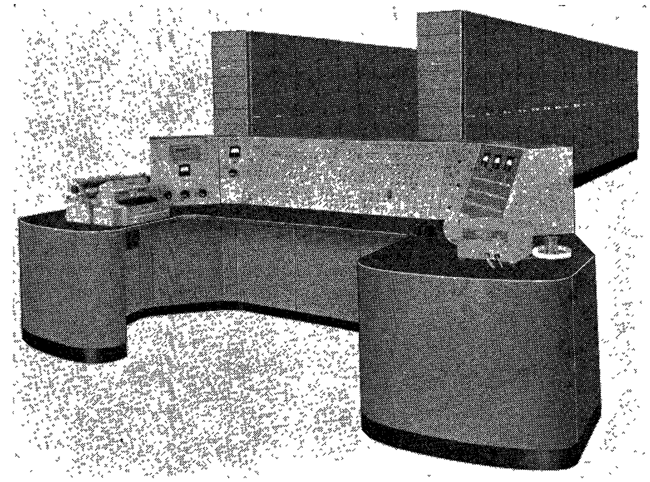

Fig. 4. Computer

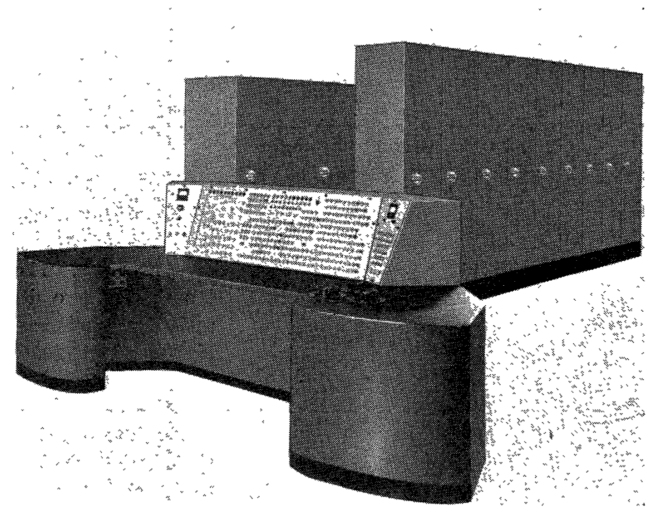

Fig. 5. Sorter

cate recording is displaced half the width of the tape and 1/8 inch along the length of the tape. As only one or the other of the dual recordings need be read to obtain satisfactory operation, dual recording is a very effective means of avoiding data loss due to any imperfection in the magnetic tape.

As mentioned before, all tapes requiring frequent access are mounted on tape stations which can be electrically connected to other equipments. These trunk connections are made remotely through a switching unit containing telephone-type relays.

For reasons of flexibility and ability to alter schedules rapidly, the system central is manually controlled. With this flexibility comes the necessity for accuracy control. Consequently each setup of a trunk line connection, each instruction to a particular machine, is either machine-checked or independently operator-checked. The system central concept and design has been human engineered for more efficient and accurate operation.

The RCA BIZMAC sorter will not be described in detail in this paper, and hence a few words of explanation may be appropriate. While it is called a sorter, actually its major use is in extracting by list or class, and merging. It actually is a wired program machine which has some 13 separate modes of operation including a simultaneous merge, substitute, extract, and delete mode. This is the method used to update the reference file and to extract from it the active accounts for the next processing cycle. The sorting method used builds up progressively longer strings of messages arranged in ordered sequence. It takes advantage of any inherent order in the list of messages to be sorted.

In practice, business data often contain much ordered data. Depending on its modes of operation, the sorter may have anywhere from two to six tapes connected to it. Once the appropriate tapes are connected to the sorter for sorting, the successive passes through the data on the tapes are accomplished automatically by the sorter without system central intervention. It is only when the sorting is completed and the data are recorded on the output tape that the system central switches that one tape to the next operation. It is possible on the sorter to sort, merge, or extract on a criterion consisting of up to 32 characters in the first 50 characters of the message. This criterion may be a composite one consisting of more than one data item. To give an idea of speed, assuming random order of messages, the sorter can sort 16,000 100-character messages in approximately 90 minutes. It can merge 150 such messages into 16,000 in $4^1/_4$ minutes. Similarly, it can extract the same number of messages in $4^1/_4$ minutes.

As can be seen, the sorter can relieve

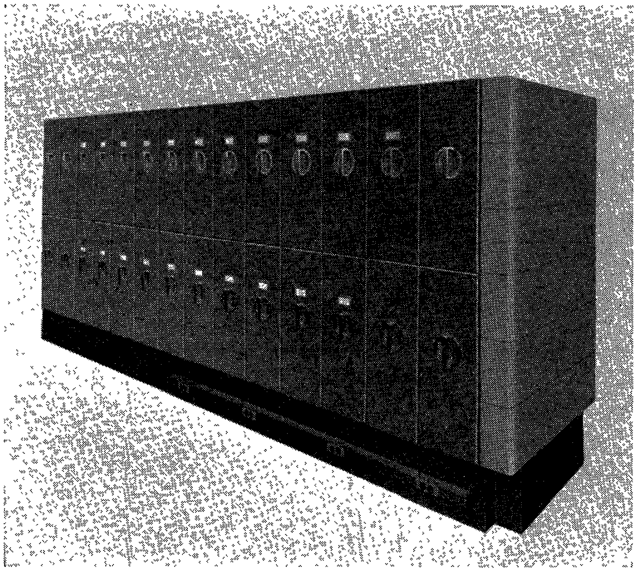

Fig. 6. Tapefile

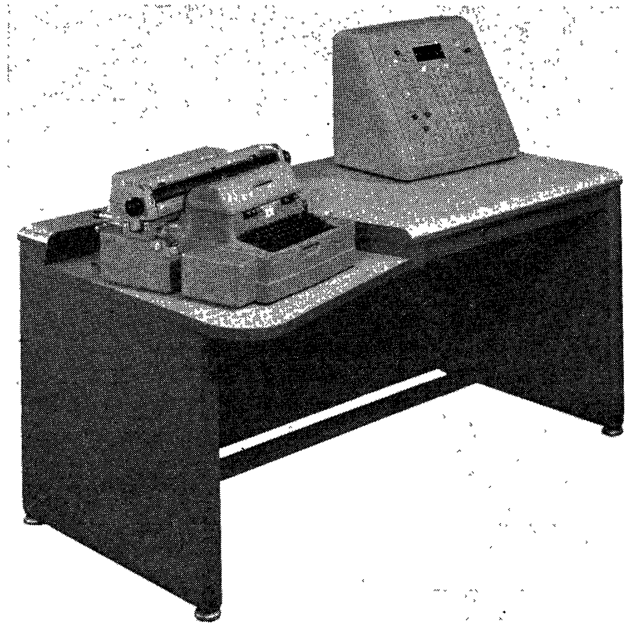

Fig. 8. Interrogation unit

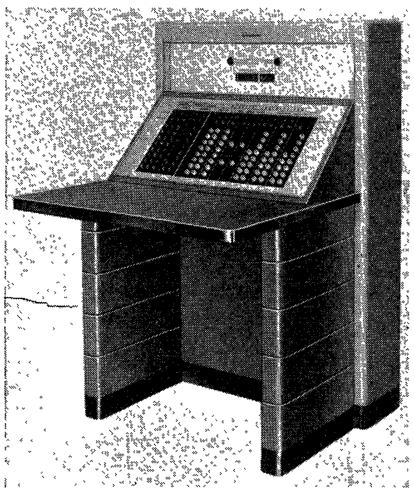

Fig. 7. Operator-verifier console

the computer of many of the data-shuffling processes and, of course, perform these simultaneously with computer operations. The saving in elapsed time in the OTAC application is considerable. There are three sorters in the Ordnance installation to handle the required amount of data shuffling.

The RCA BIZMAC computer is shown on the chart (Fig. 4) and will be discussed later in greater detail. One of the characteristics to point out at this time is that up to five tapes may be connected to the input of the computer, and up to ten tapes to the output of the computer. When so connected through the system central, the use of these tapes is entirely under the control of the computer, and no system central intervention is required until the computer is finished with the use of a tape. It is a binary-coded alphanumeric machine, handling data serially by character with a 3-address program. The rate of computation is such that two decimal digits may be added in 40 microseconds. It has both a high-speed magnetic-core memory and auxiliary internal storage, primarily for program instructions.

The interrogation unit can have any tape station within the tapefile connected to it, and any particular message recorded thereon can be extracted. To accomplish this, an operator connects the appropriate tapefile from the control console of the interrogation unit by referring to an index. Incidentally, the interrogation unit can prepare its own tape station index. Once the tape station is selected, the operator then types in the identification of the particular data desired and presses the "interrogate" button. The tape is run and comparisons made until equality is obtained, at which time the data are read from the magnetic tape, and then are used to actuate the same tapewriter on which the operator typed the identification number. Provision is also made for printing the interrogation output at remote points. The over-all time for a complete interrogation averages approximately 4 minutes.

Looking at the output side of the RCA BIZMAC system, two types of outputs are indicated. The first, the electromechanical printer, is a multiple-wheel rotating-shaft printer which will print at the rate of 600 lines per minute up to 120 characters per line. Editing for horizontal and vertical tabulation is accomplished at the printer and up to three carbon copies can be obtained.

The other type of output provides means for translating data from magnetic tape into punched paper tape. The unit for accomplishing this is called the magnetic-tape transcriber. The paper tape is punched in the RCA BIZMAC machine-language code. It can be fed into an output device known as the document printer. Besides providing suitably tabulated hard copy output, it can print both lower and upper case letters. In the particular application at the Ordnance Corps, this feature is used to provide copy for typesetting catalogues where upper and lower case letters are desired. In addition there is a 7-hole to 5-hole paper-tape converter known as the paper tape coder, which can transform the data into code suitable for teletype winter transmission or for input to tape-to-card converters.

A final point is the important system consideration of accuracy control. Its implementation must be related to the accuracy requirements of business data processing. These, we believe, do not call for either the extreme of complete duplication of hardware or the opposite extreme of complete dependence on programmed or procedural checks. Where uniform procedures of accuracy control can be applied repetitively, automatic hardware checks should be employed, consistent with the cost of such hardware. Such hardware can usually save heavy programming and processing costs. On the other hand, where flexibility of checking is desired to suit varying conditions, programming and processing checks are usually best. The philosophy in the system has been reflected in various ways, which will be covered in the four following papers.

About 1,300,000 messages or 230,000,000 characters of reference information must be processed daily. An additional 7,500,000 characters are handled to process the day's transactions. Keeping up-to-date information on all open orders: vendor's name, material ordered, shipping dates, destinations, performance against purchase orders, etc., calls for record keeping on 120,000 ordered messages.

System Innovations

To accomplish these mass data-handling tasks, certain new concepts were indicated.

It was realized that there were several special characteristics in business data handling for which special system and equipment provision were then made.

First of all it was realized that business data themselves were highly variable in content as well as length of data items. This can be an asset if handled in the right manner. If one makes provision in the recording of the data for actual length of data, rather than maximum possible length, very significant savings are realized in length of magnetic tape used and processing time. This approach was pursued and the entire RCA BIZMAC system was planned to handle variable item and message lengths of data. (An item is a single piece of data such as a stock number of quantity. A message is all the information relating to a particular stock number or transaction.) In the Ordnance application, the ratio of maximum to average length of inventory messages is 5 to 1. Since a basic limitation on speed of data processing is the rate at which useful data can be read from•the file, the advantage of having data recorded in the compressed form indicated is obvious. With the same instantaneous rate of data flow, a fixed word organization of data would require approximately five times as long to process as variable-data-length organization. Similarly, the data compression has made it economically feasible, for the first time, to leave tapes mounted at their tape stations and to provide enough tape stations so that all tapes which are to be used regularly can be mounted simultaneously. The design of the tape station has been considerably simplified and reduced in cost. For instance, one amplifier control unit can service up to five tape stations on a time-shared basis, and one power supply can handle seven amplifier control units.

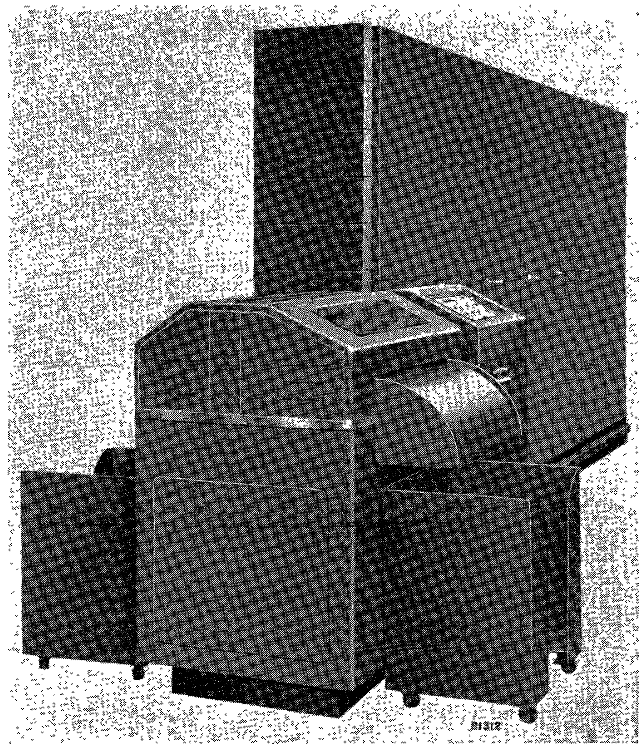

Fig. 9. Electromechanical printer

Leaving tapes at tape stations requires a form of switching to connect a tape station first to one processing machine and then to another. This permits the imposition of centralized control over the entire system operation. The switching unit and control consoles are called the system "central." In basic concept this is similar to a telephone exchange. Trunk connections can be made between any tape station and any operating equipment. To handle a large flow of data, such as in the Ordnance application, this was found to be the only method to accomplish the task in the available time. There are over 1,000 trunk connections to be made daily. In addition, machine setups as required are made by the system central.

Another important characteristic of business data processing is the relatively large amount of rearrangement of data that takes place. When data are recorded serially on magnetic tape, it is necessary to arrange these data in different ways for various parts of the job. For instance, inventory messages need to be extracted from a reference file according to a list of stock numbers, or according to a classification such as new or used. The RCA BIZMAC system has termed these operations "extract by list" and "extract by class." Two message sequences need to be merged together, such as updated inventory messages being merged into a master file, either together with the previous data or replacing them. These operations are called "merge" and "merge-substitute." Incoming transaction messages may require sequencing in an order different from the order in which they are transcribed into the system. This is known as sorting. These various operations must not only be performed rapidly, but they must be performed using varying criteria, i.e., sort on stock number, then on depot location. In the particular inventory control job of the Ordnance Corps, this kind of data shuffling operation is approximately three times the amount of computational operations. While it is true that the various functions of sorting, extracting, and merging can be accomplished in most computers, these operations are not strictly computing.

In order to handle these operations more efficiently, a special purpose machine has been designed which is called a sorter.

System Flexibility

The innovations in the RCA BIZMAC system bring to the large-scale data-processing field a flexibility of operation which has not heretofore been available. This ranges all the way from the detailed but important structure of information as it is recorded on tape, through a highly flexible programming system for the computer, to the manner in which the system as a whole is operated from a central location. These subjects are described in detail in following papers (pp. 124–42).