A HIGH SPEED MAGNETIC-CORE OUTPUT PRINTER

By

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In many data processing and scientific computing applications there exists a need for very rapidly converting a mass of coded data, centrally stored, to either immediate visual display or to a permanent form capable of being directly read. At present, the full potential effectiveness of many systems has been negated, not by their central decision-making arithmetic equipments, but by the limitations of their output conversion units. The need for a high-speed output device having the properties of flexibility and reliability, and yielding characters of high quality, yet still capable of being produced at an economical cost has been painfully evident.

In recent months the fruits of several endeavors to remedy the situation have been presented in the form of electromechanical, rotating magnetic-drum or electrostatic systems. These novel systems have approached the high-speed requirements, but in general they have been extremely complex or adjustment-sensitive and do not meet the requirement of economy.

This paper will introduce and discuss a new technique; the magnetic-core output printer. Its development arose, in part, from the needs of a particular electronic data-filing and inventory-control system under construction at the Laboratory for Electronics, Inc. In that system, a mass of data-decisions must be simultaneously printed out to a large number of users, remotely located. Speed, reliability, quality of output symbol and economy were primary aims of the development. The resulting output conversion unit is capable of accepting and converting input data at a rate of 500,000 characters per minute. Economy and reliability are indicated by virtue of the fact that less than 50 vacuum tubes are used in the entire printer. No adjustments are included nor are any required.

The heart of the system to be described is a two dimensional magnetic core matric, each core of which represents one element of a dot-selective symbol array. Any character to be presented may be decomposed into a particular set of "yes-no's" in a manner analogous to the common newsprint photographic technique. Although experience has shown that a 5 by 7 array of dots is adequate for the synthesis of alphabetic and numeric symbols, it has been deemed proper in the interests of character quality and form-versatility to make available an array containing almost twice that number of potential dots. Figure 1 shows the number seven in appropriate dot representation, as selected from a 7 by 8 array.

The magnetic cores of the two-dimensional array are interrogated in fixed rectangular-coordinate order. Any character which may be represented in an appropriate selection from a 7 by 8 array* may be picked out of the matrix in the form of a dot-modulated signal on a line wired through only the appropriate cores. A separate output line may be appropriately connected for any symbol desired. A particular dot modulated signal may be selected as dictated by data stored in the computer or data processing device. This selected signal intensity modulates the grid of a cathode ray tube. This dot-modulation together with vertical and horizontal sweep signals, locked with the interrogation, yields the desired character as a visual display.

Before proceeding with an explanation of the actual printer it may be well to illustrate some of its properties with a typical example. Consider the case where a policy holder of an insurance company sends in a claim but fails to supply such pertinent data as policy number, coverage, etc. It is necessary for the insurance company to check through its file, to compare by name and address, to extract the desired information, and to record and transmit that information. Figure 2 shows a typical file-extraction card resulting from use of the magnetic-core printer. In the lower portion of the card is seen the name and address of the insured as typed according to the received information.

* Actually, there are 2^{56} factorial possibilities.

This typed-in information is to be the basis for comparison on a name, address or name-address basis. Typing in this information automatically sets up a comparator for an appropriate selection decision. Thus, as the contents of the file are very rapidly fed into the printer, it continuously compares and decides what information to select for printing. When a proper comparison is found, dot-selective characters, as shown in the upper portion of the card, related to such pertinent information as policy number, coverage, extent, prior claims, etc. are rapidly printed out.

Operation of the printer may be understood by a consideration of its major component, the two-dimensional magnetic core array. Figure 3 shows a seven by eight array of cores physically arranged exactly as the geometric array of possible symbol dots. Each core has two interrogation windings, one from the vertical dot selector shift-register and the other from the horizontal dot selector shift-register. As shown in Figure 3a, the cores have square-type hysteresis loops. It is desired that each core, in turn, be pulsed so as to make an excursion between its zero and one states. Thus, as advancing pulses are fed into the vertical dot selector the vertical levels 0,1,2,....7,8 are in turn excited. When a complete vertical cycle is finished, the horizontal dot selector is advanced. Only that core around which both interrogating windings are excited is pulsed through its excursion, so that the cores are interrogated in the order 00,01......07;10,11,......18; 60,61,....67. In this manner the entire geometric array is swept over.

Now in order to generate the necessary intensity-modulating signal for a given character, it is merely necessary to pass a read-out wire continuously thru the appropriate cores.

Figure 3 shows the simple wiring for the numeral 7. It should be noted that merely passing the wires thru the core in the manner shown is equivalent to a complete turn. The levels of magnetic flux density are such that this simple wiring technique is more than adequate with respect to signal amplitude.

An important point, and one that relates to the economy of this technique, is that but a single core-array is required to generate all desired symbols. That is, as many read-out wires as may be desired may be threaded thru the cores. Each wire may be made to assume any desired geometric shape within the array without adversely affecting the signals induced in the other lines. Thus, for example, an entire ensemble of arabic numerals, English and Greek letters, punctuation marks, and special geometric symbols may be simultaneously made available from but 56 magnetic cores.

If, at any time, it is desired to change or add to the set of available characters, it is merely necessary to rewire the appropriate output lines thru the related cores in the same manner in which a child strings beads. It is no more complicated than that.

Figure 4 shows the actual magnetic-core array with all the read out wires removed save one. This figure illustrates the simple wiring technique for the numeral 7. The cost of this entire pattern-generating physical array may be measured in terms of tens of dollars.

Having generated in dot-modulating form all the possible alpha-numeric and geometric symbols simultaneously, each with its own read out wire, it is only necessary to gate through the proper signal upon command of coded input data. It should be clear that a single magnetic-core array matrix may be used as the sole output conversion source for the simultaneous display to many users, each with his individual instantaneous information. That is, a central conversion unit, with a single input and output line from and to each user or terminal, may handle the entire output needs for a complex data-processing or filing system.

Although the fundamental magnetic-core printer provides a basis for a variety of applications, the complete system to be described here will be that presently being used in an air traffic-control system. In this system the controller wishes to be presented with a visual display and to permanently record the instantaneous locations and ancilliary data related to all aircraft in the general vicinity. Very much like an inventory controller he may wish to take account of his total stock or arbitrarily, he may wish to select only those items (aircraft) which fit into certain categories or into certain ranges or ancilliary values (speed, heading destination, etc.). Also he may wish to change the printed form, that is, to adjust the column and tabulation spacings according to his mode of operation.

Figure 5 shows a simplified block diagram of the magnetic core printer which may be made to operate in such a mode as to search for and print only the desired data. The major components include:

1. Magnetic-core pattern generator: which generates all dot-modulated intensity signals for numerals, alphabetic characters and special geometric symbols.

2. Comparator: which examines all incoming data for conformity with the manually set-in category or data range.

3. Symbol Gate: which decodes the accepted data and gates through only the appropriate dot-modulating signals.

4. Position Programming Counter: which under the control of a manual plug-board derives the desired printed form and generates appropriate locked sweep signals for deflection of the cathode ray beam.

5. A Cathode-Ray Display: on which the desired data may be read visually or from which a permanent recording may be made.

6. A Recording Medium: which keeps a running account of all transactions.

Very briefly, operation is as follows: Coded input data from the central store is continuously fed into the input gate at rates up to one item every 100 microseconds or about 500,000 per minute. Assume that the controller wishes to print out only that data which relates to aircraft conforming to a specific category. (For example he may wish to call for the aircraft type, register number, and pilot's name of only those commercial aircraft which have scheduled landings at Detroit between the hours of 1400 and 1430). The comparator as set-up manually according to category and ancilliary data, constantly surveys all incoming data. When the data fits the classification, the comparator opens the signal gate and advances the position program counter to its next position as dictated by the form set up in a plug board. This gated signal is decoded in the symbol decoder which selects the appropriate read-out line from the magnetic-core pattern generator. At the same time advancing pulses are allowed to cycle the vertical dot-selector and in turn, the horizontal dot-selector thru the rectangular coordinate sequence so that the cores are serially interrogated. Digitally-locked sweep-signals are generated in synchronism with the core interrogation so that a one-to-one correspondence exists between C.R.T. beam position and the instantaneously interrogated core. The intensity dot-modulating signal together with the rectangular coordinate deflection signal sets up the display of the alpha-numeric or geometric symbols on the face of the cathode ray tube in the form as dictated by the position programming counter. The 56th or final digit core, core 67, generates a "print complete" pulse which sets up the position program counter for the next character.

The unit, as built, will accept information either serially or on parallel lines. Input decoding units have been devised to accept both analogue potentials or binary-coded pulse trains as input information.

A photograph of the electronic portion of the first model of the magnetic-core printer is shown in Figure 6. The unit is composed of four subassemblies. These are, from top to bottom, the decoding units, the position programming counter, the sweep circuits and the magnetic-core pattern generator.

Both dry and wet permanent recording techniques may be used with the magnetic-core printer. The particular technique employed in any data-processing system depends to a large extent on the particular application. When a continuous running account recording is to be made, a process similar to the Xerographic technique may be used. When the device is to be employed merely as a visual display unit, with only occasional need to permanently record the data, less sophisticated standard photographic techniques will be adequate. A low-cost recording unit may be built using inexpensive dual time-shared recording mechanisms. That is, two recording cameras may be used together with medium-persistence cathode-ray tubes so that entire "pages" of data may be recording in one register. While the film of one camera is not in motion and the lens is held open the other advances its film to the next register (page) position. Then, alternately, the first advances while the second records. It is of some interest to note that, using a 7 by 8 array and 1/8" characters, over 6000 characters may be simultaneously recorded from the face of a 15 inch cathode ray tube.

It is not difficult to think of a multiplicity of applications for a low-cost high speed output unit within the fields of computing and data processing. Representative applications are briefly discussed below:

1. High-Speed Computer Output Because of its high-speed and inertialess action, the magnetic-core printer can accept data at speeds equal to or greater than the internal

access time of most high-speed digital computers. Thus, the requirements in terms of temporary store and synchronizing equipment may be reduced and data may be accepted and presented as fast as it can be transferred from central store.

2. Computer Supervisory-Control or Service Instrument In many instances, during semi-automatic computer operation and especially during fault location periods, it is advantageous for the operator to be able to quickly ascertain the meaning of coded information stored in a particular arithmetic register or memory location. An inexpensive portable read-out unit with a probe input would greatly facilitate servicing and reduce down time.

3. Running Account Recorder In many activities such as traffic control systems or in industrial process controls it would be desirable to keep a running account of all data, decision, and results. Such records would allow a more scientific approach, via real operations-research based on statistical studies, to many control problems whose decisions are now made very much "off the cuff."

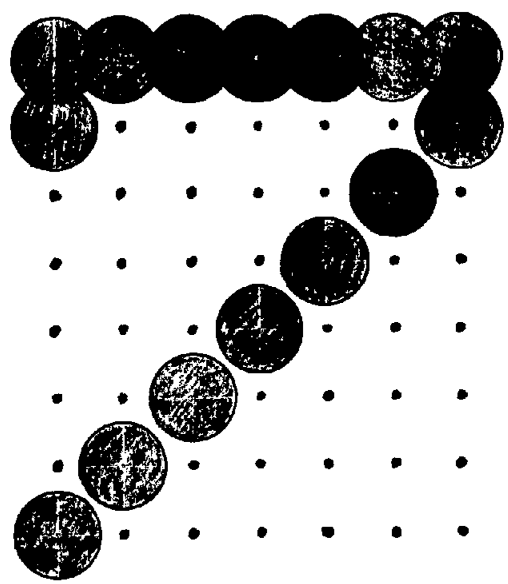
4. Communication Terminal Equipment In this application, information may be directly displayed as received over communication links. In complex organizations, where direct communication and visual verification is desired, such as commercial chains, banks, etc., an inexpensive visual intelligence device will find high utility.

In summary, the development of the magnetic-core output printer arose from the need for a low-cost, reliable, flexible high-speed output conversion device. The unit is a low-cost one because it uses only standard proven components and indeed, has very few of these. It is probable that in small production quantities, the units could be reproduced at a cost of approximately fifteen hundred dollars.

Reliability has been achieved, in part, for the reasons given above for the realization of an inexpensive device. Also, the character-forming elements are non-moving, passive magnetic units, while the few vacuum tubes employed serve only as non-critical current sources. As such, they are called upon only to perform service functions where the actual parameters are of no critical significance. Reliability has also been enhanced by heavy derating of all components and the design assumptions have been such that the unit should still operate when all components simultaneously drift to the outer limits of their tolerances. Although a speed of 500,000 characters per minute has been mentioned, it should be realized that this figure is based on a serial selection of read-out lines. Actually, since all of the symbols are generated all of the time and are thus simultaneously available for selection and read-out, the magnetic printer may be made to operate orders of magnitude faster than the above mentioned figure.

Flexibility with respect to both modes of operation and character change has been one of the major design aims. The available symbols may be altered in a matter of minutes, while the unit may be easily modified to accept either analog or digital input information.

The authors sincerely wish to express their appreciation for the major contribution by Dr. An Wang of Wang Laboratories toward the successful development of the magnetic-core output printer.



7 BY 8 ARRAY SHOWING NO. 7
FIGURE 1.

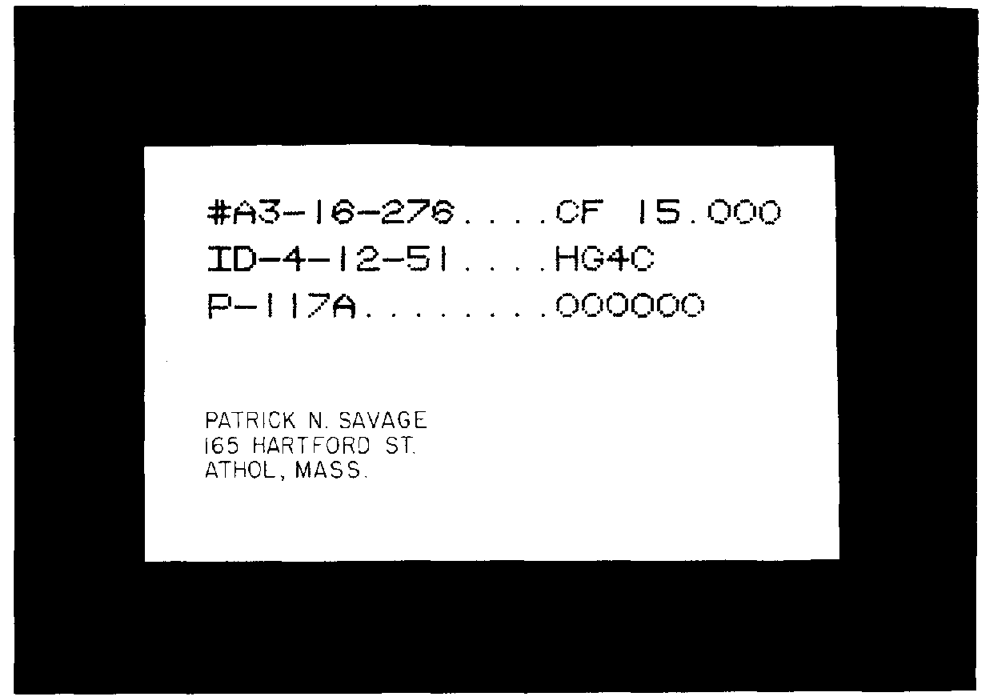
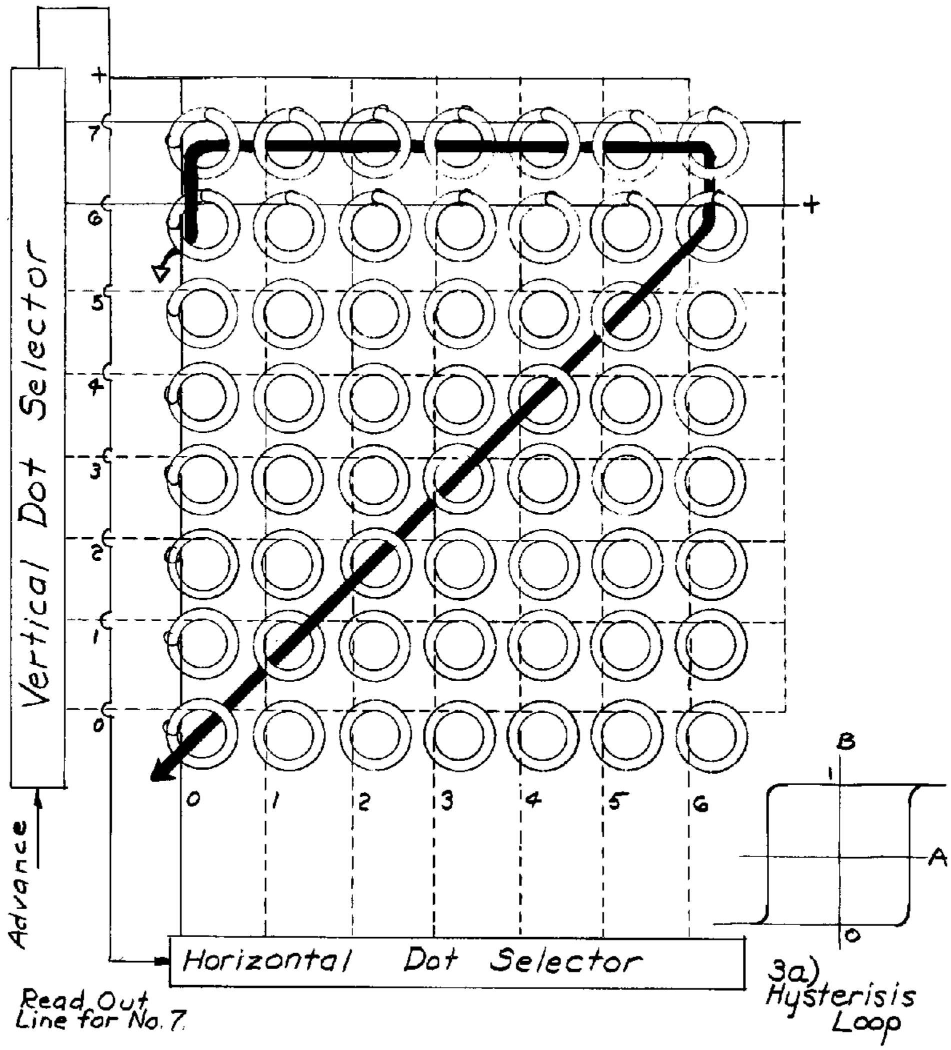


Figure 2 Typical Application



2 Dimensional Symbol Array
Figure 3

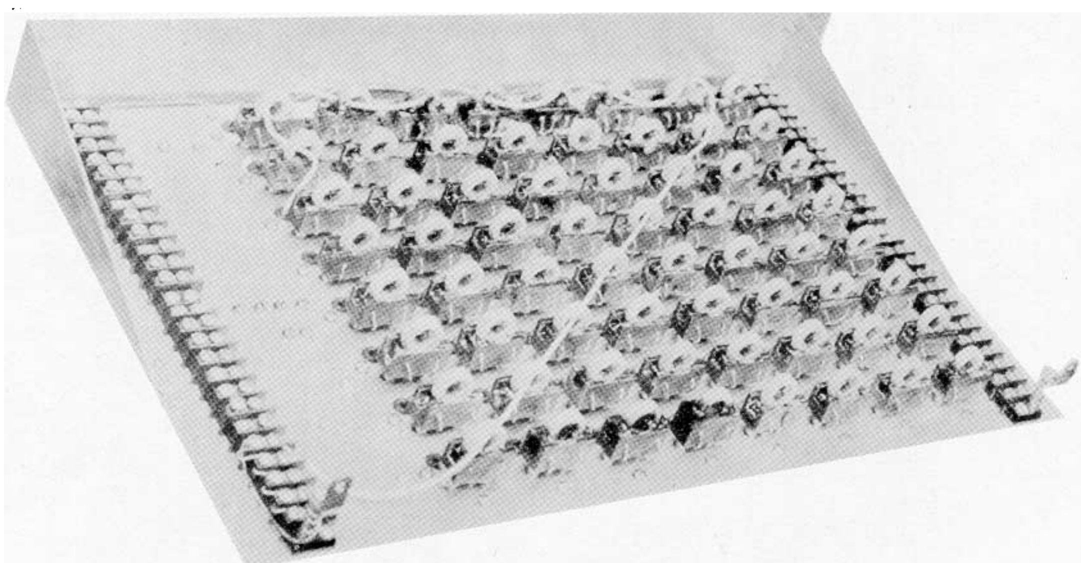
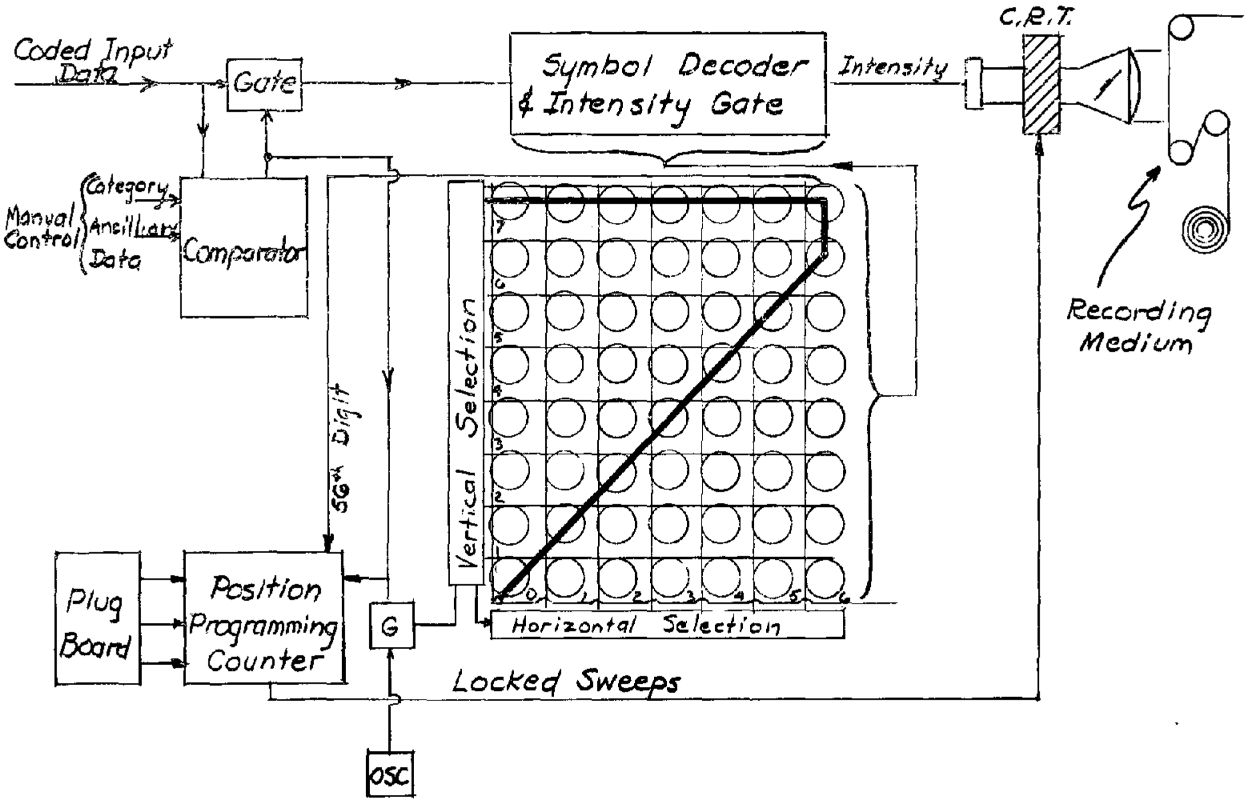


Figure 4 Photograph of Magnetic Matrix



Simplified Block Diagram
Figure 5.

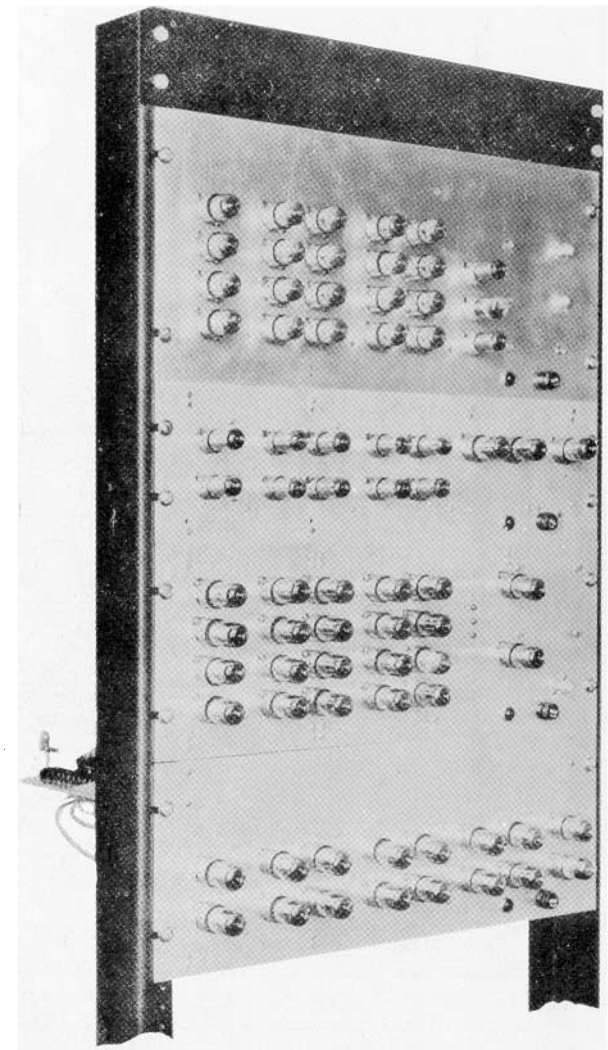


Figure 6 Photograph of Electronic Equipment