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Automatic Data Reduction Equipment for Wind Tunnels

by

G. C. Rowley, Grad. I.E.E.

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Automatic Data Reduction Equipment for Wind Tunnels

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G. C. Rowley, Grad.I.E.E.

SUMMARY

A review is given of the developments since 1947 in the data recording equipment used in R.A.E. wind tunnels. The latest equipment now going into use is described in detail with Appendices of operating instructions.

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1 Review of early equipment

During the war the 10 ft by 7 ft wind tunnel was being used very fully for routine testing and considerable delay occurred between the completion of each test and the results being available in the completely processed form. About half the delay was due to the computing, the rest of the time being absorbed in the transcription of the data. The tunnel instruments were read visually and photographed, the visual indication allowing the tunnel engineer to plan the test programme, and the photographs, after processing, providing the data for accurate computation. The calculation of the final answers was carried out at first on slide rules and later on desk calculating machines, the final results being plotted on graphs by hand. Because of the pressure of work, the need for speeding up this process became very great, and it was obvious that automatic recording and transcribing equipment needed to be developed for use with a digital computer if the wind tunnel were to be used to the fullest advantage. In 1947, K. V. Diprose proposed a system[1] which could be applied to existing wind tunnels as well as to new ones. The main feature of this plan was that all readings would first be converted to shaft rotations and these rotations transmitted by step repeater motors to a central point. The shaft rotations at this central point would be converted into digital form suitable for automatic typing or punching of cards, which would then be used as the input to a digital computer for the calculation of the final results of the test. Plotting of results could be arranged by means of automatic equipment either during the test or after calculation in the digital computer. Another feature was that if any part of the automatic equipment failed, the tunnel operator would not be in a worse position than if none of the automatic equipment had been installed.

Until 1943, mechanical balances were used in the tunnels for measuring forces on models, but about that time self-balancing steelyards came into use in the high speed tunnel. The riders of the steelyard were controlled by servos to provide automatic balancing, the rotation of a suitable shaft of the servo being transmitted to dials giving an indication of the position of the rider, and therefore of the magnitude of the force. These dials were photographed to provide a permanent record. Since 1948, however, the emphasis has shifted away from weigh-beam balances towards resistance strain gauges for measuring the forces on models and in the early data handling equipment, provision was made for the output from each strain gauge to be connected to a servo balance via a high gain amplifier, the rotation of the servo shafts indicating the magnitude of the force, as before.

At first, readings were taken direct from the indicator drum associated with the balance potentiometer, as shown in Fig.1, and written down by hand. Fig.2 shows the next stage, where hand set switches were provided below the servo units, the readings on the balances being set on these switches and transferred automatically to a scanner and the associated typewriter and card punch. The third stage is shown in Fig.3 which gives a general view of the first fully automatic installation. The position of the servo indicator drum was indicated by means of an electrical synchronous link to the equipment at the central point. There it was digitised and displayed on a typewriter, the information also being punched onto Hollerith cards for subsequent reduction by the automatic digital computer.

A block schematic of this fully automatic system is shown in Fig.4. The analogue quantities to be measured are fed through high gain amplifiers to servo balance units. Null indicators are provided on the amplifiers to indicate when the servo bridge is balanced, and a hand control is available on the servo unit to allow the bridge to be balanced by hand, in conjunction with the null indicator, should failure of the servo occur.

Two transmitter contacts are fitted to the servo balance units, one of these being used to transmit the position of the servo balance shaft to the digitiser in the central equipment and the other being available for controlling an automatic graph plotter. The digitisers are selected in sequence by a scanner, which controls the feeding of the digital information to the typewriter and card punch. Should failure of any part of the system occur, the servo balance units may be adjusted for a null reading by hand, and the necessary reading taken direct from the indicator drum.

Fig.5 shows a servo balance unit constructed by Elliott Brothers Ltd. to a design by Mathematical Services Department. The two sets of transmitter contacts can be seen, together with the balance potentiometer and the indicator drum.

Fig.6 shows a digitiser chassis used at the central point. This contains a two inch repeater motor which receives the impulses from the transmitter contacts and moves the digitiser input shaft round to correspond with that of the servo balance unit. Each digitiser chassis is permanently associated with a servo balance unit via a synchronous link.

Fig.7 shows an exploded view of a three digit digitiser. It will be seen to consist of three units which are cascaded through interconnecting gearing. Each of these units deals with one decimal place, the gearing between units being 10:1 step down so that successive units in an assembly deal with increasingly more significant decimal digits. Each unit is arranged to have a rotation of one tenth of a turn for unit change of output and the exploded view of the middle unit shows ten contacts on a stationary insulating disc which are brought out to ten pins on the output plug. Two brushes, which rotate, are mounted on a further sub-assembly, with slip rings on the input shaft. With the aid of some external relay circuitry, errors due to backlash in the gearing may be eliminated by the switching of these brushes in accordance with the position of the brushes in the next less significant unit.

The first scanner to be built was a laboratory prototype and was not used in an installation. The Mark II unit was used with the hand set switches in the partially automatic system already mentioned and shown in Fig.2. The Mark III unit, shown in Fig.8, was designed for use with the gear type digitisers as described above and was also arranged to accept information from the new coded disc digitisers being developed at this time in Mathematical Services Department. The unit is built up from standard Post Office uniselectors and relays and a Hollerith type plugboard is mounted on the front. By means of this plugboard, up to 180 digitiser units may be plugged to be read out in any order, and code letters and digits may be introduced into the typewritten display by suitable plugged connections. Various check facilities are also available: for example, it is not possible to initiate the scanner whilst the typewriter carriage is returning or the Hollerith card punch is ejecting a full card and introducing a new one. Some checking is also applied to the information received from the coded disc digitisers. This is desirable, since the accuracy of the reading depends upon a pattern of contacts representing each decimal digit being correct, and false readings may be obtained due to a faulty brush contact. By checking for combinations which do not represent decimal digits, it is possible to detect such a fault and prevent corrupt data reaching the scanner.

The central equipment is mounted in a rack as shown in Fig.9. At the top of the rack are two ancillary units: the serial counter and the clock. The serial counter is available, from a point on the plugboard, if required, to allow a serial count of the number of times the scanner has been initiated to be displayed on the typewriter and card punch. The clock is similarly available and provides a display of the date and the time to the nearest minute. Below these units is the scanner and 24 digitiser chassis. At the bottom is the power unit for the rack.

Mention has been made of the coded disc digitiser and its influence on the design of the Mark II scanner. The fitting of such a digitiser direct to the indicator drum of a servo balance unit, as shown in Fig.10, was an experiment to see if this type of digitiser were reliable. It was found to be so, and offered the immediate advantage that the electrical synchronous link between the servo unit and the central equipment became unnecessary, the digital information being transmitted from the servo unit along a highway of twelve channels to the scanner. This highway could be used by all such digitisers, and a saving in cabling would result. The digitiser itself was also much simpler than the gear type, and production of these was halted for new installations. This decision meant that the Mark III scanner contained parts which would no longer be used. A new design was therefore initiated to suit the new type of digitiser only, and to provide some features which experience with the Mark III scanner had shown to be desirable. This is the new system now going into use into R.A.E. tunnels, and is described in detail in the subsequent sections of this Note.

2 The new system

Fig.11 shows the block schematic of the new system. The coded disc digitisers are fitted to self-balancing bridges associated with resistance strain gauges with the same facilities of manual control and visual reading from the bridge as in the old system. They may also be associated with capsule manometers for reading pressures or with any measuring device which indicates the magnitude of a quantity by the rotational position of a shaft. A data highway is common to all the digitisers, with each of 16 wires in the highway associated with a channel of given significance in the digitisers. A further 9 wires in the highway are used for control purposes making a total of 25. Information passes along the highway in the form of pulses, the presence of a pulse indicating a digit "1" in the digitiser code and the absence of a pulse indicating a digit "0", and enters the scanner for decoding and feeding out to typewriter and card punch. Also connected to the data highway are the serial counters and hand set switch unit. These are normally mounted on the same rack as the scanner, but may be placed elsewhere in the installation if desired. The output signals from these units are in the same code as those from the digitisers and they may, therefore, be connected to the highway in precisely the same way.

A call-up wire from the scanner, associated with each of the digitisers, allows an investigate pulse from the scanner to pass through a selected digitiser and reach the data highway channels in accordance with the pattern set up within the digitisers. This pattern is stored within the scanner in readiness for decoding. Fig.12 shows the complete rack of equipment, with the serial counter at the top, the scanner below, and below that again, the hand set switch unit. Below the hand set switch unit are a number of chassis which are identical with those used with the gear type digitisers. These are available for housing any small ancillary equipment which may be added at a later stage. At the bottom is the power unit.

The scanner itself, Fig.13, is built up from relays and uniselectors. Since, unlike the Mark III version, it does not have to deal with gear type digitisers as well as the coded disc type, it is rather simpler and more accessible for maintenance. The only routine maintenance which is necessary is the removal of dust from the uniselector banks and the lubrication of the uniselector ratchet wheel with a paste of molybdenum disulphide in light oil approximately every million steps. This corresponds to about $5\frac{1}{2}$ hours of continuous running of the fastest uniselector in the scanner. In practice, of course, the scanner will be used at an average rate much slower than this, and these operations may conveniently be carried out once a week.

The scanner is able to drive both a solenoid operated electric typewriter and a modified Hollerith type 29 programme board punch, either singly or together. The typewriter may be either an Underwood, or a slightly modified I.B.M. As the card punch contains its own power supplies which are not compatible with those in the scanner, a relay circuit is built into the punch to link the two devices. This circuit also provides a checking circuit which gives an indication to the scanner if a card is being ejected into the hopper, so that the scanner sequence may be held up until this operation is complete. A similar circuit within the typewriter guards against information being fed to it whilst it is tabulating or the carriage is returning.

It will be seen that the fundamental difference between the old and new system is in the method of transmitting the data from the output shaft of the measuring device to the scanner. In the old system, because of the size and complexity of the digitisers with their associated relays, it was necessary to house them centrally and transmit the shaft rotation to them by means of an electrical synchronous link. With the advent of the simpler coded disc digitiser, the digitising became possible at the shaft itself, with the possibility of transmitting the data to the scanner along a path common to all the digitisers.

2.1 Coded disc digitisers

The coded disc type digitiser developed in Mathematical Services Department is based upon the representation of decimal numbers in what is known in this country as a cyclic progressive code, and in America as a Gray or reflected code. The essential feature is that in proceeding from the representation of one number in the coding sequence to the next, only one channel in the code changes[3]. In the normal decimal counting sequence the digits occur in the sequence 1,2,3....8,9,10,11,12 etc. If the digit 0 is prefixed to the units digits so that the sequence becomes 01,02,....08,09,10,11 etc. it will be seen that the progression from 09 to 10 contains a change in both tens and units channels. Similarly, the transition from 099 to 100 involves a change in each of the three channels. If a device were to be developed able to give positional information in digital form, using some form of commutator and brushes, it is obvious that errors could occur if the reading brushes were on the boundary 099 to 100 and were not quite in line. Readings of 000 or 199 might be obtained which would be grossly in error. If a code in which only one channel changed at any stage were found, then this difficulty would be overcome since the reading could never be in error by more than unity in the least significant place. In the decimal form this may be achieved by inverting alternate decades so that the sequence now reads 00,01,02,....08,09,19,18,....12,11,10,20,21,22, etc. This procedure may be extended to the hundreds and thousands and subsequent orders of significance. In a practical digitiser it is wasteful of space to have ten parallel channels to represent one decimal digit, and in practice the decimal digits are coded into a binary type code which only requires four channels to specify each decimal digit. However, if the cyclic progressive feature is to be retained, this binary code must itself be cyclicly progressed. Such a code is shown in Table I and is chosen from a large family of such codes to provide simple decoding.

/Table I

Table I

Decimal digit	Cyclic progressive binary coding w	x	y	z
0	0	1	0	1
1	0	0	0	1
2	0	0	1	1
3	0	0	1	0
4	0	1	1	0
5	1	1	1	0
6	1	0	1	0
7	1	0	1	1
8	1	0	0	1
9	1	1	0	1

The procedure for coding a decimal number into the cyclic progressive form is as follows. Consider the digits one at a time commencing at the most significant end. If the digit more significant to the one being considered is even, no change is made: if, however, the next more significant digit is odd, the digit under consideration is complemented on 9. Thus the number 273 becomes 276 in the coded form, and the number 1477 becomes 1572. To decode, a similar rule is applied. In this case, the sum of the digits on the more significant side of the one being considered is found. If this sum is even, the digit remains unchanged; if the sum of the digits on the more significant side is odd, the digit is complemented on 9. This decoding procedure would appear to require counting of the digits on the more significant side of the one being considered. However, a feature of the code shown in Table I enables this to be avoided. It will be seen that the even digits have even numbers of binary digits 1 in their representations and the odd digits have odd numbers of binary digits 1. By means of a simple relay changeover circuit a check may be kept of the oddness or the evenness of a chain of decimal digits without counting being necessary. Such a chain of contacts may be seen in Fig.22 immediately below relay RS. Another feature of the code which facilitates the decoding is its reflected nature. It will be seen that decimal digits which are complements on 9 have the same coding in the x, y and z channels. Thus when decoding is taking place, a simple decoding tree may be used to determine which of the complementary pairs contains the digit concerned, and the w channel in conjunction with the relay changeover circuit indicating the parity, i.e. the oddness or evenness of the sum of the digits to the left of the one being considered, will determine which of the pair is the correct digit.

Fig.14 shows a coded disc and a number of concentric patterned rings will be seen. These rings consist of conducting and insulating areas which indicate the position of the disc to one thousandth of a turn by means of cyclic progressive decimal representations arranged radially. Thus a set of brushes positioned over these concentric rings and lying along a radius of the disc may be used to read out the rotational position of the disc in the cyclic progressive coded form. A further digitiser has been developed of comparable size to a repeater motor, which digitises a shaft rotation to one part in a hundred, and which counts up to 100 turns (Fig.15). This digitiser may be used as a direct replacement for a repeater motor having been arranged with identical fixings. It is being fitted to capsule manometers to give a digital readout into the scanner similar to the data form available from the strain gauge equipment[4]. A third type of digitiser has a range from -29.95 to 29.95 in steps of 0.05, and is used for measuring the incidence angle of tunnel models.

2.2 The data highway

The outputs of all the digitisers in the system are connected to the data highway through isolating rectifiers to prevent back paths through the digitisers. There are 16 wires in the data highway concerned with routing digital information from the digitisers to the scanner and a further 9 wires which are used for control purposes. The input connection to each digitiser is connected through a relay contact to one side of the power supply to bias the rectifiers and prevent spurious operation of relays in the scanner by back impedances of many rectifiers in parallel. When it is desired to transfer the digital information from a given digitiser to the scanner, a relay associated with that digitiser is operated by the call-up wire from the scanner, to transfer the input connection from that power supply to the investigate pulse line. The scanner then emits a short investigate pulse which passes through the conducting areas of the digitiser which are in contact with the brushes, and the associated rectifiers to the data highway. This may be seen in Fig.16 which shows a block of ten digitisers with their associated rectifiers and call-up relays. The ten call-up relays A to K associated with the digitisers are shown on the left, their contacts being connected to lines W and Z on the data highway and to the common connection of the digitiser. Normally, the digitiser common connection is fed through the resting contact of the associated relay to -50 volts on line W. Upon calling the digitiser from the scanner by operating its relay on the associated call-up wire, the -50 volt bias is removed and the digitiser common connection is fed from the investigate line Z through the make contact of the relay.

In addition to the sixteen digit outputs there are four special highway lines which may be fed with the investigate pulse from the scanner by means of suitable strapping within the digitiser assembly. The scanner may thereby be made to complement a digitiser reading, insert a negative sign prior to a reading, indicate to the scanner that a multi-turn digitiser is being read, and indicate to the scanner that the third type of digitiser is being read which operates in the range -29.95 to 29.95 in steps of 0.05. In the absence of any signal indicating otherwise, the scanner is arranged to decode a coded three decimal digit number. If it is not possible to arrange a shaft to represent an increase in the measured quantity by a rotation in the direction of increasing numbers on the digitiser, then the complementing facility may be employed to invert the digitiser readings. This avoids having two types of digitiser, one for each direction of rotation. The negative sign may be used to indicate a quantity going negative from a zero datum.

The rectifiers associated with corresponding output lines from each digitiser are connected together, and if only ten digitisers are in use, these common points are connected direct to the data highway. If more than ten digitisers are in use, they are connected in blocks of ten, and further isolating rectifiers inserted between these blocks and the data highway. One such set of isolating rectifiers is shown on the right of Fig.16. The use of these improves the impedance in the back paths which exist from some data highway lines through the digitisers and back to other highway lines.

2.3 The Mark IV scanners

The scanner (Fig.13) is the heart of the data handling system and is in complete control throughout each sequence of operations. Its purpose is to call up the digitisers in a predetermined order, transfer their settings as a pattern of pulses along the common data highway back to the scanner, decode the settings into decimal and present the decoded information on a typewriter and a card punch.

The scanner may be divided into two main parts - the selector switch and the decoder circuit. The function of the selector switch is to connect the call-up signal, in order, to the digitisers to be read. There are 50 discrete steps on the selector and these are brought out as connections to the plugboard on the front of the scanner (Fig.17). Also brought out here are the call-up wires to the digitisers in the installation. It is possible, therefore, to call up the digitisers in any order by suitable cross connecting on the plugboard. The selector feeds out a signal on the selected call-up wire which operates the relay associated with the called digitiser. This relay connects the digitiser to the data highway.

The purpose of the decoder circuit is to transfer the reading of the digitiser to the scanner, decode it, and feed the decoded information out to the typewriter and card punch. When the scanner is initiated at the beginning of a sequence, the relay associated with the selected digitiser allows an investigate pulse from the decoder circuit to pass through the parts of the digitiser pattern which are in contact with the brushes, and out to the data highway. These signals reach the scanner and operate relays within the decoder circuit to store this information. The decoder then proceeds with the decoding and feeds the typewriter and card punch with the decoded information. At the end of the decoding cycle, the relays are cleared and the selector stepped once. The sequence proceeds without any break, the next digitiser being dealt with similarly.

A number of special facilities are provided to assist in the display of information, and to make the scanner more flexible. Provision is made for the typing and punching of a sensitivity digit before the data itself, to indicate the sensitivity setting of a Strain Gauge Bridge, where one is driving the digitiser being read. This appears as a single decimal digit in the range 1 to 6, corresponding to the setting of a six way switch on the bridge. Some special operations are brought out as connections onto the plugboard and may be called up at any stage in the sequence of operations. These are as follows:

(a) <u>Typewriter carriage return</u>

This operation takes effect at the selected step in the sequence before any data from the digitiser associated with that scanner step is decoded.

(b) <u>Clear selector</u>

This enables the scanner to be cleared rapidly should less than the full complement of 50 digitisers be required for a given test, and is plugged to the scanner step after that associated with the last digitiser to be read.

(c) <u>Centre zero</u>

This facility, in effect, subtracts 500 from a digitiser reading, to give the effect of a digitiser with a centre zero. It is useful where a 0 to 999 digitiser is being used with a shaft whose zero position is a central one, rather than at one end.

(d) <u>Halt selector</u>

It is sometimes necessary to halt the scanner part way through its sequence to allow some manual switching of equipment to take place. By means of this circuit, the sequence can be halted, being restarted by an external short circuit to the "restart selector" socket of the scanner.

(e) <u>Punch out and typewriter out</u>

If it is required to prevent any given piece of decoded data from reaching either the typewriter or card punch, it is possible by means of this facility to block data on a given selector step.

(f) Servo groups

When the scanner is not being used to read out the settings of digitisers, any strain gauge bridges which are in use will be following variations in the resistance of their associated strain gauges by means of their servos. When the scanner starts its sequence, all digitisers must be stationary if ambiguous readings are to be avoided, and it is necessary to freeze all the servos. This is done automatically at the beginning of the scanner sequence, but as soon as a given strain gauge bridge digitiser has been read, the servo may be freed. Provision is made for the servos to be arranged in three groups which may be freed at any stage in the scanner sequence.

(g) Negative sign

It is possible to insert a negative sign before a piece of decoded data by plugging on the plugboard.

(h) Decimal point

Provision is made for a decimal point to be inserted before the most significant digit of a piece of data, or between any of the digits. The position of the decimal point is controlled by plugging on the plugboard, the digitiser call-up wire being plugged into one of five sockets, all of which operate as call-up lines, but which set the decimal point in different positions.

Fig.17 shows the layout of the scanner plugboard, which consists of 20 rows of 34 sockets. The rows are numbered 1 to 20 from the top, and the columns 1 to 34 from the left. Columns 1, 12 and 23 are used for the call-up wires to the digitisers, the two serial counters and the eight hand set switch circuits. Columns 2 to 6, 13 to 17, and 24 to 28 are connected to the selector switch and provide the 50 separate steps within the sequence of the scanner for connection to the digitiser call-up wires. The five sockets in a row correspond to a given step in the sequence, and the chosen socket within that row determines the position of the decimal point in the display on the typewriter. Columns 7, 18 and 29 are used for calling the special operations and are effective at the same time as the digitiser call-up wires in the same row. The remaining columns are used for the special operations and these are called by connecting them to the "call special operation" sockets corresponding to the required step in the sequence. The interconnecting plug leads are available as standard Hollerith equipment, being identical to those used for setting up the programme board punch. Should two special operations be required at the same step in the cycle, however, it is necessary to use a special plug lead which splits, through rectifiers, to prevent spurious calling of one operation should the other be called alone elsewhere in the sequence. Some straps for commoning are provided, and two special sockets near the bottom right hand corner (in column 30) which enable either the typewriter or punch to be taken out of circuit for the complete sequence. This avoids having to disconnect the cables to do this.

2.4 The electric typewriter

When attention was turned to the development of data handling equipment to ease the feeding of experimental data from experiments to the digital computers, careful consideration was given to the types of electric typewriters than available, to find one most suited to automatic operation. The I.B.M. machine, already modified for automatic operation was available, but only for dollar expenditure. Since no modified British machines were available, a few I.B.M. models were obtained for use with early equipment whilst development of a suitable British replacement was proceeded with. Of the British types, that manufactured by Messrs Underwood was the simplest to modify for the functions which were required, and this model was chosen.

The machine, when modified, was required to operate either as a normal electric typewriter, or from external electrical pulses, although for data reduction applications only certain of the characters were required. These were, the digits 0 to 9, hypen (as negative sign), full stop (as decimal point), tabulate, carriage return, and space. Solenoids were fitted under the keys, so that by energising the solenoids electrically, the keys were pulled down and the mechanism tripped. It was found that the machine could be operated reliably at 10 characters per second, with a maximum speed of about 13 characters per second. Since then, interest in this modification has been shown by the manufacturers, and they have produced an improved version of the electric machine, with an improved solenoid system based on the R.A.E. design. These are now available and are being used with all R.A.E. data reduction equipment.

2.5 The Hollerith programme board punch

Since the method of feeding information to the digital computer, DEUCE, is by Hollerith punched cards, some means had to be found of modifying a standard Hollerith card punch for connection to the data handling equipment. To make it possible for the data to be placed on parts of the card acceptable to the DEUCE, the programme board punch was chosen. This is an electrically operated machine, with a plugboard giving the following facilities.

(a) Skip

This enables a card to be moved rapidly through the machine, skipping certain columns not required to be filled with data. For example, the first 31 columns on a card are not acceptable to the DEUCE input circuits, these columns on the card being reserved for serial numbers, job numbers and so on. When a new card is drawn into the punch, therefore, it is made to skip direct to column 32 in readiness for the first piece of data.

(b) Space

This facility is used to space the card once to jump over an unwanted column of the card. When the skip facility is being used over more than a few columns it is wise to skip to the column before the one actually required, and to space over the last one. This improves the reliability of the skip.

(c) Number emitters

It is useful to be able to punch a job number or some other reference code on each card as it passes through the card punch. Sockets are provided on the plugboard which may be plugged to any column of the card, so that as the card reaches that column, the selected digit is punched automatically, and the card moved on to the next column.

Since the power supplies in the punch and the scanner are at very different levels, it is not possible to drive the relays in the punch direct from the output of the scanner. A buffer circuit is therefore required, and this has been designed to fit inside the case of the punch. It is important that the data from the scanner reaches the correct columns on the card and any displacement of the data, say by one column, due to a failure of the punch, will give completely erroneous information to the computer. A check circuit is therefore provided in the buffer unit which indicates to the scanner when the card fails to step to the correct column after the punching of a piece of data. Some of the sockets on the plugboard are connected to this check circuit so that plugged connection may be made between the columns where the card is expected to stop and this circuit. Failure to reach a selected column stops the scanner until the engineer in charge steps the card to the correct position.

2.6 The serial counter unit

The serial counter unit contains two identical counters, which, like the scanner, are built from relays and uniselectors (Fig. 18). They are capable of registering counts in the range 0000 to 9999, and their outputs are in cyclic progressive code like the digitisers. The normal method of stepping the counter is by energising the call-up wire. Thus if it is required to record the number of scanner sequences, it is only necessary to call the counter when the display of the count is required. The counter will automatically increase its count by one, immediately upon being called, and the investigate pulse from the scanner will convey the augmented count back to the scanner for decoding and typing. An external socket is provided to allow the counter to be stepped at times when it is not being called by the scanner. This may be done by applying a short circuit to the "step counter" socket, but must not be done whilst an investigate pulse is being emitted from the scanner.

Numbers may be preset on the counter, by setting up the uniselectors by hand. Since the counter steps upon being called, the required number less one should be set. Clearance buttons are provided on the unit for clearing the counters to 9999, so that the first indicated count after clearance is 0000.

2.7 The hand set switch unit

As an aid to computing and to visual inspection of the typewritten data, it is desirable to have certain constants fed to the typewriter and card punch. The hand set switch unit is provided to meet this requirement, and has eight separate switch circuits built in. Four of these are of four decimal digits, two of three digits and two of only one digit (Fig. 19). As for the serial counters, the outputs from the switches are coded into cyclic progressive code so that the switch circuits may be called in exactly the same way as the digitisers, and the data fed back on the data highway.

2.8 The power unit

The uniselectors in the scanner are driven from the 50 cycle mains, but a 50 volt DC supply is required for the relays. A power unit is therefore provided capable of supplying five amps at 50 volts. This is more than adequate for the Mark IV scanner, but since the design for previous equipments was available and satisfactory, it was decided not to redesign. The only change required was the connection of the positive side of the 50 volt supply to the neutral line of the mains. A three core cable connects the power unit with the scanner, carrying line, neutral, and -50 volts.

3 Future developments

Improvements in data handling systems for wind tunnels appear likely in two main directions; first, the introduction of a fully electrical system with no moving parts, and second, an increase in operating speed. The elimination of moving parts from the system should result in improved life and reduce the amount of maintenance required, thereby improving reliability. An increase in operating speed would be of value in intermittent tunnels where the time available for a test is limited.

An interim measure towards the elimination of moving parts would be the introduction of an optical digitiser using photo-electric cells and glass scales, in place of ball contacts and etched discs. The scanner could then be electronic in character and relays and uniselectors eliminated. The use of an electronic scanner with the present design of digitiser is not thought to be practicable since problems of noise, contact resistance, and cross-talk are introduced when electronic circuits are driven from mechanical contacts. If an electronic digitiser could be designed to replace the self balancing bridge, then the system could be made fully electronic and all moving parts would be eliminated. An alternative method of approach is to delay the digitising of the quantities being measured, and transmit the information in an analogue form to the central equipment to be digitised there. Whilst this system would raise a number of problems, the amount of equipment required would be considerably reduced, resulting in improved reliability. The switching of the analogue information would, however, probably be done by means of a mechanical switch, and this might be a disadvantage.

Providing that elimination of moving parts can be achieved, it becomes possible to speed up the operation of the scanner, and the presentation of the results. Fast typing and card punching devices are available, and the introduction of electronic techniques into the data handling equipment would result in a more efficient use of tunnel time, and provide more information, if required, for subsequent calculations.

The developments mentioned should help towards the trouble free operation of wind tunnel data handling equipment, and also provide the speed necessary for intermittent tunnel installations.

4 Conclusion

Much development has taken place in the design and application of coded disc digitisers to wind tunnel measurements. These digitisers can be used to convert from analogue to digital form any measured quantity which can be represented by the rotational position of a shaft; in particular, the output from resistance strain gauge bridges and capsule manometers. Scanning and decoding equipment for use with these digitisers, built from Post Office relays and uniselectors, has been designed, and feeds out information to typewriter and card punch. Digitisers may be investigated at the rate of about 1 per second, a complete cycle of 50 digitisers in an installation taking rather less than one minute.

Although this is a comprehensive and effective system, higher speeds are required for some applications and it appears attractive to replace the mechanical parts of the equipment by solid state or other electronic devices.

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Attached:- Appendices I to V

APPENDIX I

Detailed operation of the typewriter

Fig. 20 shows the electrical circuit of the typewriter. There are fifteen solenoids controlling the digits 0 to 9, hyphen (for minus sign), full stop (for decimal point), carriage return, tabulate and space. One side of each solenoid is connected to a pin on a 25 pin Mark IV plug which is mounted under the body of the typewriter. The other ends of the solenoids are connected in three groups; solenoids 0 to 4 to pin X on the plug; solenoids 5 to 9 to pin Y; and the remainder to pin Z. This is done to ease the decoding procedure in the scanner, the simple choice of either the X or Y return being sufficient to complement a digit on 9 in the light of the parity of the number being decoded.

Two changeover contacts are built into the typewriter, designated CK and MS in Fig.20. Contact CK is the check contact which is operated during the tabulating and carriage return operations. This indication can be used to hold up the equipment driving the typewriter thus preventing digits being lost whilst these operations are proceeding. In its normal position the MS contact allows pulses fed to pin T of the plug to reach the tabulate solenoid. When the carriage reaches the right hand margin, contact MS operates, and the next tabulate pulse is diverted to the carriage return solenoid. This facility allows data to be fed continuously to the typewriter without a check of the carriage position being necessary.

APPENDIX II

Detailed operation of the card punch buffer circuit

Because of the difference in the levels of the power supplies in the scanner and the Programme Board Punch, it is necessary to insert a buffer circuit between the two pieces of equipment. The circuit of this is shown in Fig.21. It consists of 14 relays, 13 being double coil high speed with one contact, the 14th being medium speed with two contacts. There are twelve possible positions in each column of a Hollerith card for a punched hole and these are designated X, Y, and 0 to 9 reading from the top of the card downwards. The X and Y punchings may be used to indicate negative and positive; when connected to the scanner, only the X punching is effective and this represents a negative sign. Output from the scanner is fed to the buffer circuit by a 25 core cable connecting to a 25 pin Mark IV plug shown on the left of Fig.21. Pins A to K carry pulses representing the digits 1 to 9 and 0, respectively, and operate the appropriate one of the relays A to K connected to the plug. As with the typewriter, the three earth return system is used to aid the decoding in the scanner, and a selected relay operates over its left-hand coil from the associated pin A to K and either the X or Y earth. The relay holds over the other coil and its own contact to the punch power supplies, care being taken to see that the polarities are correct. The junction of the contact and the coil is fed to the corresponding punch relay controlling the punching of the required digit. Thus a pulse from the scanner calling a digit 3, for example, operates relay C, which holds over C1 contact and operates the relay in the punch controlling the punching of a digit 3. When the punching has taken place, the holding circuit for the buffer relay is automatically interrupted within the punch, and the relay releases. The X relay operates when a negative sign is called, using the Z return to the typewriter, but only remains operated for the duration of the pulse, no holding circuit being provided. Relay S is concerned with checking and has one side of its coil connected to the check sockets on the plugboard of the punch. When a card steps to the required position, relay S operates to the punch power supply through the plugged connection on the plugboard, and holds over S2 and T1 contacts. Contact S1 provides a short circuit between pins Q and R, indicating to the scanner that all is well. If a card fails to reach the correct position, relay S does not operate, pins P and R remain in contact, and the check relay within the scanner operates to prevent any further operation until the error is corrected. At the end of the decoding cycle relay T is operated by the tabulate pulse fed to the typewriter. T1 contact opens to release relay S which only reoperates if the card reaches the correct column.

APPENDIX III

Detailed operation of the scanner

Upon depressing the start button on the front of the unit, or applying a short circuit to the "External Start" socket (Fig.22), relay ST operates from neutral, RRA1, start button (or external s/c) and ST1. ST locks over ST1, CC1, ER2, and CS2 to neutral. ST2, ST3 and ST4 contacts provide a signal to the servo units via output sockets designated "Servo group A", "Servo group B" and "Servo group C" to freeze the servos and halt movement of the digitisers. ST5 contact connects the coil of USC drive magnet through HS2 and CK1 to neutral, and USC thereby receives half wave rectified mains pulses through the RM4 rectifier (A) and the 220 ohm, 10 watt resistor. It therefore commences to step round at 50 steps per second.

The function of USC is twofold: it provides paired stepping pulses for USD from levels USC1 and USC2 so that an adjacent pair of mains pulses are fed to USD in every five, and it also controls the charging of condenser C1 and its discharge through the relay decoding networks to the solenoids in the typewriter and card punch.

When the wiper associated with level USC1 reaches contact 2, (assuming that the sequence of operations commences with each of the four uniselectors standing on contact 1), neutral on the wiper reaches the drive magnet of USD through HS3, ST6 and USD interrupter contacts. Thus the next half wave rectified mains pulse will step both USC and USD, USC stepping to its third contact and USD to its second. Neutral on USD5 wiper is now extended to line Z on the data highway input plug, and connection is made from neutral through the pattern of contacts within the digitiser and back to the scanner via the data highway. Lines A to Q on this highway are reserved for digits in the range 0000 to 9999, and the relays A to Q associated with these lines are operated by the signals from the digitiser. Any relay which operates locks over its number 1 contact, thereby disconnecting its coil from the highway and preventing any spurious operation of other relays should the digitiser change its position during the decoding process. When USC reaches its third contact a path is made through USD1 wiper and contact 2 to the drive magnet of USD, and as USC steps from its third to its fourth contact, USD steps from its second to its third. Thus the investigate pulse to line Z of the data highway from USD5 level is of 20 milliseconds duration.

When USD reaches its third contact, a path is made from C1, USC3 contact 4, USD4 contact 3, to CR2. CR is a special operation relay, brought out to the plugboard for calling up a carriage return operation of the typewriter (see Fig.22). Should this operation be plugged from the first "call special operations" socket to one of the "carriage return" sockets, CR relay will already be operated by neutral through USA5 level, contact 1, and the energy stored in C1 will be discharged through CR2 contact to pin S of the typewriter plug and thence to the carriage return solenoid. Within the typewriter is a check contact which is operated whilst the machine is tabulating or carriage returning (see Fig.20). Normally, Q and R on the typewriter plug are in contact, but during these two operations, R is in contact with P. During the carriage return operation, therefore, neutral on the typewriter pin P will be routed back on pin R, to operate the check relay CK. CK1 interrupts the connection between neutral and the drive magnet of USC and holds up any further operation of the scanner until the typewriter carriage is fully returned. CK relay then releases, and USC recommences to step. CK relay is also operated should the card punch not be in the correct position for the next piece of data. A check circuit is arranged within the punch which connects pins P and R of the punch plug together when the tabulate pulse is fed to the typewriter at the end of the scanner decoding cycle. Providing the card has reached the correct position for the next piece of data, as determined by a plugged connection on the programme board associated with the punch, this connection is broken and the scanner cycle may proceed for the next piece of data.

Whilst USC is stepping over contacts 4, 5 and 6, no path is provided to the coil of USD and thus USD stands on its third contact for a period of 60 milliseconds. However, C1 is only connected through USC3 to USD4 for the first 40 milliseconds of this period: for the remaining 20 milliseconds it is routed back to the RM4 rectifier (B) to be recharged in readiness for the next digit to be typed and/or punched.

When USC reaches contacts 7 and 8, two more successive half wave rectified mains pulses step USD to contact 5. The next digit sent to the typewriter and card punch indicates the sensitivity setting of the servo unit whose reading is being observed. A six-way switch is available on each servo balance to allow its sensitivity to be set as required, connections being brought out from this switch to a six-way highway connecting all the servo units to the scanner. This investigate pulse to the digitiser in the servo unit on line Z of the data highway also reaches the common of this switch, and a pulse therefore reaches one of the sensitivity relays SDA, SDB, SDC, SDD, SDE or SDF in the scanner to record the sensitivity setting. The relay holds, as the digit relays, over its number 1 contact. The number 2 contact allows condenser C1 to discharge through USC3, USD4 contact 5, and the appropriate sensitivity relay contact to the associated digit line to the output plugs. Further reference to Fig. 20 will show that the solenoids controlling digits 0-4 are connected to the X earth line, and the digits 5-9 are connected to the Y earth line within the typewriter. This is for convenience in decoding the cyclic permuted decimal code used in the digitisers. Thus, as well as feeding the pulse from C1 to the appropriate digit line, it is also necessary to select the correct earth. Levels USD3 and USD2 are used for this purpose and have their wipers connected to the X and Y earths respectively. They are used throughout the decoding operation to select the earth to be used to give the correct range of the digit to be typed or punched. If the sensitivity digit is 1, 2, 3 or 4, contact 5 of USD3 will be connected by the number 3 contact on the selected sensitivity relay to neutral, thus completing the return path for the pulse from C1. When the sensitivity digit is 5 or 6, however, contact number 3 on SDE or SDF will connect the neutral on USD2 contact 5 to the Y earth.

When USC steps past contacts 12 and 13, USD steps to contact 7 on two successive mains pulses, and C1 is connected through USC3 and USD4 contact 7 to CZ7 contact. Should neither CZ nor SN be operated, a pulse will reach pin W on the output plug to space the typewriter once. The card punch is unaffected by this signal. Relay CZ is available for connection from the plugboard at the front of the scanner and is used when it is desired to use a normal digitiser with an imaginary centre zero. The circuits associated with relay CZ, in effect, subtract 500 from the reading so that 000 is converted into -499 and 999 becomes 499. Contacts CZ3 and CZ4 interchange lines B and C on the data highway and reference to the digitiser code (Table I) will show that this performs the necessary modification of the first digit. Relay AA when operated, is used to provide the correct sign for the typewriter display, and is operated in place of A due to the action of contact CZ2. Contacts CZ5 and CZ6 are used in conjunction with USD2 and USD3 to provide the correct earth return for the first digit of the digitiser reading to be typed. Thus if relay CZ is operated, the pulse from C1 through contact 7 on USD4 will reach pin M of the output plugs if AA is released, to type a negative sign and make an X punching on the Hollerith card. If AA is operated, the pulse will reach pin W to type a space, indicating that the number typed is positive. Condenser C1 now recharges on steps 16, 17 and 18 of USC3 level, and as USC steps over contacts 17 and 18, USD steps to contact 9.

Some of the digitiser in the installation may be of a five digit type giving readings in the range 00000 to 19999. These digitisers have their most significant channel (which only has to indicate a 0 or a 1) connected to line T on the data highway. When the digit is 1, the investigate pulse will reach relay BDA in the scanner to indicate that an initial digit 1 is required prior to the remaining digits in the decoded display. The discharge of C1 through USC3 contacts 19 and 20, and USD4 contact 9, reaches BDA2 contact. If this contact is normal, indicating that the digit is 0 (or that there is no digit since the digitiser is not a five digit type anyway), then the typewriter will receive an impulse from C1 on the space line W. If, however, BDA2 is operated, the discharge from C1 is diverted to pins A and H on the output plugs to indicate either a 1 or an 8. Which of these is displayed will depend on the parity indicated to levels USD2 and USD3. The 9th contact on these levels are connected to CO2 contact at the beginning of the parity contact tree (to the right of USD1 level on the circuit schematic, Fig.22). Providing that CO relay is released, neutral will reach USD3 and the X earth line and the display will be of a digit 1. CO relay is another special purpose relay which may be called from the digitiser by means of a strap in the digitiser circuit (see Fig.16) when the digitiser is used with the zero position of the shaft at the 9999 end of the digitiser. This facility has been provided to avoid having digitisers for clockwise and anti-clockwise directions of rotation, and the reading from the digitiser may be complemented on 9999 by the operation of this single relay. Thus, if relay CO is operated, the neutral line reaches the Y earth via USD2 level, and the digit displayed is an 8. Due to the operation of this contact at the beginning of the parity tree, all subsequent digits from the digitiser will have their parity changed and the complete number will be complemented.

Provision is made in the circuitry of the scanner for a decimal point to be inserted in the display of decoded information on the typewriter. Each digitiser is available for interconnection on the plugboard at the front of the scanner (Fig.17) and may be called at any of the 50 decoding cycles in the full cycle of the scanner. The plug lead which is used for the cross connection may be plugged into any of the five sockets marked "decimal point" corresponding to a given time in the scanner cycle: socket A placing a decimal point before the first digit from a four digit digitiser, socket B before the second digit and so on, the fifth socket being used to call a digitiser when no decimal point is required at all in the display. Levels 1-4 on USA and levels 1-6 on USB are connected to these points on the plugboard to select the plug points in sequence throughout the scanner cycle, relays DPA, DPB, DPC and DPD being associated with the decimal point positions A, B, C and D: relay DPO is used when no decimal point is required. Thus, when a digitiser is called, the selected decimal point relay operates in series with the relay associated with the digitiser (see Fig.16). As USC steps over contact 22, USD steps with it to contact 10, due to the connection of neutral from USC1 level contact 22, HS3, ST6 and the interrupter contact of USD. As USC steps over contact 23, neutral will be extended from the wiper of USC1 and contact 23 to DPA1 contact. If DPA relay is not energised, USD will step with USC and reach contact 11, but if DPA is operated, USD will remain on contact 10. Contact 10 on level USD4 is connected, together with the next three even numbered contacts, to line O on the output plug, which feeds the decimal point solenoid in the typewriter. Thus, as USC steps to contact 24, the condenser C1 is connected through USC3 contact 24 and USD4 contacts 10 to pin O, and the typewriter prints a decimal point. USD next steps to contact 11 as USC passes contact 27 by the extension of neutral through HS3 and ST6, but fails to receive a stepping pulse from contact 23 of USC2 since it is on an odd contact on USD1 level. By this arrangement, USD remains on contacts 10 and 11 for 100 milliseconds each, allowing a full charge and discharge cycle of C1, and time for a decimal point to be inserted in the typewritten display.

Contact 11 on USD4 is connected to the input of the digit decoding tree associated with relays B, C and D. The most significant digit of a four digit coded digitiser reading will be stored on these relays, together with relay A, and a path will be set up from contact 11 of USD4 to one of the five output wires from the tree. Each of these wires is connected through rectifiers to a complementary pair of digits on the typewriter and card punch output plugs. Which digit of the pair is printed and punched will be selected by levels USD2 and USD3 and the parity tree contacts CO2, BDA3, BDA4, A2 and A3. Should none of these relays be operated, or certain faulty combinations, the pulse from C1 will leave the decoding tree on the line to DTA2 contact. For four digit digitisers, this relay will be operated by the strap within the local digitiser circuit (see Fig.16) and the pulse will reach relay ER, the error relay. ER will operate and hold from -50 volts, ER coil, ER1, SW1 to neutral. ER2 contact releases ST relay and lights the error lamp. ST5 and ST6 contacts halt the stepping of USC and USD, and no further decoding operations are carried out until the start button is depressed by the operator. This allows any required note to be made of the error before proceeding, and upon the reoperation of relay ST, from the start button, the cycle of the scanner proceeds. Should the digitiser be of a three digit type, relay DTA will be released, and the discharge from condenser C1 through USD4 level contact 11 will reach pin W on the output plugs through the resting side of DTA2. The typewriter will space once and thereby preserve the relative position of digits in the display by ensuring that all the least significant digits are in line down the page.

By a similar process to that described above, a decimal point may be inserted before the second, third, or fourth digits of the decoded display from the digitiser being read. The decoding of the second, third and fourth digits also proceeds as already described for the first, an error check being provided on each of these digits also.

As USD steps to contact 18, USC steps from contacts 42 to 43 if no decimal point has been called for, or from 47 to 48 if a decimal point has been called. The step from contacts 18 to 19 on USD will occur on the following half wave rectified mains pulse through USD1 contact 18, and USD1 wiper.

Two relays, DTB and BDB are provided to deal with the type of digitiser having a binary channel at the least significant end. Relay DTB indicates that this type of digitiser is being read, and relay BDB indicates whether the binary channel is reading a 0 or a 1. This type of digitiser has a centre zero, and to avoid having readings of -0005, -0000, 0000, 0005 as the sequence about the centre point, the digits 2 and 7 are used in the display in place of 0 and 5. This has the added advantage of simplifying the circuit, since 2 and 7 are complementary digits on nine. The readings either side of the centre zero now become -0007, -0002, 0002 and 0007, and the change about the centre point becomes four instead of just a change of sign. This gives, therefore, a smooth transition about the centre point. Thus contact 19 on USD4 is connected through DTB2 contact to the 2/7 line out of the decoding trees, and either a 2 or a 7 will be displayed depending on the indication from the parity circuit through USD2 and USD3 levels to the X and Y earths.

When a decimal point has already been displayed in the decoding cycle, USD will step from contact 19 as USC steps from 2 to 3. DPO will be released and USD will step on the following half wave rectified mains pulse to contact 21, and USC will step to contact 4. If, however, no decimal point has been printed, USD will step from contact 19 as USC steps from 47 to 48. DPO will be operated in this case and USD will rest on contact 20 for 100 milliseconds causing a space signal to be sent to the typewriter from USD4 level contact 20 through pin W on the typewriter output socket. USD, in this case, will step from contact 20 to contact 21 as USC steps from 2 to 3.

When USD is on contact 21, the pulse from condenser C1 is routed through contact 21 on USD4 level to pin T on the output plugs to operate the tabulate solenoid in the typewriter, and to operate the check circuit in the card punch. USD steps from contact 21 when USC steps from 7 to 8 and homes to contact 1 through USD1 level at 50 steps per second.

When USD reaches contact 22, relay RRA operates from neutral, wiper of USD5, contact 22 of USD5, coil of RRA to -50 volts. RRA holds from -50 volts, coil of RRA, RRB1 and RRA2 to neutral. RRA1 removes the neutral line from the holding contacts on relays SDA to SDF, A to Q, SN, BDA, BDB, CO, DTA and DTB. Any of these relays which were operated now release.

As USD steps from contact 23 to contact 24, USA steps from contact 1 to contact 2 from neutral, wiper of USD5 level, contact 24 of USD5 and interrupter contact of USA. USB follows one half wave rectified mains pulse later due to the cross coupling circuit between the banks of these two uniselectors. This method of drive is more reliable than feeding the same pulse to both drive magnets. The stepping of USA and USB causes the digitiser selected by contact 1, through one of the decimal point circuits, to be released, and the next digitiser is called up in readiness for the next decoding cycle of the scanner.

When USD reaches contact 24, RRB operates. RRB1 releases RRA, and neutral is restored to the holding contacts of the relays associated with the data highway in readiness for the storage of the next set of data to arrive.

When USD reaches contact 1 again, USC will have just reached contact 12, and as USC steps over contacts 12 and 13, USD will step to contact 3 and a new decoding cycle will be initiated.

In this way, up to 50 decoding cycles may be employed within one cycle of the scanner to investigate the readings on 50 digitisers, decode them, and display the decoded results on a typewriter and/or card punch. If it is desired to eliminate any such result from either typewriter or card punch, relay TO or PO may be called from the plugboard at the front of the scanner for any of the 50 decoding cycles, and will exclude information from the typewriter or card punch respectively for that cycle.

A negative sign may be associated with any piece of typewritten data with the aid of SN relay which is available both on the data highway and from the plugboard. Thus a negative sign may be permanently associated with a given digitiser by suitable strapping within the local digitiser circuit (see Fig.16) or may be programmed as required from the plugboard.

When all the digitisers associated with a given group of servo balances have been read, the servo balance may be allowed to follow up the input signals again by operating relay SA, SB or SC. These three relays are available from the plugboard and may be called at any stage during the scanner cycle. Thus a group of servo balances may be frozen for, say, one third of the scanner cycle, whilst their digitisers are being read, and then released for the rest of the cycle. Other groups may be similarly treated. Each of these relays holds over its number 1 contact, the number 2 contact being used to interrupt the circuit previously made by an ST contact to the output sockets designated "Servo group A, B or C".

Relay HS is provided to enable the scanner to be halted during its cycle to allow for any manual switching of strain gauges to servo balances which may be required. Relay HS operates, as USA steps to the selected position from neutral, through USA6 wiper and contact, plugboard, HS coil and RS1 contact to -50 volts. It holds over HS1 contact; HS2 halts USC and HS3 halts USD. When it is desired to restart the scanner, a short circuit is applied to the "restart selector" socket. RS operates, and RS1 contact releases HS. The scanner cycle then resumes.

If less than the maximum of 50 digitisers are to be read, it is possible to clear the scanner to its dormant position by plugging CS relay (brought out on the plugboard as "clear selector") to the first spare step on USA by means of the plugboard. CS1 holds CS operated, CS2 releases ST, CS3 prepares a path for CC relay on USA5, and CS4 connects the drive magnet of USA to neutral. USA and USB therefore commence to step at 50 steps per second from half wave rectified mains pulses. With the release of ST, the drive magnet of USC is connected to contacts on USC1 level through ST6, and USC self drives to the next contact which is connected to HS3. This ensures that USC halts on a contact where the condenser C1 is being charged and prevents the first digit of the next display being dropped. When USA reaches contact 1, neutral is extended through USA5 wiper, contact 1, CS3 contact and CC coil to -50 volts. CC relay therefore operates. CC1 is not effective in this case, CC2 released CS relay, and CC3 breaks the neutral line to the drive magnet of USA. With the release of CS, CC is no longer held through CS3 and it released. The scanner is then ready to start a further cycle upon the depression of the start button.

Should the full sequence of 50 readings be required, CS relay is not used. When USA reaches contact 50, neutral is extended through USA6 wiper and contact 50, CS3 contact and CC coil to -50 volts. CC relay operates, therefore. CC1 disconnects the path from ST relay through ST1, CC1, ER2 and CS2 to neutral. CC2 is not effective in this case, CC3 disconnects contact 1 of USA7 from CS4 and is not effective either. Towards the end of the decoding cycle, when USD reaches contact 22, RRA operates from neutral, USD5 wiper and contact 22, and RRA coil to -50 volts. RRA1 releases the data highway relays, as before, and RRA2 drops out ST and holds RRA operated. When USD passes contact 23, USA steps once to contact 1 and CC releases. When USD reaches contact 24, RRB operates to release RRA, and the scanner is then ready to start a fresh cycle of operations.

APPENDIX IV

Detailed operation of the serial counter

When a serial counter is called from the scanner, relay CR in the counter operates in series with relay DPO in the scanner. (The serial counter may not be used with the decimal point facility.) Relay CR thus remains operated until the scanner steps to call up the next device in the plugged sequence.

Half-wave rectified mains pulses are available at CR1 contact from line, through the RMO rectifier and B2 contact. Upon the operation of CR1 contact, these are extended to the circuit associated with relay A. For the duration of the pulse, current will flow through CR1 contact, bypass the relay coil and produce a P.D. across the 10 kilohm resistor R1 equal to the amplitude of the applied pulse. Current will also flow through RMO3 rectifier to charge C1 through A1 contact. Since the forward impedance of the rectifier is low in comparison with the resistance of the relay coil, there will be little difference in P.D. across the coil and relay A will not operate. At the back edge of the pulse, however, the junction of relay A coil and RMO3 rectifier will be held at +300 volts by the charge on C1 and as the potential on the other side of the coil falls with the back edge of the pulse, current will increase through the coil until the operate current is reached. Upon the operation of relay A, contact A1 provides a holding path from the +300 volts DC supply. Contact A2 provides a path for the operation of relay B and A3 extends neutral to the drive magnet of the least significant uniselector. The next mains pulse therefore energises the drive magnet of this uniselector and also charges the condenser C2 associated with relay B. At the back edge of this pulse, the least significant uniselector moves on to register the next count and relay B operates. Contact B1 holds relay B operated; B2 disconnects half wave rectified mains pulses from the relay circuit; B3 disconnects neutral from the drive magnet of the least significant uniselector to prevent any further stepping of the counter, and B4 releases relay A. Relay B remains operated until the release of CR at the end of the decoding cycle, when CR2 contact opens and releases it. Thus the counter steps once immediately upon being called by the scanner.

The uniselectors have eight levels but have single ended wipers, giving 50 separate connections for a full rotation of the ratchet motor, with adjacent wipers strapped in pairs. Thus five decades can be accommodated in one full rotation. The decades are wired so that the output from the counter is in cyclic progressive code. The counter thus appears to the scanner identical with the digitisers in the installation, and may be called and read in precisely the same way. Levels 1 and 2 are strapped in groups of five, corresponding to the W channel in the code of Table I. Levels 3 and 4 are concerned with clearance and carry. If the clear button is pressed, neutral is extended to contacts 0 to 8 in each decade, and the uniselectors home to the nearest 9th contact. Whenever a uniselector leaves a 9th contact within a decade, the pulse which operates the drive magnet also passes through the 9th contact to operate the drive magnet of the next more significant stage. As the less significant stage steps from 9 to 0, therefore, the next more significant stage is stepped once to record the carry. Levels 5 and 6 generate the X, Y and Z channels of the code, the lines to the data highway plug being routed through rectifiers to prevent interaction between the two counter circuits in the chassis. Levels 7 and 8 are concerned with the parity check and it will be seen from Fig.23 that the two connections from the bank of UD(A)8 level go to UC(A)1 level, with similar cross-connections between the other uniselectors. Thus if the most significant digit is even, the investigate pulse from pin Z on the data highway plug passes through UD(A)7 or 8 level to reach contacts 5 to 9 in each decade on UC(A)1 and 2, thereby generating the W channel of the code in Table I. If, however, the most significant digit is odd, then the investigate pulse reaches contacts 0 to 4 in each decade on UC(A)1 and 2, and the digit held on this uniselector is complemented on 9 by inversion of its W channel. This modification of a less significant digit by its next more significant neighbour applies to each counter stage and is in accordance with the rule given in section 2.1 for coding a decimal number in cyclic progressive form.

APPENDIX V

Detailed operation of the hand set switch unit

Fig.24 shows the circuit of the hand set switch unit, which contains eight separate switch circuits. Four of these each contain four decade switches (see Fig.19) which can be set with a four decimal digit number. Two more circuits can be set with a three decimal digit number each and the remaining two circuits are for a single decimal digit only. As with the digitiser circuits, call-up relays are provided to connect the outputs from the switch circuits to the data highway, and each switch circuit appears to the scanner identical with a digitiser. Relay CRC is the call-up relay associated with switches SWA, SWB, SWC and SWD, these being the top row of switches on the left-hand side of Fig.19. Wafers (a) and (b) on each switch are concerned with the generation of the x, y and z channels of Table I. Wafers (c) and (d) modify the w channel of the next less significant circuit in the light of the oddness or evenness (parity) of the more significant of an adjacent pair, thus coding the decimal number set on the switches into a fully cyclicly progressed form. Rectifiers are provided at the output of each switch circuit to prevent feedback between the switch circuits on the panel through the connections to the common data highway. These are biassed from the -50 volt supply on the data highway, when the associated relay is released, to reduce the effect of many back impedances in parallel on the data highway lines. When a relay is called from the scanner on the appropriate call-up line, this bias is removed, and the switch circuit is connected to the investigate line on the highway. The investigate pulse passes through the connections set up by the switches and reaches the appropriate data highway lines for return to the scanner. Switches SWE to SWH, SWJ to SWM, and SWN to SWQ, are wired identically with SWA to SWD, each having its associated call-up relay CRD, CRE and CRF, respectively. Switches SWR to SWT and SWU to SWW with their associated relays CRG and CRH allow three decimal digit numbers to be set. These are connected to the data highway lines corresponding to the three least significant decimal digits of a four digit digitiser, since the feeding of no signals at all to the decoding trees in the scanner other than the most significant would cause an error condition. Switches SWX and SWY are for the setting of single digits only. Due to the requirement for an error detection circuit within the scanner, however, it is not possible to feed nothing to the decoding trees, and codes corresponding to 0 have been permanently wired into circuit, so that the display from the scanner shows the set digit in the hundreds place, followed by two zeros. If some reduction in the effectiveness of the check circuit in the scanner is allowable, the 0 codes may be replaced by one in which the channels x, y and z in the code are all energised. This does not correspond to a digit (see Table I) and can be ignored by the decoding trees in the scanner by a simple modification of their circuit. The display would then consist of just the set digit.

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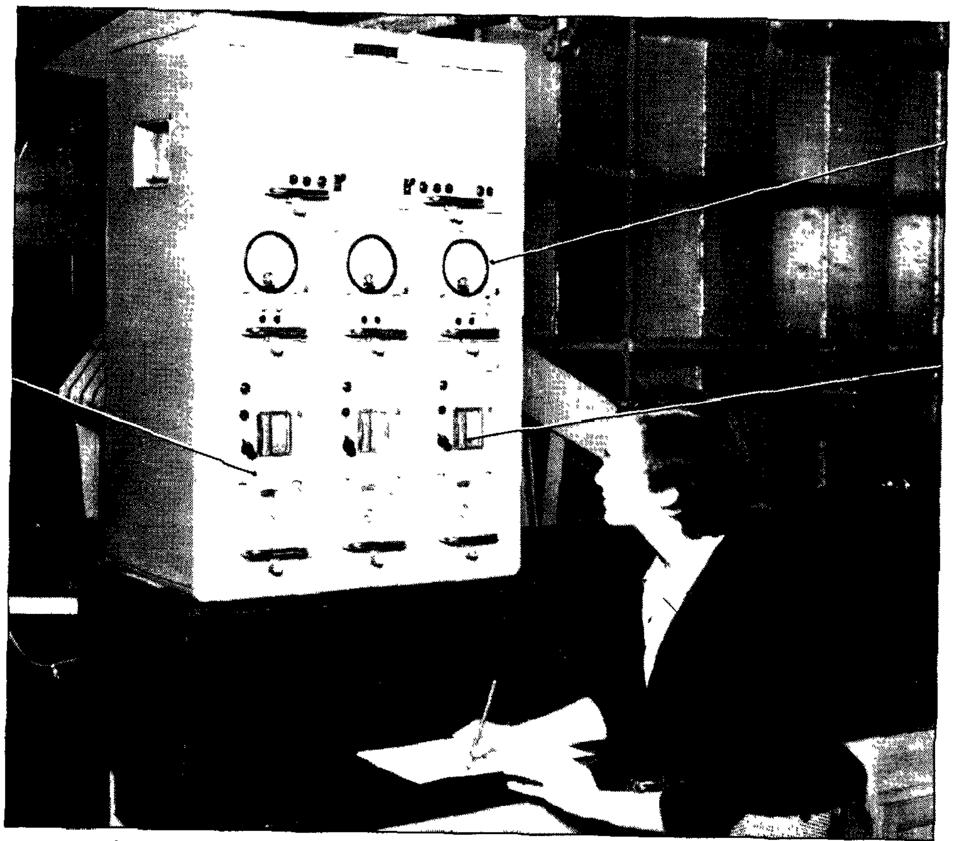


FIG.1. VISUAL READING OF STRAIN GAUGE BRIDGE EQUIPMENT

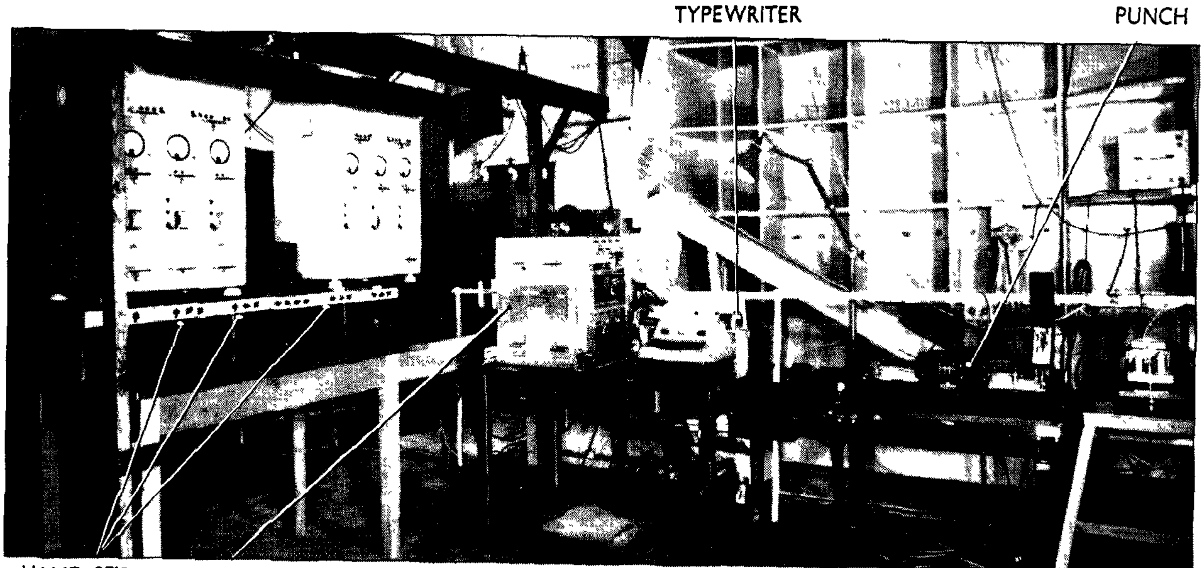


FIG.2. SEMI-AUTOMATIC DATA RECORDING SYSTEM

FIG.3. GENERAL VIEW OF FULLY AUTOMATIC SYSTEM

FIG.1,2 & 3. THREE STAGES IN THE DEVELOPMENT OF WIND TUNNEL DATA HANDLING

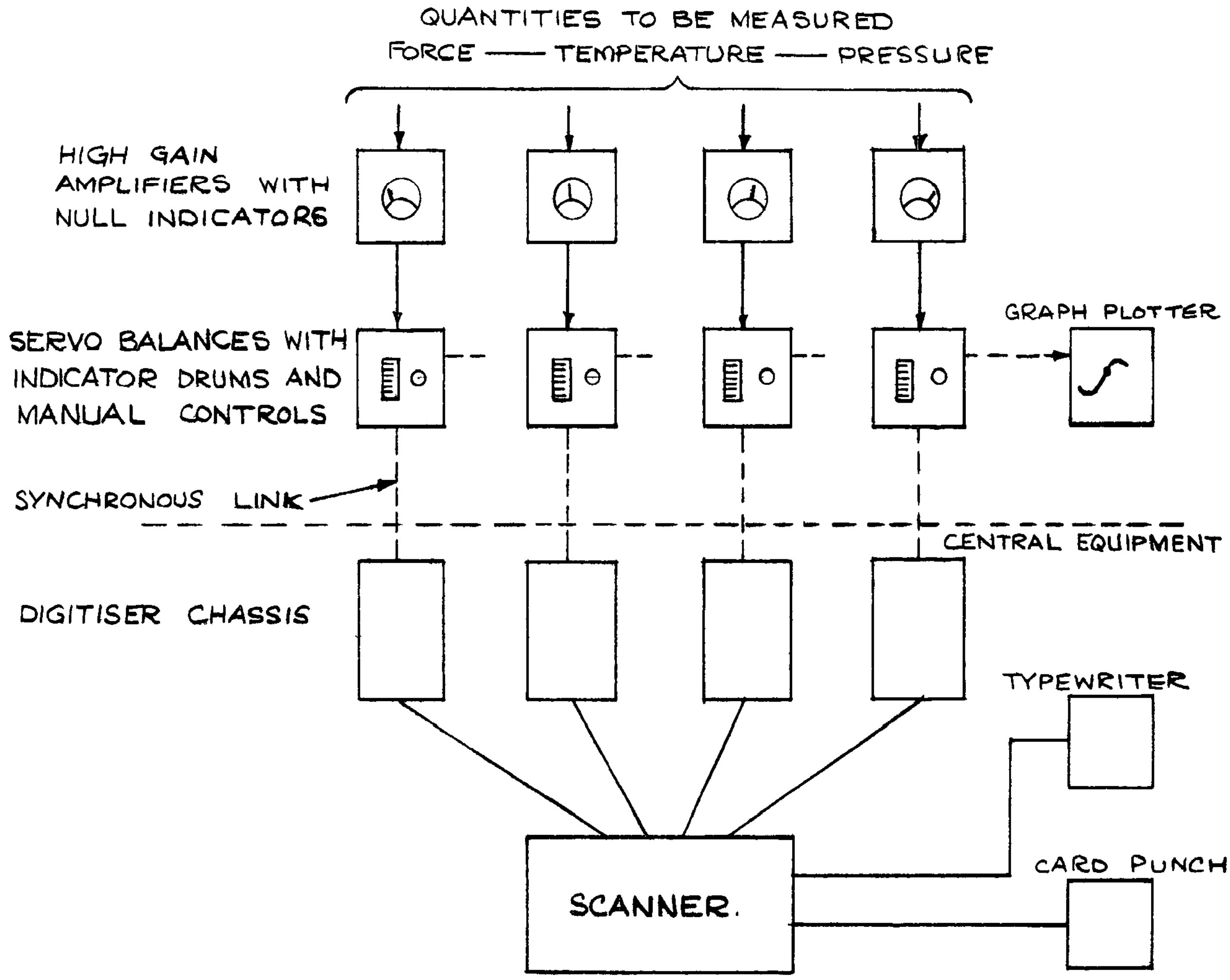


FIG.4. BLOCK SCHEMATIC OF FULLY AUTOMATIC SYSTEM

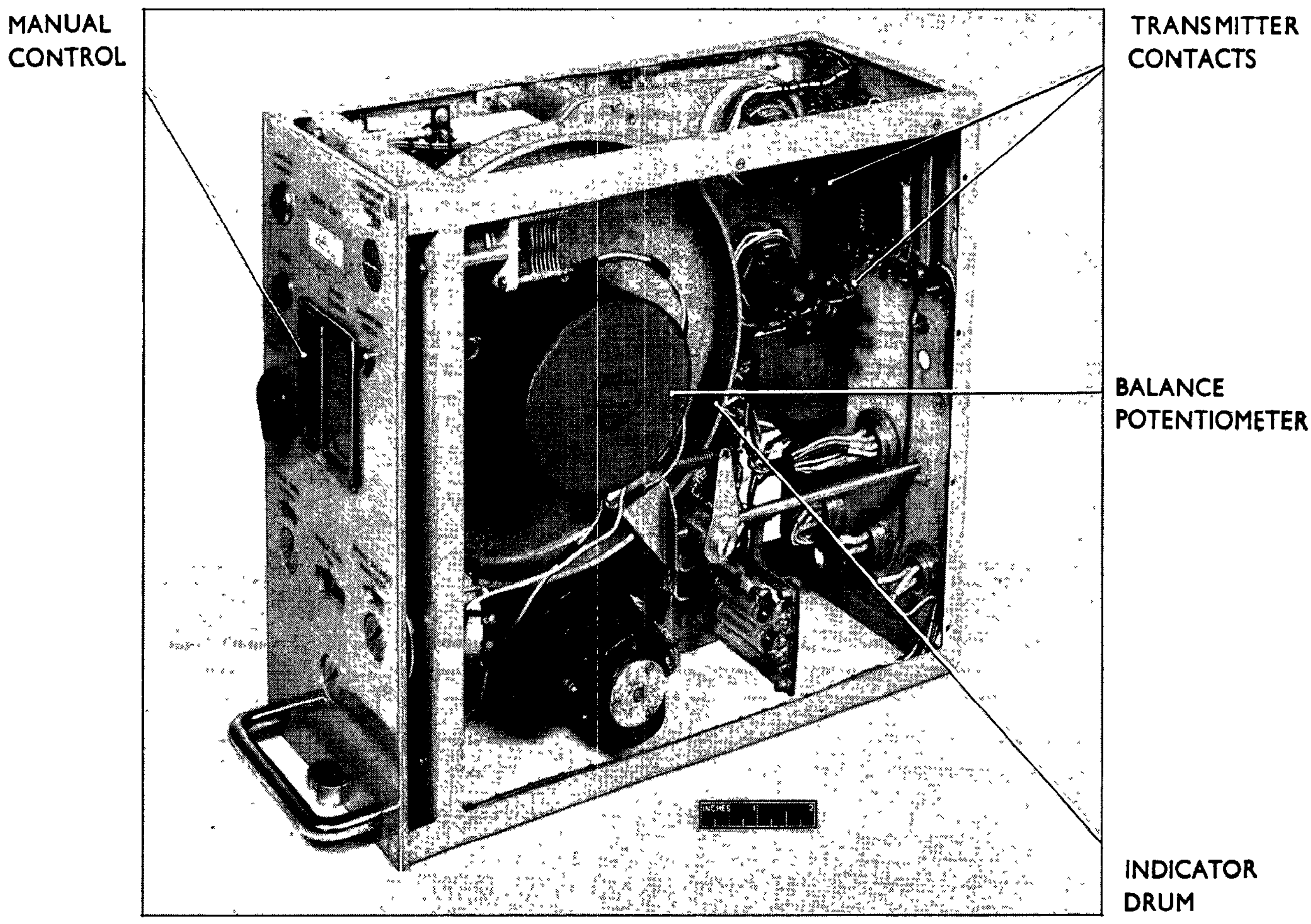


FIG.5. ELLIOTT STRAIN GAUGE BRIDGE

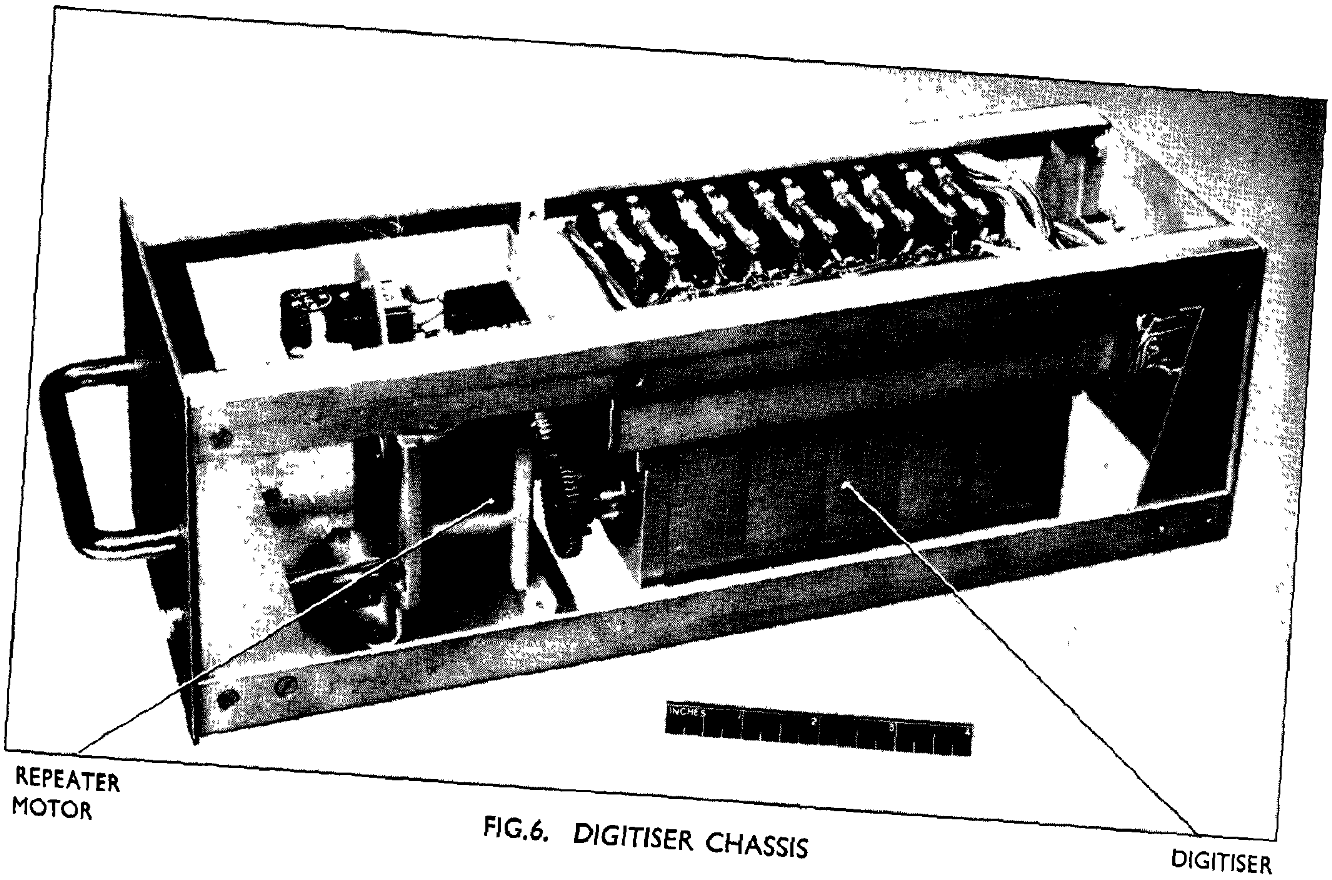


FIG.6. DIGITISER CHASSIS

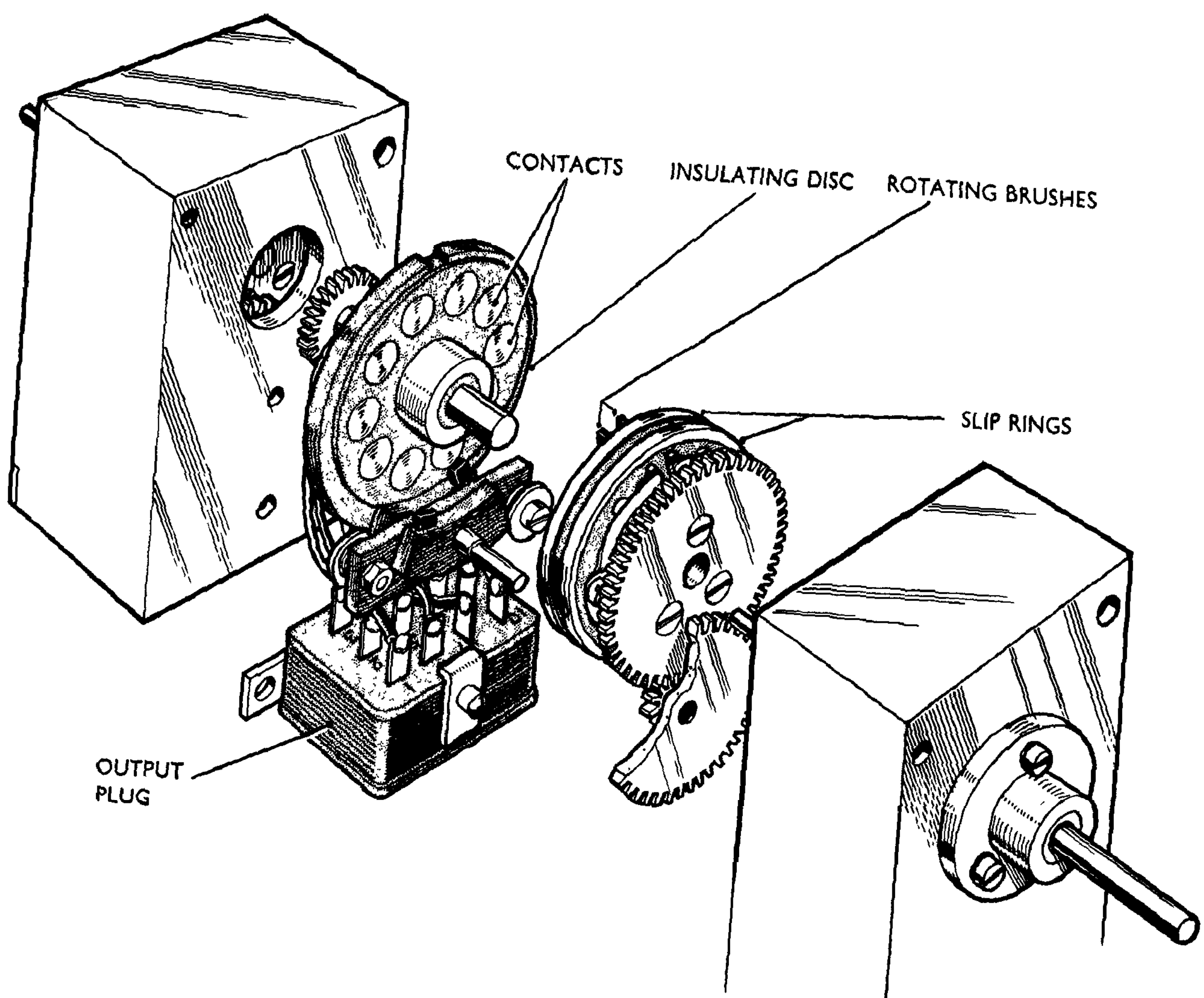


FIG.7. EXPLODED VIEW OF DIGITISER

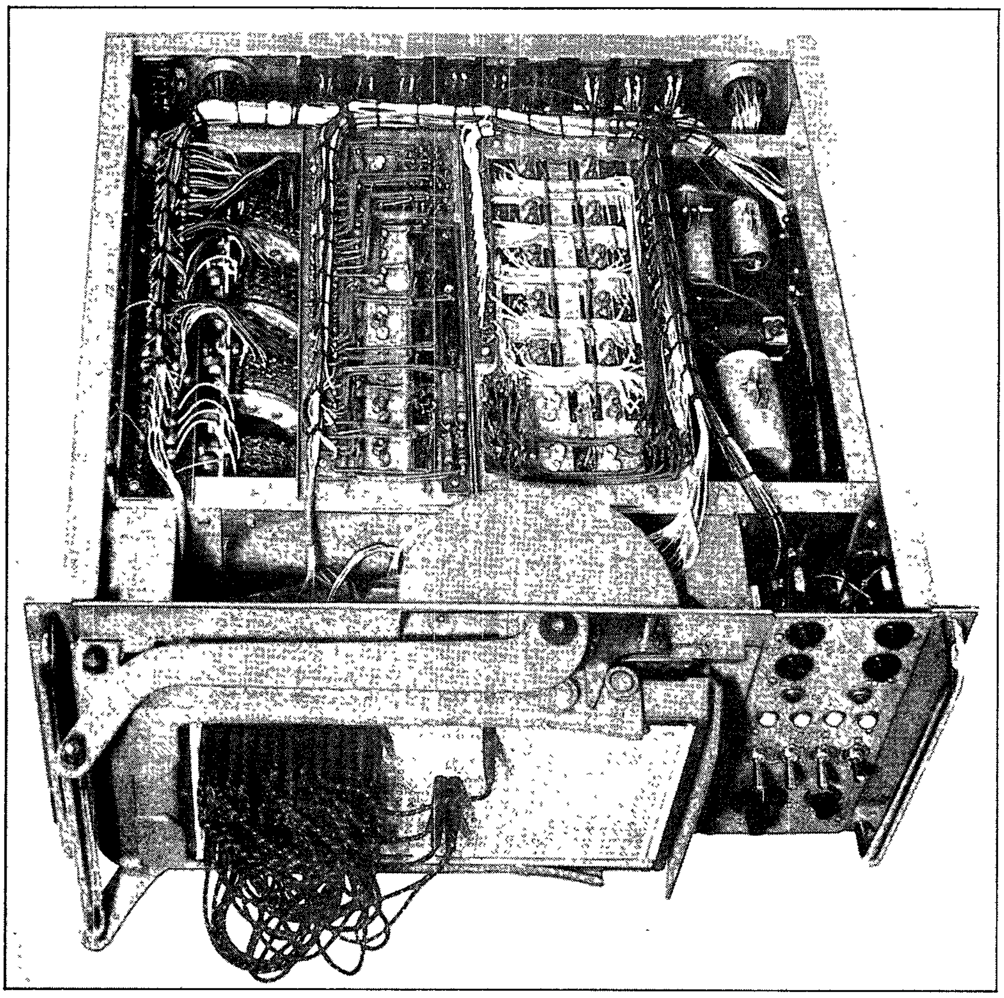


FIG.8. MARK III SCANNER CHASSIS

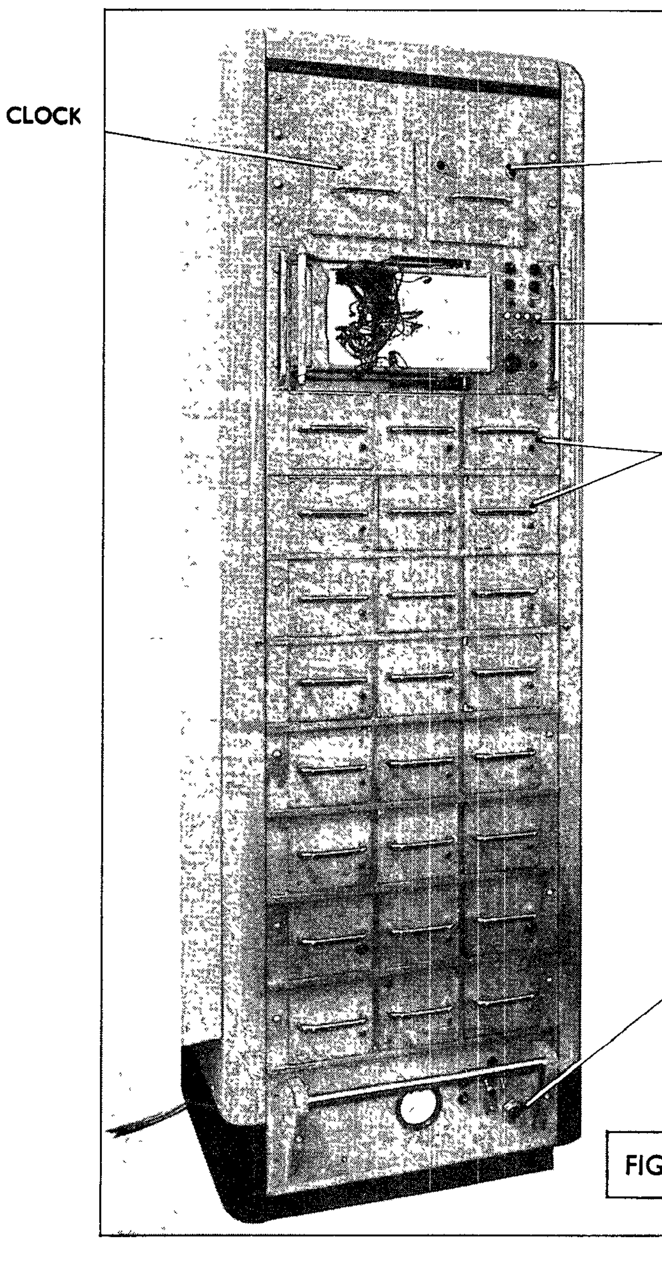


FIG.9. MARK III EQUIPMENT CABINET

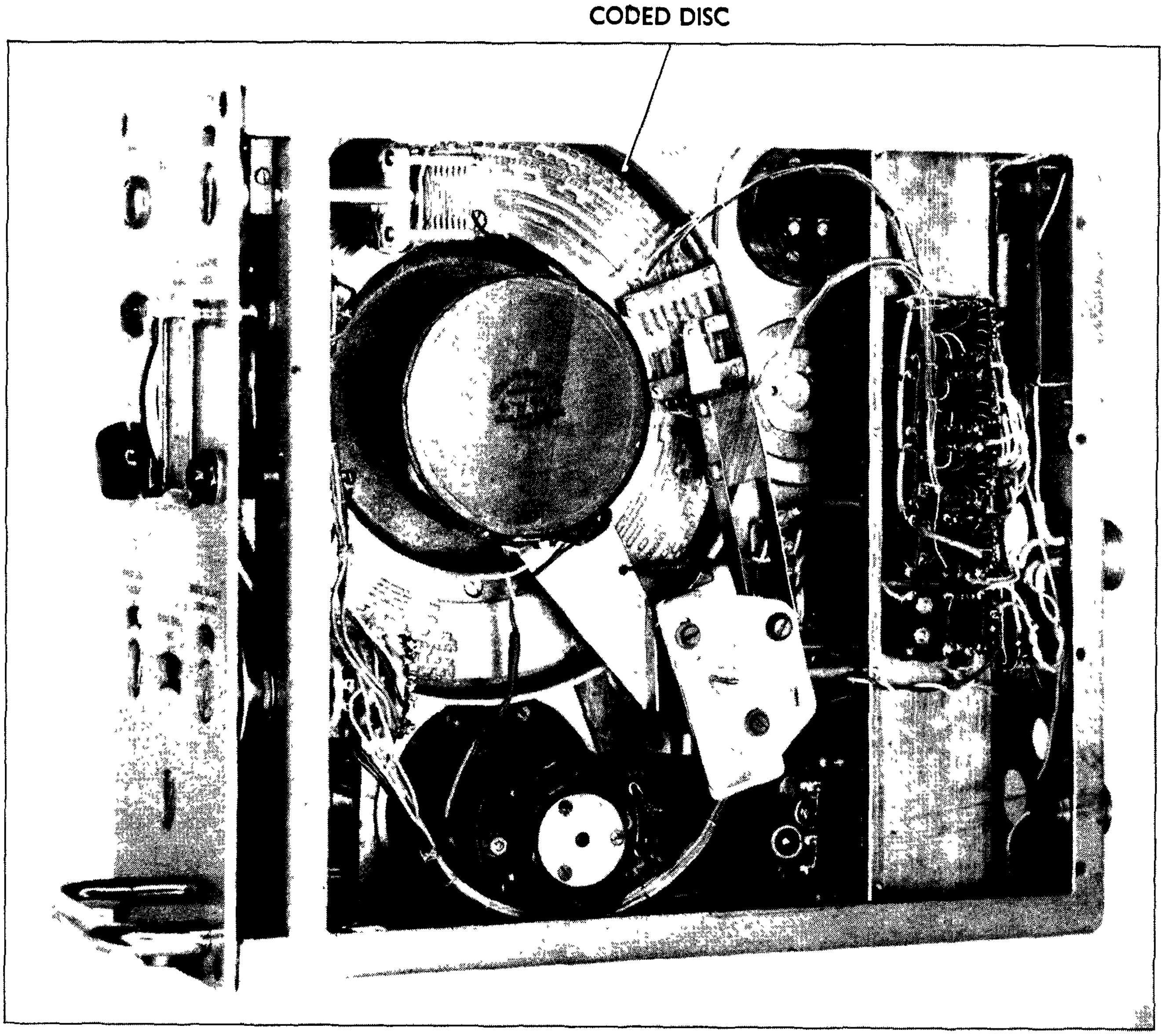


FIG.10. ELLIOTT BRIDGE WITH EARLY TYPE OF DIGITISER

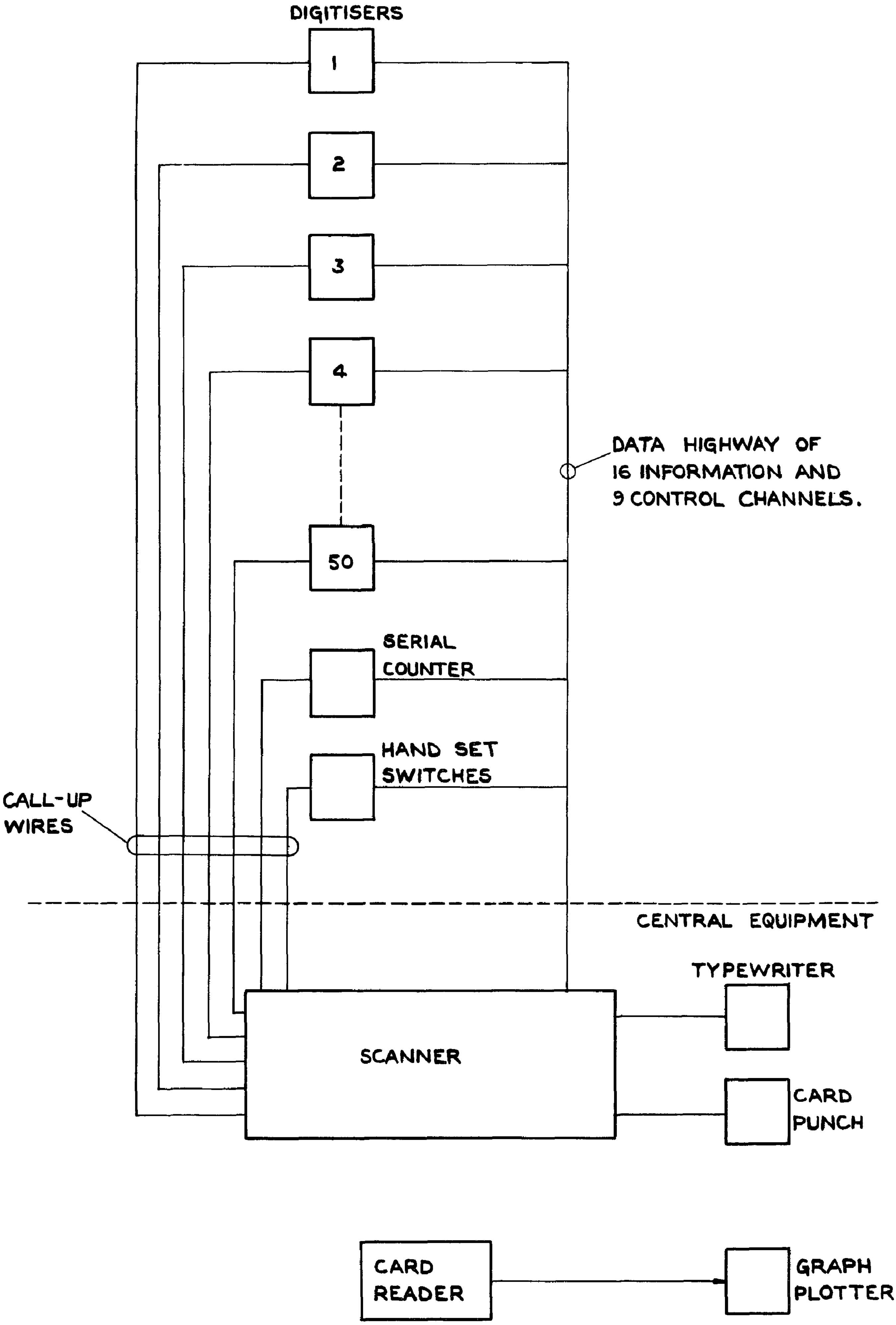


FIG.11. BLOCK SCHEMATIC OF NEW SYSTEM.

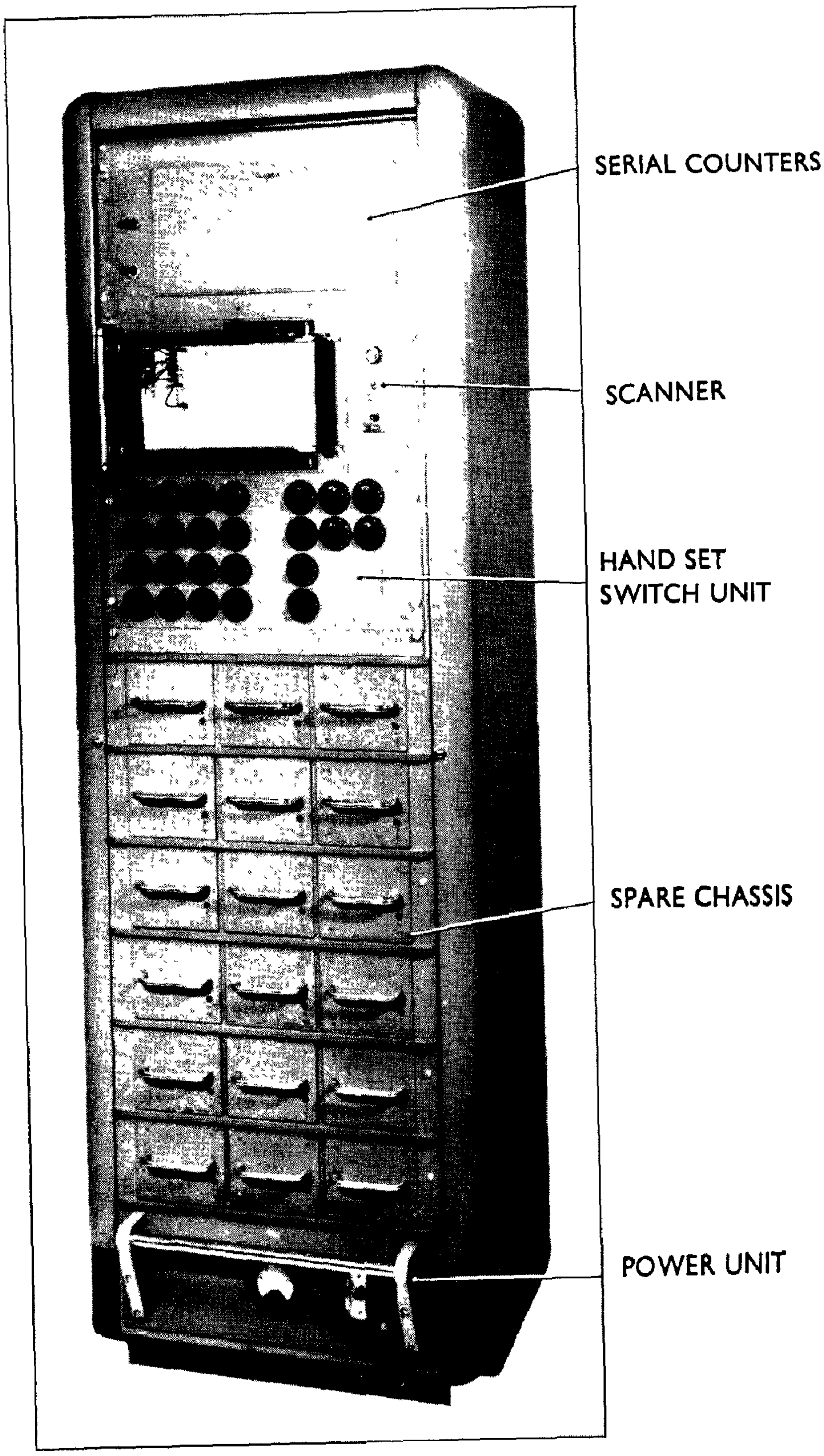
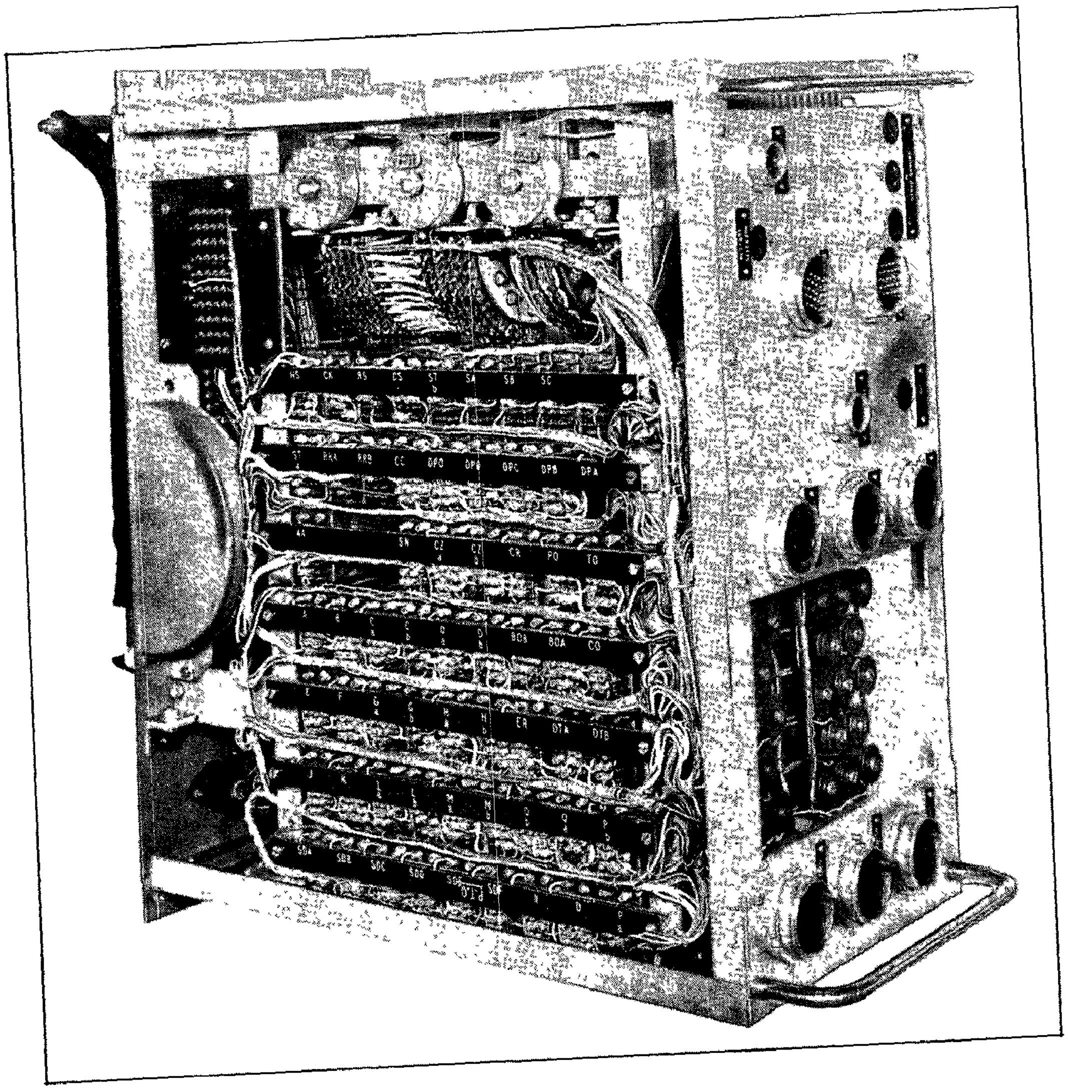


FIG.12. MARK IV EQUIPMENT CABINET



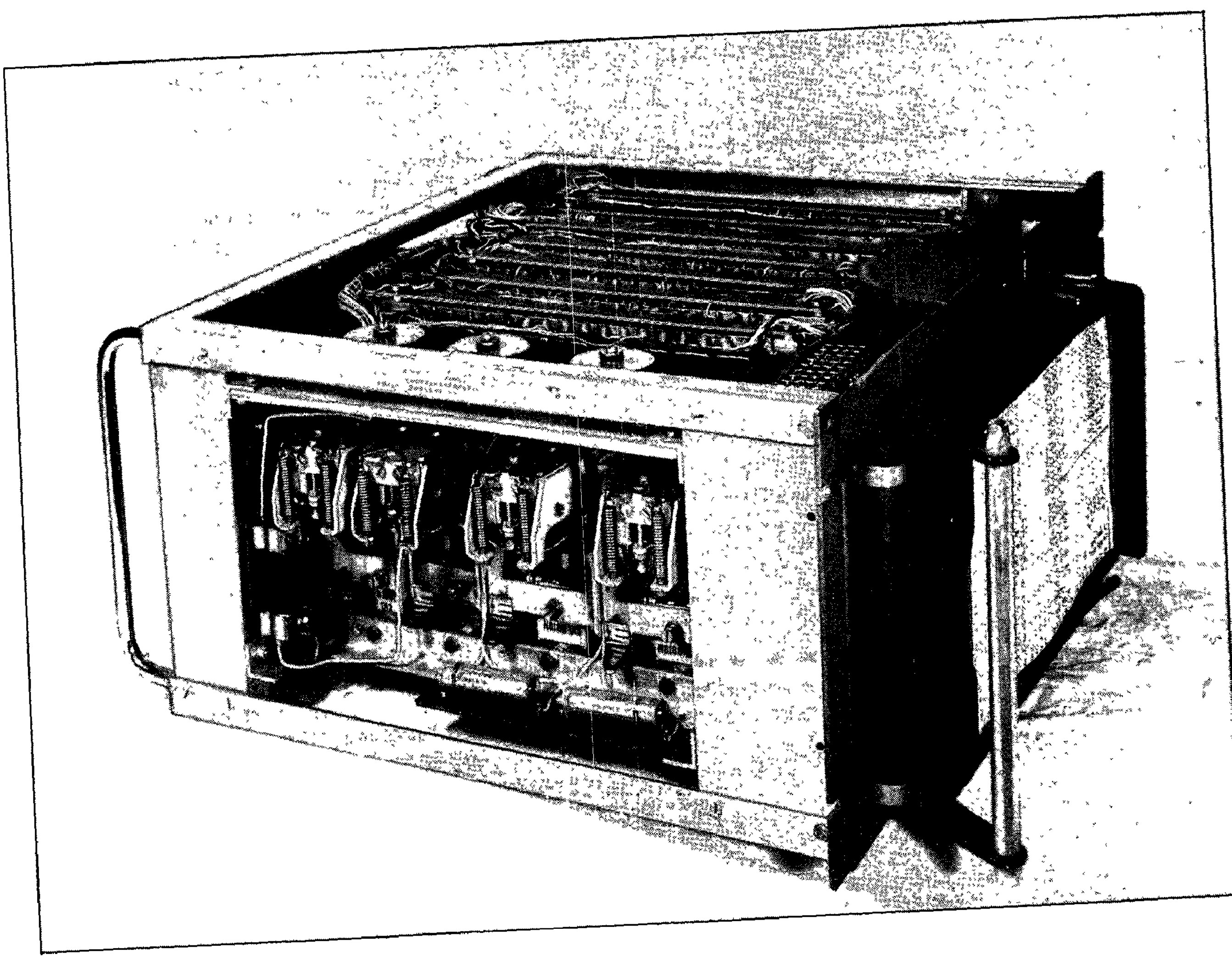


FIG.13. TWO VIEWS OF THE MARK IV SCANNER

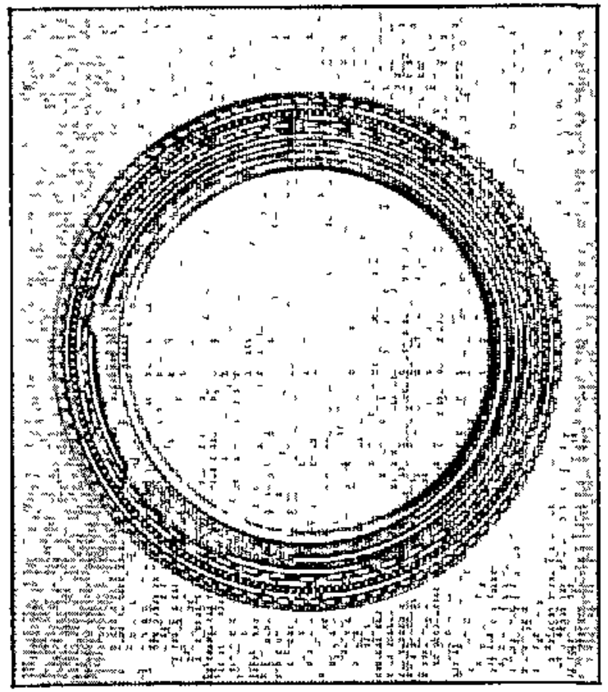


FIG.14. CODED DISC

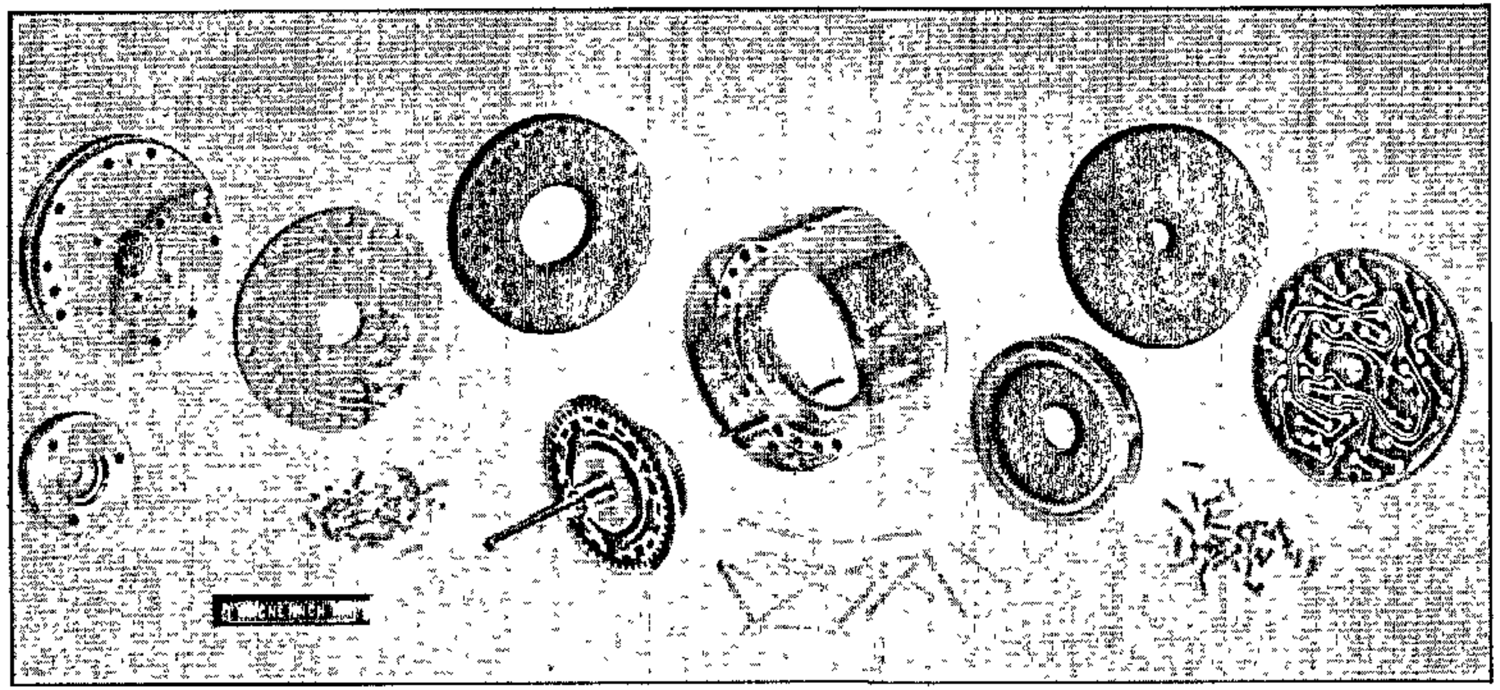


FIG.15. MULTI-TURN DIGITISER

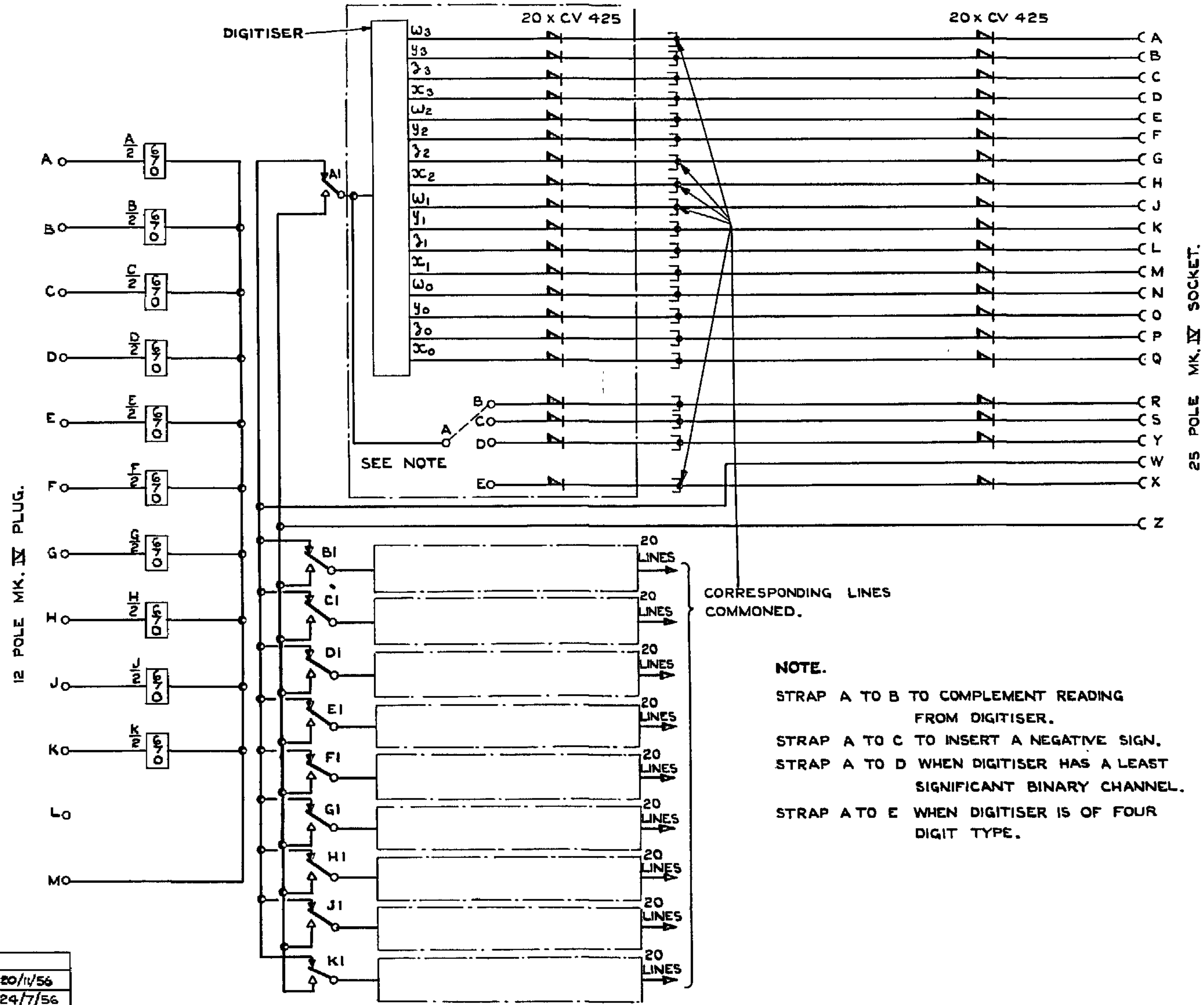


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FIG. 16. LOCAL CIRCUIT FOR A GROUP OF 10 CODED DISC DIGITISERS.

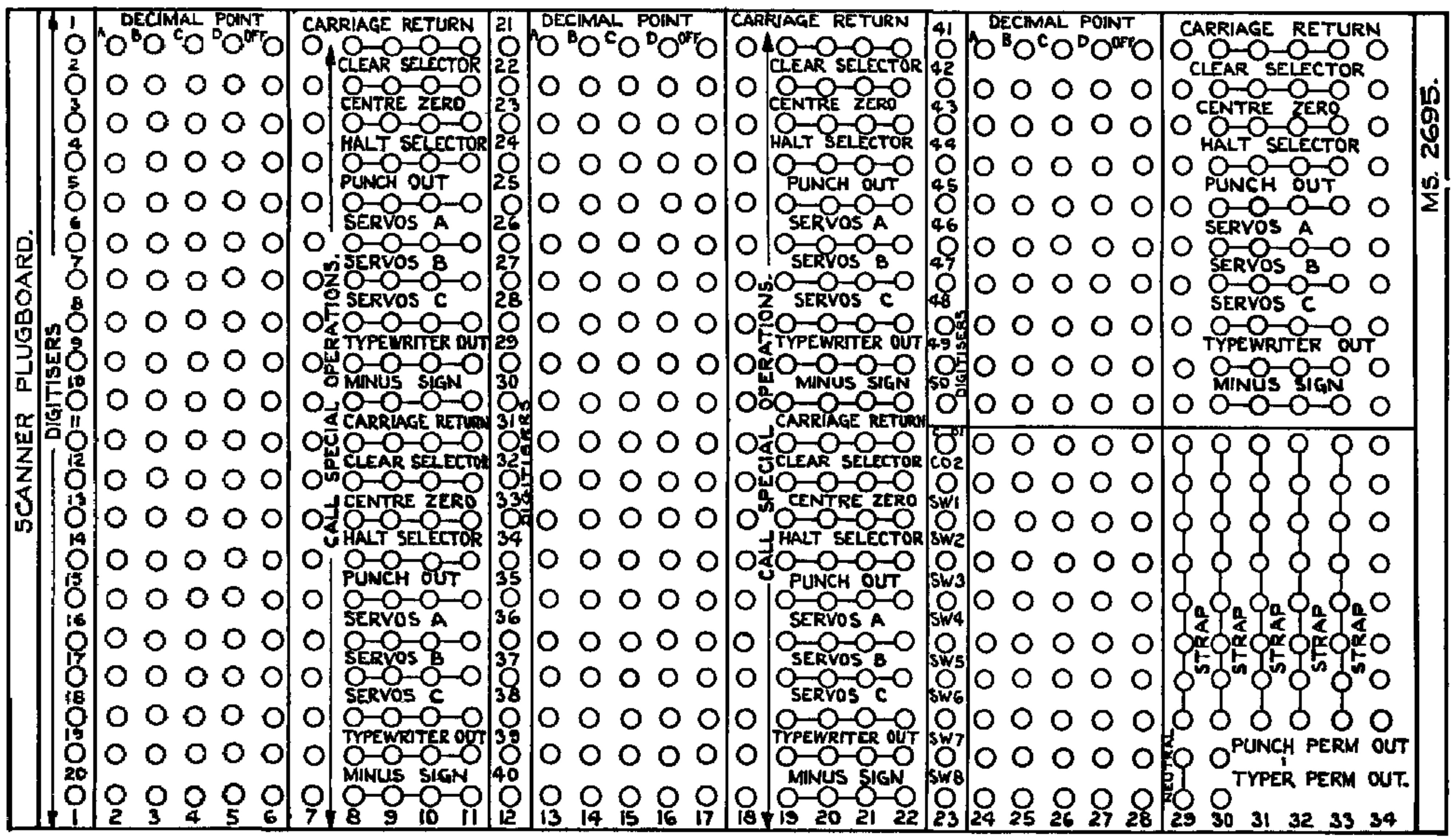

FIG. 17. SCANNER PLUGBOARD LAYOUT.

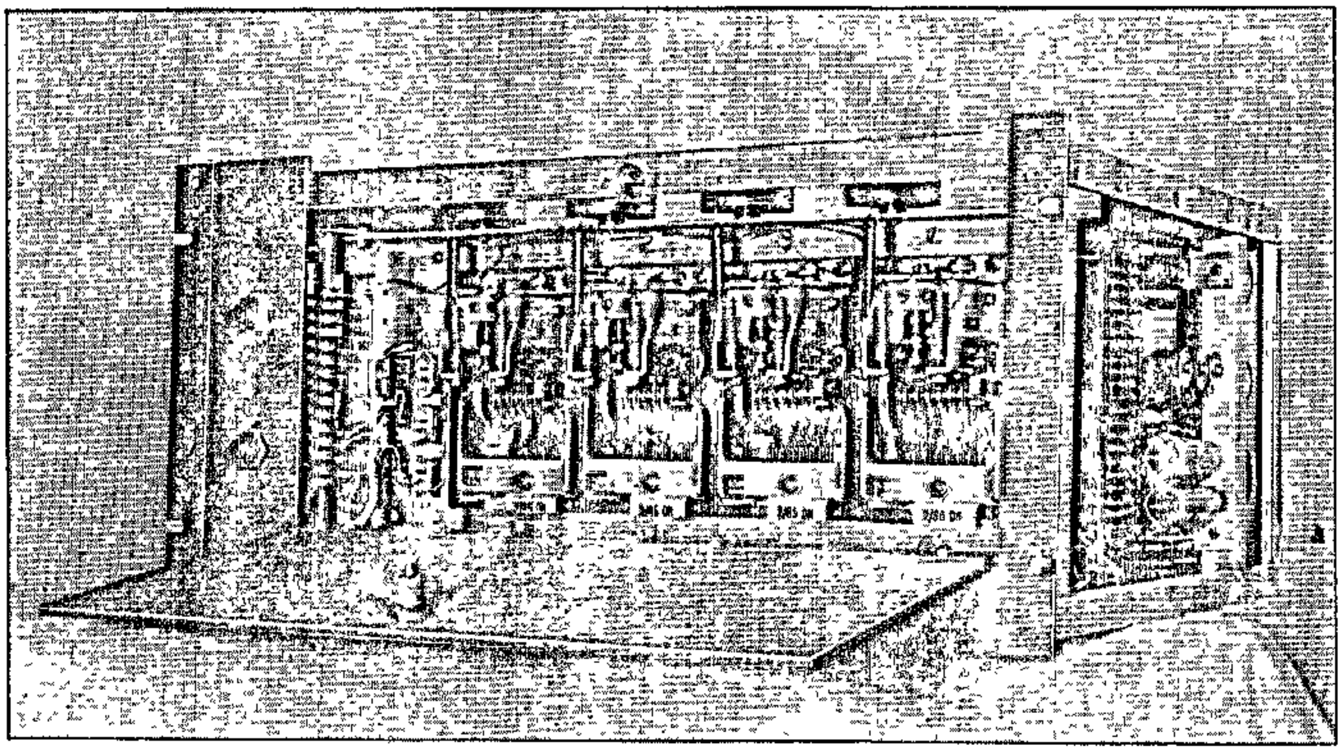

FIG.18. SERIAL COUNTER

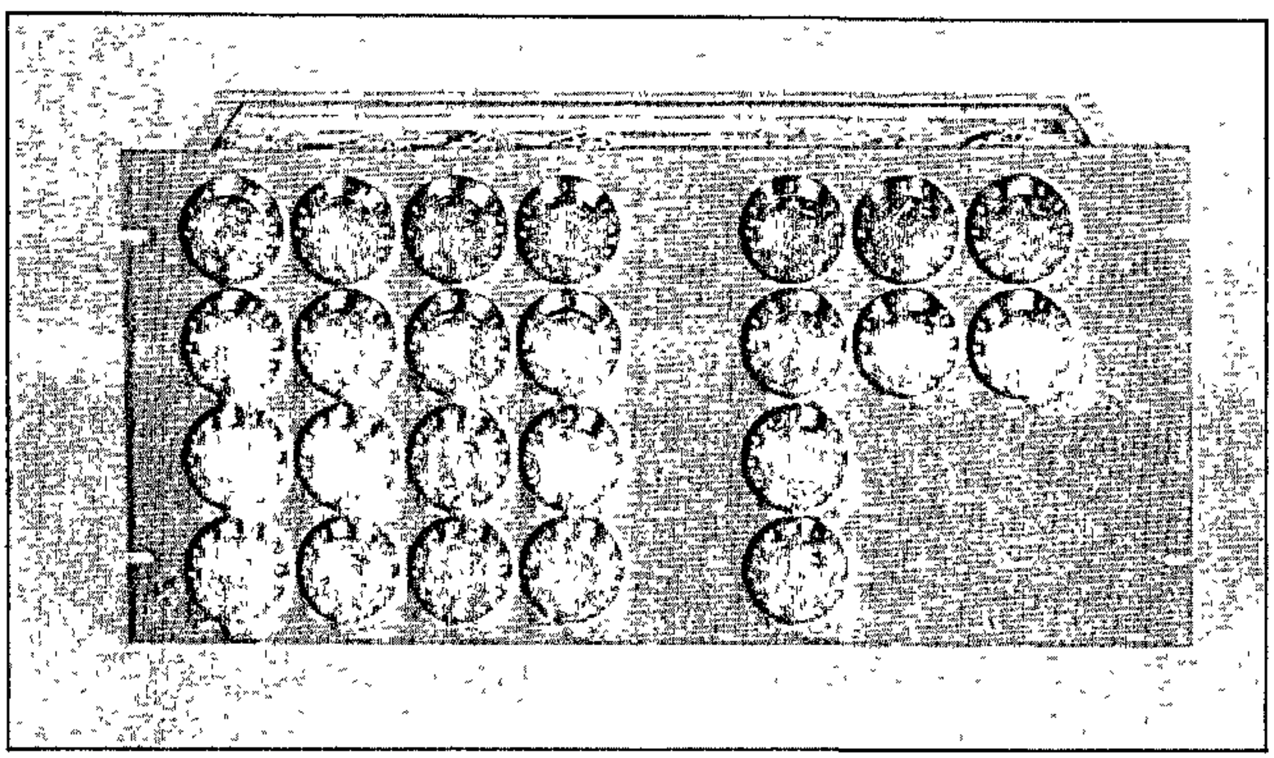

FIG.19. HAND SET SWITCH UNIT

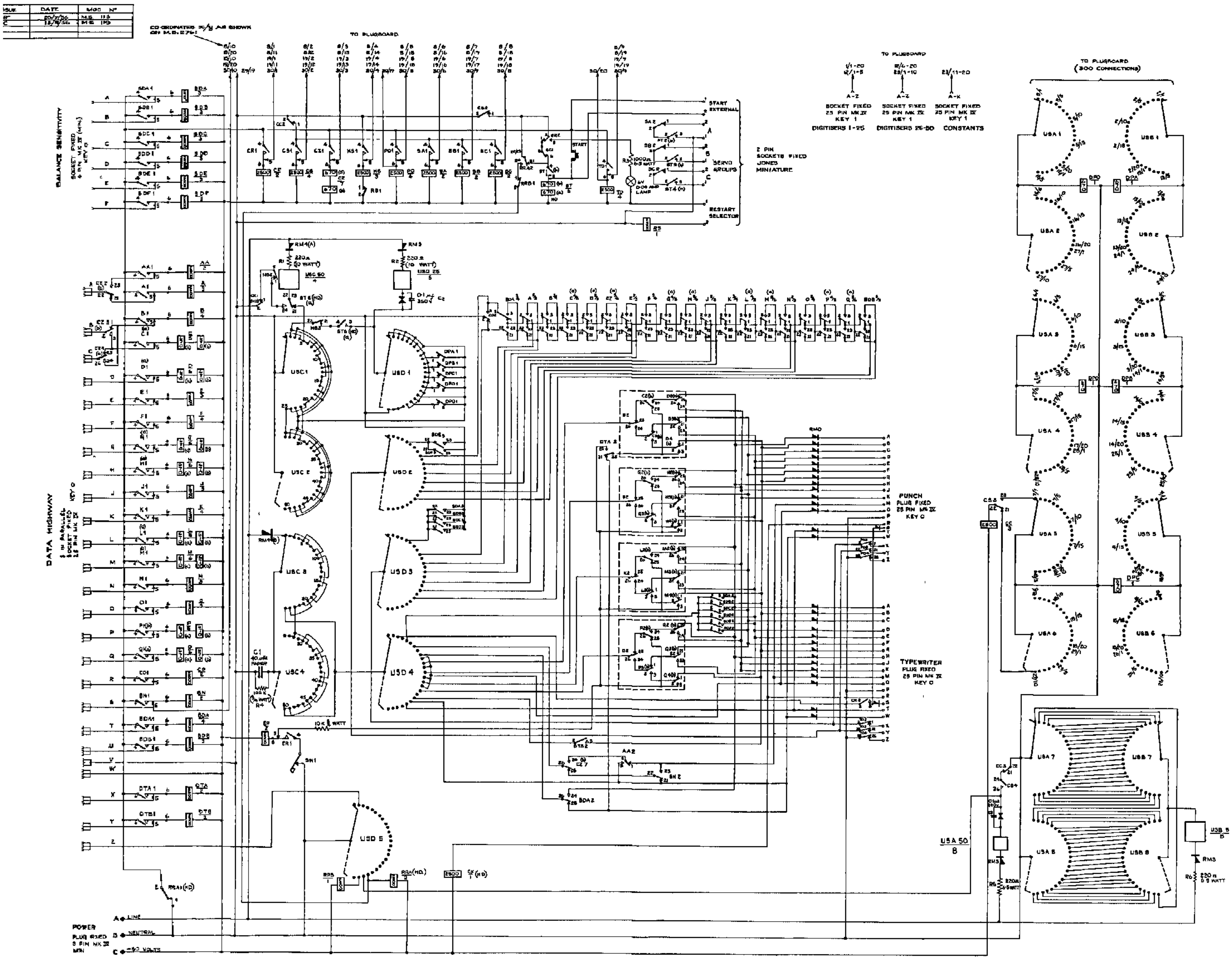

FIG. 22. CIRCUIT OF SCANNER.

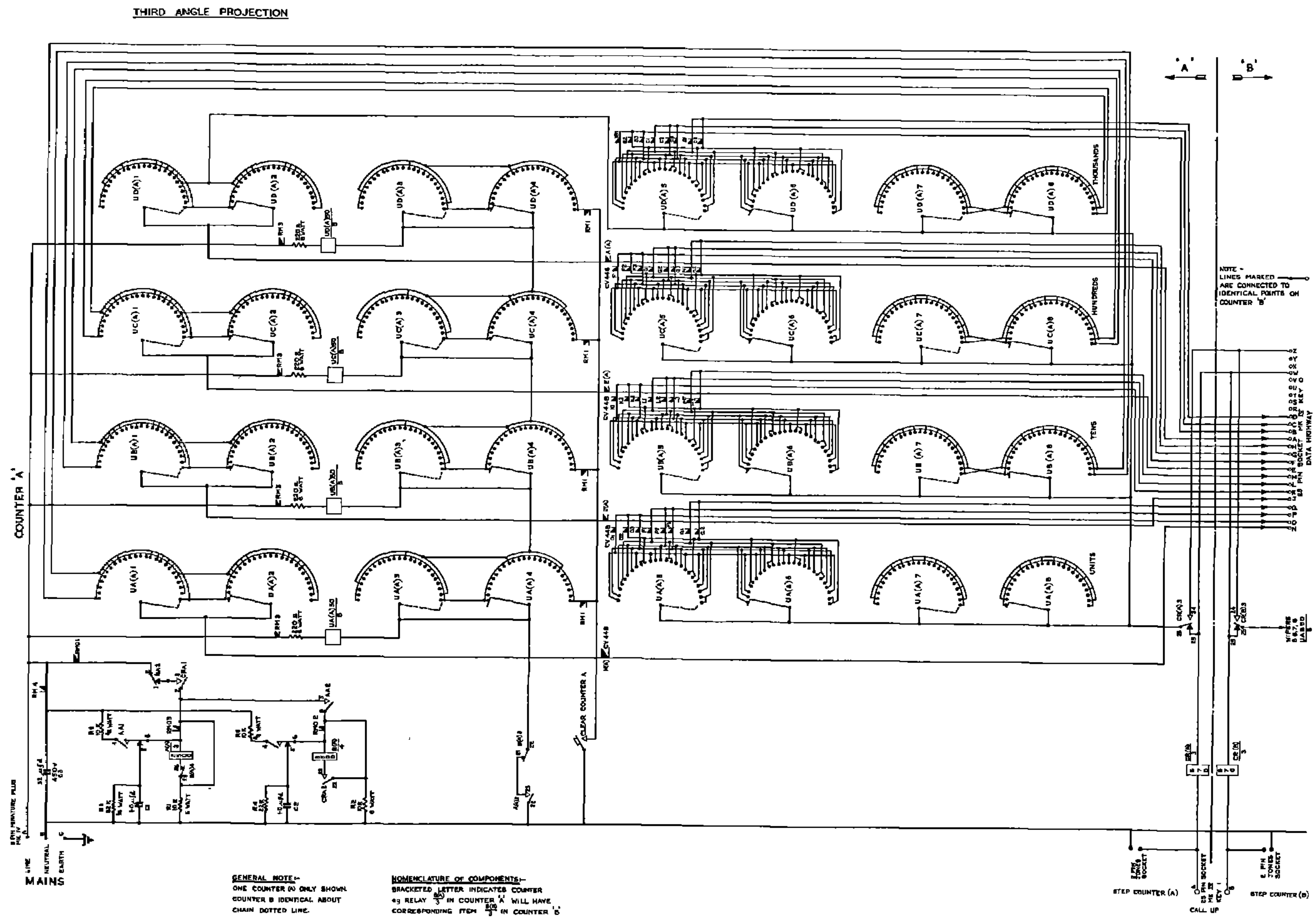

FIG. 23. CIRCUIT OF SERIAL COUNTER.

THIRD ANGLE PROJECTION

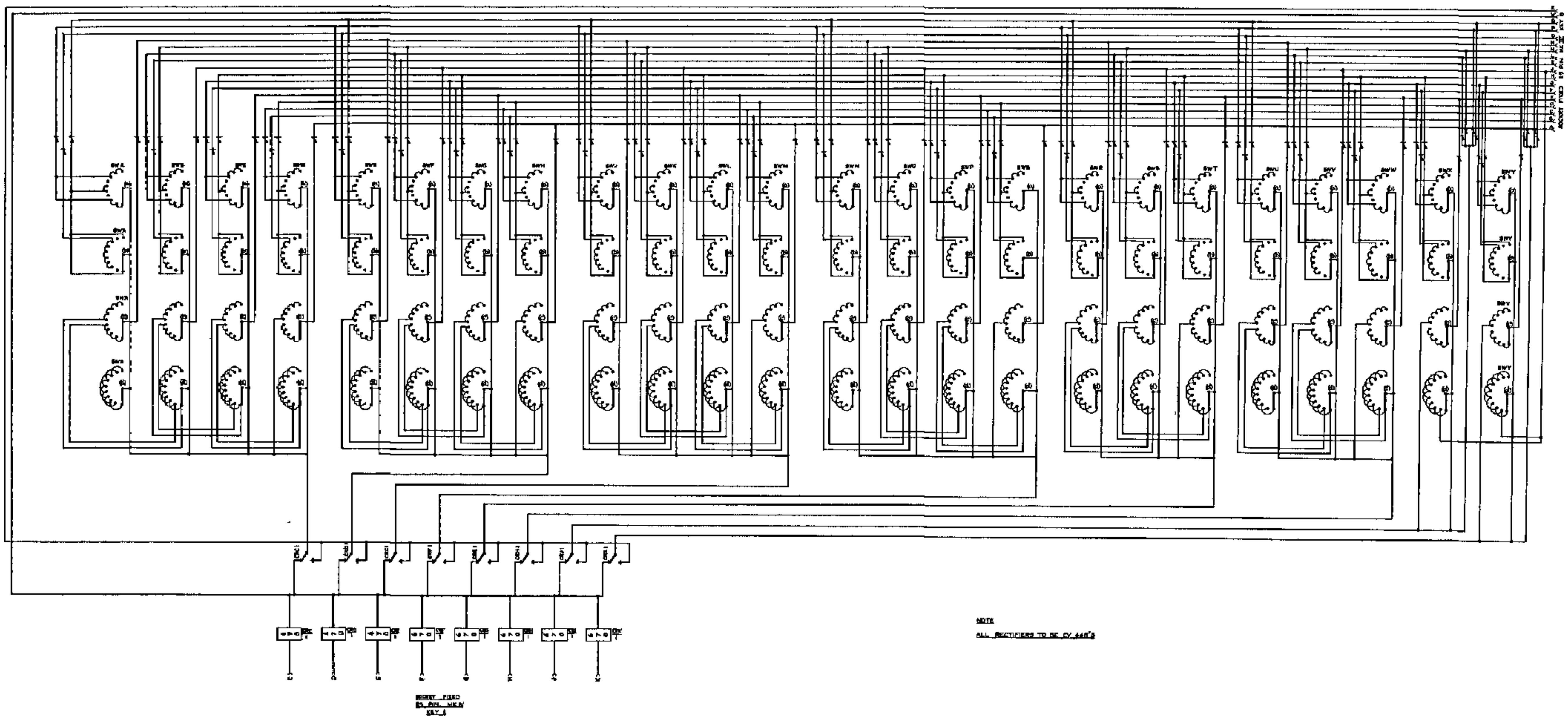

FIG. 24. CIRCUIT OF HAND SET SWITCH UNIT.

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