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Commentary

THE recently published Annual Report and Accounts of the BBC for the year ending 31st March, 1953 (H.M.S.O. Cmd. 8928) follows very closely the pattern set in previous years in presenting a most detailed analysis of the many and varied activities of the Corporation.

Since sound broadcasting and television have such an overwhelming influence on our daily lives, it is no great surprise that the report consists largely of programme matters and that relatively little space is devoted to technical and engineering development. This does not, however, reflect any discredit on the Research and Engineering Departments of the BBC for the year under review is primarily one of consolidation.

If there is an absence of any spectacular advancement it is due principally to two causes of which the foremost is the control of capital expenditure which is still in force and preventing the solution of a number of problems vexing both the BBC and the listening public. The most urgent one, which was extensively discussed in the recent report of the Television Advisory Committee, is the unsatisfactory state of home broadcasting.

In spite of the addition of several low power stations in those areas where the need is greatest there are still regions where satisfactory reception of the Home, Light or Third programmes is unobtainable because of fading and/or interference from foreign stations. It is probably difficult to obtain an accurate assessment of the degree of foreign interference caused in the country as a whole but it comes as a great surprise to learn that after nearly thirty years of sound broadcasting there are some four million of the population who cannot satisfactorily receive the Home Service during the winter evenings.

The causes are well known and equally well known are the remedial steps to be taken by the BBC, but with the present restrictions the BBC can do little more than " hope it will be given permission at the earliest possible moment to start on the construction of the proposed V.H.F. stations." Its plans have been well prepared and all that is needed now is the signal to proceed.

The second cause arises from much happier circumstances in as much as the first stages of the BBC's post war expansion plan have been successfully completed. The greatest emphasis has, of course, been given to television and with the opening of the television transmitter at Wenvoe in August, 1952, the chain of five high power stations covering some eighty per cent of the population is now in operation.

Much still remains, and awaits the lifting of the controls on capital expenditure. There are a number of low power stations to be erected to give full coverage of the present single television programme to be followed by a chain of transmitters required for the proposed alternative programme.

It is unlikely that next year's report will record any great advance in these projects but it would be comforting to read that at least a start had been made.

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The German Radio, Gramophone and Television Exhibition held at Düsseldorf at the beginning of last month is perhaps the only counterpart to our own Radio Show at Earls Court and the natural tendency of the visitor to both exhibitions is to compare them on the more superficial points.

In actual floor space the Düsseldorf Exhibition was larger and there were more than twice as many exhibitors, but the German Exhibition was wider in its scope than its name implied, being more of a combination of Earls Court and the exhibitions of the RECMF and Physical Society.

The potential purchaser of a radio or television set may therefore have found the exhibition bewildering in its complexity but it is nevertheless a unique exhibition in that it is the shop window for the entire German radio and electronic industry.

Great strides have, of course, been made in the post war recovery of German industry as a whole and nowhere is this more noticeable than in the radio and electronic industry.

As is well known, Germany faced the post war years with no television and almost nothing of the vast pre-war sound broadcasting network, but today the picture is quite different. There is already completed a television network of some seven transmitters and more are in course of erection, but the most remarkable feature is the F.M. network of about 90 stations covering the major portion of Western Germany.

The design of receivers has kept in step with this development and the radio industry has produced a wide variety of radio and television receivers from the humble portable receiver to the luxury *musikschränke* containing a four band radio receiver, three speed record player, tape recorder and large screen television receiver.

Measurement of the Size-Distribution of Spray Particles

By L. K. Wheeler*, B.Sc., A.M.I.E.E. and E. S. Trickett†, B.Sc., A.C.G.I.

The apparatus was designed and constructed for the automatic assessment of the distribution of sizes of spray particles. A phototelegraph transmitter is used to scan spot patterns produced by a spray. The resultant signals, which are proportional in duration to the chord lengths produced by the interception of the scanning beam by the spots, are presented to a discriminating device which records the numbers of chords exceeding predetermined limits. Ten size-groups can be recorded simultaneously. From the data thus obtained, if certain assumptions can be made regarding the type of distribution within size-groups, the complete distribution of spot sizes in the scanned sample may be calculated with fair accuracy. The apparatus was developed at the Post Office Engineering Research Station.

IN the past few years the need has arisen in many fields of research for some rapid means of assessing the size distribution of particles[1], e.g. dust particles in studies of air pollution, blood corpuscles in biology, fuel atomizers and agricultural sprays. The sizes of particles in these various fields range possibly from the order of 10 microns to 10 millimetres. The range considered in this article is at the larger end of this group—from 0·5mm upward—agricultural sprays. The method hitherto employed to collect data on the size-distribution has been to examine visually the spray patterns collected on sampling sheets of absorbent paper, the spray solution being dyed to increase visibility. Either a complete sheet was examined with a low-power microscope and measuring graticule, a very laborious process, or alternatively, small sample areas, selected by an "experienced eye", were measured. The accuracy of this last must be a matter of conjecture. A typical time for the thorough measurement and grouping of a sample comprising 1 800 spots is 8 hours. The relation between spot size and droplet volume is found experimentally, using a microburette.

To reduce the labour and time taken to examine samples, the obvious approach is to employ some suitable automatic scanning system in conjunction with a counting device. The realization of a machine which will detect spots on a sample sheet and determine whether they fall into a given size group is very complicated. Other workers have developed an experimental machine on these lines[2], but have not succeeded in obtaining a 100 per cent count. The scanner is complex and requires readjustment and a rescan for each size group to be counted. The method to be described is straightforward and enables the data for the calculation of the distribution over a range of size-groups to be recorded with one scanning of the sample.

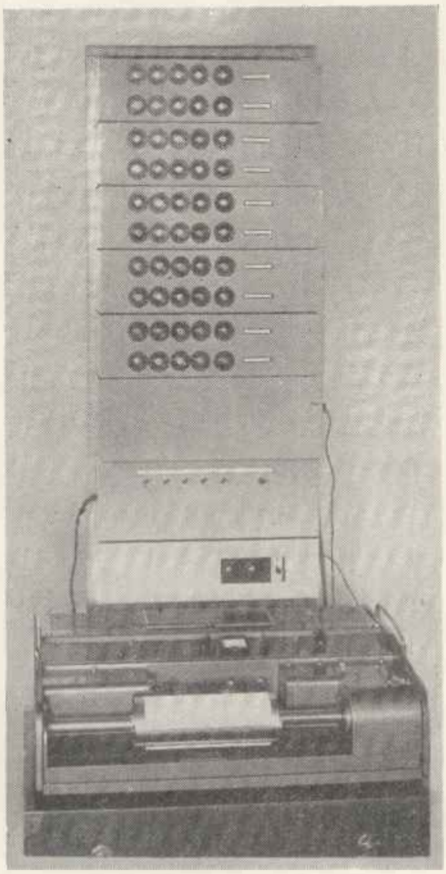

Fig. 1. The complete equipment

Outline of Apparatus

The basis of the method is to scan the sample in straight lines at a uniform interval and record in size-groups the intercepts or chords which are made on the scanning lines by the spots. Provided that the spots are of uniform shape and that it can also be assumed that, within the individual size-groups into which the range is divided, the sizes are uniformly distributed, the size distribution of the spots can be calculated from the distribution of chord lengths[3,4].

The apparatus[5] comprises a scanner, a pulse-length to pulse-amplitude convertor, a series of pulse-amplitude discriminators and counters associated with each discriminator (Figs. 1 and 2).

The scanner[6] is a conventional photo-telegraph transmitter with some very slight modifications. The sample sheet to be scanned is fastened by clips to the drum which is rotated at constant speed by a synchronous motor fed from a stable frequency source and also traversed axially at a uniform rate by a lead-screw mechanism. A portion of the drum surface is floodlit and an image of this portion is projected optically on to a scanning aperture, the light passed by the aperture exciting a photocell. The photocell current modulates a 10kc/s carrier to produce an output signal modulated in amplitude in accordance with the light reflected from an elemental area of the sample sheet. One of the clips holding the sample on the drum is always at the same point on the circumference; the position of the other is dictated by the length of the sample sheet. When the first clip is passing the scanning point, a cam on the drum-shaft closes a pair of contacts, the use of which is explained later.

The maximum size of sample sheet which can be accommodated is 10in by 11in, of which area 9in by 10in can

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* *Post Office Engineering Research Station.*
† *National Institute of Agricultural Engineering.*

be scanned conveniently. Two speeds of rotation, 1 and 2 R.P.S., are selectable and scanning pitches of 1/150 and 1/30in are available. The surface velocity at the higher speed of rotation is approximately 56cm/sec. With the various combinations of speeds, the total time of scanning a maximum sized sample ranges from 2½ to 25min.

The modulated carrier from the scanner is demodulated and then "sliced" to provide a two-condition signal, i.e. one that is either at "black" level (indicating a spot intercept) or "white" level (indicating the blank sample sheet). The sequence of signal conversions and circuit operation is indicated in Fig. 3. A chord of a spot is now indicated by a black-level signal of duration directly proportional to the chord length. These signals are applied to an integrator so that they are converted to pulses, the amplitude of which is proportional to duration. The resultant train of pulses of varying amplitude is applied to a range of voltage discriminators, each of which is biased from a reference source so that it is triggered when the amplitude of a pulse exceeds the reference potential. The triggering of a discriminator causes the operation of an associated counter, so that cumulative totals of chords exceeding predetermined limits of length are recorded. The reference potentials for the discriminators were chosen to correspond to chord lengths of $< 0{\cdot}5$, 0·5, 0·7, 1·0, 1·4, 2·0, 2·8, 4·0, 5·7 and 8·0mm for a scanner speed of 2 R.P.S., these lengths being halved for a speed of 1 R.P.S. Since, in the size-field contemplated, the counting rate to be expected may attain 1 000 per second, electronic counters are employed. To prevent mis-operation by abnormally long black-level signals, the operation of the last discriminator suppresses the input to the integrator until white level is restored. Spurious signals due to the passage of part of the scanner drum uncovered by the sample sheet past the scanning point are prevented by a blanking pulse of adjustable duration initiated by the cam-operated contacts which are closed as the first clip approaches the scanning point.

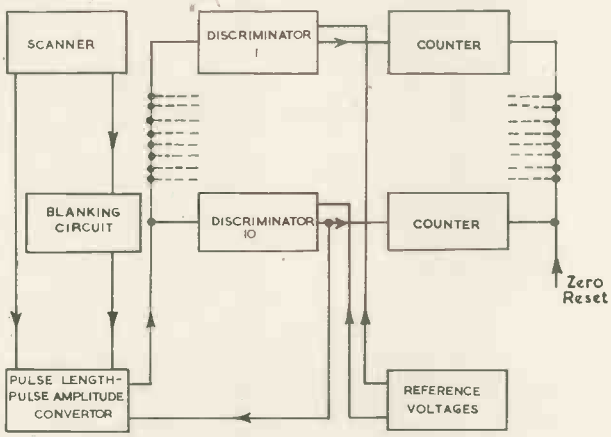

Fig. 2. Block diagram of the equipment

Circuits

Signal Shaping and Pulse-duration to Pulse-amplitude Conversion

The circuit is shown in Fig. 4. The A.M. input signal is amplified by V_1 and after phase-splitting by V_2 is rectified by V_3, the following smoothing circuit suppressing carrier ripple, but passing all significant modulating frequencies. The signal is also rectified by one half of V_4 and applied, across a smoothing circuit with a large time-constant, in opposition to the signal derived through V_3. V_4 supplies a bias equal to half of the signal amplitude, thus stabilizing the half-amplitude potential of the combined signal against slow variations in white-level. The stabilized signal is applied via the cathode-follower V_5 to the "slicer". The slicer circuit comprising V_6V_7 is a multiar[7], a positive feedback circuit which triggers and releases at similar input potentials. The anode potential is at a maximum value during a black signal and via R_{24} raises the potential of the suppressor of V_8 from the cut-off value to earth, permitting the valve to conduct, since the grid is normally positive. The anode waveform of V_8 is inverted by V_{10} for application to the integrator circuit. V_{13} and V_{14} form a conventional Miller integrator circuit, the feedback being via the cathode-follower V_{14} to produce rapid recovery. In the quiescent condition, the grid of V_{13} is clamped via V_{12} and the right-hand half of V_{11} (the left-hand half being cut off); R_{45} permits adjustment of the output voltage at the cathode of V_{14}. When a black signal (positive-going) is applied to the left-hand grid of V_{11}, the cathode potential together with that of V_{12} rises and removes the clamping effect, so that the grid of V_{13} is free to rise in potential and the integrator to function. The rate of the integrator is adjusted by means of R_{41}.

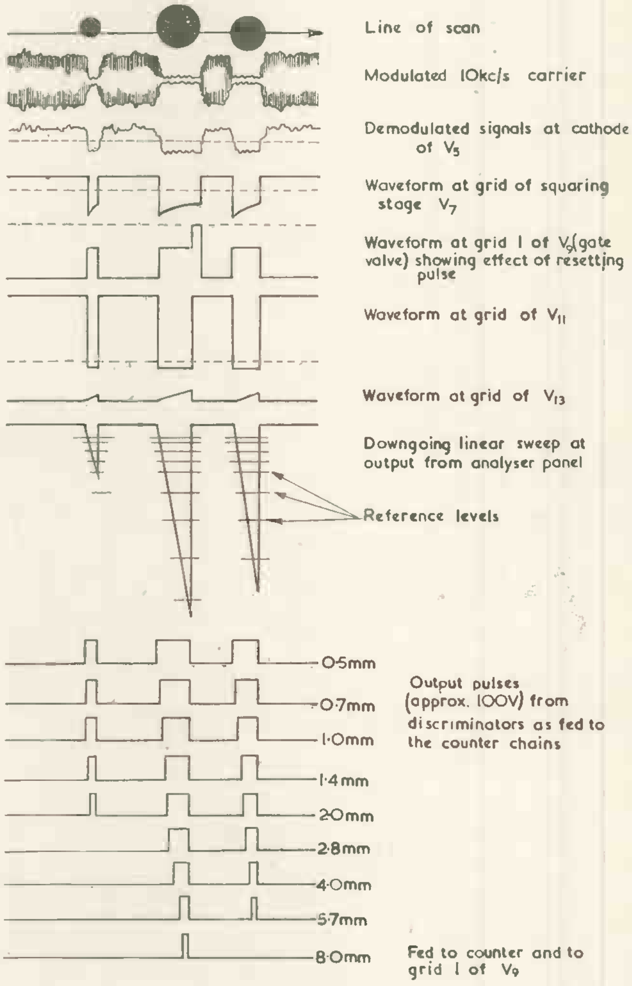

Fig. 3. Circuit waveforms

When the last discriminator operates, a positive-going pulse is applied via C_{10} to the grid of V_9, which is connected to V_8 screen-circuit to form a bistable trigger, so that V_8 now becomes cut off at the control grid, terminating the input to the integrator. When the input signal returns to white level, the trigger V_8V_9 is restored to normal, but V_8 is held cut off at the suppressor until the next black signal occurs.

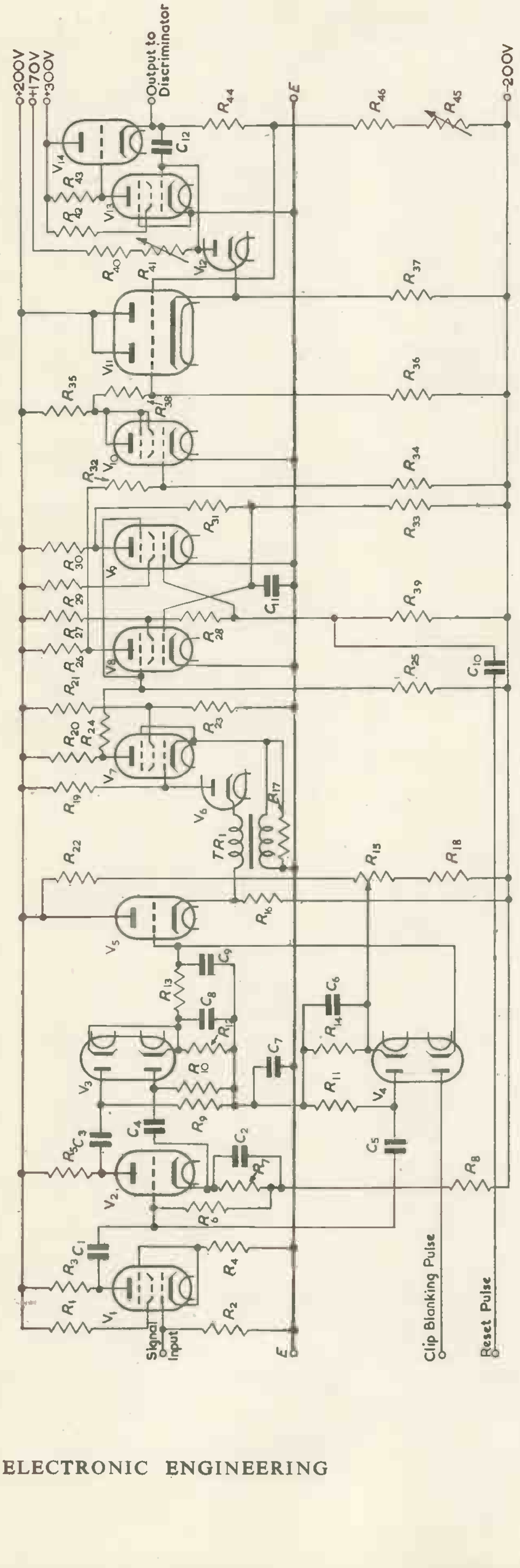

Fig. 4. Analyser panel

During the passage of the paper clip and any uncovered area of the scanner drum past the scanning point, a positive potential is applied via one half of V_4 to the grid of V_5 to override the incoming signal. The blanking circuit is shown in Fig. 5. The contacts S_1 are closed by the cam on the scanner drumshaft before the first clip is scanned and initiate the action of the monostable trigger comprising V_1, the period of which is adjustable to cover the transit of the second clip. The switch S_2 provides a convenient means of applying the blanking condition at will when it is desired to make the analyser quiescent.

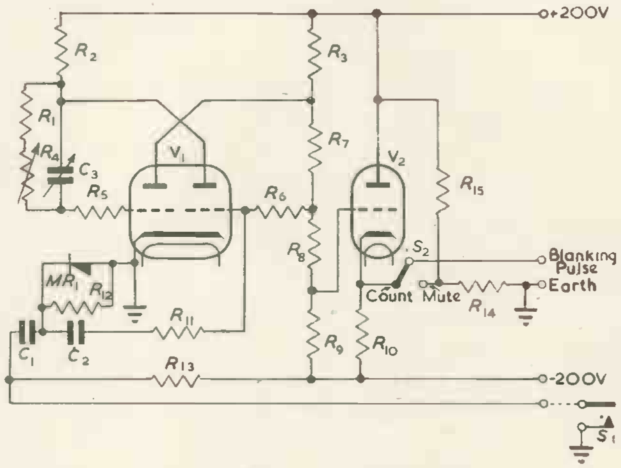

Fig. 5. Clip blanking pulse generator

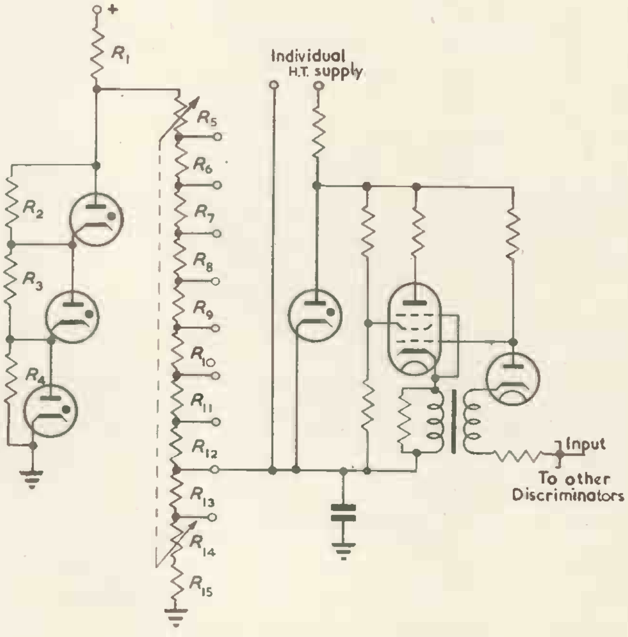

Fig. 6. Discriminator and reference level supply

DISCRIMINATORS

The discriminators consist of ten multiars, each with an individual H.T. supply (Fig. 6). The negative-going voltage waveform from the integrator circuit is applied to the common input of the ten discriminators and as it passes through the bias value of each discriminator in turn, the discriminator valves cease to conduct abruptly due to the positive feedback via the coupling transformers. The

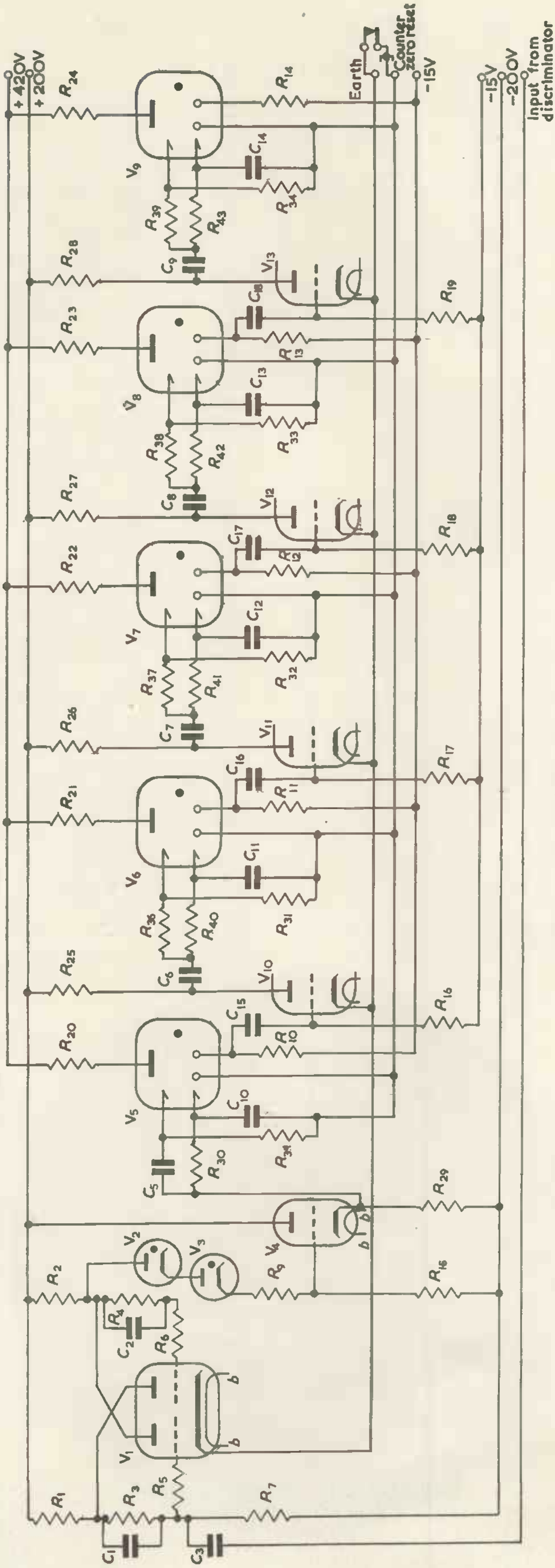

Fig. 7. One five-digit Dekatron counter chain

period of the transformer circuit is designed to hold the valve cut-off during the transit of the input waveform across the grid-base, after which the valve is held cut off by the input alone.

The reference-voltage for each discriminator is derived from a potentiometer (R_{5-15}) connected to a stabilized voltage supply. The relative values of the component resistors are chosen to produce the chord size-group scale mentioned earlier. The variable resistors R_5, R_{14} facilitate adjustment of the absolute voltage level without affecting the current through the stabilizer valves.

COUNTERS

The highest rate of counting required is about 1 000 per second and in the lower chord sizes a range of about 10^5 is desirable. Dekatrons[8] were the most convenient form of counter to use and the circuit is shown in Fig. 7. The output of a discriminator is capacitively coupled to the input trigger V_1 which produces a pulse of predetermined shape and period. This was found necessary to realize the full capability of the Dekatron, since if the integrator waveform only just attains a discriminator level, the resultant pulse from the discriminator is very short. V_4 forms a buffer stage between the trigger and the first counter tube, and is D.C. coupled via gas-discharge tubes to the trigger. The operation of the Dekatron is now well known and will not be described here.

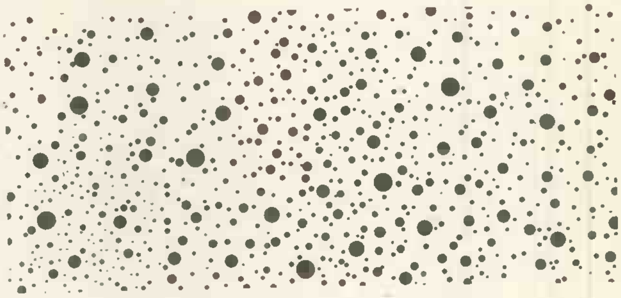

Fig. 8. Section of test sample (reduced 2 : 1)

Five stages are provided in each counter, the GC10B tube being used in the first two stages and the lower speed GC10A in the remainder. The common main cathode leads of all the Dekatrons in all counter units are connected to one key for zero resetting.

Discussion of Operation

The field samples with which it is hoped to use this analyser consist of spray deposits collected on sheets of filter paper. At best, this produces a rather "noisy" background to the scanned signal and one of the practical difficulties in collecting samples is to keep the sheets free from undesired soiling. The dye content of the sprayed solution must provide adequate contrast with the background; a reflectance ratio of background to spot of the order of 20db is required. This is obtainable with a suitable concentration of Nigrocene dye.

Initial tests of the apparatus were made by constructing a sample of spots with a random size distribution, photographically, so that the contrast was very high and the spots well defined. A section of this sample is shown in Fig. 8. The results of analysing the complete sample automatically and by direct optical measurement are shown in Fig. 9. The agreement is quite striking, but considerably greater deviation would be expected from field samples, possibly no better agreement than within 10 per cent. The great saving in time by the use of the analyser is a considerable advantage and if it is compared with the old area-sampling technique on a basis of equal time spent, then the analyser probably provides a much more reliable estimate. The stability of the pulse analyser portion of the apparatus has been tested by repeated scanning of the same pattern and the spread of results of chord group counts is less than ±3 per cent.

It has been mentioned previously that conversion from a chord distribution to a size distribution necessitates some assumptions concerning the type of distribution, so that if the type of distribution is incorrectly predicted considerable inaccuracies may result. Nevertheless, it is found that rapid assessment from chord counts alone gives very reliable indications of the effects of change in some parameter such as size of nozzle, shape of jet or applied pressure. Also, estimation of the spray dosage for a given area may easily be derived from the summation of the chords, although this would be more easily obtained from a separate chord-length integrator; it is intended to add this feature to the analyser at a later date.

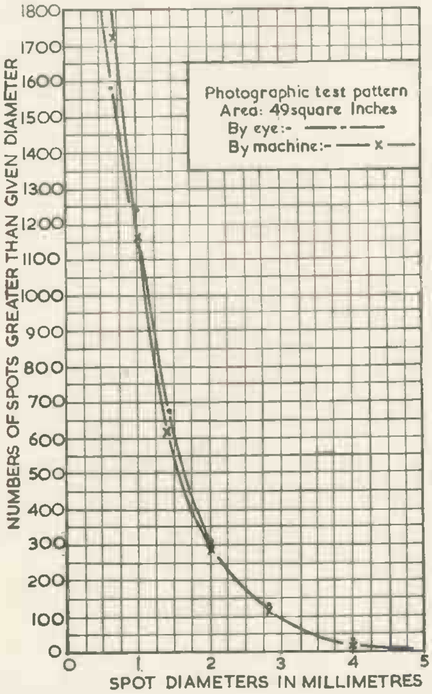

Fig. 9. Comparison between the results obtained by machine and computation in about ½ hour, and the visual analysis taking about 2 days

The complete apparatus was designed for spot sizes of 0·5mm upwards, but, obviously, smaller sizes can be accommodated by the simple expedient of photographic enlargement before analysis. The chord-size analysing and counting apparatus could, of course, be used with other types of scanner, e.g., an electronically controlled flying-spot scanner.

Acknowledgments

The authors wish to thank the Agricultural Research Council, the Engineer-in-Chief of the Post Office and the Director of the National Institute of Agricultural Engineering for permission to use the information published in this article.

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NEW MARINE AND AIRFIELD CONTROL RADAR

A new marine radar equipment, known as the Decca 45, has recently been introduced by Decca Radar Ltd. The most notable feature of this equipment is the provision of two pulse widths of 0·1μsec and 1μsec which successfully provides for optimum performance on both short and long ranges. The six ranges provided are ½, 1, 3, 10, 25 and 45 miles. The efficiency of the equipment has been increased by 15db compared with the Type 12, which is equivalent to increasing the magnetron power from 10kW to 320kW. Another important feature is the provision of a standby switch which cuts the H.T. supplies to the C.R.T. and the magnetron, so that although the radar picture is instantly available, unnecessary wastage of the more costly components is avoided. A differentiation circuit is also incorporated to mitigate the effects of rain.

The photograph shown was taken on the 1-mile scale of the Decca 45 installed on a tall building by the River Thames at Hammersmith. It presents a map-like definition of a highly congested area, and shows the exceptional degree of definition, discrimination and picture clarity provided by this new equipment. Many features of the Hammersmith district which can be unmistakably identified are shown. Below the winding curve of the River Thames the four sections of Barnes Reservoir are shown to the south-west, and a pleasure launch can be seen moving up river. Hammersmith Bridge is clearly marked, together with the main road leading to it. The closely packed streets of houses account for the pattern of echoes near the centre of the picture, with Fulham Palace Road running through from north-west to south-west. In the eastern sector the two blank squares are the recreation grounds of St. Paul's School and Queen's Club.

An airfield control radar has also been recently announced by the same firm. Known as the type 424, it has been designed primarily to meet the need of modern fighter forces for a radar aid capable of controlling the landing of jet fighters under all conditions of visibility. Although considerably less elaborate than the standard G.C.A. systems (e.g. no height indication is given) it is capable of handling aircraft at a higher rate, and the capital cost is about one-tenth that of a modern G.C.A. installation.

Photograph taken from screen of Decca 45

Computing Machines

Input and Output

By R. Bird*, M.Sc., D.I.C.

Digital computors are most simply conceived in the binary scale of notation, while their input and output usually needs to be decimal and sometimes in £ s d and other variable radix notations. Methods are described for the conversion of conventional punched card holes into the binary scale and the reconversion of the computor output from binary to a form suitable for the operation of a printer or card punch.

ELECTRONIC computing machines have proved their worth in the scientific and mathematical fields by performing calculations which would have taken much too long by conventional methods. Their application to business and commercial fields will remove much tedium and drudgery, by tackling calculations which have previously been too lengthy or too costly to mechanize.

From a study of the type of problems which may be tackled by computors in the business and commercial field it appears that:

(1) A large number of similar problems requiring the same type of calculation, but on different data must be tackled consecutively. (For example: the production of a pay roll).

(2) The length of calculation per problem will be short compared with the scientific field, though the amount of input data and results to be printed may be quite large. The computor will therefore have to spend a much higher proportion of its time accepting and transmitting numbers.

(3) Numbers will not only be in decimal, but in other scales, for instance, pounds, shillings and pence will frequently have to be dealt with.

A machine to enter the business field must be economical, reliable, and easy to maintain without the services of a large highly trained staff. Simplicity and a small number of parts would therefore seem to be desirable.

Almost all the computors so far produced, work in the binary scale, since this is ideally suited to the use of two state devices. Reliability of a valve is greatest as a two state device—(conducting or not conducting) as is storage on magnetic tapes or drums, cathode-ray tubes or ultrasonic delay lines. The use of binary code therefore leads to simplicity and economy within the computor, and if the conversion to and from any other scale can be achieved with economy, the binary scale would seem to have great merits.

Punched Card Equipment

As a method of input and output from a computor, electro-mechanical punched card equipment has many advantages. This equipment has been in existence for many years and is thus fully developed and reliable. It is capable of reading data from punched cards at a high rate, and of printing or punching out results of as many as 80 figures (or letters) at a time. Thus the computor can prepare a printed document as its output and at the same time punch results in another card for long time storage in the form needed for re-input to the computor.

Ancillary equipment for handling punched cards such as the sorter, the collator and the reproducer is available.

Magnetic tape must be considered as an alternative to punched cards for computor input for it has a potentially higher speed and greater storage per unit volume, but equipment is not readily available and machines for sorting and collating data would need developing. For speed of printing a document, the printers employed on punched card machines which produce a whole line at once are only rivalled by recent American developments of very high speed single character printers[1] and photographic printing off the end of special cathode-ray tubes[2].

Assuming that a punched card input and output is to be used with a binary computor the methods for conversion from any scale of notation (decimal, £ s d, tons cwt qtr lb, etc.), into the binary scale and its reconversion at the output must be examined.

Conversion Methods

A digital computor, if logically complete, can, of course, convert the input data from any scale of notation to pure binary and reconvert the binary answer to a scale suitable for printing out. This process, while needing no extra equipment, may be too time consuming, as the steps in the programme are many.

In business calculations where the number of numerical operations in the main programme are few, since the problems are simple, the numerical operations in each of the conversion (in and out) may exceed in length the main calculation. These numerical operations for conversion will be used many times during the calculation, once for every input number and once for every answer. We are then faced with the position that the computor is spending only a small portion of its time actually producing answers from data and most of its time changing scales. It is therefore worthwhile to consider the construction of special apparatus for input and output conversion.

The Punched Card

The surface of a punched card is normally divided into 80 columns, each of which is again divided into twelve sections or "index points" as shown in Fig. 1. To record, say, 751603 in decimal on the card, a hole would be punched in the first column opposite the seventh index point, opposite the fifth index point in the second column and so on. To "read" the information off the card, it is moved by rollers past a row of 80 wire contacts or "brushes". When a hole in the card is opposite a brush it drops through it and makes an electrical contact with an earthed roller on the other side of the card.

Attached to a shaft which makes exactly one revolution for each card passing the brushes, are a number of cams which actuate electrical contacts. These cams may be shaped to open and close their associated contacts at any time during the card passage. For example, if an electrical signal is required at each hole position or index point from 1 to 9, this may be provided. If such a contact is connected in series with a card reading brush and a relay to a voltage

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* *The British Tabulating Machine Company Limited.*

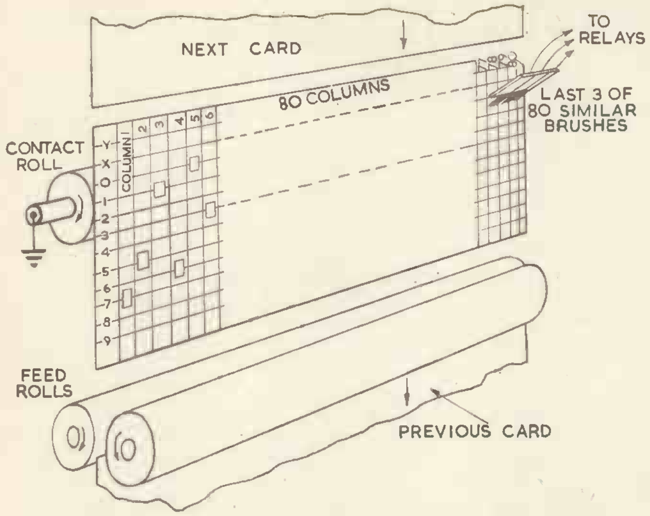


Fig. 1. Punched card being "read" by brushes

source, the relay will only pull up at the index point time at which there is a hole under the brush. Suppose a 7 hole had been punched, then the brush would drop on to the earthed roller at "7 time" and when the cam contact in series with it closed, the relay would energize at a time indicating that a 7 had been punched.

Input Conversion to Binary Scale

METHOD

The holes punched in the columns of the card can represent numbers in scales of notation other than decimal, (up to a radix of 12, using 1 hole per column) but we shall not exceed 10.

Take as an example six columns of a card punched 751603 representing £75 16s. 3d. which it is desired to convert into pence expressed in the binary scale.

A "1" hole on the card in the

6th	=	1 penny or	1	in binary	=	*F*
5th	=	10 pennies or	1010	,,	=	*E*
4th	=	12 pennies or	1100	,,	=	*D*
3rd	=	120 pennies or	1111000	,,	=	*C*
2nd	=	240 pennies or	11110000	,,	=	*B*
1st	=	2400 pennies or	100101100000	,,	=	*A*

Assuming a serial computor with some sort of storage such as a magnetic drum, we may record the binary equivalents *A*, *B*, *C*, etc., in sequence on one of the tracks, and if we accumulate $(7 \times A) + (5 \times B) + (1 \times C) + (6 \times D) + (0 \times E) + (3 \times F)$ while the card is passing the brushes we shall have converted the punchings into binary code.

CIRCUIT ARRANGEMENT

Fig. 2 shows one circuit arrangement for a conversion to binary code by combining well-known techniques.

One track of the magnetic drum shown will hold, for example, 8 numbers or "words" of 32 digits each. Let the first 6 of these be *A B C D E* and *F*.

A second track on the drum contains timing impulses, one per word, in the space between words—thus there are 8 round the periphery. These pulses are fed to a 3-stage binary counter which will thus hold a different pattern for each number round the drum, being 000 for the first number and 111 for the last.

Each anode of each counter trigger supplies a potential to one of the horizontal lines of the diode mesh. The 8 vertical lines are connected to the six horizontal lines through rectifiers of the germanium or selenium type. These are so arranged that every vertical line has a rectifier to one of the three pairs of lines from the counter stage anode with no two similar. Each vertical is also connected to the anode of a master trigger by a 4th rectifier, and to a source of H.T. through a resistor. It will be seen that the potential of a vertical cannot rise above that of the lowest rectifier cathode. With all 8 master triggers storing a 0 none of the verticals can rise, but if they all contain 1's each vertical will in turn rise for one word time only as the counter steps round.

The lower end of the verticals are connected through 8 diode "buffers" to one grid of a double triode gate.

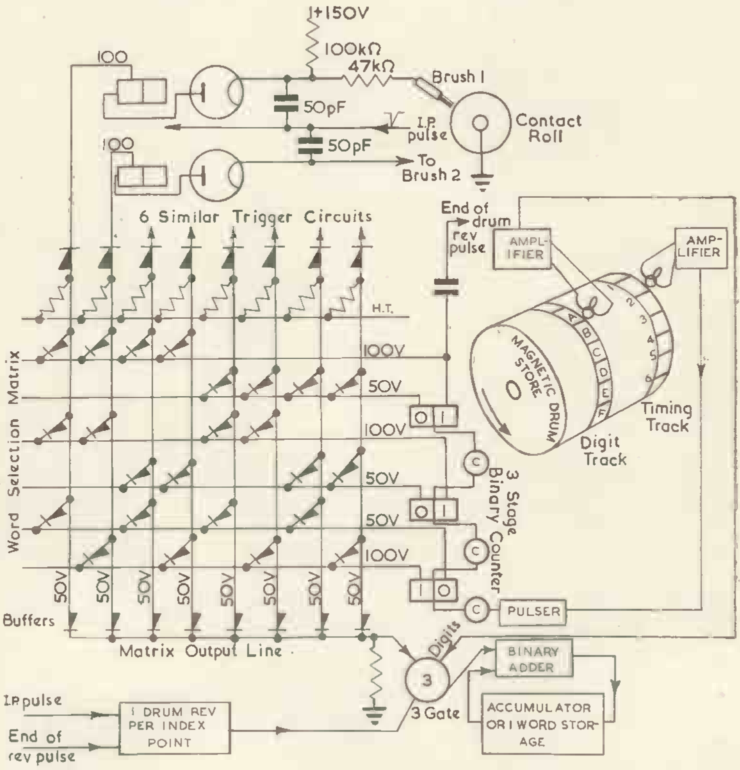
For ease of description, assume the left and right anode potentials of a trigger to be 50V and 100V when storing 0. Thus one of the verticals will only rise to 100V when all the 4 trigger anodes to which it is connected via rectifiers are 100V. When this happens the output line will also rise to 100V through the associated buffer. Each of the 8 master triggers are connected to a card brush reading one of the columns of the card (shown by line 2 in Fig. 2). A cam on the card feed produces sharp pulses at each index point (I.P.) from 9 to 1 inclusive and a second cam produces a pulse at "0" I.P. time.

When the brush drops through a hole it allows the I.P. pulse at that time to pass through a diode gate and switch the connected master trigger to 1.

All eight master triggers are switched to zero by the "0" time I.P. pulse.

Since it is not desirable to add complication by having to synchronize the magnetic drum store to the card feed, it is necessary to provide a circuit which allows output of the binary equivalents *A B C D E F* from the reading amplifier for one drum revolution only for each index point. The need for this "1 Rev. per I.P." device will be seen later;

Fig.2. Punched card hole to binary conversion



the circuit is shown in Fig. 3. It will be assumed that the drum makes at least two revolutions per index point. For a 3 000 R.P.M. drum this means a card feed of 80 per minute.

Each I.P. from 9 to 1 switches the trigger *A* to the 1 state via the back coupled diode gate and the following "End of Drum Revolution" zeroes it again through a similar gate. The negative-going 50 volt step function off the left-hand anode of A at this time switches trigger B to the 1 state. One drum revolution later the next "end of drum revolution" pulse zero's *B* which has therefore been at 1 for one drum revolution only cannot do so again until A has been set to 1 by the next I.P. pulse. The timing chart (Fig. 4) will help to explain the sequence of actions.

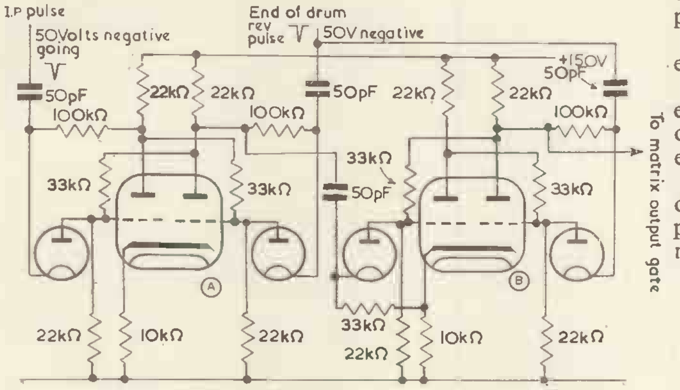


Fig. 3. Circuit for selection of one drum revolution per index point

Returning to the example of £75 16s. 3d. Let column 1's brush be connected to master trigger 1 which controls vertical 1 on the mesh, this tries to rise to 100V when word 1 is being read off the drum. Columns 2 to 6 are similarly connected.

Column 2 has a 5 punched in it, so its associated master trigger will remain at 0 until the I.P. at 5 time when the brush finds a hole. From 5 time to 0 time vertical 2 can rise to 100V when word 2 on the drum is opposite the reading head. The "1 Revolution per I.P." circuit and vertical 2 allow word 2 to pass through the "3" gate into the adder and be "accumulated" 5 times. Word 1 selected by column 1 and vertical 1 passes 7 times into the adder and similarly with the other card columns. Thus, if the accumulator was empty at the start of the card passage it will contain the binary equivalent of £75 16s. 3d. at 0 time. This number is then stored on the drum until needed in the computation.

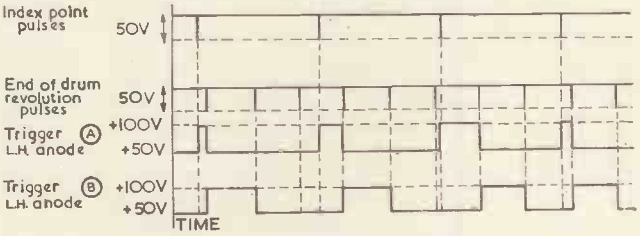


Fig. 4. Timing chart for Fig. 3

Output Conversion from Binary Scale

The computor having finished its computation produces its answers in binary code. The card printing mechanism can be made to accept in binary code, the value of *each digit* to be printed, e.g., it will print a 9 if presented with 1001 on 4 relays and we will assume we will print up to 11 (1011 in binary). 80 digits may be printed simultaneously at a speed of 120 lines per minute. We therefore have to convert a pure binary number into a series of binary groups, each of which represents the value of an output digit, e.g., if the answer to a problem was £75 16. 3d. the computor would need to convert its equivalent in binary pence (100,011,100,010,011) to the five binary groups 0111/0101/0001/0110/0011.

This form has been called a programmed scale of notation—(P.N.) because the radix of each group in the notation is decided by the programme.

Each digit of the binary number has a P.N. equivalent, e.g., the 11th digit of the binary answer represents 1024 pence that is £4 5s. 4d. or 0100/0000/0101/0100 in P.N.

A method of converting the binary answer into its equivalent series of groups in P.N. will now be considered.

If we store on a drum track the P.N. equivalents of a 1 in each binary position then by summing the P.N. equivalents of each 1 in the binary number to the converted, the P.N. equivalent of the whole answer will be formed.

The adder necessary to sum these P.N. equivalents cannot of course be a simple binary adder and Fig. 5 shows one possible circuit arrangement for converting a binary number into its P.N. equivalent.

Considering £ s. d.: round the chosen track the

1st word would be 0000/0000/0000/0001 or 1d $= 2^0$ pennies
2nd ,, 0000/0000/0000/0010 or 2d $= 2^1$,,
3rd ,, 0000/0000/0000/0100 or 4d $= 2^2$,,
4th ,, 0000/0000/0000/1000 or 8d $= 2^3$,,
5th ,, 0000/0000/0001/0100 or 1/4d $= 2^4$,,
6th ,, 0000/0000/0010/1000 or 2/8d $= 2^5$,,
7th ,, 0000/0000/0101/0100 or 5/4d $= 2^6$,,
8th ,, 0000/0000/1010/1000 or 10/8d $= 2^7$,,

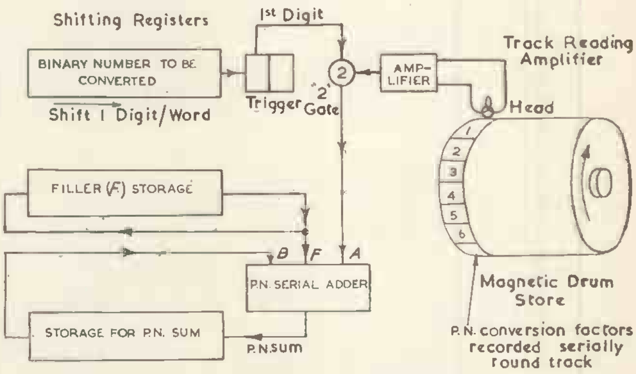


Fig. 5. Binary to programmed notation (P.N.) conversion

The binary number to be converted to P.N. is stored in a shifting register, the least significant digit being in the end trigger which controls a gate between the drum amplifier and P.N. adder. At the start of a drum revolution the first P.N. equivalent is read off the drum and if the least significant digit of the binary numbers is a 1 it flows into the cleared P.N. accumulator.

At the end of word 1 the binary storage is shifted one place right, thus replacing the 1st digit by the 2nd. If this is 1, its P.N. equivalent enters the adder followed by a further shift to test the 3rd binary digit and so on until the end of the binary word.

For £75 16s. 3d. or 100,011,100,010,011 pennies, words number 1, 2, 5, 9, 10, 11 and 15 would be added together giving the P.N. equivalent, this is then passed to output relays which decode it into a printed answer of £75 16s. 3d.

P.N. Adder

The principles of a P.N. adder will be described in a detailed article on the various types of P.N. adders and will appear elsewhere[3].

Numbers in which the radix of the digits vary but are always less than 16 will now be examined. The radices of £ s. d., for instance, may be 10 for £, 2 for 10s., 10 for 1s., 12 for d. and 4 for farthings if required. On adding together two groups in P.N. we need a carry at the end of the group when the sum is equal to or exceeds the radix (r). A true binary adder will produce a "group" carry when the sum of 2, 4 digit binary groups exceeds 16, e.g., 1001 + 1000 = 1/0001, but for radix 10, for instance, we need a group carry when the sum is equal to or greater than 10 instead of 16. To produce this effect an extra group of 4 "filler" digits representing 6 is added to the two groups if their sum is equal to or exceeds the radix. If their sum is less than the radix the "filler" is not added and a P.N. adder is a device which accomplishes this.

Conclusion

A method of conversion of numbers from any scale of constant or variable radix to and from binary notation has been outlined. The input of numbers to a computor from punched cards with simultaneous conversion to binary code uses less than 50 valve envelopes in addition to the normal components of a computor. The output conversion from binary to programmed notation takes about 32 addition times for a 32 digit binary number and uses about 30 envelopes assuming that the number storage necessary is already part of the computor.

Acknowledgments

The author wishes to thank his colleagues at the Research Laboratory of the British Tabulating Machine Company, Letchworth, for their help and encouragement and in particular to acknowledge his debt to Mr. A. Trussell for his original proposal of the input conversion method.

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1. *Electronics 25*, 116 (May 1952).
2. *Proc. of Joint I.R.E., A.I.E.E., and A.C.M.* Computer Conference in November 1953.
3. TOWNSEND, R. Serial Digital Adders for a Variable Radix Notation. *Electronic Engng. 25*, 410 (1953) (*see below*).

Serial Digital Adders for a Variable Radix of Notation

By R. Townsend,* M.Sc., A.M.I.E.E.

A description is given of four different methods of adding numbers, in a digital computor, which are represented in serial coded groups, the digit within each group being in a serial binary code. Each group can portray a number with a different radix of notation, so that quantities having a variable radix such as sterling, tons, hundredweights and quarters, etc., can be represented. The radix of notation of the groups may be changed at will during the course of a programme.

ONE of the main problems in the use of a computor as a business machine is the handling of a large quantity of numerical data upon which comparatively simple calculations are to be performed, and to present it in a form with which the ordinary person is conversant, such as decimal or sterling notation. Most computors constructed so far have operated in binary notation. If this is used, to take advantage of its much greater engineering simplicity, then arrangements must be made to convert from the notation in use to binary notation.

It can be arranged that encoding and decoding from decimal or sterling to binary coded decimal or sterling is performed by the input-output organ, either by mechanical or electrical decoders. For scientific purposes the conversion from binary coded decimal to pure binary and back can be quite suitably performed by means of programmes which are stored in the main store of the machine. Conversion in this way can take up to a second on slower machines, but this is not significant in scientific applications, as it is usual to find that complicated calculations are being performed on a comparatively small amount of data, so that time taken in conversion from binary coded decimal to pure binary and back is a relatively small part of the total time of the computation.

In commercial applications by contrast, it is found that fairly simple calculations are being carried out on a large amount of numerical data, so that it is desirable to keep the time taken in conversion to a minimum, or at least less than the time taken for the mechanical operations such as printing or punching.

One method of overcoming this is to build special conversion units. Methods of automatic conversion from decimal to binary and back have been discussed by Bird[1] and one method of conversion from pure binary to binary coded decimal or sterling makes use of an adder which adds directly in binary coded decimal or sterling.

An alternative solution to the problem is to perform the complete calculation in the form of coded groups, and this has been used in some American machines. These machines, however, only work in decimal codes, whereas in Britain it is important to be able to work directly with variable scales of notation such as sterling, tons, hundredweights and quarters. A completely universal adder should be able to add in any scale of notation either uniform or non-uniform where binary is a special case. This article is concerned with adders of this form, which will add directly in serial binary coded groups in which each group can have a different radix of notation. As this type of adder is able to have its scale of notation altered at will during the programme, these have been named programmed notation adders. They can be used in a method of conversion from binary to binary coded decimal, sterling or any other scale of notation, and they also indicate a line of development for a special arithmetic unit working in binary coded groups.

Suppose it is wished to add two numbers in programmed notation. Each group of 4 binary digits can contain any number up to 16 and it must be arranged that each group carries 1 over into the next group if the number exceeds the particular radix of notation, leaving the remainder in the group. This is done by adding 16-r, where r is the radix of notation for that group, and 16-r is called the "filler." This can be generalized for any radix of notation, and the rules are:

$A + B < r$	no filler added
$r \leqslant A + B < 16$	filler added
$16 \leqslant A + B < 32$	filler added.

Some examples of addition in programmed notation are shown in Table 2.

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* *The British Tabulating Machine Company Limited.*

The description of the various methods will be made in terms of block diagrams and engineers familiar with computor circuits will be able to visualize suitable circuits to fill the blocks. Some of the details of the contents of the blocks used in the experiment may be found in a series of papers by Booth[2]; the present description being restricted to the logical blocks for simplicity.

The systems described were originally conceived for use in a machine using electronic shifting registers and a magnetic drum store, and the philosophy of the particular machine has conditioned the designs, but the basic principles can be adapted to any serial machine.

TABLE 1

Binary Coded Decimal

DENOMINATION	TEN THOUSANDS	THOUSANDS	HUNDREDS	TENS	UNITS
Numerical example	9	7	6	4	5
Binary coded decimal equivalent ..	1001	0111	0110	0100	0101
Radix	10	10	10	10	10
Filler	6	6	6	6	6
Filler in binary	0110	0110	0110	0110	0110

Programmed Sterling

DENOMINATION	TEN POUNDS	POUNDS	TEN SHILLINGS	SHILLINGS	PENCE
Numerical example	2	9	1	7	11
Programmed notation equivalent ..	0010	1001	0001	0111	1011
Radix	10	10	2	10	12
Filler	6	6	14	6	4
Filler in binary	0110	0110	1110	0110	0100

Programmed Hours, Minutes and Seconds

DENOMINATION	HOURS	TEN MINUTES	MINUTES	TEN SECONDS	SECONDS
Numerical example	2	4	3	3	7
Programmed notation equivalent ..	0010	0100	0011	0011	0111
Radix	10	6	10	6	10
Filler	6	10	6	10	6
Filler in binary	0110	1010	0110	1010	0110

TABLE 2

Addition in Binary Coded Decimal

DECIMAL	TEN THOUSANDS	THOUSANDS	HUNDREDS	TENS	UNITS	REMARKS
39828 49137	0110 0100	1001 1001	1000 0001	0010 0011	1000 0111	— —
—	1000	$\underline{0010}$	1001	0101	$\underline{1111}$	Binary sum Underlined groups filled
		0110			0110	
88965	1000	1000	1001	0110	0101	

Addition in Programmed Sterling

£ s. d.	TEN POUNDS	POUNDS	TEN SHILLINGS	SHILLINGS	PENCE	REMARKS
38 13 8 29 14 7	0011 0010	1000 1001	0001 0001	0011 0100	1000 0111	— —
	0110	$\underline{0001}$	$\underline{0010}$	0111	$\underline{1111}$	Binary sum Underlined groups filled
		0110	1110		0100	
68 8 3	0110	1000	0000	1000	0011	

Programmed Adder Type 1

A logical diagram of the first type of programmed adder is shown in Fig. 1. The scheme is based on the use of a binary adder which has been designed to accept an input of three serial binary numbers, which will be described later. The numbers to be added are the stored digit A from the accumulator, the incident digit B from the main store, and the filler digit F. The adder produces two outputs, the unfilled sum $A + B$ and the filled sum $A + B + F$.

The two binary sums, the filled and unfilled numbers, pass simultaneously into two 4-stage shifting registers which give a 4-digit delay. At the end of each group of 4 digits a test is made to see if a carry has occurred at the end of the group, from either the sum $A + B$ or $A + B + F$. If there has been a carry the filled number is required, and the filled-unfilled selector sets the filled-unfilled flip-flop to the filled state which opens a gate allowing clock pulses to pass to the shifting diode which shifts the contents $A + B + F$ of the filled 4-stage register into the main accumulator. If, on the contrary, there is no carry from $A + B$ or from $A + B + F$ at the 4th digit, then the unfilled number is required and the filled-unfilled flip-flop is set to the unfilled state which allows the unfilled sum $A + B$ to be shifted into the main accumulator. This procedure is repeated for each of the eight groups of 4 binary digits in a 32-digit number.

If the adder is being used for conversion from binary coded decimal, sterling, or whatever notation is being used, then there will be an addition for every 1 in the binary number when that particular binary coded equivalent is being added. When the complete number in binary coded form has been accumulated, that is after up to 32 additions, (as we are working with 32 digit binary numbers), another order in the programme will transfer the number in the accumulator into the multiplier register preparatory to printing out.

The various blocks of which this adder is composed will now be described in greater detail.

THE THREE INPUT BINARY ADDER

When designing Type 1 adder it was desired that there should be a simultaneous output of $A + B$ and $A + B + F$ so that a three input adder was made having these two simultaneous outputs.

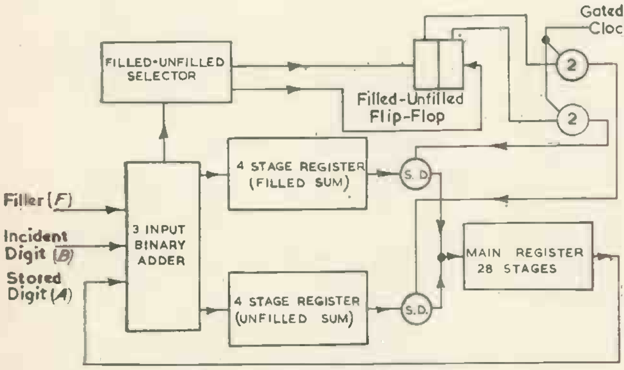


Fig. 1. Programmed Adder Type 1

S.D. = *Shift direct.*

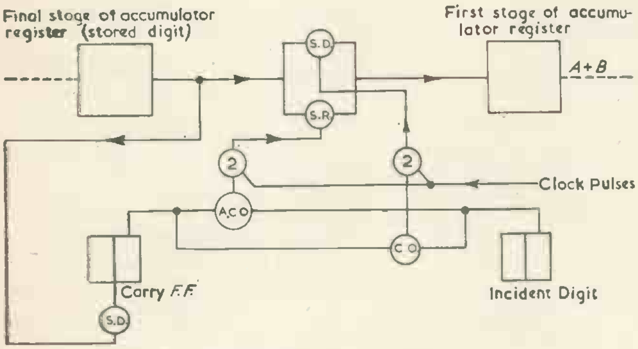


Fig. 2. Bird's Binary Adder

S.D. = *Shift direct,* S.R. = *shift reversed,* CO. = *coincidence gate,* A.CO. = *anti-coincidence gate.*

A binary adder has been described by Booth and a modification of this has been introduced by Bird. The three input adder consists of a combination of two of these binary adders in a single unit, and Bird's adder will first be described (Fig. 2). All these adders were designed to work with a shifting register as described by Booth and operate by the principle of shifting the digit standing in the final stage "flip-flop" of the accumulator register into the first stage, either direct or reversed, by shifting diodes which are shown as S.D. for Shift Direct or S.R. for Shift Reversed. Various conditions for adding two binary inputs and the carry are shown in Table 3. The incident digit and the carry are stored on flip-flops and the states of these flip-flops are compared on coincident and anti-coincident gates which gate shifting pulses to the shifting diodes according to the following rules:

1. If the incident digit B and the carry digit are coincident the stored digit A is shifted into the first stage of the accumulator direct.
2. If the incident digit and the carry digit are anti-coincident, the stored digit is shifted into the first stage of the accumulator reversed.
3. If the incident digit and the carry digit are coincident the carry flip-flop is not changed.
4. If the incident digit and the carry digit are anti-coincident, the stored digit is shifted into the carry flip-flop direct.

TABLE 3

Binary Addition of 2 Digits and a Carry Digit

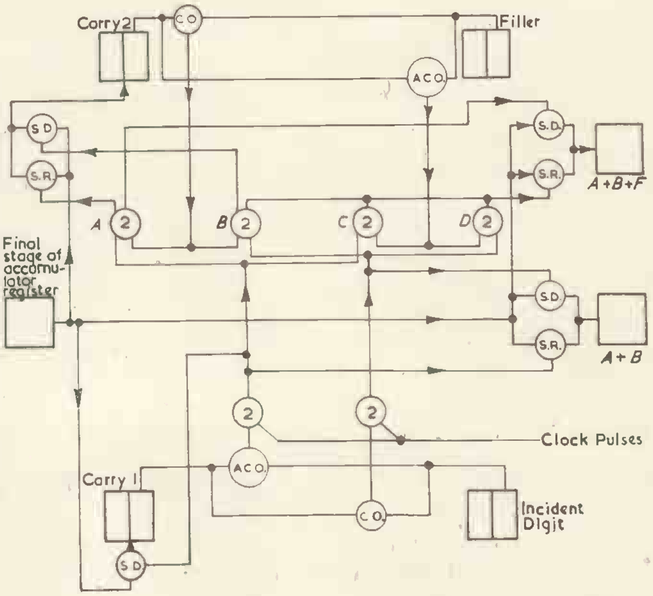
Stored digit (A) ..	0	0	1	0	0	1	1	1
Incident digit (B) ..	0	1	0	0	1	0	1	1
Carry digit	0	0	0	1	1	1	0	1
Sum	0	1	1	1	0	0	0	1
Next carry digit ..	0	0	0	0	1	1	1	1
State of stored digit compared with sum ..	S	R	S	R	S	R	R	S
State of stored digit compared with new carry	U	S	U	S	U	S	S	U

S = same. R = reversed U = unchanged

The Three Input Adder consists of the combination of two of these binary adders blended into a single unit. It would not be possible to use two of this type of 2 input binary adders in cascade as there is inherently a delay of 1 digit period in the addition and it was essential that all the inputs and outputs should be simultaneous.

The logical diagram of the Three Input Adder is shown in Fig. 3, and if this is compared with Fig. 2 it will be seen that the lower half is similar in that there are two flip-flops containing the incident digit and the carry 1 digit which are compared on coincident and anti-coincident gates and which gate clock pulses to two shifting diodes which shift the stored digit in the final stage of the accumulator into the unfilled register direct or reversed, as shown in Table 3. The stored digit is also shifted into the carry 1 according to the same rules. At the top of Fig. 3 are two other flip-flops which contain the filler digit, which is to be added to $A + B$ to provide the filled number and the carry 2 flip-flop. These two flip-flops are again compared

Fig. 3. Three Input Binary Adder



on coincident and anti-coincident gates which control "2" gates which route the output pulses from the first adder into shifting diodes which shift the stored digit into the filled 4-stage register and into the carry 2 flip-flop according to rules which will be described below.

A scheme can be worked out showing the addition in binary notation of the stored digit, incident digit, carry 1, filler digit and carry 2 and this is shown in Table 4. The results obtained from the full table of addition are summarized in the lower table. The operation of shifting into the carry 2 and filled sum can be reduced to the four simple relations between coincidence and anti-coincidence of the carry 1 and incident digit and coincidence and anti-coincidence of carry 2 and the filler digit.

These relations are provided by the set of "2" gates lettered $A\,B\,C\,D$ in Fig. 3 which route pulses from the comparison of carry 1 and the incident digit to the appropriate shifting diodes for the filled sums $A + B + F$ and to carry 2. Before commencing an addition both carry 1 and carry 2 flip-flops are set to zero.

It can be shown that at the end of the addition of any group, whatever the radix, it is only possible for one carry to be stored in the carry flip-flops 1 and 2. Thus, before addition, A and B cannot exceed r and therefore their maximum values are $r - 1$. Therefore the maximum value of

$$A + B + F = 2(r - 1) + 16 - r = r + 14.$$

As the largest radix which can be represented is 16 and in the worst case $r = 16$, the maximum sum $A + B + F = 30$, which is less than 32 and therefore there can only be a single carry from a group.

It is possible for this carry appearing at the end of the group to be either in carry 1 or carry 2. Thus if $A+B \geqslant 16$ the carry will be in carry 1 but if $A+B \geqslant 16$ but $A+B+F < 16$ then the carry will be in carry 2. The carry between groups must be added to both filled and unfilled sums of the next groups and this only occurs if the carry is left in carry 1, so it has been necessary to shift the carry standing in carry 2 into carry 1 at the end of each group by means of shifting diode gates (not shown in Fig. 1).

Filled-Unfilled Selector

The logical diagram of the filled-unfilled selector is shown in Fig. 4 and the rules for the selection of the filled or unfilled sum are as follows:

If there is a 1 in carry 1 or carry 2 then select the filled sum $A + B + F$.

If there is 0 in both carry 1 and carry 2 then select the unfilled sum.

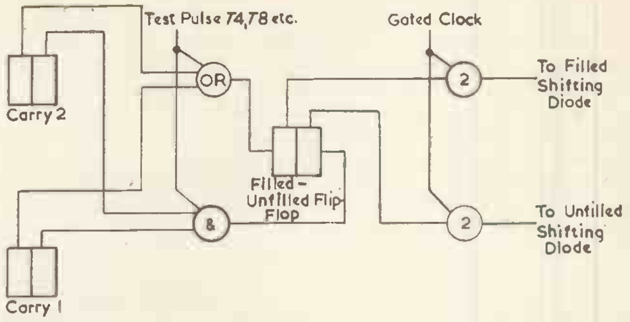


Fig. 4. Filled-unfilled Selector

TABLE 4

Binary Adder of 3 Digits and 2 Carry Digits

Stored digit A	0	1	0	0	1	0	1	1
Incident digit B	0	0	1	0	0	1	1	1
Carry 1	0	0	0	1	1	1	0	1
First sum	0	1	1	1	0	0	0	1
New carry 1	0	0	0	0	1	1	1	1
Filler digit F	0101	0101	0101	0101	0101	0101	0101	0101
Carry 2	0111	0011	0011	0011	0011	0011	0011	0011
Total sum A+B+F	0110	1001	1001	1001	0110	0110	0110	1001
New carry 2	0001	0111	0111	0111	0001	0001	0001	0111
State of stored digit compared with total sum	SRRS	SRRS	RSSR	RSSR	RSSR	SRRS	RSSR	SRRS
State of stored digit compared with carry 2	UUSU	USUU	URUU	URUU	UURU	UUSU	UURU	USUU

Summarised Rules

Incident digit compared with carry 1	Coincident	Coincident	Anti-Coincident	Anti-Coincident
Filler digit compared with carry 2	Anti-Coincident	Coincident	Anti-Coincident	Coincident
Shift of stored digit to total sum	Reversed	Direct	Direct	Reversed
Shift of stored digit to carry 2	Direct	Unchanged	Reversed	Unchanged

As can be seen on the diagram, this is done by using "or" and "&" gates. If either carry 1 or carry 2 contain 1 then the potential of their left-hand anodes is high, the "or" gate is opened and when the test pulse appears it passes through and sets the filled-unfilled flip-flop into the filled state which opens a "2" gate and allows the next four clock pulses to pass to the diode which shifts the filled number from the filled 4-stage register into the main accumulator. If both carry 1 and carry 2 are at 0 then both their right-hand anodes are high and the "&" gate is opened, allowing a test pulse to pass to set the filled-unfilled flip-flop to the unfilled state, and thus opening a "2" gate which allows the next 4 clock pulses to shift the contents of the unfilled 4 stage register into the main accumulator. It can be seen that when there is a 1 in either carry flip-flop nothing can pass through the "&" gate and likewise when both are at "0" and the "&" gate is open, nothing can pass through the "or" gate.

Programmed Adder Type 2

The logical diagram of the Type 2 programmed adder is shown in Fig. 5. This scheme is based on the use of a serial comparison circuit which will be described and as it is possible to perform the serial comparison of two binary numbers simply, this is the best way found so far for adding two serial programmed notation numbers. The numbers to be added are as before, the stored digit A, the incident digit from the main store B and the filler digit F when required.

The stored digit A and the incident digit B are first added in a straightforward two input binary adder of the type described previously and the sum $A + B$ passes into the 4-stage register. At the same time the sum $A + B$ is compared with the radix of notation minus one ($r - 1$) in the serial comparison circuit. It so happens that it is easy to obtain $r - 1$ by "notting" the filler F, that is transposing the 0's and 1's and vice-versa, which may be simply done by reversing two leads from the filler store.

At the end of each group the flip-flop in the comparison circuit called the comparison flip-flop will contain 1 if the sum $A + B > r - 1$ and it will contain "0" if the sum $A + B \leqslant r - 1$. The test pulse examines this flip-flop and also the carry 1 flip-flop. If either the comparison flip-flop or carry 1 contains 1 then the number must be filled and the filled-unfilled flip-flop is set to the filled state. If both the comparison flip-flop and carry 1 contain 0 then the filled-unfilled flip-flop is set to the unfilled state. When the comparison flip-flop contains 1 it indicates that the sum $A + B$ exceeds $r - 1$, but does not exceed 15, the total capacity of the group.

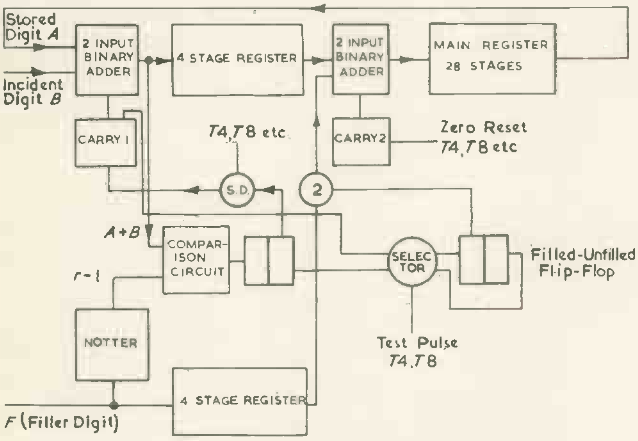


Fig. 5. Programmed Adder Type 2

When the filled-unfilled flip-flop is at the filled state it opens gate n and allows the filler F, which has also been delayed by 4 digit periods to be added to the sum $A + B$ in binary Adder 2, forming the sum $A + B + F$ for that particular group in the main accumulator. If the filled-unfilled flip-flop is set to the unfilled state then it allows the sum $A + B$ to pass through the binary adder unaltered so that the particular group remains unfilled.

A condition arises when the sum of a group passing through Adder 1 has a value $16 > A + B > r - 1$, in which case the filler is added in Adder 2 because $A + B > r - 1$, and this causes a carry to be stored in the carry store of Adder 2 at the end of a group. If the sum in the next group has a value of $A + B = r - 1$ no indication is given that this group should be filled, but the addition of the stored carry in Adder 2 makes the sum of this group exceed $r - 1$. This is overcome by suppressing the carry in Adder 2 at every 4th digit, but a carry digit is put into the carry store of Adder 1 every time the comparison circuit indicates $A + B > r - 1$. By this means the correct carry is always added before comparison and indication for filling is correctly given.

Another simpler method is to remove the resetting pulses to the comparison flip-flop so that if it has indicated that the number lies between $r - 1$, and 15, it will start comparison for the next group with a 1 in the comparison flip-flop. The effect of this is that the comparison circuit will compare the sum $A + B$ with $r - 1$ if there is a 0 in carry 2, but if there is a 1 in carry 2 the comparison circuit has started with a 1 in the comparison flip-flop so that the sum $A + B$ is now compared with r instead of $r - 1$.

COMPARISON CIRCUIT

The logical diagram showing the principles of the comparison circuit is shown in Fig. 6. Suppose a binary number A to be stored in register A and a binary number B to be stored in register B and that a comparison is to be made. Before starting the operation the comparison flip-flop (C.F.F.) is set to zero. Then the state of the comparison flip-flop is compared with the first binary digit of B, and the first digit of A is shifted or not into C.F.F. according to the rules given below. This is repeated for each digit successively to the end of the binary number. The rules are as follows:

If the last stage of register B and C.F.F. are anti-coincident, leave C.F.F. unchanged and shift both registers 1 digit.

If the last stage of register B and C.F.F. are coincident shift, what was in the last stage of register A into C.F.F., and shift both registers. At the end of the operation for a complete binary number of any length, C.F.F. will be 1 if $A > B$, or 0 if $A \leqslant B$.

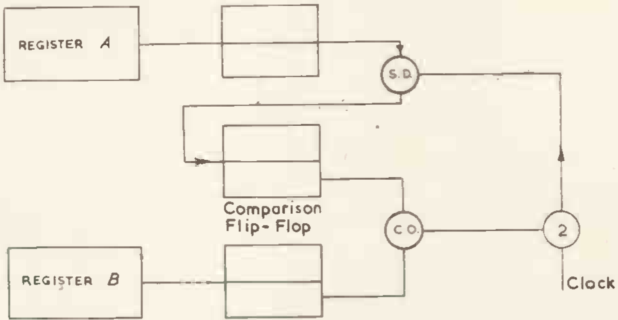


Fig. 6. Comparison circuit

The basis of these rules is as follows denoting the n^{th} binary digit of the numbers being compared as A_n and B_n.

(a) If C.F.F. = 0 assume that $A \leqslant B$ up to $(n-1)^{\text{th}}$ digit.

Then if $B_n \neq$ C.F.F. B_n is 1 and at worst $A = B$ (i.e., if $A_n = 1$ and $A = B$ up to then).

Again if $B_n =$ C.F.F.$_n$, $B_n = 0$ and the comparison is $A \leqslant B$ if $A_n = 0$ and $A > B$ if $A_n = 1$.

Whence shifting A_n into C.F.F. assures the truth of the proposition.

(b) If C.F.F. = 1 assume that $A > B$ up to the $(n-1)^{\text{th}}$ digit then if B_n is $\neq$ C.F.F. B_n is 0 and $A > B$ whatever A_n.

Again, if $B_n =$ C.F.F. $B_n = 1$ and $A > B$ if $A_n = 1$, but $A \leqslant B$ if $A_n = 0$

whence again shifting A_n into the C.F.F. assures the truth of the proposition.

Now if C.F.F. = 0 initially and $B_1 = 1$, then $B_1 \neq$ C.F.F. and $A \leqslant B$ whatever A_1.

Again, if $B_1 =$ C.F.F. $A > B$ if $A_1 = 1$, $\leqslant B$ if $A_1 = 0$, when shifting A_1 into C.F.F. if $B_1 =$ C.F.F. assures the truth of the proposition for $n = 1$ and is therefore true for $n = 2$ and by induction generally.

Referring to Fig. 6 C.F.F. and the last stage of the shifting register containing B are compared from a coincident circuit. If they are in coincidence the "2" gate is opened allowing the next clock pulse to pass to the shifting diode which transfers the contents of the last stage of register A into C.F.F.

Programmed Adder Type 3

The logical diagram of the Programmed Adder Type 3 is shown in Fig. 7. As before, numbers to be added are the

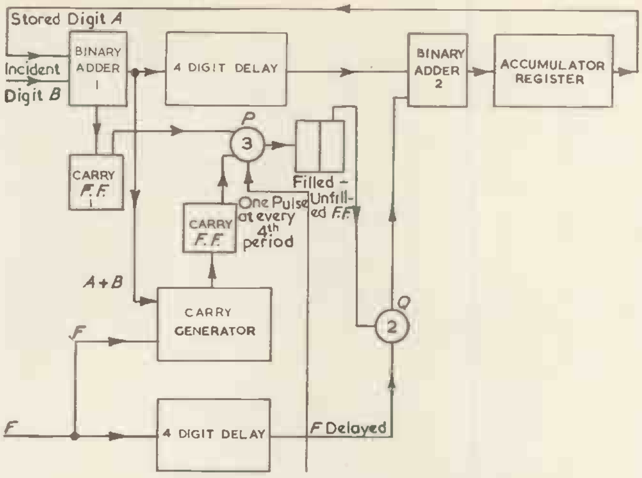


Fig. 7. Programmed Adder Type 3

stored number A and the incident number B both represented in programmed notation. These numbers are first added in pure binary manner in binary adder 1 and the binary sum of $A+B$ passes into the 4-stage shifting register. At the same time the sum $A + B$ is added to the filler F in what has been called the carry generator.

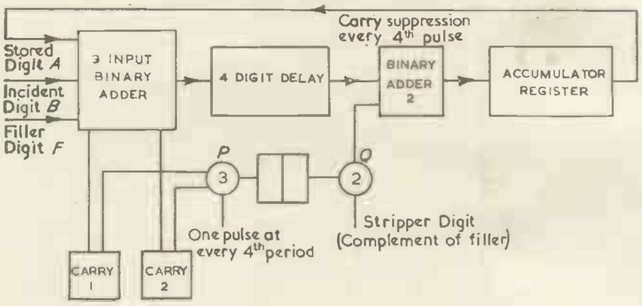
The carry generator is really a rudimentary binary adder in which only the components necessary to set up the carry flip-flop correctly are used.

If the addition of a group of 4 binary digits produces a sum which exceeds 16 then the carry 1 flip-flop and binary adder 1 will have a 1 stored at the end of a group. If the sum of a group lies between the radix of notation and 15 inclusive, that is $r<A+B<16$, then a 1 will remain in the carry generator flip-flop at the end of a group. Thus if at the end of addition of a group a 1 is in the carry 1 flip-flop or carry generator flip-flop then it is necessary to fill the number. The carry 1 flip-flop and the carry generator flip-flop control the filled-unfilled flip-flop through a gate circuit similar to that described in Adder Type 1, so that if the carry 1 flip-flop or the carry generator flip-flop contain 1 at the end of a group the test pulse is allowed to pass through to set the unfilled flip-flop to the filled state. If the carry 1 flip-flop and the carry generator contain 0 the filled-unfilled flip-flop is set to the unfilled condition. The filled-unfilled flip-flop controls a gate which allows the filler which has been delayed for 4 digit periods in a 4-stage register to be added to the sum $A + B$ in Binary Adder 2. This scheme is logically very similar to the Type 8 Adder.

Programmed Adder Type 4

In this last method shown in Fig. 8, a 3 input binary adder is again used, the binary sum of the stored digit, incident digit, and the filler digit all being added together, and the sum $A + B + F$ flows into the 4 digit delay. The 3 input adder has two carry stores and these are tested at the end of each group as usual. If there is a carry in either of the carry stores the filled-unfilled flip-flop is set to the filled state, since gate P is open. When the flip-flop is in the filled state it closes gate Q and allows the sum $A + B + F$ to pass through the Binary Adder 2 unchanged into the accumulator.

Fig. 8. Programmed Adder Type 4



When on the contrary there is no carry in either of the carry stores of the 3 input binary adder then the gate P is closed and the filled-unfilled flip-flop is reset (gates not shown) to the unfilled state. When the flip-flop is in this state it opens gate Q and allows the complement of the filler to pass to the binary adder 2, where it is added to the sum $A + B + F$, and having the effect of subtracting the filler from the sum $A + B + F$ leaving it as $A + B$ to enter the accumulator register. The carry store in the Adder II is reset to zero at the end of each group to get rid of the unwanted carry produced when the complement is added.

This scheme has been included for completeness, although it appears to be impracticable in using an unnecessary amount of components, requiring as it does both a 3 input binary adder and a 2 input binary adder.

Programmed Excess Notation Adder

The difficulties inherent in subtraction in ordinary programmed notation have led to the suggestion of a type of notation in which subtraction is easier, which has been called Programmed Excess Notation.

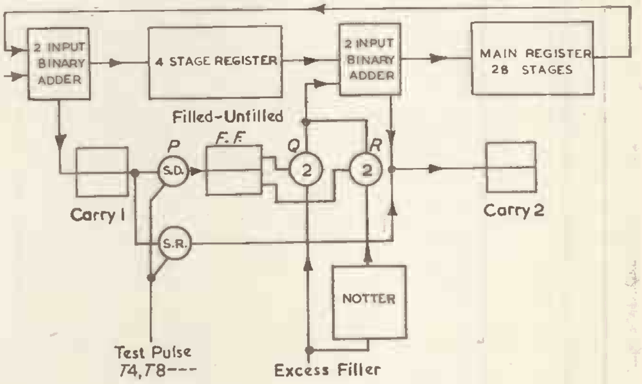


Fig. 9. Programmed Excess Notation Adder

The use of excess three notation for decimal representation is well known. In this code 3 is added to each decimal digit and the resulting digit is represented in binary coded form. The advantage gained by using this representation is that the complement to 9 needed in subtraction can be obtained by transposing 0's and 1's.

The rules for excess 3 code can be summarized as:

(1) If the sum of the two excess 3 groups produces a carry at the end of the group, then 3 must be added to the sum of the two groups.

(2) If the sum of the two excess 3 groups does not produce a carry at the end of a group, then 3 must be subtracted from the sum of the two groups. It can be seen that this is very similar to the ordinary programmed notation case in which the filler is added or not, as required.

The excess 3 idea can be extended to using a programmed excess notation for non-uniform radices of notation: thus in scale of 12 the excess will be 2, or in scale of 8 the excess will be 4, and in the general case the excess will be $16 - (r/2)$. This has the limitation that only even radices of notation can be used, but it so happens that most of the important non-uniform scales of notation in

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general use have an even radix of notation. The logical diagram of an adder for adding in programmed excess notation is shown in Fig. 9. The two numbers to be added are the stored number A and the incident number B. These two numbers are added together in a straightforward manner in the 2 input binary adder 1 and the sum passes into the 4-stage register. At the end of each group of 4 digits the contents of the carry 1 flip-flop of the binary adder 1 is shifted directly by the test pulses through the shifting diode P into the filled-unfilled flip-flop. Thus when there has been a carry at the end of the group, the filled-unfilled flip-flop is set to the 1 or filled state and when there has been no carry the filled-unfilled flip-flop is set to the 0 or unfilled state as required by the rules.

The filled-unfilled flip-flop controls the 2 gates Q and R which allow the filler to pass into adder 2 direct through Q if the filled-unfilled flip-flop is in the filled condition, or allow the "notted" filler with 0's and 1's transposed to pass through R if the filled-unfilled flip-flop is in the unfilled condition. Transposal of 0's and 1's can be easily obtained by reversing the wires from the flip-flop from which the excess filler is obtained. It is still necessary to take care of the elusive 1 when the excess has to be subtracted. This can be done by shifting the contents of carry 1 into the carry 2 flip-flop reversed by the test pulses, thus, when carry 1 contains 1 at the end of a group, the excess is to be added and therefore no elusive 1 has to be added and carry 2 is set to 0. When carry 1 contains 0 the excess must be subtracted so that the elusive 1 is put into carry 2 by shifting in 0 reversed. The normal carry digits during addition will be shifted into carry 2 by a shifting diode and this will provide buffering between the inputs to carry 2. It can be shown that carry 2 will not have a wanted 1 put into it at the end of a group due to the addition of the excess. It will always have a 1 placed in it after subtracting the excess, by adding the complement, but this must always be suppressed. Therefore it is quite correct to set the carry 2 flip-flop to 1 or 0 as required at the end of a group.

Acknowledgments

The author is indebted to Mr. J. R. Womersley for the original suggestion of the idea of programmed scale of notation, and for continual encouragement in the work, and to his colleagues for much helpful discussion.

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A RADAR SONDE INSTALLATION

A fully automatic meteorological system for accurately observing, or sounding, weather conditions in the upper air is at present being installed at a new Meteorological Station near Crawley, Sussex, and, as far as is known, it is the world's first fully automatic equipment. This equipment, which is based on research work undertaken some years ago by the Telecommunications Research Establishment of the Ministry of Supply, has been developed and built for the British Meteorological Office by the Research Laboratories of Mullard Ltd.

The system consists basically of an automatic ground interrogator and computing station, working in conjunction with airborne transponders. Two types of transponder are available; one is confined to wind measurements only; the other, in addition, provides sonde information. During the operation of the system, one of these units, depending on the extent of the observations to be made, is suspended from a hydrogen-filled balloon. The maximum slant range of the system is about 100 nautical miles (185km). In order to reach this extreme range under normal conditions, the balloon would have to ascend to a very great height. A standard balloon, as at present used, would burst before this height is reached. Thus, although the equipment is capable of working at a ceiling height of at least 100 000ft, the performance is largely limited by the height range of the balloon.

As the balloon ascends into the upper air, its airborne transponder is interrogated from the ground station by radar pulses of 2μsec duration. These are transmitted from a 50kW (peak) transmitter, operating on a primary frequency of 152·5Mc/s. The interrogating pulses are received by the balloon-borne unit. Here they are used to make the airborne transmitter send back pulses to the ground station on a secondary frequency of 2 850Mc/s (10cm band). These pulses, in turn, are received at the ground station by an automatic following aerial.

The slant range of the airborne unit is readily determined by measuring the transit time of the pulse to and from the transponder. From this, and from the values of the azimuth and elevation angles of the aerial unit, the drift of the airborne unit in space is computed. Wind speed and direction are computed automatically and continuously from the rates of change of the measured parameters. The height of the balloon is also computed and a correction for the curvature of the earth is applied automatically.

Telemetering of temperature, pressure and humidity information, registered by the meteorological elements in the sonde unit, is effected by causing the sonde to transmit twin pulses each time it is interrogated from the ground station. The degree of separation between the two pulses serves as a measure of the meteorological parameter in circuit at any particular time. The three elements for measuring pressure, temperature, and humidity are switched into the telemetering circuit in sequence by a motor-driven switch. In this way, a complete cycle of sonde observations is telemetered to the ground station every 15 seconds during the flight of the balloon. A fourth element is included in the cycle providing a constant reference reading. Any change in the constants of the telemetering circuits affecting the accuracy of the meteorological readings will be indicated by a change in the reference reading. When the balloon bursts on reaching its maximum altitude, a parachute opens and the transponder unit slowly descends. During the descent, the airborne unit continues to be interrogated by the ground station provided, of course, that it remains within the 100 nautical mile range of the equipment.

The transmitting and receiving aerials are mounted on a common pedestal on the roof of the ground station. The transmitter radiates through a pair of vertically polarized Yagi arrays. These are mounted on either side of a 5ft diameter receiving paraboloid and nutating dipole which provides a conical scan. Misalignment of the aerial causes amplitude modulation of the incoming signal at the coning frequency. An error signal is thus produced and is fed to a servo system which re-aligns the aerial.

In the operations room, the equipment may be broadly divided into two sections, the radar equipment and the computing and recording equipment. The radar equipment comprises a V.H.F. transmitter; a microwave receiver; a display unit and a control column.

The transmitter and receiver are built into 6ft consoles and form the left- and right-hand sections, respectively, of a 4-unit console. The display unit is located between them and houses the range display oscilloscope and aerial azimuth and elevation repeater magslips. The control column extends from the top of the display unit to the ceiling and carries the controls and indicator lamps for the main power supplies.

The computing and recording equipment includes a wind computor and a 3-unit console comprising a wind recorder, a telemetering unit and a sonde recorder.

The wind computor is a separate unit and is built around a 4ft diameter rotable table. Wind direction is computed and recorded on a polar chart fixed to the table.

The recording and telemetering unit is a 3-unit console at the left-hand of which is the wind recorder. This unit houses the wind-speed and true-height pen recorders and the main controls for the complete console. The telemetering unit is the centre desk unit of the console and houses a teleprinter and telemetering circuits. The sonde recorder forms the right-hand unit of the console and houses the pressure, humidity and calibration recorders. The latter monitors the operation of the sonde airborne unit.

The airborne units have been designed for economic mass production to enable costs to be kept to a minimum, since in normal operation two of these expendable units may be released every day.

New Constructional Techniques

(Part 1)

By G. W. Dummer*, M.B.E., M.I.E.E., and D. L. Johnston†, A.M.I.E.E.

Early radio equipment was built in the manner of electrical instruments but tended towards unit construction when the 19-inch telephone relay rack was adopted as a basis to replace arbitrary dimensions. Other sizes of standard panels were used with early radar equipments, and the requirements of the Services raised the quality of both components and assemblies. To supply economically the quantities required, research and development have proceeded on a number of new techniques, notably potting, printed conductors and automatic soldering. The reliability desired of complex machines, such as electronic computors, may be obtained ultimately by using quality-control methods in an automatic factory.

THE first radio equipment was manufactured in the form of the contemporary electrical apparatus of its day, being panel mounted in switchboard style and enclosed like a resistance box or Wheatstone bridge, with principal components such as valves and coils projecting on the outside, the internal wiring being carried out with self-supporting bare conductors (Fig. 1).

During the late 1920's the supporting panel or "breadboard" for the components tended to become horizontal in the box, with a simplified front panel carrying the controls, and ebonite began to give way to brown and black laminated phenolic panels.

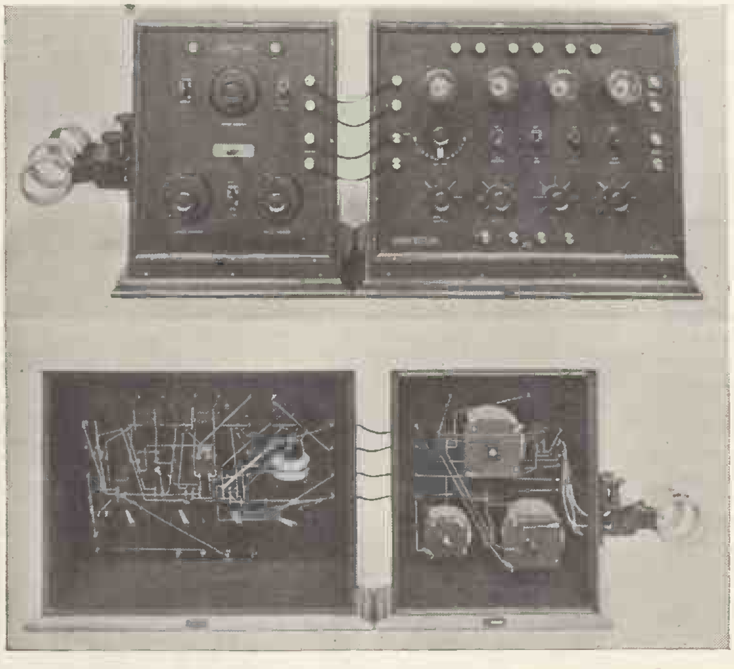

Fig. 1. Burndept four-valve receiver of 1923, showing (a) front and (b) rear views of tuner and detector-amplifier units

(From an exhibit in the Science Museum, South Kensington)

In 1924 the screened grid valve and in 1928 the pentode valve made possible higher stage gains. Metallic screening then became necessary and at first thin foils were used as linings for the wooden structure, but were replaced by brass, copper or sheet aluminium to combine both functions. In the late 1930's it was general practice to employ a panel and box-chassis construction with underwiring, and the larger manufacturers frequently employed steel, suitably protected against corrosion.

Industrial applications of electronics were unknown until recent years, but high powered transmitters were constructed as cubicles, on a panelled-in structural framework, solid brass frequently being used. The first requirement for low power apparatus of high reliability arose in connexion with repeater amplifiers for carrier telephony. These were made up to fit in the type of racks or 19in wide relay panels which had been introduced in telephone practice about 1923, in the early days of automatic exchanges. This was the first general application of modular construction, the width being fixed, and the panel height a multiple of $1\frac{3}{4}$in. In the telephone field the system has evolved since the war[3] into an assembly of plug-in mounting frames, instead of the screw-on panels (Fig. 2).

Standardization and Unitization

The use of the 19in panel for communication equipment led to its adoption for audio frequency instruments, and in the 1930's the General Radio Company of Cambridge, Mass., designed a complete range of such electronic instruments suitable for mounting in either 19in racks or portable cabinets. The use of this principle for electronic instruments was further encouraged in the U.S.A. and later here by the availability of standard ranges of 19in racks, cabinets, panels and blank chassis and cabinet frame-work components priced substantially lower than the cost of designing and making special cabinets. The majority of industrial electronic equipment now follows the 19in standard except for miniature portable[9] instruments. Chassis runners are frequently employed so that heavy chassis may be drawn out. A wider panel (22in) has been used by the BBC and a narrower one (14in) in one range of instruments.

With the advent of aircraft radar a standard panel size of 8in high by 9in or 18in wide was adopted about 1942, the depth being variable. After the war a civil aircraft racking system was adopted by members of the S.B.A.C. and R.C.E.E.A. (Fig. 3), the height being 8in and the horizontal width module a multiple of 3, 4 or 5in. There are several standard depths ($2\frac{1}{2}$, 4, $5\frac{1}{2}$, 7 or $9\frac{1}{2}$, 11, $12\frac{1}{2}$, 14, $15\frac{1}{2}$in), $12\frac{1}{2}$in being preferred, and rear-mounted plug-in facilities are provided. It has been found useful to extend horizontal subdivision to the 19in rack construction for digital and analogue computors, where a large number of small plug-in circuits are employed (Fig. 4(a and b)). In both applications there is a considerable saving in manufacturing cost, as standard assemblies are used throughout.

It is found that complex systems can best be designed

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† *Elliott Brothers (London) Limited.*

as assemblies of functional units, not only for economy in manufacture, but to simplify the equipment logically from the point of view of servicing and maintenance by relatively unskilled personnel.

For example a computor containing 1 000 valves could be made up from about 50 large chassis, each comparable with a television set to manufacture. But it is not easy to carry out fault finding on such large units, or to handle them in the factory and it is preferable to resolve the system into 250 plug-in sub-assemblies of about four valves each. Only elementary knowledge is required to service these, and fault finding can be done by tracing it logically to two or three units, and exchanging them for spares. The unit circuits are also much more readily handled in production. It has been found possible in the case of digital computors, to meet all requirements in the arithmetic and control circuits with only three standard types of multi-function circuit units, mechanically identical.

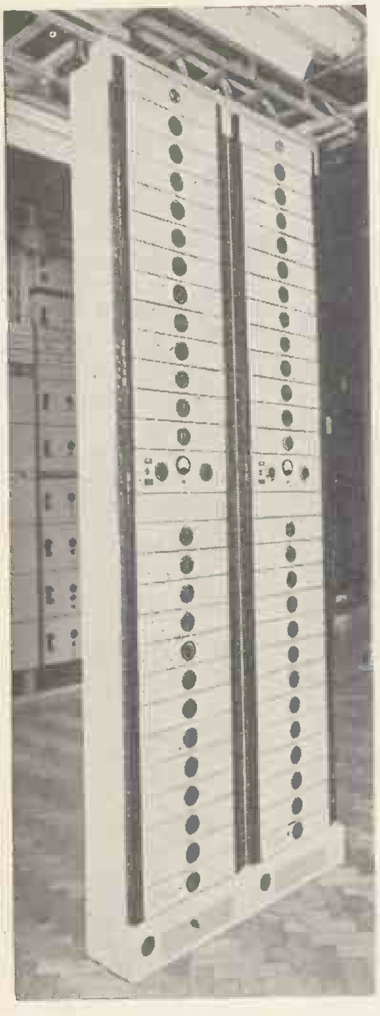


Fig. 2. 19in telephone rack with plug-in mounting frames

(*Courtesy S.T. & C.*)

Influence of Services Requirements

For special purposes, such as military equipment, it is more important to meet the requirements of miniaturization, pan-climatic conditions and pressurization than to provide the cheapest commercial construction. A survey of this field was given in a recent article[2]. The best solution may vary according to tactical requirements, as for example early in the last war when radar and other navigational aids were developing very rapidly. it was then desirable that construction should be as elementary as possible, so that new devices and counter measures could be applied operationally with prototype or even development models of equipment.

German radar equipment, on the other hand, was designed elaborately and great use was made of die-cast assemblies and highly tooled parts (Fig. 5) which were economical in large scale production, but entailed a long tooling-up period, and made it difficult to incorporate later modifications.

Now that system-design techniques have matured, it is possible to expect a longer period of service before obsolescence, and it is necessary to engineer the equipment specifically for ease of manufacture and servicing, particularly as a modern bomber may now carry 1 300 valves as against a complement of 30 in 1939. Servicing *in situ* in an aircraft or ship, or at an advanced army post is out

Fig. 3. An airborne magnetometer instrument built on standard S.B.A.C. racking

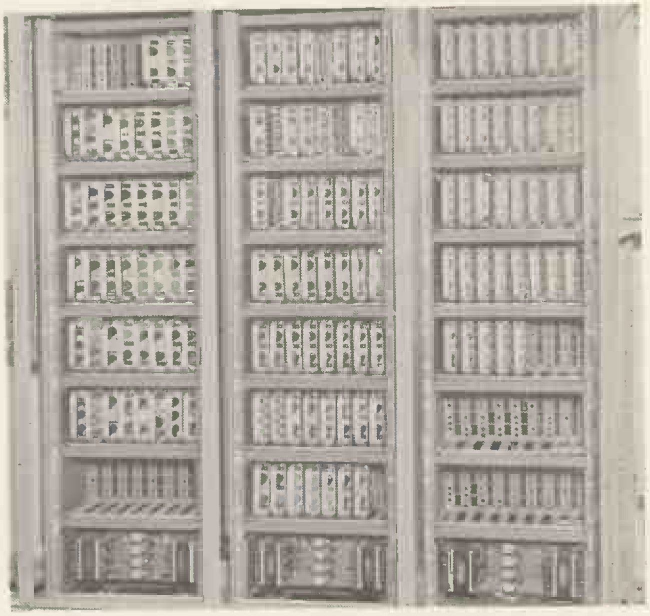
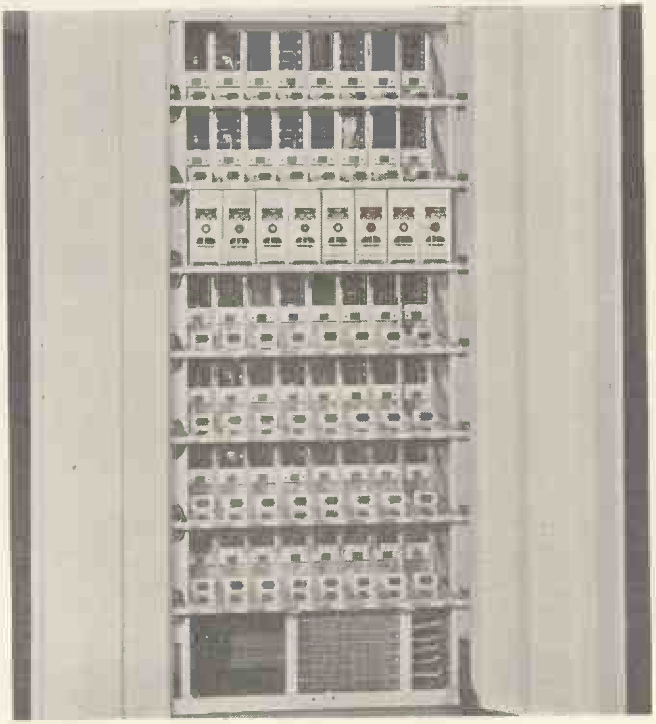


Fig. 4(a). Cabinets for a digital computor to 19in standard, subdivided horizontally for groups of eight standard plug-in circuit units

(*N.R.D.C. and Elliott Bros. (London) Ltd.*)

Fig. 4(b). Cabinet for analogue computor, employing rather larger plug-in chassis units, different circuits being indicated by a colour code



of the question—instead there must be held available spare units which can rapidly be exchanged for the faulty ones. An example of this type of application is the pressurized radar equipment, divided up internally into removable sections (Fig. 6).

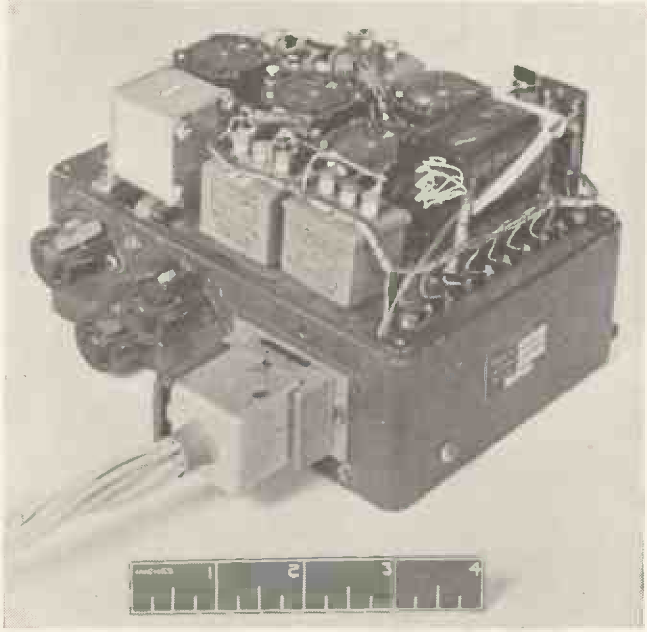


Fig. 5. A diecast radar chassis of German manufacture

It then becomes a problem in military logistics whether the faulty unit should be thrown away or returned to base workshops for repair. Obviously no repair is attempted with a receiving valve, and as long ago as 1926 the Loewe multiple valve was in production combining several triodes with their associated intercoupling components in a single bulb. The trend today is for new constructional techniques to be developed such as circuit printing, automatic assembly, hermetic sealing and potting, so that complex equipment can be manufactured semi-automatically in unit "packages" with a minimum of manpower, and serviced by interchange with little technical diagnosis. A complex radar set can be manufactured in quantity only by a large company with substantial assembly facilities, but when it is divided into sub-units, most of the work can be sub-contracted to smaller manufacturing organizations. If the manufacture is sufficiently rationalized it becomes economic for the circuit unit to be expendable in both military and commercial applications. At present some compromises are practised, the valves being mounted externally and so recoverable, and the circuit being repairable if supplies of replacements are not available.

Research and Development of Manufacturing Processes

There is no doubt that the effort devoted to engineering and production research in this country lags behind that directed to fundamental research in physics and in radio system design. The problem of obtaining a sufficiently high reliability in complex electronic equipment is not yet completely solved, nor have we the solution yet of how to make such machines as electronic digital computors cheap and compact enough for their potentialities to be fully applied in the economic and commercial life of the country.

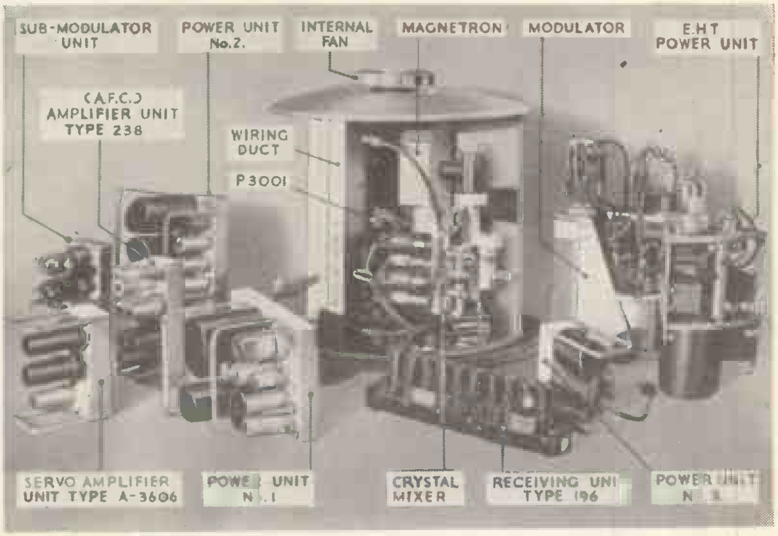


Fig. 6. A pressurized radar set with internal blower

The answer lies in semi- or completely automatic manufacturing processes which are at once of high productivity and subject to quality control of the product. This can only be accomplished if the demand is created for very large numbers of similar units, so that batch production can be replaced by continuous manufacture, using equipment sufficiently flexible that different assemblies can be handled. To meet this requirement it is desirable to limit the variety of valve types employed, and rationalize and simplify the range of different circuit units required in a system using common mechanical forms wherever possible. For example, it has been estimated that 800 000 television sets will be made in Great Britain this year, so there is a possible demand for perhaps half a million standard I.F. or R.F. strips. In the U.S.A. one company alone is installing over a million valves each year in commercial punched-card business machines, an almost untouched field for electronics in this country. There is still a vast market for low cost simplified radio receivers for the populations of under developed territories[44].

Up to a certain point, sub-division and miniaturization make it easier to adopt semi-automatic methods of manufacture because the handling problems are facilitated. It is understood that one radio valve factory today produces miniature valves in ten times the quantity turned out pre-war on the same factory floor, as a result of reducing the manual operations and the variety and size of the product.

Circuit manufacture can be approached in two ways, firstly the application of components by their manufacture *in situ* on a suitable base, and secondly by automatic assembly of discrete components separately manufactured.

The former method was first developed extensively in the early 1940's by Sargrove[45] in this country, and in the U.S.A. by the National Bureau of Standards and contractors for proximity fuses[4]. Since the war standard interstage coupling units or "multiple components"[46] have been made available, and this is the main present-day application of printed circuits. One American company has already manufactured 30 million of these (Fig. 7). Recently the second approach has received a good deal of interest, as components are used that are in existing production and control of the process therefore becomes less exacting: the most important single contribution is the technique of dip soldering, whereby a large number of suitably disposed connexions may be soldered in one operation. Although long used in wiring automatic telephony equipment[47] the method is new to radio assemblies.

The printed circuit is essentially a flat two-dimensional

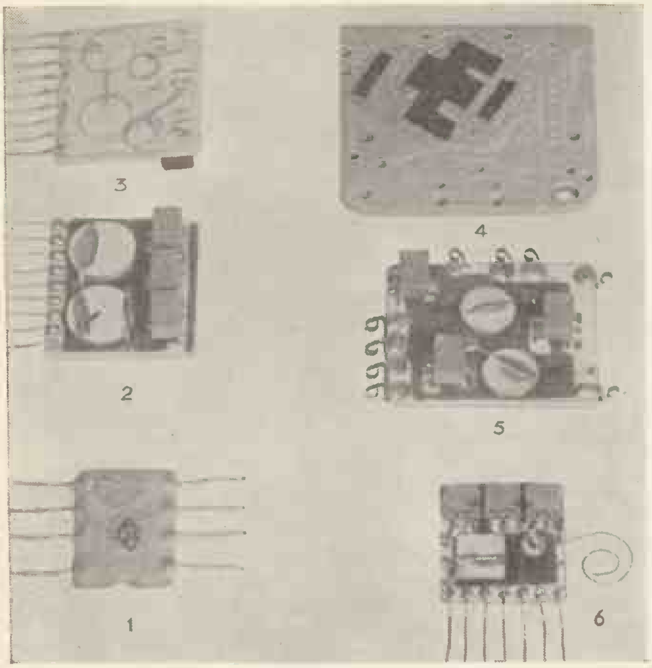


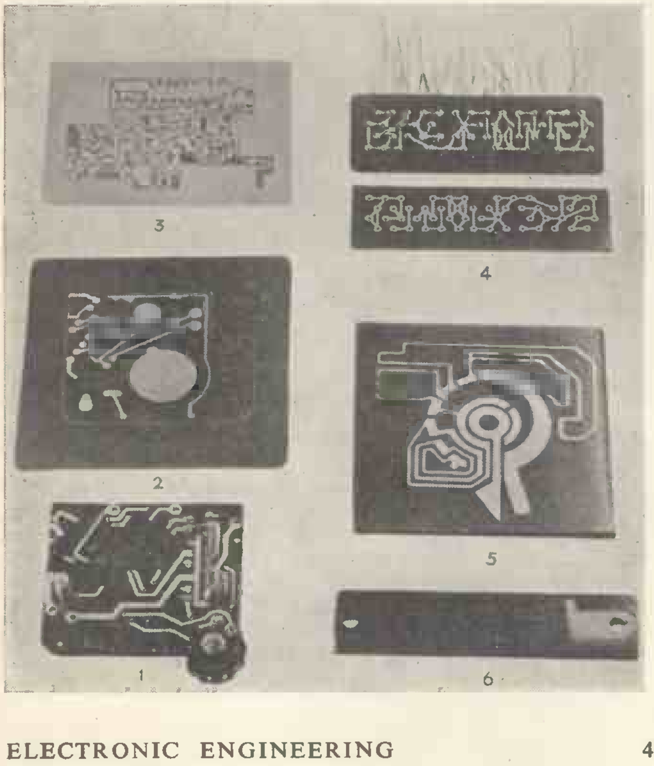
Fig. 7. A selection of printed circuits on ceramic bases

(1) *Interstage coupling;* (2), (3) *three-stage audio amplifier for sub-miniature valves;* (4) *circuit assembly to which accessories are connected by bolting them on to the silvering;* (5) *clip-in amplifier with spring contacts* (6) *three-stage amplifier, 1in by 1⅛in.*
(2-3, 5-6 *Centralab Div. of Globe Union Inc.*)

arrangement, and yields a circuit "card", which can, of course, be employed in stacks to give a three-dimensional array, or can be folded, rolled or processed in cylindrical form. A flat or two-ended multiple plug or socket can be integral in the construction[36].

Fig. 8. A selection of printed circuits on plastic bases

(1) *Hearing aid on silicone bonded glass fibre board;* (2) *silver powder pressed on* S.R.P.B. *base;* (3) *etched foil circuit (Technography);* (4) *connecting panel for dip-soldering the end connexions of a potted circuit (Hunt);* (5) *printed switch contacts (Plessey);* (6) *printed potentiometer track with four grades.*



In these systems it is usual to make connexions to the opposite extremities of an array of wire-ended components, yielding a three-dimensional unit of chassis-less or "inside-out" construction, the components being inside the structure rather than on it. For most industrial purposes the assembly could be air-insulated or hermetically sealed and oil filled, but it is usually more convenient to "pot" the unit in a synthetic resin, obtaining the support for the components in this way to withstand rough handling.

One other technique has arisen, the cold welding or swaging of wire connexions. It has found wide application in connecting the ferrules of aircraft wiring harnesses[34], and is coming into use in a wrapped-joint technique for telephone equipment, where the contacts themselves are brought out as wires rather than connecting tags[35].

Heat Dissipation

Unfortunately miniaturized electronics is not always associated with "miniature watts"! It is generally true that if a circuit is properly scaled down physically, the driving impedances can be raised as reductions are made in the stray admittances due to unwanted capacitance and inductance. For example, if all the physical dimensions are reduced by a scale factor $1/x$, the stray capacitances are also reduced by $1/x$. Thus miniaturized equipment will usually have a lower wattage dissipation per stage, and if we preserve constant voltage output and scale the current to $1/x$ and the impedances by x, the wattage becomes $1/x$. However, the volume is now $1/x^2$, and the power unit value is x^2 times as much, and per unit surface area x times. Therefore if we halve the size the rate of heat flow per unit area will be doubled, with corresponding increase in surface temperature.

Fig. 9. Sealed and oil-filled printed circuit units 5in × 3in, and rack with water-filled cooling baffles in which they are placed

The baffles have flexible sides which form good thermal contact with the unit when hydrostatic pressure is applied.

In consequence the cooling problem becomes acute with only a slight degree of miniaturization, particularly as circuits may now be surrounded by other circuits, so losing their external dissipating surfaces.

Air blast convection cooling has been resorted to, but it brings with it difficulties due to dust in industrial equipment and humidity in equipment subject to tropical conditions. The same heat can be extracted with about 1/1 500th the volume of coolant if a liquid such as oil is used instead of air.

One intermediate method is to increase the radiating area of subminiature valves by sandwiching them between aluminium plates arranged in an air-stream which also cools the components, the heat being removed from the air in the cabinets by water in radiator honeycombs and low pressure blowers such as are employed in car heating systems, so that extensive air ducting in large equipments is replaced by water pipe connexions.

Alternatively the valves may be inserted in holes bored in metal blocks, the blocks being in contact with a piping system in which cooled or refrigerated liquid is circulated[54]: the valve holes can with advantage be packed with silicone grease. The latter arrangement may achieve a "heat-pump" efficiently of 300-500 per cent, that is to say that a 1h.p. refrigerating machine consuming about 1 000 watts will extract 3-5 times as much heat. Where coolant is circulated through an electronic equipment at a temperature below the ambient, precautions must be taken against electrical breakdown due to condensation during periods of high atmospheric humidity. The simplest step to take is to have an enclosed ventilating system in the equipment. This is not opened to the atmosphere nor the coolant circulated until the equipment has warmed up, and circulation is turned off before the electrical shut-down.

The most effective cooling and "tropicalization" is obtained with oil immersing equipment. This is rather messy with large assemblies, but it is quite practical to oil fill and seal small assemblies, and remove the heat by conduction through thin baffle walls to a secondary water cooling circuit (Fig. 9). Useful lives of 30 000 hours are being experienced now with certain subminiature valves, so that it is quite economical to seal these in expendable circuit assemblies.

The rate of heat transfer is, of course, proportional to the temperature difference, and an alternative approach has been followed in the U.S.A. of setting up a target specification of 200°C, and developing components and high temperature insulation to meet it[48-51]. Amplifiers have been made to work at this temperature, and also as low as 14°K. The variation in gain for the range 14-290°K was in the ratio 1 : 3, mainly due to the temperature coefficients of resistors and capacitors[52].

Looking ahead, it is likely that evaporative cooling will be eventually adopted, as it is already being used for cooling valves[55,56]. It has the advantage of controlling the operating temperature exactly at the boiling point of the liquid, and if water is employed the 100°C temperature compares favourably with the 200°C specification mentioned above. In addition the energy removed as latent heat at boiling point is equivalent to that removed as specific heat for an 80°C differential, so less volume of coolant has to be circulated in the evaporative system. The system, in fact, has energy available, and there is no reason why it should not be self running as a heat engine, deriving the pressure differential for circulation from the condensing cycle.

Unfortunately semi-conductor devices such as germanium diodes and transistors will not operate satisfactorily at these high temperatures, as the semi-conducting properties have a considerable temperature coefficient of resistance. On the other hand, however, transistor circuits will operate with supply voltages of the order of 10-50 volts and at low currents, and the total power requirements in a typical signal stage may be only 10 milliwatts as against 10 watts when using, for example, a television pentode where half the power is used to heat the cathode. In transistor circuits many of the current components are virtually wattless. so they can be as small as it is possible to manufacture them.

(*To be continued*)

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The Silver-Zinc Accumulator

By C. L. Chapman*

THE storage battery or accumulator has in this modern world become such a common factor in everyday life that it is taken for granted. The first storage battery was given to the world by Gaston Planté in 1860. At that time the only means of charging such a battery were primary cells. Since then many reversible reactions have been investigated, a number exploited, a few commercialized.

Ever since Alessandro Volta and his famous voltaic pile the combination of silver and zinc has promised the possibility of a very light and efficient battery. Many attempts have been made to develop a silver-zinc accumulator, but always certain apparently insuperable obstacles prevented the full realization of the possibilities inherent in this combination.

It was left to Henri Andre, of Paris, after twenty years of patient work, aided by the introduction of new materials and techniques unknown to earlier inventors, to solve the problem and introduce the first practical silver-zinc accumulator.

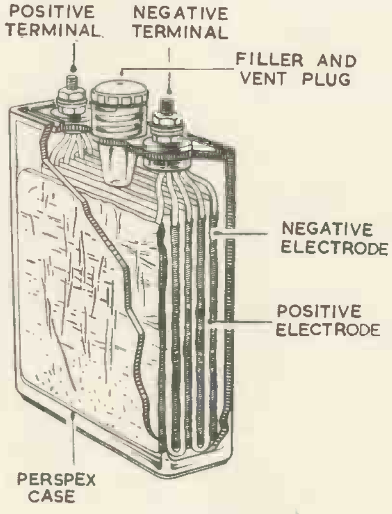

Fig. 1. Construction of cell

The earlier models of Andre's accumulator had soluble zinc negative plates, but during the last war Henri Andre produced the first batteries with insoluble negatives. It was shortly after the war that the world rights in this new accumulator were acquired by the Yardney International Corporation of New York. Licensees were appointed throughout the world, Venner Accumulators Ltd. accepting responsibility for manufacture and distribution of the new cell in the United Kingdom and most of the British Commonwealth.

All these manufacturing concerns throughout the world maintain laboratories, the developments from each being freely circulated, by which means the technical progress of the new battery is maintained at a high rate. Where necessary, types and sizes of cells have also been standardized enabling ready interchange or replacement.

To understand why the silver-zinc accumulator is able to offer special advantages in weight and size it is necessary to study briefly the characteristics of the elements used and the basic method of construction of the cell.

The electro-chemical efficiencies of silver and zinc are high on a weight-for-energy basis and the excellent conductivity of silver oxides is, of course, a contributory factor of no small importance. Fig. 1 provides a pictorial suggestion of the method used to provide the essential features of this storage battery.

The positive plates of pure silver, specially processed, are separated from the negative plates of zinc oxide by a cellulosic material which allows good diffusion of the electrolyte, at the same time preventing migration of metal particles from one plate to the other.

No grids or other forms of support are necessary, the current being distributed from the terminals to the plates through leads or strips of silver which are an integral part of each plate.

The excellent conductivity of the materials used, especially that of the positive plate, removes the necessity for the use of grids for current distribution. All the plate structure is therefore actively used with consequent high capacity in a relatively small space. Terminals are of steel or copper, and busbars, where required, are of copper, silver plated.

Case materials in general use include polystyrene and methyl methacrylate, injection moulded, though other materials, including certain metals, are used for special applications.

The electrolyte is strong alkali, potassium hydroxide (KOH), which is held mainly in an absorbed condition in the general assembly. The whole plate system, together with the separator, is confined under lateral pressure within the case and is thus able to withstand shocks and vibration.

During the first two or three formation cycles after manufacture, the potassium hydroxide becomes saturated with zinc assuming the form K_2ZnO_2, potassium zincate. The subsequent charge-discharge reactions are expressed by the formula:

$$\underset{\text{Discharged}}{Ag + Zn(OH)_2} \rightleftharpoons \underset{\text{Charged}}{AgO + Zn + H_2O}$$

As will be seen the electrolyte takes no part in the reaction expressed above, in common with certain other types of alkaline accumulators. A small excess of free electrolyte in the cell indicates sufficiency, but it is unnecessary for the plates to be submerged. Thus a relatively simple vent system ensures a spill-proof cell, especially since gassing is almost completely absent during the normal cycle of operation. On overcharge, of course, decomposition of water from the electrolyte will be expected to occur with evolution of hydrogen and oxygen.

When reasonable charging procedures are followed, topping-up is required only at rare intervals; a few drops of distilled water replacing losses.

Since the silver-zinc cell reaches full charge when its voltage on charge is 2·1 volts, most standard charging equipments can be used without modification. Only where fully automatic charging is required is it necessary to provide equipment specifically designed for silver-zinc accumulators. The cells will float satisfactorily on a system set between 1·95 and 2·0 volts per cell, and full capacity can be expected on a subsequent discharge.

As might be assumed, a cell using high conductivity active materials, in which the electrolyte takes no part in the reaction, will accept very high rates of boost charge. In fact, the practical realization of high rate charging is limited more by charging equipment than by the cells.

A charge equal to about 70 to 80 per cent of the nominal capacity can be put into a standard cell in a period as short as 15 minutes. Maximum efficiency will, of course, be attained with a more normal ten- or twenty-hour rate charge, but the ability to accept a high rate charge is a useful property in any accumulator.

At normal rates of charge the subsequent discharge can be expected to reach an ampere hour efficiency of 90 to 95 per cent with a watt hour efficiency of 80 to 90 per cent dependent to a small degree upon the rate of discharge. The current which the cell is called upon to supply hardly affects the capacity, but at very high rates the watt hour efficiency will be influenced by any voltage drop which takes place.

Fig. 2, which illustrates typical discharge characteristics

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* *Venner Accumulators Limited*

of the smallest cell made, of 0·75 ampere hour capacity, is representative *pro rata* of the whole range. It will be seen that a two-stage oxidation process occurs in the cell, the initial high voltage during discharge at low rates resulting from silver peroxide while the major part of the discharge, which is remarkably flat at a nominal 1·5 volts, results from reduction of silver-oxide to silver. The peroxide stage does not appear at rates of discharge higher than the four-hour rate since the reduction of silver-peroxide to silver-oxide becomes polarized to the potential of silver-oxide.

Fig. 3 clearly shows the corresponding two-stage oxidation which occurs during charging. The first voltage rise provides, incidentally, a useful control facility for the operation of automatic charging equipment.

The discharge curves illustrate that this small cell is no toy, but perhaps the most striking indication of its potentialities is realized by the statement that the peak current, on short-circuit, from this cell reaches 40 amperes. The lower conductivity of the alkaline electrolyte is more than compensated by the greater plate surface area which can be accommodated in a given space and by the high current density at which the silver-zinc accumulator can operate.

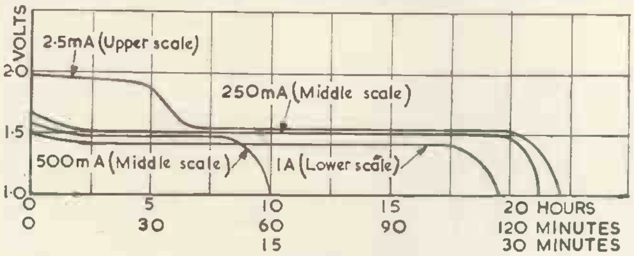

Fig. 2. Discharge curves

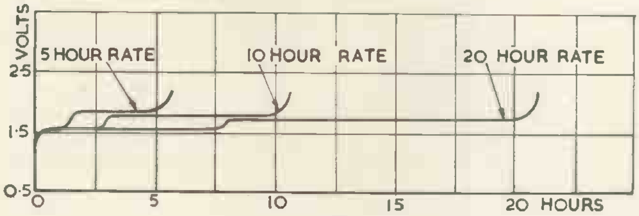

Fig. 3. Charge curves

At a current density of up to 3 amperes per square inch plates which can be made as thin as five thousandths of an inch, but which are normally no thinner than fifteen thousandths of an inch, can provide very high current outputs from a very small space.

These very high outputs frequently present a major design problem to provide adequate terminals in the space available. A cell smaller than a standard nine-volt grid bias battery may have as much as a hundred and twenty square inches of plate surface area providing a capacity of twenty ampere hours at discharge rates of 100 amperes with a peak current output approaching 600 amperes. A recent cell weighing 10 pounds with a volume of 110 cubic inches provided 300 ampere hours at a discharge rate of 1 500 amperes.

Table 1 quotes sizes and weights of the present production range available, but larger sizes up to 200 ampere hour capacity are now being introduced.

Charge retention of the cells at normal temperatures is good, ranging from a useful shelf life of up to two months in the small sizes to a year in respect of the larger cells. As a practical example, a ten ampere hour cell charged and stored in normal temperature conditions will provide 70 to 80 per cent of its marked capacity at the end of six months. At elevated temperatures the rate of loss on standing is, of course, increased.

Many applications require discharges from accumulators at extremes of temperature. Silver-zinc accumulators show, with varying temperatures, similar effects to other types. That is, increase of internal resistance and some reduction of capacity as the temperature is lowered. However, the standard cell provides useful output down to −20°C and can meet certain applications at −40°C.

Complete freezing and consequent failure to operate at all does not take place until the temperature falls to −59°C at any state of charge. No damage will result from such freezing. The upper limit of operating temperature is imposed by the softening point of the case materials which occurs at about 80°C. Standard cells can therefore be used in ambient temperatures up to 60°C.

Special case materials provide for higher temperature operation. At elevated temperatures the internal resistance of the cells is, of course, reduced, which is explained by the fact that the temperature coefficient of the electrolyte is negative. The resistivity of the plate and lead system, which is metallic and therefore has a positive coefficient, is much less significant.

The silver-zinc accumulator behaves excellently in the low-pressure conditions encountered at high altitudes, the cells showing no tendency to boil. It is interesting to note that the Canberra aircraft which recently established a height record of 63 668 feet carried a silver-zinc accumulator, thereby effecting a weight saving of some 140 pounds.

TABLE 1
Sizes of Cells at Present in Production

CELL TYPE	CAPACITY (AH)	OVERALL SIZE (inches) L.	H.	B.	WEIGHT lb.	oz.
H075	0·75	0·562	1·5	1·125	—	¾
H105	1·5	0·625	2·0	1·125	—	1⅛
H705	7·5	0·812	2·937	2·062	—	4½
H15	15·0	0·75	4·812	2·312	—	8
H20	20·0	0·830	3·875	3·657	—	12
H25	25·0	0·830	4·375	3·657	—	14
H60	60·0	1·657	4·375	3·657	1	12

Since silver and zinc are expensive raw materials, the silver-zinc cell is, of course, relatively costly as compared for instance with lead-acid accumulators. Very often, however, it is possible to use a much smaller and lower capacity cell for a given application. This is especially true where high currents are involved, since accumulators which have chemical reactions which include the electrolyte often show a considerable drop in the effective capacity as a result of a sustained discharge at high rates.

This drop in capacity resulting from the inability of the electrolyte to diffuse very rapidly is absent in the silver-zinc reaction where, as has already been stated, the electrolyte takes no chemical part during charge or discharge, serving merely as a carrier.

The silver-zinc accumulator has therefore very considerable advantages when used in applications where weight and size have to be seriously considered. Generally it may be said that for all portable and transportable equipment the merits of this cell are worth considering.

An intensive development programme is continually directed towards improving the already spectacular performance of the silver-zinc combination. The susceptibility of the cells to damage by overcharging has now been eliminated.

In addition, all cells have recently been upgraded in capacity by 50 per cent with no increase in size and only a fractional increase in weight. Charge retention characteristics have been greatly increased and formation has been simplified to the point where cells can be sent out filled but unformed in which state they can be stored for long periods without deterioration. The cells are available for use immediately after the first charge.

An Electronic Batching Counter

Using Dekatron Counting Tubes

By R. T. Craxton*, D.H.F.

A predetermined batching counter is described comprising four scale of ten decade units, employing Dekatron counting tubes, together with the necessary power supplies, photo-electric scanning head and a separate push-button unit which controls the selection of the batching number. Details of the application of this equipment to the length measurement of veneer are also given.

IN the sphere of industrial counting, there are many applications where counting in batches is required, or where a control signal is required after a predetermined number of counts. Often these applications involve a counting speed considerably beyond the capabilities of a mechanical or electro-mechanical counter. High speed batching or predetermined binary counters have been available for some years. Such counters may be considerably simplified by the use of Dekatron[1] scalers, and an important advantage is that the display is in decimal form and may be easily read by unskilled labour.

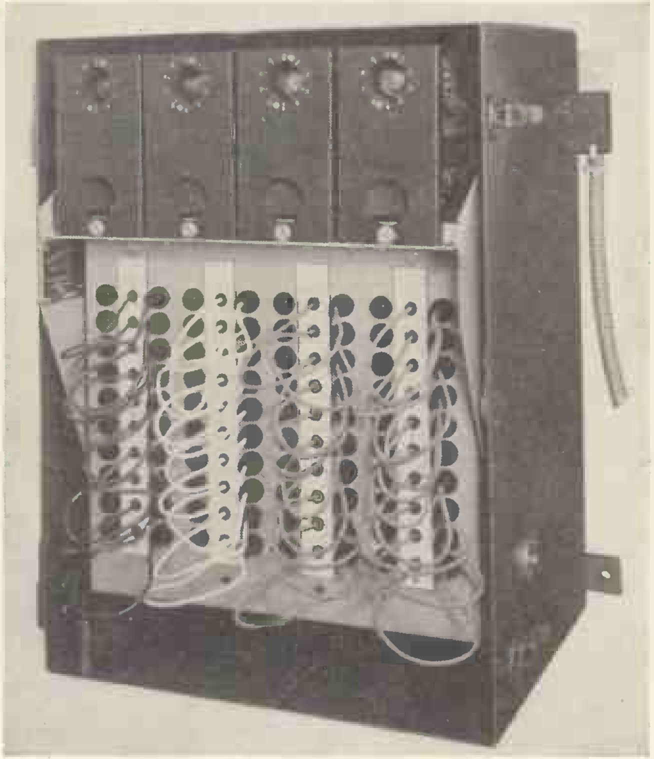

Fig. 1. The counter with cover removed

The BTH Co. Ltd. have recently developed a 4-decade predetermined counter with a maximum batching speed of 40 000 counts per minute and using Dekatron counting tubes (Ericsson Type GS10B).

The equipment comprises essentially four scale-of-ten decade units, together with the necessary power supplies, photo-electric scanning head, etc., and a separate push-button unit which controls the selection of the batching number.

The counter is housed in a substantial sheet steel dustproof case, connexions to the photo-electric scanner and push-button unit being run in flexible conduit. The chassis is pivoted at the lower end, so that when hinged out, all the components mounted on the back are accessible for servicing. The decade units are located on a platform at the top of the chassis, connexion to the chassis being via 18-way interconnectors.

Fig. 1 is a view of the counter with cover removed, and shows clearly the mounting of the decade units, and also the arrangement of the plug-and-socket jumper-board which allows for the pre-setting of each of ten selected numbers. This jumper-board is also pivoted, and secured at the top by two Oddie type fasteners. When hinged forward, access is obtained to the ten batching number selection relays which are mounted on the rear, and also to the valves, fuses, and pre-set controls mounted on the main chassis.

Circuit Details

DECADE UNIT

All four decade units are identical (Fig. 2), and are built as plug-in units to facilitate servicing.

Each comprises a Dekatron counting tube, together with the necessary driving circuits. The GS10B Dekatron used in this equipment is a cold-cathode gas-filled tube, with ten cathodes equally spaced around the circumference of the circular disk anode. The glow discharge may rest on, or " invest " any one of the ten cathodes. Between adjacent cathodes are two guide electrodes, and by applying negative pulses to these electrodes in the correct sequence, the glow discharge is caused to move clockwise from one cathode to the next. The negative driving pulses are in this case derived from a multivibrator circuit, using a double triode valve.

The valves V_{1a} and V_{1b} form a cathode coupled one shot multivibrator which is triggered by a positive pulse resulting from the differentiation, by C_1 and R_1, of the input signal. This is obtained either from the 0 cathode of the preceding decade, or in the case of the first decade, from the photo-electric scanner via the input trigger circuit.

The negative-going pulse at the anode V_{1a}, with a duration of approximately 200μsec, is applied direct to the first guides, and via the integrating circuit R_9C_4 to the second guides. Divider chain R_7R_8 is provided to equalize the amplitudes of the two guide pulses. Rectifiers MR_1 and MR_2 are for clamping purposes.

Each cathode of the Dekatron has its own load resistor. The 0 cathode, which is the carry electrode, is connected to the input of the following decade unit. Cathodes 1 to 9 are taken out to the jumper-board to be selected as required. All cathode load resistors are returned to earth direct with the exception of the 9th, R_{19}, which is returned to earth via rectifier MR_8 in the reset circuit. The reason for this will be explained later.

COINCIDENCE CIRCUIT (Fig. 3)

When the glow discharge invests a particular Dekatron cathode, that cathode will rise to a potential of approximately 30V. Suppose that the required batching total is 1 728. If now the four arms of the coincidence circuit shown in Fig. 3 are connected to the corresponding cathodes of the appropriate decades, then the output, which is connected to the grid of thyratron V_2 via R_{29}, will only

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* *The British Thomson-Houston Co. Ltd.*

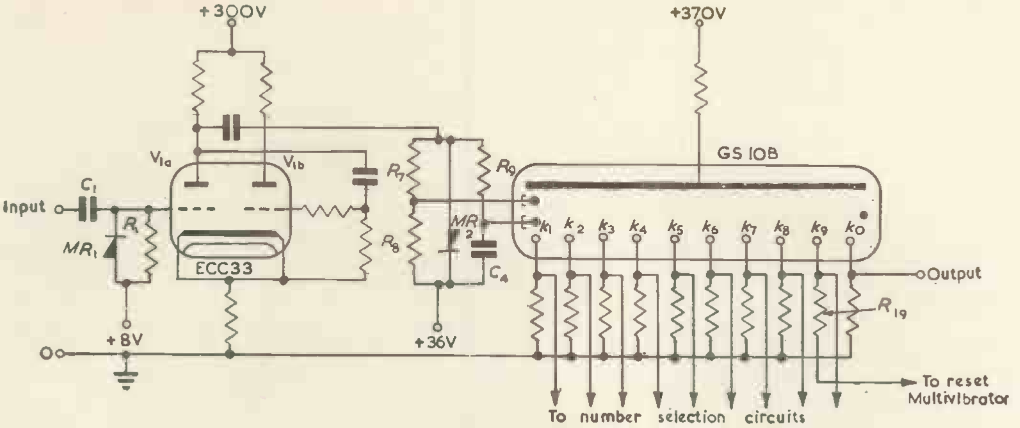

Fig. 2. Decade unit

rise to 30V when this number is reached, and only for as long as the glow remains on the 8th cathode of the units tube. The thyratron is thus caused to conduct as soon as the selected number is reached.

It should be noted that no connexion to a 0 cathode is necessary, so that where the selected number contains a zero, the appropriate arm of the coincidence circuit is left unconnected. An example should make this clear. Suppose the selected number is 1 000. The only arm of the coincidence circuit connected will be that to the 1st cathode of the thousands tube, and the *first* time that the glow discharge invests this cathode, will be when the 1 000th count is registered, when the thyratron will be triggered and the counter reset.

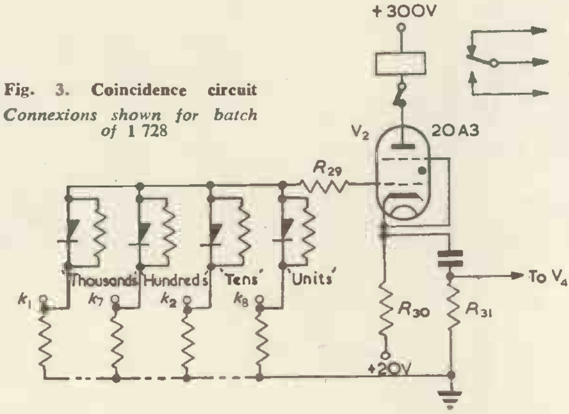

Fig. 3. Coincidence circuit
Connexions shown for batch of 1 728

In the anode circuit of the thyratron is a relay which is provided with contacts suitable for operating a solenoid, contactor, or other mechanism depending on the application. Also in the anode circuit are the normally closed contacts of a relay or microswitch, which are opened momentarily after each batch to reset the thyratron.

The voltage appearing across the thyratron cathode resistor R_{30} is differentiated, the short positive pulse across R_{31} being used to trigger the reset multivibrator V_{4a}.

RESETTING

There are a number of methods available for resetting Dekatron scalers and one of these is to apply a negative pulse of suitable amplitude to each of the 0 cathodes, thus forcibly transferring the glow discharges from wherever they may be to these cathodes. A disadvantage of this method is the necessity of having to provide a gating circuit for the inter-decade drive, since the termination of the reset pulse would tend to index on the following decade, the coupling of necessity being taken from the 0 cathode.

A simpler method*, used in this equipment, is to apply the reset pulse to the 9th cathode of each decade. The counter is thus first reset to 9 999, and gating circuits are unnecessary. The reset pulse itself is differentiated and a positive signal coincident with its trailing edge is applied to the input circuit, transferring the display from 9 999 to zero.

With reference to Fig. 4, V_{4a} and V_{4b} form a cathode coupled one-shot multivibrator, which is triggered by a short positive pulse obtained by differentiating the voltage appearing across the thyratron cathode resistor R_{30} (see Fig. 3). The negative pulse at the junction of R_{47} and R_{48} is applied to the lower end of R_{19} in each decade unit, these resistors being connected to chassis via rectifier MR_8. The negative pulse is also fed to the differentiating circuit comprising C_7, R_{46} and R_{45}. The positive pulse appearing across R_{45} coincident with the trailing edge of the negative reset pulse is fed to the input of the units decade.

INPUT CIRCUIT (Fig. 4)

The input signal for the units decade is obtained from the cathode coupled bistable multivibrator V_{3a} and V_{3b}, the photocell or switch contacts being direct coupled to this stage. The counter is thus responsive down to zero frequency, an essential feature when counting slow-moving objects. For simplicity, the projector lamp is supplied with A.C. and rheostat VR_{39} is provided in the anode circuit of V_{3a} so that the differential, or backlash, of the input circuit may be set at a higher voltage than the peak of the 100c/s ripple appearing across R_{37}.

Batching Number Selection

To select a particular batching number, the four arms of the coincidence network must be connected to the

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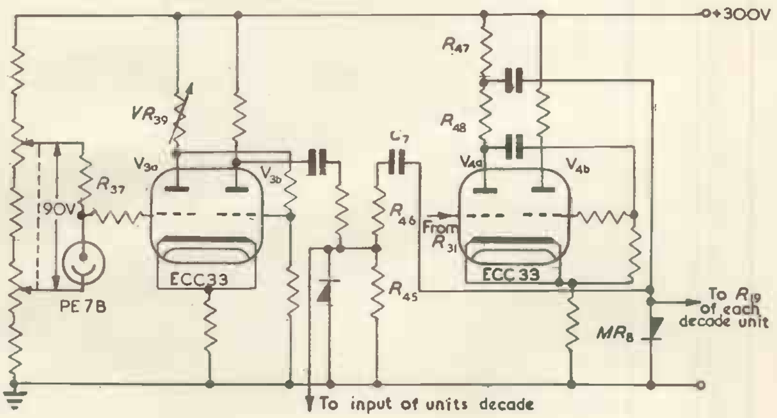
* *Patent applied for.*

Fig. 4. Input and reset circuits



required cathodes of each decade. For example, assuming that the desired total is 1 728, then the four arms are connected to cathodes 1, 7, 2 and 8 of the "thousands", "hundreds", "tens" and "units" decades respectively. These connexions may conveniently be made by means of 10-way selector switches, one for each arm or decade, so that the batching number can be easily changed when necessary. This arrangement is entirely satisfactory where the counter is permanently set to batch one quantity, or where changes are infrequent. Where, however, a limited number of different batching numbers are in regular use, and more particularly where the application requires a rapid change of number, a more elaborate switching arrangement is necessary. In effect, a number of banks of selector switches are provided, each bank being set to one of the required batching numbers. Any one of these banks may then be selected by means of a relay. Where more than, say, three or four pre-set numbers are required, the necessary array of switches would be both cumbersome and expensive, and a suitable alternative is a simple plug-and-socket jumper-board giving essentially the same facilities. Such an arrangement is used in this particular model, and the jumper-board may be seen in Fig. 1. It is possible to set up ten different four figure numbers using this board, the particular number required at any instant being selected by energizing the appropriate one of ten telephone type relays mounted on the back of this board. These relays are controlled by a ten-way push-button unit, which is mounted in any convenient position, remote from the main unit.

Some applications require that a warning or control signal be given preceding the final count. An example of this is in the batching of small objects which can be counted at a rate much higher than that at which accurate batching is possible, due to mechanical limitations. The conveyor may be run at a high speed for most of the count, being slowed down by the warning circuit just before the final count. This can be catered for by the provision of an additional coincidence network and thyratron. The additional thyratron is in this case triggered off when the warning count is reached, and remains conducting until reset, together with the main coincidence thyratron after the final count.

Since variations in the design of individual counters, due to differences in application, are mainly confined to the arrangements for batching number selection, these circuits are mounted on a separate panel which may be modified without involving changes to the counter proper.

Application

An interesting application of the batching counter is that of length measurement, and Fig. 5 is a photograph showing the counter set up for this purpose, operating in conjunction with a clipping machine installed in the works of a plywood manufacturer.

Veneer is first peeled from a log and subsequently passed through the clipping machine to be cut into suitable lengths. The length of the material passing through the machine is measured by means of a friction wheel pressing on the veneer and driving, through suitable gearing, a disk provided with a series of holes around its periphery. A projector lamp and photocell are mounted on opposite sides of the disk, and interruptions of the light beam are integrated by the counter. By so arranging that ten holes pass the scanning head for each inch of linear travel of the veneer, the counter indicates the length directly in inches and tenths of an inch.

Fig. 5 shows a reel of peeled veneer about to pass through the guillotine. The four chains seen resting on the surface of the veneer are not part of the drive, their function being to hold the veneer flat as it enters the machine. The counter can be seen below the run-in table to the right of the operator, the count displayed being visible through the four windows at the top. Although in the case of a batching counter a displayed count is not necessary, it is, however, very valuable as an indication that the counter is operating correctly. In this photograph the mounting of the push-button unit on the control pulpit can also be seen, while the perforated disk is just visible at the left of the counter.

The operator examines the veneer as it is unreeled and if no flaws are present will press the button corresponding to the longest standard length. The machine will then proceed to cut off this length, without any intervention. Should a flaw appear in the veneer the operator must then quickly decide what is the maximum standard length that can be cut before the flaw reaches the guillotine and press the appropriate push button. She will then make a random cut immediately after the flaw, thus cutting out the faulty piece, and by pressing the original button resume cutting the longest standard length. The counter is reset to zero whenever the random button is pressed.

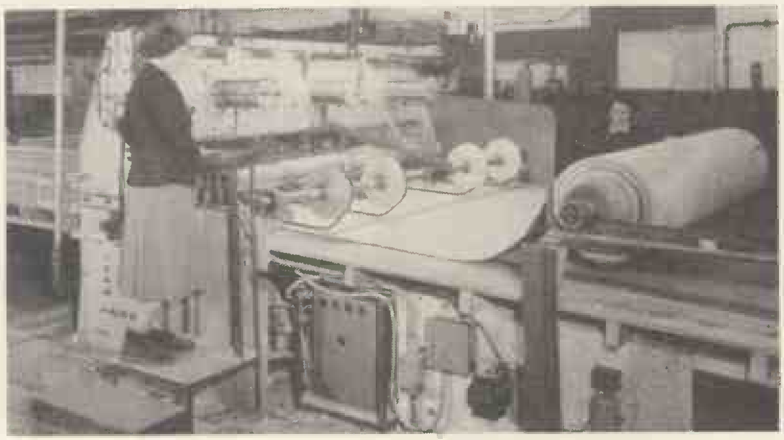


Fig. 5. Length measurement of veneer

When a button is depressed it latches itself down and releases any previously pressed. An indicator lamp adjacent to the button is also illuminated. An ivorine strip above the push buttons is provided so that the length corresponding to each push button may be written down by the operator. This lettering may be readily erased and changed should it be necessary to alter the standard lengths.

In this particular installation the veneer runs at a speed of up to 130ft/min. From this it will be realized that push-button control as described above is the only method of changing the selected length in the time available.

The accuracy obtained at this speed is $\pm\frac{1}{4}$in, this error being partly due to slip between the measuring wheel and veneer, and partly due to the inherent counting error of $\pm 1/10$in. At slower speeds the error is reduced to $\pm\frac{1}{8}$in or less. In certain cases it would be possible to reduce the inherent counting error to $\pm 1/100$in by counting 100 impulses per inch.

It is expected that this equipment will find a wide field of application in industry, as a solution to many batching and length-measuring problems.

Acknowledgment

The author wishes to thank the Directors of the BTH Co. Ltd for permission to publish this article and for the use of photographs.

REFERENCE

1. Bacon, R. C., Pollard, J. R. The Dekatron. *Electronic Engng. 22*, 173 (1950).

V.H.F. Aerial Radiation Pattern Measurements

By E. G. Hamer*, B.Sc.

The precautions to be taken when measuring the polar diagram of V.H.F. *aerials are discussed and certain criteria evolved. These include the avoidance of errors due to induction fields, surface wave, and variation of Brewster angle. The actual techniques of measurement are discussed, and also the method of presentation and analysis of the results obtained. A brief description is made of machines for automatically plotting radiation patterns.*

A CONSIDERABLE improvement has been made in the performance of V.H.F. radio systems in recent years by careful attention to the electrical design of the various units. The harmonic distortion, cross modulation, etc., have been greatly reduced in present designs of equipment, and the range of a fixed link, or area of coverage of mobile systems increased. One of the major factors limiting the range of a V.H.F. system is the noise which is added to the received signal, and which if large enough will seriously degrade or obliterate the wanted intelligence. The signal-to-noise ratio at a receiver output will depend upon the transmitted power, the receiver sensitivity and noise factor, the type of modulation used and the gains of the aerial systems in use. Improvements to the receiver noise factor will only improve the overall performance with regard to thermal noise, whereas the other improvements help with regard to both thermal, atmospheric, and man-made noise. The improvement due to increased receiver aerial gain might not hold, however, if the major lobe, (or any large minor lobes) in the aerial pattern happened to point at a local source of man-made noise.

Dealing in succession with these possible improvements, the maximum transmitted power is now limited by the system economics, and by what the local licensing authorities will allow, because suitable valves now exist for all reasonable power outputs in the V.H.F. band. The receiver sensitivity has been increased to such an extent that the performance of a receiver is now limited by thermal and man-made noise. Various types of audio frequency limiting circuits can be used with simple radio links to give an improved subjective listening performance when impulsive type man-made noise is present; and the noise factor of modern V.H.F. receivers is now sufficiently good for the performance to be completely limited by man-made noise.

The type of modulation used is often decided by the nature of the service, and the cost and complexity of any special equipment required. Most V.H.F. radio systems use amplitude or frequency modulation, although simple types of pulse modulated systems have been used at the higher frequencies.

Improvements can still be made at a relatively low capital cost by reducing the losses in the aerial feeders, and increasing the gain of the aerials. Low loss air dielectric feeders are now available, and it is usually the balance of the reduced losses against the increased cost of the special coaxial cables which must be decided. In many cases reducing the receiver feeder losses will give no improvement in the system performance, in regard to man-made noise.

In some systems the aerial gain may be increased, but this often means a reduced radio frequency bandwidth, low aerial feed impedances, and possibly very critical adjustments of the elements forming the aerial array. At the present time the biggest unknown factor in a V.H.F. radio system is the aerial, because of the difficulty and cost of making measurements or theoretical calculations on the gain, feed impedance, and bandwidth of the aerial. Unless the measurements of the aerial performance can be made with either the aerial in its final position, or in a close approximation to its final position, errors may occur between the laboratory measured performance and the actual performance. These errors are caused by the effects of the ground, nearby objects, and the support for the aerial itself.

One of the most important factors which must be known is the gain of the aerial system in the wanted direction expressed either as the gain relative to an omnidirectional source, or relative to a simple dipole. Because the concept of an omnidirectional aerial cannot be realized in practice, gain measurements are usually made by comparison with a dipole aerial, except when the gain has been computed graphically or mathematically, in which case the omnidirectional source is used as a reference. A simple dipole has a gain of 2·15db in the direction of maximum radiation over an omnidirectional source, hence conversions from one standard to the other are easily made.

The gain G of an aerial over an omnidirectional source may be defined as either the ratio of 4π times the radiation intensity in the required direction to the total power input to the aerial (power gain); or the ratio of 4π times the radiation intensity to the total power radiated by the aerial (directive gain). In the former case the effects of aerial and matching network losses are taken into account. These losses are usually small except in cases where the aerial is designed to have a very large gain (supergain aerials), in which case, because of the large currents in the matching networks and radiators the losses may be large. Radiation intensity ϕ is defined as the power radiated per unit solid angle in the direction under consideration and if E is the field intensity then:

$$\phi = E^2r^2/R_0$$

where r = distance from the source and R_0 = impedance of free space.

The effective area A of an aerial is defined as:

$$A = \lambda^2 G/4\pi$$

and it can be shown that for a receiving aerial the received power, neglecting losses, is equal to the total power passing through the effective area due to the incident wave.

The resultant signal received at an aerial has several components and these are the direct wave, the reflected wave from the ground, the surface wave, and those due to the induction field. Induction field components are the ones to be expected from normal electrostatic and magnetic theory, and their amplitudes vary as the inverse square of the distance; whereas the amplitude of the direct

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* *The General Electric Company Limited, Wembley, England.*

and reflected waves vary as the inverse of the distance. The radiation and induction fields have equal amplitudes at a distance of one-sixth of a wavelength from the source, and if the receiving and transmitting aerials are separated by 10 wavelengths the induction field is reduced to 1·6 per cent of the radiation field.

Surface wave effects are of importance when the receiving aerial is close to the ground relative to the wavelength. This gives the curious effect that for a vertically polarized wave as the aerial height is reduced the received signal diminishes until at some height it ceases to decrease and remains at a constant value until the aerial is on the ground. The height at which this phenomenon occurs is termed the minimum effective height, and the surface wave is the controlling factor for aerial heights less than the minimum effective height. For aerials mounted above the minimum effective height the surface wave may be neglected. Over good soil the minimum effective height is approximately nine feet at 100Mc/s and three feet at 300Mc/s for vertical polarization, and if it is horizontally polarized the surface wave may be completely neglected at V.H.F. for all heights.

To meet the two previous criteria when measuring the polar diagram of an aerial, the aerial under test and the pick-up aerial should be at least 10 wavelengths apart; and each aerial should be mounted so that it is at least twice the minimum effective height above ground, for the frequency and polarization in use. These precautions will eliminate any unwanted components due to the induction field and surface wave, and the resultant signal at the pick-up aerial will be the vector sum of the direct and reflected waves.

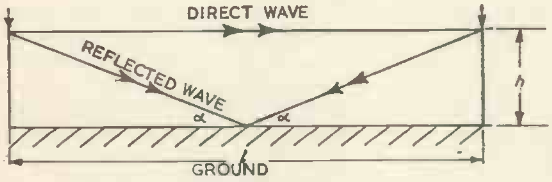

Fig. 1. Ground reflected wave

The magnitude and phase-angle of the reflected wave relative to the direct wave will depend upon the path difference attenuation, and phase change caused by the reflexion from the ground. As the path lengths are only slightly different the variation in amplitude can be considered as due to the reflexion attenuation only.

Fig. 1 shows a receiving and transmitting aerial mounted at equal distances above the ground, the path difference δl is:

$$\delta l = l - 2 \sqrt{(h^2 + l^2 4)}$$

and the resulting phase difference ϕ between the direct and reflected wave is:—

$$\phi = 2\pi/\lambda[l - 2\sqrt{(h^2 + l^2/4)}]$$ ①

If l is at least 10 times greater than h the above may be expanded by the binomial theorem and all except the first two terms neglected, we then have:

$$\phi = 4\pi h^2/\lambda l$$ ②

this phase difference ϕ must be combined with the phase shift due to reflexion to give the resultant phase shift. The magnitude and phase-angle of the reflected wave depend upon the polarization of the wave, the angle of incidence and the properties of the ground. Fig. 2 shows the magnitude and phase-angle of the reflexion coefficient for vertical and horizontal polarization over good earth as the angle of incidence α is varied. It will be seen that for a horizontally polarized wave the reflexion coefficient amplitude for small angles is nearly equal to 1, and the phase shift is 180°. In the case of horizontal polarization there can be quite wide variations of α with little effect. When, however, the wave is vertically polarized the reflexion coefficient amplitude at 0° is 1 and decreases until a minimum is reached, the angle at which this occurs is termed the "Brewster" angle. Beyond this angle the value again increases, but never again reaches 1. Coincident with the minimum value of the amplitude of the reflexion coefficient at the Brewster angle there is a rapid change of reflexion coefficient phase-angle. The importance of these effects is that if measurements are being made, and the aerial under test is radiating vertically polarized components, great care must be taken that the angle of incidence is not near the Brewster angle, or slight variations of the Brewster angle due to changes of frequency, or ground conditions, say, due to rain, may cause large errors. These precautions are only necessary when a vertically polarized wave is being measured, but the effects have led to large errors in the past, particularly when complex aerials were laid on their sides in order to measure the vertical polar diagrams.

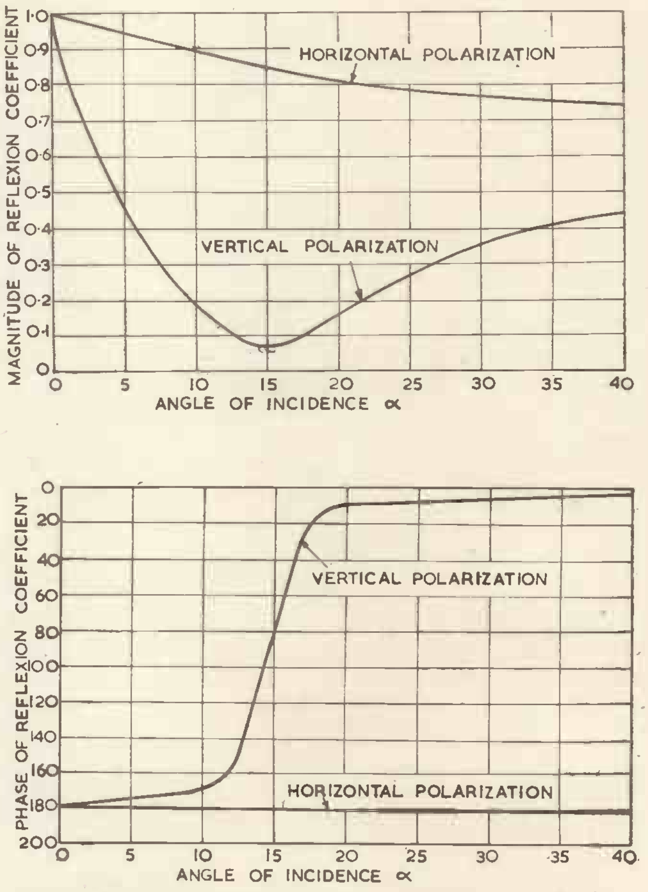

Fig. 2. Reflexion coefficients for vertical and horizontal polarization

Summarizing the conditions for accurate results when measuring polar diagrams we have:

(a) Aerials to be separated by at least 10 wavelengths.

(b) Each aerial height to be at least twice the maximum effective height.

(c) Angle of incidence to be kept low to be below Brewster angle for vertical polarization and to ensure that initial magnitude of direct and reflected wave are equal; particularly if there are rapid changes in the polar diagrams in planes mutually at right-angles to the one being measured.

① Reads. $\phi = \frac{2\pi[l - 2\sqrt{(h^2 + \frac{l^2}{4})}]}{\lambda}$

② " $\phi = 4\pi h^2 l$

Rousseau Diagram

When the aerial has been sited and measurements made of the field strength along various radials, at a fixed distance away from the aerial under test the radiation pattern or polar diagram may be plotted. From this diagram the gain of the aerial over the equivalent omnidirectional source may be evaluated in certain cases by the use of "Rousseau's Construction." This is illustrated in Fig. 3 where the radial distances are proportional to the radiated power (i.e., proportional to the square of the field strength). The Rousseau diagram is constructed by dropping the perpendiculars from where the radial lines intersect a circle, and distances proportional to the radiated power are then plotted along these perpendiculars and a new curve obtained. This is shown in Fig. 3, where the radial at 40° is marked and $OA = O_1A_1$.

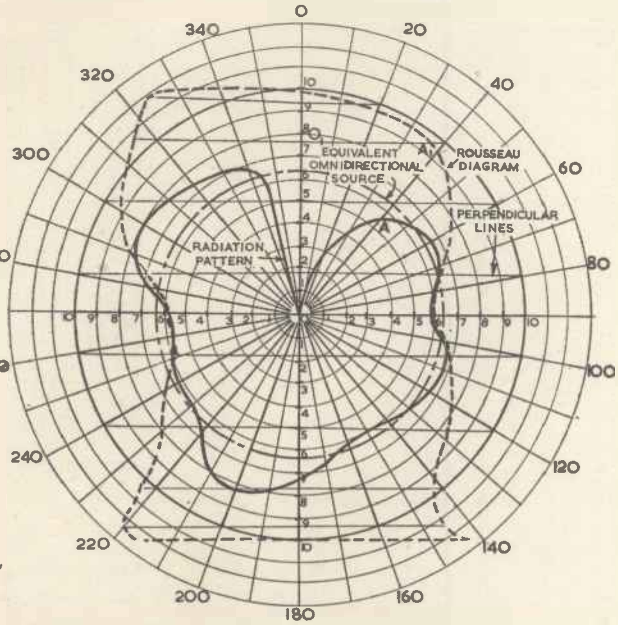

Fig. 3. Rousseau construction for radiation pattern

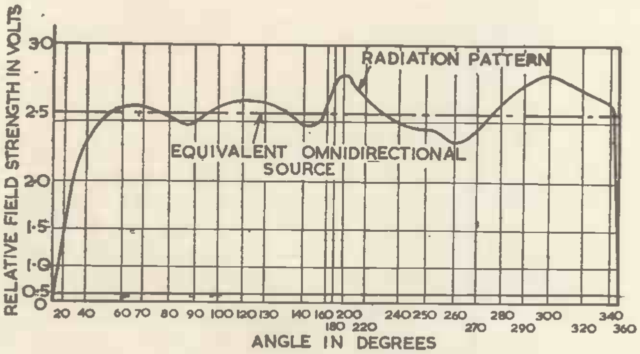

Fig. 4. Radiation pattern plotted on special graph paper

By the use of a planimeter or other means the mean height of the Rousseau curve is obtained, and this height represents the mean spherical radiated power, to the same scale as the remainder of the diagram. The gain of the aerial in any direction relative to the mean spherical power (i.e. the power radiated by an omnidirectional source with the same total power output) may then be obtained. This form of construction is only strictly true if the polar diagram in the plane at right-angles is a circle. If this is not the case then the mean of several Rousseau diagrams in different planes must be taken. To avoid the laborious graphical construction required to obtain the mean radiated power special graph paper may be used, where the ordinate has a square law scale for field strength, and the abscissa has a cosine scale for the angular position[1].

Fig. 4 shows the diagram of Fig. 3 plotted on this type of paper, and the mean height is found in the same way. The proof of the validity of the Rousseau construction in obtaining the mean spherical radiated power is given in the Appendix.

Where the performance of several aerials is being compared the polar diagrams may have their scale and size adjusted to have the same equivalent omnidirectional source, and in that way a direct comparison may be made between their performance. This method of comparison avoids the errors caused by comparing pattern measurements made over a long period of time when the pick-up sensitivity and radiated power may have varied.

Measurement of Radiated Patterns

This may be achieved in several ways depending upon the accuracy required and the speed and number of measurements. The aerial to be tested and a suitable pick-up aerial are mounted over flat ground, or a level wire mesh screen, and satisfying the conditions previously mentioned. For ease of measurement it is usual to rotate the aerial under test rather than move the pick-up aerial while keeping it at a fixed radius. All reflecting objects such as wire fences, buildings, trees, etc., should be at least 10 times the distance between the aerials away. If this is not possible, the effect of echoes can be minimized by making the pick-up aerial directional and arranging that the offending object is behind the pick-up aerial, and on the line through the two aerials.

It is essential that when the main lobe of the aerial under test is pointing at a reflecting object, any received echo signal should be at least 10 to 20db less than the minimum received signal from the aerial under test. This minimum received signal may itself be 30 to 40db less than the maximum received signal, hence the echo signal in the worst case should be at least 50 to 60db down on the signal causing it. Simple tests can be made using a suitable oscillator, either modulated or unmodulated, to feed the aerial with a calibrated receiver connected to the pick-up aerial. The oscillator must be designed to give a constant output, at a constant frequency, irrespective of mains or battery fluctuations, and varying ambient temperature; the same also applies to the calibrated receiver. If long feeder cables are used, great care must be taken to ensure that they are well matched to the aerials, and that there are no R.F. voltages or currents on the outside of the screening. Otherwise the feeder itself may act as an aerial and considerably modify the results obtained.

An alternative and more accurate method is to fit a crystal detector at the pick-up aerial and either measure the rectified direct current or the demodulated signal. The aerial is fed from a suitable oscillator via a slotted line, the slotted line being used to measure the power flowing into the aerial. As the aerial is rotated, the oscillator power output is varied to keep the pick-up signal constant, in this way eliminating any errors due to the input-output characteristics of the pick-up detector. The crystal detector is usually mounted as an integral part of the pick-up aerial and should be well shielded from the direct rays of the sun to avoid large changes of ambient temperature.

The slotted line measures the standing wave pattern in the feeder to the aerial and the power flow to the aerial is proportional to the product of the maximum and minimum standing wave voltages. Thus for a given aerial with a constant standing wave ratio under the test conditions, the radiated power is proportional to the square of the maximum standing wave voltage. When taking a set of readings the position of the moving probe is set to coincide with a voltage maximum, and as the aerial is rotated and the oscillator power varied to keep the pick-up signal constant, the reading being taken of the standing wave voltage. The inverse of this voltage is proportional to the field strength, and the inverse of the square proportional to the radiated power, in the given direction and at a fixed distance for a constant power input to the aerial. A calibration of the slotted line can easily be made at the frequency being used, and provided that reasonable precautions are taken this calibration will hold over long periods of time[2].

This method is particularly suitable when comparing the performance of an aerial with that of a dipole, as the power input can be adjusted and measured to give the same pick-up signal in each case. If the product of the maximum and minimum standing wave voltage is taken, errors due to the aerials having different standing wave ratios are eliminated. The slotted line itself may be of the slotted coaxial type, or of "slab-line" construction; a slab line is to be preferred as it is easier to manufacture, and there are smaller errors due to the variation in depth of probe penetration. Fig. 5 is a photograph of a typical V.H.F. slab-line formed from aluminium channel sides, and fitted with a taper and step end to reduce the size to a suitable cable connexion.

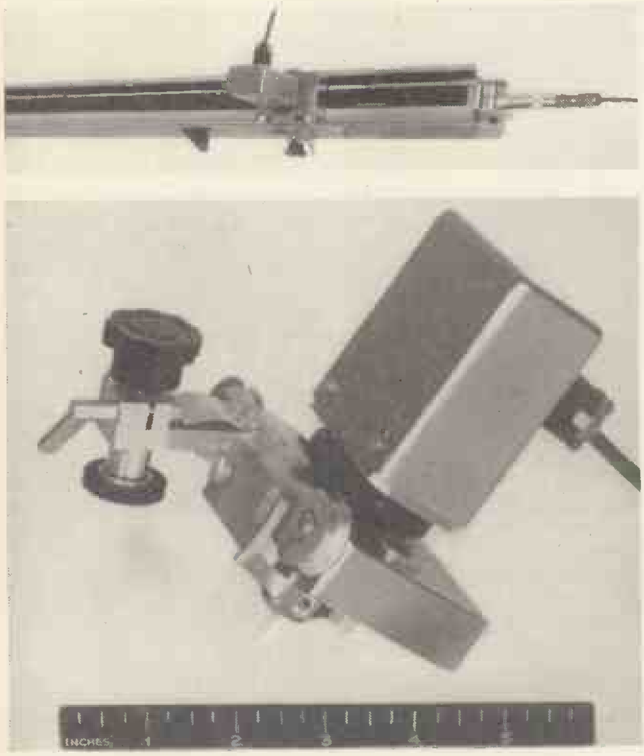

Fig. 5. The "Slab Line"

It is essential that there should be no extraneous pick-up of unwanted signals, and to avoid the large currents induced by medium wave broadcast stations a simple tuned circuit may be fitted in the pick-up aerial. This is shown in Fig. 6 where the tuned circuit rejects the unwanted signal and also matches the aerials to the crystal detector used. Fig. 6 also shows the dimension of a standard dipole aerial. The suppressor sleeve is to ensure that the outside of the feeder is "dead"; and the spacing of this sleeve from the dipole may require slight adjustment in individual cases to reduce the external current on the feeder cable to zero.

Another requirement is a knowledge of the aerial feed impedance, both at its centre frequency and over its working bandwidth. A slotted line usually gives the most accurate measurement provided that care is taken to select and measure the electrical characteristics of the connecting coaxial cable. The tolerances on coaxial cables are often large, say 5 to 10 per cent on the characteristic impedance and velocity ratio, and the impedance and electrical length of the cable must be accurately known to enable the slotted line impedance measurements to be transformed to give the actual aerial impedance. The properties of the cable are easily measured by use of the slotted line[2], but to reduce errors to a minimum the electrical length of the feeder cable should preferably be an integral number of half wavelengths. When used for polar diagram measurements the cable properties are not so important because the cable can be considered as part of the aerial and it is only required to know the power flowing into the aerial.

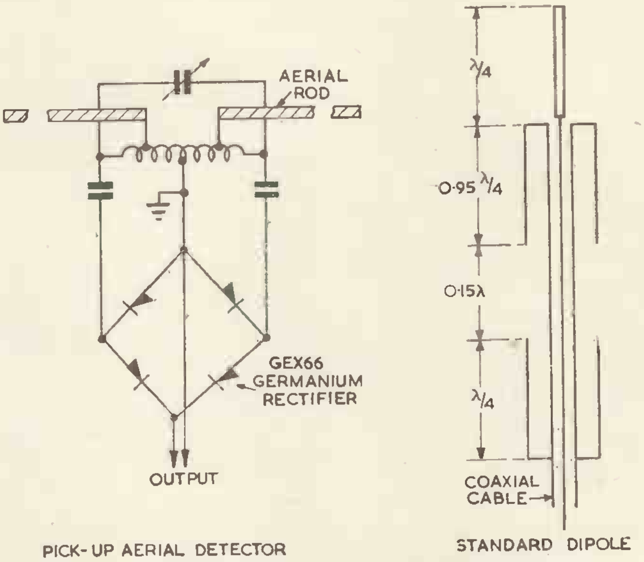

Fig. 6. Details of pick-up aerial and standard dipole

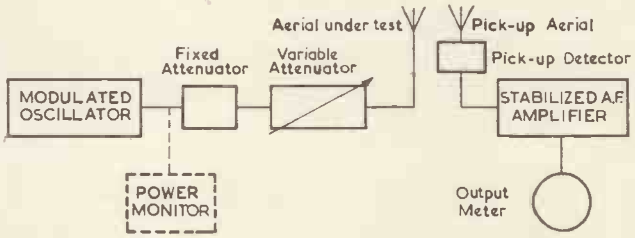

Fig. 7. Variable attenuator used for polar diagram measurements

If a slotted line is not available the radiation pattern may be measured by means of a technique often used at U.H.F. The oscillator power output is kept constant but the power flowing to the aerial is varied by means of a precision V.H.F. attenuator. This attenuator may be a piston attenuator, where the attenuation (which has a logarithmic characteristic) may be evaluated from the physical dimensions. Owing to the large minimum insertion loss of the attenuator (20 to 30db) it is usual to employ a modulated oscillator, and follow the pick-up detector by an audio frequency amplifier. A primary requirement of the audio frequency amplifier is that its gain must be constant, and it should be designed to have stabilized supplies, and a generous amount of negative feedback. By arranging that the amplifier has frequency selective circuits, the noise and unwanted signals can be reduced to a low level even when the overall amplifier gain is 80 to 100db. A typical block schematic diagram is shown in Fig. 7 where it will be seen that an additional fixed attenuator is inserted between the oscillator and the variable attenuator. If this is not done the load on the oscillator will change as the attenuator is varied and will cause fluctuations of the output, and hence invalidate the results obtained.

Where it is required to take large numbers of polar diagrams the plotting may be done automatically by the use of suitable equipment as shown in Fig. 8. The aerial under test is mounted on a turntable and fed at constant power by means of a suitable oscillator. The output from the pick-up aerial is switched alternately from a known signal from a standard source and attenuator to an amplifier and detector. It is arranged that the detector output feeds a servo motor which drives the attenuator so as to set its output to be the same as that from the pick-up aerial.

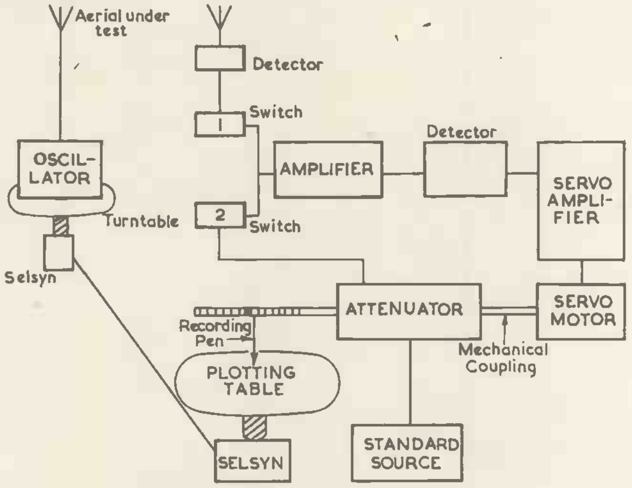

Fig. 8. Automatic aerial pattern plotter

Switch 1 then controls the receiver local oscillator and switch 2 the output for the attenuator, usually at the receiver intermediate frequency; or switch 1 can control the aerial oscillator. If a piston attenuator is used the plotting table scale can be linearly calibrated in decibels. Modulated oscillators may be used and here the attenuator takes the form of a precision potentiometer. The servo motor may be either a split field D.C. machine or a two-phase induction motor. To avoid hunting, feedback networks are connected from an auxiliary generator on the servo motor spindle to the servo amplifier.

These special equipments, although costly to construct, have the great advantage of speed of obtaining results, and present an immediate picture of the aerial radiation pattern; and what changes, if any, have occurred due to adjustments. An extra advantage is the greater accuracy due to the speed at which the results are obtained. This last statement may appear on the surface to be contradictory, but most errors in aerial measurements occur due to slow variations of many quantities, and speed usually leads to more accurate and consistent results.

APPENDIX

If the polar diagram about O_1OO_{11} as an axis is assumed

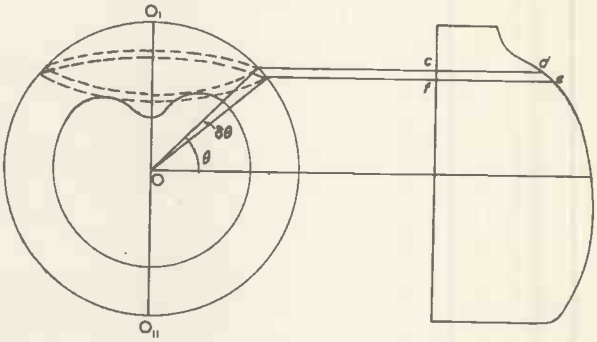

Fig. 9. Proof of Rousseau Construction

to be a circle (Fig. 9), and the radiation intensity at P is equal to ϕ, and r = radius of enclosing sphere then:

$$\text{Total power flow through annular ring} = \frac{\phi 2\pi r \cos\theta r\delta\theta}{r^2}$$

$$= \phi 2\pi \cos\theta\delta\theta$$

$$\therefore \text{Total Radiated Power} = \int_{-\pi/2}^{\pi/2} 2\pi\phi \cos\theta d\theta$$

$$\therefore \text{Mean Spherical Power} = \frac{\text{Total Radiated Power}}{4\pi}$$

$$= 1/2 \int_{-\pi/2}^{\pi/2} \phi \cos\theta d\theta$$

On the Rousseau Curve Area cdef = ef × cf = $\phi r\delta\theta\cos\theta$

$$\therefore \text{Total Area} = \int_{-\pi/2}^{\pi/2} r\phi \cos\theta d\theta$$

$$\therefore \text{Mean Height of Rousseau Curve} = 1/2r \int_{-\pi/2}^{\pi/2} r\phi \cos\theta d\theta$$

$$= 1/2 \int_{-\pi/2}^{\pi/2} \phi \cos\theta d\theta \qquad = \text{Mean Spherical Power}$$

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1. SCHELDORF, M. W. Antenna Gain by Graphical Means. *Electronics* p. 144 (March, 1952).
2. HAMER, E. G. Slotted Line Techniques. *Electronic Engng. 23*, 466 (1951).

New Receivers for BBC Monitoring Service

The BBC monitoring service, developed during the war to listen to broadcast transmissions from foreign countries for intelligence purposes, was retained after the conclusion of hostilities as a source of information for BBC news bulletins and press information, as well as for the benefit of Government departments. The General Electric Co. Ltd has recently supplied a further 30 receivers of an improved design for this service.

The new receiver (the BRT400D) is a 14 valve superheterodyne receiver with a frequency range which has been modified to suit BBC requirements, 150-385kc/s and 0·51-30·0Mc/s in six bands.

Selectivity has also been adjusted to suit the BBC. There are six switched bandwidths, overall bandwidths for 6db attenuation being 5·5kc/s, 9·0kc/s, 13·0kc/s for telephony and 0·5kc/s, 1·0kc/s and 2·0kc/s for telegraphy, the last three positions with a crystal filter in circuit between the mixer and I.F. amplifier. By operation of the filter phasing control an interfering signal 1kc/s away from a wanted signal can be attenuated by at least 45db.

A useful innovation is the provision of an outlet from the I.F. amplifier at suitable level and impedance (5 millivolts across 100 ohms). This allows the equipment to be used for frequency shift keying.

In the new receivers the local oscillator frequency stability has been improved. The specification required that oscillator frequency drift should not exceed 5kc/s measured at 29Mc/s, 3kc/s measured at 19Mc/s and 2kc/s measured at 8 and 3Mc/s. In practice, when the receivers reach a stable operating temperature, drift figures much lower than these are normally obtained.

The Design of ELECTRO MAGNETS

(Part 2)

By L. R. Blake*, B.Sc., Ph.D., A.M.I.E.E.

Example of Design

It is required to produce a field of 5 000 gauss in a region 1in × ½in between the poles of the magnet which are 1in apart. The region over which the field is required and the variation of the field which is tolerable is given in Fig. 8. Access is required to the gap and to 2in beyond on both sides. The magnetizing coils are to be natural air cooled, and their hot spot temperature rise must not exceed 110°C with a 25°C ambient temperature.

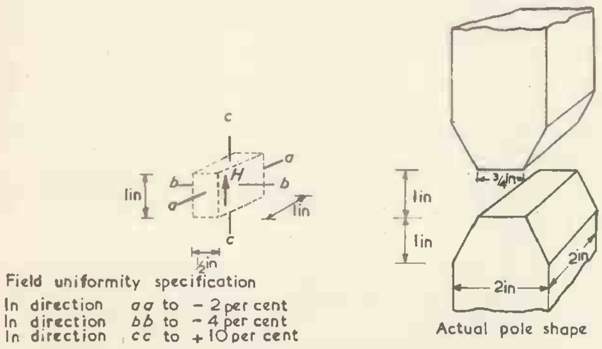


Fig. 8. Field uniformity specification of magnet and actual pole shape achieving the specification

One or two attempts at a design led to the general form shown in Fig. 9, which appears to satisfy the requirements. In estimating the field uniformity the curves of Fig. 13 were used. The curve $r/g' = 2$ suggests that to be safe the overlap in the 1in direction should be ½in on each side so the width of the pole becomes 2in. In the short direction in the mid plane the curve $r/g' = 1$ shows that at ¼in from the axis ($x/g' = 0{\cdot}5$) the field has fallen by 5 per cent; it is desirable therefore for the pole width to be about the gap separation (1in), but since this curve is pessimistic due to the poles being longer in the other direction, and since the pole must inevitably taper, it is possible to reduce the pole width in the *b* direction to ¾in. From the curves of Fig. 16 it is seen that, assuming the field at the centre to lie on a curve somewhere between $r/g' = 1$ to $r/g' = 2$, the variation tolerable in the direction across the gap can just be met.

The core material to be used is low carbon steel, so for 10 per cent M.M.F. drop in the iron the field in the iron must be:

$$H = \frac{0{\cdot}1\ H_g \,.\, g}{l} = \frac{0{\cdot}1 \times 5\,000 \times 2{\cdot}5}{100} = 12{\cdot}5 \text{ oersteds.}$$

where l is given the approximate value of 100cm. From Fig. 11 it is seen that the operating flux density at all points in the iron should be about 13 kilogauss.

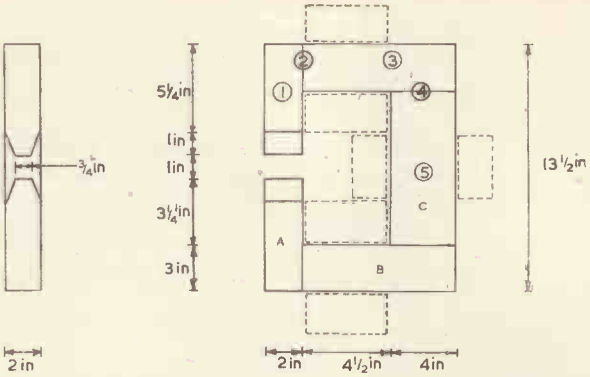


Fig. 9. Penultimate design of magnet to a particular specification

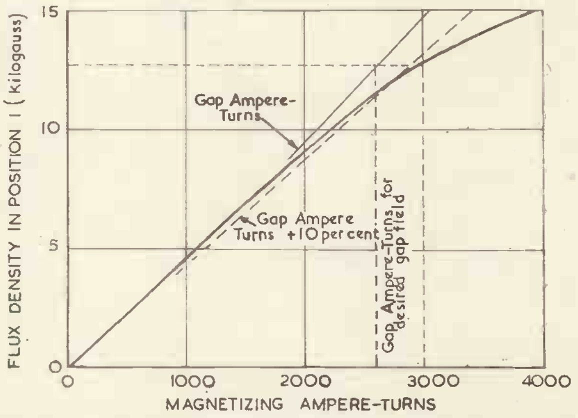
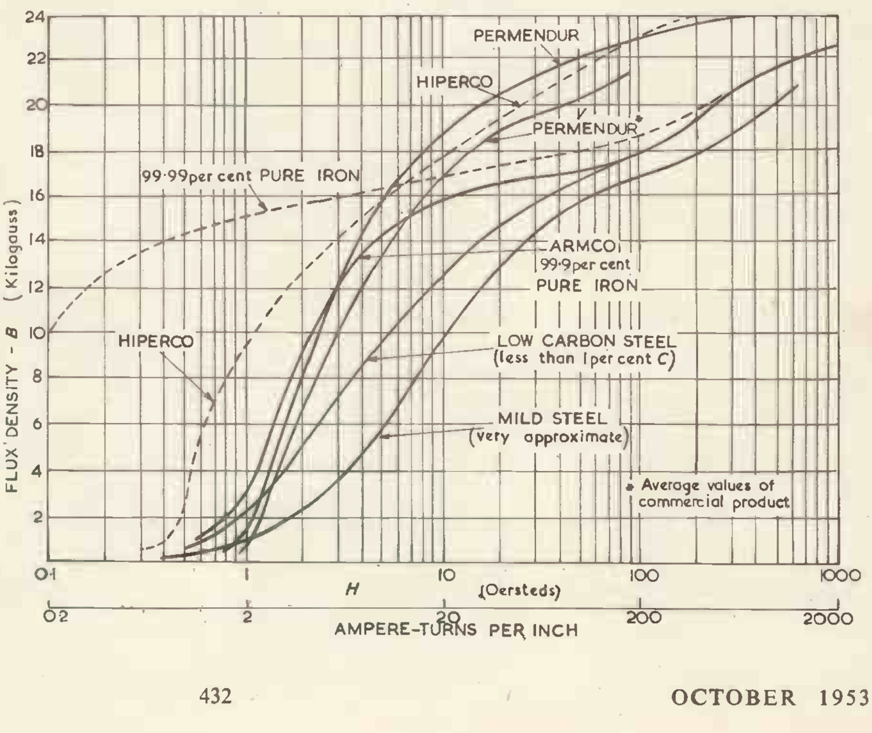


Fig. 10. Magnetization curve of a quarter scale model of the magnet of Fig. 9

Rough estimates of the various permeance paths suggest that the iron sections should be as indicated in

Fig. 11. The magnetization curves of various materials commonly used in D.C. magnets



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* The British Thomson-Houston Co., Ltd.

Fig. 9 to achieve a density of 13 kilogauss reasonably uniformly everywhere. It would involve practical difficulties to grade the iron around the whole section, so a reasonable course is to make it with three sections of different area, running the density low at positions such as 2 and a little high at positions such as 3.

A quarter size model was made to check the design. The flux density at position 1, is shown plotted against the ampere turns in Fig. 10. For a mean field of 1·03 × 5 000 in the gap of the model, the ampere turns required at the gap is 2 610. It will be seen that at this figure the applied ampere turns is 2 900 which is just over 10 per cent greater than the gap ampere turns. The original estimates proved to be surprisingly accurate but if the total ampere turns had been much greater than this, it would have been evident that the leakage flux calculations had been optimistic: if the ampere turns had been almost the same as 2 610, then the operation densities would be too low and the leakage calculations would have been pessimistic. If the flux density at position 1 is denoted by unity, measurements on the model give the flux density at positions 2 to 5 as 1·09, 1·26, 0·97, 1·03 respectively. Section B therefore appears to be a little too small and should be increased by about 15 per cent, especially since the magnetic properties of the core material of the model appear to be very good and may not be achieved in the final design, for in the model the actual flux densities are in the region of 14 to 18 kilogauss whereas it was intended that they should be 12 to 14 kilogauss.

Field measurements in the gap of the model show that the fringing was approximately as estimated and no reduction of the pole size is worth while.

Acknowledgments

The author wishes to thank Mr. L. J. Davies, Director of Research, The BTH Co. Ltd, Rugby, for permission to publish this paper.

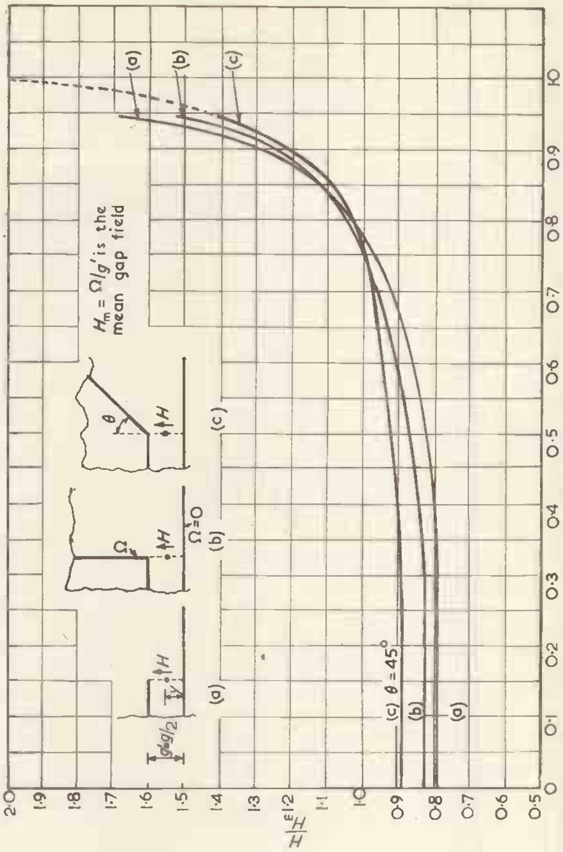


Fig. 14. Variation of the field across the gap at the edge of simple semi-infinite poles

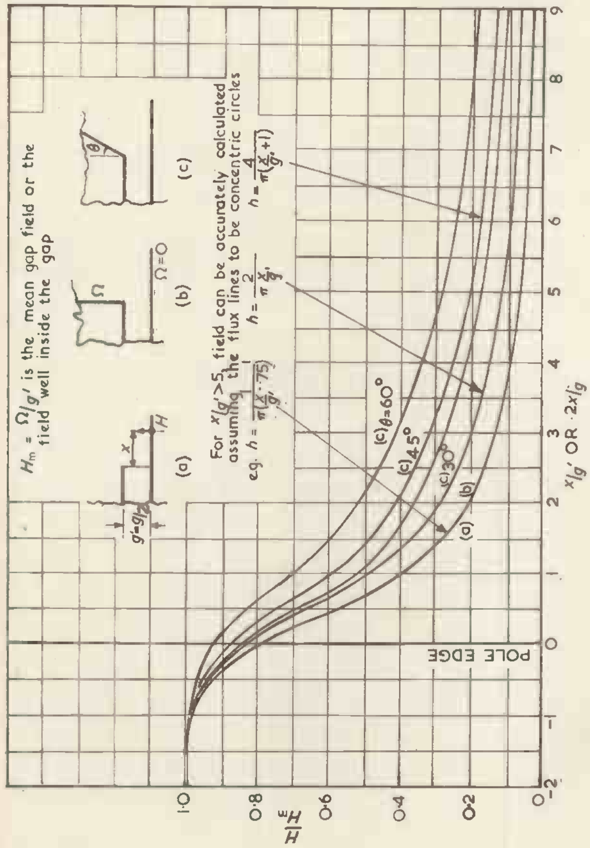


Fig. 12. The variation of the field midway between similar semi-infinite poles

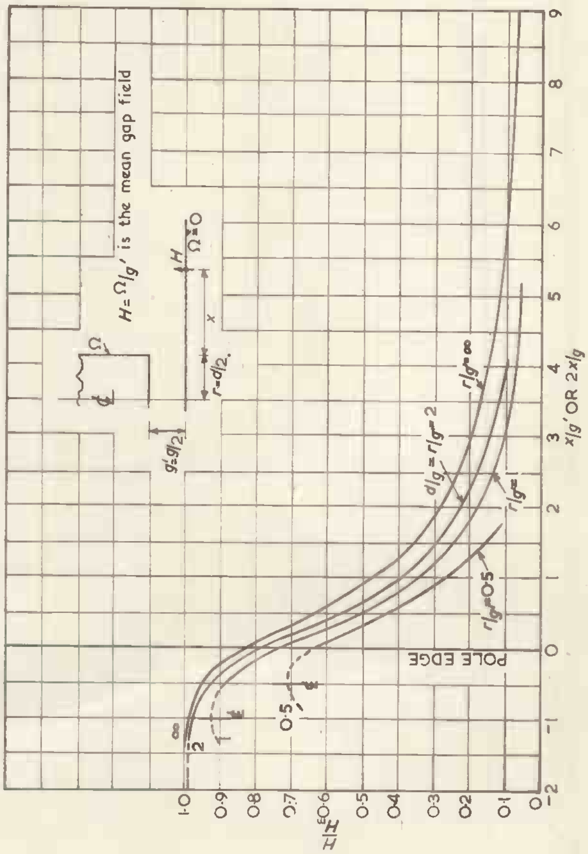


Fig. 13. The variation of the field midway between cylindrical poles

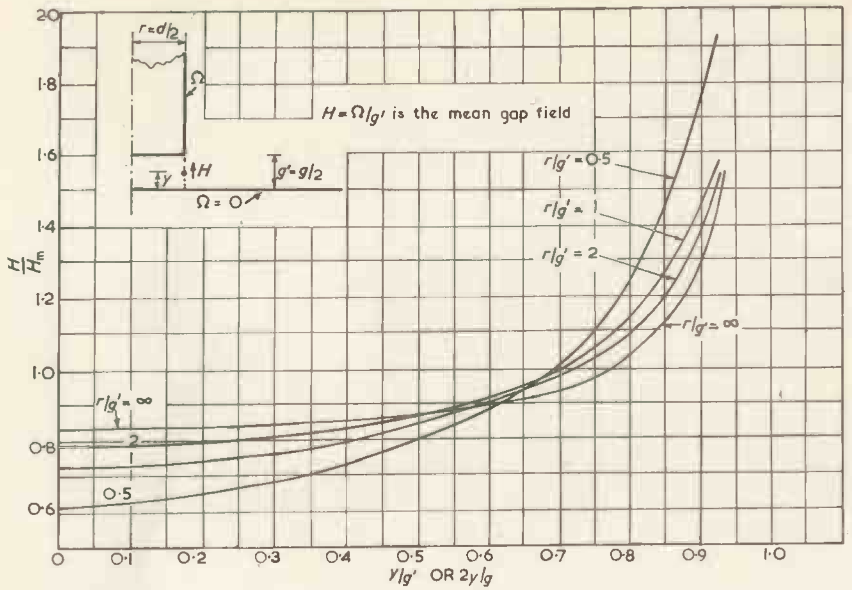


Fig. 15. Variation of the field across the gap at the edge of similar cylindrical poles

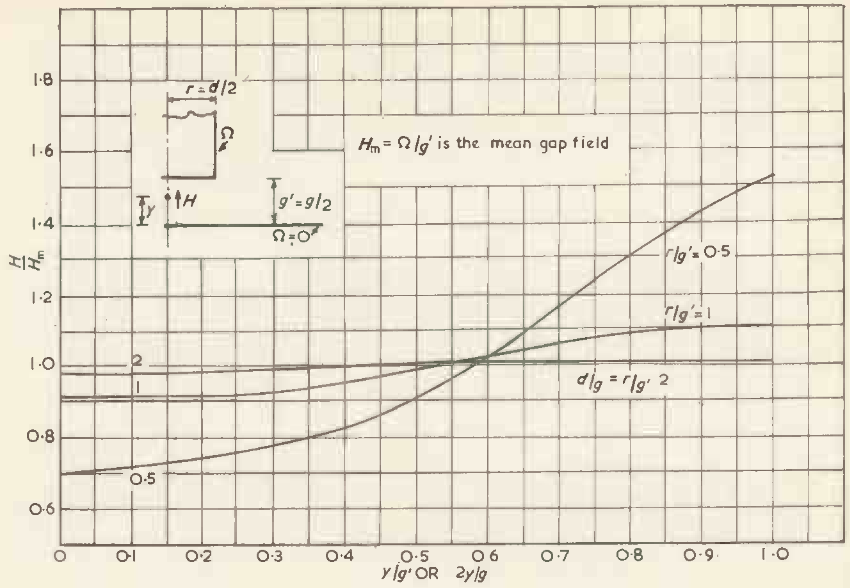


Fig. 16. Variation of the field across the gap at the pole axis

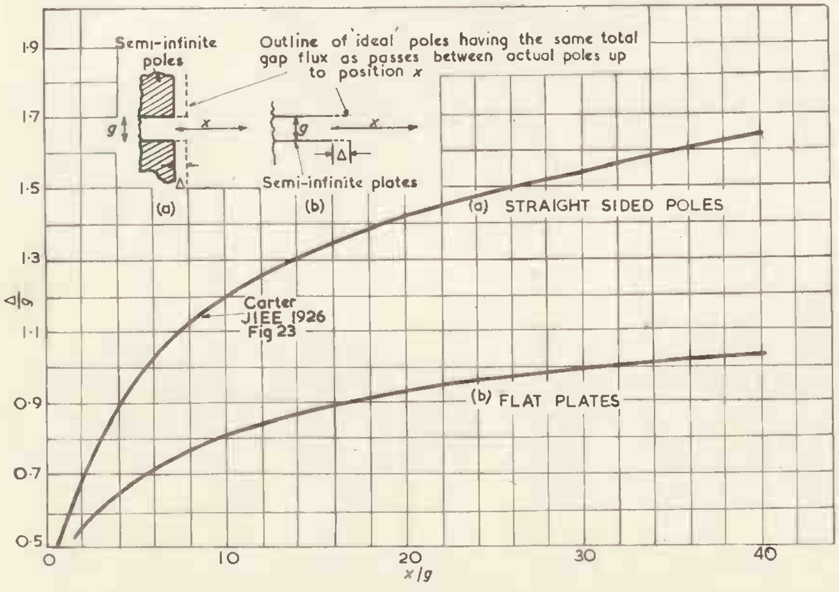


Fig. 17. The estimation of the permeance between semi-infinite poles

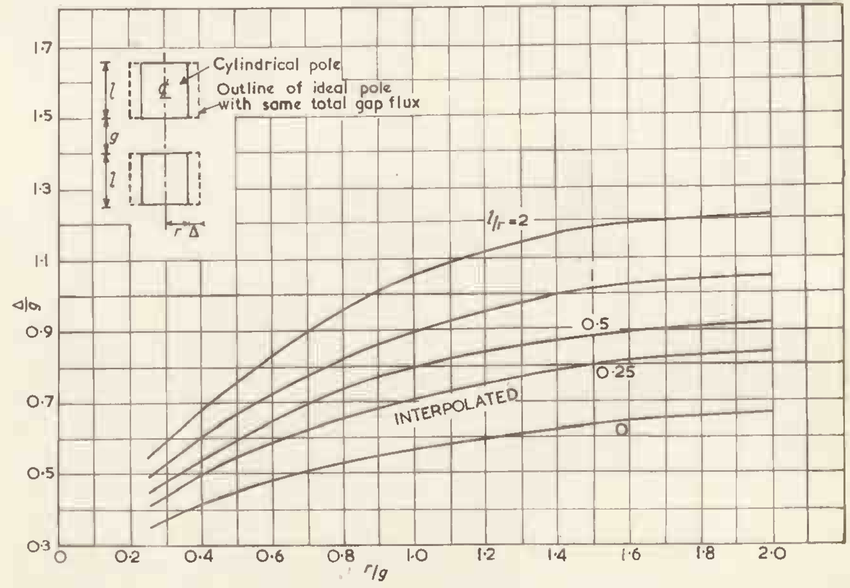


Fig. 18. The permeance between short cylinders

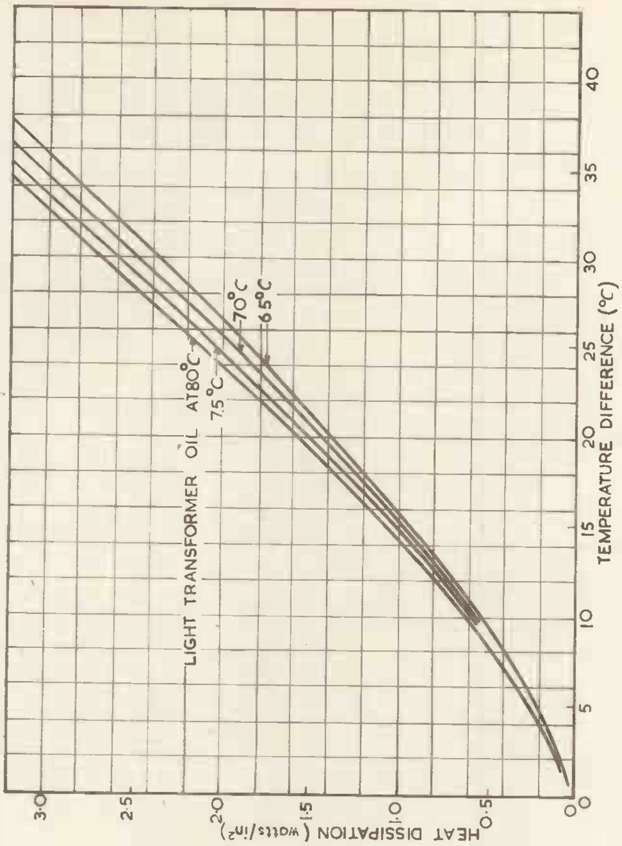


Fig. 20. Dissipation of heat by natural convection in oil

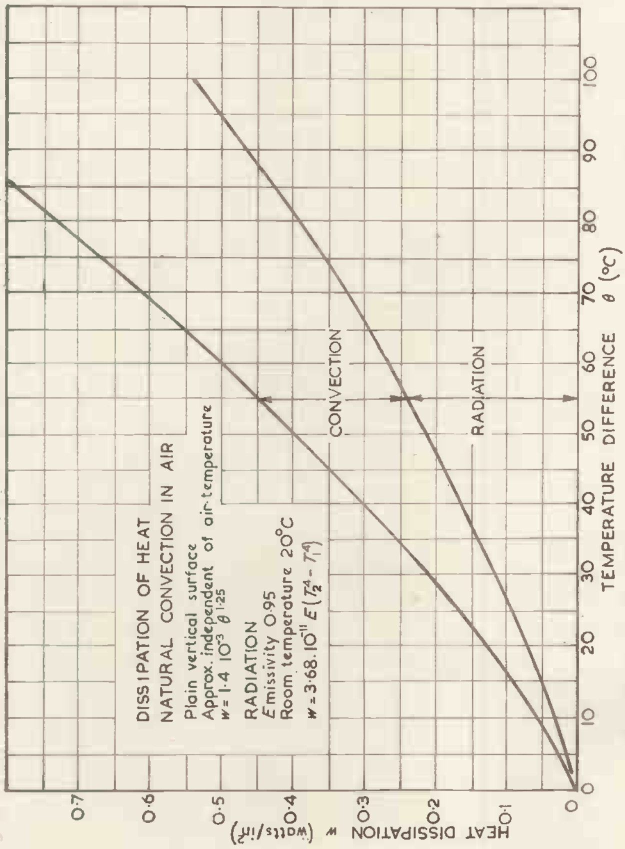


Fig. 19. Dissipation of heat by natural convection in air and by radiation

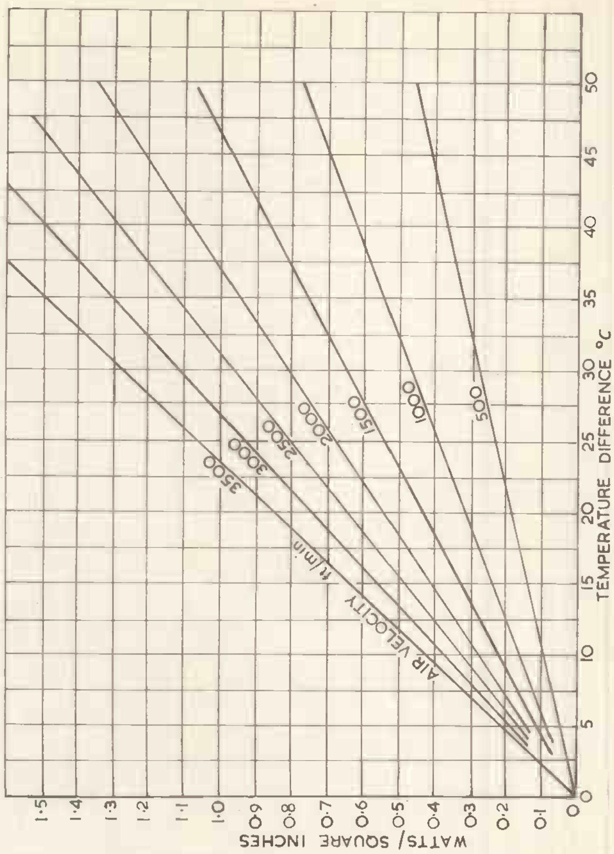
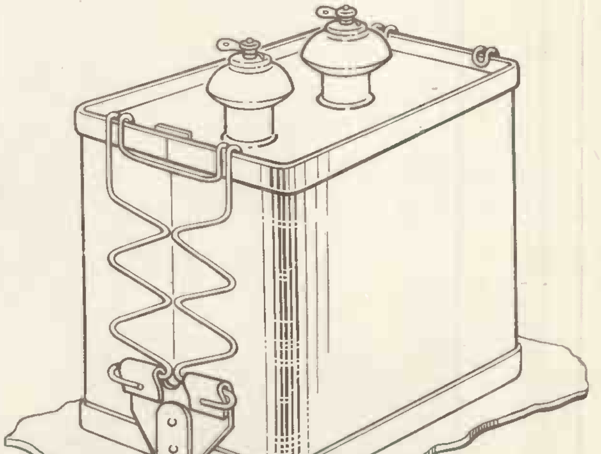


Fig. 21. Dissipation of heat by forced convection in air

SPRUNG CAPACITOR CLAMP*

The illustration below shows a sprung clamp designed to hold down the standard range of rectangular metal canned capacitors having dished ends, but no fixing lugs.

Each clamp consists of the one pattern of "spring claws" fitted to a suitable size of "studded strap."



The object of this design was to develop from previous patterns of clamps a saving of space and also to make allowance for the large height tolerance on the metal cans so that the component assembler could not damage the capacitor by screwing down too tightly.

The flat W spring achieves both these objects and has proved adequate in tests.

It is understood that a firm in Britain proposes to manufacture and distribute these clamps in the near future.

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* *A communication from the Ministry of Supply. Radar Research Establishment.*

BOOK REVIEWS

Information Theory and its Engineering Applications

By D. A. Bell. 138 pp., 30 figs. Demy 8vo. Sir Isaac Pitman & Sons Ltd. 1953. Price 20s.

THIS book is a condensation of work published since 1948 on the subject of information theory. Addressed to the professional engineer whose mathematical armoury is that of an honours degree in electrical engineering or physics, its aim is to save him much of the labour and time required to study the original papers.

The first chapter explains that the information content of a signal is measured quantitatively by regarding it as being proportional to the number of possible values that the signal could have assumed, with the further proviso that, to satisfy an intuitive notion about the increase of information with increase in number of signals, logarithmic proportionality is usually employed.

Chapter II shows that information can be regarded as proportional to negative entropy. Entropy, from the statistical point of view, is a measure of the probability of a physical state. (It is, incidentally, a difficult notion and one not familiar to all electrical engineers; a more detailed introduction to this chapter would have been an asset.) Now the greater probability of a message, the less the information it gives; to take an extreme example, the question whose answer is known in advance with certainty elicits no information whatever. Hence we may regard information as inversely proportional to entropy or, using logarithmic units, to the negative of entropy.

The next three chapters are concerned with the best way of transmitting information over a channel. The well-known Hartley law states that the maximum rate at which pulses can be transmitted over a channel is proportional to the bandwidth. In considering information, however, one must remember that the information transmitted by each pulse depends upon the number of separate amplitude levels that the pulse may be allowed to take, and here the question of noise comes in, for the number of separate amplitude levels that can be recognized at the receiving end is limited by the noise in the circuit. Hence we have the Shannon-Hartley law which relates information rate to bandwidth and signal-noise ratio, and shows that bandwidth can be traded for signal-noise ratio and vice versa. Given that there are these two interchangeable variables, it is understandable that one must have a signal whose form is suitable to the circuit chosen. The process of matching the form of the signal to the circuit is known as coding, which is enlighteningly treated as a problem in co-ordinate geometry.

Chapter VI deals with the practical applications of information theory and treats of frequency modulation, pulse and pulse-code modulation (with a clear account of the theory of sampling of waveforms), and monochrome and colour television. No practical coding devices have yet been developed in the light of information theory, which so far therefore only fulfils the role—but a valuable and stimulating role—of showing us how far short of the ideal our existing coding practices fall.

The final chapter is concerned with the work of Wiener, Bode and Shannon on the design of filters to discriminate against noise in favour of signal. The field of applicability of filters designed on the explained techniques is laid down, and it is pointed out that where something is known of the character of the noise (e.g., that it is not random), or of the signal, other forms of filter may be more appropriate and that here is a large field awaiting study.

A great deal of ground is covered in this slim volume, and the only criticism that can be levelled arises out of the degree of compression that has been attempted. This is not a painless introduction to information theory; rather is it a concentrate of learning. The mathematics is clear and relieved by much text, but the author might with advantage have lent a helping hand, even at the risk of being tedious, by more explanation of the significance of the various branches and the way in which they fit together. One must remember that many readers will be treading ground unknown both to themselves and to their colleagues.

But those who are prepared to devote study and thought to this book will be rewarded by the quick acquisition of a considerable background of knowledge in a new field, and by the satisfaction of knowing that they have mastered many of its difficult hurdles. If they wish to read further, they will find numerous footnote references throughout the book.

T. L. CRAVEN.

Die Messwandler Ihre Theorie Und Praxis

(Instrument Transformers, Their Theory and Practice)

By Dr. J. Goldstein. 212 pp., 210 figs. Medium 8vo. Verlag Birkhäuser, Basel. 1952. Price S.fr.29·10.

WITH the ever increasing size of broadcasting and television stations the boundary lines between communication engineering and power engineering become less pronounced and a book on instrument transformers, although intended in the first line for power engineers, becomes also of interest to electronic engineers, particularly those concerned with the design and operation of large transmitter stations. The present volume is the second and revised edition of a book which appeared in 1928 in Germany and which was one of the first monographs in this field. B. Hague's well-known treatise appeared eight years later. The author of the present volume has a special gift of treating technical problems in a clear, perspicuous manner. The reviewer became aware of this fact many years ago when reporting for an abstracting journal on an article of the same author dealing with the derivation of the circle diagram of a transformer from its equivalent circuit.

In the first edition the bulk of the practical examples of design was of German origin as at that time the author was in charge of the development laboratory for power and instrument transformers of the A.E.G. In the present edition many Swiss designs are described and illustrated in the development of which the author took an active part as a consulting engineer to one of the leading Swiss firms in that field. In the theoretical parts of the book foreign literature, particularly American, is also taken into consideration.

The three main sections of the book deal with current transformers, voltage transformers and the testing of instrument transformers. In the first section first the theoretical principles are dealt with. Artificial connexions and A.C. biased current transformers are treated at some length. Then the various designs are described, important characteristic quantities, particularly as regards the measures for making the transformers dynamically and thermically short-circuit proof, are discussed. Special fields of application and the possible errors are investigated and a brief paragraph deals with D.C. current transformers. A similar arrangement is used in the section on voltage transformers. In the third section some introductory words on the testing of the materials used are followed by a short chapter on the valve voltmeter and a more detailed one on the various bridge methods in use. A comparative table for the MKS and CGS systems of units and an extensive bibliography conclude this well-produced book.

R. NEUMANN.

Electrical Measurements and The Calculation of The Errors Involved. Part II

By D. Karo. 343 pp., 280 figs. Demy 8vo. Macdonald & Company (Publishers) Ltd. 1953. Price 30s.

THE title, including the sub-title, is already long enough, but too short to be fully representative of the scope of the book. This Part II deals with A.C., following the earlier Part I on D.C. But it is almost entirely devoted to the measurement of circuit parameters and readers will look in vain for measurement by deflexional instruments of alternating current, voltage, power and the host of other quantities the engineer requires to measure. The author's aim is to present the theory for advanced students studying the subject of electrical measurements in the B.Sc. examination, and to workers in research and works laboratories. Within the scope of the book the treatment is admirable; the advanced student, lecturer and examiner will find much to study profitably. The laboratory worker will perhaps be a little less happy, unless he is concerned with measurements of the highest accuracy, when he will find the treatment very thorough. It is not a beginner's book. Although about a quarter of the book is of mathematical expressions, no higher mathematics are used and it should be within the scope of the advanced student: examiners will find it a mine of possible examination questions. Three chapters deal with various networks and circuit elements under A.C. conditions—all fundamental. Then follow chapters on the vibration galvanometer, telephone as detector, and the C.R.O. While these chapters contain useful material, they are somewhat unbalanced, since the vibration galvanometer and the telephone are losing place to the various A.C. null detectors. The valve voltmeter is mentioned in the text of the book but is not described. A.C. bridges are well covered in three chapters, the author including only those he considers useful. A final chapter deals well with A.C. potentiometers. The theory makes little reference to basic units, and where used they are CGS. Terminology and symbols are in general good, but it is unfortunate that a book of this high standard still uses "capacity" where "capacitance" is intended. The book has no index, but the full table of contents of seven pages may be meant to replace this. There is no bibliography. Considering the high production standard of the book, the expense of setting up so much mathematical work the 343 pages and nearly 300 figures, the publishers are to be congratulated on the very reasonable price.

E. H. W. BANNER.

Servo-Mechanism Analysis

By G. J. Thaler and R. G. Brown. 408 pp., 120 figs. Demy 8vo. McGraw-Hill Publishing Co. Ltd. 1953. Price 64s.

THE number of text-books now published in this field justifies the assessment of a newcomer on the basis of the question: "What has this book got which others have not—or vice versa?"

Apart from a survey of some aspects of basic theory the present volume has useful, though necessarily introductory chapters on relay servo-mechanisms, on the root-locus method of analysis and on electrical analogues of a wide field of components. It also contains, in appendix form, worthwhile information on error detectors, controller elements and servo-motors.

But the merits of these unusual additions are considerably offset by a slovenly and incomplete treatment of basic theory in the earlier chapters. A sound mathematical treatment appears to be avoided by intention and any problems which would normally arise in the intelligent student's mind are glossed over or not mentioned at all. Terminology lacks precision and misprints are too frequent even for a first edition. A few instances must suffice.

We are told that the overall transfer function of a number of non-interacting components is the product of their separate transfer functions, an argument used to justify the use of block diagrams. But we are not told how to proceed when, as is more frequently the case, the elements interact.

The well-known "differential theorem" in connexion with Laplace transforms is stated to be invalid when the differentiated function is discontinuous although the all-important step-function is used to illustrate the difference between $f(O+)$ and $f(O-)$! No attempt is made to evaluate the differential of a discontinuous function through impulse-functions. Instead the student's disquiet is soothed by the statement that "in most servo-mechanisms ... $f(t)$ is continuous"!

The chapter on stability is another instance of poor presentation which concludes with the application of the Nyquist criterion to three loci, the transfer functions of which are not stated. The second of these is stated to be stable when in actual fact it appears to be unstable, the authors revising their definition of an encirclement for the purpose.

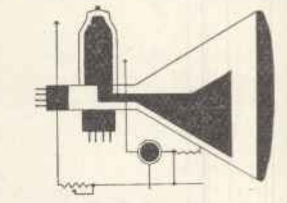
Taken as a whole the new features of the book hardly compensate for its demerits in presentation.

J. M. LAYTON.

Radio Designer's Handbook

Edited by F. Langford-Smith. 1 474 pp., 200 figs. Demy 8vo. 4th Edition. Iliffe & Sons Ltd. 1953. Price 42s.

THIS fourth edition is more than four times as large as the previous edition and is the work of 10 authors and 23 collaborating engineers. It is a comprehensive reference handbook for all who are interested in the design and application of radio receivers and audio amplifiers. The large amount of data it contains has been made readily accessible by means of a fully-detailed list of contents and a very complete index.



BOOK REVIEWS (Continued)

Fundamentals of Thermometry

By J. A. Hall. 48 pp., 13 figs. Crown 8vo. The Institute of Physics. 1953. Price 5s.

THE aim of this book is to give Higher National Certificate students and others concerned with the practical measurement of temperature a sufficient knowledge of the temperature scales on which their measurements are based. Attention has therefore been concentrated on the international temperature scale rather than on the thermodynamic scale. The treatment leads to a discussion of the instruments which are used in the realization of the scale and of the methods by which they are calibrated at the freezing and boiling points on which the scale is based.

Practical Thermometry

By J. A. Hall. 51 pp., 8 figs. Crown 8vo. The Institute of Physics. 1953. Price 5s.

THIS book is a companion volume to "Fundamentals of Thermometry" in this series. The same instruments which have already been discussed as the means for the realization of the international temperature scale may be used for the routine measurement of temperature, but for industrial purposes modified forms may be necessary. These modifications are considered in this book, which also deals with other useful types of instrument and the methods of calibration which can most conveniently be employed.

Dielectric Aerials

By D. G. Kiely. 132 pp., 45 figs. Demy 8vo. Methuen & Co. Ltd. 1953. Price 8s. 6d.

MOST aerials consist of some arrangement of metallic conductors but at microwave frequencies it becomes possible to use aerials made from dielectric materials. Although such aerials have been studied for a number of years, they are not well known and the present monograph is intended to draw attention to their properties and possibilities. The chief examples of dielectric aerials are cylindrical rods and tubes and the bulk of this monograph is devoted to them. They resemble the Yagi array, used in the V.H.F. band, in that the directivity depends on the length of the aerial. Other dielectric aerials, such as the dielectric horn, are also described.

Too much work has to be done before dielectric aerials can be fully understood for it to be possible to write a textbook on the subject and, as the author points out, this monograph is to be regarded rather as a critical essay. An obvious requirement of such an essay is that it should integrate the available published material. The major criticism of this book is that this has not been done and that instead the reader is presented with a number of virtually self-contained summaries of the principal papers. This leads to unnecessary duplication as for example in Chapter IV where much of the material on the dielectric tube aerial is virtually identical to that given in Chapter II for the dielectric rod aerial. The space, which might have been saved by a joint treatment of the rod and tube, could well have been used to amplify the most important section of the book in which the author puts forward a new theory explaining in a qualitative manner the observed properties of these aerials.

Original papers are unfortunately very often difficult to follow and one of the objects of a book such as this should be to give an intelligible interpretation of such papers. The reviewer, for example, has never been able to follow an important paper (on dielectric aerials) by Wilkes and had hoped to find in the present book a more readable account of this work. In this he has been disappointed, for all that appears is a summary which does nothing to remove the obscurities of the original.

Despite the blemishes mentioned above this book is of value in that it brings together material which was previously only available in references, many of which are not accessible to the ordinary research worker.

J. BROWN.

Analysis of Alternating Current Circuits

By W. R. Lepage. 144 pp., 300 figs. Demy 8vo. McGraw-Hill Book Co., Ltd. 1952. Price 55s. 6d.

THIS book should become a classic. Its unpretentious title covers a considerable field in electro-technology, and fundamentals are treated both widely and deeply. The preface states that in the development of the text the goal has always been to impart understanding of fundamental principles to the student, rather than merely to have him acquire a dexterity in working problems. This has been well carried out, the work is a scholarly study with a range from the first year student to the advanced student and teacher: it has no less application to the practising engineer. Although this is the first edition, earlier publication of parts of the text in mimeographed form have led to the advantages of checking and evolution with the author's colleagues and others, so that the book is no untried version. Many American books are not easy for an English reader, owing to the spelling contractions, non-standard terms, etc. This book is a notable exception, it is written in excellent English and most of the terminology follows British Standard practice, which of course is itself as international as it can be with the various national ideas to be followed. Trigonometry and algebra are first introduced, then calculus ("integrodifferential"). The mathematics includes the author's "sinor" and "phasor" terms for directed lines in circuit analysis. Rationalized MKS units are used. An appendix deals with D.C. circuit analysis, so that the scope covers basic principles and some direct applications—measuring instruments are shown to follow from the various principles given, and the analogy between elementary A.C. theory and the mechanical reciprocating engine is explained, as examples to be cited. Chapter II, on introductory concepts, leads to electromagnetic induction, piezoelectricity, electronics, variable circuit elements, etc., thus introducing many practical applications with the fundamental theory. In Chapter V the concept of duality is given by which *L* and *C* circuits may be interchanged. Star-delta and other transformations are of course to be found in the book. It is only at Chapter VIII that complex numbers are introduced, after the simpler explanations based on geometrical treatment. In Chapter XIV, on variable response networks, will be found much to interest the electronics engineer, dealing with *L, C,* harmonics resonance to interest the electronic engineer, dealcise problems and questions: no answers are given. A short bibliography and an index are included. There are some 300 explanatory diagrams, and many more in the various problems.

E. H. W. BANNER.

Electro-Magnetic Machines

By R. Langlois-Berthelot. 535 pp., 309 figs. Demy 8vo. Macdonald & Co. Ltd. 1953. Price 65s.

THIS book was first published in France. British engineers and educationalists who read the French edition realized the importance of the work and its method of presentation. They felt that students, lecturers, technicians, industrialists and all concerned with electrical plant should have the opportunity of profiting by M. Langlois-Berthelot's experience of this subject. The volume, divided into six parts, deals with questions common to the different classes of electro-magnetic machines, that word covering transformers and rotating machines. It is, in effect, a grammar or abstract study of the machines.

Electric Resistance Heating

180 pp., 170 figs. Demy 8vo. British Electrical Development Association. 1953. Price 9s.

THIS is the fifth in the Electricity and Productivity series. Starting with the theory of electric resistance heating and the types of elements which may be used, examples are then described of electric heating equipment of every type from large heat treatment furnaces to electric soldering irons. There are thirteen chapters which leave the reader with the impression that in practically every case where electric heat is used in industry it helps to increase production either directly or indirectly.

Radio Upkeep and Repairs

By Alfred T. Witts. 220 pp., 159 figs. Crown 8vo. 7th edition. Pitman & Sons Ltd., 1953. Price 12s. 6d.

THIS practical handbook has been revised and considerable new matter included to bring it up to date with modern practice. It explains how to locate faults, how to remedy them, and how to keep modern radio receiver apparatus in the best possible working condition.

Notes from the Industry

The Department of Electrical Engineering of Bradford Technical College are holding a course of lectures on Electronic Motor Control. The lectures are to be held on Wednesday evenings at 7 p.m. and the fee for the course is £1 10s. Students should possess a degree or higher national certificate in electrical engineering or similar qualification, but exceptions may be made. Applications should be sent to the Principal, Technical College, Bradford, 7.

The Council of the British Institution of Radio Engineers has re-elected, for a second year's office as President, W. E. Miller, M.A., Editor of "The Wireless and Electrical Trader."

Mr. W. O. Fenwick, Technical Editor of the "Electrical Review" died suddenly at the end of August. Mr. Fenwick joined the "Electrical Review" in 1918 as assistant to the late Mr. A. H. Allen, the Technical Editor, and continued in this position with Mr. C. O. Brettelle until the latter's retirement in 1948 when he was appointed Technical Editor.

E.M.I. Sales and Service Ltd announce that recent orders from the British Broadcasting Corporation for their tape recorders and associated equipment exceed £100,000. Apart from the tape recorders, an extensive range of accessories including "Emitape" recording tape and large numbers of "Emidisc" lacquer recording blanks are regularly supplied to the Corporation for use in their activities.

Honeywell-Brown, Ltd., have established a new branch office in Sheffield. It will be the headquarters for sales and service personnel dealing with the company's range of industrial instruments, serving customers in Lancashire, Yorkshire and the Northern Midlands.

Their new factory at Newhouse, Motherwell, Lanarkshire, was officially opened on 18 September. The move from Blantyre to Newhouse took place during the company's annual two week shut-down period.

Fleming Radio (Developments) Ltd have erected a new factory at Stevenage which will take over the complete manufacture of the range of electronic equipment marketed by this company.

The Radio Corporation of America announces a Seminar on Solid State Physics to be held in London on 20 and 21 October, 1953, during the visit of a group of research scientists from the RCA Laboratories, Princeton. There will be morning and afternoon sessions with talks and discussions on recent developments in the fields of semiconductors (transistors), electronically active solids, photoconductivity, television camera tubes. The place and time of the meetings will be announced later. Admission will be free. Those interested are invited to apply for further particulars to the European Technical Representative, 55 Pall Mall, London, S.W.1.

The Radio Trades Examination Board and the City and Guilds of London Institute have announced that for the 1953 Radio Servicing Certificate Examination 309 candidates attended, of which 126 qualified for the award of the certificate. The 1954 examination will be held on 4 and 6 May for the written papers and 15 May for the practical test. The closing date for entries is 1 February, 1954. Regulations and forms of application may be obtained from the Secretary, Radio Trades Examination Board, 9 Bedford Square, London, W.C.1.

The Automatic Coil Winder and Electrical Equipment Company announce that the "Avo" instruments used by the British North Greenland Expedition, which left last year for the Arctic, have proved most satisfactory. Commercial instruments available to any user in this country were supplied to the expedition and the performance they have given under arduous conditions reflect their durability.

The South East London Technical College, Department of Electrical Engineering, are holding courses of lectures on High Voltage Engineering and Communication Networks commencing on 13 and 23 October respectively. Application for admission to the courses should be made as early as possible to the Head of the Electrical Engineering Department, South East London Technical College, Lewisham Way, London, S.E.4. Copies of the College prospectus are also available on application.

Borough Polytechnic have arranged a course of eight lectures on Crystal Valves and Transistors beginning on Tuesday, 20 October 1953. The lectures will be held weekly on Tuesday evenings at 7 p.m. The course fee is £1 10s. Students wishing to enrol should apply to the Secretary of the Polytechnic, Borough Road, London, S.E.1.

London and Home Counties Regional Advisory Council for Higher Technological Education have issued a bulletin of special courses in higher technology for the 1953-54 season. Part I of the bulletin is now available at a charge of 1s. 6d. and a subscription of 2s. 6d. secures one copy of Part I and of Part II (spring and summer 1954) which will be published in December, 1953. There are special rates for subscriptions for six or more copies. Applications and remittances should be sent to the Secretary, Regional Advisory Council, Tavistock House South, Tavistock Square, London, W.C.1.

Erratum. On p. 398 of the September, 1953, issue the rise-time of the Airmec Wideband Oscilloscope should read "25mμsec" not "25msec".

PUBLICATIONS RECEIVED

NATIONAL PHYSICAL LABORATORY REPORT FOR THE YEAR 1952 gives details of the progress made last year by the various divisions of N.P.L. despite the research work for defence and other pressing needs which took up an increasing proportion of their resources. Department of Scientific and Industrial Research, Charles House, 5-11 Regent Street, London, S.W.1. Published by Her Majesty's Stationery Office. Price 2s. 6d.

THE BRITISH PRESSED METAL INDUSTRY is a report by a Productivity Team from the United States of America which visited the United Kingdom in 1951. The main objective of the team was to report all factors that might increase productivity in British stamping plants. British Productivity Council, 21 Tothill Street, London, S.W.1. Price 3s.

"FIFTY THREE" ENAMELLED WINDING WIRES is a brochure introducing a new range of enamelled winding wires to meet the need for a covering having electrical and physical characteristics intermediate between those of oil-base and vinyl-acetal base enamels, but retaining their high space factor. Copies are available from British Insulated Callender's Cables Ltd., 21 Bloomsbury Street, London, W.C.1.

RESISTORS FOR THE SERVICE ENGINEER is a catalogue giving details of the range of Dubilier Resistors available through agents and distributors at home and overseas. Dubilier Condenser Co. (1925) Ltd., Ducon Works, Victoria Road, North Acton, London, W.3.

THE JOURNAL OF PHOTOGRAPHIC SCIENCE is published in alternate months and with Section A, published separately, forms the official organ of the Royal Photographic Alliance. Single copies, price 5s. post free. The Royal Photographic Society of Great Britain, 16 Princes Gate, London, S.W.7.

REPORTS OF PROGRESS IN PHYSICS, VOL. XVI. This volume contains articles on the following subjects. Neutron Diffraction; Physical Properties and Atomic Arrangements in Crystals; Raman Effect in Solids: Paramagnetic Resonance: Semiconductor Circuit Elements: Electrical Discharges; Fluctuation Theory in Physical Measurements; Cosmology: The New Unstable Cosmic-Ray Particles. The price to Non-Fellows is £2 10s. and to Fellows 27s. 6d., postage 1s. 6d. The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

WEBB'S CATALOGUE contains valuable information on electronic and radio supplies. Subscribers will, in addition, receive by post "Webb's Information Folder" which contains details of new lines, hints on the use of current apparatus, revised prices and general information on the latest trends in radio and electronic techniques. The catalogue, price 1s., may be obtained from Webb's Radio, 14 Soho Street, London, W.1.

BUYERS GUIDE FOR PLASTICS MATERIALS has been published by the British Plastics Federation to help home and overseas buyers generally. While not exhaustive, this booklet is claimed to cover all the more important plastics materials produced in Great Britain. The guide is obtainable from the British Plastics Federation, 47-48 Piccadilly, London, W.1, price 2s. post free.

SYNCHROHEAT is a booklet describing the range of synchronous electronic welding controls manufactured by Bates & Bates Ltd, 73 Ashville Avenue, Birmingham 34.

ELECTRO-PL AIR FILTER is a brochure describing this dry-type electronic air filter. It may be varied at will, performing as an electric air cleaner under heavy dust conditions or in smoky winter atmospheres and as an economical dry-type filter in less severe conditions. Air Control Installations Ltd, Ruislip, Middlesex.

ELECTRONIC EQUIPMENT

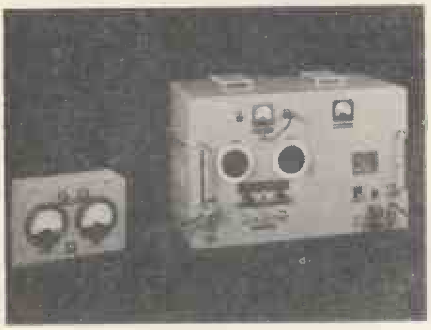
A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

Machine Tool Load Indicator

(Illustrated below)

THIS compact electronic load measuring device has been designed specifically to meet the requirements of the engineering industry in general. Its basic function is to indicate stresses involved in the operation of heavy machine tools, at any reasonable number of points, thereby facilitating controlled production and prevention of damage to the machinery by over-loading. The overload protection gear may be remotely controlled and can be pre-set to operate at any required level.

A sensitive electromagnetic strain gauge detects the magnitude of the load by measuring the compression or expansion of the load-carrying member. The type of load cell or transducer employed may vary with the particular application, but the standard load cell can be used in the majority of applications.



Examples of the types of machines to which the load indicator could be applied are: rolling mills, heavy duty winches and jacks, cranes and grabs, heavy presses used in the plywood, sheet metal and plastic industries.

The remote load indicator unit, shown on the left of the illustration, may be mounted at any convenient observation point, thus enabling simultaneous operation of several similar machines to be controlled by one operator. The whole unit is designed to withstand the vibration and general operational conditions associated with heavy engineering plant.

Boulton Paul Aircraft Ltd.,
Wolverhampton.

High Stability Power Unit

(Illustrated top centre column)

THIS new unit has been designed as a standard power supply unit, providing a fixed output voltage with a low source impedance and ripple content. By the use of a stabilizing technique employing two amplifying stages within the control loop, the complete unit has been produced in prototype form on a chassis measuring 6in by 9in by 6in high. The unit provides a fixed output of 250V at 50mA and the stability for a ±10 per cent mains input change is better than 0·025 per cent coupled with a D.C. output resistance of 0·5 ohm. The output connexions are made to a paxolin panel mounted in the side of the chassis and provide a D.C. output of 250V isolated, A.C. 6·3V C.T. at 4A and 6·3V at 1A. This connexion strip enables the entire unit to be built into existing apparatus and facilitates wiring of supplies. In addition, reversible angle brackets are provided so that the unit can be mounted in any convenient position.

Solartron Laboratory Instruments Ltd.,
High Street,
Kingston-on-Thames,
Surrey.

Humidity Test Cabinet

(Illustrated below)

THIS is a self-contained unit which has been especially developed for testing electrical equipments in accordance with RCS.11, K.114 and RIC.11.

Temperature range is from 20°C to 111°C, normal control being within ±0·5°C, the resultant humidity adjustment being from 40 to 100 per cent according to the dry heat temperature.

The metal cased heaters and humidifying unit are controlled by "dry" and "wet" bulb adjustable contact thermometers in conjunction with relays.

The model illustrated is 6ft cube, larger sizes and special types are also available.

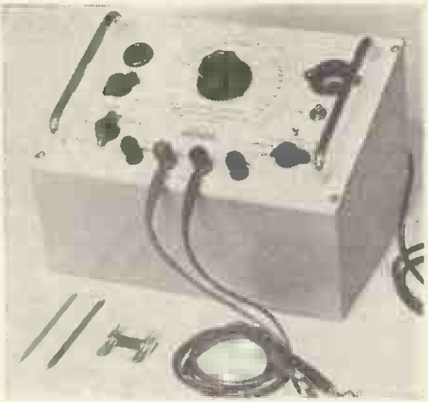
Barlow-Whitney Ltd.,
Coombe Road,
London, N.W.10.

Capacitance-Resistance Bridge

(Illustrated below)

THE type CRB3 capacitor analyser and resistance bridge employs a Wien bridge for capacitance measurements and operates in the range from 20pF to 500μF. The power factor of all types of electrolytic capacitors can be read directly from a scale which is calibrated from zero to 50 per cent. Resistance measurements can be made in the range from 5Ω to 100MΩ. A cathode-ray indicator is used to indicate bridge balance on all ranges. A special test jig is supplied for use when measuring small values of capacitance.

A. H. Hunt (Capacitors) Ltd,
Garratt Lane,
London, S.W.18.



Stabilized Light Source

THE Casella stabilized D.C. light source has been designed for use on occasions when a good constancy of light is a necessity. Since a 1 per cent change in voltage produces a 4 per cent variation in illumination a method of monitoring the actual light source and not the supply voltage has been adopted.

The apparatus obtains its supply from the mains and consists of an *RC* oscillator operating at 3kc/s, the output of which is fed to the lamp via a power amplifier and matching transformer.

The lamp is monitored by a photocell, the output from this being fed back to the oscillator via a servo amplifier.

The stability is such that a change in mains supply of ±8 per cent causes a variation in illumination of +0·6 per cent or −1·2 per cent.

The lamp used in the standard equipment is of the 6V 48W type, but units for other types can be supplied to order.

Casella (Electronics) Ltd.,
46-48 Osnaburgh Street,
London, N.W.1.

Magnetizer

(Illustrated above right)

THE Advance magnetizer type K.1 is a transportable equipment for the processing of permanent magnets. It is designed primarily for ring magnets such as those used in loudspeakers and for focusing cathode-ray tubes, but short bar and block magnets of the type often used in meters can also be accommodated.

The magnet is placed in the air-gap of a symmetrical iron circuit which is then magnetically saturated by passing a large current through an associated multi-turn winding. The large peak power required for this purpose is obtained by the rapid discharge of a capacitor, thus enabling the equipment to operate from standard main supplies with a consumption of only 30 watts.

The discharge is controlled by a cold-cathode gas-filled tube, and consistent results are ensured by a device which makes it impossible to initiate the discharge until the voltage across the capacitor has reached a predetermined value. The use of the cold-cathode tube prevents any overswing of the current which might otherwise occur in a circuit consisting of inductance and capacitance.

The capacitor is permanently connected to the power supply so that it recharges immediately after each operation, and the time-constant is such that magnets may be processed at the rate of about three per minute.

Advance Components Ltd,
Back Road, Shernhall Street,
London, E.17.

Tubular Paper Capacitors

(Illustrated below)

A NEW range of metal-cased tubular capacitors has recently been introduced to meet the requirements of Category A Class H.I. of RCS 131 and RIC 131 (red grade).

Known as type 4 800C, the capacitor is contained in a hermetically sealed tinned brass tube with solder sealed glazed ceramic end disk and provided with bare wire tail terminations. The tubular element is of the extended-foil type to ensure the minimum of self inductance, being impregnated in a mineral oil dielectric to provide a long working life.

The normal capacitance range is ·001μF to 1μF with a tolerance of ±20 per cent, or closer to order.

Dubilier Condenser Co. (1925) Ltd.,
Ducon Works,
Victoria Road,
London, W.3.

Pressure Transducers

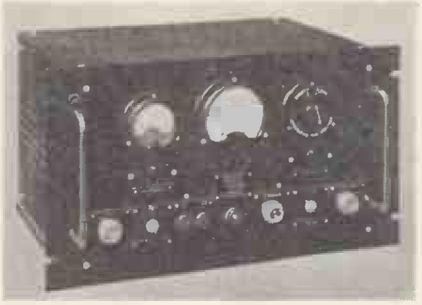
(Illustrated below)

THESE transducers (type 548) are intended for the remote indication and measurement of static pressures. They comprise a standard bourdon tube which operates a small micro-friction potentiometer by means of a linkage system. The linkage mechanism is so designed that a linear change of resistance with pressure is achieved.

The wiper arm is made from 0·005 in. diameter platinum-irridium wire and the coil assembly is close wound with wire of the same alloy. The wiper arm and potentiometer coil is so designed that the voltage or resistance increment never exceeds 1 per cent.

The transducers are available in a wide range of pressures from 5lb/sq.in to 4 000lb./sq.in.

J. Langham Thompson Ltd.,
Springland Laboratories,
Bushey Heath, Herts.



Logarithmic Ratemeter

(Illustrated above)

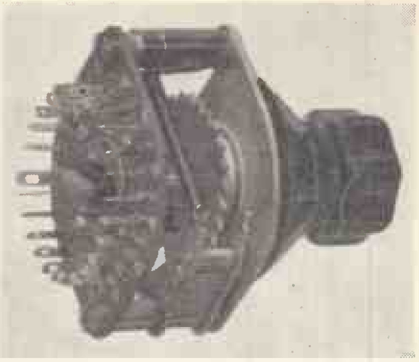
THE ratemeter type 10052 has a logarithmic scale, thus, when the output is recorded on a linear chart an exponential decay rate is recorded as a straight line, the presence of contaminating isotopes being indicated by deviations from the straight line and the half-life of the decay can be estimated by simple proportion. The panel mounted meter is calibrated logarithmically from 10 to 1 000 pulses per second.

Fleming Radio (Developments) Ltd.,
18-20 Laystall Street,
London, E.C.1.

Precision Multi-Way Switches

(Illustrated top right)

WINKLER precision switches are available in single, double and three pole design with from one to six banks operated from a common shaft. Positive switching up to 30 ways per switch bank is achieved by the use of a step-wheel mechanism, a spring loaded pawl arresting the rotary motion at each contact. The contacts are hard silver plated, the pressure between contacts being 250 grammes.



G. A. Stanley Palmer,
Maxwell House,
Arundel Street,
London, W.C.2.

Talk and Listen Beacon Equipment

(Illustrated below)

"TALBE" is a complete V.H.F. beacon and R.T. transmitter-receiver designed by the Vidor-Burndept Group for use in search and rescue operations. It operates in conjunction with the standard V.H.F. homing equipment employed by search aircraft or naval craft.

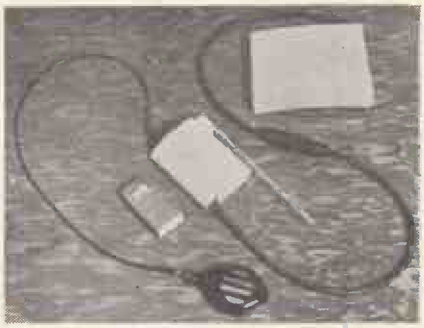
The beacon automatically transmits a distress signal as soon as the aerial is erected. Aircraft operating at 5 000ft can pick up the signal at a range of 50 miles. The R.T. transmitter-receiver has an effective range of 20+ miles.

The specially designed battery, which weighs only two pounds, will permit 6 hours operation of the beacon plus a minimum of 30 minutes two-way R.T. communication. If the equipment is used in conjunction with a dinghy, a larger and longer life battery can be used.

Because of its small overall dimensions and light weight, the complete equipment can be stowed easily in the pilot's Mae West.

There are three units, each being accommodated in special pockets of the Mae West.

Vidor Burndept Group,
18 Abbey House,
Victoria Street,
London, S.W.1.



LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

Stability in Negative Feedback Timebases

Dear Sir,—The article by Mr. Starks-Field in the May 1953 issue, entitled "Stability in Negative Feedback Timebases," investigates the conditions under which stroke to stroke instability can occur in a periodically switched circuit comprised entirely of linear elements.

I suggest that when such conditions do arise, they must be due to the existence of one or more normal modes of oscillation of the system with zero or negative damping, and conversely, that in a system in which all the modes are positively damped, any one complete cycle of current caused by a regularly repetitive switching process tends, after a sufficiently large number of switching cycles, towards an exact replica of its predecessor.

The reasoning on which this statement is based is as follows. Suppose that we have a generalized four terminal network, including amplifiers, whose input terminals a . b are periodically switched between a resistance R_A in series with a source of D.C. voltage E_A, and a second resistance R_B in series with another D.C. voltage E_B, the current i in which we are interested flowing in the mesh c-d (See Fig. 1), and that the only restrictions on the network are:

(a) That all its component elements, including any amplifier contained therein, are linear as regards their current-voltage relationships.

(b) That the network is stable in both positions of the switch S, i.e. the natural modes of free oscillation of the network, when terminated by either R_A or R_B are positively damped.

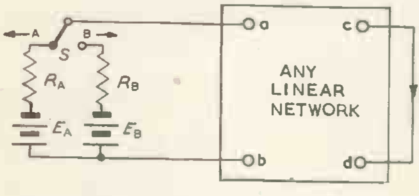


Fig. 1. Generalized four terminal network

By virtue of condition (a), it is permissible to compute the current i as the algebraic sum of two components, one due to E_A with E_B zero and the second due to E_B and E_A zero.

Secondly, by virtue of condition (b), it is clear that if E_B is always zero, whilst E_A is inserted into the circuit of one single operating cycle of s and thereafter removed whilst s continues to operate regularly, there will be an initial response current due to E_A which will ultimately die away towards zero after a sufficiently large number of cycles.

The continued existence of any response due to E_A in the cycles subsequent to its removal is, of course, due to energy storage in the inductive and/or capacitive elements in the network. The exact manner in which the response dies out is unimportant—it will not necessarily be the same in successive cycles of the switch—the important fact being that it ultimately becomes negligibly small.

Now let the voltage E_A be introduced at the instant that S goes to A in the first (reference) cycle, and remain in circuit thereafter. At any time t after the n^{th} closure of the switch on the B side, the current i will be made up of n components, one from the n^{th} closure on A, one from the $(n\text{-}1)^{th}$, and so on back to the first cycle. As n tends to infinity, the sum of all these components must tend to a finite limit, i.e. it ultimately becomes dependent on t only, and independent of n. Thus as regards the response due to E_A, the n^{th} cycle becomes identical with the $(n\text{-}1)^{th}$ and all its predecessors for a sufficiently large value of n. The same reasoning applies when E_B is introduced, so that finally we have the result that for the conditions assumed, the current i follows exactly the same variation throughout each cycle.

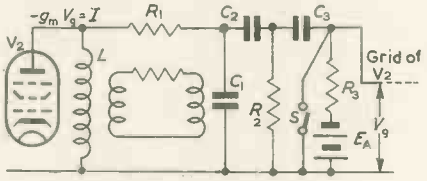


Fig. 2. Equivalent circuit of transformer coupled time-base

This being the case, it now remains to find a mechanism which might cause stroke to stroke irregularity in an apparently linear system. Apart from such obvious causes as supply voltage variations, noise or other irregularities in the switching (synchronizing) process, and from the non-linear effects mentioned by Mr. Starks-Field, there is the possibility that one or more of the natural modes, in one or other of the switching cycles themselves, in which case there will be a phenomenon akin to beats between the switching cycle frequency and a multiple of the non-positively damped mode.

The particular circuit shown in Fig. 11 of Mr. Starks-Field's article is potentially capable of maintaining such an oscillation as may be seen by redrawing its essentials in Fig. 2 in which the driving valve V_1 is replaced by a switch S across R_3, S being open during the forward stroke of the time-base when V_1 is cut off. It will be seen that whatever the values for the inductive, capacitive and resistive components, there will always be a frequency (possibly an exceedingly low one) at which a given current I entering the network from the anode of V_2 would produce a voltage B_g across R_3 which is phased displaced from that current by 180 degrees, owing to the phase advance action of C_2R_2 and C_3R_3 in combination with the approximate 90° phase lead of the voltage across L compared with the current through it. If the magnitude of V at this frequency is sufficiently large that g_mV_2 equals or exceeds I, then a mode with zero or negative damping exists. The critical value of the mutual conductance g_m of V_2 at which this happens can be determined in any particular case, given the values of the remaining components.

It may be noted that the grid capacitor and leak combination have been omitted from Fig. 2 as these may be made sufficiently large to have negligible effect on the network transfer impedance. If this is not the case, the effect will be to introduce a further stage of phase advance and in general to lower the critical value of g_m.

It is believed that the above explanation may account for at least one of the causes of multiple stroking.

Yours faithfully,
D. G. Reid,
Ministry of Supply,
Royal Aircraft Establishment.

The author replies:

Dear Sir,—In reply to Mr. Reid's letter, I agree with him as long as the circuit is working under the conditions he specifies, namely, that the discharging device can be considered as a constant current source during the period of switching. However, the mode of operation which my analysis covers is that in which a blocking oscillator or multivibrator is used as a low impedance switching device, an arrangement which is in common use in domestic television receivers. Furthermore, my analysis cannot be applied to a linear network since the switching action considered is such as to cut the final valve off.

There is, however, one point that must be checked if my analysis is to be applied, and that is that the conditions immediately preceding the scan are suitable for an integration to proceed without appreciable time delay.

The circuit shown in Fig. 11 of my article is perhaps a bad example in that there is this other cause of instability, namely, phase shift around the loop, and I do recall that, when using a blocking oscillator which switched for a very short period, and was therefore operating under conditions approximating to those specified by Mr. Reid, the circuit did operate with a low frequency "bump" embracing several scans.

Double stroking is however a more prevalent fault when using a low impedance switching device and, under these conditions, is quite definite when it does occur.

I would therefore suggest that when using a low impedance switching device in circuits of this sort there is ample practical evidence that the mode of instability described in my article is probable, and though I have not checked it practically, I believe that the trouble would be present even if the loop gain and phase-shift characteristics were such as to preclude the possibility of phase shift oscillations.

Yours faithfully,
A. B. STARKS-FIELD,
Baddow Research Laboratories,
Marconi's Wireless
Telegraph Company Ltd.

Ten-Volt Effect with Oxide-Coated Cathode

DEAR SIR,—A sudden deviation in the characteristic curve has been observed at about 10 volts anode potential in DAF91 pentodes. The magnitude of the deviation varies from valve to valve, but the voltage of onset is the same in each case, being also independent of operating conditions. The effect is stable and reproducible after several months.

The effect was observed during the construction of a "starved-current" D.C. amplifier (3-10μA per valve) in which the anode voltage of a DAF91 was required to be as low as possible, so that a second stage of amplification could be efficiently used.

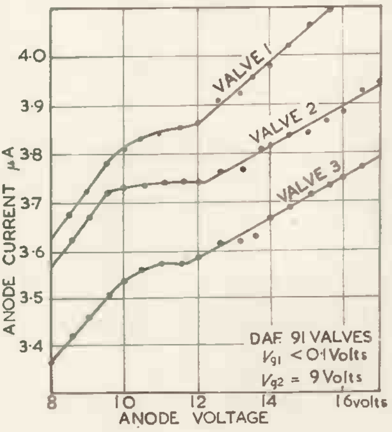


Fig. 1. I_a/V_a curves of DAF91

The "kink" in the characteristic curve was first observed on the V_a'/V_g curve with an anode resistance of 10 megohms. (V_a was measured by a Baldwin-Farmer high impedence valve-electrometer.) Separate measurements with low anode resistance were made to obtain the I_a/V_a curves shown in Fig. 1.

Fig. 1 shows the "kink" corresponding to reduced emission at about 10 volts. $I_a^{3/2}$ is plotted against V_a and a straight line would be expected, since V_g is less than 0·1 volt. The observed deviations from the 3/2 law are similar to those recorded by Hamaker, Bruining, and Aten[1] and by Matheson and Nergaard[2]. These authors found the effect to be independent of valve geometry and of frequency, and suggested that it was due to secondary emission from the anode, on to which a layer of extraneous material had been evaporated during evacuation. The important material may be[2] BaO, or, more likely[1], $BaCl_2$. The effect may be observed for low voltages other than 10 volts[3].

In practice it is desirable to avoid this anomalous part of the characteristic, so the valve should not be operated with an anode potential between 7½ volts and 15 volts.

The overall amplification which we obtained in two such stages operating at low current was 10 000. It is likely that in any work with "starved current" amplifiers (i.e. with low anode voltage) using valves with oxide-coated cathodes this phenomenon should be taken into account.

My thanks are due to Dr. C. A. Walley, of the Electrical Engineering Department, King's College, Newcastle, for helpful discussion.

Yours faithfully,
JOHN F. FOWLER,
Radiotherapy Department,
Royal Victoria Infirmary,
Newcastle-on-Tyne.

REFERENCES

1. HAMAKER, H. C., BRUINING, H., ATEN, A. H. W. *Philips Res. Rep. 2*, 171 (1947).
2. MATHESON, R. M., NERGAARD, L. S. *RCA Rev. 12*, 258 (1951).
3. GAYDON, A. G. Dissociation Energies. (Chapman & Hall 1947).
$BaCl_2 \rightarrow BaCl + Cl^-$ at 7.8eV.
$BaCl_2 \rightarrow Ba + Cl^- + Cl^-$ at 10.2eV.
$BaCl_2 \rightarrow BaCl^+ + Cl^-$ at 13eV.

A Range of 400c/s and 1 600c/s Transductors for Service Use

DEAR SIR,—I was very interested to read in the August issue the article by Messrs. Milnes and Hudson describing the proposed range of standard transductors. The standardization will enable circuit engineers who are not primarily concerned with the "art" to make greater use of this potential amplifier than at present. I hope the standardization will be extended to 50c/s amplifiers.

There are a number of points I should like to raise with the authors regarding the proposed range and the design procedure outlined in the report. Firstly I should like to emphasize that a knowledge of (a) power gain/sec, (b) stability of the characteristic, is necessary before it can be decided that the magnetic amplifier is applicable to a problem. Although the designs have attempted to increase the stability, no specification for minimum stability has been laid down. Unless some criteria are fixed for this quantity and used to specify the stability of the characteristics, the user will always be in doubt as to whether the amplifier meets his requirements.

I feel that the discarding of the two-element output winding because of the practical difficulty in the provision of the number of seals on the cans has greatly restricted the range of application of the units. Apart from restricting their use in series-connected units mentioned in the article, they cannot be used in the bridge type circuit described in "An Improved Magnetic Servo Amplifier", by A. W. Lufcy, A. E. Schmidt, R. W. Barnhart, *Communication and Electronics*, p. 281-289, September 1952. These amplifiers, I think, will become of increasing importance in the near future; in quick response amplifiers they use about half the number of components and have a better current-gain performance compared with the equivalent auto-self-excited reactor. In cases where a large power gain is required at the expense of the response time, the time-constant of the input stage can be suitably increased by the inclusion of a choke.

Most of our work has been connected with quick response amplifiers using Permalloy F as the core material. Our results indicate that there will be application for extending the Permalloy F power range into the input range.

The remarks concerning the condition for optimum power gain per second seem hardly to get at the crux of the matter. When the resistances of the output windings R_ω and rectifiers R_r are taken into account Equation (5) becomes

$$P/\tau = 2/\pi \frac{X R_L}{R_\omega + R_r + R_L)^2} \quad \ldots\ldots\ldots\ldots (5a)$$

Where R_L is the load resistance. When optimum power gain per second is the sole criterion it is obvious that

$$R_L = R_\omega + R_r \quad \ldots\ldots\ldots\ldots (6)$$

and the core and winding area should be proportioned for a maximum X/R_ω ratio. However, for large core sizes and high supply frequencies the winding dissipation limits Equation (6) to

$$R_L + R_r = K R_\omega$$

where K is given by

$$(1 + K)^2 = \frac{(\pi B_m A \,.\, f^N o)^2}{R_\omega W}$$

where B_m is the maximum flux swing
A the core area
and W the total allowable power dissipation in the output windings per core.

The rectifier forward and backward resistances play an important part in determining the characteristics of magnetic amplifiers. I think it is indeed unfortunate that they have not given the limits imposed by the rectifiers in the standard designs and laid down a specification for the rectifiers in order to get the standard amplifier characteristics. Our results have shown that when standard commercial selenium rectifiers are used (10V peak inverse/disk) with Permalloy F cores working at a flux density = 6 500 lines/cm² and a supply frequency of 400c/s the rectifier is the determining factor which limits the power gain/sec of the amplifier. The current rating of the rectifier has been found to be very much smaller than that of the reactor if the leakage current requirement for the rectifier is to be satisfied.

Yours faithfully,
D. F. WALKER,
Ferranti Ltd, Edinburgh.

The author replies:

DEAR SIR,—I am grateful to Mr. Walker for his comments on the paper by Dr. Hudson and myself.

The half-wave quick response circuits

described by Lufcy have not been fully evaluated yet but the designs quoted have winding proportions rather different from those of normal transductors. When the requirements are clearer, the range of transductors will be extended to include units specially suitable for these and other quick response circuits.

The reverse and forward resistances of a rectifier are temperature and age-dependent and therefore their influence on transductor behaviour should be minimized. In the high gain condition advocated by Mr. Walker (equation (6)), the rectifier forward resistance tends to be somewhat too large in relation to the total circuit resistance for the stability to be good.

If the matter is treated analytically it may be shown, quite simply, that the ratio of rectifier reverse to forward resistance sets an upper limit to the value of X/R that is practical in an auto-self-excited transductor. For example, if the rectifier ratio is 2 000:1, the useful limit of X/R is perhaps 600:1 which corresponds to an ampere-turn amplification of about 200. The standard transductors are designed within these limits and are intended to be used with rectifiers which have leakage currents of less than 2 per cent of rated forward current at the full 25 volt/disk rating and which are derated to 10 volts (peak)/disk for auto-self-excitation purposes.

Other remarks on the influence of rectifiers on transductor stability are to be found in the *Proc. Instn. Elec. Engrs.* 97, Part I, 302 (1950).

Yours faithfully,
A. G. MILNES,
Royal Aircraft Establishment.

Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: October 21. Time: 6 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1.
Annual General Meeting followed by lecture at 7 p.m. Printed Circuits: Some Principles and Applications of the Foil Technique.
By: P. Eisler, Dr. Ing.

North-Western Section

Date: October 1. Time: 7.15 p.m.
Held at: College of Technology, Manchester.
Lecture: The Detection and Cure of Parastic Oscillations in Radio and Electronic Equipment.
By: H. Whalley, A.M.Brit.I.R.E.

Scottish Section

Date: October 8. Time: 7 p.m.
Held at: Institute of Engineers and Shipbuilders, Glasgow.
Lecture: The Microwave Test Bench and its Components—a practical introduction to Waveguide Work.
By: J. Bilbrough, Assoc.Brit.I.R.E.

North-Eastern Section

Date: October 14. Time: 6 p.m.
Held at: Institution of Mining and Mechanical Engineers, Newcastle-upon-Tyne.
Lecture: The Impact of Communication Theory on Television.
By: D. A. Bell, M.A., B.Sc., Ph.D.

BRITISH KINEMATOGRAPH SOCIETY

Date: October 7. Time: 7.15 p.m.
Held at: The Gaumont British Theatre, Film House, Wardour Street, London, W.1.
Lecture: Considerations of Wide Screen and Stereo-Cinematography.
By: R. J. Spottiswood, M.A., M.B.k.s.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Date: October 8.
Inaugural address as President.
By: H. Bishop, C.B.E., B.Sc.(Eng).
Date: October 19.
Informal discussion on Television.
Opened by the President.

Radio Section

Date: October 14.
Chairman's Address.
By: J. A. Smale, C.B.E., B.Sc.
Date: October 26.
Discussion: Long Playing Disc Records Compared with Magnetic Tape for Sound Reproduction in the Home.
Opened by: H. F. Smith.

Supply Section

Date: October 28.
Chairman's Address:
By: L. G. Brazier.

North Midland Centre

Date: October 6. Time: 6.30 p.m.
Held at: Offices of the British Electricity Authority, Yorkshire Division, 1 Whitehall Road, Leeds.
Chairman's Address.
By: G. Caton.
Date: October 13. (Time and place as above).
Discussion: Technical College Examinations.
Opened by: R. A. H. Sutcliffe.
Date: October 15. Time: 7.15 p.m.
Held at: Offices of the Yorkshire Electricity Board, Ferensway, Hull.
Chairman's Address.
By: G. Caton.

Sheffield Sub-Centre

Date: October 21. Time: 6.30 p.m.
Held at: Grand Hotel, Sheffield.
Chairman's Address.
By: F. Seddon.

North-Western Centre

Date: October 6. Time: 6.30 p.m.
Held at: Engineers' Club, Albert Square, Manchester.
Chairman's Address.
By: H. West.

North-Eastern Centre

Date: October 12. Time: 6 15 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Chairman's Address.
By: H. Esther.
Date: October 26. (Time and place as above).
Lecture: Television Broadcasting Stations.
By: P. A. T. Bevan, B.Sc.

North-Eastern Radio and Measuremen's Group

Date: October 5. Time: 6.15 p.m.
Held at: King's College, Newcastle-upon-Tyne.
Chairman's Address.
By: F. H. Birch.
Date: October 19. (Time and place as above).
Lecture: Recent Ideas and Experiments in Magnetism.
By: Professor L. F. Bate, Ph.D., D.Sc.

Tees-Side Sub-Centre

Date: October 7. Time: 6.30 p.m.
Held at: Cleveland Scientific and Technical Institute, Middlesbrough.
Chairman's Address.
By: C. Richards.

South-East Scotland Sub-Centre

Date: October 6. Time: 7 p.m.
Held at: Heriot-Watt College, Edinburgh.
Chairman's Address.
By: H. V. Henniker.

South-West Scotland Sub-Centre

Date: October 7. Time: 7 p.m.
Held at: 39 Elmbank Crescent, Glasgow.
Chairman's Address.
By: Professor F. M. Bruce, M.Sc., Ph.D.

South Midland Centre

Date: October 5. Time: 6 p.m.
Held at: Grand Hotel, Birmingham.
Chairman's Address, Annual General Meeting and Conversazione.

Southern Centre

Date: October 7. Time: 6.30 p.m.
Held at: Municipal College, Portsmouth.
Chairman's Address.
By: Cdr. (L) C. V. Robinson.

Western Centre

Date: October 12. Time: 6 p.m.
Held at: South Wales Institute of Engineers, Park Place, Cardiff.
Chairman's Address.
By: J. Vaughan Harries.

Northern Ireland Centre

Date: October 13. Time: 6.15 p.m.
Held at: The Presbyterian Hostel, Howard Street, Belfast.
Chairman's Address.
By: J. R. W. Murland, B.Sc.(Eng.).

North Scotland Sub-Centre

Date: October 7. Time: 8 p.m.
Held at: Caledonian Hotel, Aberdeen.
Chairman's Address.
By: R. S. Goddard.
Date: October 8. Time: 7 p.m.
Held at: Royal Hotel, Dundee.
Chairman's Address.
By: R. S. Goddard.

East Midland Centre

Date: October 1. Time: 7.30 p.m.
Held at: The Masonic Hall, Pinchbeck Street, Spalding.
Lecture: Overhead Distribution.
By: H. W. Grimmitt and R. F. Proctor, B Sc.
Date: October 6. Time: 7 p.m.
Chairman's Address, Annual General Meeting and Reunion.

Cambridge Radio Group

Date: October 13. Time: 6 p.m.
Held at: The Cambridgeshire Technical College.
Chairman's Address.
By: D. Weighton.

Mersey and North Wales Centre

Date: October 5. Time: 6.30 p.m.
Held at: Liverpool Royal Institution, Colquitt Street, Liverpool.
Chairman's Address.
By: T. Coates, M.Eng.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: October 6. Time: 5 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.
Chairman's Address: Recent Developments in Subscribers' Apparatus and Services.

Informal Meeting

Date: October 21. Time: 5 p.m.
Held at: Conference Room. 4th Floor, Waterloo Bridge House, London, S.E.1.
Vice-Chairman's Address: Some Aspects of the Growth and Maintenance of the Telephone Service.

THE PHYSICAL SOCIETY

All meetings, unless otherwise stated, will be held at The Lecture Theatre of the Science Museum, Exhibition Road, London, S.W.7.

Date: October 23. Time: 5 p.m.
Lecture: Chree's Influence on Present day Geophysics.
By: Professor J. Bartels.
This meeting includes the presentation of the 7th Charles Chree Medal and prize to Professor Bartels of the University of Gottingen.

Low Temperature Group

Date: October 8. Time: 5.30 p.m.
Lecture: Supraconductivity.

Acoustics Group

Date: October 16. Time: 5.30 p.m.
Lecture: Sound Insulation in Buildings.
By: P. H. Parkin.

THE TELEVISION SOCIETY

Date: October 9. Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue. London, W.C.2.
Lecture: Recording Television Programmes.
By: C. B. B. Wood.
Date: October 22. (Time and place as above).
Lecture: Flywheel Synchronizing and Scanning Circuits.
By: H. Fairhurst.

Leicester Centre

Date: October 19. Time: 7 p.m.
Held at: The College of Art and Technology, The Newarkes, Leicester.
Lecture: Application of Cathode Ray Oscilloscope to Television Servicing.
By: J. H. Beech, A.Brit.I.R.E.