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Commentary

THE professional season may be said to start with the transition from summer, with its holidays and exhibitions, to autumn, with its series of learned papers and evening lectures; the Presidential Address of the Institution of Electrical Engineers usually being looked upon as the opening meeting. For this session both the President of the Institution and the Chairman of the Radio Section are intimately concerned with telecommunications, and their addresses form a landmark and a pointer to future progress in this field.

In his Presidential Address, Mr. H. Bishop, C.B.E., Director of Technical Services, BBC, reviewed the development of the broadcasting service in this country since 1941, the year in which his predecessor at the BBC, Sir Noel Ashbridge, was President of the Institution. One important thought provoked by his address is that not all the problems of the electronic engineer are technical; indeed, at the higher levels they are decreasingly so, the vagaries of the human element, often proving of greater consequence. For instance, national, international and intercontinental agreements may be made on frequency allocations to make the best possible use of the frequency bands available for broadcasting; agreements which are based on scientific investigation over a long period and involve much experimental research by many scientists and engineers. But, in some cases through lack of agreement and in others by subsequent disagreement, these plans may be frustrated. One well known example is that for about five million people in this country, reception of the Home Service programme is unsatisfactory after dark, due mainly to strong interference from Continental transmitters which are not adhering to the Copenhagen Plan.

The growth of broadcasting requirements is such that the quality of reception is likely to decrease in the next decade. This is not due to a falling off in the technical standards of transmitter or receiver design, nor to " utility " methods, but to the plain fact that as time goes on more and more transmitters, and services other than broadcasting, are jostling for space in the limited frequency bands. Historically long-wave radio was the basis of wide coverage broadcast transmissions. Successively we have had hopes based on medium-wave and short-wave bands and, still moving in the same and inevitable direction we now find ourselves looking hopefully towards the very high and ultra high frequency bands. The internationally agreed V.H.F. band for sound broadcasting is 87·5 to 100Mc/s and, small though this is, it is still further limited in this country since approximately half of this band has been allocated to services other than broadcasting. Nevertheless, the V.H.F. band does seem to offer a partial solution and the experimental transmissions by the BBC from Wrotham on A.M. and F.M. show advantages for the latter which may well lead to a new broadcasting system for the country in the years to come. The Government has, in fact, already given permission in principle for a start to be made on the building of V.H.F. stations and the BBC contemplates building 51 transmitters at 19 locations, 19 for the Home Service and 16 each for both the Light and Third Programmes. This will constitute a major, though no doubt gradual change since most existing receivers will have to be scrapped or fitted with convertors of relative complexity.

In the television field much experience has been gained and the decision to adhere to the pre-war standard of 405 lines on the reopening of the service in 1946 can be amply justified. From the programme interchange viewpoint it is unfortunate that there are now some five different standards in international use. From the technical viewpoint, however, there is the compensation that this varied experience makes easier the task of selecting an optimum system for future use. It may even conceivably be shown that a still different system is both desirable and technically possible. The debatable question of monochrome versus colour is only partly technical, as is the provision of an alternative programme. The overwhelming cost of television is due largely to the number of engineers required to operate the equipment, both in the studio and the control and apparatus rooms. In sound broadcasting this problem has been largely overcome by the development of automatic, semi-automatic and remotely controlled equipment and it is envisaged that similar techniques will be applied to television in the future.

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Mr. J. A. Smale, C.B.E., in his inaugural address as Chairman of the Radio Section of the Institution gave a short history and surveyed the present position with regard to Commonwealth Telecommunications. He showed how cable and radio have ceased to be competitors and now form a truly complementary system by which a close approach to 100 per cent reliability is attained. At the same time electronics is playing an increasingly important part in line communications; the submerged repeater is now standard practice, electro-mechanical relays are giving way to electronic devices while the cable-laying ships themselves abound with radio aids, depth-sounding recorders and electronic testing apparatus.

From these two addresses it is abundantly clear that electronic engineers have a still growing scope in the sphere of broadcasting and telecommunications; a field of activity which forms an increasing part of our daily life and is truly the medium by which Nation speaks unto Nation.

A Remote Control and Telemetering System for a Van De Graaff Generator

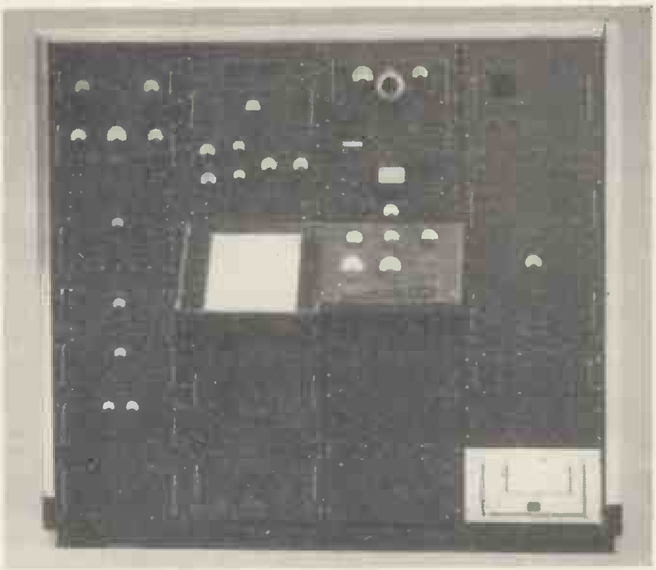
(Part 1)

By B. Millar*, B.A.

A remote control and metering system for the equipment in the high voltage electrode of a Van de Graaff electrostatic generator is described. Communication between the base and the high voltage electrode of the generator is by modulated light beams, thus avoiding all mechanical connexions. The control system has seven channels, though only one of these may be operated at a time. The metering system gives a continuous indication at the control position of the values of five variables in the high voltage electrode, with an accuracy of about 2 per cent.

VAN DE GRAAFF electrostatic generators are high voltage direct current machines producing an output which may reach several million volts. For a description of these machines, the reader is referred to the papers by Lown[1], who gives a good basic description, and by Fortescue and Hall[2], who go into greater detail and also give a number of further references.

A 4MV generator of this type has been built at the A.E.I. Research Laboratory for use in nuclear physics research. The high voltage electrode of the generator contains an ion source of the type described by Thonemann *et alia*[3] to produce free protons or deuterons which are subsequently accelerated as they pass from the high voltage electrode to the base of the generator through an evacuated accelerator tube. The high voltage electrode also contains the power and gas supplies needed for operating the ion source. These include a 200W, 20Mc/s oscillator and two D.C. supplies. Power for operating them is obtained from a 1 200VA, 2kc/s alternator in the high voltage electrode, driven by an endless belt which passes between the base and the high voltage electrode of the generator. This use of the belt is in fact only a secondary one, its primary function is to convey electric charge to the high voltage electrode, so producing and maintaining the output voltage of the generator.



The Control Panels

The power supplies in the high voltage electrode must be controllable from outside the generator, and remote indication of various currents, voltages and gas pressures inside the high voltage electrode must be provided. In other generators it has been usual to effect the control by means of glass strings, Perspex rods, or similar devices operated, for example, by electric motors in the base of the generator and at earth potential. Metering has commonly been done by an optical system consisting of a telescope and a number of prisms or mirrors by which the operator may view meters or indicator lamps in the high voltage electrode.

It was thought that the mechanical connexions used for the control of earlier generators might be a limiting factor on their voltage performance. Further, the usual optical metering system was difficult to apply in the present case, as the generator had to be operable from either of two control positions, one just below the generator and by the target, and the other, for use when radiation close to the generator was excessive, in a room about 30 yards away. These difficulties were avoided by using modulated light beams as links between the high voltage electrode and the base of the generator both for the up-going control system and for the down-coming metering system. The control system uses a sine wave modulated light beam and provides seven control channels, with the limitation that only one may be operated at a time. The metering system uses a pulse modulated light beam to give apparently simultaneous and continuous indication at the control position of the values of five variables in the high voltage electrode. The pulses are generated in a number of special saturable reactors, and the final display is on a cathode-ray tube. The overall accuracy of the system is about 2 per cent. One of the control channels may be used to switch some of the inputs of the metering system to different parts of the circuits in the high voltage electrode, so that a number of subsidiary quantities may be metered when desired in place of those normally indicated.

To improve the insulation of the Van de Graaff generator, it is built inside a steel pressure vessel which is filled with nitrogen, or a mixture of nitrogen and freon, at a pressure of up to 400lb/sq.in. This has two effects on the design of the electronic equipment which has to be inside the generator tank. Firstly, the components must withstand this pressure, which means that the types used must be carefully selected, and sometimes that special components must be made. Secondly, pumping the nitrogen from the generator tank to a storage vessel and open-

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ing the tank takes about a day, and the reverse process takes a similar period, so that a fault, however simple, may put the generator out of action for two days. A high premium is therefore placed on reliability. A number of difficulties were experienced at first due to the use of unsuitable components, chiefly relays and capacitors, but the system is now very reliable.

Fig. 1 is a block diagram of the complete control and metering system. Keys on the control desk govern the operation of the control transmitter which is contained in a rack near the generator. The transmitter output is used to modulate a crater lamp[4] light source which is situated at the base of the generator, and is viewed by an electron multiplier photocell in the high voltage electrode. The signal from the photocell is fed to the control receiver, which controls the power supplies of the ion source. In the reverse direction various currents and voltages in the ion source circuits are fed to the telemeter transmitter. Its output is fed via a crater lamp, light beam, photocell and head amplifier to the telemeter receiver which operates the display cathode-ray tube on the control desk.

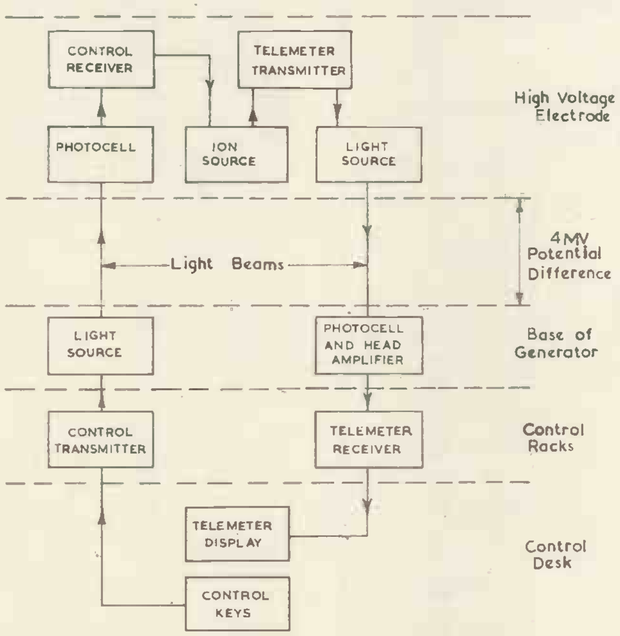


Fig. 1. The control and metering system

Control System

Fig. 2 is a block diagram showing the arrangement of the control system in more detail. There are seven control channels and each has a corresponding frequency which may be applied as a sine wave modulation of the light intensity. The control frequencies lie in the range 3 to 8kc/s. The seven keys on the control panel are of the 3-position biased type. If a control key is operated in the forward direction the control oscillator is made to function at the corresponding frequency. Its output signal modulates the crater lamp light source*. In the high voltage electrode the signal is received by the multiplier photocell, and passed via an amplifier and cathode-follower to seven tuned circuits, one tuned to each control frequency. A large signal is produced at the output of the circuit tuned to the incoming frequency and corresponding to the control channel concerned. This causes anode current to flow in an associated detector valve, and so operates a relay. In the majority of the channels the relay energizes a small

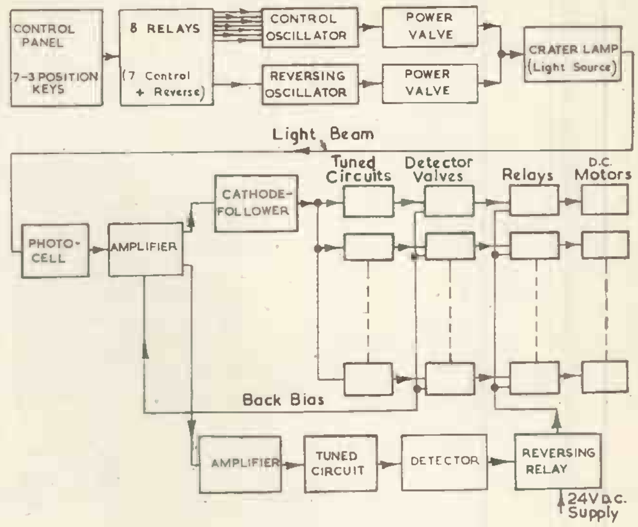


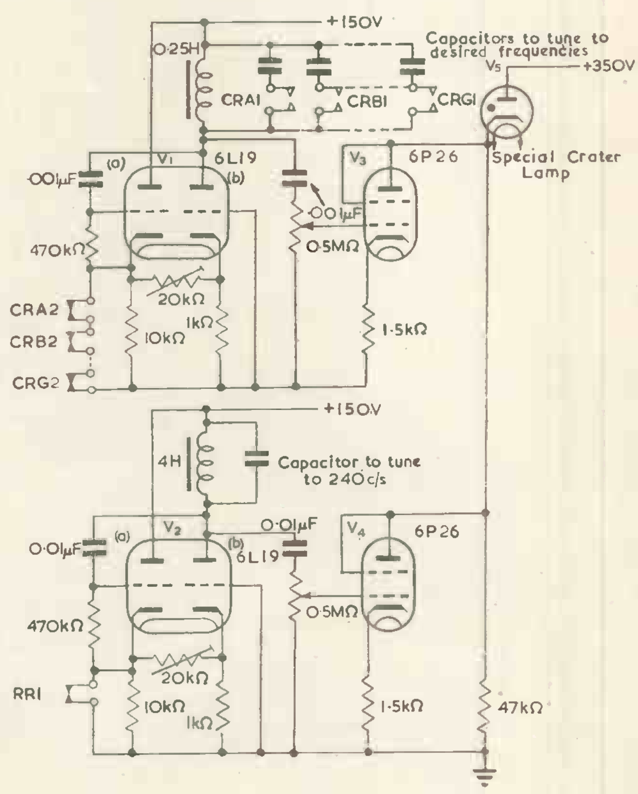
Fig. 2. The control system

D.C. motor which drives a "Variac" auto-transformer, so effecting the desired control. The Variac is driven round for as long as the control key is pressed.

If a control key is operated in the reverse direction, then in addition to the effects outlined above, a "reversing" oscillator common to all the channels is operated. Its frequency is 240c/s. The light beam is then modulated with the control and reversing frequencies simultaneously, and an additional relay in the high voltage electrode is operated. This reverses the polarity of the armature supply of the D.C. motors, leaving the field supply unaltered.

The aim in design was to devise a system with the widest possible tolerance of frequency drifts and of changes of signal amplitude. The receiver circuits described will

Fig. 3. The control transmitter



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* *Crater lamps are hot cathode gas discharge lamps, filled with a mercury-argon mixture. They give a blue light, of intensity proportional to the current passed through them. The ones used in this equipment were specially made by Messrs. Ferranti Ltd. as the standard type would not withstand the high external gas pressure to which the lamps are subjected in this application.*

operate correctly over a 20:1 range of input signal amplitude.

Control Transmitter

In Fig. 3, which is a simplified circuit diagram of the control transmitter, V_1 and V_2 are the control and reversing oscillators respectively. The oscillator circuit used is particularly convenient in equipment which is only to be made in small quantities since it uses a coil with only a single winding, and, further, the loop gain can easily be adjusted to obtain a satisfactory output waveform by varying the resistor which is connected between the two cathodes of the double triode valve. The oscillators are normally prevented from functioning by relay contacts which short circuit the cathode load resistors of the (a) sections of the valves. The operation of any control key, working through a relay, removes the short-circuit from the cathode resistor of V_{1a}, so that the control oscillator functions, and at the same time connects a capacitor in the anode circuit of V_{1b}, to tune it to the correct frequency. Operation of a control key in the reverse direction additionally removes the short-circuit from the cathode resistor of V_{2a}. The outputs of the two oscillators are fed to the power valves V_3, V_4 and mixed by connecting the crater lamp as their common anode load.

Control Receiver

A simplified circuit of the control receiver is shown in Fig. 4. The control signal is received by the 27M1 electron multiplier photocell V_2 and amplified by V_3. At this point the circuit splits into two sections, one for the control frequencies and one for the reversing frequency.

Considering first the control frequencies, the signal is passed through cathode-follower V_{4a} and then applied to seven series tuned circuits connected in parallel. One of these circuits resonates at each control frequency. The outputs of the tuned circuits, taken across the inductors, are applied to the grids of the seven detector valves V_6 to V_{12}. The earthy ends of the tuned circuit inductances are returned to a common bias point at $-8V$, obtained by rectifying the 6·3V heater supply. Thus the detector valves are normally biased to a little beyond anode current cut-off. If an alternating potential of sufficient amplitude is applied to the grid of any detector valve the valve will pass anode current during the positive half cycles and so operate a relay connected in its anode circuit. A signal at one of the control frequencies received by the photocell will be passed through the amplifier and applied to the tuned circuits. The circuit tuned to this frequency will give a greater output than any of the others, and so, with suitable signal levels, the relay in the anode of the detector valve coupled to it will be operated while the others will not. If the signal at the grid of the detector valve is so great that the valve passes grid current, this will charge up the filter capacitor of the bias supply, so increasing the bias not only on that detector valve, but also on all the others. This eliminates the danger of a control signal at large amplitude operating several controls instead of just one. The increased bias is also applied to the amplifier valve V_3, so reducing its gain when large amplitude signals are used.

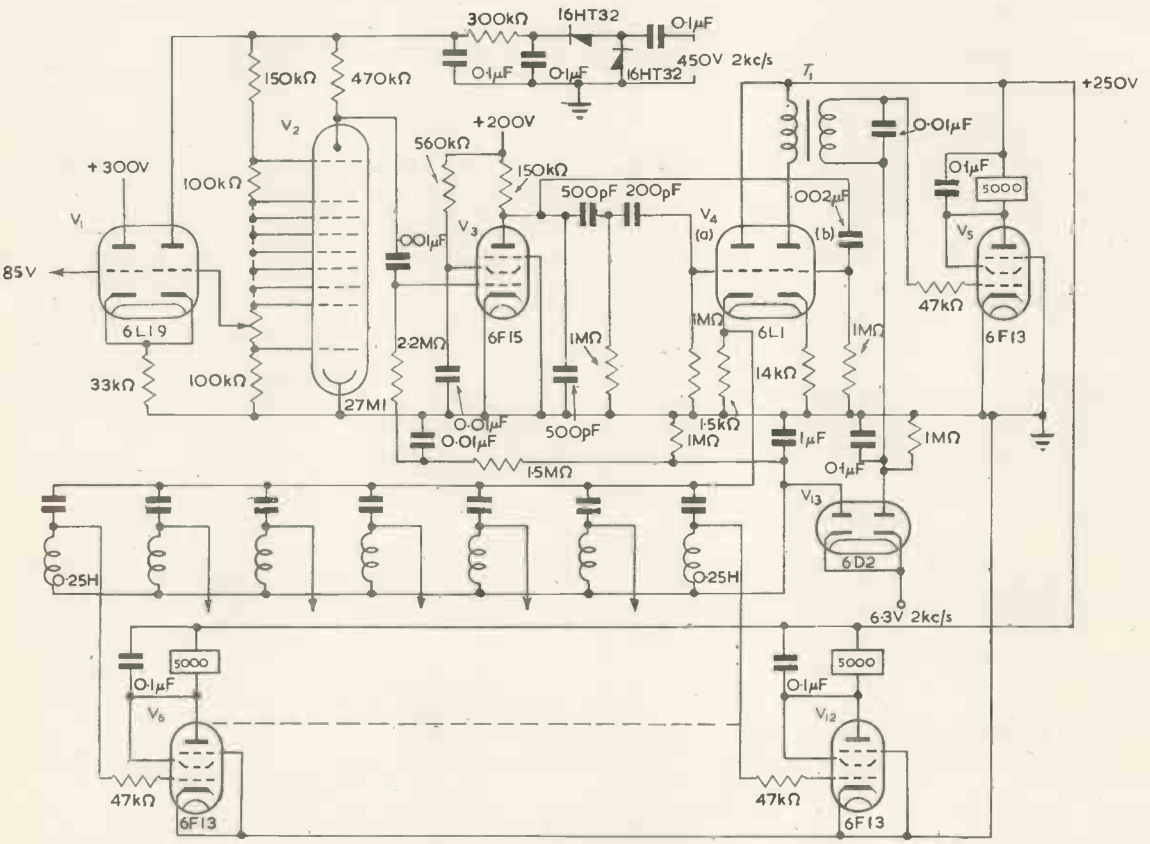

Fig. 4. The control receiver

The received signal is also fed from V_3 to V_{4b}, which has a resonant circuit tuned to 240c/s in its anode circuit and thence to the reversing detector V_5, which has the reversing relay in its anode circuit.

The control frequencies are arranged in an arithmetic progression, in the ratios 7:9:11:13:15:17:19, thus minimizing possible troubles due to the generation of harmonics when the amplifiers are overloaded with a large amplitude input signal. To keep the components of the tuned circuits small the frequencies used should be high, but they should be below the upper frequency limit of the crater lamp, which is at about 12kc/s. The frequencies selected lie between about 3 and 8kc/s.

The reversing frequency, 240c/s, is well spaced from the control frequencies, and the 240c/s tuned circuit ensures that very little control frequency signal gets to the grid of the "reversing" detector. This prevents incorrect operation of the reversing relay by a large amplitude signal at a control frequency. The upper limit to the permissible input signal amplitude is set by an effect due to cross modulation when the amplifiers overload. The result is that if both control and reversing frequencies are present in the receiver at very large amplitude the mean current in the control detector valve is small, and the control relay will not operate. The signal amplitude at which this occurs is rather more than 20 times the lowest amplitude at which all the relays work correctly, so that quite large changes in the gain of the system can occur without upsetting its operation.

The power supply to the photocell is regulated by the simple shunt stabilizer shown (V_1). The reference voltage is obtained from a neon used in the telemeter transmitter.

Telemeter System

Since the control system does not provide an indication of the setting of the variables which it controls, it is essential to have some separate system to indicate in the control room the values of various currents, voltages, etc.,

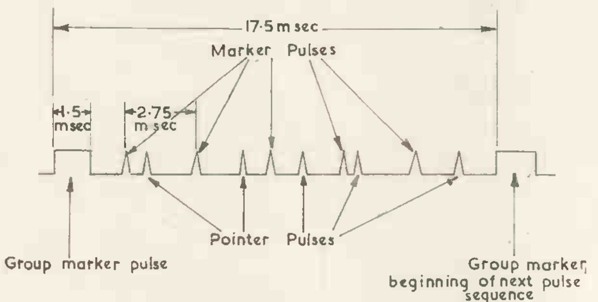

Fig. 5. Telemeter waveform

in the high voltage electrode. This is done by the telemetering system, which uses a pulse modulated light beam to transmit information of the values of five currents or voltages in the high voltage electrode to the control room. The pulses are generated in saturable reactors of a special type, (peaking transformers).

The pulse sequence used is of the form shown in Fig. 5. The sequence repeats at intervals of 17·5msec. Each pulse sequence consists of a long pulse (1·5msec), referred to as the "group marker", followed by a sequence of ten shorter pulses, each about 30μsec long. These ten pulses are formed of five pairs, and in each pair the first pulse will be referred to as the "marker" pulse and the second as the "pointer" pulse. The marker pulses occur at equal time intervals of 2·75msec during the 16msec period between group marker pulses. The five pointer pulses occur each in the interval between its associated marker pulse and the following marker pulse, and the time intervals between the five marker pulses and the following pointer pulses indicate the values of the five variables being telemetered. If any variable has the value zero, its corresponding pointer pulse follows 0·24msec after its marker pulse, and if the value of the variable increases, this time interval increases linearly, attaining the value 2·04msec at the nominal maximum value of the variable.

The receiver provides a display on a cathode-ray tube of the form sketched in Fig. 6. This has five sweeps across the tube face, one above another, produced by a linear time-base. The sweeps of the time-base correspond to the five channels of the telemeter system, and are triggered by the five marker pulses. The marker and pointer pulses deflect the trace in the Y direction at the beginning of the sweep and during it respectively. The positions of the five pointer pulses on their respective traces indicate the values of the corresponding currents etc., in the high voltage electrode. A sixth sweep appears, partly at the top and partly at the bottom of the display. This is triggered by the group marker pulse, and is only an incidental effect in the system.

Telemeter Transmitter

SATURABLE REACTORS

The saturable reactors used to generate the telemeter pulses are illustrated diagrammatically in Fig. 7, while Fig. 8 is a photograph of two of them. Each consists of an iron core, formed from four U-shaped permalloy laminations, bridged by a single piece of 0·001in thick mumetal strip. At the middle of this strip two transverse cuts are made, one from each side, leaving a very narrow neck (about 0·002in) at the centre. An output coil A is wound round this strip at the point of the constriction. Other coils, B, C, D, may be wound on the main core.

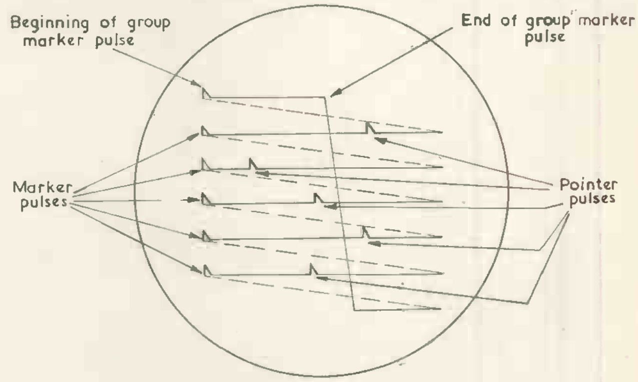

Fig. 6. Telemeter display on C.R.T.

The portions shown in broken line are suppressed by modulating the grid of the C.R.T.

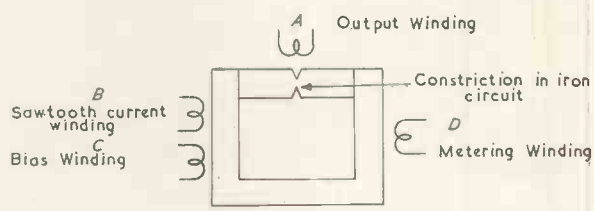

Fig. 7. Principle of the saturable reactors

Suppose that a varying current is passed through coil B, the other coils being open-circuited. Then the iron at the constriction under coil A will be saturated, except for a short period as the flux reverses every time the current in B passes through zero. At this time a voltage pulse will be induced in coil A. If now a constant bias current is passed through coil C the output pulse in A will be produced when the ampere-turns in B are equal and opposite to those in C.

In the telemeter transmitter, ten such saturable reactors are used. All the output windings A are in series, so that a pulse is obtained at the output terminal whenever a pulse is produced by any of the reactors. A saw-tooth current is passed through the windings B, which are connected in series, and which all have the same number of turns. The windings C, known as the bias windings, are all connected in series, but have different numbers of turns. A constant current is passed through them. The magnetization of the cores due to the bias windings is in the opposite sense to that due to the saw-tooth current in the B coils. Hence at each repetition of the saw-tooth waveform ten pulses are produced in the output circuit, at the times at which the saw-tooth ampere-turns are equal to the ampere-turns of the bias windings.

The ten reactors are grouped into five pairs, the two reactors in each pair having nearly equal numbers of bias turns. The numbers of bias turns on the different pairs are in arithmetic progression, so that the output pulses appear as five pairs, the two pulses of each pair being close together in time, and the five pairs being equally spaced, covering most of the period of the saw-tooth. The second reactor of each pair has an additional or metering winding (*D* in Fig. 7). If a current of correct polarity is passed through one of these coils, the delay of its output pulse (the pointer pulse) after the pulse from the first reactor of the pair (the marker pulse) will be increased by an amount proportional to the current in the meter winding. Thus the sequence of 10 pulses described previously is built up. These pulses are fed to the input of an amplifier, the output of which modulates the crater lamp.

At the flyback of the sawtooth current waveform, pulses of reverse polarity and large amplitude are produced in the pick-up coils of the saturable reactors. These are suppressed in the amplifier, and replaced by the long group marker pulse. Thus the auxiliary circuits (see Fig. 9)

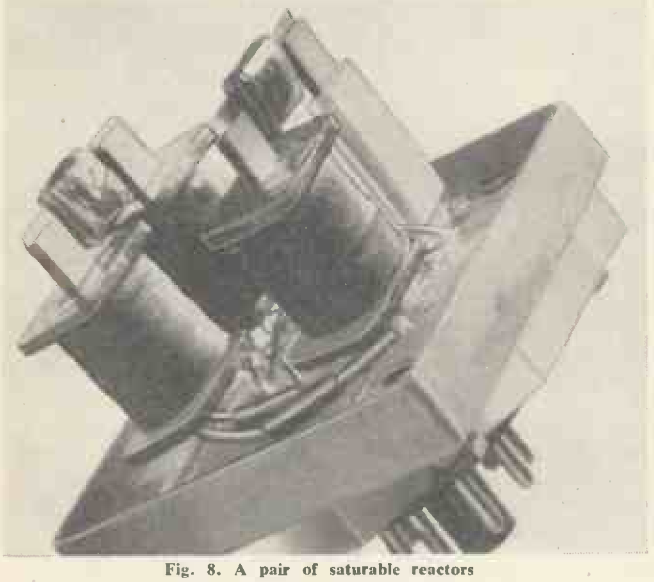

Fig. 8. A pair of saturable reactors

needed in conjunction with the saturable reactors are:
(a) a sawtooth current generator;
(b) a bias current generator; and
(c) a pulse amplifier.

The stability of calibration, so far as the transmitter is concerned, depends only on the rate of the sawtooth current sweep. Changes in the standing current in the sawtooth driver valve delay both marker and pointer pulses by the same amount, and so do not affect the period between them. Changes in the current in the bias coils similarly have no effect on the calibration except a very small one due to the difference between the numbers of bias turns on the two reactors on each pair. However, both the standing current in the sawtooth coils and the bias current must be held reasonably constant, since otherwise either a lot of the sawtooth sweep amplitude must be wasted at each end, or else one would run the risk of losing one or more pulses at one end of the sweep.

The sawtooth current coils of the saturable reactors have 1 000 turns each, while the numbers of turns on the bias coils of the several marker reactors range from 1 180 to 500. Each pointer reactor has 15 fewer bias turns than its associated marker reactor. The output windings have 200 turns each. The current in the bias coils is about 27mA, and so the first and last marker pulses are produced when the sawtooth current has values 31·9 and 13·5mA respectively. With zero signal in the meter coils, the first and last pointer pulses are produced at sawtooth current values of 31·5 and 13·1 mA. An input of 4·2 ampere-turns in a meter winding moves the corresponding pointer pulse from its zero position to coincidence with the next marker pulse, and so to allow time for the flyback of the time-base circuits in the receiver and to avoid upsetting the system if a current to be metered exceeds its expected maximum value slightly, the metering coils were designed on a basis of 3 ampere-turns for full scale modulation. Thus, for example, to provide remote indication of the value of a current which is expected to be between 0 and 1mA, a reactor with a 3 000 turn meter coil would be used.

If an impedance is connected across a winding of one of the saturable reactors, then the voltage induced across that winding due to the excitation current in the sawtooth current winding will cause a current to flow in the impedance and so in the winding. This will alter the flux in the reactor core and so affect the timing and sometimes also the amplitude of the output pulse from the reactor.

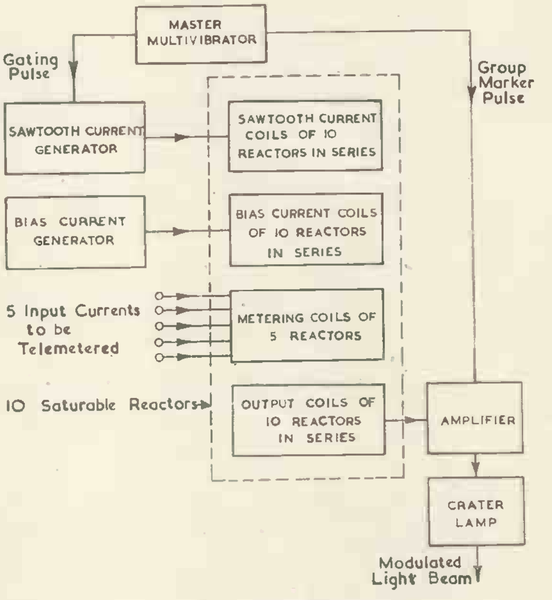

Fig. 9. The telemeter transmitter

It is thus essential to feed all the coils of the reactors from high impedance sources. In the case of the sawtooth and bias coils, this condition is satisfied by their connexion in the anode circuits of pentode valves which have degenerative resistors in their cathode circuits, thus giving very high output impedances.

In the case of the meter windings the individual circuits have to be so designed that this condition is satisfied. In some tests made on the first experimental telemeter transmitter it was found that for a 1mA coil (3 000 turns) the output pulse position was delayed by about 1 per cent of full-scale by a resistance of 100kΩ connected across the meter coil. The shift varied approximately inversely as the resistance loading the coil, and for a given resistance with different coils, as the square of the number of turns. This is in agreement with the results obtained from a rather simplified analysis in which the reactors were regarded as transformers.

(*To be continued*)

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AUDAR

By R. H. James*, A.M.I.E.E.

The name Audar has been given to an equipment which has been constructed to provide audio detection and ranging for the purpose of demonstrating radar principles. The displays obtained are similar to true radar displays, and in its present form may be of either the P.P.I. *or the range-amplitude type.*

Sound wave pulses, of 1msec duration and 6kc/s frequency, are transmitted by a highly directional loudspeaker which is used as a microphone for the reception of echo signals. The signals are amplified in a tuned receiver and, after rectification and video amplification, are applied to the indicator in a conventional manner. The C.R.T. *is a 12 inch, long persistence type.*

The loudspeaker is mounted on a pedestal and driven by a motor to rotate at 3 R.P.M. *A sine-cosine potentiometer, driven from the other end of the same shaft as the loudspeaker, is used to obtain the synchronized radial time-base required for the* P.P.I. *display.*

The equipment normally operates in a laboratory approximately 50ft long and 18ft wide, good echoes being obtained from walls, corners, cupboards and equipment racks all around the laboratory. Echoes from people are obtainable up to about 20ft, using transmitted pulse powers which are not objectionably loud. A 6in metal corner reflector may be detected at 25ft.

The range resolution is approximately 6in, and the angular resolution is a few degrees. Range marks are provided at 5ft intervals. The minimum range is sensibly zero.

THE first steps taken in the design of the equipment were calculations of P.R.F., pulse width and carrier frequency. It became apparent that, due to the comparatively low velocity of sound waves, it would be necessary to use the whole interval of time between transmitted pulses for the reception of echoes if a reasonable P.R.F. was to be used. Even so, for a maximum range of approximately 25ft, the P.R.F. is only 22 per second.

A range discrimination of 6in, it was found, would require a pulse width of approximately 1 millisecond. In order to obtain a large number of cycles in each transmitted pulse the carrier frequency would have to be supersonic, but a compromise frequency of 6kc/s was finally chosen as this could be handled reasonably by a loudspeaker. Thus, in the final arrangement, there are 6 cycles of carrier frequency in each transmitted pulse.

Range-Amplitude Display

A block diagram of the system used for the range-amplitude display is shown in Fig. 1.

A Miller-transitron oscillator is used to generate the sweep signal for the C.R.T. The sweep time for 25ft MAX range is approximately 45 milliseconds, and the flyback time is nominally 1 millisecond. Both are variable over a fairly wide range.

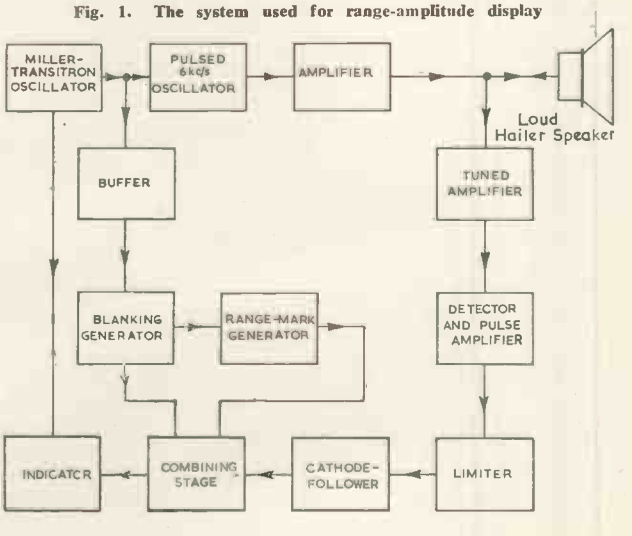
Negative pulses taken from the screen-suppressor circuit of the Miller-transitron oscillator are used to key a 6kc/s oscillator during the flyback. The output from the pulsed oscillator is applied, through a volume control, to an amplifier which drives a loud hailer speaker. This type of speaker is used because it is highly directional and enables the direction of reflecting objects to be determined.

For the reception of echo pulses, the same loudspeaker is used as a microphone (equivalent to common aerial working in radar), the signals being fed into the receiving portion of the equipment. Both transmitted pulses and echo pulses are fed into the receiver, which is arranged so as to limit the former and amplify the latter. In the receiver output the transmitter pulses are no larger than the largest echo pulses. A tuned stage in the receiver reduces the response of the equipment to extraneous room noises occurring at frequencies other than the signal frequency of 6kc/s. The stage is flatly tuned so as to accept the sidebands produced by the pulse modulation.

Following the detector stage, five *RC* filtering circuits are used to remove the 6kc/s carrier frequency from the 1msec pulses. These circuits are distributed through the last stages of the receiver.

A blanking generator, synchronized via a buffer amplifier from the screen-suppressor circuit of the Miller-transitron oscillator, serves two purposes. Firstly it is used on the

Fig. 1. The system used for range-amplitude display



* *Ministry of Transport and Civil Aviation.*

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P.P.I. display to darken the flyback and the first part of the forward trace, and secondly, for both displays, it delays the start of the range marks. This is necessary if it is desired for range to be indicated as distance from the mouth of the loudspeaker. The loud hailer speaker used has a double re-entrant horn and the actual sound source is effectively 2ft 6in behind the mouth of the speaker. The duration of the blanking pulses is 4·6msec approximately, equivalent to a range of 2ft 6in. The back edge of each blanking pulse triggers the range mark generating circuit and the first range mark coincides with the mouth of the loudspeaker (i.e. 2ft 6in from the sound source).

The range mark generating circuit produces ½msec pulses at a frequency of 110 per second, equivalent to 5ft apart. Range marks are suppressed during blanking pulses.

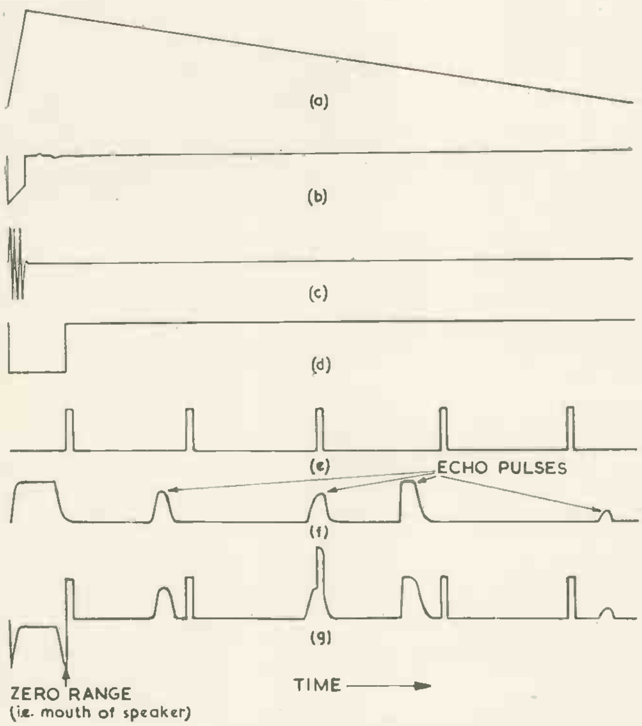


Fig. 2. Waveforms in various circuits

(a) *Time-base.*
(b) *Switching-synchronizing pulses from screen-suppressor circuit of Miller-transitron oscillator.*
(c) *Transmitter pulses (6 cycles per pulse).*
(d) *Blanking pulse.*
(e) *Range mark pulses.*
(f) *Video signal from receiver.*
(g) *Combined video, range mark, and blanking signals.*

The output from the range mark generating circuit is fed via an amplitude control to a stage which combines range mark signals, video signals from the receiver and blanking signals from the blanking pulse generator. The output from this combining stage is fed to the Y deflector system of the indicator, the display obtained being like one complete cycle of Fig. 2(g).

Fig. 2 shows the waveforms existing in the various circuits. It will be noted in Fig. 2(f) that the transmitter pulses in the receiver output appear considerably longer in duration than the original transmitted pulses due to their large amplitude and the action of the limiting and filtering circuits. The width increases as the transmitted pulse power is increased and is normally as wide as, or slightly wider than the blanking pulse. This is of little consequence, however, as the "clutter" produced occurs at ranges almost entirely within the loudspeaker.

On the C.R.T., range marks and signals may be displayed separately, or combined, by operating the transmitter output and range mark amplitude controls. The range mark pulses are of the same polarity on the display as the echo signals. This is mainly for ease of changing over from A-scope to P.P.I. display, when the range marks produce rings on the C.R.T.

P.P.I. Display

A block diagram of the arrangement for P.P.I. display is given in Fig. 3.

For this display, video signals are obtained as before, but are now applied to the C.R.T. grid circuit. The radial time-base is obtained by phase splitting the time-base signal from the Miller-transitron oscillator and then applying it via cathode-followers to the two ends of a sine-cosine potentiometer. The sine-cosine potentiometer is mechanically coupled to the loudspeaker which is mounted and driven by a motor to rotate once every 20 seconds. Sine and cosine components of the time-base signal are applied to the X and Y inputs of the indicator to produce a radial timebase which rotates as the speaker rotates.

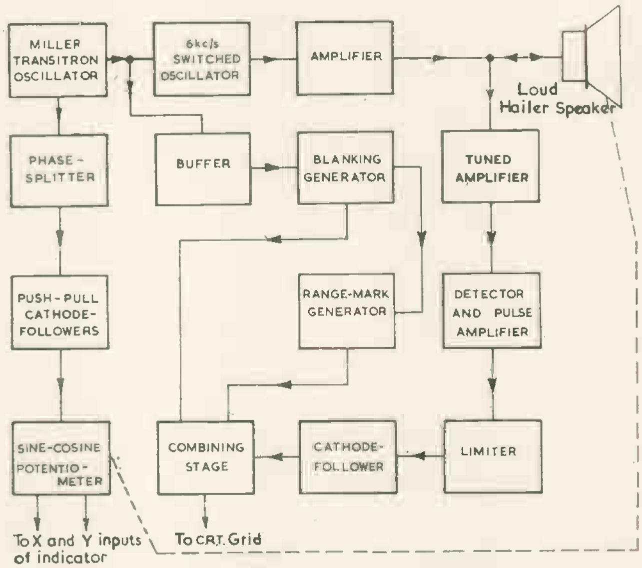


Fig. 3 The arrangement for P.P.I. display

Speaker and sine-cosine potentiometer coupled together and rotated once per 20sec by motor.

In order to "anchor" the start of the trace in the centre of the C.R.T. direct current components of opposite polarity are applied to the two ends of the sine-cosine potentiometer, their amplitudes being equal to the peak amplitude of the time-base signal. This is done in the cathode-follower stage. From the sine-cosine potentiometer onwards, D.C. coupling is employed.

The rotation of the loudspeaker once every 20 seconds and the P.R.F. of 22 gives 440 radial traces per revolution of the scanning system, or rather more than 1 trace per degree on the C.R.T. There are, therefore, gaps between the traces at the edge of the C.R.T., but no reflecting objects are missed when scanning, because the beamwidth of the speaker is several times wider than the amount it turns between one transmitted pulse and the next.

Circuits

The main circuit is shown in Fig. 4.

V_1 is a Miller-transitron oscillator which generates the time-base waveform and the transmitter switching pulses. Both the repetition frequency and pulse width are variable, being centred approximately on their nominal values of 22 P.R.F. and 1 millisecond pulse width.

The sawtooth waveform from the anode is fed directly to the X input of the indicator for the A-scope presentation or via the following stages to the X and Y inputs of the indicator for the P.P.I. display.

For the P.P.I. display the sawtooth signal is applied first to V_{2a}, which is a phase-splitter, then to V_3 which is a push-pull cathode-follower stage, and from there via the sine-cosine potentiometer to the X and Y inputs of the indicator.

This is done with the blanking signal alone applied to the C.R.T. grid so that the first 2ft 6in of range on the scan is blackened by the blanking pulse, and it is the start of the visible trace which is centred on the C.R.T. The reason for darkening the start of the trace has already been discussed.

The pulses generated in the screen-suppressor circuit of V_1 (see Fig. 2(b)) are used to switch the transmitter on during the flyback, and to synchronize the blanking and

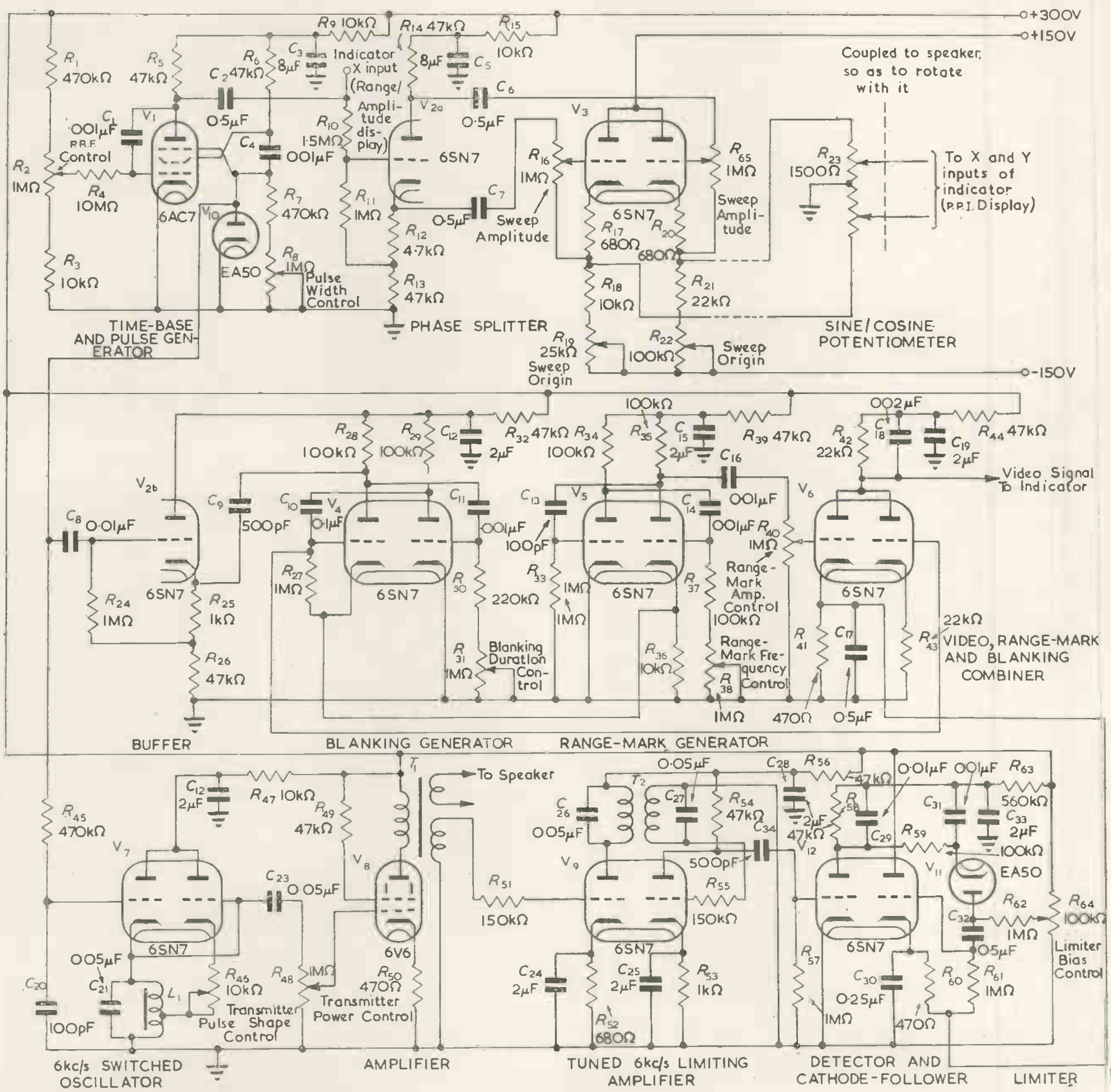


Fig 4. The main circuit (*Crown copyright*)

The H.T. supply to V_3 is +150V to the anodes and −150V to the cathode circuits. The cathode circuits are adjusted by means of R_{19} and R_{22} so that one lead to the since-cosine potentiometer is positive with respect to earth and the other is negative by amounts approximately equal to the peak value of the sawtooth signals. In practice R_{16} and R_{65} are adjusted so that the length of the trace on the C.R.T. equals the C.R.T. radius as the trace rotates, and the origin of the trace is centred by adjusting R_{19} and R_{22}.

range mark generators. V_{10} maintains the suppressor grid of V_1 at earth potential during scan periods.

V_{2b} is a buffer cathode-follower which isolates the blanking generator from V_1 and V_7. Its output is used to synchronize the blanking generator via C_9.

V_4, the blanking generator, is a multivibrator producing blanking pulses at the same frequency as the P.R.F. (see Fig. 2(d)). When it runs freely its own P.R.F. is lower than the lowest frequency of the time-base, and it is speeded up to the same frequency as the time-base by the synchronizing pulses applied from V_{2b}. The duration of the blanking pulses is controlled by R_{31}, and is set to 4·6msec approximately by placing an object across the mouth of the speaker and adjusting the back edges of the blanking generator pulses to coincide with the front edges of the echo pulses thus obtained.

Positive blanking pulses from the first grid of V_4 are fed to the combining stage V_6 and appear negative in the final output.

The first cathode of V_4 is directly connected to the second cathode of the range mark generator V_5 which is another multivibrator. This connexion ensures that during blanking pulses the second half of V_5 is biased off by the cathode current of the first half of V_4, and range marks are suppressed. At the end of each blanking pulse the first half of V_4 becomes non-conducting and V_5 is triggered into operation to generate the $\frac{1}{3}$ millisecond range mark pulses at a P.R.F. of 110 per second. The first range mark, therefore, occurs immediately after each blanking pulse. The P.R.F. of the range mark pulses is set by R_{38}.

Negative going range mark pulses are fed via the amplitude control R_{40} to the combining stage, V_6, and appear positive in the output.

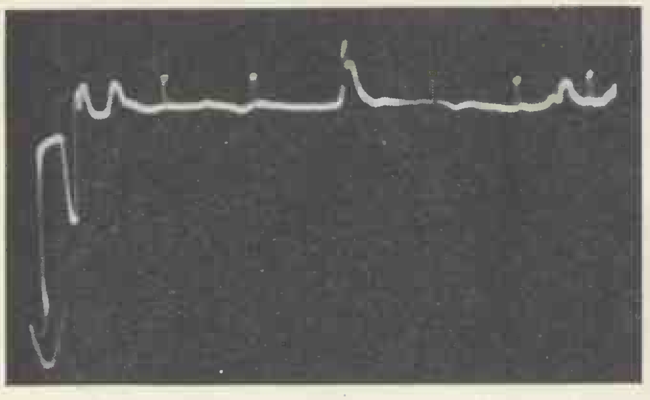


Fig. 5 (a). Range-amplitude display showing echoes at 2½ft, 15ft and 27-28ft

V_7 is the switched 6kc/s oscillator stage. The second half is an inverted Hartley oscillator, R_{46} being the feedback or amplitude control. When the first half of V_7 is conducting, oscillation is prevented because the tuned circuit is damped by the output impedance of the first cathode. The negative pulses applied to the grid of the first half cut it off, removing the damping and so kicking the tuned circuit into oscillation which is maintained by the second half. The input switching pulses are rounded off by R_{45} and C_{20} so that the initial oscillation is no greater than can be maintained by the oscillator. R_{46} is adjusted so that all the cycles in the oscillator pulses are of the same amplitude (see Fig. 2(c)). Oscillation is suppressed when the first half of V_7 returns to a conducting state at the end of each switching pulse. The output of V_7 is applied through a volume control R_{48} to the grid of the amplifier V_8.

The output transformer T_1 has two secondary windings. One, low impedance, feeds the loud hailer speaker, and the other, high impedance, is connected to the receiver input. Echo pulses are thereby stepped up in amplitude by the turns ratio of the two secondary windings.

Both transmitted pulses and received echoes go into the receiver, but the former are limited and the latter amplified by the receiver.

The first two stages of the receiver, in V_9, are coupled by a 6kc/s tuned transformer T_2. The bandwidth is adequate for the 6kc/s carrier signal and sideband components. The stages reduce the sensitivity of the receiver to room noises and raise the signal level prior to detection. R_{51} and R_{55} are grid limiters to limit the amplitude of the transmitter pulses. The cathodes are decoupled for higher frequencies only, affording a further reduction in gain at lower room noise frequencies. The second stage has a resistive anode load, R_{54}, and its output is fed to the detector.

The first half of V_{12} acts as a leaky grid detector and pulse amplifier. The transmitter pulses are further limited in this stage by the very low anode voltage and shortened grid base resulting from the large decoupling resistor R_{63}.

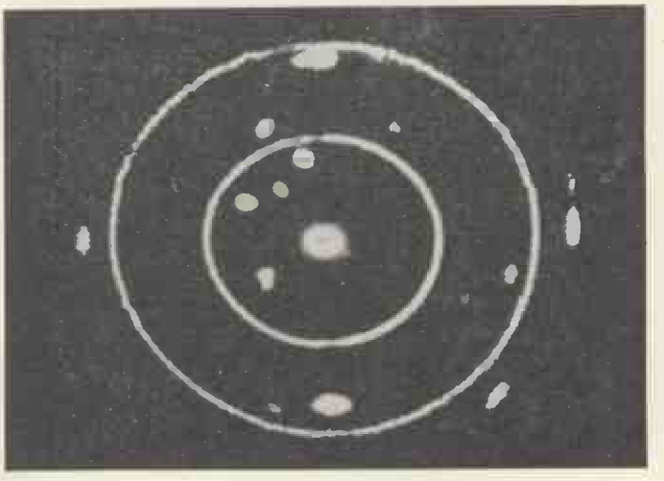


Fig. 5 (b). Short range P.P.I. display showing echoes up to 12ft

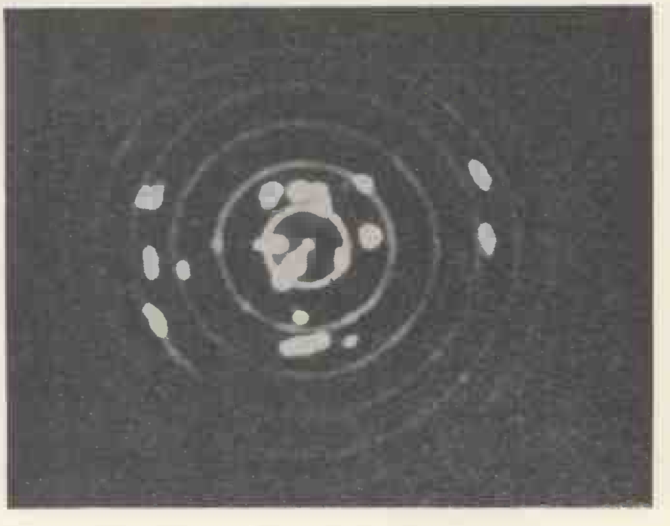


Fig. 5 (c). P.P.I. display with maximum range of 30ft

C_{29}, across the anode load R_{58} provides the first stage of 6kc/s filtering, and is followed by R_{59} and C_{31} which comprise the second stage.

The signals, which are positive going at this point, are then applied to the cathode of the diode limiter V_{11} whose anode is given a variable, normally set positive, bias from R_{64}. So long as the cathode potential of V_{11} does not rise positive with respect to its anode, it conducts, and signals applied to the cathode appear at the anode, across the load resistor R_{62}. Large positive pulses are limited at the point where their amplitude equals the positive bias on V_{11}.

From the limiter the signal is fed to the grid of the second half of V_{12} which is cathode coupled to the first half of the combining stage V_6.

Further filtering of the 6kc/s component is obtained from C_{30}, and R_{60}, which acts as bias resistor for V_{12} as well as filtering, in conjunction with C_{17} in the combining stage.

In the combining stage, V_6, variable amplitude range mark signals are applied to the first grid, blanking signals to the second grid, and video signals to the first cathode. The two anodes are connected to a common load resistor R_{42}. C_{17}, which acts as a filter for 6kc/s components of the video signal, decouples the first cathode of V_6 for higher frequencies and results in partial differentiation of the range mark signals. C_{13} across the anode load, however, squares up the range mark signals again and provides further filtering of the 6kc/s signals. R_{43}, in the cathode of the second half of V_6, sets the blanking signals to a convenient level.

The output of V_6, consisting of combined blanking, range mark and video signals as in Fig. 2(g), is fed to the indicator where it is applied to the Y input for A-scope display or to the C.R.T. grid for the P.P.I. display.

Indicator

The indicator is a 12in, long persistence C.R.T. which was originally part of a ground radar set. The console in which the C.R.T. is mounted houses the complete equipment with the exception of the loudspeaker system.

The associated circuits of the C.R.T. include X and Y amplifiers which are D.C. coupled, and have a maximum sensitivity such that a 4 volt peak-to-peak signal produces full screen deflexion. Photographs of the displays are shown in Fig. 5.

Acknowledgments

Acknowledgments are due to the Director of Navigational Services (Telecommunications) for permission to publish this article, and to Messrs. D. W. McQue and S. Langford, of the Civil Aviation Signals Training Establishment, who assisted with the construction of the equipment and contributed some of the ideas.

Anodige *

A New Discrete-Digit Voltage-Indicating Device

A NEW device has recently been developed at the U.S. National Bureau of Standards for obtaining readings of continuously variable unknown voltages, or other electrical quantities, in discrete digits. Measurements to the nearest three digits are registered on indicating lights or are printed on paper tape. At the Bureau the device is known as "Anodige", a name coined from "analogue-to-digital convertor".

In certain applications, electronic digital indicating systems offer important advantages over more conventional "analogue" indicators—those in which a pointer moves over a continuous scale, or in which the indication otherwise varies continuously with the measured quantity. In moving-pointer meters, speed of response is usually limited by mechanical characteristics of the meter, and the accuracy to which the meter can be read—about 0·5 per cent in precision analogue meters—is limited by a number of factors. By contrast, a current model of Anodige can make 400 or more readings a second and is accurate to 3 digits or 1/10th of 1 per cent of full-scale. Furthermore, Anodige gives electrical coded-pulse output suitable for recording or transmission—an important advantage in various electronic-computor and instrumentation applications. Development of Anodige was undertaken primarily to meet the need for instrumentation usable in conjunction with electronic digital computors.

It is essentially a device for counting electronically the number of equal, discrete voltage increments, of known value, required to equal the unknown voltage being measured. This is accomplished with an effective "analogue integrator" circuit that charges a capacitor in equal increments until the capacitor voltage reaches the unknown voltage.

Two models of Anodige have been constructed. In the first model, the measurement operation is automatically repeated 100 times a second. At the beginning of each measurement, a 100c/s programming oscillator turns on a 100kc/s master oscillator through an electronic switch. The analogue integrator starts simultaneously to build up D.C. voltage at the rate of one 1·0V step per master-oscillator cycle. The increasing voltage, E_i, across the integrating capacitor is fed to one side of a balance detector, and the unknown voltage, E_x, is applied to the other side. As soon as E_i equals E_x (or exceeds E_x by a fraction of an increment), the balance detector transmits a stop signal to the electronic switch. This turns off the master oscillator and stops the increase of E_i.

Meanwhile, three electronic decade counters have been counting the number of increments. While they are counting, their indicator units are blanked. The electronic switch, when it turns off the master oscillator so that the counters come to rest in their final count state, simultaneously unclocks the counter indicators. Subsequently, before a new programme is begun, the programming oscillator provides a reset signal that returns the decade counter and the analogue integrator to zero.

The speed with which Anodige can make a measurement is limited by the time required to apply the necessary number of voltage increments to the integrating capacitor, now being done at the rate of 100 000 increments per second. In the first model, the number of increments may be as high as 999. In the second model, a cascaded arrangement of three integrators reduces the number of increments to be counted to a maximum of 27, greatly increasing the possible speed of measurement. The first of the three integrators obtains the "tens" digit, the second then obtains the "units" digit, and the third furnishes the "tenths" digit. (The basic voltage increment is 0·1V in the second model, instead of 1·0V as in the first). This second model is currently being operated at a rate of 400 measurements per second, though this is far from the maximum speed attainable.

Two types of indication are being used with Anodige. Instantaneous readings are given by three rows of lights, 10 lights to a row; one light goes on in each row to give the three-digit measurement. Continuous recording is obtained on a moving three-inch-wide strip of electrosensitive recording paper. A dashed line, a dotted line, and a solid line are all printed at all times, but their positions vary with the voltage being measured. The position of the dashed line, any of 10 definite positions from zero to nine, indicates the "tens" digit, the position of the dotted line gives the "tens" digit, and the solid line gives the "tenths" digit.

At present, with 0·1V increments, Anodige reads 100 volts full scale. Now under development at the Bureau is a balance detector that is expected to be substantially more sensitive than the present one. This will make it possible to use a smaller basic increment, which in turn will permit a lower full-scale range. For instance, with 1mV increments the range would be 1V full scale.

* *Communication from M. Lorant.*

New Constructional Techniques

(Part 2)

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

FACTORS determining the form of construction of electronic equipment were discussed in Part 1 of this article, which appeared in the previous issue together with the bibliography.

The techniques described here relate particularly to potted and printed circuits. A great deal of work is going on towards the general miniaturization of components, and to improve the reliability and operating temperatures of existing components, as reported from time to time in this journal. Parallel developments in the U.S.A. have been put on record in the published proceedings of two recent conferences[7,8].

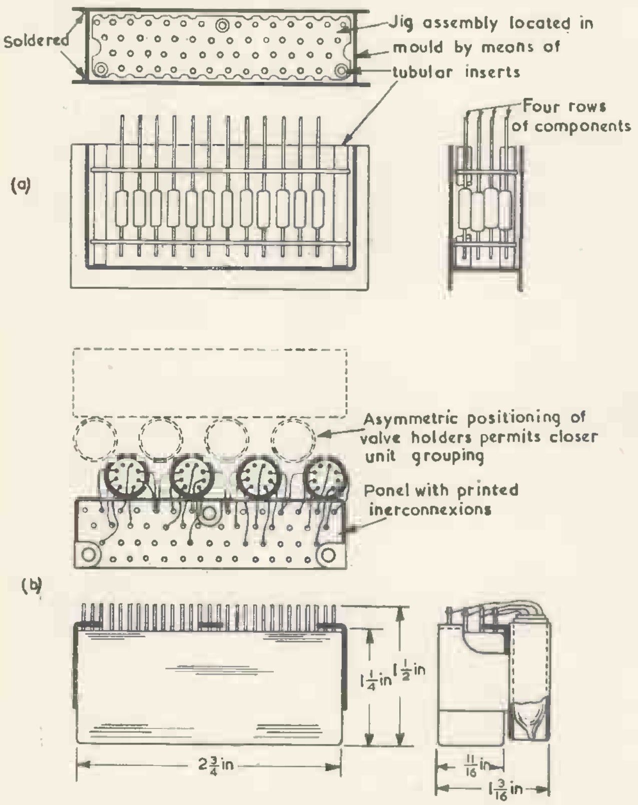


Fig. 10. Typical assembly of four-valve potted circuit
(a) Jig assembly in mould, (b) complete with sub-miniature valves in cooling sleeves.

Potting Technique

The potting of electrical apparatus in wax or bitumen compounds was carried out for many years, but it is only recently that plastics suitable for this purpose have become available, in the form of cold-polymerizing casting resins. There is no doubt that the small sub-unit is now an essential part of modern electronic equipment, and potting techniques lend themselves to this construction, provided that means are available to dissipate the heat developed. The resins are relatively expensive, and mechanically and economically are not attractive for castings exceeding a few inches in major dimensions.

The casting resins are converted into rigid plastics by the addition of a catalyst and accelerator, without the application of the considerable pressures and temperatures normally associated with the polymerization of thermosetting resins. A cast circuit unit has the advantage that each component is encased to protect it against mechanical shock, vibration and the effects of humidity. No mounting brackets, tag strips or chassis are necessary other than one or two simple strips of plastic to hold the components together, and these can carry the printed circuit for the interconnexions, so that the number of soldered connexions is reduced considerably.

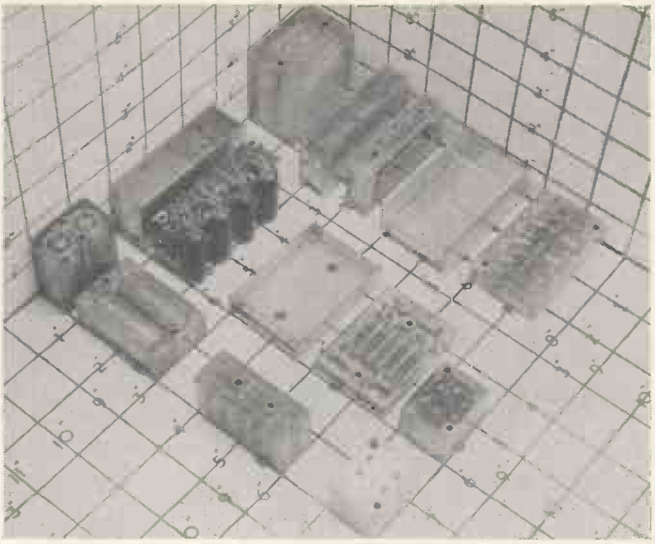


Fig. 11. Specimens of potted circuit "bricks."

A typical arrangement is shown in Fig. 10 and specimens of circuit "bricks" in Fig. 11. The former unit weighs 109 grammes, of which one-third is resin, one-third valve sleeves, and one-third valves and components. Units of the same shape and with identical fixing centres are preferable, since they can be mounted back to back and in rows with the minimum of waste space. Considerable economy in wiring can be obtained by providing supply points at both ends of a "brick", so that common heater and anode supplies can be provided with short interconnexions. Conducting gauze, preferably silver plated, may be used as an internal screen in the brick.

There are four main classes of potting resin:

- rigid
  - (a) Polyester resins (Marco, etc.)
  - (b) Ethoxyline (epoxy) resins (Araldite, Epikote)
- flexible
  - (c) Polyurethane resins
  - (d) Casting rubbers

The first two are generally available in this country. Polyesters seal by shrinkage, and to avoid excessive internal strains the cross section of any rigid member protruding from the cast block must be small, for example connecting wires or small diameter studding or tubes. Some of the

* *Ministry of Supply, Telecommunications Research Establishment.*
† *Elliott Brothers (London) Limited.*

ethoxyline resins require heat to polymerize, which may exceed that which certain components can withstand. On the other hand these resins are good adhesives, and so seal well against moisture. The cold setting versions adhere best to surfaces which at some stage of manufacture have been coated with a hot-setting ethoxyline resin.

The polyurethane resins are a new and large group which is not yet generally available. Those made by cross-linking castor oil with tolylene di-isocyanate have potential uses as casting resins, and they also provide good sealing by adhesion. They have the advantage of being flexible throughout the temperature range of −40 to +100°C, whereas the first two resins are hard solids. This overcomes the effect of internal strains due to differential coefficients of expansion in the components of a potted assembly. The material also has a very high damping factor, so the effects of shock and vibration on fragile components such as valves are minimized.

Rubbers of the natural and synthetic types are usually met with in vulcanized form, but they may also be cast from a latex dispersion. These are modified by a thermo-chemical treatment to form high viscosity liquids, known as depolymerized rubbers, and become a typical rubber-like solid after heating in a mould for 1-4 hours at about 120°C. Excellent electrical and mechanical properties are obtained over the temperature range −40 to +100°C. These flexible materials can be used for sealing the backs of miniature plugs and sockets to preserve the "float" necessary to allow mating between pin and socket.

The reaction temperatures experienced in a particular application of polyester resin are given in Table 1, for a one-inch cube cast in a metal can.

TABLE 1

Minimum Reaction Temperatures

TYPE NO.	CATALYST CONTENT (PERCENTAGE)	ACCELERATOR CONTENT (PERCENTAGE)	GELLING TIME (MINUTES)	MAXIMUM REACTION TEMPERATURE (DEGREES CELSIUS)
1	0·5	1	270	27
2	1	2	60	96
3	2	2	10	115
4	2	4	5	121

It is unsatisfactory to permit an excessive temperature rise, for internal strains may remain even if at first no visible cracks appear. Some trials are necessary to find the best conditions in particular cases, as the polymerization reaction is exothermic and also dependent on temperature. In an extreme case this could lead to an explosion of the specimen, particularly if it is large in volume and the internally generated heat is unable to get away.

It is desirable to use small proportions of catalyst and accelerator, and speed up the reaction somewhat by external heating in an oven, so that the reaction is stabilized by being less dependent upon the heat generated exothermically, and there is also less wastage of resin when mixed in quantity for production use.

Certain materials such as bare brass and copper surfaces inhibit the action of the catalyst, so that the resin does not harden: such surfaces should be tin or silver plated. Some shrinkage occurs during setting, and the concave surface remains "tacky" due to neutralization of the catalyst in contact with the air. A level hard surface can be obtained before the mass has completely gelled by flooding the concave surface with a thin layer of resin containing a higher proportion of catalyst and accelerator.

Exhibition models and museum specimens are made in clear plastic, but for heavy duty service it is more practical to use loaded resins, the strength thereby being increased, as in concrete by the addition of aggregate to pure cement. It is, however, useful to make prototypes in clear resin, because any points of stress concentration will then be observed, and can be reduced by modifying the internal structure, which should be as open as possible. Then, on using a loaded resin, the additional strength and reduced coefficient of expansion will confer a margin of safety.

The following mixtures have been found suitable for most castings:

	Parts by Weight
Polyester resin (type Marco 28C)	100
Catalyst	1
Accelerator	1
Mica flour (200 mesh) ...	25
Ethoxyline resin (type Araldite B)	100
Hardener	25
Calcium carbonate	60
or mica flour	25

In handling these resins it is important to remember that they may act as an irritant in contact with the skin, and a barrier cream should be applied to avoid dermatitis.

The characteristics of casting resins loaded with various fillers are given in Table 2:

Other electrical and mechanical properties of polyester and ethoxyline casting resins are given in Tables 3 and 4. Some of the types of resin referred to are not yet available in this country.

Moulds for polyester resins can be of soldered tinplate, polythene, P.T.F.E. or unplasticized P.V.C., and a cellophane lining may be used.

The adhesive property of ethoxyline resins is such that the choice of mould materials is limited. Silicone mould

TABLE 2

Characteristics of Loaded Casting Resins

FILLER	COEFFICIENT OF LINEAR EXPANSION (AT 60°C.)	THERMAL CONDUCTIVITY	WATER ABSORPTION *	SPECIFIC GRAVITY	COMPRESSIVE STRENGTH	TENSILE STRENGTH	BRINELL HARDNESS †	ELECTRIC STRENGTH	POWER FACTOR FROM 1 TO 100 MC/S.	PERMITTIVITY FROM 1 TO 100 MC/S.
	($\times 10^{-6}$)	W/in²/°C/in $\times 10^{-3}$	mg.		lb/sq in	lb/sq in		volts/mil	tan δ	
Polyester resins—										
None	97	6·5	50	1·23	18,000	7,000	49	250–300	0·0180–0·0160	3·30–3.10
Mica (25%) ..	65	7·4	50	1·38	19,600	5,000	49	400	0·0213–0·0176	3·62–3.44
Glass (60%) ..	70	7·3	40	1·55	25,000	5,000	49	380	0·0165–0·0160	4·53–4·25
Alumina (100%)	70·5	10·9	60	1·87	26,600	3,700	76	270	0·0194–0·0177	5·05–4·80
Calcium carbonate (65%)	84	6·9	50	1·50	18,500	4,250	65	280	0·0173–0·0164	4·75–4·51
Ethoxyline resins—										
None	72	8·0	24	1·20	15,900	9,700	—	320	0·029 –0·020	3·90–3·60
Mica (25%) ..	43	12·0	22	1·41	5,700	5,650	—	420	0·035 –0·026	4·05–3·70
Glass (60%) ..	—	12·0	24	1·52	—	—	—	370	0·026 –0·023	4·05–3·75
Calcium carbonate (60%)	57	8·0	24	1·20	7,540	6,000	—	370	0·026 –0·023	4·45–4·05

* *7-day test similar to B.S.972 : 1941.* † *500kg. load ; 10mm. ball.*

TABLE 3 Casting Resins—Polyester Type

RESIN	MARCO 28C	MARCO 28C	LAMINAC 4128	LAMINAC 4128	BAKELITE 17438 } Mixed 17431 }	BAKELITE 17431	CATALIN 477G
Filler	None	Mica	None	Mica	None	None	None
Specific gravity	1·23	1·38	1·22	1·331	1·23	1·24	1·221
Water absorption after 7 days' mg.	47	47	—	—	—	—	—
Coefficient of linear expansion (at 60°C) $\times 10^{-6}$	97	65	128	80	162	—	158
Thermal conductivity (watts/-in²/°C/in)	0·0065	0·0074	0·0070	0·0086	—	0·0088	—
Permittivity	Permittivity varies with catalysing and cure—usually between 3·0 and 4·0						
Loss angle tan δ	All these resins have high loss at R.F.—tan δ usually between 0·005 and 0·03.						
Catalyst	H.C.H.	H.C.H.	LUPERSOL D.D.M.	LUPERSOL D.D.M.	LUPERSOL D.D.M.	LUPERSOL D.D.M.	B.P.
Accelerator	Cobalt Naphthenate	Cobalt Naphthenate	Cobalt Naphthenate	Cobalt Naphthenate	Cobalt Naphthenate	Cobalt Naphthenate	Cobalt Naphthenate
Method of curing	Room Temp.	Room Temp.	Room Temp.	Room Temp.	Room Temp.	Room Temp.	Room Temp.
Remarks	Good general-purpose resin	Good general-purpose resin Mica lowers expansion rate and improves electrical qualities	—	—	Two resins mixed to provide flexibility	Very clear resin but hard and brittle	—

TABLE 4 Casting Resins—Ethoxyline Type

RESIN	ARALDITE B	ARALDITE B	EPIKOTE 828	EPIKOTE 828	EPIKOTE 834	EPIKOTE 834	ARALDITE D	ARALDITE D	ESSELEN 22361
Filler	None	Mica	None	Mica	None	Mica	None	Mica	None
Specific gravity	1·2	1·41	1·184	1·326	1·184	1·328	1·193	1·250	1·264
Water absorption after 7 days mg.	22	21	20	20	20	20	30	—	25
Coefficient of linear expansion (at 60°C) $\times 10^{-6}$	72	43	80	56	66	51	138	119	—
Thermal conductivity (watts/in²/°C/in	0·008	0·012	0·009	0·012	0·008	0·013	0·0083	0·0096	—
Permittivity	Permittivity varies with catalysing and cure—usually between 3·0 and 4·0								
Loss angle tan δ	All these resins have high loss at R.F.—Tan δ usually between 0·01 and 0·04.								
Catalyst or hardener	25% 901	25% 901	6% Piperidine	6% Piperidine	6% Piperidine	6% Piperidine	10% 951	10% 951	2236–2A
Method of curing	14 hrs. at 120°C.	14 hrs. at 120°C.	3 hrs. at 100°C.	3 hrs. at 100°C.	3 hrs. at 100°C.	3 hrs. at 100°C.	Room temp. followed by 30 hrs. at 80°C.	Room temp. followed by 30 hrs. at 80°C.	Room temp.
Remarks	Excellent resin with low shrinkage. Curing temperature very high	Excellent resin with low shrinkage. Curing temperature very high	Excellent resin with low shrinkage. Pours at room temperature	Excellent resin with low shrinkage. Pours at room temperature	Excellent resin with low shrinkage, but high viscosity and short pot. life	Excellent resin with low shrinkage, but high viscosity and short pot. life	Low Viscosity room temp. gelled resin long curing cycle for stability	Low Viscosity room temp. gelled resin long curing cycle for stability	Low Viscosity room temp. gelled resin of U.S.A. origin

release liquids, carnauba wax and silicone rubber coatings have been used, but the best parting is obtained with P.T.F.E., either in massive, film, dispersion or rubbed-on forms.

The resin must be poured into the mould with care, so that bubbles of air are not trapped, and it may be necessary for the filled mould to stand under vacuum for a time. Many thermo-plastic materials, such as polystyrene, etc., are attacked by the resin, and should be used with care.

Manufacturing Conductors

A great many methods of producing conducting patterns have been developed experimentally[1,4,5,6], but the ones that have come into general use are silvered conductors screen-printed as an ink on to ceramic bases and fired, and

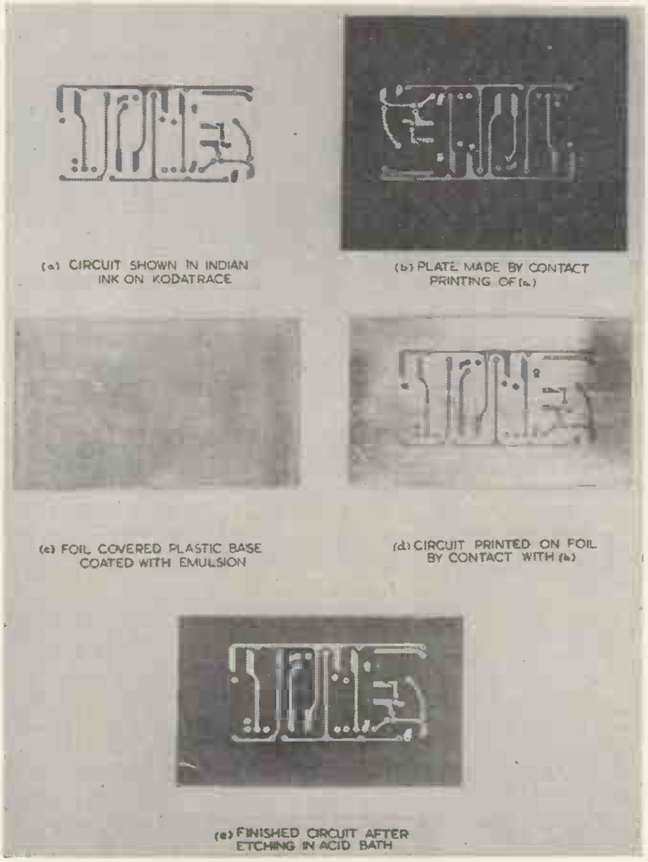


Fig. 12. Stages in the production of etched foil circuits

copper foil bonded to a suitable base and etched (Fig. 12). The former is particularly satisfactory for small assemblies such as hearing aids, multiple components and interstage couplings (Fig. 7 of Part 1) particularly as interconnexions from one side of the plate to the other can be made by silvering through holes.

The etched foil technique can be used to provide units of very low cost, and has been applied in the U.S.A. to radio receivers and switched television tuners[58,59]. It has also been used to make strip waveguide devices[28,30] at much less cost and more compact than their solid counterparts.

A considerable range of firing silver inks is available from several sources suited to particular applications. The adhesion obtained on ceramic and glass is excellent, and sliding contacts such as plugs and wafer switches can be made up to withstand 30 000 operations. Good results are obtained by screen printing with a silk or metal screen, this form of printing being preferred because it gives an ink deposit of up to 0·01in, whereas other methods of printing generally give less than 0·001in. Automatic screen printing machines have been made[32], and accuracies of 0·005in in a 12in length have been claimed[33]. It is usual to protect ceramic-based circuits against a tendency to tracking when dust accumulates by baking on a suitable coating resin.

Photo-etched circuits can be produced very economically by photo-printing a resist image of the circuit on a sheet of synthetic resin paper laminated board with copper foil bonded on each side. A large sheet is frequently employed, with the circuit repeated many times. The foil is usually about 0·001in in thickness, the bond strength of the adhesive being insufficient to withstand the elastic stress developed by the temperature difference in a thicker foil when dip-soldering. Flexible bases have also been used, and it is practicable to form a multi-layer transformer winding by folding (Fig. 13).

Plug and socket systems have also been developed integral with this form of printed circuit[36], on thin base laminate conferring the flexibility necessary in a multiple connector, and a neoprene gasket providing the contact pressure and locking action.

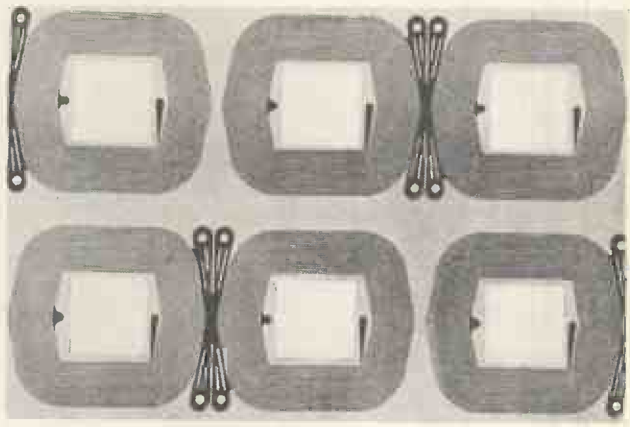


Fig. 13. Transformer winding of etched copper on foldable backing (*Technograph Printed Circuits Ltd.*)

Small coils can be printed, but the stray field associated with a flat or printed coil usually limits the diameter to about one inch; such coils can be useful at television frequencies. The inductance can be adjusted by backing the coil either with iron-dust powder (to increase inductance) or with a metal powder (to reduce it). The undamped Q factor is only about half that obtained with normal coils, and some of this loss is due to the relatively rough edge of the printed or etched pattern. The power factor of potting resins is considerably higher than that of polythene or polystyrene, so if a coil is potted a further loss of Q will be observed from this cause. The Q will be particularly low if the resin is not completely cured.

Mechanized Soldering

The assembly of miniaturized equipment by conventional means requires the use of pencil-bit soldering irons handled with skill. If the circuit unit is designed to bring all connexions out in one or two horizontal planes (as in Fig. 10) all points can be made simultaneously by dip-soldering[25,26,27].

In the direct method the end plate with printed wiring and projecting component leads is dipped in a hot solder bath which has a film of palm oil to reduce oxidation. Using an eutectic solder (63 per cent tin, 37 per cent lead) at a temperature of 240°C a 5-second dip is sufficient and short enough to avoid overheating the components. It is necessary to insert and withdraw the plate at a slight angle

I

because of the surface tension of the solder. All wires and conductors should have a clean tinned or silver plated finish, and be pre-fluxed by dipping. The solder bath must be skimmed at intervals, and plates can conveniently be drawn through by a simple conveyor to which a series of skimming paddles are attached.

Where close spacing of solder connexions is essential bridging of the solder can be avoided by using perforated masks to allow the solder to rise by capillary action where required.

Printed circuits on ceramic and glass bases can be soldered by oven heating, as the base can withstand the temperature. Solder-flux pastes are used, or solder rings dropped over connecting wires, where they pass through holes in the base. It is advantageous to use an inert atmosphere to prevent oxidation of silver surfaces.

Resistors for Printed Circuits

Resistors are the components most easily "printed", as neither inductors nor capacitors can be manufactured integral with the base except for a limited range of the lower values.

Three broad methods of application exist:

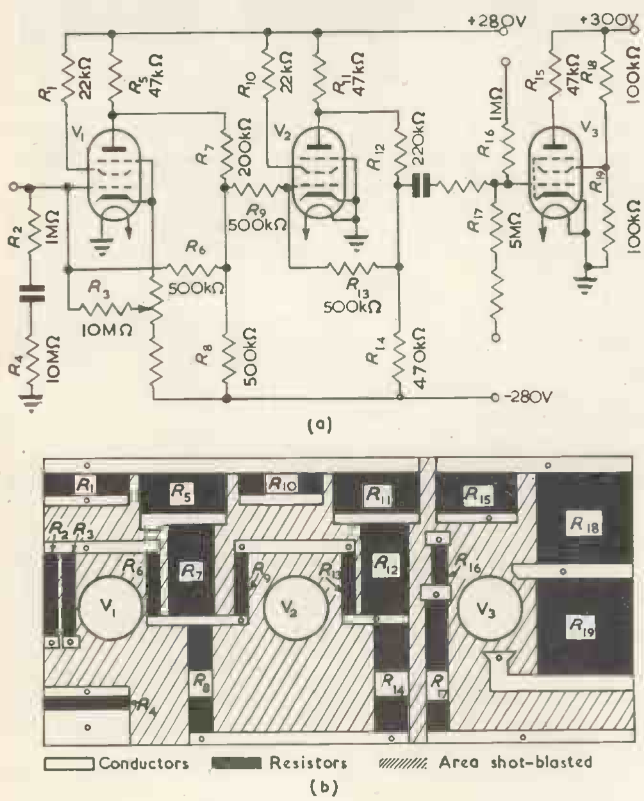
(a) aspect ratio approach,

(b) tape resistors,

(c) automatically adjusted resistors.

An example of a three-stage servo amplifier with aspect ratio resistors is given in Fig. 14. The plate is either uniformly coated with a graphite dispersion and shot-blasted, or sprayed through masks to provide the rectangles of resistance material. The area of these is proportional to the wattage rating that is required, and the rectangular proportions or aspect ratios are chosen to provide the desired resistance values, the resistance of a unit square in this instance being 100kΩ on the side of the plate illustrated, and 1kΩ on the reverse side where are situated the low value resistors unnumbered in the circuit diagram. The permissible wattage rating of printed resistors depends upon the total heat dissipated by the particular circuit and the method of cooling, but will be of the order of 1 watt per square centimetre for a ceramic base $\frac{1}{8}$in to $\frac{1}{4}$in thick, or about $\frac{1}{4}$ watt per square centimetre for 1/16in laminated board.

Fig. 14. Servo feedback amplifier using ratio resistors



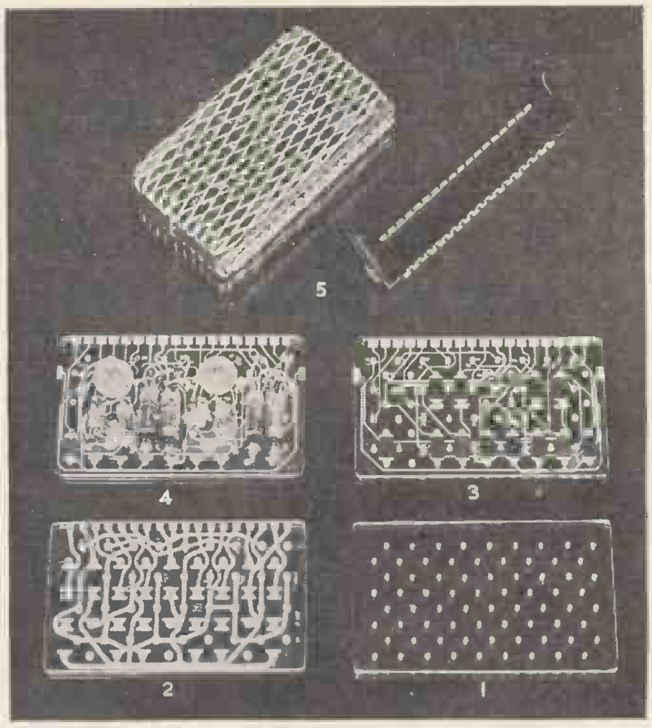


Fig. 15. Stages in the production of circuits on glass plates 5in × 3in

(1) Glass with pattern of 72 holes, (2) silver circuit printed and fired, (3) resistors sprayed on, baked and engraved, (4) four sub-miniature valves and other components fitted, (5) enclosed unit with 18-way socket.

Tape resistors were originated by the National Bureau of Standards in order to facilitate control of the application process and resulting value of resistance[43]. Asbestos tape is coated with a graphite dispersion by repeated spraying, and partially cured. It is then cut into pieces of the desired sizes, such as the rectangles in Fig. 14, and bonded in position.

One form of automatically adjusted resistor is shown in Fig. 15, an application to digital computors[53], where nearly all resistors are of a low rating, not exceeding $\frac{1}{2}$ watt. It is then possible to standardize the size of the rectangle (1cm by $\frac{3}{4}$cm), and arrange them in standard positions on a ceramic or glass plate 5in by 3in, having 72 holes in a regular pattern. Any circuit can be provided by interchanging the printing screens and dispersion spraying masks, using the standard base plate without re-tooling. The rectangles are brought to the desired resistance value by "zig-zagging" (the equivalent of "spiralling") with an engraving head controlled by the actual resistance value to increase the initial value up to 100 times. All resistors on a plate are brought to value by simultaneous operations in under a minute, and subsequently protected by a baked varnish coating.

These three resistor application processes have been described in relation to graphite-resin dispersion coatings, which themselves can be formed by screen printing, dip or "doctor-blade" coating or spraying over a wide range of resistance per square, by varying the mixes. It is not easy to control the processes of either depositing or baking to within the usual ±20 per cent resistor tolerance except on a continuous basis and with temperature controlled within a few degrees. The improvement resulting from automatic control of the spraying process[41,42] is shown in Fig. 16. Because of these limitations it is necessary in many applications either to adjust to value individually, or employ the sorting technique used in manufacturing individual composition resistors.

Pyrolytic film resistors generally have a stability performance approaching 1 per cent, superior to all but the best of baked-on dispersions[40], but their use in printed techniques is limited to the form shown in Fig. 14. Metal films[39] can be deposited in patterns, and have very good stability characteristics (approaching 0·1 per cent) up to a resistivity of a few hundred ohms per square. Individual values can be increased with fine zig-zag patterns, but it is not easy to provide above a megohm in a convenient size. Foil resistors, etched from foil bonded on a plastic film backing Fig. 17 are, of course, limited to quite low values of resistance, but their stability approaches a part in a million and consequently they are excellent as strain gauges[28].

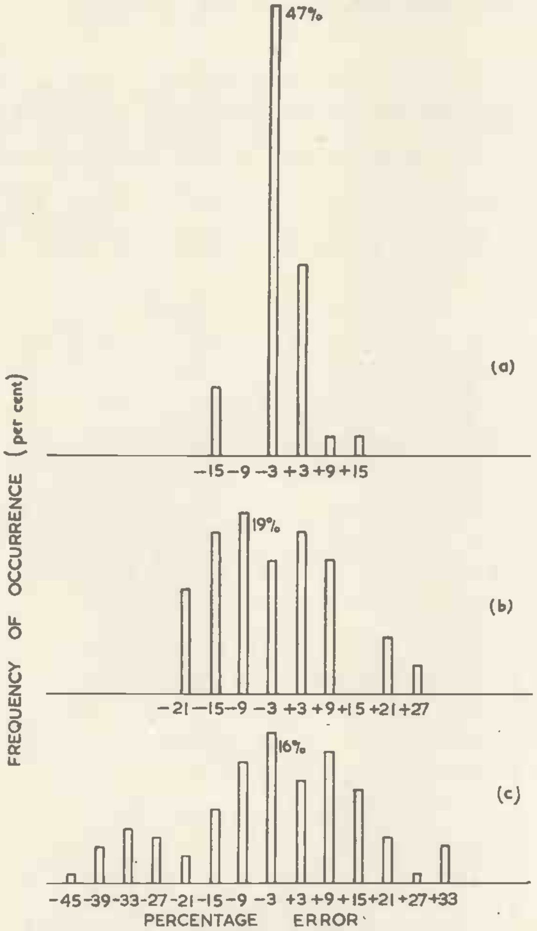


Fig. 16. Effect of controlling resistor spraying process

(a) automatic traverse and feed (b) automatic traverse only (c) hand spraying

The Automatic Factory

The advantage of automatic processes is that statistical control of quality becomes possible. If a girl operator is soldering joints all day, it is statistically certain that occasionally something will distract her attention, and a dry joint will be produced, and now and again these will escape the inspector. Now if an automatic dip-soldering process is used, the product will tend to be extremely uniform. Should the temperature or the flux-application be wrong, the product will be uniformly bad, which will be obvious if an elementary record of quality control is kept. When the quality is good, chance works on our behalf instead of against us, for it is statistically unlikely that a chance fault will occur.

We have today automatic process control in the chemical and oil refinery industries, and semi-automatic assembly of motor cars but not yet is there automatic continuous production even of radio valves. The reliability inherent in such production, which is needed for the future application of electronics, will only come if there is sufficient demand for individual valve types or circuits to justify such methods, which necessarily involve a large capital investment in development and plant.

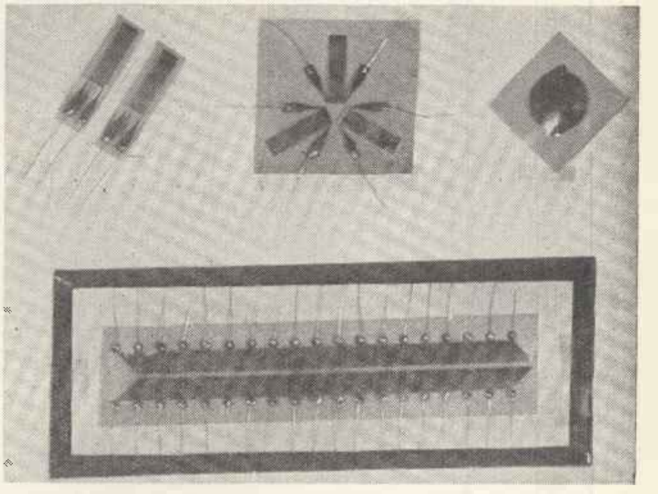


Fig. 17. Resistance strain gauges of etched platinum foil

No individual manufacturer can show immediate short-term economies by adopting the new constructional techniques that have been outlined here, and this is the reason why so much has been said and published about printed circuits and allied techniques, but so little of it applied.

There is, however, no doubt that automatic manufacture can provide a considerable step forward in reliability and economy of unit cost, and it is to be hoped that by rationalization of demand a suitable subject can be found for a full-scale trial.

Acknowledgments

The authors are indebted to the Chief Scientist, Ministry of Supply, for permission to publish this article.

Italian Band III Television

The Italian television stations at Rome and Pisa employ what are probably the first British built band III (174-216Mc/s) transmitters of medium power. These transmitters, which have been built by Marconi's Wireless Telegraph Co., Ltd, are designed to meet C.C.I.R. and R.M.A. standards and both sound and vision transmitters are rated at 2·5kW. An amplifier which will increase the vision power to at least 7½kW is under construction, and the addition of this unit will enable the Stockholm plan to be met in respect of sound and vision power ratios. High-level modulation is employed in the vision transmitter which is used in conjunction with a vestigial filter. Coaxial line techniques are used exclusively in the high power R.F. stages of both vision and sound transmitters.

Mechanically, the transmitters are built on the unit principle and are installed in line. Apart from the fan, automatic voltage regulator, vestigial sideband filter and combining unit they are self-contained. Control is by means of push buttons so making unattended operation practicable. To this end high speed overload protection circuts are incorporated, Xenon type rectifier tubes are employed and reflectometers—for continuous monitoring of standing wave ratios in the feeder—are provided. Each transmitter functions quite independently and incorporates its own power supply circuits.

Characteristics of the Temperature-Limited Diode Type 29C1

By F. A. Benson*, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E., and M. S. Seaman*, B.Eng.

The characteristics of several Mazda Type 29C1 diodes have been investigated. Details are given of the static characteristics of the valves together with some information obtained from long-term tests.

THE use of the Mazda Type 29C1 diode as the controlling element in a voltage stabilizer[1] and also for measurement purposes[2] has already been described. Very little information about the characteristics of the diodes has been published, however. The present article describes tests on nine of these diodes, the nine consisting of three lots of three from different production batches. The investigations have been concerned with the variations in the static characteristics of the valves and the effects of fairly long term continuous operation.

The Static Characteristics

The circuit used for testing the valves is shown in Fig. 1. The filament voltage was measured with a potentiometer, in conjunction with a potential divider since it was found

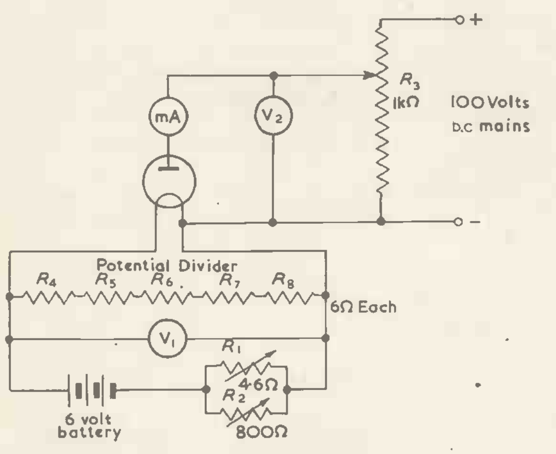


Fig. 1. Test circuit for 29CI diode

that meter accuracy was not good enough. The divider consisted of five nominally-equal resistors, and was calibrated by measuring the voltage across each section in turn with the voltage across the chain maintained constant. Fine control of the filament voltage was obtained by shunting the main variable resistor, R_1, in the filament supply lead with a second variable resistor, R_2, of higher value. Filament power was obtained from a six-volt accumulator, and anode power from 100 volt D.C. mains.

Tests were carried out on the diodes at constant filament voltages between 3·4 and 4·2 volts, the voltage being kept constant during a test to within ±0·001 volt. Readings of anode current were taken for anode voltages between 20 and 100 volts.

* *The University of Sheffield.*

Each valve was tested on at least three different occasions, and the results of these tests show that the characteristics are readily reproducible, although three of the valves tested required a short running-in period before they settled down. During this period, the anode current at given anode and filament voltages rose by amounts varying from approximately 2 per cent to 16 per cent from the initial value to the final steady value.

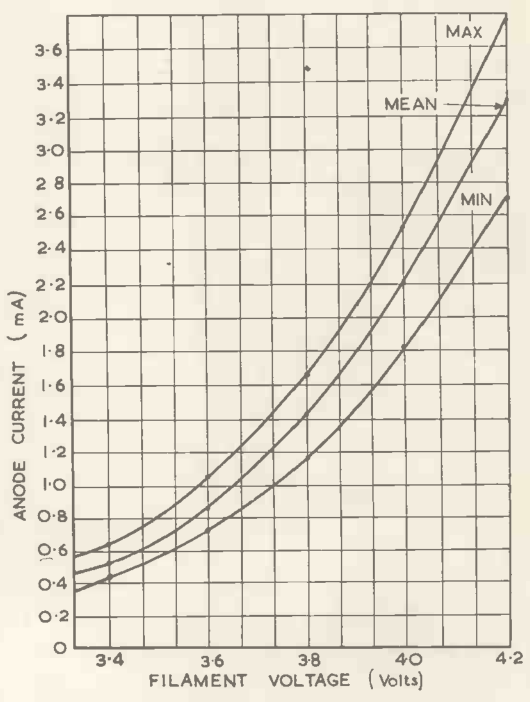


Fig. 2. Anode current/filament voltage curves
Anode voltage = 85V

This effect was in general complete within about the first 10 to 20 hours of operation.

The valves were also tested at filament voltages as low as 3·0 volts, but from these tests it would appear desirable not to operate the valve at filament voltages below 3·4 volts, as the characteristics are then somewhat unreliable.

It was found advisable to allow the valve to settle down for a few minutes after changing the filament voltage, as small drifts in anode current occurred. This was especially so after switching on from cold, when a drift of about

2-3 per cent occurs in the first five minutes. This is probably due to the high filament temperature causing appreciable changes in the dimensions of the electrodes, etc. After this initial warming-up period, the valve is quite stable and, as stated by Attree[2], is practically uninfluenced by changes in ambient temperature.

The characteristics of the valves when run at constant anode voltage are shown in Fig. 2. These characteristics are all of a similar nature, but as will be seen, quite large variations in the anode current at given anode and filament voltages were observed. Table I gives the variation from the mean value of the anode current for a filament voltage of 4·0V and an anode voltage of 80V. It is seen that two of the nine valves differed from the mean value by over 15 per cent.

As the valve operates in the saturation region one would expect the anode current to be practically independent of the anode voltage. This is so as shown in Fig. 3, which gives the mean of the tests on the nine diodes. It will be

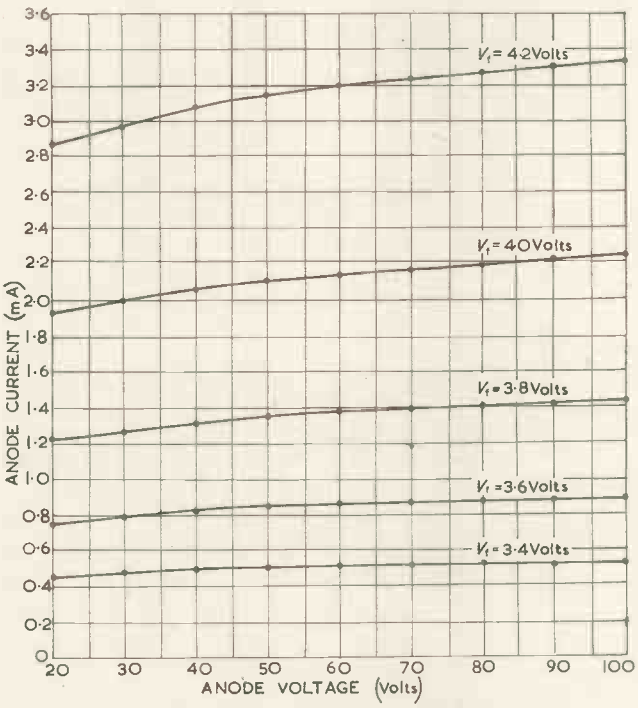


Fig. 3. Constant filament voltage operation
Mean of test on nine valves

seen that the anode current increases by about 17·5 per cent as the anode voltage is increased from 20 to 100 volts. This increase varied from about 12 to 21 per cent among the nine diodes, and the rate of increase at 100V is approximately one-third of that at 20V.

The anode current can be related to the filament voltage by a law of the type $I_a = k.V_f^n$, for constant anode voltage. The value of the index n is practically independent of the anode voltage in the range 30 to 100 volts, but it depends on the filament voltage. The values of n found in this series of tests are given in Table 2. Due to the limitations of the meters used, these values may be in error by as much as ±0·1.

TABLE 1

Characteristics of 29C1 Diodes at a Filament Voltage of 4.0V and Anode Voltage at 80V.

VALVE NUMBER		ANODE CURRENT (mA)	DIVERGENCE FROM MEAN ANODE CURRENT
First Batch	1	2·32	+0·14mA.= 6·4 per cent
	2	2·09	−0·09mA.= 4·1 „
	3	2·13	−0·05mA.= 2·3 „
Second Batch	4	2·23	+0·05mA.= 2·3 „
	5	1·81	−0·37mA.=17·0 „
	6	2·04	−0·14mA.= 6·4 „
Third Batch	7	2·31	+0·13mA.= 6·0 „
	8	2·52	+0·34mA.=15·6 „
	9	2·20	+0·02mA.= 0·92 „

Mean Anode Current=2·18mA.

Overload Tests

A few of the diodes were tested at ratings considerably in excess of the maker's maximum limits (max. anode voltage is 100V, and anode current is 3mA), and appeared none the worse for the experience.

TABLE 2

Values of the Index n in the Relationship $I_a = KV_f^n$

AVERAGE FILAMENT VOLTAGE (V)	n
3·3	9·3
3·5	9·0
3·7	8·9
3·9	8·6
4·1	8·4

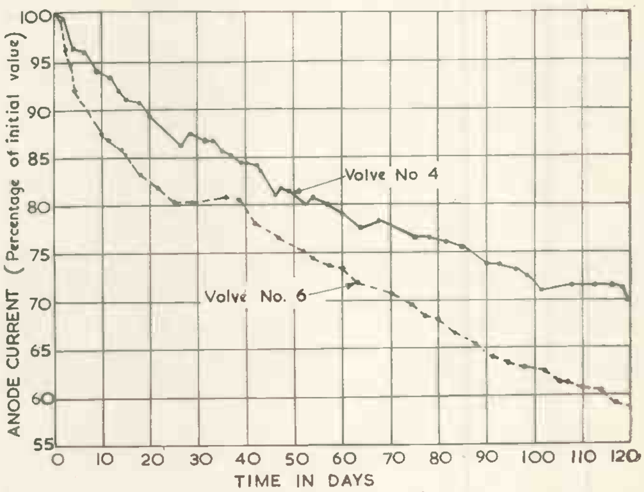


Fig. 4. Life tests on valves 4 and 6
V_4 : V_f = 3·5V, V_a = 90V, initial I_a = 0·704mA
V_6 : V_f = 4V, V_a = 90V, initial I_a = 2·09mA

For anode voltages up to 200 volts, the curves for constant filament voltage operation are in general continuations of those for the range 20-100 volts. The rate of increase of anode current with anode voltage is practically constant for voltages in excess of 100 volts.

For filament voltages up to 4·35 volts (anode currents up to approx. 5mA) the curves for constant anode-voltage operation are again continuations of those obtained within the specified ranges. It should be noted that at a filament voltage of 4·35V, saturation is not complete for anode voltages below about 30 volts.

Long-Term Tests

Four diodes were put on test to determine the manner in which the anode current varies with life when run at constant filament and anode voltages.

The circuit used was basically similar to that of Fig. 1, except that it was modified to allow operation of the valves without meters being permanently in circuit. Provision was also made for charging the filament supply battery from the mains.

Two of the valves were operated at ratings within the maker's limits, and two under overload conditions. The first two were both operated at an anode voltage of 90 volts; one of these was run at a filament voltage of 3·5 volts and as it showed no signs of having reached a settled condition after five weeks of continuous running, another was put on test at a filament voltage of 4·0 volts to see if it would settle down quicker.

The result of these tests are given in Fig. 4, which shows that in general the anode current continues to decrease with time. Small variations, of a somewhat random nature, occur, as occasionally the anode current tends to remain steady for a few days, or even to rise slightly. These variations may be partly due to occasional large variations in the mains voltages, causing both anode and filament voltages to rise or fall excessively for short periods, although the valves were always allowed to settle down under controlled conditions for about 10-15 minutes before any readings were taken.

It will be seen that the proportionate rate of decrease of anode current is greater at a filament voltage of 4·0 volts than at 3·5 volts. A drop in anode current of 10 per cent in the first 200 hours and 25 per cent in the first 1 250 hours occurred at a filament voltage of 4·0V, compared with 10 per cent in 460 hours and 25 per cent in 2 100 hours at a filament voltage of 3·5 volts.

One valve was put on test at an overload of anode current, running at a filament voltage of 4·30 volts and an anode voltage of 90 volts. The results of this test are given in Fig. 5, from which it will be seen that the anode current decreased by 10 per cent of its initial value in the first 390 hours, and 25 per cent in the first 1 370 hours of operation.

The last valve was run under conditions of an overload of anode voltage, operating at a filament voltage of 4·0 volts and an anode voltage of 200 volts, with the results as shown in Fig. 5. In this case the anode current decreased by 10 per cent in 480 hours and 25 per cent in 2 050 hours.

As the last two valves were not from the same batch as the first two, it is not possible to draw many conclusions from these tests. It is, however, apparent that the rate of decrease is less for lower filament voltages, and that the valve is capable of withstanding overloads without suffering serious damage.

The life tests have occasionally been interrupted to test the static characteristics of the valves over the normal range. This has shown that the anode current at all values of filament and anode voltages (within the saturation range) has decreased by approximately the same amount. The life tests are still continuing to find the useful life of these valves.

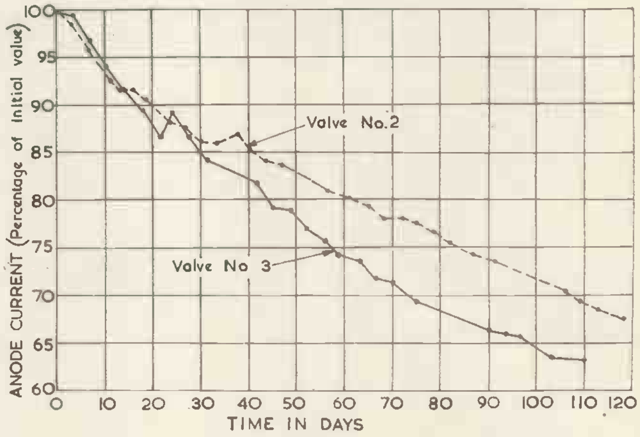


Fig. 5. Life tests on valves 2 and 3

V_2 : $V_f = 4V$, $V_a = 200V$, initial $I_a = 2{\cdot}3mA$
V_3 : $V_f = 4{\cdot}3V$, $V_a = 90V$, initial $I_a = 3{\cdot}91mA$

Acknowledgments

The work reported in this article has been carried out in the Department of Electrical Engineering at the University of Sheffield. The authors wish to thank Mr. O. I. Butler for the facilities afforded in the Laboratories of this Department.

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A Polarity Indicator for Quartz Crystals

By H. L. Hammatt*

A simple instrument is described which will indicate which face of a crystal becomes positive on compression. The indication can be held for as long as required. The construction of a suitable crystal holder is also described.

When a quartz plate is subjected to compression a small potential difference appears across the faces during the structural movement of the quartz, and when the pressure is released the molecular movement is in the opposite direction, which causes the charge across the faces to reverse polarity. This phenomenon has many useful applications.

It is sometimes necessary to establish which face becomes positive upon compression, for instance, in a pressure gauge asembly where many X-cut plates are to be placed in series. The usual method had been to observe the trace on an oscilloscope when the crystal was compressed between metal electrodes, but, for various reasons, this was not entirely satisfactory.

It was therefore decided to develop a small test unit that would give a definite indication of polarity and hold that indication for as long as required, while the crystal plate was being marked accordingly.

The unit to be described fulfils that purpose.

* *Brookes Crystals Ltd.*

Development of the Circuit

Various circuits were tried, but difficulty arose in establishing which positive pulse triggered the circuit, the positive side when the crystal was compressed, or the other side, which became positive when the polarity reversed as the crystal expanded back to normal.

As the circuit responded to both positive pulses it became obvious that means must be found whereby the first (compression) pulse registered and the circuit immediately rendered insensitive to further pulses.

This was done by feeding two thyratron valves, V_{3-4} (Fig. 1), through a common anode resistor, R_{12}, so that directly one valve fired the voltage drop across R_{12} left insufficient voltage at the anode of the other valve for it to fire.

Next came the matter of indication, and although neon lamps could have been used, it was felt that for an unskilled operator, a meter marked POSITIVE SIDE UP and NEGATIVE SIDE UP would be better, and a 10mA centre zero milliammeter was adapted.

It will be seen that R_{10}, V_3 and R_{11}, V_4 form the arms of a bridge circuit, and that with no current flowing in either arm the meter terminals are at equal potential, giving a zero meter reading, but immediately one valve fires, the circuit is unbalanced and current flows until such time as the anode

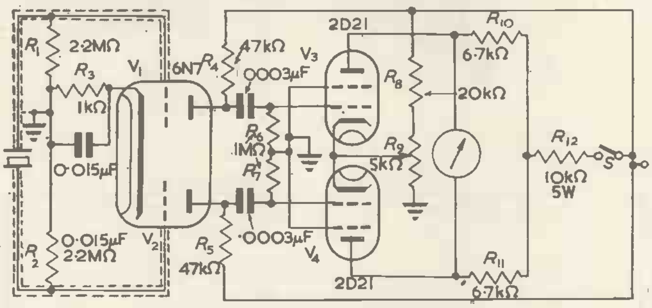

Fig. 1. Crystal Polarity Meter

circuit is broken to reset the thyratron, thus the indication is held until reset.

Both thyratron valves are biased to the non-conducting state by positive cathode voltage derived from R_9, and as a safety factor the bias is kept somewhat higher than the minimum required for cut-off.

As the crystal pulse is insufficient to overcome this bias, amplification is necessary, therefore it is the negative pulse from the crystal which fires the valve, and this should be borne in mind when marking the meter.

Action of the Circuit

The action of the circuit may now be summarized in that a quartz plate squeezed between electrodes produces a negative potential at one input grid and a positive potential at the other. Assuming that the plate happens to be placed in the position where compression makes the grid of V_1 positive, an amplified negative pulse appears at the anode and is applied to the grid of V_3, but, being negative, merely increases the bias and the valve does not fire.

Meanwhile, the other side of the crystal has produced a negative potential on the grid of V_2, whereupon the anode passes a large positive pulse to V_4, which immediately fires, and prevents the other valve firing when the following pulse arrives. If the crystal had been inserted the other way round V_1 and V_3 would have operated and V_2 and V_4 remained static.

Crystal Holder

The easiest way of producing the crystal pulse is to place the plate between two metal electrodes and give the upper electrode a light tap. The lower electrode should be mounted on a solid insulated base, and the top one may be 3in. of 1in. diameter Keramot rod with a brass electrode fixed to one end. The Keramot is for holding in position and to receive the tap. In the production unit the crystal holder was made to reset automatically the thyratrons when the top electrode was lifted to change the crystal: the lower electrode moves up and down to make or break a pair of contacts in the anode circuit of the thyratrons. (See Fig. 2.) An improved version has been considered where the crystal is tapped by a solenoid operated ram which also makes the H.T. contacts, in this case the operator would merely insert a crystal, press a button and note the reading.

General Notes

No particular layout is necessary and the instrument may be built to conform to any requirement.

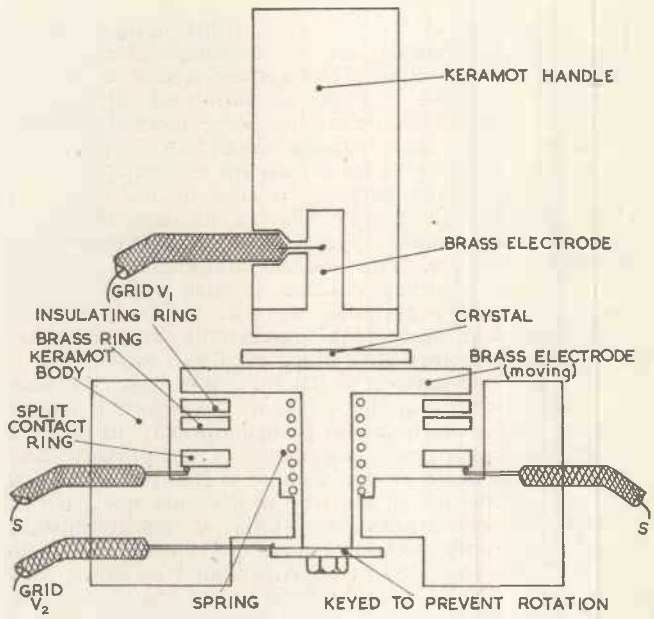

Fig. 2. Crystal holder

The leads from electrodes to grids should be screened and may be run in a bunch with the H.T. contact wires.

Polarity may be checked by touching the electrodes across a 9V bias battery.

The bias control should be pre-set so as to be above cut-off, but not so high as to necessitate a very hard blow on the crystal.

The electrodes should not be touched by the hands, as this will cause a firing pulse.

An X-cut crystal given a tap on the edge will respond when the tap is along the Y direction, but not along the Z, thus affording a means of identifying the crystal axis. Care must be taken in this test to avoid shock excitation of the plate, and the tap must be light, as with a pencil. Polarity will indicate oppositely to the compressional test across the faces, because a compression along the Y axis is equivalent to an expansion across the faces.

The unit works well with blocks of quartz and can be used to identify the Z or optical axis where no reading is obtained when tapped.

Acknowledgments

Finally, the writer wishes to express thanks to Messrs. Brookes Crystals, Ltd., for kind permission to publish this article.

The Wurlitzer Organ

By Alan Douglas

THE majority of musical instruments using electrical tone sources make use of rotating generators or oscillating valves. Basically, whatever system is decided on should be capable of forming a variety of tone-colours, and most commercial organs use some method whereby in theory at least, any required sound can be produced.

It is very tempting to over-reach the real capabilities of such generators, and perhaps because of the ease with which amplification can be effected the tendency is to make electronic organs appear larger and more powerful than they really are. This leads to coarseness of tone and an incorrect frequency balance at high volume levels, sometimes creating prejudice against the art. A large organ must have many tone sources and many tone outlets and these factors are fundamental and inescapable.

There is sound sense in so designing a generating system for a small organ that the nature of the signals is limited by some factor which cannot be maladjusted. In the case of all Wurlitzer organs, this factor is the physical laws governing the mode of vibration of a free reed. At first sight, the properties of the free reed would not seem to be ideal for tone generation; yet this statement must be based on the only method of observation otherwise available, viz., the free reed in an American reed organ or a harmonium. Now here, the coupling of the reed to the soundboard is generally very arbitrary and unequal, causing the higher harmonics to be more readily heard than the fundamental tones. The free reed vibrates with a harmonic series as in Table 1, from which it will be seen that the series is discordant. This accounts for the harsh and snarling tone of the free reed acoustic organ. It is true that by suitable scaling of the reed tongues, resonating tubes and acoustic filters[1], comparatively smooth tones can be produced, and this was carried to a considerable pitch of perfection by the Aeolian Company of New

TABLE 1
Properties of a Free Reed

(*a*) NATURAL FREQUENCY OF A VIBRATING REED TONGUE :—

$$f = \frac{l}{2u}\,\frac{x}{l^2}\sqrt{\frac{Ek}{\Delta k\,(1 \times 4.1K)}}$$

where l = length of tongue in cm.
x = breadth of ,, ,,
Ek = modulus of elasticity of the material in dynes per sq. cm.
Δk = density of material in gm./cm.
K = ratio of mass at end of tongue to tongue itself.

(*b*) TYPICAL OVERTONES FOR A FREE REED

NUMBER OF TONE	NUMBER OF NODES	DISTANCE OF NODES FROM FREE END	FREQUENCIES AS RATIO OF FUNDAMENTAL TONE
1	0	—	f
2	1	0·2261	$6{\cdot}267f$
3	2	0·3121	$17{\cdot}55f$
4	3	0·3558	$34{\cdot}39f$

TABLE 2
Specification of Series 21 Organ

COMPASS, MANUALS CC TO C⁴, 61 NOTES ; PEDALS, CCC TO G, 32 NOTES

GREAT		SWELL		PEDAL	
Bourdon	16 ft.	Bourdon	16 ft.	Major Bass	16 ft.
Viola	16	Stopped Flute	8	Dolce Gedackt	16
Open Diapason	8	Flauto Dolce	8	Octave	8
Flute	8	Viola	8	Diapason	8
Flauto Dolce	8	Dulciana	8	Super Octave	4
Viola	8	Voix Celeste	8	—	
Dulciana	8	Stopped Flute	4	Great to Pedal	
Celeste	8	Violina	4		
Octave	4	Flute Twelfth	$2\frac{2}{3}$	Balanced Expression Pedal	
Flute	4	Flautina	2	Balanced Crescendo Pedal	
Violina	4	Oboe	8		
Twelfth	$2\frac{2}{3}$	Tremulant		5 combination pistons	
Fifteenth	2	—		—	
String Mixture	2 rks.	—		—	

York; but the power from free reeds acoustically coupled to the air must be very limited, the extreme bass notes are masked by their harmonics, and the reeds are generally over-driven by too much wind so that their mode of attack and decay is ragged and unsatisfactory.

If power in the sense of acoustic energy were not required from the reed, it would be possible to control the starting and stopping characteristics and limit the time taken to reach full vibratory amplitude. Also, reeds could be selected to conform with and regularize these requirements, regardless of their tonal efficiency.

The Wurlitzer company has exploited the resources of the free reed to the economic limit by accurate attack control and the conversion of the vibrating tongue into an electrostatic transmitter or pick-up.

Observe the specification, Table 2. The basic tonal content of all organs not primarily designed for entertainment is the diapason chorus. The theatre or cinema organ is based on the tibia[2]. Note the word "chorus"; this means the whole family of diapasons in pitches of 16, 8, 4 and 2ft. In addition, pipe organs might have mutation stops of $5\frac{1}{3}$ and $2\frac{2}{3}$ft pitch to brighten the chorus as well as mixtures. It is true to say that if the diapason

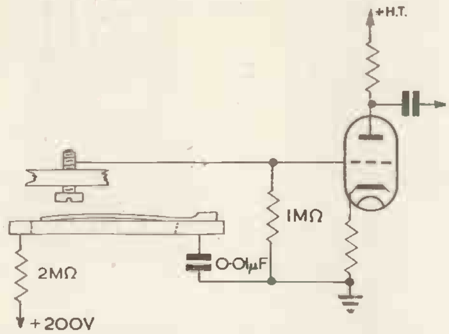

Fig. 1. Basic reed circuit

chorus is complete, including a suitable pedal department, the organ will be tonally satisfactory and sound like an organ, full, round and brilliant. This is not only a function of the kind of tones, but the number of tone sources. In the Wurlitzer organs there are quite separate and independent tone sources for each note; harmonics are not borrowed from generators already supplying a tone, which must inevitably lead to thinness in the build-up and ensemble, with masking of many frequencies. There is a full diapason chorus, a full string chorus, a partial flute chorus and a synthetic oboe; a separate celeste division adds charm to quieter registrations.

Fig. 1 shows a vibrating reed electrically polarized and with a suitable pick-up element connected to a valve grid. Variations in capacitance caused by the vibration of the reed tongue change the grid voltage accordingly, producing an output voltage change of the same frequency as the reed. But it has not the same timbre; if the area of the pick-up is large the harmonics will be masked or at least only appear in a fringing fashion, and the output is nearly all fundamental. By a suitable number of pick-ups per reed, comparatively smooth tones can be produced, but it must be remembered that the movement of the tip of the tongue is not sinusoidal—the tongue dwells for an instant at the moment of reversal. The slightly flat-topped wave so produced is very useful for electrical tone forming, as described later. The thinner tongued reeds used for the string section have different pick-ups and more upper harmonic development is allowed; keen string tone requires a very extensive harmonic series.

Each reed is mounted in a wooden cavity board as in Fig. 2. These cavity boards are horizontally grouped above each other on a common windchest containing the magnetic valves which admit the pressure wind to each reed. Small plates having holes which can be adjusted are fitted to the end of each reed cavity, exactly to set the flow of wind (shown dotted). The air exhausts below the reeds and is allowed to escape through felt in the metal reed bank covers, these being acoustically treated to reduce the direct sound output and act as electrical screens as well. To prevent any electrical pick-up from the magnet coils the wind passages are screened with metal gauze and the interior of the wind chests are hot sprayed with a metallic coating. Each magnet coil has a spark-quenching resistor across it.

Fig. 3 (p. 468) shows part of the reed base polarizing circuits. Here equalizing resistors can be seen between certain groups of reed bases, and volume setters for the different

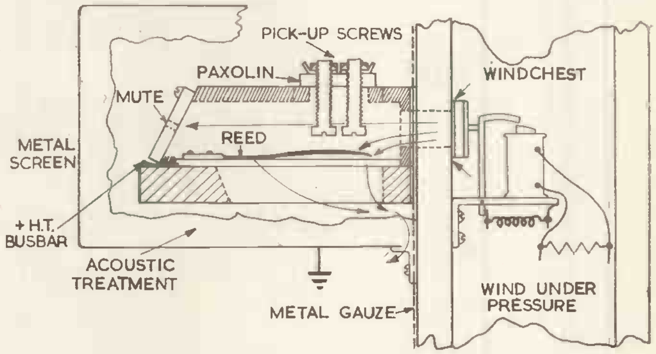

Fig. 2. Reed mounting and wind valve

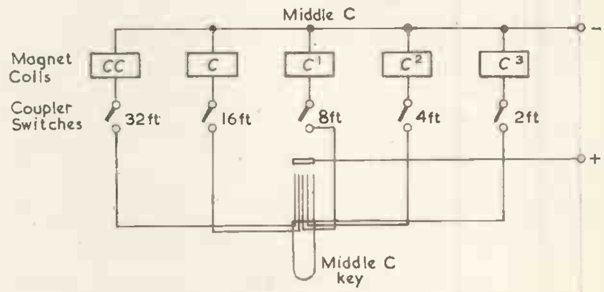

Fig. 4. Principle of extension

tonalities. It will be noted that all the pick-up screws for any one tonality are paralleled, this lead eventually going to the appropriate pre-amplifier valve grid. The relative loudness of the tones is altered by varying the polarizing voltage and contacts on the stop keys control this; but in addition, other contacts on the same keys operate the magnets which select the proper pallet valves to correspond to that pitch range in use. This is necessary because these organs use the extension system, much practised in pipe organs[3]. Fig. 4 shows what this means. Briefly, one complete set of, say, 85 sound sources is provided for any one tone-colour (e.g., flute). Since the voicing of any one kind of flute is practically uniform for any pitch range, there would seem to be little need to have quite separate sets of reeds or pipes for each pitch range; all of the tones in 16ft, 8ft and 4ft pitches could be obtained from 85 sources instead of three complete sets (= 183 pipes or reeds). True, one note is occasionally sacrificed when full chords are played, but in the main the effect is satisfying and most modern pipe organs use the method. From Fig. 4 it is clear that the one playing key can select not only one but several notes when properly connected. Fig. 5 shows a small part of the extension couplers to illustrate how Fig. 4 is applied. The rocking contact bars operated by the key-tails cannot contact the vertical silver wires unless these are pulled

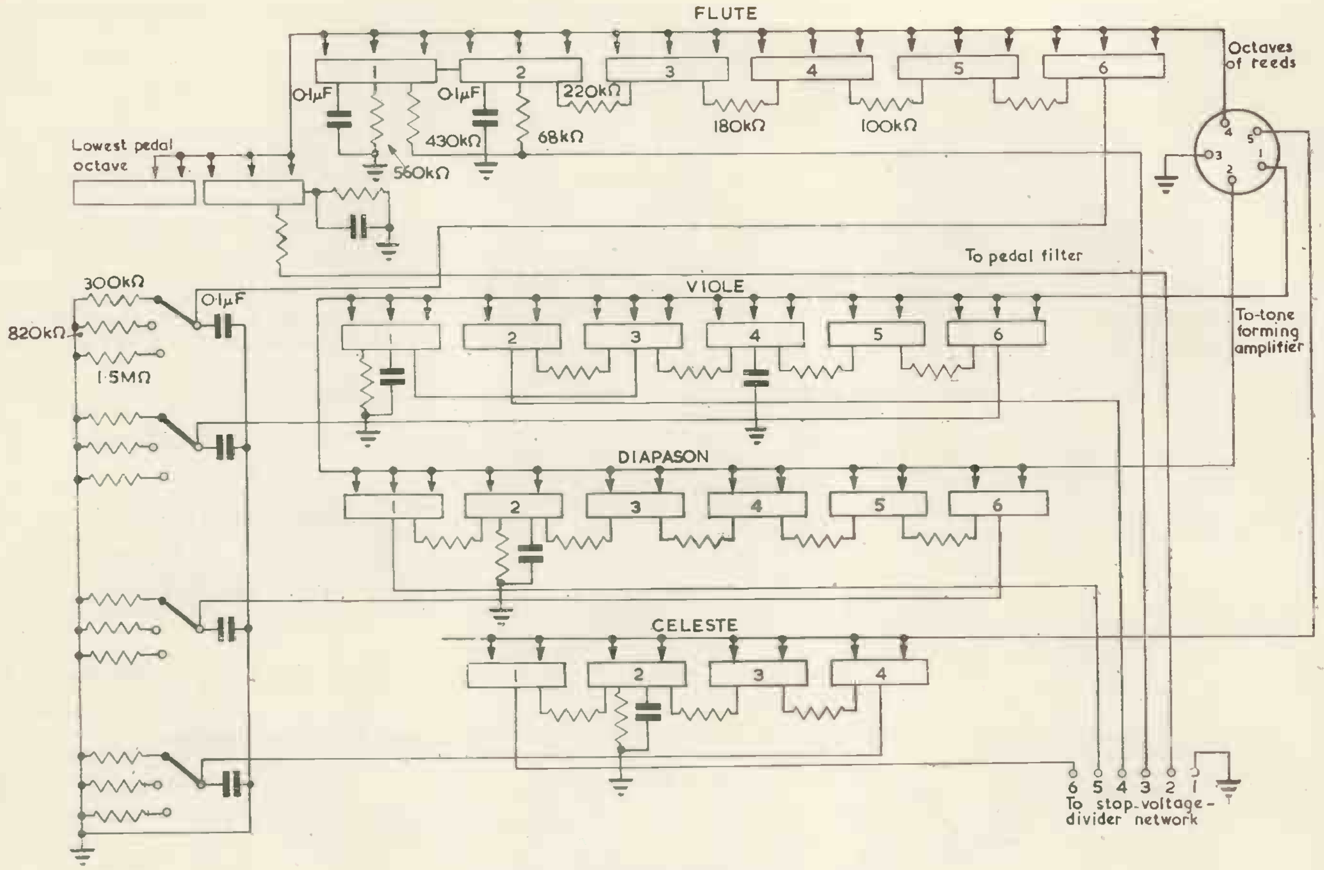

Fig. 3. Part of polarizing circuit

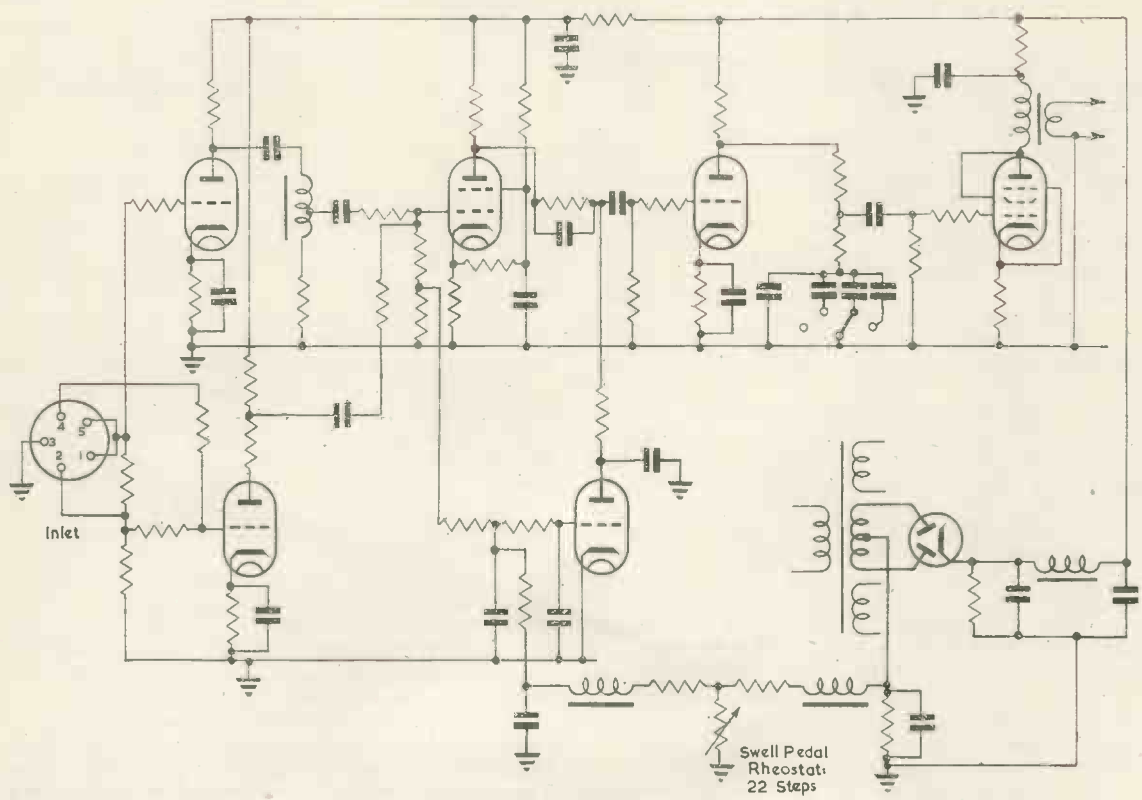

Fig. 6. Tone-forming amplifier

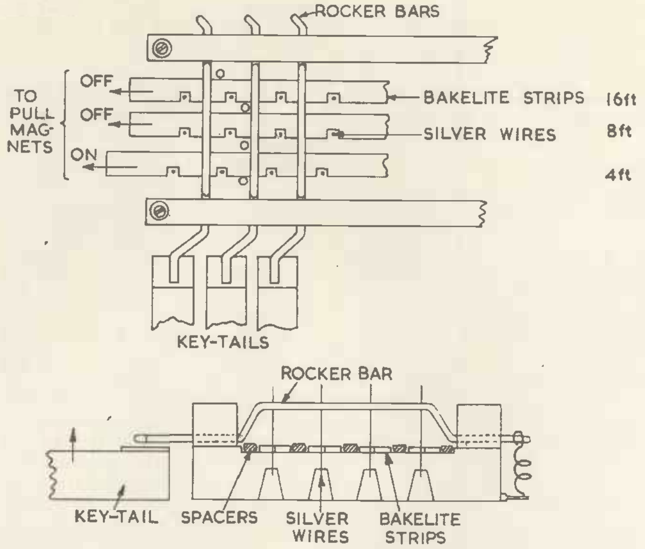

Fig. 5. Key coupler details

into the working position by the appropriate pitch slide. Thus one rocker may contact many wires if need be, so causing the magnetic wind valves to open and set the appropriate reeds into vibration. In some later Wurlitzer organs the couplers are of a different form, die-cast in metal, but the effect is the same.

The waveform from the reeds is treated in a tone-forming amplifier, Fig. 6 (p. 468). Separate inlet channels take the different signals and pass them to the control sections of the amplifier. These amplifiers again feed larger ones if greater power is required. The usual practice is to use 15in loudspeakers for the bass and 12in ones for the treble, pairs of each being made up as one unit. These loudspeakers do not usually face the listener, reflected sound being preferred as giving better diffusion. The author was impressed with the methods used to achieve this at the Wurlitzer studios in Cincinnati, which could be adapted to most churches. There was a complete absence of focusing with ample diffusion and the power from two groups of the above units was adequate for the organ with no suggestion of forcing or coarseness. This would seem to dispense with the provision of costly enclosures with equal if not better effect. A tremulant is provided by a rotating paddle in front of the treble speakers, the Doppler effect so produced varying both the pitch and intensity in the proper manner.

Wind is supplied at a pressure of about 2·7in water gauge by a small high-speed fan built into the base of the organ. The higher synchronous speed obtainable from a 60c/s supply allows the fan wheel to be only 8in diameter. A felt lined acoustic labyrinth silences the air intake and the fan is quite inaudible. No reservoir is used, leading to compactness in design; the organ is only 48in high, 63½in wide and 47in deep including pedals.

The Wurlitzer organ is a development of the Everett Orgatron, based on the original patents of Hoschke; it is made in two single manual and three two manual and pedal models; the series 21 is described here. A noteworthy feature of this instrument is that the speaking characteristics are perhaps more like a pipe organ than any other electronic instrument; this is primarily due to the careful selection and control of the reeds, every single one of which is numbered so that a correctly treated replacement can be obtained from the factory in the event of a failure.

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Exploring the Ionosphere by Means of Rockets

Summaries of papers from the Oxford Conference

by E. Burgess, F.R.A.S.

The Oxford Conference on the use of the rocket for the exploration of the upper atmosphere was held at Queen's College under the auspices of the Gassiot Committee of the Royal Society. In addition to a number of papers on the rockets and their instrumentation there were several papers on the techniques employed for ionospheric investigations. Summaries of a selection of these papers follow.

Ionospheric Research with Rocket-borne Instruments, by J. R. Lien, R. J. Marcou, J. C. Ulwick, J. Aarons, D. R. McMorrow, Air Force Cambridge Research Centre, Mass.

A series of flights made by the United States Air Force from White Sands Proving Grounds and Holloman Air Force Base have used high altitude rockets to measure effective electron density, collisional frequency and propagation modes over long paths.

The data concerning effective electron density have been gathered from measurements of the retardation time of a radio signal which is approximately 1Mc/s above the critical frequency for the E region. In order to compare the time, two synchronized signals were radiated from the ground. First was the probing signal and the other was a U.H.F. reference signal which suffered negligible retardation. A number of profile curves relating electron density to altitude have been obtained for the ionospheric regions between 90 and 130km. They show the E region to be in two parts with a separation between the layers of about 15km. This supports the theory that two definite and distinct processes of ionization are responsible for the E layers.

By measuring the strength of the probing signal as the rocket traversed the ionosphere it was found possible to estimate the collisional frequency within the D region. Agreement with independent determinations by other methods was obtained.

Propagation Measurements in the Ionosphere with the Aid of Rockets, by J. Carl Seddon, Naval Research Laboratory, Washington.

Day-time measurements of the electron density, ion density and electron collision frequency were made during V2 rocket flights. Basically the experiments consisted of radiating two harmonically related c.w. frequencies from the rocket to two stations on the ground which were located six miles apart. The frequencies used were 4·274Mc/s and its sixth harmonic, the higher frequency acting as the reference frequency. The ordinary and extraordinary components of the low frequency were separated by using crossed dipoles and a cable type magic-T. After frequency multiplication, each component was heterodyned with the reference frequency and the resultant beat frequency contained all the information from which the index of refraction could be calculated.

Results obtained showed that in early autumn the E_1 layer remains dense up to the E_2 layer, whereas in winter there is a decrease in electron density between the layers to a fairly low value. It was shown too, that at 4·274Mc/s and higher frequencies, the Lorentz polarization term should be omitted for the E layer.

The Determination of Charge Density in the Ionosphere by Radio Doppler Techniques, by W. W. Berning, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland.

Data from the missile tracking system known as DOVAP (Doppler, Velocity and Position) can be used to obtain equivalent electron densities in the ionospheres. The basic principles of DOVAP are that it is an instrumentation system which compares continuously the phase of two radio frequency signals which are transmitted from one ground station to another, one signal travelling directly and the other via the missile being tracked. The two signals are mixed at the receiving ground station and the resultant gives an indication of the missile velocity in the transmitter-receiver missile path. The present system uses a frequency of 36·94Mc/s, broadcast by a transmitter south of the launching site. This is picked up by the rocket, doubled, and then re-radiated. Three or more ground stations receive the rebroadcast signal from the rocket and beat it with a suitably doubled control signal received directly from the first ground station. The missile's position can then be obtained as a function of time.

However, when the missile passes through the ionosphere, the change in phase wavelength leads to a discrepancy in the position. It was shown that by comparing the computed trajectories of V2, Bumper-WAC and Viking rockets, with DOVAP results, it was possible to obtain electron densities which corresponded quite well with Bureau of Standards data for the same times.

A New Technique for Investigating the Ionosphere at Low and Very Low Radio Frequencies, by C. W. Bergman, R. S. Macmillan, W. H. Pickering, California Institute of Technology.

If a study of the ionosphere is being made with very low frequency radio waves, one problem is that of obtaining a suitable source of the transmissions. Usually an existing transmitting station is used or a "small" aerial is built and it is pulsed with a large peak power. Some preliminary data were presented on a new type of low frequency aerial which was built over the Mojave Desert where the rock is essentially a dielectric. A horizontally polarized wave was radiated vertically upwards and no energy radiated along the ground in a direction normal to the aerial. The radiation efficiency was high.

About 80 miles north of Pasadena, the Mojave Desert is reasonably flat and the surface rocks consist of a few feet of decomposed granite. The subterranean rock is believed to be solid granite with the water table at least 1 000 feet down. A 2 000 metre experimental aerial, laid on the tops of bushes alongside the road, gave satisfactory sky wave signals at a distance of 55km. Then a more permanent aerial was erected. This consisted of a wire, 26 000 feet long, supported by posts about 11 feet above the ground. Switches at intervals of 1 000 feeet allowed the aerial to be tuned from 18 to 250kc/s. Matching to the 100 ohm impedance, 800 watt, C.W. transmitter was obtained by feeding the aerial at a point 1 700 feet from the centre.

The receiving site was located 64km away, using aerials in the form of crossed dipoles of about 100 feet in length oriented parallel and normal to the transmitter aerial. At the receiving station the phase-angle between the received signal and a reference signal of constant phase relationship to the transmitted signal was measured. The link was by means of a V.H.F. communication channel. The phase-angle was measured by means of a recording phase meter, normally observations being made for five minute intervals first on the N-S receiving aerial and then on the E-W one. Field strength measurements were made similarly.

To date only a limited number of measurements have been made. These include sky-wave field strength and phase-angle data for the components polarized in and normal to the plane of incidence on the night of 28-29 October, 1952. Now that the technique has been found successful, it is hoped that during the coming year the system can be used to collect more data. New experiments will include a determination of the plane of polarization of the received signal and the effects of sunrise and sunset.

A Mass Spectrometric Study of the Upper Atmosphere, by J. W. Townsend, E. B. Meadows, E. C. Pressly, Naval Research Laboratory, Washington.

Electronic circuits were designed for a modified version of the Bennett type of radio-frequency mass spectrometer so that it could be used to investigate the composition of the upper atmosphere. This was mainly to determine if diffusive separation of the atmospheric gases takes place. Use was made of miniature components wherever possible and power supplies for the filament of the spectrometer tube and the electronics were derived from silver cells.

The evacuated spectrometer tube was made with a glass tubulation so that it could be broken open at the correct time during the flight. When flown in an Aerobee rocket the instrumentation consisted of a telemetering transmitter type AN/DKT-7 mounted at the base of the warhead. Above this were the rocket safety and control electronics, and the lead acid batteries which supplied power for the telemetering transmitter, the safety devices and for the spectrometer dynamotor. The electronic circuits for the spectrometer, consisting of the radio frequency oscillator, the bias and stopping potential rectifiers, the sweep generator, and the D.C. amplifier, together with the dry batteries, silver cells, dynamotor and control circuits were housed in a quadrant section.

Forward of this was the spectrometer itself, mounted in a cradle of sponge rubber.

In the rocket launched on 12 February, 1953, the spectrometer measured the relative abundance of all gases between mass numbers 54 and 6. One hundred and seventy-two traverses of this range of mass ratios were made at the rate of 0.94 per second. The instrument had been calibrated in the laboratory for its sensitivity to the gases argon, oxygen, and nitrogen, but in the flight no change in the ratio of argon to molecular nitrogen as a function of altitude was detected. This differed from results of the University of Michigan using a sampling bottle technique.

Meteor Impacts by Acoustical Techniques, by M. Dubin, Temple University.

The apparatus consisted of microphones mounted flush with the skin of the rocket. The method of detection was to use a tuned amplifier and a crystal microphone having a peak response at the frequency of the tuned amplifier. The tuned bands were ultrasonic in the region of 30 to 60kc/s with a bandwidth of 10kc/s. The microphone gave little response to tapping with a pencil, but the dropping of a grain of sand a distance of one inch produced a response of several volts for telemetering. The interpretation of results indicated that meteorites had been detected and that they are likely to be more prevalent than had been assumed.

Density-Gauge Methods for Measuring Upper Air Temperature, Pressure, and Winds, by N. W. Spencer and W. G. Dow, University of Michigan.

In this paper details were given of the uses of Alphatron and thermionic ionization gauges for determining the pressure of the upper atmosphere, and an explanation of how self-acting circuit changes had been employed to maximize the sensitivity response for each order of magnitude of the pressures being measured during the rocket flight.

Day Airglow Measurements with Rocket-borne Photometers, by J. F. Bedinger, Air Force Cambridge Research Centre, Mass.

Photomultiplier tubes (RCA 1P21) were used as detecting units in the photoelectric photometers with interference filters of 150Å bandwidth which were employed to measure the zenith sky light intensities up to 135km.

Because of the high voltage requirements the entire unit had to be enclosed in a pressurized container. Varying sensitivities were obtained by switching different load resistors into the circuit. The conclusions reached were that the atoms and molecules of the upper atmosphere may be excited by resonance radiation from the sun and thus account for the high altitude light of the day air glow which is 3 per cent of the ground value.

Information Theory

By A. M. Andrew*, B.Sc.

The concept of information as a measurable quantity is explained and the unit of information is defined. Communication over a noisy channel is considered and Shannon's expression for the capacity of a continuous channel perturbed by white Gaussian noise is quoted and its implications discussed. The connexion between information and entropy is outlined. The theory has applications in the evaluation of the efficiencies of modulation methods and in connexion with nervous transmission, reaction time and sensory prosthesis.

DEVELOPMENTS in information theory during recent years have placed new knowledge in the hands of communication engineers. At present it is difficult to point to any practical apparatus or system whose development can be regarded as a direct result of an application of the theory, but the theory has provided a new point of view for consideration of communication problems, and it will almost certainly find increasing application in the future. It seems likely to be of use to many people, particularly physiologists and psychologists, who are not primarily communication engineers.

Information theory depends on the fact that information, in a certain sense of the word, can be regarded as a physical quantity and expressed in units. The kind of "information" we can treat in this way is not quite the same as what we mean by information in everyday usage. In the remainder of this article the word "information" will be used in its information theory sense. In this sense, the amount of information in a message is a measure of the difficulty of transmitting the message from place to place, or of storing it, not of its significance.

The Unit of Information

A message may be of either of two types. It may consist of a sequence of symbols (e.g. letters, spaces and punctuation marks) or of a sequence of values of some continuously variable quantity (e.g. the instantaneous amplitude of the waveform representing a speech sound). Information theory is applicable to both types of message, but to begin with only the type consisting of discrete symbols will be considered.

For this kind of message, the origination of the message is a process of selection. The individual symbols are selected in turn from the set of possible symbols, and any message is a selection from the set of possible messages, a set which is finite if the message length is limited.

The smallest number of possibilities from which a selection can be made is two. An obvious choice, therefore, for a unit of information is the amount required to indicate a choice between two possibilities which were equally likely to be selected. It will be seen later that the average amount of information per selection is smaller where the probabilities are not equal. A choice from four equiprobable possibilities involves two such units of information, for the possibilities may be represented by 00, 01, 10, 11 and then the choice from the four may be resolved into a choice between two equiprobable possibilities for the first digit, plus a similar choice for the second digit.

Proceeding in this way, it can be seen that three units of information correspond to eight possibilities, four units to 16 possibilities, and so on. It is clear that if n, the number of possible and equiprobable messages, is a power of two, then H, the amount of information per message, is given by:

$$H = \log_2 n \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

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The unit of information is called a "bit"; the word being a contraction of "binary digit". If it is required to represent a message by a sequence of binary digits, it will be found that a message containing H bits of information, H being an integer, can be represented by a sequence containing H binary digits.

When the message is selected from a set of n equiprobable possibilities and n is not a power of two, it is still permissible to calculate the amount of information by the use of Equation (1). The value obtained for H is then not an integer, so if the message is to be represented by a sequence of binary digits, it is not possible to use a representation consisting of exactly H digits. The message may either be represented by a number of binary digits which is the next higher integer to H (see code 1, below), or if a succession of messages has to be represented, coding systems can be devised such that the average number of binary digits per message approximates H (see codes 3 and 4 below).

It is usually more convenient to use Equation (1) to calculate the amount of information per symbol than the amount per message. The distinction between a message and a symbol is not sharp.

Example

Suppose it is required to transmit messages consisting of ten equiprobable symbols ABCDEFGHJK over a channel which can transmit only binary digits. The following code (code 1) could be used:

A	0000	D	0011	G	0110	K	1001
B	0001	E	0100	H	0111		
C	0010	F	0101	J	1000		

Then the messages may be transmitted as sequences of binary digits, and if the coding device (transmitter) and decoder (receiver) have once been synchronized, the receiver can divide up the received binary digits into the correct batches of four, and can decode them correctly. This system requires four binary digits per original symbol, although the selection from ten possibilities only involves an amount of information:

$$H = \log_2 10 = 3{\cdot}32 \text{ bits} \quad \ldots\ldots\ldots \quad (2)$$

It might appear at first sight that a code of the following kind could be used to effect an economy of binary digits (code 2):

A	0	D	01	G	000	K	011
B	1	E	10	H	001		
C	00	F	11	J	010		

Using this code the average number of binary digits to represent a symbol is 2·2, but unless some dividing signal is sent between the groups, the receiver cannot divide the binary digits into the correct groups, so this code does not help.

A code which could be used is the following (code 3):

A	000	D	011	G	1100	K	1111
B	001	E	100	H	1101		
C	010	F	101	J	1110		

In receiving a message when this code is in use, the receiver counts off batches of three binary digits, unless the three happen to be 110 or 111, in which case the receiver includes yet another digit in that group. Using this code, the average number of binary digits per symbol is 3·4.

Yet another system of coding is possible if the original message symbols are grouped into threes. There are 1 000 possible groups of three. Now 10 binary digits give 1 024 possible representations, so the following (code 4) may be used:

AAA	0000000000		KKH	1111100101
AAB	0000000001	and so on to	KKJ	1111100110
AAC	0000000010		KKK	1111100111

Then the average number of binary digits per symbol is 3·33, which is not greatly in excess of the value given by Equation (2) above. The use of groups of more than three symbols would give an even closer approximation to 3·32 bits per symbol.

Symbols or Messages Not Equiprobable

When the possible symbols or messages do not occur with equal probability, the average amount of information per symbol or message is less than it would be if the different possibilities had equal probability. The amount of choice in making a selection from n possibilities is reduced if the method of selection is such that some possibilities are more likely than others to be selected.

Shannon[1] has shown that if there are n possible symbols, and if p_i is the probability of occurrence of the i^{th} symbol. then the appropriate expression for the average amount of information per symbol is:

$$H = -\sum_{i=1}^{n} p_i \log_2 p_i \quad \ldots\ldots\ldots\ldots\ldots (3)$$

where

$$\sum_{i=1}^{n} p_i = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Equation (1) is a special case of Equation (3), obtained by letting each $p_i = 1/n$.

Now suppose it is wished to encode a message into binary digits, where the symbols of the message are not equiprobable. Since the average information per symbol is less than in the equiprobable case, it should be expected to require fewer binary digits per symbol. In fact a reduction in the average number per symbol can be achieved by forming a code in which the binary representations are of unequal lengths (as in code 3 of the above example), and then allocating the shorter representations to the more probable symbols or groups of symbols.

It should be noted that the probabilities of occurrence of symbols sometimes depend on what has gone before. If the symbols are the letters of the alphabet and the message is in English, for instance, then after the letter q the probability of occurrence of u is unity.

Communication Channels

For any communication channel there is an upper limit to the rate at which information can be conveyed. This is the informational capacity of the channel, and it will be denoted by C. The channel can only be made to transmit information at a rate approaching C if a suitable encoding device is placed between the source of information and the channel. Such a device may be regarded as a transducer of information, which matches the channel to the source. Coding processes which can be used if the source produces messages consisting of selections from ten equiprobable symbols and the channel transmits only binary digits have already been considered. A radio link designed for binary pulse code modulation would constitute such a channel.

Noise

The channel may not, of course, be noise-free. If it is a channel which transmits binary digits, it may be found that occasionally the digit 0 is transmitted and the digit 1 is received, and vice versa. It is one of the great vindications of information theory that a definite value for the informational capacity can be obtained for a noisy channel.

It can be shown that with suitable coding (the coding process being designed with the appropriate noise level in mind) the channel can be made to convey information at a rate approaching this capacity, the messages being reproduced with an arbitrarily small frequency of error.

Redundancy

To transmit messages over a noisy channel with a low rate of errors it is necessary to introduce redundancy. If the channel is such that the messages have to be represented by sequences of binary digits, redundancy would be introduced as follows. A message which is a selection from M possibilities would be represented by a sequence of B binary digits, where $2^B > M$. 2^B is the number of binary representations available, and of these a number M would be used to represent messages.

A received sequence, which has been affected by noise, will be one of the 2^B possible sequences, but will not, in general, be one of the M which represents messages. However, if $\log_2 M$ is a sufficiently small fraction of B, and if M and B are large, the received sequence will generally be such that one of the M sequences which represent messages is much more likely to be the source of the received sequence than is any other. Hence a suitable receiver can determine the message from the received sequence with a small probability of error. The theoretical possibility of such a receiver has been considered by Woodward and Davies[2].

Shannon[1] has shown that where M and B are very large the M sequences which represent messages can be a random selection from the 2^B possible sequences, and the messages can be conveyed with a low rate of errors as described above provided $\log_2 M$ is a sufficiently small fraction of B. However, for practical values of M and B it is advantageous to select the set of M sequences so that each member of this set differs from every other member in as many places as possible. The problem of making such a selection has been reviewed by Laemmel[3]. Expressions for the informational capacity of a noisy channel have been derived by Shannon.

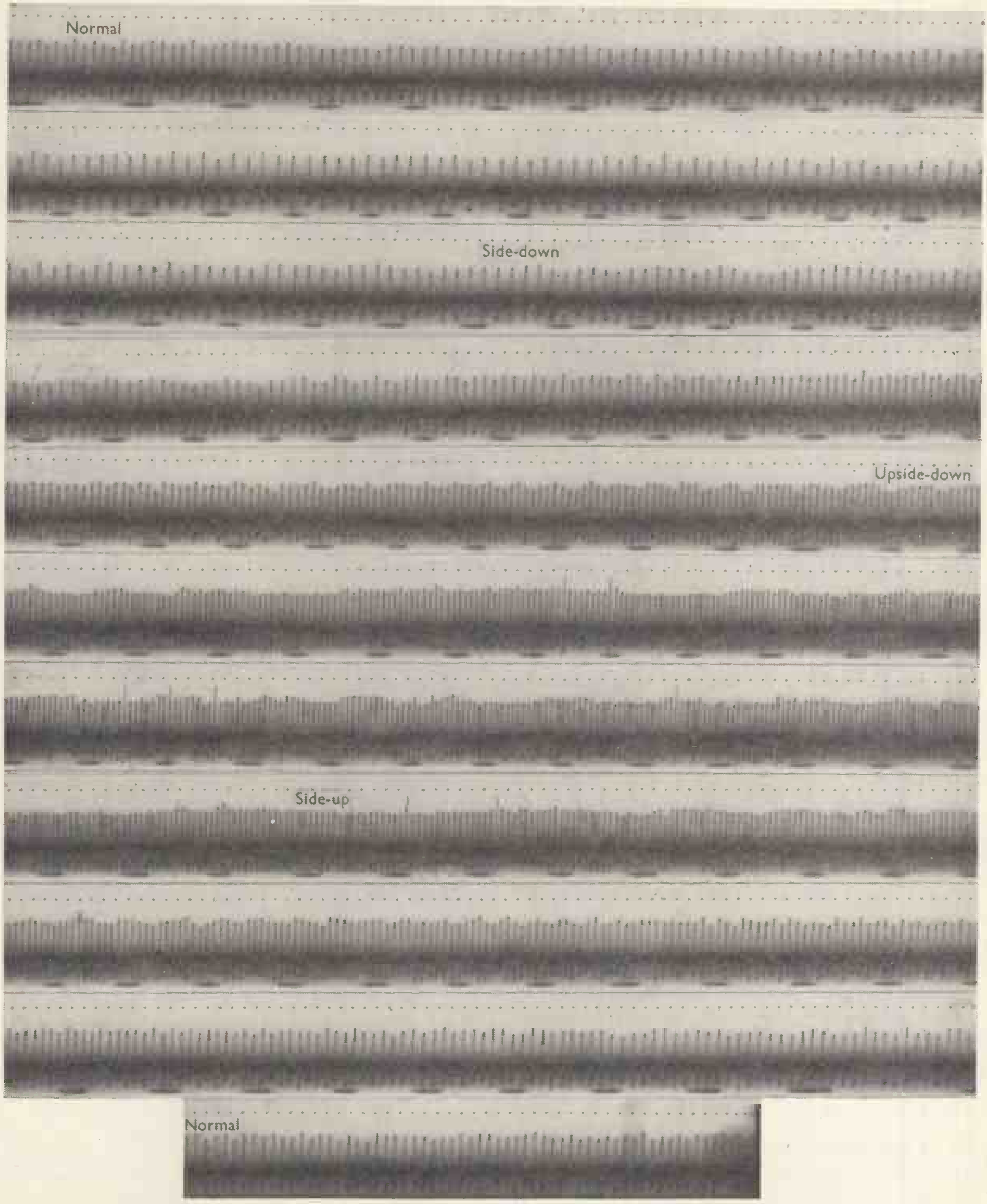
Language, whether written or spoken, has a high degree of redundancy. It is because of this that a written or spoken message is often intelligible when some words or letters are illegible or inaudible. If there were no redundancy, crossword puzzles would be very easy to compose and rather pointless, since any combination of letters would form a word.

Continuous Messages

Where the message consists of variations of some quantity which can vary continuously an infinite amount of information is required to indicate the value of the variable at any one point in time, since it has an infinity of possible values. However, since thermal noise is always present, no communication system is capable of reproducing a continuous message with complete exactness. By taking into account the fidelity of the reproduction a value can be found for the informational capacity of a system which transmits continuous information.

Shannon[4] has obtained an expression for the informational capacity of a channel of bandwidth W, perturbed by white thermal noise of power N, when the average transmitter power is limited to P. The capacity is given by:

$$C = W \log_2(1 + P/N) \quad \ldots\ldots\ldots\ldots (5)$$



An example of transmission of information along a nerve fibre from a sense organ to the central nervous system. The oscillograph record shows "action potential" pulses from a nerve fibre coming from the labyrinth of a thornback ray. During the record the labyrinth is rotated through 360° about a horizontal axis. The pulse frequency at any time is a function of the angular position and of the angular velocity (here a constant). In the intact animal a large number of such fibres convey information about the direction of the gravitational pull and acceleration undergone by the animal. The apparent amplitude modulation is an artefact due to hum and noise. The few small pulses near the middle of the record are from another fibre. Time marker at top of record: 24/sec. Rotation signal at the bottom: one gap every 3°. Speed of rotation: 10°/sec approx. (From O. Lowenstein and T. D. M. Roberts, Journal of Physiology 110, 392 (1949), by kind permission of the authors and the Editor of the Journal of Physiology.)

This shows that the informational capacity depends not only on bandwidth, but also on signal-to-noise ratio. Furthermore, it is clear from the form of the expression that given a sufficiently high signal-to-noise ratio, television programmes of the usual standard of definition could be transmitted on a 10c/s band!

Television on this waveband is not a practical possibility, because an impossibly high signal-to-noise ratio would be required and also because, as will be clear from what follows, very complex transmitting and receiving apparatus would be necessary. Nevertheless the theoretical possibility exists.

On the other hand, it is usually considered necessary to have a bandwidth of a few megacycles per second for television, and it is true that this is necessary if we are not prepared to submit our signals to a certain kind of coding process. The following considerations will make this clear.

In one of his classical papers Shannon[4] states the theorem: "If a function $f(t)$ contains no frequencies higher than Wc/s, it is completely determined by giving its ordinates at a series of points spaced $1/2W$ seconds apart." Thus a message of duration T and bandwidth W is specified by giving $2TW$ dimensions, just as the position of a point on a line is specified by giving one dimension or the position of a point in a square by giving two dimensions—the x and y co-ordinates.

Now the co-ordinates of a point cannot be measured and specified with complete exactness. Suppose that, in some arbitrary units of length, the x and y co-ordinates are represented with sufficient accuracy by the two numbers 645 and 332. Then without ambiguity and with the same accuracy the point may be specified by the single number 645332. Thus two numbers, each of three decimal digits, have been replaced by a single number of six digits.

In a television system it is required to transmit the degree of brightness of each of about 200 000 picture elements 25 times per second. Hence about 5 million dimensions have to be transmitted per second. These dimensions determine a signal of limited waveband, and it is clear from Shannon's theorem that a signal of 2·5Mc/s waveband is specified by this number of dimensions per second. Thus a conventional television channel can be established using a 2·5Mc/s waveband, provided a signal-to-noise ratio can be achieved which is sufficient for the required picture quality.

However, if an extremely low-noise channel is available, so that dimensions may be transmitted with great exactness, it is permissible to reduce the number of dimensions per second and hence the bandwidth, by the method which was used above in specifying the position of a point in a square by a single number. Two or more dimensions may be incorporated into one, which must then be reproduced very exactly at the receiver. This explains the discrepancy between 10c/s and 2·5Mc/s as the bandwidth of a television channel; if it is not wished to change the number of dimensions per second then 2·5Mc/s is required, but otherwise a smaller band could be used.

Efficiency of Modulation Methods

Probably the most important application of information theory to date is the comparison of alternative methods of modulation for radio or carrier telephony communication. Some modulation methods, such as frequency modulation and the various types of pulse modulation, use a greater bandwidth than does amplitude modulation for a given message bandwidth, but these methods have the advantage over A.M. that they give higher signal-to-noise ratios under given conditions of transmitter power and interfering noise. The process of pulse modulation increases the bandwidth and reduces the susceptibility to noise interference, and is thus the opposite of the process described in the last section, by which the bandwidth was reduced and the susceptibility to noise increased. One may speak about bartering bandwidth for signal-to-noise ratio.

It is possible, at least in principle, to estimate the rate at which information can be conveyed by any given modulation system under stated conditions of bandwidth and signal-to-noise ratio, and to compare this rate with the theoretical maximum C as given by Equation (5). The comparison gives an indication of the efficiency of the modulation method. Modulation methods have been analysed in this way by Shannon[4], Oliver, Pierce and Shannon[5] and Jelonek[6].

Connexion with Thermodynamics

The close connexion which exists between information and entropy has not hitherto been mentioned, for it is not essential for an appreciation of most aspects of the theory. It can be shown that information is interchangeable with, and may be regarded as identical with, negative entropy, or "negentropy".

In statistical thermodynamics, the entropy of a system in a certain state is proportional to the logarithm of the probability of the state occurring. This definition of entropy, with the appropriate constant of proportionality, can be shown to be equivalent to the apparently quite dissimilar definition given in the less advanced treatments of thermodynamics. High entropy, or low negentropy, corresponds to high probability.

Consider the negentropy of a medium through which a message can be transmitted. When no message is being transmitted certain characteristics of the state of the medium are not specified, and the probability of the medium being in one of its allowed states is high. When a message is impressed on the medium, the state is more exactly specified and therefore of lower probability, so the negentropy is greater. If the message is perturbed by noise, the perturbed message may take any of a number of forms all corresponding to one initial message, so the probability of having one of these forms is higher, and the negentropy lower than in the noise-free case.

The connexion between information and entropy has been analysed in detail by Brillouin[7], who has also used it to explain the paradox of Maxwell's Demon[8] in thermodynamics. The connexion is of great philosophical interest, especially since Schrödinger[9] has shown, independently of information theory, that life can be regarded as a constant struggle to maintain a high level of negentropy. A living organism is a highly improbable thing and therefore has high negentropy.

Biological Applications

Information theory has attracted the attention of biologists, partly as a result of the works of Wiener[10,11]. Many communication systems present their information to a human observer whose eyes or ears and their connexions with the brain transmit the information a stage further. The eye and the ear do not transmit to the brain all the information which they receive—they select certain elements of it and transmit these. The ear, for instance, ignores the phase relationships between the frequency components of a sustained tone, and so the signal from ear to brain contains less information than would the output signal of a microphone with the same sound reaching it. Similarly, as has been pointed out by Rushton[12], the eye does not transmit to the brain all the information which could be derived from the responses of its light-sensitive elements.

The study of these mechanisms of hearing and vision is of direct interest to biologists, and it may enable communication engineers to economize when designing communication systems, by refraining from transmitting information which would be rejected at a later stage anyway. For instance, the vocoder[13], by transmitting only certain characteristics of speech sounds, makes possible speech communication over a 300c/s band. This kind of frequency compression should not be confused with that considered previously (in relation to television) in which the amount of information transmitted was not affected by the compression.

The higher living organisms contain a complex communication network. Information is transmitted along nerve fibres, and also by the circulation of hormones in the bloodstream. An attempt to evaluate the informational capacity of a nerve fibre has been made by MacKay and McCulloch[14,15], with some assistance from Andrew[16]. In our present state of knowledge in neurophysiology it is impossible to say whether the messages transmitted by nerve fibres are so encoded as to make full use of this informational capacity.

Reaction Time

When a person is instructed to respond to a signal in a certain way, say by releasing a morse key, his response to the signal occurs after a certain delay, called his reaction time. If he has to respond in different ways to a variety of signals his reaction time is longer than it is for one type of signal and response.

Let there be n forms of stimulus associated with an equal number of forms of response. Hick[17,18] has found that if a subject's reaction time is determined for values of n from one to ten, the reaction times conform closely to the relation:

$$R.T. = K.\log(n+1) \quad \ldots\ldots\ldots\ldots (6)$$

where K is a constant.

When the stimulus occurs, the subject receives a message which is a selection from $(n + 1)$ possibilities—the n possible stimuli plus the possibility of no stimulus at all. If these are regarded as equiprobable, Equation (6) shows that the reaction time is in proportion to the amount of information required to indicate the choice from these possibilities. (See Equation (1), and note that a difference in the logarithmic base affects only the constant of proportionality K).

Hick has also carried out experiments in which the subject intentionally responded more quickly than his normal reaction time. He can only do this if he is allowed to make errors. If the errors are regarded as due to noise, the response times are very close to what would be expected from the theory of transmission over a noisy channel (which has not been considered in detail here) on the assumption that response time is proportional to the amount of information transmitted.

Sensory Prosthesis

There have been various attempts to replace one of the body senses by another. Devices have been made which enable a blind person to read[19] or to find his way about[20,21], by arranging that information which would normally be received visually is transformed so that it can be received by one of the other senses, usually by ear. The substitution of sight for hearing has also been accomplished[22], and at least one totally deaf person has carried on a telephone conversation. The substitution of touch for hearing and of position-sense of the fingers for sight have also been suggested[23].

Information theory is useful in connexion with prosthesis because it indicates limits to what can be done. For instance, the rate at which information is received visually is much higher than the rate at which it can be received aurally. It follows that no device which substitutes hearing for vision can enable a blind person to "see" so well as one with normal vision. On the other hand, the prospects of replacing hearing with sight are good.

Acknowledgments

Since this article is original in little more than the method of presentation of the subject, I am indebted to the authors of the papers listed as references, particularly Dr. C. E. Shannon, on whose work most of modern information theory depends. The papers by Shannon should be read by anyone whose interest has been aroused by this introductory article.

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NEW SOURCE OF SELENIUM

In recent years selenium has become increasingly important, due mainly to its use in photocells and rectifiers, it is also used as a red colouring agent in the plastics industry and for decolourizing in glass making.

There is no known deposit of selenium as such which is worth mining. The element occurs with sulphide ores and most of it is obtained as a by-product of copper refining. The U.S.A. is the biggest producer of selenium, but its supplies are still inadequate for its own use Most of Great Britain's supplies come from the copper refining plants of Canada. Small quantities are also produced by Sweden and Japan.

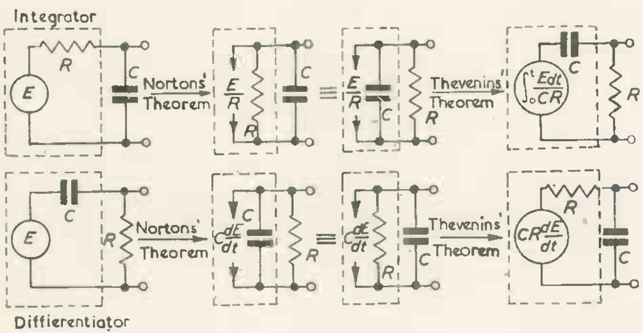
Any increase in the World supplies of this element would be welcome and a possible source of supply in this country is the subject of an investigation now being carried out by the Chemical Research Laboratory of the Department of Scientific and Industrial Research. Iron sulphide, or pyrites, is used in Great Britain in the manufacture of sulphuric acid and, like copper sulphide, it contains selenium. Flash roasting of pyrites is one of the fairly new processes which are used to escape the necessity of using sulphur as a raw material. The wastes from three of these flash roasting plants have been examined so far and at least one appears likely to contain sufficient selenium to make recovering it worthwhile. As is the case with copper refining the problem is to develop a method of recovery which will not interfere with the primary object of the process and will be cheap and simple enough to make selenium production pay. As far as can be seen at the moment the potential yield of selenium from this source will run into tons which would be a very valuable increase of the present supplies.

Electronic Analogue Integration and Differentiation

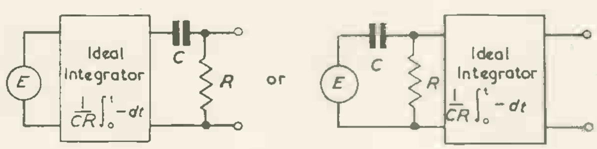
By P. S. Brandon*, M.A., A.M.I.E.E., A.Inst.P.

In the January 1953 issue of ELECTRONIC ENGINEERING *there appeared "A Note on Electronic Analogue Integration and Differen iation" by M. J. Tucker. It is the purpose of this short article to give other interesting deductions that can be made from these and related analogues.*

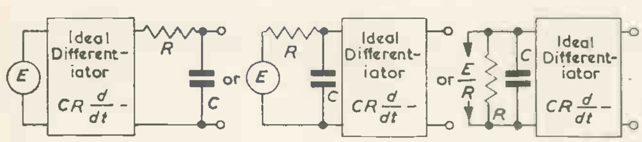
BOTH analogues in the article by Tucker[1] can be derived by alternate application of Norton's and Thevenin's theorems as follows:—



Further analogues can also be deduced. If it is realized for example that it does not matter in which order isolated cascaded networks occur, then an integrator can also be represented by:—

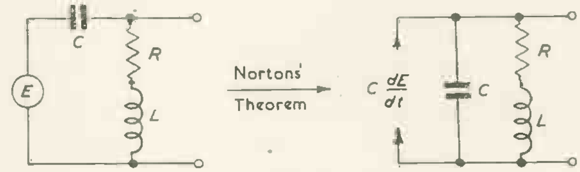


The ideal integrator shown is assumed to have infinite input impedance and zero output impedance. In a similar way a differentiator can be represented by:—



Similar assumptions are made for the ideal differentiator as for the ideal integrator.

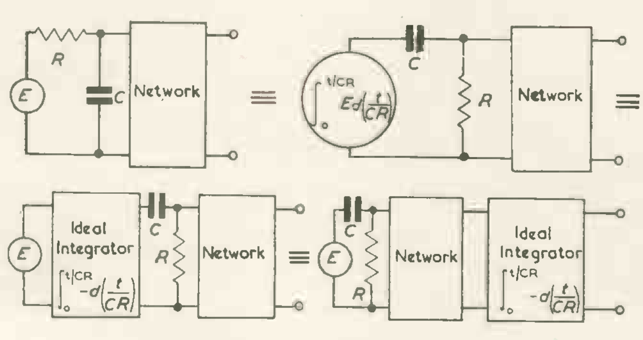
These last two analogues can be extended further to include the cases where the integrating or differentiating *CR* circuits are incorporated into an amplifier. Then the integrating or differentiating circuits can be replaced by their analogues. The ideal integrator or differentiator can be taken right outside the rest of the amplifier either in the input or the output circuit. Interesting design considerations can be obtained from these last analogues. The integrating circuit is in effect replaced by an intervalve *RC* coupling, or the differentiating circuit by an ideal pentode of mutual conductance $1/R$ with an anode load made up of *C* and *R* in parallel. Thus it can be seen that the integrating circuit time-constant would be treated in the same way as for any of the other intervalve *CR* coupling circuits. There is very little advantage to be obtained by making this time-constant any greater than the others. Similarly the time-constant of a differentiating circuit can be chosen as if it were an anode load of the amplifier. It follows that there is no great advantage in using a very much smaller time-constant for this than in the other anode loads. A similar equivalence applied to a modified differentiating network (as shown below) when incorporated into an amplifier gives a useful result.



By this equivalence it can be seen that an inductance can be inserted in series with the resistance of a differentiating circuit and can produce correction of response in a similar way to the peaking coil sometimes used to level the frequency response of an anode load. In fact such a modified differentiating circuit can be designed by treating the equivalent anode load as one of the anode loads in the overall amplifier, e.g. the valves can be chosen in conjunction with the other anode loads to produce an overall flat response.

These composite equivalent circuits described above are often useful in estimating the overall performance from a composite integrator-amplifier or differentiator amplifier. The ideal integration or differentiation (which it should be noticed is in respect to t/CR) can be performed either on the input or the output of the equivalent amplifier. The choice would depend on whether the effect of the frequency distortion of the equivalent amplifier could be estimated easier on the input before or after integration or differentiation.

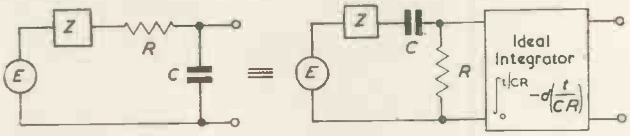
It is also useful to realize that some of the analogues apply in more general circuits, for example sometimes the output terminals can be shunted by an impedance or feed into some four terminal network as shown below:—



The differentiating circuit with shunted output has similar equivalents. Also the analogues in some cases apply when the input voltage source itself has an internal impedance. These, however, are only true when the output of the *CR*

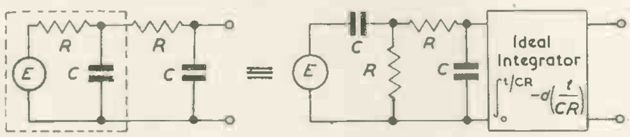
* *Marconi's Wireless Telegraph Co., Ltd.*

network is unshunted. The reason for this is that when the output is unshunted the CR input voltage is unaffected by reversal of the position of the C and R. Thus there are the following equivalents:—

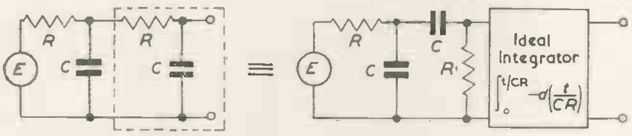


There is also a parallel equivalence for a similarly modified differentiating circuit.

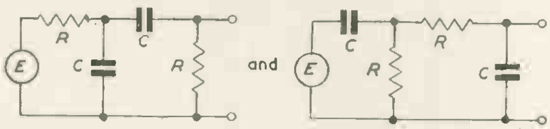
An interesting indirect application of these more general analogues is shown below:—



Also:—



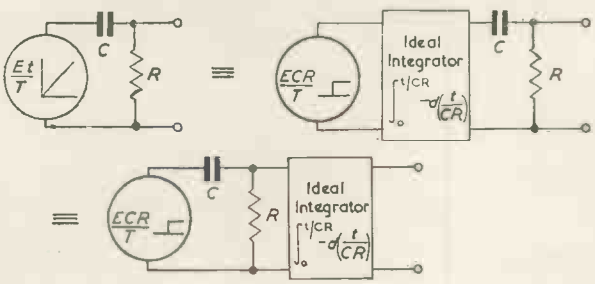
These two equivalences also show that the outputs of the two circuits below are equal.



The outputs obtained from a more complicated CR or LR network can be broken down into the sum of the outputs of a number of simple integrating or differentiating circuits. The equivalence is deduced by algebraic expansion of the transfer ratio of the original network into partial fractions. The inputs of these equivalent simple networks can in many cases be broken up into the sum of simpler units, the outputs caused by each such simpler input can then be added to find the result for the whole.

A useful theorem which can be used for finding the output of an integrating or a differentiating circuit from simple inputs is the one mentioned earlier, i.e., it does not matter in which order isolated cascaded networks are. For example this theorem can be applied to a network with an input voltage given by $\frac{Et}{T}$ starting at $t=0$ feeding into a differentiating circuit.

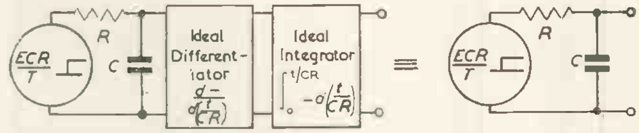
This input voltage can be represented by a step function of value $\frac{ECR}{T}$ (for which input, the output of the network is known) followed by an ideal integrator (in respect to t/CR). Thus



The output across the R in this last equivalence is known to be $\frac{ECR}{T} e^{-t/CR}$ which after ideal integration gives an output

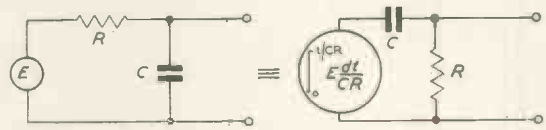
$$\frac{ECR}{T}\left(1 - e^{-t/CR}\right)$$

Alternatively the output can be obtained directly by use of a further equivalence of these three given by

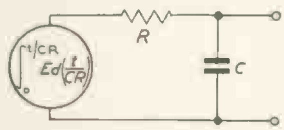


Inputs with higher powers of t can be reduced to step functions followed by several integrators and so on.

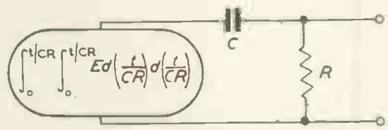
A useful extension for cases where the input waveform is too complicated to expand as the sum of a number of simple inputs but may be known graphically, can be found by use of the analogues. Suppose it is required to know the output from an integrating circuit with such an input. Then the following circuits have equal outputs.



The departure of the output of these circuits from the ideal integration is given by the voltage developed across the capacitor, i.e., the output of the circuit:—



This circut has the same output as:—



Thus it can be shown by successive application of this kind of argument that the output of the original integrating circuit is given by:—

$$\int_0^{t/CR} Ed\,(t/CR) - \int_0^{t/CR}\int_0^{t/CR} Ed\,(t/CR)\cdot d(t/CR)$$
$$+\int_0^{t/CR}\int_0^{t/CR}\int_0^{t/CR} Ed\,(t/CR)\cdot d(t/CR)\cdot d(t/CR)$$

which can be perhaps calculated graphically.

REFERENCE

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STORM-WARNING RADAR

Decca Radar Limited have recently introduced a new radar set which has been developed specially for the detection of storm clouds dangerous to aircraft. The first set, which was developed in consultation with the East African Meteorological Department, has now been in service for some months at Entebbe, Uganda. This set has proved capable of detecting large storms at ranges exceeding 100 nautical miles. Production models of the Type 40 incorporate a number of substantial improvements which are expected to increase the performance considerably, and optional photographic equipment is being made available to facilitate research.

The Design of High Q Iron Cored Inductors

By N. H. Crowhurst, A.M.I.E.E.

BECAUSE of the similarity between the resulting components produced by the design charts given in this data sheet and those designed by means of the data sheet on iron cored inductances with D.C. flowing[1], it is well at the outset to clarify the distinction between them. Both types of component use an air-gap in the magnetic circuit but for different purposes.

In the components designed by the earlier data sheet the problem is to achieve the maximum inductance or impedance for a specified value of D.C. and winding resistance. Losses other than that due to winding resistance are seldom of any importance.

In the present data sheet, D.C. will not usually be present and the problem of attaining maximum Q necessitates the reduction of overall losses to a minimum, including losses due to magnetization of the core.

Basis of Design

The losses associated with the inductor can be divided into two groups: series loss due to winding resistance; and shunt loss due to the energy required for magnetizing the core material. Within the audio range, the core losses can be divided into two components: that due to eddy currents and that due to hysteresis.

As shown in the data sheet on transformer iron losses[2], eddy current losses can be referred as a constant shunt impedance to any given winding, proportional to turns squared. From the viewpoint of the present designs, only the loss component of this impedance need be considered, as the reactive component will contribute only very slightly to the resultant inductance value, because the air-gap dimensions principally control inductance value. For the purpose of the present design charts, inductance value will be assumed as entirely controlled by air-gap dimensions. Where inductance value has to be critically adjusted, this can be achieved by experimental variation of the air-gap, using the charts to find an initial design point.

At higher frequencies the eddy current component of the core losses is predominant so that signal level becomes unimportant. At lower frequencies the hysteresis component becomes predominant so the loss impedance will not be strictly constant as signal level is varied. Fig. 1 shows a typical variation of core loss at 50c/s with flux density. For application over a range of frequency the hysteresis component of this can be separated from the eddy current component and plotted, forming a curve similar to that at Fig. 1 using ordinates of watts per cycle against flux density.

The dotted line in Fig. 1 represents the loss due to a constant resistance connected in circuit. For flux densities below saturation of the core material the loss in this resistance is never less than that due to actual hysteresis. For these charts the loss represented by such a resistance value, represented by this dotted line, has been taken for each material. This means that at some signal levels the actual Q achieved will slightly exceed the calculated value. The difference will be small, however, because the remaining losses due to winding resistance and eddy currents will remain truly constant.

Another factor affecting the value of shunt loss resistance is the thickness of laminations used for the core. This does not appreciably affect hysteresis loss beyond the slight effect on space factor which will modify the effective cross sectional area of the iron. It does, however, affect eddy current loss, which, at a given flux density and frequency, is approximately proportional to the square of

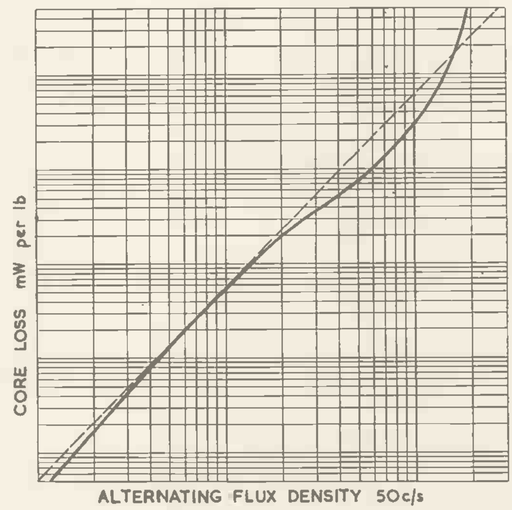


Fig. 1. Plot of core loss against flux density for typical magnetic material

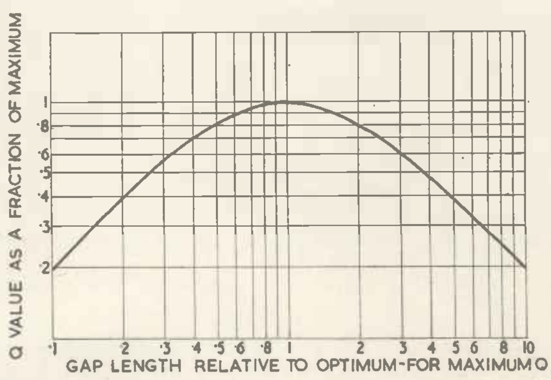


Fig. 2. Variation of Q value as air-gap is changed—frequency constant

lamination thickness, although at very small thicknesses the proportionality index falls to about 1·7.

The condition for maximum Q at any specified frequency is that the reactance of the inductor shall be the geometric mean between the winding resistance and the total core losses referred to as a shunt resistance across the winding. From this it will be appreciated that a different air-gap will be required to produce maximum Q for different frequencies. Fig. 2 illustrates the variations of Q as air-gap is varied, the measurement being made at a fixed frequency. Fig. 3 shows the variation of Q for an inductor with air-gap fixed to give maximum Q at the centre scale frequency for two limiting cases: A, when eddy current losses completely swamp hysteresis losses producing a curve that is completely symmetrical about the maximum Q frequency; and B, for a case where hysteresis losses completely swamp eddy current losses, in which case although the Q has been adjusted to its maximum possible value at the centre scale frequency, its value continues to rise at higher frequencies, reaching a theoretical limit at an infinite frequency of double the Q value. This latter case is, of course, purely hypothetical because at higher frequencies eddy current loss always predominates, eventually degrading Q after the manner of curve A. A practical curve where both hysteresis and eddy current components contribute appreciably to the losses at the design frequency will take the form represented by the dotted curve.

The procedure in these charts follows the direct approach, similar to that used in the data sheet for iron cored inductors carrying D.C. To achieve this it has been necessary to relate the various losses to the physical dimensions of the component.

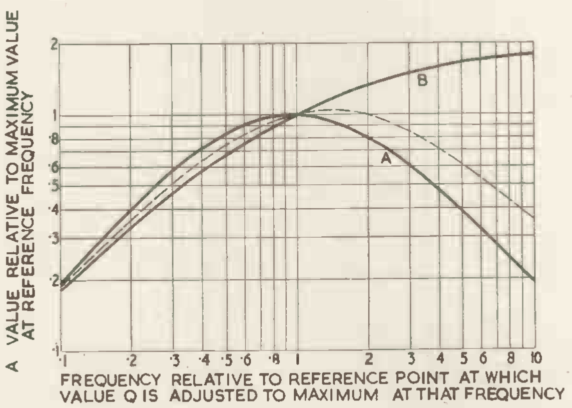


Fig. 3. Limiting cases in variation of Q value with frequency—air-gap constant. *See text for significance of curves*

The resistance of a given number of turns on a winding arranged to fill completely the available space will be proportional to the mean turn length and inversely proportional to the effective winding area. For the purpose of this chart, it is assumed that round section enamel covered copper wire is used, and the winding area figure is the net value after space occupied by the bobbin and top clearance to laminations has been deducted from the window area.

For any given operating conditions in the core material, the shunt loss impedance referred to the same turns as winding resistance is proportional to the cross sectional area of the core and inversely proportional to the flux path length in the core.

Design Method

Chart 1 enables an appropriate core size and material to be chosen in order to obtain a suitable Q value. The curves in the top left-hand corner represent the variation in referred core loss shunt impedance with frequency for different core materials in various lamination thicknesses.

The bottom left-hand part of the chart completes the information about core losses to produce a horizontal reference in the bottom right-hand portion representing a referred value of total shunt loss.

In the top right-hand part of the chart, winding area and length of mean turn are used to derive a similar referred winding resistance as a vertical reference in the bottom right-hand part.

The intersection between these references gives two resultant figures for further use: A maximum value of Q; and a turns constant designated k. Provided the winding space is completely filled, the Q value will be independent of the number of turns and wire gauge employed, since both the series and shunt losses will vary in proportion to turns squared.

The turns constant k is used in the next chart for calculation of the number of turns necessary to produce the geometric mean value of reactance at the maximum Q frequency. The figure presented on the chart as turns constant is actually the reactance of a 1 000 turn winding in kilohms. Fig. 4 illustrates the method of using Chart 1.

The choice of core material will depend upon several factors quite apart from the probable question of availability in the desired lamination sizes. A study of the curves in the top left-hand part of Chart 1 will show that mumetal gives the greatest advantage over other materials at low frequencies, but that in this range there is little advantage in using thinner laminations. In the high frequency range, however, thinner laminations of mumetal produce considerable increase in Q.

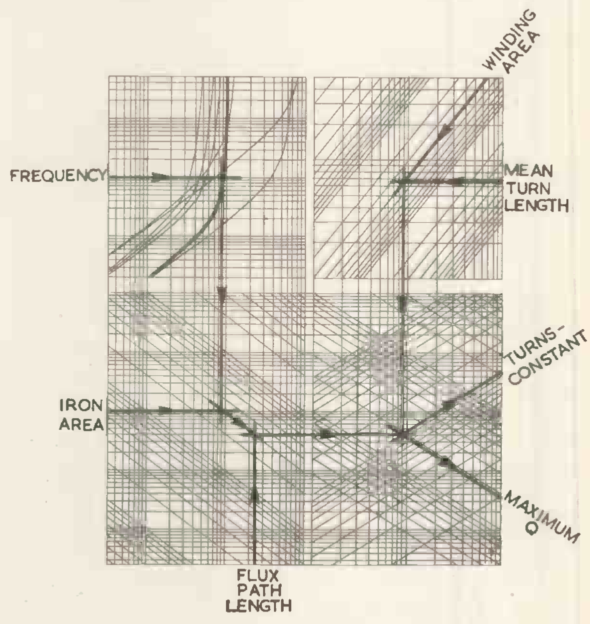


Fig. 4. Illustrating the use of Chart 1

Radiometal produces negligible improvement at low frequencies over the usual grade 2 transformer iron, but at high frequencies there is about a 50 per cent improvement. A further point should not be overlooked however: although the Q value at low frequencies is not appreciably improved, the saturation flux density is raised quite considerably by changing to radiometal, and this may be a deciding factor for inductors required to handle a high signal level.

There are practical limitations, not immediately evident from the chart, to the air-gap length resulting. If this comes to too low a value, less than say 1/1 000th of the flux path length, the supposition that inductance value is principally dependent upon air-gap dimensions no longer holds, nor can it be regarded as sensibly constant with variation of frequency or signal level. At the other extreme, the air-gap length given may become a large proportion of the total flux path length, in which case the inductor becomes virtually air-cored and again the design method does not apply.

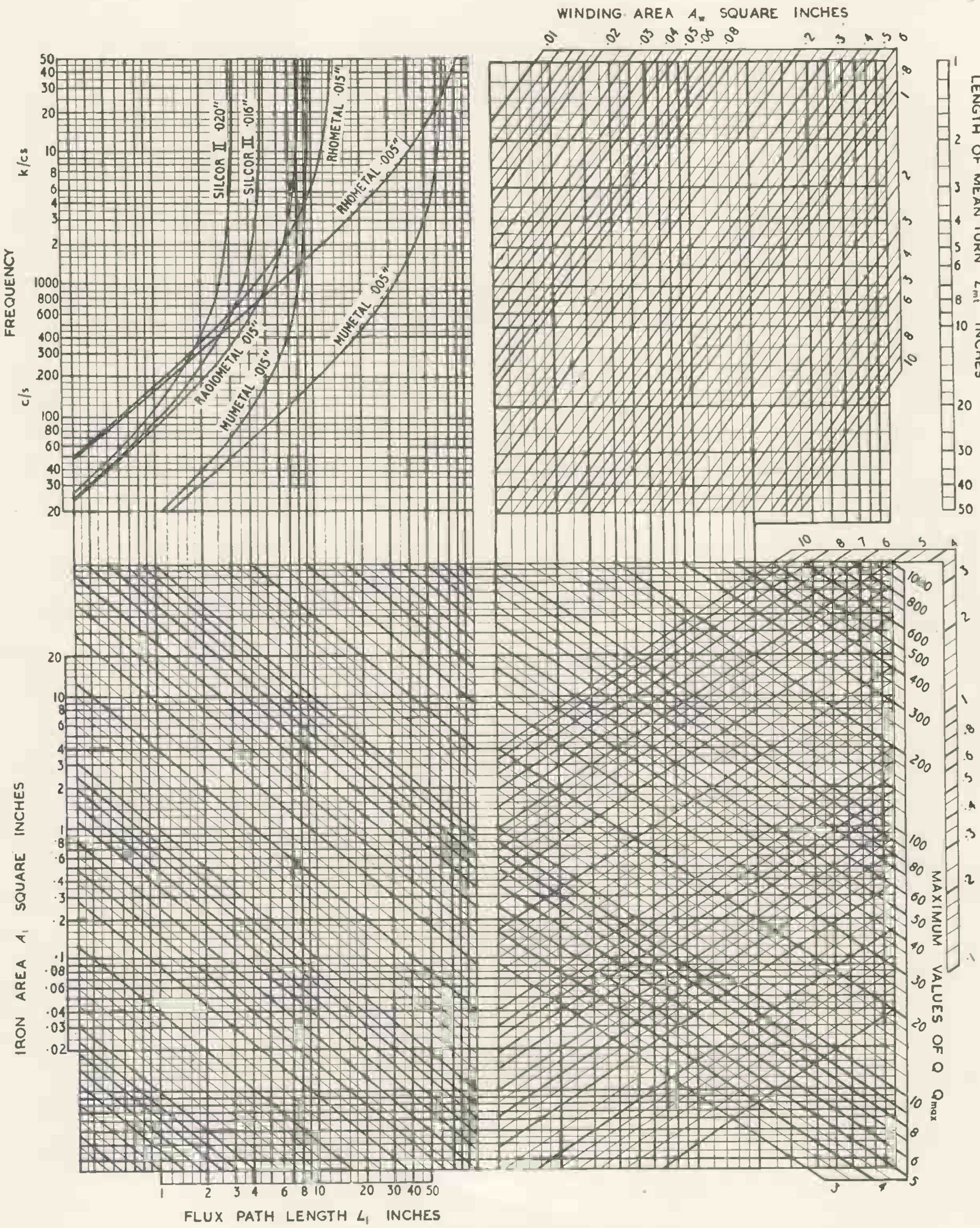


Chart 1. Core Size, Material, Q, Turns-constant

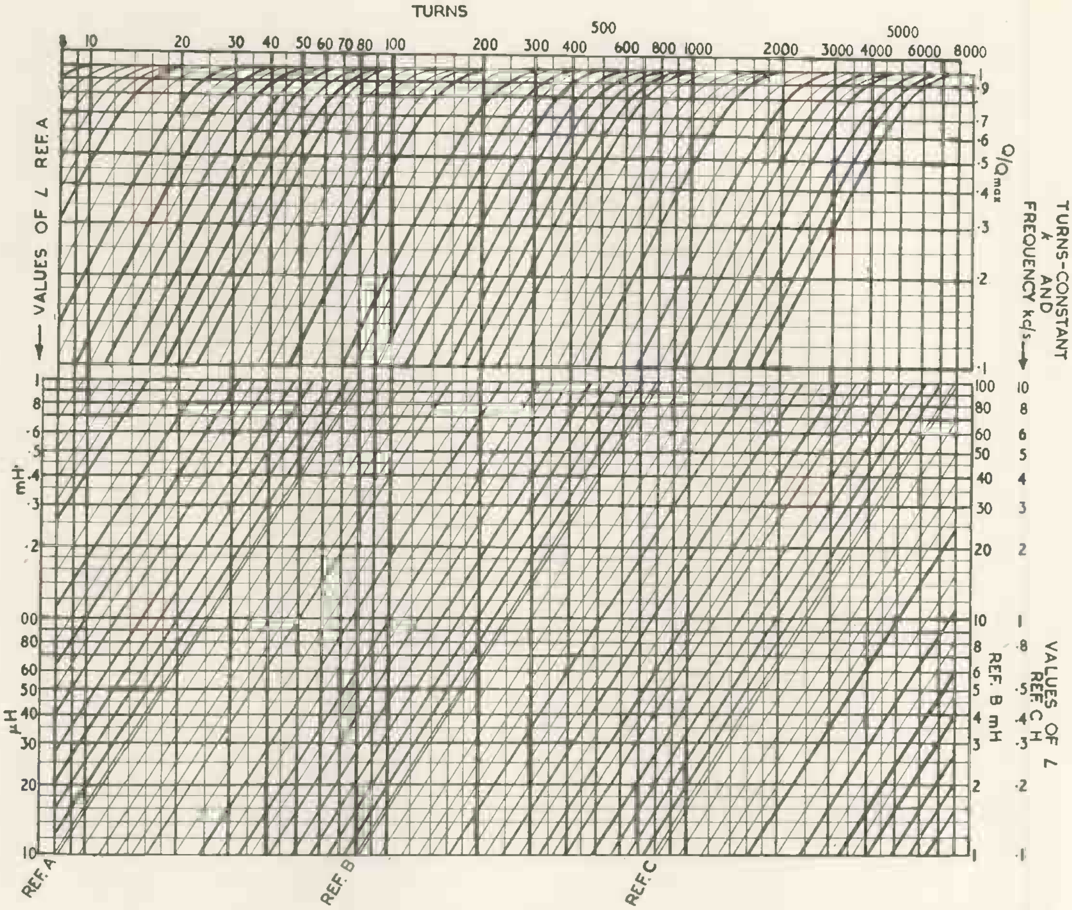
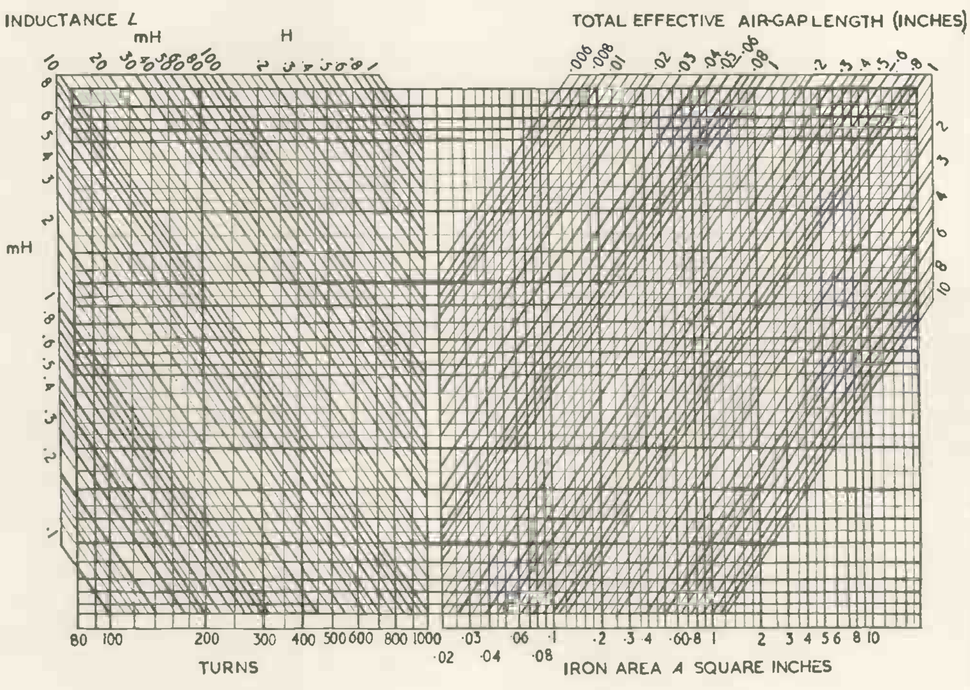


Chart 2. Turns determination

Chart 3. Air-gap determination



To obtain the benefit of the magnetic material in improved Q, the material chosen should be such that the air-gap is of reasonable dimensions. It will be found in practice that theoretical maximum Q values can only be achieved at high frequencies, by use of mumetal or rhometal 0·005in. laminations. This does not mean that a relatively high Q iron-cored inductor could not be produced using one of the other core materials at these frequencies, but the theoretical maximum Q could not be achieved because the air-gap becomes impracticably long and may even exceed the value of flux path length for the laminations chosen.

Chart 2 is used to determine the number of turns required on the chosen core size. The lower part of the chart converts inductance value at the design frequency into reactance and employs the turns constant k to determine the number of turns to give maximum Q. To save space three reference lines have been provided, each with different associated values of L required. Fig. 5 illustrates the procedure for use with one of these reference lines according to the inductance value required.

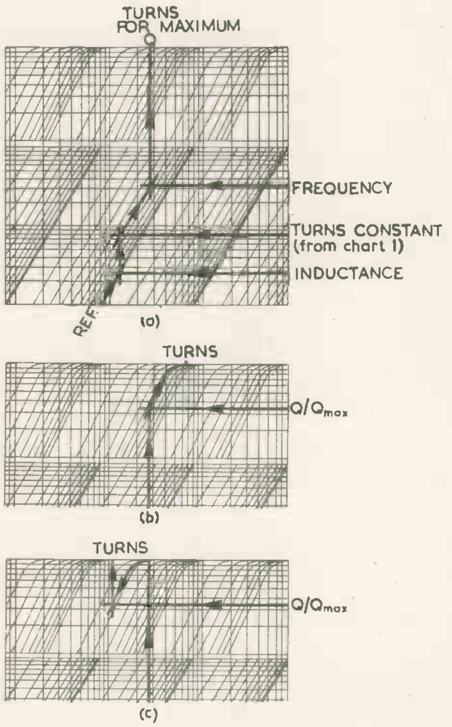


Fig. 5. Illustrating the use of Chart 2

(c) Method of reference for air-gap smaller than Q max value
(b) Method of reference for air-gap larger than Q max value
(a) Method of reference using air-gap for Q max

The top part of the chart enables reduced values of Q by using either greater or lesser number of turns to be estimated. At low frequencies a larger gap than the theoretical value for maximum Q may be desired, in which case the number of turns will be greater than the value for Q maximum. At high frequencies, to bring the air-gap down to a reasonable value, a lower number of turns will be required. The methods of reference for both these cases are illustrated at (b) and (c) of Fig. 5 respectively.

Chart 3 simply determines the effective total air-gap from the information so far obtained. If two gaps are effectively in series in the magnetic circuit, each will be half the value found. Fig. 6 illustrates its use. Here again space has been saved by presenting only a limited range of turns and inductance on one scale. To extend the range to cover the same turns and inductance values presented in Chart 2, inductance values shown may be multiplied or divided by 100, and turns values similarly multiplied or divided by 10 respectively.

Extremely small air-gaps may be invalidated due to the fact that an appreciable part of the total magnetizing current is required to magnetize the iron. The assumption is that the reactive component of magnetizing current is sensibly due to the air-gap only.

Large air-gaps may likewise be in error, due to fringing effects, which tend to make the effective area larger than the iron area. Alternatively this may be viewed as a reduction of effective gap length, with unchanged area. It is not practical to predict large gaps with accuracy, due to the number of variables influencing them—tongue width, gap length, and window shape. The advantage of the present approach is that when the correct gap is achieved the inductor will have maximum—or at least a specified Q. Having investigated the problem relatively quickly with the charts, the only variable to trim for precision results is the air-gap.

Example 1

Core material, Silcor II, 0·016in. laminations: Magnetic & Electrical Alloys No. 29, Richard Thomas and Baldwins No. 430A, Sankeys No. 111, G. L. Scott No. 43, Rola-

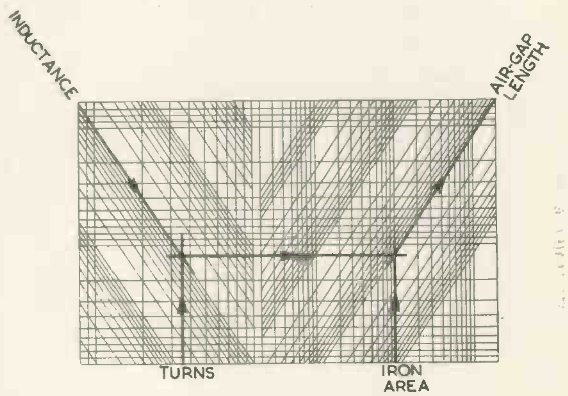


Fig. 6. Illustrating the use of Chart 3

Celestion No. 4; stack 1in.; L_i = 6in.; A_i = 1sq.in.; L_{mt} = 6in.; A_w=0·5sq.in. (after allowing bobbin space); frequency 1 000c/s; inductance 1 henry.

From Chart 1, maximum Q = 30; k = 1.

From Chart 2, maximum Q uses 2 500 turns.

From Chart 3, total effective air-gap is 0·5in. This can be something over ½in. cut off the centre limb, or just over ¼in. gap spacing between complete E and I sections. The gap can be reduced by using less turns. A Q of 25 is 5/6 of maximum, 0·83. This requires 1 800 turns (from Chart 2), giving a total air-gap of about 0·26in.

Example 2

Core material, mumetal 0·005in.; laminations, Telcon No. 500T; stack ¼in.; L_i = 2in.; A_i = 0·0625sq.in.; L_{mt} = 2in.; A_w = 0·08sq.in.; frequency 1 000c/s; inductance 1 henry.

From Chart 1, maximum Q = 28; k = 2.

From Chart 2, maximum Q uses about 1 800 turns.

From Chart 3, total effective air gap is 0·017in; which is far more practical than Example 1, for the same component.

REFERENCES

1. Crowhurst, N. H. Design of Iron Cored Inductances Carrying D.C. *Electronic Engng. 22*, 516 (1950).
2. Crowhurst, N. H. Transformer Iron Losses. *Electronic Engng. 23*, 396 (1951).

Notes from the Industry

R.I.C. Premiums for Technical Writing. The Panel of Judges appointed by the Radio Industry Council to award premiums to authors of articles increasing the prestige of the industry in this country and overseas will be meeting shortly to consider articles submitted during 1953. It will be remembered that the object of the scheme is to encourage the writing and publication of articles reporting technical progress and development in radio and electronics in Great Britain. Last year five 25 guinea premiums were awarded, including an interim award for an article of outstanding merit. In addition, two awards of £10 each were also made. Articles accepted for publication by journals on sale to the public between January and December, 1953, should be submitted, not later than 30 November, to the Secretary, The Radio Industry Council, 59 Russell Square, London, W.C.1, together with five copies of the journal in question. By arrangement with the Radio Industry Council, however, five copies of each issue of ELECTRONIC ENGINEERING are automatically sent to the Panel of Judges so that an author need not include copies with his submission.

The National Academy of Sciences, Washington, is administering a scheme whereby the United States Government has provided funds of over a million dollars to enable 150 outstanding young scientists from Europe to travel and live in the United States for up to two years in order to study and gain experience in American research institutions. The Royal Society has accepted the invitation of the Academy to advise on the selection of candidates from the United Kingdom. About twenty-five fellowships will be open for award to candidates from the United Kingdom. They must be in possession of a doctoral degree in science recognized in institutions of higher education or have equivalent experience. Applications, which may be made at any time, will be considered at regular intervals. Forms of application and further detailed information are obtainable from the Assistant Secretary, the Royal Society, Burlington House, London, W.1.

RCA Photophone Ltd, who manufactured the first Sonar (echo-ranging) equipment produced in Britain under the U.S. Off-shore Procurement Programme, delivered this to U.S. Navy officials in London recently and they handed the equipment over to a representative of the Government of Norway. The contract, amounting to approximately $3 500 000 was placed last year by the U.S. Navy Bureau of Ships, Washington, with the Radio Corporation of America. It is administered by the U.S. Navy Purchasing Office in London and most of the equipment is intended for use by Navies of the North Atlantic Treaty Organization.

The Association of Plastic Cable Makers has recently been formed by a substantial number of plastic cable manufacturers with the objects of the promotion and advancement of the interests of the industry and the establishment of standards of quality for plastic cables. The address of the Association is 381 Salisbury House, London Wall, London, E.C.2.

The Ministry of Supply announce that the Isotope School at Harwell is to introduce an additional course for the second time this year. This will be held from 16 November to 11 December. Applications should be sent to the Isotope School, A.E.R.E., Harwell, Berkshire, as soon as possible.

The Electrical Industries Benevolent Association is holding its annual Dinner and Ball on Friday, 13 November. Tickets can be obtained from the Association at 32 Burlington Street, London, W.1.

Sir George Nelson, Chairman of the English Electric group of companies, was recently host to some 800 guests at a dinner and dance in honour of delegates who were in London from all parts of the world for the seventh Plenary Assembly of the International Radio Consultative Committee. This committee is one of four permanent consultative committees of the International Telecommunications Union. The committee studies technical problems arising from the increase of broadcasting and telecommunications in general.

The Seventh Annual Amateur Radio Exhibition organized by the Incorporated Radio Society of Great Britain, will be held at the Royal Hotel, Woburn Place, London, W.C.1, from Wednesday, 25 November, to Saturday, 28 November. The exhibition will be opened by Mr. Rene Klein, Founder-member and Vice-President.

The Electrical Development Association's Testing House at Leatherhead, Surrey, was formally opened by the Association's President, Sir Henry Self, K.C.B., K.C.M.G., K.B.E., on 5 October. The Testing House was established in London at the end of the war, when firms had switched in great numbers from munitions to the manufacture of normal domestic goods. There was a great demand for electrical appliances and the situation had inevitably arisen that some of the goods produced were not up to the standard required by the electrical industry. In order to recapture the country's place in overseas markets it was important that there should be a real warranty attaching to British designs and British goods.

Ekco Electronics Ltd announce that Mr. R. Y. Parry has been appointed Technical Manager, Nucleonics, and Mr. E. B. Thompson, Sales Manager.

PUBLICATIONS RECEIVED

PERMANENT MAGNETS is a publication which has been compiled jointly by members of the Permanent Magnet Association with the express purpose of providing authoritative information on the subject of Permanent Magnets. The PMA were the first to produce the now universally known magnet material, ALNICO, and also developed the original anisotropic alloys which led to the introduction of ALCOMAX and all other uni-directional magnets. Permanent Magnet Association, 301 Glossop Road, Sheffield 10.

FUNDAMENTAL PROCESSES OF CONTACT PHENOMENA, Radio Research Special Report No. 24 is a survey of existing knowledge of the physical processes occurring at contacts and is intended to provide those making or designing contact equipment with the practical and theoretical information which is now available on the subject. The report is published by Her Majesty's Stationery Office for the Department of Scientific and Industrial Research, price 3s., by post 3s. 2d. The Department of Scientific and Industrial Research. Charles House, 5-11 Regent Street, London, S.W.1.

COPPER IN INSTRUMENTATION is a book which deals with the uses of copper and its alloys in certain classes of measuring and control instruments. They are considered under three main headings. Pressure and strain-responsive instruments, electromagnetic instruments and temperature-responsive instruments. Copies are obtainable free of charge on application to the Copper Development Association, Kendals Hall, Radlett, Herts.

ROTARY PUMPS, MOISTURE AND MERCURY VAPOUR TRAPS. VACUUM COATING PLANT and VACUUM TECHNIQUE are four brochures issued recently by W. Edwards and Co. (London), Ltd., dealing with sections of their range of high vacuum equipment. Copies may be obtained from W. Edwards and Co. (London), Ltd., Worsley Bridge Road, Lower Sydenham, London, S.E.26.

THE BRITISH PRODUCTIVITY COUNCIL is a comprehensive booklet on the policy and programme of this Council. A list of the productivity Reports issued is also included. Copies may be obtained from The British Productivity Council, 21 Tothill Street, London, S.W.1. Price 6d.

RCA TRANSISTORS is a booklet describing the first commercially available RCA Transistors recently announced by the Tube Department of the Radio Corporation of America. There are four transistors available, namely, for pulse or switching application, for oscillator applications up to 50Mc/s, and for low-power, low-frequency applications. RCA Photophone Limited, 36 Woodstock Grove, London, W.12.

ELECTRONIC FUNDAMENTALS and ELECTRONIC APPLICATIONS are two recent publications of the Machinery Publishing Co. Ltd. The former gives an explanation of basic electronic devices and their function in industrial circuits, while the latter draws examples from practice of the use of electronic devices in the machine shop and factory. These two books are from the Yellow Back range of over 50 titles and cost 4s. each. The Machinery Publishing Co. Ltd, National House, West Street, Brighton 1.

THE QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS, Volume VI. Part 3, is now available and contains contributions of its usual high standard and interest. The Clarendon Press, Oxford. Price 15s.

SIMA LIST OF PREFERRED VALVES. This is the second edition and takes into account the greater range of miniature valves now available and to accord with the greater use being made of valves of this size. The booklet provides a useful guide to a selected number of valves in each category, both of size and function. Wherever possible American and Service equivalents are listed. Full technical data on the valves is given, together with base diagrams and other information. Copies of this second edition may be obtained on application to the Secretary, Scientific Instrument Manufacturers' Association, 20 Queen Anne Street, London, W.1. Price 3s. 6d. post free.

ELECTRONIC EQUIPMENT

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

High Speed Tape Reader

(Illustrated below)

THE Ferranti tape reader mark II was originally designed for use with high speed digital computors, but it has many applications in the field of communications. It will read standard 5 or 7 hole teleprinter tape at the rate of 200 characters per second if run continuously. The tape is driven by friction and can be passed through the reader many times without damage. A photo-electric system of reading is employed. Light from a single lamp is projected through the holes in the tape to form images on a series of photocells. Each photocell is connected to a single valve amplifier whose output signal level changes from approximately −20V under no hole conditions to zero volts when a hole is

being read. These amplifiers are built into the tape reader. The tape can be stopped from full speed within 0·03in and accelerated from rest to its full speed of 20in/sec within 5msec.

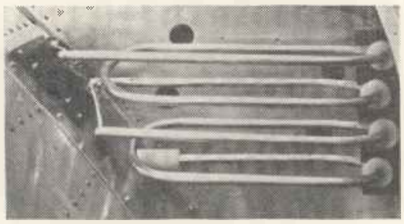
Ferranti Ltd,
Hollinwood,
Lancashire.

Suppressed Aerial System

(Illustrated above right)

ONE of the main disadvantages of externally mounted aircraft aerials is the increased "drag" when applied to high-speed aircraft. However, the new suppressed aerial of Ekco Electronics Ltd. overcomes this difficulty because it is incorporated within the structure of the aircraft, and at the same time it simplifies problems associated with mechanical strength. Suitable for use with either 12 or 24 channel transmitter-receivers, this new type aerial operates successfully at high altitudes due to the fact there is a considerable reduction in corona troubles associated with thin-section external aerials.

The system employs coil coupling to the aircraft skin, the coil being remotely tuned and matched automatically. The required channels are pre-set by means of a selector unit mounted in the fuselage of the aircraft and a control unit in the



cockpit allows instant selection of any pre-set channel. (The illustration shows the coupling unit mounted in the wing of an aircraft.) A meter on the control unit indicates aerial resonance and tuning capacitor position, while interlock arrangements ensure that the transmitter is suppressed during channel changing.

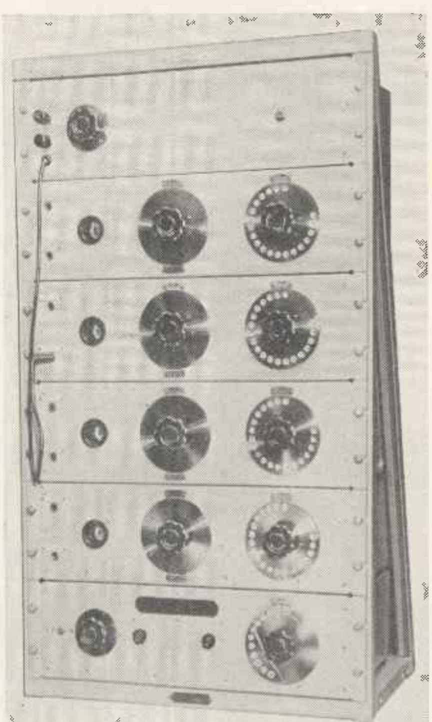
Ekco Electronics Ltd,
Ekco Works,
Southend-on-Sea,
Essex.

Precision Frequency Measuring Equipment

(Illustrated below)

THIS equipment is designed to allow even an unskilled operator to make rapid precision frequency measurements by direct reading. The range of the equipment extends from 10c/s to 10Mc/s and the accuracy of observation is better than 1c/s plus the error of the source of standard frequency.

The general principle of operation is to heterodyne the unknown signals with a selected series of standard frequencies chosen from a standard decade series in



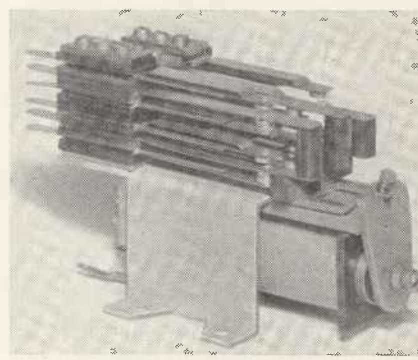
descending order of magnitude until a residual frequency less than 1kc/s remains. This is then measured on a frequency meter stage having a discrimination better than 1c/s. The digits defining the unknown frequency are automatically selected in the course of a measurement and the appropriate figures are illuminated at the end of the measurement.

The General Electric Co., Ltd,
Magnet House,
Kingsway,
London, W.C.2.

D.C. Relay

(Illustrated below)

THE design of the type B.02 relay is based on the type 3 000 telephone relay but with increased robustness and



insulation which makes it more suitable for industrial and general switching applications.

The coil is layer wound and vacuum impregnated and can be supplied in any value up to 20kΩ; the operating power varying from 0·05 to 1·5W depending on the contact load. Up to six sets of contacts can be fitted, typical ratings for these varying from 15A at 24V A.C. or D.C. to 3A at 440V A.C.

A "centre of gravity" fixing bracket is normally fitted which minimizes the effects of shock and vibration.

Besson and Robinson Ltd,
6 Government Buildings,
Kidbrooke Park Road,
London, S.E.3.

Ionization Anemometer

(Illustrated above right)

THIS equipment has been developed in conjunction with the Medical Research Council for the measurement of low speed air currents such as are encountered in ventilation measurements. It is a robust and portable instrument employing a radioactive source in the measuring head.

The equipment consists of two units. The amplifier, which operates from A.C. mains or a 6V battery, and which contains the indicating meter and controls; and the measuring head which is essentially a radioactive source and the

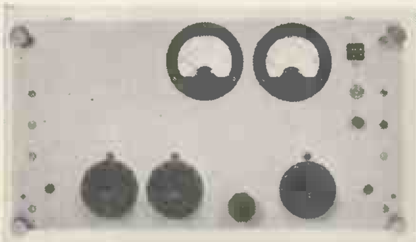
surrounding electrodes in a spherical cage with a supporting handle. Two air speed ranges are provided; 0-100 and 0-30ft/min.

Isotope Developments Ltd,
120 Moorgate,
London, E.C.2.

Line Transmission Measuring Equipment

(Illustrated below)

THIS is a portable equipment for measuring the levels of the line control and maintenance pilots. It has a selective measuring circuit which will pick out the pilots and reject traffic signals, and can therefore be used while the system is in traffic. It is primarily intended for testing repeater equipment.



A probe unit is incorporated which enables both through and terminated level measurements to be made, the probe being connected to the measuring set via a 10 foot cord.

The equipment includes facilities for standardizing the gain of the measuring circuit to ensure accuracy of measurement.

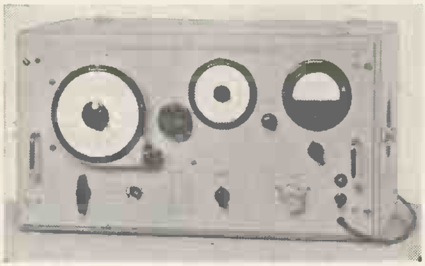
Power supplies are derived from the spare amplifier position on the repeater bays.

Standard Telephones and Cables Ltd,
North Woolwich,
London, E.16.

Decimetric Wave Signal Generator

(Illustrated below)

THE type SDR signal generator, manufactured by Rohde and Scharz of Munich, has a frequency range of 300 to 1 000Mc/s, which is covered in eight



ranges. The output voltage is continuously variable from $1\mu V$ to 4V; above 0·4V this is indicated by a crystal diode voltmeter while below this value a calibrated voltage divider is used. 100 per cent 1 000c/s rectangular modulation is provided. The frequency stability, after an initial warm-up period is $\pm 5 \times 10^{-5}$.

Distributed by:

Dawe Instruments Ltd,
130 Uxbridge Road,
London, W.7.

Portable Strain Indicator

(Illustrated below)

SINGLE channel static strain measurement is provided by this wide-range manually balanced indicator. Calibration is in terms of micro-inches per inch. The instrument is portable and is powered from A.C. supply or self-contained battery.

The instrument is designed for operation with 100Ω resistance wire strain gauges of gauge factors 1·7-2·2. A

gauge factor adjustment is provided on the panel. A panel outlet is provided for connexion to a cathode-ray oscilloscope to display dynamic strain.

Elliot Brothers (London) Ltd,
Century Works,
Lewisham,
London, S.E.13.

R.F. Induction Heater

(Illustrated above right)

SEVERAL of the disadvantages previously associated with induction heating have been overcome in the design of the new Airmec 5kW electronic heat generator Type 850.

Both manual power control and facilities for automatic power control have been incorporated, thus enabling a high standard of heating precision to be obtained, particularly in repetitive operations.

The problem of heating objects at a distance has been solved by the provision of a small remote work unit which enables articles to be heated up to 12 feet away from the generator without loss of power. The remote work unit

contains the oscillator tank circuit and associated components together with duplicate on-off switches.

The generator, continuously operated, is rated to develop a maximum power of 5·5kW in the work, and the difficulty of obtaining optimum power in widely differing conditions has been overcome by providing very versatile output matching arrangements.

Airmec Ltd,
High Wycombe,
Bucks.

Cable Sealing Sleeves

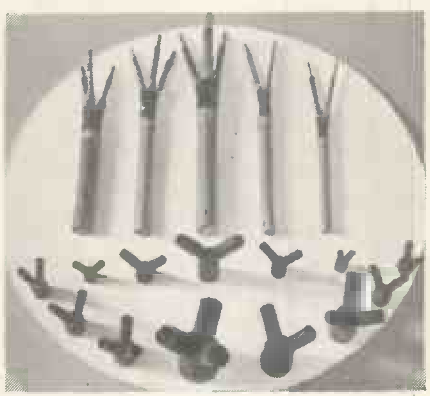
(Illustrated below)

BRITISH Insulated Callender's Cables Ltd. have developed a range of polychloroprene sealing sleeves for terminating cables used in normally dry conditions, where sealing by the more orthodox method is considered unnecessary.

These sleeves have been developed for use on medium voltage, two and three core, cambric-insulated cables, and are particularly suitable for ship wiring. The range is to be extended, however, to cater for mass-impregnated non-draining power cables for industrial installations generally.

The sealing sleeve—which is fitted over the prepared end of the cable as illustrated—is a means of terminating cables where space is a consideration, and where the more complete protection afforded by a compound-filled box is not warranted.

British Insulated Callender's Cables Ltd,
21 Bloomsbury Street,
London, W.C.1.



BOOK REVIEWS

Grundlagen der Elektronenoptik

By Walter Glaser. 699 pp., 445 figs. Demy 8vo. Springer Verlag, Vienna. Price £10 4s. 6d.

THIS is the latest, the largest, and the most comprehensive of all textbooks on theoretical electron optics. Dr. Glaser is well known as one of the earliest and most prolific authors in this field, to which he has contributed the concept of the refractive index in general fields, the Hamiltonian theory of lens aberrations, the aberration theory of beam deflexion, the theory of the combined effect of geometrical aberrations and of diffraction, and the calculation of innumerable special systems and problems. At a rough estimate, at least 2 000 out of the more than 3 500 formulae in this book are the author's own. Specialists in theoretical electron optics will be glad to have Glaser's work, until now scattered in scores of often inaccessible papers, collected in a handy volume. The representation of the work of other authors is less complete. To mention only a few conspicuous omissions, Scherzer's celebrated formula for the spherical aberration is quoted only in the special cases of purely electric and purely magnetic fields, not in its general form, and D. B. Langmuir's formula for the optimum density of a beam issuing from a hot cathode is not quoted at all, which is rather regrettable, as this can be considered as far and away the most important formula of practical electron optics.

The book has three main parts: Imaging Fields and Gaussian Dioptrics, Theory of Geometrical Aberrations, Electron Optics and Wave Mechanics. Of the 32 chapters we can only quote a few; those which contain particularly distinctive contributions of the author, not to be found in other textbooks. Chapter IX contains the exact calculation of paraxial trajectories in Glaser's "bell-shaped" magnetic lens, Chapter XI a detailed discussion of Newtonian and osculating Newtonian imaging fields, Chapter XIV a discussion of strong magnetic lenses including saturation. Chapter XVII contains the complete Hamiltonian theory of the aberration of electron lenses, comparable to Born's treatment of ordinary lenses in his "Optik." Chapter XIX specifies the third order aberrations for Glaser's "bell-shaped" lens field. Chapter XX is an attractive discussion of the caustics, Chapter XXIII is the theory of the aberrations of beam deflecting systems. The third part, Chapters XXV-XXXII, is a treatment of electron optics as a consequence of wave mechanics, which may be found also in de Broglie's "Optique Electronique et Corpusculaire," but in much more detail, and which may be understood also by those who had no previous acquaintance with wave mechanics. The book is well illustrated not only with line drawings but also with photographs of apparatus and of some outstanding achievements of electron microscopy.

No specialist in electron optics can afford not to have this book on his shelf. For most students, unfortunately, its high price may prove prohibitive.

D. GABOR

The Cathode Ray Oscillograph in Industry

By W. Wilson. 273 pp., 201 figs. Demy 8vo. 4th Edition revised. Chapman & Hall Ltd. 1953. Price 36s.

SOME criticism of this book may be made by workers in electronics, particularly by those engaged in the field of "pulse techniques", for the omission of many novel applications of the cathode ray tube in recent years. Such applications as a "flying spot" scanner as a signal storage device, as a generator of waveforms and pulse trains and as a means of filtering signal trains into discrete channels on a time sharing basis come to mind. It is felt that such recent applications, although like the electron microscope, not strictly oscillography, would have helped to bring the work more up to date and would have given workers in other fields knowledge of some of the more unusual applications of the cathode-ray tube in addition to its principal use as a laboratory or test instrument.

The main purpose of the book is the introduction of the cathode-ray oscillograph to potential users in fields where the instrument is not well known, and the main value of the work lies in the presentation of the subject in a form so easily digested as to stir the imagination and inventiveness of the reader towards thinking of new applications.

The first four chapters are devoted to the general principles of the cathode-ray tube, both the glass "sealed off" and the continuously evacuated types being described, to the basic accessories required with the tube to form the oscilloscope, and to descriptions of some well known commercial instruments. Chapters V to X inclusive cover a most comprehensive range of application which, although mainly limited to the field of engineering, are, undoubtedly, of great value to potential users in other fields as a means of showing the versatility of the instrument and providing food for thought. Chapter XI is devoted entirely to descriptions and uses of the electron microscope. Chapter XII gives some useful hints on the construction, operation and maintenance of cathode-ray oscillographs. Several appendices deal with features of some of the electronic devices associated with oscillography and two of the more recent developments.

The book is well written and illustrated, and is useful as a basic guide for beginners in the field of electronics where the instrument is now a firmly established necessity. It is recommended to workers in branches of engineering where the C.R.O. is not so well known, and recommended in particular to research workers using electrical or electronic equipment in industries outside the field of engineering where there are, undoubtedly, many unexplored applications for the instrument.

It is regretted that the death of the author occurred during the preparation of the final proofs of this revised fourth edition of his book which first appeared in 1943. He made several noteworthy contributions to electrical engineering literature.

G. SHAND

Principles of Radar

By J. F. Reintjes and G. T. Coate. 985 pp., 280 figs. Royal 8vo. 3rd Edition. McGraw-Hill Publishing Co., New York and London. 1953. Price 55s. 6d.

IN reviewing the third edition of this excellent book written by members of the staff of the Radar School, Massachusetts Institute of Technology, one is tempted to think of a title which will also attract those who do not work in the field of radar, for an enormous amount of information is collected together here concerning modern circuits, ultra high frequency and microwave devices.

The book begins and ends with radar from elementary first principles and only the very minimum of mathematical ability is needed throughout.

Circuits to provide special waveforms including pulse modulators and timing circuits are explained in a very simple manner by the use of accompanying diagrams showing the waveforms generated at critical points in the circuit. The method of presentation, following as it does the principles which would be used in servicing the circuits when in use, should be welcome to all.

Although the possibilities of saturable core reactors in pulse modulation are discussed a noticeable omission is the mercury switch—D.C. transformation circuit modulator.

The presentation of data by means of cathode-ray tubes with various scanning systems is well covered as are the different servo-mechanisms, their possible instabilities are also briefly treated.

The chapter on receivers is developed from an analysis of the spectrum of the incoming pulse signals, the steady and transcient response of simple circuits and the effect of internal valve reactances to the more complicated wide band I.F. amplifiers and A.F.C. systems. The contributions of the various circuit elements to the overall receiver noise figure are also simply dealt with.

While nearly all of the latter half of the book is concerned with microwaves there is also a chapter on U.H.F. triode oscillators which are discussed in relation to their equivalent circuits and the importance of mechanical layout are made apparent.

Klystrons and magnetrons are covered in what is probably sufficient detail for an intelligent user of these devices, but not for those concerned more with their detailed design and operation. The choice of Q_E to represent electronic change in this context is an unhappy one as also is the statement that the zero order mode frequency of a magnetron is unaffected by the size of resonators (p. 772). The field configuration of this mode (Fig. 13A p. 771) is again misleading as the electric field is largely circumferential and not radial.

Much useful information on transmission lines, waveguides, the reactances of discontinuities and the equivalence of lumped circuits with cavity resonators is included.

In the chapter on transmitting and receiving systems the multitudinous radio frequency components which may lie between the transmitter and the I.F. amplifier of a modern radar set are dealt with in some detail.

Aerials and propagation each have chapters to themselves and complete a very well produced and extensive study of the whole field.

H. A. H. Boot

Sound Reproduction

By G. A. Briggs. 368 pp., 304 figs. Demy 8vo. 3rd Edition. Wharfedale Wireless Works, 1953. Price 17s. 6d.

THE third edition of this book is a considerable enlargement upon the previous two editions. Mr. Briggs maintains his interesting style of presentation, but has improved his coverage of the subject as a result of the interest shown by readers of the earlier editions.

In this reviewer's comments on the earlier edition, the technical accuracy of some explanations was criticized. It is admittedly difficult for a semi-technical writer to avoid this. It is also difficult for a writer with the more advanced knowledge necessary, to avoid being too technical for this book's intended readers. In this edition Mr. Briggs has overcome this difficulty quite successfully by obtaining the assistance of "specialists" able to give him an accurate technical basis for his presentation. For example, because the reviewer called attention to weakness of the earlier chapter on Intermodulation, Mr. Briggs asked him to prepare material for this chapter. Then Mr. Briggs takes over the batting from time to time to prevent the going from getting as heavy as it otherwise might for the semi-technical reader.

The book is divided into two parts. The first deals with aspects of reproduction related to loudspeakers, from a description of what constitutes high fidelity to the various factors that contribute to it—acoustics, response curves, forms of distortion, types of loudspeaker, loudspeaker grouping, and the use of dual and multiple unit systems; the second part deals with aspects of reproduction derived from recordings from whole systems down to practical details.

The additional material is largely resultant from the growing interest in high fidelity—the growing band of people known in America as "audiophiles", but some indication of its increased scope is given in the size of the new edition, and the fact that over half of the illustrations are quite new.

N. H. Crowhurst

Controllers for Electric Motors

By H. D. James and L. E. Markle. 426 pp., 80 figs. Demy 8vo. McGraw-Hill Publishing Co., New York and London. 2nd Edition. 1952. Price 59s. 6d.

THIS book provides a comprehensive guide to American practice in the control of electric motors of all powers. Magnetic and valve amplifiers are dealt with and their application to speed control expounded. The book is essentially practical and contains no mathematics other than of a very elementary nature.

Guide to Broadcasting Stations

104 pp. Demy 16mo. Iliffe & Sons Ltd. 7th Edition. 1953. Price 2s.

THIS useful little book, compiled by the staff of *Wireless World*, has been fully revised and enlarged and now provides data on the world's broadcasting stations. The book lists first in order of frequency and then geographically all the European long and medium wave stations, and over 1 600 short wave broadcasting transmitters working on a power of over one kilowatt, throughout the world.

Other tables give operating details of some 40 television stations in Europe, over 160 European metre-wave stations, Consol transmitters, and standard-frequency stations. Another useful feature is the table of international call sign prefixes, covering the world.

B.I.M.C.A.M. Handbook for 1953

133 pp. Demy 8vo. British Industrial Measuring and Control Apparatus Manufacturers' Association.

THIS is the first handbook produced by the British Industrial Measuring and Control Apparatus Manufacturers' Association to illustrate the achievements and potentialities of instrumentation and control. The members of the Association are listed and the handbook includes a comprehensive list of products and names of members of the Association.

Scintillation Counters

By J. B. Birks. 148 pp., 62 figs. Demy 8vo. Pergamon Press Ltd. 1953. Price 21s.

THE scintillation counter has become one of the most powerful and versatile instruments for detection of nuclear radiation during the past few years. It comprises a luminescent crystal emitting light on bombardment by nuclear particles or radiation and a photoelectric multiplier which detects the light and amplifies the resulting pulse or photocurrent many millions of times, so that a sizeable voltage pulse appears at its output for each particle or photon incident on the system. Its performance depends on many factors such as response efficiency of the luminescent material, light collection efficiency, photoelectric response of the photomultiplier and on the multiplier noise and multiplication. Up to the present there has been no comprehensive text available to the user of such a counter which treats all these matters and also the requirements of specific applications. The present volume is an attempt to do this and also to give detailed information on important problems such as time and energy resolution, varieties of luminescent crystals and liquids available and the types of commercial photomultiplier suitable for the counter. Although there is now another book published on the same topic the lower cost of the present volume, which includes much of the material available in the more expensive text, may make it attractive to the reader who has to make use of the scintillation counter for routine or fundamental nuclear measurements. The text is well up to date and there is no lack of references to all aspects of the counter design and its applications. Only one major error occurs in the text which may mislead the reader. The statement on page 51 that zinc sulphide crystals are very inefficient for detection of beta and gamma rays, compared with their efficiency for alpha particles, is incorrect. The absolute scintillation efficiencies are similar in all three cases but thin screens of microcrystalline type do not act as efficient stoppers for beta and gamma rays and also absorb a large fraction of emitted light because of multiple internal scattering and absorption. Single crystals of the same phosphor do not show such adverse properties.

G. F. J. GARLICK

MEETINGS THIS MONTH

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: November 11. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1.
Lecture: A High Definition General Purpose Radar.
By: J. W. Jenkins, A.M.I.E.E., J. H. Evans, A.M.I.E.E., A.M. Brit. I.R.E., G. A. G. Wallace, D. Chambers, B.Sc.

Scottish Section

Date: November 5 Time: 7 p.m.
Held at: The University, Edinburgh (Natural Philosophy Department).
Lecture: Vibration Generators—Their Ancillary Equipment and Application.
By: H. Moore.
The Lecture will be preceded by the Annual General Meeting of the Section which will begin at 6.30 p.m.

Merseyside Section

Date: November 5. Time: 7 p.m.
Held at: The Merseyside and North Wales Electricity Board Service Centre, Whitechapel, Liverpool.
Lecture: Multi-Channel Tuners for Television.
By: S. L. Fife and W. E. Hosey, B.Sc.

North-Eastern Section

Date: November 11. Time: 6 p.m.
Held at: The Institution of Mining and Mechanical Engineers, Newcastle-upon-Tyne.
Lecture: Principles of Electronic Computing Machines.
By: Dr. B. V. Bowden.

West Midlands Section

Date: November 24. Time: 7.15 p.m.
Held at: The Wolverhampton Technical College, Wulfruna Street, Wolverhampton.
Lecture: Remote Control Devices and Servo-mechanisms.
By: A. E. W. Hibbitt.

THE BRITISH KINEMATOGRAPH SOCIETY

Date: November 4. Time: 7.15 p.m.
Held at: The Gaumont-British Theatre, Film House, Wardour Street, London, W.1.
Lecture: Factors Affecting 16mm Picture Illumination and Quality.
By: D. S. Morfey.

THE INSTITUTION OF ELECTRICAL ENGINEERS

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

Ordinary Meeting

Date: November 5.
Lecture: The Co-ordination of Insulation of High-Voltage Electrical Installations.
By: J. S. Cliff.

Radio Section

Date: November 11.
Lecture: Some Aspects of the Design of V.H.F. Mobile Radio Systems.
By: E. P. Fairbairn, M.C., B.Sc.

Date: November 23.
Lecture: Loudspeaker Systems—Recent Trends in Design.

Measurements Section

Date: November 3.
Discussion: Standardized Protective Transformers from the Point of View of Maker and User.
Opened by: H. S. Petch and J. G. Wellings.
Date: November 17.
Lecture: Alternating Current Instrument Testing Equipment.
By: A. H. M. Arnold, Ph.D., D.Eng.

Extra Meeting

Date: November 12.
Discussion: Safety Precautions in Electronic Apparatus, with particular reference to Medical Applications.
Opened by: H. W. Swann, O.B.E., and W. Grey Walter, M.A., Sc.D.

Cambridge Radio Group

Date: 3 November. Time: 6 p.m.
Address by Section Chairman: J. A. Smale, B.Sc.
Held at: Cambridgeshire Technical College.

North-Eastern Centre

Date: November 23. Time: 6.15 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture: Design Features of Certain British Power Stations.
By: S. D. Whetman, B.Sc.

North-Eastern Radio and Measurements Group

Date: November 2. Time: 6.15 p.m.
Held at: King's College, Newcastle-upon-Tyne.
Lecture: Transformer-Analogue Network Analysers.
By: M. W. Humphrey Davis, M.Sc., and G. R. Slemon, Ph.D., M.A.,Sc.
Date: November 16 (Time and place as above).
Lecture: A method of Designing Transistor Trigger Circuits.
By: Prof. F. C. Williams, O.B.E., D.Sc., D.Phil., F.R.S. and G. B. Chaplin, M.Sc.

North-Western Centre

Date: November 3. Time: 6.15 p.m.
Held at: The Engineers Club, Albert Square, Manchester.
Lecture: Economic Aspects of Overhead Equipment for D.C. Railway Electrification.
By: O. J. Crompton, M.Eng., and G. A. Wallace, B.Sc. (Eng).

North-Western Radio Group

Date: November 25. Time: 6.30 p.m.
Held at: The Engineers' Club, Albert Square Manchester.
Lecture: Some Aspects of the Design of V.H.F. Mobile Radio Systems.
By: E. P. Fairbairn, M.C., B.Sc.

North Scotland Sub-Centre

Date: November 12. Time: 7 p.m.
Held at: The Royal Hotel, Dundee.
Lecture: Electronic Telephone Exchanges.
By: T. H. Flowers.

South-West Scotland Sub-Centre

Date: November 13. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow.
Lecture: Nuclear Reactors and their Applications.
By: Sir John Cockcroft, C.B.E., M.A., M.Sc.Tech., Ph.D., F.R.S.

South Midland Centre

Date: 19 November. Time: 7.15 p.m.
Held at: The Winter Gardens Restaurant, Malvern.
Lecture: Printed and Potted Electronic Circuits.
By: G. W. A. Dummer, M.B.E., and D. L. Johnstone, B.Sc. (Eng.).

THE INSTITUTE OF PHYSICS

Electronics Group

Date: November 17. Time: 5.30 p.m.
Held at: The Institute's House, 47 Belgrave Square, London, S.W.1.
Lecture: Electron Multipliers.
By: Dr. A. S. Baxter.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: November 10. Time: 5 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, Victoria Embankment. London, W.C.2.
Lecture: The Influence of Signal Imitation on the Design of V.F. Signalling Systems.
By: S. Welch, M.Sc. (Eng.), A.M.I.E.E.

THE PHYSICAL SOCIETY

Date: November 20. Time: 5 p.m.
Held at: The Science Museum, South Kensington, London, S.W.7.
Lectures: Some Magnetic Measurements—Techniques and Applications.
By: Professor W. Sucksmith; and Cathode-Ray Tube Storage for Digital Computors.
By: Prof. F. C. Williams.

THE RADIO SOCIETY OF GREAT BRITAIN

Date: November 20. Time: 6.30 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Lecture: The Television Society's new Television Station.
By: H. de L. Banting, D. N. Corfield, A.M.I.E.E., and E. A. Dedman.

THE SOCIETY OF INSTRUMENT TECHNOLOGY

Date: November 24. Time: 7 p.m.
Held at: Manson House, Portland Place. London, W.1.
Lecture: Unusual Aspects of Automatic Control in the Chemical Industry.
By: R. D. Mylon.

THE TELEVISION SOCIETY

Date: November 13. Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue. London, W.C.2.
Discussion: Competitive Television.
Date: November 26. (Time and place as above).
Lecture: Convertors for V.H.F. or U.H.F. Television.

Leicester Centre

Date: November 30. Time: 7 p.m.
Held at: The College of Art and Technology, The Newarkes, Leicester.
Lecture: Fly Wheel Synchronizing.
By: S. E. Gent, B.Sc. (Eng.).