Electronic Engineering

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES, 28, ESSEX STREET, STRAND, W.C.2.

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Monthly (published last Friday of preceding month) 2/- net.

Subscription Rate: (Home or abroad) Post Paid 12 months 26/-, or $ 3.75 (U.S.).

Vol. 22. No. 263 January, 1950

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Television Progress

IT has been wisely said that the true way to measure television progress is by the extent to which it becomes a national service. By this reckoning British television is making its first determined step into the Provinces with the opening of the Birmingham station on December 17—but only the enthusiasm of the B.B.C. and the energy of the radio manufacturers responsible for the equipment deserve any credit for the extended service area.

Television progress in this country has been frustratingly slow, in spite of the post-war bonds on industry, and public disappointment has frequently been expressed, and with every justification. When the Television Advisory Committee was formed in 1945, at the instigation of the Hankey Committee on Broadcasting Policy, it was obviously intended to take the lead and guide the Postmaster-General, the B.B.C. and the radio industry along the proper path to put and keep British television in the forefront throughout the world. But it is doubtful if the Television Advisory Committee ever acted in full accordance with its original terms of reference, which were ambitious and promising. Many believe the Committee's membership ruled out the possibility of an adventurous career for television, which it surely deserved—since Great Britain, apart from providing the first regular television service in the world, was responsible for so much of the early research work and development in that sphere.

The Television Advisory Committee, consisting mainly of Government officials of the Treasury, the Ministry of Supply and the Post Office and the B.B.C.—the radio industry is not included—has recently been given revised (and we feel more limited) terms of reference: they are "to advise the Postmaster-General on current development problems of the B.B.C.'s television service." Thus the urge to "adventure" that was originally inherent has been taken away from the T.A.C., and only "current problems" need ripple the pool of complacent discussion.

If television is to take its rightful place in this country—both in the cultural and industrial fields—there is a degree of urgency unprovided for in the Government's present plan for stations to serve 80 per cent of the population by 1954. This is the view of the industry, which is anxious for a flourishing home market in television receivers (a prerequisite for a useful export trade) in order to justify the cost of further research and the probability of cheapening sets with increased demand. The B.B.C. is eager also to expand its services to the benefit of all; but its capital expenditure is controlled by the Government and is only granted from year to year.

The T.A.C. has the ball at its feet; but the game is slow—so slow, in fact, that after a recent meeting between the Committee and the Radio Industry Council the latter felt that under its revised terms it would not be possible for the Television Advisory Committee to be effective in developing television in this country. The Council therefore decided that no useful purpose would be served by attending further meetings of the Television Advisory Committee.

Meanwhile the Beveridge Committee is considering the renewal of the B.B.C. Charter, which is due in 1951, and perhaps a remedy for the present unimaginative approach to television will arise out of these discussions. It may be that television will eventually secure its independence within the B.B.C. administration: such a policy would be likely to please all who have faith in British television.

W.H.K.

Precision Measurement of Rotary Motion

By

H. J. FINDEN, M.I.E.E.*

IN measuring rotary motion we can determine the number of revolutions occurring in a given time, or alternatively the time taken for a given number of revolutions can be measured. The former method has the advantage of being direct reading in r.p.m. and it is convenient to make the measurement in terms of frequency.

There are many methods of measuring frequency, and which method is employed will depend on the conditions of test and the accuracy desired. In the laboratory, manually operated electrical bridges such as the Maxwell can give accuracies as high as 0.5 per cent when measuring frequency which is reasonably constant over the measuring time and where the waveform is free from harmonics. The need for manual operation can be a serious objection on the test bed where many other phenomena are required, and frequency meters which make use of R.-C. networks have been produced to give a voltage which is proportional to the input frequency. Accuracy at full scale deflexion is rarely better than 1 per cent, although the use of a polystrene capacitor and an Ayrton-Perry wirewound resistor for the network can improve the accuracy. In the bridge and integrating frequency methods it is an advantage to use a suitable low pass filter in the input circuit when the approximate frequency is known.

For aircraft use the electro-tachometer of the magnetic drag cup type has been developed to give accuracies better than 1 per cent at the top end of the scale reading. The reading presented is continuous, but there is an appreciable time constant in the indicator mechanism. In the indicator mechanism a copper sleeve surrounds a four-pole magnet driven by a three-phase synchronous motor of the self-starting type. The rotation of the sleeve is controlled by a spring and drives a pointer mechanism which consists of two pointers. The longer pointer indicates hundreds and the shorter one registers thousands, thus for a five turn indicator good scale reading accuracy is obtained. The motor is driven by the output from a three-phase generator which is located and driven by the shaft whose rotation is to be measured. In this way a remote indication of the rotary motion is provided by using electrical transmission.

The need for a reading approaching an instantaneous one has been compromised by using a counting technique over a short time interval. As the counting method is limited to an integral count, frequency multiplication of the signal is usually required and this has proved a limitation in the reliability of the method. Developments sponsored by radar have led to pulse shaping, frequency division and multiplication techniques which can be analysed and are therefore reproducible and the circuit engineer can now use these methods with confidence.

* The Plessey Co., Ltd., Ilford.

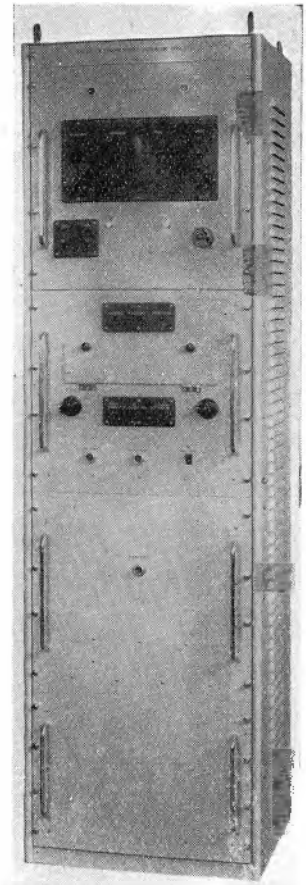


Fig. 1. Electronic precision engine speed indicator

Electronic Counting

In the electronic counting method, engine speed is determined by an integral count of the number of revolutions occurring in a given time. For high-speed operation a mechanical counter would be impracticable, hence the electronic counter possessing negligible inertia is used. Moreover, the use of electronic circuits avoids errors due to the introduction of switching delays, yet also permits a relatively short and accurately known time interval to be employed for the period of counting.

The time interval can be derived from a valve maintained tuning fork, a quartz crystal oscillator or other suitable frequency standard. The need for a short time interval necessitates the use of a frequency dividing unit in order to obtain a sub-multiple of the reference frequency. It is, therefore, an advantage to use a low frequency for this purpose in order to restrict the amount of division. Tuning forks made from elinvar are available with frequency/temperature coefficients of the order of 10 parts in a million per degree centigrade, and frequencies in the spectrum 800-1,000 c/s. are most suitable in actual practice.

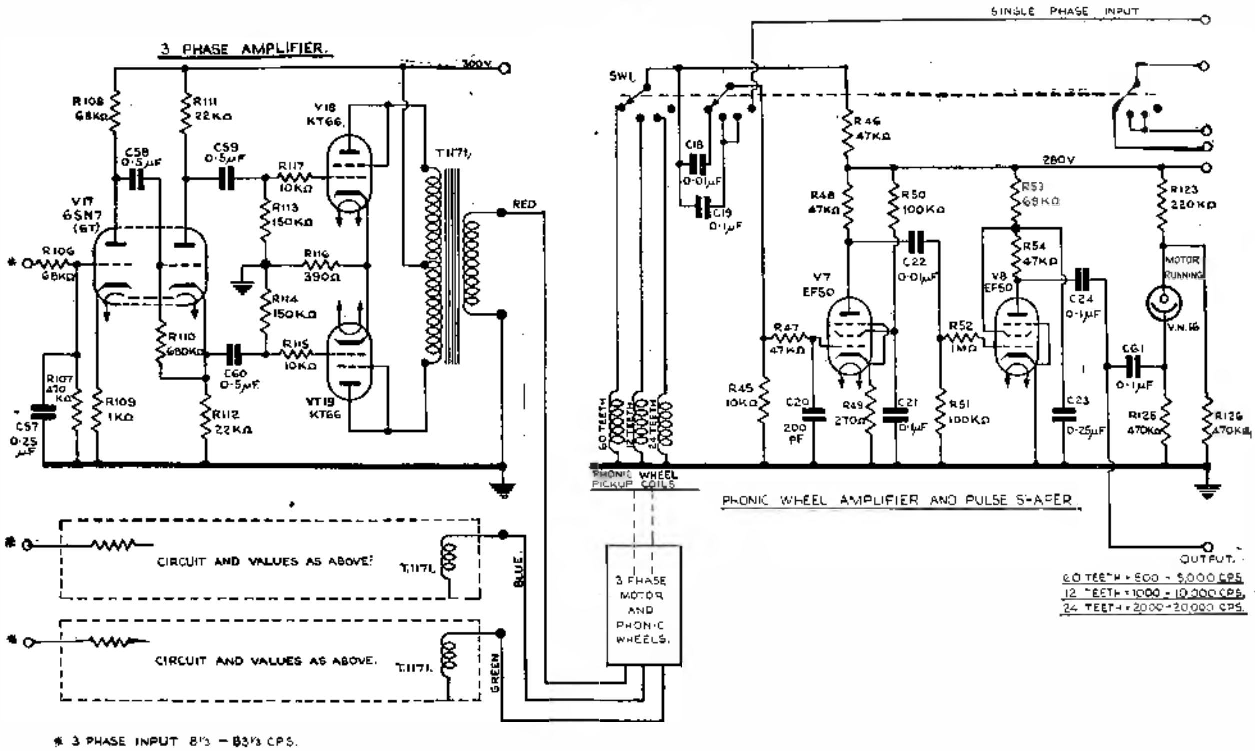


Fig. 2. Circuit diagram of input amplifier and frequency multiplier

An accuracy of 0.1 per cent for a revolution counter over an ambient temperature range of ±10° C., i.e., average conditions of the laboratory and test bed, can be realised with such a standard, since it will be shown that nearly all the error for this degree of accuracy is due to the timing interval.

For higher accuracies the fork can be maintained at a given temperature, although the physical size of such a standard will limit its use to ground applications. Recent developments in quartz crystals with the N.T. cut vibrating in a flexural mode permit standards to be made as low as 800 c/s. Experience has shown that crystals of 4 Kc/s. are reproducible Frequency/temperature coefficients less than two parts in a million per degree centigrade are obtainable with negligible pressure/frequency coefficients, whereas tuning forks have three to five parts in ten million per mm. of pressure.

There are several types of frequency dividing circuits, e.g., the regenerative modulator, the Trochotron and the bi-stable trigger relay of the Eccles-Jordan type. These are of the self-suppression type, i.e., no output is given in the absence of an input signal. Dividers of the controlled astable multivibrators form permit reliable division up to a factor of ten, but are preferable limited to a division of five, and when used with a scale-of-two divider very reliable division of five is obtained.

Where a one second timing interval is required cascaded scale-of-two dividers can be employed by using a standard whose fundamental frequency is 2^n. The output from the 1 c/s. stage is differentiated to produce sharp leading edged pulses with negligible rise times. These pulses are fed to a self-locking electronic relay stage which functions by the first pulse to arrive after a manually operated switch has been closed. In effect the relay is a gate which opens for one second and transmits any applied signal for one second only as the next timing pulse to arrive closes the gate. The total number of cycles in the applied signal passing through the gate are registered by a counter.

As the revolution counter may have to accept a wide range of input voltages with waveforms which are distorted, some form of input amplifier and pulse forming circuit is necessary. The pulses so formed can then be presented to the electronic relay and the total number occurring in the gated time interval are fed to the high speed counter. There are a number of forms of electronic counters and the easiest from the circuit aspect makes use of a scale-of-two counter, which is a logical development from the scale-of-two divider. For most applications a binary scale would not be acceptable as we use a scale-of-ten. Practical counters of the sequence operated type are available and are designed to re-cycle automatically after a pre-determined number of input pulses giving an output pulse in the process. A feedback method can be employed to a cascade of scale-of-two counters to convert to a scale-of-ten. To obtain a four-figure result from such cascades the tenth pulse applied to a given decade, can be utilised, resetting that decade to zero and initiating a pulse which is applied to the next higher decade.

The indication of the number of counts can be presented by several methods and a convenient one is to use a neon tube to show which valve of a trigger pair is "*off*".

Example of Revolution Counter

Fig. 1 shows an electronic precision engine speed indicator which has been produced for test bed work incorporating the followng features:

(1) A visual indication of the r.p.m. over a one-second time interval which is available until cleared manually.

(2) Three operating ranges:

(A) 500-5,000 r.p.m. mainly for reciprocating engines.

(B) 1,000-10,000 r.p.m. for medium speed turbo-jet engines.

(C) 2,000-20,000 r.p.m. for high speed turbo-jet engines.

(3) To operate up to 10 Kc/s. (i.e., 600,000 r.p.m.) from a single phase input or over the range specified in (2) with a virtual no-load output from the conventional electro-tachometer.

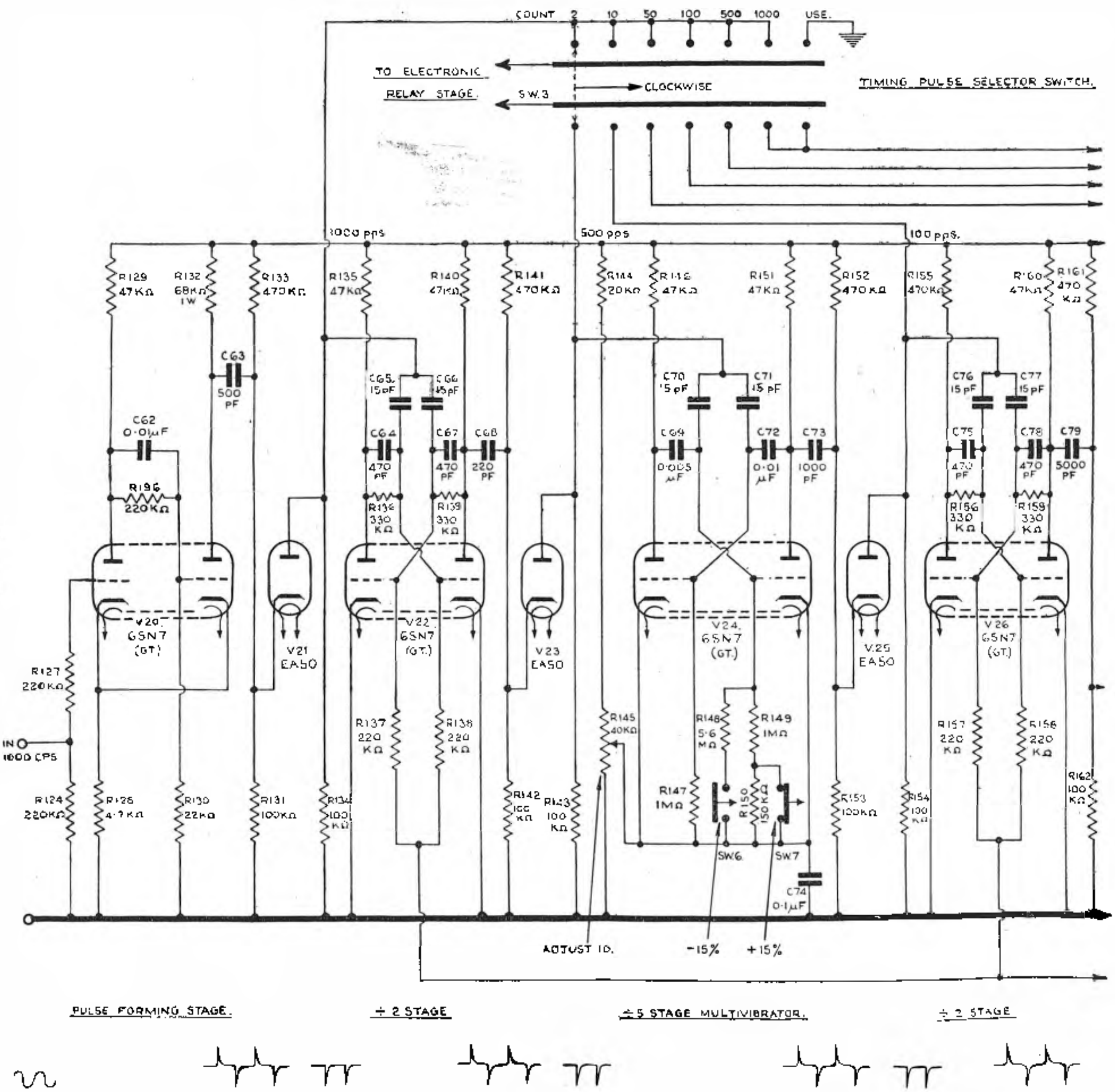
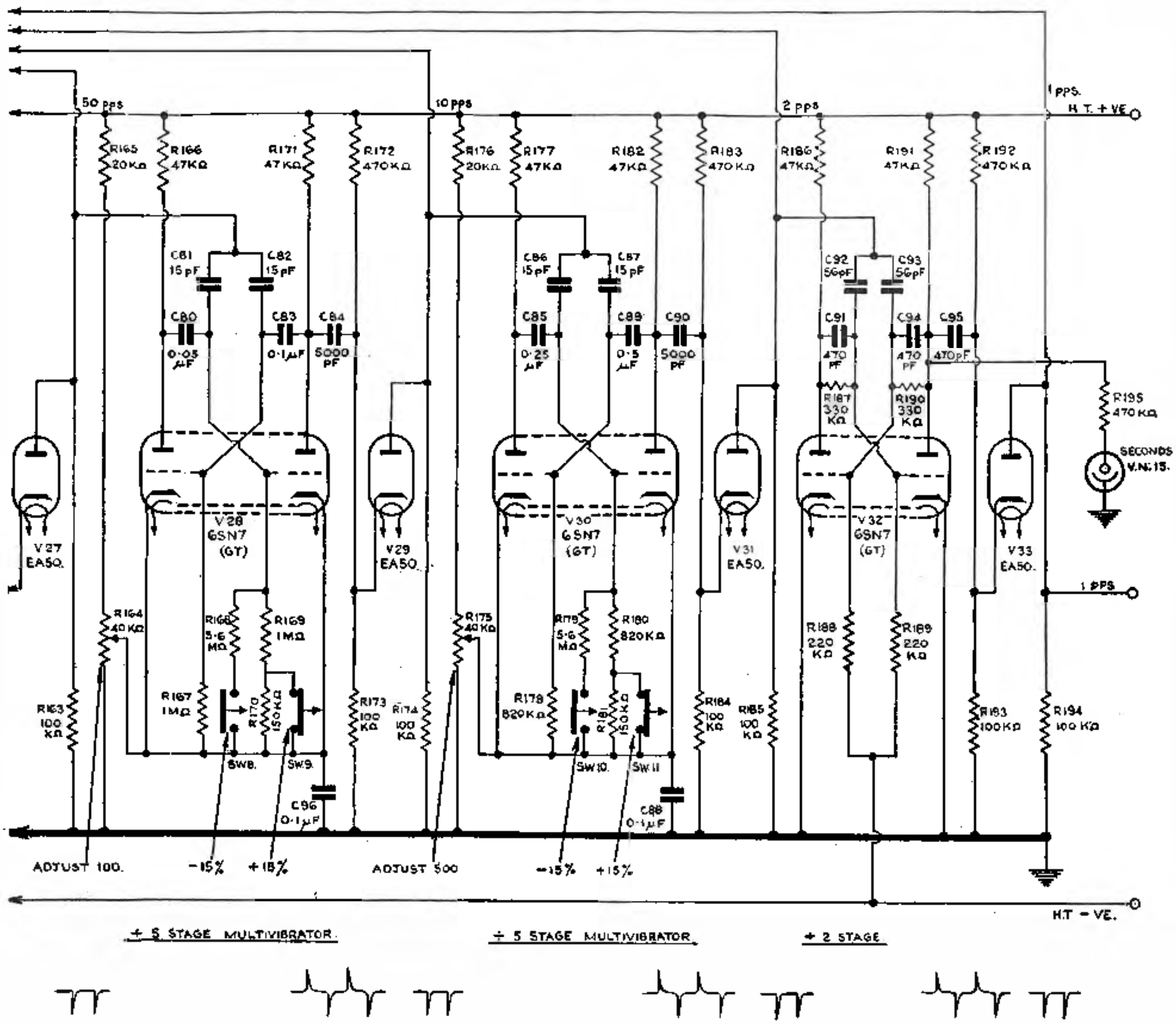


Fig. 3. Circuit diagram of

The last feature is difficult to carry out in practice, but as the multi-turn indicator of the electro tachometer type has been fitted universally to aircraft engine test beds, the psychological effect on testers accepting an electronic counting technique has been strengthened by retaining the existing approximate tachometer.

Fig. 2 shows a circuit diagram of the input amplifier and frequency multiplier. Where the three-phase output from the tachometer is used, frequency multiplication is necessary as the output at 500 r.p.m. is $8\frac{1}{3}$ c/s. The output from each phase of the engine speed indicator is fed separately to three identical amplifiers. The voltage output amplitude varies about 6/1 over the speed range and R106, R107 and C57 form a network to reduce this ratio to less than 1.5/1. The amplifiers give 5-7 watts/phase whose outputs are fed to a three-phase synchronous motor with phonic wheels. Thus the generator output is converted direct to r.p.m. for case 2(a), (b) and (c) when driven at engine speed, at a 2/1 reduction and at a 4/1 reduction; i.e., normal conditions of installation. The phonic motors forms a frequency multiplier unit and for each of the three ranges the engine speed will vary between $8\frac{1}{3}$ to $83\frac{1}{3}$ c/s. Thus for direct reading in r.p.m. phonic wheels of 60, 12 and 24 teeth are provided to give 5,000, 1,000 and 2,000 c/s. for top speeds of 5,000, 10,000 and 20,000 r.p.m. respectively in conjunction with scale multiplying factors of 1, 10 and 10.

The timing interval is derived from a 1 Kc/s. Elinvar valve maintained tuning fork and Fig. 3 shows a circuit diagram of the complete divider. Division ratios of 2, 5, 2, 5, 5 and 2 in cascade, i.e., frequencies of 500, 100, 50, 10, 2 and 1 c/s., are



the complete divider

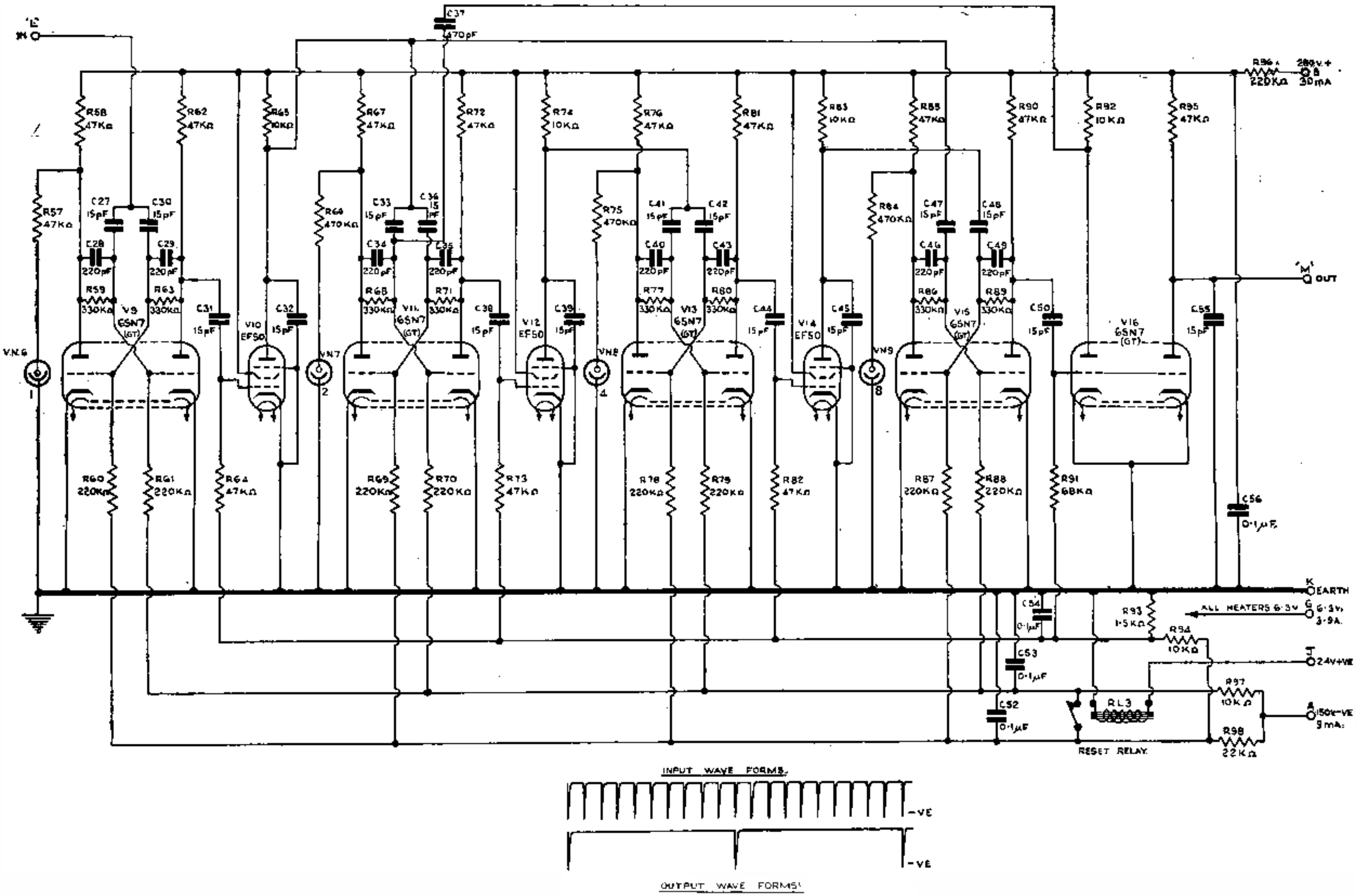


Fig. 5. Scale-of-ten counter

obtained from a combination of scale-of-two dividers and scale-of-five multivibrators. The natural frequency of the multivibrators can be varied by operating non-locking press switches which alter their R value ± 15 per cent to facilitate setting of the rheostats to bring the stages within the range of synchronism of the desired sub-multiple of the input frequencies. Diodes are used to pass negative going differentiated pulses for the locking signals.

To check that the correct order of division is given, a switch SW3 selects the output from the divide by 2, 10, 20, 100 and 500 stages, and when the division is correctly carried out frequencies of 500, 100, 50, 10 and 2 c/s. respectively are used to control the electronic relay, while the 1,000 c/s. from the fork is fed into the gate when counts of 2, 10, 20, 100 and 500 will be recorded. A count " 1,000 " and " *use* " positions are provided when the relay is operated for one second and thus permits the whole division chain to be checked. The counter needs a negative pulse of suitable shape and minimum amplitude to function correctly, and the output from the frequency multiplier unit or from the single phase input is fed to the pulse forming stage shown in Fig. 5. At the instant of triggering a sharp positive pulse is passed through the differentiating network C2, R11 to the control grid of the gate valve V3. This gate will conduct only when the control and suppressor grids are lifted and the time duration is selected by SW3 in Fig. 3.

There are a number of forms of electronic relay and an example of a self-locking type is shown in Fig. 4.

V4 and V5 with their components form a relay stage where pentodes are used to allow locking by the application of a negative pulse to one suppressor grid. V4 is normally " *on* " when the stage is reset ready for use. Negative pulses at the selected timing interval are applied to the grid of V5 and to the suppressor of V4. The pulses applied to the grid of V5 make no difference as that valve is already off and the negative potential applied to the suppressor of V5 by the locking stage V6 override the negative timing pulses applied to V4 suppressor. When the " *start* " switch is operated the pulse generated in this process turns the locking stage over and removes the negative potential from the suppressor of V5. Hence the next timing pulse applied to the suppressor of V4 will turn the relay stage over and apply positive potential to the suppressor of the gate valve V3. Thus the frequency applied to the gate is presented to the counter and as V4 is now off VN1 is struck to indicate count in progress. The next timing pulse turns the relay stage over again and thus closes the gate. As this stage goes off a negative pulse passes through C12 and turns the locking stage over, applying negative to the suppressor of V5, preventing the relay stage from coming on again until the whole apparatus is reset. In this way only the number of cycles of the input fre-

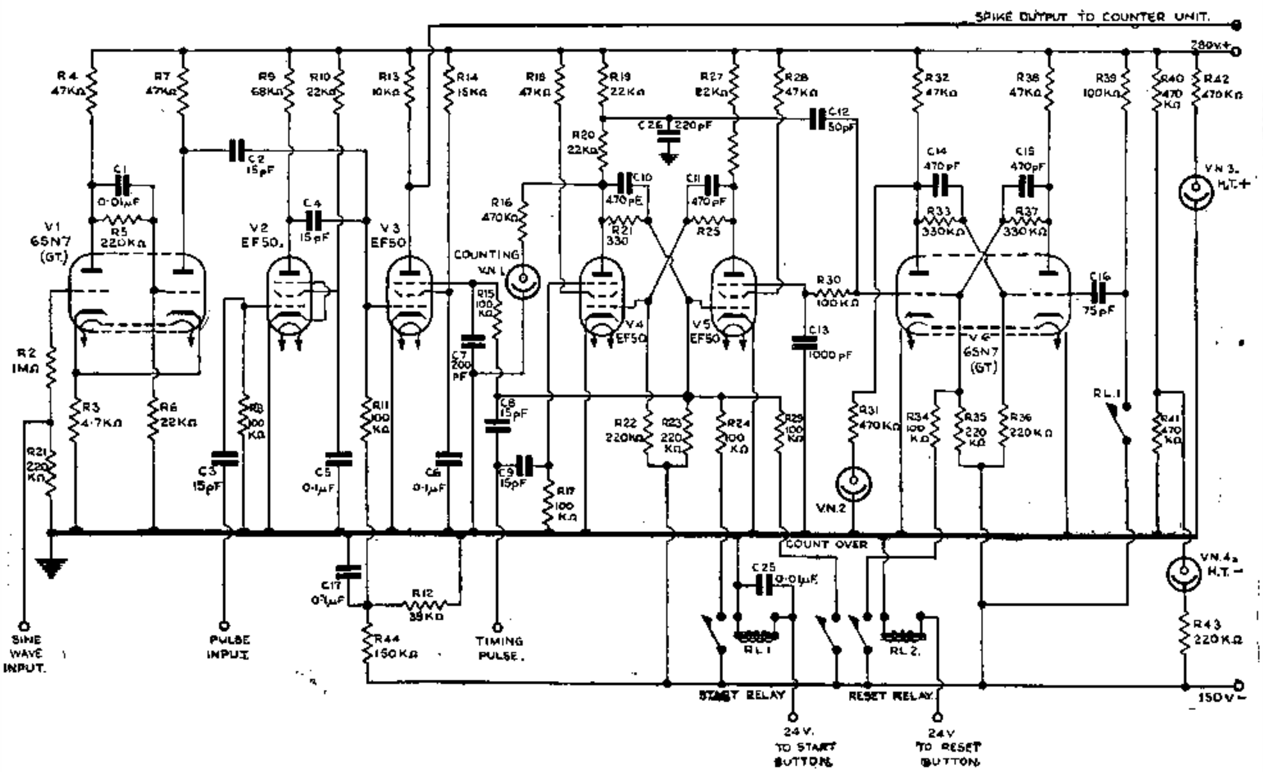


Fig. 4. Self-locking type of electronic relay

	THOUSANDS	HUNDREDS	TENS.	UNITS
ONE	○	○	●	●
TWO	●	○	○	●
FOUR	○	●	●	●
EIGHT.	○	○	○	○

BLACK DOT INDICATES NEON STRUCK

Fig. 6 (*above*). **Neon presentation for 2457**

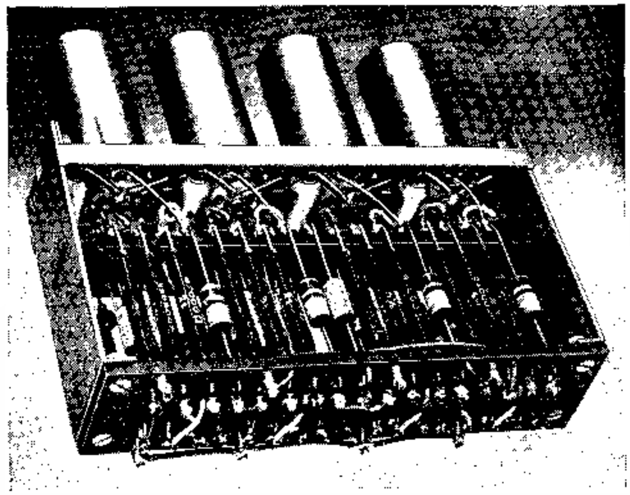


Fig. 7 (*right*). **Miniature decade counter using four twin triodes**

quency occurring in the timing interval are able to reach the counter.

The counter is of the sequence operated type and comprises four identical units employing four scale-of-two counters of the Eccles-Jordan type with a feedback application to convert to a scale-of-ten. The principle of operation has been described, but it is important to note that V15 in Fig. 5 is not fed symmetrically, as the negative pulse given by V14 is applied to the L.H. grid of V15. It is possible to modify the circuit so that nine neons are used per decade; however, the ideal arrangement would give a Veeder type presentation. Fig. 6 shows the combination of neons for a count of 2,457 and it will be noted that three additions are necessary for the integer 7. The score is cleared by manual operation of the manually operated reset relay when all the left-hand triodes of each trigger pair are conducting and hence all neons are out.

Conclusions

The method of determining r.p.m. by electronic counting has proved so reliable and accurate that investigations in the developments necessary for flight test work have been undertaken. The need for automatic observation can be met by synchronising the operation of the camera with the indicator. Considerable weight and size can be saved by replacing the three-phase amplifier and phonic motor used in the test bed equipment by a suitable pick-up and photo-cell unit. A miniature decade counter (Fig. 7) employing four twin triodes of type ECC91 has been produced. By the use of an N.T. cut quartz crystal for the timing standard and other miniaturisation technique it is anticipated that a revolution counter accurate to the nearest 10 r.p.m. can be constructed in a size 14 in. by 8 in. by 7 in. to cover a range of 4,000-20,000 r.p.m.

The work has been carried out on a development contract for the Ministry of Supply, and the author is grateful for permission to publish this paper.

Recording of Television

With the advent of television recording or "telefilm" as it is called, a new tool has been placed in the hands of the television programme builders. Until now, television pictures have been ephemeral: however notable the event, however great the labour devoted to planning and rehearsal, the picture flashed on the screen and was gone. Now, thanks to this new system, the pictures are captured in a photographic record on ordinary cinema film.

The method was proposed by H. W. Baker, Engineer-in-Charge, Alexandra Palace, H. G. Whiting, now Engineer-in-Chief of the new Sutton Coldfield station, in collaboration with D. R. Campbell, one of the senior engineers at Alexandra Palace, and perfected by W. D. Kemp, of the Planning and Installation Department of the B.B.C. It is covered by a patent application, and is one of several that have been, and indeed still are, being investigated.

This result has been achieved by a detailed study of the deterioration of picture quality that must inevitably take place in any process, such as recording, that combines complex electronic, optical, and photographic methods. The B.B.C. engineers have assessed these losses, and have introduced into the process accurately judged degrees of electrical over-compensation which almost exactly counter-balance the degradation in picture quality that accompanies the recording process.

The recording system uses a continuous-motion camera—actually, of course, two are provided to enable continuous recordings to be made—in which the movement of the film is "chased" by an optical image of the television picture reflected from a rotating mirror drum. By this means, all the 405 interlaced lines of the picture are recorded on the film, and the difficulties of relating the television frame frequency to the picture repetition frequency on the film are overcome.

The new recording equipment came into service at the beginning of November, 1949.

An Inexpensive Valve Voltmeter

By S. W. AMOS, B.Sc.(Hons.) Grad.I.E.E.*

A VALVE voltmeter is one of the most useful measuring instruments the radio engineer can possess, but its uses are possibly less widely appreciated than they should be; for example, it can be used in determining the frequency response curves of A.F. and R.F. amplifiers up to frequencies of several Mc/s., for tracing signals and determining stage gains in amplifiers and receivers, and even for the direct measurement of A.G.C. voltages.

This article describes the design and construction of a simple peak-reading valve voltmeter. Except for the mains transformer, all the components are war surplus and the total cost of the parts for the complete instrument is about £3 10s. The voltmeter is A.C. mains-operated, consuming less than 15 watts from the mains, and has five voltage ranges with full-scale deflexions of 1, 5, 25, 100 and 250 volts. The meter is a 2-in. moving-coil type with a full-scale deflexion of 500 μA and its calibrations hold with reasonable accuracy on all ranges except the lowest. The calibration errors on the 1-volt range increase from a few per cent at full-scale deflexion to about 50 per cent at readings near zero and a calibration curve should be used for accurate measurements on this range. Although primarily intended for measurement of alternating voltages, the instrument can also be used for measurement of steady voltages up to 250 volts. The input impedance is over 2 MΩ on all the A.C. ranges except the lowest and is over 10 MΩ on all the D.C. ranges.

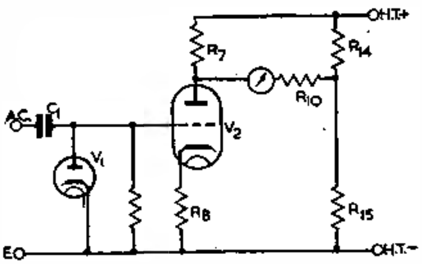


Fig. 1. Basic circuit of the valve voltmeter

Basic Circuit

The basic circuit is shown in Fig. 1; it consists of a diode detector directly coupled to a triode amplifier. The meter is connected in the anode circuit of the amplifier to form a bridge network, which, with no input signal, is balanced by adjustment of $R14$, the "zero" control. When a signal is applied to the diode, the grid of $V2$ is driven negative, the bridge is unbalanced and the meter gives a reading. The magnitude of the deflexion is controlled by $R10$ connected in series with the meter; $R10$ is therefore labelled "calibrate." An important feature of the design is that $R10$ and $R14$ can be adjusted independently of each other.

Design Considerations

As shown in the full circuit diagram (Fig. 2), the amplifier $V2$ is a pentode connected as a triode. An EF50 was chosen for this position because this type has a high slope, is cheap and readily obtainable. It also has the advantage over other types that it is particularly economical in heater power, requiring less than two watts; this is a consideration of some importance when the power is supplied, as here, from a very small mains transformer.

On the lowest voltage range the instrument was required to give full-scale deflexion for a 1-volt peak input signal. The meter requires 0.5 mA for full-scale deflexion, but as it is in a bridge circuit, the anode current of $V2$ must change by more than 0.5 mA to give full-scale reading. The design was based on the assumption that the anode current of $V2$ changes by 1 mA for a 1-volt grid input. The mutual conductance of an EF50, connected as a triode, is more than 7 mA/V, but is reduced to approximately 1 mA/V by the use of negative feedback. The feedback gives a useful improvement in the linearity of the valve characteristic and also makes the gain of the amplifier substantially independent of changes in H.T. or L.T., i.e., of mains voltage. Thus there is no need for frequent adjustment of $R10$ which, once set, should not require attention until $V1$ or $V2$ is

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changed. For this reason $R10$ is a pre-set component, operated by means of a screwdriver inserted through a hole in the front panel. The feedback also tends to make the gain of the amplifier independent of the constants of the particular valve used and $R10$ needs little readjustment even when the EF50 is replaced. The feedback voltage is developed across $R8$ in the cathode circuit of $V2$. $R8$ also provides grid bias and it is a little difficult in a D.C. amplifier such as $V2$ to distinguish the feedback voltage from the grid bias voltage, if indeed, there is any distinction. It should be sufficient to say that if $V2$ has a fixed grid bias voltage, such as that obtained from a battery in the grid circuit, and if the cathode is earthed, the anode current changes by approximately 7 mA/V for a 1-volt change in grid potential. But if bias is obtained automatically by, say, the use of a 1,000 Ω cathode resistor, this change in anode current produces a 7-volt change in P.D. between cathode and earth, with the result that 8 volts must now be applied between grid and earth to give the same effect on anode current that was produced by 1 volt before. Thus the effective g_m is reduced to one-eighth of its normal value by current feedback. If this calculation is repeated in general terms it is easily shown that the effective mutual conductance g_m' with feedback is given by

$$g_m' = \frac{g_m}{1 + g_m R_k}$$

where g_m = mutual conductance without feedback and R_k = cathode resistor.

From this

$$R_k = \frac{g_m - g_m'}{g_m g_m'}$$

Substituting g_m = 7 mA/V and g_m' = 1 mA/V

$$R_k = \frac{6 \times 1000}{7} \approx 860\ \Omega$$

This value of cathode resistor gives greater than optimum grid bias, but experiments showed that the relationship between the anode current and grid potential was linear for grid inputs up to 1 volt negative and no additional circuit complications were considered necessary to adjust the grid bias.

H.T. is supplied from the miniature mains transformer (details of which are given later) and a selenium rectifier. Half-wave rectification is used and the only smoothing necessary is provided by an 8 μF electrolytic capacitor. Smoothing can be simple because of the particular meter circuit used. Due to feedback the anode current of $V2$ is directly proportional to the H.T. voltage; similarly the current in $R13$, $R14$ is directly proportional to the H.T. voltage. Thus by adjustment of $R14$ the potential at A can be made exactly equal to that at B and a precise zero reading can be obtained from the meter. The bridge is unbalanced, of course, when a signal is applied to the instrument and a certain minimum amount of smoothing is necessary to avoid 50 c/s. flutter of the needle, but the single 8 μF smoothing capacitor has proved quite adequate to give a steady meter reading.

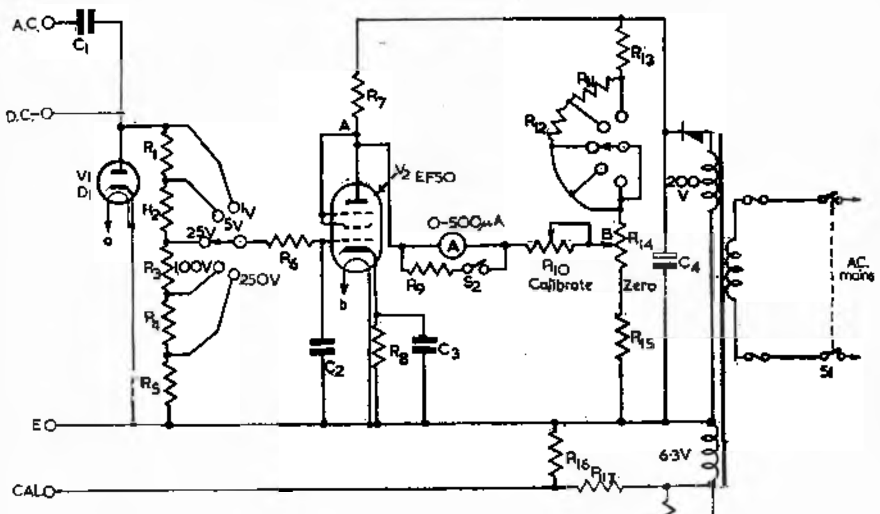


Fig. 2. Full circuit diagram of the valve voltmeter

C1 0.01μF	R1 10MΩ		R6 5MΩ	R11 82Ω	R16 100Ω
C2 0.01μF	R2 2MΩ		R7 1KΩ	R12 18Ω	R17 680Ω
C3 0.001μF	R3 375KΩ	±1%	R8 820Ω	R13 200Ω	R18 12Ω
C4 8μF	R4 75KΩ		R9 10Ω	R14 120Ω	
	R5 50KΩ		R10 1KΩ	R15 15KΩ	

Relative Merits of Series-fed and Shunt-fed Diodes

For the detector a choice must be made between the series-fed type (Fig. 3) and the shunt-fed type (Fig. 4). The series-fed circuit as illustrated in Fig. 3 has a higher input impedance than the other, but in a practical circuit a fixed resistor must be connected across the input terminals to provide a D.C. path for the diode current. This resistor is essential when the instrument is used to measure the voltage of a source having no D.C. continuity between the output terminals, but it also means that the advantage of the high input impedance is lost. Moreover, a series-fed diode has the disadvantage that the zero control needs readjusting for every change of signal-source impedance. The reason for these zero changes is worth considering in some detail because it also causes changes in zero on operating the range switch. If there is a conducting circuit between the anode and cathode of a diode, the anode takes up a negative potential with respect to the cathode even in the absence of A.C. or D.C. potentials applied to the anode from an external source. This potential is referred to in the subsequent text as the standing bias, and with an anode-cathode resistance of several megohms is commonly as much as 0.7 volt. It can be seen from Fig. 3 that when the input terminals are short-circuited and the range switch is set to the lowest voltage range, the full value of this diode anode-cathode potential is applied to the grid of the amplifier and is registered by the meter. The reading so obtained is in the forward direction if the amplifier is designed for positive inputs, but is a reverse reading if the amplifier is intended as here for negative inputs. Whatever the sense of this reading it can, of course, be reduced to zero by operation of the zero control, but if this is done and the input terminals are then open-circuited, the anode load impedance of the diode is increased and the bias applied to the triode falls, with the result that the meter tends to give a reading in the opposite sense. It is clear that the fraction of the standing bias applied to the amplifier varies with the value of D.C. resistance connected across the input terminals and thus the zero must be reset for every change in signal-source impedance.

In the shunt-fed diode circuit the standing bias applied to the amplifier is independent of the resistance connected between the input terminals and there is no change in meter reading as the signal source resistance is varied.

The series-fed circuit is sensitive to steady as well as to alternating potentials. This may be an advantage in certain applications, but it is inconvenient if measurements are to be made of alternating signals at the anode of a valve; for if a series capacitor is inserted in one of the diode input leads to block the steady component, the readings obtained are inaccurate because the output of the diode is shared between the true load and the resistor shunting the

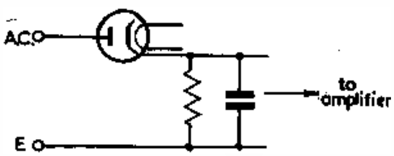


Fig. 3. Series-fed diode detector

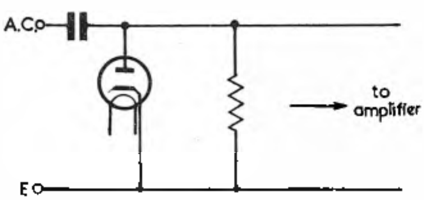


Fig. 4 Shunt-fed diode detector

input terminals. The shunt-fed circuit is better because the input terminals labelled A.C.— and E in Fig. 4 are sensitive only to A.C. For this reason and also because the zero setting is independent of the source resistance the shunt-fed circuit was chosen and is shown in Fig. 2.

In both diode circuits the fraction of the diode standing bias applied to the amplifier varies with the setting of the voltage range switch. Thus the zero control must be reset every time the range switch is operated, particularly on switching to or from the lowest voltage range. If the standing bias is 0.7 volt, the zero error is nearly three-quarters of full-scale deflexion for the lowest voltage range. Attempts were made to obviate this difficulty by including in the diode circuit an additional bias to offset the standing bias due to the diode. Although this reduced zero changes it also reduced sensitivity and had adverse effects on the linearity of the instrument. This method was therefore abandoned and instead the zero changes were prevented by alterations to the values of certain resistors in the backing-off circuit brought about by contacts on the range switch. The resistors $R11$ and $R12$, the values of which are chosen empirically, perform this function; both resistors are in circuit on the high voltage ranges, but $R12$ is shorted out on the 5-volt range and both are shorted out on the 1-volt range.

Measurement of Steady Potentials

Steady potentials can also be measured by a voltmeter employing a shunt-fed diode by connecting the source to the terminals marked D.C.— and E in Fig. 2, but some care is necessary to obtain accurate readings, because the standing bias of the diode causes difficulties. These will be illustrated by an example. Suppose the D.C. source to be measured has an E.M.F. of less than 1 volt and a resistance of several megohms. Suppose also that the voltmeter range switch has been set to 1 volt and that the zero has been adjusted with no connexions to any of the input terminals. In these circumstances the full standing bias of the diode is applied to the grid of $V2$. When the D.C. source is connected between the D.C.— and E terminals two effects occur: firstly, the diode load is effectively reduced, causing a drop in standing bias which, in the absence of the second effect, would be registered by the meter as a reverse reading; secondly, the E.M.F. of the source biases the grid of $V2$ negatively and the meter gives a corresponding reading which offsets the reading due to the first effect. Thus the reading obtained is low, perhaps even negative, and cannot be corrected because the magnitude of the first effect is unknown.

Accurate readings can, however, be obtained, if, before the D.C. source is applied, the zero control is set with the D.C.— and E terminals joined by a resistance equal to that of the source to be measured. The deflexion obtained when this passive resistance is removed should be ignored, and the reading obtained when the source is connected is then accurate. Thus the procedure to be adopted in measuring a D.C. source is as follows:

1. Set the range switch suitably.

2. If possible, remove the E.M.F. from the source to be measured, but leaving the internal resistance unaltered, and connect the source between D.C. — and E.

3. Set the zero of the valve voltmeter.

4. Restore the E.M.F. and note the valve voltmeter reading.

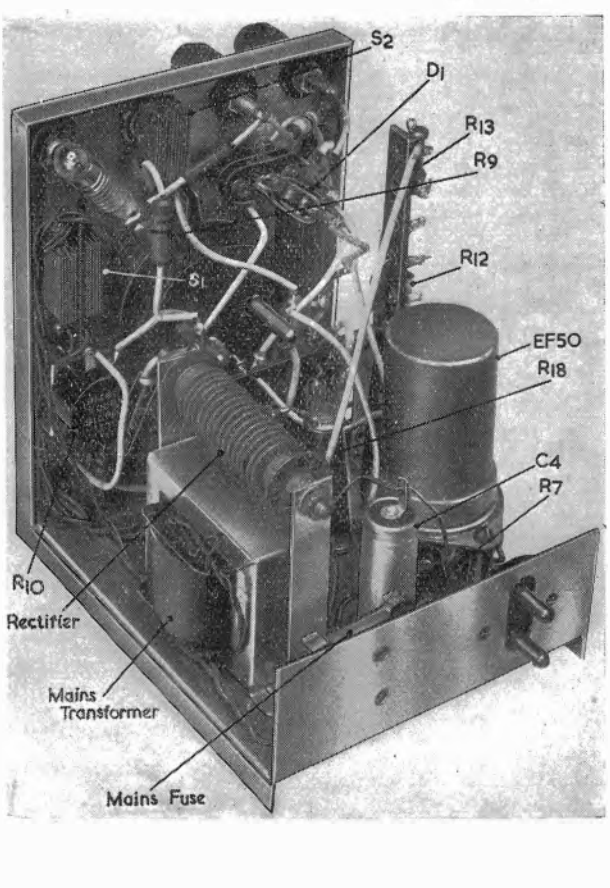
If the range switch of the valve voltmeter is changed, the above sequence of operations must be repeated. If the source is of very low resistance, say, less than 100,000 ohms, results will be reasonably accurate if the D.C.— and E terminals are short-circuited while the zero is set. The above precautions are necessary only when the source resistance is not negligible compared with the diode load (12.5 MΩ).

$R14$ must have sufficient range to bring the meter deflexion to zero with full standing bias or with zero volts applied to the grid of $V2$. To meet this requirement $R14$ must not be less than 120 Ω, the value quoted in Fig. 2; it should not be greater, otherwise it becomes difficult to set the zero with precision.

Procedure on Switching On

The decision to use the shunt-fed diode necessitates that the EF50 grid is driven negative during measurements. Negative inputs are preferable to positive ones for the following reason. The bleeder circuit takes its normal current immediately the mains switch *S*1 is closed, but *V*2 takes about 25 seconds to warm up, and until the anode current of *V*2 has reached its full value, an excessive current flows through the meter circuit. This current might damage the meter, and precautions must be taken to prevent this. The simplest protective device is an on-off switch (*S*2 in Fig. 2) which is manually operated to short-circuit the meter during the warming-up period, but this simple circuit has the disadvantage that there is no means of telling when it is safe to open *S*2. The method can be improved, however, by including a low-value resistor *R*9 in series with *S*2. If *R*9 is made about one-tenth the meter resistance, the meter gives about half-scale deflexion immediately after switching on and the reading falls as *V*2 warms up. When the reading reaches zero, the anode current of *V*2 is normal and *S*2 may be opened. The meter now gives visual indication when *S*2 should be opened and that the instrument is ready for use. Thus the procedure for switching on is first to close *S*2, then *S*1. When the meter deflexion falls to zero, open *S*2, select the desired range and adjust the zero. The instrument is then ready for use.

This rear view of the chassis shows the compact layout of the components



The values of all resistors and capacitors are given under Fig. 2. The resistors forming the diode load must be accurate and a tolerance of ± 1 per cent is advisable. The 75 KΩ component was made up of 50 KΩ and 25 KΩ in series, and the 375 KΩ of 1.5 MΩ and 0.5 MΩ in parallel. To minimise capacitance in the diode load the 10 KΩ component is composed of four approximately equal resistors in series. The 15 KΩ resistor in the bleed circuit dissipates over 2 watts and should preferably be given plenty of surface area (e.g., by using three 5 KΩ 1 watt components in series) and good ventilation to ensure rapid stabilisation of zero setting after switching on.

In the instrument illustrated, which is 6 in. high, $4\frac{1}{2}$ in. wide and $5\frac{1}{2}$ in. deep, the diode and associated components are mounted behind the front panel close to the input terminals. With this type of construction the readings of the voltmeter are accurate up to several Mc/s., but by mounting the diode and associated capacitor in a probe, the upper frequency limit can be raised to 40 or 50 Mc/s.

The values of *R*11 and *R*12 are obtained empirically in the following way. *R*11 is replaced by a variable resistor of, say, 100-ohms value, the instrument is switched on and left on the 1-volt range with no input signal until there is no longer any change in meter reading. The variable resistor is then adjusted until there is no change in meter reading on switching from the 1-volt to the 5-volt range. The potentiometer is replaced by a fixed resistor of the same value. *R*12 is then replaced by the potentiometer which is adjusted until there is no change in meter reading on operating the range switch from the 5-volt to the 25-volt range, after which the potentiometer should be again replaced by a fixed resistor of equal value. It must be emphasised that the values of *R*11 and *R*12 should be determined only when the meter reading has finally settled down. The values of *R*11 and *R*12 will probably need adjusting if *V*1 or *V*2 is changed.

Sensitivity Checking

To check the sensitivity of the instrument a source of alternating voltages of 1-volt peak is provided by *R*16 and *R*17 connected in series and across the L.T. winding of the mains transformer. The values of *R*16 and *R*17 must be selected to give a 1-volt peak signal; in the instrument illustrated this voltage was obtained by resistors with nominal values of 100 Ω and 680 Ω respectively. The junction of *R*16 and *R*17 is brought out to a terminal labelled CAL on the front panel. A link on the A.C. input terminal can be swung round so as to connect with the E terminal for zero setting or with the CAL terminal for sensitivity checking. When this check is made, full-scale deflexion should be obtained on the 1-volt range and 20 per cent of full scale on the 5-volt range, but if these readings are not obtained the mains voltage should be measured before any adjustments are made to the "calibrate" control.

The mains transformer is a midget component measuring $2\frac{1}{2}$ in. by 2 in. by $1\frac{3}{4}$ in. wound on a stalloy core of 1 sq. in. cross section and delivering 200 volts at about 20 mA and 6.3 volts at 0.6 amps. A suitable component is the type 653 obtainable from Stern's Radio, Fleet Street, London, E.C.4.

The Design of R.C. Oscillator Phase Shifting Networks

By W. R. HINTON, A.M.I.E.E., Member I.R.E.

RECENT correspondence[2] on the subject of R.C. oscillators has certainly shown the need for reliable design formulæ, and what is probably more important, for a demonstration of the most suitable mathematical tool for the job. Formulæ have already been published which, apart from including computational errors,[1,4] neglect to take into account the effect of the internal impedance of the driving circuits. In addition to this, enormous discrepancies[3] have been reported between the calculated frequency of oscillation and the measured value, and this is unfortunate as it is liable to give the impression that theoretical analysis is hardly worth while and thus encourage poor engineering practice of trial-and-error methods.

Trial-and-error methods are not to be despised where the mathematics is prohibitively difficult, but this is not so in the case of R-C. oscillators and it is the experience of the author that there is no difficulty in obtaining an actual frequency within a few parts per cent from the calculated value. If a serious discrepancy occurs between a predicted result and the actual one, in any problem, either some feature has been overlooked in the analysis or a mistake has been made in observation or computation. This implies that the mathematical tool should be capable of handling the complete system so as to give the general case, then known and justified approximations may be made for any particular case.

Fortunately the mathematics for the R-C. oscillator analysis is particularly simple provided the correct approach is made, and this is to regard the oscillator as a chain of four-terminal networks where each network is described by its linear parameters. This method is introduced by Starr[6] (pp. 168 and 183), but does not seem to be widely used, possibly because the parameters themselves have not been appreciated as most descriptive and useful constants.

Briefly, for any linear four-terminal network we can write the sent voltage and current in terms of the received voltage and current by the pair of equations:

$$\left.\begin{aligned} V_S &= a_{11}V_R + a_{12}I_R \\ I_S &= a_{21}V_R + a_{22}I_R \end{aligned}\right\} \qquad (1)$$

where a_{11}, a_{12}, a_{21} and a_{22} are known as the linear parameters of the network. (The suffixes are read as "one one," "one two," etc., for a reason which will be seen later.)

Notice that: $a_{11} = V_S / V_R$ when $I_R = 0$, that is, a_{11} is the voltage ratio when the receiving end is open circuited. Likewise: $a_{21} = I_S / V_R$ when $I_R = 0$, i.e., on open circuit; $a_{12} = V_S / I_R$ when $V_R = 0$, that is, when the receiving end is short circuited, and: $a_{22} = I_S / I$ when $V_R = 0$, i.e., on short circuit.

In practice these parameters are written down by inspection of the open-circuited and short-circuited conditions.

Of these parameters a_{11} and a_{21} are the most useful in the discussion of oscillators since a_{11} gives the voltage ratio and phase shift introduced by the network, therefore the condition for oscillation is that the a_{11} parameter for the whole of the network external to the amplifier valve shall have a negative real part and a zero imaginary part. The gain required to maintain oscillation is then numerically equal to the real part of a_{11} and the significance of the minus sign is that voltage received from the network is 180° out of phase with that sent into the network.

Now notice that:

$$a_{11} / a_{21} = V_S / I_S = Z_{in} \text{ when } I_R = 0$$

This means that parameter a_{21} is indirectly required for the calculation of input impedance.

(A word of warning is necessary at this stage to emphasise that Z_{in} is the impedance looking in to the network when it is open circuited at the receiving end and therefore this is invalid as soon as the network is terminated in any finite impedance. If a termination is encountered, this must be added to the transmission chain as a further four-terminal network and the overall parameters then calculated by a method to be described later.)

Obviously there is a limit to the complexity of the network for which the parameters can be written down by inspection, so it becomes necessary to break the transmission chain down into a number of simple four-terminal networks and to find a method for calculating the overall parameters.

A chain of two four-terminal networks is shown in Fig. 1 where the first is described by the pair of equations (1), and the second by:

$$\left.\begin{aligned} V_S' &= b_{11}V_R' + b_{12}I_R' \\ I_S' &= b_{21}V_R' + b_{22}I_R' \end{aligned}\right\} \qquad (2)$$

Notice that the sending end voltage and current for network "b" corresponds to the received voltage and current of network "a," therefore $V_S' = V_R$ and $I_S' = I_R$ and substituting these values in (1) gives:

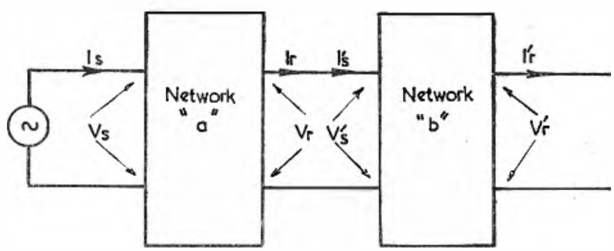


Fig. 1. Two Four-terminal networks in Tandem

$$\left.\begin{aligned} V_S &= (a_{11}b_{11} + a_{12}b_{21})V_R' + (a_{11}b_{12} + a_{12}b_{22})I_R' \\ I_S &= (a_{21}b_{11} + a_{22}b_{21})V_R' + (a_{21}b_{12} + a_{22}b_{22})I_R' \end{aligned}\right\} \quad \ldots \quad (3)$$

The quantities in the parentheses are the linear parameters of the combined networks, and this process can be repeated indefinitely.

The rule for combining networks can be seen more clearly if the parameters are extracted from the equations in blocks, or arrays; for example, write the pair of equations (1) for network "a" as:

$$\begin{Vmatrix} V_S \\ I_S \end{Vmatrix} = \begin{Vmatrix} a_{11}a_{12} \\ a_{21}a_{22} \end{Vmatrix} \times \begin{Vmatrix} V_R \\ I_R \end{Vmatrix} \ldots\ldots\ldots\ldots\ldots \quad (4)$$

where it is understood that the $\times$ sign means that (4) is expanded into the more familiar pair of equations (1) by expanding each row of the first array into the columns of the second array.

Notice that an array by itself is absolutely meaningless, but that the association of arrays connected by the $\times$ sign has the meaning, by definition, that (4) represents the pair of equations (1). (Double vertical lines are used to enclose the arrays to prevent confusion with determinants.)

The "b" network can be represented by a similar array:

$$\begin{Vmatrix} V_S' \\ I_S' \end{Vmatrix} = \begin{Vmatrix} b_{11}b_{12} \\ b_{21}b_{22} \end{Vmatrix} \times \begin{Vmatrix} V_R' \\ I_R' \end{Vmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

But since $V_S' = V_R$ and $I_S' = I_R$ we can substitute the pair of arrays (5) in (4) thus:

$$\begin{Vmatrix} V_S \\ I_S \end{Vmatrix} = \begin{Vmatrix} a_{11}a_{12} \\ a_{21}a_{22} \end{Vmatrix} \times \begin{Vmatrix} b_{11}b_{12} \\ b_{21}b_{22} \end{Vmatrix} \times \begin{Vmatrix} V_R' \\ I_R' \end{Vmatrix}$$

This must correspond to equations (3) which can, from the above definition, be represented by:

$$\begin{Vmatrix} V_S \\ I_S \end{Vmatrix} = \begin{Vmatrix} (a_{11}b_{11} + a_{12}b_{21}) & (a_{11}b_{12} + a_{12}b_{22}) \\ (a_{21}b_{11} + a_{22}b_{21}) & (a_{21}b_{12} + a_{22}b_{22}) \end{Vmatrix} \times \begin{Vmatrix} V_R' \\ I_R' \end{Vmatrix}$$

Therefore:

$$\begin{Vmatrix} a_{11}a_{12} \\ a_{21}a_{22} \end{Vmatrix} \times \begin{Vmatrix} b_{11}b_{12} \\ b_{21}b_{22} \end{Vmatrix} = \begin{Vmatrix} (a_{11}b_{11} + a_{12}b_{21}) & (a_{11}b_{12} + a_{12}b_{22}) \\ (a_{21}b_{11} + a_{22}b_{21}) & (a_{21}b_{12} + a_{22}b_{22}) \end{Vmatrix} \ldots\ldots\ldots\ldots \quad (6)$$

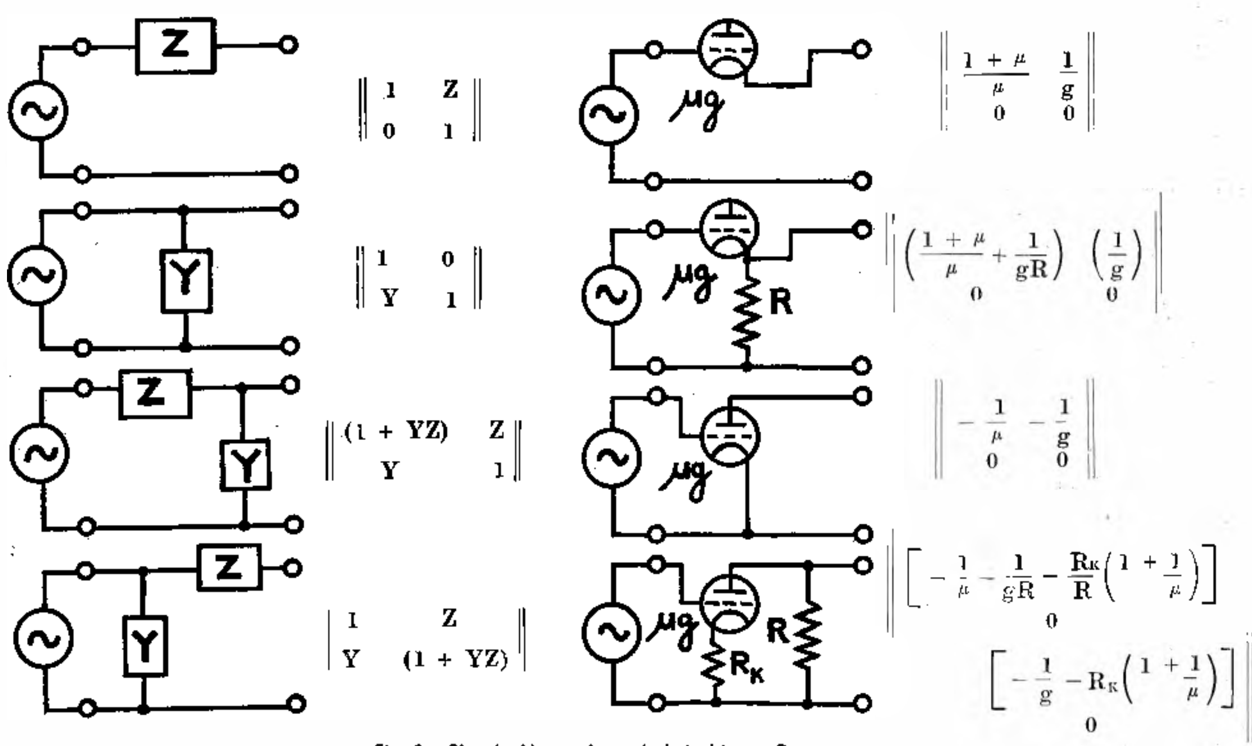
which is a convenient way of stating the rule for calculating the parameters of combined networks.

Notice that in presenting the rule in this way the order of writing down the arrays is important, the "a" network is nearer the source of energy than the "b" and the direction of transmission is from left to right by convention. This means that the arrays of parameters representing the networks must occupy the same relative positions as the networks themselves, and this is particularly important when making substitutions, therefore in general:

$$\| a \| \times \| b \| \neq \| b \| \times \| a \|$$

In other words, the performance of a chain of networks "a" and "b" in that order from the source of energy is not necessarily the same when the networks are interchanged.

In a long chain of networks the calculations can be made by pairing off any adjacent arrays, but the relative positions must be maintained, just as a physical transmission chain can be boxed up into successively larger units provided the correct sequence of connexion is maintained. This pairing is continued, by application of rule (6), until four parameters remain and these are then interpreted



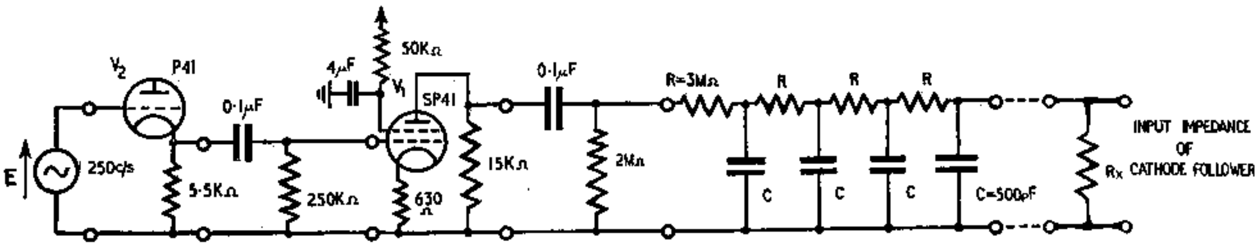
$$\begin{Vmatrix} 1 & Z \\ 0 & 1 \end{Vmatrix} \qquad \begin{Vmatrix} \frac{1+\mu}{\mu} & \frac{1}{g} \\ 0 & 0 \end{Vmatrix}$$

$$\begin{Vmatrix} 1 & 0 \\ Y & 1 \end{Vmatrix} \qquad \begin{Vmatrix} \left(\frac{1+\mu}{\mu} + \frac{1}{gR}\right) & \left(\frac{1}{g}\right) \\ 0 & 0 \end{Vmatrix}$$

$$\begin{Vmatrix} (1 + YZ) & Z \\ Y & 1 \end{Vmatrix} \qquad \begin{Vmatrix} -\frac{1}{\mu} & -\frac{1}{g} \\ 0 & 0 \end{Vmatrix}$$

$$\begin{Vmatrix} 1 & Z \\ Y & (1 + YZ) \end{Vmatrix} \qquad \begin{Vmatrix} \left[-\frac{1}{\mu} - \frac{1}{gR} - \frac{R_K}{R}\left(1 + \frac{1}{\mu}\right)\right] & \left[-\frac{1}{g} - R_K\left(1 + \frac{1}{\mu}\right)\right] \\ 0 & 0 \end{Vmatrix}$$

Fig. 2. Simple Networks and their Linear Parameters



$$\begin{Vmatrix} 1.08 & 125 \\ 0 & 0 \end{Vmatrix} \times \begin{Vmatrix} (1-j0.0255) & (-j0.00637) \\ 4.10^{-6} & 1 \end{Vmatrix} \times \begin{Vmatrix} -0.05 & -748 \\ 0 & 0 \end{Vmatrix} \times \begin{Vmatrix} (1-j0.00319) & (-j0.0637) \\ (0.5\ 10^{-6}) & 1 \end{Vmatrix} \times \begin{Vmatrix} (-51.7-j68.1) & (-87.9\ 10^{6}+j31.5\ 10^{6}) \\ (-8.27\ 10^{-6}-j23.05\ 10^{-6}) & (-26.75+j1.06) \end{Vmatrix} \times \begin{Vmatrix} 1 & 0 \\ \frac{1}{R_x} & 1 \end{Vmatrix}$$

$$= \begin{Vmatrix} (1.08-j0.0276) & (125-j6890) \\ 0 & 0 \end{Vmatrix} \times \begin{Vmatrix} (-0.0504+j0.00016) & (-748+j318.5) \\ 0 & 0 \end{Vmatrix} \times \begin{Vmatrix} (-51.7-j68.1) & (-87.9\ 10^{6}+j31.5\ 10^{6}) \\ (-8.27\ 10^{-6}-j23.05\ 10^{-6}) & (-26.75+j1.06) \end{Vmatrix} \times \begin{Vmatrix} 1 & 0 \\ \frac{1}{R_x} & 1 \end{Vmatrix}$$

$$= \begin{Vmatrix} (-0.0545+j0.001564) & (-800.2+j365.2) \\ 0 & 0 \end{Vmatrix} \times \begin{Vmatrix} (-51.7-j68.1) & (-87.9\ 10^{6}+j31.5\ 10^{6}) \\ (-8.27\ 10^{-6}-j23.05\ 10^{-6}) & (-26.75+j1.06) \end{Vmatrix} \times \begin{Vmatrix} 1 & 0 \\ \frac{1}{R_x} & 1 \end{Vmatrix}$$

Fig. 3. Resistance – Capacitance Oscillator

by putting them back in the definition equation (1).

Now the reason for the suffix notation can be appreciated, for example:

- a_{11} is the parameter in the first row and first column of the array
- a_{12} is that in the first row, second column
- a_{21} is that in the second row, first column
- a_{22} is that in the second row, second column

and this notation is universally used.

An enormous amount of useful work can be done with rule (6) and definition (1), using a little common sense with regard to the relative positions of the networks (arrays), and the reader should attempt the derivation of the sample arrays shown in Fig. 2 and practise combining them by rule (6). In calculating parameters, it is a useful check that the determinant of the array of a passive network is always unity:

$$\begin{vmatrix} (1 + YZ) & Z \\ Y & 1 \end{vmatrix} = 1$$

In other words, only three of the four parameters are independent. Another valuable check is that a_{11} and a_{22} are pure numbers (ratios), also a_{12} has the dimensions of impedance and a_{21} of admittance.

There are two main advantages of this linear parameter technique of dealing with four-terminal networks, firstly the great economy of labour, especially since in many cases only one of the final parameters is required (for example, a_{11} in the case of oscillator analysis). Secondly, the method is particularly suitable for successions of dissimilar networks and can therefore analyse the effects of valves and coupling circuits in an R-C. oscillator chain.

The reader should be wary of possible error in approach to this problem. Suppose, for example, the oscillator comprises an amplifier followed by a phase-shifting network, and the phase shift in the oscillator requires to be calculated. In this case the phase shift must be that of the amplifier when it is loaded by the phase-shifting network, therefore it is necessary first to calculate the input impedance of the phase-shifting network and add this shunt impedance as a four-terminal network across the amplifier terminals. The a_{11} parameter of the combined network gives the amplifier voltage ratio and the phase shift on load. (The input impedance is calculated by dividing the a_{11} parameter by a_{21} as explained above.)

As an example of this technique of analysis, consider Butler's oscillator[1] which is redrawn as shown in Fig. 3, with the parameter arrays below their respective networks, calculated for the alleged frequency of 250 c/s.

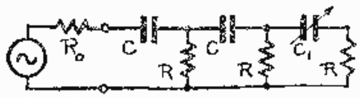
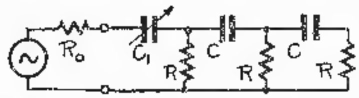
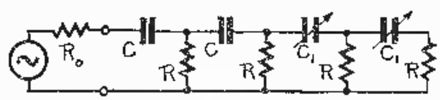
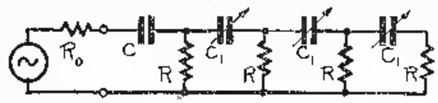
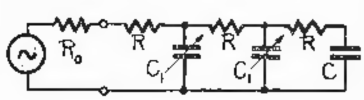
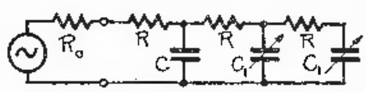
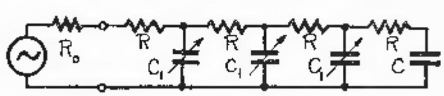
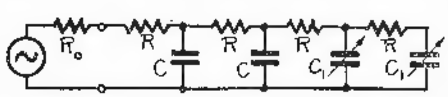
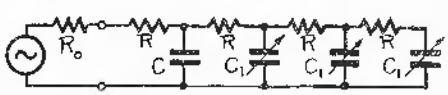
In this case the shunting effect of the phase-shifting network on the amplifier is negligible, so the a_{11} parameter of the amplifier alone will also be its voltage ratio and phase shift on load, for all practical purposes. (In actual fact the shunting effect of the phase-shifting network causes an additional phase shift in the amplifier of about 2°, but this has been ignored in the following notes.)

By inspection of Fig. 3, the a_{11} parameter of the phase-shifting network shows that at 250 c/s. there is a voltage ratio of 85.6 to 1, with a phase shift of 233°, whereas the a_{11} parameter of the amplifier shows that the available gain is 18.3 with a phase shift of 1° 39′ at 250 c/s. Therefore the circuit given could not possibly maintain oscillations at 250 c/s. as the phase of feed-back is incorrect by about 53°, and about four-and-a-half times the gain would be required.

It is very significant that the available gain of 18.3 is almost exactly the right amount to maintain oscillations at the theoretically correct frequency of 127 c/s., when the phase-shifting network has a voltage ratio of 18.4 (Fig. 4) and the correct phase shift of 180°. This rather suggests that an error was made in observing the "actual" frequency reported by Butler, due to being misled by a factor of 2 in the design formula.

Butler suggests valve inter-electrode capacitance as a possible cause of the discrepancy between calculated and measured frequency, but at 250 c/s. the phase shift due to this amounts to something in the order of 0° 6′ for valve $V1$ and about 0° 27′ for $V2$ with their associated input circuits. His other suggestion regarding coupling capacitors has already been included in the calculation of amplifier phase shift, 1° 39′, above.

Since these suggestions do not explain the dis-

NETWORK	COEFFICIENTS "A" TO "Z" AND "a" TO "z"		
	f: numerator / denominator	**ρ: numerator**	**ρ: denominator**
	(0 0)(5 2)(1 2)(0 0) / (1 0)(0 0)	[10 4 0][16 12 2 0][3 7 2 0][0 0 0 0][0 0 0 0] [0 0 0 0][0 0 0 0]	[(1 0)(0 0)(0 0)]^1
	(0 0)(3 4)(3 0)(0 0) / (1 0)(0 0)	[3 7 4][14 16 0 0][12 0 0 0][0 0 0 0][0 0 0 0] [0 0 0 0][0 0 0 0]	[(1 0)(0 0)(0 0)]^1
	(0 0)(0 0)(9 7)(1 3) / (2 0)(5 1)	[0 0 0][158 146 28 0][430 490 154 14][284 464 218 30][29 110 73 12] [0 0 0 0][0 0 0 0]	[(2 0)(5 1)(0 0)]^2
	(0 0)(7 3)(3 7)(0 0) / (4 0)(3 1)	[84 36 0][342 270 48 0][352 536 180 12][114 326 190 30][9 42 55 14] [0 0 0 0][0 0 0 0]	[(4 0)(3 1)(0 0)]^2
	(4 0)(6 10)(0 0)(0 0) / (6 0)(1 1)	[224 0 0][436 560 0 0][212 540 336 0][29 110 137 56][0 0 0 0] [0 0 0 0][0 0 0 0]	[(6 0)(1 1)(0 0)]^2
	(0 0)(1 1)(0 0)(0 0) / (3 2)(3 1)	[0 0 0][3 5 2 0][14 20 7 0][12 13 3 0][0 0 0 0] [0 0 0 0][0 0 0 0]	[(0 0)(1 1)(0 0)]^1
	(0 0)(1 1)(0 0)(0 0) / (5 2)(1 1)	[0 0 0][10 9 2 0][16 23 7 0][3 6 3 0][0 0 0 0] [0 0 0 0][0 0 0 0]	[(0 0)(1 1)(0 0)]^1
	(1 1)(6 5)(0 0)(0 0) / (6 3)(4 1)	[0 0 0][29 67 50 12][212 457 321 73][436 852 540 110][224 380 197 29] [0 0 0 0][0 0 0 0]	[(1 1)(6 5)(0 0)]^2
	(0 0)(4 3)(3 3)(0 0) / (7 2)(3 2)	[0 0 0][0 0 0 0][84 115 47 6][333 589 328 56][352 735 486 100] [123 293 226 56][9 24 21 6]	[(0 0)(4 3)(3 3)]^2
	(2 1)(5 5)(0 0)(0 0) / (9 3)(1 1)	[0 0 0][158 203 86 12][430 788 431 73][284 678 504 110][29 87 87 29] [0 0 0 0][0 0 0 0]	[(2 1)(5 5)(0 0)]^2

$$f = \frac{1}{2\pi R C_1 \sqrt{\dfrac{(A+B\delta)+(C+D\delta)\alpha+(E+F\delta)\alpha^2+(G+H\delta)\alpha^3}{(K+L\delta)+(M+N\delta)\alpha}}}$$

$$\rho = \frac{\left\{\begin{array}{l}[a+b\delta+c\delta^2]\alpha^{-1}+[d+e\delta+f\delta^2+g\delta^3]+[h+k\delta+l\delta^2+m\delta^3]\alpha^{+1}+[n+p\delta+q\delta^2+r\delta^3]\alpha^{+2}+[s+t\delta+u\delta^2+v\delta^3]\alpha^{+3}+\\ \quad +[w+x\delta+y\delta^2+z\delta^3]\alpha^{+4}+[P+Q\delta+R\delta^2+S\delta^3]\alpha^{+5}\end{array}\right\}}{[(T+U\delta)+(V+W\delta)\alpha+(X+Y\delta)\alpha^2]^Z}$$

where $\delta = \frac{R_o}{R}$ and $\alpha = \frac{C}{C_1}$

IMPORTANT. NOTE THE INDEX

Fig. 4. Phase Shifting Networks

crepancy, the writer has taken the liberty of examining other ways in which a frequency of 250 c/s. could be generated.

For example, consider a cathode follower input impedance of R_x as an additional four-terminal network as shown in Fig. 3. Calculation shows that R_x would have to be 0.46 megohms to cause the imaginary part of a_{11} of the combined networks to be zero at 250 c/s., but also that the amplifier gain would then have to be 242 to maintain oscillations; therefore this cannot be the explanation.

Next the possibility of error in the phase-shifting network resistors was considered, but it was found that the only reasonable possibility was that the first series resistor in the network might be 30 kilo-ohms instead of 3 megohms, due to an error in colour code marking.

In this case the imaginary part of a_{11} is zero at about 250 c/s., but the gain would have to be 27. Since the gain is controlled by a lamp in the cathode connexion of $V1$, this is a possibility as the resistor may not be stable and a value of 300 ohms would result in the required gain of 27.

Poor insulation resistance of the phase-shifting network capacitors could result in the required 180° phase shift at 250 c/s., but this would have to be as low as 5.4 megohms across each capacitor and the required gain would then be 116, so this is not a likely explanation.

Finally, the effect of imperfect decoupling of the screen grid circuit[3] was examined, but the phase shift due to this cause, at 250 c/s., amounts to something in the order of 0° 4′, and can therefore be ignored.

This critical analysis suggests that in the absence of some effect which may have been overlooked, the most probable explanation of the reported discrepancy is that an error was made in observing the frequency, and that the oscillator was actually operating at, say, 125 c/s. and not 250 c/s. This error would be extremely easy to make with a complicated Lissajous figure, especially if one were expecting 250 c/s. because of an error in the design formula.

A list of carefully checked design formulæ is given in Fig. 4, and obviously either "C" or "$C1$" could be made the variable or one could make $C = C1$ and gang all the capacitors together. The general formulæ are given at the foot of the diagram showing constants and coefficients "A" to "Z" and a to z, which vary for each network. These constants and coefficients are listed opposite their respective circuits, in the same relative position as they appear in the general equation, and parentheses are provided to assist their recognition. For example, for the first network in Fig. 4 the frequency is given by:

$$f = \frac{1}{2\pi RC1\sqrt{(5+2R_o/R)C/C1+(1+2R_o/R)(C/C1)^2}}$$

and the amplification required to maintain oscillations is given by:

$$\rho = (10+4R_o/R)C1/C+(16+12R_o/R+2(R_o/R)^2) + (3+7R_o/R+2(R_o/R)^2)C/C1$$

(Care should be taken to notice and include the index "Z.")

Since the ratio of internal resistance of the source of energy, to the network resistance, is involved, the calculation of network resistance for a given frequency must be done by iteration.[10] For example, first calculate the value of "R" for a given frequency ignoring the internal resistance of the source. (Put R_o = zero in the formula.)

Now put this calculated value of "R" in the right-hand side of the equation which includes the effect of R_o and calculate a new value for "R." Put this new value in the right-hand side and re-calculate "R" and so on. This process is known as "iteration" and is continued until the required precision is obtained.

The choice of a CR versus an RC network is largely a matter of personal preference. The former eliminates the need for precautions to prevent positive bias reaching the grid but, on the other hand, the RC network allows one terminal of each capacitor to be earthed.

The choice of the number of sections depends on the amplifier gain available and the use of more than three sections is seldom justified. There is also little to choose between the RC and CR sections from the point of view of harmonic distortion, as the necessary purity of waveform can be obtained with either kind of oscillator by careful design.

In conclusion, the author hopes that the reader will try the derivation of parameters from the short and open circuit conditions of simple four-terminal networks for himself, and carry out one or two combinations by rule (6). The effort is really worth while as it gives more meaning to the otherwise strange symbols and notation, and nothing but a personal attempt will convince the reader of the simplicity of elementary matrix algebra, as this is what the rules of manipulating arrays of symbols is called. Most advanced mathematical tools are aimed at simplifying the work of calculation and prediction, and here we have seen the matrices handling two equations at a time, dealing with the coefficients only, with a note of their conventional relation with the independent variables represented by the × sign between the matrices (arrays).

The author wishes to acknowledge the permission of the chief scientist of the Ministry of Supply to publish this article, and to record appreciation of Mr. T. C. Skipper, B.Sc.(Tech), A.M.I.E.E., who gave so freely his knowledge of this and other subjects.

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The Synthesis of Quartz

THE extensive use of specific cuts of quartz crystal to act as oscillator plates for the control of radio frequencies aroused considerable interest in the possibility of growing the synthetic material. Since quartz is the term used to describe a certain crystallographic form of silica, the problem is basically one of making silica molecules crystallise into the required pattern from a solution. Where an aqueous solution is used, it is found that the required quartz is far less soluble at very high pressures and elevated temperatures than such amorphous forms of silica as silica glass. The essence of this hydrothermal method is, therefore, to surround a chosen seed crystal of quartz with an aqueous solution of silica, molecules of which will then be deposited on the seed crystal when the temperature and pressure have reached the right level.

Pioneer work in this field was carried out by Spezia[1] in Italy at about the beginning of this century. He used a high pressure container filled with a solution of sodium meta-silicate, and sodium chloride. This solution was replenished from lumps of crystalline quartz situated at the upper, hotter part of the container, while the seed crystal was placed near the bottom. Under these conditions, the temperature of growth was a little below 300° C.

When, in 1942, attempts were made to overcome the war-time shortage and expense of natural quartz obtainable from Brazil, the experiments of Spezia and subsequent workers appeared to show that methods employing aqueous solutions offered good chances of success. It was found that silica glass can be used to replenish the Spezia solution in place of the crystalline quartz used by the early workers. The solubility of the vitreous silica obtained from the glass is much higher than that of silica in the crystalline form, so that a growth cycle will take place at an even temperature. This isothermal method[2] is being developed at the Research Laboratories of The General Electric Company, Limited and is essentially one in which silica glass dissolves in the aqueous Spezia solution while quartz is being deposited on the seed crystal.

The process is carried out in a heavy steel container or bomb (Figure 1), capable of withstanding pressures of a thousand or more atmospheres at temperatures in the range of 350-400° C. The most important feature in its construction is the sealing of the joint between the lid and the main body of the container. A mild steel lens ring is used, having spherically ground surfaces which make line contacts with the conically turned surfaces on the lid and the flange of the bomb. Even loading of the lens ring is ensured by bolting the lid on to the flange of the bomb at several places round its periphery. A special heat resistant steel is used to ensure that the nuts and bolts do not stretch excessively in the furnace, thus breaking the seal.

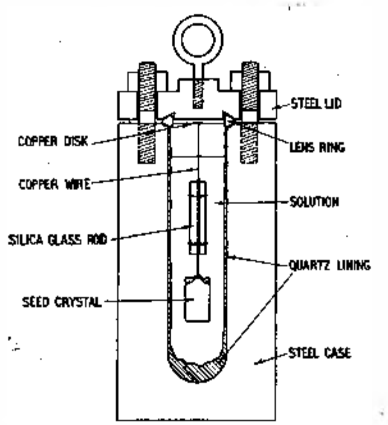


Fig. 1. 500ML. bomb for synthesising crystalline quartz

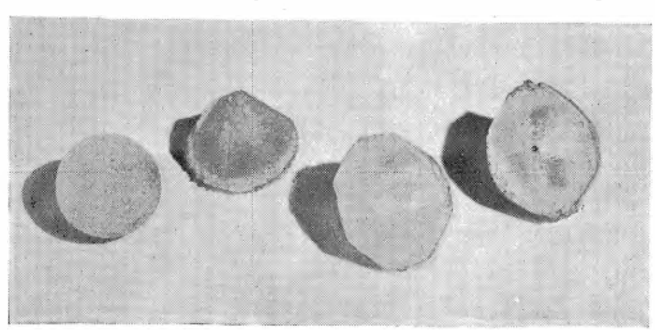
When such an autoclave has been used for two or three growth cycles, each of about eighteen hours' duration, the interior walls become covered with a heavy coating of polycrystalline quartz. The presence of this coating appears to be essential to the process.

The most critical features of the process are the composition of the solution, freedom from contamination (especially from exposed steel surfaces) and pretreatment of the seed. The pressure is controlled by the degree of filling and the temperature, the latter being normally kept below the critical point of water, about 375° C. The silica glass necessary to replenish the solution may be in rod form, when it is usually suspended above the seed crystal, or in the form of broken lumps, in which case it rests on the bottom of the autoclave. Either silver or copper wire may be used for suspending the seed crystal, and a copper disk is attached to the underside of the lid so that only the minimum of steel surface is exposed to the contents of the autoclave.

A typical solution used contains sodium metasilicate at a concentration of 50 grams per litre, together with a mineralising substance. The latter usually consists of such salts as the sodium or potassium acid fluorides and its function is to improve the crystalline perfection of the deposited quartz. Although it is difficult to investigate the actual chemistry of the growth cycle it is known that alkaline silico-fluorides are produced. It seems likely, therefore, that the mineraliser takes part in some intermediate chemical reaction in the process.

In order to find the most suitable crystal cut for the seed, experi-

Fig. 2. Stages of growth of a crystal on to a spherical seed



ments were carried out in which quartz was deposited on spheres of the natural material. It was found that the resultant crystal had pyramidal terminations at both ends of a barrel-shaped prism (Figure 2). Further work supported the conclusion that rectangular plates cut parallel to the rhombohedral faces, known as *R*-plates, would be most satisfactory as seed crystals. Such plates may be cut from previously manufactured material or from a natural crystal.

The synthetic quartz layer is built up in successive growing cycles of 18 hours each, the autoclave being recharged with raw materials after each cycle. The temperature is raised to 360° C. over a period of 5 hours and is then kept constant for a further 13 hours before cooling. About five successive growth processes are necessary to produce a synthetic crystal large enough for the manufacture of oscillator plates. Figure 3 shows some of the earlier synthetic quartz specimens obtained. The top row illustrates a sequence in which an entirely synthetic slice is obtained by successive depositions of good quality quartz on a seed crystal, while the bottom row shows some typical ways in which the process may fail under unsuitable conditions.

In particular, if the synthetic layer is deposited too quickly, its crystalline quality is appreciably

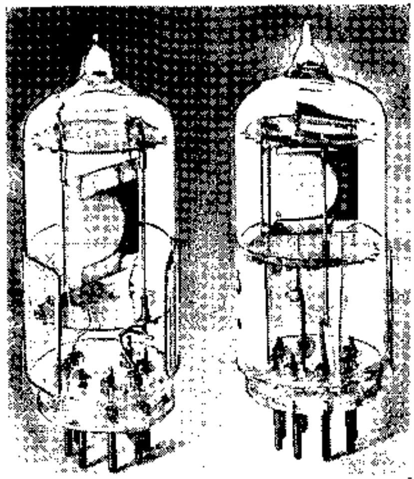


Fig. 4. Two 8Mc/s synthetic crystal units using different cuts

lowered and a loss in activity of the finished oscillator unit results. Various X-ray methods[3] can be used to examine the crystalline texture of the synthetic quartz layer. The presence of mechanical faults or inclusions, such as bubbles, can be discovered by visual or microscopic inspection. This part of the examination is extremely important since quartz which is otherwise of a high crystalline quality may be useless for oscillator purposes owing to a single very slight flaw.

In 1945, the first synthetic quartz oscillator plate was made at the G.E.C. Research Laboratories, but its performance was found to be poor. Since that time, the effects of the many variables in the isothermal process have been investigated during the course of several hundred experiments. As a result, it is now possible to produce synthetic quartz giving certain cuts of oscillator plates, which are of the same standard as those made from natural quartz. Figure 4 shows two 8 Mc/s. crystal units using different crystal cuts, both made entirely from synthetic quartz.

This ability to grow quartz crystals, satisfactory for oscillator plates, on a laboratory scale is itself an achievement, while the knowledge of the fundamentals of crystal growth which has been gained during these researches may lead to even greater developments in the future.

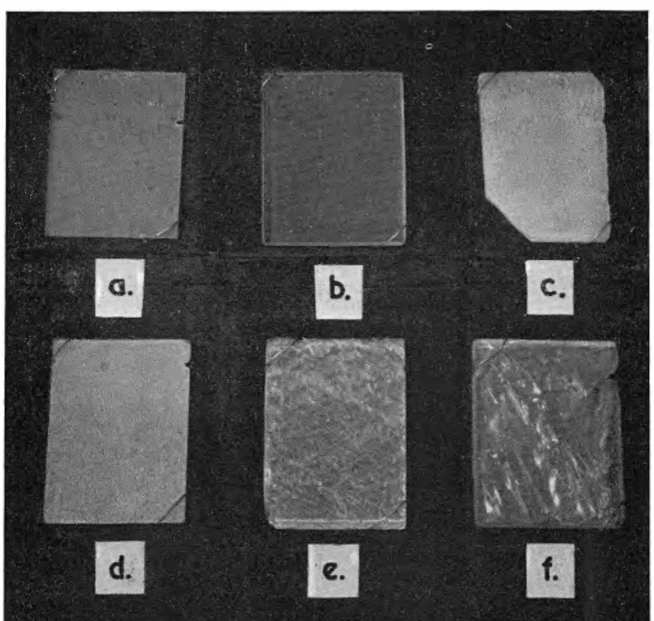


Fig. 3. Synthetic Quartz Specimens :
(a) Seed crystal
(b) Good quality growth
(c) Entirely synthetic slice.
Faulty growths are illustrated at (d) (polycrystalline) (e) (cracked) and (f) (heavy growth with flaws)

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2 Nora Wooster and W. A. Wooster, *Nature*, *157*, 297 (1946).

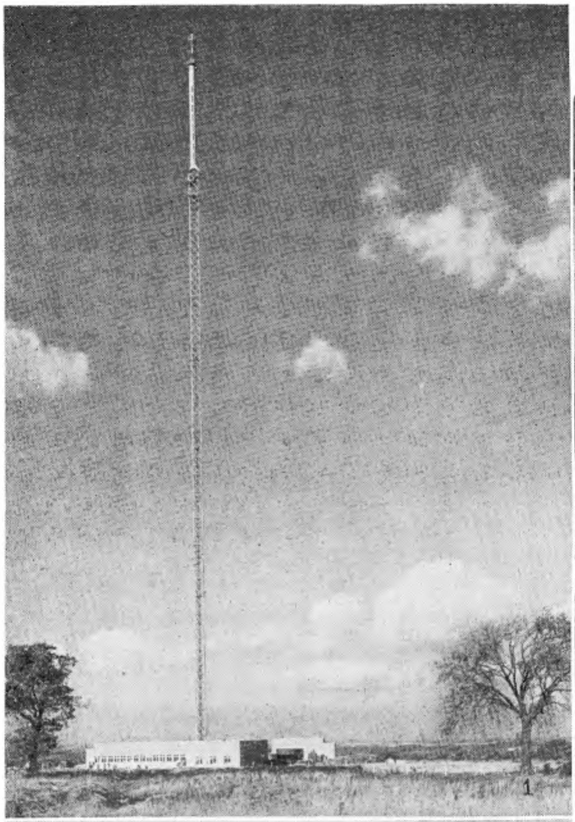
3 W. A. Wooster and G. L. Macdonald, *Acta. Crystallographica*, 1, 49 (1948).

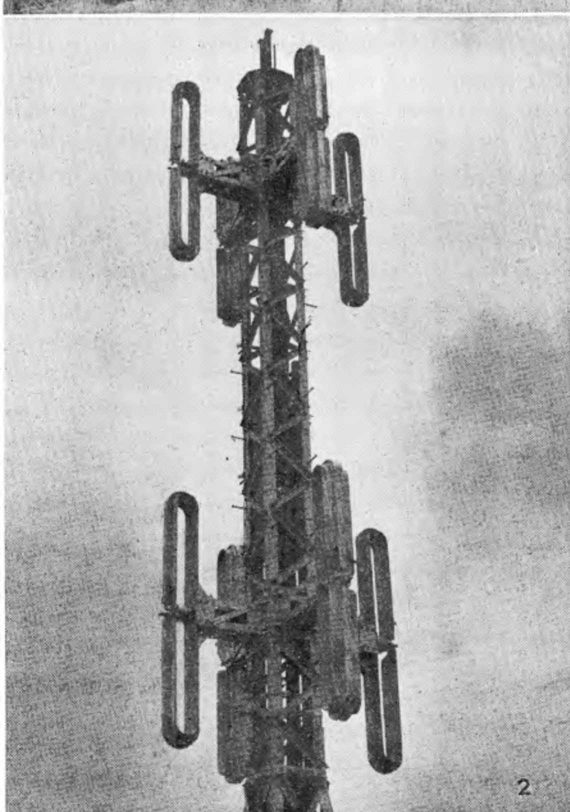
SUTTON COLDFIELD TELEVISOR BOOKLET

ERRATA

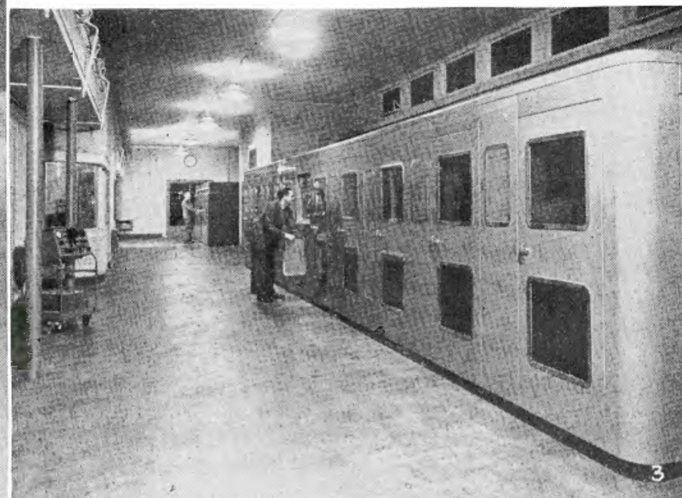
The following corrections will be incorporated in the second edition of the Midland Televisor booklet :

Page 26	Fig. 8: *Delete* second line of caption.
,, 30	Upper part of Fig. 9 (c): The top row of coil mounting positions are drawn rather too high, although the measurement shown (1 $\frac{11}{16}$") is correct.
,, 31	Fig. 10 (a): " L8 " should read " BL12 ".
,, 38	Fig. 13: *Omit* BR40.
,, 39	Fig. 14: *Add* caption, " Wire gauge as for BL 1, 2, 3, etc."
,, 40	Upper part of Fig. 15: The drilling measurement for BL16 should be $1\frac{1}{8}$".
,, 47	Tolerance of BR51 should be 10.
,, 50	After sixth line *add* " A.M.C. (saddle type) coils are treated similarly ".
,, 50	Bottom of page: *Substitute* V16 and 17 for BC16 and 17.
,, 51	Fourth line from bottom: " 5 2BA bolts and nuts ".
,, 57	List of components: After BC74 *read* BC75.
,, 75	Value of BC29, 30, 33, 34, 37, 38, 44, 45 should read 500pF.
,, 74-6	*Add* " A.M.C." as makers of chassis, screening boxes and gantries.
,, 76	Line ten from bottom: *Amend* to " For Haynes and A.M.C. coils ".
,, 77	After ninth line *add* " or 1 A.M.C. Scanning Coil Assembly ".
Wiring diagram	Reverse top two leads feeding into left side of vision chassis.
,,	*Omit* BR40 from sound chassis.
,,	Alter " BR49 " at top right of diagram to " BR44 ".





The Sutton Coldfield



The B.B.C.'s second television transmitter was opened on December 17th. The photographs on these pages give a preliminary view of the transmitter and aerial system ; fuller technical information will be published in a later issue.
Details of the Radio Relay Link between London and Birmingham were contained in the December issue of " Electronic Engineering."

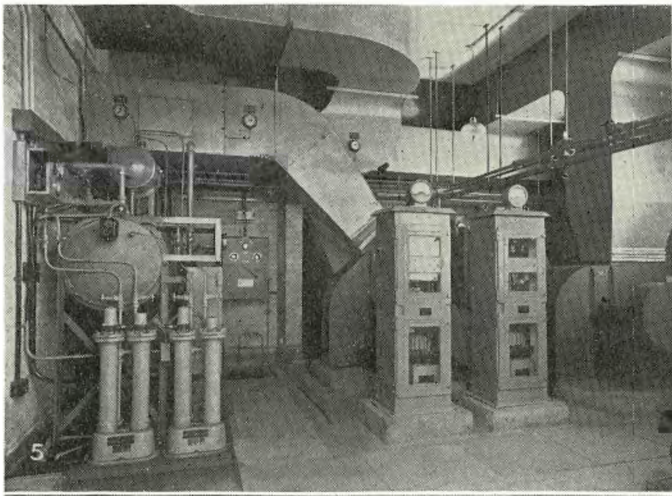
1. The transmitter building and the 750 foot mast. At the top of the mast is the wide-band aerial, consisting of two tiers of four vertical folded dipoles arranged in cruciform, which will radiate both sound and vision signals.

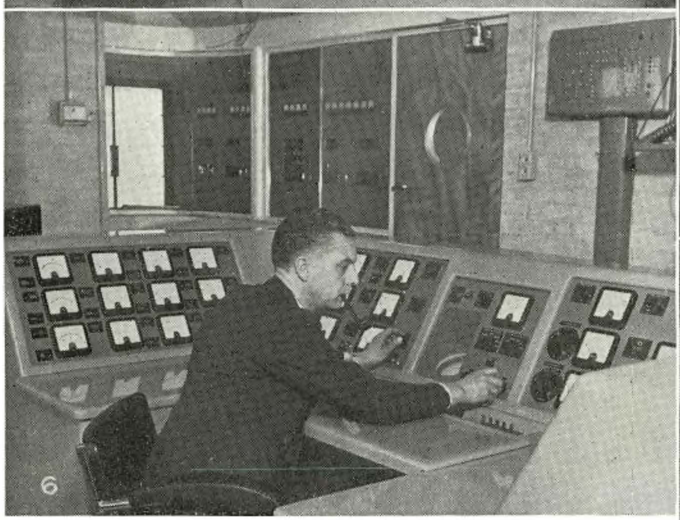
2. The combined sound and vision aerial array. The array consists of 8 vertical folded dipoles arranged in two groups placed one above the other and separated by a distance of approximately one wavelength. The dipoles are made of galvanised steel strip and incorporate 7½ KW heaters to prevent ice formation in cold weather

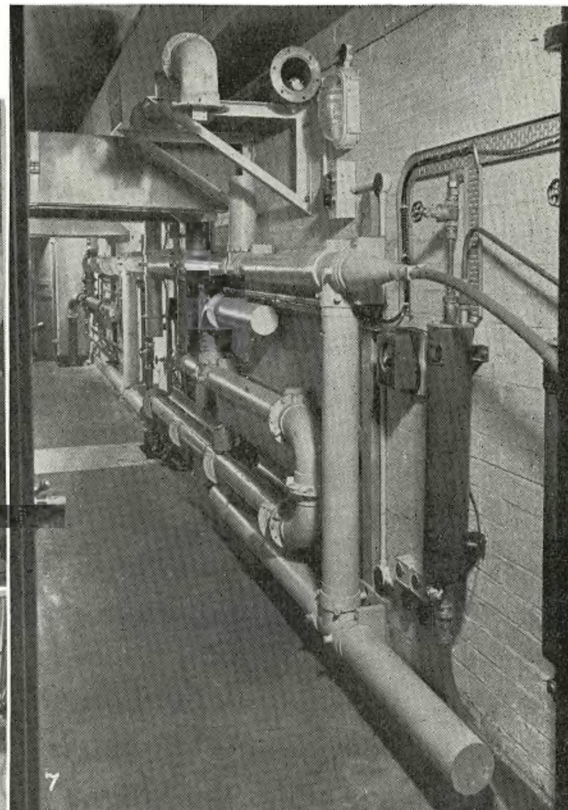
3. The transmitter hall. In the foreground is the vision transmitter, which is capable of a peak output of approximately 40 KW. Beyond is the sound transmitter, which has an average carrier power of 12 KW On the left, through the curved window, is the control room.

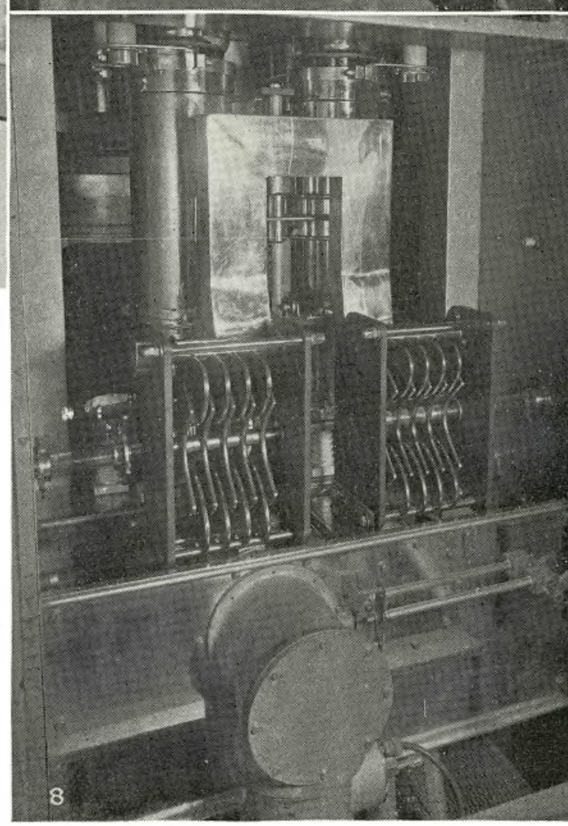
4. The vision transmitter. The modulator stages are on the left and the radio-frequency stages on the right.

Television Transmitter









5. Valve cooling plant. Left, part of the water system for cooling the CAT21 valves in the modulated output stage of the vision transmitter. Centre, the air-blower for cooling the valves in the vision transmitter : the air can be circulated either round a closed system in order to raise its temperature quickly, or drawn in from and discharged outside the building. Right, the air-blower for cooling the water circulated through the CAT21 valve jackets. The warmed air can be discharged into the transmitter hall to provide space heating, or discharged externally.

6. Combined control desk for the sound and vision transmitter.

7. The vestigial sideband filter, constructed of lengths of concentric feeder, which is connected between the output of the vision transmitter and the feeder to the aerial. The filter is of the constant-resistance type, and comprises a high-pass and a low-pass section. The low-pass section (*in the background*) is terminated by the feeder to the aerial, and the high-pass section (*in the foreground*) by a water cooled, constant-resistance, absorber load (*on the right of the picture*).

8. Rear view of modulated output stage. The CAT21 valves are above the vertical tubes, which form the anode tuning inductance. In front of the tubes is the output coupling coil, and below are the output tuning capacitors. At the bottom is the concentric feeder leading to the vestigial sideband filter.

Birth Centenary of AMBROSE FLEMING — PART II

By J. T. MacGREGOR-MORRIS, D.Sc.(Eng.) London, M.I.E.E.*

Sequence of events leading Sir Ambrose Fleming to the use of the wireless valve for radio reception

FROM a general examination of Sir Ambrose Fleming's life and his methods of work we now turn to a study of the chain of events which unconsciously led him to make those discoveries which proved to be such notable contributions to the foundations of electronic engineering. The most widely known of these is the practical application of the two-electrode valve for the rectification of alternating currents, and its use for the reception of radio signals.

As we have seen, after training as a chemist, Fleming became more and more attracted to Physics, and in this he was notably influenced by Professor Guthrie of the Royal College of Science. In 1873 Professor Guthrie was studying experimentally the way that hot bodies lose electrical charges. He showed that the hotter the body the more rapidly did it lose a charge of electricity, and also that when an iron ball was at a bright red heat and well insulated it could be charged with negative electricity, but could not for an instant retain a positive charge.[1] It is more than probable that Fleming assisted his Professor in these experiments.

In the light of more recent events it is interesting to note that here we have the embryo of the idea underlying the action of the wireless valve, but the world had to wait some 30 years before this experimental result was applied to the wireless field by Fleming.

Hittorf and Goldstein had, in 1885, shown the unilateral conductivity of vacuous spaces having unequally heated electrodes when the negative electrode is rendered incandescent, and later Elster and Geitel contributed further to the subject in 1889.

About the same time (1884) we find Edison announcing his discovery of the effect in carbon filament lamps named after him, and further examined by Preece in the following year. It is interesting to speculate whether Fleming, when he visited the U.S.A. in 1884 and met Edison, was shown the Edison effect.

However this may be, we find Fleming later making quantitative measurements of the effect, the results being given in a paper published in the Proceedings of the Royal Society, January 9, 1890, entitled: "On Electric Discharge between Electrodes at Different Temperatures in Air and in High Vacua."

In his earlier papers of 1883 and 1885 we find that his attention is concentrated upon molecular shadows in incandescent lamps, but it is not until 1889 that Fleming shows by his writings that he is interested in, and has been experimenting with, the unilateral conductivity of the space between an insulated plate and a hot carbon filament in a vacuum.

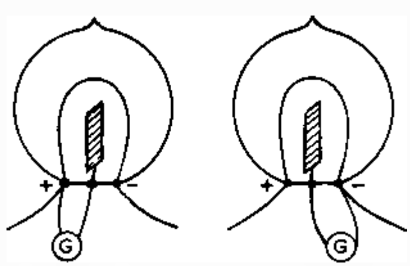


Fig. 7. Incandescent lamp used to demonstrate the Edison effect

In his Royal Society paper of 1890 he opens with the following statement:

"It has been known for some time that if a platinum plate or wire is sealed through the glass bulb of an ordinary carbon filament incandescent lamp, this metallic plate being quite out of contact with the carbon conductor, a sensitive galvanometer connected between this insulated metal plate enclosed in the vacuum and the external *positive* electrode of the lamp indicates a current of some 4 to 5 milliamperes passing through it when the lamp is in action, but the same instrument when connected between the *negative* electrode of the lamp and the insulated plate indicates no sensible current—it is less than 0.0001 of a milliampere. This phenomenon was first observed by Mr. Edison in 1884, and further examined by Mr. W. H. Preece[2] in 1885." (Fig. 7).

Then comes the following pregnant statement:

"(Section 6) When the lamp is actuated by an *alternating* current a *continuous* current is found flowing through a galvanometer connected between the insulated plate and *either* terminal of the lamp. The direction of the current through the galvanometer is such as to show that negative electricity is flowing from the plate through the galvanometer to the lamp terminal."

Further on in the same paper he says:

"We may say that a vacuous space bounded by two electrodes—one incandescent and the other cold—possesses a unilateral conductivity for electric discharge when the electrodes are within the distance of the mean free path of the projection of the molecules which the impressed electromotive force can detach and send off from the hot negative electrode."

In Section (19) he shows that similar effects are produced with an electric arc when a third electrode touches the flame. In Section (20) he concludes that negative electricity can pass along the flame-like projections of the arc from the hot negative carbon to the cooler third carbon, but

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* Emeritus Professor of Electrical Engineering in the University of London.

not in an opposition direction.

In his Royal Institution lecture of the same year, Fleming says: "Pass in imagination from the iron balls (of Guthrie's experiment) to carbon molecules—consider a carbon molecule or small congerie of molecules just set free by the high temperature from the negative leg of the incandescent horse-shoe." And later: "This action would cause a torrent of negatively charged molecules to pour across from the negative to the positive side of the carbon shoe."

To sum up, in common parlance the space is just like a "one way street" in which traffic is found to go only in one direction, and nowadays we know that all the "vehicles" are exactly alike. There is not a mixture of large and small cars and motor vans—all are identical in size and form, simply electrons, whatever they are.

Thermionic Valves

Six years later, in a paper entitled "A Further Examination of the Edison Effect in Glow Lamps" read before the Physical Society in 1896, he sums up the position by saying that the plate can be replaced by a grid of wire of the same general outline without apreciably altering the effect.

And later in the same paper: "The whole of the experiments seem to be capable of consistent interpretation if we may justifiably make the hypothesis that these carbon molecules or atoms so projected from the conductor when intensely heated by the current flowing through it are all *negatively* charged. Some of the observed facts seem to point to the conclusion that the molecules projected from the incandescent conductor, whether they are portions of the conductor or molecules of the residual gases respectively carry away negative charges proportional in magnitude to the potential of the conductor of the point from which they are thrown off.

Later on, he says, "There is much to lead to the conclusion that from all parts of the incandescent carbon conductor there is a constant radiation of matter carrying a negative electric charge.""

He calls this *molecular electrovection.*

Now we must direct attention to some work which bears on an allied subject, i.e., that of the focusing of cathode rays by means of a magnetic field.

Magnetic Focusing of Cathode Rays

It is not generally known that Fleming was the originator of the use of the so-called "focusing" coil now employed very largely for the magnetic focusing of cathode rays in television, cathode-ray oscillographs and in electron microscopes. A note on the subject was published by him in *The Electrician* of January 1, 1897. The present writer, who was then his assistant, was surprised that the matter was pushed no further. Many years later he discovered that the load Fleming was then carrying was at least enough for two men of good mental stature, and it was quite impossible to take on further work. The following quotations from his personal diary reveal this clearly.

"1896. January-February. Gave four Cantor Lectures to the Society of Arts on "Alternate Current Transformers experimentally illustrated." My leisure time, chiefly in the evening, was occupied with the preparation of the New Edition of 1st Vol. of "*Alternate Current. Transformers*," largely re-written.

February-March. Gilchrist Lectures at Batley, and Holmfirth in Yorkshire, Newark, and at Leigh and Widnes in Lancashire. In the course I addressed about 10,000 people. Subject: "Magnets and Electric Currents."

February. Physical Society Paper with Petavel on A.C. Arcs.

March. Read paper before the Physical Society, "Quantitative Measurements of the Edison Effect in Glow Lamps."

June. Royal Institution, Friday evening Discourse, Low Temperature Electrical and Magnetic Research.

September. British Association. Working Men's Lecture. Liverpool.

October. I lectured at Birmingham on "The Earth a Great Magnet," and on "Polarised Light."

October-December. Greenock, Birkenhead, Blundellsands, Grassendale, Portsmouth, Newcastle-upon-Tyne, Hull, Walsall, Congleton, Westbourne Park, Wednesbury, Gloucester, Anerley and Norwood. In nearly all cases on "The New Photography."

December. Xmas Lecture at the London Institution.

1896-97. The most important event was the Memorial Committee to Sir John Pender."

If one stops to imagine the work needed to carry out such a programme on the top of his regular duties as Professor at University College, one ceases to wonder that he went no further with the elucidation of the magnetic focusing experiment.

In order to place this experiment in its right historical setting, however, it may be said that the development of the magnetic focusing of cathode rays can be divided into two periods, i.e., the experimental and the mathematical.

The experimental era.

Plücker	1858
Gassiot	1859
Hittorff and Goldstein ...	1869
Crookes	1878
Puluj	1890
Fleming	1896

The mathematical era.

Busch	1927
Knoll and Ruska ...	1931

It is appropriate to give an account of the actual discovery of this effect as recorded in an article in ELECTRONIC ENGINEERING of June 1945.

"One morning in December, 1896, at the end of the term, I well remember Dr. Fleming coming with his quick step into his laboratory at University College, and after his usual "Good morning" he said, "Morris, I want you to try out an experiment on the effect of an axial field upon the discharge in a vacuum tube." For this purpose, he produced a Crooke's tube having a Maltese cross near one end, and I was to use his 10-in. spark coil and a strong bar magnet about a foot long.

The bar magnet applied axially at the end of the enlarged end of the tube was expected to reduce the voltage necessary to excite the tube, and also produce some changes in the shadow.

Having got the apparatus working, Mr. (later Professor) Clinton joined me, and Dr. Fleming (as he was always called by staff and students) had to hurry off and did not reappear until the late afternoon.

Clinton and I found a slight effect on the voltage required to excite the tube, but we were much more interested in the effect produced on the Maltese cross shadow by the magnet. It was apparently most erratic, and seemed to require great precision in centring the magnet, and in getting it accurately aligned with the axis of the tube.

Continuing the account in the words of Dr. Fleming's letter to *The Electrician* (January 1, 1897):

"Mr. Morris and Mr. Clinton, who were experimenting with it, finally were led to try a coil traversed by current, placed round the tube as shown in Fig. 8, as a substitute for the magnet.

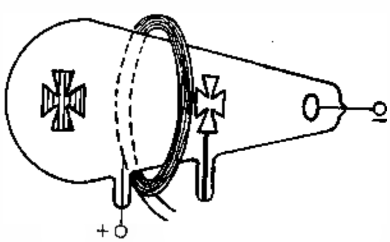

Fig. 8. The first experimental focussing of cathode rays

The following striking effects were then noticed. When the coil embraced that part of the vacuum tube between the metal cross and the end wall on which the shadow is formed, and when no current traversed the coil, the shadow of the cross was a dead-black shadow on an apple-green phosphorescent ground and was strictly the shadow of the cross defined by cathode rays as in Fig. 9(a). When the embracing coil had a current passed through it, the shadow rotated clockwise or the reverse according to the direction of the coil current, and the arms of the shadow were a little distorted or twisted round so as to resemble Fig. 9(b), the leading edge of the shadow being rather sharper than the trailing edge. Moreover, the shadow was altogether smaller than in the first case. As the current through the coil was increased, the shadow cross twisted itself more round, and got still smaller as in Fig. 9(c); and finally as the coil current was still more increased the cross shadow was further rotated and diminished until it vanished . . . at this stage the coil current was increased still more, and a new and larger cross shadow made its appearance. This shadow was not so well defined, and the background less uniformly green; but it, too, as the coil current was still more augmented, screwed itself round very slightly. This second shadow had its arms more sickle shaped than the previous one . . . "

It will be noticed that at the time we performed the experiment, no mention was made of "focusing the cathode rays," but now this system is extensively used in connexion with all kinds of cathode-ray tubes to focus the beam sharply on the screen."

During the following Session, 1897-98, work was going on in his laboratory with coherers and P.O. relays. Attempts were being made to obtain quantitative results of the fields around electrical oscillators of the Hertz type, but with no real success.

Returning now to his work directly connected with the production and detection of electric waves, Fleming writes in his "Memories":

"As a pupil of Maxwell I had for long taken an interest in his theory of electro-magnetic waves, and in the experimental proof given by Hertz in Germany in 1887 of the existence of these waves and their production by very rapid alternating electric currents, I had also followed very closely the important researches of Sir Oliver Lodge on the same subject, and had myself made apparatus for repeating Hertz's notable experiments.

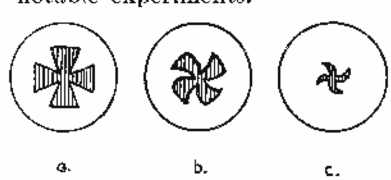

Fig. 9. Pictures produced on the end of the tube shown in Fig. 8. by varying the coil current

Hence, when in 1896 it began to be known that a young Italian inventor had succeeded in using electro-magnetic waves to operate telegraphic apparatus over distances of several miles without the use of inter-connecting wires, and thus had invented a practical system of wireless telegraphy, my interest in the matter enormously increased."

Marconi had improved an instrument called a coherer, invented by Sir Oliver Lodge, and by a French scientist, M. Branly, for detecting the presence of electric waves, and had made a notable addition by the use of long vertical wires attached to high masts which radiated and collected these waves. He had in this way produced the first really practical system of electric wave telegraphy and brought it to England in 1896 with an introduction to Sir W. Preece." Preece was then Engineer in Chief of the British Post Office Telegraphs.

The First Transatlantic Wireless Transmission

Fleming's extraordinary successful lecture at Dover before the British Association for the Advancement of Science was entitled the "Centenary of the Electric Current." It was given in September, 1899 and was a landmark in the history of electrical engineering. Through the co-operation of Marconi, wireless signals from Wimereux (Boulogne) were received on an aerial erected on the tower of the Dover Town Hall, and demonstrated audibly during the lecture in the Hall (Fig. 10).

It was in this year that Fleming was appointed scientific adviser to the Marconi Company—a position which he was to hold for 30 years.

In passing we may note that in 1900 he gave four Cantor Lectures to the Royal Society of Arts on "Electrical Oscillations and Electric Waves."

In the same year Fleming was entrusted by the Marconi Co. with the duty of specifying for the power plant necessary to produce the powerful electrical oscillations deemed essential if Marconi's project of the transmission across the Atlantic and the reception of such signals were to be realised. The scale of the transmitting plant would have to be gigantic in comparison with the puny 10-inch spark coils and Leyden jars, working off a few cells. A 25 horsepower oil engine was specified by Fleming to drive an alternator, and he designed and tested the special high voltage condensers at U.C.L. for use with the plant. The plant was installed at Poldhu, Cornwall, by the late R. N. Vyvyan, one of the Marconi Company's engineers. After many alterations, due to Marconi and Fleming, the plant was sufficiently reliable to do its work. In September, 1901, however, a great gale wrecked a large part of the aerial system, and so for the actual trials a smaller fan-shaped array had to be used.

After Marconi and his two assistants had arrived at Glace Bay, Newfoundland, and had elevated their aerial by means of balloons, gales damaged their aerial, this time at the receiving end. However, on December 12, 1901, they heard in earphones, faintly but distinctly, the pre-arranged signals ... ... , the letter S in the Morse code, which were being transmitted from Cornwall round one-eighth of the globe.

The Birth of the Thermionic Valve

To return to less exciting work, Fleming gave in 1903 further Cantor Lectures on Hertzian Wave Telegraphy.

In 1903-4 he was continuously working on methods of making quantitative measurements for wireless purposes by magnetic and thermal methods.

Then we find him devising apparatus for measuring the length of these electric waves—the instrument being named by him a cymometer. Later he was studying the propagation of electric waves along spiral wires. It will thus be seen that his mind was well prepared for developments in the methods of production as well as those for the detection of electric waves.

And now it will be best to resume quotations from his "Memories,"[4] where he gives his own account of his invention of the wireless valve.

"After the success in transmitting the 'S' signals across the Atlantic Ocean, Mr. Marconi invented a new type of receiver called a magnetic receiver, based on a discovery by Lord Rutherford, that very rapid electric currents can knock the magnetic state out of an iron wire.

"This magnetic detector was more certain in its action than the coherer, but it had the disadvantage that the signal could only be heard as sounds in a telephone, and could not be recorded on a tape. When the recording tape is used it is possible often to separate out false signals from alphabetic signals by a careful inspection subsequently. But that cannot be done when the signals are only audible sounds in a telephone.

"In the case of submarine cables, William Thomson (afterwards Lord Kelvin) invented a beautiful instrument called a syphon recorder, which records on paper tape the messages in Morse code signals, the 'dot' being denoted by a little jerk of a pen to one side, and the 'dash' by a jerk to the other side. But this instrument can only be worked with a direct electric current—that is one flowing always in the same direction. The high-frequency electric currents created in the receiving aerial wire are, however, alternating currents, that is, they reverse their direction several thousand or several hundred thousand times a second.

"The problem before me then was to discover how to change this feeble electric oscillation into a feeble direct current which could work the ordinary cable recording instruments. There were known devices for rectifying, as it is called, low-frequency alternating currents, but nothing then known which would do it for rapid electric oscillations.

"Thinking over the subject intensely, I had in October, 1904, a sudden very happy thought. I recalled to mind my experiments on the 'Edison Effect,' and in particular my observation that the space between an incandes-

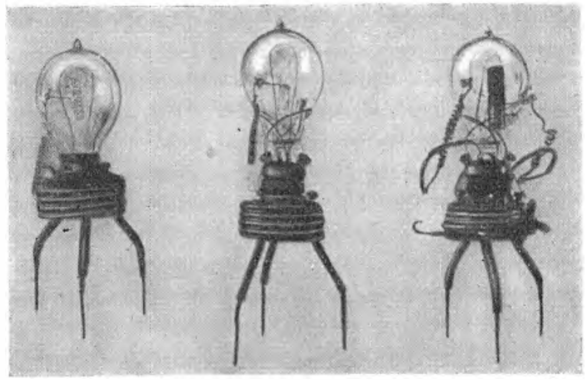

Fig. 11. Some of Fleming's earliest two-electrode valves

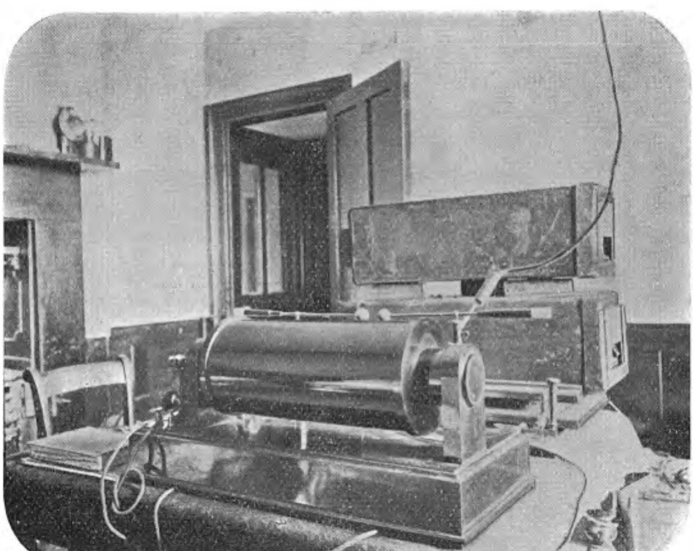

Fig. 10. Marconi spark coil set used for transmission between N. Foreland and Wimereux, 1899

cent carbon filament and a cold metal plate in a bulb exhausted of its air had a one-way conductivity for electricity. Then I said to myself, 'If that is the case we have here the exact implement required to rectify high-frequency oscillations.' I asked my assistant, Mr. G. B. Dyke, to put up the arrangements for creating feeble high-frequency currents in a circuit, and I took out of a cupboard one of my old experimental bulbs. (Figs. 11 and 12.)

"The experiment was at once a great success, and I found that I could use a mirror galvanometer, which is one of the instruments Lord Kelvin invented for submarine cable signalling, to detect feeble electric oscillations and denote their intensity by the movement of a small magnetic needle having a little mirror attached to it, and from that mirror a ray of light was reflected.

"The next day I asked the manager of the Edison-Swan Lamp Factory to make me twelve carbon filament lamps, the filament of each being rendered incandescent by a pressure of twelve volts. Round each lamp filament I asked for a metal cylinder to be fixed carried on a wire sealed through the glass bulb, and I asked that the vacuum in the bulb should be as good as possible—that is, the air very perfectly exhausted.

"When I received these bulbs I made the filament incandescent by the current from six cells of a storage battery or accumulator. I then found that the space between the filament and the cylinder would only allow negative electricity to pass from the filament to the cylinder, but not the other way. Hence the bulb acted like a valve in a pipe, which lets water or air only move in it one way.

"Accordingly I called this instrument a 'valve.' At first I named it an oscillation valve, but before long it was usual to speak of the small particles of electricity sent out from the hot surface as 'thermions,' and accordingly I called it a 'thermionic valve.' This name has been very widely adopted, although it is often called a 'Fleming valve.'

"My valve had the great advantage that it could not be injured or set out of action by

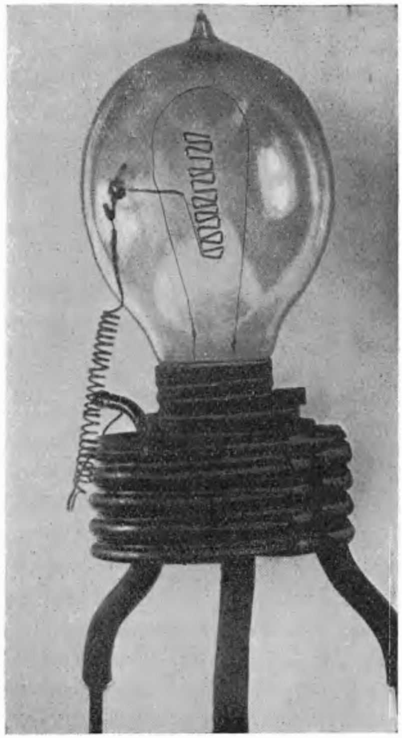

Fig. 12. Close-up view of the diode valve shown at the left of Fig. 11

'atmospherics,' as is the case with the coherer.

"On November 16, 1904, I applied for a British Patent, No. 24,850, for this invention, and in due course obtained also patent protection in the United States of America, and in Germany, which were granted, as well as patents in other countries . . . then three years later, after the date of my valve patent application, an American electrician, Lee de Forest, who had been following my work very closely, appreciated the advantage to be gained . . . by making a valve in which a metal plate was fixed near a carbon filament in an exhausted bulb, and placed a grid between the plate and the filament, thus making the first rudimentary form of the so-called three-electrode valve."

When one attempts to sum up, it is abundantly clear that few men could have been so well qualified as Fleming to make that notable step forward which undoubtedly prepared the way for the vast developments which were to follow.

It put, for the first time, a reliable tool into the hands of technicians, by means of which quantitative results of signal strength could be obtained, instead of spending one's energy in trying to counter those exasperatingly fitful habits of the coherer.

Later on it was only human that he should regret not having made the further invention of the introduction of the third electrode or grid, which vastly increased the utility of his own invention.

Some are apt to belittle this step that Fleming made, by drawing attention to the fact that it had been known for some thirty years that an alternating current of power frequency—say of 50 to 100 cycles per second—could be converted into a unidirectional current, and this being so then it was only "common sense"[3] to expect it to work as well at wireless frequencies, say of 1,000,000 cycles per second.

In reply it may be pointed out that until one understands the underlying mechanism of the operation one cannot predict that it will operate satisfactorily at 10,000 to 100,000 times the speed. One might just as well say that because a bicycle pump and valve operates well when air is being pumped into a tyre at one stroke per second, that therefore it will operate equally well if one could operate the pump at the rate of 10,000 strokes per second. We know enough about the properties of air and rubber at these frequencies to realise that this would be hopelessly impossible.

Now that we know that we are operating with electrons in the wireless valve, and that their velocity of travel is terrific, say some 20,000 miles a second, it may seem quite obvious that the wireless valve should operate quite easily at these high frequencies. But it is easy to be wise after the event.

In concluding I must express my thanks to Lady Fleming for permission to make short extracts from the book entitled "Memories of a Scientific Life," written by her late husband Sir Ambrose Fleming.

References

[1] *Phil. Mag.* Vol. XLV, p. 308, 1873.

[2] Proc. Roy. Soc. Vol. 38, 1885, p. 219: "On a peculiar behaviour of glow lamps when raised to high incandescence."

[3] In this paper there is no mention of the alternating currents being used to heat the filament and therefore of rectifying effects.

[4] "Memories of a Scientific Life," by Sir Ambrose Fleming. Marshall, Morgan & Scott.

Telescopic Mountings in Electronic Equipment

By C. H. DAVIS*

THE principle of withdrawing electronic equipment on extending slides is becoming increasingly popular; these notes have been written to guide designers and others in the application of such devices. These mountings offer the most convenient way of ensuring the complete accessibility of rack-mounted equipment. Each component unit or chassis in the rack is mounted on to telescopic mountings or slides, when it can be withdrawn completely clear of its framework for easy examination. This avoids the necessity of having to have access to the back and sides of the unit in its normal position for maintenance purposes, and space is therefore saved.

Telescopic mountings overcome other limitations of the conventional draw-slide. The effort required to pull out a heavily-laden drawer, due to friction, limits its weight to about 50 lb. Ball-bearing telescopic slides enable drawers weighing several hundreds of pounds to be taken out with ease. Normally, drawers can only be partially withdrawn, and even then they are unstable. Complete rigidity and complete withdrawal can be secured from the use of telescopic mountings.

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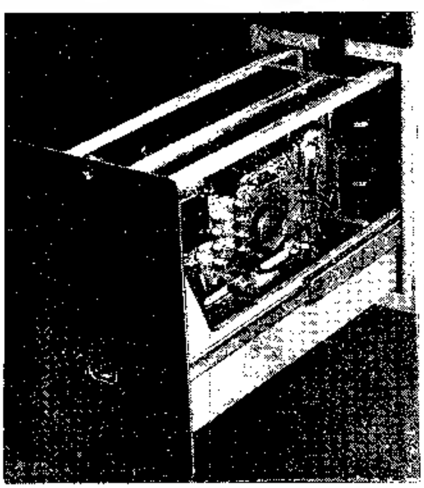
Fig. 1. Equipment mounted on telescopic mountings can easily be withdrawn for maintenance. The chassis in this case is vertical, allowing both valves and components to be accessible without difficulty



As is suggested by its name, a telescopic mounting consists of a series of sections sliding one into the other. There is usually:—

1. An outer section which is permanently fixed to the framework.

2. An inner section which is fixed, either directly or indirectly, to the moving chassis or cradle.

3. An intermediate connecting member, which, when opened, extends from the halfway position on the outer fixed section, to halfway on the moving member.

Normally all these members are of the same order of length and the amount of extension is equal to the closed length.

The original and most widely known application of this construction is seen in office filing cabinets, although there are several reasons why mountings designed for this application are not very satisfactory in electronic equipment.

Generally, filing cabinets are moved empty, but as electronic gear is normally mounted in the rack before leaving the manufacturers, transit shocks are likely to be more severe. It is also desirable that the mountings should have an adequate thickness of metal on the inner slide so that substantial means of fixing can be provided for the moving chassis, and the general design should be of a generous and robust nature.

The sliding action between members can be arranged on ball bearings, wheels, or simple metal-to-metal slides. The use of ball bearings ensures the minimum of both friction and slide play, but the sections should be so shaped as to ensure that the balls are adequately trapped, so as to avoid the danger of these falling out under severe conditions of shock. In order to spread the load over as wide an area of the ball tracks as possible, groups of balls are to be preferred to single balls. Internal stops should be mechanically sound; substantial metal ones are generally satisfactory. Noise arising from such stops as the mounting is closed or opened is not a general objection in industrial application.

Wheels or rollers are not so suitable as balls, as a greater degree of slide play is necessary between a wheel and the sides of the section than is the case when a ball is used. This results in a considerable increase of side play at the free end of the mounting. Moreover, the wheels are mounted on axles through which the whole of the load is transmitted. It is difficult to arrange for either a satisfactory design or fixing of the axles which will be adequate for this condition.

Simple metal-to-metal slides have the advantage of simplicity, and friction can be minimised by using

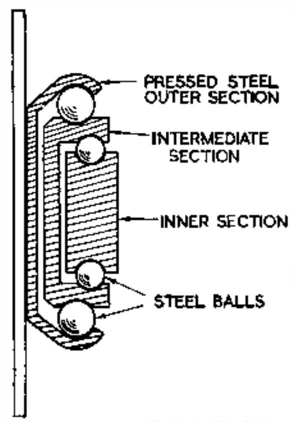


Fig. 2. Sectional view showing the construction of the Admiralty type mounting

dissimilar metals, although side play may be serious unless allowed for in the design. The use of friction mountings is generally limited to use with lighter units.

Fig. 2 shows a sectional view of the ball bearing mounting standardised by the Admiralty. This uses substantial solid steel sections for the intermediate and inner members, with ball bearings. A commercial mounting of similar size and design is also available in which the inner members are made from pressed steel sections instead of solid steel. Fig. 3 indicates a smaller mounting originally developed for the Post Office and now meeting the requirements of numerous commercial installations where the heavier construction of the larger designs is not justified. The design is unusual

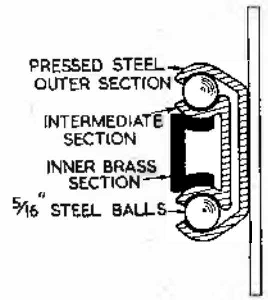


Fig. 3. Sectional diagram of the "Widney" light duty mounting

in that it uses balls between the fixed and intermediate members and friction between the intermediate and inner sections. This combination lends itself not only to a compact mounting, but enables simple fixing arrangements to be made.

Safe Loading Factors

The load which can be safely applied to each mounting should be considered in relation to the particular application in question. The length of extension, the distance between mountings and the density of loading must all be taken into account, together with local conditions of use.

The actual load on a runner is a function of both length of extension and weight. This is a common condition of many mechanical problems and it will be convenient to recall the elementary theoretic mechanics involved. The strain on a beam, or "bending moment" is the product of the weight in pounds and the distance in feet from the fulcrum point to the centre of gravity of the load. The resultant units are termed "foot-pounds." This nomenclature enables a heavy load extended a short distance to be compared with a light load extended a longer distance, and the bending moments are equal when $W1L1 = W2L2$.

Manufacturers of telescopic mountings either specify the maximum foot-pounds each type will carry, or state a maximum load for a given extension. Heavier loads can be carried if it is possible to reduce the extension; alternatively, a light load can be extended, a greater length, provided in either case the product length × weight is not greater than that specified by the manufacturers. While considering this question, care should be taken that figures given for a pair of mountings are not confused with those for a single mounting. If the load in the tray or chassis is reasonably central the total bending moment is equally divided between the two mountings. If, however, the load is one-sided (for instance, if there are heavy transformers or chokes on the extreme side of the chassis) then that mounting will be carrying a greater proportion of the load than the other.

The manufacturer's recommended maximum loading is the maximum strain which, in use, can be expected and this is not necessarily merely the static dead weight of the equipment. The weight to be carried should be multiplied by a safety factor and this product should be within the carrying capacity of the mounting. In assessing this safety factor, consider (a) transport and (b) local conditions of use.

(a) Transit conditions. If the gear is to be assembled on its mountings before leaving the factory, thought must be given to the amount of shock to be expected in handling. A severe jolt may cause damage to heavily loaded mountings owing to the heavy mass of equipment. It is possible to avoid this danger by fitting special transit screws so as to secure the load directly to the framework.

(b) Local conditions of use. Consider the application of the equipment and the conditions that will be met on the site. For instance, conditions at sea are obviously more severe than on land. Wartime conditions, with the ever present danger of explosions were even more drastic. Expected frequency of use should be considered. Mountings seldom used may be loaded more heavily than those in frequent use. Consider also the type of personnel who will be expected to withdraw the equipment. It has been known for drawers to be pulled out and stood on in order to reach a shelf above the panel!

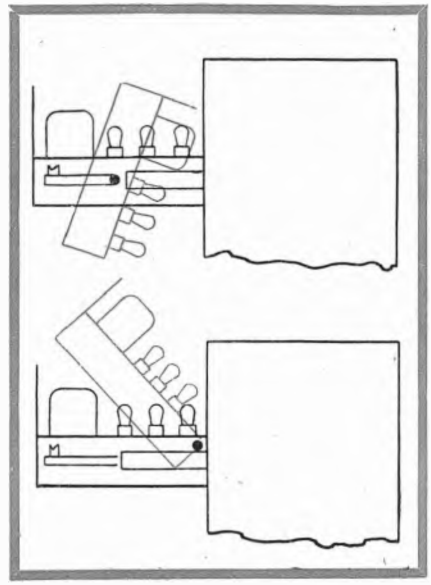
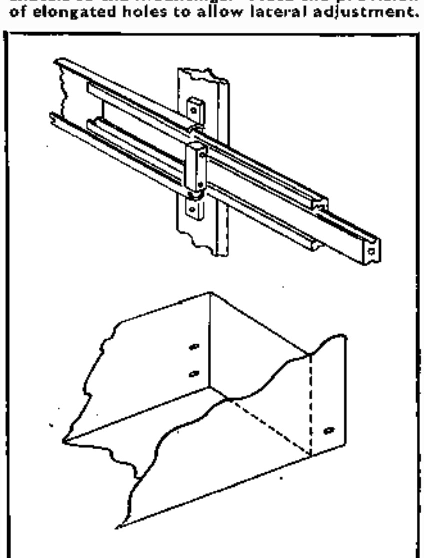


Fig. 5 (a) (above). The use of pivots near the centre of gravity allows the chassis to be tilted for easy inspection

Fig. 5 (b) (below). Inspection is obtained in this arrangement by hinges which can be placed at the back of the chassis

Fig. 4. A simple method of attaching the chassis to the mountings. Note the provision of elongated holes to allow lateral adjustment.



Method of Mounting

Fig. 4 illustrates a typical method of attaching a tray to its cabinet with telescopic mountings. The outer section is fixed through the brackets by means of screws, to the cabinet framework. The drawer or tray is held at the back by screws passing through the tray into a block on the mounting, and at the front by a screw passing through the panel into the tapped hole in the front of the mounting. Precautions must be taken to ensure that dimensional tolerances in either tray or framework do not cause side strain on the mountings. The simplest way of arranging this in the present example is to provide elongated holes in both the panel and the back of the tray. Alternatively, alignment of the slides can be achieved by inserting packing shims between the framework and the mounting.

Accurate alignment in this manner

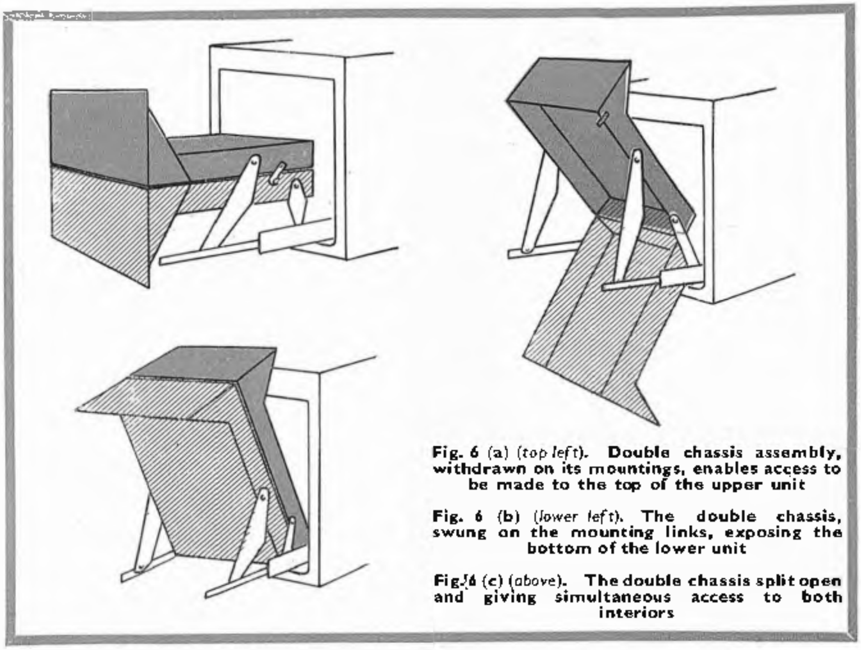


Fig. 6 (a) (*top left*). **Double chassis assembly, withdrawn on its mountings, enables access to be made to the top of the upper unit**

Fig. 6 (b) (*lower left*). **The double chassis, swung on the mounting links, exposing the bottom of the lower unit**

Fig. 6 (c) (*above*). **The double chassis split open and giving simultaneous access to both interiors**

is essential where the two mountings are on the same level. More latitude can be gained by fixing one mounting towards the bottom of the chassis and the other towards the top. This allows the drawer to sit at a slight angle if the frame and chassis dimensions do not coincide. With reasonable manufacturing limits on these parts the angle of the panel is too small to be noticed.

In the above arrangements the tray remains horizontal when withdrawn, and access to the underside for maintenance is only possible by physical contortions. It is therefore best restricted to power packs and other cases where the bulk of the components is mounted on the top of the chassis, and one of the three following suggestions should be considered as a solution to the question of accessability of the chassis interior:

1. Incorporate hinges or pivots to allow the tray, when withdrawn, to be tilted or swung around, so as to bring the components into a convenient position for inspection and replacement.

2. Mount the conventional type of chassis vertically instead of horizontally. The deck of the chassis thus forms a screen with the valves projecting on one side and the components on the other, and both are simultaneously accessible.

3. Arrange for the chassis units to be suspended in slots on the telescopic mountings, so that the unit can be easily removed from the framework for repairs.

Hinges can either be arranged at the back of the chassis or at about half the depth of the chassis, ideally on the line of centre of gravity. Fig. 5 shows these two arrangements in diagrammatic form. In both cases the open position for maintenance is shown in colour. While a central pivot is the better mechanical system, the connecting leads have to turn through a large arc and are therefore more difficult to handle. Connexions are easier to arrange with a rear hinge, but a support to hold the unit in its open position should be provided. This arrangement may be improved by allowing over-extension in the mounting, so as to bring the hinge forward from the framework. The chassis can then turn a full right-angle into the vertical position without fouling the framework.

In all cases a permanent cross bar or brace should be provided at the back to ensure that the two mountings move simultaneously. Without such a bar one mounting may move more quickly than the other and result in a twist across the hinge points. Catches or locking links are of course essential to prevent the unit accidentally falling.

Mechanical balance and easy connexions can be obtained by a double chassis assembly with rear hinges. Fig. 6(a) shows the front view of such an assembly. The lower chassis is mounted upside down, immediately below the upper unit. The hinges are fixed between the junction of the two chassis at the back and this complete assembly is suspended on to the runner by a special set of links. When simply withdrawn, access to the top of the upper chassis is possible, as shown in Fig. 6(a). When the cradle is tilted so as to rock back on its links, Fig. 6(b), the underside of the lower chassis is revealed. When the cradle is split as shown in Fig. 6(c) the whole of the interior is accessible. In this state the advantage of mounting the lower unit upside down can be appreciated, since it exposes the interior of both chassis at the same time. This arrangement is very convenient physically, owing to the high degree of balance obtained through the link mechanism. In addition the long interconnecting cables which would be necessary with the equivalent two-drawer arrangement is avoided. The system may appear complicated, but this is offset by making one pair of mountings serve two chassis and the simplification of wiring.

This split chassis method of mounting was developed during the war by the Admiralty for radar panels; the photograph in Fig. 7 shows the original design, corresponding to Fig. 6(c). This panel incorporated a cathode-ray tube, and as it was desirable to view the screen during maintenance, arrangements were included to allow the tube to be re-positioned as shown.

Fig. 1 shows a vertically mounted chassis in which access to both valves and components is possible without any tilting mechanism. Those components on the same level as the mountings may not be easily accessible as the mountings may act as a barrier. In the example shown good use has been made of this space to accommodate transformers, paper capacitors and other bulky components which do not require frequent attention.

The suggestion already made to position the two mountings at different levels to simplify alignment may be coupled with the desire to position the mountings where minimum inconvenience arises. It may, for instance, be possible to place one mounting at a height on the valve side of the screen or chassis where there will be no valve, and to select another height on the component side corresponding to a minimum of interference with components.

A vertical chassis may be adapted with the runners mounted horizontally above and below the chassis. This is similar to the orthodox method of mounting, but the whole assembly of chassis, mountings and framework is turned through 90°, so that the width of the drawers now appears as the height. With this arrangement several units can be mounted next to each other, with the simplest of frameworks and minimum waste of space for constructional features. Normally, runners are used vertically or upright as shown in Fig. 4, and if they are used horizontally they must not be so heavily loaded. It is obvious that not only is a natural bending tendency of the component sections greater in this plane, but the balls are not so effectively trapped.

In passing, it may be noted that the British Standard Specification BS1106/45 says: "It is desirable that valves should be mounted base down and with the axis vertical." This condition is not complied with in all of these suggested arrangements, and while this is not in itself a general ground for rejection, such precautions as are possible should be taken. For instance, the valve manufacturers should be consulted and the plane of the filament of directly heated valves should be vertical. Similarly the plane of the major axis of the control grid of

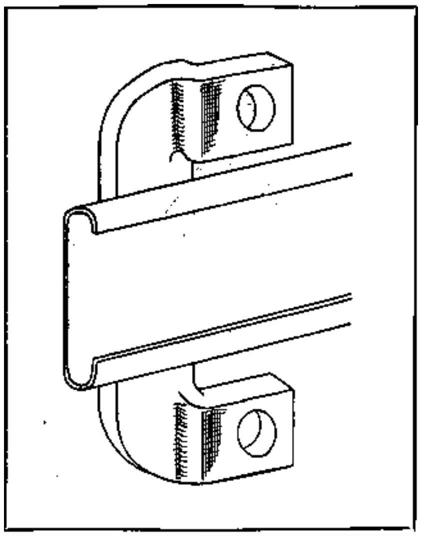
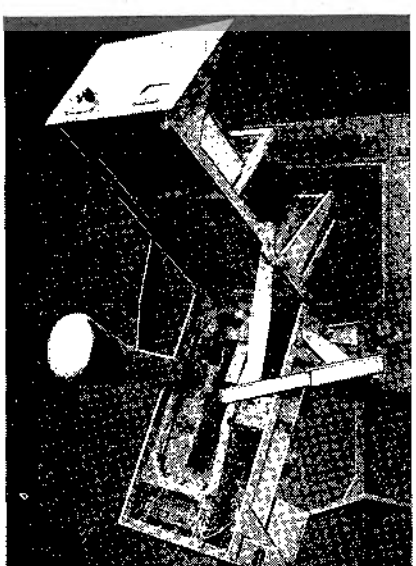


Fig. 8. Bracket to attach the mounting to the equipment framework (interior of mounting omitted) which takes up no effective space—see text

certain indirectly heated valves having a high mutual conductance should be vertical.

Fig. 7. Admiralty Radar Panel constructed on the double chassis system, in the open position



In certain circumstances it may be desirable to arrange for the unit to be easily removed from the framework. This may be useful, for instance, when spare chassis can be kept on hand for immediate replacement and the defective unit examined in a workshop when convenient. This is very easily arranged by fitting permanent vertical plates to the inner member of each mounting, which plates have V-shaped notches cut in their top edges. Corresponding pegs are provided on the chassis to engage in these slots. It may be advantageous to replace the simple V-notches with bayonet slots at the front, so as to prevent the chassis being lifted accidentally.

The light duty runner illustrated in Fig. 3 lends itself to a particularly compact and useful method of mounting. By removing two accessible screws the inner member can be slid out of the main mounting. The chassis can therefore be screwed directly to the inner section, saving space and weight.

Generally speaking, it is not recommended for the drawer width to exceed 3 ft.

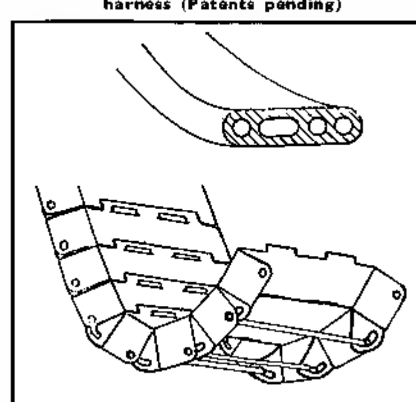
A word may be useful on the various means by which the fixed or outer section of the mounting can be secured to the main framework. As the forward half of the fixed section is permanently obscured by the intermediate member, simple fixing holes are not usually possible, although when the load to be carried is not heavy, a central single row of holes may be possible, when access is provided through a hole specially provided in the intermediate section. Two or more transverse blocks fitted across the back of the mountings are generally more suitable. These fittings can either be wide and thin, as shown in Fig. 4 or be of substantial square section, with the fixing bolts running parallel to the mounting. The latter arrangement helps to economise space, but care must be taken to ensure that the tightening of the two sets of bolts does not result in unequal strain and bad sitting due to framework tolerances. These difficulties can be avoided by using brackets of the type shown in Fig. 8, which take up no effective space. These brackets are positioned alongside the main framework member and the two "ears" bend around so that the fixing surface is in the same vertical plane as the back of the telescopic mounting. Framework space can also be saved by using a channel section instead of the more usual angle section for the same ultimate strength, when the fixing blocks of the mountings can be housed in the channelling.

In designing these and other fittings for mountings, it is better to specify riveting rather than welding and in no case should welding be carried out near the ball tracks, owing to the danger of softening the metal. Riveting enables the individual parts to be plated before assembly, and this avoids any danger of trapped plating acid causing corrosion.

Locks and Handles

In certain conditions, such as a

Fig. 9. Typical metal and rubber cable harness (Patents pending)



rolling ship, it may make it necessary to fasten telescopic mountings, while both open and closed. Such a catch mechanism can be operated from the front panel by means of a car-type handle, which if desired could incorporate a barrel lock and key to prevent unauthorised opening.

Electrical Connexions

Connexions between the framework and chassis can be in the form of a trailing lead, or arranged on plug and socket basis. Besides certain mechanical difficulties of the latter the equipment is automatically disconnected as the tray is withdrawn, a condition not conducive to easy maintenance. This can be overcome by providing a removable test lead fitted with the correct plugs and sockets to enable the apparatus to be readily reconnected.

When considering the use of plugs and sockets, due regard must be given to mechanical tolerances throughout the whole assembly. Either the plug or socket strip should float, and correct location should be ensured by two generously designed locating dowels. Sufficient play in the chassis strip may already be available from the method of mounting employed, for instance, if the chassis is held by pegs on V-slots. Sockets should be of adequate length and surface area. Besides certain proprietary sockets, contacts made from beryllium copper mounted on ceramic strip have been found satisfactory.

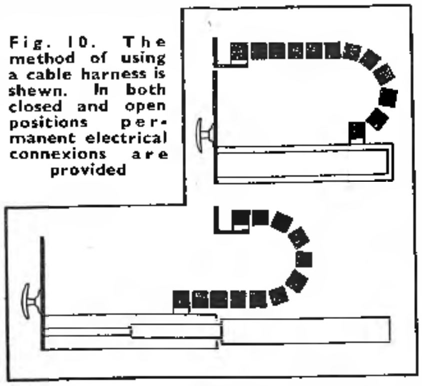


Fig. 10. The method of using a cable harness is shewn. In both closed and open positions permanent electrical connexions are provided

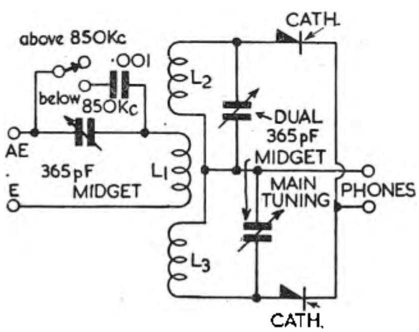
It is generally easier to use trailing cables, although precautions must be taken to prevent the slack cable being sharply bent or otherwise deformed, particularly with metal braided cables, and to prevent the loose cable from falling on to components. These problems are overcome by using a "cable harness"; Fig. 9 illustrates typical types that are available, while Fig. 10 shows how these accessories are employed in use. The metal type is so designed as to limit the radius on bends. It is also non-sagging so that there is no danger of either the harness or the cables from touching components. In certain equipment objectional electrical noises may be caused through these metal sections being loosely joined together. This difficulty can be removed by soldering a continuous copper earthing braid to each section. For small equipment the rubber patterns may be more suitable.

Acknowledgments

In conclusion, the author would like to express his thanks to The Sperry Gyroscope Co., Ltd., for the use of Fig. 1; to the Controller of H.M. Stationery Office for the use of Fig. 7; to his former colleagues in the Admiralty Signal & Radar Establishment, especially Mr. T. C. Finnimore, M.B.E., M.I.E.E., who was originally responsible for the development of the double linked chassis mechanism and to Messrs. Hallam Sleigh & Cheston, Ltd., who are the Admiralty Contractors for these mountings and accessories.

Push-Pull Crystal Receiver

BOTH the sensitivity and selectivity of a crystal radio may be improved greatly by using a two-crystal push-pull detector circuit and by tuning the antenna coil as well as both halves of the secondary. The circuit is shown in the diagram. This arrangement has pronounced advantages over a simple detector and one-coil tuning. Loud signals, long-distance reception and sharper tuning are obtained with the new circuit, which is only slightly more complicated than the usual simple crystal sets.



Two crystal diodes are used. The primary coil *L1* is wound between the two halves *L2* and *L3* of the secondary coil. The main tuning capacitor is a dual 365 pF unit. The primary coil is tuned separately by means of a single-section, 365 pF variable capacitor. For all the frequencies lower than 850 Kc/s., a fixed .001 μF capacitor is connected in parallel with the primary trimmer by closing the switch.

The coil is wound in three sections with 32 S.W.G. enamelled wire on a 1-in. diameter polystyrene or bakelite tube 4 in. long, the turns of each coil being close-wound. *L2* and 3 have 137 turns and *L1* has 43. The inner ends of *L2* and *L3* are connected together and to the rotors of the main tuning capacitor. Space coils ⅛ in. apart.

The components are mounted on a wooden board 8½ in. long, 5½ in. wide, and ¾ in. thick. The crystals are connected directly between the stator lugs of the tuning capacitor and one of the headphone jack connexions. The crystal polarity indicated in the schematic must be observed carefully.

Operation of the receiver is very simple. Connect an aerial and a good earth to the aerial and earth terminals. Tune in the station by adjusting the main tuning capacitor, then adjust the primary trimmer for maximum volume. If the frequency of the desired station is 850 Kc/s. or higher, leave the switch open. If it is lower than 850 Kc/s., close the switch. The entire medium-wave broadcast band can thus be covered.

This receiver has amazing headphone output, even when receiving low-powered broadcasters. When a long, outside aerial and a good earth are used, high-powered local broadcast stations will operate a high-impedance magnetic loudspeaker, (but not a permanent-magnet dynamic). The double tuning scheme allows separation of strong local stations. In tests using the same aerial, this receiver has brought in distant stations not even heard with the best ordinary crystal set. The D.C. output of the set (taken across the headphone jack with headphones disconnected), is 2.5 mA when picking up a 250-watt broadcast station 5 miles away.

—*Radio Electronics*, November 1949.

A Practical Ionisation Gauge Circuit

IN the method to be described for measuring low gas pressure, a diode with a negatively biased anode is placed in the low pressure chamber so that, when a constant source of ionisation is applied to the gas space between the diode electrodes, an ionisation current flows in the anode circuit. This current is caused to flow in a resistive circuit associated with the input of a valve voltmeter so that the voltmeter reading is a measure of the ionisation current, and therefore indicates the degree of vacuum in the chamber. In order to give reliable operation the valve voltmeter must be stable, accurate, free from zero-wander and free from errors due to small mains fluctuations. The accompanying circuit shows a simple voltmeter having these features, and having the additional advantages that the valves do not have to be matched and that the meter readings are highly linear and independent of valve variations.

The ionisation gauge used in the present apparatus is in the form of two parallel anode plates of tantalum having dimensions 1 in. by $\frac{5}{8}$ in. and about $\frac{3}{8}$ in. apart. Between them is a tungsten filament which carries a heating current of 6 to 8 amps. when conducted to a filament supply of about 8 volts. The tantalum anodes are shown in the circuit as *D*1 and *D*2.

The filament current of the ionisation gauge is supplied from a source *CC* controlled by a variable resistor *R*1. The filament current is adjusted to such a value that an electron emission current of a standard value (in this case 10 milliamps) flows to the anode *D*1 when the high tension of 360 volts is applied across the diode. The constant electron current flowing to *D*1 acts as a constant ionisation source, and the ions produced by it in the space between *D*1 and the filament flow towards the negatively biased anode *D*2. The ionisation current in the gauge is collected at the anode *D*2 which is connected, in operation, to a stabilised negative potential supply of 60 volts. The potential developed across the ends of one of the resistor combinations R, $R+9R$ or $R+9R+10R$ by the ionisation current is applied to the input of the valve voltmeter.

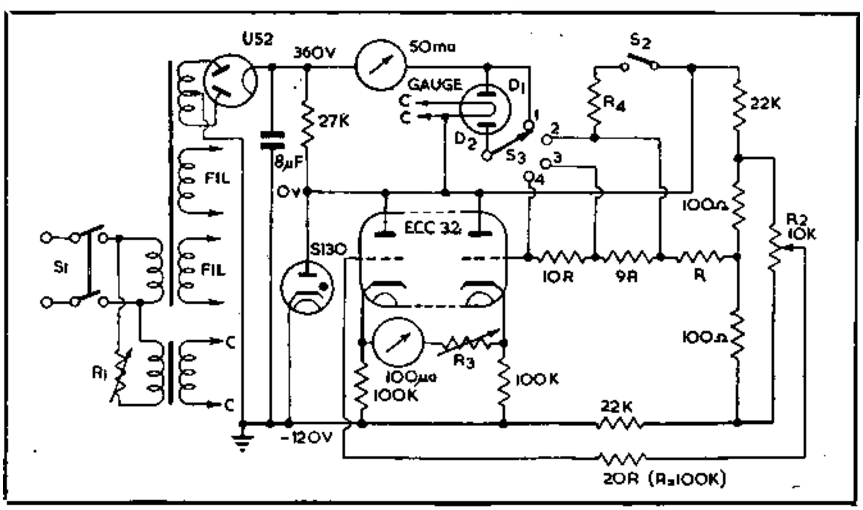
A pair of triode valves, shown in the circuit as an ECC32 or 6N7G double triode, forms the basis of the voltmeter. They are connected as cathode followers with a current meter, in this case a microammeter with a scale reading up to 100µA, connected between their cathodes, while the grid voltage of one valve is adjusted by means of the slider of *R*2 to bring the meter setting to zero. A similar total grid resistance is provided for each valve so that the meter setting is not affected by any ion current that may flow in the grid circuits of the double triode amplifier.

A preliminary adjustment is required to set the meter to give its full scale deflexion. With switch *S*3 in position 1, the press switch *S*2 is closed so that *R*4 (6 megohms) is placed across the 60 volts dropped by one of the 22K resistors connected between the terminals of the stabilised 120 volt supply. This provides a current of substantially 10 µA in the lowest section *R* of the grid resistance, and the meter resistance *R*3 is then adjusted to give a full scale reading under these conditions.

In operation, the gauge is evacuated, and with switch *S*3 in position 1, the filament control resistor *R*1 is adjusted until an electron current of 50 milliamps flows in the gauge in order to de-gas the electrodes. During de-gassing the potentiometer *R*2 is adjusted to set the meter to zero. *S*2 is then closed and *R*3 set to give an accurate full scale deflexion. To take a reading of pressure, the filament current is first reduced as a safety measure by means of *R*1 so that the electron current flowing to anode *D*1 falls to zero. The switch *S*3 is set to the appropriate range, and *R*1 is re-adjusted until an electron current of 10 milliamps flows to anode *D*1. The ion current flowing to the negative electrode of diode *D*2 depends upon the gas pressure, and the gas pressure can therefore be determined from the reading on the microammeter. The resistors *R*, 9*R*, 10*R* can be selected so that a full scale deflexion of the microammeter is obtained with ion currents of 0.5, 1.0, and 10 microamps, corresponding to pressures of 5×10^{-6}, 10^{-5}, 10^{-4} mm. of mercury.

The circuit may be modified to suit the convenience of the operator; for example, the 50 milliammeter, which is also required to indicate 10 milliamps, may be shunted by a network of resistors connected to a switch ganged to *S*3, so that in the first switch position a full scale deflexion is produced by 50 milliamps while in the measuring position a full scale deflexion is produced by 10 milliamps. Further, the voltmeter may be used to measure heavy currents (of the order of amperes) by selecting suitable proportions between the sections of the grid resistance of the right-hand triode section of the ECC32.

—*Communication from E.M.I., Ltd.*



LETTERS TO THE EDITOR

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

Sealed Transformers

DEAR SIR,—With reference to the letter of Mr. H. F. Haynes in the July, 1949, issue, we do not agree with his remarks regarding R.F. heating for sealing-in bushes. The failure of the metallising round such bushes during sealing-in is usually due to lack of appreciation of the requirements of such methods leading to improper usage.

We ourselves have sealed many hundreds of metallised bushes of various shapes and number per lid into both copper and iron lids, and provided the metallising is sound have had excellent results with R.F. heating. It is essential to choose the correct working conditions, i.e., type of work coil and rate of heating-up, with great care to suit the type of job being sealed, otherwise the heat will be excessive and "burn" the metallising. In addition the solder should be in the form of an overlapping ring, so that when it melts, the ends of the ring do not open out, leaving a gap.

With regard to the electrical heating referred to by Mr. Haynes, we have seen cases where this has given trouble due to uneven heating of the lid, but with proper choice of conditions it can be quite satisfactory. Of these two methods we prefer R.F. heating.

A further method which has much to recommend it, from the point of view of control and cleanliness, is that using a bath of hot oil. Palm oil is particularly suited to this method at a temperature of 225-235° C. The assembled lid with seals is lowered into the bath, left till the solder flows and unites the metallising to the lid, then lifted out carefully and cooled.

Yours faithfully,
L. MACFARLANE,
Research and Development Dept.
United Insulator Co., Ltd.

Mr. M. C. Jones has written to say that the word "no" was omitted from a sentence in his letter printed under the above heading in our July issue. The sentence should have read "I cannot agree, however, that . . . the hermetically sealed transformer need be no more costly than its open counterpart."

Hum in A.C. Valves

DEAR SIR,—I have read with interest the letter of Mr. W. H. Aldous in your January issue, in which he informed us relating to his investigation of the causes of hum due to running the heaters of receiving valves on A.C. I think that for the sake of completeness my results may also serve the development of better valves.

My investigation had shown that, using screen-grid valves, hum results due to periodic variations of the current distribution between screen grid and plate caused by the deflexion effect of the alternating magnetic field of the heater current. I observed also that the hum varies with the operating point so that varying the control or screen grid bias caused the hum to pass through zero.

With reference to the magnitude of the hum caused by this distribution effect, the tests have given the ratio of the hum current to steady plate current in maximum to 3×10^{-5} to 6×10^{-5} for different examples of AF7. More detailed results are given in the November 1948 issue of *Electronics*.—Yours faithfully,

IMRE ZAKARIAS,
Csalma-utca 1,
Budapest III.

Mr. Aldous Replies

I have found Mr. Zakarias' letter and his article in "Electronics" *very interesting in adding support to the conclusion that the increase in hum in pentodes as compared with triodes is due to the deflexion effects of the magnetic field of the heater, giving periodic variations of the current distribution between screen and anode. In particular, I am glad of the confirmation of the larger effect in variable-mu types, which I have not seen mentioned elsewhere.*

The order of the magnitude of the hum quoted is, as might be expected, the same as obtained in our work.

It is worth mentioning that this current distribution hum may occur also in grid leak detectors, due to the dependence of the grid current on the value of the magnetic field, though it will only be apparent with low level signals. Usually there are other causes of hum present in the valve, some of which give rise to higher harmonics of the supply frequency, that tend to mask the distribution hum.

Reducing the Effect of Capacitance in Screened Cable

DEAR SIR,—In recent issues of ELECTRONIC ENGINEERING a number of circuits have been given for reducing the input capacitance of a cathode follower. It appears, however, that the stray capacitances between grid and earth in the valve and its mounting have been overlooked by your correspondents. The input capacitance of a cathode follower connected and mounted in the customary manner is about 10 pF at audio frequencies. To reduce this it is essential that the valve should be mounted within a screen that can be connected to the cathode and that the screen-grid should be coupled to the cathode and not by-passed to earth. The input impedance of a cathode follower constructed in this manner with a CV 138 valve was measured with a 1,000 c/s. and found to be 0.7 pF. in parallel with 70 MΩ.

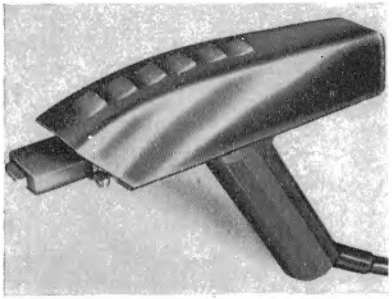
Yours faithfully,
G. H. RAYNOR,
Electricity Division,
National Physical Laboratory

B.T.H. Advanced Engineering Course

The Advanced Engineering Course is a post-graduate course for the better qualified university graduates. The purpose of the Advanced Engineering Course, is to provide instruction in the advanced analytical methods required in modern engineering work in order to maintain the progressive development which is essential for success. Although the activities of the company cover an extremely wide field, ranging from heavy electrical and mechanical engineering to light-current work, the course is arranged so as to be of value to future engineers who may be engaged on technical work of any kind.

The work of the course consists of two weekly lectures during working hours, homework associated with these lectures (about eight hours a week), and an evening tutorial class of two hours.

Further details of this course can be obtained from British Thomson-Houston Co., Ltd., Rugby.



Ultrasonic Soldering Iron
(Illustrated above)

THE soldering gun consists of a removable copper soldering bit and a magneto-striction transducer. The soldering bit, which is heated by means of a conventional resistance winding, is secured to a brass block held in firm contact with the nickel core of the transducer. The ultrasonic power necessary to drive the transducer is supplied by an electronic amplifier which forms part of the power supply unit.

Although primarily designed for soldering aluminium, the ultrasonic soldering iron may also be used for soldering a number of other metals and alloys, such as magnesium, duralumin, etc. To avoid electrolytic action, it is advisable to use a solder with tin-zinc base instead of the usual tin-lead alloy.

The operating frequency chosen is well above the normal audible range, so that no discomfort is experienced by the operator.

Mullard Electronic Products Ltd., Electronic Equipment Division, Aboyne Works, Aboyne Road, London, S.W.17.

Audio Oscillator

THIS instrument provides a convenient source of audio frequency power, and is suitable for checking audio frequency response of amplifiers, loudspeakers, etc.

A conventional R.C. oscillator circuit is used, employing two triodes with negative feed-back. The maximum power available is 500 milliwatts matched to either 600 ohms centre tapped, or to 5,000 ohms. Three ranges are provided, covering from 20 to 20,000 c/s. The ranges are selected by a switch, and the frequency is read on a dial which is marked 20-200 cycles per second. Four controls are provided covering frequency, output, range selection, and mains voltage adjustment.

The manufacturers claim that the accuracy of frequency calibration is 3 per cent, and the total harmonic distortion does not normally exceed 3 per cent. Output sockets are provided for 600 ohms centre tapped and 5,000 ohms. The audio oscillator is mains operated, with an adjustment covering 110V or 200-250V.

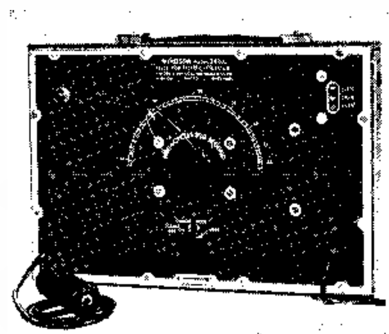
Taylor Electrical Instruments Ltd., 419-424, Montrose Avenue, Slough, Bucks.

Television Pattern Generator
(Illustrated below)

THE Windsor Pattern Generator is designed for television service work and may be set to give vertical bars, horizontal bars, or unmodulated R.F. (white raster) on any frequency within the television band, and so is suitable for both London and Birmingham areas. On " Horizontal " position the modulation is at a medium audio frequency, so at this position the sound channel and audio section may be tested.

It has a frequency range of 40 to 70 Mc/s, directly calibrated, with output voltages of approximately 50 mV, 5 mV, and 500 μV, at the end of a 75 ohm co-axial cable. Power supply is 100-125 and 200-250 volts 40-100 c/s.

Taylor Electrical Instruments Ltd., 419-424, Montrose Avenue, Slough, Bucks.



Mutual and Self-Inductance Bridge
(Illustrated right)

MUTUAL and self inductance can be measured without complicated circuit changes, and the phase sensitive detector used ensures that the inductance and resistance controls are largely independent. Special circuit arrangements are made to eliminate the effect of the series resistance of leads and contact resistance of clips, so that full use may be made of the low resistance ranges.

The instrument has a range of inductance measurement of 0.03 mH to 30 mH, or self inductance first scale reading 0.001 mH. It has twelve ranges, which overlap so that no reading need be taken at less than one-third of the full scale. The range of resistance measurement is 0.003 ohms to 3,000 ohms. Its accuracy is plus or minus 1 per cent. on all ranges, frequency is 1,592 c/s and power supply 100-250 volts, 40-60 c/s.

Applications of the instrument include the measurement of the inductance of tuning coils, correcting inductances, loading coils, transmission lines and cables and stray inductances in circuit wiring. Since it is sensitive down to 0.001 mH it is useful for the latter purpose in television and radar circuits.

Cinema-Television Ltd., Worsley Bridge Road, Lower Sydenham, London, S.E.26.

Electronic

A selection of the latest equipment ex- the 2nd-4th November, 1949, at the don, W.C.1, compiled from information will furnish further

Magnetic Tape Equipment
Home Recorder

THE precision tape recorder is operated from one control for record, stop and play. Tape is used rather than wire for elimination of breakage and snarling, and for longer life. The recorder has a frictionless turret drive to avoid speed variations, resulting in flickering.

The recorder has a frequency response of 50-5,000 c/s at 7½ inches a second, an output power of 10 watts ; a power consumption of 75 watts and a power supply of 200-250V, 50 c/s. Input channels are provided, one for high impedance for a microphone and one for a gramophone or radio. At maximum level, distortion is below 2 per cent. Playing time of the recorder is 30 minutes, and the rewind time is less than one minute.

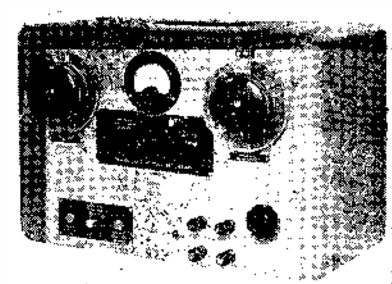
Magnetic Sound Recording Equipment

THE Scophony Baird magnetic sound recording attachment is available in various types to fit different projectors. A " double " system is used, with the sound on a separate strip from the picture. The two run through the projector in synchronism.

The outfit comprises three principal parts : the tape drive with the recording head, the amplifier and the loudspeaker.

The tape used is standard ¼ inch wide cellulose base coated with an iron compound. It is two thousandths of an inch thick, which means that a reel which will hold 200 ft. of cine film will hold approx. 600 ft. of the tape. This has been used as a basis for the design of the Scophony Baird equipment ; the tape runs at approximately 3 times the film speed. With 8 mm. film shot at 16 f/s the tape speed will be the same as a 16 mm. 24 f/s track, i.e. 7½ inches per second.

Scophony-Baird Ltd., Wells, Somerset.



Equipment

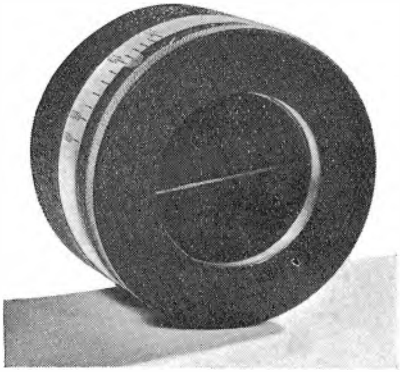
hibited at the S.I.M.A. Symposium on Examination Hall, Queen Square, London supplied by the manufacturers, who details upon request.

Colour Temperature Meter

THIS instrument is a self-contained instrument of cylindrical shape. At one end of the cylinder is the dial of the zero galvanometer, and at the other, behind a rotating annular shutter, with half of its circular aperture blacked out, the two half-moon shaped photo cells covered by a blue and red glass filter of identical shape. The finish of the instrument is black stove-enamel, except the silver-coloured ring on which the temperature scale is engraved, and the index line on the shutter.

The meter is held about 8 inches from the eye and aim is taken at the light source through the ⅛ inch diameter hole penetrating through the whole length of the instrument. The shutter is rotated until the pointer of the zero galvanometer coincides with the zero line across the hole. The temperature can then be read opposite the index on the shutter.

Megatron Limited,
115a, Fonthill Road,
London, N.4



Stroboloom

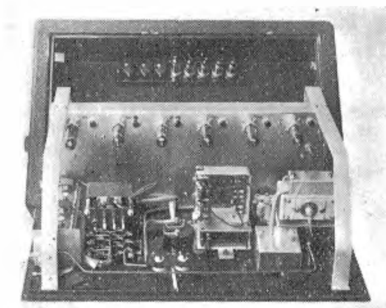
THE Stroboloom has been designed for studying the shuttle movement through the weft on textile looms.

The flash tube gives an intense flash of white light of about 50 microseconds, which is exactly synchronised with each cycle of the mechanism under investigation, thus giving a visual effect of "freezing" the movement. The maximum flashing rate is 220 per minute.

It is synchronised with the machine motion by a contactor, which enables the flash to be "locked" to a rotating shaft on the boom. The phase of the flash, i.e. its time in the flashing cycle, can be adjusted by means of a remote control up to a distance of 12 ft. The speed of the shuttle can be accurately determined by relating the shuttle position to stroboscopically determined angular settings of the drive shaft on the loom.

For convenience of operation the phase control is combined with the lamp assembly. Due to the use of an extremely high intensity flash the shuttle can be seen clearly in position, although the repetition rate may only be about 100 per minute. In order to obtain the longest possible life from the flash tube a press switch is provided on the lamp handle adjacent to the phase control.

The instrument enables the lay of the thread behind the shuttle to be accurately determined at each stage of its progress through the loom, thereby enabling the operator to locate quickly the development of a broken thread or other weaving defects due to shuttle faults.



Drytester

This equipment is designed for measuring and controlling the moisture content of textiles during all the drying processes. The operating principle is based upon the fact that a static electric charge develops on warps and cloths of fibrous material during drying and movement. The magnitude of this charge depends almost entirely upon the degree of moisture in the material. The electric charge is collected from the yarn by means of an electrode and conveyed to the measuring instrument, which detects it and converts it into an indication of the moisture content.

The charge collector consists of a metallic brush which is held in permanent contact with the textile material, but is insulated away from other metal work. This collector must be mounted at the delivery end of the drying machine across the whole width of the warp or fabric.

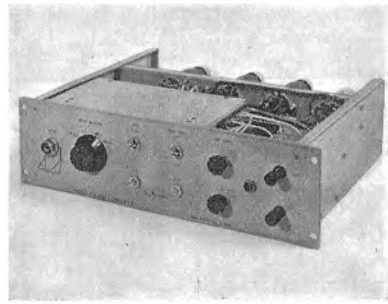
The indicator employs an electronic amplifier which detects the small charges of static electricity, and operates the meter, together with signal lamps corresponding to the normal moisture (yellow), wet (green), and dry (red) conditions.

The sensitivity of the whole installation is adjustable by means of a panel control to suit four degrees of moisture.

For the correct moisture content the needle of the meter is in the middle of the yellow area and the appropriate lamp above is illuminated. With increase of moisture in the textile the needle will move to the green sector, and with moisture decrease, the pointer will be directed to the red sector. The drying process can thus be readily supervised by means of the indicator as well as the two signal lamps.

The equipment can be used in three different ways: by direct hand adjustment, by semi-automatic control, or by automatic adjustment.

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



Drift-Corrected Direct Coupled Amplifiers

THE MR235 D.C. pre-amplifier employs a direct-coupled valve amplifier in conjunction with a chopper circuit which detects and corrects for any drift due to warming up and to changes in cathode emission that may take place. Thus it retains the wide frequency band of a normal amplifier.

The amplifier consists of two balanced stages followed by two cathode-followers. A considerable degree of negative feedback is provided, with a switch in the feed-back circuit to enable a gain of either 10 or 100 times to be obtained. Although the amplifier is fully balanced for the sake of stability, an unbalanced output is taken from one side only.

For drift correction, a fraction of the output is selected by a potentiometer set to have an attenuation ratio exactly equal to the gain of the amplifier, so that if the amplifier has been correctly set up the voltages should be equal.

These two voltages are fed through low-pass filters to a chopper switch consisting of a Carpenter relay operating from a 50 cycle supply. As soon as there is any difference between them, a square-wave output is produced, whose peak-to-peak amplitude is equal to the difference. The square wave is amplified by a single coupled pentode and rectified by a second Carpenter relay operating sychronism with the first. This produces an amplified D.C. voltage which, after filtering, is fed back into the amplifier and is of the correct polarity to counteract the drift.

Southern Instruments Ltd.
Fernhill, Hawley,
Camberley, Surrey.

BOOK

Components Handbook

Edited by John F. Blackburn. XVII, 626 pp. McGraw-Hill Publishing Co., Ltd., 1946. Price 68s.

VOLUMES 18 to 23 of the well-known series compiled by the Radiation Laboratory of the Massachusetts Institute of Technology, under the auspices of the National Defence Research Committee (U.S.A. Office of Scientific Research and Development), deal with amplifiers, waveforms, electronic time measurement, electronic instruments, cathode tube displays and microwave receivers. The book under review forms Volume 17 of this series, and is intended as a companion and reference work for the volumes mentioned above. Each of its 14 chapters, dealing with wires and cables, various types of resistors, iron-core inductors, piezoelectric devices, electromagnetic and supersonic delay lines, potentiometers, variable capacitors, rotary inductors, instrument motors and tachometers, power supplies, relays and receiving tubes, is written by one or two specialists in the respective fields, and gives the available information on properties and characteristics of the various components, and in particular the results of original measurements made at the Radiation Laboratory.

In the foreword it is stated that the work described in the MIT volumes is the collective result of work done in the laboratories of U.S.A., England, Canada and other Dominions. But the bulk of the material presented in this new volume is taken from American sources. References to British work are the Ayrton-Perry type of non-inductive windings and investigations on the high-frequency properties of composition resistors, where due credit is given to the work of L. Hartshorn and G. W. O. Howe. Reference is also made to B. Hague's "A.C. Bridge Methods" and to experiments made at the British T.R.E. on the use of rubber bags for the oil filling of transformers and other coils and on methods for increasing the bandwidth of crystal cartridges. A design of a water delay line developed at the R.A.E., Farnborough, is also mentioned.

As will be seen, these references are none too numerous considering the fact that the book has over 600 pages and that the contributions to the development of radar and related techniques by British scientists and engineers have been rather conspicuous. One well may ask for the cause of such a discrepancy. As usual, there is not one cause, but several. First of all it is quite natural that an American team of writers will use primarily American sources of information as they are much more easily accessible. Besides, there is, and has always been, a much greater readiness on the part of American individuals, laboratories, manufacturers and institutions to publicise the results of their investigations. Then there were, and still may be, restrictions due to secrecy and austerity regulations.

References to literature are also comparatively scarce. They are given partly in footnotes at the beginning or end of some of the chapters.

The fact that mainly American designs are dealt with does not impair in the least the value of the book for British readers. On the contrary, it cannot be emphasised too frequently that the intimate knowledge of foreign practice, be it American or Continental, is most desirable for our own designers.

The book is well produced and contains a large amount of valuable information. It can be commended to all concerned with the design and construction of radar and similar equipment.

R. NEUMANN.

Vacuum Tube Circuits

By Lawrence Baker Arguimbau. 668 pages, 576 figs. John Wiley and Sons Inc. and Chapman and Hall. Price 36s.

THE title of this book is rather misleading, since the subject matter is restricted to circuits applicable to radio communication; no reference is made to the specialised circuitry developed for radar, or the many important applications of vacuum tubes in counting, relay, control and similar electronic devices.

The author has drawn from his experiences in lecturing to present his subject matter in a rather unconventional and very refreshing colloquial style, which is easily digestible and which makes interesting reading, both for the student and professional engineer; the mathematics has been kept to reasonable proportions, and the typography and illustrations are excellent throughout.

The opening chapter on basic radio communication is followed by two on rectifier, triode, pentode and linear amplifier circuits. Chapter IV deals with the transient response of video amplifiers, and Chapters V and VI with normal valve amplifiers. In Chapter VII on valve oscillators, the elementary theory is presented clearly, but the reader will be ill-informed if he considers the author's treatment of frequency stability or amplitude control to be comprehensive; the author seems,

REVIEWS

in fact, to be quite unfamiliar with the most important aspects of these subjects. Further chapters deal with modulation and pulse generators, and the concluding chapter with "microwaves." This latter chapter commences by illustrating the shortcomings of normal types of valves at very high frequencies, and then advances to the consideration of special valves, and finally to magnetrons and klystrons. The general description of these items is well presented, but it is a pity that the author makes no mention of the pioneer work on these subjects undertaken outside the U.S.A.; there is, in fact, but one Italian and not a single British reference throughout the book.

The absence of any reference to the pioneer work of Lea on frequency stabilisation, of Booth on crystal oscillators, of Megaw and Randall on magnetrons, of Bell on high frequency triode oscillators, of F. C. Williams on time base generators, and many others, is unpardonable in a book of this type, and detracts from its value as an authoritative work.

Taken as a whole, however, the book provides a readable and clearly presented survey of communication circuit techniques with just sufficient mathematics to illustrate the various subjects without making reading by the average student too difficult.

H. A. Thomas

Fundamentals of Electric Waves

By Hugh H. Skilling, 2nd Edition. John Wiley and Sons, Inc., New York and Chapman and Hall, Ltd., London, Price 32s. net.

THIS book will be of value to the student who wishes to acquire a thorough knowledge of electromagnetic field and wave theory since the author not only presents the theory, but explains it in particularly clear and lucid terms. The process of understanding what is admittedly a somewhat difficult subject is made easier by working through the admirably practical examples which are given at the end of each chapter. Comparatively little mathematical background is assumed, and a useful introduction to vector analysis—one of the most essential mathematical tools for developing electromagnetic wave theory—is given.

The first seven chapters of the book prepare the background for Maxwell's equations and the theory of wave radiation and propagation; the later chapters are concerned with more practical topics such as the characteristics of aerials and the propagation of waves in rectangular and cylindrical waveguides and in ionised media. The treatment of aerials and waveguides is too cursory to be really satisfactory, serving only to illustrate some of the applications of the general theory, and the reader is advised to refer to specialised textbooks for a more complete treatment. It is gratifying to note that in this new edition the rationalised M.K.S. system of units is used throughout.

There are a few rather surprising omissions, for example, the gain of an aerial is not discussed, although the less important concepts of effective height and length are explained in some detail. Some of the diagrams could be improved, for example, Fig. 72 is difficult to follow and the conditions relating to the three curves in Fig. 82 are not given. Although the author makes excuses in the preface for the absence of a bibliography, on the grounds of the extensiveness of the literature on electromagnetic theory, it is felt that a list of selected references to textbooks and the more important papers would have been of value to the student. However, these are minor criticisms and on the whole the book is thoroughly recommended, not only for use by the student, but also by the practising engineer who wishes to revise his knowledge of fundamental theory.

W. J. Bray.

Maintenance Manual of Electronic Control

Edited by R. E. Miller. 304 pp. Figs. 201. McGraw-Hill, London. 38s. 6d. net.

WITH electronic control equipment slowly finding its way into the province of the works engineer it is commendable that a book has been compiled which will show him exactly what he will have to contend with in installing and maintaining this new, and maybe frightening, plant.

The material in this book first appeared in the magazine *Electrical Construction and Maintenance* as a series of articles by eight specialist engineers employed by the General Electric Co. of America, and the keynote of the whole work is that it is intended for the man who is responsible for the day-to-day maintenance of industrial electronic equipment.

After a substantial chapter on industrial electronic circuits in general, there are two shorter chapters on the general installation and maintenance of electronic equipment, also on the cathode ray oscillograph and how to use it. Then follow six good chapters on installing, maintaining and servicing various kinds of electronic relays; motor

BOOK REVIEWS (Continued)

controls; resistance-welding controls; temperature controls and sealed ignitron rectifiers.

All the equipment described is of American origin and this sometimes means that British equipments will differ, but on this matter, and indeed through much of the book, the reader must regard the information as dealing with the principles rather than details, because when the latter are given they apply to particular types of apparatus. In connexion with details it is felt that rather complex circuit diagrams should have been entirely omitted because few readers will study them thoroughly, and here again, they really only apply to a single equipment. Diagrams of the circuit-element type are far more suitable for the works engineer who is meeting electronic control at close quarters and at least one of the authors is apparently in agreement with this view.

The book is freely illustrated but not all the illustrations are of value; though they may tend to counteract the frightening effect of vector diagrams, oscillograms, circuits, etc., and maybe their inclusion is psychologically justifiable.

A number of the chapters conclude with fault-locating tables, which are useful if regarded as providing signposts to possible faults, but not as giving an easy answer to every problem.

To sum up, if the works engineer reads this book in small doses and thinks carefully how the equipment mentioned is the same as, or differs from that under his care, it will help him a lot on the subject of industrial electronic control.

JOHN H. JUPE

Sound Film Projection

By F. W. Campbell, T.A. Law., L. F. Morris, A. T. Sinclair. 242 pp. 170 figs. Geo. Newnes, Ltd. 21s. net.

THIS is the third edition of this book within four years, which is an adequate testimonial to its value. The four types of equipment described in detail—Western Electric, B.T.H., R.C.A., and British Acoustic—are the most commonly encountered in cinemas, and each has been described by an expert with knowledge of his particular equipment.

The remainder of the book contains chapters on installation, maintenance and fault tracing and repairs. These are of particular value to the practical cinema technician, and are well illustrated by photographs specially taken.

In the new edition, additional material on the Westrex Sound System and on picture projection has been added, making the book an up-to-date practical handbook for all concerned with the projection of films.

G. PARR

Atomic Energy

By Karl K. Darrow. 80 pages, 13 figs. Chapman and Hall, 1948. 12s.

THIS book should not really be reviewed by a physicist at all. It is designed—and as far as a physicist can tell, very well designed—for the educated layman, or, in Dr. Darrow's own words, for "people whose special fields of interest were other than physics."

The book, which is more valuable than is suggested by its title, consists with but minor changes of four lectures given at North Western University in 1947.

Dr. Darrow has given not only a fascinating account of the nuclear processes involved in what is popularly, if inaccurately, described as the release of atomic energy. He has also given a most able account of our present view of the structure of atomic nuclei, illuminating one of the main growing points of modern science and one of the greatest intellectual achievements of the human race.

The book is not written for physicists, although any physicist interested in the giving of popular lectures could learn a great deal from it. It should appeal very greatly to that large number of people who would like to know something of the results of modern science without the rigorous training required to understand the methods by which these have been discovered and confirmed, and for this purpose it can be heartily recommended.

J. H. FREMLIN

Measurement of Stress and Strain in Solids

"Physics in Industry" Series. 109 pages, 33 Figs. and 8 plates. The Institute of Physics. 17s. 6d. net.

THIS is a collection of papers based on the conference held by the Institute in Manchester (1946), with an introduction by Professor Hartree, the chairman.

The twelve papers include five on strain gauges, three on stress patterns, and two on the use of X-rays for measurement and investigation of stresses. Those on strain gauges are particularly valuable, and give a thorough survey of present-day practice which will be useful for all engaged in this measurement work. At the reasonable price asked, this book should have a wide circulation among research laboratories and training institutions.

NOTES FROM THE INDUSTRY

Exhibition of Electronics

The first annual exhibition of industrial electronics in the Midlands will take place in Birmingham on the 5th, 6th and 7th January. The following firms will exhibit their electronic and television equipment: Aerialite, Automatic Coil Winder and Electrical Equipment Co., Ltd., Bakelite Ltd., Barber Electrical Services, Ltd., Birmingham Gazette, British Electronic Products (1948), Ltd., Cornelius Electronic Instruments, Ltd., Dawe Instruments, Ltd., Eagle Components Co., Ltd., ELECTRONIC ENGINEERING, Ether, Ltd., Everett, Edgcumbe and Co., Ltd., G.P.O., Hudsons Technical Bookshop, Lydiate Ash Laboratories, Metro-Pex, Ltd., Marconi Instruments, Ltd., Metropolitan-Vickers, Ltd., Midland Amateur Radio Society, Parmeko, Ltd., Presshouse Scientific Journals, Ltd., Scophony Baird, Ltd., Southern Instruments, Ltd., the Television Society and J. Langham Thompson and Co.

The exhibition will take place at the Exhibition Floor, Messrs. Lewis's, Ltd., Bull Street, Birmingham 4. Preview for the trade will be held on January 5 from 9 a.m. to 12 noon. Free admission tickets for this day are available on request to: W. Summer, 31 Beech Road, Bournville, Birmingham 30.

Precision Drawn Wave Guide Tubing

The increasing use of wave guides in communication and radar apparatus, coupled with the need for greater dimensional accuracy in the tubing as frequencies increase, has led to considerable attention being paid to manufacturing techniques. Johnson, Matthey and Co., Ltd. have developed a method of manufacture capable of producing a guide in long lengths (10 ft.) having close dimensional tolerances, small radii of internal corners and a very high quality internal finish.

This guide is available not only in brass and copper but also in silver lined brass or copper, silver-copper alloy and aluminium. A range of sizes is available from 2.0 by 0.667 inches including the normal service requirements down to 0.180 by 0.09 inch internal dimensions.

Tubes having non-standard dimensions can be manufactured to specification providing the quantities involved can justify the production of special tools.

A technical service has been made available to assist in establishing satisfactory service to the consumer both in choice of guide and subsequent processing.

Change of Address

Messrs. George Bray and Co., Ltd. announce that their London offices have moved to 305/306 Grand Buildings, Trafalgar Square, W.C.2.

New Permanent Headquarters for Television

The B.B.C. announce that they have decided to develop their 13 acres White City site in two stages. Mr. Graham Dawbarn, C.B.E., M.A., F.R.I.B.A., has been appointed architect for the first stage, in association with Mr. M. T. Tudsbery, C.B.E., M.I.C.E., the Corporation's Civil Engineer.

The appointment has been made from names put forward by the R.I.B.A., who were informed of the nature and scope of the project. The first stage will absorb some seven acres and will be devoted to television.

The decision to develop the site in this manner, instead of holding a planning competition for the whole, as was originally intended, has been taken in order to preserve the flexibility necessary to meet changing demands in the most efficient manner.

Mr. Howard M. Robertson, A.R.A., M.C., F.R.I.B.A., and Professor W. G. Holford, M.A., F.R.I.B.A., have consented to act as architectural advisers to the B.B.C. in connexion with the project.

New Atomic Energy Establishment

The Ministry of Supply announces that a site has been selected at Capenhurst, near Chester, for the construction of an establishment connected with the Ministry's atomic energy programme.

Survey work has begun, and construction work, which will employ several thousand men, will begin this year. The establishment will ultimately employ an operating force of a similar size.

Television Sales Record

The Radio Industry Council reports that more than 21,000 television receivers were sold by manufacturers to the trade in September, 1949, as many as were sold in all the years before the war, and only 6,000 less than in the whole of 1947.

Estimated production of television receivers during November was 35,000, 8,000 higher than the October figure which was the previous highest.

It is estimated that so far 40,000 sets have been sold by manufacturers to dealers in the Midlands.

Tiluma Cement

In the December issue of ELECTRONIC ENGINEERING Tiluma Cement was inadvertently referred to as "Timula" Cement. As we have had many inquiries concerning this, we would like to advise readers that it may be obtained from most ironmongers, builders' merchants, etc. It is manufactured by Messrs. J. H. Sankey and Son, Ltd., Ilford, Essex.

Publications Received

The Nickel Bulletin. August-September, 1949.

A summary of current information on nickel, with abstracts. *The Mono Nickel Co., Ltd., Sunderland House, Curzon Street, London, W.1.*

Hunts Capacitors.

A small publication intended to indicate the wide range of fixed capacitors made by this company. *A. H. Hunt, Ltd., Bendon Valley, Garratt Lane, Wandsworth, London, S.W.18.*

Nettlefolds. Forms No. A133 and A134.

Two pamphlets describing Phillips Recessed Head Screws, which are stocked by *Buck and Hickman, Ltd., 2, 4, 6 and 8 Whitechapel Road, London, E.1.*

Electrons in Triodes.

This is the second of a series of educational booklets being produced, and it explains the history and working principles of the triode in a simple manner. *The Edison Swan Electric Co., Ltd., 155 Charing Cross Road, London, W.C.2.*

Nickel—Properties and Applications.

A further publication in the series dealing with the properties and applications of their alloys, published by *Henry Wiggin and Co., Ltd., of Wiggin Street, Birmingham, 16.*

Loudspeakers and Transformers.

A leaflet describing the range of loudspeakers and transformers manufactured by the *Electro Acoustic Industries, Ltd., of Stanford Works, Broad Lane, Tottenham, London, N.15.*

G.E.C. Quartz Crystal Units.

This is a pamphlet giving particulars of the G.E.C. Quartz Crystal units for aircraft and general communication service. *Salford Electrical Instruments, Ltd., Peel Works, Silk Street, Salford 3, Lancs.*

S.E.I. Photocells.

The purpose of this booklet is to acquaint the reader with the characteristics of photocells, and to enable him to use them to advantage. *Salford Electrical Instruments, Ltd., Peel Works, Silk Street, Salford 3, Lancs.*

Sound Throughout.

The booklet describes the "Bafflette" loudspeakers, and the various methods of installing them. *Richard Allen Radio Ltd., Caledonia Road, Batley, Yorks.*

This is Ediswan.

A brochure intended to give some idea of the company's interests and activities. *The Edison Swan Electric Co., Ltd., 155 Charing Cross Road, London, W.C.2.*

MEETINGS THIS MONTH

Institution of Electrical Engineers

Unless otherwise stated, all meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Date: January 12. Time: 5.30 p.m.
Lecture: "Radar Echoes from Precipitation."
By: J. E. N. Hooper, B.Sc., and A. A. Kippax, B.Sc.Tech.

Date: January 18. Time: 6.30 p.m.
Held at: The Central Hall, Westminster, S.W.1.
Lecture: Faraday Lecture on "Radar."
By: R. A. Smith, M.A., Ph.D.

Radio Section

Date: January 11. Time: 5.30 p.m.
Lecture: "The Relative Merits of Presentation of Bearings by Aural-Null and Twin-Channel Cathode-Ray Direction-Finder."
By: S. de Walden, Dipl.Ing. and J. C. Swallow, M.A.
Lecture: "Some Experiments on the Accuracy of Bearings taken on an Aural-Null Direction-Finder."
By: F. Horner, M.Sc.

District Meetings

Date: January 23. Time: 7 p.m.
Held at: The Great Western Hotel, Reading.
Lecture: "Trends in Development in Atomic Energy."
By: T. E. Allibone, D.Sc., Ph.D., F.R.S.
The Secretary, Institution of Electrical Engineers, Savoy Place, W.C.2.

Cambridge Radio Group

Date: January 17. Time: 8.15 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Lecture: "The Application of Differential Analysers with Electrolytic Tanks for Tracing Electron Trajectories."
By: K. F. Sander, M.A.
Secretary: G. E. Middleton, M.A., University Engineering Laboratory, Cambridge.

Mersey and North Wales Group

Date: January 2. Time: 6.30 p.m.
Held at: The Liverpool Royal Institution, Colquitt Street, Liverpool.
Lecture: "Hot-Cathode Thyratrons: Practical Studies in Characteristics."
By: H. de B. Knight, M.Sc.
Secretary: A. V. Milton, 12 Bevington Hill, Liverpool 3.

North-Western Centre

Date: January 3. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: "Radar Echoes from Precipitation."
By: J. E. N. Hooper, B.Sc., and A. A. Kippax, B.Sc.(Tech.)
Secretary: A. L. Green, 244 Brantingham Road, Chorlton-cum-Hardy, Manchester 21.

North-Western Radio Group

Date: January 18. Time: 6.30 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: "Some Considerations in the Design of Negative-Feedback Amplifiers."
By: W. T. Duerdoth, B.Sc.(Eng.).
Secretary: A. L. Green, 244 Brantingham Road, Chorlton-cum-Hardy, Manchester 21.

Southern Centre

Date: January 20. Time: 6.30 p.m.
Held at: The Guildhall, Southampton.
Lecture: The Faraday Lecture on "Radar."
By: R. A. Smith, M.A., Ph.D.
Secretary: A. Abbott, 82 St. Thomas' Street, Old Portsmouth.

Western Centre

Date: January 2. Time: 6 p.m.
Held at: The South Wales Institute of Engineers, Park Place, Cardiff.
Lecture: "The Application of Frequency Modulation to V.H.F. Multi-Channel Radiotelegraphy."
By: J. H. H. Merriman, M.Sc., and R. W. White, B.Sc.

Date: January 13. Time: 6.30 p.m.
Held at: The Brangwyn Hall, Swansea.
Lecture: As Southern Centre on January 20.
Secretary: J. Vaughan Harries, 28 St. Mary Street, Cardiff.

Institution of Post Office Electrical Engineers

Date: January 10. Time: 5 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: "Trends in the Design of Line Transmission Equipment."
By: R. J. Halsey, B.Sc., D.I.C., A.C.G.I., A.M.I.E.E.
Secretary: W. H. Fox, Engineer-in-Chief's Office (T.P. Branch) Alder House, London, E.C.1.

Inc. Radio Society of Great Britain

Date: January 27. Time: 6.30 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: "The Use of V.H.F. for Radio Telephone Services."
By: J. Neale, B.Sc.(Eng.),
General Secretary, New Ruskin House, Little Russell Street, W.C.1.

Television Society

Constructors' Group

Date: January 12. Time: 7 p.m.
Held at: Cinema Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.
Lecture: "Some Aspects of Single Sideband Receiver Design."
By: W. M. Lloyd, B.Sc., A.R.C.S.

Main Society

Date: January 27. Time: 7 p.m.
Held at: Cinema Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.
Lecture: "High Frequency Cables in Television."
By: R. C. Mildner.
Secretary: T. M. Lance, 35 Albemarle Road, Beckenham, Kent.

Midlands Centre

Date: January 2. Time: 7 p.m.
Held at: Lecture Hall (1st Floor), The Crown Restaurant, Corporation Street, Birmingham.
Lecture: "Some Problems Associated with Synchronising Signals."
By: C. E. Horner.
Hon. Lecture Secretary: W. Summer, 31 Beech Road, Bournville, Birmingham 30.

The Institute for Physics

Electronics Group

Date: January 17. Time: 5.30 p.m.
Held at: The Institute's House, 47 Belgrave Square, S.W.1.
Lecture: "Fluctuation Noise and Recent Developments."
By: D. K. C. MacDonald, Ph.D.
Hon. Secretary: G. W. Warren, F.Inst.P., Research Laboratories of the G.E.C., Ltd., Wembley, Middx.

British Sound Recording Association

Date: January 27. Time: 7 p.m.
Held at: Royal Society of Arts, John Adam Street, W.C.2.
Lecture: "Magnetic Tape, its Properties and Measurement."
By: G. F. Dutton, Ph.D., D.I.C.
Hon. Gen. Secretary: Richard W. Lowden, "Wayford," Napoleon Avenue, Farnborough, Hants.

British Institution of Radio Engineers

London Section

Date: January 19. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.
Lecture: "The Performance and Stability of Permanent Magnets."
By: A. J. Tyrrell.
General Secretary: 9 Bedford Square, W.C.1.