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The International Television Study Group

FOR a period of six weeks, some 60 delegates of the No. 11 Study Group of the Comité Consultatif des Radiocommunications (C.C.I.R.) have been investigating television systems and visiting factories and research laboratories in the U.S.A., France, Holland and Great Britain.

This Television Study Group is now meeting in London and the results of its deliberations will have a profound bearing on Television for many years to come. It is important therefore that a brief outline be given of its terms of reference and of the problems which are before it.

The C.C.I.R. is a body of technical experts meeting under the regulations of the International Telecommunications Union (I.T.U.) and the first postwar meeting was held at Stockholm in 1948. Among the problems discussed were the technical aspects of co-ordinating television standards in order to facilitate manufacture of equipment and to allow the ready interchange of programmes between neighbouring countries.

Accordingly, an International Television Study Group (No. 11) was set up under the chairmanship of Dr. E. B. Esping, of Sweden, and the first meeting was held at Zurich in July 1949, to study the difficult technical issues involved in a common television standard and to report their recommendations to the C.C.I.R.

Since April 26 of this year, the delegates, representing some 15 countries, have been making a similar tour in this country and during their stay have seen television demonstrations arranged jointly by the G.P.O., the B.B.C., and the Radio Industries Council. They met finally in London on May 8 to discuss their tour and in due course to make their recommendations to the C.C.I.R.

A report which has been issued just as we are going to press, is summarised in an official statement issued by the Postmaster-General as follows:—

"The 405, 525, 625 and 819 line systems were examined. The French, United Kingdom and United States delegates confirmed the continued use of their present standards.

"France and the United Kingdom maintained their previous proposal to consider the unification of the standards of the London and Paris television transmitters.

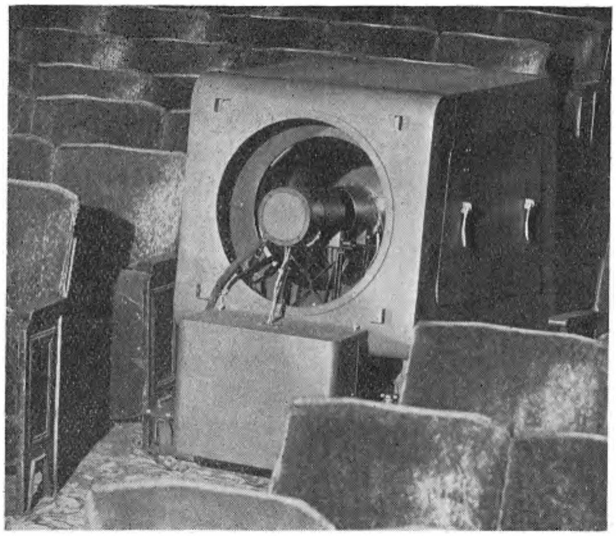
"Austria, Belgium, Denmark, Italy, the Netherlands, Sweden and Switzerland declared themselves in favour of the 625 line system and addressed an appeal to their colleagues to reconsider the position."

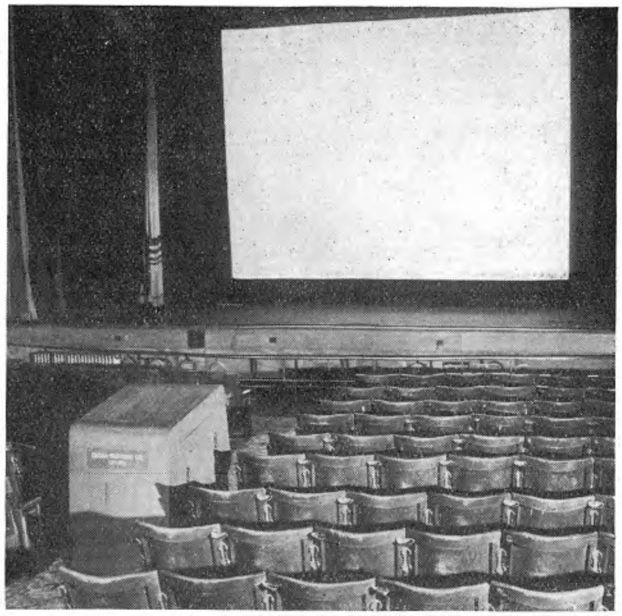
Commenting on the decisions of the Group as detailed in the official statement, Vice Admiral J. W. F. Dorling, Director of the R.I.C., said: "The R.I.C. is glad that some standard is in the process of being agreed upon for television on the Continent of Europe; it does not want everyone to be on a different system. We think television would have spread faster if the group had decided on 405 lines, particularly because of the difficulties Continental countries are likely to encounter in the use of the necessary wide bandwidths for the higher line definition.

"The decision is also regretted because of the increased costs of getting television into the homes of the people. British manufacturers will be able, of course, to make equipment for the 625 line system— in fact, they were the first in the world to demonstrate the system publicly."

"At home, the 405 line system will be established for a number of years. Nothing has happened to make us believe that there would be anything to be gained by a change."

LARGE SCREEN TELEVISION DEMONSTRATION TO THE C.C.I.R.





The first instantaneous large screen television demonstration of the Football Association Cup Final was made to the delegates of the C.C.I.R. at the Odeon Theatre, Penge, on April 29th, 1950.

The photographs above show the special metallized fabric directional viewing screen and the projector unit installed in the auditorium of the theatre. The unit comprises a high power cathode ray tube providing a very bright image of 5 in. by 6 in., which is projected by a large mirror system with plastic correcting plates on to the theatre screen.

The unit, which is remotely controlled, is enclosed in a metal framework to prevent the emission of X-rays and it complies with the Home Office Fire Restriction Regulations.

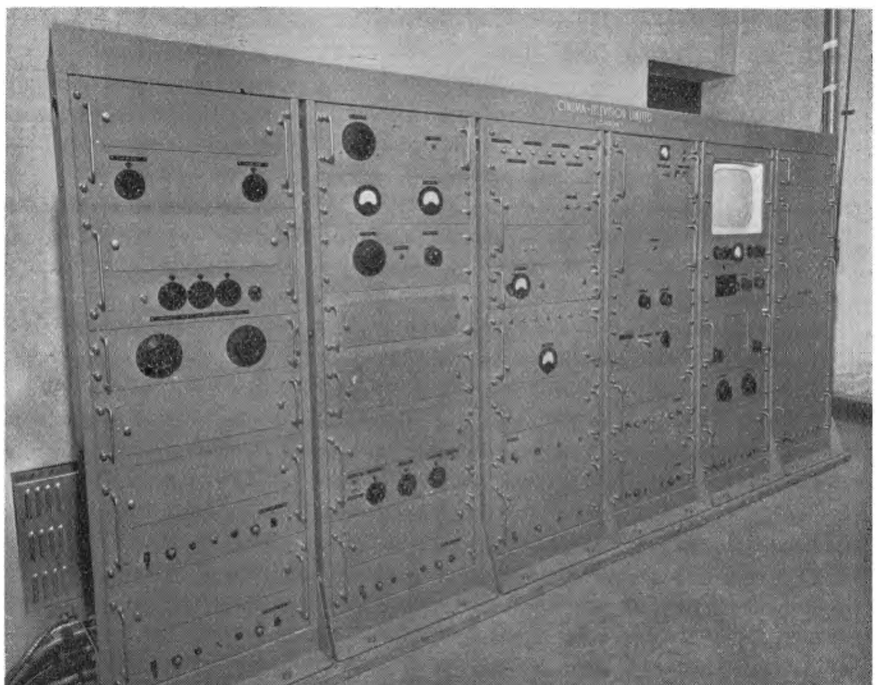
The perforated viewing screen is normally placed in front of the theatre speakers and may thus be used for standard 35 mm. film projection.

The control unit shown in the photograph on the right contains an interchangeable vision and sound coupling unit to deal with the various signal inputs

Other units of the control unit are the line and frame scan generators, focus modulator, the video "B" amplifier and programme sound coupling unit. Normally the programme sound is fed into the existing cinema sound system.

The picture signal received from the aerial is fed into the television receiving rack where it passes through the first video amplifier, and where the synchronizing signals are filtered out and passed into the synchronizing signal separator. This unit takes out the line and frame synchronizing signals, which are passed into their respective scanning generators for transmission to the scanning coils of the projector tube. The video signal passes through various correcting units dealing with phase, gamma and black level clamping, being finally fed into the output amplifier which applies approximately 450 volts of vision signal to the cathode of the cathode ray projection tube.

The complete equipment was designed and manufactured by Cinema Television Ltd.



An Electrical Displacement Meter

By ALAN DOUGLAS

(*Head of Instrument Section, Mechanical Working Division, British Iron & Steel Research Association*).

IN the course of investigations into suitable methods of measuring very small physical displacements for industrial research purposes, a survey of existing methods indicated that many electrical gauges suffered from one or more of the following disadvantages:

(1) Non-linearity.
(2) Zero shift.
(3) Sluggishness in response.
(4) Temperature effects.
(5) Small output.
(6) Hysteresis.
(7) Lack of robustness.

These disadvantages tend to fall into groups associated with a particular method. For example, magnetostrictive gauges may suffer from 1, 2, 4 and 6; the capacitative gauge from 2, 3, 5 and possibly 7; resistance gauges of the carbon type are particularly susceptible to 1, 2 and 7; and of the wire type, to 2, 4 and 7. The electromagnetic gauge may suffer from 1, 5 and 6.

It is an indisputable fact that no one method is suitable for every gauging requirement; but after careful consideration it was decided to devise an electromagnetic gauge as being most generally useful.

One instrument of this type which has been widely used consists of a ferrous armature located in a magnetic path which is completely closed except for a small air-gap on either side of the armature. Inductance coils are wound on the two limbs of the magnetic circuit adjacent to the armature, and form part of an impedance bridge operated from A.C. mains of commercial frequency. Subsequent deflexion of the armature from the balance position alters the air-gap and so affects the inductance of the coils. This changes the impedance of the bridge and a current flows. It is usual to rectify this current by metal rectifiers, and a millivoltmeter indicates the degree of unbalance, which is an indication of the armature position. Owing to the fact that a mains frequency of only 50-60 c/s. is employed, the coils must be quite large to obtain an appreciable change in inductance. Another disadvantage is that the iron circuit must have a substantial cross-section at these frequencies; this means that the bulk of the device may be quite considerable. The regulation on commercial A.C. mains is no better than $\pm 2\frac{1}{2}$ per cent, and, while a barretter is generally employed to assist in controlling these changes, this will make adjustment for changes in voltage but not in frequency, and the accuracy of indication may depend upon frequency to a greater extent than upon voltage. The amount of current available for operating the indicating meter is very small, which necessitates a rather delicate movement and construction, and precludes the use of a writing or recording instrument except one of the dotting-millivoltmeter type.

It is difficult to secure linearity in output, since the movement of the armature in the air-gap does not alter the impedance in a linear fashion; but if the change in air-gap due to change in load is a small fraction of the static gap, the output may be approximately linear, and other external means of electrical correction may be employed to improve the scale shape and sensitivity. It is also difficult to amplify the signal satisfactorily, since mains pickup may readily occur at the same frequency, and it is possible thus to mask partially the actual signal.

Such simple circuits have a low efficiency. In Fig. 1, the air-gap inductance L_x forms one arm of a Wheatstone bridge. The remaining three arms are resistive and inductive, and if the third of these arms comprises an inductance L and a resistance R, they can be adjusted to bring the bridge into balance.

Fig. 1.
Non-resonant impedance bridge

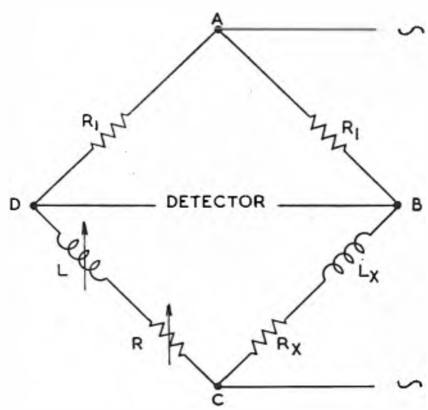
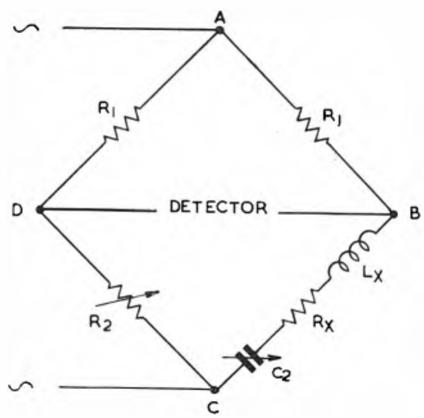
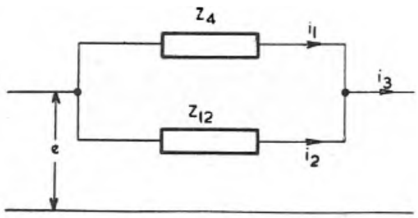


Fig. 2.
Resonant impedance bridge





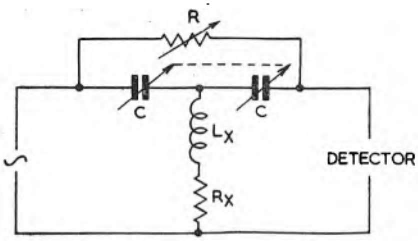
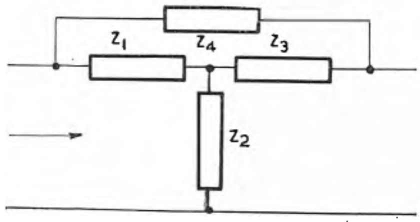


Fig. 3. *(left)*
Schematic of Bridged-T network

Fig. 5 *(right).*
Bridged-T circuit as used



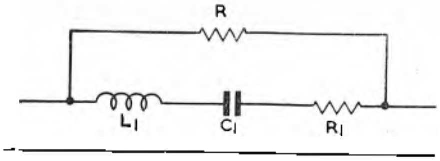


Fig. 4 *(left).*
Equivalent circuit of Bridged-T network

Fig. 6 *(right)*
Equivalent circuit of Fig. 5

If the change in L_x due to displacement is $\triangle L_x$, then the fractional change in impedance of the bridge arm BC is:

$$\frac{\omega \triangle L_x}{\sqrt{R_x^2 + \omega^2 L_x^2}} \quad \dots\dots\dots\dots \quad (1)$$

where $\omega = 2\pi f$ and f = oscillatory frequency. As, in general, ωL_x is much greater than R_x, $\omega L_x / R_x$ is the Q or magnification factor of the coil and the above fraction (1) becomes $\triangle L_x / L_x$.

If the displacement of the air-gap for full load is 1 per cent of the initial air-gap and the Q value is 20, then $\triangle L_x / L_x = 0.01$. Thus a change of 1 per cent in the length of the air-gap causes a change in impedance of the arm BC of 1 per cent.

On account of these limitations it was decided to consider the conversion of the simple bridge to a resonant bridge, Fig. 2.

If the air-gap inductance is connected in series with a variable air capacitor the bridge may be converted into a resonant circuit.

Let C_2 be the variable capacitor. For balance, R_2 and C_2 are adjusted to satisfy the conditions:

$$R_2 = R_x \text{ and } 1/\omega C_2 = \omega L_x \quad \dots\dots\dots\dots \quad (2)$$

Under these conditions the positive reactance of the coil is neutralized by the negative reactance of the capacitor.

When the air-gap changes in length, L_x changes to $L_x + \triangle L_x$ and the impedance of the arm BC changes by an amount $\omega \triangle L_x$, which is reactive. Hence the fractional change in the arm BC is $\omega \triangle L_x / R_x$.

Taking the values already given, viz., $\triangle L_x = 0.01 L_x$, and $\omega L_x = 20 R_x$, then for maximum displacement the above fraction becomes:

$$\frac{\omega \triangle L_x}{R_x} = 0.01 \times 20 = 0.2 \quad \dots\dots\dots\dots \quad (3)$$

Thus by using a resonant bridge the sensitivity has been increased twenty times.

This only obtains when $1/\omega C_2 = \omega L_x$. Therefore ω and C_2 must be stable quantities. However, this presents no great difficulty in practice, although since $\omega = 2\pi f$, it is clear that effective frequency stabilization must be provided; hence the inadvisability of operating from commercial A.C. mains.

There is a drawback to any type of A.C. bridge which, while not of great importance in a laboratory, has considerable significance in practice. It must be noted that the bridge alone cannot be dissociated from the frequency source and the detecting apparatus, but must be treated as a whole. Viewed in this light, it is essential to have complete stability in the system, and this is almost impossible to achieve unless one side of the frequency source, the pressure-measuring element, and the detector, are all at earth potential. Such a circuit arrangement is not possible for any normal bridge network without elaborate precautions. Consequently modifications to the circuit were introduced to convert the 4-arm resonant bridge to a T-network, having a common connexion to which the frequency source, coil, and detector could be earthed. The valuable properties of this type of circuit* (not previously exploited for this method of measurement) permit the application of a continuous earth-line to each part of the measuring equipment; this confers a high degree of stability to the system, even though it is dispersed over a wide area.

A further advantage—of significance when using a high operating frequency—is that there is much less chance of electrostatic coupling between the oscillation generator and the detector, and the body capacitance of the operator has very little effect on the whole circuit without the need for elaborate screening.

Bridged-T Circuit

The condition under which a bridged-T circuit may be brought to balance is that state in which the output current and voltage from the network are zero when the input voltage is finite. To examine the special properties of the T-circuit, the quantity known as transfer impedance must be determined. This is the ratio of input volts to output current when the output terminals are short-circuited.

Fig. 3 represents a bridged-T circuit. The transfer impedance of the T-portion of the network formed

* Brit. Pat. 568701; U.S. Pat. 2414224.

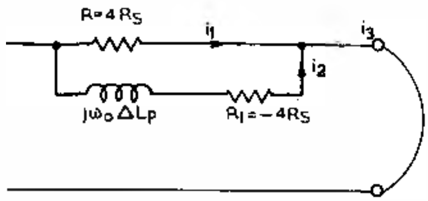


Fig. 7.
Equivalent circuit of inductive T-Bridge unit, unbalanced

by Z_1, Z_2 and Z_3 is:

$$Z_{12} = Z_1 + Z_3 + \frac{Z_1Z_3}{Z_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Considering the output current only, Fig. 3 may be redrawn as Fig. 4.

The output current is then:

$$i_3 = i_1 + i_2$$

but $i_1 = e/Z_4$, and $i_2 = e/Z_{12}$

$$\therefore\ i_3 = e\left(\frac{Z_{12} + Z_4}{Z_{12}Z_4}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

i_3 will be zero—the condition for balance—when:

$$Z_{12} + Z_4 = 0$$

Thus the condition for balance is:

$$Z_1 + Z_3 + Z_4 + \frac{Z_1Z_3}{Z_2} = 0 \quad \ldots\ldots\ldots\ldots \quad (6)$$

To apply the foregoing to the practical type of T-circuit, consider Fig. 5, in which L, with its inherent loss resistance, R_s, represents the inductance in the measuring element, and the remaining components form part of the balancing network in the bridge.

From a comparison of Figs. 3 and 5:

$$Z_1 = Z_3 = 1/j\omega C$$
$$Z_2 = R_s + j\omega L$$
$$Z_4 = R$$
$$Z_{12} = \frac{2}{j\omega C} - \frac{1}{\omega^2C^2}\left[\frac{1}{R_s + j\omega L}\right]$$
$$= \frac{2}{j\omega C} + \frac{1}{\omega^2C^2}\left[\frac{j\omega L - R_s}{R_s^2 + \omega^2L^2}\right]$$

Here, we may neglect R_s^2 in comparison with ω^2L^2, which is Q^2 times as great, so that:

$$Z_{12} = \frac{2}{j\omega C} + j\omega\left[\frac{1}{L\omega^4C^2}\right] - \left[\frac{R_s}{L^2\omega^4C^2}\right]$$

The T-section is thus equivalent to Fig. 6, where

$$C_1 = C/2$$
$$L_1 = \frac{1}{L\omega^4C^2}$$
$$R_1 = \frac{R_s}{L^2C^2\omega^4} \text{ (negative resistance)}$$

and the bridge will be in balance if:

$$(1)\ \omega = \frac{1}{\sqrt{2LC}} = \frac{1}{\sqrt{L_1C_1}}$$

and

$$(2)\ R = -Z_{12} = -R_1 = 4R_s.$$

The bridging resistance R must therefore be numerically equal to the pure negative resistance of the T-section at resonance, i.e., equal to four times the loss resistance of the coil.

At resonance:

$$Z_{12} = \frac{2}{j\omega C} + j\omega\left(\frac{1}{L\omega^4C^2}\right) - \left(\frac{R_s}{L^2\omega^4C^2}\right)$$
$$\frac{dZ_{12}}{dL} = -j\omega\left(\frac{1}{L^2\omega^4C^2}\right) + \left(\frac{2R_s}{L^2\omega^4C^2}\right)$$
$$= -4j\omega \text{ (neglecting } 2R_s/\omega L)$$

For a small departure from resonance, L changes to $L + \Delta L$ and the circuit becomes equivalent to Fig. 7, the output of which is proportional to:

$$\frac{1}{4R_s} - \frac{1}{4R_s + 4j\omega\Delta L}$$

If $j\omega\Delta L$ is small compared with R_s, this decreases to $j\omega\Delta L/4R_s^2$ and the output is proportional to ΔL.

The T-Bridge unit is simple to adjust and is

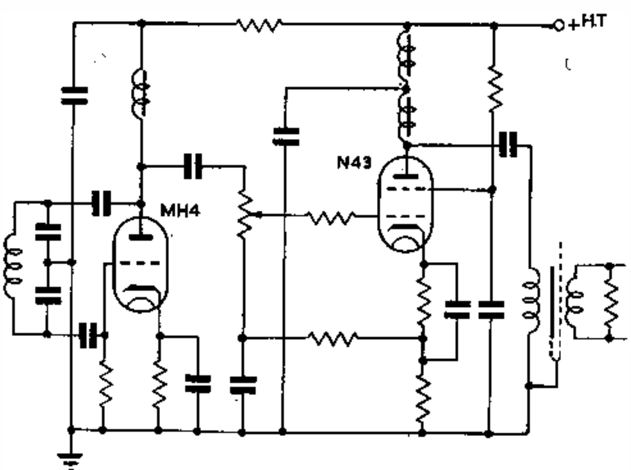
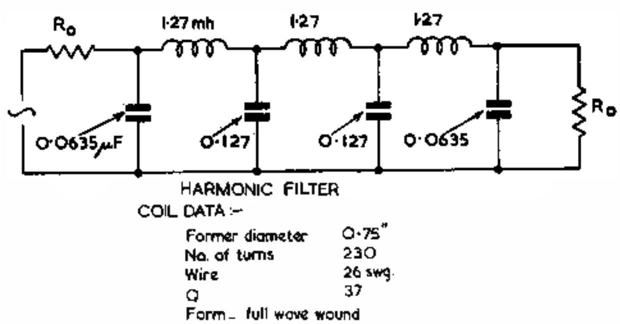


Fig. 8 *(left)*.
Oscillator circuit

Fig. 9 *(below)*.
Circuit of the harmonic filter



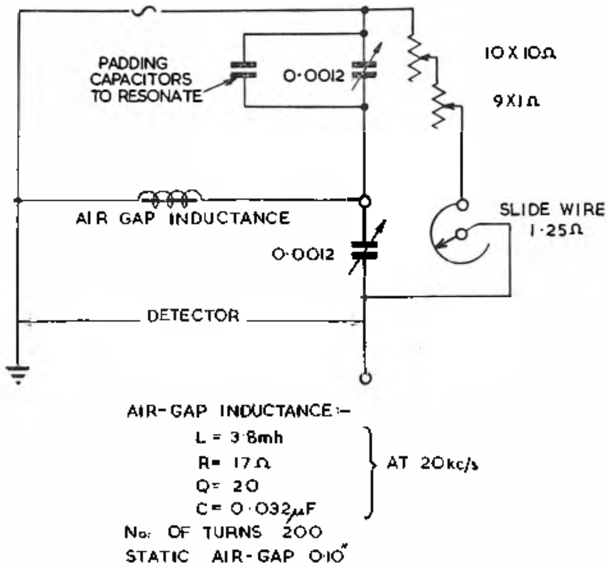


Fig. 10.
Bridge circuit as used

capable of maintaining balance for long periods. In the practical interpretation of the method the system is divided into the following parts:

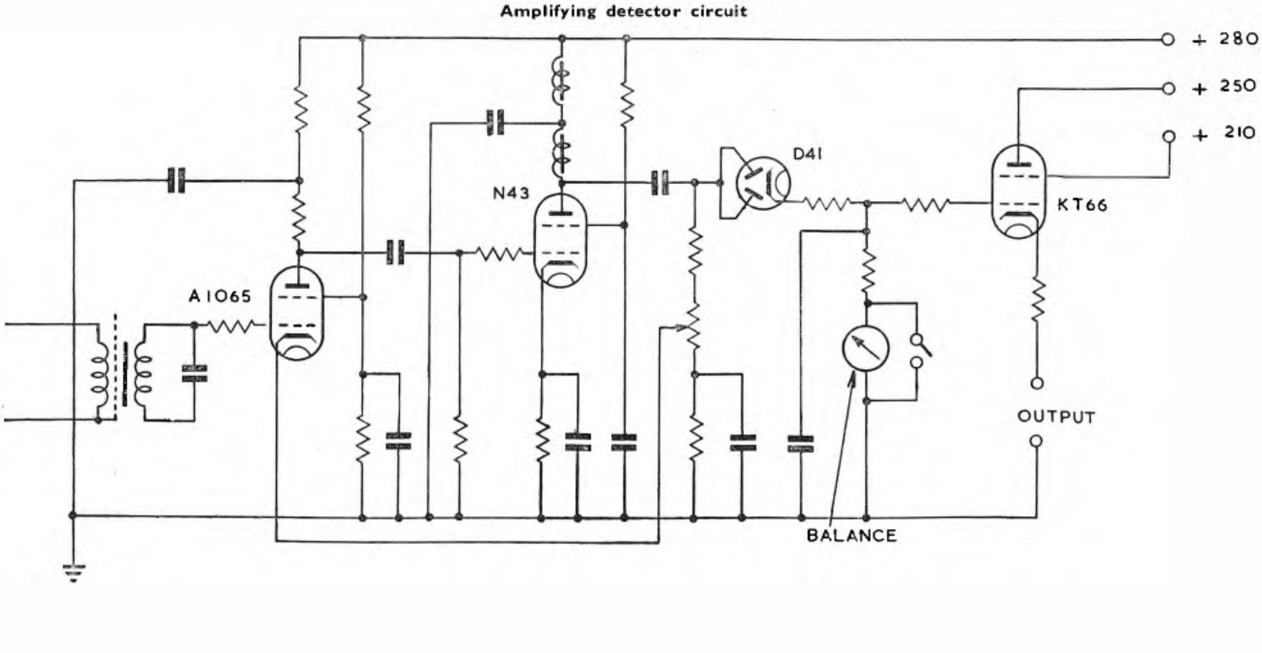
Oscillator, T-bridge, detector, air-gap inductance. Taking these in turn, the oscillator frequency will depend upon the speed of response required of the air-gap inductance. A simple Colpitts circuit of the type shown in Fig. 8 with a Sullivan temperature-compensated inductance and operating at a frequency of 20 kc/s. was found to be stable to one part in 20,000 over a period of six hours. This is adequate for most purposes. The stability is improved by the use of valves of the kind shown, with heavy-current heaters; these are also shielded from daylight to reduce any photo-emissive action. The output is two volts.

Between the oscillator buffer valve and the T-bridge there is a harmonic filter. The bridge, when resonating at the fundamental frequency, can pass higher harmonics (if present). The attenuation of the filter shown in Fig. 9 is 65 db. at 35 kc/s., thus preventing any higher harmonics from adding to the rectified signal frequency.

The bridge unit contains the necessary transformers, capacitors and resistors. The air-gap inductance is connected to this by a cable which may be 40 ft. or 50 ft. in length. The cable used does not introduce sufficient resistance to flatten the resonance curve at all.

For an operating frequency of 20 kc/s. a suitable air-gap inductance might have the characteristics shown in Fig. 10, which also gives the values of the other bridge components for this frequency. The physical size of the air-gap inductance is small, about a one-inch cube. It is thus easily mounted on any device required to vary the gap. In practice, the T part of the core is made variable, as only an extremely small force is needed to displace it. The greatest care must, of course, be taken to lock the stampings tightly together and, since full-scale deflexion of the indicating and recording meters can be obtained for a change in air-gap of only 1/10,000 in. the pole faces must be accurately ground. Since the T-bridge (in this application) is a parallel resonant circuit, the impedance at resonance is high, therefore no signal from the oscillator is transferred to the detector. As the air gap is altered, the tuned circuit departs from resonance more and more, and an increasing voltage will appear across the detector input. The combination of a good Q factor for the inductance and a high ratio for the detector input transformer ensures a useful step-up in sensitivity at this important point.

Fig. 11.
Amplifying detector circuit



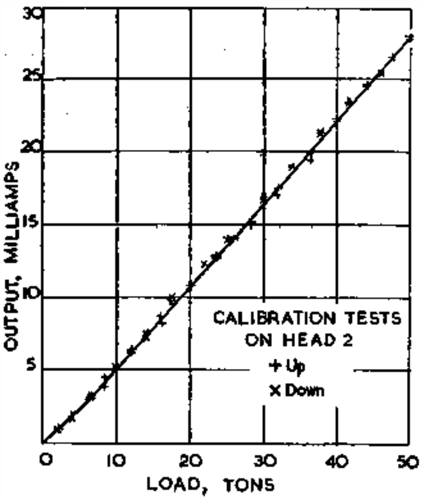


Fig. 12.
Typical calibration curve

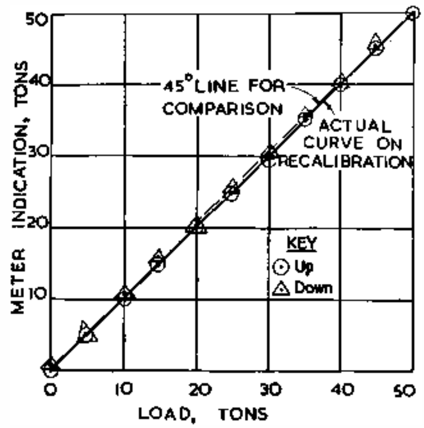


Fig. 13.
Check calibration after 10 months' continuous use

The amplifier-detector unit provides a D.C. signal to energize pointer meters or direct writing chart recorders. A simple circuit of good stability which has proved very satisfactory is shown in Fig. 11. Note that following the diode rectifier is a filter to remove any 20 kc/s. ripple remaining, and that the rather high standing current of the output valve is suitably backed-off. In this circuit, 30 mA is available for the meter circuits, which are cathode-connected.

The small inertia of this type of air-gap inductance permits a much higher speed of operation than d'Arsonval movements can respond to, should this be necessary; with the apparatus described, satisfactory response has been obtained up to a rate of change in air-gap of 3,000 c/s.

The power supplies for an apparatus of this sensitivity must be very well stabilized, and electronic stabilizers are used for the H.T. circuits with constant-voltage transformers for the heaters. The overall regulation is practically perfect.

The actual performance of a meter of the kind described is interesting, especially if in daily use, and after the lapse of some time. To attain the highest degree of stability, it was found necessary to keep the valve heaters permanently alive, and the whole apparatus at a fairly uniform temperature; for most applications, these precautions are not necessary.

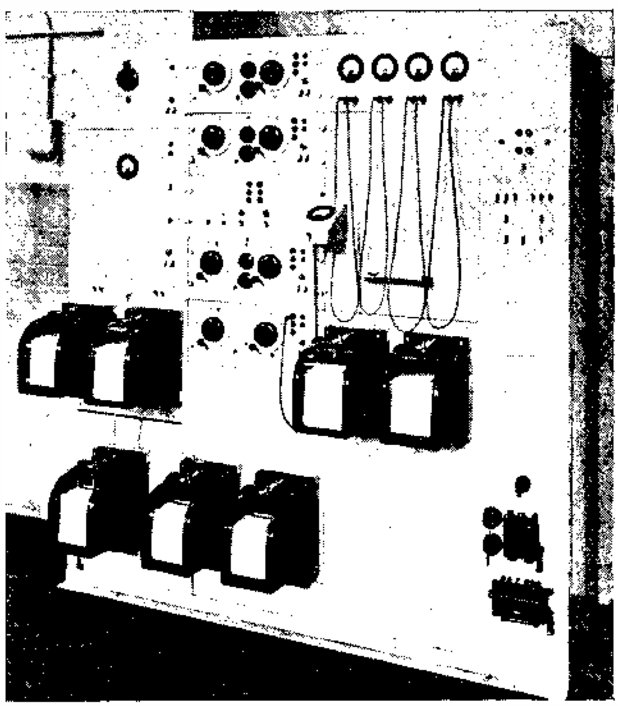
In one form, the air-gap inductance was fitted to a steel rolling mill to indicate the rolling load. Fig. 12 shows typical actual calibration curves for the output current plotted against load in tons. Fig. 13 shows a check of calibration of the indicating meters against true load after 10 months' continuous running. It can be seen that the errors over the full range are not greater than half a ton, i.e., 1 per cent.

Other applications of an air-gap inductance of this type include the measurement of surface finish; accurate gauging of thickness (e.g., the absence of any large restoring force makes it possible to gauge thin foils of aluminium, gold, etc., without marking the surface); sensitive weighing apparatus, torque, or bending in rotating elements; tensile forces, as in extensometers and stress-recorders; and any kind of relative movement between two points of contact, whether any appreciable force is available or not.

Fig. 14 is a photograph of a complete six-channel recording apparatus employing the apparatus described in this article, which represents part of the instrument development work carried out by the author on behalf of the British Iron & Steel Research Association.

A much more detailed analysis of gauging methods appears in a joint paper by the author and Dr. H. Ford, published as special report No. 34 by the Iron & Steel Institute.

Fig. 14.
Six-channel recording unit, using the method described



Frequency Generation and Measurement

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

(The Plessey Co., Ltd., Ilford, Essex)

This paper describes a method of generation which enables any frequency to be produced that is harmonically related to a sub-multiple of a standard frequency. The apparatus employs a decade system of frequency indication and selection which is extremely simple to set up, and considerable care is taken to eliminate ambiguity.

DURING recent years enormous progress has been made in the technique of crystal controlled oscillators. Standards of frequency better than 1 in 10^8 are now available and are checked in terms of the earth's rotation. It is now possible to compare three such standards to 1 part in 10^{10}, deducing drift rates due to the ageing of the crystal to enable standard time to be established to a very high order of accuracy. Standards of frequency are especially useful since they are available internationally by radio transmissions. Every endeavour should therefore be made to take advantage of such services since the fundamental quantity of time can be used for many derived measurements in standardizing work.

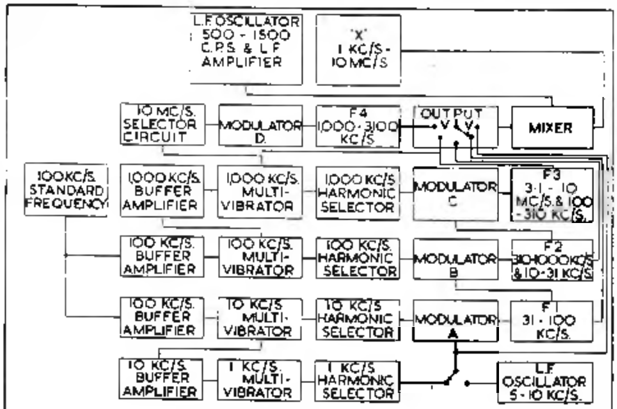


FIG. 1. BLOCK SCHEMATIC DIAGRAM.

A calibrated oscillatory circuit maintained by one or more valves can provide a known source of frequency. It is necessary, however, to refer the calibration to a standard of frequency for the precise establishment of that calibration. This is necessary due to many factors, the chief of which are due to the temperature coefficient of the *L-C* circuit, variations in the maintaining circuit and the mechanical imperfections in the variable element of the circuit. In order to carry out the comparison it is necessary to bring the frequency of the standard within the range of measurement in which it can be made with the highest possible accuracy. Thus, a harmonically related series of the standard can be generated to calibrate the oscillator at definite intervals, but to be of any practical value the fundamental of the harmonic must represent a very small percentage of the oscillator frequency. When the spacing becomes very small, ambiguity arises as to which harmonic is used, due to the uncertainty of the initial calibration of the oscillator.

To reduce the harmonic order required and to facilitate the identification and separation of the harmonics the process of harmonic generation can be carried out in several stages. From a standard frequency, f, controlled oscillations are produced at frequencies af/b where a and b are whole numbers. A scale of frequencies naf/b is thus obtained, where n is the order of the harmonic and by a suitable choice of a and b it is possible to obtain a frequency close to the unknown one and yet have a reasonable spacing between harmonics. This method of operation does not, however, permit a direct frequency reading although the values of n, a and b can readily be obtained. Harmonic tables can be provided which facilitate the choice of the appropriate value of a and b and the actual value of the frequency naf/b can be read from the tables.

These limitations of frequency generation have been overcome by an apparatus which has been called a frequency synthesizer and which enables any frequency harmonically related to a sub-multiple of a single standard frequency to be generated. The frequency generated is substantially pure irrespective of the order of the harmonic, and its value can be identified with certainty.

Principle

A standard frequency f, e.g., 100 kc/s., is converted to a sub-multiple f/n by a frequency dividing unit and n is made a power of 10 to form a decade system direct reading in frequency. The order of the sub-multiple f/n is determined by the smallest frequency interval between adjacent harmonics desired to be generated and by the value of f. Any harmonic of f/n, e.g., 1 kc/s., up to the ninth order can be selected individually by means of tuned cir-

FIG. 2.

SELECTED HARMONIC of f/n DECADE	9	8	7	6	5	4	3	2	1	0
SCALE DESIGNATIONS X f/n RANGE 1	9	8	7	6	5	–	–	–	–	0
RANGE 2	1	2	3	4	–	–	–	–	–	–

SELECTED HARMONIC of $10f/n$ DECADE	10	9	8	7	6	5	4	3	2	1	0
SCALE DESIGNATIONS of $10f/n$ RANGE 1	10	9	8	7	6	5	4	3	2	1	0
RANGE 2	9	8	7	6	5	4	3	2	1	–	–

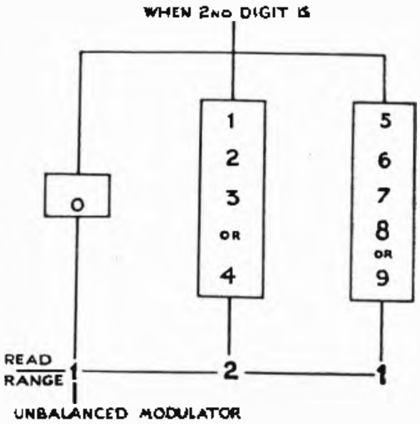


FIG. 3.

cuits. A second decade system controlled by a frequency divider from f generates harmonics of $10\ f/n$, e.g., 10 kc/s., and any harmonic up to the tenth order can be selected individually by a second series of tuned circuits. A further decade of $100\ f/n$, i.e., f and a frequency multiplier, to give harmonics of $10\ f$, e.g., 1,000 kc/s., can be arranged in a similar manner as shown in Fig. 1.

The outputs from any two selected harmonics n_1 $(10\ f/n)$, e.g., 6×10 kc/s., and n_2 (f/n), e.g., 8 kc/s., are fed balanced with respect to earth to a balanced modulator system A which produces the modulation products $[n_1(10f/n) \pm n_2(f/n)$ e.g., 60 kc/s.$]$ ± 8 kc/s., namely, 68 kc/s. or 52 kc/s. These modulation products are fed to a calibrated continuously variable filter amplifier $F1$ which covers a frequency spectrum of $0.31f$ to f. The required product can therefore be selected, and the unwanted one substantially eliminated provided there is a reasonable frequency separation between the sum and difference products.

Good attenuation of the unwanted product with respect to the wanted one can be obtained in the following manner. When the second digit of a two-figure combination is 1, 2, 3 or 4 f/n its complement is selected, i.e., 9, 8, 7 or 6 f/n respectively. This frequency is mixed in A with another frequency n_1 10 f/n where $n_1 = 1$ plus the value of the first digit of the required frequency.

Example : To generate 81 kc/s.

The ninth harmonic of a 1 kc/s. series representing the complement of 1 kc/s., the digit value of the second figure of the required frequency, is mixed in modulator A with the (1 + 8th), i.e., ninth harmonic of the 10 kc/s. series. The modulation products will therefore be 90 kc/s. ± 9 kc/s., i.e., 99 kc/s. and 81 kc/s., and are separated by more than 10 kc/s.

When, however, the second digit of a two-figure combination is 5, 6, 7, 8 or 9 f/n, a harmonic of the value given by the second digit is selected and mixed in modulator A with another harmonic n_1 $(10\ f/n)$ whose value is that of a first digit.

Example : To generate 78 kc/s.

The eighth harmonic of a 1 kc/s. series is mixed with the seventh harmonic of a 10 kc/s. series, when

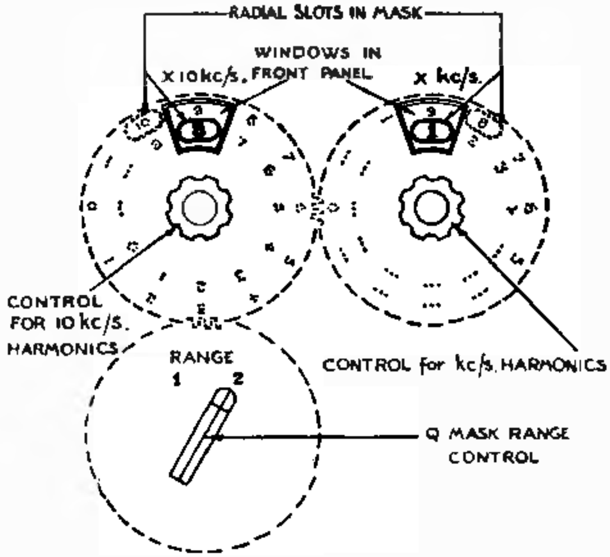


FIG. 4.

the modulation products of A will be 70 kc/s. ± 8 kc/s., i.e., 78 kc/s. and 62 kc/s., which are again separated by more than 10 kc/s.

It will be noted that the harmonic selected to represent the second digit of a two-figure frequency combination is never less than the fifth by employing the above method. Thus the modulation products are separated by at least twice the frequency given by the value of the fifth harmonic, i.e., the value of the higher product will be more than 10 per cent added to the lower product, enabling efficient filtering to be simply carried out.

The modulator A, being balanced, requires unbalancing when it is desired to generate a two-figure frequency whose second digit is 0. It can be seen, therefore, that with a suitable choice of harmonics any two-figure frequency can be generated substantially pure, by efficient attenuation of the unwanted product produced in the modulator, by utilizing either the sum or difference products. Both harmonic selector switches have scales with two combinations

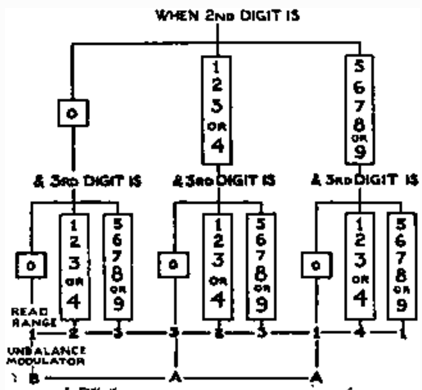


FIG. 5.

SELECTED HARMONIC OF f/n DECADE	...	9	8	7	6	5	4	3	2	1	0
SCALE DESIGNATIONS $\times f/n$	RANGE 1 ...	9	8	7	6	5	–	–	–	–	0
	RANGE 2 ...	1	2	3	4	–	–	–	–	–	–
	RANGE 3 ...	9	8	7	6	5	–	–	–	–	0
	RANGE 4 ...	1	2	3	4	–	–	–	–	–	–

SELECTED HARMONIC OF $10f/n$ DECADE		10	9	8	7	6	5	4	3	2	1	0
SCALE DESIGNATIONS $\times 10f/n$	RANGE 1	10	9	8	7	6	5	–	–	–	–	0
	RANGE 2	–	0	1	2	3	4	–	–	–	–	–
	RANGE 3	0	1	2	3	4	–	–	–	–	–	–
	RANGE 4	9	8	7	6	5	–	–	–	–	–	–

SELECTED HARMONIC OF $100f/n$ DECADE		10	9	8	7	6	5	4
SCALE DESIGNATIONS $\times 100f/n$	RANGE 1	10	9	8	7	6	5	4
	RANGE 2	9	8	7	6	5	4	3
	RANGE 3	9	8	7	6	5	4	3
	RANGE 4	–	9	8	7	6	5	4

FIG. 6 DESIGNATIONS OF HARMONICS FOR 3 FIGURE FREQUENCIES

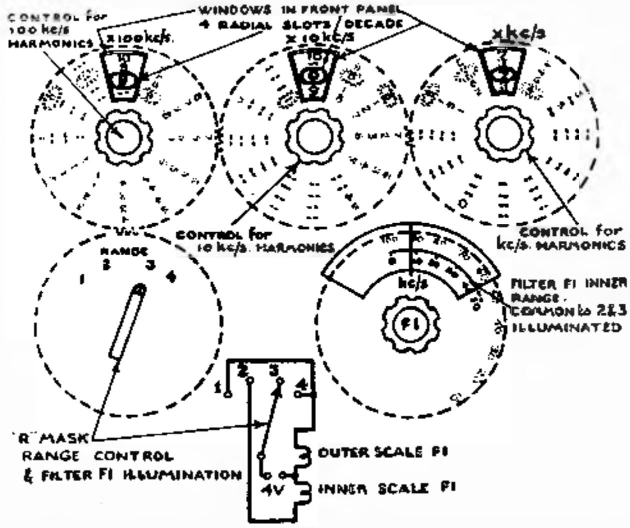


FIG. 7.

of numerals as shown in Fig. 2, and the appropriate scale to be read is determined by a chart known as a frequency tree, Fig. 3. Reference to Fig. 3 shows that the scale to be read depends on the value of the second digit and that these scales follow the method outlined above.

In order to make the equipment direct reading for frequency, masks are provided in front of the scales as shown in Fig. 4. These masks are set by means of a single control marked "Q" to the appropriate range as determined by the frequency tree, Fig. 3, before switching to the required frequency.

It would appear to be quite simple to follow the above rules without the complications of masks, but it will be apparent that means adopted to synthesize a three- or four-figure frequency will necessitate the use of masks and multiple scales to preserve a direct reading instrument and to avoid ambiguity of result. When a three-figure frequency is required lying in the spectrum $3.1f$ to $10f$, e.g., 310 kc/s.—1,000 kc/s., a frequency representing that of the second and third digits is selected by means of the filter *F1*. The output from *F1* is mixed with a frequency representing the value of the first digit obtained from the f harmonic selector in a second balanced modulator system *B*. A second filter amplifier *F2* selects the required modulation product and the modulation products are so arranged that their difference is never less than f, e.g., 100 kc/s. A second frequency tree, Fig. 5, specifies the setting for the masks whereby this condition can be realized. Filter *F2* covers the frequency ranges $3.1f$-$10f$, and $0.1f$-$0.31f$.

When the second digit of a three-figure frequency is 1, 2, 3 or 4 a second calibration of the filter *F1* is necessary whereby the spectrum $0.31f$-f is represented as $0.69f$-0, i.e., the sum of the calibration is f kc/s. at any setting. The appropriate calibration to be read can be shown by illuminating the desired scale, such illumination being controlled by the masked position switch.

Example : To generate 907 kc/s.

Referring to Fig. 5 it will be seen that the mask must be set at position 3, and when the decade selector switches are set at 907 kc/s. reference to Fig. 6 will show that 1,000 kc/s., 100 kc/s. and 7 kc/s. respectively have been selected. The modulation product produced will be 100 kc/s. $\pm$7 kc/s., i.e., 107 kc/s. and 93 kc/s. When the filter *F1* is tuned to the setting represented by 07 kc/s. the frequency given by the last two digits, it will select the difference product of 93 kc/s. This frequency which will be substantially pure is mixed in the second balanced modulator system *B* with 1,000 kc/s. The modulation products will therefore be 1,000 kc/s. $\pm$93 kc/s., i.e., 1,093 kc/s. and 907 kc/s. The filter *F2*, when tuned to 907 kc/s., will substantially eliminate the sum product as we have realized the condition of separating the two products by more than 100 kc/s. Fig. 7 shows the masks set for the above example.

A division of the frequency spectrum f-$10f$, e.g., 100 kc/s.—1,000 kc/s., is made at $3.1f$, e.g., 310 kc/s. When it is required to synthesize a frequency in the spectrum 100 kc/s.—309 kc/s. it is necessary to tune a further filter *F3* as well as *F2* filter to the required frequency. This condition arises because the modulation products utilized have been so chosen that any harmonic distortion of either product is much higher in frequency than that of the difference product which is always used when tuning *F3* in the spectrum f-$3.1f$.

Example of Frequency Synthesizer

Fig. 9 shows a frequency synthesizer covering the range 1 kc/s.—10 Mc/s. in kilocycle steps. An output of 0.1 volt loaded with 100 ohms is available at the output socket. The standard controlling frequency is obtained from a 100 kc/s G.T. cut crystal which is maintained at 60° C. An output from this oscillator is fed to two 100 kc/s. buffer amplifiers as shown in Fig. 1.

The first 100 kc/s. amplifier is used to lock a nominal 100 kc/s. multivibrator on its fundamental frequency. Part of the grid resistance is brought out to the top of the equipment and can be adjusted to bring the uncontrolled frequency of the multivibrator within the range of a synchronism by the 100 kc/s. input. The multivibrator consists of a triode hexode with the hexode anode tuned by preset coupled circuits to 1,000 kc/s., i.e., the tenth harmonic, and an output from this circuit is fed to a 1,000 kc/s. amplifier. Fig. 10 shows a triode hexode used in this way, and Fig. 11 shows the scale markings of the harmonic selector control.

An output from the 100 kc/s. multivibrator is fed to a selector amplifier whose grid and anode are tuned by means of pre-set capacitors to 1,000 kc/s., 900 kc/s., 800 kc/s., 700 kc/s., 600 kc/s., 500 kc/s., 400 kc/s. and 300 kc/s. A ganged switch is employed to select these capacitors and the optimum Q of the tuned circuits is at 1,000 kc/s. in order to get the maximum selectivity between the closest spacing of harmonics used.

The output from this stage is fed balanced with respect to earth to the triode grids of two triode hexodes used in a balanced modulator system *B*. The hexode control grids can receive frequencies balanced with respect to earth from the filter *F*1. This filter covers the range of frequency 31 kc/s.—100 kc/s. The sum or difference modulation products produced by *B* are selected by the filter amplifier *F*2. This filter covers two frequency ranges of 310 kc/s.—1,000 kc/s. and 10 kc/s.—31 kc/s., the appropriate ranges being selected by a switch. Two tuned circuits are employed, and the range is covered by a ganged continuously variable capacitor which has a scale calibrated direct in frequency to facilitate the selection of the desired component. The output from *F*2 is fed to a phase inverter stage with an internal impedance of 100 ohms and outputs balanced with respect to earth are fed to the modulator *C* and unbalanced with respect to earth to the output selector switch.

The second 100 kc/s. buffer amplifier is used to lock a 10 kc/s. multivibrator at 10 kc/s. A pre-set resistor is brought out to the top of the equipment and is adjusted to bring the natural frequency of the multivibrator within the range of synchronism of $f/10$ of the 100 kc/s. input. A 10 kc/s. tuned circuit in the hexode anode circuit of the multivibrator system provides an output which is fed to a 10 kc/s. amplifier. A further output from the multivibrator is fed to a selector amplifier whose grid and anode circuits are tuned to 100 kc/s., 90 kc/s., 80 kc/s., 70 kc/s., 60 kc/s., 50 kc/s. and 40 kc/s. A ganged switch is employed to select these capacitors and carries a scale as shown in Fig. 12. The output from this stage is fed balanced with respect to earth to the triode grids of the modulator system *A*. The hexode grids can receive frequencies balanced with respect to earth from the 1 kc/s. unit and the sum or difference frequencies are selected by the filter *F*1 which covers the frequency spectrum 31 kc/s.—100 kc/s. Two tuned circuits adjusted by means of ganged capacitors permit efficient selection of the required modulation product and the output is fed unbalanced with respect to earth to the output selector switch and balanced with respect to earth to the modulator system *B*. Modulator systems *A* and *B* can be unbalanced by breaking the cathode circuit of one valve where it is desired to synthesize a frequency employing 0 as the second or third digits. A single control is used to select one of sixteen mask positions necessary and also illuminates the true or reciprocal calibrations of the various filters.

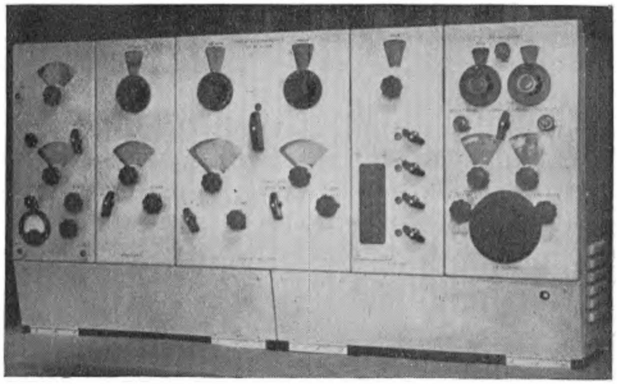


Fig. 9.
A frequency synthesizer for the range 1 kc/s to 10 Mc/s

A 10 kc/s. input from the 10 kc/s. buffer amplifier is used to lock a 1 kc/s multivibrator at 1 kc/s. and a rheostat pre-set can be adjusted to make the natural frequency of the 1 kc/s. multivibrator lie within the range of synchronism of one-tenth of the input frequency. The output from the multivibrator is fed to a selector amplifier whose grid and anode circuits are tuned by means of capacitors from 9 kc/s.—1 kc/s. A ganged switch with a scale marked as in Fig. 13 is used to select the appropriate capacitors, and toroidal dust core coils give the required selection of harmonic. Outputs from the amplifier balanced with respect to earth are fed to

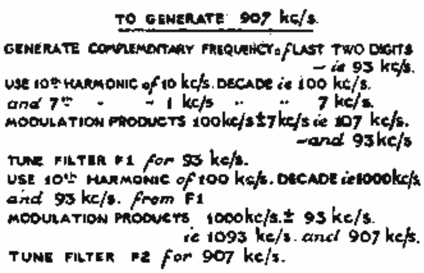


FIG. 8

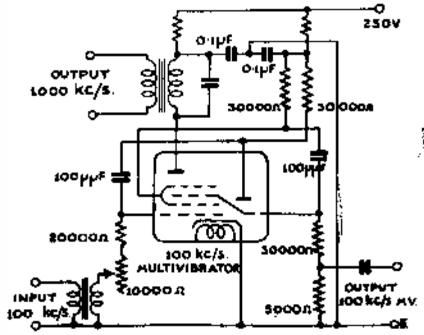


FIG. 10.

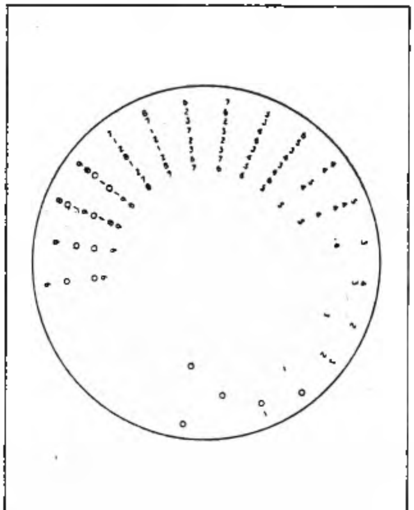


FIG. 11 100 KC/S. HARMONIC SELECTOR SCALE

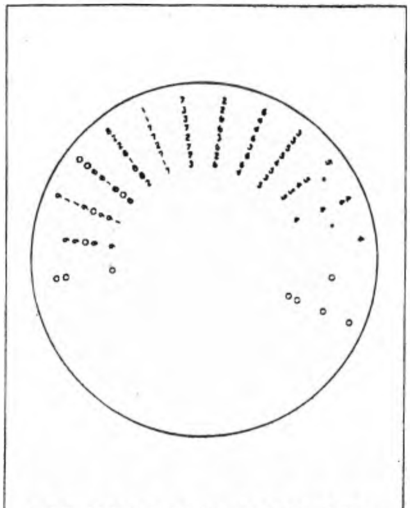


FIG. 12 10 KC/S. HARMONIC SELECTOR SCALE

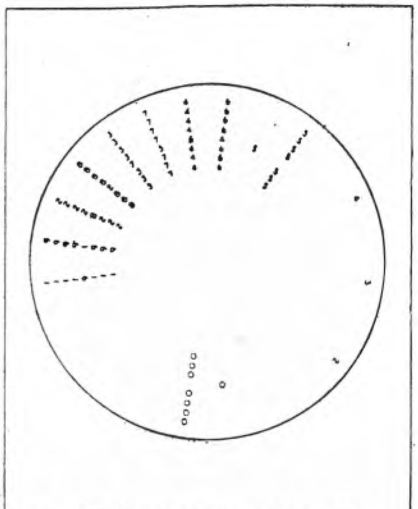


FIG. 13 1 KC/S. HARMONIC SELECTOR SCALE

modulator *A* and unbalanced with respect to earth to the output selector switch. A switching indicator chart to specify the necessary mask and filter range to be selected is provided.

The 1,000 kc/s. input from a tuned 1,000 kc/s. amplifier is used to lock a 1,000 kc/s. pulse amplifier and an output from this amplifier is selected to give the tenth harmonic, i.e., 10 Mc/s. A second output is fed to a selector amplifier whose grid and anode circuits are tuned by pre-set capacitors to 10 Mc/s., 9 Mc/s., 8 Mc/s., 7 Mc/s., 6 Mc/s., 5 Mc/s., 4 Mc/s. 3,000 kc/s. and 1,000 kc/s. The output from the amplifier is fed balanced with respect to earth to the triode grids of the modulator system *C*. A selector amplifier *F3* tuned from 3.5 Mc/s.—10 Mc/s. and from 100 kc/s.—310 kc/s. is used to select the required modulation product and two outputs, both unbalanced with respect to earth, are fed to the output selector switch and to the modulator *D*. The modulator *D* can receive an input from the 10 Mc/s. amplifier, and when mixed with the output from modulator *C* provides difference products which can be selected by means of the filter amplifier *F4* which covers the range 1,000 kc/s.—3,100 kc/s. An output from this amplifier is fed to the output selector switch.

A valve voltmeter enables the various filters to be tuned to the required modulation product, and the output selector switch is arranged to receive the outputs from the various modulators in turn.

Example : To generate 199 kc/s.

Reference to Fig. 14 will show that the mask must be set at position 7 and *F2* at its reciprocal calibration F_r. When the decade selector switches are set at 199 kc/s., reference to Figs. 15, 16, 17 and 18 respectively will show that 1,000 kc/s., 900 kc/s., 90 kc/s. and 9 kc/s. have been selected. Modulation products produced are 90 kc/s. ±9 kc/s. and *F1* is tuned to 99 kc/s. the frequency represented by the last two digits. The productions of *B* are 900 kc/s. ±99 kc/s. and *F2* is tuned to the frequency represented by 199 kc/s., i.e., the reciprocal calibration of 801 kc/s., namely, the difference product. 801 kc/s. is now mixed in a third modulator *C* with 1,000 kc/s. and the difference product of 199 kc/s. selected—the required frequency. Had 99 kc/s. been mixed with 100 kc/s. to give 100 kc/s. ±99 kc/s. at *B*, any second harmonic of either 99 kc/s. or 100 kc/s. generated in the modulator system would have given 198 kc/s. and 200 kc/s., either of which, although small in amplitude, would not be effectively attenuated when *F2* is tuned to the required frequency of 199 kc/s.

Frequencies in the spectrum $10f$-$31f$, f-$3.1f$ and $0.1f$-$0.31f$ are therefore obtained by a further stage of mixing as compared with frequencies in the spectrum $31f$-$100f$, $3.1f$-$10f$ and $0.31f$ to f. By employing the above principle it is possible to obtain 10,000 frequencies at intervals of 1 kc/s. individually

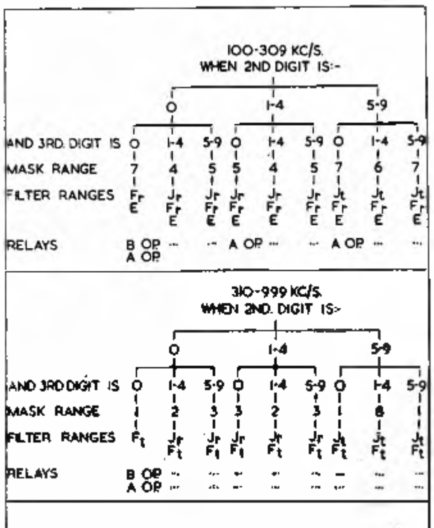


FIG. 14 - FREQUENCY TREE - 100 TO 999 KC/S.

SELECTED HARMONICS OF 1000 KC/S DECADE		10	9	8	7	6	5	4	3	1	0
SCALE DESIGNATIONS X 1000 KC/S.	RANGE 1...	10	9	8	7	6	5	4	3	1	0
	RANGE 2...	–	9	8	7	6	5	4	3	1	0
	RANGE 3...	–	9	8	7	6	5	4	3	1	0
	RANGE 4...	9	8	7	6	5	4	3	2	0	–
	RANGE 5...	9	8	7	6	5	4	3	2	0	–
	RANGE 6...	9	8	7	6	5	4	3	2	0	–
	RANGE 7...	9	8	7	6	5	4	3	2	0	–
	RANGE 8...	–	9	8	7	6	5	4	3	1	0
	RANGE 9...	–	0	1	2	3	4	–	–	–	–
	RANGE 10...	–	0	1	2	3	4	–	–	–	–
	RANGE 11...	–	0	1	2	3	4	–	–	–	–
	RANGE 12...	–	0	1	2	3	4	–	–	–	–
	RANGE 13...	0	1	2	3	4	–	–	–	–	–
	RANGE 14...	0	1	2	3	4	–	–	–	–	–
	RANGE 15...	0	1	2	3	4	–	–	–	–	–
	RANGE 16...	0	1	2	3	4	–	–	–	–	–

FIG. 15. TABLE SHOWING HARMONICS SELECTED IN EACH RANGE IN THE 1000 KC/S. DECADE.

SELECTED HARMONICS OF 10 KC/S DECADE		10	9	8	7	6	5	4	0
SCALE DESIGNATION × 10 KC/S	RANGE 1	–	9	8	7	6	5	4	0
	RANGE 2	–	0	1	2	3	4	–	–
	RANGE 3	0	1	2	3	4	–	–	–
	RANGE 4	–	0	1	2	3	4	–	–
	RANGE 5	0	1	2	3	4	–	–	–
	RANGE 6	9	8	7	6	5	–	–	–
	RANGE 7	–	9	8	7	6	5	–	0
	RANGE 8	9	8	7	6	5	4	–	–
	RANGE 9	–	0	1	2	3	4	–	–
	RANGE 10	0	1	2	3	4	–	–	–
	RANGE 11	–	9	8	7	6	5	–	0
	RANGE 12	9	8	7	6	5	–	–	–
	RANGE 13	–	9	8	7	6	5	–	0
	RANGE 14	–	0	1	2	3	4	–	–
	RANGE 15	0	1	2	3	4	–	–	–
	RANGE 16	9	8	7	6	5	–	–	–

FIG. 17 TABLE SHOWING HARMONICS SELECTED IN EACH RANGE IN THE 10 KC/S DECADE

in the spectrum 1 kc/s.—10 Mc/s. with the four decades as shown in Fig. 1.

In order to make the equipment continuously variable, a free oscillator covering the range 5 kc/s.—10 kc/s. can be substituted for the kilocycle decade. When this is synthesized the resultant frequency will have an additional inaccuracy over that given by the crystal due to the calibration accuracy of the free oscillator.

Applications to Frequency Measurements

In the field of frequency measurement and calibration the frequency synthesizer is invaluable. There are two generally known methods of measuring frequency, i.e., interpolation at radio frequency and successive heterodyning to reduce the frequency for measurement to be carried out at low frequency. Both methods involve limitations to the precision attainable, and considerable skill is necessary on the part of the user in making the measurement.

The interpolation method needs a stable open scale oscillator covering the range of frequencies desired to be measured. The oscillator is adjusted in the region of the unknown frequency fx and is set to zero beat successively with fx and with harmonic standard frequencies above and below fx. This interpolation oscillator must have a known frequency law which should preferably be linear and can be calibrated by reference to the harmonic series from the standard. Frequency given by a scale setting θ_1 representing fx can be determined by interpolating between scale readings θ_2 and θ_3 given by adjacent harmonic frequencies from the standard. The accuracy with which fx can be measured depends on the linearity of the frequency law with respect to the scale divisions and on the reading accuracy of the scale, which is limited by the number of ranges employed to cover the desired frequency spectrum. Other limitations are due to the "approach error" of the variable element of the L-C circuit. This limitation is always present to some degree in any mechanically operated device.

SELECTED HARMONICS OF 100 KC/S DECADE		10	9	8	7	6	5	4	3	1	0
SCALE DESIGNATIONS X 100 KC/S.	RANGE 1...	–	9	8	7	6	5	4	3	1	0
	RANGE 2...	9	8	7	6	5	4	3	2	0	–
	RANGE 3...	9	8	7	6	5	4	3	2	0	–
	RANGE 4...	–	0	1	2	3	4	–	–	–	–
	RANGE 5...	–	0	1	2	3	4	–	–	–	–
	RANGE 6...	0	1	2	3	4	–	–	–	–	–
	RANGE 7...	0	1	2	3	4	–	–	–	–	–
	RANGE 8...	–	9	8	7	6	5	4	3	1	0
	RANGE 9...	–	0	1	2	3	4	–	–	–	–
	RANGE 10...	–	0	1	2	3	4	–	–	–	–
	RANGE 11...	0	1	2	3	4	–	–	–	–	–
	RANGE 12...	0	1	2	3	4	–	–	–	–	–
	RANGE 13...	–	9	8	7	6	5	–	–	–	0
	RANGE 14...	9	8	7	6	5	–	–	–	–	–
	RANGE 15...	9	8	7	6	5	–	–	–	–	–
	RANGE 16...	–	9	8	7	6	5	–	–	–	–

FIG. 16. TABLE SHOWING HARMONICS SELECTED IN EACH RANGE IN THE 100 KC/S. DECADE.

The order of the harmonic used must be ascertained, and when this cannot be done with certainty a harmonic series of a wider spacing, i.e., of a higher order, is used to locate a cardinal point near fx. A series having a finer spacing can then be used by counting the heterodyne beats from the cardinal point as the interpolation oscillator is adjusted to the adjacent harmonic below fx.

Owing to the frequency drift of the interpolation oscillator, the accuracy of setting is limited by the time necessary to carry out the test and this process is very unsatisfactory when tests are being made on a frequency which is drifting, e.g., transmitter drift from "switching on".

Successive Heterodyning

When the difference frequency between the unknown frequency fx and the adjacent harmonic of a standard frequency is too large to be determined by low frequency comparison devices, successive heterodyning is utilized to reach this condition. The frequency fx is mixed with a frequency H_1 where H_1 is the adjacent lower frequency obtained from the harmonic series of the standard. The difference frequency $(fx-H_1)$ is then mixed with a second harmonic H_2, where H_2 is the adjacent lower frequency obtained from a lower order of harmonic series. This process is repeated as shown in Fig. 19 until the final difference frequency can be determined by any of the known low frequency devices. The difference frequencies are obtained by modulators which mix the two components to produce their sum and difference frequencies. The unknown frequency fx can therefore be determined in terms of the standard, if the low-frequency comparison is carried out by reference to a sub-multiple of the standard. The accuracy of measurement is then only limited by the accuracy of the standard.

The number of stages of mixing employed will determine the simplicity of measurement. Where fx

SELECTED HARMONIC OF KC/S DECADE	9	8	7	6	5	4	3	2	0
SCALE DESIGNATIONS KC/S RANGE 1	9	8	7	6	5	4	3	2	0
RANGE 2	1	2	3	4	-	-	-	-	-
RANGE 3	9	8	7	6	5	-	-	-	-
RANGE 4	1	2	3	4	-	-	-	-	-
RANGE 5	9	8	7	6	5	-	-	-	-
RANGE 6	1	2	3	4	-	-	-	-	-
RANGE 7	9	8	7	6	5	-	-	-	-
RANGE 8	1	2	3	4	-	-	-	-	-
RANGE 9	1	2	3	4	-	-	-	-	-
RANGE 10	9	8	7	6	5	-	-	-	-
RANGE 11	9	8	7	6	5	-	-	-	-
RANGE 12	1	2	3	4	-	-	-	-	-
RANGE 13	9	8	7	6	5	-	-	-	-
RANGE 14	1	2	3	4	-	-	-	-	-
RANGE 15	9	8	7	6	5	-	-	-	-
RANGE 16	1	2	3	4	-	-	-	-	-

FIG.18 TABLE SHOWING HARMONICS SELECTED IN EACH RANGE IN THE KC/S DECADE

is not known approximately, the order of its frequency may be ascertained by means of a reference oscillator. The required calibration accuracy of the reference oscillator will depend on its frequency spectrum. For simplicity of measurement it should locate the frequency fx within an audible range, e.g., 10 kc/s. If, therefore, the higher limit of the frequency spectrum is 10,000 kc/s., an accuracy of 0.1 per cent will be required.

When the harmonic series is arranged on the decade system and means are provided for selecting the harmonics individually, the process will be considerably simplified.

Example : Let fx be 9,876.543 kc/s.

The approximate frequency of fx is determined by heterodyning to zero beat with a reference oscillator. This will locate the frequency of fx as lying between 9,886 and 9,866 kc/s., when the reference oscillator has a calibration accuracy of 0.1 per cent. The first two digits of the frequency have therefore been determined as 9 and 8.

With fx = 9,876.543 kc/s.

H_1 = 9,000.000 kc/s. = 9th harmonic of 1,000 kc/s. series

$fx - H_1$ = 876.543 kc/s.

H_2 = 800.000 kc/s. = 8th harmonic of 100 kc/s. series

$fx - H_1 - H_2$ = 76.543 kc/s.

The value of the third digit has been determined by the reference oscillator as 8, 7 or 6. Using a 10 kc/s. harmonic series:—

The 8th harmonic—76.543 kc/s. = 3.457 kc/s.

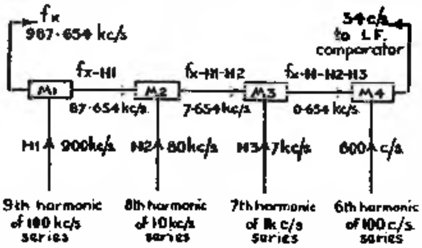
76.543 kc/s.—7th harmonic = 6.543 kc/s.

76.543 kc/s.—6th harmonic = 16.543 kc/s.

It will be noted that there are two audible frequencies which are less than 10 kc/s. In order to make the sum of the harmonic values indicate fx it is necessary to select the lower of the two harmonics which give a difference frequency less than 10 kc/s., i.e., 70 kc/s., is selected and not 80 kc/s. The difference frequency of 6.543 kc/s. is then mixed with the 6th harmonic of a 1 kc/s. series, and so on.

Fig. 19.

Block diagram illustrating successive heterodyning



It is found in practice that the number of stages of mixing is limited, because each modulator will produce some distortion. There will therefore be harmonics of each difference frequency which may cause some ambiguity in the final beat note.

With the frequency synthesizer of the type illustrated it is possible to produce a frequency close to a radio frequency to be measured, and a low frequency oscillator covering the range 500 c/s.—1,500 c/s. is provided to measure the beat frequency produced between fx and fs (the frequency given by the frequency synthesizer). This difference frequency can always be between 500 c/s. and 1,500 c/s. If the synthesizer frequency is set low of the frequency to be measured, then fx is the sum of fs and the audio difference frequency. Moreover, it is very simple to check whether the synthesizer is set high or low of fx as 1 kc/s. intervals are available. Radio transmissions can be effectively de-modulated by feeding the relatively large output from fs into the aerial circuit, when the clear beat frequency can be readily measured.

Acknowledgment

Finally, the author desires to express his thanks to the Plessey Company Limited, for permission to publish a description of this work, which is the result of development spread over a considerable period.

Electronic Colour Television

A SIMULTANEOUS demonstration of two types of three-colour television receivers was recently given in Washington by Radio Corporation of America engineers. The all-electronic scanning and modulating circuits were fed to basically similar cathode ray tubes; one a single beam type, the other, triple.

525-line vertical definition was used, but the horizontal definition was rather inferior to the usual standard achieved with a purely black and white tube because of the metal masking screen interposed between the fluorescent surface and the electron gun, or guns. This masking screen contains 117,000 perforations, each of which allows electrons to pass through as required to activate either the red, green or blue phosphor, or a combination of these.

Great emphasis was laid on the "compatibility" of the new system—older type receivers reproduce the demonstrated transmission as if it were wholly black and white, and conversely the new colour receivers reproduce a monochrome programme in black and white without adjustment.

Microwave Lenses

By J. BROWN, M.A., and S. S. D. JONES, M.A.*

Part III

A PAIR of perfectly conducting parallel plates as shown in Fig. 18 can support an infinite number of modes, each of which has a different field distribution and velocity of propagation. If the electric vector is normal to the plates, the principal mode has only transverse components of both electric and magnetic vectors and the field configuration is identical to that of a plane wave propagating in free space. The velocity of propagation between the plates is the same as for free space, this being the only mode for which this is the case. If, on the other hand, the electric vector is parallel to the plates it must vanish on the plates since they are perfect conductors, and it is not possible for the above mode to be established. All the possible modes have components of the magnetic field in the direction of propagation as well as transversely, and it may be shown from Maxwell's equations that the simplest of these modes has the field components

$$\left.\begin{array}{l} E_y = E_0 \sin \pi x/a \,.\, \exp j(\omega t - \kappa z) \;:\; E_x = E_z = 0 \\ H_x = -\kappa/\omega\mu \,.\, E_0 \sin \pi x/a \,.\, \exp j(\omega t - \kappa z) \\ H_y = 0 : H_z = -\pi/j\omega\mu a \,.\, \cos \pi x/a \,.\, \exp j(\omega t - \kappa z) \end{array}\right\} \quad (28)$$

where the system of axes x, y, z is shown in Fig. 18,

a is the spacing between the plates,

ω is the angular frequency,

$\kappa = \sqrt{(K^2 - \pi^2/a^2)}$ is the propagation constant within the plates,

K is the free space propagation constant,

μ is the permeability of free space.

M.K.S. units are used throughout.

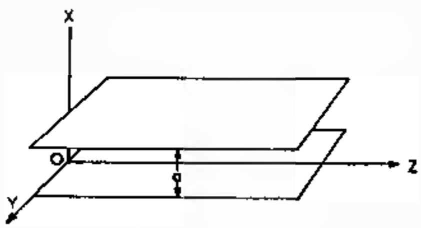


Fig. 18.
Parallel conducting plates

This will be recognised as being the H_{01} mode which exists in rectangular waveguides.[19] Because of this, metal plate lenses are frequently referred to as waveguide lenses. The phase velocity of this mode is

$$v = \omega/\kappa = v_0/\sqrt{(1 - \lambda_0^2/4a^2)} \quad \text{.............. (29)}$$

where λ_0 is the free space wavelength.

If the plate spacing a satisfies the condition

$$\lambda_0/2 < a < \lambda_0 \quad \text{.............................. (30)}$$

then the above mode is the only one which is freely propagated within the plates. All the other modes which may exist within the plates are rapidly attenuated and do not cause any flow of power.

The possibility of using this mode of propagation in a lens was suggested during the recent war by N. M. Rust[2] in this country and independently by W. E. Kock[6] in America. If a stack is formed by a number of plates spaced apart at equal intervals a, then it follows from Equations 2 and 29 that the stack will behave as a dielectric of refractive index,

$$n = \sqrt{(1 - \lambda_0^2/4a^2)} \quad \text{......................... (31)}$$

The value of this refractive index is always less than unity, as in the case of the rodded dielectric discussed at the end of the last article. This type of dielectric is, in fact, a limiting case of the rodded dielectric, where the rod radius r and the spacing d (c.f. last article) both tend to zero, while the spacing a must exceed $\lambda_0/2$. The metal plate dielectric was, of course, in use before the rodded dielectric was suggested, and is the oldest of the artificial dielectrics.

It might be thought that a refractive index of less than unity, implying a velocity of propagation exceeding that of electro-magnetic waves in free space, is at variance with the theory of relativity. The velocity, involved in the definition of refractive index, is the phase velocity, which may be regarded as the velocity with which the shape of a wave is propagated. The velocity with which energy flows between the plates, i.e., the group velocity, is, in fact, less than that in free space. Since this is also the velocity with which a signal is transmitted, the theory of relativity is not violated.

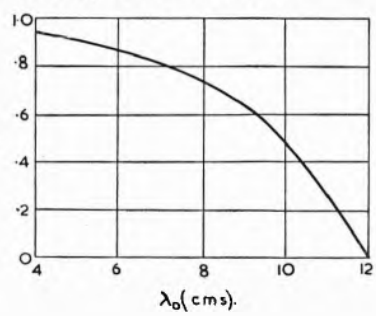


Fig. 19.
Dependence of refractive index on wavelength

The refractive index varies with the free space wavelength: i.e., the medium is dispersive. The variation is shown in Fig. 19 where the refractive index is plotted against free space wavelength for a plate spacing of 6 cms. If the wavelength exceeds 12 cms., no propagation is possible (c.f. Equation 30).

Profiles

The calculation of the profile of a waveguide lens designed to produce a pencil beam follows the same

* Radar Research and Development Establishment, Ministry of Supply.

general principles as for the dielectric lens considered in Part I, but there are two important differences[20]: the first is, of course, the fact that the refractive index is less than unity, and the second that within the lens the waves may only travel in directions parallel to the plates. This constraining action of the plates means that Snell's law does not necessarily hold at the interface of a waveguide lens, and leads to some complication in the calculation of the lens profiles. The discussion of the profiles is most simply carried out if two cases of a cylindrical lens, i.e., one which focuses the incident radiation in only one plane, are considered independently: in the first case, Snell's law is always obeyed, and in the second the constraining action of the plates is introduced.

In the first case, all the plates are of the same shape and are spaced apart at intervals a in the y-direction as shown in Fig. 20. The primary feed for this lens must be a line source extending at right angles to the plane of the diagram and producing a field whose electric vector lies in the plane of the diagram. The most general case, when both lens surfaces are curved, is shown and it is obvious that the ray path through the lens will not be parallel to the axis if the emerging beam is to be parallel. It is not possible to determine both surfaces unless some additional condition is postulated. For the simplest case, in which the outer face is to be plane, the equation of the inner face is determined exactly as in Part I, except that n is less than unity. The cartesian form of this equation is from Equation 10

$$x^2 + (1-n^2)z^2 + 2(1-n)fz = 0 \qquad (32)$$

where f is the focal length, FO. This equation now represents an ellipse, since n, which is the eccentricity, is less than unity. In this special case of a plane outer face, the ray path through the lens must be parallel to the axis, since the outer face cannot contribute to the collimation of the beam.

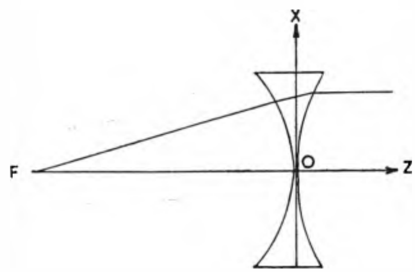


Fig. 20.
E-plane cylindrical lens

In the second case, shown in Fig. 21, all the plates are rectangular in shape and extend at right angles to the diagram in which direction they are all of the same length. In the plane of the diagram they are of varying length, as shown. The primary feed once again extends at right angles to the plane of the figure and must radiate a field having its electric vector also in this direction. Within the lens the ray paths are necessarily parallel to the axis, and so Snell's law will not necessarily be obeyed at the lens surfaces. The equations of the lens surfaces must satisfy a relation obtained from the condition that the optical path lengths must be such as to produce a plane phase front emerging from the lens. If the equations of the two lens surfaces are $z = f(x)$ and $z = g(x)$, then it follows immediately by considering the paths FOC and FAB, that

$$f+g(x)=n\left\{g(x)-f(x)\right\}+\left[x^2+\left\{f+f(x)\right\}^2\right]^{\frac{1}{2}} \qquad (33)$$

since the points A and B have the co-ordinates $[x, f(x)]$ and $[x, g(x)]$ respectively. Once again some further condition is necessary for the complete determination of both surfaces. If this condition be that the outer face be plane, i.e., $g(x) = 0$, then Equation 33 reduces to

$$f = -nf(x) + \left[x^2 + \left\{f + f(x)\right\}^2\right]^{\frac{1}{2}} \qquad (34)$$

and so the equation of the inner surface becomes, after some simplification,

$$x^2 + 2(1-n)fz + (1-n^2)z^2 = 0 \qquad (35)$$

which is identical to Equation 32. It is only in this special case of a plane outer face that the two types of cylindrical lenses discussed here have identical profiles. The distinctive feature of this case is that in the first type of lens the ray paths are parallel to the lens axis.

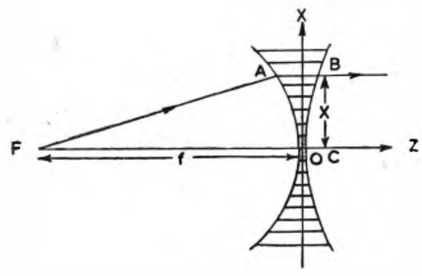


Fig. 21.
H-plane cylindrical lens

It is evident from this discussion of cylindrical lenses that the design of a spherical lens must be approached with some care. The special case of a plane outer face is the simplest since the contours in both planes of the spherical lens are identical. This, of course, follows from the results of the discussion on cylindrical lenses above. It may be shown by further analysis that the inner face of the spherical lens is the surface of revolution obtained by rotating the curve of Equations 32 or 35 about the z-axis. When both surfaces are curved, however, the cross-sections of the spherical lens in the electric and magnetic planes are not identical and so the lens will not be a simple solid of revolution. The calculation of the equations of the surfaces in this case is a matter of some complexity.

It is possible, however, to obtain a symmetrical spherical lens even though both surfaces are curved. This is achieved by inserting conducting plates at right angles to the original set, so that the waves passing through the lens are constrained in both planes, to travel parallel to the lens axis. If it is only desired that the lens should operate with the original plane of polarization, then the spacing between the additional plates is not critical but should preferably be less than the free space wavelength. On the other hand, if this spacing is also made equal to a, then the lens will operate for any plane of polarization as may be seen by resolving the incident electric vector into two components respectively parallel to the two sets of plates. There are two simple methods of constructing symmetrical lenses: (i) the various plates may have slots cut in them and are then fitted together just as are the spacing sections in an egg-box; for this reason such lenses are often referred to as egg-box lenses: (ii) the lens may be assembled from tubes of square cross-section welded together. The contours of spherical egg-box lenses are obtained by rotating the curves of the cylindrical lenses of the constrained type about the z-axis.

It is, of course, possible to apply the stepping process, described in Part I with reference to dielectric lenses, and in practice all metal plate lenses, with the exception of the very smallest, are stepped. The modifications required to the contour equations are quite straightforward and may be derived as for the dielectric lens. When the outer surface of the lens is plane and the inner surface is stepped, which is the commonest case, the equation of the jth curve $P_{j-1}Q_j$ (see Fig. 22) is

$$x^2 + (1-n^2)z^2 + 2fz(1-n) + 2(j-1)nz\lambda - (j-1)^2\lambda^2 - 2(j-1)f\lambda = 0 \qquad (36)$$

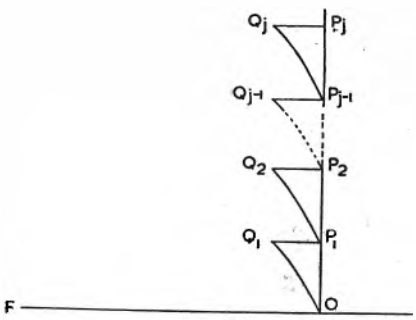


Fig. 22.
Stepped lens

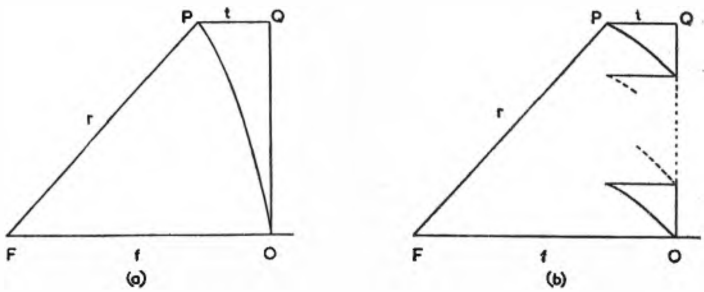


Fig. 23.
Lens contours for bandwidth discussion
(a) Unstepped lens. (b) Stepped lens.

This equation will apply to either of the two types of cylindrical lens, because of the special symmetry when the outer face is plane, and the spherical case may be obtained by rotation about the z-axis.

So far in this article it has been tacitly assumed that all the plates used in the construction of metal plate lenses are perfectly conducting and infinitely thin. The conductivity of metals such as aluminium, copper, etc., is so high that the attenuation of the wave caused by the finite conductivity is negligible, being of the order of 0.02 db. for lenses of practical thickness. If the spacing between the plates is maintained at the correct value, then plates of reasonable thickness may be employed without any deterioration of the radiation pattern and only a slight loss of gain. At a wavelength of 10 cms., for example, aluminium plates $\frac{1}{8}$ inch thick may be safely used in the construction of lenses.

Tolerances and Bandwidth

Metal plate lenses (this now being taken to include the case of egg-box lenses) are subject to the same tolerances on lens thickness and refractive index as the metallic delay lenses discussed in Part II. Since the refractive index depends both on the plate spacing, a, and the free space wavelength, λ_0 (Equation 31), the tolerance on the refractive index imposes a tolerance on the plate spacing and a limitation on the range of wavelengths over which the lens may be used.

The tolerance on the plate spacing (δa) is readily obtained by differentiating Equation 31 and is

$$\delta a = 4a^3\, n\delta n/\lambda_0^2 \qquad (37)$$

Substituting the value $\delta n = \lambda_0/16x$ from Equation 25, where x is the lens thickness, there results,

$$\delta a = a^3\, n/4x\lambda_0 \qquad (38)$$

Consider the case of a lens operating at 10 cms. with a refractive index of 0.6 whence the plate spacing a is 6.25 cms. If the lens is unstepped and of thickness 50 cms. (a high value) the tolerance δa is approximately 0.8 mm. It is possible to insert metal spacers at right angles to the plates and so this tolerance on the plate spacing may be satisfied. Since these spacers are at right angles to the electric vector, they will exert only a small influence on the performance of the lens. If the lens is stepped its maximum thickness is approximately $\lambda_0/1-n$, i.e., 25 cms., for the above wavelength and refractive index. The tolerance on plate spacing for a stepped lens is therefore about 1.5 mm. and does not depend on the number of steps.

The discussion of the bandwidth of metal plate lenses is complicated by the dependence of the equation for the profile of a stepped lens on the design wavelength.[20] Stepped and unstepped lenses will therefore be considered separately. It may be readily shown that the maximum phase error, arising when an unstepped lens is operated at a wavelength differing from the design wavelength, occurs at the outer edge of the lens where the thickness is a maximum. The phase difference in radians between the two points O, Q on the outer surface of the unstepped lens of Fig. 23a is

$$\phi = 2\pi(r + nt - f)/\lambda \qquad (39)$$

At the design wavelength λ_0, this difference must be zero, and so

$$f - r = n_0 t \qquad (40)$$

Equation 39 therefore gives the phase error at the outside of the lens when the wavelength differs from λ_0, and so on substitution from Equation 40 the phase error becomes

$$\phi = 2\pi(n - n_0)t/\lambda \quad \text{.................. (41)}$$

If the wavelength λ differs from the design wavelength λ_0 by the small quantity $\delta\lambda$, then it may be shown by differentiating Equation 31 that

$$n = n_0 - \frac{(1-n_0^2)\ \delta\lambda}{n\ \ \lambda} \quad \text{.............. (42)}$$

and so the phase error is

$$\phi = \frac{2\pi(1-n_0^2)t\ \delta\lambda}{n_0\lambda_0\ \ \lambda} \quad \text{.............. (43)}$$

Since the amplitude distribution is usually tapered off at the edges of the lens, a larger phase error can be tolerated than the value of $2\pi/16$ radians used in discussing the random errors arising from variations in lens thickness and plate spacing. In fact, Kock has verified experimentally that phase errors of up to $2\pi/8$ radians are permissible at the outer edge of the lens, before the radiation pattern deteriorates noticeably. When this value is substituted in Equation 43, the maximum permissible deviation in wavelength $\delta\lambda$ is obtained. Let B be the bandwidth expressed as a percentage of the design wavelength and allowing for both positive and negative values of $\delta\lambda$. Then B is given by

$$B = \frac{25n_0\ \ \lambda_0}{(1-n_0^2)t} \quad \text{.................... (44)}$$

When $n = 0.6$ the bandwidth will be

$$B = \frac{75\ \ \lambda_0}{8(1-n_0)t} \quad \text{.................... (45)}$$

For reasonably large unstepped lenses, $(1-n_0)t$ will be several times the wavelength λ_0, so that the bandwidth will never exceed a few per cent and decreases as the size of the lens increases.

In the case of a stepped lens (Fig. 23b) the phase error is again worst at the edge, provided that the lens contains a number, say j, of complete zones. The phase difference between the two points O, Q will be $2\pi(j-1)$ radians at the design wavelength because of the stepping process and so

$$r - f = (j-1)\lambda_0 - n_0 t \quad \text{................. (46)}$$

At any other wavelength the phase difference between the points O, Q will be given by Equation 39. The phase error ϕ' is obtained from this by subtracting the desired phase difference of $2\pi(j-1)$ radians and becomes after substitution from Equation 46

$$\phi' = 2\pi/\lambda[(j-1)(\lambda_0 - \lambda) + (n - n_0)t] \quad \text{........ (47)}$$

When λ is replaced by $\lambda_0 + \delta\lambda$ and the value of n given by Equation 42 is inserted, Equation 47 reduces to

$$\phi' = 2\pi\delta\lambda/\lambda \,.\, [(j-1) + (1 - n_0^2)t/n_0\lambda_0] \quad \text{.... (48)}$$

For a stepped lens $(1-n_0)t = \lambda_0$, and so the bandwidth for the same phase error as above may be readily obtained and is

$$B = 25n_0/(1 + jn_0) \quad \text{.................. (49)}$$

If $n = 0.6$, the bandwidth of a lens having three steps will be about 5.4 per cent. An unstepped lens of the same aperture will have a maximum thickness given by $(1-n_0)t = 3\lambda_0$ and so its bandwidth will be only 3.1 per cent, which is considerably less than for the stepped lens. It may be shown that a stepped lens has always a greater bandwidth than an unstepped lens of the same aperture. Since it was shown above that a stepped lens also has a greater tolerance on plate spacing than the corresponding unstepped lens, it will be seen that the case for stepping metal plate lenses is a strong one.

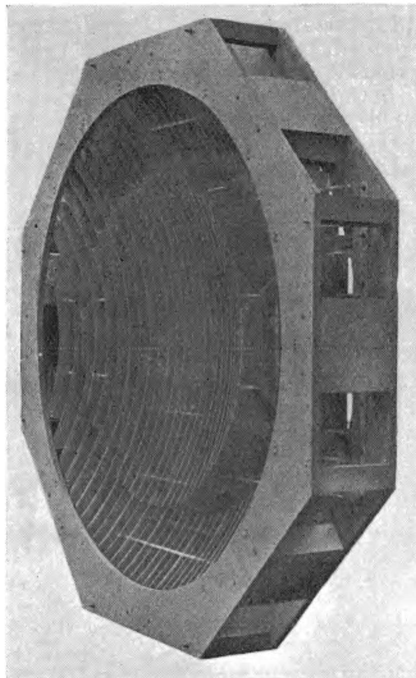


Fig. 24.
8 ft. metal plate lens

Bandwidths of the order of a few per cent are quite sufficient for many practical purposes, but, if required, metal plate lenses may be made to operate over a larger range of wavelengths than that given by the above relations.[20] It may be shown that for small changes in wavelength the effective focal length of the lens is changed, and that most of the phase error caused by the change in wavelength may be removed by an alteration in the position of the primary feed. Accordingly, if provision is made for adjusting the primary feed position the range of wavelengths over which the lens will operate successfully is increased.

A second method of increasing the bandwidth is to make an achromatic doublet, i.e., to combine two lenses with opposite frequency characteristics just as is done in optics. A metal plate achromatic doublet may consist of a combination of a convergent stepped lens with a divergent unstepped lens, the combination being such as to produce a pencil beam from a point source.

Methods of Construction

For wavelengths from about 3 to 11 cms., metal plate lenses are most easily made by using sheets of aluminium or copper and maintaining the correct spacing by means of metal spacers. The lens shown in Fig. 24 is constructed in this way and the spacers may be clearly seen. This lens is 8 ft. in diameter and is designed for a wavelength in the 10 cm. region, the refractive index being 0.6. It has one step which may be clearly seen in the photograph. A lens with several steps and intended for use in the 3 cm. band has already been shown in Part I.

When the wavelength is less than 3 cms. it becomes difficult to maintain the tolerance on plate spacing by the above method: in addition, the thickness of the metal plates required to achieve a rigid construction becomes objectionably large in terms of the design wavelength. It has been suggested by the Bell Telephone Laboratories that at these wavelengths the spacing be maintained by the light weight

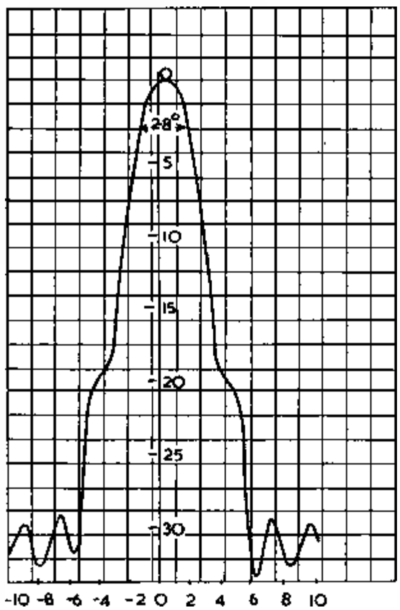


Fig. 25.
E-plane radiation pattern of 8 ft. lens

foam plastics used in the construction of delay lenses and that the metal plates take the form of thin sheets of metal foil.

Kock has also suggested replacing each metal plate by a curtain of wires, such a system being possible at longer wavelengths. If the spacing between the wires is less than $\lambda_0/4$, then each curtain will behave electrically in almost exactly the same way as the metal plate it replaces. Such a system is a special case of the rodded lens discussed at the end of Part II, and it appears that when this type of construction is possible, it is preferable to use a rodded lens of the more general type described in Part II. The principal difference between metal plate lenses and rodded lenses is that the latter impose no constraints on the direction in which the waves flow, and thus more nearly approximate the homogeneous nature of a solid dielectric lens.

Performance of Metal Plate Lenses

A considerable amount of experimental work has been carried out both in this country and in America on metal plate lenses. It has been found that the shape of the radiation pattern of such lenses agrees well with theoretical predictions; a typical pattern, that for the E-plane of the lens shown in Fig. 24, is shown in Fig. 25. The level of the first side-lobe is about 22 db. below that of the main beam, a normal value for a well designed lens. This side-lobe level is about the same as that of a delay lens and compares well with that of paraboloids which rarely exceeds 16 db. below the main beam. On the other hand, the gain of a waveguide lens is invariably lower than that of a paraboloid of the same aperture size: the reasons for this will be discussed in Part IV.

Circular Polarization

The metal plate structure of Fig. 26 may be used to produce a circularly polarized wave from an incident plane polarized wave. If the electric vector is inclined at 45° to the plane of the plates, it may be resolved into two components respectively parallel and perpendicular to the plane of the plates. The wave whose electric vector is parallel to the plates

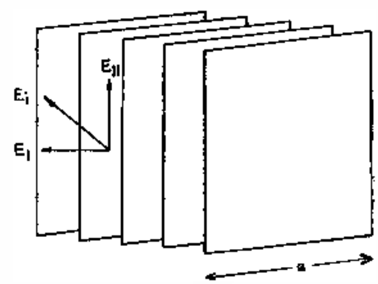


Fig. 26.
Metal plate structure to produce circular polarization

will be propagated through the stack of plates as though it were a dielectric of refractive index n, while the wave whose electric vector is perpendicular to the plates will be propagated through the stack in exactly the same way as through free space. These two waves will therefore undergo different phase changes in traversing a length l of the plates, the phase difference between them being $2\pi l(1-n)/\lambda$ radians. If the length l is selected so that this phase difference becomes $\pi/2$ radians, the two waves will combine on emerging from the plates to form a circularly polarized beam. The length l required in order to achieve this is $\lambda/4(1-n)$. Experimental verification of this shows that the length l, which actually produces circular polarization, differs slightly from this value, the reason for this being the reflexion effects which occur at the interfaces of the stack.

(To be continued)

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Reactive Circuits as Computers and Analogues

By D. A. BELL, M.I.E.E.

THE idea of an *R-C* combination of short time-constant as a "differentiating" network is very familiar, and the idea of a capacitor-charging circuit as an integrator arises from time-base work; but the exploitation of capacitive or inductive circuits for solving differential (or integral) equations requires some refinements, the technique for which has developed during the past ten years. The term "reactive-circuit computer" is here suggested, in preference to the more usual "electronic computer or analogue," in order to emphasise the distinction from electronic *digital* computers, which are very much more elaborate.

The use of reactive-circuit computers for gunnery "predictors"[8,9] illustrates the point that they are applicable where the numbers of computers required would prohibit the use of the bulky and costly digital electronic computer, and there is the same argument for the use of these computers in industrial problems.[10] Their limitation is that the accuracy of answer depends on accuracy of reading a current or voltage, and cannot be increased by using more intricate circuits; digital computers, on the other hand, can be made as accurate as may be required at the cost of adding more circuits to provide additional digits, and with only on/off output indications.

Apart from computers which form part of the working system of some piece of equipment, the other main use of these differentiating and integrating circuits is in "analogues"[1,2] or "simulators,"[3] which are devices to cause electric current (or voltage) to vary with time in the same way as some mechanical property of an actual system (e.g., position or speed of a rotating shaft, temperature of a temperature-controlled system, etc.). The reasons for constructing an analogue, rather than experimenting on the actual system, may include the following:—

(1) The analogue is not liable to damage if operated in "fault" conditions.

(2) The time-scale may be either faster or slower than that of the actual system, to facilitate observation.

(3) Adjustments are easily made to the analogue until a satisfactory result is seen to be achieved. One can then try to modify the actual system to have the same characteristic equation as the successful analogue.

The object of the present paper is to examine the general principles involved in these computing circuits, and suggest reasons for the concentration of technique on a very few of the possible circuit arrangements.

Many mechanical systems can be represented to a reasonable approximation by linear differential equations with constant coefficients, and such equations need the following mathematical operations:—

(i) Add and subtract.

(ii) Multiply a variable by a constant.

(iii) Either differentiate or integrate.

A differential analyser for solving more general equations would also have to perform a fourth operation:—

(iv) Multiply together two variables.

Operation (iv) is difficult to perform accurately. It is necessary for a machine designed to solve mathematical equations in general (a differential analyser), but is unnecessary in the analogue treatment of many mechanical systems, and falls outside the scope of this article. For reference, however, the main methods of multiplication are summarized as follows:

1. Mechanically by a servo-driven potential divider.[3]

2. Electronically by using a modulator (which is essentially a multiplying device). If the two inputs to the modulator are at different frequencies it is possible to use negative feed-back of the individual frequencies to linearise the modulator, as has been suggested in frequency modulators.[7]

3. Electronically by taking logarithms, adding and taking the antilogarithm. Devices for electronically converting into logarithms and back again can be based on the exponential law of current versus voltage which occurs when electrons have to pass a potential barrier, e.g., in barrier-layer rectifiers or in retarding-field diodes.

4. Electronically by the method of "quarter-squares" (see the last instalment of Mynall's paper[4]), which uses the identity

$$A \times B = \tfrac{1}{4}\left[(A + B)^2 - (A - B)^2\right].$$

Subtracting is provided for (operation (i)) and squaring can be done by using a pair of approximately square-law valves with push-pull input and parallel output to eliminate the residual linear term and odd harmonics.

5. "Electron-mechanically"[1] by the combination of a cathode-ray tube and a mask cut to the shape of one of the functions. This is similar to the servo-driven potential divider, but with electronic deflexion instead of a servo motor and with a varying second voltage produced by photo-following the mask edge in place of the second voltage which is applied across the potential divider in method 1.

6. By "crossed fields" and electron beams.[11,12] This method depends on the fact that a moving electron is equivalent to a current, and when moving through a magnetic field it experiences a magnetic force proportional to its velocity and at right angles both to its direction of motion and to the direction of the magnetic field. Consider then a C.R.T. with a deflecting voltage applied to the first (Y) pair of plates. When the electron beam enters the second (X) pair of plates, it has a velocity along the Y axis, as well as the forward velocity towards the screen. A coil is wound round the tube near the X plates, so as to produce a longitudinal (Z) magnetic field (like a focusing coil). The combination of Z magnetic field and Y velocity will produce an X deflexion,

which is annulled by means of a photocell detector feeding back voltage to the X plates. The output is then the voltage on the X plates.

It is also fairly easy to represent electronically non-linear systems which are excessively complicated to handle mathematically. Biased diodes[3] and metal rectifiers can represent respectively discontinuous linearities such as back-lash or "stiction" and continuous non-linearities such as friction varying with speed or saturation of magnetic circuits.

The basis of performing electrically operations (i), (ii) and (iii) is a circuit for obtaining an output voltage proportional to the current in a circuit, while leaving the current strictly proportional to the input voltage only. In every case there is a current-determining impedance (which must be high) and a current-to-voltage transforming device of which the impedance must be low enough to have negligible effect on the magnitude of the current. The latter device is therefore similar to the shunt used with a millivoltmeter to make an ammeter; and the essential feature of analogue technique is the use

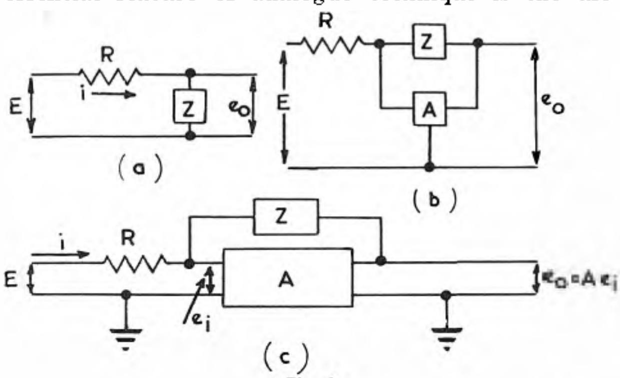


Fig. 1.

(a) Basic circuit for operations (i), (ii) and (iii)
(b) Shows the feed-back amplifier added
(c) A more conventional layout of (b)

of negative-feed-back amplifiers to minimize the effect on the circuit current of the current-operated device. In the simple circuit of Fig. 1(a) the whole of the output voltage e_o operates to disturb the flow of current i. (If Z is a pure resistance, e_o simply opposes the current; but if Z is a reactance, as in a differentiating or integrating circuit, e_o is in quadrature with i and tends to change the phase as well as the magnitude of the current). The modified circuit with a feed-back amplifier is commonly drawn as in Fig. 1(b), but is more easily understood if drawn as Fig. 1(c). As a result of the input voltage e_i there will be an output voltage from the amplifier of magnitude Ae_i. The impedance Z is then connected between two points having potentials (relative to earth) of e_i and Ae_i, so that the current flowing through it is

$$i_z = (1 - A)e_i/Z \quad \text{.................} \quad (1)$$

But if A has practically infinite input impedance, i_z must be equal to i; and therefore with i determined by R, e_i is to be deduced from i by means of Equation (1):

$$e_i = Zi/(1-A) \quad \text{........................} \quad (2)$$

whence

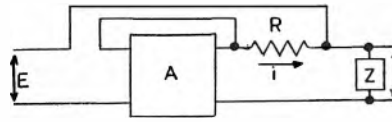
$$e_o = Ae_i = Zi \,.\, A/(1-A) \quad \text{...............} \quad (3)$$

To get a useful result A must be made negative, so write $A = -a$: then for large values of a the factor $-a/(1+a) \rightarrow -1$ so that the output voltage is of the same magnitude as if Z had been directly in circuit as in Fig. 1(a) but has its phase reversed. The disturbing voltage in the current circuit, on the other hand, is now only $e_i = e_o/(1+a)$, and for the same output voltage is reduced by the amount of the voltage amplification ratio of the feed-back amplifier.

Instead of lowering the effective impedance of Z we might in principle have raised the impedance of the current-controlling circuit by using an amplifier with current-derived negative feed-back, as shown

Fig. 2.

Higher impedance current control using current-derived feed-back



schematically in Fig. 2, to represent an infinite-impedance source of current. There are two practical difficulties which make the scheme unattractive:

(a) It is difficult to contrive the current-derived feed-back while still having an earth on one side of both input and output circuits.

(b) It is often convenient in the first place to use circuit elements having an impedance of the order of a megohm, and it is desirable to use a feed-back factor of at least 1,000 times. If instead of lowering the effective value of Z to a few ohms we raise the effective value of R to thousands of megohms, both leakage and capacitive pick-up are liable to be troublesome. We can now perform the operations of addition and subtraction with the circuit of Fig. 3 which is a particular case of Fig. 1(b). By the use of the high-gain feed-back amplifier A the summing resistance R_s is made to have negligible effect on the currents in the circuit, so that to a good approximation the total current is independent of R_s and is

$$i_s \approx E_1/R + E_2/R + \text{........} + E_k/R \quad \text{...........} \quad (4)$$

assuming equal resistors R in all the input branches. (For subtraction the polarity of the appropriate E's is reversed.) Using Equation (3) with A large and negative,

$$e_o \approx (-R_s/R)(E_1 + E_2 + \text{......} + E_k) \quad \text{...........} \quad (5)$$

The exact formula, to take account of finite amplification and different values of R which may be used in the individual input circuits, is given by Korn[2]:

$$e_o = -R_s \Sigma \frac{E_k}{R_k} \times \left[\frac{-A}{1 - A + R_s \Sigma (1/R_k)} \right] \text{......} \quad (6)$$

Any voltage developed across R_s tends to feed current back into all the input resistors in parallel, hence the term in the denominator of the correction factor which multiplies R_s by the sum of the input conductances, i.e., it is of the form R_s/R_e where R_e is the effective resistance of R_1, R_2, etc., all in parallel.*

* It has been claimed that the magnetic amplifier provides an ideal method of adding or subtracting a number of independent quantities without interconnecting them, by providing a separate set of windings for each of the quantities on a common magnetic core system. The author does not wish to belittle the value of the magnetic amplifier in general, but this particular claim for it is very dubious. If the quantities to be added were truly constant, the claim would be true though the result achieved would be trivial; but if at least one of the quantities is variable, there must surely be interaction via the mutual inductances between the several sets of windings on a common core system. Another objection to the usual type of magnetic amplifier for computing circuits is that the efficiency factor of the rectifier in the output circuit of the magnetic amplifier introduces a margin of uncertainty, in addition to the fact that the amplifier itself is at least as non-linear as a valve amplifier. It is therefore necessary to use negative feed-back over the magnetic amplifier, which, combined with its limited input resistance, makes it relatively insensitive.

Multiplying by a constant is easy provided that the constant is less than unity, which can be ensured by first dividing the equation through by the largest of the constant coefficients. It is then only necessary to apply the signal to a potential divider which has been set to a ratio equal to the desired (fractional) constant.

For the third operation there is a four-fold choice: one can either differentiate or integrate, and for either of these operations one can use either inductances or capacitors. Taking the second pair of alternatives first, it is almost universal practice to use capacitors because they give a nearer approximation to a pure reactance than do coils. This general proposition is particularly true at the low frequencies which are usual in analogue circuits, because dielectric loss tends to decrease with the frequency, while the reactance increases with falling frequency, so tending to infinite Q at zero frequency. The resistance of a coil, on the other hand, tends to a constant value at low frequency, while the reactance decreases with the frequency, so tending to zero Q at zero frequency. Thus, the resistance associated with self-inductance usually introduces an excessive error as indicated in Fig. 4(a), where the output

$$e_o = (L \,.\, di/dt + ri) \;\ldots\ldots\ldots\ldots\ldots\; (7)$$

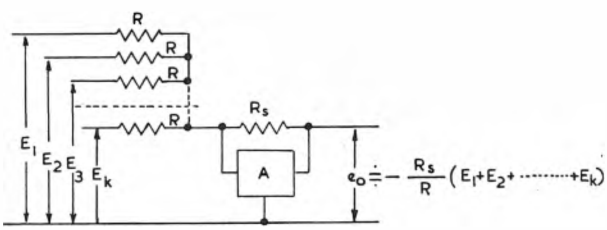


Fig. 3.
A particular case of Fig. 1 (b)

is not a true differential of i, even if the current is unaffected by the back E.M.F. e_o. However, there is a well-known device in measuring technique for avoiding the resistive impurity of self-inductance: to use a mutual inductance instead. The E.M.F. induced in the coupled coil in Fig. 4(b) is $-M.di/dt$, independent of the resistance r_1 of the primary coil; and as long as no appreciable current is drawn from the secondary, the output voltage will be independent of r_2 and will be

$$e_o = -M.di/dt \;\ldots\ldots\ldots\ldots\ldots\; (8)$$

(The sign of e_o can, of course, be adjusted as required by using either positive or negative mutual inductance.) Fig. 4(b) is thus a true differentiating circuit, and J. G. Clarke[4] has suggested its use as such, though not primarily in computing or analogue circuits. There still remain the objections that the magnitude of the inductive reactance is small at low frequencies and that Fig. 4(b) is more easily used with a constant-current generator (*cf.* Fig. 2) than with a feed-back output circuit of the type of Fig. 1(b).

Fig. 4(c) is an approach to an integrator of the inductive type, since the current in a loss-free inductance would be

$$i = (1/L)\int E.dt \;\ldots\ldots\ldots\ldots\ldots\; (9)$$

The effect of the output resistance R could be minimized by a circuit of the Fig. 1(b) type, but the only way to eliminate the effect of the internal resistance r of the coil would be to make R negative, which is likely to be a tricky arrangement.

Since it seems undesirable to use inductive circuits on account of unavoidable resistance, the question is whether to use capacitor circuits as differentiators or as integrators. At first sight it might seem obvious to use differentiators, since an integrator can so quickly become "full" and have to be reset to zero. In Fig. 5(a) we have a circuit giving $e_o = (1/C)\int i.dt$, and clearly the integrating process must be stopped when e_o approaches in magnitude the voltage of the source driving the current i, or failing that when it approaches the break-down voltage of the capacitor, but no such limit is obvious in the circuit of Fig. 5(b) where $e_o = Ri \approx CR.dE/dt$. But consider the waveforms of input and "differentiated" output in Fig. 6. In Fig. 6(b) the input has twice the slope of that in Fig. 6(a), so the output has twice the amplitude. But in Fig. 6(c) we have gone to the limit with a square step of input (infinite slope). Ideally the output should now be a

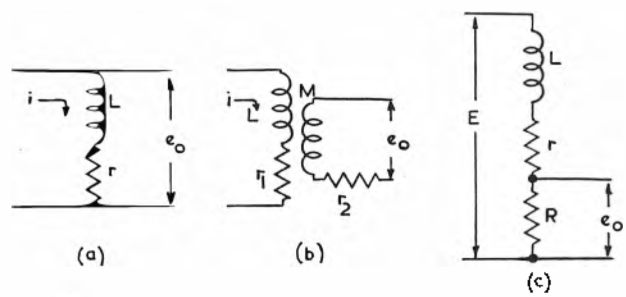


Fig. 4.
(a) Self-inductance introducing error
(b) The remedy: use a mutual inductance
(c) Inductive type of integrating circuit

pulse of infinite height and zero width, but in fact it is merely a pulse of height equal to the height of the input step, and of width governed by the CR product. So the differentiating circuit is limited in relation to the steepness of slope it can handle, just as much as the integrating circuit is limited to a finite time of integration. The practical reason for preferring the integrator to the differentiator seems to be that any interference is likely to be at a higher frequency than the signal (e.g., distortion products generated in a valve amplifier) and the circuit of Fig. 5(a) will tend to attenuate high frequencies while Fig. 5(b) would exaggerate them.

The application of a constant voltage to an integrator of the type of Fig. 5(a) is intended to produce a voltage e_o which rises linearly with time, and in fact the most familiar example of an integrator is the linear time-base generator. But since the RC product is finite, the rise of voltage in the Fig. 5 type of circuit is in fact exponential, $e_o = E(1 - \varepsilon^{-t/CR})$. By expanding the exponential in powers of t/CR it can be shown[2] that the time for which integration may be allowed to continue is related to the tolerable percentage error P by the

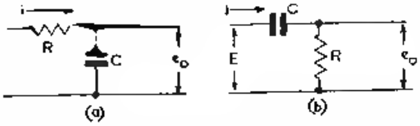


Fig. 5. Capacitive integrator (a) and differentiator (b)

formula

$$t_{max} = PRC/50 \quad \text{.................. (9a)}$$

and the corresponding output voltage is then related to the supply voltage by

$$e_{max} = PE/50 \quad \text{.................... (9b)}$$

The use of a feed-back amplifier across the capacitor, on the principle discussed in relation to Fig. 1, multiplies the effective value of the capacitor capacitance (because it reduces the potential rise across the amplifier input for a given current flow into the integrating system) and hence increases the time-constant of R and C. Because the back E.M.F. in series with the charging resistance is reduced below the output voltage by the amplification ratio of the feed-back amplifier, the output can now be a correspondingly larger proportion of the source voltage than that given by Equation (9b). A particular example of this is the Miller integrator (or Miller-Blumlein-Whiteley time-base circuit) which uses a single-valve amplifier with capacitor directly between anode and grid. However, it is not possible to obtain adequate gain from a single valve for really accurate work, and it is usual to employ something like a 3-stage D.C. amplifier.

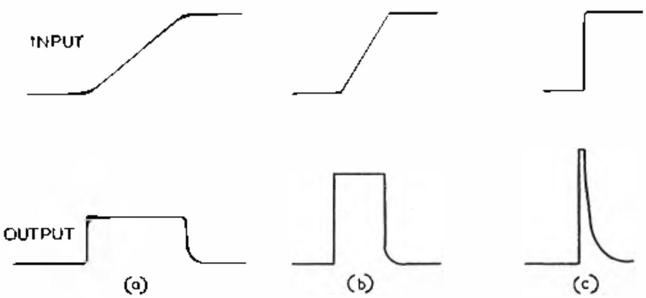


Fig. 6.
Input wave shapes and corresponding differentiated output pulses

The error caused by imperfection of the integrating or differentiating circuits depends on the particular application, but in general it results in the analogue representing a system with more dissipation (e.g., more frictional loss in a mechanical system); and since all real systems have some dissipation it is frequently possible to allow for the inherent dissipation factor of the integrators by setting to a smaller value the factors in the analogue which are deliberately included to represent the dissipation. The damping effect is illustrated in Fig. 8 of F. C. Williams' paper,[3] where it is seen that an amplification of 1,400 times in the feed-back amplifiers of the integrators still leaves a detectable error in the representation of an under-damped mechanical system. In a recent example[6] of equipment for setting up analogue circuits, the feed-back amplifier circuits have a gain of 2,500 times.

The fact that the CR circuit is not a true integrator or differentiator can be demonstrated by taking the extreme case of the equation.

$$d^2y/dt^2 + y = 0 \quad \text{............. (10)}$$

which represents a system capable of undamped sinusoidal oscillations of frequency $1/2\pi$ (e.g., an LC circuit of infinite Q and with the LC product equal to unity.) If we attempt to represent d^2/dt^2 in this equation by cascading two of the "differentiating" circuits of Fig. 5(b), the equation of the electronic circuit which is supposed to represent (10) will be

$$\frac{d^2y}{dt^2}\left[+\frac{1}{RC}\cdot\frac{dy}{dt}+\frac{1}{2R^2C^2}\cdot y = 0\right] \text{...... (11)}$$

This looks like the equation of a damped oscillation of frequency $1/2\pi RC$ and with Q of unity only. Practically, of course, two stages of Fig. 5 coupled together in a loop by amplifying valves constitute a multivibrator, and not a sinusoidal system.

It is convenient to insert buffer-driver stages between successive operative networks, so that the output of the earlier circuit can be connected to a high impedance load, while the later circuit is driven from a low impedance source, and such stages should give a voltage transfer ratio which is independent of valve characteristics. The simplest choice for the buffer stage is a cathode-follower, but it has the defect that the output voltage is always a trifle less than the input voltage—perhaps 1 per cent less. The same is true of the "anode-follower," which also has a lower input impedance. Probably the best is the "see-saw" circuit[5] in which the circuit values can be adjusted to compensate for the finite amplification of the valve and give an output voltage exactly equal to the input voltage. Although the aim is to make the *voltage* amplification equal to unity in all these circuits, they give a considerable *power* gain, because the input impedance is high but the output impedance low.

The combination of the various circuit elements to make a complete computer or analogue must be varied to suit each particular application, but a number of examples have been described in the literature, and they are being increasingly used as their convenience is appreciated.

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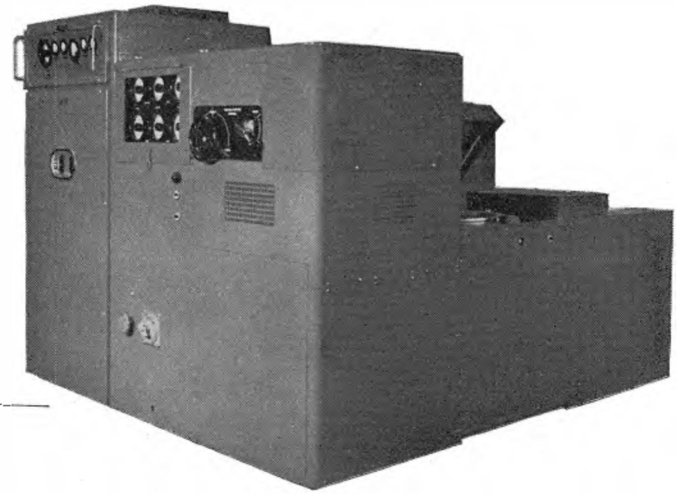
A New Induction Heating Equipment . . .



THE Ford Motor Company of England have just taken delivery of an induction heating equipment for the production of starter ring gears.

The special requirements with regard to the range of sizes to be treated, simplicity of operation and the avoidance of coil changing were as follows:

1. To harden the teeth in three sizes of starter rings varying between 10.2 in. diameter by 0.312 in. thick and 16.2 in. diameter by 0.5 in. thick to approximately 0.1 in. below the roots. This depth to be controllable within limits.
2. To remove each of the rings from the quench bath at a predetermined rate so that they emerge at a temperature of approximately 200° C. for stress relief.
3. The equipment should be capable of being operated by unskilled labour.
4. Change-over from one size ring to another to be effected simply and rapidly. Coil changing to be carried out automatically within the machine.
5. The rate of production to cover a total output of 900 small, 240 medium and 220 large rings per 18 hours.

The equipment was supplied by Redifon, Ltd., and comprises the following:

1. a standard 25-kW radio frequency oscillator Type IH.5;
2. power supply unit for the oscillator;
3. a loading station consisting of the actual work coils, locating frame and quench bath.
4. a sequence timing control unit.

The complete assembly—less the power supply unit which can be located at a convenient distance from the operating equipment—is shown in Fig. 1 (see above).

Method of Operation

After a ring is placed in the circular locating frame at the loading station (Fig. 2), the lid is closed and the subsequent sequence of operating events is entirely automatic.

The ring is passed to a hydraulically operated carriage which conveys it to a position immediately below the heating coils. Internally operated mechanical fingers then raise it from the carriage into the heating coil (Fig. 3). The carriage then returns to the loading station and the lid opens ready for the next ring to be inserted at the operator's convenience.

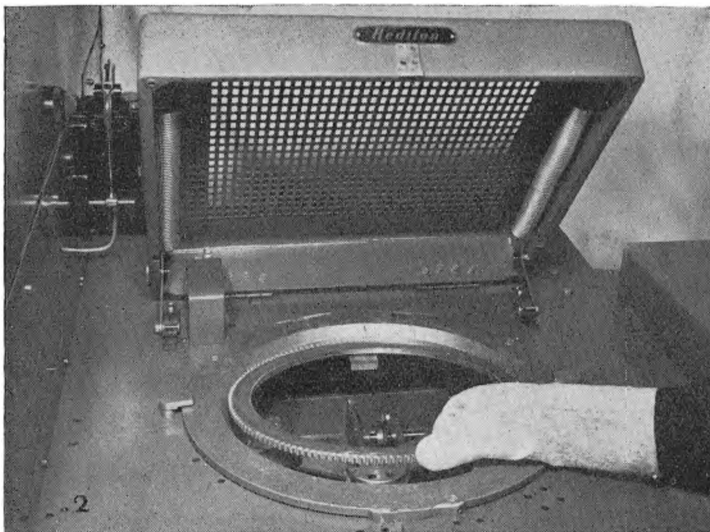
When the ring is in position inside the heating coil the R.F. power is automatically applied. At the Curie point a power-factor correction capacitor is brought into circuit to provide correct matching.

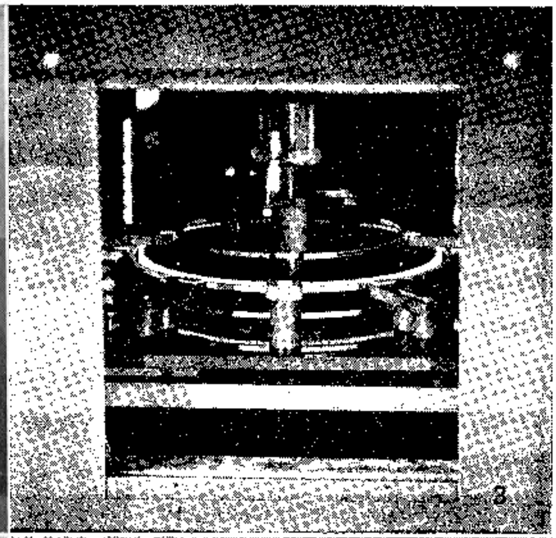
On the completion of the heating cycle the fingers release the ring so that it drops into the quench bath beneath. A wire mesh conveyor then removes it from the water and delivers it to the ejection bay. Heat exchanger coils are incorporated in the tank to limit bath temperature. The speed of the belt is regulated to ensure that the delivery temperature is of the order of 200° C. for stress relief, the necessary turbulence being created by the passage of the belt through the quench.

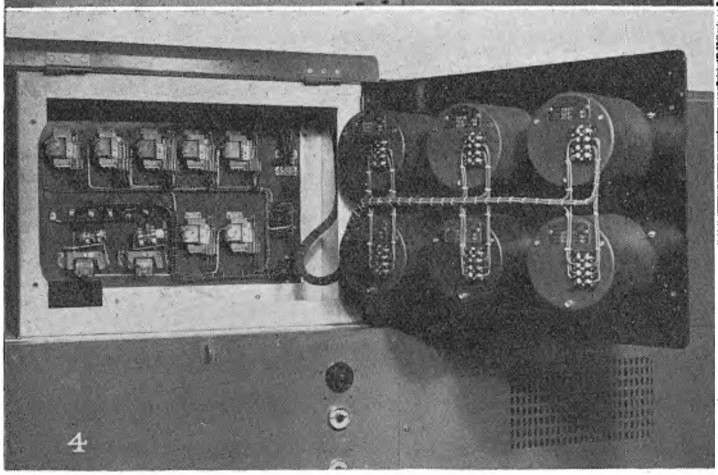
Preselection and Trimming

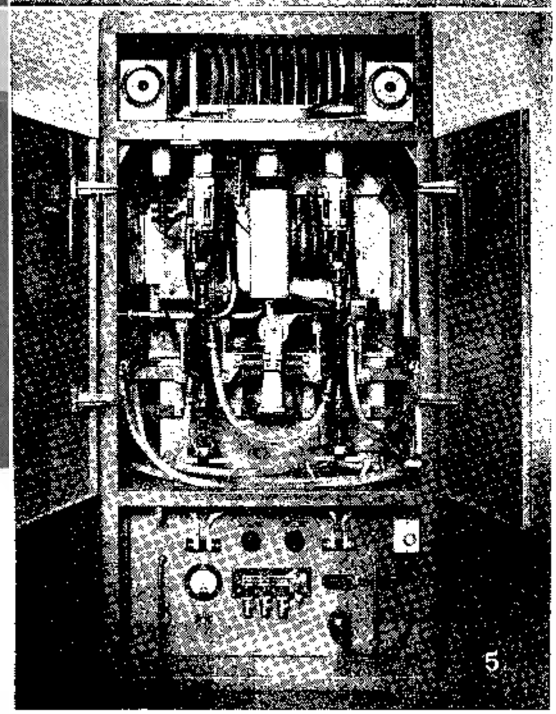
Changing production from one size to another is an extremely simple operation occupying a matter of only 30 seconds. The lever on the front panel of the loading station is put in the "reset" position and the correct locating frame is placed in the loading station. The main control wheel is then turned to the appropriate position for "small", "medium" or "large" rings and the lever reset to the "ready" position. The conveyor speed control is then adjusted to the correct setting which is indicated by the lighting up of a neon lamp.

Circuit pre-selection and process timing are all automatic and are controlled by an interlocking switch circuit operated by contacts on the locating frame and on the control wheel. The system is foolproof and R.F. power cannot be applied until controls are properly matched and the correct size ring inserted. This is checked by pressing the "on" button on the sequence timing control unit, when a blue lamp lights up indicating that the setting is correct and the hydraulic system is ready for operation.









Considerable attention has been paid to the selection of component parts and materials for the equipment to ensure its continuous and reliable service. A typical example is the provision of a built-in "one-shot" lubricating system.

The entire equipment, including the self-contained water cooling unit, occupies a total floor area of 18 ft. by 8 ft.

Fig. 1 (See p.236)

A general view of the Redifon gear hardening equipment developed for the Ford Motor Company. On the left is the IH.5 generator and front panels carry the process timers and controls. The raised lid of the loading station can be seen at the middle of the right-hand side. Hardened rings are delivered at the far end of the " bench-height " section

Fig. 2

A close-up of the loading station, showing a ring being inserted in the locating frame. The closing of this lid performs all the switching operations for the complete hardening cycle

Fig. 3

An unretouched photograph of the interior of the equipment showing a medium size ring in the course of being heated. Heating coils for the smaller and larger rings can be seen immediately above and below

Fig. 4

The Sequence Timing Control section of the Redifon Gear Hardening Equipment with the timing unit panel swung open. The relays control the hydraulic and electro-magnetic actuating mechanisms of the machine

Fig. 5

Rear view of Generator, showing oscillator bay and stabilized filament supply unit. The instruments at the top indicate anode cooling water pressure and temperature, and ensure that neither exceeds a safe level

A Critical Survey of Some

Phase-Angle Measurements

Using a Cathode-Ray Tube

By F. A. BENSON, M.Eng., A.M.I.E.E. *and* A. O. CARTER, M.Eng., A.M.I.E.E.
(*The University of Sheffield*) (*The University of Liverpool*)

THE cathode-ray tube is still widely used for determining the phase-angle between two quantities. One of the simplest methods of making the measurements is to produce two voltages proportional to the quantities and apply one voltage (maximum value V_1) to the vertical deflector plates of the tube and the other voltage (maximum value V_2) to the horizontal plates. These voltages will give deflexions on the screen of the tube $Y = k_1V_1$ and $X = k_2V_2$ where k_1 and k_2 are constants which depend on the sensitivity of the tube. Account must be taken of any distortion, etc., in producing the required voltages at the deflector plates.

First Method

If voltage V_2 leads voltage V_1 by an angle α, an ellipse will result (provided the voltages are sinusoidal) which is bounded by a rectangle with sides $2X$ and $2Y$ (Fig. 1). Since this ellipse cuts the horizontal axis at a distance $X \sin \alpha$ from the origin O, then $\sin \alpha = OC/OD$ and so α can be found from measured values of OC and OD.

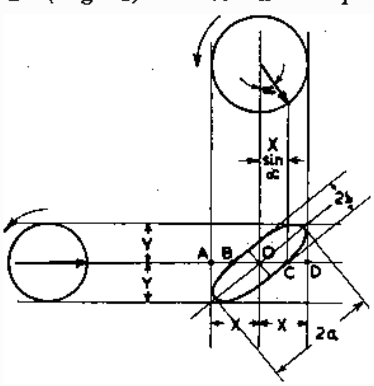


Fig. 1.
Voltage V_2 leading V_1 by an angle α

In practice, however, it is easier to measure the ratio of $2OC/2OD$ rather than OC/OD since then it is unnecessary to determine the position O. In this case $\sin \alpha = BC/AD$.

Second Method

An alternative method is to measure the major and minor axes of the ellipse, $2a$ and $2b$ respectively, together with $2X$ and $2Y$.

Then, the area of the ellipse $= \pi ab = \int_{\theta=0}^{\theta=2\pi} y\, dx$

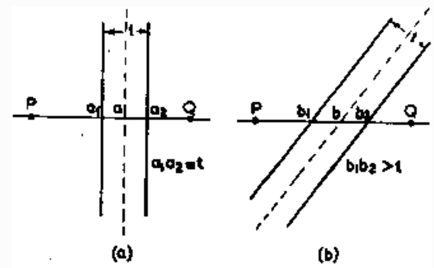


Fig. 2.
Measuring the axes of the ellipse

where

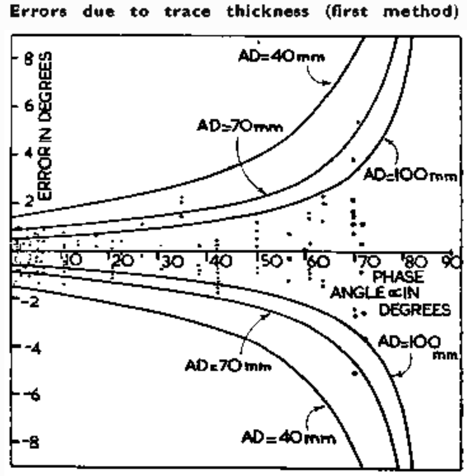
$$y = Y \sin \theta$$
$$x = X \sin (\theta + \alpha)$$
$$\therefore \pi ab = \int_{\theta=0}^{\theta=2\pi} Y \sin \theta \, . \, X \cos (\theta + \alpha)\, d\theta = \pi XY \sin \alpha$$

Thus α can be calculated from the expression:—

$$\sin \alpha = \frac{(2a)(2b)}{(2X)(2Y)}$$

Little information appears to be available on the accuracies of the two methods and their limitations. An estimation of the magnitudes of the maximum errors likely to be produced by errors in measurements caused by trace thickness and any harmonics present is given below.

Fig. 3.
Errors due to trace thickness (first method)



Trace Thickness Errors

Expressions for Errors

In making any measurements on the screen of the cathode-ray tube errors are introduced due to the thickness of the trace at either end of each dimension involved.

Suppose, for example, it is required to measure the distances Pa and Pb in Fig. 2(a) and Fig. 2(b) which represent traces of thickness t crossing a line PQ at right-angles and acutely respectively. In Fig. 2(a) distance Pa can be estimated to within about 0.5 mm., since a trace thickness of 1 mm. is typical of ordinary oscillographs. In Fig. 2(b), however, where b_1b_2 is greater than the trace thickness t, the error in measuring Pb is larger than 0.5 mm. In fact, the smaller the angle ψ the larger the error.

Assuming that an error of ± 0.5 mm. is introduced at either end of each dimension measured, expressions for the errors in phase angle can be written down.

Thus, in the case where $\sin \alpha = BC/AD$ the maximum and minimum values of α, α_{max} and α_{min} respectively are given by:

$$\sin(\alpha_{max}) = \frac{BC+1}{AD-1} \quad \text{and} \quad \sin(\alpha_{min}) = \frac{BC-1}{AD+1}$$

where BC and AD are expressed in mm.

The curves of Fig. 3 show the variation of error with α. These have been calculated from the expression

$$\delta\alpha = \tan \alpha \left\{ \frac{\delta(BC)}{BC} + \frac{\delta(AD)}{AD} \right\}$$

for values of AD equal to 40 mm., 70 mm. and 100 mm. which are suitable for screen diameters of about $2\frac{1}{2}$ in., $4\frac{1}{2}$ in. and 6 in. respectively. For the case where

$$\sin \alpha = \frac{(2a)(2b)}{(2X)(2Y)}$$

the maximum and minimum values of α are given by

$$\sin(\alpha_{max}) = \frac{(2a+1)(2b+1)}{(2X-1)(2Y-1)}$$

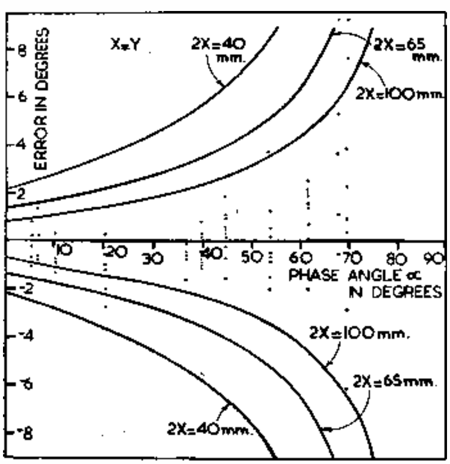


Fig. 4.
Errors due to trace thickness (second method: X = Y)

and $\sin(\alpha_{min}) = \dfrac{(2a-1)(2b-1)}{(2X+1)(2Y+1)}$

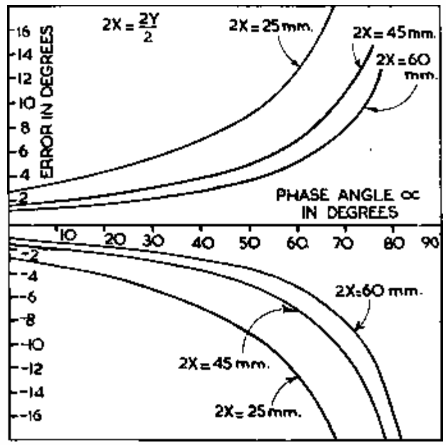
where all quantities on the right-hand sides of the equations are expressed in mm.

The curves of Figs. 4 and 5 show the variation of error with α. These have been calculated from the expression

$$\delta\alpha = \tan \alpha \{ \pm\delta a/a \pm \delta b/b \pm \delta Y/Y \pm \delta X/X \}$$

first for the case where $2X = 2Y$ equals 40 mm., 65 mm. and 100 mm. respectively, and then where $2X = 2Y/2$ equals 25 mm., 45 mm. and 60 mm. respectively. These figures have again been chosen to suit screen diameters of about $2\frac{1}{2}$ in., $4\frac{1}{2}$ in. and 6 in.

Fig. 5.
Errors due to trace thickness (second method: 2X = 2Y/2)



Experimental Procedure

Tests have been carried out to compare practical results with the above theoretical curves. A phase difference between two sine-wave voltages, maximum values V_1 and V_2, was produced by a simple resistance/capacitance circuit (Fig. 6). The phase difference was calculated accurately from the exact values of C, R and supply frequency f.

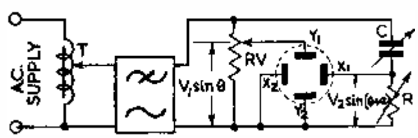


Fig. 6.
Circuit used to provide two sine-wave out-of-phase voltages

An ordinary commercial oscillograph with an overall screen diameter of 110 mm. (about $4\frac{1}{2}$ in.) was used throughout the tests. The elliptical trace was adjusted in each case to the figures already quoted for a $4\frac{1}{2}$ in. screen diameter. The magnitude of V_2 could be adjusted by varying the tapping point on the auto-transformer T, and that of V_1 by varying the slider on potentiometer RV. Readings of $2OC$, $2X$, $2Y$, $2a$ and $2b$ were obtained for various values of α between 0 and 90°. The observations were carried out by fourteen independent operators.

Results

The phase-angles calculated from the readings obtained in the above tests by the formulae

$$\sin \alpha = \frac{BC}{AD} \text{ and } \sin \alpha = \frac{(2a)(2b)}{(2X)(2Y)}$$

are shown by the scattered points in Figs. 3 and 4. It can be seen that, in both cases, there is a good distribution of points lying mainly inside the boundaries set by the theoretical curves. Thus a reading error of 0.5 mm. for a 1 mm. trace thickness appears to be a reasonable assumption.

Other Limitations of the Trace

Two obvious deductions can be made in order to obtain minimum errors. First, the elliptical trace should be adjusted always so that it is as large as the screen will allow. Also, for best results with the first method of making measurements it is highly desirable to compare two voltages of about the same magnitude, otherwise the ellipse lies with its major axis either too near the horizontal or too near the vertical. If the major axis is too near the horizontal it is impossible to obtain an accurate reading of BC (Fig. 1), while if it is too near the vertical the ratio $\delta(BC)/BC$ becomes large.

Errors Produced by Harmonics in the Waveforms

When harmonics are present in either of the waves, additional errors may be introduced. Some workers have stated that for small harmonic content the errors produced are negligible. In making such statements, however, no attempt is made to explain what is meant by the words "small" and "negligible." In fact, the remarks must be treated with extreme caution, as shown by the following analysis.

It is difficult to calculate the error for any given harmonic content, but for small magnitudes the maximum corresponding error can be found for measurements using either of the two methods.

First Method

Fig. 7(a) shows an ellipse with a third harmonic added to the Y deflexion. If, as is usual, the dimension BC is to be measured, the observed $B'C'$ is less than the required BC. Fig. 7(b) shows the ellipse with a second harmonic added, and here the two errors BB' and CC' tend to cancel out. Reasoning in this manner it can be shown that errors produced by even harmonics are smaller than those produced by odd ones.

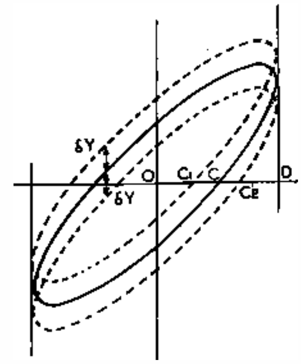


Fig. 8

Ellipse with figures produced by any harmonic with a deviation $\pm\delta Y$ in the Y axis

Consider the required ellipse in Fig. 8. The envelopes of all possible figures produced by any harmonic of given magnitude $\pm\delta Y$ in the Y axis are shown by the dotted ellipses, displaced by $\pm\delta Y$ from the original ellipse. It can be seen that the maximum error in BC is $2CC_1$ or $2CC_2$.

Let the fundamentals of the two waves be:

$$x = X \sin (\theta + \alpha)$$
$$y = Y \sin \theta$$

Taking the Taylor's Series expansion of $x = f(y)$ then

$$f(y_0 + \delta Y) = f(y_0) + (\delta Y/1!)Df(y_0) + [(\delta Y)^2/2!]D^2 f(y_0) + \ldots + [(\delta Y)^n/n!]D^n f(y_0) + \ldots$$

where D has the usual operational significance.

At point C (Fig. 8) where $y_0 = 0$ and $\theta = 0$, $f(y_0) = OC$ then

$$f(y_0 + \delta Y) - f(y_0) = [\delta Y/1!]Df(y_0) + [(\delta Y)^2/2!]D^2 f(y_0) + [(\delta Y)^3/3!]D^3 f(y_0) + \ldots$$

$$= [\delta Y/1!][X \cos \alpha / Y] - [X/2!] \sin \alpha \, (\delta Y/Y)^2 + 0 \, . \, (\delta Y/Y)^3 + \ldots$$

gives $\delta(OC)$, i.e., CC_1 or CC_2 depending on the sign of δY. Now,

$$\sin \alpha = \frac{BC}{AD} = \frac{2OC}{2OD} \therefore \cos \alpha \cdot \frac{d\alpha}{\delta(OC)} = \frac{1}{OD}$$

Fig. 7(a).

Third harmonic added to Y axis

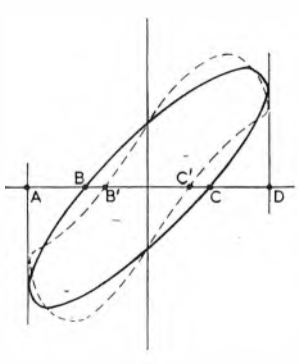


Fig. 7(b)

Second harmonic added to Y axis

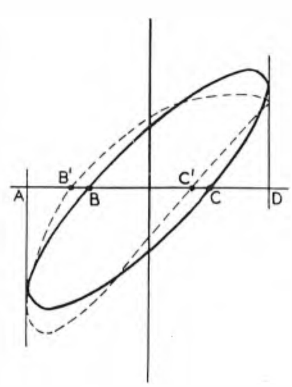


Fig. 9(a)

Third harmonic added to X axis

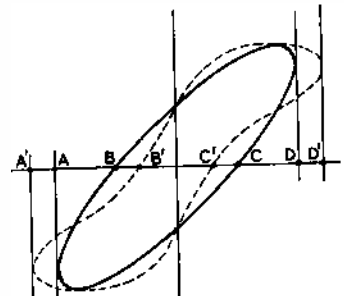
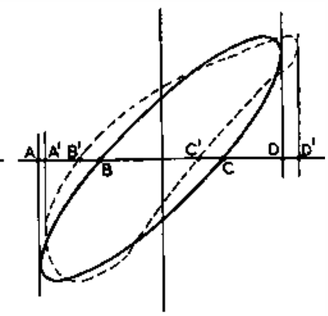


Fig. 9(b)

Second harmonic added to X axis



Also, $\delta\alpha_Y \approx \frac{d\alpha}{d(OC)} \cdot \delta(OC)$ i.e., $\delta\alpha_Y \approx \frac{d(OC)}{OD \cos\alpha}$

$$\therefore \delta\alpha_Y \approx [1/X \cos\alpha]\,[X\cos\alpha\,(\delta Y/Y) - [X \sin\alpha/2!](\delta Y/Y)^2 + 0\,.\,(\delta Y/Y)^3 + \ldots]$$

$$\delta\alpha_Y \approx \delta Y/Y - [\tan\alpha/2!](\delta Y/Y)^2$$

With a harmonic on the X-axis instead of the Y-axis, similar considerations for odd and even harmonics apply, as can be seen from Figs. 9(a) and 9(b) where a third and a second harmonic respectively have been added to the ellipse. Fig. 10 shows

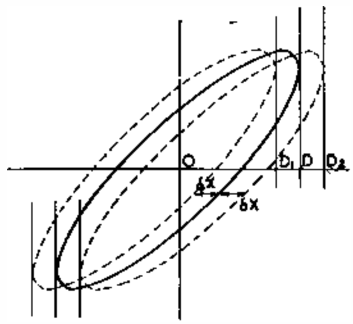


Fig. 10
Envelopes of harmonics $\pm\delta X$ on the X axis

the envelopes of harmonics of magnitude $\pm\delta X$ on the X-axis.

In this case, since $\sin\alpha = \frac{2OC}{2OD}$ then

$$\delta\alpha_X \approx \frac{\partial\alpha}{\partial(OC)} \cdot \delta(OC) + \frac{\partial\alpha}{\partial(OD)} \cdot \delta(OD)$$

$$\approx \frac{\delta(OC)}{X\cos\alpha} - \frac{\tan\alpha\,.\,\delta(OD)}{X}$$

Now $\delta(OC) = \pm\delta(OD) = \pm\delta X$

$$\therefore \delta\alpha_X \approx \pm\frac{\delta X}{X}\left\{\frac{1 \pm \sin\alpha}{\cos\alpha}\right\}$$

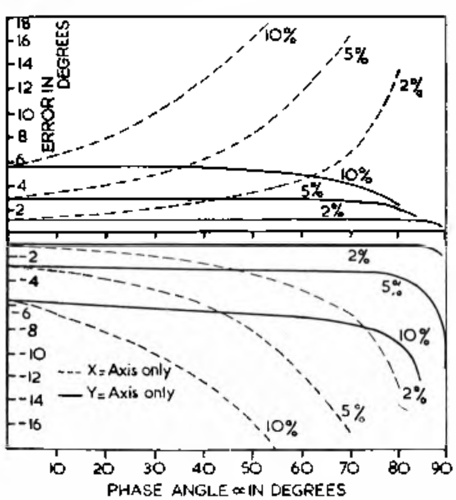


Fig. 11.
Errors due to waveform (first method)

Hence, the maximum errors $\delta\alpha_T$ are given by:

$$\delta\alpha_T \approx \left\{\pm\frac{\delta Y}{Y} - \frac{\tan\alpha}{2!}\left(\pm\frac{\delta Y}{Y}\right)^2\right\} \pm \frac{\delta X}{X}\left\{\frac{1 \pm \sin\alpha}{\cos\alpha}\right\}$$

Actual values will depend upon the phase and the harmonic number of the harmonic.

The maximum errors $\delta\alpha_X$ and $\delta\alpha_Y$ have been calculated for various percentages of harmonic and are plotted on Fig. 11.

With angles approaching 90° the errors become very large, but the curves should be treated with some reserve, since for any angle $\alpha°$ a positive error greater than $(90-\alpha)°$ is impossible. The curves have been plotted for harmonic contents of 2 per cent, 5 per cent and 10 per cent on either axis.

Second Method

If, as is usual, measurements of $2a$, $2b$, $2X$ and $2Y$ are made, then even harmonics will have a smaller effect than odd ones.

At any point P on the required ellipse (Fig. 12)

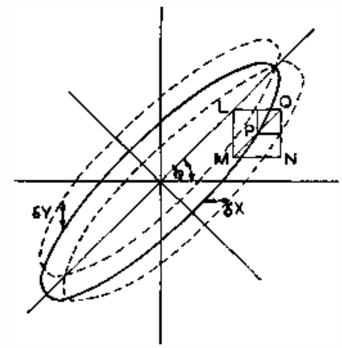


Fig. 12.
Harmonic variations $\pm\delta X$ and $\pm\delta Y$

the harmonics present in both voltages can produce additional deflexions $\pm\delta X$ and $\pm\delta Y$, so that depending on the phase of the harmonics, the trace point can lie anywhere within a rectangle $LMNQ$ where PQ is equal to half the diagonal.

This produces errors in $2a$, $2b$, $2X$ and $2Y$, and therefore in the phase angle.

The maximum error in a, $\delta a =$

$$\pm(\delta X \cos\phi + \delta Y \sin\phi)$$

where ϕ is the angle shown in Fig. 12.

Similarly, the maximum error in b, $\delta b =$

$$\pm(\delta X \sin\phi + \delta Y \cos\phi)$$

The error in X is $\pm\delta X$

and the error in Y is $\pm\delta Y$.

Thus, since phase angle α is given by:

$$\sin\alpha = \frac{2a\,.\,2b}{2X\,.\,2Y} = \frac{a\,.\,b}{X\,.\,Y}$$

$$\frac{\delta(\sin\alpha)}{\sin\alpha} = \pm\delta b/b \pm \delta a/a \pm \delta Y/Y \pm \delta X/X$$

$$= \pm\delta X\,[\cos\phi/a + \sin\phi/b + 1/X] \pm \delta Y\,[\sin\phi/a + \cos\phi/b + 1/Y]$$

When $\delta X = 0$, $\frac{\delta(\sin\alpha)}{\sin\alpha} =$

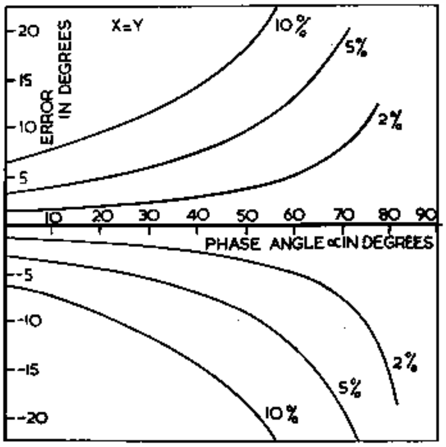


Fig. 13.
Errors due to waveform (second method)

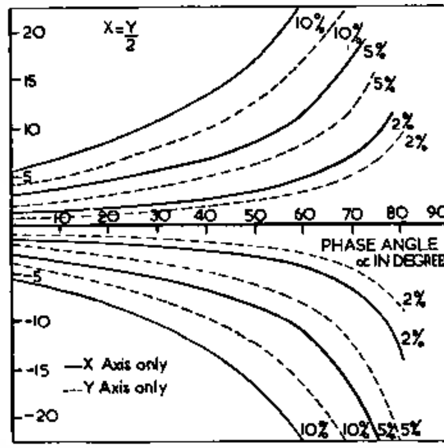


Fig. 14.
Errors due to waveform (second method)

$$\pm \delta Y\,[\sin \phi / a + \cos \phi / b + 1/Y] = \delta_{sY} \text{ say.}$$

When $\delta Y = 0$, $\dfrac{\delta(\sin \alpha)}{\sin \alpha} =$

$$\pm \delta X\,[\cos \phi / a + \sin \phi / b + 1/X] = \delta_{sX} \text{ say.}$$

From δ_{sY} and δ_{sX} the corresponding errors $\delta\alpha_Y$ and $\delta\alpha_X$ can be found.

In performing the above calculations the quantities $\cos \phi$, $\sin \phi$, a and b must be known. The following procedure can be used for the determination of these quantities:—

$$\text{Since } x = X \sin(\theta + \alpha)$$

and $y = Y \sin \theta$, $r^2 = x^2 + y^2 = X^2 \sin^2(\theta + \alpha) + Y^2 \sin^2 \theta$

$\therefore$ the conditions for $r_{max} = a$ or $r_{min} = b$ are

$$\tan 2\theta = -\frac{X^2 \sin 2\alpha}{X^2 \cos 2\alpha + Y^2}$$

For given values of X, Y and α these values of θ can be found and, hence, the corresponding values of x, y and r (say x', y' and r').

Then $\cos \phi = x'/r'$ and $\sin \phi = y'/r'$.

Curves of maximum error, based upon the preceding calculations, are shown in Figs. 13 and 14. Again it is obvious that at an angle $\alpha°$, a positive error of more than $(90-\alpha)°$ cannot exist, but all the negative errors are quite feasible. It is also possible to get measured values of $(2a\,.\,2b)/(2X\,.\,2Y)$ greater than 1, but such results must be discarded since $\sin \alpha$ is not greater than unity. Fig. 13 has been plotted for an ellipse with a ratio $X:Y = 1$, while Fig. 14 is for $X:Y = \frac{1}{2}$.

The authors are indebted to Final Year students in the Department of Electrical Engineering at the University of Liverpool for assistance in making observations. They also wish to express their thanks to Professor F. J. Teago, D.Sc., M.I.E.E., for experimental facilities afforded in the laboratories of the above Department.

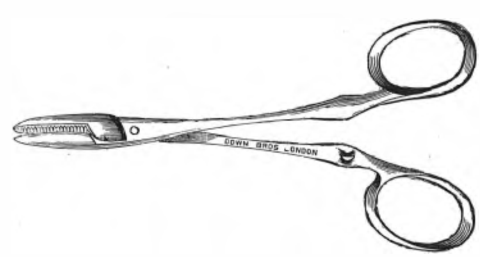
A USEFUL TOOL

By G. P. BURN

AN instrument which the author has found very valuable in electrical wiring and assembly work is a pair of Spencer-Wells forceps, which are normally used by surgeons for clamping arteries. These forceps have an overall length of about 5 in., and have the general construction of a pair of scissors.

The blades comprise a pair of serrated clamps, and they are provided with a small rack, by means of which the forceps may be secured in the closed position. The cross-section of the first 4 in. of the instrument has maximum dimensions of 5/16 by 1/4 in., which are far smaller than those of any form of pliers of the same length.

Thus, it is possible to place a 4 B.A. nut between the blades and, holding the handles tightly between the thumb and finger of the left hand, to insert the nut deeply into the heart of the equipment under construction and then to screw the bolt into the nut, with a screwdriver in the right hand. It is possible to hold the nut tightly enough so that the subsequent application of a spanner is unnecessary.



Spencer-Wells surgical forceps can be used as a versatile addition to the experimenter's and constructor's tool-kit

(Illustration by courtesy of Down Bros., 23 Park Hill Rise, Croydon)

The other main use of the forceps is to hold a piece of wire while it is being soldered. Sooner or later one's finger always gets burnt on the iron, but if the wire is held between the blades, this will not happen. Also, when unsoldering a wire which is twisted round a tag, it is possible to take hold of the end of the wire while the solder is liquid, and to untwist it.

These forceps may be obtained from any of the surgical instrument makers, costing about 12s. 6d.

R.E.C.M.F. Exhibition

A Selection of New Equipment and Components shown at Grosvenor House, Park Lane, W.1, from 17th to 19th April, 1950.

Lectrona Loudspeakers

THE new range of 6½ and 5-in. diameter speakers are of entirely new construction, and cones are now completely moulded with speech coil former.

The magnetic system has a negligible external magnetic field, and incorporates the latest developments in magnetic alloys. The new element niobium is incorporated in the magnet, which is of the ring type to ensure uniformity throughout its cross-sectional area.

The acoustic performance of the orthodox speaker has been retained, with a reduction in overall size approaching the wafer or disk type of speaker. The overall depth of the 6-in. speaker is only 2 in. for a total flux of 30,000 maxwells and 1¾ in. for the 5-in. model.

The vibrating system consists of a main diaphragm and voice coil moulded in one piece. The voice coil has a high frequency diaphragm directly coupled to it to ensure good high frequency response. The coil drive is coupled to the effective diaphragm at a point which eliminates marked resonances in the high frequencies. Bass resonance is controlled by means of a resistive element in conjunction with an acoustic capacitance, and is nominally 120 cycles for the 6½-in. model, 140 cycles for the 5-in. model.

Acoustic Products Ltd., 50-58, Britannia Walk, London, N.1.

Teletape
(Illustrated below)

THE teletape is designed as a piece of business equipment to receive and store for short periods messages that can be later played back and typed.

A person wishing to use the installation lifts his telephone and dials a pre-arranged number. Should all teletape channels be in use the engaged signal is heard, but if available, an announcement is heard telling the user that he is connected to the teletape system. The duration of each message can be ten minutes, towards the end of which time a warning is given that only thirty seconds is available.

When the telephone is replaced, the channel upon which the message has been recorded automatically indicates to the exchange that it is in use and lights the appropriate indicator lamp on both the remote take-off points. The operator wishing to deal with the channel presses the "listen" switch and the recorded message is then played back to the operator who either types or teleprints it. The "listen" switch action also extinguishes the indicator lamp on the other take-off unit.

Should any parts of the message be difficult to understand the foot switch can be depressed to make the recording reverse and replay the section.

Associated Electronic Engineers Ltd., Dalston Gardens, Stanmore, Middx.

"Douglas" Progressive Wave Winder

THE "Douglas" Progressive Wave Winding Machine has been developed to meet the demand by coil manufacturers for a machine which will provide efficiently wound progressive wave-wound coils, giving the designer a very great latitude in the spacing and sizes of coils which can be handled.

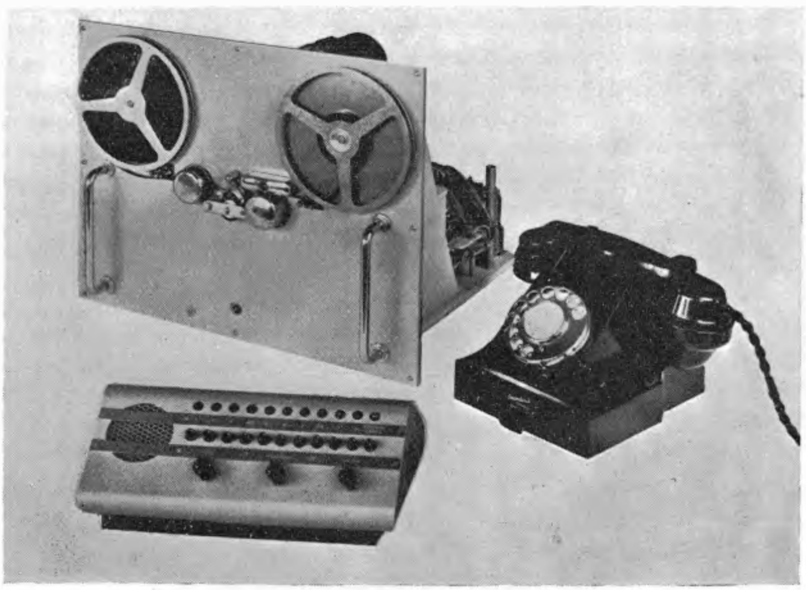
Progressive wave-wound coils up to 5 in. (127 mm.) in length and with a maximum diameter of 3 in. (76 mm.) can be handled.

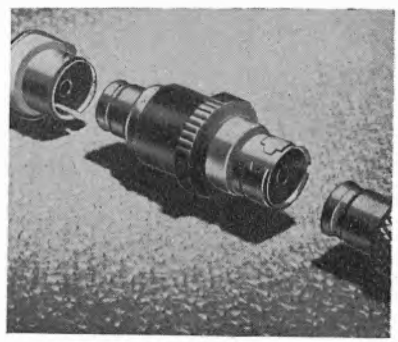
Conventional wave-wound coils for $\frac{5}{64}$ in. (2 mm.) to 1½ in. (38 mm.) wide and from ⅛ in. (3 mm.) to 3 in. (76 mm.) diameter can be handled. Only one coil can be wound at a time and in the case of the pie-wound coils provision is made for the winding of quadruple, triple, double, single, half, third or quarter wave coils.

In the case of progressive wave-wound coils, gear changes are provided to enable a wide range of rates of progression. This extends from 0.002 in. 0.05 mm.) per turn to 0.0715 in. (1.82 mm.) per turn and for the greater part of this range gear changes are available to the nearest 0.0002 in. (0.005 mm.).

The machine will handle wires from 20 S.W.G. (0.036 in.—0.9 mm.) to 46 S.W.G. (0.0024 in.—0.06 mm.) and also Litz wires with a cross-sectional area within the range given for the single strand wires.

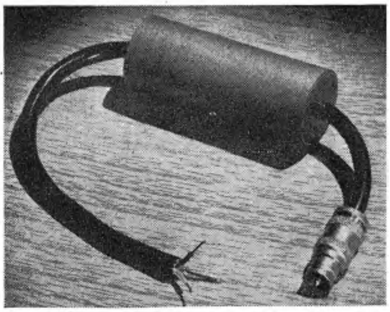
Automatic Coil Winder & Electrical Co., Ltd., Winder House, Douglas Street, London, S.W.1.





Co-Axial Line Attenuator
(Illustrated above)

THE Co-axial Line Attenuator has been developed with insertion losses of 6, 12, 18, 24 and 36 db. It is plugged into the coaxial outlet box, type L624, made by this firm, which is generally used with the L600 coaxial feeder, but provision has been made to enable an unscreened balanced feeder to be loaded, when the same attenuator is applicable.



"Balon" Balanced to Unbalanced Transformer

Television receivers may be designed with balanced or unbalanced input, requiring twin or co-axial feeders. In practice, the type of feeder may not be significant, but in some cases the wrong feeder may cause receiver instability. If for any reason it is necessary to change the input conditions, the "Balon" transformer can be applied to dispense with the necessity of rewiring from the aerial. There is an insertion loss of a few decibels but, except in the fringe areas this is not likely to be noticeable.

Belling & Lee Ltd.,
Cambridge Arterial Road,
Enfield,
Middlesex.

Power Rheostats

(Illustrated centre)

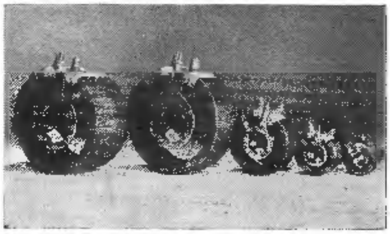
THE Power Rheostats are designed with a ratings range from 25 watts on the smallest size to 300 watts on the largest model, for various ohmic values from 1 to 15,000 ohms.

These units can be used to replace the larger sliding resistors and regulators, with consequent economy in panel space. They are also suitable where rotary action is preferred.

The main features of the rheostats are: moulded insulation between live parts and earth, tested at 2,000V—T25, 3,000V—T50 and T100; winding permanently embedded in vitreous enamel when required; die-cast frame allows for maximum ventilation; the rheostats have three terminals or potentiometer connexions, and off position can be fitted at either end of the winding.

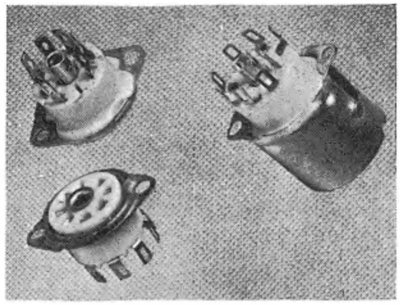
The spindle is insulated from the electrical circuit to withstand a pressure test of 3,000V R.M.S. on models up to 100 watts dissipation and 6,000V R.M.S. on the larger models.

British Electrical Resistance Co., Ltd.,
Queensway,
Ponders End,
Middlesex.



Cinch B7G Ceramic Valve Base

(Illustrated top right)



THIS valveholder, primarily intended for communication and government equipment, is suitable for tropical conditions, and can be either saddle mounted or with a lower shield, both types being available with or without radial screen between pins 1 and 7. The mounting has two holes for rivets or eyelets.

Wiring connexions are soldering tags with elongated slots set slightly out beyond the pin position. The contacts provide a good grip on the pin and are of hardened beryllium-copper alloy silver plated, with soldering tags hot tin dipped. The top can is attached by bayonet fitting to the types with lower shield. A centre screen is included in all types.

The material used is low-loss ceramic with rustproofed steel saddle for the body. The lower shield is of plated brass in one piece with the saddle. The top can is of aluminium alloy with an internal spring to retain the valve. For communications equipment brass is available in black bronze finish or silver plated.

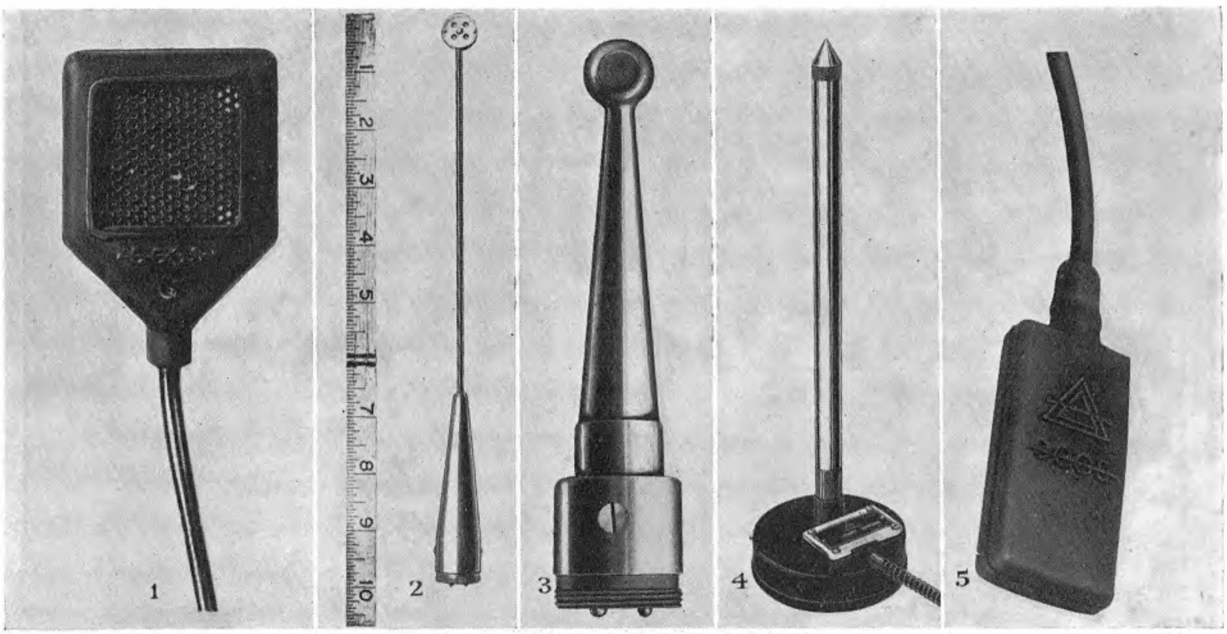
Carr Fastener Co., Ltd.,
Stapleford,
Nottingham.

Cosmocord Components

(Illustrated below)

1. *Lapel Microphone*

THIS small non-directional microphone has been designed to allow freedom of movement for public speakers or radio broadcasters. It is housed in a soft moulded rubber case, and hooks on to the lapel of a suit or coat. A 20 ft. cable is supplied with the microphone. The M.I.C. 28 has a level frequency response throughout the major part of the audible



frequency spectrum, and consequently gives great fidelity of reproduction.

2 and 3. *Wide-range Microphones*

These microphones are divided into two classes (1) general acoustic types with a frequency range of 10 c/s. to 30 kc/s., and (2) ultrasonic, 100 c/s to 200 kc/s. They are noteworthy for the small size of the microphone head, thus reducing diffraction errors to a minimum and enabling them to be used as wide-range exploring type microphones.

The ultrasonic microphones are suitable for use in either air or water and the frequency range given above is that for water. Because of the difference of wavelength of sound in air and water, the upper frequency limit of the ultrasonic microphones in air is approximately 25 to 30 kc/s. The major difference between the ultrasonic and the low-frequency microphone is in the source capacitance of the generating system. This capacitance must be considerably increased in the low-frequency microphones in order to keep the signal to noise ratio low at the very low frequencies. This latter requirement is not necessary with ultrasonic microphones and advantage can be taken of very small crystal elements with consequent increase in the high frequency range.

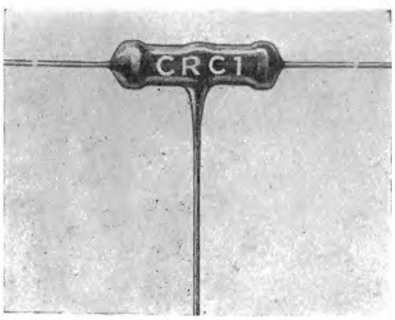
4. *ACOS Vibration Pick-up*

This device has been designed for industrial use to convert the motion of vibrating objects into electrical potentials which may be observed and studied by means of an oscilloscope or other indicator. Typical usages are the location of a source of noise in any reciprocating or rotating machine, the production testing of all kinds of bearings and motors, the measuring of vibration in buildings, bridges, etc., and other applications involving any body with vibratory motion.

5. *ACOS Vibro-Pick-up*

This is a contact pick-up of the inertia type, dimensionally small, designed for use with musical instruments, particularly of the stringed type, so that their sound can be electrically amplified. The output voltage ranges from 0.05 to 0.1 of a volt and higher, and any amplifier having high impedance input will be found satisfactory for use with the VP1. The frequency response ranges from 30 to 6,000 c/s.

Cosmocord Ltd.,
700, Great Cambridge Road,
Enfield,
Middlesex.



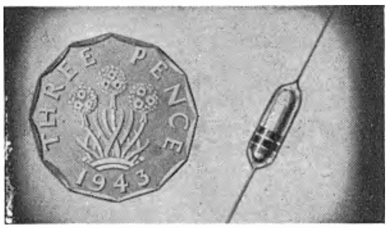
Dubilier Diode Filter
(Illustrated bottom left)

THIS Dubilier multiple component unit (British Patent Application 34197/47) provides a complete diode filter in a single compact form, only three connecting wires project—one input and one output—at opposite ends of the tube, with a centre wire for the earth connexion.

The unit is constructed of a tubular ceramic dielectric element which furnishes the two capacitors and has the resistance element housed in the interior of the tube.

To a special order, these diode filters can be supplied moulded into a hard resin casing which provides greater mechanical stability and furnishes full humidity protection over the temperature range of $-40°$ C. to $+70°$ C.

The normal filter CRC1 is supplied with values of 100 pF each for C1 and C2 and 47,000 Ω for R, but other values are available. The dimensions over the wax coating being but $\frac{7}{8}$ in. long and $\frac{1}{4}$ in. diameter. Normal working temperature, $0°$ to $+ 50°$ C.



Dubilier Miniature Metallized Paper Capacitors
(Illustrated above)

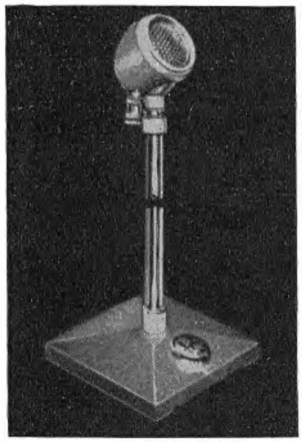
A NEW Dubilier development in miniaturization consists of a metallized paper capacitor unit of special construction enabling an extremely compact and small size to be achieved.

The capacitors are cylindrical in shape, with axially projecting tinned wire terminals. The capacitor elements are moulded in a special phenolic resin of high insulation, providing a rugged casing of great homogeneity. They have a very high insulation resistance, good capacitance stability, low effective inductance and are impervious to moisture.

They can be operated over the exceptionally wide temperature range of $-40°$ C. to $+70°$ C. and are colour coded by the standard colour code bands, giving the capacitance in picofarads. Possessing the familiar self-healing properties of metallized paper capacitors their excellent characteristics are maintained in the most arduous conditions of use.

They are available in a range of capacitance values up to $0.003\mu F$ for a working voltage of 350V D.C. and in capacitances over $0.003\mu F$ up to 0.01 for 150 volts D.C. working.

Dubilier Condenser Co. (1925) Ltd.,
Duncan Works, Victoria Road,
North Acton, London, W.3.

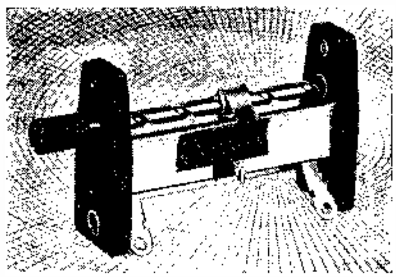


Diaphragm Piezo Microphone
(Illustrated above)

THE Diaphragm Piezo Microphone is a new type with a Rochelle salt element of approximately $0.001\mu F$. The frequency response is uniform for this type of microphone, and the output, approximately 51 db. below 1 volt per bar at 1,000 c/s., is sufficient for a normal public-address amplifier to be adequate in most circumstances. A standard $\frac{1}{4}$ in. coaxial plug and socket are provided, and if low capacitance coaxial cable is employed a very long lead can be used without loss of quality and with only slight fall in volume. For shorter runs standard single or twin-screen leads can be used.

The mounting and screening are such that noise and interference are at a minimum, and the microphone is robust. There are two possible mounting positions for the unit on its stand. One is with the axis at 30° above horizontal, and the other is with axis vertical, giving omni-directional response.

The Edison Swan Electric Co., Ltd.,
155, Charing Cross Road,
London, W.C.2.

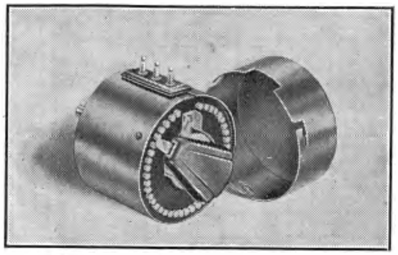


Egen Pre-set Resistor
(Illustrated above)

THE latest Egen pre-set variable resistors are designed mainly to meet the needs of television designers. The features are: rotary control; midget construction, which permits six units to be mounted on a panel $3\frac{1}{2}$ in. square, with the knob controls at centres 1 in. apart in both directions; single hole fixing with "pip" location; panel or chassis mounting and ratchet action safety measure which prevents damage by over-turning.

The control knob is provided with both knurling and slotting for either thumb or screwdriver adjustment. The assembly is arranged so that all live points are adequately insulated to meet modern test practice. The worm-drive provides smooth control, which is unaffected by vibration. The open construction of the resistors allows free heat dissipation. The control knob is permanently pressed in place on the spindle, and need not therefore be removed when mounting.

Egen Electric Ltd.,
Craven Avenue,
Canvey Island, Essex.



Faders and Attenuators

(Illustrated above)

THIS new range of faders and attenuators incorporates a new design of brush and collector assembly making possible higher contact pressures and therefore low contact resistance, and yet having much lower torque figures than normal, and very smooth movement in operation. Typical figures are: total pressures, 550 grammes, torque, 4 in./oz., total internal resistance of brush and collector assembly, 0.01 ohms.

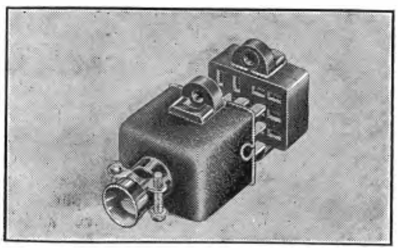
The brushes are afforded complete protection during service cleaning by moulded brush shrouds. They are "y"-shaped in formation, and double anchored, with multiple laminations to provide greater resilience with the absence of a radial whip.

Plugs and Sockets

(Illustrated below)

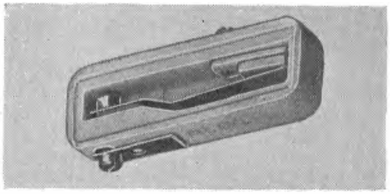
A NEW range of plugs and sockets has been produced which have a completely moulded body not employing any laminated materials, to ensure the highest possible insulation value under humidity conditions.

Other important features are: joints between the cavities are sealed by neophrene gasket under compression; no drillings or rivets are made through the mouldings; the plugs and sockets



are moulded on mounting lugs with a self-spanner cavity for fixing nuts; provision is made for fitting non-rotating tapped inserts for chassis or panel mounting; the units have positive case fixing without screws; there is a cable entry which is of solidly fixed tubular type with flared mouth, and there is a non-slipping cable clamp that takes the cable strain.

Electronic Components,
Weedon Road Industrial Estate,
Northampton.

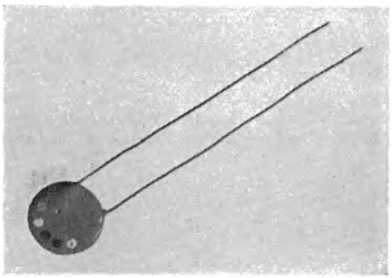


Thermostat, Type T22

(Illustrated above)

A NEW "snap-action" thermostat, Type T22, has been designed for controlling the temperature of electric heating and other resistance circuits. The quick make and break is achieved by the use of a small bar magnet. The standard design has a temperature range of from 80° F. to 300° F., or 25° C. to 150° C., with a differential of ±5° F., and a current carrying capacity of 2 amps. A.C. Designs differing from the standard one can be supplied.

Electrothermal Engineering Ltd.,
270, Neville Road, London, E.7.



Erie "Teledisc" Ceramicons

(Illustrated above)

THE Erie "Teledisc" Ceramicon is a ceramic dielectric capacitor on a disk $\frac{1}{2}$ in. diameter and $\frac{1}{32}$ in. thick with a maximum capacitance of 10,000 pF in this size. Insulation is 3,800 Phenolic, and the maximum working voltage is 400V.

Carbon Track Potentiometer

(Shown bottom right)

ANOTHER new development is the Erie $1\frac{1}{8}$ in. carbon track potentiometer, which is fully sealed and tropicalized. The resistance ranges from 1,000 ohms to 5 megohms, with a tolerance of ±20 per cent. The potentiometers can be supplied with or without a double-pole single-throw switch (250V, 1 amp., or 125V, 3 amp.).

Erie Resistor Ltd.,
Millora Works, Beevor Road,
South Denes, Great Yarmouth.

New Osram Valves

A COMPLETE range of miniature valves on the B7G base for battery operated A.C. and D.C./A.C. receivers, including a new triode hexode frequency changer on the Noval (B9A) base, for the D.C./A.C. range, were shown. In the battery range the X17 is capable of operation at short wavelengths with a wide range of battery voltage; in the A.C. and D.C./A.C. ranges the triode hexodes X78 and X109 respectively are outstanding in performance, particularly on the short wavebands. In the battery range again, microphony in the ZD17 has been kept at a minimum, and the complete range makes for lowest possible current consumption and high efficiency.

In the A.C. and D.C./A.C. ranges two new high-slope output pentodes, types N78 and N108 respectively, have all the characteristics of their octal predecessors without any loss in slope or reliability.

These new Osram miniature valves for battery operation at 1.4 volts, A.C. operation at 6.3 volts, and D.C./A.C. operation at 0.1 amp., exhibit the characteristics comparable with any similar valves in this class to-day.

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

P.M. Loudspeakers

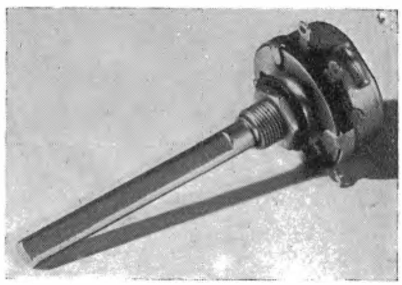
THE new Goodmans 12-in. loudspeakers are single cone heavy duty reproducers. The magnet assembly, using anisotropic material, provides a total flux of 158,000 maxwells on a $1\frac{3}{4}$ in. pole, the back centring device being a dustproof linen disk with concentric corrugations.

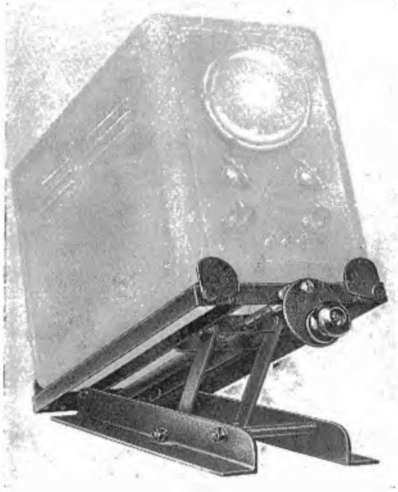
These loudspeakers have a fundamental resonance of 75 c/s., and a voice coil impedance of 15 ohms. The power rating is 15 watts peak A.C., and flux density 14,000 gauss. The magnetic field of these reproducers is completely shielded.

Goodmans Industries Ltd.,
Lancelot Road,
Wembley, Middx.

Oscilloscope Stand

THE Widney oscilloscope stand has been designed to enable oscilloscope and other bench instruments to be easily tilted so as to bring the controls and screen into the most convenient operating position.





The handle can be attached to either end, so that the stand can be used to tilt upwards or downwards. (*Illustrated above*)

Widney-Dorlec Cabinet System

THE Widney-Dorlec cabinet system consists of a range of formed sections in aluminium alloy, corner diecastings and connecting brackets in various styles which enable a cabinet or rack of any size to be easily erected with very little skill or tools. The completed product is a rigid practical housing that lends itself to many finishes.

Parts are available for two basic sizes—the Standard gauge in which the outside sections and corners have a radius of $1\frac{3}{16}$ in. and the " Small " gauge having a radius of $1\frac{3}{16}$ in.

Hallam, Sleigh & Cheston Ltd.,
Widney Works,
Bagot Street,
Birmingham, 4.

Midget Moldseal Metallized Paper Capacitor, Type W99

THE Midget Moldseal Metallized Paper Capacitor, type W99, is a new miniature capacitor with a tough moulded casing, and is proof against humidity. It has a wide range of temperature operation and is partiuclarly suitable for use in light-weight, compact equipment employing miniature valves, and for television apparatus.

The standard capacitance tolerance is $\pm$20 per cent; temperature range is from $-40°$ C. to $+71°$ C., though higher temperature types are available; the insulation resistance is not less than 20,000 megohms and the inductance is not greater than a straight piece of wire the diameter and length of the wound unit.

Ranges

	Dimensions $\frac{3}{16} \times \frac{7}{16}$ in.	$\frac{1}{4} \times \frac{9}{16}$ in.
150 volts D.C. Wkg.	0.004 μF to 0.01 μF	0.02 μF to 0.04 μF
350 volts D.C. Wkg.	0.001 μF to 0.003 μF	0.004 μF to 0.01 μF
600 volts D.C. Wkg.	2.5pF to 0.0005 μF	0.001 μF to 0.0025 μF
300 volts A.C. Wkg.	0.00005 μF to 0.001 μF	0.002 μF to 0.0025 μF

A. H. Hunt Ltd.,
Bendon Valley,
Garratt Lane,
Wandsworth, S.W.18.

Blocking Oscillator Transformers

TWO types of blocking oscillator transformers are available, the KP7841, of the line type, and KP7842 of the frame type. They are both bobbin wound with adequate insulation between windings, and are wax impregnated.

The primary inductance of KP7841 is 0.5H and of KP7842 is 250H. The former has a ratio of 3 to 1, and the latter one of 2.85 to 1.

Igranic Electric Co., Ltd
Bedford.

Pullin A.C. Dynamometer Testing Set

THE Pullin Type PD440 Test Set has been designed mainly for laboratory, test-room and college work, and combines the functions of a precision dynamometer ammeter, voltmeter and wattmeter. There are five ranges of A.C. volts, seven current ranges, including a 25 milliamp A.C. and D.C. range, and thirty ranges of power from 12.5 to 12,500 watts.

The iron-free dynamometer movement is used in this instrument. The weight of the moving parts has been kept to a minimum to ensure the maximum torque-to-weight ratio, consistent with a robust assembly.

Careful shielding of the movement ensures that the accuracy is not affected by extraneous magnetic fields.

The bakelite panel of the testing set, fitted with the instrument terminals and range change switches, is totally enclosed by a hinged lid. The lid of the instrument can be removed, if desired, during use.

Measuring Instruments (Pullin) Ltd.,
Electrin Works,
Winchester Street,
Acton, London, W.3.

Morganite Type D.A. Potentiometers

THESE new midget potentiometers are suitable for all deaf-aids and midget applications, and can be supplied with or without a cam-operated single pole switch. The overall resistance values are between 10k and 3 megohms, $\pm$30 per cent standard tolerance, available in both linear and logarithmic gradings. The end stop strength is over 30 oz./in. The switch is designed for battery operation up to 10 volts $\frac{1}{4}$ amp. or 150 volts, 25 mA, and the contact resistance is less than 0.5 ohms. The switch insulation is over 100 megohms at 100 volts.

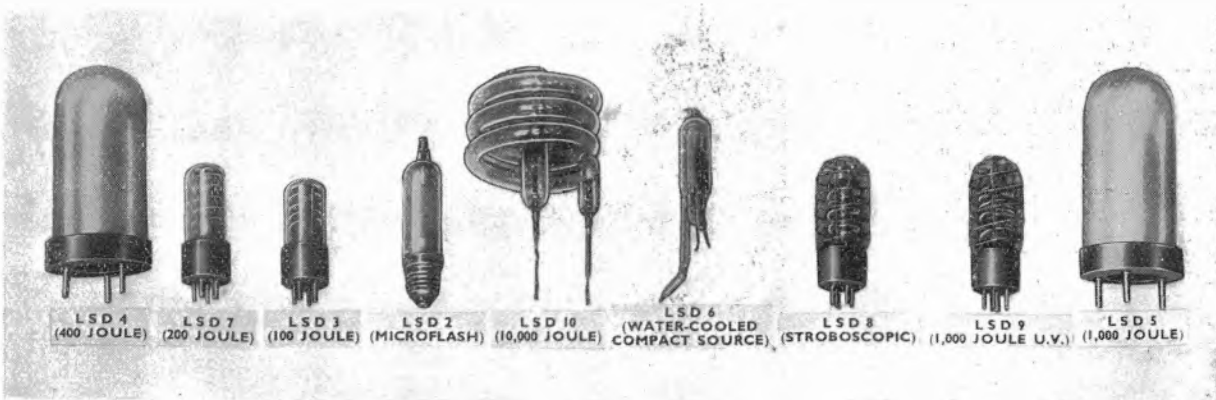
The potentiometers are sealed to be dustproof, and are single nut mounted.

Morganite Resistors Ltd.,
Bede Trading Estate,
Jarrow, Co. Durham.

Mullard Electronic Flash Tubes

THE Mullard Electronic Flash Tubes shown (*below*) are representative of the range at present available. The latest addition is the LSD9, which is a photographic flash tube, suitable for studio or portable photoflash equipment. It is basically similar in construction to the LSD7, but has a quartz spiral and produces flashes in ultra-violet. It has a protective cage instead of a glass bulb, and increased rating to 1,000 joules as against 200 joules for the LSD7.

Mullard Electronic Products Ltd.,
Century House,
Shaftesbury Avenue, W.C.2.



Multicore Solders

FOR use by radio and electronic equipment manufacturers, Ersin Multicore solder containing three cores of non-corrosive Ersin flux, is now supplied in six standard tin-lead alloys from 20 per cent to 60 per cent tin content in nine gauges, two flux percentages and three types of Ersin flux. Three methods of packing—7 lb. reels, 1 lb. reels and 1 lb. cartons—are available to suit factory requirements.

Extra activity of the N-type Ersin flux enables the bulk of Ersin Multicore solder to be now supplied with only a 2.2 per cent flux content, which is claimed to be a considerably lower flux percentage than other cored solders.

Multicore Solders Ltd.,
Mellier House,
Albemarle Street,
London, W.1.

Tantalum

TANTALUM, a metal which has been previously manufactured by Siemens & Halske in Germany and the Fansteel Metallurgical Corporation of Chicago, is now made in this country by Murex Ltd.

Tantalum resists the attack of most chemicals, and even mineral acids such as hydrochloric and nitric acids and their compounds have no effect. It is a readily workable metal, and can be welded satisfactorily, not only to itself, but to other metals such as nickel, tungsten and molybdenum.

The properties of tantalum make it suitable for the construction of chemical plant, and especially for equipment involving heat transfer.

Its main uses are for surgical purposes, as it is non-irritating to living tissues. Tantalum is also important in the production of high vacuum valves because of its strength, non-volatility at high temperatures, and ability to absorb gases when heated.

Murex Ltd.,
Rainham, Essex.

"Neptune" Hermetically Sealed Transformers and Chokes

THE "Neptune" range of hermetically sealed transformers and chokes are small and light, and if compared with the standard shell-core types, they offer up to 30 per cent saving in volume and weight. By using a high efficiency core and steel container, the external magnetic field is greatly reduced. Further magnetic screening may be obtained on Models 6000/31 to 6000/35 by the use of high permeability nickel-steel containers. All components, excepting two, in this range are provided with fixing bushes at the top and bottom to allow for inverted mounting, and are supplied with one set of slotted hexagon-headed steel fixing bolts and lock washers.

Parmeko Ltd.,
Percy Road,
Aylestone Park,
Leicester.

"C" Type Core Transformers

PARTRIDGE Transformers Limited are manufacturing transformers employing the new type of transformer core made from cold rolled grain orientated steel. The construction takes advantage of the superior properties of the material in the direction of rolling provided that the magnetic flux is caused to flow in this direction.

The cores are wound on a mandrel from continuous strip, securely bonded into a solid and finally cut into two solid C-shaped pieces. The faces of these pieces are accurately ground to give a minimum air gap which is as low as 0.00075 in. per gap.

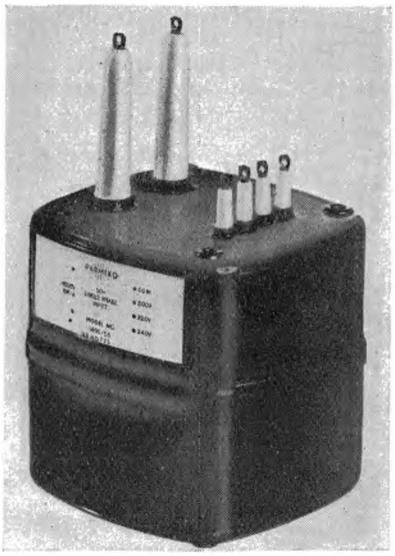
The strip used for these cores is made at the present time in three standard thicknesses—0.013 in., 0.005 in. and 0.002 in. The first of these is used for applications where the frequency is less than 200 c/s., the second for use in the range of 200 c/s. to 2,000 c/s. and the last-named where extremely high rates of change of flux are required, as in pulse transformers.

The low magnetizing VA and low core loss of this new core material mean that considerable improvement can be effected in the design of small mains transformers and especially so in vibrator transformers where battery current is an important consideration. The high flux density which can be utilized also greatly increases the output available from a given size.

The greater effective permeability and greater flux swing promise good performance characteristics for audio transformers, especially wide band output types.

Smoothing chokes also are improved, being smaller in size and having less volts drop.

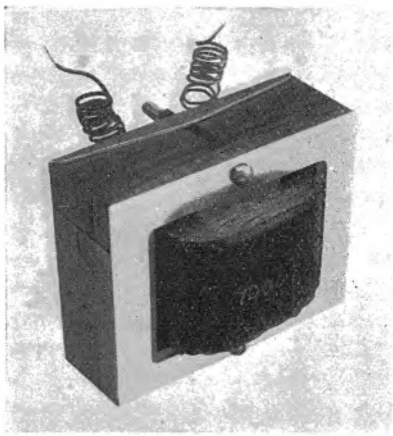
Partridge Transformers Ltd.,
Tolworth,
Surrey.



Television Components

THE Plessey Company exhibited a wide range of television components, recently introduced, embracing deflector coil assemblies, scan output transformers and focusing units (*shown below*) as well as control resistances, loudspeakers, R.F., I.F. and filter coils and chokes and transformers.

Also shown was the recently announced television grade of "Caslam" moulded core material; low losses at the higher audio and ultrasonic frequencies, and freedom from objectionable noise producing magneto-striction effects make this material eminently suitable for use in television applications.



Produced in block form, it is simple to assemble, reducing damage to delicate windings of the type necessary in scanning components.

The company also exhibited examples from the range of basic shapes of cores manufactured from "Caslite" iron dust core material. This material is now being produced in six grades suitable for use in a range of frequencies varying from normal broadcast to ultrasonic, each grade possessing individual characteristics which render it particularly suitable for use in a specific application.

The Plessey Co., Ltd.,
Ilford, Essex.

Multiway Cables

A MULTIWAY cable carrying power and water has been developed in conjunction with E.M.I. for use with their Model EH10A 1 kW induction generator, for the purpose of outgassing thermionic valves; but since its inception, there have been found several other applications to which it could be applied. Its main object is the transference of

current from the high frequency generator to the work circuit without the necessity for a separate matching unit and water supply which would be required if standard co-axial cables were used. The cable is suitable for use wherever the work circuit load does not exceed 60 kVA, and is so designed that its insertion loss does not exceed 15 per cent when this rating is applied. This cable is made up with 34 separately insulated conductors, laid up round two water-carrying tubes into a cable of circular cross-section, and T.R.S. sheathed overall.

The Reliance Electrical Wire Co., Ltd., Staffa Road, Leyton, London, E.10.

R. and A. Series 900 Loudspeakers

THE R. and A. Series 900 Reproducer embodies the standard R. and A. principle of machined cylindrical surfaces, as seen in Series 700 and 800. The inside diameter of the magnet pot, outer and inner poles are machined to the same close tolerances as well as the centring member and magnet assemblies. The construction principle ensures that inner and outer pole pieces are accurately centred on the box of the pot, giving exact and permanent alignment and uniformity of gap. The pot in turn is located on the external diameter of the outer pole, which is machined to the same close limit, and to which the cone and speech coil assembly is also jig assembled.

The Series 900 can be defined as having the simplified cone, voice coil and centring member construction of the Series 800, but with substantially great gap energy.

The four models in the new series cover the range from 6½ in. to 12 in. in diameter. They can be supplied both with or without transformers; flux densities of 10,000 and 12,000 Gauss available; fully tropical specification.

Reproducers & Amplifiers Ltd., Frederick Street, Wolverhampton.

Selenium Rectifier Type Photo-Electric Cells

(Illustrated centre)

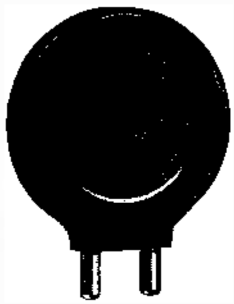
THESE selenium photocells are extremely stable when exposed continuously to light, and tests have shown that after 300 hours' exposure to an illumination of 50 foot-candles, with an external load resistance of 100 ohms, the output does not fall by more than 2 or 3 per cent.

In most practical work the angle of incidence is rarely greater than 50° from normal, and over this range the G.E.C. cells give true cosine response within 2 per cent and at 65° from normal the departure averages only about 5 per cent.

The sensitivity to light is practically independent of temperature over the normal range of ambient temperature, the temperature coefficient being less than 0.5 per cent per degree Centigrade, and therefore negligible in most applications. With load resistance of the order of 100 ohms and less, the current output is closely proportional to the incident light.

The spectral sensitivity is very similar to that of the average eye. The illumination from tungsten filament lamps at all operating colour temperatures can therefore be measured to commercial accuracy without making correction for the effect of the colour temperature of the light.

Salford Electrical Instruments Ltd., Peel Works, Silk Street, Salford, 3.



Headmaster Interchangeable Pick-up Heads

THE Goldring Headmaster is a pick-up designed with three interchangeable heads. It takes no longer to change the heads than to change the needle on a conventional pick-up, and the Goldring colour code system tells at a glance which head plays which record.

Fitted with the standard 0.0025 in. head, the Headmaster gives high quality reproduction of the latest wide-range recordings. Some recent recordings are prone to distortion in the inner grooves, and a wide range head of 0.002 in. stylus can be fitted to play them. For records made prior to 1946, or of U.S. origin, the 0.0035 in. stylus should be used.

The frequency range is well balanced to cover the entire audible range, and the record wear is low as the pick-up will track at all frequencies with less than 20 grammes, combined with high stylus compliance and low inertia. The output is 40 millivolts at 1,000 c/s. The pick-up is of the moving iron type, which is the most robust type of construction available for lightweight pick-ups.

It is an easy matter to change a head; a small thumbscrew locks the head firmly on to the arm. Slacken this a couple of turns and the head can be unplugged from the arm. The semi-resilient pins make good electrical contact in the sockets, and at the same time the downward pressure of the thumbscrew gives added security. There is no danger of noise developing in the contact system.

Erwin Scharf Ltd., 49-51, De Beauvoir Road, Kingsland Road, London, N.1

Sentercel Rectifier, Type RM4

(Illustrated below)

THE range of miniature SenTerCel selenium metal rectifiers which was developed for use in A.C.-D.C. radio receivers has now been extended by the introduction of a larger rectifier specifically for use in television receivers. This rectifier, which is known as Type RM4 , is made with square aluminium high voltage plates and has these ratings:—

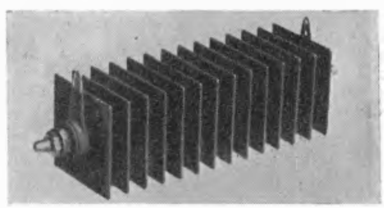
Ratings :
Maximum ambient air temperature: 40° C.
Maximum output current: 250mA.
Maximum RMS input voltage: 250 volts.
Maximum peak inverse voltage: 700 volts.
Maximum instantaneous peak current: Unlimited.

Typical Operating Conditions :
Reservoir capacitor: 60μF.
Input: 250 volts, 625 mA R.M.S.
Output: 290 volts, 250 mA mean D.C.

Dimensions :
Width: 1.375 in.
Height: 1.875 in.
Length: 4.75 in. (fixing centres).
Overall length: 5.50 in.

Samples can be supplied for development and prototype work immediately, and deliveries in quantity by September.

Standard Telephones & Cables, Ltd., (Rectifier Division), Warwick Road, Boreham Wood, Herts.



Helical Membrane Cable

THE Helical Membrane Cable was developed primarily for radio-frequency applications to provide a highly efficient construction which would not have the same frequency limitations as disk-spaced cables. The insulation comprises of a thin polythene tape lapped edge-on around the inner con-

-ductor. A practical method of achieving this basic form of the insulation has been sought unsuccessfully for many years but Telcon have succeeded in overcoming the difficulties involved. In the practical form which has been realized, the effective permittivity is as low as that of any commercial form of disk-spaced cable, and preliminary tests indicate that an extremely high degree of uniformity has been achieved. In combination with an aluminium sheath as an outer conductor and as a water-tight covering, it has electrical characteristics closely approaching the optimum and yet is mechanically robust and reliable.

Telegraph Construction and Maintenance Co., Ltd., 22, Old Broad Street, London, E.C.2.

High Stability Carbon Resistors

WELWYN high stability carbon resistors have been developed for use at very high frequencies, with a wide range of applications.

The advantages of this range of components are that: cracked carbon is a most suitable material on account of its high specific resistance and its use in very thin films; the "skin" effect is minimized when the conductor comprises a thin film of high resistivity; the high specific resistance of cracked carbon enables resistors to be fabricated in very simple shapes designed to reduce the reactance; very small components can be manufactured, thus keeping the reactance to the absolute minimum, and low-loss ceramics are used as the base for the application of the cracked carbon film.

There are four types of components available: rod, disk, rod for use with disks, and load resistors. The rod resistors are similar to the Welwyn SA range of high stability carbon resistors and have the same properties in respect of electrical performance and stability. The disk type is designed for insertion in coaxial lines, either as the shunt elements in π or T attenuators, or as terminating resistances. The rod resistors are designed to work with the disk type to form the series elements in coaxial attenuators. The last-named—the load resistors—are a range developed for large power dissipation in H.F. use.

Welwyn Electrical Laboratories Ltd., Bedlington Station, Northumberland.

Westalite Rectifiers

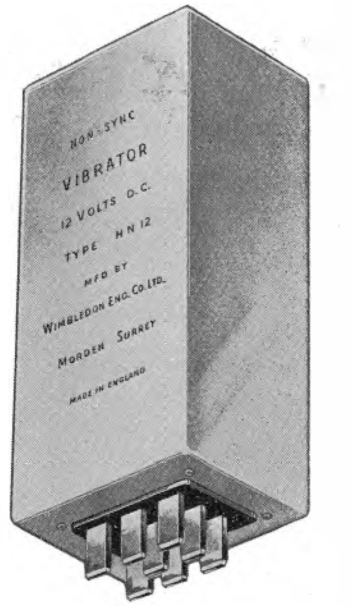
THIS new range of high voltage metal rectifiers has been developed to meet the demand for a small, compact metal rectifier to provide E.H.T. where current demand is not more than 1 mA D.C. It is possible to obtain D.C. output voltages as high as 8,400 (with sine wave input), or 15,700 volts (with pulse input), from a single rectifier unit.

The rectifiers incorporate high voltage "Westalite" rectifier elements which can withstand a very high reverse voltage.

Type 36 E.H.T. are tubular in construction; the outside diameter is $\frac{7}{16}$ in. throughout the range. In order to reduce the size and weight to the minimum, tag connexions are provided at the ends. For the majority of television applications, the shorter units are used, and these may be soldered directly to tag boards or the other components, the rectifier connecting tags alone providing sufficient support. An alternative construction type 36K is available in the range, and this type is hermetically sealed by neoprene gaskets against damp.

The rectifiers are particularly recommended for E.H.T. half-wave rectification from sine wave input, or for voltage multiplication E.H.T. supply from a sine wave or pulse input.

Westinghouse Brake & Signal Co., Ltd., 82, York Way, King's Cross, London, N.1.



Heavy Duty Vibrators

(Illustrated above)

THE Wimbledon Heavy Duty Vibrator is designed to convert D.C. electrical supply of voltages up to 250 volts into A.C.

The vibrator is housed in a specially constructed metal case, and is designed to plug into a socket holder assembled into the apparatus in which it is used. The outer metal case serves as a static screen for the internal mechanism. The vibrator unit is totally enclosed to be free from external mechanical vibrators.

There are two types of vibrator—the non-synchronous and the synchronous, of which the latter is the more popular version, and can be obtained, if required, with a split-reed which isolates the output from the input. Models are available for voltages of 2, 4, 6, 12, 24, 110 and 220, with corresponding watts ratings of 10, 25, 50, 75, 110, 275 and 440.

Wimbledon Engineering Co., Ltd., Garth Road, Lower Morden, Surrey.

British Television Export

The first dollar-earning television contract for Britain has been gained by Marconi's Wireless Telegraph Co. Ltd. This contract (placed by the Canadian Broadcasting Corporation through the Canadian Marconi Company) calls for the equipping in both Toronto and Montreal, of two studios and control rooms, a master control room, and a Film-Projector room.

Each city will have a large and small studio. In the large studios will be three complete Marconi Image Orthicon camera chains and, in each studio control room, all the Vision Mixing, Distribution Amplification, Power Supply, Intercommunication, Producers' and Engineers' control equipment, engineered in the latest style Consoles and Cabinets. The small studios are similarly equipped but will only have two Marconi camera chains each.

The Master Control rooms will contain studio picture monitors, waveform monitors, and Master Control switching equipment, while the Film and Projector equipment will enable the two stations to televise 16 mm. films, slides, and film strips. The film projectors can be remotely controlled from any of the Control positions.

Thus in both cities the television producers will have five Marconi cameras at their disposal and they will be able to provide a varied series of programmes for Canadian viewers.

NOTES FROM THE INDUSTRY

New D.S.I.R. Advisory Council Chairman

The Lord President of the Council has appointed Professor Sir Ian Heilbron, D.S.O., F.R.S., to be Chairman of the Advisory Council for Scientific and Industrial Research in the place of Sir Geoffrey Heyworth, who resigned owing to pressure of other public duties.

The Advisory Council for Scientific and Industrial Research is composed of persons eminent in industry and science. Its task is to advise the Lord President of the Council on the policy and activities of the D.S.I.R.

Sir Ian Heilbron is now Director of Research of the Brewing Industry Research Foundation near Redhill, Surrey.

Mullard Overseas Limited

The large and continuing expansion of the Mullard Company's business in all parts of the world has rendered it necessary to segregate its export activities from its home trade.

To achieve this, a new private company entitled "Mullard Overseas Limited" has been incorporated, with a nominal capital of £250,000. This company will co-ordinate the export trade of the Mullard Company from the United Kingdom.

Cambridge Summer School in Electron Microscopy, 1950

By the courtesy of Professor Sir Lawrence Bragg, O.B.E., F.R.S., a Summer School in Electron Microscopy will be held again this year in the Cavendish Laboratory.

The School will provide a grounding in the theory and applications of the electron microscope. It is intended for those who are already, or in the near future will be, operating it in physical, chemical or biological laboratories. The lectures will deal with the fundamental theory and operating principles of the electron microscope. The various techniques of specimen preparation will be demonstrated, and practised in small groups by the class. The three leading models of instruments will be used, and discussions held on their special characteristics.

The School will be held from July 18-29 inclusive. A detailed syllabus and form of application for admission may be obtained from G. F. Hickson, M.A., Secretary of the Board of Extra-Mural Studies, Stuart House, Cambridge, to whom the completed application form should be returned not later than June 5, 1950.

New Television Demonstration Film

Since the television service re-opened after the war in June 1946, Test Card "C" has been transmitted each weekday from 10.00 to 11.00 and the Demonstration Film has followed from 11.00 to 12.00 except latterly on Saturdays, when a composite newsreel has been substituted.

The change will involve continuous transmission, between the hours of 10.00 and 12.00, of the Demonstration Film and Test Card "C," alternating at approximately fifteen minute intervals.

The Demonstration Film itself has been completely re-made accordingly. It will always carry the current edition of the Television Newsreel as well as the previous Sunday's edition of the Children's Newsreel.

Further Belgian Order for Communications Equipment

A further order for communicatons equipment from the Belgian Government is announced by E. K. Cole, Ltd. This is in addition to a large order placed with the firm last November, and brings the total value of business with this hard currency area up to over £80,000 to the last six months.

Thin Copper Foil

As a preliminary to commencing production on a new plant, it is announced by the Royal Mint Refinery, of 19 Royal Mint Street, London, E.1, that limited supplies of very thin copper foil are available from a pilot plant. This foil extends the range of commercially available copper down to 0.00012 in. in thickness.

At present the foil is supplied in sheets 30 in. by 5 in., but eventually it is expected that lengths of several hundred feet will be available in widths of $7\frac{1}{4}$ in. (18.5 cm.).

The foil is of hard temper and is easily handled in spite of its thinness. Its electrical conductivity is 95 per cent I.A.C.S. minimum and its chemical composition conforms to electrolytic copper standard. It is supplied with one side polished and may, if necessary, have one or both sides plated with gold, silver, nickel, zinc, cadmium or tin.

If required, light-tested material, free from pinholes, can be made available in certain cases.

It is expected that the advent of this material will open up new possibilities in many industries, particularly those dealing with the manufacture of printed circuits and electrical capacitors.

Publications Received

Machining Bakelite Laminated.

This booklet describes the machining of this particular type of bakelite, and is obtainable from *Bakelite, Ltd., 18 Grosvenor Gardens, London, S.W.1.*

Nickel Alloy Spring Materials.

A new publication describing the use of high nickel alloys as springs, operating under unusual and exacting service conditions, issued by *Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham 16.*

Telcon House Magazine.

This publication is of interest to all those in the Telcon organisation, and it also contains a technical article on H.F. cables. *The Telegraph Construction and Maintenance Co., Ltd., Telcon Works, Greenwich, London, S.E.10.*

B.B.C. Television Service.

This booklet is a technical description of television engineering carried out by the B.B.C. It costs 2s., and can be obtained from the *B.B.C., Broadcasting House, Portland Place, W.1.*

Carbon Steels.

This is a reprint of an article from *Iron and Steel*, November, 1949, and explains new atmosphere for decarburization-free treatment. The article was written by F. F. Hancock, B.A., who is a member of *Birlec, Ltd., Tyburn Road, Erdington, Birmingham 24*, from where copies can be obtained.

G.E.C. Television Season 1949-1950.

This catalogue gives the designs and particulars of the sets available from the *G.E.C., Magnet House, Kingsway, W.C.2.*

Eclipse Permanent Magnets.

This is a collection of pamphlets concerning permanent magnets, containing technical information for users in the electrical and allied industries. *James Neill and Co. (Sheffield), Ltd., Composite Steel Works, Napier Street, Sheffield 11.*

Aluminium Wire and Cable.

This brochure describes the Aluminium Wire and Cable Co., Ltd.'s activities. Copies are available on request to *The Aluminium Wire and Cable Co., Ltd., 10 Buckingham Place, S.W.1.*

Inconel and Monel and K Monel.

Two new publications on inconel and monel and K monel, their applications and properties. Issued by *Henry Wiggin and Co., Ltd., Wiggin Street, Birmingham 16.*

BOOK

Radio Engineering—Vol. II.

By E. K. Sandeman. 579 pages. Chapman and Hall. 1949. Price 40s.

SHOULD a text book be judged solely on the usefulness of the facts it presents or should the presentation also be a matter of concern to the author? The reviewer holds that presentation is just as important as the facts themselves, and the author leaves much to be desired in his presentation of useful material. A drastic editorial purge is required if the author's contribution to radio engineering is to be as effective as he would wish. An excellent illustration of the need for compression and clarification is provided by paragraph 4, page 126. Few will doubt the wisdom of Gower's strictures on clichés in "Plain Words," and the constant repetition of "in the case of" throughout the first 100 pages will prove most irritating to the reader, especially when it is sometimes difficult to know whether an actual box (paragraph 3.7.2. page 24) is meant.

There are nine chapters, as many appendices, a bibliography of over 70 pages, and an index, which is almost a repeat of that at the end of Volume 1. The level of treatment varies widely from chapter to chapter; the first four, and chapter 22, appear to be aimed mainly at the operator, whereas the others cater more for the engineer.

The first chapter (17) is a short one on balanced and unbalanced circuits. Fig. 1. XVII. 5f is in error and the text to Fig. 4. XVII: 9 seems to suggest unbalance as a cause of feedback rather than stray capacitance (the real cause). A general discussion on interference and noise, with hints and tips on how to reduce its effectiveness, form the subject of the next chapter. It is unfortunate that the only reference (on page 41) to the 70 page bibliography in the text should be a misprint. The author deals in a descriptive manner with radio receivers for the next 50 pages, starting with the simple T.R.F. detector and ending with the superheterodyne. In paragraph 17 (page 93) the following statement is puzzling. "If one sideband uses the same voltage excursion that was previously utilised by one, the sideband power is doubled." The R.M.A. receiver tests are described and notes are given on fault finding. Chapter 20 is concerned with measuring instruments and in particular the diode voltmeter, on which the author has had considerable practical experience. The ohmmeter, megger, and various other types of bridges, including R.F., are briefly surveyed. Next follows a description of measurements of frequency, phase and modulation percentage by the cathode ray oscilloscope. The chapter ends with short discussions on the harmonic analyser, distortion factor and meter and peak programme meter.

With equalizer design (chapter 21) the author opens his sections at engineering level. The thirteen generalized loss and phase shift curves, which are given, cover most of the equalizer networks in general use.

In the next short chapter on Level Range Compression B.B.C. practice is described. It is never easy to take one's own specialized technical writings and with minor alterations to fit them into a textbook; Chapter 23 suffers from this disability and from the use of non-standard terms for voltage and current feedback. A student fresh to the subject will find himself in deep waters because in the fundamental analysis too many factors are considered at a given time. A more gradual approach would have been wiser. It is surprising that neither in the section on instability nor in the bibliography does there occur mention of Bode's "Network Analysis and Feedback Amplifier Design." The Cathode Follower and Miller effect are used as practical illustrations of feedback.

Chapter 24 deals with network analysis and synthesis by a method which avoids the use of hyperbolic functions. It does not appear to be any simpler than the classical approach and it will have some disadvantages when a student meets the latter. The same may be said of the development of matrices in which a positive direction for I_2 of a fourpole network is taken opposite to that employed by Guillemin. A number of tables and examples provide a very useful illustration of the application of matrix algebra to network problems. There are misprints on page 269 (see expression for V2) and on page 277 in referring to Fig. 1. XXIV. 3. d and e.

In Chapter 25 on filters, the author confines himself to presenting easy methods of design and estimates of performance; he wisely borrows Shea's method of tabular presentation of filter characteristics.

The nine appendices are rather in the nature of "Leaves from My Casebook." Physical and mathematical formulae are indiscriminately mixed in the first. The second discusses tuning problems in circuits having different frequencies of phase and amplitude resonance.

REVIEWS

The titles of others are: "Impedance matching in long wave aerial circuits," "Phase shift measurement by cathode ray oscilloscope," etc.

It is difficult to appreciate the reason for the lengthy bibliography since the author admits that it was not planned to link up with his text. Would it not have been better to save the 70 pages by referring to Science Abstracts, which goes much further than listing articles from a few of the English and American technical publications?

K. R. STURLEY.

TV Picture Projection and Enlargement

By Allan Lytel. 192 pp. 119 figures. J. F. Rider Publisher, Inc., 1949. Price 3 dollars.

THIS little book is one of a series produced by Rider Publications, which has the object of introducing the radio or television service engineer to the new features of projection television receivers.

The beginning of the book is concerned with a simple explanation of the principles of reflexion and refraction as applied to mirrors and lenses. There are some notes with diagrams of the direct image magnification by large liquid-filled magnifiers.

Then the book deals with the arrangement of Schmidt projection systems in the American type of home projection receiver and includes notes on the new Philip's "Protelgram" system. The illustrations of this part of the subject matter have the most interest for the radio reader, as they show clearly the various methods employed in America for mounting and adjusting optical systems and cathode ray tubes in five well known makes of sets.

The final chapter deals with the development of projection television for large screens, and here the author is not up to date and does not give any original information. At great length he describes the skiatron or dark trace tube, the supersonic television projector and the relay projection tube, none of which has been developed to an interesting stage at the present time.

A good bibliography of large screen television papers and a set of questions at the end of each chapter concludes the matter contained in this little book. On the whole "TV Picture Projection and Enlargement" is a very simple book, the need for which has not appeared in this country to date. No indication is given of the quality of picture obtained with any of these projection sets in comparison with direct viewing. One has the impression that the information has been taken out of catalogues, from which point of view it is quite interesting to flick over the pages and glance through the drawings and figures collected together by the author.

T. M. LANCE.

Sound Reproduction

By G. A. Briggs. 140 pp. 118 illustrations. Wharfedale Wireless Works, 1949. Price 7s. 6d. net.

THE first impression, upon a casual glance through this book, is that the author has condensed rather more information than space. In his preface it is stated that his original intention of answering many questions evoked by his previous booklet, "Loudspeakers; the Why and How of Good Reproduction," has been extended to include a consideration of records and pick-ups.

A great deal of work must be represented in the book, measured by the number of tests reported in the loudspeaker section. As a compilation of relevant information from authoritative sources, some previously published, and some supplied specially to the author, the book puts more data in less space than any contemporary work of British origin, while the 60 per cent or so of space devoted to original work presents the appearance of a laboratory notebook in print. The reviewer feels that as a result the conclusions drawn by the author may be more than obvious to those who have performed similar work, while to those less informed in the field, some of the material may remain somewhat obscure.

A more notable example of weakness in presentation appears in Chapter 10, on Intermodulation. After excusing himself for not possessing the "knowledge of the science of high frequency radio transmission necessary for a complete understanding of the phenomenon," he quotes a lucid explanation by Mr. Beaumont with a suitable diagram. To this he adds a further verbal and graphic illustration that shows some confusion is still present in the author's mind on the subject, presumably leaving the reader without previous knowledge of the principle in a similar position.

The material in the section on pick-ups and records is well compiled, and includes some excellent photomicrographs specially prepared by Mr. C. E. Watts. Closing

BOOK REVIEWS (Continued)

chapters summarize the subject of "Electronic Musical Instruments" as treated by S. K. Lewer, and give useful representative design values for crossover networks.

For those who found Mr. Briggs' first booklet interesting and provocative, this book will undoubtedly bring further interest, and probably provoke as many questions. Many will appreciate the added value of the interspersed poetic quotations, and the author's sense of humour, exemplified in describing one design of pick-up as "guaranteed to pick up the hum from a piece of Gorgonzola."

N. H. CROWHURST.

The Technique of Radio Design

By E. E. Zepler, Ph.D. 2nd edition. 394 plus XV pp. 283 figures. Chapman & Hall, Ltd. 1949. Price 25s.

THE object of the book is, in the author's words, "to convey to the reader some of the experiences of a radio designer obtained over a number of years in a large works laboratory . . . . The technique of design consists in foreseeing complications and in being able to work out on paper the electrical circuit and the mechanical construction so that serious trouble is not likely to occur. To develop qualities necessary for such work, i.e., a feeling for the right order of magnitude, a quick grasp of essential facts and common sense in approaching the problems, is the principal aim of this book."

The book deals mainly with problems closely connected with the work of developing and of testing radio receiving apparatus of all types. It contains a rich store of practical knowledge and of wisdom based on first-hand experience, the arrangement being methodical and in logical order in 15 chapters under the following headings speaking for themselves: 1. Some fundamental theoretical facts; 2. Transfer of energy from the aerial; 3. The amplifier stage; 4 Detection and frequency changing; 5. Selectivity; 6. Receiver noise; 7. Gain control; 8. The principles of screening; 9. Undesired feedback; 10. Hum, spurious beats; 11. Distortion; 12. Parasitic resonance; 13. Power supply; 14. Routine measurements; 15. Fault finding. A number of useful formulæ is assembled under a separate heading.

The presentation of the subject is throughout at an even level, coherent, fluent and lucid, aided by 283 clearly designed figures and a considerable number of practical examples. It may be said without qualification that the author has admirably achieved his aim.

A few observations, of a minor nature, may perhaps be considered in a further edition of the book. It would be helpful for the reader to find all figures provided with captions, and to see the headings of sections and sub-sections in Chapters 2 and 4 signified by the method applied, e.g., in Chapter 5; a few more sub-headings would break up the text, e.g., Direct coupled amplifier on p. 70, Feedback on p. 71, Design of coils on p. 90. Some formulæ and equations are referred to in other places of the text, for direct finding numbering would be an advantage. "Capacitor," "inductor," and "anode slope resistance" might, respectively, replace "condenser," "choke," and "valve impedance," and on p. 222 "volume control" is meant to read "gain control." Instantaneous values of currents and voltages should be signified by small letters.

The book, of which the first edition was published in 1943, with a second impression in the same year and a third impression in 1945, is a revised version, brought up to date, of the first edition, and is excellently printed. It is warmly recommended as a valuable guide and reference book for workers who are confronted, either in their daily work or occasionally in the laboratory, with the task of designing and/or testing an apparatus of the radio receiver type.

R. FEINBERG.

The Practical Electrician's Pocket Book

Edited by R. C. Norris. 52nd Edition. 518 pp. Electrical and Radio Trading. 1950. Price 5s.

THIS useful annual pocket book this year includes several new features: a chapter on Battery Electric Vehicles; the Agriculture and Horticulture section has been extended; new guidance on ventilation has been included; a new review "Electronics in Industry" has been added; "Soldering" and "Winding resistance" are new subjects, and "Rewinding small motors" has been completely rewritten.

A new Mains Voltage Table, covering over 5,000 places, has been compiled with the aid of the Area Boards.

LETTERS TO THE EDITOR

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

Permanent Magnet Lenses for Television Tubes

DEAR SIR,—I notice that the diagram Fig. 1 in D. Hadfield's article in the April issue of ELECTRONIC ENGINEERING shows electrons spiralling in ever decreasing radii under the action of the focusing field.

It appears to me that the electrons only execute a helical motion while they are under the influence of the magnetic field, and do not continue spiralling until they reach the screen as shown in the diagram.

In addition it can be shown by quite a simple piece of mathematics that if the magnetic field is uniform over the whole of the electron path and parallel with the axis of the tube and if an electron leaves the cathode on an axis but at an angle to the axis, then this electron will follow a helical path, with the axis being a generator to the surface containing this helix. The pitch of this helix depends only on the axial component of velocity of the electron and the strength of the field, so that if a number of electrons leave the cathode at different angles but with the same component of velocity parallel to the axis then they will each execute helices of equal pitches. Thus the electrons will all return to the axis at points that are distant from the cathode by some multiple of this pitch. For a given distance from points that are distant from the the cathode to screen this means that there are a number of possible values of field which will produce focusing, the lowest value of which corresponds to the single helix of the electron trajectory.

When the electron velocity is not constant throughout its path and the axial distribution of the magnetic field is not uniform then the action is more complicated, but it is to be expected that it will be analagous to the above description of the simple case.

I think it is at any rate quite clear that the electrons do not execute spirals about the tube axis, but to one side of it as explained. Also the field is usually adjusted to give focusing with the lowest value of flux, showing that the electrons only rotate through one coil of the helix in their path to the screen.

Yours faithfully,

E. J. WAYMAN,
Queen Mary College,
London University.

Mr. Hadfield replies:—

"Mr. Wayman's assumption of a uniform magnetic field over the whole of the electron path and parallel with the tube axis is purely hypothetical and certainly does not arise in practice. The magnetic field is a maximum at the centre of a magnet and decreases along the axis on either side.

The field is not really parallel to the tube axis at any point but the tube axis is tangential to the lines of force at the point of maximum field strength, thus the particles start their journey in a very weak magnetic field which increases in intensity to a maximum as they pass through the centre of the magnet and it then decreases to a minimum as they travel onwards towards the screen.

There is only one value of field strength to produce optimum focusing, this factor being proved experimentally.

Mr. Wayman is probably correct in that the electrons may traverse only one coil of a helix before striking the screen but I disagree with him that there are a number of possible values of field strength which will produce focusing depending on the pitch of the helix. Neither can I agree that the electrons execute spirals to one side of the tube axis.

It should be pointed out that Fig. 1 is over-simplified in order to avoid more detailed mathematical analysis of the physical principles involved.

The action of the field on an electron is felt before the electron reaches the centre of the magnet, the force increasing as the field strength increases and thus some bending of the electron path will take place before it reaches the centre of the magnet.

I would like you to express my thanks to Mr. Wayman for going into the matter in such detail."

Semi-Conductors

DEAR SIR,—May I thank you for publishing an article which enables engineers to keep abreast of physical and chemical progress on the nature of electrical phenomena.

Since the action of selenium has not been published, although that of copper oxide in the metal rectifier has been dealt with in detail, Dr. Harris may care to comment on the following:

It would appear that both copper oxide and selenium are deficit semi-conductors, the difference in forward direction of their rectifiers being due to the former having a back wall and the latter a front wall barrier layer.

Williams and Thompson (*J.I.E.E.* 1941, *88*, Part I), explain that the selenium rectifier is poisoned by sulphur and tellurium but is rendered suitable for use by adding 0.1 per cent halogen compounds, which are in the same column of periodic table and to the right of it respectively. The probability is, therefore, that selenium owes its action to F centres, which are vacant halogen ion sites in the lattice, carrying a positive charge, and able to hold an electron. These are the impurities.

Dr. Harris's explanation of the Ferni diagram does not appear to tally with that of Professor Mott, (*J.I.E.E.*, 1949, Part I, *96*, page 257), since Professor Mott gives $E_1 + E_2$ as the work function of the surface between the metal and the semi-conductor, and Professor Mott regards this as constant under varying electric fields taken as the contact potential.

The same remarks apply to Fig. 5, save that 5b and 5c are interchanged in the text.

Finally, since no rectifier would work with equal front and back layers, why is a potential photocell imagined as having equal layers at front and back? (Fig. 6).

With compliments to Dr. Harris for the way in which he has dealt with a very difficult subject.

Yours faithfully,

D. G. PEARCE, M.Sc., A.M.I.E.E.
Bolton, Lancs.

Dr. Harris replies:—

"I regret the errors which have crept in, since Fig. 4 was copied from the illustration on p.179 by Mott and Gurney's "Electronic Processes in Ionic Crystals", which is a most valuable reference book. Of course, the contact potential is E_1 and height $E_1 + E_2$ should appear constant as Mr. Pearce remarks. Incidentally, in Figs. 5 and 6 the vertical lines should not project above the lines representing the potential energy of an electron in the first empty level. The reference to Figs. 5b and 5c in the text should be interchanged. As for Fig. 6, it seems to me simpler to depict a symmetrical system which could be made asymmetric by illumination of one boundary only, but it is certainly true in practical cases that two dissimilar boundaries are illuminated and the net photo E.M.F. is the difference between the photo E.M.F's set up on each boundary."

Time-Calibrated C.R.T. Traces

DEAR SIR,—In the February issue of ELECTRONIC ENGINEERING, C. H. Banthorpe has described an interesting circuit which he proposes for use as a time marker for an oscillograph or as a component part of a television bar generator. I would suggest that the same circuit may be employed to generate a signal for line wobbling in a television receiver, although it is probable that an amplifying stage will be required.

The scanning waveform may be differentiated and the positive pulse removed, the resultant signal being applied to the suppressor grid of the valve to cut off the anode current during the flyback period. The output square-wave signal may be applied to two deflector plates to cause the line trace to wobble in a vertical direction. The peak-to-peak amplitude of the line wobble should be equal to the distance between adjacent scanning lines in alternate traces.

Let us assume that the picture is 10 inches high and that the distance between scanning lines is, therefore, 0.677 mm. Let us also assume that the peak-to-peak output potential, after amplification, is 100 Volts. The deflexion sensitivity required is then 0.00677 mm./Volt. If the deflector plates are about 15 inches behind the plane of the screen and ¾ inch apart, they must be about ½ inch square when a potential of 8,000 Volts is applied to the anode of the cathode ray tube. For experimental purposes the plates may be made a little larger than this and they may take the form of metal foil, glued, or otherwise fixed, to the outside the cathode ray tube.

Since an output of only about 10 Volts can be expected from the circuit given in Banthorpe's article, an amplifier will be required to provide the output of 100 Volts postulated above.

The advantages of line wobbling are as follows:—

Eye-strain is greatly reduced since the observer can sit nearer to the screen and he is then able to see fine detail more easily. Furthermore, it is not necessary for him to force his eyes to reject the gap between the lines while struggling to accept details in image which are of even smaller dimensions.

Yours faithfully,

O. S. PUCKLE.
Beaconsfield, Bucks.

Mr. Banthorpe replies:—

Mr. O. S. Puckle's suggested application of the circuit is interesting, and it would clearly function as he describes. There seems no virtue, however, in triggering the "jitter" scanner and the circuit will, of course, self run if the suppressor grid is joined to cathode.

If the B.B.C. were to use a similar jitter however, such locking might be an advantage.

I feel that if "jitter" is to come, it would be best be done at the transmitter and receiver, and a ready made sync. could be used. There already exists in the video output of a good receiver a 3.5 Mc/s component (the beat between sound and vision carriers) and if this were extracted and doubled or trebled, this 7 Mc/s or 10.5 Mc/s signal could be used for line wobbling. The B.B.C. could lock their wobble in the same way, and the limitation on vertical definition would be eased. Work on these lines should be extremely interesting, and the results be very important when "selling" a system.

Electronic Instruments in Diagnostic Medicine—Part II

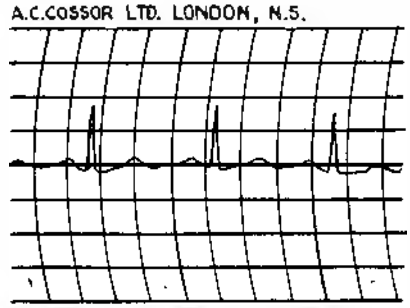
DEAR SIR,—It was with great interest that we read an article on Electronic Instruments in Diagnostic Medicine (Part 2) by Mr. H. A. Hughes in the March issue of ELECTRONIC ENGINEERING.

We would like to bring to your notice that Fig. 12, which shows a "sketch of typical trace from Cossor Model 1314 Electro-Cardiograph," is not strictly accurate and we were wondering whether you would be good enough to print a true reproduction of an actual tracing.

Yours faithfully,

A. C. COSSOR LIMITED

A.C.COSSOR LTD. LONDON, N.5.



ELECTRO-CARDIOGRAPH MODEL 1314

Atomic Energy

DEAR SIR,—In the editorial in the April issue of ELECTRONIC ENGINEERING on Atomic Energy is stressed the danger of waste products and the difficulty of disposing of them. I would suggest that the simplest way would be to contain them in pellets, quite big ones, and fire them into space where they would settle in an orbit around the Earth, and be out of the way. We are almost in sight of being able to do this, and by the time waste products are a big problem, the design of a pellet should be possible.

Yours faithfully,

C. H. BANTHORPE,
Hayes, Middx.