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CONTENTS

Exhibitions

OFFICIAL details have now been released of the Radio Industry's contribution to the British Industries Fair to be held in London and Birmingham from May 2 to May 13, and television will undoubtedly be the main theme, both at the London and Birmingham sections.

At Birmingham an Image Orthicon Television Camera will be televising from inside the Fair and a similar camera just outside the main scenes including the arrival and departure of aircraft from the adjacent airport. Visitors to the Fair will thus have the opportunity of seeing televised scenes from the crowds of which they themselves are a part. These demonstrations will show that British television has reached a new stage far in advance of anything hitherto achieved.

The equipment providing these facilities will be operating on the 625 line systems and will thus form the first public demonstration of television operating on the standards recently recommended for adoption by countries not already committed to the British or American standards.

Similar apparatus was used for televising the Boat Race, a technical description of which appears in this issue.

Of special interest, too, will be the actual vision transmitter destined to be the B.B.C's third television transmitter and which will incorporate many new and unique features. This transmitter will operate in the 42-46 Mc/s. band with positive modulation at a power of 35 KW as compared with the 17 KW of the existing Alexandra Palace transmitter.

In the Radar Section will be a new cloud and collision warning equipment designed to give warning to aircraft pilots of certain types of cloud formations associated with storm areas at a distance of 40 miles.

In the section devoted to Electronic apparatus there is much that is both new and novel in the ever widening application of electronics to measurement, control and selection.

It is axiomatic that with this wider use, important conditions must be fulfilled in the design of the apparatus. It must be reliable in operation, give indications which are capable of easy interpretation and possess the ability to withstand abuse by the non-technical user. But British manufacturers appear to be fully aware of these problems and have produced new and valuable tools which are more than "gadgets."

For example, farmers will now have a portable pH meter which, by inserting an electrode into the soil, will give a direct reading of soil acidity or alkalinity. A demonstration can also be seen of an electronic method of treatment and drying grass to ensure full nutritional value for consumption by livestock.

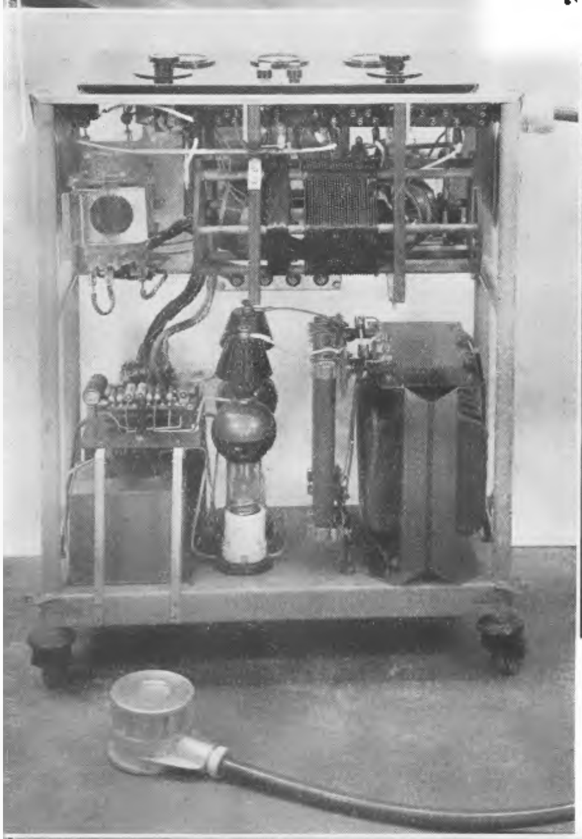
The Physical Society's 33rd Exhibition of Scientific Instruments and Apparatus was held last month at the Imperial College, South Kensington. Lack of space, however, prevents a detailed review of new electronic apparatus, some of which was displayed at the earlier R.C.M.F. Exhibition and subsequently reviewed in these pages in the April issue.

NEW BRITISH ULTRASONIC GENERATOR

(See page 161)

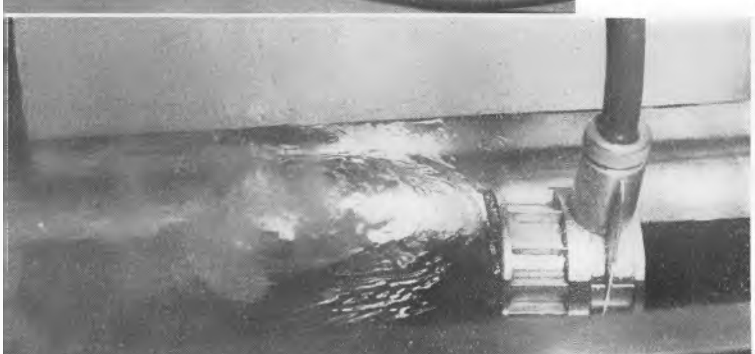
Left : **Ultrasonic fountain and mist**

Right : **Defraction patterns produced on surface of a liquid**

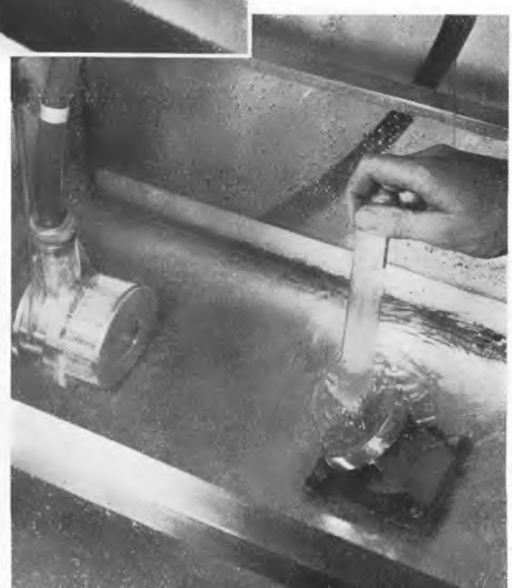


The new Mullard Ultrasonic Generator with covers removed with transducer head in foreground

Centre : **Defraction of ultrasonic beam by a vertical rod showing production of separate fountains at a deflector plate**



Bottom left : **Agitation of water and production of mist over a deflector plate immersed in path of beam**



Bottom right : **Treatment of a sample in a test tube by immersion at the focus of a parabolic reflector**

Photos supplied by courtesy of Mullard Electronic Products Ltd.

VOLTAGE STABILISERS Part I

By F. A. BENSON, M.Eng., A.M.I.E.E.*

IT is generally desirable to operate equipment from power supplies fed directly by the mains rather than to employ batteries. The necessary power supplies are usually obtained from the mains through rectifier units, each of which normally incorporates a transformer, a rectifier, and a smoothing circuit. Large changes in the output voltage of such a rectifier unit are produced by load current variations. Further, the mains voltage and its frequency may vary. The effect of variations in frequency on the output voltage of the rectifier unit, however, is usually fairly small. Many circuits only operate satisfactorily from a power supply the voltage of which is independent of both fluctuations in the mains voltage and variations in load current. To meet these requirements, voltage stabilisers are employed. They have been developed for stabilising either A.C. or D.C. power supplies and some arrangements can deal with either. Voltage stabilisers, in general, also have the further beneficial effect of reducing any ripple voltages present in the output of a power supply to which they are connected. Typical cases where the above requirements have to be satisfied are found in work involving the use of high-frequency oscillators (klystrons), photocells or electronic measuring instruments. In the case of a klystron, for example, the output and the frequency depend on the magnitudes of the voltages applied to the various electrodes and ripple voltages produce frequency modulation of the output. Again, certain photocell equipments require a light source whose candle-power remains sensibly constant.

This series of articles reviews the various methods of stabilising the voltages of both A.C and D.C. power supplies. Circuits which employ magnetically saturated elements are considered first. Then follow descriptions of circuits employing gaseous discharge tubes. The characteristics of the available tubes are quoted and the limitations of the tubes are discussed. Thermionic-valve circuits are then dealt with. After a brief account of the available methods of using thermionic valves as stabilisers, several practical circuits which have been found extremely useful are described in detail. The performances to be expected of these circuits are given. Although the articles are essentially non-mathematical, the theory of a number of thermionic-valve circuits has been included in an appendix for the benefit of readers who wish to go into the subject more fully. Finally, several miscellaneous circuits are briefly described.

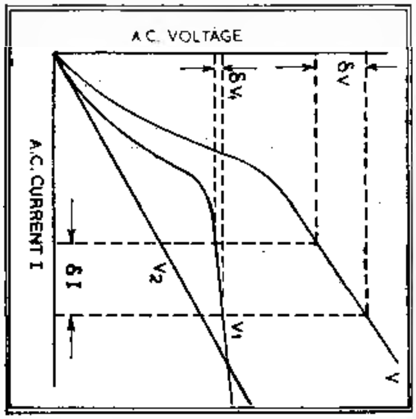


Fig. 1. Current and voltage with saturated and unsaturated reactors connected in series

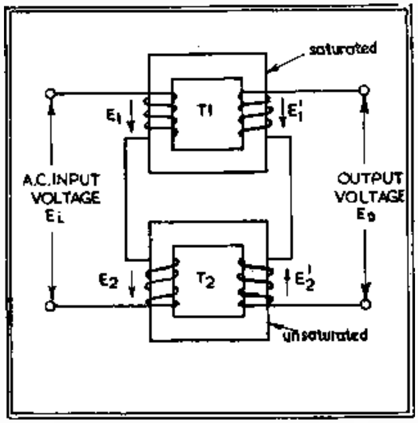


Fig. 2. Transformer-type stabiliser

Much has been published on the subject of voltage stabilisers. Most of the articles describe particular circuits and give details of their performances. As it is impossible to include details of all the circuits a fairly extensive bibliography is included.

Stabilisers Employing Magnetic Saturation

Stabilisers employing magnetic saturation deal with A.C. power supplies and many circuit arrangements have been devised. A number of different designs are considered in detail below. Each has an element which is magnetically saturated so that the output voltage does not vary in accordance with input voltage changes but tends to remain constant.

One of the simplest circuits consists of saturated reactor connected in series with an unsaturated reactor.[1,2] The voltages across the saturated and unsaturated reactors, V_1 and V_2, respectively, vary with the current I flowing in the circuit in the manner shown in Fig. 1. At any particular value of current the input voltage V is the sum of V_1 and V_2. It will be seen that a change δV in the voltage V produces only a change of δV_1 in the voltage V_1. Thus, by correct choice of components, the percentage change of V_1 may be made much less than the percentage change of V. The arrangement can, therefore, be used as a voltage stabiliser by connecting

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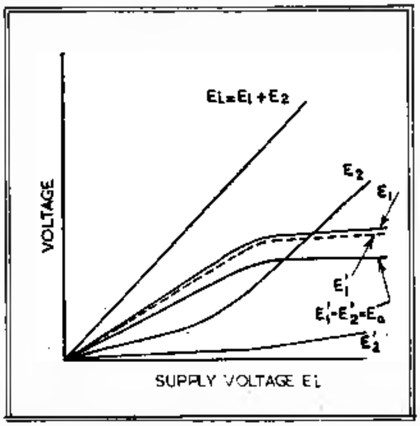


Fig. 3. Variations of E_1 and E_2 with respect to E_1

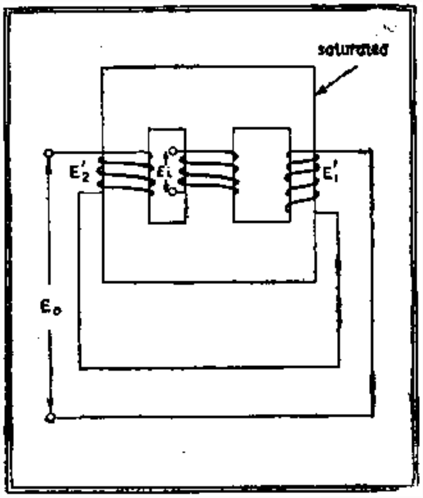


Fig. 4. Modification of the arrangement shown in Fig. 2

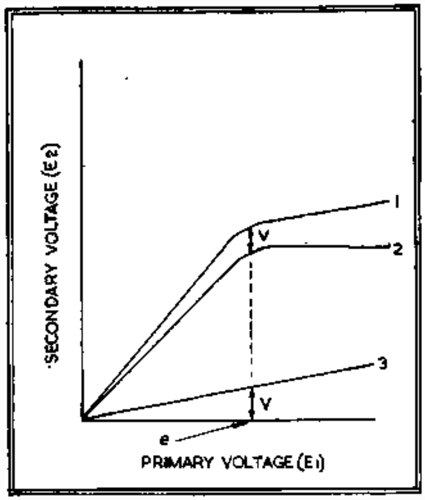


Fig. 5. Characteristics of a transformer having leakage as well as a saturated magnetic circuit

the load directly across the saturated reactor.

Another stabiliser of this type is shown in Fig. 2.[1,3] It consists of two transformers T_1 and T_2, one of which has a magnetically saturated core under the working conditions. The primaries of the transformers are in series and the secondaries, which are connected in opposition, supply the load.

By considering the primaries of the transformers and making further reference to Fig. 1, the variations of the voltages E_1 and E_2 with E_1 may be plotted as in Fig. 3. If the saturated transformer develops most of the output voltage, then the secondary voltages E_1' and E_2' vary with E_1 in the manner shown in Fig. 3. Thus the output voltage E_1'-E_2' remains nearly constant over a considerable range of E_1.

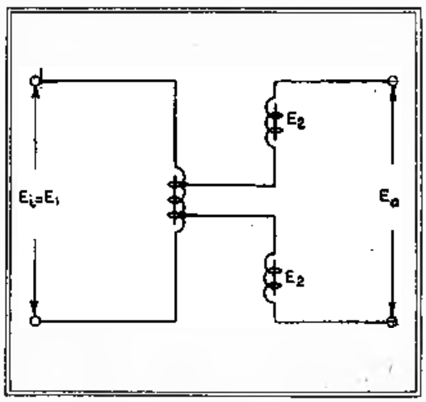
Many modifications of the above design have been suggested[4,5,6,7] and several three-legged transformer circuits have been used instead of the two separate transformers by simply combining either the primary or secondary windings. One such arrangement[7] is shown in Fig. 4 in which the primary windings of Fig. 2 have been combined. In the circuit of Fig. 2 saturation of transformer T_1 can easily be achieved by making the number of ampere-turns on the primary winding greater than those on T_2. However, in the present case this method cannot be employed as there is only one primary winding; so saturation is produced by using one limb of small cross-section.

A further method for obtaining a constant voltage irrespective of input voltage variations has been described by Bedell and Kuhn.[8] Here stabilisation is attained by employing a transformer which has considerable leakage as well as a saturated magnetic circuit. The secondary voltage of a transformer of this nature does not increase proportionally with the primary voltage as seen in curve (1) of Fig. 5. For voltage stabilisation a relation between primary and secondary voltages as shown in curve (2) is required where above saturation the secondary voltage is constant. To obtain (2) from (1) a curve such as (3) must be subtracted from (1). It is found that (3) is very nearly a straight line, *i.e.*, the amount to be subtracted (v) at any particular value of primary voltage (e) is proportional to that primary voltage. This required quantity v may be obtained by tapping off part of the primary voltage and if it is then subtracted from the secondary voltage a constant output voltage will result. The circuit arrangement used by Bedell and Kuhn is shown in Fig. 6. The secondary windings are placed in series with part of the primary winding and are in opposition to it. The primary winding is on one leg of the magnetic circuit and the secondary on another of smaller cross-section.

Bedell and Kuhn have given results for a 150-watt transformer. An increase of primary voltage of about 30 per cent produces an increase in output voltage of about 2.5 per cent. Units can be produced in which the output voltage remains constant over a considerable range of input voltage. Both the power factor and the efficiency of such a stabiliser are rather low, which may be an objection where large sizes are involved.

Improvements in the operation of some of the above stabilisers have

Fig. 6. The Bedell and Kuhn circuit



be obtained by inserting capacitors in various parts of the circuits with a view to acquiring better voltage regulation and output voltage waveforms [9]

Limitations of above circuits

The majority of the early designs of stabilisers working on these principles, including the ones already considered, suffer from a number of disadvantages. First, the output voltage waveform is seriously distorted. This is caused by saturation of the iron which results in harmonics in the magnetising current and harmonic currents flowing through impedances in the circuit produce harmonic voltages. Secondly, the regulation is poor so that the output voltage does not remain constant for variations in load current. Further, the output voltage generally depends on the frequency of the input voltage and in many cases the form factor (*i.e.*, the ratio and R.M.S. value to average value) of the output voltage waveform changes with variations in load current which for some applications is a disadvantage.

The "Stabilistor" Equipments

Recent designs have overcome these difficulties, however, one satisfactory arrangement being the "Stabilistor."[10,11,12] Two types of this equipment are available, the first is stabilised against variations in both supply voltage and load current, but there is no compensation for changes in frequency of the input voltage. The second type is designed for a fixed resistive load and is stabilised for changes in both the input voltage and its frequency.

"Stabilistor" Type 1

The circuit of the first type of "Stabilistor" is shown in Fig. 7. It is basically similar to that of Fig. 2. It consists of a transformer T_1, an auto-transformer, T_2, the core of which is worked at a high-flux density and an inductance L in series with a capacitor C. The saturated transformer supplies most of the secondary voltage as in the previous case.

The L-C circuit serves two purposes. It is designed so that at 50 c/s. (the usual supply frequency) it behaves as a capacitative reactance and draws a leading current which tends to offset the effect of the large magnetising current in the transformer primaries. At 150 c/s. the circuit is resonant; it thus provides a short circuit for any third-harmonic currents and therefore no third-harmonic voltages appear across it. Hence, third-harmonics are absent in the output voltage waveform. The units are available in various sizes to give outputs ranging from 30 VA to 1,200 VA at 230 volts.

Performance

It is possible to hold the output voltage constant to within ±2 per cent for input voltage variations of about ±15 per cent and within the range zero to full load. For changes in input voltage of less than ±15 per cent the figure ±2 per cent is correspondingly reduced. The waveform is very nearly sinusoidal; the form factor is within ±.05 per cent of 1.11. Frequency variations affect the output voltage, a variation of ±1 per cent from the nominal 50 c/s. changes the output voltage by about ±1.5 per cent. The power factor of the unit at full load when supplying a load of unity power factor is about 0.7 lagging and the efficiency is about 85 per cent.

"Stabilistor" Type 2

The second type of "Stabilistor" is a modification of the above circuit, it is shown in Fig. 8. It employs a further transformer T_3 and a second filter circuit L_2C_2 which

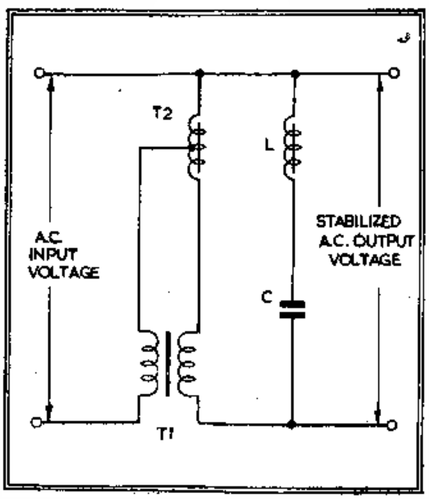
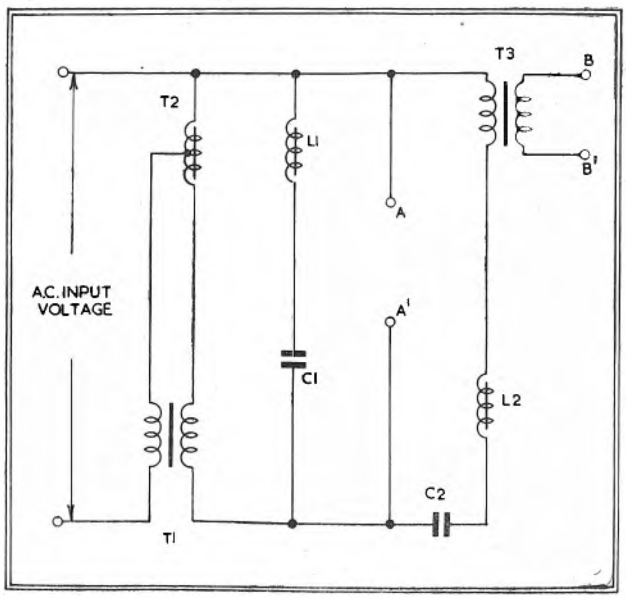


Fig. 7. (Left) Original "Stabilistor" circuit

Fig. 8. (Right) Second "Stabilistor" circuit



compensates for variations in supply frequency. In this case two alternative stabilised outputs are available but cannot be obtained simultaneously. The output from terminals AA' is the same as that obtained from the first model and is thus constant irrespective of changes in input voltage or load current. The other output from terminals BB' is only suitable for supplying a fixed resistive load but the output voltage is practically independent of variations in both the input voltage and frequency, and, further, the output-voltage waveform is sinusoidal.

These units, as in the case of the first type, are also available in various sizes to give outputs from 30 VA to 1,200 VA at 230 volts from terminals AA' or alternative outputs from 12 to 480 watts at a chosen voltage from terminals BB'.

Performance

In this case a 1 per cent change of input voltage produces a change of 0.04 per cent or less in the output voltage from terminals BB' and a 1 per cent change in the frequency of the input voltage produces not more than 0.05 per cent change in output voltage over the ranges input voltage 200 to 250 volts, frequency 48 to 52 c/s. The power factor of the unit is again about 0.7 lagging, but the efficiency in this case is only of the order of 55 per cent.

The principle of this type of stabiliser is that over a certain range of current flowing through a neon discharge tube (or similar cold-cathode discharge tube) the voltage across it remains nearly constant. This can be seen by reference to Fig. 9 where typical current-voltage curves for several available tubes are plotted. Hence, if a neon tube is placed across a D.C. supply voltage V_i and fed through a series resistance R (Fig. 10), the latter will absorb any fluctuations in V_i. An increase of input voltage increases the IR voltage drop across R and the voltage across the neon tube remains practically constant. Further, an increase of load current results in a drop of current through the tube, the voltage drop across R and the tube voltage both remaining nearly constant. Thus, if on no load the tube takes a current i_{n1} then when a load current I_L is taken the tube current is reduced to $(i_{n1}-I_L)$ approximately. When the load is removed the tube current rises again to i_{n1}. It follows that full load current must not be greater than i_{n1} – (the minimum tube current), and also that the tube current is a maximum at no load.

The value of the resistance R and the input voltage V_i must be chosen so that the tube will "strike" and the current through it is less than the maximum safe current for all values of load current. Too large a value of current through the tube causes an arc which destroys it.

(To be continued)

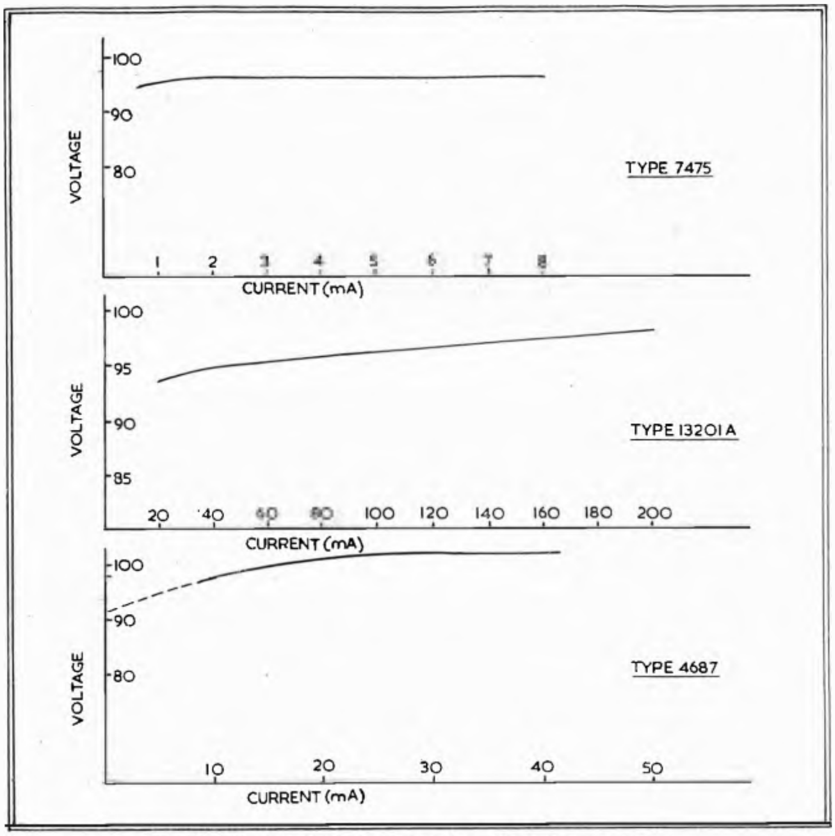


Fig. 9. Current voltage curves for different neon tubes

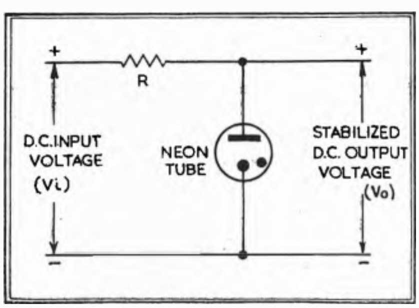


Fig. 10. Basic neon tube stabliser circuit

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Combined Current and Voltage Feedback

By K. R. STURLEY, Ph.D., M.I.E.E.*

IN amplifiers employing negative feedback it is common practice to apply voltage negative feedback from the output into the cathode circuit of an earlier stage. The feedback voltage is developed across an impedance (generally a resistor) which also carries the anode current variations of the valve in whose cathode circuit it is placed. This leads to current feedback, the effect of which cannot be ignored. Some textbooks take this into account by considering first the reduction of overall amplification due to current feedback and then the reduction of the new value of overall amplification due to voltage feedback, so that the final amplification is given by:

$$A = \frac{A_1'A_2}{1 + A_1'A_2\beta}$$

where A_1' = amplification of the first stage with current feedback

A_2 = amplification of the remaining stages

and β = voltage feedback factor.

A more rigorous examination of the problem shows that there is inter-action between the current and voltage feedback sources, which modifies the above expression. Though the error is of a second order—its maximum value is of the same order as the voltage feedback factor—the analysis may be of interest to designers and users of precision equipment employing this type of feedback.

Theory

As a rule two factors, overall amplification and equivalent output impedance, require to be known for an amplifier having negative feedback. The second can be derived from the first.

Overall Amplification

The simplest form of circuit is illustrated in Fig. 1. A triode is shown, but a tetrode or pentode could equally well be used. Voltage feedback is supplied via the potential divider R_1 and R_2, and current feedback by R_2. The equivalent circuit is shown in Fig. 2, and the following current and voltage relationships can be derived from it.

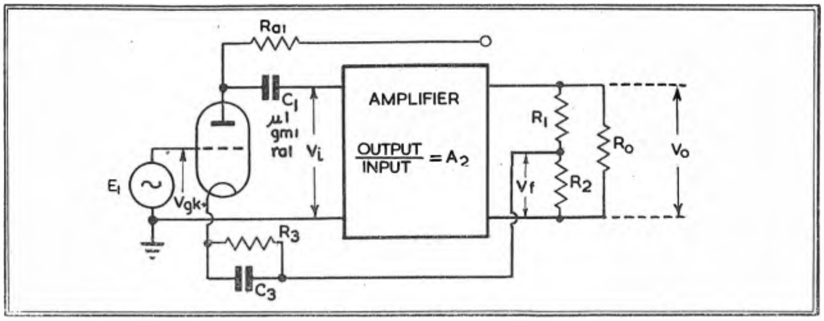


Fig. 1. Simple circuit illustrating voltage and current feed-back

$$E_1 = V_{gk} + V_f \quad \text{.......} \quad (1)$$

$$V_o = -A_2V_i = I_1R_2 + I_2(R_1 + R_2) \quad (2)$$

$$V_i = -I_1R_{a1} \quad \text{.......} \quad (3)$$

$$\mu_1V_{gk} = I_1(r_{a1} + R_{a1} + R_2) + I_2R_2 \quad .. \quad (4)$$

where $A_2 = V_o/V_i$ = amplification of the second stage of the amplifier.

R_{a1} = parallel combination of the anode load resistance of V_1 and the input resistance of the amplifier section A_2.

Solving (2) and (3) for I_2 gives

$$I_2 = \frac{I_1(A_2R_{a1} - R_2)}{R_1 + R_2} \quad \text{.......} \quad (5)$$

Since $V_f = (I_1 + I_2)R_2$

$$\mu_1V_{gk} = \mu[E_1 - (I_1 + I_2)R_2] = I_1(r_{a1} + R_{a1} + R_2) + I_2R_2$$

from which

$$E_1 = \frac{I_1}{\mu_1}\left[r_{a1} + R_{a1} + (1+\mu_1)(R_1 + A_2R_{a1})\frac{R_2}{R_1 + R_2}\right]$$

Overall amplification with feedback

$$A_f = \frac{V_o}{E_1} = \frac{A_2I_1R_{a1}}{E_1}$$

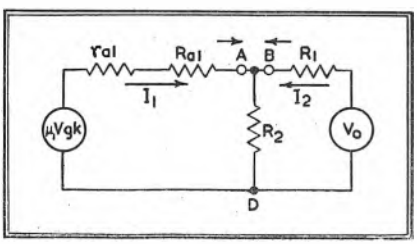


Fig. 2. Equivalent circuit of Fig. 1

$$= \frac{\mu_1R_{a1}}{r_{a1} + R_{a1} + (1+\mu_1)R} \cdot A_2 \ldots \quad (6)$$

where $R = (R_1 + A_2R_{a1})\dfrac{R_2}{R_1 + R_2}$

$$= (R_1 + A_2R_{a1})\beta = R_2(1-\beta) + A_2R_{a1}\beta$$

and $\dfrac{R_2}{R_1 + R_2} = \beta$, the voltage feedback factor.

The expression

$$\frac{\mu_1R_{a1}}{r_{a1} + R_{a1} + (1+\mu_1)R}$$

is the amplification of valve V_1 with current feedback provided by an unby-passed resistor R. In appendix 1 it is shown that R is the actual equivalent resistance R_{AD} looking towards V_o, so that it is possible when calculating A_f to consider the circuit as a current feedback stage followed by an amplifier of stage gain A_2. Expression (6) can be rearranged as follows:

$$A_f = \frac{\dfrac{\mu_1R_{a1}}{r_{a1} + R_{a1}} \cdot A_2}{1 + \dfrac{1+\mu_1}{r_{a1} + R_{a1}}[R_2(1-\beta) + A_2R_{a1}\beta]}$$

$$= \frac{A_1A_2}{1 + \dfrac{(1+\mu_1)}{r_{a1} + R_{a1}} \cdot R_2(1-\beta) + \dfrac{1+\mu_1}{\mu_1}A_1A_2\beta} \quad .. \quad (7)$$

where $A_1 = \dfrac{\mu R_{a1}}{r_{a1} + R_{a1}}$ = amplification of V_1 with no current feedback.

The approximate expression gives

$$A'_f = \frac{A_1'A_2}{1 + A_1'A_2\beta}$$

* Head of B.B.C. Engineering Training Dept.

$$= \frac{A_1A_2}{1+\frac{(1+\mu_1)R_2}{r_{a1}+R_{a1}}+A_1A_2\beta} \quad \ldots\ldots (8)$$

because $A_1' = \dfrac{A_1}{1+\frac{(1+\mu_1)R_2}{r_{a1}+R_{a1}}}$

In most practical circuits $A_1A_2\beta$ will be the largest factor of the denominator so that A_f' approaches $A_f \cdot \frac{(1+\mu_1)}{\mu_1}$ and this represents the maximum possible error. Hence, the approximate result will tend to give a value $\frac{100\%}{\mu_1}$ higher than the correct value.

If tetrode valves are used,

$$\frac{1+\mu_1}{r_{a1}+R_{a1}} \approx g_{m1} \text{ and } \frac{1+\mu_1}{\mu_1} \approx 1$$

$$A_f = \frac{A_1A_2}{1+g_{m1}R_2(1-\beta)+A_1A_2\beta}$$

and $A_f' = \dfrac{A_1A_2}{1+g_{m1}R_2+A_1A_2\beta}$

In this instance there is very little difference between A_f and A_f' because $g_{m1}R_2$ is usually much less than $1+A_1A_2\beta$ and has little influence on the result.

The Impedance presented by the Amplifier to the Load R_0

The equivalent output impedance, r_o, of the amplifier can conveniently be found by rearranging (6) into the form $\frac{K R_o}{r_o+R_o}$. If it is assumed that the second part of the amplifier contains a single valve of constants, μ_2, g_{m2} and r_{a2}, appendix 2 shows

$$r_o = \frac{r_{a2}}{1+\frac{\mu_2R_{a1}\beta(1+\mu_1)}{r_{a1}+R_{a1}+(1+\mu_1)R_2(1-\beta)}} \quad \ldots\ldots (9)$$

The approximate method yields

$$r_o' = \frac{r_{a2}}{1+\frac{\mu_1\mu_2R_{a1}\beta}{r_{a1}+R_{a1}+(1+\mu_1)R_2}} \quad \ldots (10)$$

Comparison of (10) with (9) will again show that the maximum possible error is of the order $\frac{100\%}{\mu_1}$ with r_o' larger than the real value r_o. If tetrode valves are used

$$r_o = \frac{1+g_{m1}R_2(1-\beta)}{g_{m2}A_1\beta}$$

and $r_o' = \dfrac{1+g_{m1}R_2}{g_{m2}A_1\beta}$

and maximum possible error is 100β per cent with r_o' larger than the real value r_o.

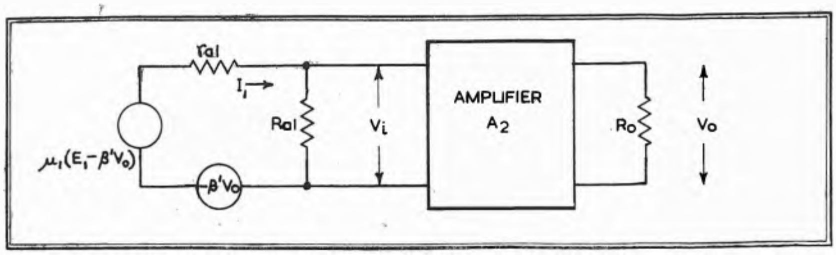


Fig. 3. Equivalent circuit for V. I

An Alternative Solution

The circuit may also be solved as a voltage feedback problem when overall amplification is given by

$$A_f = \frac{A_1A_2}{1+A_1A_2\beta'\frac{1+\mu_1}{\mu_1}}$$

where $\beta' = \dfrac{R_{BD}}{R_1+R_{BD}}$

and $R_{BD} = \dfrac{R_2.\ (A_2R_{a1}+R_1)}{A_2R_{a1}-R_2}$

(see Appendix 1).

The factor $(1+\mu_1)/\mu_1$ occurs because the feedback voltage $\beta'V_o$ is injected into the cathode lead and not the grid lead of the valve. Hence it not only subtracts from the input voltage E_1 so that the generated voltage is $\mu(E_1-\beta'V_o)$, but it is in series with the anode cathode circuit of V_1. Hence the equivalent circuit for V_1 is that of Fig. 3, from which

$$V_o = A_2I_1R_{a1}$$

$$= \frac{A_2[\mu_1(E_1-\beta'V_o)-\beta'V_o]R_{a1}}{r_{a1}+R_{a1}}$$

$$= \frac{\frac{\mu_1E_1R_{a1}A_2}{r_{a1}+R_{a1}}}{1+\frac{(1+\mu_1)R_{a1}}{r_{a1}+R_{a1}}.A_2\beta'}$$

$$= \frac{A_1A_2}{1+A_1A_2\beta'\frac{(1+\mu_1)}{\mu_1}}$$

It should be noted that the impedance presented by V_1 to R_2 is not that normally associated with the cathode circuit, *i.e.*, $1/g_{m1}$. The valve is supplying current to R_2 in the same direction as the driving voltage V_o so that it is a source of energy and therefore presents a negative resistance to R_2 making the total resistance R_{BD} (Fig. 2), looking away from V_o, greater than R_2.

Conclusions

If overall amplification alone is considered, an amplifier having a network providing simultaneous current and voltage feedback may be regarded either as an amplifier with voltage feedback alone or as a stage of current feedback followed by an unmodified amplifier. The effect of the combined feedback on the output impedance r_o is predominantly that of voltage feedback, *i.e.*, r_o is always less than the output impedance of the amplifier without feedback, though the current feedback makes r_o greater than the value it would have if voltage feedback alone were operative.

The effect of interaction between the sources of current and voltage feedback is small and it tends to make overall amplification and output impedance smaller than that calculated by ignoring the interaction.

APPENDIX I

The current voltage relationships for Fig. 4 are

$$E_1 = I_1R_a + (I_1+I_2)R_c \quad \ldots\ldots (1)$$

$$E_2 = I_2R_b + (I_1+I_2)R_c \quad \ldots\ldots (2)$$

From (2)

$$I_2 = \frac{E_2-I_1R_c}{R_b+R_c}$$

and replacing I_2 in (1) gives

$$E_1 = I_1\left(R_a+\frac{R_bR_c}{R_b+R_c}+\frac{E_2R_c}{I_1(R_b+R_c)}\right)$$

Hence looking towards E_1

$$R_{AD} = \frac{R_bR_c}{R_b+R_c}+\frac{E_2R_c}{I_1(R_b+R_c)}$$

Substituting appropriate values for R_b, R_c, E_2 and I_1 from Fig. 2 gives

$$R_{AD} \text{ (Fig. 2)} = \frac{R_1 R_2}{R_1 + R_2} + \frac{A_2 R_{a1} R_2}{R_1 + R_2}$$
$$= R_2(1-\beta) + A_2 R_{a1}\beta$$

$$\text{and } R_{BD} \text{ (Fig. 2)} = \frac{(r_{a1} + R_{a1})R_2}{r_{a1} + R_{a1} + R_2}$$
$$+ \frac{\mu_1 V_{gk}}{I_2} \cdot \frac{R_2}{r_{a1} + R_{a1} + R_2}$$
$$= \frac{(r_{a1} + R_{a1})R_2}{r_{a1} + R_{a1} + R_2} +$$
$$\left[R_2 + \frac{(R_1 + R_2)\ (r_{a1} + R_{a1} + R_2)}{A_2 R_{a1} - R_2}\right]$$
$$\cdot \frac{R_2}{r_{a1} + R_{a1} + R_2}$$
$$= \frac{R_2(A_2 R_{a1} + R_1)}{A_2 R_{a1} - R_2}$$

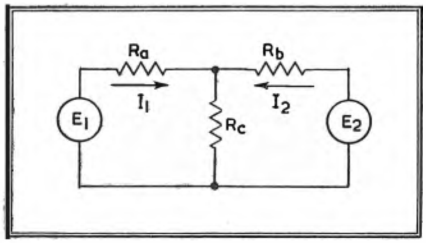


Fig. 4. Equivalent circuit for Appendix I

APPENDIX 2

$$A_f = \frac{\mu_1 R_{a1} A_2}{R_3 + A_2 R_4}$$

where R_3

$$= r_{a1} + R_{a1} + (1 + \mu_1)R_2(1-\beta)$$
$$R_4 = (1 + \mu_1)R_{a1}\beta$$

$$A_f = \frac{\mu_1 \mu_2 R_{a1} R_o}{R_3(r_{a2} + R_o) + \mu_2 R_o R_4}$$

if the A_2 amplifier is a single valve stage of valve parameters μ_2, g_{m2}, and r_{a2}.

$$A_f = \frac{\dfrac{\mu_1 \mu_2 R_{a1} R_o}{R_3 + \mu_2 R_4}}{\dfrac{R_3 r_{a2}}{R_3 + \mu_2 R_4} + R_o}$$

Hence the output impedance of the amplifier is

$$r_o = \frac{r_{a2}}{1 + \dfrac{\mu_2 R_4}{R_3}}$$

$$= \frac{r_{a2}}{1 + \dfrac{\mu_2 R_{a1}\beta(1 + \mu_1)}{r_{a1} + R_{a1} + (1 + \mu_1)R_2(1-\beta)}}$$

Ultrasonic Tests in Agriculture

EXPLORATORY experiments on possible uses in agriculture of ultrasonics, or high-frequency sound radiations produced electrically, are now under way at the U.S. Department of Agriculture Research Centre at Beltsville, Maryland. The following agricultural uses seem to warrant immediate investigations: biological effects of ultrasonics on plant and animal materials, bacterial control, sterilisation or pasteurisation of milk and other food products, homogenisation of milk, emulsification and near dispersion in liquids, coagulation of particles suspended in fluids, control of insects and diseases and production of mutations in grains, bulbs or other plant materials.

Although ultrasonics research by the Department agricultural research engineers is still very much in its initial stages, tests were carried out at Beltsville in which mosquito larvæ were killed by these sound vibrations within 5 seconds. The limited tests showed the percentage of mortality of the larvæ to be directly correlated with the amplitude of the waves and, within limits of the experiment, the percentages did not differ significantly with length of exposure. On examination, mosquito larvæ killed by high intensity sound waves appeared literally to be torn apart. Under similar conditions larvæ of the codling moth required exposures of up to a full minute for killing, but when they were imbedded in fruit these larvæ apparently were undisturbed.

Other preliminary tests showed decreasing vitamin C content in orange juice exposed to the treatment, the decrease depending on the time of exposure. The preliminary work also showed that particles of DDT could be reduced by ultrasonic vibration to sizes smaller than have hitherto been possible to produce by the usual processes.

Fundamental studies yet to be undertaken, according to the Department of Agriculture investigators, necessarily must be aimed at evaluations of frequencies and combinations of frequencies, intensities of wave propagation, radio frequency electromagnetic and electrostatic field effects, heat developed in various products through ultrasonic treatment, length of exposures, and technique of applying ultrasonics.

MICHAEL LORANT.

Britain's First Commercial Ultrasonic Generator

(See Frontispiece on page 154)

THE Mullard Ultrasonic Generator, is the first commercial generator to be produced in this country. It is designed as a laboratory tool for the use of research workers in industry to whose products and processes the science of ultrasonics has special application.

Circuit Details

The generator, comprising a control panel with meters, power oscillator, output voltmeter, relay panel and power supply, is mounted in a tubular frame. Four pull-out handles simplify lifting the generator and a removable panel—with quick release fasteners at the rear of the cover—gives access for fuse and valve replacements.

The R.F. output is generated directly by a silica triode capable of producing one kilowatt of R.F. power. Four plug-in coil assemblies, which are rapidly interchangeable, are provided for operation around nominal frequencies of ¼, ½, 1 and 2 Mc/s.

The valve is matched to the crystal impedance by tapping the anode down the coil in the output circuit. Fine tuning of the output circuit and adjustment of grid coupling are effected by means of variometers.

The oscillator is housed in the upper portion of the frame with the control panel immediately above. On the lower deck is the power supply comprising two grid-controlled mercury vapour rectifiers, the filament transformer and the H.T. transformer.

The quartz crystal is contained in a metal case. It is connected to the generator by means of a co-axial cable. The crystal has silver electrodes, fired on both sides, to which the driving voltages are applied.

To give the maximum ultrasonic output in the forward direction the generating crystal is air backed. The limitations on the temperature at which the transducer can work are set by the polythene of the cable and the rubber sealing rings. If silastic rubber is used and the back of the holder is adequately cooled, the crystal can safely be immersed in liquids at temperatures up to at least 150° C.

The Neutralisation of Input Capacitance on L.F. Amplifiers

By V. H. ATTREE, B.Sc.(Eng.)*

WHEN an amplifier is fed from a high resistance generator (*e.g.*, a photo-tube), the frequency response of the arrangement is normally determined by the product of the generator resistance and the total stray-capacity at the input. In order to obtain a good response the usual practice is to make the stray-capacitance as small as possible, and then, if necessary, to reduce resistance. Unfortunately, any reduction in the resistance lowers the signal level. This is inconvenient, especially when the subsequent amplifier is direct-coupled, as it means that the amplifier gain must be increased. A better approach, therefore, is to neutralise the capacitance at the input: an improved frequency response may now be obtained *without* loss of signal level. The neutralising is best achieved with a simple correcting amplifier which can also be used to give a low-impedance feed to the main amplifier.

The principle is shown in Fig. 1. R_0 is the high impedance generator, C_0 represents the total capacitance at the amplifier input while C_1 is the neutralising capacitor. Assuming that the amplifier is perfect, so that the gain is $\times m$ at all frequencies, then zero current will flow through R_0 when:

$$C_0 \frac{de_1}{dt} = C_1 \; (m - 1) \frac{de_1}{dt}$$

i.e., $C_0 = C_1 \; (m - 1)$

If this condition can be achieved then the frequency response will be uniform at all frequencies. Now in a practical case C_0 is small, perhaps 10 of 20 $\mu\mu$F, so that it is better to use a low value of m which will make C_1 of the same order as C_0. An obvious choice for m is $\times 2$, giving correct neutralisation when $C_1 = C_0$. The use of a low gain has the further advantage that the performance of the correcting amplifier may be made virtually independent of valve characteristics.

In a practical circuit there is a small distributed capacitance associated with the generator itself. This distributed capacitance cannot be neutralised by feedback through C_1, so that the extension of frequency

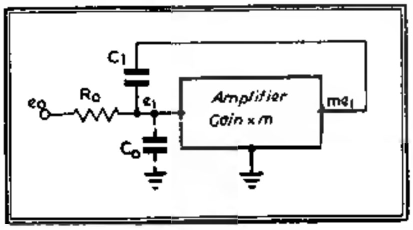


Fig. 1. Principle of operation

range obtainable is not unlimited. In most cases an improvement of about ten times is possible.

The limitations imposed by the distributed capacitance at the input enable the frequency response required in the correcting amplifier to be estimated. If f_0 is the frequency at which the uncorrected input circuit is 3 db. down (*i.e.*, $2\pi f_0 C_0 R_0 = 1$), then the response of the correcting amplifier should be uniform up to about 30 f_0. Furthermore, it is unnecessary for the response to extend below about 0.3 f_0. With a simple resistance-capacity amplifier it is sufficient that the two frequencies where the response is 3 db. down should be about 0.1 f_0 and 100 f_0. These figures are, of course, empirical, but they give a useful starting point for the design.

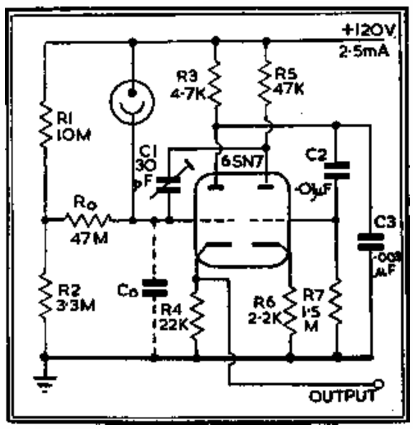


Fig. 2. Neutralising on a photo-tube circuit

In a practical case it was required to record a very small mechanical movement by means of a spot of light illuminating a high-vacuum photo-tube. The frequency response was to extend from zero (d.c.) up to 1,000 c/s. The circuit used is shown in Fig. 2. The stray capacitance C_0 was 30 $\mu\mu$F, which, with an effective photo-tube load (R_1; R_2 and R_0) of 50 M, gives a time-constant of 1.5 m.sec., *i.e.*, f_0 is 106 c/s. Thus, the 6SN7 correcting amplifier is required to have a response 3 db. down at about 10 c/s. (0.1 f_0) and 10,000 c/s. (100 f_0). This is accomplished by choosing R_4C_2 = 15 m.sec. and R_3C_3 = 15 μsec. The gain to the anode of the first triode is made small ($\times 0.2$) so that the increase of input capacitance by Miller effect is negligible. The overall gain, from the grid of the first triode to the anode of the second, is almost exactly $\times$ 2. The cathode of the first triode feeds the subsequent D.C. amplifier which is of relatively low gain. The signal level at the cathode is, of course, substantially the same as at the photo-tube.

Frequency response curves are readily obtainable by injecting a tone to the earthy end of R_2. Without neutralisation the response is 3 db. down at 100 c/s. while, with optimum adjustment of C_1, this is improved to 1,100 c/s. Too great a value for C_1 causes a rise in the response at about 900 c/s. while further increase in C_1 results in oscillation.

The use of neutralisation to reduce the input capacitance in radio transmitters and tuned R.F. amplifiers is well known but little use has been made of the technique at low frequencies. When the frequency is low the effects of unwanted inductance are negligible and, providing the distributed capacitance in the source resistance is not excessive, a considerable reduction in effective input capacitance is possible. The separate, low-gain, correcting amplifier is not absolutely essential as a suitable in-phase feedback voltage may be derived from the main amplifier. However, experience has shown that the separate amplifier arrangement is to be preferred. In a recent paper to this Journal Hughes† has mentioned the limitations set by valve input capacitance when using electronic methods of measuring dosage; it is probable that neutralisation would be of value in this application.

* Biophysics Research Unit, University College, London.

† Hughes, H. A., *Electronic Engineering*, 21, 1949, p. 80.

Frequency Allocation for Five Channels and Recommendations for Receivers for Asymmetric Sideband Reception

Frequency Allocation Plan

THE frequency band from 41.0 Mc/s. to 66.5 Mc/s. is at present available for the television service, but there is reason to hope that within the next few years it may be extended to the full band of 41.0 Mc/s. to 68.0 Mc/s. which was allocated to television by the Atlantic City Conference.

A plan for allocating the frequencies in this band has been agreed to by the Television Advisory Committee and by the Radio Industry Council, and is indicated in Fig. 1. By adopting asymmetric sideband transmission, five independent channels will be obtained, as soon as the full band up to 68 Mc/s. is available. This number of channels is essential if a large part of the population of this country is to receive a television service on this waveband, for experiments have shown that the sharing of a channel by television transmitting stations is satisfactory only if the stations are separated geographically by 300 miles or more.

The Alexandra Palace transmission is to remain unchanged in its characteristics, *i.e.*, no attenuation of the upper sideband is to be introduced at the transmitter, so as not to react unfavourably on the large number of existing receivers in the London area which rely largely on reception of the upper sideband to preserve their overall video response.

It will be seen that in each channel the spacing between sound and vision carriers is standardised at 3.5 Mc/s. and that the spacing of the vision carrier of any of the new channels from the sound carrier of the channel next higher in frequency is 1.5 Mc/s. No serious difficulty should be experienced in receiver design in discriminating sufficiently against adjoining channel interference, because of the asymmetric response characteristics which will in any case be necessary.

The design of the vision chain of all future transmitters will permit, as at Alexandra Palace, the transmission of vision signals substantially undistorted in amplitude and phase up to a vision frequency of 2.75 Mc/s. The carrier and the complete lower-frequency sideband of the amplitude modulated vision signal, together with the upper sideband for vision frequencies up to 0.75 Mc/s., will be transmitted substantially unattenuated and with negligible phase distortion. This corresponds to a pass band of 3.5 Mc/s. in width. For vision frequencies above 0.75 Mc/s. the upper sideband will be considerably attenuated.

Channel 4 has already been allocated to the Sutton Coldfield transmitter, whose vision carrier frequency will therefore be 61.75 Mc/s., with a pass band extending from 59.0 to 62.5 Mc/s. The sound carrier frequency will be 58.25 Mc/s. and will be amplitude modulated. The allocation of Channels 2, 3 and 5 to transmitting stations to be erected after Sutton Coldfield has not yet been decided, but it is probable that Channel 5 will be the last to come into operation, because agreement to the extension in this country of the television band from 66.5 Mc/s. to 68.0 Mc/s. must first be obtained.

Receiver Characteristics

The technique to be used in the reception of the asymmetric sideband vision transmissions originat-

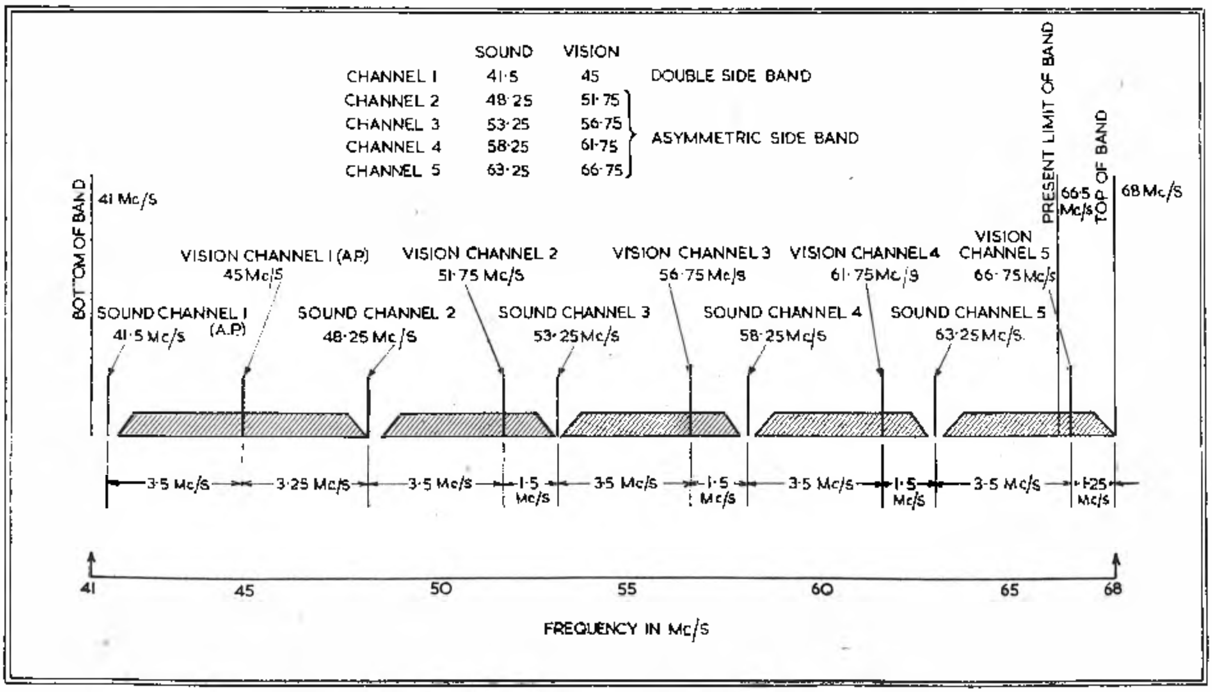


Fig. 1. Television frequency allocation plan within the band 41 — 68 Mc/s.

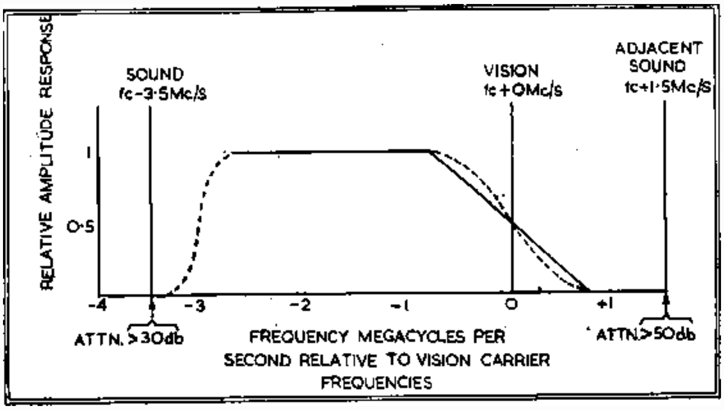


Fig. 2. Ideal Frequency Response Characteristic of Television Receiver for B.B.C. Transmissions

ing from B.B.C. television transmitters will be similar in some respects to that used in television receivers in the U.S.A. for transmitters operating according to the F.C.C. Standards of Good Engineering Practice. The lower, instead of the upper, sideband will, however, be used to provide the vision signal.

An idealised frequency-response characteristic for a receiver is shown in Fig. 2, and this characteristic is summarised in Table I:

TABLE I

Part of Frequency Band Megacycles per second	Receiver Response Per cent
(f_c 2.75) to (f_c 0.75)	100
f_c	50
above (f_c +0.75)	0

The shape of the response curve of the receiver between the frequencies of (f_c −0.75) and (f_c +0.75) Mc/s. is indicated in the diagram, the idealised curve being shown by the full line. It is not, however, necessary in practice that the linear relationship indicated should exist, the actual requirement being that for vision frequencies up to 0.75 Mc/s. the total response of the receiver to the lower and to the upper sideband frequency should be 100 per cent. In practice, the response curve of most receivers will probably be similar to that shown by the dotted line in the diagram.

It is not feasible to specify the permissible limits of phase distortion in the receiver, because in practice these limits will be determined by a compromise in design between the cost of mass-produced receivers and the degree of visible picture distortion which can be tolerated. The problem is further complicated by the transient distortion inherent in an asymmetric sideband system (*see*, for example, Kallmann and Spencer, *Proc. I.R.E.*, December, 1940, page 557).

The vision receiver, while preserving substantially 100 per cent response down to a frequency of (f_c −2.75) Mc/s., will need to attenuate, by at least 30 decibels, the sound carrier on (f_c −3.5) Mc/s. in order to avoid interference on the picture from the sound modulation of the adjacent channel. The more sensitive type of receiver will also need to attenuate by at least 50 decibels a signal on (f_c + 1.5) Mc/s., in order to allow for a sound channel on that frequency, on the basis that in fringe areas of reception the field strengths of the wanted and unwanted television transmissions may be approximately equal. Less discrimination may perhaps suffice for receivers intended only for more local reception, but it cannot be too highly stressed that interference on the picture due to a beat frequency of 1.5 Mc/s. is very easily visible.

Reception of Alexandra Palace

A receiver designed according to these principles will also be suitable for receiving the transmissions from Alexandra Palace, despite the fact that this station will continue to radiate both sidebands. The same fundamental design of receiver will, therefore, serve for the reception of all British television transmissions as at present proposed, whether the adjustment for the desired channel be made by the tuning of a beating oscillator in a superheterodyne receiver, by the trimming of pre-set signal-frequency circuits, or by ganged circuit tuning arrangements. Information supplied by:—

Engineering Information Department,
The British Broadcasting Corporation.
Broadcasting House, London, W.1.

Ultrasonic "Stethoscope" for Testing Generator Rotors

AN ultrasonic "stethoscope" that enables engineers to explore solid pieces of steel as much as 30 ft. thick by means of sound waves is being used successfully by the American Westinghouse Company to assure flawless quality in its giant electric generators.

The new technique beams ultra high frequency sound waves through massive steel parts. The reflected sound reveals the quality of the metal with all the accuracy of a super X-ray while penetrating thicknesses that X-rays cannot reach. By checking that all the rotor shafts are free of internal flaws, Westinghouse scientists ensure that they will stand the strain of making 3,600 revolutions a minute under working conditions.

An application of wartime developments, the ultrasonic process is based on the same principle as radar, but whereas radar projects radio waves through the air, the high frequency sound projector sends waves of sound through solid metal.

A crystal, similar to the crystal used in most record player pick-up arms, changes electrical impulses into sound waves, which are projected through the metal. Tiny cracks, cavities or foreign particles in the metal reflect sound back to the crystal, and these reflexions, changed back into electrical impulses, appear as bright, vertical lines on the viewing screen of an electronic receiver.

By measuring the time it takes the sound waves to go through the metal and bounce back to the crystal, metallurgists can locate any flaw exactly. When the metal is flawless all the way through the sound waves reflect from the opposite side of the object.

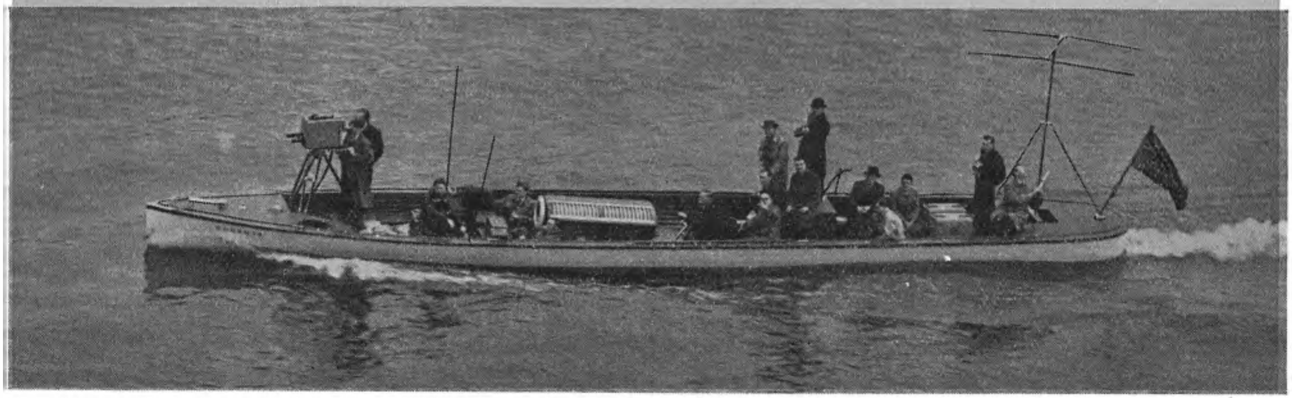
In addition to testing generator rotors, the ultrasonic technique is used also for testing other metal parts ranging from 25/100ths of an inch to 30 ft. thick. X-ray, which is used in many quality tests, is practical only for metal thicknesses up to about 6 in.

Among the giant machines being produced by Westinghouse with the aid of the ultrasonic equipment are large steam turbine generators, some of which are rated above 100,000 KW. The rotors for these huge generators are 40 in. thick.

M. LORANT.

Televising the 1949 Oxford and Cambridge Boat Race

By T. C. MACNAMARA and P. A. T. BEVAN*



THE B.B.C.'s successful television broadcast of the whole of the Oxford and Cambridge Boat Race from start to finish on Saturday, March 26, can reasonably be said to represent a further milestone in the history of television outside broadcast engineering technique. In the past it has been feasible to televise only the start and finish of the race from the shore, using the two massive pre-war control room units, each of which comprises the apparatus for three camera channels and six microphones, permanently rack-mounted in vans constructed on bus type chassis. The new E.M.I. and Pye outside broadcast television equipments recently brought into service to supplement the pre-war units are, however, constructed on the portable unit principle and may readily be removed from their transporting vehicle and installed at sites which were previously inaccessible to the pre-war equipments because of their fixed construction in the van.

This feature of easy portability has proved invaluable in practice, because not only has it enabled the number and scope of possible television outside broadcasts to be vastly increased, but the labour of installing the equipment and running the cables to the camera positions has been much lessened and the time necessary to complete the installation greatly reduced.

The actual apparatus units, which are carried in light tubular steel racks are considerably lighter and smaller than their pre-war counterparts owing to the use of miniaturised components and valves and the adoption of new and improved circuits.

Experience with these light-weight equipments encouraged the B.B.C. engineers in the belief that a television broadcast of the complete Boat Race could be achieved by mounting a single camera with the minimum of associated apparatus in a river launch following the race. Linkage of the picture to a shore station or stations whence it could be relayed to Alexandra Palace for broadcasting could, it was thought, be effected by a low-power radio transmitter operating in the very high frequency or microwave bands.

The choice of a camera fell upon an instrument incorporating a pick-up tube of the Image Orthicon type and provided with a four-lens turret for which a range of lenses was available.

The considerations dictating this choice were several. First, the sensitivity of such a camera is very high so that there would be a good chance of obtaining a workable picture even on a dull day.

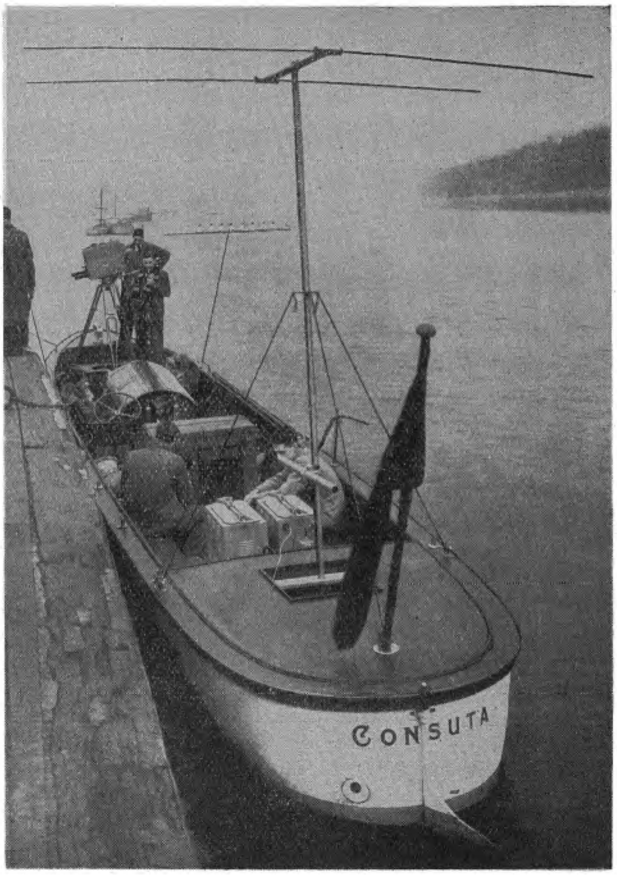
Secondly, this particular camera equipment has been designed for extreme portability, at the expense of some of the facilities normally required for outside broadcasts of the more orthodox type, and the bare necessities of equipment required for its efficient operation are built into four suitcase containers of average weight of about 50 lb. each.

The unit is thus very suitable for use in places where weight and space are at an extreme premium and where the cueing, intercom and preview facilities required for a normal multi-camera outside broadcast can and must be dispensed with.

Considerable thought was devoted to the choice of a vision transmitter and its operating frequency for the purposes of radio linkage. A microwave transmitter provided with a 4 ft. paraboloid reflector was available, but after due consideration its use was abandoned. The reasons for this decision were two-fold. First, grave doubts were felt as to the safety with which a 4 ft. paraboloid could be mounted in a small launch.

A second reason was that as a consequence of the high gain required for the successful operation of microwave links in which the power available is limited to a few milliwatts, the beam emitted is only a few degrees wide, and it was not thought that such a narrow beam could be consistently brought to

* Engineering Division, B.B.C.



The 63 ft. launch "Consuta" showing the two units forming the Pye portable vision transmitter and the transmitting aerial

The petrol engine generator set providing the power supplies for the whole of the equipment can be seen immediately forward of the transmitter. The Marconi camera is mounted in the bows

bear on a remote receiving paraboloid from a boat which, if the water was choppy, might roll considerably.

Consequently a small portable transmitter designed to give an output power of 25 watts at peak white on a radio frequency between 50 and 60 Mc/s was chosen as an alternative more likely to give successful results under the conditions which would be experienced in the boat.

The problem of a suitable power supply for the equipment was by no means simple as the total consumption was some 3 KVA at 230 V 50 cycles. To obtain such an output for any reasonable period from a battery-driven inverted rotary would require batteries of great weight. Moreover, the difficulties associated with the frequent charging necessary during the tests on the river would have been extremely inconvenient.

Attention was turned, therefore, to the use of a petrol-driven generator set, which at first sight would appear to be a simple solution of the difficulty. Reflexion, however, shows that the qualities required of such a generating set are not easily realisable. For example, it must have a high degree of freedom from mechanical and exhaust noise, because a healthy bark or loud valve clatter could not be tolerated in close proximity to the launch carrying the B.B.C. sound commentator. Moreover, the engine must be free from excessive vibration which would upset the operation of the delicate apparatus. Also the generated voltage and, above all, the frequency of the supply must be stable within very close limits if violent flashing and travelling stroboscopic humbars are to be avoided in the transmitted picture.

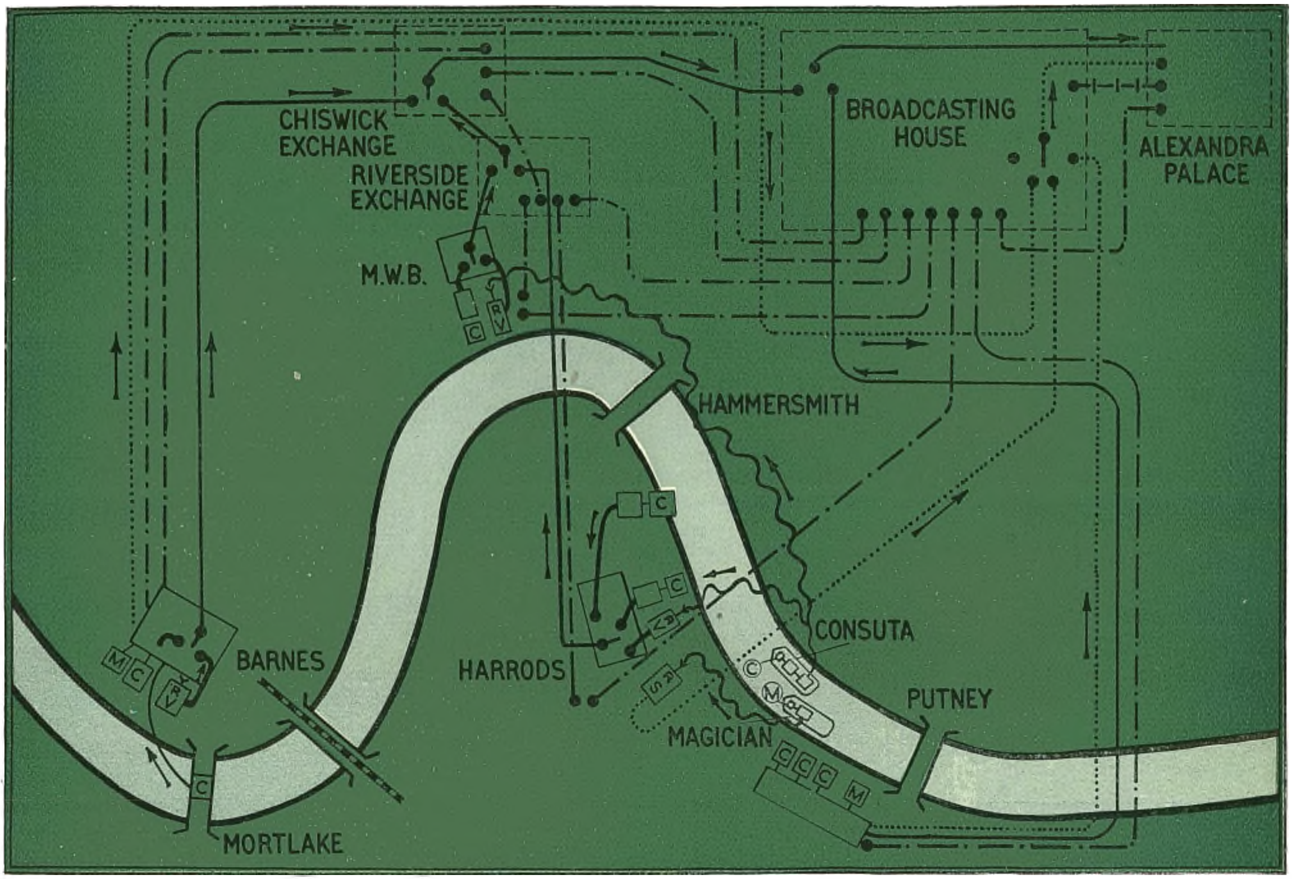
It will be appreciated that the requirements imposed by the foregoing are extremely stringent, especially when coupled with the further purely practical necessity that the engine generator unit must be small enough to be accommodated in the launch and light enough to be taken aboard without too much difficulty.

The B.B.C. engineers had available, however, a type of small portable petrol electric generator capable of delivering sufficient output incorporating a four-cylinder water-cooled engine with built-in radiator and capable of exceptionally smooth and quiet running. The set was fitted with a high-grade sensitive governor, which held the frequency sufficiently close to 50 cycles to satisfy even the exacting requirements of the television equipment.

The camera, which weighed approximately 100 lb., was effectively floated on rubber cushions, and the tripod was secured by stays formed of heavy elastic. The camera was raised to a height of some 6 ft. above the water to give the best angle of elevation to the shot consistent with safety and operational convenience.

The elaborate anti-vibration mountings were necessary on two main counts. First, the pick-up tubes are unavoidably somewhat microphonic and any appreciable vibration generates spurious signals which appear as horizontal black lines across the picture. Secondly, any vibration of the camera lens system causes the optical image to vibrate upon the photo-cathode of the pick-up tube and this, coupled with the slight memory phenomena experienced in all tubes of the storage type, causes a reduction in definition.

This effects a softening of the transmitted image, resulting in an "out-of-focus" appearance in the final picture. The magnitude of the effect increases with the focal length of lens used, and with lenses of the telephoto type the loss of definition can be very serious indeed owing to



Map showing division of river into three sections. The receiver in the first section is situated on the Surrey side of the river on the roof of Harrods depository and receives pictures from the " Consuta " from the start at Putney to a point nearly opposite Harrods and close to Hammersmith

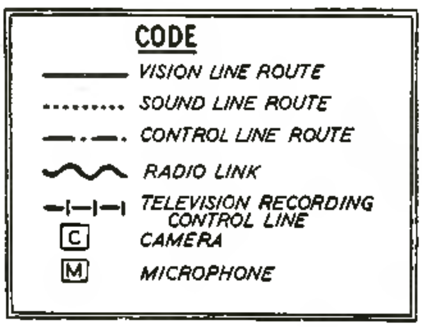
The second receiver located at the Metropolitan Water Board pumping station on the Middlesex side beyond Hammersmith Bridge picks up after Hammersmith Bridge and functions as far as Barnes Bridge. The final section of the course and the finish of the race is covered by a third receiver having an aerial mounted on a fire escape positioned a few yards downstream from Chiswick Bridge.

the large optical leverage involved.

The camera control equipment was disposed immediately aft of the camera and the transmitter and petrol generator set were stowed in the stern. The transmitting aerial was rigged astern and arranged to give horizontally polarised radiation.

The aerial was of the straightforward horizontal half-wave dipole type with a single reflector element to direct the main radiation lobe towards the aerials of the relaying vision receiver sites on the shore.

The use of horizontally polarised radiation for the transmission of the pictures from a launch was decided upon because under the special conditions encountered with a low aerial on the river, horizontally polarised waves were found to give substantially steadier propagation conditions and to be far less subject to the effects of random reflexions from buildings and high ground than vertically polarised waves.



With the very high carrier frequencies necessary for high definition television transmission, the resulting reflexions from nearby buildings and from the four bridges spanning the river over the course constituted the greatest difficulty of this broadcast, since it will be appreciated that the reflected waves can give rise to multiple images and violent variations in the strength of the vision signals received from the launch at the shore relay receiving point. For this reason, and because the bridges form a natural barrier to the radio waves, the useful operative range of the launch transmitter was rather restricted, and to obtain consistently satisfactory reception it was necessary to divide the course into three sections and to establish three shore relaying receiving stations to cover the whole of it.

In order not to break the continuity of the pictures transmitted during the race at times when the transmitting launch was close to or passing under the bridges, and thus in an area where violent reflexions made its signals unusable, fixed shore cameras were also stationed at the Harrods Depository and Metropolitan Water Board sites. Shots from these cameras were switched into the picture relaying network during the periods when pictures received from the launch were unsuitable; they also served to give a different angle of view and a better indication of the relative position of the Oxford and Cambridge boats as they passed these points. In addition to these continuity cameras, three shore cameras were also provided at the start at Putney and two more at the finish, thus making eight cameras in all. From this point of view alone the Boat Race broadcast constituted the most ambitious vision equipment set-up the B.B.C. have so far attempted.

The line, cable and repeater network required to relay all these picture sources to Alexandra Palace for broadcasting was necessarily somewhat complex and was provided by the Post Office Engineering Department.

A general appreciation of the circuits involved can be obtained from the diagram. The circuits were part normal telephone line, equalised and phase corrected for wideband television transmission, and part coaxial cable.

The selected picture from the shore-based cameras at Putney was routed through the Broadcasting House television repeater station to Alexandra Palace, but in the case of Harrods and the Metropolitan Water Board sites the selected picture (launch or shore camera) had first to be routed via Riverside Exchange to Chiswick Exchange where they met the pictures coming from the finish at Mortlake.

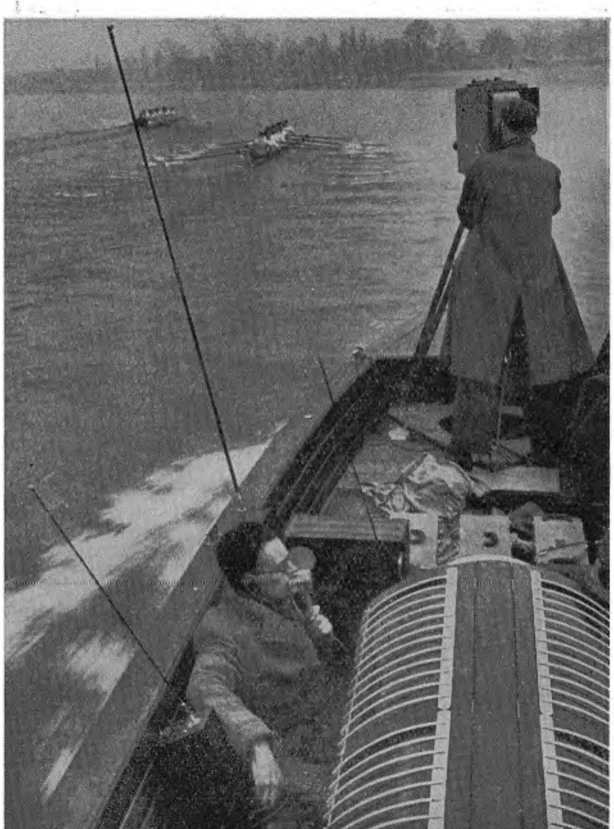
The appropriate changeover from the initial pictures received at Harrods to those received later at the Metropolitan Water Board was made at Riverside, and the change from Metropolitan Water Board to the Mortlake pictures of the finish was made at Chiswick Exchange. From Chiswick a coaxial cable delivered in sequence the selected pictures to the Broadcasting House repeater station whence they were passed to Alexandra Palace by means of the special balanced television cable. The illustration also indicates the routing of the engineering control lines associated with this vision network, the route of the television sound commentary lines from the start and finish, and the radio link sound commentary given from aboard the sound launch "Magician," which commentary was transmitted to viewers and Home Service listeners alike during the period of the race itself.

In view of this necessary arrangement of vision routing it was not possible to arrange for all pictures to be made available simultaneously at a central point so that programme production in the normal sense was not feasible for this broadcast.

The weather inevitably plays an important part in a television broadcast of this sort. Fortunately, however, the day was clear and fears of the consequences of rain on the inadequately weatherproofed equipment in the launch evaporated in the sunshine.

The light value was so high, in fact, that with the launch camera lens stopped down to F.22 (the smallest aperture available with the iris provided) the incident light was too great easily to be handled and it became necessary to fit a filter. In spite of the inevitable early troubles the whole of the equipment behaved most satisfactorily during the race itself and viewers' reactions suggest that the attempt was indeed very worthwhile.

The broadcast was a concerted effort on the part of the television manufacturers, including E.M.I., Pye, Limited, Marconi's Wireless Telegraph Co., Ltd., and others whose equipment was used, the Post Office Engineering Department who provided the vision cable equipment and the B.B.C. Specialist Engineering Departments who planned the broadcast and operated the equipment, in collaboration with the Television Outside Broadcast Engineering Organisation.



Another view of the "Consuta" with its portable television equipment

The camera is mounted on a tripod carried on a rubber cushioned supportingplatform to insulate it from vibration set up by the launch engine. The crew consists of driver, camera man, camera control operator, transmitter operator, engine attendant, aerial steerer and sound communication operator, together with two reserve technicians

Cathode-Ray Tube Applications in Photography and Optics†

PART II

By CARL BERKLEY* and RUDOLF FELDT*

Gear and Sprocket Studies

ONE of the basic problems in the motion picture industry is that of obtaining accurate repeated sprocket teeth on motion-picture cameras and that of obtaining accurate repeated sprocket perforations on motion picture films and papers.

If these perforations or sprocket teeth are not properly made, then the final theatre image will weave up and down or from side to side or jump erratically as anyone who has seen prints of old movies may readily testify. The accuracy and reproducibility of these perforations and sprocket teeth may be easily studied by oscillographic methods. These methods involve a combination of optical and electronic magnification of the defects encountered. In order to display these defects on a cathode-ray oscilloscope, a scanning technique is adopted in which the scanning element consists of a slit or small aperture placed in front of a photocell. The output of the photocell is then applied to the vertical plates of the oscilloscope, after amplification, if necessary. In testing sprocket teeth or the gears on motion picture cameras, for example, the gear may be rotated at the operating speed and the outline of the gear tooth picked up by means of the scanning slit. Fig. 15 shows the optical setup just described. If the sweep frequency on the oscilloscope is equal to the time it takes for one tooth to pass the slit, then a repeated image of each tooth appears on the oscilloscope screen. This image may have been enlarged optically before reaching the slit and may then be further enlarged by means of the vertical and horizontal amplifiers on the oscilloscope. Any eccentricity in the gear tooth, either angular or or radial, may readily be seen and amplified to the desired value. As shown in Fig. 16, this method has the advantage that it tests the gear

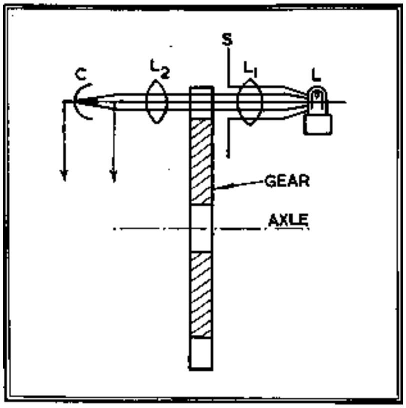


Fig. 15. Optical setup for gear testing

under operating conditions so that effects of dynamic unbalance or bearing eccentricity are apparent. A vibration pickup may similarly be used in a conventional manner on the oscilloscope to determine which of the gears in a motion-picture camera is causing a repeated noise in the sound track, for example, by correlating the frequency of repetition of the pattern on the oscilloscope with the rate at which various gears move in the camera. In the case of sprocket-perforation-accuracy measurements exactly the same technique is used, the scanning slit being similar to a sound track slit.

This technique of combined optical and electronic magnification will be illustrated by a very similar example, taken from another field, the testing of razor blades. Razor blades are manufactured in a continuous strip which are sharpened on special grinding machines and are then honed and stropped. A microscope and photocell has been used to look at the edge of each blade as it passes by. Fig. 17 shows the optical setup used. The sweep frequency on the oscilloscope is synchronised with the repetition rate of the blades. The resultant patterns are shown in Fig. 18. The dips between patterns are due to the gaps between blades. The sensitivity here is equivalent to a magnification of 1,000 : 1, about 100 of this magnification being accomplished optically, the other factor of 10 accomplished electronically in the oscilloscope amplifier so that a deflection of one inch on the cathode-ray tube screen is equivalent to 1/1000th of an inch on the razor blade. The pictures show a number of blades which are perfect and some blades which have nicks about 1/2000th of an inch deep.

Automatic Printer Adjustment

One of the basic problems in the photo finishing industry is to obtain a properly exposed and developed set of prints from a widely varying series of negatives. This is usually accomplished by a hit-or-miss system which is based solely upon the judgment of the printer in the darkroom. This precludes accurate duplication of results from one photofinisher to another. Some attempts have been made to use electronic exposure controls which automatically adjust at least the exposure for these widely varying negatives. The darkroom operator

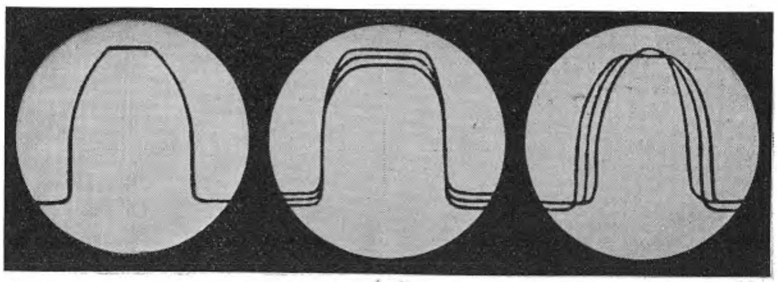


Fig. 16. Typical patterns obtained with perfect and defective gears

(a) A perfect gear (b) An eccentric shaft or angular spacing (c) Irregular tooth size

† Based on a paper presented at the National Electronics Conference, November 5th, 1948.

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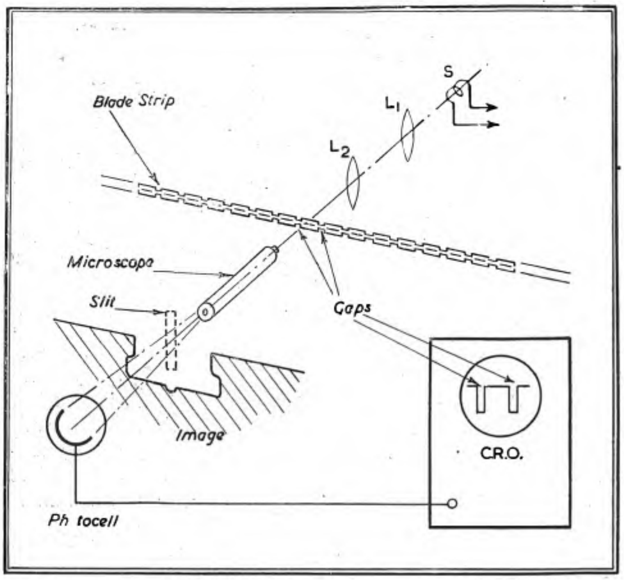

Fig. 17. Optical setup for razor blade testing

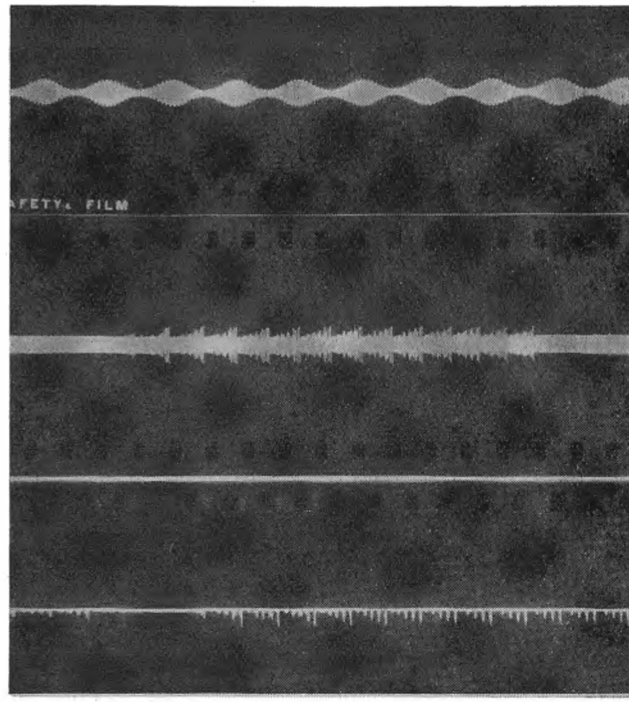

Fig. 19. Typical cathode ray tube sound track recordings

still has to select the proper grade of printing paper.

A suggested approach to this problem is to print each negative to suit the personal preferences of ths customer instead of attempting to make all pictures of uniform quality. These personal desires with respect to the artistic effect of the print may be determined by means of electronic equipment operating as follows:

This machine, to be placed in the photofinisher's anteroom, consists of a simplified television imaging system such as a flying spot scanner. When the negative is placed into the machine, a positive image appears on the cathode-ray tube screen which shows how the final print will look. There may be only two adjustable controls on this machine, one controlling the gamma of the image and calibrated directly in the contrast grade of the printing paper. The second control is a brightness control calibrated directly in exposure time required for the selected brightness. After adjusting the controls until a picture having the proper aesthetic effect is obtained, the print can be made under well-defined reproducible conditions.

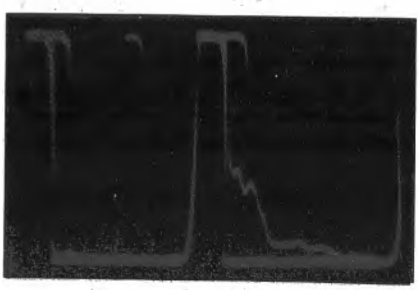

Fig. 18. Pattern obtained with razor blade tester, showing a number of defective blades, compared with the edges of good blades

Another and more serious problem exists in colour film printing. It is very difficult to make a good colour print from a colour negative without a trial-and-error process. Much of the guesswork can be taken out of this process by applying the above principles to it. Various methods have been proposed in the patent literature to enable an electronic viewing of a negative and a suitable phase and colour reversal so that the appearance of a positive may be directly determined and the proper corrective measures taken.

Sound Recording

Since the earliest days of the cathode-ray tube, various types of tubes have been proposed for use as sound recording elements in sound on film systems. One of the first to suggest this use and to build cathode-ray tubes for this purpose was Von Ardenne, who built the equipment and actually made such recordings. It is possible to make such sound recordings with perfectly standard cathode-ray oscillograph equipment and a continuous recording camera such as the Type 314 camera. Fig. 19 shows some examples of such sound recordings made by voice modulating a 100-Kc. signal in a mixer tube and recording the result with the camera. These signals may readily be played back on the oscilloscope by scanning them with an illuminated slit in a conventional manner. The advantage of the cathode-ray oscilloscope here is that there is no limitation as to frequency response in the recording element itself, since modulating frequencies as high as desired may be recorded and played back. Obviously a cathode-ray oscilloscope is the best tool for properly studying, adjusting and describing the performance of electronic motion picture sound equipment. Such phenomena as hum, cross modulation and inter-modulation may readily be recorded by standard

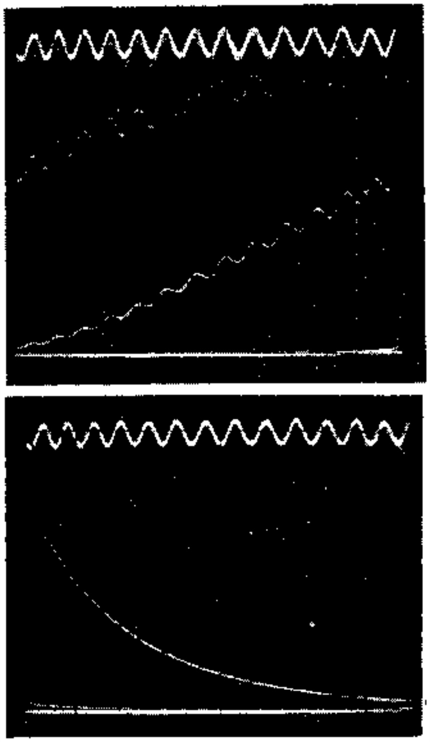

Fig. 20. Ripple in small A.C. operated lamp

(a) Showing incandescence

(b) Showing nigrescence

These recordings made with repeated sweep

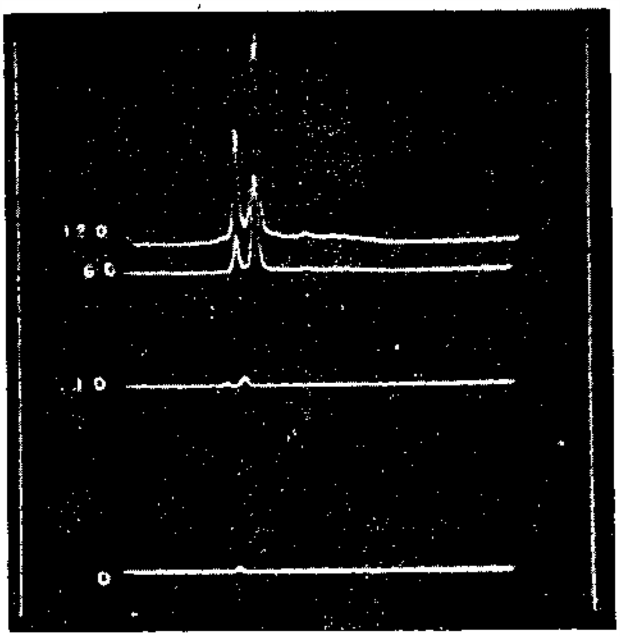

Fig. 21a. Spectograms of a low pressure mercury arc at various times after starting. (Figures in diagram relate to seconds after starting)

techniques and many references appear in the literature to these methods.

Study of Light Sources for Ripple

One of the difficulties in illuminating a motion picture set with tungsten lamps is that the power supply must, in many cases, be direct current in order to avoid a brightness flicker in the final image due to the 120 cycle variation in the light emitted from A.C.-operated lamps. This variation causes an annoying beating of the frame frequencies with the ripple frequency, and if a camera is to be operated at high speed this flicker may become very annoying. Particular difficulty is encountered in cases where a motion picture has been made at high speed of a phenomenon illuminated by A.C.-operated lamps and then the film printed on a high-speed printer also operated on A.C. Occasionally the dips in the exposing light output and printing light output become synchronous, with resulting light fluctuation in the final projected image. In recent years, many new types of filament construction have been adopted to minimise this defect and to produce as little ripple as possible. The best way to study this ripple is on a cathode-ray oscilloscope, equipped with D.C. amplifier, so that the ripple may be expressed as a percentage of the total light output. Figs. 20a and b illustrate some typical examples of the ripple percentage of a certain lamp. In making these oscillograms, it was also of interest to determine which of these lamps lent themselves most readily to modulation for the transmission of information over light beams. The incandescence and nigrescence curves can easily be seen and studied on these cathode-ray oscillograms.

Colour Specification

Another problem in photography and optics is the proper description and specification of various colours. A cathode-ray tube spectrograph for accomplishing this very result has been described by the authors.[9] Figs. 21a and b show some typical cathode-ray-tube-produced spectograms obtained with this instrument. This instrument produces the colour information required within 1/120th of a second. The information may readily be put into various other standard forms such as into International Commission on Illumination Co-ordinates. To obtain the I.C.I. co-ordinates requires certain standard integrations, additions and divisions which may be accomplished electronically, by converting the information into digital form. To indicate these I.C.I. co-ordinates, a cathode-ray tube again is a useful tool since a universal I.C.I. colour diagram may be placed over the face of the tube, the position of the spot enabling reading of the co-ordinates directly. The output of a three-filter photometer may also be shown in this manner instantaneously on the cathode-ray tube screen.

Another use of the cathode-ray tube spectrograph in optics is in the study of the colour aberrations of

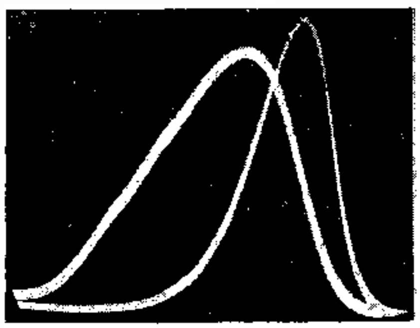

Fig. 21b. Light distribution in image showing chromatic aberration. Pattern at left, at centre of image; at right, at edge of image

optical systems. Fig. 21b shows the colour distribution of the image of a rather poor lens along the axis, and the colour at one of the fringes of the image. Many other uses for this instrument have already been described, such as the immediate drawing of filter-transmission curves or the reaction between chemical solutions, indicating, for example, when a developer has reached the exhaustion stage.

Conclusion

While it has not been possible to give here a complete description of all cathode-ray tube applications considered in optics and photography, it should now be obvious that cathode-ray tubes and oscilloscopes are valuable tools for solving many technical problems. Because of lack of space we have not been able to consider many of these in the detail they deserve.

It has been mentioned at the beginning of this paper that the procedures here suggested could find valuable application in many other industries as well. Choosing the automobile industry as typical, for example, the gloss measurement technique could readily be applied to the paint finish of automobiles. The goniophotometric technique could be used to measure the light distribution from various types of headlights. The techniques used for shutter, flashbulb, and synchroniser testing could be used for studying the operation of the vibrator in the car radio. The cathode-ray-tube-light source could be used as an ignition-timing light. The gear-and-sprocket testing system would find obvious application and the vibration studies could be carried out to indicate the degree of riding comfort obtainable with particular suspension methods.

It is hoped that this brief consideration of some applications will stimulate the use of these oscillographic techniques in as wide a range of problems as possible.

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A Chart for Hyperbolic Functions

By H. M. CLARKE, M.Sc., M.I.E.E.*

A SIMPLE aid in calculating exponentials can be readily made from single log paper having uniformly scaled abscissæ as in Fig. 1. Draw the straight line from the origin to $A = 2.303$ $y = \log 10$, thus the ordinate through any point X between $A = 0$ and $A = 2.303$ cuts this line at a value of $y = E^A$. Moreover, the straight line from $A = 2.303$, $y = \log 1$ to $A = 4.606$ $y = \log 10$ can be used to determine $y = E^A$ for A lying between 2.303 and 4.606, provided y is now taken as $\times 10$ of previous ordinate scale value. Similarly, for each addition to the abscissæ of 2.303, the vertical scale can be taken as $\times 10$ of the previous value.

Furthermore, if a straight line be drawn from $A = 0$, $y = \log 10$ to $A = 2.303$, $y = \log 1$, ordinates at any abscissa A cut this line at E^A and for every addition to the abscissæ of 2.303 the scale of y is $\times 1/10$ of the previous value.

To determine cosh A or sinh A, E^A and E^{-A} can be read from the appropriate ordinates and the value of cosh A and sinh A required are $1/2\times$ their sum or difference. Tanh A and coth A are similarly obtained.

A common size of log paper is 25 centimetres representing log 1 to log 10, and abscissæ up to 25 or 50 centimetres. The former can be readily used up to $A = 2.303$ and the latter $A = 4.606$, using 10 centimetres to the unit. This paper allows reading to 0.5 mm. or about 1/250.

The accuracy of reading the ordinates being limited to 1/250 precludes the use of this method for A is greater than 4.606 for hyperbolics. Beyond this value, E^{-A} may be ignored in the calculation of cosh, sinh, tanh, and coth, etc. It may, however, be used for E^A or E^{-A} to 1/250.

Fig. 2 is a modification of Fig. 1 which may have more appeal than the latter.

An example of the use of graph may be seen at $A = 1.6$, E^A is read as 4.97 and E^{-A} as 0.203 giving sinh A as 2.383, cosh A as 2.586, and tanh A as 0.922.

By expansion, corresponding values are 2.3738, 2.577, and 0.921.

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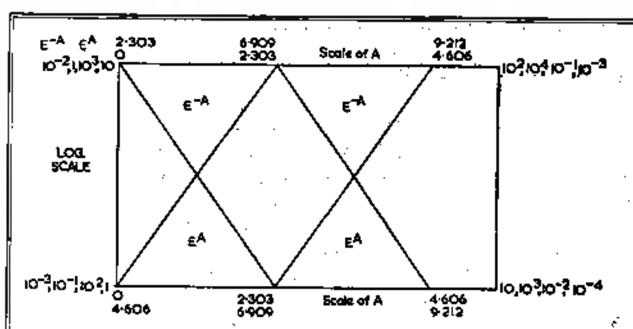


Fig. 1. Construction of chart for functions E^A and E^{-A}

$$\left(\cosh A = \frac{E^A + E^{-A}}{2}\right.$$

$$\left.\sinh A = \frac{E^A - E^{-A}}{2}\right)$$

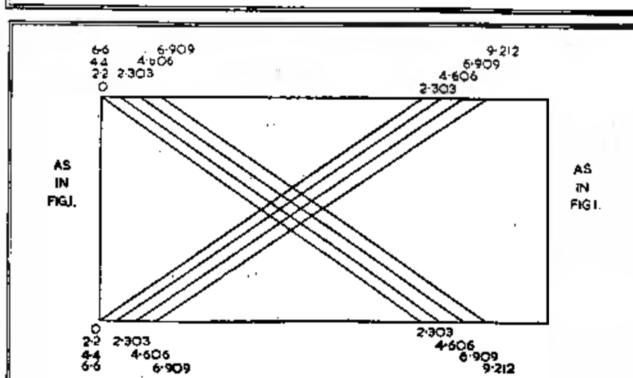
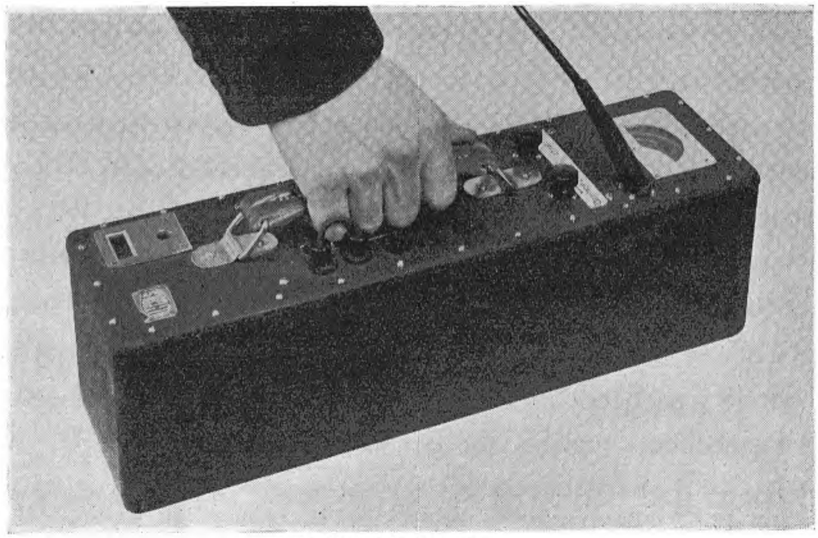


Fig. 2. Modification of Fig. 1 showing alternative construction

Portable Counter for Geological Research

By O. J. RUSSELL, B.Sc., A.Inst.P.*



The Portable Counter

THE portable counter illustrated has been developed for prospecting for radio-active uranium and thorium minerals, geological investigations generally, and as an ultra-sensitive detector of lost or mislaid radium. It should be noted that quite apart from locating radio-active ores, the investigation of the slight residual activity present in virtually all minerals offers a new and exciting field for geological research, as changes in strata can be identified in this way.

Results of investigation of the feeble activity present in all normal mineral ore should be of the utmost importance to geologists, as this new geophysical technique offers a fresh angle of attack upon many problems. Suggested applications are the confirmation of theories of the genetic relationship between rocks, the measurement of the gamma radiation from oil or rare mineral bearing formations, the investigation of the potash content of rocks, and as an aid to geological mapping. A paper (No. 91) presented at the 18th International Geological Congress (London, 1948) reviewed the question of geological mapping employing surface measurements with the aid of this portable G.M. counter. This field of research is so new that the full extent of its possibilities cannot yet be assessed; however, it is clear that it offers a new and exciting field for research.

The necessity for precision measurements and high sensitivity for these refined investigations profoundly influences the design of the instrument, especially as the paramount consideration is portability. To combine sensitivity with ruggedness, while keeping size and weight to a minimum, has necessitated the abandonment of conventional types of design commonly employed in portable G.M. equipments employed for uranium location or the recovery of lost radium tubes. The equipment developed by the Alltools Research Laboratories, employs a miniaturised multi-valve circuit embodying a valve extinction circuit and a patented multi-vibrator circuit for pulse equalising and limiting functions. The equipment is, in fact, a scaled down version of a standard laboratory Geiger-Muller counter. All power supplies, including bias and a variable V.H.T. supply for the G.M. tube are derived from an external 6-volt accumulator as the basic power source. A light-weight motor cycle type is ideal. An accumulator which is readily rechargeable from a base station motor car, if necessary, has been chosen in preference to the doubtful advantages of dry batteries, which tend to deteriorate rapidly when under tropical climatic conditions. A built-in meter enables the battery voltage to be checked, together with the V.H.T. voltage applied to the G.M. tube.

A direct counting circuit is employed, so that precision indications of small variations of the apparent background may be made. This sensitivity is such that the normal statistical limitations apply. As the cosmic ray background count on the built-in G.T.21 tube is approximately 200 per minute variations in local activity which are a small fraction of this can be readily detected. A variation equivalent to 4 per cent of the cosmic ray background can be detected by a three-minute count, and even smaller differences by longer counts. Such sensitivity enables small—but geologically significant—traces of activity to be detected on the surface. The use of headphone methods, or even "count-rate" meter type indicators, cannot give any approach to this degree of sensitivity. The use of counting methods was adopted as a result of a careful study of the possibilities of existing equipments, and was embodied in the first model produced for the National Physical Laboratory. The value of the counting technique has been amply proved during five years' refinement of the design. The sensitivity enables deposits to be located, when more deeply buried, and the extent and direction of ore deposits to be more accurately located, as compared with detectors needing a high activity level before any positive indication is given. The value of this sensitivity has been shown also in the location of lost radium, even when deeply buried. In one fairly recent case, radium was immediately recovered from a site which had been repeatedly and unsuccessfully surveyed by other types of locating equipments.

In the field "iso-active" contours can be plotted if desired, while by means of plugs an external tube can be operated as an alternative to the built-in tube. This enables a probe head containing a G.M. tube to be used in narrow crevices, or an M.R.C. type tube can be employed for tests on powdered rock samples or separates obtained in the field. The unit provides, in effect, mobile laboratory facilities, in a single compact robust unit. Rubber sealing has been extensively employed to give protection in humid climates.

It is considered that the unit

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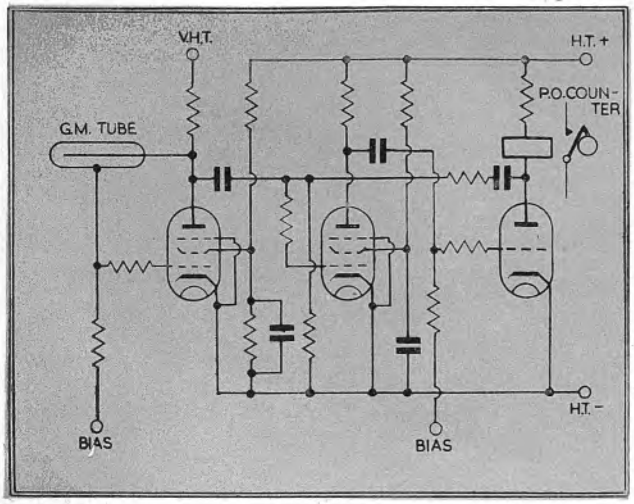
* Alltools Research Laboratories, Ealing.



Schematic of Portable Geiger-Muller Counter

represents a considerable advance upon other commercial designs, including those available abroad.

Finally, it may be noted that it is quite general to find uranium minerals associated with other valuable heavy metals such as copper, silver, tin, lead and even gold. Despite the present concentration upon uranium, it is probable that the value of deposits of other valuable metals may be worth far more than the uranium associated with them. Conversely, the examination of mining residues from tin, copper, lead and other deposits may reveal workable concentrates of uranium.

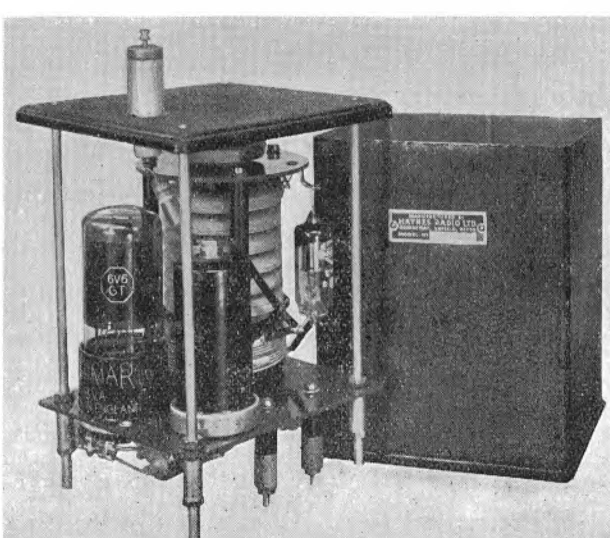
5 to 8 KV Radio Frequency E.H.T. Unit

THIS R.F. oscillator E.H.T. supply unit manufactured by Haynes Radio, Ltd., occupies little space, being about the same in volume as the transformer alone as used for mains connexion.

The circuit consists of a simple R.F. oscillator of the tuned anode type used with a small tetrode valve. A secondary coil of high L/C ratio is coupled to the anode coil and across this an R.F. potential is developed which after subsequent rectification provides in the present instance some 8 KV with an available current up to 300 microamperes. The small rectifier valve used derives its heater current from a coil of a few turns which is linked with the anode coil.

Current for the oscillator is taken from the set H.T. supply and does not exceed 30 mA for the 8 KV output. This additional current is small in comparison with the total H.T. loading and can usually be taken without modification of the H.T. power supply unit. A small reservoir capacitor is charged by the rectifier and the E.H.T. supply is taken off through a limiting resistor.

Voltage adjusting resistors are provided in the anode and screen leads with which by-pass capacitors prevent R.F. leakage to the H.T. supply. The oscillator valve is the 6V6 biased by a leaky capacitor and working with a relatively low screen voltage. Litzendraht wire is used for the anode winding. The E.H.T. coil consists of eight sections, graded in diameter for a uniform voltage distribution. Supported by its wire ends, the rectifier, an EY51, charges a capacitor of 0.001 mfd. rated at 10 KV working. In series with the tall ceramic output terminal is a current limiting resistor of 220,000 ohms.



The R.F., E.H.T. unit with cover removed, showing general construction.

Total screening is afforded by a strong copper container, possessing the required good conductivity for minimising losses in the coils, to which it must couple in some measure. The heater input is 6.3 V 0.45 A and the H.T. 225/300 V 20/28 mA, connected through a pair of under-base terminals. The container measures 4 in. by 3½ in. by 5 in. high. The oscillator frequency is low, being 100 Kc/s., to give good efficiency as well as to ensure against R.F. brushing and the resulting destructive action of ionisation.

The possible limitation of an available H.T. supply to 300 V has been taken into consideration and the 8 KV output is given when drawing 28 mA. A check of either voltage or current to these limits at the input is desirable to avoid excessive output. Not more than 250 V at 24 mA gives the generally needed 6 KV E.H.T. At 225 V an output of 5 KV is obtained. The facility of obtaining a graded E.H.T. potential up to 8 KV is an advantage and adjustment is effected by interposing a suitable resistor at the H.T. input terminal.

The Optimum Performance of a Wave Analyser

By N. F. BARBER, M.Sc.*

THE article shows why the "ringing" of a filter or resonant system sets a limit to the speed with which the spectrum of an electrical signal may be explored by a wave analyser. If a wave analyser is to be fitted with a mechanical drive so that the spectrum is explored automatically, it appears that there are certain optimum conditions which allow a maximum frequency discrimination to be obtained when the spectrum is to be explored in a given time.

The frequencies present in a complicated electrical signal such as the electrical output of a microphone are commonly examined by a wave "analyser" which selects and measures the energy present in any desired narrow range of frequency. The adjustment of a dial determines the frequency selected and this adjustment is usually manual.

The purpose of this article is to suggest that if the tuning dial were provided with a slow mechanical drive, and if the energy output of the wave analyser were recorded continuously by a pen or a camera, the business of exploring the spectrum could be expedited. In some studies it is of importance to obtain the maximum possible information in a brief time and a manual operation of a wave analyser in these circumstances demands considerable attention and much experience on the part of the observer. A manual operation undoubtedly permits greater flexibility in the adjustment of sensitivity and the re-examination of portions of the spectrum which appear to be of greater interest, but an automatic method is speedy and is less trying to the operator.

This suggestion of a mechanical drive is not a new one, but some of the problems which arise in this technique have not hitherto been solved. There are two conflicting aims, one is to provide the greatest possible resolution of frequency and the other is to make the analysis in the minimum time. The phenomenon known as "ringing" makes it impossible to obtain more than a certain degree of resolution in a given time; when the pass band of the filter is very narrow and the selecting dial is rotated rapidly it is found that a single pure tone in the input signal gives rise to an output which builds up rapidly to a maximum near the correct position of the dial, but which decays only slowly and so confuses later signals. The effective pass band in continuous analysis is therefore wider than the nominal pass band of the filter and some errors also arise in the measurement of frequency and amplitude. These points are discussed below.

The "ringing" of a transient resonance

Fig. 1 shows the calculated transmission of a simple Q circuit on the assumption that the input to the circuit is an electrical signal of constant frequency and amplitude and the natural frequency of the system is changed slowly and continuously. The curves also apply to the converse case of a filter of constant frequency fed with a signal whose amplitude is constant but whose frequency slowly changes. The ordinate of the curve represents the power or square of the amplitude of the transmitted signal on a decibel scale; the abscissa represents the difference between the fixed and variable frequencies expressed as a multiple of the band width of the filter. Curve (a) is the transmitted power when the frequency is changed infinitely slowly, and this curve is the usual characteristic curve of the simple Q filter; the peak of the curve is arbitrarily set at zero on the decibel scale. Curves (b) to (g) show the transmission curves when the rate of change of frequency assumes various values, and the curves are drawn on the assumption that the time increases from left to right in the diagram, though the actual time interval represented by the diagram varies for the different curves, being least for curve (g) in which the frequency is changed rapidly. It will be seen that the transmission of the filter increases smoothly, but decays in a series of beats, which are more pronounced the greater the rate of change of frequency. This beating appears to be an interference between the forced transmission of the filter when its natural frequency is no longer equal to that of the input signal, and the free oscillations of the filter resulting from the energy it acquired near resonance. If in practice it is proposed to use a rapid change of frequency so that the transmission curve is similar to curves (e) or (f) it will probably be desirable to use a recorder sufficiently sluggish to give a fair representation of the transmission curve without these more rapid beatings.

The various curves are labelled with the value of the quantity f^1/δ^2 where

$f^1 = df/dt$ = rate of change of frequency with time,

$\delta = f_0/Q$ = the frequency pass band of the filter indicated by curve (a) of Fig. 1 and is the frequency range within which the transmitted power is more than half the peak value.

It is the value of this parameter which determines the shape of the transmission curve in any specified case. The parameter f^1/δ^2 will be referred to as K.

The errors associated with a continuous analysis are evident from the curves of Fig. 1. The peak transmissions of curves (b) to (g) are all less than the peak transmission in curve (a) and the amplitude of the input signal will be correspondingly underestimated; for convenience the peak transmission is plotted against the parameter f^1/δ^2 as a continuous curve in Fig. 2. It will also be seen that the peak transmissions always occur a little later than the instant at which the frequency of the filter is equal to the frequency of the input signal, and the estimated frequency of the input signal will be too high or too low, depending upon whether the variable frequency is being increased or reduced; the frequency error is plotted against the parameter f^1/δ^2 as a continuous curve in Fig. 3. A further point is that the width of the transmission curve is greater in curves (b) to (f) than in curve (a), and the frequency discrimination in a rapid continuous analysis is therefore always less than the discrimination attainable with a slow

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analysis; the width of the various transmission curves, that is the frequency interval within which the transmitted power is more than half its peak value, is plotted against the parameter f'/δ^2 as a continuous curve in Fig. 4. In estimating the band width a small amount has been added to those curves showing marked beating since it may be necessary to use a sluggish recorder to suppress the beats. The effective pass band is indicated by the symbol δ_1.

TABLE I

Continuous analysis with a filter whose pass band is 5 cycles wide ($\delta = 5$)

Rate of change f' = df/dt	Parameter K = f'/δ^2	Power error	Frequency error	Effective pass band δ_1	Curve in Fig. 1
c/s²		db.	c/s	c/s	
20	.8	0.6	1.9	6.2	(b)
40	1.6	1.0	3.2	7.2	(c)
80	3.2	1.6	5.0	8.8	(d)
160	6.4	2.9	7.8	12.0	(e)
320	12.8	4.2	12.0	18.0	(f)
640	25.6	6.1	19.5	24.0	(g)

Numerical Example

If the filter has a band width of 5 cycles, the transmission curve has a form very nearly the same as the curves (b) to (g) in Fig. 1 when the frequency is changed at the rate of 20, 40, 80, 160, 320 and 640 c/s². The associated errors in frequency and power of the signal may be deduced from the curves of Figs. 2 and 3 and they are given in Table I together with the effective band width estimated from the curve of Fig. 4.

If it is not proposed to make any corrections to the measured strength and frequency of the signal it is perhaps tolerable to work at $K = 1$. The frequency error is then a little less than half the pass band, as can be seen from Fig. 3, and the power error is about ½ db. as given in Fig. 2. At this parameter the rate of change of frequency is equal to the square of the band width; a filter with a pass band of 5 c/s. would change frequency at the rate of 25 c/s. For more rapid analyses, at higher values of K, some correction might be desirable though it should be noted from Table 1 or Fig. 3 that the frequency error is relatively small since it never exceeds the effective band width of the filter.

The Technique of a Rapid Analysis

When it is desirable to make an analysis as quickly as possible, the consideration which limits the speed of analysis is not the associated errors in the estimation of frequency and power, for a suitable correction to these measured values can be made from the theoretical curves of Figs. 1, 2 and 3; the limitation is the increased effective band width of a filter used at high values of K. With a given filter a reduction in the time taken to make the analysis is always accompanied by a reduction in the discrimination of frequency; this is illustrated by Fig. 4 where K is proportional to the speed of analysis of a given frequency range and the ordinate δ_1/δ shows the factor of effective increase in the band width. An experimenter working with a given filter may adopt some technique intermediate between taking a long time to make a good analysis and making a coarse analysis rapidly. If it can be said that a sufficiently good analysis would be obtained if the effective band width were twice that of the given filter then Fig. 4 shows that the analysis may be made at a parametric value of 4.0; thus an analysis at an effective band width of 10 c/s. may be made using a filter of true band width 5 c/s. if the rate of change of frequency is 100 c/s., and a spectrum from 0 to 10,000 c/s. would be explored in

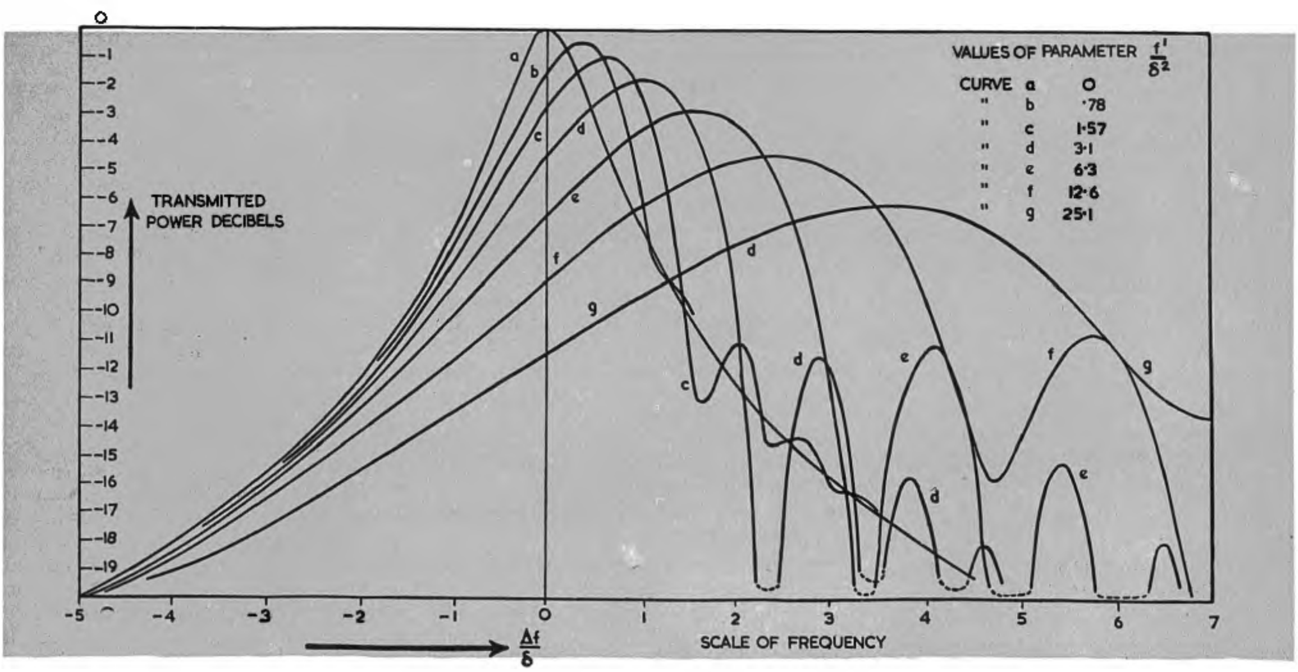

Fig. 1. Transmission of a simple filter in continuous frequency analysis

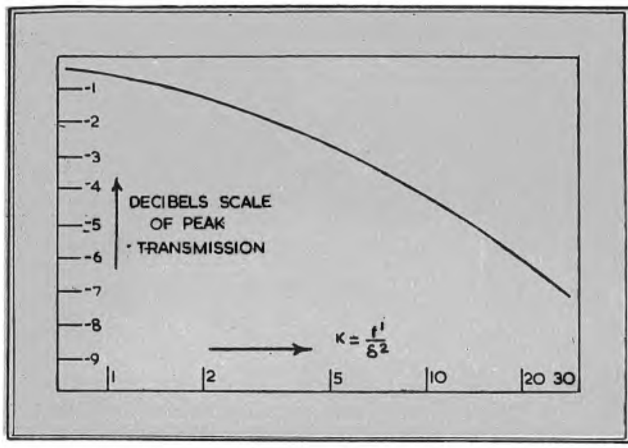

Fig. 2. Power transmitted by a filter in continuous analysis

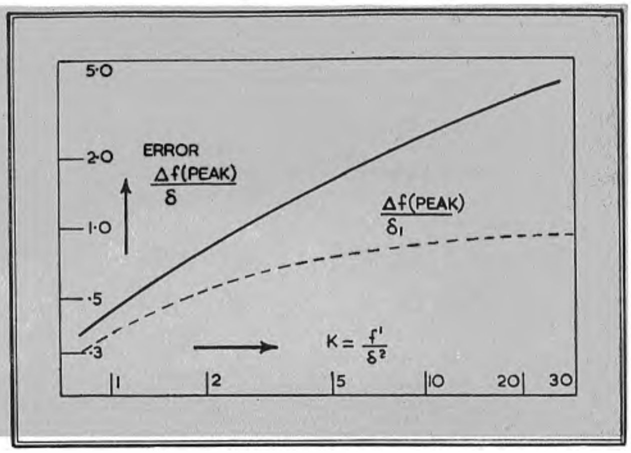

Fig. 3. Frequency lag in peak transmission in continuous analysis as a fraction of the nominal band width δ (full line) and as a fraction of the effective band width δ (broken line)

100 seconds. The errors in the estimates of frequency and power would be 6.3 c/s. and -2.0 db., and it may be thought necessary to make an appropriate correction.

Analysis Using a Constant Parameter

It is possible to arrange the apparatus so that the spectrum is explored in such a manner that the parameter K remains constant throughout the analysis. The advantage of this arrangement is that the corrections to be made to amplitude and frequency are then the same throughout the spectrum; so far as amplitude is concerned it may be unnecessary to introduce any correction if the parameter is kept constant, for it is usually the relative amplitudes of the different frequencies rather than their absolute amplitudes which are of interest. A constant parameter may be arranged in the following ways.

For a filter with a constant pass band δ it is clear from the definition of the parameter

$$K = f'/\delta^2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

that the parameter is constant if f' is constant, or if the frequency of the filter increases (or decreases) in a linear manner with time.

For a filter which is constructed to have a constant Q value over the frequency range, the pass band δ is proportional to the frequency.

$$\delta = f/Q$$

The parameter K may be expressed as

$$K = f'Q^2/f^2$$

and if K is constant

$$\frac{1}{f} = \frac{K}{Q^2}t + \text{constant} \quad \ldots\ldots (2)$$

and the frequency should vary inversely with time.

For a filter of fixed natural frequency f_0 investigating a spectrum of gliding tones such as would be produced by an engine whose speed was gradually falling, it appears that the analysis proceeds at a constant parameter if the engine speed S revs/sec. decreases exponentially. The overtone of frequency f which is being transmitted by the filter must be nearly equal to f_0 and is a multiple f_0/S of the engine speed. It follows that

$$\frac{dS}{dt} = \frac{S}{f_0} \cdot \frac{df}{dt}$$

Since the parameter is given by

$$K = \frac{df}{dt}\,\delta^2$$

and the pass band δ is constant, the analysis proceeds at a constant value of K if df/dt is constant. It therefore follows that

$$\frac{1}{S} \cdot \frac{dS}{dt} = \text{constant} =$$
$$\delta^2 K/f_0 = f'/f_0 \quad \ldots\ldots\ldots\ldots (3)$$

and the speed S should change exponentially with time.

It will be appreciated that an analysis need not be made under these special conditions, but that if they are attainable the interpretation of the results is somewhat simpler, a constant value of K leading to a constant power correction.

Optimum Characteristics of a Filter

If a given frequency range is to be explored in a given time, then a filter can be chosen which provides the best possible frequency discrimination. A filter with too wide a pass band is clearly unsuitable and a filter with a very narrow pass band might have to work at such a high parameter that its effective pass band would again be very wide. Between these limits there is an optimum width of pass band and a filter possessing a pass band of about this width provides the best analysis.

The optimum is illustrated in Fig. 5 which is a re-plot of the curve of Fig. 4. The statement of the problem determines the rate f' at which the spectrum must be explored, and in Fig. 5 the effective pass band δ_1 is expressed as a fraction of the known quantity $\sqrt{f'}$ and is plotted against the parameter K. It will be seen that the effective pass band is a minimum in the region of $K = 8$. The effective pass band is then about $0.98\sqrt{f'}$ and the nominal pass band is $0.35\sqrt{f'}$.

As a numerical example we may suppose that it is desired to explore a spectrum between 50 c/s. and 10,000 c/s. in a time of 10 seconds, and we may consider the cases in which this is done by a filter of constant band width or by a filter of constant Q. If the band width is constant it is evident from Equation (1) that the rate of change of frequency f' must be constant in order to provide a constant value of parameter K. The rate of change of frequency must therefore be

1,000 c/s. very nearly, and at the optimum parameter, $K = 8$, the nominal pass band, δ must be about 11 c/s. The effective pass band in the analysis would be $0.98 \sqrt{f'}$ or about 31 c/s. If on the other hand the filter is to have a constant Q, it has been shown that the frequency should vary inversely as the time,

$$\frac{1}{f} = \frac{K}{Q^2}t + \text{constant} \;\ldots\ldots\; (2)$$

so that for an analysis from $f = 50$ to $f = 10{,}000$ in 10 seconds at the optimum parameter $K = 8$ it follows that

$$Q = 63$$

or the nominal band width at, say, 1,000 cycles is

$$\delta = 1000/Q = 15.8 \text{ c/s.}$$

The effective band width in the analysis at this frequency is .98/.35 times this value or

$$\delta_1 = 44 \text{ c/s.}$$

and the effective Q throughout the analysis is in similar proportion to the nominal Q

$$Q_1 = 23.$$

These two methods of analysis would occupy the same time, but the filter of constant Q would spend relatively more time and give greater resolutions in the lower frequencies.

An optimum condition also appears if it is desired to analyse a given spectrum at a given effective band width or with a given effective Q, for there is a filter which will produce the required analysis in a shorter time than any other. The curve of Fig. 5 serves to interpret the optimum conditions, for it shows how $\delta_1/\sqrt{f'}$ varies with the parameter K. Since δ_1 is prescribed the shortest time of analysis is provided when f' is greatest, that is when $\delta_1/\sqrt{f'}$ is least, at the optimum value of parameter, $K = 8$. The desired filter must have a nominal pass band

$$\delta = 0.35\,\delta_1/0.98 = 0.36\,\delta_1$$

The minimum time may readily be calculated in any particular case since

$$f' = K\delta^2 = 8\,\delta^2$$

for the optimum filter.

Thus if it is desired to explore a spectrum from 50 to 10,000 c/s. with a filter whose effective band width in the analysis is constant and equal to 10 c/s. the filter should have a nominal band width of 3.6 c/s.; the rate of change of frequency should be 102 c/s. and the analysis would therefore take 98 seconds. If it is desired to explore the same spectrum with a filter of constant effective Q equal to 100 the nominal Q of the filter should be

$$Q = Q_1/0.36 = 280.$$

The analysis would occupy a time given by Equation (2) as

$$t = \frac{Q^2}{K}\left(\frac{1}{f_1} - \frac{1}{f_2}\right) = 182 \text{ seconds.}$$

It is worth pointing out that the minimum in the curve of Fig. 5 is very flat. The examples above are worked for a parameter 8, but in practice any convenient value between 2 and 20 could be used without any serious loss in discrimination.

Multiple Filters

It may be impossible for a single filter to explore the spectrum with the desired discrimination in the allowable time, and the frequency range must then be explored by two or more filters working over different sections of the frequency scale. From the examples in the section dealing with optimum characteristics it is clear that the range from 50 to 10,000 c/s. cannot be examined with an effective band width of 10 c/s. in a less time than 98 seconds if a single filter is used. The range can be covered in 50 seconds using two filters working above 5,000 c/s. and below it, or in 33 seconds using three filters in the ranges 50-3,300-6,600-10,000 c/s. Further, it may not be necessary to explore all parts of the spectrum with the same band width, and the spectrum should be divided up so that the various sections can be explored in the same time, the time taken to explore a range of F c/s. is given by

$$\text{Time of analysis} = F/f' = F/K\delta^2 = F/1.04\,\delta_1^2$$

the final expression being obtained by using the optimum relations

$$K = 8 \text{ and } \delta = 0.36\,\delta_1.$$

Thus if the range of 50 to 10,000 c/s. is divided up into ranges of 50-1,000-10,000 c/s. and it is desired to explore these ranges with effective band widths of 10 c/s. and 30 c/s. respectively, the times required are about equal, being given by

$$t_1 = 950/104 = 9.1 \text{ secs.}$$

$$t_2 = 9000/940 = 9.6 \text{ secs.}$$

and by using two filters with nominal pass bands of 3.6 c/s. and 10.8 c/s. working simultaneously the desired analysis is complete in 9.6 seconds.

Fig. 6 shows a series of analyses of the same electrical signal. These analyses were all made in the same

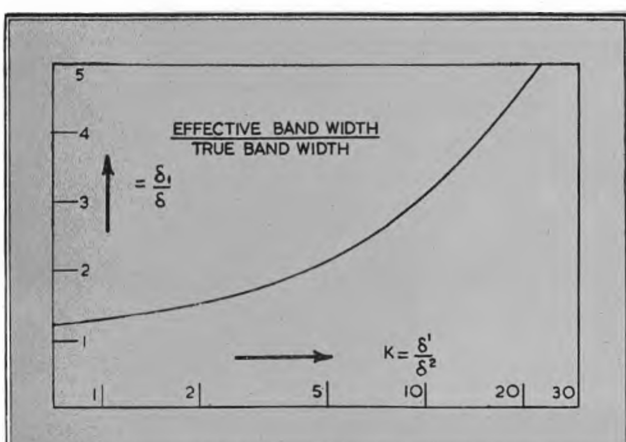

Fig. 4. Increase in effective band width with increase in speed in continuous analysis, the nominal band width being prescribed

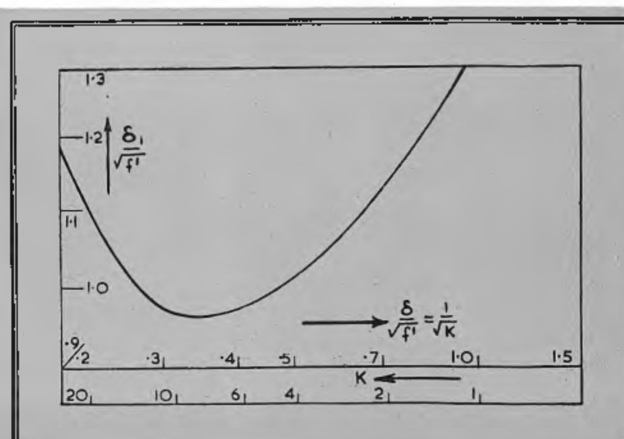

Fig. 5. Relation between effective band width and nominal band width in continuous analysis when the rate of change of frequency is prescribed

time but with filters having different band widths. The parametric values are indicated on the curves. The electrical signal was one with a large number of overtones at equal frequency intervals. When the band width of the filter is very small, that is when the value of the parameter K is large, the various harmonics begin to lose definition. The beats on the decay of each transient resonance are obvious though they have been somewhat masked by the sluggishness of the pen recorder.

The analyses were made with the power-driven machine described by Barber, Ursell, Darbyshire and Tucker[1] which is the one used by this research group for the analysis of ocean wave records, and the true spectrum would consist of a series of isolated ordinates corresponding to the various harmonics of the very complicated wave form of the record. These ordinates are represented by the peaks in the various curves and the degree of resolution of successive peaks gives a good idea of the relative frequency discrimination in the various analyses. The filter had a natural frequency of 135 c/s., but the optimum conditions that this series indicates would be found for analyses at higher or lower frequencies.

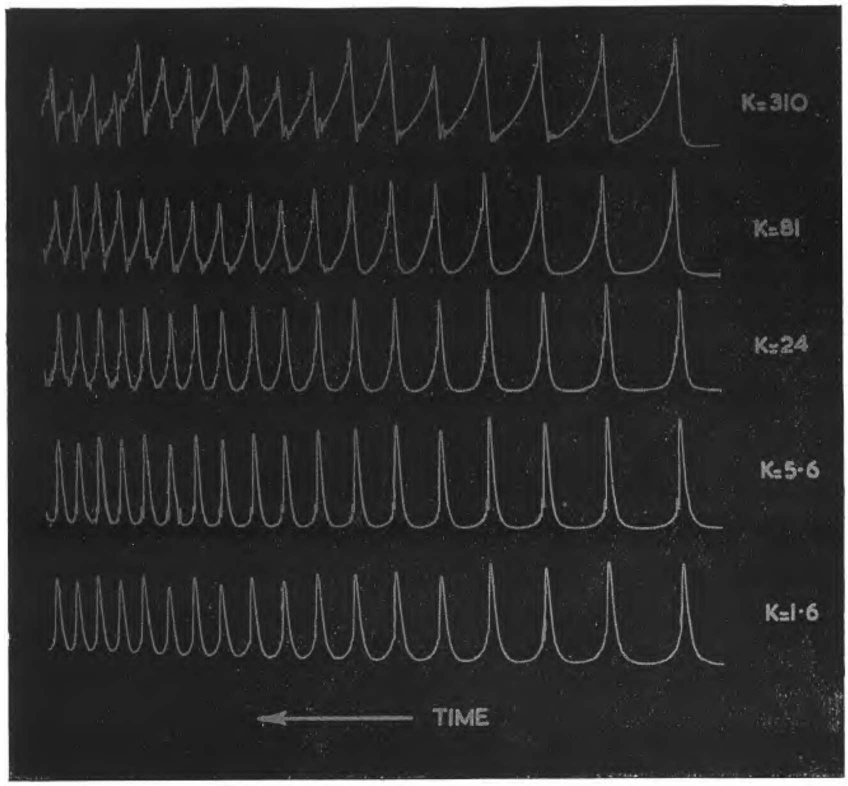

Fig. 6. Examples of the continuous analysis of an electrical signal rich in overtones. The spectrum was explored at the same rate of change of frequency in all cases, but the band width of the filter was varied. When the band width is very small (upper curve) the resolution is bad. This is to be expected by the very large value of the parameter K

Theory

The amplitude of the output signal from a simple Q filter supplied with an input signal of constant amplitude and slowly changing frequency is shown by Barber and Ursell[2] to be given by

$$\text{Amplitude} = \sqrt{(A^2 + B^2)}$$

where A and B are given at any time t by the expressions

$$\left.\begin{matrix} A \\ B \end{matrix}\right\} = \frac{1}{2}\int_0^\infty e^{-n\omega n} \left.\begin{matrix} \sin \\ \cos \end{matrix}\right\} (a\omega tu - \tfrac{1}{2}a\omega u^2)du \qquad \text{..........} (1)$$

and the expression is equally applicable to a filter of variable frequency investigating a spectrum of tones of constant frequency. It is convenient to write the result in terms of

f_0 the filter frequency $= \omega/2\pi$

f the signal frequency $=$
$f_0 + \Delta f = \omega(1 + at)/2\pi$ approx.

δ the frequency pass band of the circuit measured as frequency interval within which the amplitude of the transmitted signal is more than 0.7 of its peak value.

$$\delta = 2nf_0 = f_0/Q$$

f^1 the rate of change of f or

$$f_0 = df/dt \text{ or } df_0/dt$$

Then

$$\left.\begin{matrix} A \\ B \end{matrix}\right\} = \frac{1}{2}\int_0^\infty e^{-u\pi\delta} \left.\begin{matrix} \sin \\ \cos \end{matrix}\right\} (2\pi.\Delta f.u - \pi f^1 u^2)du \qquad \text{..........} (2)$$

The Admiralty Computing Service has given tabulated values of the functions

$$\left.\begin{matrix} S \\ C \end{matrix}\right\} = \sqrt{k}\int_0^\infty e^{-v} \left.\begin{matrix} \sin \\ \cos \end{matrix}\right\} (2T.\sqrt{k}v - kv^2)dv \qquad \text{..........} (3)$$

and it can readily be shown that the expressions (2) and (3) are related and that

$$\left.\begin{matrix} A \\ B \end{matrix}\right\} = \frac{1}{2\pi\delta\sqrt{k}} \left\{\begin{matrix} S \\ C \end{matrix}\right.$$

and amplitude $= \sqrt{A^2 + B^2} = \sqrt{S^2 + C^2}/2\pi\delta\sqrt{k}$

provided that

$$T = \Delta f/\delta\sqrt{k}$$
$$k = f^1/\pi\delta^2$$

The curves of the present report are the values of $\sqrt{S^2 + C^2}/\sqrt{k}$ plotted in terms of the variable

$$T\sqrt{k} = \Delta f/\delta$$

which is a scale of frequency in units of the band width δ. The parameter K which denotes the various curves is simply related to k

$$K = \pi k = f^1/\delta^2$$

and this parameter is also used as abscissa in the curves of Figs. 2, 3, 4 and 5.

Attention is directed to other mathematical treatments of "ringing" given by Lewis[4] and Hok.[5] References to work on "ringing" prior to 1935 are given by Meyer.[6]

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AN ELECTRONIC STOPCLOCK

By K. J. BRIMLEY, B.Sc.*

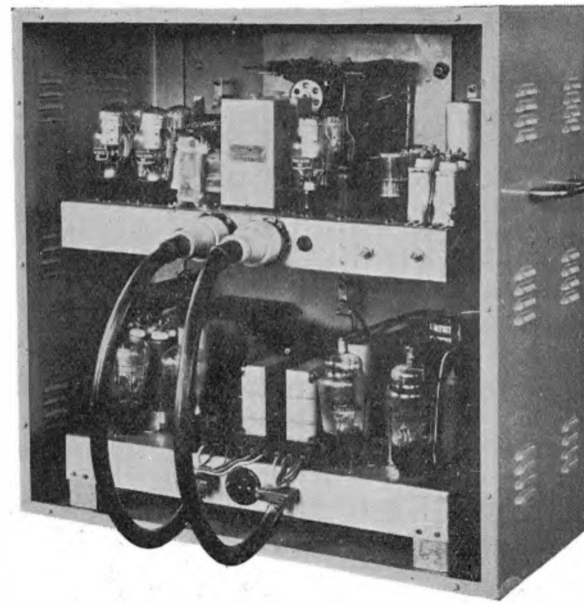


Fig. 1. Rear view of the Electronic Stopclock

IN the testing of delay detonators a requirement arose for apparatus capable of timing intervals of up to 12 seconds to an accuracy of better than 1/100 second. The apparatus had to be robust and reliable and capable of accurate operation by unskilled labour, which meant that the reading must be direct and simple.

A variety of schemes was put forward and a number of commercial instruments considered, but nothing existed which completely fulfilled the requirements.

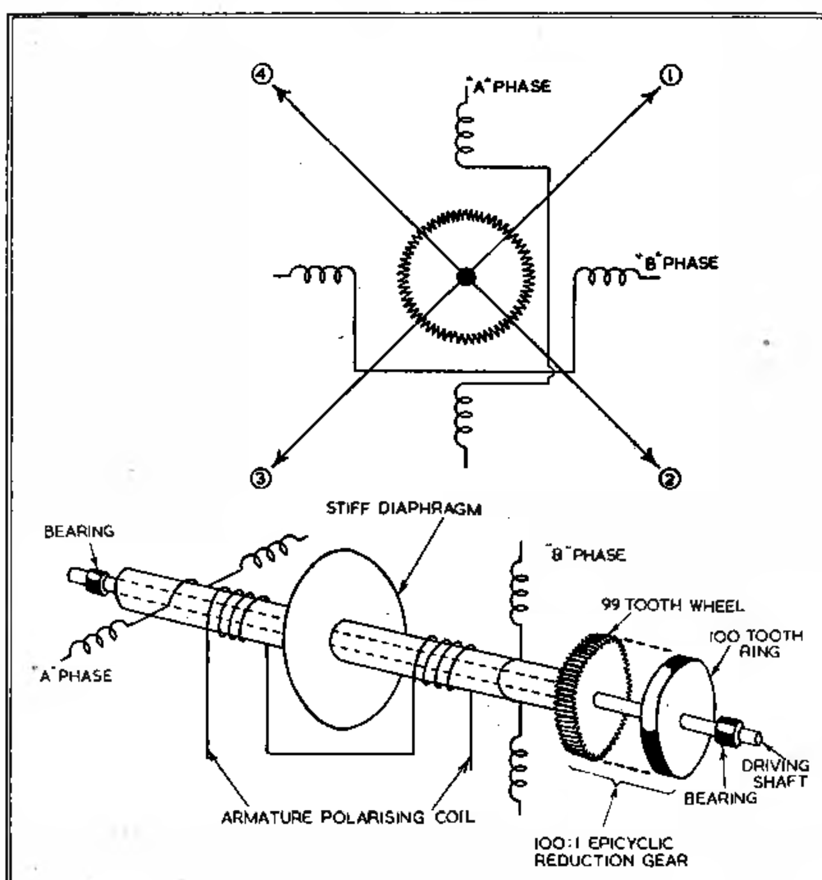
The resulting instrument (*see* Fig. 1) has been completely satisfactory and is capable of considerably improving on the specification laid down. In addition to its use as a timing apparatus, the circuit has interesting possibilities as a high speed mechanical counter, and has been tested as such.

Fundamentally the arrangement is a high speed mechanical counter, in which a Scophony "torque motor" type BTM is used, in conjunction with two thyratron inverters. This combination totals the quarter cycles of a standard oscillator within the interval defined by two trigger circuits, the latter being operated by the events forming the interval.

In this case the two events were, respectively, the firing current of the detonator and the sound of the detonation picked up on a suitably placed microphone.

The oscillator, trigger and gating circuits are perfectly conventional. A tuned R.C. oscillator is used as frequency standard and, with a very high degree of negative feedback, the frequency stability is better than the 1/1200 required, provided that the temperature range in which the instrument is used is not excessive. A frequency of oscillation clear of mains harmonics was selected to avoid possible pulling. The trigger circuits employ GT1/C thyratrons and the gating circuit two "Carpenter" high-speed polarised relays. The latter were found to have an operating time shorter than the permissible error,

Fig. 2. (*Below*) Principle of the motor drive



* Imperial Chemical Industries, Limited, Nobel Division, Research Department, Stevenston, Ayrshire.

and the scatter of their operating times was exceedingly small.

The interesting part of the apparatus is the actual counting arrangement. The Scophony motor† is shown schematically in Fig. 2. Although intended as a split phase A.C. motor, the method by which it is used here is somewhat different. The two fields are normally D.C. energised, thus the armature is locked into a position mid-way between two poles. If the fields are now commutated in turn, the armature will move discontinuously between four fixed positions, thus producing discontinuous rotation of the shaft at a rate of 1 rev. for each 400 commutations. As explained in the article referred to above, the tooth cut of the reduction gear is small, enabling a large arc of contact, and thus quite high torque can be transmitted. The small tooth size also means that the actual motion of the armature is small, with the result that the movement from one locked position to another can be executed very quickly. This method of operation prevents any overshoot after the final count since the D.C. polarisation of the field locks the armature into its final position. Using the circuit of Fig. 3, the motor will respond to pulses fed in at a rate of up to about 1,200 per second, and this can be slightly increased for short periods if the standing currents in the windings of the motor are increased.

The operation of Fig. 3 is straightforward. V_1 is an Eccles-Jordan D.C. coupled trigger circuit, triggered between stable states by negative pulses. This produces positive pulses alternately at each pair of inverter grids. (The negative pulses between the positive ones are not effective). Each positive pulse produces the commutation of the appropriate inverter and thus the arrangement shown commutates the two motor fields alternately.

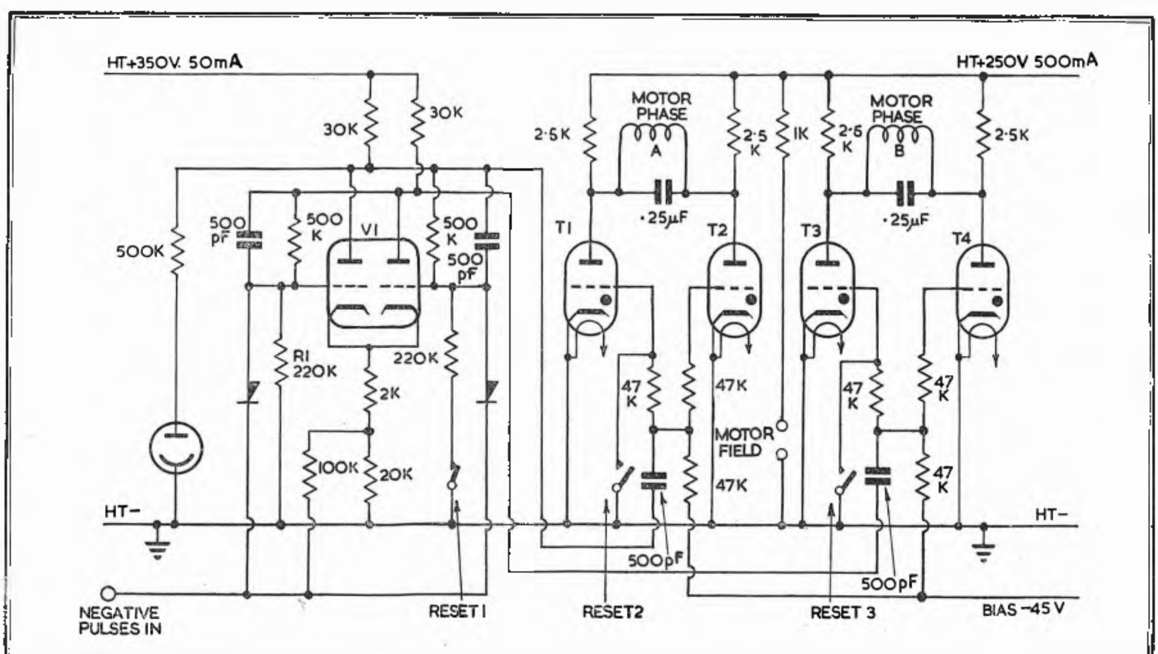
This arrangement was originally used to drive the "clock." The standard frequency input was fed to V_1 as a gated sine wave in parallel with R_1, thus giving one positive pulse to each inverter each cycle. A difficulty arose in this method, namely that it was necessary to start with the trigger circuit and the two inverters in pre-determined relative positions, otherwise the sense of rotation of the motor was indeterminate. This was readily accomplished, but it was found that occasionally electrical interference might trigger one of the inverters prior to the arrival of the appropriate signal, in which case the signal, when it did arrive, would operate the inverter in the wrong direction, putting the relationship of the trigger circuit and the inverters in error. This would reverse the direction of rotation of the motor.

To overcome this difficulty, the arrangement shown in the final circuit diagram was adopted (*see* Fig. 4(a)). In this case each thyratron was fed separately with a sinusoidal signal, obtained from the two phase-shifting networks in the secondary of transformer T_1. Thus the four thyratrons must always fire in a predetermined order and any stray strikes will be automatically compensated for.

This arrangement needs half the oscillator frequency of the arrangement of Fig. 3 to give the same rate of motor rotation, since each inverter must fire in both directions in each cycle—thus the motor registers 4 counts per cycle. Using this arrangement as a timer and neglecting any possible gating error, there is a possibility of the time being in error by 3 counts, *i.e.*, 1 count for the random phase of the oscillator, and an additional 2 counts for the following reason: Since two thyratrons must fire directly the gate switches on, the armature will move from "free" to a fixed position, depending on which two thyratrons strike. This new position may be up to either ±2 positions different from its previous stopped position, and the reduction

† *Electronic Engineering*, Oct. 1946, p. 308.

Fig. 3. Original clock-driving circuit



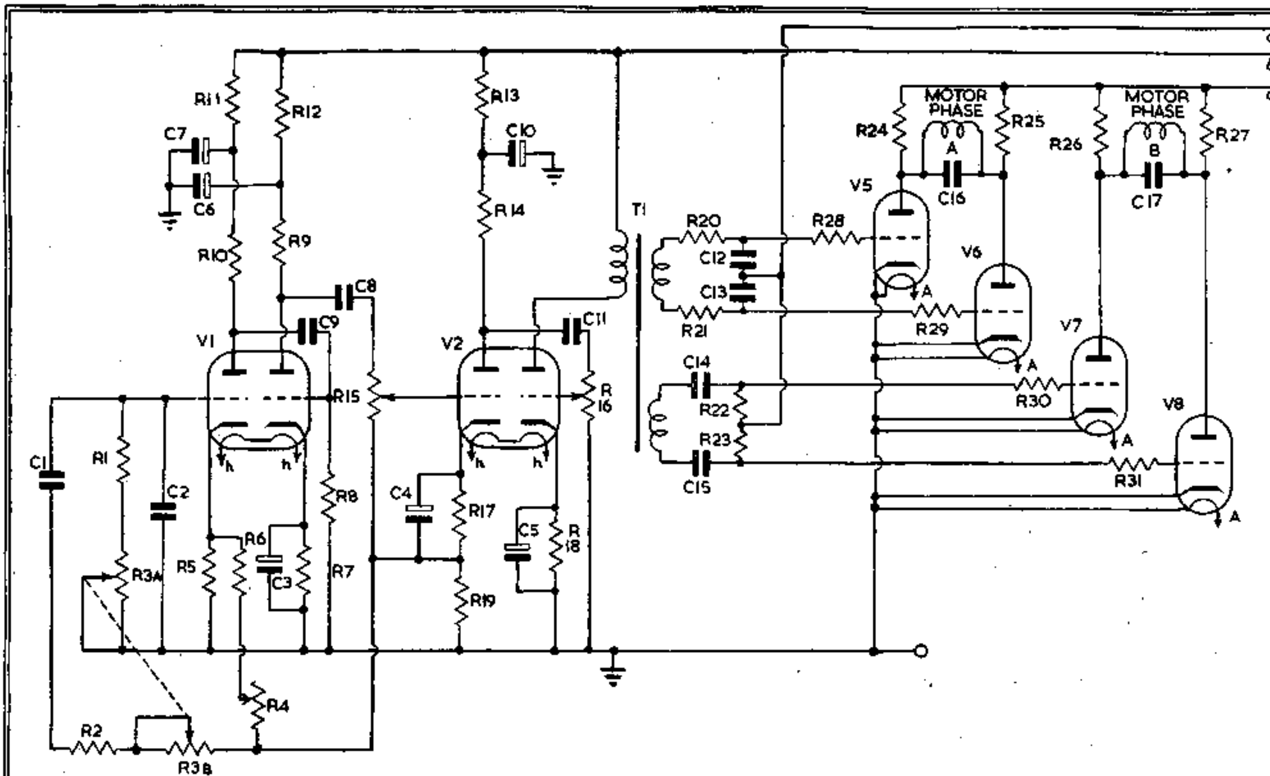
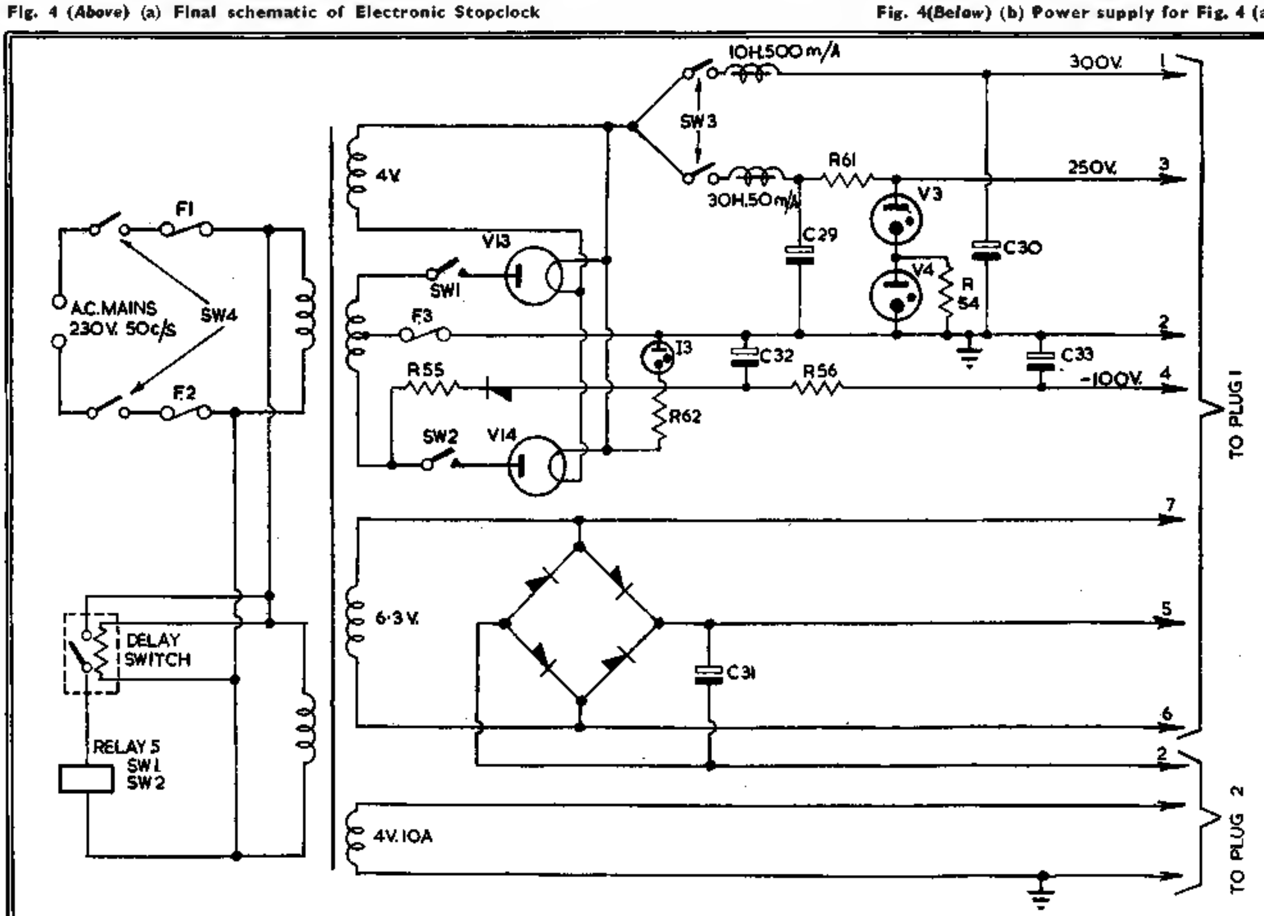
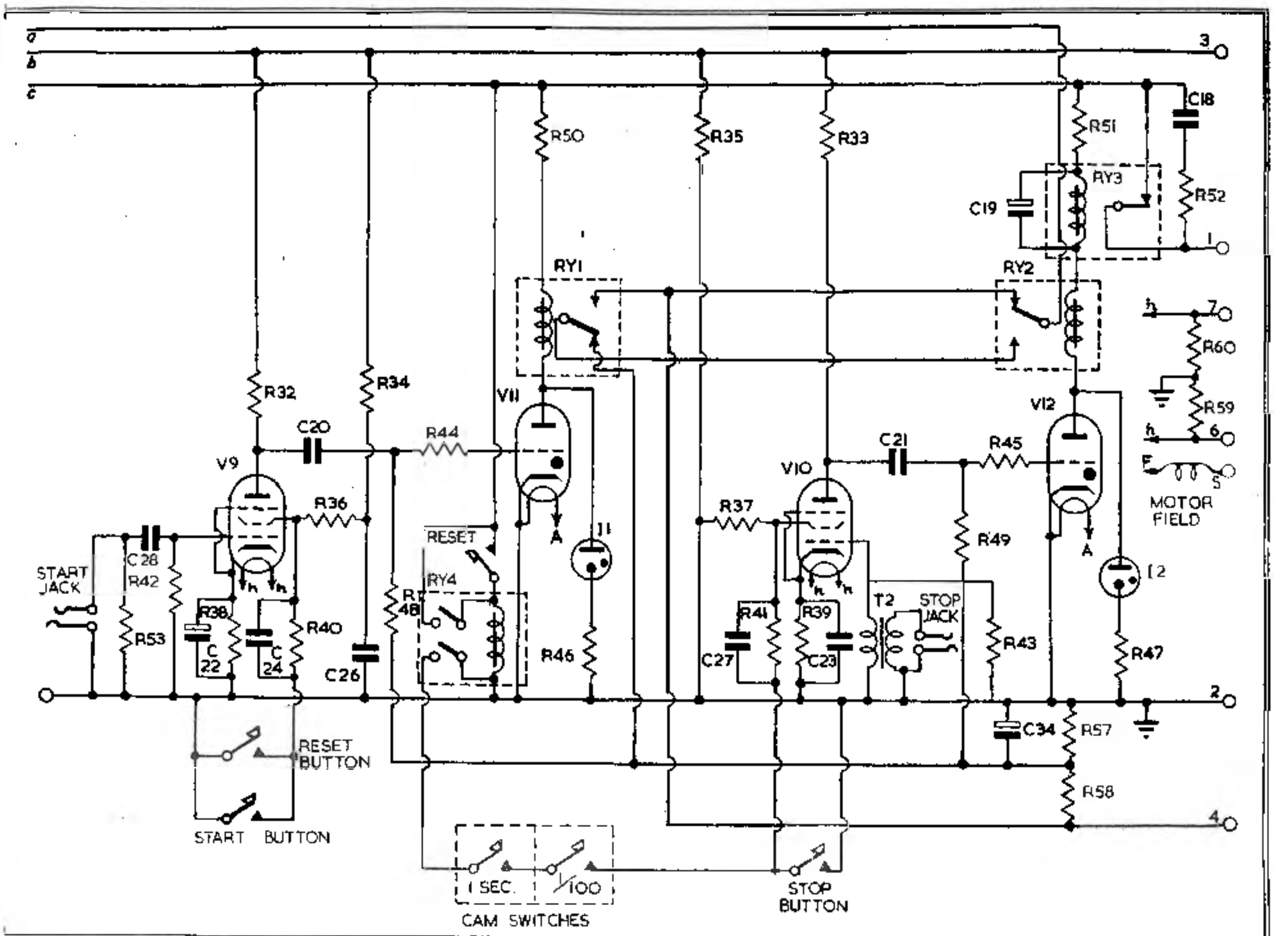


Fig. 4 (*Above*) (a) Final schematic of Electronic Stopclock

Fig. 4(*Below*) (b) Power supply for Fig. 4 (a)





gearing may be "instantaneously" moved by a corresponding amount. In one hundred trials no reading was found in error by more than ±2 counts, but allowance was made for the possibility of greater positional errors by increasing the oscillator frequency so that a 3 count error was less than the specified error of the apparatus.

In the form illustrated the motor drives the hands through a 100-54 reduction, corresponding to an oscillator frequency of 185.2 c/s. and a counting rate of 741 counts/second. This speed is well within the instrument's capabilities and it delivers adequate torque to operate the two sets of reduction gearing for the hands.

Cam switches are provided for the zero adjustment of the instrument. This is done by re-starting the clock and operating the stop trigger circuit by means of the cam switches. To simplify the operation of the instrument, resetting of the trigger circuits is automatic. The stop thyratron operates an auxiliary relay which, when energised, interrupts the H.T. supply to all thyratrons.

The power supply is conventional, except that very good regulation is required since the quiescent H.T. current is about 30 mA, but the full load H.T. is about 200 mA.

The complete circuit details are shown in Figs. 4(a) and (b).

The apparatus has created interest as a possible adjunct to conventional electronic scaling apparatus on account of its high speed and robustness. Its speed of better than 1,200 counts/second had been exceeded by refined mechanical escapement counters, but the combination of speed and robustness is believed to be better than the majority of mechanical high-speed counters. Used directly as a counter it has a number of disadvantages, but these should not be difficult to overcome if it were needed as a unit-reading high-speed scaler. The chief disadvantage is the large numbers of counts per rev., *viz.*, 400, and since the torque falls with speed, it is not advisable to use speed-increasing gearing. A 6 in. dial can be read accurately, but not comfortably, to one count with a fine pointer. Any scale would have to be individually plotted since the increments are not exactly uniform, alternate increments being approximately equal in size. On the other hand, it is very robust and delivers very high torque compared with most counters, making it possible to use conventional gearing for subsidiary scales.

At the time of writing the prototype of the instrument described has done 16 months' routine testing, corresponding to several million counts and on recent inspection appeared to be in perfect order.

NOTES FROM THE INDUSTRY

B.B.C. Television Masts

Further details are now available concerning the Television Masts at Sutton Coldfield and Wrotham, to be erected by Messrs. B. I. Callender's Cables, Ltd.

The Sutton Coldfield mast for the new Midlands Transmitter will have a total weight of 140 tons and the pivoted base pedestal is designed to permit angular movement in any direction and to withstand a maximum working thrust of 350 tons.

At an elevation of 710 feet is a short square tower carrying the eight dipoles forming the television aerial, which, with its obstruction light and lightning conductor extends the mast height to 750 feet.

A two man electric lift will ascend to the top of the mast with landings at intermediate levels. The difficulties inherent in a normal push button control system due to long hanging cables are eliminated by an unusual method. The car is controlled from ground level and communication will be maintained by a VHF " Walkie Talkie " system.

A second mast 500 feet in height but of similar design to the Sutton Coldfield mast is to be erected at Wrotham, near Maidstone, Kent.

This mast will form part of an experimental VHF Broadcasting station from which high power tests on different system of modulation will be carried out.

Messrs. Marconi's Wireless Telegraph Co., Ltd., are associated with B. I. Callender's for the supply and installation of the television aerial and feeders on the Sutton Coldfield mast, and the feeders on the Wrotham mast.

Edinburgh Exhibition

The Edison Swan Electric Company, Ltd., are holding an exhibition of electro-medical apparatus, including the Ediswan Electronic Wave Analyser and the Electro-Encephalograph, in the Lecture Hall on the premises of the South East Scotland Electricity Board Electricity Showrooms, 127 George Street, Edinburgh 2, from May 17 to May 20 inclusive.

Admission will be by invitation, and those wishing to attend may obtain tickets on application to the company at 155 Charing Cross Road, London, W.C.2.

Taylor Electrical Instruments, Ltd.

An alternative to the model 30A oscillograph is available upon special request, incorporating a cathode ray tube with a blue trace, having a yellow-green after-glow.

The list price of this instrument is £33 10s. and delivery can be effected in approximately three weeks from receipt of instructions.

Staff Changes

The Dubilier Condenser Company (1925), Ltd., announce with regret that Mr. G. F. Mansbridge, O.B.E., M.I.E.E., has decided to retire from the board as at March 31, 1949. Mr. Mansbridge has been connected with the condenser industry for 50 years and his first condenser patent was applied for in 1899.

Mr. E. C. Deering, B.Sc., A.R.I.C., has been appointed a joint managing director of Johnson, Matthey and Co., Ltd., to take effect from April 1, 1949.

He joined the company in June 1918 as a member of the analytical laboratory where he stayed for some two years until transferring to the newly formed research department at the beginning of 1921.

National Physical Laboratory

The National Physical Laboratory at Teddington is holding an "Open Day" on Thursday, May 26, from 2.30-6 p.m., to which representatives of industrial organisations are being invited.

This is an opportunity for members of industry to see the wide range of scientific research and investigational work undertaken at the Laboratory and a number of tickets is being reserved for postal applications.

Accredited representatives of industrial organisations who would like to visit the Laboratory and who are not already in contact with its work are invited to apply to the Director, National Physical Laboratory, Teddington, Middlesex, not later than May 14.

Change of Address

The address of the Sheffield office of Wild-Barfield Electric Furnaces, Ltd., and the Sheffield office of their associates, Messrs. G. W. B. Electric Furnaces, Ltd., is now 4 Paradise Square, Sheffield 1: the telephone number remains unaltered as Sheffield 22776.

Travelling Exhibition in Electrical Research

The Caroline Haslett Trust of 35 Grosvenor Place, London, S.W.1, are now inviting applications for a Travelling Exhibition in the early autumn, tenable in Holland.

The successful applicant, who must possess the Diploma in Electrical Housecraft awarded by the Electrical Association for Women, will travel in Holland for one or two months to study Home Economics, particularly in the application of electricity to housecraft, and will acquaint herself with the publicity methods adopted there. She will visit works where domestic electrical equipment is manufactured and will hope to see, both in the home and out of it, the latest electrical developments.

Publications Received

" Some Electrical Instruments of Precision."
Leaflet on their products issued by:
Doran Instrument Co., Ltd., Wallbridge Works, Stroud, Glos.

" Eddystone " Leaflets.
A series on their " 640," " 659 " and " 680 " communication receivers, and other products available from:
Stratton and Co., Ltd., Eddystone Works, Birmingham, 31.

" High Vacuum Equipment."
A booklet dealing briefly with this range of equipment issued by:
W. Edwards and Co. (London), Ltd., Kangley Bridge Road, Lower Sydenham, London, S.E.26.

Siemens Electric Lamps.
List No. 972.
Tungsram Valves.
List No. 966.
Both available from:
Siemens Electric Lamps and Supplies, Ltd., 38 and 39 Upper Thames St., London, E.C.4

Ardent Acoustic Laboratories.
Leaflets WP/12700, WP/14504, WP/14507, WP/14509, WP/14511 dealing respectively with their " Ship's Master Communicator," intercommunication system, " Philomel " reproducer, general price list and public address equipment for police.
The Automatic Coil Winder and Electrical Equipment Co., Ltd., Winder House, Douglas Street, London, S.W.1.
Clydesdale Supply Co., Ltd., 2 Bridge Street, Glasgow, C.5.

Telcon Cables for Radio Frequencies —Publication No. 10 reprinted with additions. *The Telegraph Construction and Maintenance Co., Ltd., 22 Old Broad Street, London, E.C.2.*

Government Department Electrical Specification. The Committee on the Standardisation of Electrical Cables and Wires for Government Services (Secretary's address: Ministry of Supply, I.E.M.E., " Walsingham," Chislehurst, Kent) has recently issued two new specifications. These are G.D.E.S. No. 25 for " Tough Natural Rubber and Polychloroprene Compounds for Heating Electric Cables and Flexible Cords " and G.D.E.S. No. 26 for " Low Voltage Starter, Lighting and General Purposes Cables for Automobiles." Both are obtainable from H.M.S.O. the former price 1. and the latter price 2d.

CORRESPONDENCE

High Dielectric Ceramics

DEAR SIR,—In connexion with Mr. Lorant's note on ceramic materials of high dielectric permittivity (ELECTRONIC ENGINEERING, December, 1948, p. 403), the following comment may be of interest with regard to his reference to dielectric losses in mixed titanate compositions.

The loss tangents for capacitors with barium titanate as the dielectric are of the order of 0.01 to 0.02 at temperatures up to the Curie point, in the region of 120° C., beyond which they fall rapidly to relatively low values. The admixture to barium titanate of certain compounds such as strontium or lead titanate, possessing crystal structures of a similar type (*i.e.*, the "perovskite structure"), results in the displacement of the Curie point, and hence of the tan δ-temperature curve. By the addition of compounds possessing a Curie point below that of barium titanate, solid solutions may be obtained, the low-loss region of which extends to the working temperature range of the capacitor, and it is therefore apparent that the dielectric losses depend not only on the relative proportion of the additives, but also on the individual Curie temperatures of the latter.—Yours faithfully,

GEORGE V. PLANER.

Calculation of Parallel Resistances

DEAR SIR,—The following is often an improvement on Mr. F. Oakes' method of calculation of parallel resistances by slide rule (ELECTRONIC ENGINEERING, January, 1949, p. 20).

(1) Set cursor on highest resistance R_1.

(2) Set sliding scale unity on R_2.

(3) Cursor reading gives R_1/R_2.

(4) Move sliding scale till cursor reads $R_1/R_2 + 1$.

(5) Unity on sliding scale gives R_{12}.

If a further resistor R_3 is also in parallel

(6) Move cursor to R_3 (on final scale).

(7) Cursor reading gives R_3/R_{12}.

(8) Move sliding scale till cursor reads $R_3/R_{12} + 1$.

(9) Unity on sliding scale gives R_{123}.

This method is easier because the only mental arithmetic is to add one, but the decimal point must be watched. The proof is as follows:

$$R_{12} = \frac{R_1}{R_1/R_2 + 1}$$

$$\therefore R_{12} = \frac{R_1 R_2}{R_1 + R_2} \text{ or } 1/R_{12} = 1/R_1 + 1/R_2.$$

Yours faithfully,

E. G. WEBB.

Mr. Oakes Replies

Although the alternative method suggested by Mr. Webb may offer an occasional advantage by virtue of its simple addition of one, the extra sliding operation (and consequently reduced accuracy) as well as the incurring of potential mistakes in placing the decimal point render this method lengthier and less reliable generally.

Cathode-Ray Tubes with Post-Deflection Acceleration

DEAR SIR,—With reference to Mr. White's article on cathode-ray tubes with post-deflection acceleration in the March issue of ELECTRONIC ENGINEERING, it may be mentioned that the effects described can be demonstrated with an ordinary tube by the use of an external electrode.

I demonstrated the effect some years ago, using a Cossor oscilloscope. A narrow strip of copper foil was placed round the tube just behind the screen and was connected to the 700 V secondary of a transformer, the other end of which was earthed. The 100 V peak-to-peak mains waveform was then shown on the tube. On switching on the supply to the P.D.A. electrode the peak of the sinewave was brightened and the negative peak was blacked out. The distortion of the wave readily showed the reduction in sensitivity occurring.—Yours truly,

G. H. L. THOMAS.

Reducing the Effect of Capacitance in Screened Cables

DEAR SIR,—May we refer to the article in the March issue of your journal by your contributor, V. H. Attree, B.Sc. (Eng.)?

In this article we note that he refers to Coaxial Cables with an intersheath not being generally available, and we should esteem it a favour if you were to draw your readers' attention to the range of Telcon "Wye" Cables which have been in general production since the latter part of 1947.

In this range of cables the two screens can be supplied in continuous contact or separated by an intersheath.

A. W. J. CORDREY.

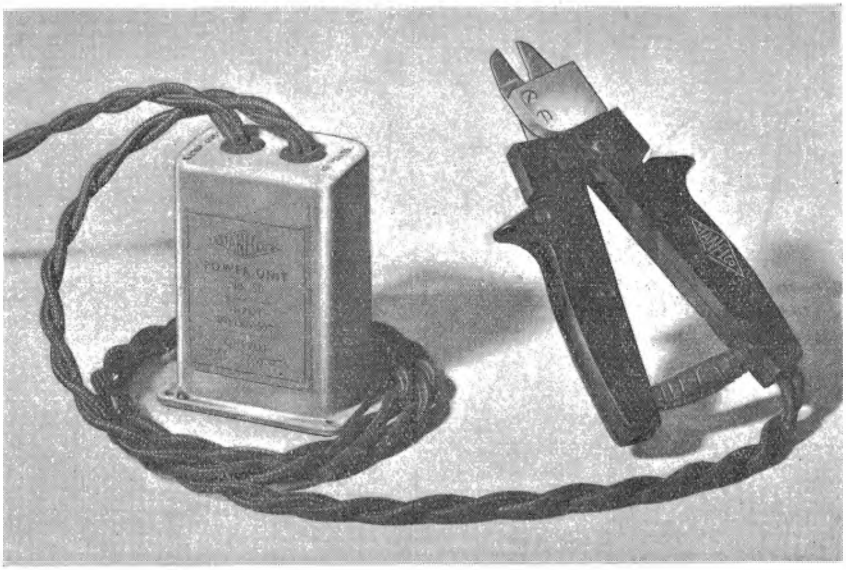
The Telegraph Construction and Maintenance Co., Ltd.,
Greenwich, S.E.10.

Mr. Attree Replies

The Telcon Wye type PT1 MYM would appear to be similar to the composite cable 1 described. Referring back to the article, it is interesting to note that if the outer screen is omitted altogether, the intersheath is relatively insensitive to pick-up from stray fields: this is due to the low impedance at the cathode of the valve. Thus, in applications where the residual pick-up can be tolerated, it is possible to use an ordinary coaxial cable with the screening driven from the valve cathode. A low-capacity air-spaced cable, having a nominal capacity of 4.1 $\mu\mu$F/ft., enables an effective capacity as small as 0.3 $\mu\mu$F/ft. to be obtained. The remarkably low value of effective capacity may be appreciated from the fact that a 44-gauge bare wire, spaced 4 in. from an earthed chassis, has a capacity of 1.0 $\mu\mu$F/ft.

Electronic Equipment

A monthly record of British electronic apparatus, components and accessories, compiled from information supplied by the manufacturers.



Potentiometers

(Illustrated below)

EGEN ELECTRIC LTD., of Canvey Island, Essex, announce that the following standard products with a $2\frac{1}{4}$ in. spindle are immediately available:—

(*a*) Log Type "A" (10 per cent resistance at 50 per cent effective rotation).
(*b*) Log Type "B" (20 per cent resistance at 50 per cent effective rotation).
(*c*) Linear Law.
(*d*) Anti-Log Type.

These are stocked with a single-pole or double-pole switch and without switch. Switches only can be supplied separately if required.

Features of the Egen carbon potentiometer are: Smooth action movement, positive location tags, rigid fixing to chassis, rustproof plating of all steel parts, silent operation and mains switch design with quick make-and-break action and self-cleaning contacts.

Retail prices quoted by the Company for potentiometers of 1,000 ohms to 5 megohms resistance are:—

Potentiometer only	2s.	9d.
Potentiometer with S.P. switch	4s.	6d.
Potentiometer with D.P. switch	5s.	3d.

Egen Electric Ltd.
Craven Avenue, Canvey Island, Essex

Audio Signal Generator

(See below, right)

A NEW audio signal generator, suitable for checking the frequency response of audio amplifiers, modulators and radio receivers, is announced by Pennine Amplifiers.

It possesses frequency coverage in two ranges—40 c/s.-1,000 c/s. on range 1, and 900-16,000 c/s on range 2—these being indicated clearly on the 4-in. diameter scale on the front panel.

Output sockets are provided on the front panel for low and high output impedances of 2.5 ohms and 3,000 ohms, with a maximum output of 3 watts.

Output voltage control scale on front panel is calibrated in output volts 0—2 and 0—100. The output voltage being held within plus or minus 10 per cent over entire range.

The instrument itself is enclosed in a blue-grey crackle finish case, with a smart and legible calibrated front panel, the size being 7 in. by $5\frac{1}{2}$ in. and 4 in. deep, and the approximate weight $6\frac{1}{2}$ lb.

Pennine Amplifiers,
Southgate, Elland, Yorkshire.

Electrically Heated Hand Pliers

(Photo above)

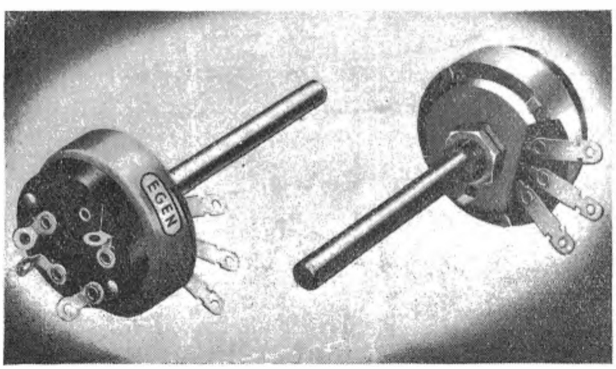
LATEST addition to the range of "Stanelco" tools marketed by Standard Telephones and Cables Limited (Industrial Supplies Division), the new P.V.C. stripper pliers are specially designed to remove the insulation from plastic-covered wires without damage to the conductor.

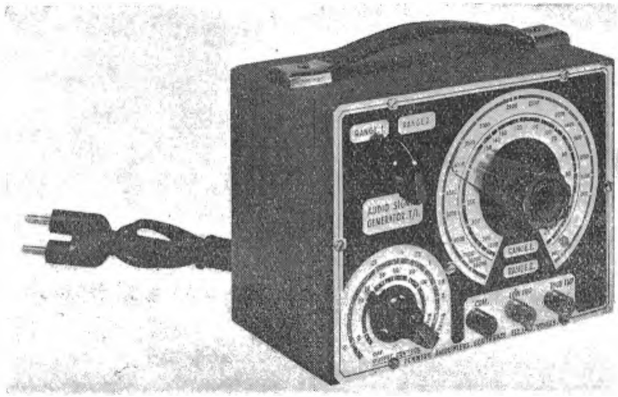
The jaws of the pliers are heated by a low-voltage current, which ensures perfect safety to the operator, and power consumption is negligible (over 100 hours' operation on one unit of electricity).

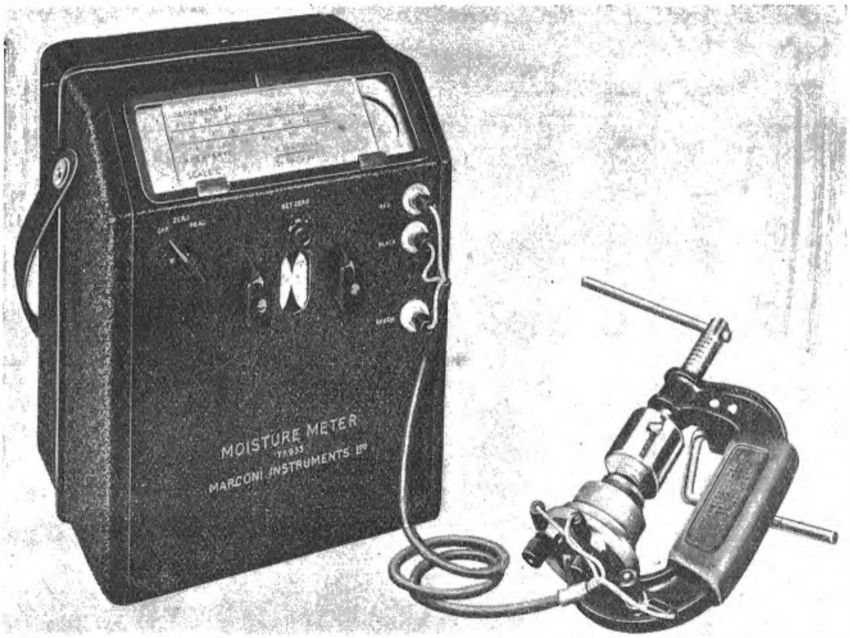
"Stanelco" stripper pliers will remove the plastic insulation from any conductor, stranded or solid, up to $\frac{1}{8}$ in. diameter, faster than any other method. No switching is necessary and the pliers can be left connected without risk of damage or overheating.

Supply voltage: A.C. only, 200/250 volts, 50 c/s.
Working voltage: 12 volts.
Power consumption: Under 10 watts.

Standard Telephones and Cables, Ltd.,
Connaught House, Aldwych,
London, W.C.2.







Marconi Moisture Meter

(Illustrated above)

THE National Institute of Agricultural Engineering has now issued its report on the first instrument of its kind to be submitted for test : the new Marconi Moisture Meter TF933. The Institute supports the manufacturer's claim of an absolute accuracy of $\pm$ 1 per cent moisture content—equivalent to an *error of prediction* of about 0.4 per cent m.c. In the words of the report No. CNR48071 : "The results of the tests show that the meter is a practical piece of apparatus for agricultural use with wheat and barley . . . and support the manufacturer's claim of an accuracy of $\pm$ 1 per cent in the range 10-20 per cent moisture content."

In design, the moisture meter employs a D.C. resistance-bridge circuit with electronic null-detector which makes reading independent of valve characteristics and supply voltages. In conjunction with its compression cell the instrument has advantages over the typical capacitance method of moisture determination in both reduction of packing and other errors and improved behaviour on freshly damped grain.

Another advantage of the instrument is its ability to test a wide range of materials using only a single scale corrected for temperature variations. Measurement range is 8 per cent to 25 per cent and readings are reproducible to within 0.2 per cent. The deviation from gravimetric methods is generally within 0.5 per cent in the case of stable, conditioned samples, while unstable, freshly gathered grain may cause deviations of $\pm$ 1 per cent within the normal moisture range.

Marconi Instruments Ltd., St. Albans, Herts.

Revolution Speed Indicator

DETAILS of a new system of recording the revs. per minute of the engines of motor cars and motor lorries, etc., are available from Runbaken Electrical Products, Ltd.

Previously, due to mechanical difficulties, revolution counting has been impossible unless a special drive has been built into the engine.

The new tachometer operates from the electrical impulses of the ignition system and the readings are proportionate to the number received per second, irrespective of voltage.

The same principle can also be used as a speedometer when the vehicle is operating in top gear, and has advantages over the mechanical type as there are no wearing parts.

Runbaken Electrical Products, Manchester, 1.

The Test Oscilloscope Monitor Type M.200

THIS provides facilities not given by the usual laboratory oscilloscope and has the advantage of being rack panel mounted uniform with the remainder of the equipment. Technical features are as follows—*Amplifier :* Gain controlled by switch on front panel to give fixed gains of x2 or x4. Frequency response within 1.5db up to 3 Mc/s. *Time Base :* May be triggered from + 10 volts or — 20 volts pulse with sweep speeds continuously variable from 15 micro-seconds up to 10 milli-seconds by means of five range switch and fine control. *Dimensions :* 19 in. by 8¾ in. by 14 in. deep. Weight 57 lb.

Dynatron Radio Ltd., Maidenhead, Berks.

Electronic Tube for the Measurement of Acceleration

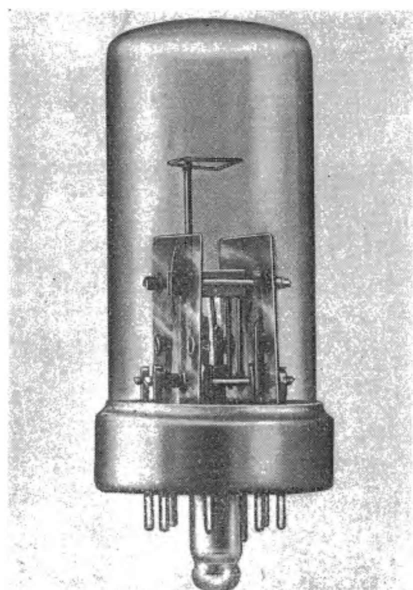
(See below)

THE accurate measurement and recording of acceleration by electronic methods is made possible by the DDR100 Accelerometer Tube recently announced by Mullard Electronic Products Ltd. This device is basically similar in construction to an all-glass valve of the loctal type, and has the advantage that it may be mounted in any position. This feature, coupled with the high output and excellent response of the tube at low and zero frequencies, enables it to be used with great advantage as a low mass pick-up for measuring and recording the acceleration and vibration of high velocity elements. One of the chief advantages resulting from the high output of the tube is that it makes possible the observation and recording of acceleration without the necessity of using a special high gain amplifier. It may also be used quite successfully for displacement velocity measurement and recording.

The DDR100 Accelerometer is a double diode with anodes elastically supported so that the anode impedance is varied when the tube is subjected to acceleration. In practice, the tube is rigidly clamped to the structure under test and the measurement is expressed in terms of a current change in a Wheatstone bridge circuit, of which the anode/cathode impedance of the accelerometer tube forms adjacent arms.

The resonant frequency of the tube is 1 kc/s and the maximum acceleration range is 100 *g*. The tube is designed for a heater voltage of 6.3 V and a maximum anode voltage of 10 V.

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



DDR100

BOOK

Industrial Electronics Reference Book

By Westinghouse Electric Corporation, 680 pp. 1260 Figs. First Edition 1948. (Chapman & Hall, Price 48s.).

NO less than 37 engineers of the Westinghouse Electric Co. have combined to produce this veritable *magnum opus* with the object as the preface states "of providing sufficient theoretical data and application information so that when an electronic device is designed and put into operation, its possibilities as well as its limitations can be appreciated."

Judged by the many original contributions made each of the 37 authors is an expert in his particular branch of the subject and all have wide interest and association with industrial electronics.

With such an array of talent, therefore, it is not surprising that so impressive and massive a book has been produced and it is easily one of the largest single books yet published. As such it is beyond the capabilities of a single reviewer to give constructive criticism of its contents, and indeed the present reviewer has none to offer.

In producing this book the authors have very wisely stressed the limitations of electronics as a tool in industry for it is all too obvious that in the past electronics has been applied in industry without a proper study of economic and other considerations.

They have carefully assessed the position and have made no sweeping claims, but accurately lay down the guiding fundamental principles of electronics in industry and the result is a reference book which will be the standard authority for some time to come.

Chapters 1 to 3 cover the fundamental and theoretical concepts of electron emission and control while Chapters 4 to 10 embrace the design, operation and constructional features of the different types of high vacuum valves, cathode ray tubes and photo-electric cells used in industrial electronics.

Chapters 11 to 14 deal with circuit components, and are followed by Chapters 15 to 18 on the design and operation of rectifiers, amplifiers, oscillators and control circuits. Transmission lines and aerial systems which are finding increasing application in industrial electronics are dealt with in Chapters 19 and 20.

No less than 14 more chapters are given over to the design and application of equipment, ranging from radio-frequency heating, electron microscopes and stroboscopes to precipitation equipment and electronic speed control of motors. Two valuable and informative chapters conclude the book on the care and maintenance of industrial electronic apparatus. Each chapter is complete with an extensive list of references.

H. G. FOSTER

Klystrons and Microwave Triodes

By D. R. Hamilton, J. R. Knipp and J. B Kuper. 533 pp. (McGraw-Hill Book Co. 45s. net).

THIS book is No. 7 of the series of 28 volumes issued by the Radiation Laboratory of Massachusetts Institute of Technology which cover the work done in the United States on Radar and allied subjects. The authors have made many contributions in their particular field and in compiling this volume have had access to all the literature, a great deal of it in the form of reports hitherto unpublished, which has grown up during the war years both in the United States and in this country.

It is therefore a matter for regret that in these circumstances the authors have chosen to limit themselves, apart from one or two cursory references to English valves, to the development of klystrons and microwave triodes in the United States. The pioneering work of English laboratories on microwave triodes and on klystron oscillators which resulted in the first practical use of the reflex klystron in 1940 is not mentioned, nor is the theoretical work by groups in this country on the co-axial line type of tube and the reflexion oscillator, which played a considerable part in the development of the ideas set forth in the book. Apart from these omissions which inevitably detract from the value of the book as a record of the historic developments of the last nine years, the authors have endeavoured to make their account as complete as possible even when this involves some sacrifice in ease of reading.

The book is primarily a treatise on valve theory and design and contains no discussion of the problems of manufacture and of how these affect the evolution and ultimate realisation of the valve. It deals mainly with phenomena in the region above 3,000 Mc/sec., although of course the relations derived are applicable to lower frequencies.

It is divided into three parts, the first of which, after an introductory chapter and a chapter on the basic functions and types of microwave valves, treats of the basic phenomena of the interaction of electrons with high frequency fields and of the properties of circuits at high frequencies. Both subjects are treated mathematically with some generality so that the results are applicable to the theory

REVIEWS

of microwave triodes which is discussed in the second part of the book and also to the theory of klystrons which forms the third part.

The second part of the book deals in four chapters with planar space-charge valves of the lighthouse type; Chapter 4 is a valuable resume of the mathematical theory of this type of valve, while the remaining chapters of this section are devoted to a discussion of the properties of these valves when used as amplifiers, oscillators and as pulsed oscillators.

The third and largest section which occupies more than half of the book is devoted to a discussion of valves of the klystron type. After a consideration of the general theory of the klystron including space charge debunching and large signal operation, an excellent account is given of the klystron amplifier, and frequency multiplier. This contains much hitherto unpublished material and should be very valuable in drawing the attention of workers in this field to an aspect of the klystron which is likely to become increasingly important in the immediate future. In the last chapter the theory and operation of the reflex klystron is discussed in considerable detail; this type has been the most widely used of the klystrons during the war and in consequence a great deal of information is available most of which has been included by the authors.

It will be evident from the above remarks that the book is one for the specialist rather than for the general reader, and is likely to become a standard reference book for those engaged in the design of valves in this region. A few detailed omissions may be noted: for example, there is no reference to the theorem of Petrie which enables an average coupling coefficient to be readily calculated for any gap, or to the application of relaxation methods to the evaluation of resonator properties, or the calculation of bunching properties in non-homogeneous fields by numerical integration. Also no experimental method is described of determining that very important quantity, the shunt impedance of a resonator, although two such methods have been frequently used. On p. 505 appears the incorrect statement that "thermally tuned tubes stand shock and vibration about as well as the mechanically tuned types." Nevertheless the authors are to be congratulated on having accomplished a difficult task well.

L. F. Broadway

Microwave Duplexers

By L. D. Smullin and C. G. Montgomery. Pp. 437 — xiv. McGraw Hill Book Co. Inc., New York. Price 39s. in U.K.

THIS book is Vol. 14 of the M.I.T. Radiation Laboratory series on radar techniques and principles.

L. D. Smullin and C. G. Montgomery have been responsible for the editing of this volume. They have been joined by W. C. Caldwell, H. K. Farr, H. A. Leiter and C. W. Zabel in forming a group of six contributing authors, and each of the nine chapters in this book has been written by one or by two members of this group. In spite of this division of responsibility the editors have succeeded in producing a clear and unified treatment of the subject.

Chapter one is a short introduction by C. G. Montgomery. He outlines the main features of microwave radar and explains that the advantages to be gained by using a single antenna for both transmission and reception made the development of high speed switches a necessity. Most modern radar sets incorporate two types of switch. One of these, the TR cell, has the function of protecting the crystal mixer during the transmission of the pulse; the other, the ATR cell, disconnects the transmitter during reception in such a manner that practically all of the received power enters the receiver. In very high power sets a third cell, the pre-TR, is used in conjunction with the TR. The larger part of the book is concerned with the properties and development of these cells. It is appropriately pointed out in the introduction that the use of the term duplexer, as applied to pulsed radar equipment, is not strictly justified, since the transmitted and received pulses, in normal operation, are not simultaneous.

The book deals with developments in the microwave region over the range of 1,000 Mc/s. to 30,000 Mc/s. In particular, most of the development work has taken place in the S, X and K bands, and British readers who have been engaged in work in these bands during the war will find themselves on very familiar ground in spite of the fleeting references in the text to British developments in techniques and components.

Chapters two, three and four deal with the performance of TR, ATR and pre-TR cells at low power levels and equivalent circuits are developed for these devices. In chapter four there is a very good discussion of the theory and development of the bandpass TR. A useful feature of this chapter is the illustration of the use of the matrix method in estimating the loss due to the multiple iris structures used in the construction of broadband components. The data contained in these chapters lose some value for many British workers because of the unfortunate

BOOK REVIEWS *(continued)*

fact that, in the past, standard American and British waveguides have been made to slightly different dimensions.

Chapter five, the longest chapter in the book, deals with microwave gas discharges. Before the development of high power magnetrons the complex subject of gas discharges had been confined to fairly low frequencies. Now it has become possible to use high powers and high frequencies to extend our knowledge. But there is still comparatively little information about, or understanding of, the very high frequency gas discharge and such devices as the TR cell were developed empirically in the absence of a theory capable of providing useful design information. The discussion given in this chapter shows how far theory has yet to develop before a complete explanation can be given of the known properties of devices such as the TR cell, but the information available at the end of the war in regard to the microwave gas discharge is well summarised and clearly stated.

Chapter six gives further information on the experimental results on the high power performance of TR and ATR tubes and includes some information on construction techniques.

Chapters seven and eight deal with the microwave circuit arrangements used to connect the TR, ATR and pre-TR to other components in the R.F. portion of the radar set. These chapters will be of wider appeal than the earlier chapters because the waveguide and coaxial line arrangements discussed, such as branched and balanced circuits, find applications outside the field of radar. A knowledge of transmission line theory and of impedance diagrams is assumed and some use is made of matrix methods in discussing the T-junction and magic T.

The book ends with a chapter on measurement techniques with particular reference to the measurement of the properties of TR and ATR cells.

There are altogether 28 volumes in the M.I.T. Radiation Laboratory series, and some of these will appeal to a much wider circle of readers than the others. The present volume is for the specialist and will be of great value to those whose interest lies in the field of microwave radar. A good knowledge of the fundamentals of microwave techniques is assumed and this knowledge is provided by other volumes of the series. Those who are interested in communication techniques will find much valuable material in chapters seven and eight.

The binding and printing are excellent and the few errors noticed were trivial and not likely to confuse the reader.

T. J. Buchanan

Velocity-Modulated Thermionic Tubes

by A. H. W. Beck, Cambridge University Press, 180 pages, price 15s.

THE reviewer feels some doubt of the accuracy of Mr. Beck's second sentence to the effect that "a thermionic generator or amplifier is usually conceived as an . . . enclosure with a number of terminals, 2 or 4 which have significance in the performance of the system considered as an active network." However, there is no doubt that Mr. Beck himself is in no way confined to this somewhat arid conception.

The main part of the book is devoted to a detailed analysis of the theory of V-M and its application to practical tubes. Many may find the concentration of mathematics rather formidable but it is difficult to see how the author could have avoided this in the space available without leaving serious logical gaps in the analysis and he has taken very commendable care to see that the general argument and the significance of the results are quite clear to those who may prefer to skip the larger formations of symbols.

Very large modifications of the results given by elementary theory are found when the finite dimensions of the gaps and the limitations imposed by electron optical requirements are considered. The conflicts between the various desiderata and the ways in which the best compromise may be determined are well brought out. As would be expected by those who know of the author's war-time work, the sections on heavy-current beams and on high-power tubes are particularly good.

Of outstanding merit, in the reviewer's opinion, is the final chapter, on design and manufacture. This could be read with pleasure and profit by those interested in the design of almost any electronic device. It is impossible to resist quoting the description of patent literature on oxide cathodes as "like an alchemist's notebook." There are few authors who can deal so happily with theory and practice.

Among the few errors may be mentioned a misprint at the top of page 18—the transit time between gaps in the Heil tube is $n + \frac{1}{4}$ periods—the omission of plane "A" in Fig. 4.1 and the statement (page 133) that the maximum conversion efficiency of the plane monotron is about $2\frac{1}{2}$ per cent at 2.3 radians transit-time.

A larger peak of about 17 per cent occurs near $7\frac{1}{2}$ radians. This requires a radio-frequency amplitude of several times the applied D.C. voltage and hence, although it does not lead to electron reflection, as in the case given by Müller and Rostas, owing to the large transit angle, the losses are too high to allow the construction of a useful tube.

There is no question that this is an excellent book for anyone seriously interested in any of the many applications of velocity-modulation. It easily maintains the high standard set by other members of the series on Modern Radio Technique, edited by Mr. J. A. Ratcliffe.

J. H. Fremlin

Micromeritics

by J. M. Dallavalle (Pitman and Sons, Ltd.) 2nd edition. Price 42s. 6d.

THE word micromeritics has been proposed to cover the technology of small particles ranging from 10^{-5} to 1 cm. These are larger than the usual colloidal particles, and they constitute so many systems to be found in technological practice that this realm is steadily developing into a separate science. Mr. Dallavalle deals with the physical properties of such systems and gives a useful treatment of the varied instances in which they are to be found.

The author has enlarged the work in its second edition by some 130 pages, and has made very extensive and critical revisions.

Particle technology involves the determination of the particle size, shape, surface-area and volume as well as the state of packing and reaction to pressure. This leads to a study of the behaviour of particulate matter to heat, electric fields, optical and sonic effects, chemical reaction and absorption phenomena.

The practical consequences of these effects is shown up in a wide variety of processes: e.g., grinding operations, filtration, sedimentation, transport of particles by flow. Industrial dust clouds and powder mixtures are successfully treated by electrical, electrostatic conductance, and pyroelectric precipitation. The spontaneous combustion of dust particles in the atmosphere of flour mills and the like is an ever-present fire and explosion hazard.

All such processes are demanding control, and it is here that the electronic engineer can make useful contributions. Improvements in the electron microscope which permit of *direct* measurements of particles, would be of especial value.

Some interesting observations are recorded in the section devoted to the electrification of dust particles in air, the electrical conductivity of pressed powders, and the magnetisation of finely divided magnetite.

The author has done a good service in bringing together the varied factors involved in a study of particular systems. The usefulness of the book could, however, be enhanced by a still more detailed index.

S. R. Carter

MAY MEETINGS

The Inst. of Electrical Engineers

All meetings, unless otherwise specified, are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Measurements Section

Date: May 3. Time: 5.30 p.m.

Lecture: "Some Electromagnetic Problems."

By: Professor G. W. O. Howe, D.Sc., Ll.D.

Education Discussion Circle Meeting

Date: May 9. Time: 6 p.m.

Discussion: Graphical Methods in Teaching Electrical Engineering (including Radio).

Opened by: S. N. Ray, M.Sc., B.Sc.(Eng.)

Ordinary Meeting

Date: May 12. Time: 5.30 p.m.

Annual General Meeting.

The Secretary: The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Cambridge Radio Group

Date: May 10. Time: 6 p.m.

Held at: Cambridgeshire Technical College.

Lecture: "Magnetic Amplifiers."

By: A. G. Milnes, M.Sc.(Eng.).
Hon. Secretary: G. E. Middleton, M.A., University Engineering Laboratory, Cambridge.

North Midland Centre

Date: May 10. Time: 6.30 p.m.

Held at: Yorkshire Electricity Board Offices, 1 Whitehall Road, Leeds.

Annual General Meeting and Visit of President.

Hon. Secretary: H. S. Moody, The Yorkshire Electricity Board, Manor Farm, Bramhope, Leeds.

North-Western Centre

Date: May 3. Time: 6.15 p.m.

Held at: Engineer's Club, Albert Square, Manchester.

Annual General Meeting.

Hon. Secretary: A. L. Green, 244 Brantingham Road, Chorlton-cum-Hardy, Manchester, 21.

Northern Ireland Centre

Date: May 24. Time: 6.45 p.m.

Held at: Queen's University, Belfast.

Annual General Meeting.

Hon. Secretary: J. K. Carrothers, 2 Abbeydale Park, Ballysillan, Belfast.

South Midland Centre

Date: May 2. Time: 6 p.m.

Held at: James Watt Memorial Institute, Great Charles Street, Birmingham.

Lecture: "Semi-Conductors and Rectifiers."

By: Professor N. F. Mott, M.A., F.R.S.

Hon. Secretary: H. Hooper, British Electricity Authority, 53 Wake Green Road, Moseley, Birmingham, 13.

Southern Centre

Date: May 4. Time: 6.30 p.m.

Held at: City Council Chambers, Clarence Parade, Portsmouth.

Annual General Meeting.

Lecture: "Overhead Line Regulations."

By: H. W. Grimmit.

Hon. Secretary: W. M. Read, The Oaks, Ashurst, Southampton.

Irish Branch

Date: May 19. Time: 6 p.m.

Held at: Trinity College, Dublin.

Annual General Meeting.

Hon. Secretary: R. N. Eaton, 42 Jame's Street, Dublin.

The Institution of Electronics

Date: May 18. Time: 7 p.m.

Held at: Chamber of Commerce, New Street, Birmingham.

Lecture: "Some Applications of Electronics."

By: Professor T. Sayer, M.Sc., Ph.D.

Hon. Secretary: A. A. Barber, "Newlyn," Fiery Hill Road, Barnt Green, Worcestershire.

North West Section

Date: May 26. Time: 6.30 p.m.

Held at: Reynolds Hall, College of Technology, Manchester.

Lecture: "Radio Astronomy."

By: Dr. A. C. B. Lovell, O.B.E.

The Secretary: L. F. Berry, 105 Birch Avenue, Chadderton, Lancs.

Institution of Post Office Engineers

Date: May 3. Time: 5 p.m.

Held at: Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Annual General Meeting.

Lecture: "The Scientific Work of the Post Office."

By: Dr. L. E. Ryall, Ph.D., B.Sc., M.I.E.E.

Local Secretary: W. H. Fox, A.M.I.E.E., Engineer-in-Chief's Office (T.P. Branch), Alder House, London, E.C.1.

British Institution of Radio Engineers

Merseyside Section

Date: May 4. Time: 7 p.m.

Held at: The Incorporated Accountants Hall, Derby Square, Liverpool, 2.

Lecture: "The Measurement of F.M. Transmitter Performance."

By: D. R. Willis.

Secretary: J. Gledhill, B.Sc., 123 Portelet Road, Liverpool, 13.

North Western Section

Date: May 5. Time: 6.45 p.m.

Held at: College of Technology, Sackville Street, Manchester 1.

Lecture: "Ceramic Capacitors."

By: W. G. Roberts, B.Sc.(Eng.).

Secretary: G. T. Y. Stennett, 123 Parrswood Road South, East Didsbury, Manchester, 20.

North Eastern Section

Date: May 11. Time: 6 p.m.

Held at: Neville Hall, Westgate Road, Newcastle-on-Tyne.

Annual General Meeting.

Chairman: A. S. Dunstan, 26 Denewell Avenue, High Heaton, Newcastle-on-Tyne.

The Television Society

Main Society and Programme Group

Date: May 5. Time: 7 p.m.

Held at: C.E.A., 164 Shaftesbury Avenue, London, W.C.2.

General Discussion on Television Programmes, with Cecil McGivern, Director of Television Programmes at Alexandra Palace.

Constructors Group

Date: May 12. Time: 7 p.m.

Held at: C.E.A., 164 Shaftesbury Avenue, London, W.C.2.

Lecture: "Some Devices for Reducing the Effects of Interference and Fading on Television Pictures."

By: D. McMullan, B.A.

ABSTRACTS OF ELECTRONIC LITERATURE

An Instrument for the Measurement and Time Integration of Small Voltages and Currents)

(I. A. D. Lewis, A. C. Clark)

The instrument described may be used for the simultaneous measurement and time integration of potentials varying between 0 and 0.5 V with an accuracy of 3 per cent. The instrument has a high input impedance and can be used for measurement of currents down to 0.01 μA full-scale deflection. Currents are read on a microammeter and time integration results are obtained as counts on a standard Post Office call register. A detailed analysis of the Miller type of integrating circuit has shown that, when a larger value of input potential (say 10 V) is available, an accuracy of within 0.2 per cent is expected over most of the range. This has been verified experimentally (Authors' abstract.)

Illustrated by one diagram, one graph, seven references.

—*J. Sci. Instrum.*, March, 1949, pp. 80-84.*

High Frequency Absorption Phenomena in Liquids and Solids

(W. Jackson, J. A. Saxton)

Extension of the electrical frequency spectrum beyond 10^{10} c/s opens up a new field of dielectric study. This paper discusses briefly the work on liquid and solid dielectric substances carried out during the war when the emphasis was on substances of technical importance, e.g., polythene, water and ice, and during the immediate post-war period when a fuller attempt was made to study the scientific significance of this data, and also to supplement it with measurements on simpler systems. This work has revealed the limitations of existing theories of dipolar absorption in liquids and solids and refers to the possibility of observing resonance absorption effects in solids in the microwave region. (From authors' abstract.)

Illustrated by six graphs, 17 references.

—*Proc. I.E.E.*, March, 1949, pp.77-80.*

A Method of Measuring Very High Speed Transient Currents

(A. M. Zarem, F. R. Marshall)

A deflection coil suitable for use in measuring very high speed transient currents is described. When used with a type 912 cathode-ray tube operated at a 15,000 volt accelerating potential, this coil provided a spot deflection of 1 in. at approximately 50 amperes of current. A mutual inductance device was constructed to extend the range of measurement of the deflection coil. The current under study is allowed to flow in one coil, and the other coil is connected to the deflection coil. Results are given of an analysis of the transient response of such a circuit, taking into account increased losses caused by the transient skin effect. Accurate design of a transformer and deflection coil system to meet specific requirements is facilitated by the analysis. (From authors' abstract.)

Illustrated by two photographs.

—*Rev. Sci. Instrum.*, February, 1949, pp. 133-134.*

A Storage System for Use with Binary Digital Computing Machines

(F. C. Williams, T. Kilburn)

The requirements for digital computing machines of large storage capacity have led to the development of a storage system in which the digits are represented by a charge pattern on the screen of a cathode-ray tube. Initial tests have been confined to commercial tubes. Short term memory of the order of 0.2 sec. is provided by the insulating properties of the screen material. Long term memory is obtained by regenerating the charge pattern at a frequency greater than 5 c/s. The regeneration makes accurate stabilisation of the position of the charge pattern on the c.r. tube unnecesssary. The properties required of a storage system and its operation, as part of a machine, are stated. (From authors' abstract.)

Illustrated by two photographs, 12 diagrams, 23 graphs, 11 references.

—*Proc. I.E.E.*, March, 1949, pp. 81-100.*

A Note on Analogue Computer Design

(J. A. Bronzo, H. G. Cohen)

A method is proposed for the simplification of computers designed to solve certain types of partial differential equations. The equations are those in which the spatial derivatives may be replaced by finite difference expressions. The resulting difference-differential equations are reformulated as a system of linear simultaneous equations by making use of La Place transforms, and matrix notation is introduced. By applying a similarity transformation to the matrix a new system is obtained which lends itself more readily to the construction of an analogue. As an example, the analogue of the equation of the vibrating string with fixed ends is discussed. (Authors' abstract.)

Illustrated by four references.

—*Rev. Sci. Instrum.*, February, 1949, pp. 101-102.*

Measurements of the Mechanical Properties of Polymer Solutions by Electromagnetic Transducers

(T. L. Smith, D. Ferry and F. W. Schremp)

A concentrated polymer solution is sheared by a rod oscillating axially with a very small amplitude in a closed tube. The rod is driven by a coil in a magnetic field; from electrical measurements on the coil, the mechanical resistance and reactance of the system are calculated by transducer relationships. Equations are given for obtaining the dynamic viscosity, η', and rigidity, G', of the solution. In the case of some polymer solutions, the audio frequency range covered by the present apparatus falls in the dispersion zone where η' and G', change rapidly with frequency. In the other cases the frequency range covered appears to be at the upper end of the dispersion zone; η' is far smaller than the viscosity in steady flow, and G' changes very little with frequency. (Authors' abstract.)

Illustrated by four diagrams, six graphs, one table, 20 references.

—*J. Appl. Phys.*, February, 1949, pp. 144-153.*

Exposure Meter for Precision Light Dosage

(H. F. Launer)

The exposure meter is an electronic device of the type in which a phototube charges a capacitor to the firing voltage of a trigger tube, whose pulse is amplified by a thyratron. The device has been adapted to high intensity sources and is used for the regulaton of carbon arc light dosage in the standardisation of light-sensitive paper at the National Bureau of Standards. Two instruments simultaneously viewing a gradually ageing monochromatic source gave count values whose ratios showed a coefficient of variation of 0.32 per cent in two weeks of continuous measurement. One instrument was tested for suitability of application by comparing counts with reflectance changes of light-sensitive paper under arc exposure. The instrument was later used to test the variability of the uranyl oxalate actinometer. (From author's abstract.)

Illustrated by one photograph, one diagram, four tables.

—*Rev. Sci. Instrum.*, February, 1949, pp.103-109.*

* Abstract supplied by courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester