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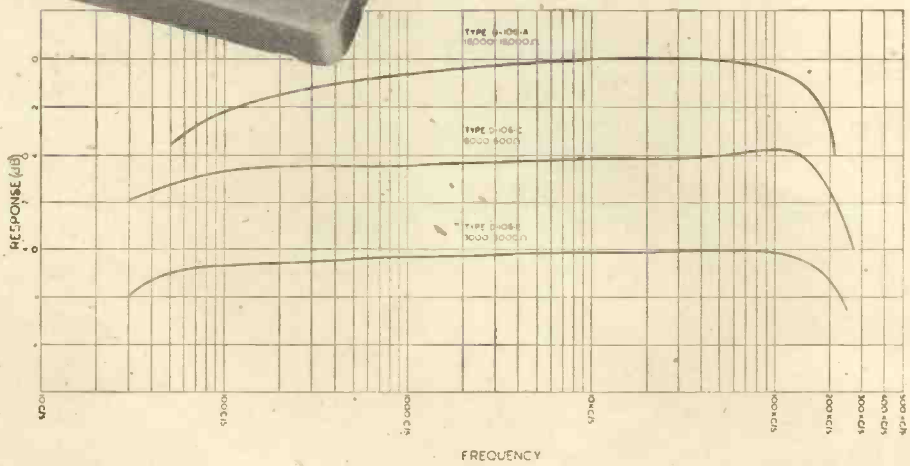

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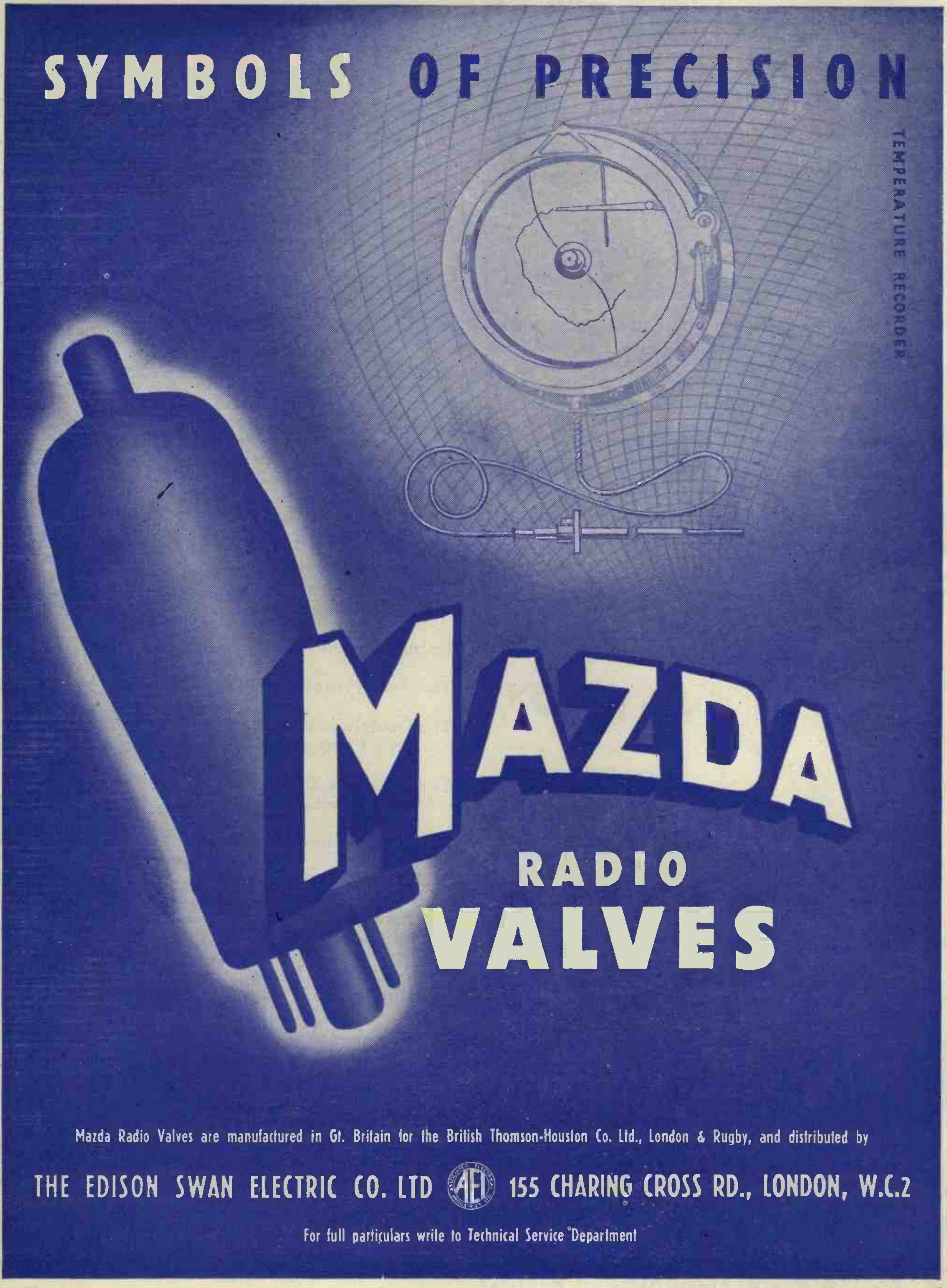
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TELEGRAMS: HULTONPRES LUD LONDON.

Keeping Mum

IN a letter to *Nature* (Sept. 12th), K. G. DENBIGH draws attention to the practice of many British firms of refusing publication of research carried out by their staffs.

He says: " Each year a considerable amount of scientific investigation is carried out by research workers in industry, the results of which remain quite unknown to the scientific world in general. This is generally on account of the unwillingness of industrial companies to allow their competitors to obtain any information which might be useful to them.

" . . . The non-publication of research carried out by private enterprise seems to be far less pronounced in the United States than Britain. In the writer's view, the vigour and progress of American industry can be ascribed very largely to the wealth of information which is available in the American literature of applied science."

The letter might well be quoted in full, but space must be left for a reply which was given by Dr. N. R. CAMPBELL, of the G.E.C. Research Laboratories. He suggests that by " many " Mr. DENBIGH means " nearly all," and points out that the statements do not apply to his Company, and that evidence is needed to show that the practice Mr. DENBIGH denounces is typical of British industry.

He concludes: " What a manufacturer would like to learn from his competitors is not simply how to do something, but the way of doing it that has been found the best. The method most scientifically interesting is by no means the most commercially effective. By publishing scientific work that indicates some new alternative, the manufacturer does not disclose the method he is actually using."

At the present time it is difficult to enter into a discussion on the desirability of publishing scientific information. So much is considered likely to be of use to the enemy that an exaggerated importance is given to the most harmless disclosures and manufacturers are preferring to clamp down on all their latest developments rather than run the risk of giving away something.

In normal times, however, many people would be inclined to agree with Mr. DENBIGH's statements, and comments have frequently been made on the quality and quantity of information available from America compared with that issued over here.

It would not be difficult to find a number of British firms who are well-known in the radio industry and yet whose contributions to the literature of the subject are negligible.

A policy of keeping mum may ensure that nothing is given away but it may also earn an undeserved reputation that there is nothing to give away and nobody to give it

It is to be hoped that the good habits of exchange of information which the war is engendering may persist in the post-war Utopia that the industry is hoping for.

The Generation of Groups of Harmonics

By D. G. TUCKER, B.Sc.(Eng.), A.M.I.E.E.*

HARMONICS may be produced with reasonable efficiency by the following methods :—

(a) Distortion due to overloading an amplifier valve.

(b) Switching effected by rectifiers (metal or diode).

(c) Switching effected by a non-linear (saturated) iron-inductor.

Method (a) is not convenient if a series of harmonics is required, but is useful if only one particular harmonic need be selected. The results are somewhat unpredictable as they depend on the rather inconstant overload characteristic of the individual valve, but descriptions of the method have been published by Terman and others.[1, 2]

Method (b) has been used considerably, but very little published information is available on the design of suitable circuits.

Method (c) is probably the best if the higher harmonics (above the 7th or 8th, say) are required, but the design of the non-linear coil becomes exceptionally difficult at frequencies above about 50 kc/s. It should be noted that certain oscillatory and quasi-oscillatory circuits, of which the best-known is the multi-vibrator[3], may also be used to generate a group of harmonics; in such cases the fundamental input is used as a synchronising signal.

It is proposed in this article to deal with methods (b) and (c).

(b) Circuits using Rectifiers

In all the circuits shown below, metal rectifiers or diodes may be used. Generally, diodes are preferable at high frequencies owing to their lower capacitances; in any case they are rather more efficient as rectifiers, although the necessity of providing a filament or heater current is a disadvantage.

The "Chopped" Wave (Using Shunt Rectifiers)

A series of odd harmonics may be produced by "chopping" or limiting the input sine wave so as to produce an approximation to a square (or rectangular) wave. A suitable circuit for this is shown in Fig. 1. R_1 is the internal impedance of the source of fundamental frequency and R_2 is the output load. W_1 and W_2 are rectifiers, biased back by a voltage V, and C_2 is a condenser for equalising the harmonic series produced.

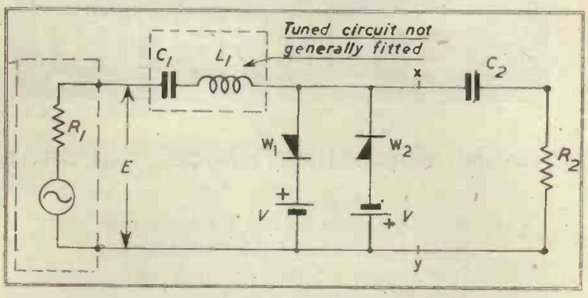


Fig. 1. A circuit for generating odd harmonics by means of rectifiers.

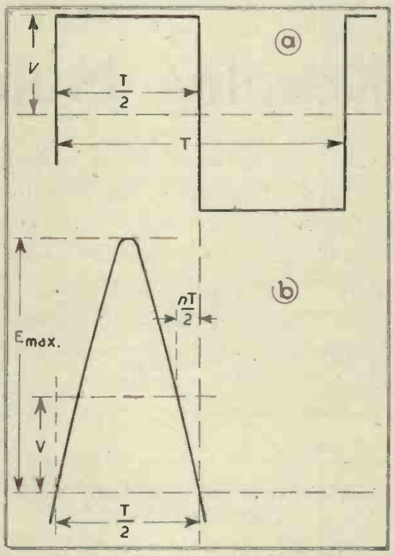


Fig. 2. (*a*) Square wave, and (*b*) chopped sine wave.

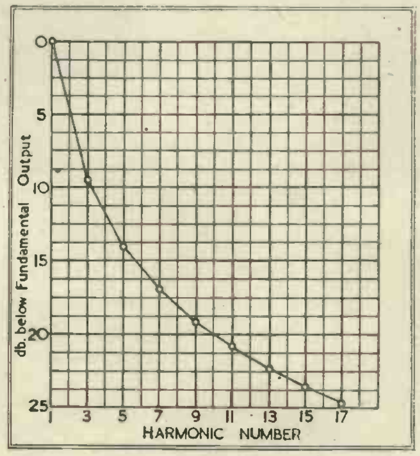


Fig. 3. Curve giving the theoretical analysis of a square wave.

The input wave of fundamental frequency is shown in Fig. 2(b), and it will be seen that the rectifiers limit the voltage to a value V equal to their bias voltage, because as soon as the applied voltage exceeds V one of the rectifiers conducts, short-circuits the applied voltage, leaving only the battery voltage. The voltage wave across the circuit at the points X and Y then becomes trapezoidal, and as a first approximation may be considered a "square" wave, as shown in Fig. 2(a). The analysis of this wave may be obtained by the Fourier expansion[4], which is represented by the following expression :

$$\frac{4V}{\pi}\left[\sin \omega t + \frac{1}{3}\sin 3\omega t + \frac{1}{5}\sin 5\omega t + \ldots\right] \quad (1)$$

The coefficients of each term give the relative voltage of each harmonic and it will be seen that only odd harmonics are present. The analysis is shown graphically in Fig. 3 up to the 17th harmonic. The voltage of each is expressed in decibels relative to the output of fundamental.

The series of harmonics will generally be required to have equal voltages over a certain range. This equalisation can be effected by choosing a suitable value for the condenser C_2. Theoretically, perfect equalisation should be effected in this way and all harmonics are reduced to the voltage of the highest one required. Actually, as the wave at X, Y is trapezoidal and not square, the equalisation will be worse by an amount depending on the proportion of the period occupied by the slope of the wave, i.e., on the factor n shown in Fig. 2(b). It can be shown that the amplitude ratio of the mth. harmonic of the square wave to that of the trapezoidal wave is

$$\frac{\pi n m}{\sin \pi n m} \quad \ldots \ldots \quad (2)$$

from which n may be determined for any specified departure from the ideal equalisation : and also, if n is fairly small,

$$\frac{V}{E\ max} = \pi n \quad \ldots \quad (3)$$

so that the ratio of "chopping" may be determined.

* P.O. Research Station.

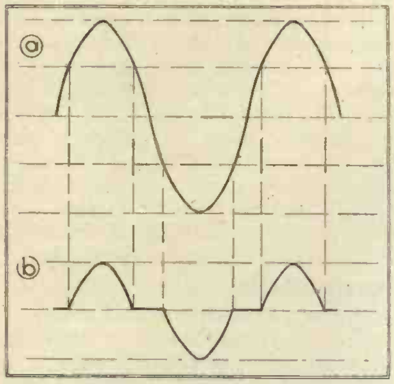


Fig. 5 (left). (*a*) Input sine wave. (*b*) Output wave of circuit of Fig. 4.

The forward resistance of the rectifiers should be low compared with R_1. Good results are obtained if the source of supply is a pentode amplifier, which has a high impedance. However, the tuned circuit C_1L_1 will help to compensate for a low R_1; it must be tuned to the fundamental.

Rectifiers Connected in Series

To produce a group of odd harmonics the rectifiers may also be connected in a series circuit as shown in Fig. 4(a). Here the effect is not one of "chopping" to produce a square wave, but the opposite effect of leaving only the peaks instead of removing them.[5] The waveform is shown in Fig. 5. This circuit is generally inferior to that of Fig. 1, but is sometimes more convenient. The output can be equalised (but only very approximately) with a condenser as before.

In Fig. 4(b) is shown an auto-bias circuit which may replace the batteries in Figs. 1 and 4(a). The bias is produced by the drop in potential in R due to the direct current produced by the rectifiers. C must be large enough to smooth the bias potential.

The Production of Even Harmonics

(*a*) *The Rectifier Bridge.*

When an equalised series of odd harmonics is produced as described above, an equalised series of even harmonics can be obtained very simply by means of the rectifier bridge shown in Fig. 6. A series of odd harmonics without any evens is still available on the straight-through circuit, and the series of even harmonics obtained at the conjugate terminals of the bridge is free of odd harmonics. This is only true, however, so long as the bridge is balanced. The voltage of the even harmonics is about one-quarter of the voltage of the odd harmonics.

(*b*) *The "Frequency-Doubler."*

Fig. 7(a) shows the "frequency-doubler" circuit, so-called because the output of second harmonic is only 7.5 db. below the input of fundamental. However, other even harmonics are produced with reasonable efficiency and no odds are present in the output provided the two rectifiers are identical. If the rectifiers are not identical, the odds can be balanced out by connecting a small potentiometer between the rectifiers and taking the output from the variable point, as shown in Fig. 7(b).

If the ratio $R_2/R_1 = N^2$ then the ratio of the total secondary turns of the transformer to the primary turns is $2N$.

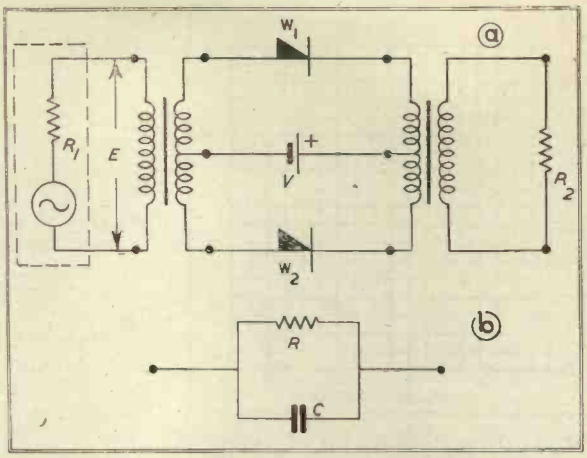


Fig. 4 (right). An alternative circuit for generating odd harmonics.

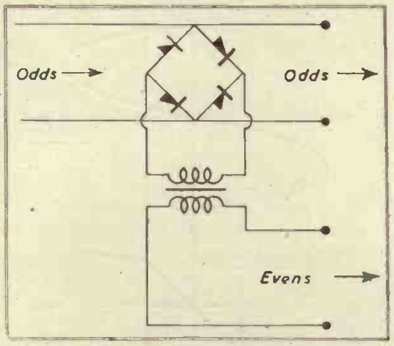


Fig. 6. Circuit of the rectifier bridge.

Fig. 8 shows how the circuit functions, and (b) shows the output waveform. There is a direct current component. The output is represented by the following expression:—

$$\frac{2E}{\pi} - \frac{4E}{\pi}\left(\frac{1}{1\times 3}\cos 2\omega t + \frac{1}{3\times 5}\cos 4\omega t + \ldots\ldots\right) \quad (4)$$

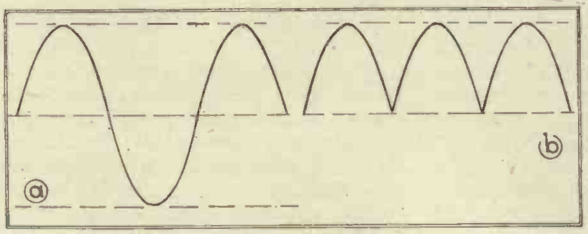


Fig. 8. (left) (*a*) Input sine wave. (*b*) Output wave of "Frequency doubler" circuit.

which may be derived by combining the equations of a sine and a square wave.[6]

The analysis of this output is shown in Fig. 9. It will be seen how the efficiency of production of second harmonic greatly exceeds that of all others. It is worth noting that it is simpler to obtain an equalised output of the higher even harmonics by using the "chopped" wave circuit of Fig. 1 followed by the rectifier bridge of Fig. 6 than it is to equalise the output of the frequency doubler. The overall efficiencies of the two methods are of the same order.

Tuned Circuits for Selecting Single Harmonics

It should be noted that if only a single harmonic is required, the above circuits can be used with R_2 replaced by a parallel tuned circuit adjusted to resonate at the required harmonic frequency The efficiency of production in such a case may be considerably better than when a series of harmonics is required.

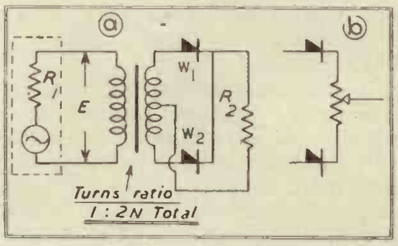


Fig. 7 (above). (*a*) "Frequency Doubler" rectifier network for generating even harmonics. (*b*) Rectifier balancing circuit.

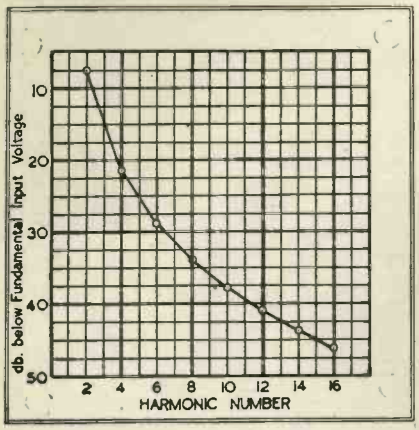


Fig. 9. Theoretical analysis of output of "Frequency Doubler."

(c) Electromagnetic Generation using an Iron-Cored Inductor

A more efficient and generally more convenient method of harmonic generation is that utilising the non-linear properties of an inductor with a core of magnetic material which is operated well into its region of saturation.[7] The basic circuit is shown in Fig. 10. R_1 is the impedance of the generator of the fundamental frequency. C_1L_1 is a circuit tuned to the fundamental in order to maintain the current as sinusoidal as possible. L_2 is the saturated inductor. C_2 is a condenser used for equalisation of the group of harmonics generated, and R_2 is the load. A simple way of considering the operation of the circuit is as follows:—Assume that the saturation of the core of L_2 occurs suddenly, so that the B-H curve consists of straight sections only, as shown in Fig. 11(a). Then, during that part of the cycle of fundamental frequency in which the current is small, the core will not be saturated, so that the inductance (which depends on the slope of the B-H curve) is large, say L_{2max}, whereas when the current has a large value, the inductance is very small, say L_{2min}, as shown in Fig. 11(b).

It will now be readily seen that when the fundamental current is small, the inductance L_{2max} causes very little shunting loss across the output circuit C_2R_2; but when the fundamental current is large, C_2R_2 is practically short-circuited. In the first period C_2 is able to charge up to a certain voltage, but in the second period it is suddenly discharged through the load and the short-circuit of L_{2min}. As the fundamental current decreases and then builds up in the reverse direction, C_2 acquires an opposite charge to its first one, and then discharges once more. The waveform of the current in R_2 (i.e., the output current) is consequently as shown in Fig. 12.

It is well known that a wave-form of this type is very rich in harmonics. If the value of C_2 is carefully chosen, the harmonics (all odd ones, of course, since the wave is symmetrical) can be obtained at a constant voltage up to a very high order of harmonic.

The Use of a Rectifier Bridge to Separate Odd and Even Harmonics

It has been stated that only odd harmonics are produced in the process described above. It is a great advantage in most practical cases to have only alternate harmonics in one group, because if the harmonics are required to be filtered out separately, then the filtration problem is considerably simplified. But even harmonics may be required as well as odds; they are readily obtained by connecting a rectifier bridge in the output circuit, so that while odd harmonics are still obtained on the direct output, a full series of even harmonics is obtained on the conjugate terminals of the bridge. A somewhat reduced voltage is obtained for the even harmonics, because of the loss in the bridge rectifier network. A ratio of 4 between voltage of odds and voltage of evens is a normal value.

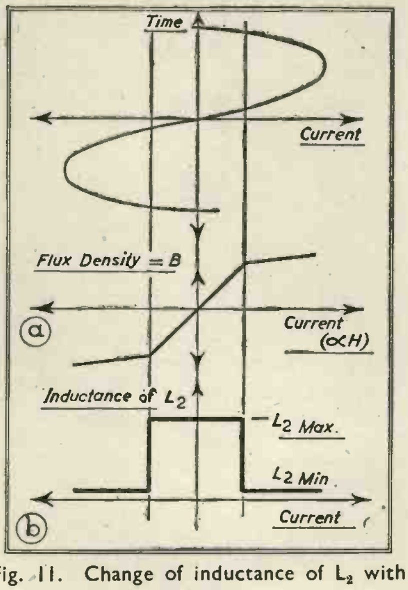


Fig. 11. Change of inductance of L_2 with current.

The Effect of Direct Current in the Coil

It was pointed out that the output wave shape was symmetrical, and that only odd harmonics were present in it. It will be clear, then that to obtain even harmonics along with the odd, all that is necessary is to make the wave asymmetrical. This is achieved by connecting a direct current biasing circuit so that direct current flows through L_2 all the time. The presence of the direct current will cause saturation to occur earlier on one half-cycle and later on the other, according to whether the direct current aids or opposes the instantaneous A.C. By adjusting this direct current to a suitable value, a series of all harmonics can be obtained with nearly constant voltage. As pointed out earlier, however, it is generally more convenient to have odds and evens separately.

Practical Design

(*a*) *Choice of Component Values.*

1. The saturated coil is obviously the most important component to be determined. The following factors must first be known:—

(1) Fundamental frequency.

(2) Impedance (which should be resistive) of load R_2.

(3) The maximum input voltage of the fundamental frequency available.

For ordinary low frequencies the most suitable material for the core is mu-metal, and a typical B-H curve is shown in Fig. 13. It will be seen that this departs greatly from the ideal simplified characteristic shown in Fig. 11. However, the knee of the curve, where H = 0.5 may be considered equivalent to the point at which the inductance changed in Fig. 11. This condition should be reached well inside the current range during the half-cycle.

Now let N = number of turns on coil.
a = cross-section of core in sq. cms.
l = length of magnetic path in cms.

Let μ_s = incremental permeability of core at knee of B-H curve.
= dB/dH = slope of B.H curve, at knee.

Let H_s = value of H at knee.

Let E = applied r.m.s. voltage at angular frequency ω.

Then it can be shown that, approximately,*

$$Na = \frac{E \times 10^8}{5\omega\mu_s H_s}$$

and

$$\frac{N}{l} = \frac{12.5\, H_s R_2}{\pi E} \quad \dots \quad \dots \quad (1)$$

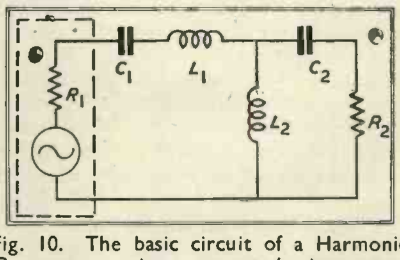


Fig. 10. The basic circuit of a Harmonic Generator using saturated iron-cored inductor.

* For explanation and full working, see Appendix. These formulae are very empirical and somewhat better values can often be obtained by experiment.

From these two relations connecting N, a and l, values can be chosen in accordance with the range of core materials available. With mu-metal, μ_s = about 3,000 and $H_s = 0.5$. It should be pointed out that at high frequencies, say above 50 kc/s, the size of the core becomes extremely small, and therefore difficult to construct.

2. The tuned circuit, C_1L_1, must resonate at the applied frequency, and must have a reasonable selectivity, but is not critical.

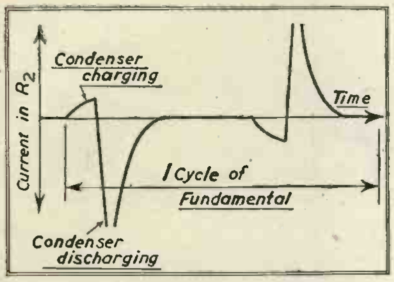


Fig. 12. Output Current.

3. The condenser C_2 must be chosen to give the desired equalisation of harmonics; it is best determined experimentally. However, the order of magnitude is given by the following empirical equation

$$C_2 = \frac{30,000}{\omega R_2}\ \mu F \qquad \ldots \ (2)$$

Since it will not always be possible to analyse the output wave conveniently it may be necessary to judge the adjustment of C_2 by inspection of the output wave form on an oscillograph. The waveforms and analyses given in the example below should be of assistance in this.

(*b*) *Driving Amplifier.*

If some values are tried in equation (1) it will quickly be seen that, to get reasonable dimensions of the core, the value of E must be fairly large. The input voltage will generally be obtained from a valve amplifier, so that the question of input power is one of considerable importance. It is worth noting that the most economical arrangement, if more power is required than can be obtained from a small triode or h.f. pentode, is a push-pull circuit. The reason for this is that even harmonics can then be balanced out, and odd harmonics do not matter in any case, since the output will only be used to generate more odd harmonics in the harmonic generator. Even harmonics should not be allowed to enter the generator circuit in cases where separate odd and even groups are to be generated. Where a d.c. bias is used to generate all harmonics in one group, however, the presence of evens in the input is evidently of little importance. For the same reasons the amplifier output transformer may be somewhat more heavily loaded than is usual, provided the resultant direct current field is small.

Example. Harmonic Generator for 50 c/s Fundamental.

A harmonic generator was designed and built, to work with a 50 c/s fundamental, on the lines indicated above. The r.m.s. voltage available was taken as 20. The core material was mu-metal, so that $\mu_s = 3{,}000$ and $H_s = 0.5$. The angular frequency $\omega = 2\pi \times 50$ rads/sec.

So from equation (1) we obtain

$$Na = 1{,}000 \text{ approx.}$$

$$\text{and} \qquad \frac{N}{l} = \frac{R_2}{12} \text{ approx.}$$

A convenient laminated core had $l = 12$ cms. approx. and R_2 was chosen as 1,000 ohms.

This gives $N = 1{,}000$
and $a = 1$ sq. cm.

These somewhat "round numbers" are quite accurate enough. The coil actually made had 1,000 turns of 34 S.W.G. on a $\frac{3}{8}$ in. by $\frac{3}{8}$ in. cross-section core made up of 5 mil. mu-metals stampings type No. 39T (Telcon).

The tuned circuit L_1C_1 had $L_1 = 1$ henry and C_1 about 10 μF, adjusted to resonate at 50 c/s. From equation (2), $C_2 = 0.1\ \mu$F very approximately.

In order to obtain easily a long series of measurements, the generator was driven in the first instance from a mains transformer with a 1,000 ohm resistor in series to simulate the impedance of an amplifier output. In Fig. 14 (*a* to *f*) are shown photographs of the output obtained from the harmonic generator (across the load R_2) as shown on a cathode ray oscillograph. The waveforms *a* to *d* were obtained with the circuit exactly as described above, with 40 volts across the terminals of the mains transformer, thus giving about 20 volts on the input of the generator. The condenser C_2 was set at a number of different values between 0.01 and 1 μF, and the output wave analysed in each case. The best result was obtained with $C_2 = 0.1\ \mu$F, the waveform being shown in Fig. 14b. The waveforms of *a*, *c* and *d* show the general trend as C_2 is altered from this value. The analyses of the first three of these waves up to the 21st harmonic are shown in Fig. 15. It will be seen that the advantage of 0.1 over 0.05 μF is chiefly that it gives practically double the output voltage. At much higher harmonics, 0.05 μF is better. Actually the best equalisation is obtained with $C_2 = 0.07\ \mu$F, but the choice of condenser value will naturally depend on the circumstances of use of the generator and on what range of harmonics is required.

To illustrate the importance of the tuned circuit L_1C_1, an oscillogram of the output obtained when it is omitted is given in Fig 14*e*. It will be seen that the output of higher harmonics falls off badly compared with the corresponding case with the tuned circuit (i.e., Fig. 14*a* and Fig. 15).

To show the effect of inadequate applied voltage, Fig. 14*f* gives an oscillogram of the output waveform obtained with the same circuit as, but only one-quarter the voltage of Fig. 14*b*; the analysis of this is shown in Fig. 17, and it will be noted that the equalisation of the harmonics is extremely poor.

It will be noticed that in a number of the oscillograms there is evidence of a tendency for the discharge of the condenser through the coil and the load to be oscillatory, lasting for a cycle or two before being damped out. This is because the coil has still some inductance left (L_{2min}), and the discharge will only be non-oscillatory if the total effective resistance under these conditions exceeds $4L_{2min}/C_2$. It is not desirable to have the resistance of L_2 high, however, since this would adversely affect the generation of the harmonic series through making the switching effect of the coil less marked. It is best to aim at keeping L_{2min} as low as possible. However, the oscillatory discharge does not matter seriously provided its frequency is higher than that of the highest harmonic required; its frequency is actually a harmonic frequency of the applied fundamental. Regarding the amplifier for use when the harmonics are to be generated from say, an oscillator output, in the case being described, an H.T. voltage of only 130 volts was available. To get a voltage of 20 volts of 50 c/s to drive the harmonic generator, two PX25's in push-pull were used with 15 volts grid bias. The circuit diagram of the whole equipment, *i.e.*, amplifier and harmonic generator, is shown in Fig. 18. If it is preferred to use pentodes in

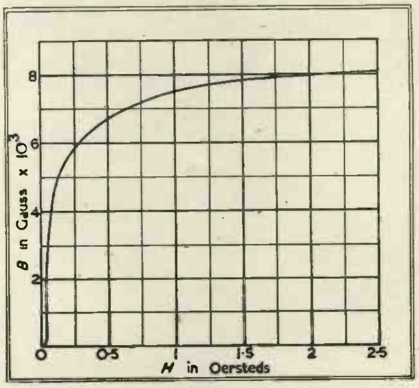
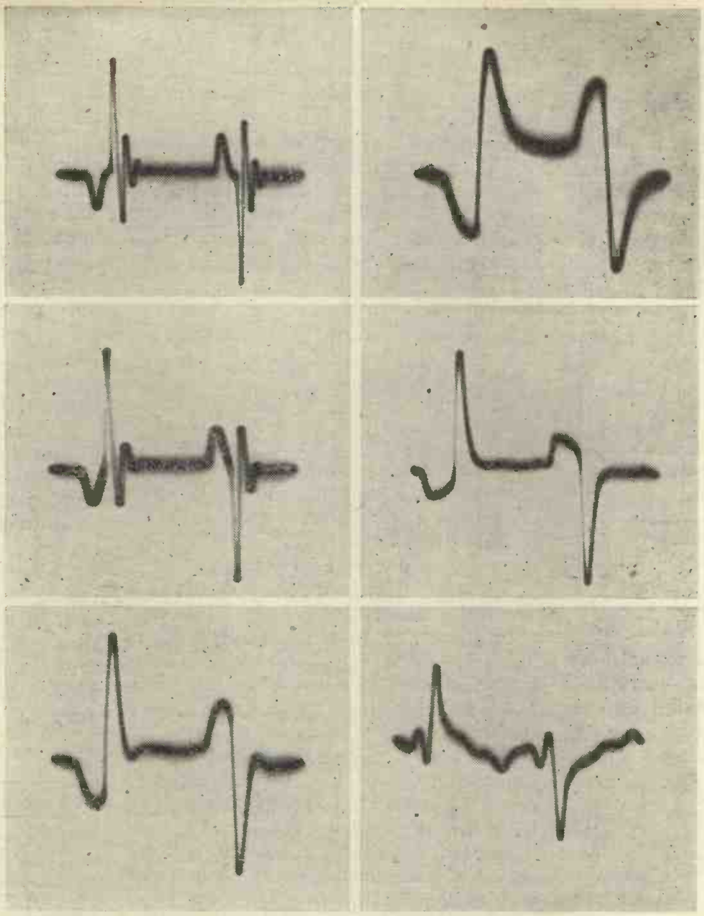


Fig. 13. A B-H curve for mu-metal.



(a) 40 v. transformer output with L_1C_1, R_2 = 1,000 ohms, C_2 = 0.05 μF.

(b) as above, but with C_2 = 0.1 μF.

(c) as above, but with C_2= 0.4 μF.

(d) as before but with C_2= 1.0 μF.

(e) without L_1C_1, R_2= 1,000 ohms, C_2 = 0.05 μF. Volts as before.

(f) with L_1C_1, R_2 1,000 ohms, and C_2 0.1 μF. Voltage to 10 v. only.

Fig. 14. Oscillograms showing the output obtained from the Harmonic Generator.

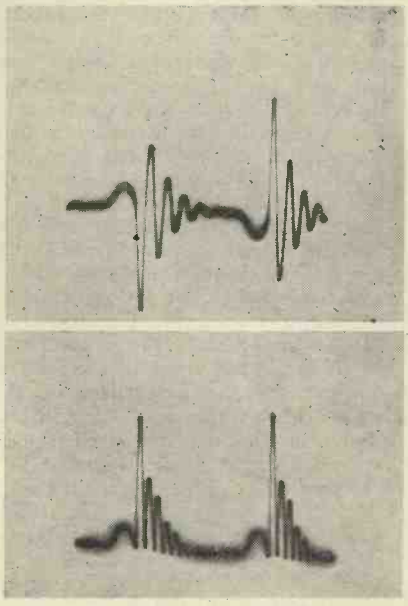


Fig. 14 (*g*) and (*h*). Oscillograms of the output of the final circuit of Fig. 17, (*g*) showing odd harmonics and (*h*) even harmonics.

order to obtain more gain in the amplifier, then Pen A4's are suitable, but an interesting point arises owing to the high impedance of pentodes. It has been stated that the tuned circuit L_1C_1 is intended to keep the input current as sinusoidal as possible; it will be clear that if a high-output-impedance pentode amplifier is used, then the current will tend to keep fairly sinusoidal in any case, since the changes in load impedance during the cycle will be small compared with the generator impedance of the amplifier. The tuned circuit therefore has a much smaller effect on the equalisation and can be omitted if only a limited range of harmonics is required. Fig. 19 shows the effect of the tuned circuit in these circumstances. The best equalisation of all is obtained when a 1,000 ohm resistance is connected in place of the tuned circuit, as will also be seen from Fig. 19.

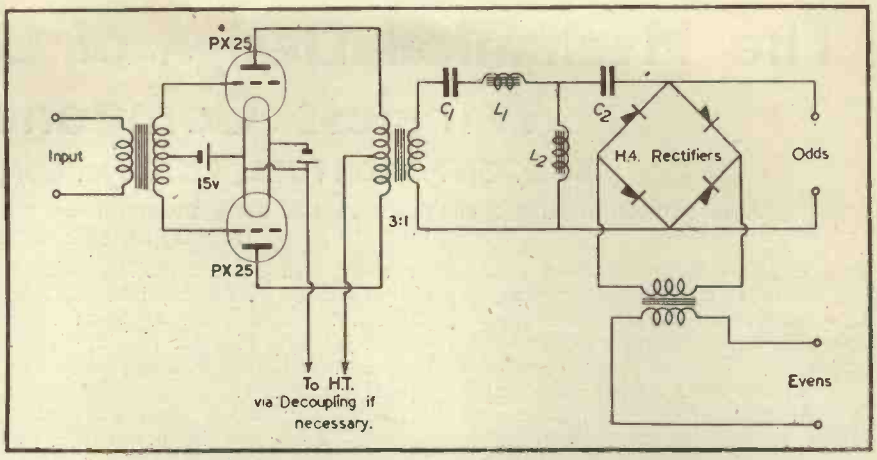


Fig. 18. Complete Amplifier and Harmonic Generator.

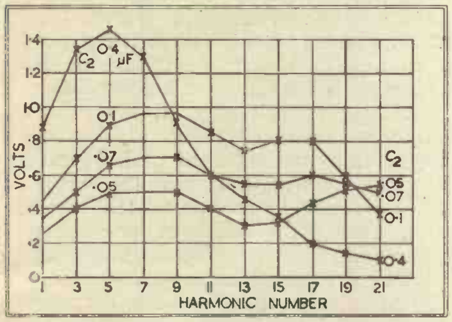


Fig. 15. Analysis of wave-forms of Fig. 14 a—c.

The output wave-form from the complete circuit using pentodes is shown in Fig. 14*g* (odd harmonics) and Fig. 14*h* (even harmonics). The oscillatory discharge of the condenser C_2 will be noted in this example particularly; it is quite a normal condition, as explained earlier.

APPENDIX

Derivation of an Empirical Method of Design of the Saturated Inductor for the Harmonic Generator

A B-H curve for the magnetic core material is required; that for mu-metal has been shown in Fig. 13. Although the theory assumes a sudden change of permeability, in practice the change is gradual as the magnetising force (H) is increased. However, the curve has some sort of knee; in the case of mu-metal this occurs where H = about 0.5.

Let H_s = value of H at knee.

μ_s = incremental permeability at knee = dB/dH.

$I_0 \sin \omega t$ = input current, r.m.s. value = I.

N = number of turns on coil.

a = area of cross-section of core in sq. cms.

l = length of magnetic path in cms.

L_s = incremental inductance of coil at instant when $H = H_s$

Then $L_s = \frac{4\pi}{10} \frac{N^2 a \mu_s}{l} \times 10^{-8}$ henries.

Assume that the knee of the B-H curve should be reached when the instantaneous current in the coil, $i = I/5$.

$$\text{Then } H_s = \frac{4\pi}{10} \cdot \frac{Ni}{l} = \frac{4\pi}{10} \cdot \frac{NI}{5l}$$

$$\text{So that } \frac{N}{l} = \frac{12.5\, H_s}{\pi I}$$

Now also assume that $\omega L_s = R_2$

$$\text{i.e., } \omega \frac{4\pi}{10} \frac{N^2 a \mu_s}{l} \times 10^{-8} = R_2$$

$$\text{i.e., } Na = \frac{R_2 \times 10^8}{\omega(4\pi/10)(\mu_s N/l)} = \frac{R_2 l \times 10^8}{5\omega\mu_s H_s}$$

It is generally more convenient to work in terms of the output voltage of the amplifier (or other circuit) generating the fundamental measured across its design load impedance, this voltage being a factor more normally considered in design than current. It has been found in practice that the effective voltage measured across the input to the harmonic generator is very nearly the same as that measured across a resistance equal to R_2 connected at the same point. Let this voltage be E, then $I = E/R_2$

$$\text{and we get } Na = \frac{E \times 10^8}{5\omega\mu_s H_s}$$

$$\text{and } \frac{N}{l} = \frac{12.5\, H_s R_2}{\pi E}$$

Thus Na is first determined, and then N/l. Knowing these, suitable values of N, a and l can be chosen in regard to the range of cores available.

For mu-metal, on which the above working is based, $H_s = 0.5$ and μ_s = 3,000 approx.

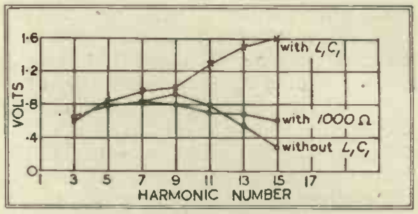


Fig. 19. Analysis of wave-form of Fig. 14 g.

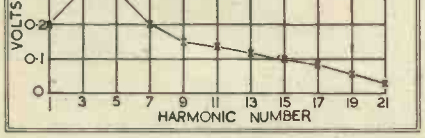


Fig. 16. Analysis of wave-form of Fig. 14 e.

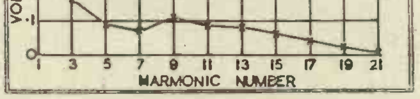


Fig. 17. Analysis of wave-form of Fig. 14 f.

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2. F. E. Terman, *Radio Engineering* (Text Book), 2nd Edn. (McGraw-Hill) p. 338.
3. See F. E. Terman, *Measurements in Radio Engineering* (Text Book) (Mc Graw-Hill) p. 129.
4. For derivation, *see* standard Text Books, *e.g.* A. T. Starr, *Electric Circuits and Wave Filters.* 2nd Edition, 1938 (Pitman) p. 333-5.
5. For a general discussion of Pulse Wave Form, see F. R. Stansel, *B.S.T.J.* 1941, p. 331.
6. See A. T. Starr (refer to footnote 4).
7. This method has been fully described from the theoretical point of view by its originators, Peterson, Manley and Wrathall, in an article "Magnetic Generation of a Group of Harmonics," in *B.S.T.J.* Oct. 1937, p. 437.

The Mechanical Design of German Army Wireless Components

By D. GIFFORD HULL, Lt., Royal Corps of Signals

A description of some of the more unusual designs found in German Army wireless equipment captured during operations in the Middle East

GERMAN Army wireless equipment is comparatively straightforward in electrical design, although sometimes unusual circuits are employed. The mechanical design of some of the components, however, is in some cases unique, and the reason for departure from the more standard designs is not always obvious. Sometimes an unusual design is adopted for the sake of achieving improved electrical performance, sometimes for greater mechanical strength, and sometimes for simplicity of operation; but a design is never adopted with a view to ease of assembly or accessibility, ease of manufacture, low cost or economy of material.

Chassis Castings

One of the most striking points about German field wireless equipment is the extensive use of aluminium alloy (Elektron) die-castings. For example, the chassis and front panel are, almost without exception, made of a liberal die casting, machined here and there to take a component, or a bracket. In some receivers the chassis consists of an intricate die-cast framework, bolted to the panel casting. On to this framework the various stages are bolted, each stage itself being built around a die-cast chassis. The latter may take the form of a small framework, or a cast box into which the components are fixed. Where stages are built into boxes, the entire box has to be removed if a fault occurs, since it is almost impossible to gain access to the components inside the box. With this design it is usually necessary to unsolder the connexions to the box as seldom is a disconnecting strip used to facilitate dismantling. In some of these small sub-assemblies, the castings are so intricate that even bosses are provided, upon which the components are mounted. Recesses may be provided to make room for certain components, and strengthening ribs are commonplace in these sub-assemblies. Sometimes the wiring is bunched and tied to form a " snake," and in one receiver a grooved recess is provided in the casting, subsequently lined with copper foil; in this groove the snake is both protected and shielded. With some receivers, the system of unit construction is more thoroughly carried out. The R.F., I.F., and L.F. circuits are each built on their own sub-assemblies, which are provided with male and female strips for interconnexion. With this design locating pins are employed, to ensure that the sub-assemblies fix squarely together.

Even in " pack " sets, these die castings are used in preference to pressed sheet, which is more usual for the construction of equipment to be carried by a man. Thus it may be seen that no trouble has been spared in the design and manufacture of the chassis units, and the same intricate designs are found in the control gearing systems, and the pre-set and re-set tuning mechanisms.

Fixed Condensers

The components themselves, some of which are quite straightforward, are particularly interesting although inherently German in their design. For example, silvered ceramic trimming condensers are nearly always used instead of the mica compression type, even at low frequencies. This type of component was introduced by the Germans several years ago, but is now made by most manufacturers of ceramics, both in this country and in America. Most readers are familiar with the disk-shaped low-capacity silvered ceramic condensers, and with the higher capacity tubular models. Such condensers are more or less standard for German army receivers. The moulded bakelite mica insulation type is used in transmitters, and very compact wax-paper Mansbridge types are also used. Resistor and condenser mounting strips are sometimes made of laminated bakelite, but phenol-lamin materials are not commonly used. Instead, soldering tag strips are made of ceramic, each strip having about six tags. Such tag strips are found in medium-wave receivers, as well as in short-wave apparatus.

Ganged Tuning Condensers

Tuning condensers are mostly constructed with aluminium alloy die castings. The rotor plates are usually die cast, then machined, and often mounted on a ceramic spindle. The stator plates are similarly made, and clamped on to two ceramic rods. The main frame consists of a die-cast box, the stator plates being fixed by clamps securing the ceramic rods to the box. The ceramic spindle carrying the rotor plates is mounted on two ball races, which are bolted on to the ends of the box. Inter-section shields are often integrally cast with the box, with strengthening ribs in suitable places. A lid screws on to the top, totally enclosing the condenser. Some receivers have individually designed tuning condensers, but most types follow the design described above.

In one receiver, a four gang U.H.F. condenser was constructed in the following way: The main frame, the stator plates (of which there is one per section), and the inter-section shielding, were all made from a solid block of alloy. In this way all the stator plates were at earth potential. A milling cutter was used to make semi-circular slots in the block, the single rotor plate being accommodated in the slot, giving the effect of one rotor plate and two stator plates. The rotor plates are die cast, each being mounted separately on the ceramic spindle, and phosphor-bronze wire wipers used to make contact to each rotor section. This construction certainly makes for rigidity for U.H.F. work, but a large quantity of material is used, and the production operations are intricate. The measurements of the four gang unit, as shown in Fig. 1 are 5 in. by 2 in. by $1\frac{3}{4}$ in.

Another unusual design of tuning condenser is found in a German U.H.F. transmitter. Three gangs are employed, and a $\frac{5}{8}$ in. ceramic spindle, 18 in. long, carries the sections. The M.O. section is located at one end of the spindle, the P.A. section at the other end, and the doubler section in the centre, the drive being applied by means of bevel gears. Each section of stator plates consist of a semi-circular alloy block, with grooves milled out to accommodate the rotor plates. The rotor plates are also die cast and machined, and are clamped on to the spindle. The most interesting feature of the design is that stator sections are in no way mounted on the chassis of the set, but in addition are mounted on the spindle. They are, however, prevented from rotating with the spindle by retaining arms, one end of each arm being fixed to the stator section, the other end to the chassis of the set. The purpose of this design is to ensure constant juxtaposition of rotor and stator plates, should the long ceramic spindle become warped. In such an event, the stator section rides solid with the rotor, being quite

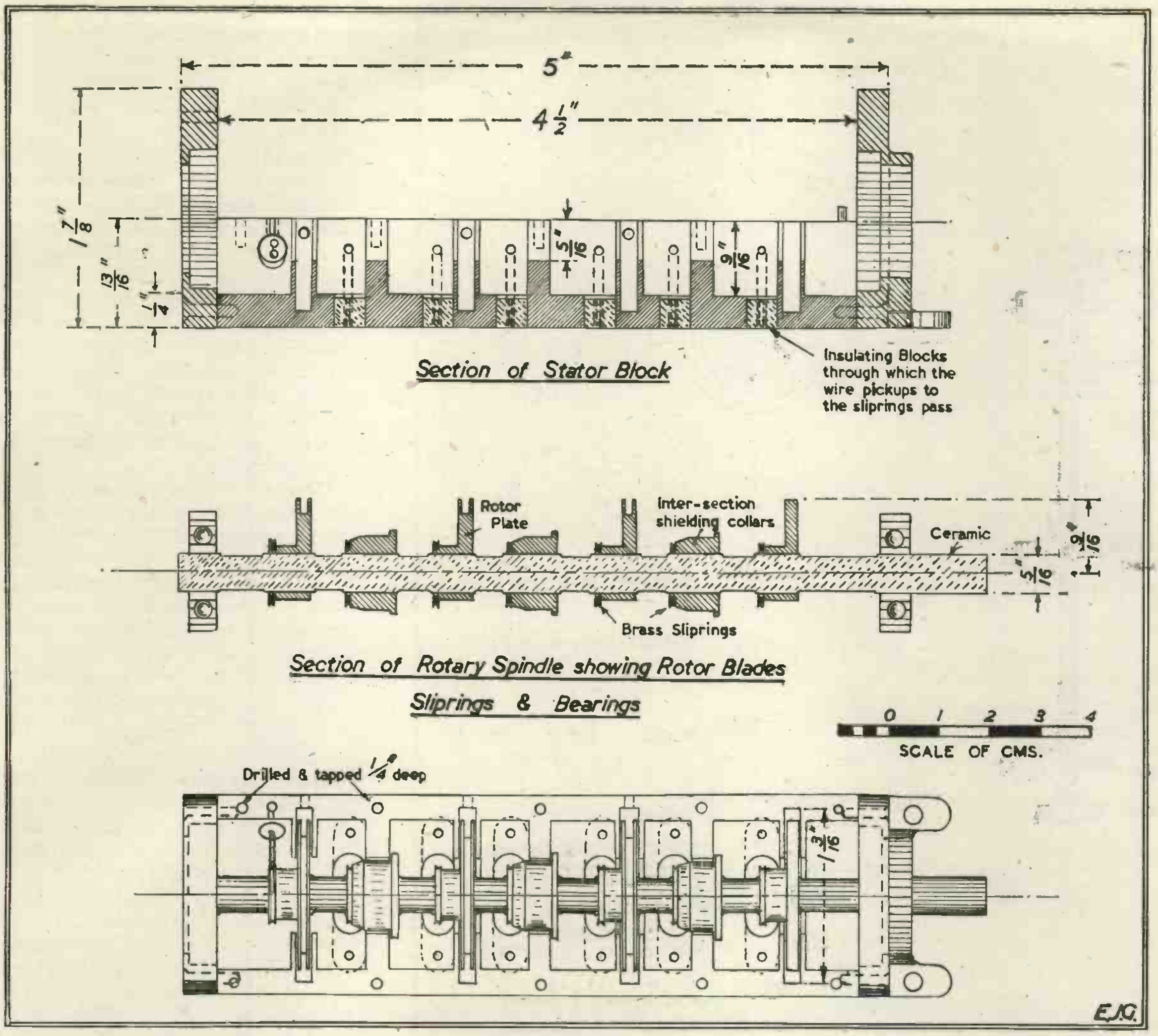


Fig. 1. German u.h.f. Condenser.

free to twist with respect to the chassis. The retaining arm is constructed to have the action of a universal joint, since it only prevents the stator section from rotating, leaving it free to twist if necessary. Alongside each rotor plate, there is one plate that is mounted on the rotor, and this plate is used as a trimmer. It meshes with the stator, and to adjust the trimmer, a set screw is loosened, and the plate rotated by means of its serrated edge.

Another feature of the construction is the method of ensuring correct tracking at all frequencies. The master oscillator section has two rotor plates and three stators. Both the doubler and amplifier section each have one rotor and two stators, as well as the trimming plate mentioned above. The rotor plate is not disposed centrally between the stator plates, but is set-off to one side, and divided by slots into several portions. The plate, as can be seen in Fig. 2, is then bent in portions to left or right as required, to ensure correct tracking.

In an older set, an aerial trimming condenser was made of two disks of ceramic 4 in. diameter, one being fixed and the other free to rotate. Each plate had half its surface silvered, the gap between the two surfaces being small. Thus, as one disk was rotated, the capacity was varied.

Moving Coil Trimming Condenser

One of the most interesting devices is the remote tuning mechanism used in a Transreceiver operating on the 224 Mc/s band. The volume control and the fine tuning control are both variable resistors mounted on a small panel that plugs into the Transreceiver. For remote tuning, the control panel is removed and a plug, with wire attached, fixed in its place. The control panel is connected to the other end of the wire, and thus the operator may carry the control panel in his hand or wear it on his belt.

Inside the Transreceiver there is a small moving coil mechanism, and instead of a pointer, two minute rotor plates are fixed to the spindle. The cover is of ceramic, and on its inner surface there are two silvered areas, constituting the fixed plates. The capacity of the condenser, therefore, depends on the current flowing in the coil, and this current is controlled by the tuning resistance. The L.T. battery supplies the current, and a minute baretter lamp is used to assist in stabilising the circuit. The dimensions of the moving coil condenser are 1 in. diameter by 2 in. long.

Coils

Certain details of coil construction are interesting; the use of metal deposit for the manufacture of U.H.F. coils is an example. A ceramic former $\frac{5}{8}$ in. diameter, has a spiral groove on its surface, and silver is deposited into this groove to form a winding, the turns of which have considerable width, but infinitesimal thickness. The deposit appears to have been put on

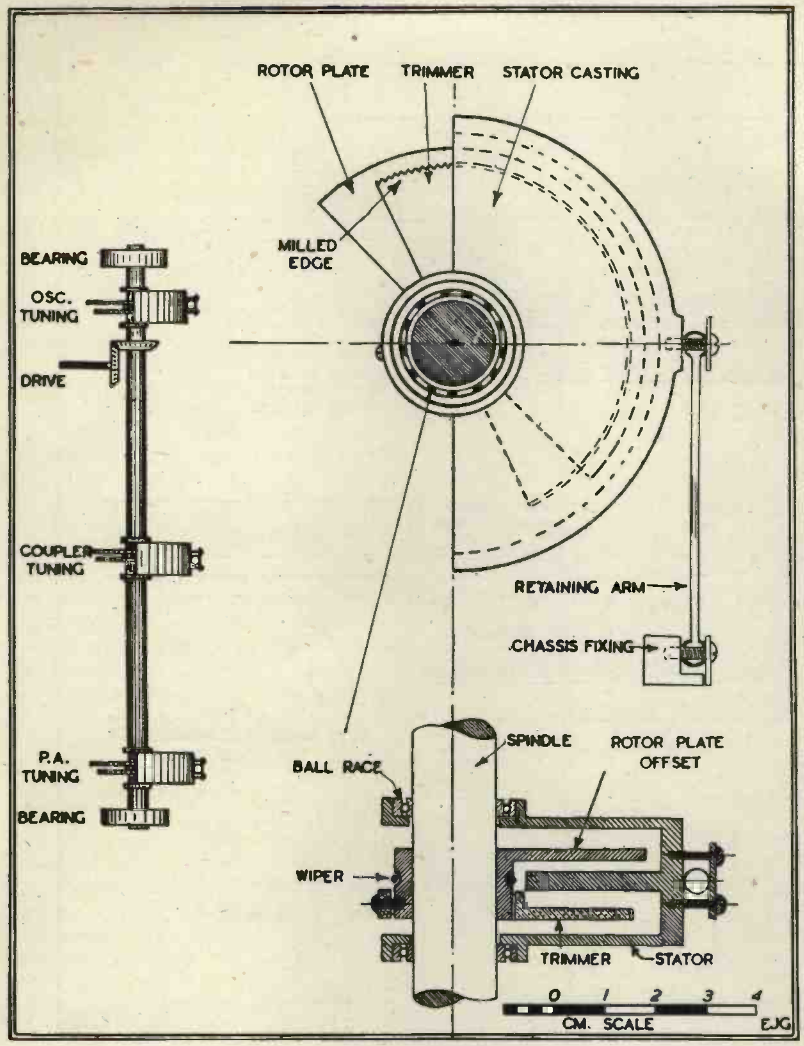


Fig. 2. A German 3-gang Transmitting Condenser of unusual design.

by electrolysis rather than by spraying, but the process is not new. The advantages of this method of construction are, a high order of electrical stability, and low capacity between turns, whilst providing a large surface for U.H.F. current.

The Germans have used iron-dust cores extensively in the production of coils, and many different types of dust-core coils are used in army receivers. It appears that little effort has been made to standardise the design of coils used for the same purposes in different models.

One type of coil construction, used in one set for the R.F. coils—and in another for the I.F. coils, is as follows: The turns are wound on a small three section bobbin, made of a plastic material. The bobbin fits over a cylindrical dust core, as can be seen in Fig. 3 moulded integrally with a disk shaped end piece. A threaded screw inside the core provides adjustment of the inductance. An iron dust shrouding, in the form of a hollow cylinder, closed at one end, totally encloses the winding in iron dust. On top of this fits a moulded bakelite cover. In one receiver, a cast aluminium cover is provided for each coil. The characteristics of coils of this nature are good.

A German transmitter employs variometers for tuning the oscillator and amplifier circuits, but the variometers are wound in such a manner that they obey a straight-line frequency law. The variometer is wound in the following manner: two paxolin cylindrical formers are used, co-axially mounted, the inner one revolving about the common axis. Each coil is wound on a semi-cylindrical surface, *i.e.*, not around the whole circumference of the former. The windings are tapered in shape, and are stitched on to the formers. This method of winding does not provide such a large frequency variation as the conventional method, but it does enable the dial to be linearly calibrated.

Valve Holders

Generally the receiving valves are of the "Knob" type, similar to those used in German Luftwaffe sets.* These valves employ a cylindrical holder, largely made of perforated aluminium sheet, with an insulator at the bottom carrying the grid connector. A bakelite ring at the top carries the radially disposed contacts for the other elements. The valve is inserted into its holder upside down, and a knob is attached to the base for handling purposes.

The advantages of this type of construction are that the valve is inserted and removed by handling the knob attached to the base so eliminating possibility of loosening the envelope from the base; and that rigid support is offered to the valve. The disadvantages, however, are that the grid connexion is very inaccessible, and also the general accessibility of the set is in no way improved when the valve is withdrawn.

Calibration Check Device

Another interesting device found in a certain German field transmitter, and also in an Italian transmitter, is the sealed crystal frequency indicator. This device consists of a tiny crystal bar, held in the prongs of a pair of tweezers, which is mounted in a glass envelope in the same way as a valve. An ordinary four-pin base is used for connexion. The envelope contains a gas, and when the crystal is fed with A.C. voltage at its resonant frequency, it glows a pink colour. The German transmitter is self excited, and the crystal connected across the tank circuit of the P.A. A mark on the tuning dial corresponds to the frequency of the crystal, and when the tuning control is set to this mark, the crystal glows, and is visible through a hole in the panel. If the set is off calibration, the crystal will glow at a different dial reading, and this denotes that the transmitter requires re-trimming. Thus it is noted that the crystal is used solely as a check on the transmitter calibration, and not to control the frequency. In one case, three such crystals are mounted in one envelope, and are connected in turn, so that three check points are provided.

German Design Policy

The points discussed previously are confined to the more widely used German field sets manufactured prior to 1940. It is noted that the mechanical design of the associated components is

* See *Electronic Engineering*, June 1942.

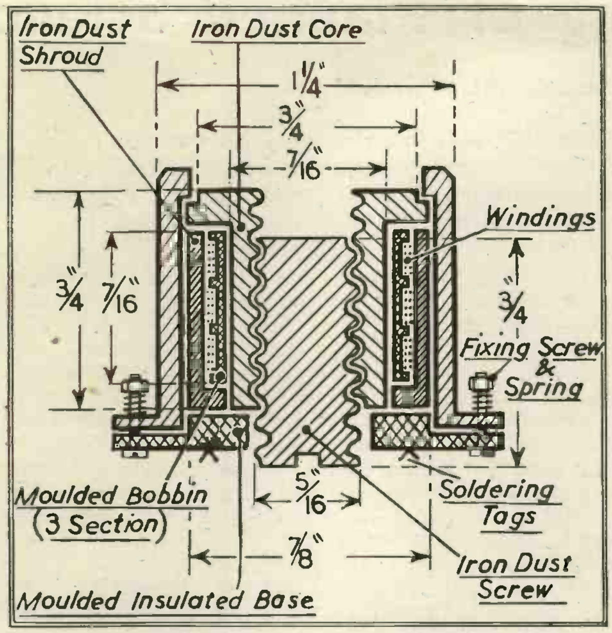


Fig. 3. A coil totally enclosed in Iron Dust Material.

based on long life and trouble-free operation, little effort being made to simplify production methods. In view of the vast requirements of the German army, one might ask if it were a better policy to adopt a slightly less thorough design, and manufacture a considerably greater number of sets from a given quantity of material and in a given time, and it might be argued that in modern warfare much radio equipment is destroyed or falls into enemy hands long before its useful life is completed.

To give an example, the average life of some of the planes destroyed in the Battle of Britain amounted to only a few months; yet the associated radio equipment was built to last for many years. This is hardly economical. Yet, in contrast to this view, it is evident that the result of a battle may depend on the reliability of communication equipment during the action, and it is with this point in mind that the German technicians have designed their equipment. However, it does appear that the weakness in the general designs, particularly of U.H.F. sets, lies in the extremely poor accessibility offered to the components for adjustment or replacement, and in uneconomical production methods.

As regards the apparatus made since 1940, it is observed that in one receiver, pressed aluminium sheet is used instead of castings for chassis and sub-assemblies. Further, the work is poorly carried out, and as a result the set is by no means rigidly constructed.

Scarcity of Materials

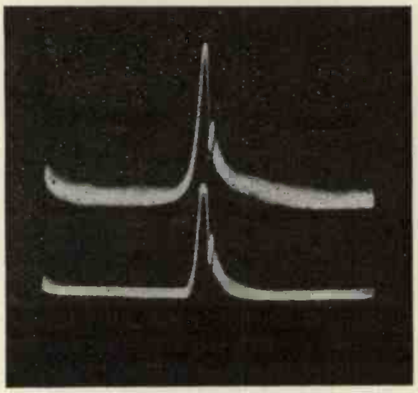
It is interesting to note how the war has at least stimulated research in the use of materials, in this country and America, as well as in Germany. Experiments have been carried out with a view to employing cardboard coil cans sprayed with metal to replace aluminium coil cans. Laminated plastics and ceramics are used for certain constructional work instead of metal.

Much of the equipment used by the Germans in recent operations indicates that they have adopted a policy of frozen designs, and having built extensive plants to produce the equipment, they cannot easily change their designs. But as the war progresses, these frozen designs will be discarded for new ones, more adapted to the growing shortage of labour and certain materials. This will entail the considerable trouble of laying out new plants.

To date, no obvious use of ersatz material has been noticed, and it is unlikely that the designs of fixed condensers will change as a result of the war. Germany is rich in ceramics for the smaller type, and for paper condensers she has access to the moisture-proofing waxes of Austria and Czecho-Slovakia. However, the Germans have for some time practised economy methods in the production of some of their domestic receivers as part of their policy of guns rather than butter. It now remains to be seen whether such economies, particularly in the direction of aluminium, will be adopted by the designers of army apparatus. Indeed the change from die castings to pressed sheet for chassis construction, as mentioned above, may be a sign of the times.

Instability and I.F. Alignment

RECEIVERS with two or more intermediate frequency amplifiers of the usual band-pass coupled type can often be difficult to align. The adjustment of such circuits is much more involved than two or more single circuit H.F. stages of tuned radio frequency (T.R.F.) or "straight" type or receiver. The reason for this is that in the latter case incipient instability (*see* Fig.) definitely denotes excessive gain for the given conditions in a receiver. It can be corrected either by lowering the gain of the H.F. valves, such as by reducing the screen voltage or increasing the grid bias, or by additional decoupling and better H.F. screening.



In the case of a superhet such incipient instability with band-pass stages may also be due to incorrect alignment of the I.F. circuits. As the resultant increase in normal gain is the product of the increased gain obtained by misalignment with each coil, the risk of instability is obvious and in cases of receivers in which the normal gain already approaches the maximum permissible instability is inevitable.

When the circuits have been correctly aligned, not only will the circuits be set at their most selective conditions, but it will be found that the receiver regains its stability. In such cases, and more particularly when the gain appears to be close to the maximum permissible (this, incidentally, is not a desirable condition and is best avoided), it may be feasible to align the circuits individually by the H.F. method except for the last I.F. stage, and then revert to the normal "Rectified Response" method with a final trimming of the various circuits.

This note appears in the new Cossor booklet on the use of the frequency modulated ganging oscillator (Model 343). Copies of the booklet can be obtained by radio engineers on application to Messrs. A. C. Cossor (price 3s. 6d. net).

The True Meaning of Planned Science

By J. D. BERNAL, F.R.S.*

In the September issue of this Journal we invited Dr. J. R. Baker to state his views on the planning of scientific research, which are opposed to those of the Association of Scientific Workers. In the article below, Prof. Bernal, Vice-President of the Association, replies to Dr. Baker. A letter on the subject appears on page 260

IN his article on *The Scientist and the Community* in a recent issue of this journal, Dr. J. R. Baker paints a horrifying picture of what he calls "planned science."

It seems that he and the Society of Freedom in Science are doing their best to frighten other scientists by bogies which they themselves have conjured up.

This would not matter over-much if we were dealing with a scientifically-minded population, but there is a danger that all those people who, out of ignorance or otherwise, dislike science should use the thesis of freedom in science to prevent its development during the war and afterwards.

The idea of science being carried out by a lot of poor individual scientists, all assigned by a leader to definite tasks of a strictly applied nature and ordered to make discoveries to a time table has never been the objective of any planner of science for the reason that it simply would not work.

Planning of science as advocated and as it has begun to be practised in this country in the war means something quite different. It means the full interchange of existing knowledge between different branches of science, a comprehensive investigation into the general problems that have to be solved and an agreement among all scientists grouped in their appropriate faculties as to how best these general problems can be tackled. In certain fields, planning in science is very old. In astronomy and meteorology, for instance, it is quite impossible to gain certain kinds of knowledge without a plan defining the work to be done in different observatories; but the author has yet to meet an astronomer who considers this a denial of his liberty of inquiry. There is no reason why it should be any more irksome over the whole field. The need for planning in modern science is essentially due to the growth of science itself; not only in the elaboration and costliness of apparatus, but in the fact that science has become much more interconnected and that a man working on his own may easily miss points of vital interest to himself because his work is not co-ordinated with others. Dr. Baker himself in his book gives an excellent example of this: he points out that in 1935 Trefouel discovered that sulphanilamide was an even more effective bactericide than the azo-dye prontosil which Domagk had discovered by accident a year before. He then goes on to point out (page 72) "The French workers did not have to discover how to make sulphanilamide: there was the method, ready and waiting for them. Sulphanilamide was discovered in Vienna by a man who was making a general study of the sulphonamides of sulphanilic acid. That man was Gelmo, and the year 1908. . . . Neither Gelmo nor anyone else had the faintest idea that sulphanilamide would become one of the world's greatest life-savers. Twenty-seven years had to pass before it was discovered that it was a chemotherapeutic agent of the foremost rank. Taylor calculates that if its properties had been known, it could have saved 750,000 lives in the last war alone, from its effects on the streptococcus of septic wounds and blood-poisoning."

One would have thought that this indicated the lack of co-ordination between chemical and pharmacological studies, but Dr. Baker takes a more charitable view, "It was just because chemists did not short-sightedly confine their attention to substances thought likely to be useful in a material way, that sulphanilamide was lying ready for instant trial directly someone had reason to believe it might serve humanity in a practical way."

The Society for Freedom in Science is very concerned with the dangers of directing science to satisfying man's material needs. It is pointed out that the great discoverers very often had no desire to serve any material end and that when they did, it was probably by mistake. This is by no means the case even for the examples which are cited in the book referred to. Pasteur for instance, as his whole life shows, was inspired throughout by the ideal of helping humanity in a material way. This, however, is not the point. Whatever the factors affecting the individuals, the field studied and the intensity of the effort in that field are what determine, by and large, the direction and the rate of progress of science.

All the great developments of science from the Renaissance onwards has occurred because of its real or supposed usefulness—not in detail, but in general. The conditions of society which encourage scientists and give them enough to live on to carry out their experiments, do not make people scientists, but they do let people of ability, who might otherwise have been distinguished churchmen or lawyers, devote themselves to scientific pursuits. The real liberty of science must include the provision of the means of carrying out research, and this, in the modern world, requires planning. Now the ends that science, in fact, served over most of the period, were the ends of the enrichment of certain individuals; all that the planners want to do is to see that science serves humanity as a whole, and serves it more effectively than ever before. This does not mean now, any more than it meant then, that the only thing scientists did was to try and solve immediate problems; that would have been technology and not science, and even technology cannot exist without the basic knowledge that only research removed from day to day needs can give.

Three hundred years ago Francis Bacon, who might be called the father of planned science, pointed out that in the invention of the cannon and the compass, *ad hoc* experiments to determine how to shoot missiles for great distances or how to find the north on a cloudy night, would have led nowhere. Only out of the pursuit of general and comprehensive knowledge can the materials be found to solve the immediate problems. All planners, moreover, have insisted on the need, not only for some fundamental scientific research, but for far more in proportion to applied research than we have now. But they want fundamental work brought more rapidly into contact with its applications and, conversely, that the problems continually being raised in tackling immediate technical difficulties should be brought to the notice of the more fundamental workers as a fruitful source of new ideas.

Just because science has grown up in a haphazard way, dictated by a series of particular needs, and was in the past because of its small size often affected by chance events, there is no reason to believe that its present structure is ideal, any more than the structure of unplanned competitive economy was, as the nineteenth century economists maintained, better than anything man could have devised. The balance of science, both on account of its internal structure and its

* Professor of Physics, University of London.

use to humanity, requires to be reviewed. It is already apparent that it leans too heavily on the chemico-physical side; that we need far more biology and social studies. Now planning science in this way can do nothing but increase its effective freedom; nor is any attack intended on the individual scientists. Planners realise that scientific work is quite different from normal routine work; that scientists cannot be effectively ordered about, not because this is particularly wicked, but because the essence of their work is thinking as they like. Most scientists, being sensible people, have no objection to discussing and planning their work together. Many who thought they had this objection have found in the course of the war how much more stimulating and enjoyable planned work can be. The fact that all the scientists quoted in Dr. Baker's book were marked individualists, really means nothing more than that they were men of their century; but rugged individualism in science is now becoming as out of date as it is in industry.

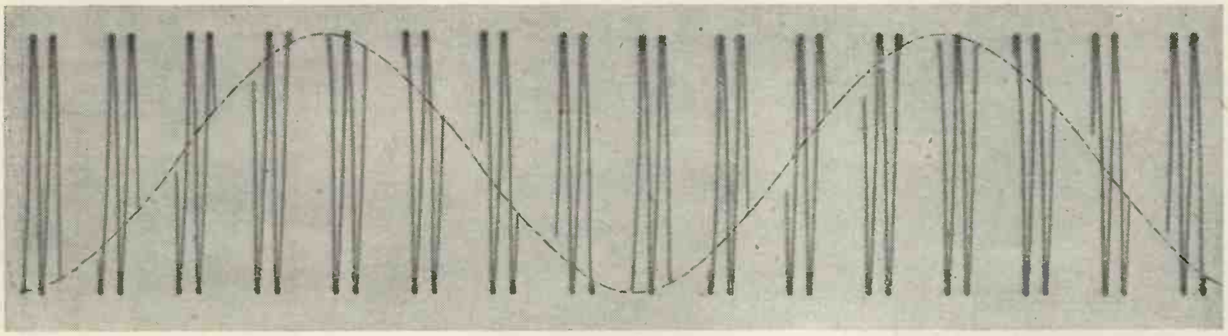
There is, moreover, no need to exclude even the most un-cooperative scientists from a planned scientific scheme If the author may be permitted to quote from his own book,* " In ideal circumstances it would probably be best to leave it to individual initiative, that is, to allow the same freedom to the scientist of staking his claim as still belongs to the prospector. Anyone who has a clear enough idea of a programme of work involving the setting up of a laboratory, and who can find suitable and willing assistants, should be allowed and encouraged to set up that laboratory. The relation of that laboratory to others would be a matter for administrative and scientific co-ordination, but in every case the organisation should exist to help the spontaneous growth of science and not to distort it into a fixed pattern. It might be in certain circumstances, however, necessary for the initiative to be taken from above if it appeared that any section of scientific work had been neglected through inadvertence or development of other fields. There should be positive encouragement for the setting up of such research, and in that case the men might be found for the job." " Places would have to be found for those scientists who combine with genuine ability in science a complete lack of social competence, who are quarrelsome, unsocial, or helpless. For them the organisation of science should offer a kind of right of asylum; they should be allowed either to work for themselves, to choose where they would prefer to work, or to wander indefinitely from laboratory to laboratory." As far as I know, no other planner of science has repudiated these statements or refused the guarantee of initiative and liberty which they contain. Real freedom of science is perfectly compatible with planning.

* The Social Functions of Science, p. 277-278.

All this argument would seem very academic if it did not have an immediate and urgent implication. Dr. Baker has recognised the need for planning of science in warfare; but those who attack planning in peace time while accepting it in war, are in exactly the same position as the business men and politicians who wish, the moment that the Armistice is signed, to return to the unrestricted commercialism that ruined the chance of real peace after the last war. The scientists who are working for this end individually and through bodies such as the Association of Scientific Workers have a hard enough task in seeing that this gets done in time. Those who at the present time are raising parrot cries for freedom of science and anti-planning are doing little service to science or civilisation.

The Determination of an Unknown Frequency from a Photographic Record

By M. SCOTT *



An oscillator of known constant frequency is connected to the grid of a cathode-ray tube and the unknown frequency is applied to one pair of deflector plates in the usual way. The output of the known oscillator should preferably be of rectangular-waveform as this gives a sharper delineation on the final record.

During the negative half-cycles of the pulses applied to the grid the beam is blacked out, but during the positive half-cycles the unknown frequency will be recorded on the paper as shown in the illustration. This was taken with a 1,000 c/s. oscillation applied to the grid of the tube.

* Cinema-Television, Ltd.

An examination of the trace shows that there are less than four complete cycles in one millisecond and an investigation of the actual length of trace recorded during one millisecond will enable the unknown frequency to be determined.

A line is drawn joining all the leading (or trailing) edges of the individual traces together, and it will be seen that the resultant is a sine wave having a frequency of 1c. in 8 mS.

If the tube were not blacked out during the negative half-cycles the reduction of length of trace in 8 mS. will be the length of one complete cycle and hence there will be a length of trace equal to 31 complete cycles in 8 mS. The length of trace recorded will therefore be equal to 31/8 cycles.

The unknown frequency is readily determined from the equation :

$$n_1 = An_2$$

where n_1 is the unknown frequency. A the actual fractional number of cycles of the unknown frequency in 1 mS., and n_2 the known frequency. In the example shown, n_2 was 1,000 c/s and A 31/8. The unknown frequency was therefore 31,000/8 or 3,875 c/s.

The Accurate Generation of Sub-Frequencies from a Standard

By E. NEWMAN*

THE way in which it has been customary in the past to derive a frequency which is an integral submultiple of a given frequency is that of the simple multi-vibrator, driven at the given frequency and providing an output at the sub-frequency. Fig. 1 shows such a standard multi-vibrator formed by a pair of cross-coupled valves V_1 and V_2 and Fig. 2 shows as an aid to following the subdivision process the kind of waveform which is generated at one of the control grids, actually, the waveform of potential on the control-grid of valve V_1.

As is well-known, such a waveform may be divided into transition portions where the circuit is regenerative and unstable and into remaining inter-transition portions where the loop gain is zero or too small for the circuit to be unstable: for example, the portions shown as PQ and P′Q′ are like transition portions of the same sense of transition, RS is a transition portion of opposite sense of transition, and QR and STP′ inter-transition portions. The unstable portions are shown as lying between the potential levels A and B. Of these levels, A is that below which the loop gain of the circuit is insufficient for the circuit to be unstable; B is that beyond which the swing of a transition such as PQ cannot extend, in view of the control-grid collecting current. Between levels A and B all changes are very rapid and of roughly exponential form. Below level A there is a portion of less rapid exponential variation, namely, ST, of time constant determined by the anode-circuit resistance of valve V_1 and the stray capacity in shunt with this resistance, and there is the further portion TP′, which completes one cycle of the waveform and is also exponential, but of comparatively long time constant determined by the constants of the coupling circuit to the grid of valve V_1.

It is the last-mentioned portion TP′ of the waveform which is of interest in obtaining frequency division. Thus there may be superposed on the control-grid of V_1 an harmonic oscillation of the given frequency such as is indicated in its modifying effect on part of the portion TP′ of the free waveform already described by the curve XYZ in Fig. 2. With this modification the multivibrator no longer commences the A-to-B transition at the end of the cycle at P′, but at Z where the grid potential runs into the unstable region between A and B, or possibly at Y, where the unstable region is just touched. It will be noticed that there is likely in practice to arise an instability in the generated sub-frequency, for if in one cycle the peak at Y just falls short of the unstable region so that the cycle has a period corresponding to a transition at Z, it is possible, on the other hand, that a slight change in a circuit parameter or within a valve or in the supply voltage may cause the transition to occur in the next cycle at Y, so that the cycle is of shorter period. A change in the anode circuit resistance of V_1, for instance, would cause a change in the level of T and so interfere with the transition at the level A. The level A is also sensible to change, as is the amplitude of the driving oscillation. For such reasons as these frequency-dividers working according to the kind of principles that have been illustrated require constant supervision to ensure stable division.

* Electrical and Musical Industries, Ltd.

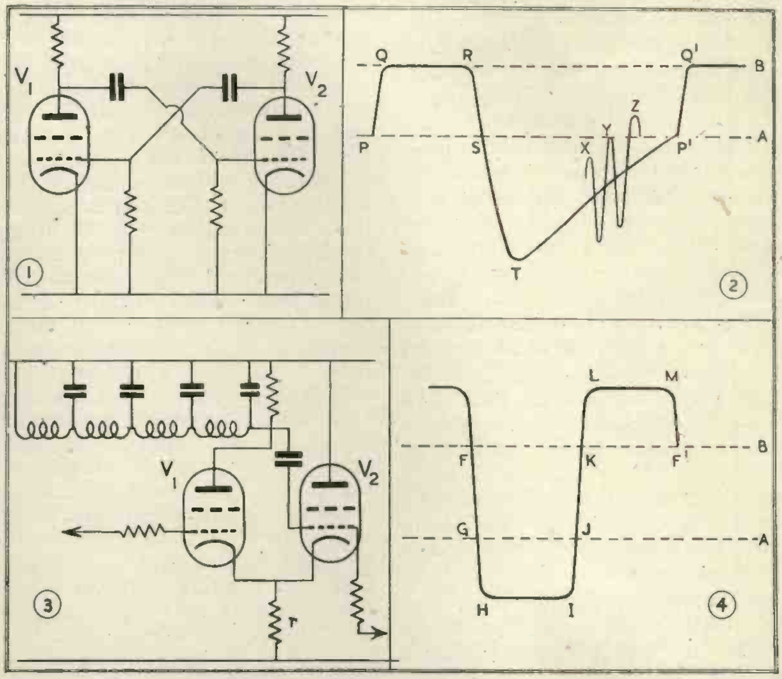


Fig. 1. Standard multi-vibrator circuit, and (2) the waveform of grid potential of V. Fig. 3 shows a form of frequency divider circuit and (4) the waveform generated.

A form of divider that has been found highly successful in practice in avoiding the difficulties just discussed is shown in Fig. 3. Fig. 4 shows the type of waveform generated by the circuit. There is again a pair of valves, V_1, V_2, coupled in regenerative manner, but the coupling in this case is constituted only in part by anode-to-grid coupling, namely, by the resistance-capacity coupling of the anode of V_1 to the control-grid of V_2—of time constant incidentally much greater than the period of generated oscillations—the remainder of the coupling being achieved by the large common cathode resistance *r*. As shown, the anode coupling impedance in the anode circuit of valve V_1 takes the form of a delay network driven at one end from the anode of V_1, at which end it is terminated by a resistance of magnitude equal to its characteristic impedance, and short-circuited at the far end. The control-grids of the valves V_1, V_2 are taken to points of appropriate positive bias potential. An output may be derived, if desired, from an impedance in the anode circuit of valve V_2.

The circuit operates so that as in a normal multivibrator the valves V_1, V_2 are alternately conducting. To understand the mode of operation, suppose the circuit to be in the unstable state and consider for convenience the potential variation taking place at the control-grid of V_2. Levels

(*Continued on page* 249)

More Television Waveforms

By ARTHUR C. CLARKE

The regular issue of Data Sheets will be resumed in the next issue, on Mr. Lockhart's return. In the meantime the present article forms a useful addition to Data Sheets 29-31 (Television Waveforms) and should be filed with them.

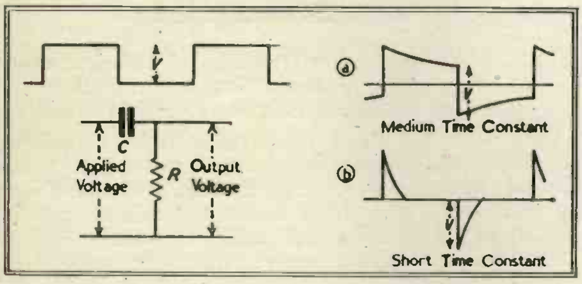


Fig. 1 (left)

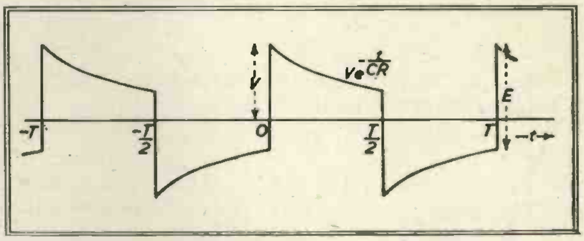


Fig. 2 (above)

MR. LOCKHART'S article on "Television Waveforms" in the June, 1942 issue of *Electronic Engineering,* dealt exhaustively with the subject of rectilinear waves, *e.g.,* sawteeth and rectangular waveforms. An additional important variety is the "peaked" or exponential wave such as that obtained when a rectangular voltage is passed through a resistance-capacity coupling.

When the time-constant of the coupling is long (*i.e.,* the C.R. product is great compared with the period of the applied wave) the output voltage is sensibly unaltered. If on the other hand the time constant of the circuit is small, distortion occurs as in Fig. 1 (a) and (b). The resulting waves have steep vertical fronts followed by exponential slopes due to the charge and discharge of the condenser. There is no d.c. component and the waves are always of equal area above and below the datum line, though they are perfectly symmetrical only when produced by square waves.

Since these "differentiated" waves have important applications their harmonic analysis is of interest, and it can be obtained without undue difficulty when certain mathematical artifices are employed. In this paper, only the results of peaking square waves will be directly considered, though as will be shown the treatment can be extended to any type of wave.

Consider a peaked wave (Fig. 2) of period T, varying between the limits $+V$ and $-V$. Assume that the origin ($t = O$) is as shown. Then from the well known discharge law of the condenser the wave can be defined by:

$$v = f(t) = Ve^{-\frac{t}{CR}} \quad \text{from } t = O \text{ to } t = \frac{T}{2}$$

$$v = f(t) = -Ve^{-\frac{t}{CR}} \quad \text{from } t = \frac{T}{2} \text{ to } t = T$$

Inspection of the wave reveals the relation $f(t) = -f(T/2 + t)$, hence the function is "odd-harmonic" (*see* for example Eagle's "Fourier's Theorem"). The absence of even harmonics is in any case revealed by the symmetry of the wave. The Fourier series may therefore be written :—

$$v = f(t) = a_1 \cos \omega t + a_3 \cos 3\omega t + a_5 \cos 5\omega t \ldots + b_1 \sin \omega t + b_3 \sin 3\omega t + b_5 \sin 5\omega t \quad \ldots \ldots \quad (1)$$

and the coefficients are given by the expressions

$$\left.\begin{aligned} a_n &= \frac{4}{T}\int_0^{\frac{T}{2}} f(t) \cos n\omega t.dt = \frac{4}{T}\int_0^{\frac{T}{2}} Ve^{-\frac{t}{CR}} \cos n\omega t.dt \\ b_n &= \frac{4}{T}\int_0^{\frac{T}{2}} f(t) \sin n\omega t.dt = \frac{4}{T}\int_0^{\frac{T}{2}} Ve^{-\frac{t}{CR}} \sin n\omega t.dt \end{aligned}\right\} \ldots \quad (2)$$

These expressions can both be directly integrated, but it is more convenient to combine them by multiplying b_n by j and adding it to a_n.

$$a_n + jb_n = \frac{4}{T}\int_0^{\frac{T}{2}} Ve^{-\frac{t}{CR}} (\cos n\omega t + j \sin n\omega t)\, dt \quad (3)$$

$$= \frac{4V}{T}\int_0^{\frac{T}{2}} e^{-t/k} e^{jn\omega t}\, dt \quad (4)$$

(putting $CR = k$)

$$= \frac{4V}{T(jn\omega - (1/k))}\left[e^{\left(jn\omega - \frac{1}{k}\right)t}\right]_0^{\frac{T}{2}} \quad (5)$$

$$= \frac{4Vk}{T(jn\omega k - 1)}\left[e^{\left(jn\omega - \frac{1}{k}\right)\frac{T}{2}} - 1\right] \quad (6)$$

Now $\omega = 2\pi f = 2\pi/T \quad \therefore \quad T = 2\pi/\omega$

$$a_n + jb_n = \frac{2V\omega k}{\pi(jn\omega k - 1)}\left[e^{jn\pi}.e^{-\pi/\omega k} - 1\right] \quad (7)$$

By Euler's well known theorem, $e^{jn\pi} = -1$ when n is odd

$$\therefore a_n + jb_n = \frac{2V\omega k}{\pi(jn\omega k - 1)}\left[-e^{-\pi/\omega k} - 1\right] \quad \ldots \quad (8)$$

Removing complex quantities from the denominator by multiplying by $(jn\omega k + 1)$

$$a_n + jb_n = \frac{2V\omega k(jn\omega k + 1)}{\pi(n^2\omega^2k^2 + 1)}\left[e^{-\pi/\omega k} + 1\right] \quad \ldots \quad (9)$$

Equating real and unreal parts

$$\left.\begin{aligned} a_n &= \frac{2V\omega k}{\pi(n^2\omega^2k^2 + 1)}\left[e^{-\pi/\omega k} + 1\right] \\ b_n &= \frac{2Vn\omega^2k^2}{\pi(n^2\omega^2k^2 + 1)}\left[e^{-\pi/\omega k} + 1\right] \end{aligned}\right\} \quad (10)$$

Referring to Fig. 2 it will be seen that

$$V\left[e^{-\pi/\omega k} + 1\right] = V\left[1 + e^{-T/2CR}\right] = E$$

the change in voltage, or the peak-to-peak voltage of the original square wave. Thus the series may be written :—

$$v=f(t)=\frac{2E}{\pi}\sum_{n=1}^{n=\infty}\frac{\omega k}{n^2\omega^2k^2+1}\cos n\omega t+$$

$$\frac{2E}{\pi}\sum_{n=1}^{n=\infty}\frac{n\omega^2k^2}{n^2\omega^2k^5+1}\sin n\omega t \quad \ldots \quad \ldots \quad (11)$$

for *odd* values of n.

These terms may be combined to give a single sine series of the form

$$v=\sum_{n=1}^{n=\infty}A_n\sin(n\omega t+\phi_n) \quad (12)$$

where A_n is the amplitude of the nth harmonic and ϕ_n is its phase angle. In this case:—

$$A_n=\sqrt{a_n^2+b_n^2}\text{ and }\phi_n=\tan^{-1}\frac{a_n}{b_n} \quad (13)$$

Hence

$$A_n=\frac{2E}{\pi}\sqrt{\frac{\omega^2k^2}{(n^2\omega^2k^2+1)^2}+\frac{n^2\omega^4k^4}{(n^2\omega^2k^2+1)^2}}$$

$$=\frac{2E}{\pi}\sqrt{\frac{\omega^2k^2(n^2\omega^2k^2+1)}{(n^2\omega^2k^2+1)^2}}$$

$$=\frac{2E}{\pi}\frac{\omega k}{\sqrt{n^2\omega^2k^2+1}} \quad \ldots \quad (14)$$

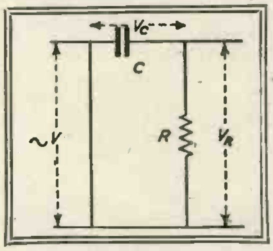


Fig. 3

and $\phi_n=\tan^{-1}\dfrac{\omega k}{n\omega^2k^2}$

$$=\tan^{-1}\frac{1}{n\omega k} \quad (15)$$

Thus the alternative form of the series is:—

$$v=\frac{2E}{\pi}\sum_{n=1}^{n=\infty}\frac{\omega k}{\sqrt{n^2\omega^2k^2+1}}$$

$$\sin\left(n\omega t+\tan^{-1}\frac{1}{n\omega k}\right) \quad \ldots \quad (16)$$

for odd values of n.

The physical meaning of this series can best be considered from a slightly different point of view. The exponential wave under consideration was obtained by passing a square wave through an R.C. coupling. As is well known a square wave with the origin chosen at the centre of a positive-going front (*see* II, table I, *Electronic Engineering*, June, 1942) may be expressed in the series:

$$v=\frac{2E}{\pi}\left(\sin\omega t+\frac{1}{3}\sin 3\omega t\ldots\right.$$

$$\left.+\frac{1}{n}\sin n\omega t\right) \quad \ldots \quad (17)$$

$$=\frac{2E}{\pi}\sum_{n=1}^{n=\infty}\frac{1}{n}\sin n\omega t \quad (18)$$

when n is odd.

If such a wave is passed through an R.C. coupling each harmonic component will be individually affected in phase and amplitude, according to the values of R, C and $n\omega$.

From elementary a.c. theory (*sec* Fig 3) if a sine wave $v=V\sin\omega t$ is applied to an R.C. coupling the output v_r across the resistance is advanced in phase by an angle ϕ and reduced in amplitude by the factor

$$\frac{R}{\sqrt{R^2+(1/\omega C)^2}}\text{ or }\frac{R\omega C}{\sqrt{R^2\omega^2C^2+1}}$$

$$\therefore v_r=V\frac{R\omega C}{\sqrt{R^2\omega^2C^2+1}}\sin(\omega t+\phi) \quad (19)$$

Now $\phi=\tan^{-1}\dfrac{1}{\omega CR}$ and putting $CR=k$

$$v_r=V\frac{\omega k}{\sqrt{k^2\omega^2+1}}\sin(\omega t+\tan^{-1}1/\omega k) \quad (20)$$

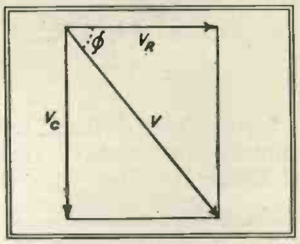
Operation on the expression for a square wave (equation 18) by the above factor gives the result:

$$v_r=\frac{2E}{\pi}\sum_{n=1}^{n=\infty}\frac{\omega k}{\sqrt{n^2k^2\omega^2+1}}$$

$$\sin\left((n\omega t)+\tan^{-1}\frac{1}{n\omega k}\right)$$

which is the equation already derived from harmonic analysis (16).

This is represented graphically in Fig. 4. a, b, c, d, e, f is a square wave of which the first two harmonics A and B are shown, together with their resultant C. When this wave is passed through an RC circuit of time constant .1 of a complete period, the exponential wave D is produced. The curves A_1 B_1 show the effect of the coupling on the original components A, B. The higher harmonic B is less affected both in amplitude and phase. The resultant of A_1 and B_1 is the wave C_1 which no longer possesses the symmetry of C and is tending towards the exponential form D. When a sufficient number of harmonics are combined the resultant is indistinguishable from D.



Vector diagram for Fig. 3

From this demonstration it follows that the harmonic content of any wave after passage through a circuit giving phase and amplitude variation may be determined without actual Fourier analysis such as that in equations 1-16.

If the series for the original wave be known, it is only necessary to operate upon it term by term by a factor expressing the characteristics of the circuit, such as was done in equation 20, and the resulting series will be that which would be obtained if the full analysis were performed. Table I in the June *Electronic Engineering* can thus be extended to deal with almost all the non-rectilinear waveforms likely to be encountered in practice.

Corrections for Data Sheets XXIX - XXXI

The following corrections should be made to the Data Sheets issued with Vol. 15, June, 1942.

D.S. 29-31 Television Waveforms

Appendix 1.—In the expansion of $\sin n(\theta-\phi)$: $(1-\cos n\phi)_2+\sin_2 n\phi$ . . . etc., should read: $(1-\cos n\phi)^2+\sin^2 n\phi$ . . . etc.

In the line below, the expression in curved brackets should read: $\cot\dfrac{n\phi}{2}$

and in the next line, $\sin\left[n\theta+\dfrac{\pi}{2}-\dfrac{\phi}{2}\right]$

should read: $\sin\left[n\theta+\dfrac{\pi}{2}-\dfrac{n\phi}{2}\right]$

Table 1.—Waveform No. 6. For $\dfrac{4E}{\pi}$ etc., read: $\dfrac{4E}{\pi^2}$ etc.

Waveform No. 7. For $e=\dfrac{2E}{\pi}$ etc., read: $e=\dfrac{4E}{\pi^2}$ and π^2 in the line below.

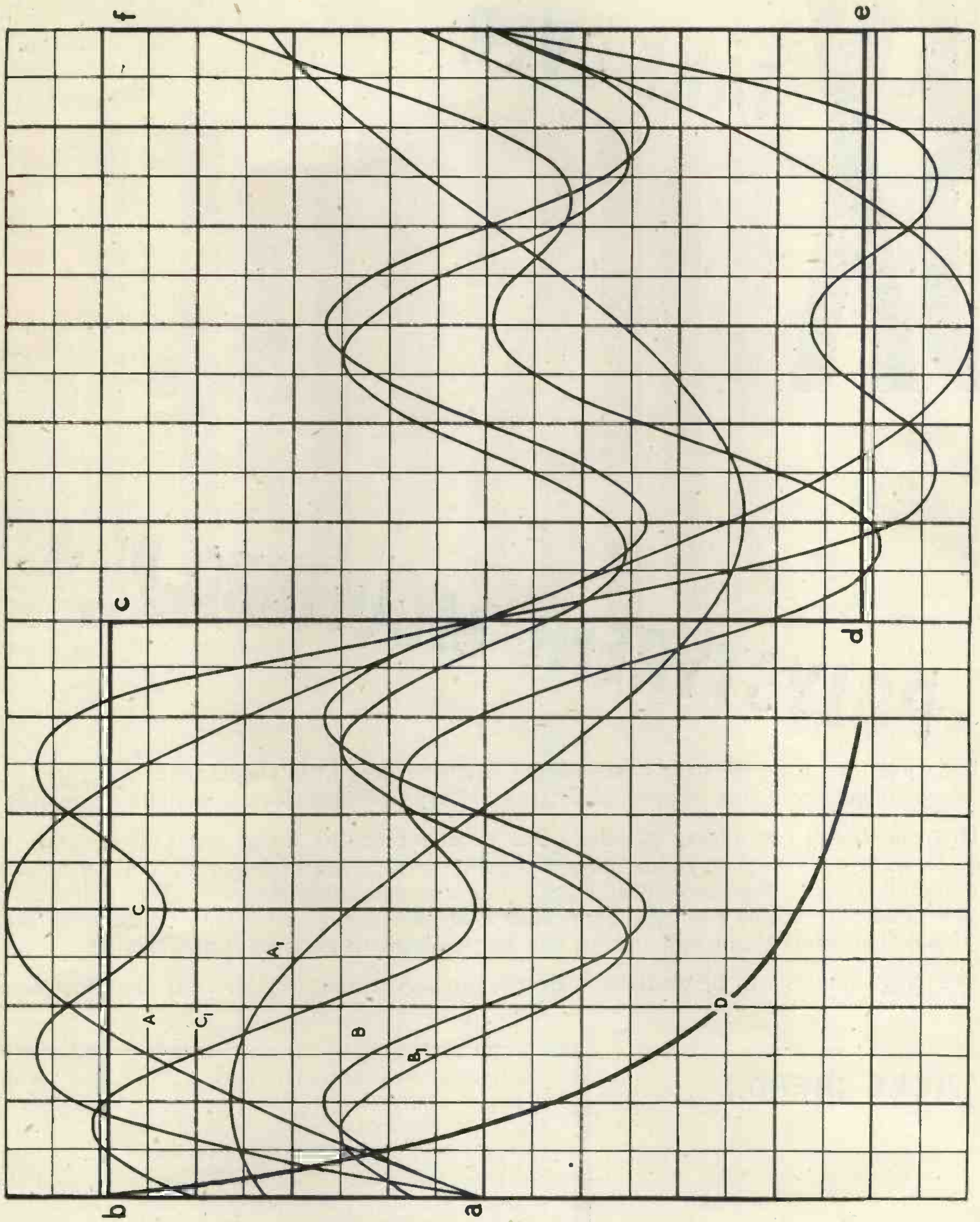


Fig. 4. Exponential Waveform resulting from Square Wave harmonics

A and B in Fig. 4 represent in manner as before the control-grid potential levels of valve V_2 between which the circuit is unstably regenerative. If the valve V_2 has been conducting we shall be concerned with that of the two transition portions of the wave form FGHIJKLMF′ in which the valve V_2 becomes less conducting with time, namely, the switching-off transition FG. At G the grid potential of V_2 has changed so much in the negative direction that the circuit has become stable again. In the process of reaching this condition the cathode of V_2 will have followed the change, with the result that on reaching G the valve V_1 whose cathode is directly connected to that of V_2 will have been carried into its most fully-conducting state. The sudden pulse of current in its anode circuit results in the building up of a potential difference across the input of the delay network in its anode circuit rather of the form of a portion of an harmonic oscillation of frequency lying in the neighbourhood of the cut-off frequency of the network. This portion of potential swing is transferred to the grid of V_2 as the portion GH of the waveform of Fig. 4. The circuit then remains quiescent as represented by the portion of curve HI until the pulse that was transmitted down the network is reflected and returns to the input in anti-phase. The reflexion is apparent at the grid of V_2 in the rising swing IJ, which carries the circuit back into instability and initiates the transition JK in which the valve V_2 becomes switched on again and valve V_1 is switched off. The cessation of the anode current of valve V_1 renders the circuit once more stable, but the swing of potential continues along KL as previously it did along GH until L is reached and the circuit is quiescent except for the propagation of the positive rise of potential down the network. The reflexion of this rise as a dip commencing at M leads to the repetition of the whole cycle.

A first point of importance about the circuit is that the period of the generated oscillation is highly stable, depending only on the time-delay of the network and not upon time constants which are apt to vary on account of resistance fluctuations. When driven by a wave of given higher frequency, say, superposed on the grid V_2, there will not therefore occur phase errors in driving on this account. Moreover, since the portion of waveform HI in Fig. 4 corresponding to TP′ in Fig. 2 is level instead of sloping, only the driving wave peak that occurs shortly subsequent to I need have any triggering effect upon the oscillator, for with a driving amplitude less than that to reach the level A from that of HI no peak can cause triggering before the point I is reached. The period IJ is clearly made most preferably about the period of one driving cycle. Ideally not more than one driving cycle should be able to function in the period; on the other hand, it is not necessary to make the period much shorter than one driving cycle. The period is determined by the design of the network. A further point of importance is that the anode current pulses may be made almost entirely independent of the valves by choosing the resistance r to be of large value so that for given values of control-grid bias potentials this resistance alone determines the amplitude of the generated pulses. Thus stability of the level HI is assured, and driving cycles occurring in the period of the portion HI must always fail to trigger the circuit.

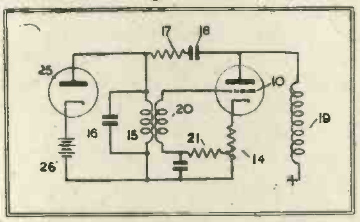
If the circuit is required to operate at low-frequencies a resistance may be shunted across the anode-to-grid coupling condenser, and if desired, the gain of such a circuit may be made independent of frequency by including a parallel resistance-capacity element in series with the impedance of the delay network in the anode circuit of V_1 the resistance and capacity being appropriately chosen.

A modified circuit that has been tried with success is one in which the short circuit is removed from the far end of the delay network and is replaced by a resistance preferably equal in magnitude to the characteristic impedance of the network. From this resistance potentials are fed back to the control-grid of the valve V_1. The circuit operation is similar to that explained earlier.

It is of very great interest that a divider employing circuits such as those just described and dividing in two stages of ten times each from one megacycle a second down to ten kilocycles a second has been in continuous operation for nearly a year without any adjustment whatever and has remained rigidly locked the whole time. The circuits have been developed in the E.M.I. Research Laboratories, and this account is given by their permission.

Stabilised Oscillator Generator

An improved oscillation generator which in addition to positive feedback at oscillating frequency provides a negative feedback at all other frequencies is described by F. E. Terman.* To prevent distortions at



the fundamental frequency, due to the positive swings of the grid, a diode is connected in series with a biasing battery for limiting the amplitude of the swing independent of the grid current.

In the circuit shown, the cathode of the triode 10 is connected to resistance 14 and the other end through coil 15 of the tuned tank circuit, resistance 17 and condenser 18 to the anode. The tank circuit 15, 16 is tuned to the operating frequency of the oscillator. Positive voltage feedback for existing oscillators in the generator is made over the lead through the inductance coil 15 to the secondary coil 20 and connected to the grid of valve 10. The other end of 20 is connected through resistance 21 to an intermediate point on the cathode resistance 14. The grid bias is furnished by the d.c. voltage drop between the cathode and where 21 connects to 14. The voltage drop gives a negative feedback voltage.

A diode connected across the tank circuit is provided with a delay biasing battery 26. This circuit serves to limit the amplitude of the oscillations generated by valve 10, the required limitation being produced by the grid current. This action necessarily increases the distortion of the generated wave. Diode 25 is biased to such a potential that before the grid of valve 10 tends to become positive, valve 25 breaks down so as effectively to short circuit the tank circuit. The amplitude of the oscillations is limited independently of the grid swing so that the oscillator may work on a straight line portion of its characteristic curve.

With this arrangement, most of the distortion in wave form results from the non-linear action of the diode and this will be small if the biasing battery is adjusted so that oscillations with the smallest possible amplitude can just be sustained.

* Pat. No. 541,423, S. T & C Ltd.

A General Purpose Coil Turns Measuring Equipment

By J. W. SNELSON and F. BRAILSFORD*

This description of a coil turns counter is reproduced by permission from the *Metropolitan-Vickers Gazette*. It is designed particularly for coils of small bore, and the number of turns on coils up to 4½ in. long having a bore of ⅜ in. diameter or more may be measured up to a maximum of 111,110 turns to an accuracy of 1 turn in 500.

ONE of the routine tests which have to be made on most types of coils used in electrical apparatus is a test to check that the number of turns is correct to within the required limits. It is essential that a tester for this purpose be simple, quick, and accurate in operation.

The present tester was required to deal with coils which, on account of their small internal bore (down to ⅜ in. diameter) could not be tested on the existing testers. Possible mechanical weakness of the core made it undesirable to use a high permeability material of the nickel iron variety which might easily be magnetically impaired in the course of use, and the tester makes use of a solid mild steel rod. In deciding to employ the ballistic principle described by Smith† it was considered necessary, for routine work, to provide for automatic reversals of the magnetising current and easy detection of the balance condition.

Principle of Operation

The principle of operation is illustrated by the elementary diagram shown in Fig. 1. The magnetic circuit is made up of mild steel bars and is magnetised by a uniformly distributed winding, as shown. The standard coils are situated below the centre of one limb, while the coil under test is slipped over the same limb, the top yoke of the magnetic circuit being detachable for the purpose. The test coil is connected in opposition to the standard coil through a turns selector switch and through the reversing switch S_2 to the d.c. galvanometer G. The magnetising winding is connected to the d.c. supply through the reversing switch S_1. Reversal of switch S_1 with S_2 closed clearly produces a throw of the galvanometer if the selected number of turns on the standard coil is not equal to that of the test coil and no deflection when, with the same flux linking both coils, the turns on the two coils are equal in number. To make the arrangement suitable for rapid routine testing, a relay of the voltage regulator type is intermittently energised through a motor-driven contact-breaker. This relay is provided with contacts corresponding to the reversing switches S_1 and S_2, which thus produce reversals of both the magnetising current, and the galvanometer connexions. The galvanometer circuit is reversed slightly in advance of the reversals of magnetising current and it will be clear that the galvanometer deflections are then always to the right or left, depending on whether the turns selected from the standard coil are greater or less in number than those of the coil under test. By the use of a suitable frequency of the reversals and a shunt producing damping on the galvanometer, a steady deflection is obtained which is reduced to zero when the correct number of turns is selected by the selector switches.

For accurate testing it is clearly essential that the total flux threading each coil must be the same within close limits. Variations of total flux along the length of the leg may be due to (a) the effect of the joints between the end pieces and the legs, (b) non-uniformity of the ampere turns per unit length, (c) non-uniformity of the permeability along the length of the leg, (d) non-uniformity of the iron cross section. The legs were made of sufficient length to provide a section in the centre, covering the standard and test

* Metropolitan-Vickers Electrical Co.
† B. M. Smith, *General Electric Review*, April, 1932. "Electric Coil Turns-Counter."

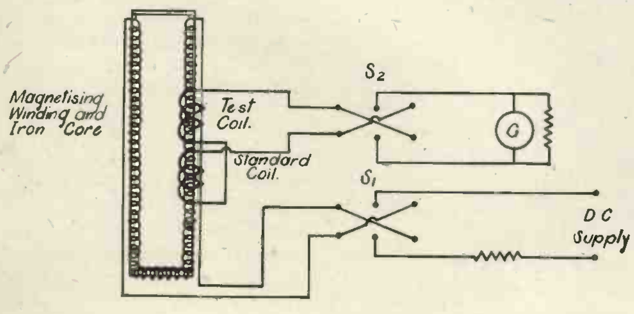


Fig. 1. (below) Simplified circuit diagram for the general purpose coil turns measuring equipment.

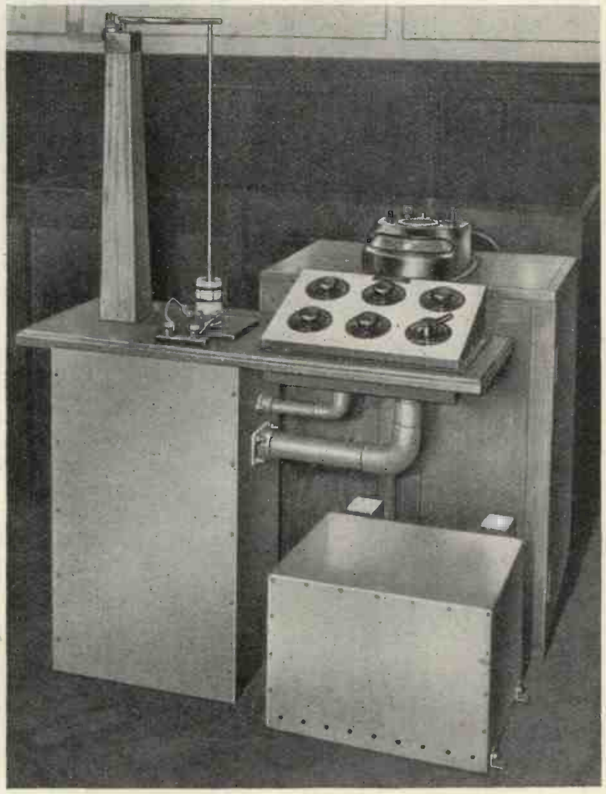


Fig. 3. (right) General view of the apparatus.

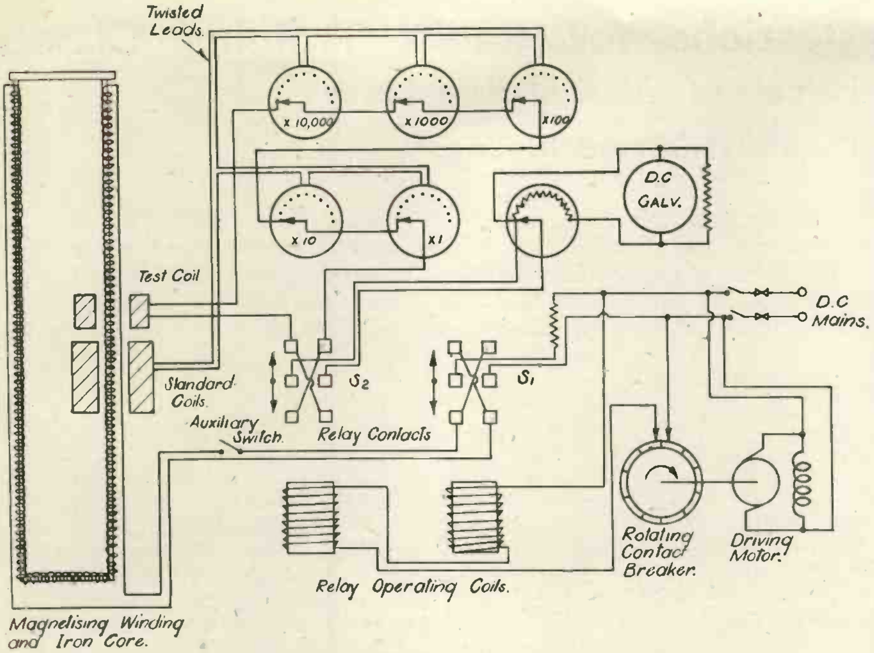


Fig. 2. Schematic diagram of the equipment.

coils, free from the influence of the joints. Quarter-inch diameter bright mild steel bar was used, this being sufficiently uniform in diameter, and great care was taken to wind the legs with a uniform continuous winding. The iron was worked at a fairly high flux density (about B 16,000 lines/cm²). By taking care with the above points, variation of total flux was kept to less than 0.2 per cent. over the required length.

Details and Performance of Tester

A schematic diagram of the tester is given in Fig. 2 and a photograph in Fig. 3.

The magnetic circuit consists of two rods of $\frac{1}{4}$ in. diameter bright mild steel bar, 48 inches long, screwed into a bottom yoke of $\frac{1}{2}$ in. square mild steel, with a hinged cross piece at the top which is lifted off to place a coil on the tester and then replaced to complete the magnetic circuit. The rods are wound uniformly with a continuous winding along the length up to $\frac{1}{2}$ in. from the top to which a mild steel ferrule is fitted. There is no winding on the top removable yoke. The core is energised from the 125 v. d.c. shop supply through a current limiting resistor.

Reversals in the magnetising current and galvanometer circuit are effected at the rate of about five per second by a voltage regulator type relay, actuated by a contact-breaker driven by a small motor with reduction gearing. Suitable Metrosil units and condensers are connected to reduce sparking and wear on the contact-breaker and vibrating contacts, which are of $\frac{1}{2}$ in. diameter silver alloy. The driving motor, contact-breaker and relay are housed in a steel case under the bench, and the supply to these and to the magnetising winding comes from the 125 volt d.c. supply through a single mains switch.

The standard coils are of compact form and consist of ten 10,000 turn coils, ten 1,000 turn coils, ten 100 turn coils, and coils of 100 turns and 10 turns tapped at each 10 turns and single turn respectively. Considerable care was taken to ensure accuracy of turn numbers, and high quality of insulation. The leads from the tappings are brought out to switches so that any number of turns up to 111,110 may be tapped off.

The galvanometer deflection for a change of one turn in a thousand is about 3 mm., and the sensitivity is arranged to be practically independent of coil resistance even on coils having a high number of turns of fine wire.

The accuracy of measurement is one turn in 500 or rather better. Coils may be tested with turns up to 111,110, and with an internal bore down to $\frac{3}{8}$ in. diameter. The maximum axial length of coil for which the stated accuracy is obtainable is $4\frac{1}{2}$ in. and coils of any radial dimensions, provided the coil can be slipped over the working leg, can be tested.

The authors acknowledge the assistance of Mr. M. Bird in the design and manufacture of the standard coils utilised in the equipment.

Experimental Demonstrations for Radio Training Classes

I.—The Effects of Internal Resistance

By T. J. REHFISCH, B.Sc. (Eng.)*

Experience has shown that there is a gap between the elementary electrical experiments of the School Certificate standard and the more advanced type of radio experimental work which may commence with tests on broadcast equipment. A number of experiments with simple apparatus have been devised to serve as an introduction to the theory of radio. The following is put forward as a useful aid to the teaching and understanding of equivalent circuit concepts.

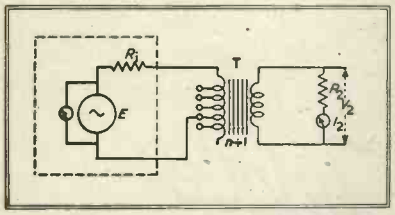


Fig. 1. Complete A.C. circuit comprising 1,000 c/s oscillator of output voltage E in series with a fixed resistance R_1, supplying the primary of the transformer T.

The load resistance R_2 is across the secondary winding in series with a milliammeter. The ratio of primary turns to secondary turns is n : 1.

The broken line encloses the source of constant voltage E and internal impedance R_1

PRACTICALLY all sources of electrical energy used in radio or communication engineering have appreciable internal resistance, and in this differ from generators of D.C. or mains frequency A.C. which are designed to have a low internal resistance (generally below an ohm).

In addition, electrical sources in radio are frequently somewhat complicated. A valve is an example and there is difficulty in comprehending the limitations of the valve equivalent circuit unless the properties of sources with internal resistance are well understood.

Analysis of the energy delivered into the load requires only simple algebra for most of the results. This will be seen from the theory given in the appendix to this article. To relieve the abstract nature of such an analysis the following experiments can be made to illustrate the physical meaning.

A high resistance source can be made up by combining a constant volttage source, *e.g.*, an accumulator or oscillator with low output impedance, with a series resistance and the behaviour of the circuit can be examined by applying this source to a variable resistance or other load and plotting the variation of current with load, etc.

Such a simple circuit serves to illustrate Ohm's Law and power calculations, but does not introduce a feature which is an important part of many A.C. circuits—the transformer. As an example we may mention the connexion of the load, *e.g.*, a loudspeaker, to the source, an output valve, through an output transformer.

The turns ratio n is defined as the ratio (turns connected to source): (turns connected to load) and the effect of changing the numerical value of n is of special interest. The usual difficulty of obtaining different ratios was overcome by using a "universal" output transformer (Goodman's Industries). By suitable series and parallel connexions, eight different ratios may be chosen, between the values 12 : 1 and 72 : 1. As the core is small, it is advisable in this case to operate with a small primary current, at not too low a frequency—say 1,000 c/s.

The complete circuit for the experiment is shown in Fig. 1: the source is the amplified output of a 1,000 c/s. oscillator (or BFO.). E is kept constant at 20 volts throughout by means of the output control and a rectifier voltmeter of either the valve or the copper-oxide type. So far, then, an ideal source of constant e.m.f. $E=20$ volts and zero internal resistance has been obtained. By placing the 5,000 ohm resistor R_1 in series with the oscillator output terminals, we now obtain a source of e.m.f. E and internal resistance R_1. The primary circuit is completed through the "high turns" of the transformer, and the secondary circuit consists of the "low turns," the 100 mA A.C. range of an Avometer, and a decade resistance box R_2, all in series.

Results obtained by varying the load and keeping n constant first at 12 : 1, then at 18 : 1 are set out in Figs. 2 and 3, V_2 and I_2 curves for n = 18 : 1 being omitted from Fig. 2. Finally, in the last part of the experiment, the load was kept constant and all the possible ratios of the transformer were used, one by one. The power in the load was calculated and is shown plotted against n in Fig. 4. It must be emphasised again at this stage that the output voltage of the oscillator was kept constant throughout, and that the meter resistance was included in the load resistance. Some general conclusions can be drawn concerning the properties of sources with internal resistance.

1. Load current decreases from a maximum value towards zero as the load resistance is increased from zero towards infinity, *i.e.*, on passing from a short to an open circuit. The maximum value of current is E/R_1.

2. As the load resistance is increased from zero to infinity load voltage increases from zero towards a constant

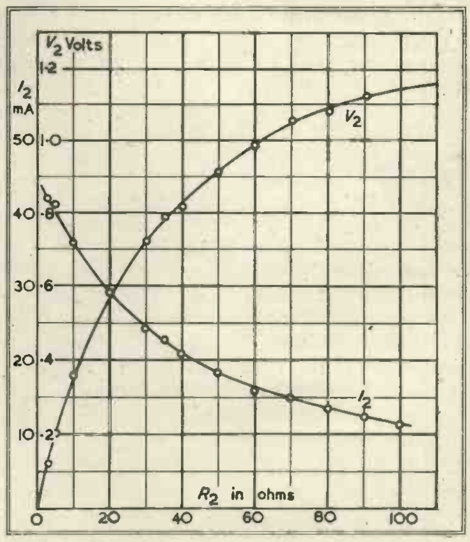


Fig. 2. Curves of load current I_2 and voltage V_2 across the secondary winding for the circuit of Fig. 1, as the load resistance R_2 is varied. E = 20 v., R_1 = 5,000 ohms, n = 12 (all constant).

* Northampton Polytechnic Institute, London, E.C.

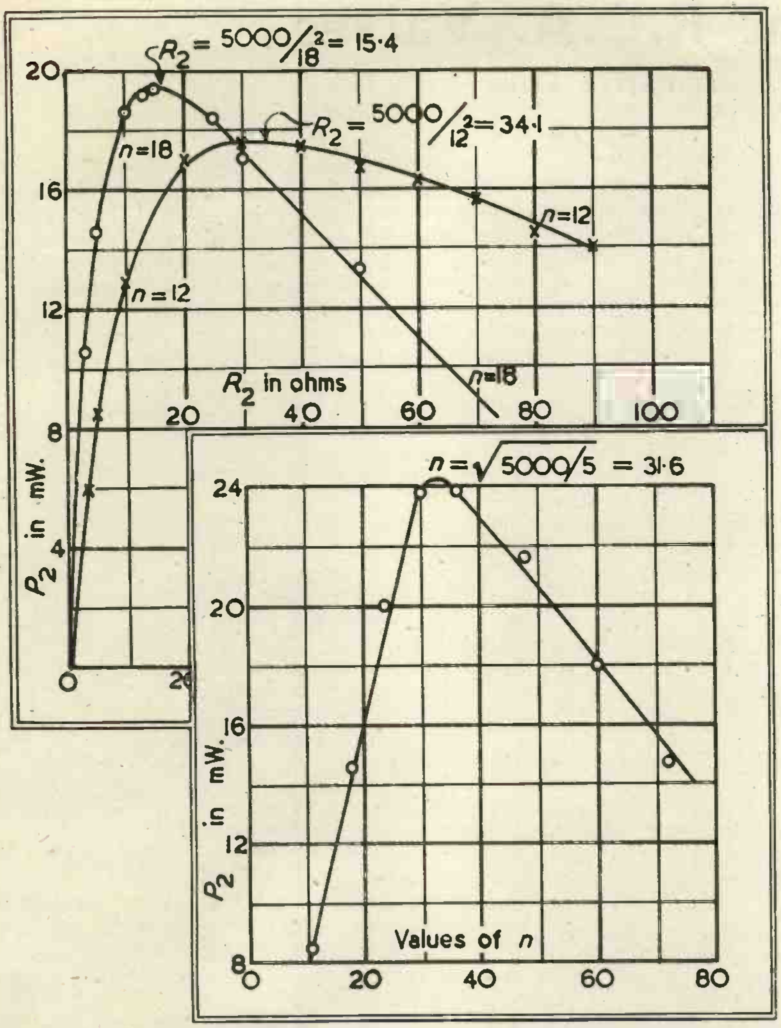


Fig. 3. (Upper curves.) The power developed in the load resistance R_2 as it is varied, with $E = 20$ v., $R_1 = 5{,}000$ ohms, $n = 12$ and 18 respectively.
Fig. 4. (Lower Curve.) Variation of load power P_2 with transformer ratio n. $E = 20$ v., $R_1 = 5{,}000$ ohms, $R_2 = 5$ ohms (all constant).

value, which theory indicates to be E, or E/n with a transformer.

3. Power in the load increases from zero towards a maximum and decreases again, though more gradually, as the load resistance is increased beyond its optimum value. The condition for maximum power or "matching" is $R = R_1$, or with the transformer, $R_2 = R_1/n^2$, $n = \sqrt{R_1/R_2}$.

The equivalent circuits of Fig. 5 may now be drawn without further comment.

The maximum power in the load is approximately equal to 20 mW here. As may be verified by checking figures, this value is equal to $E^2/4R_1$. This means that an equal amount of power must be dissipated in R_1 within the source. Hence, the A.C. efficiency of a source of this nature, defined as (power in load): (power generated by source) is only 50 per cent. for maximum power output. Although the results of the experiment allow all these conclusions to be drawn, a serious shortcoming may be observed in Fig. 3 for instance, where the maximum power seems to depend to some extent on R_2, whatever the value of n may be. This anomalous result may be explained partly in terms of the usual experimental errors (arising from imperfect observations, calibrations and frequency error of the meter) and partly in terms of the assumption that the meter impedance is purely resistive. As this will undoubtedly have an appreciable reactive component at 1,000 c/s., the power in the load will appear higher than it actually is, particularly when the meter forms the major part of the load. This difficulty will be borne in mind in designing a future experiment where power must be measured in the anode circuit of a valve. In the meantime, it may be well worth while to inspect the brief theory given below, as often no experiment, however carefully done, can surpass the easy elegance of a few algebraic equations in conveying concise and accurate information.

Appendix

With the arrangements and symbols of Fig. 5, applying Ohm's Law, the current in the circuit is

$$I = E/(R_1 + R)$$

the terminal voltage is

$$V = IR = ER/(R_1 + R)$$

and the power dissipated in R is

$$P = VI = E^2R/(R_1 + R)^2$$

To find the condition for max. P as either R_1 or R is varied, differentiate P with respect to either R_1 or R; and equate this derivate to zero, *e.g.*,

$$\frac{dP}{dR} = E^2 \cdot \frac{R2(R+R_1)-(R_1+R)^2}{(R_1+R)^4} = 0.$$

hence the result is $R = R_1$, and the load is then said to be matched to the source. For correct matching,

$P_{max} = E^2/4R$

$V = E/2$ and $I = E/2R$ (Stokes' Law)

The above theory may be extended to a load R_2 connected to the source via a perfect transformer of ratio $n:1$ when the effective load $R = n^2R_2$, the load current $I_2 = nI$ and the p.d.

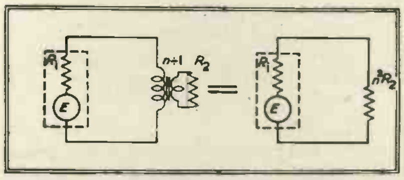


Fig. 5. Circuit with transformer coupled load and its equivalent.

across the load $V_2 = V/n$, V and I referring to the terminal p.d. across, and the current in the source, as before. A further generalisation of the theory may be obtained when the source has complex internal impedance. $Z_1 = R_1 + jX_1$; it can then be shown that the condition for maximum power with the complex load impedance $Z = R + jX$ is that $R_1 = R$ as before, and $X_1 = -X$.

Thanks are due to my colleague Mr. M. Nelkon, B.Sc., A.K.C., for his help in preparing this article.

Recent R.C.A. Valves

Tentative Data

9005.

U-H-F. Diode (Acorn Type).

The 9005 is a heater-cathode type of acorn diode suitable for use as a detector, mixer or measuring device in u.h.f. circuits. The resonant frequency of the 9005 is approximately 1,500 megacycles. D.C. output 1.0 mA. max.

Rating.

Heater Voltage (A.C. or D.C.)	3.6
Heater Current (Amps.)	0.165

Inter-electrode Capacities.

Anode to Cathode	0.8 μμF.
Anode to Heater	0.2 μμF.
Heater to Cathode	1.1 μμF.

9004.

U-H-F Diode (Acorn Type).

The 9004 is a heater-cathode type of acorn diode suitable for use as a detector, mixer or measuring device in u.h.f. circuits. The resonant frequency is approximately 850 megacycles. D.C. output 5.0 mA. max.

Rating.

Heater Voltage (A.C. or D.C.)	6.3
Heater Current (Amps.)	0.15

Inter-electrode Capacities.

Anode to Cathode	1.3 μμF.
Anode to Heater	0.3 μμF.
Heater to Cathode	2.2 μμF.

1A3.

Midget Diode.

The 1A3 is a mains type midget diode particularly useful as a discriminator valve in portable F.M. receivers and in portable high-frequency measuring equipment. Interelectrode capacities are very low and the resonant frequency isapproximately 1,000 megacycles.

The valve is fitted with a glass button base. D.C. output 0.5 mA. max.

Rating.

Heater Voltage (A.C. or D.C.)	1.4
Heater Current (Amps.)	0.15

Inter-electrode Capacities.

Anode to Cathode	0.4 μμF.
Anode to Heater	0.6 μμF.
Heater to Cathode	0.6 μμF.

1L4.

H.F. Amplifier Pentode (Miniature Type).

The 1L4 is an r.f. pentode of the miniature type with a sharp cut-off characteristic. It is recommended for use wherever a sharp cut-off pentode is required in compact, lightweight portable receivers. The valve is of interest in F.M. receivers and in other circuits not requiring A.G.C.

The 1L4 features internal shielding which eliminates the need for an external bulb shield, but a socket with shielding is essential if minimum grid to anode capacity is to be obtained. The valve is fitted with a miniature button 7 pin base.

Rating.

Filament Voltage (D.C.)	1.4
Filament Current (Amps.)	0.05
Max. Anode Voltage	110
Max. Screen Voltage	90
Min. Grid Voltage	0
Max. Total Cathode Current (mA.)	6.5
Input Capacity (μμF)	3.6

(As Amplifier.)

3A5.

H.F. Twin Triode (Miniature Type).

The 3A5 is a twin triode of the miniature type intended for use in high-frequency applications. The relatively large filament employed in the 3A5 enables it to supply the high peak currents required in r.f. power applications. In Class C service a 3A5 with its units in push-pull will deliver a power output of approximately 2 watts at 40 megacycles. It may be used at still higher frequencies with reduced efficiency. Each triode may be used independently of the other.

The filament can be operated either with series connexion on 2.8 volts or parallel connexion on 1.4 volts. The valve is fitted with a miniature button 7 pin type base.

Rating.	Series	Parallel
Filament Voltage (D.C.)	2.8	1.4
Filament Current (Amps.)	0.11	0.22
Max. Anode Voltage		135
Max. Anode Current (mA.)		5
Max. Anode Dissipation (watts)		0.5
Amplification Factor		15
Transconductance (micromhos)		1800

(As A-F Amplifier.)

1635.

Class B Twin Amplifier.

This valve is designed with a variable-mu grid to reduce distortion in the output at low signal levels. There are two ratings, one for use with sustained signal, and the other for use with variable signal only. In applications involving a sustained signal the 1635 is operated with not more than 300 volts on the anode and at that voltage can handle a power output of about 10 watts. When the valve will not be used under sustained-signal conditions, it can be operated with an anode voltage as high as 400 volts and at this voltage will handle a power output of about 17 watts.

The valve is fitted with an intermediate shell octal 8-pin base.

Rating.

Heater Voltage	6.3
Heater Current (Amps.)	0.6
Max. Anode Voltage	400
Max. Average Anode Dissipation (per anode) (watts)	4.5
Effective Load Resistance (Anode to Anode) (ohms)	14,000

(With Variable Signal.)

6C4.

H.F. Power Triode (Miniature Type).

The 6C4 is a heater-cathode type of miniature valve intended for use as Class C amplifier and oscillator in compact, light weight, portable equipment, but it is useful in other applications where a medium-mu miniature triode with high transconductance is desired. In Class C service, the 6C4 will deliver a power output of about 5.5 watts at moderate frequencies and 2.5 watts at 150 megacycles.

The valve is fitted with a miniature button 7-pin type base.

Rating.

Heater Voltage (A.C. or D.C.)	6.3
Heater Current (Amps.)	0.15
Max. Anode Voltage	300
Max. Anode Dissipation (watts)	3.5
Amplification Factor	17
Transconductance (micromhos)	2,200

(As A-F Amplifier.)

1642.

Twin-Triode Amplifier.

The 1642 is a valve which contains two medium-mu triodes in one bulb (mu – 10.4). Each triode unit has separate terminals for all electrodes except the heater which is common to both. The valve is fitted with a small shell 7-pin micanol base.

Rating.

Heater Voltage (A.C. or D.C.)	6.3
Heater Current (Amps.)	0.6
Max. Anode Voltage	250
Max. Anode Dissipation (watts)	2.1
Grid Voltage	–16.5
Anode Resistance (ohms)	7,600
Transconductance (micromhos)	1,375

(As Amplifier.)

3A4.

Power Amplifier Pentode (Miniature Type).

The 3A4 is a miniature type of power amplifier pentode designed for use in compact, light-weight portable equipment. The relatively large filament employed in the valve enables it to supply the high peak currents required in r.f. power applications. In r.f. amplifier service, the 3A4 will deliver a power output of about 1.2 watts at 10 megacycles. The filament of the 3A4 can be operated either with series connexion on 2.8 volts or parallel connexion on 1.4 volts.

The valve is fitted with a miniature button 7 pin type base.

Rating.	Series Filament	Parallel Filament
Filament Voltage (D.C.)	2.8	1.4
Filament Current (Amps.)	0.1	0.2
Max. Anode Voltage		150
Max. Screen Voltage		90
Max. Anode Dissipation (watts)		2
Grid Voltage		–8.4
Anode Resistance (ohms)		100,000
Transconductance (micromhos)		1,900
Load Resistance (ohms)		8,000

(As A-F Power Amplifier.)

829 A.

Push-pull R.F. Beam Power Amplifier.

The 829A is an improved design of the 829 and permits operation at higher anode voltage and provides improved efficiency and performance at ultra-high frequencies.

It is a universal type push-pull, beam power transmitting valve and contains two beam power units in one bulb. The total maximum anode dissipation is 40 watts. The efficiency and high power sensitivity permits full power output with very low driving power. A single valve operated in push-pull Class C service is capable of handling a power input of 120 watts with less than 1 watt of driving power at frequencies as high as 200 Mc. The valve may be operated at reduced ratings at frequencies as high as 250 Mc.

Neutralisation of the valve is unnecessary in adequately shielded circuits. The heaters are arranged to allow operation from either 12.6 or 6.3 volt supply.

Rating.

Heater Current per unit (Amps.)	1.125
Transconductance (I_a 60 mA.) (micromhos)	8,500
Grid-Screen Mu-Factor	7
Max. Anode Voltage	750
Max. Screen Voltage	225
Max. Grid Voltage	–175
Max. Anode Current (mA.)	240
Power Output (approx.) (watts)	87
Input Capacity ($\mu\mu$F)	14.5

(As Push-pull R. F. Amplifier and Oscillator.)

832 A.

Push-pull H.F. Beam Power Amplifier.

The 832-A is an improved design of the 832 and permits operation at higher anode voltages and provides improved efficiency and performance at ultra-high frequencies.

It is a universal type of push-pull, beam power transmitting valve and contains two beam power units in one bulb. The valve is designed primarily for use as a push-pull amplifier with maximum ratings at frequencies as high as 200 Mc. and with reduced ratings at frequencies as high as 250 Mc. The total anode dissipation is 15 watts for Class C service.

Neutralisation of the value is unnecessary in adequately shielded circuits. The heaters are arranged to allow operation from either 12.6 or 6.3 volt supply.

Rating.

Heater Current per unit (Amps.)	0.8
Transconductance (I_a 30 mA) (micromhos)	3,500
Max. Anode Voltage	750
Max. Screen Voltage	250
Max. Grid Voltage	–100
Max. Anode Current (mA.)	90
Max. Anode Input (Watts)	36
Driving Power (approx.) (watts)	0.19
Power Output (watts)	26
Input Capacity ($\mu\mu$F)	7.5

(As Push-pull R. F. Amplifier and Oscillator.)

1644.

Twin-Pentode Power Amplifier.

A valve containing two power amplifier pentodes in the same bulb with a common cathode. The 1644 is useful in the output stage of compact, light-weight equipment where moderate power output is desired. The units may be connected in push-pull or in parallel.

The valve is fitted with an intermediate shell octal 8-pin base. Anode dissipation 2.5 watts.

Rating.

Heater Voltage (A.C. or D.C.)	12.6
Heater Current (Amps.)	0.15
Max. Anode Voltage	180
Max. Screen Voltage	180
Grid Voltage	–9
Anode Resistance (Megohm)	0.16
Transconductance (micromhos)	2,150
Load Resistance (ohms)	10,000
Power Output (watts)	1.0

(As Amplifier.)

872 A/872 and 8008.

Half-Wave Mercury Vapour Rectifiers.

The 872-A/872 is a half-wave mercury-vapour rectifier superseding the 872-A and the 872. The 8008 is a new valve having the same electrical characteristics as the 872-A/872, but fitted with a heavy duty push type base.

These new valves combine the ability of the 872-A to withstand high peak inverse voltages and the ability of the 872 to conduct at relatively low applied voltages. Both types employ a ceramic cap insulator to minimise the danger of bulb cracks caused by corona discharge.

Two 872 A/872's or 8008's used in a full wave rectifier circuit can provide 3,180 volts at 2.5 amperes.

Rating.

Filament Voltage (A.C.)	5.0
Filament Current (Amps.)	7.5
Peak Inverse Voltage.	
Mercury Temp. 20° to 60° C. (max.)	10,000 volts.
Mercury Temp. 20° to 70° C. (max.)	5,000 volts.
Peak Anode Current (Amps.) (max.)	5

* For supply frequency up to 150 c/s.

NOTES FROM THE INDUSTRY

Important Notices

Security of Service Information

We have been requested to draw the attention of all firms who have dealings with members of H.M. Forces to the importance of safeguarding service information which they may possess.

Many firms will inevitably obtain in the ordinary course of their business, service information relating to the names of units and their locations and movements.

Whilst the location of an individual unit will be widely known and may not be of great importance, information about the locations of many units would be of considerable value to the enemy and should therefore be treated as confidential.

Any lists of service addresses, or correspondence from which such lists could be compiled, should be safeguarded from falling into unauthorised hands and should be kept under lock and key.

The locations and movements of troops should not be discussed on the telephone.

Members of H.M. Forces who purchase certain articles of clothing or equipment have to certify that the articles are required for service purposes. In doing so, they should only sign their name and rank (with their regiment or corps, in the case of Army officers), but must *not* give their unit name. They should not be asked to give any further particulars.

War Risks Insurance

The Board of Trade have reason to believe that a number of traders and firms who are required to insure their stocks or equipment under Part II of the War Risks Insurance Act, 1939, or Part II of the War Damage Act, 1941, as the case may be, are failing to comply with their statutory obligations by either not insuring at all or insuring for a sum considerably short of the full value for which the law requires them to insure.

A number of prosecutions have recently been instituted by the Board against persons who have failed to comply with their obligations and traders are warned that the Board will not hesitate to enforce the provisions in question wherever necessary.

The Radio Valve (Maximum Prices) Order, 1942

THE Board of Trade, after consultation with the Central Price Regulation Committee, have made an Order controlling the prices to be charged by official selling agents, wholesalers and retailers of all radio valves imported under the Lease Lend provisions. These prices are set out in Related Price Lists which have been certified by the Board of Trade, copies of which are lodged with the Board of Trade, the Central Price Regulation Committee and each of the Local Price Regulation Committees.

The Order provides that all agents or wholesalers dealings in these valves must supply, either before or at the time of delivery to their customers, a written notice (which can, if desired, be incorporated in the invoice) stating the correct maximum prices for the valves in question. All retailers selling these valves must display in a prominent position in their shops a notice giving the maximum price appropriate to any of these goods offered for sale by them.

This Order, which is to be known as the Radio Valve (Maximum Prices) Order, 1942, S.R. & O. 1942, No. 1934, came into force on September 28, and is obtainable on ordering through any booksellers or newsagents or direct from H.M. Stationery Office, York House, Kingsway, London, W.C.2, price 1d. (post free 2d.).

Brit. I.R.E.

At a meeting of the British Institution of Radio Engineers on Friday, September 25, at the Federation of British Industries, Westminster, S.W.1, Dr. James Robinson read a paper on "Aspects of Modulation."

The relative merits of amplitude modulation and frequency modulation occupied the major part of the paper, with special reference to the author's "Stenode" system as applied to transmission and reception, the demodulation of a weak signal by a strong one at the detector being explained in detail. He showed mathematically and by diagrams what happened to a frequency modulated signal when it was interfered with by an amplitude carrier.

Dr. Robinson declared that he would be satisfied with his efforts if he had made clear to those present this phenomenon of detector discrimination, which was really the secret of the success of the Stenode. He thought it was little understood by engineers generally.

This paper was preceded by the inaugural address of Sir Louis Sterling on assuming the Presidency of the Institution. In the course of this address Sir Louis strongly advocated the registration of radio engineers, and also dealt with the methods which should be adopted to secure specialised technical training.

Proposed Club for Scientific Kinematographers

A proposal has been put forward to form a Club for the benefit of workers who use the 16 mm. Cine-Kodak Special for the making of scientific technical and medical films.

The objects of the Club will be to promote interest in the production of such films and to afford members an opportunity to discuss technical problems connected with these particular branches of sub-standard kinematography.

It is intended to hold an inaugural meeting during the month of November, which coincides with the Exhibition of Scientific Photography being held during that month by the Association of Scientific Workers in conjunction with the Royal Photographic Society at the premises of the Society, 16 Prince's Gate, London, S.W.1.

Any person who is interested in the production of 16 mm. scientific, medical or technical films is invited to communicate with Mr. R. Mc. V. Weston, "Houndwood," Farley, Salisbury, Wilts., from whom further particulars can be obtained.

The British Kinematograph Society

We have received the following Provisional Lecture Programme for 1942-1943 from the British Kinematograph Society:

Nov. 18—"The 16 mm. Film in War-time." A symposium. Speakers to to be announced. The 16 mm. film has found many specialised applications, which will be illustrated by the projection of films.

Feb. 17—"Set Design and Construction" by A. E. Carrick. The work of the Art Director—Modern methods of construction—Influence of war-time difficulties.

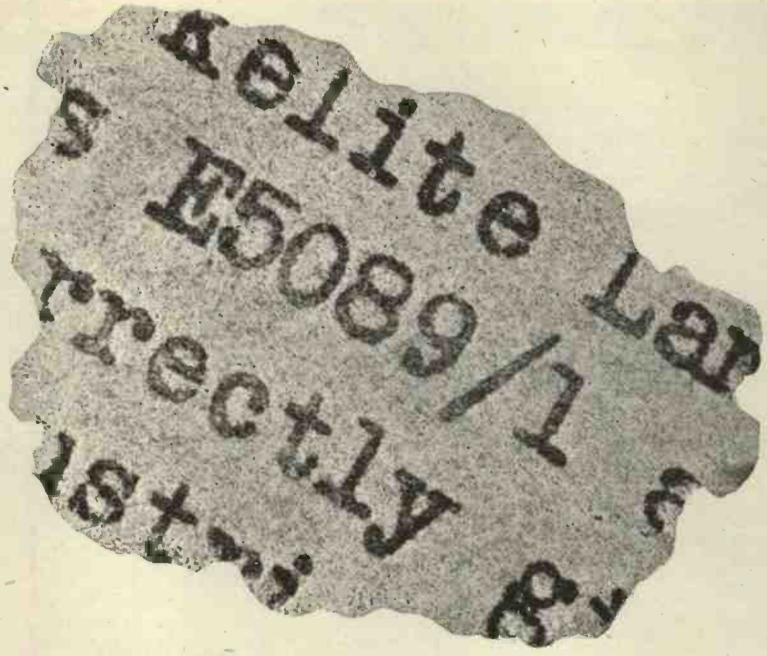
Mar. 17—"Accoustics and the Motion Picture," by N. Fleming D.Sc. Recent progress in acoustics, and its application to the sound film, will be discussed by the N.P.L. specialist.

Apr. 14—"Planning a Production" by Tom White. A survey of the work which precedes the photographing of a film.

Meetings are normally held at the Gaumont-British Theatre, Film House, Wardour Street, W.1, commencing at 6 p.m.

Tickets of admission for non-members can be obtained from the organising Secretary, Mr. R. Howard Cricks, at Dean House, Dean st., London, W.1.

(*Continued on page* 258)



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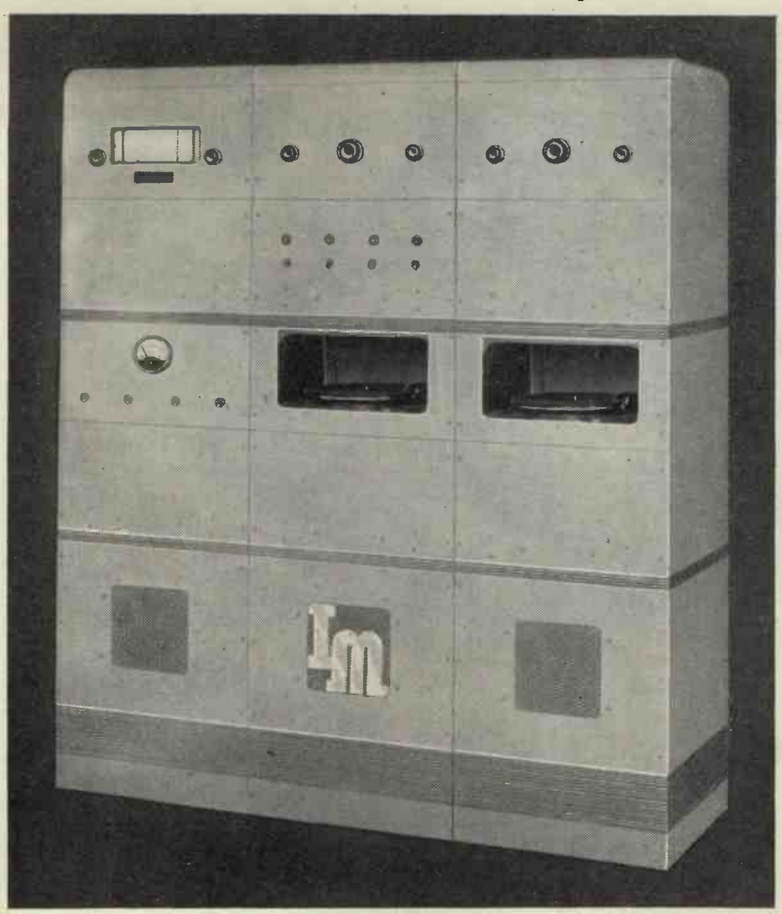

IT is generally accepted that amplifier installations for "Music while you Work" have proved their worth in producing increased output and pleasanter working conditions.

The illustration shows a large amplifier rack recently built by Messrs. Imhof to the requirements of a factory, which feeds several banks of speakers for relaying music and speech.

The rack is built on the unit system and contains in addition to the amplifiers, twin Garrard turntable and a radio receiver. The latter, which is seen at the top left-hand corner, is a 5-valve superhet with three wavebands.

The amplifiers are housed behind the blank panels shown in each rack and consist of 6V6 valves in cascade, resistance coupled which feed 2 6L6 output valves in push-pull. The power output is approximately 60 watts per amplifier, which is distributed to the banks of speakers through the distribution panel on the left hand rack.

An output meter can be switched into each speaker circuit, and below the amplifier racks are three monitoring speakers behind grilles.

The centre and right hand top panels contain the fader for microphone and pick-up and a bass and treble control. The speaker banks are isolated by means of the switches above the centre turntable.

Provision has been made in the microphone circuit for priority calls, a selected microphone being fitted with a relay which cuts out the pick-up or other microphone in action and superimposes the priority call on the system. At the end of the message the circuit is automatically restored to its original condition.

The whole amplifier equipment operates from 200-240 v.A.C. and occupies a floor space of approximately 5 ft. by 18 in. deep. The overall height is 5 ft. 10 in. The panels are finished grey crackle with chromium plated ornaments and the appearance is smart and business-like.

Single amplifiers can also be obtained at prices ranging from £20 to £70 with outputs of 15, 30 or 60 watts, and any number of these can be combined to suit individual requirements.

Further details can be obtained from Messrs. Alfred Imhof, Ltd., 112 New Oxford Street, W.C.1.

Notes from the Industry (*concluded*)

I.E.F. Wireless Section

At the first meeting of the 1942-3 session of the Wireless Section of the I.E.E. on October 7, appreciation was expressed of the work of the retiring Chairman, Mr. H. Bishop, C.B.E., and the new Chairman, Dr. R. L. Smith-Rose, delivered his inaugural address.

The final section of the paper dealt with refinements in the measurement of the velocity of light and wireless waves. The work of Michelson, Pease and Pearson, in America, using a rotating mirror and a vacuum tube a mile long, was described, and also the recent work of W. C. Anderson with more compact apparatus, using a Kerr cell with frequencies up to 56 Mc/s as an interrupter. Both methods gave a value of 2.9977×10^{10} cm/sec. in vacuo.

Dr. R. L. Smith-Rose will deliver a paper jointly with Miss A. C. Stickland, M.Sc., at the meeting of the Section on Wednesday, November 4, at 5.30 p.m. The subject will be "A Study of Propagation over the Ultra-Short-Wave Radio Link between Guernsey and England on wavelengths of 5 and 8 metres." At the informal meeting on Tuesday, November 17, at 5.30 p.m. a discussion on "Plastics in Radio Production" will be opened by C. C. Last.

Electronics Group

A further meeting of the Electronics Group will take place on Wednesday, November 25, 1942, at 3.0 p.m., in the Lecture Theatre of the Royal Institution, Albemarle Street, Piccadilly, W.1, when a paper will be given by Mr. G. T. Winch, A.M.I.E.E., F.Inst.P., of the Staff of Messrs. General Electric Company, Ltd., Wembley, on the subject "Photocells and their Applications." Opportunity will be given for discussion.

ASLIB

ASLIB (Association of Special Libraries and Information Bureaux) will hold its seventeenth conference, by kind permission, at the rooms of the Royal Society, Burlington House, Piccadilly, W.1, during the week-end of November 7 and 8, 1942.

The annual general meeting will be followed by an "open meeting" at 12 noon, under the chairmanship of Sir Harry Lindsay, K.C.I.E., C.B.E., President of ASLIB, when Sir Richard Gregory, Bart., F.R.S., will speak on "International Systems and Standards." No conference fee will be charged for this meeting, but those wishing to attend should apply in writing for a ticket of admission to the Secretary, 31 Museum Street, W.C.1.

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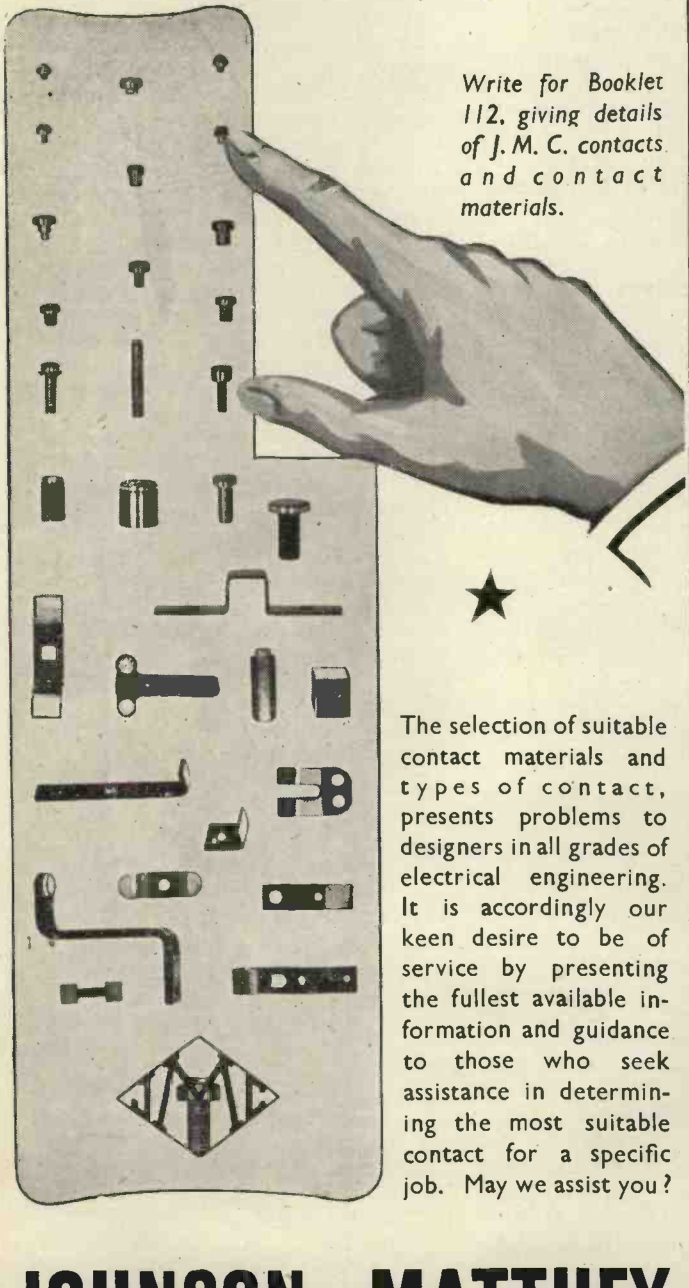

Write for Booklet 112, giving details of J. M. C. contacts and contact materials.

★

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CORRESPONDENCE

Planned Research

From Prof. A. G. Tansley, F.R.S.

DEAR SIR,—In the leading article on this subject in your September issue it is very truly remarked that "a great deal seems to depend on the precise definition of the word 'planned.'" It must surely be obvious to everyone that no consecutive research of any kind can be carried out unless there is some "plan" in the mind of the investigator. But we must further recognise that the complexity and wide range of much modern scientific research requires the co-operation of several or many workers, and that these must work to a "plan." This is seen in new fields of pure science where the ground has to be initially explored by wide surveys of the phenomena involved, where the validity of a hypothesis has to be tested in a great number of examples, and again where the solution of a complex problem requires series of experiments far too numerous to be undertaken by a single worker. All such work must be carried out to plan.

In what is properly called "applied science" extensively planned work has been and is being carried out in the biological fields of agriculture, medicine and nutrition, and we may expect to see work of this kind greatly increased and extended to other spheres directly affecting the welfare of the people, sometimes at the instance of Government Departments and often through the agency of official or quasi-official scientific bodies. Such work serves purposes of great social importance and is an excellent example of the application of science to the service of humanity.

The Society for Freedom in Science was formed primarily to combat the dictation and regimentation of scientific work by the State—in other words "central planning" as practised by totalitarian regimes. The Society desires to uphold the *autonomy* of science, such organisation and planning as is necessary being carried out by responsible men of science, and not by an external governmental authority. Dr. Baker's book, to which your leader refers, points out and illustrates by abundant examples the undoubted fact that the greatest and most fundamental discoveries have always been made by individuals freely working on their freely chosen material without regard to practical utility, and not as the result of planning in the interests of the community. Since it is likely in the future that little money for research will come from any other than public sources, a considerable share of the state funds available for science should go to properly qualified investigators freely working at their own problems without any regard to practical use; though a great deal, of course, will be quite properly allocated to collective research planned for the promotion of the general welfare work, which has an increasingly important function in national life, but is not the source of fundamental discovery.—Yours truly,

Grantchester. A. G. TANSLEY.

Magic Eyes

DEAR SIR,—On the subject of the Magic Eye Resonance Indicator, Mr. George A. Hay is quite correct in claiming priority for the suggestion that a cathode resistor gives increased sensitivity due to positive feedback. References to his paper and to several others were omitted from my note on the score of brevity.

I do not agree with Mr. Hay's statement that the circuit concerned is ineffective at audio frequencies. The inside of the "eye" is illuminated, owing to the A.C. component of the anode current, but if the bias is carefully adjusted, the D.C. component is still visible as another shadow superimposed on the first. Its edges move outwards as resonance is approached, and at that point, they become sharp rather suddenly. There is no uncertainty about the indication, and at 600 cycles/sec., a satisfactory response is obtained with 0.3 volts RMS input.

The primary cause of the reduced sensitivity of the Magic Eye at high frequencies is the capacitative input impedance of the valve. This impedance becomes smaller as the frequency is increased and leads to an error of the same nature as that arising from the use of a low-resistance voltmeter. The phase changes mentioned by Mr. Hay are secondary effects, and should not be important at 5 Mc/s.

Mr. Hay's statement that "Most of the increase in sensitivity is due to the presence of D.C. feedback" is incorrect. The D.C. feedback across the cathode resistor in the resonance indicator serves only to give the grid a negative bias, and to obtain increased sensitivity it is necessary to have A.C. feedback, in phase with the input.—Yours faithfully,

J. M. A. LENIHAN.

Newcastle-upon-Tyne.

Long-Tailed Pairs

DEAR SIR,—I am very grateful to Dr. Ipfeed and Mr. Puckle for their criticisms of the terminology used in my article "The C-R-O used stroboscopically," and regret that I was prevented from replying in time for inclusion in your last issue. I agree entirely that "the use of laboratory slang is desirable provided the meaning is clear and accurate and that the words save time and are euphonious." It is, therefore, unfortunate that in an attempt to satisfy the latter condition by the use of "scalariform," I should have been betrayed into a violation of the former. With regard to "risers" however, I consider that it fulfills all conditions and that its use is preferable for that reason to the purist "that part of the waveform at which the rate of charge of the condenser C is increased above the normal by the application of an increase of potential to the grid of the valve VT in Fig. 6."

With regard to "long-tailed pair," I regret that I was under a misapprehension about the familiarity of this term and I would like to apologise to any readers for whom it had no meaning. I hope to attempt to remedy this position, however, by publishing a summary of the theory and applications of this very useful circuit arrangement.

I would like to take this opportunity to disagree with Mr. Puckle on the question of the method of drawing circuit diagrams. Presuming Mr. Puckle's preference to be for the use of direct instead of looped cross-overs I would like to suggest a consideration of the following practical and psychological points:

1. It is sometimes difficult in printing processes to prevent the possibility of a direct cross-over blurring into a dot, especially when the diagram is on a reduced scale.
2. In general, a draughtsman will tend to omit loops less frequently than he will omit dots, and in the use of looped cross-overs the omission of a dot will be a matter of negligent consequence.
3. In a diagram containing both direct cross-overs and dots the eye tends to "see" dots at every cross-over.

The results of experiments conducted by workers of the Gestalt school of psychology (see "A Source Book of Gestalt Psychology") confirm these two last points.—Yours faithfully,

GEOFFREY BOCKING.

DEAR SIR,—I read with interest the letters by Dr. Ipfeed and Mr. Puckle, and feel impelled to add my name to those who, like your correspondents, object to the use of laboratory slang in technical literature on the score that it tends to detract from clarity. The use, wherever possible, of standard terms in the text and standard symbols in the illustrations (to take up the point in the last paragraph of Mr. Puckle's letter) should, to my mind, be the first essential of technical literature; where, however, novelty of subject demands new terminology then each new word should be defined by the author. I speak with some feeling because only recently I was greatly puzzled by the term "long-tailed pair" which I met for the first time, and I remained puzzled until by good fortune, I came across an article in which the author had the blessed sense to define his use of this term. His definition occupied a mere paragraph, yet how it added to the ease of digestion of the remainder.

I do not agree with the editorial comment on the last paragraph of Mr. Puckle's letter. I strongly advocate the use of standard symbols in electrical circuit diagrams, and I see no reason for departing from the standards laid down in the British Standard Specification. Surely the fact that the use of "straight line across and dots" method of representing conductors crossing has been recommended internationally by the International Electrotechnical Commission and in this country by the British Standards Institution is sufficient reason for the adoption of this standard? With regard to its alleged lack of clarity, I can say that I have used the standard considerably and find it no less clear than the alternative loop.—

Yours faithfully,

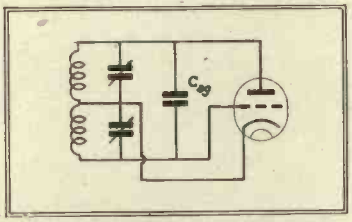
Farnborough. S. JONES.

The T.A.-T.G. Oscillator

DEAR SIR,—In the October issue of *Electronic Engineering* you published an article on the T.A.-T.G. oscillator by G. P. Pollard. Mr. Pollard starts his article with a short reference to the tuned anode feed back circuit (reverse feed back). He states that the frequency of oscillation does not depend on the coupling M. This result is, of course, only true if one entirely ignores the circuit attached to the grid regarding it as an open one. If one introduces the effect of grid current i_g for example, the theory clearly shows that its considerable adverse effect on frequency stability was to have been expected. The characteristics of the grid circuit (and for that matter of the anode circuit) would appear to have an importance which diminishes with the tightness of the coupling.

A very simple theoretical method of regarding the T.A.-T.G. oscillator may be of interest. I do not suppose it is an original exposition of the oscillator, but it seems to be very little known (though I am told that Terman has published a similar explanation).

From an A.C. point of view the circuit may be drawn thus :



In order that the phase of the anode and the grid should differ by π radians it is essential that the anode circuit and the grid circuit should offer the same kind of impedance to the frequency of oscillation, in other words, they should both be "tuned" either inductively, capacitatively, or resistively. If they are capacitative or resistive in effect then the whole circuit is non oscillatory; but if they are both inductive it is. The theory can then be deduced exactly as for a Hartley circuit except, of course, that the coil is supposed to have no magnetic coupling between its parts. This simple theory shows, too, very clearly the importance of the size of C_{ag} and its effect on the frequency stability.

Cranwell. P. GOUGH.

DEAR SIR,—Para. 1 of Mr. Gough's letter seems to bear no relation to the T.A.-T.G. oscillator, but to be merely a criticism of an obvious assumption relating to an introductory statement.

The approach to the oscillator used in the article assumes the generator to be producing *stable* oscillations and a full investigation into the factors underlying frequency stability was not part of my scheme. The facts mentioned by Mr. Gough regarding the stability of the T.A. oscillator, together with the stabilising circuits (but no full theory, including the effect of grid current) are to be found in Terman's *Radio Engineering*, Chap. 8, para. 67.

The explanation of the action of the T.A.-T.G. oscillator by conversion to a conventional Hartley circuit seems useful if only a simple physical explanation of its action is required.

It seems to me that for the phase of the anode and grid to differ by π radians in the circuit shown, the reactances of the respective circuits only are being considered; if the impedances are considered, the phase relationship will be approximately π radians difference—a minor point.

Twickenham. G. P. POLLARD.

Standards for Recording

An American committee of the NAB have issued a list of recommended standards for disk recording, from which the following main points are extracted :

Recorded Level.

The programme level measured by the standard volume indicator shall be the same as the level required to record a 1,000 c/s note at a velocity of 5 cm./sec. This standard contemplates peaks running as high as 15 cm./sec., which is the maximum velocity which can be traced without distortion in the inner radius of a 33⅓ r.p.m. disk.

Signal-Noise Ratio.

The noise level measured when reproducing a record over a frequency range of 500-8,000 c/s. shall be at least 36 db. below the level obtained under the same conditions when using a 1,000 c/s note at 5 cms./sec. This measurement is intended to give a fixed reference level for measuring noise.

Centricity of hole in disk.

The hole in the disk shall be concentric with the recording groove spiral to within 0.003 in.

Turntable Diameter.

Minimum diameter of the reproducing turntable shall be 15⅝ in.

Turntable Torque.

Minimum torque at the turntable shall be 100 in. ozs.

Turntable Speed.

Average speed of turntable shall be 33⅓ or 78.26 r.p.m. ± 5%.

"Wow" Factor.

Maximum instantaneous deviation from the mean speed of the reproducing turntable shall not exceed ± 0.3% of the mean speed.

Tracking Error of Pickup.

The maximum tracking error shall be 6° at 4 in. diameter and 10° at 15½ in. diameter.

Pickup Weight.

The maximum vertical force required by the pick-up shall be 1½ oz. (42 gm.)

In addition to the above standards the committee recommend the adoption of a glossary of recording standards which includes most of the terms peculiar to the art. This is not available at the moment.

—*Communications*, August, 1942.

ABSTRACTS OF ELECTRONIC LITERATURE

CATHODE-RAY TUBES

The Relative Sensitivities of Cathode-Ray Tubes, Photographic Film and the Human Eye
(A. Rose)

The threshold scene brightness which a picture-reproducing device can record, a measure of its "operating sensitivity" depends not only upon the lens speed and the exposure time, but also upon the amount of detail and the recorded image. A general expression for the "operating sensitivity" of a picture reproducing device is obtained which includes these factors together with the threshold number of quanta per picture element. This parameter characterises the "true sensitivity of the given device. The "true" and "operating" sensitivities of four types of cathode-ray tubes, photographic film, the human eye and an ideal picture-reproducing device are obtained.

To compare "operating sensitivities" the same exposure time and equivalent lens systems are taken for the three devices.

—*Proc. I.R.E.,* Vol. 30, No. 6 (1942), page 293.

RADIO

TRANSMISSION

A New Frequency-Modulation Broadcasting Transmitter
(A. A. Stene and N. C. Olmstead)

A new frequency modulation transmitter is described which uses a novel amplifier circuit permitting an unusually simple mechanical design and an economical valve complement. The choice and design of circuit components governed by both mechanical and electrical considerations are discussed in detail.

—*Proc. I.R.E.,* Vol. 30, No. 7 (1942), page 331.

RECEPTION

Amplitude, Frequency and Phase Modulation Relations
(A. Hund)

Comparisons between the three methods of modulation are treated from the standpoint of mode of operation, modulation factor and frequency spectrum. Graphical means of determining the frequency spectrum for frequency and phase modulation are indicated.

—*Electronics,* Vol. 15, No. 9 (1942) page 48.

CIRCUITS

Types of Light Cells and Their Circuits
(V. H. Gilbert)

The construction of various types of light-sensitive devices, comprising selenium resistance-type, gas-filled and vacuum photo-cells and selenium self-generating cells is described and the circuits with which they are associated are shown. Circuits illustrating the use of photo-cell in a simple impulse circuit and a simple balanced A.C. bridge circuit which makes use of a selenium bridge are also described. Selenium self-regenerating cells are useful as a basis for light, exposure and gloss meters, but do not find much application for quantitative measuring work.

—*El. Trading,* August, 1942, page 30*.

Wave Form Circuits for Cathode Ray Tubes
(Lewis)

Fundamentals governing the operation and construction of the cathode-ray tube are reviewed and details of several types of circuits which are suitable for generating saw tooth waveforms are given. Two circuits, the multi-vibrator and blocking oscillator, which are capable of generating impulse waveforms, are also described and the synchronisation of relaxing oscillations on to other waveforms is explained.

—*Electronics,* July, 1942, page 44.*

THEORY

Transient Temperatures in the Anode of an X-Ray Tube
(F. R. Abbott)

The rapid heating and cooling cycle of the focal area of a high speed radiographic X-Ray tube anode results in short life, although maximum temperatures produced are not excessive. Some objections are found to earlier theoretical investigations of temperature distributions beneath such focal areas. An operational solution is obtained in terms of Bessel functions. From the calculated temperature distribution the mechanism of disruption is explainable.

—*Jour. App. Phys.,* Vol. 13, No. 6 (1942), page 384.

THERMIONIC DEVICES

The Use of Valves as Variable Impedance Elements
(H. J. Reich)

The magnitude and phase angle of an impedance may be varied by means of circuits incorporating valves. The analyses of certain circuits show that they may be considered to be equivalent to a parallel combination of reactance and resistance in certain circuits the effective resistance may be made infinite these circuits acting like pure reactance, the magnitude of which may be controlled by means of electrode voltages.

Valve circuits containing only resistances and capacitances may act like an inductive reactance shunted by a negative resistance. Some types of "resistance-tuned" oscillators are based upon such circuits and may be readily analysed from this point of view.

By the use of an inverse-feedback amplifier it is possible to obtain very large effective capacitance or very low negative resistance, the magnitudes of which may be varied by means of the amplifier gain.

—*Proc., I.R.E.,* Vol. 30, No. 6 (1942), page 288.

INDUSTRY

The C.R. Indicator as a Detector
(Park)

The use of the cathode-ray tube as an indicator for an impedance bridge for the location of cable faults is described and reference is made to factors which influence the accuracy of the null-point detector method. These include external and background noise and the personal factor which is the most important source of error. The arrangement of the cathode-ray indicator circuit chosen was one in which a variation of the negative grid potential between 25 v. and zero produces a corresponding variation of the shadow angle between zero and 90°. Details of the circuit are given and methods of operating the bridge when used in conjuction with this device are reported.

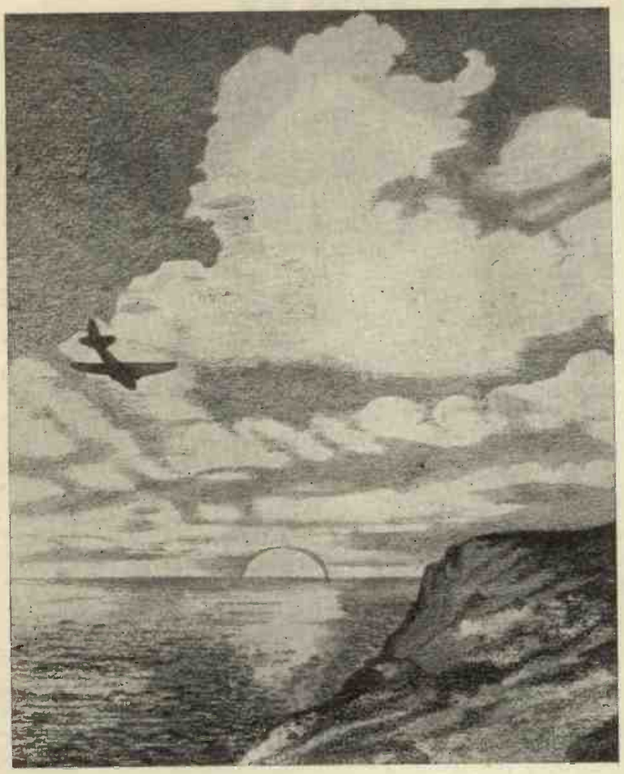
—*El. Times,* September 17, 1942, page 400.*

Impedance-Measuring Instrument
(C. E. Smith)

Following a brief discussion of impedance measuring methods, the theory underlying the operation of this instrument is presented with the development of useful equations. The merit of the scheme lies in the fact that measurements can be made while the impedance is in operation without disturbing the current distribution of the network. Practical arrangements of the parts are then considered along with the necessary adjustments. The paper ends with some results and conclusions.

—*Proc. I.R.E.,* Vol. 30, No. 8 (1942), page 362.

* Supplied by the courtesy of Metropolitan-Vickers Ltd., Trafford Park, Manchester.

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TELEVISION

Multiple-colour Television Systems

It is the object of the invention to provide a colour television system which may be viewed from a short distance.

The viewing distance of a normal black and white interlaced picture is considered as standard. A colour picture in which each of the interlaced field maintains its own colour from frame to frame would have to be viewed from a distance greater than the standard in order to obtain colour blending with consequent loss of detail. It is claimed that if each interlaced field is itself multi-coloured the composite picture can be viewed from the considered standard distance with proper appearance of colour and no loss of definition.

In the invention there is provided an interlaced multiple-colour television scanning system in which the field in one frame scanning period, which corresponds in position to a field in the preceding frame scanning period, is reproduced in a different colour.

—*Hazeltine Corp.* (*Assignees of J. C. Wilson*). *Patent No.* 546,987.

Cathode-Ray Tube Television Receivers

To provide apparatus by means of which a linear characteristic for a television receiver employing a cathode-ray tube, is secured over a working range of substantial extent. Also to correct or compensate for the non-linearity of the electron density or of the signal brightness characteristic of a television receiver tube, of the type in which modulation is accomplished by shifting the cathode beam with respect to an aperture.

The invention consists of a simple and inexpensive circuit arrangement which serves to predistort the modulating signal in just the manner and amount required to overcome the distortion introduced by the cathode-ray tube itself.

A distortion signal is derived from the image signal through the use of an auxiliary circuit arrangement, and this signal is applied along with the image signal to the modulating electrodes of the cathode-ray tube in such a way that the electron density and screen brightness are linearly related to the image signals over the full working range of the tube. A resistor is connected in series between a network carrying the image signals and a modulating electrode of the cathode-ray tube, and at the same time the image signals are supplied to the input circuit of a valve whose output circuit is directly connected to the terminals of the resistor.

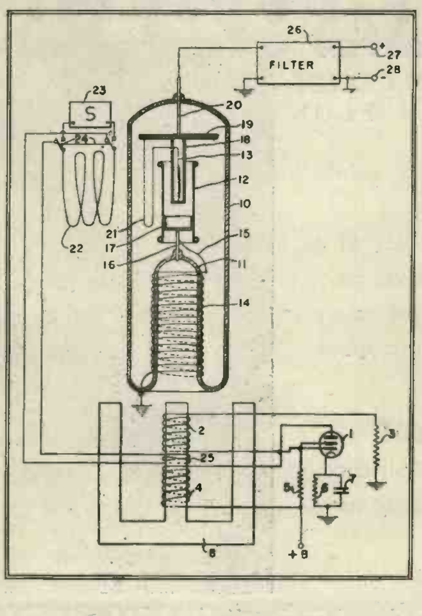
The valve is so designed to operate without substantial phase shift at image signal frequencies and whose characteristic is complementary to the non-linear characteristic of the cathode-ray tube to be corrected. The resistor and biasing arrangements of the valve are so chosen that the output to input voltage characteristic is of the shape required to correct the departure from linearity of the brightness response of the cathode-ray tube.

—*Standard Telephone and Cables, Ltd.* (*Assignees of M. W. Baldwin, Jr.*). *Patent No.* 547,124.

THERMIONIC DEVICES

Rectifier System

In the system described, the oscillator V_1, windings 2 and 4 and transformer core 8, operate in the conventional manner and generate oscillations of the order of 10,000 c/s. An oscillating current which may be of any suitable wave form is developed by the source 23 and supplied to the winding 22. Since the winding 22 is inductively coupled to the wire loop 21, a h.f. current is induced in it which flows through the cathode 13 and raises its temperature to the point of thermionic emission of electrons.



Alternately, the winding 25 which is coupled to the anode winding 4 and grid winding 2 and V_1, may be connected to the winding 22 by means of switch 24, so that the oscillating current for the coil 22 is derived from the oscillator circuit including V_1. The unidirectional voltage developed between the cathode and anode when these are energised by the h.f. alternating voltage derived from the oscillator is applied to the filter 26, in which fluctuations of the unidirectional voltage are filtered out.

The windings 14 and 21 which are inside the bulb are satisfactorily insulated without the requirements of substantial insulating materials as would otherwise be the case. Part of the advantages are obtainable even though the winding 21 is disposed outside of the bulb and provided with suitable insulation in the conventional manner.

—*Farnsworth Television and Radio Corp. Patent No.* 547,074.

RADIO RECEPTION

Radio Systems for Landing Aircraft

A radio glide path system for landing aircraft in which an intersecting pattern is given by the radiation of two frequencies and in which the strengths of the two signals received on an aircraft are compared to give an indication of the glide path. One comparison frequency is transmitted on a short wavelength, the short wave radiation giving a square law pattern. The other frequency is transmitted on a relatively long wavelength, the field contour lines of which are approximately vertical and vary inversely as the distance from the transmitter.

—*Standard Telephones and Cables, Ltd., and H. P. Williams. Patent* No. 546,970.

INDUSTRY

Protective Devices for X-ray Apparatus

A device for X-ray apparatus to prevent overloading of the X-ray tube. A control condenser is fitted in an auxiliary circuit to the transformer circuit for the tube. The rate of charging this condenser controls the current to the tube by interrupting the supply when the maximum permissible loading has been reached.

—*C. S. Norton and Messrs. Newton and Wright. Patent No.* 547,030.

BOOK REVIEWS

Short Wave Wireless Communication

A. W. Ladner and C. R. Stoner. 568 pp. 342 figs, (Chapman and Hall 35/- net.)

This is the fourth edition of this well-known textbook, and contains a great deal of new material and diagrams. Ultra-short waves are given more extensive treatment and there are short descriptive sections on velocity modulated systems, the klystron, and similar modern developments.

Naturally some of the red-hot developments in ultra-short waves cannot be touched on, and we must wait for the post-war edition for these, but the book is an excellent introduction to the better understanding of many of the Service applications of short-wave technique.

There is a good section on quartz crystals, covering 32 pages which covers the subject thoroughly and concisely and all types of electron oscillators including the magnetron, are covered in the chapter under that heading.

The concluding part of the book describes examples of commercial receivers, mainly Marconi, and telephone transmitters and circuits. Calculations of feeder theory and a brief description of valves for S.W. and U.S.W. are given in the appendix.

One of the criteria of a successful textbook is that it shall be known by the name of its author (or authors), and " Ladner & Stoner " has already qualified in this respect.

Electrical Counting

(with special reference to counting α and β particles). W. B. Lewis, 144 pp. with numerous line diagrams. (The Cambridge University Press 10/6 net.)

This book is an account of some of the work on which Dr. Lewis was engaged at the beginning of the war, but the delay in publication has not detracted in the least from the interesting and well-written account of his research and methods.

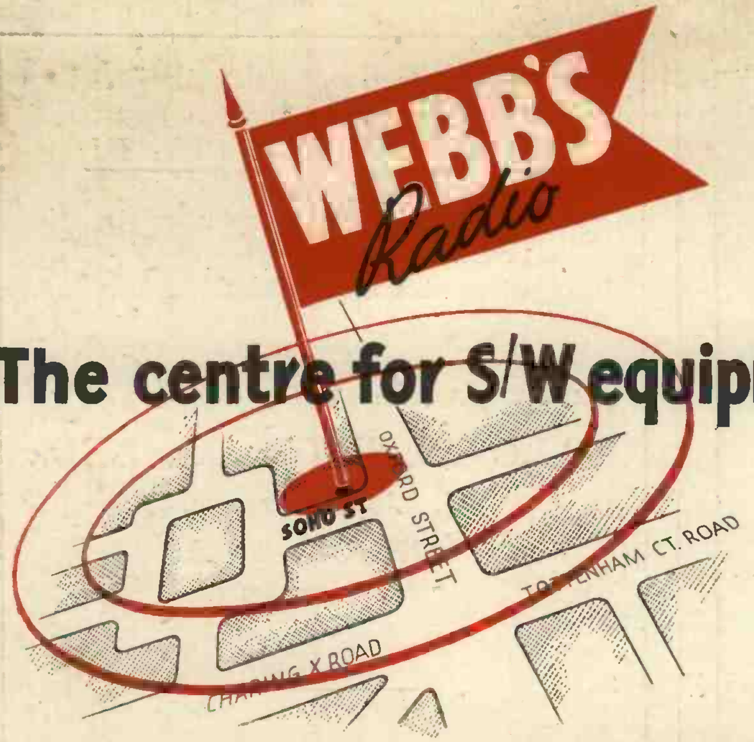
The reference to α and β particles need not deter the electronic engineer (who does not happen to be interested in this application) from reading the book, as many of the circuits are of direct value for wider applications. Chapters 3-6 deal with the limitations and design of high gain amplifiers, followed by a chapter on mixing circuits, triggered circuits, and discriminators. The description of the recording counters includes one of a scale-of-ten counter with cathode-ray tuning indicators for showing the state of the count.

One or two statements at the beginning of the book are " dated "—for example (*p.*21): " Many screen-grid valves are now made with the grid lead brought out separately at the top of the bulb " . . . and the discussion on *p.*27 *et seq.* takes no account of the modern high-slope h.f. pentode. These are minor points, for which allowance will be made by the experienced radio engineer, and do not alter the value of the book as a guide to electronic counting.

Introduction to Valves

including reference to C.R. Tubes. F. E. Henderson. (Iliffe, for the G.E.C. 4/6 net.)

The title page states that this is a manual for those who with little or no previous experience, are called upon to handle radio valves and cathode-ray tubes. Mr. Henderson has covered the subject admirably from electron emission to inverse feedback in a little over 100 pages. There is also a chapter on voltage stabilisers and gasfilled relays, and a bibliography of selected references. The book should be obtained by all laboratories using electronic devices as an aid to their work, and will also be of use to students who at the present time have no opportunity for a thorough study of radio theory before taking up jobs in the industry.



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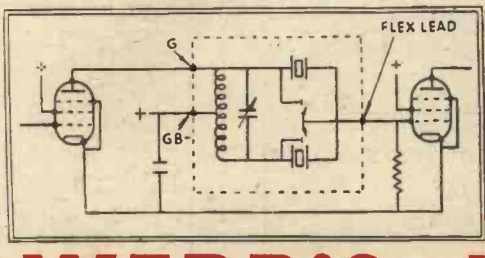

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