EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial Views.

The Amateur's Position.

WE have naturally been watching with interest the position which has been developing as to the amateur transmitter. It seems likely that before long affairs may reach a difficult stage. We have heard, and seen, some evidence that the Post Office has during the last few months altogether altered its attitude—previously a very considerate one.

The Radio Society apparently can find no reason whatever for this change, and accordingly is somewhat resentful. In fact it is preparing, we gather, to fight the P.M.G. in the Courts as to the legality of some of his actions in the matter. It is possible that its efforts may meet with success, but we cannot help feeling doubtful. It has always seemed to us that the whole intention of all the legislation which is in existence on the subject of wireless, is in reality that of placing the whole of the science entirely within the power of the P.M.G. Until recently, in fact, this view seems to have been generally held.

About a year ago there was much activity in the daily Press about receiving licences, on the ground that the Wireless Telegraph Act only dealt with transmitting. It was claimed that the P.M.G. had no right at all to deal with receiving, going by the words of the Act.

But it was realised soon that talk of this kind was useless, for if it were proved that the Act did not entitle the P.M.G. to control reception, another would soon be passed that would! In fact, the general official opinion, right or wrong, is that the P.M.G. shall have a complete control of wireless.

Suppose now the R.S.G.B. succeed in proving that the P.M.G. has exceeded his legal rights, and that he cannot refuse transmitting licences at will. The Society would next have to be prepared to fight a new Wireless Telegraph Bill which might soon be introduced to give back to the P.M.G. the powers he had lost in the Courts. And it must be remembered that the fight would be a lonely one. The three Services, the shipping and other commercial companies, and the broadcasting interests have no particular friendship for the amateur, and the P.M.G. has only to plead that their interests render it necessary for him to restrict amateur experimental work to get ample and influential backing for such a course. We feel that the R.S.G.B. would do better to start an investigation into the personnel of the G.P.O. What is the reason of this change of official attitude? Who is behind it? What is the real motive? If they could find the answer to these questions the whole matter could quite probably be straightened out.

The Experimenter's Claims.

Perhaps our readers do not realise how little respect official and commercial circles have for the amateur. In this case they will get rather a shock if they read pp. 47 *et seq.* of Capt. P. P. Eckersley's new book on broadcasting.*

Here he is dealing with the question of amateurs jamming broadcasting. He explains how the amateurs claim that they do much towards furthering the science of

* *Captain Eckersley Explains.* Publishers, Wireless Press, Ltd.

wireless. Then he discusses that claim, and says :—

. . . in my opinion the amateur has not materially, as an amateur, contributed towards the progress of the science. Where he has contributed is in getting such a knowledge by his own efforts that he eventually becomes a professional, and when he becomes a professional . . . he then becomes a valuable man and makes advances.

This is a strong statement, and by one who is well acquainted with amateur work. And there is enough truth in it to make it dangerous unless it is tackled. Let us take as an instance the recent advance in short-wave work at long ranges. The general opinion is that nearly all the spade-work in this branch was inaugurated by amateurs. Now Capt. Eckersley was at one time associated with the research department of a great commercial organisation, and he would probably reply that he knows of short-wave work by them that was better than that of the amateurs. But now we arrive at the crux of the matter.

That professional research, if it was done, was done for the advancement of one commercial organisation, not for the good of wireless. It might be patented, it might be used secretly, it might be buried to avoid making obsolete large stations designed for long waves. Curious things do happen in that way.

On the other hand, when the amateurs find out things, since they are working in the scientific spirit, they publish their work immediately. We therefore reply to our friend Capt. Eckersley that, even if the professionals discover ten facts to the amateur's one, the amateur may yet have rendered the bigger service to the science in general, for he makes his one fact available to all.

Real and Sham Experimenters.

Returning for a moment to our consideration of the transmitting position, the one fact which shows up most plainly is not that licences are being unfairly withheld, but that they have been too freely given to the unworthy. There is far too much transmission which is not in the nature of serious investigation, but is quite obviously simply a pleasant hobby for the young.

At present, a licence is granted mainly on a detailed programme of experimental work to be done—a programme which is often allowed to slide completely when the licence is once obtained, and which is at the same time very cramping to the real worker. It would seem far preferable to demand less programme and more qualifications—in fact, a stiff practical examination. At the same time the ridiculous position of a licence for artificial aerial work could be abolished.

Calibration.

We regret to inform our readers that our calibration department must be closed for a month. Instruments have been coming in faster than we can deal with them just lately, and we are anxious to clear up the arrears. When this has been done, we shall be sending our standards to the N.P.L. for their periodical check, after which we shall again be ready to receive apparatus. It is hoped that this programme will be completed within the month; but in any case a definite announcement will be made in our next issue.

Esperanto.

Everyone seems to be agreed that since the American Radio Relay League has settled upon Esperanto as the auxiliary language for international work, the best thing is to follow suit. In doing so, of course, one also adopts the A.R.R.L. view that the decision is made without prejudice to the merits of other such languages, but simply because Esperanto, being the most used of them, is *ipso facto* the most useful at present.

Hitherto, most of us have been content to sit down and say piously "an excellent idea! I hope all the other fellows will learn it at once." But this attitude does not seem likely to be immediately helpful, so we propose to go somewhat further. In an early issue we hope to publish a compact account of Esperanto, sufficient to act as a working grammar, and we propose to keep up, month by month, a small corner devoted to the language. We also hope to print a complete English-Esperanto dictionary of wireless terms, which has already been prepared as a French dictionary by Dr. Corret.

With these at hand, we can at any rate say that no reader of E.W. & W.E. has any excuse for continuing to put his continental fellows to inconvenience by insisting on their working him in English.

The Arrangement of Wireless Books and Information. [025·4

Part II: R100—General Principles.

This instalment is preceded by some references omitted in our last issue.

Below we print a further instalment of the B.S. extension of Dewey, including the whole of R100.

Before proceeding to the actual tables, we wish to give the references for some items in our last month's issue, from the titles of which the numbers were inadvertently omitted. They are as follows :—

PAGE.	ARTICLE.	REF. NO.
31	G.2KW	R612
41	Low-tension Discharge Tubes	621·327
48	Crystals and Crystal Testing	R374·009
55	Amateur Transmission	R113·1
55	Transformers	R342·700·9

The B.S. Extension *(continued)*.

R100 **General Principles and Theory.**

As explained in the summary in our last issue, this heading is not for matters of detailed or practical design. It may happen that some item to be classed apparently includes both theory and practice. In this case, one can only decide by considering (*a*) are the practical portions really only examples to help in explaining the theory? or (*b*) are the theoretical portions really only offered to help in understanding the practical design?

Type (*a*) will obviously be classed here, and type (*b*) under R300.

Note that R100 is only for general or "pure" theory: the theory of any system or application will go under R500 or R600: look at the headings of other divisions in the summary before placing items here. The numbers from R100 to R110 are divided like R000.

R110 Wave motion, ether waves, radiation, etc.

R111 Electro-magnetic theory in general.
(Clerk-Maxwell's laws, etc.)

R112 Radiation, absorption by receiving aerial, etc.
This deals with the transition from aerial current to free wave, and *vice versa*.

R112·1 Radiation.
·6 Absorption (*i.e.* reception).

R113 Free wave phenomena.

R113·1 Fading and allied phenomena.
·2 Daily and seasonal variations in signals.
·3 Directional effects (not intentional directional work, which is under R115, R125 and R500).
·4 Ionisation and Heaviside layer effects.
·5 Meteorological effects.
·55 Tropical work.
·6 Reflection, diffraction, refraction, etc.
·7 Range, intensity formulæ.
·8 Effects of eclipses and other cosmic phenomena.
·9 Wave front angle.

R114 Atmospherics.
This section is for information on atmospherics themselves : methods of preventing interference are R430.
R115 Directional properties in general.
Aerials specially designed for directional work are found under R125.
R116 " Wired wireless," *i.e.*, high frequency work on transmission lines.

R120 Aerials and their theory.

This section covers all forms of collector, even the picking up of signals in the tuning coils themselves.

R121 Aerial-earth systems, of the ordinary elevated type.
R122 Aerial-counterpoise systems. Such systems are often earthed also. Their distinguishing feature is that most or all of the current passes to the counterpoise.
R123 Ground and underground aerials, such as Beverage, etc., also aerials in mines, etc. Underground transmission as a whole is under R536.
R124 Frame aerials, for general work.
R125 Directional work.
R125·1 Direction finding aerials, *i.e.*, Bellini-Tosi, frame, etc., for reception from a particular direction.
R125·6 Directive aerials, *i.e.*, double phase-regulated systems and others for transmitting in a particular direction.
R126 Earth connections and earths.
*R126·5 Counterpoise theory.
R127 Aerial constants : the theory and calculation of aerial capacity, inductance, resistance, etc. For Measurement, see R200.
*R127·1 Natural wave-length.
* ·2 Capacity.
* ·3 Inductance.
* ·4 Resistance.
R129 Special types of aerial not covered above.

R130 Valve theory. For design and practical construction of circuits, see R300.

R131 Characteristic curves, general properties.
R132 Amplification, general action.
R132·1-3 Intervalve, input and output couplings for amplification.
R132·1 Inductive : by transformers or chokes.
·2 Capacitative.
·3 Resistance.
*R132·8 Reflex amplification.
R133 The valve as oscillator : general idea only ; details are in R344.
R134 Valve detection.
*R134·1 Anode rectification.
* ·2 Grid rectification.
·4 Retroaction, reaction.
·45 Super-regeneration.
·7 Heterodyne reception.
·75 Frequency conversion, supersonic heterodyne.
R135 Modulating.
R136 Input Impedance.
R137 Output impedance.
These two divisions should receive material dealing with the connection between valve design, etc., and impedance. The effect of such impedance on amplification should go under R132.
R138 Emission : filament design ; ionisation.
R139 Other matters.

R140 The theory of circuits, and alternating currents in general.

R141 Constants, etc., of simple circuits.
The arrangement here is not strictly logical, for R145 should come first, as a natural introduction.
R141·1 Variation of current with frequency.
·2 Resonance.
·3 Impulse excitation and free oscillation.
R142 Coupled circuits.
R142·1 Direct coupling.
·3 Inductive coupling.
·5 Capacity coupling.

* **These sub-divisions are proposed by us as a tentative further extension.**

R143 Damping and decrement.
R144 Resistance.
R145 Reactance.
R145·3 Inductive reactance.
·5 Capacitative reactance.
R146 Free harmonics.
R147 Beats.
This, as also R148 and R149, is not concerned with methods, but only with the theory of such currents and the conditions in circuits carrying them.
R148 Modulation.
R148·1 Distortion.
R149 Rectification.

R150 The generation of high frequency currents.
This is reserved to methods other than the Valve Oscillator, which is covered in R133.
R152 Spark apparatus.
R153 Arcs.
R154 H.F. alternators.
R156 Static frequency transformers.

R160 Receiving apparatus, general considerations.
Reserved for matters applicable to all forms of apparatus.
R161 Sensitivity.
R162 Selectivity.

R190 General principles not covered above.

An Easy Way to Calculate Circuits.

By P. K. Turner. **[R145**

Showing how, with nothing beyond simple arithmetic, one can find the Reactance, Impedance, etc., of any circuit, for radio or audio frequencies.

THE writer believes that there are many wireless amateurs, doing in some cases quite advanced work, who are handicapped by not being really familiar with the work of calculating and designing A.C. circuits. In most cases they are (in theory) quite conversant with the meanings of such words as Inductance, Capacity, Reactance, Impedance; but if they are called upon suddenly to understand and express their exact effect in a circuit, they are rather at a loss—simply through lack of habitual contact with them in a quantitative way.

Yet the work is not difficult. No "higher mathematics" need be involved: the work is just one degree more complicated than Ohm's Law, and for any student in wireless it is an absolute necessity that he should be able to handle it just as easily.

Just as an example, let us put three questions:—

1. Consider a crystal set. The aerial flattens the tuning because it has a resistance of (say) 20 ohms in series with the tuned circuit. The crystal does so because it has an effective resistance of (say) 5 000 ohms across the tuned circuit. Which really makes most difference?

2. A "tuned anode" circuit is known to be useful because to H.F. currents it acts as a high resistance. How high *is* its apparent resistance?

3. In a 1-valve reaction set we find a fixed condenser across the phones to by-pass the H.F. component while stopping the L.F. How big should it be?

The purpose of this article is to show how to answer such questions by simple arithmetic with an occasional touch of equally simple algebra, plus one device that may be new to the beginner, but is quite easily learnt.

We should like to emphasise the fact that these calculations are equally applicable to all frequencies, both radio and audio. But they are less accurate at radio frequencies, for they depend upon our knowing the capacities, inductances, resistances, etc., that are to be used, and we are not always certain what these are for high frequencies—we will deal further with this later on.

Since we are going to do without high-brow mathematics, we must take a great deal for granted. Firstly, we shall be dealing with alternating currents, and for the benefit of the advanced we will explain that we shall assume "pure sine wave" throughout. For the beginners, we will explain that since an alternating current is continually varying, there are three values of it which might be dealt with: The "instantaneous" value—the actual varying amount from moment to moment—which we shall *not* touch; the maximum current; and a form of average current called the r.m.s. value. The latter is defined by being the current as read on a hot-wire meter: it is ·707 times the maximum. Exactly the same three voltages will be found. The calculations which follow will apply to either maximum or r.m.s. values, *so long as we stick to one or the other for any complete calculation.*

The Three Components.

Just to clear our ideas, we will devote a few words to the three components of our circuits.

Resistance.—This is the same for direct and alternating currents (except for high frequencies). Everyone knows that it is expressed by dividing voltage by current: *i.e.*, if six volts (direct, maximum, or r.m.s.) applied to something causes $1\frac{1}{2}$ amps. (direct, maximum, or r.m.s., to correspond), then that something has 4 ohms resistance.

We usually call voltage E, current I, and resistance R, and we abbreviate volts, amps, and ohms to V, A, and O, so we express the law as

$$R = \frac{E}{I},$$

and the particular example as

$$R = \frac{E}{I} = \frac{6V}{1 \cdot 5A} = 4O.$$

Inductance offers no obstacle at all to direct voltage. Under alternating voltage, it passes a current which lags behind the voltage. The ratio of voltage to current is called the REACTANCE—sometimes INDUCTIVE reactance—to distinguish it from the other sort described below. The Reactance of a given Inductance depends on the frequency: it is not constant (as resistance is except for very high frequencies). The method of calculating reactance is given below. Do not confuse "Reactance" with "Reaction."

Capacity offers a complete interruption to direct voltage. Under alternating voltage it passes a current which leads in front of the voltage. We grant readily that this seems absurd: but it is true. For proof consult a mathematician. Better still, take our word for it. The ratio of voltage to current is in this case also called REACTANCE—sometimes CAPACITATIVE or capacity reactance to distinguish it from the Inductive variety mentioned above.

Inductance is measured in Henries (H) or Microhenries (μH): $1\,000\,000\ \mu H = 1 H$. It is usually represented for short by the letter L.

Capacity is measured in Farads (F) or Microfarads (μF) or Picofarads—sometimes called Micromicrofarads ($\mu\mu$F).

$$1\,000\,000 \mu\mu F = 1 \mu F;$$
$$1\,000\,000\,000\,000 \mu\mu F = 1\,000\,000 \mu F = 1\ F.$$

(These large numbers are awkward. We usually abbreviate by saying

$$10^{12} \mu\mu F = 10^{6} \mu F = 1 F.$$

The small figure, called the "exponent," represents the total o's in the number. To multiply two such numbers, add the exponents; to divide, subtract. A negative exponent means a decimal, with one o less than the exponent; *e.g.*,

$$10^{-4} = \cdot 000\,1 = \frac{1}{10\,000})$$

Capacity is usually represented for short by the letter C.

Reactance is measured, like resistance, in ohms. It is represented by X. If we want to keep the two sorts distinct we call them X_L and X_C.

Numerical Values.

Now to find the *numerical* value of reactance. We emphasise "numerical," for there is something else, as we shall see. Both kinds of reactance depend on frequency, which we shall refer to as f. But, as a matter of fact, f almost always appears multiplied by 6·283 2 (2π to the initiated), and so we usually denote the product $6{\cdot}28f$ by the one Greek letter ω ("omega").

To find the numerical value of Inductive Reactance, multiply Inductance in Henries by ω :—

$$X_L \text{ (ohms)} = \omega L \text{ (Henries)} = \frac{\omega L}{10^6} (\mu H).$$

To find the numerical value of Capacity Reactance, multiply Capacity in Farads by ω, and divide 1 by the product.

$$X_C \text{ (ohms)} = \frac{1}{\omega C} \text{ (F)} = \frac{10^6}{\omega C} (\mu F).$$

Just as an example, take $L = 200\mu H$ (about the usual 50-turn coil) and $C = {\cdot}000\,5\mu F$ at 377 metres. We know that we convert wave-length (λ) to frequency by

$$f = \frac{3 \times 10^8}{\lambda}$$

In this case $f = \frac{3 \times 10^8}{\lambda} = \frac{3 \times 10^8}{377} = 795\,000$

and $\omega = 6{\cdot}28 f = 4\,996\,000$.

(It would have been 5×10^6 exactly if we had been more accurate in calculation—that is why we settled on 377 metres !)

Then $X_L = \frac{\omega L}{10^6} = \frac{5 \times 10^6 \times 200}{10^6} = 1\,000$ ohms.

$$X_C = \frac{10^6}{\omega C} = \frac{10^6}{5 \times 10^6 \times {\cdot}000\,5} = \frac{1}{{\cdot}002\,5} = 400 \text{ ohms.}$$

Now suppose we have a resistance of 500 ohms in series with X_L. One is tempted to say that the whole circuit has a resistance or reactance of 1 500 ohms.

But it hasn't.

First, the result is not 1 500 ohms. Second, it is neither a resistance nor a reactance.

Another word is used to describe this mixture of both : it is called IMPEDANCE, is measured in ohms, and is usually represented by Z. As to its amount, there is a discrepancy, due (we will not attempt to explain why in this article) to the fact that the reactance causes a lagging current while the resistance does not. They must be combined in this way :—

$$Z^2 = R^2 + X^2,$$

or, in words, square the resistance and the reactance, add their squares, and the square root of the sum is the impedance. In this case,

$$\begin{aligned} R^2 &= 250\,000 \\ X^2 &= 1\,000\,000 \\ \hline Z^2 &= 1\,250\,000 \\ Z &= 1\,118 \end{aligned}$$

Dealing with Complex Circuits.

Now the above method is all right as far as it goes : but it does not go far enough. We should be landed in hopeless difficulties in dealing with parallel or complex circuits. For these we want some method of keeping all the leading or lagging currents and voltages apart from the others throughout the calculation. For example, suppose we had an R and an X in series, and then put in series another pair. It would not be correct to add the Z found from the first to that found from the second set. We must rather add the R's and then the X's, and then find the final Z.

The best method of distinguishing the two is to make use of the symbol j. This has a highly difficult and special meaning really —it is a sort of pass-word to the inner circles of the high-brow—but we will forget that. We will adopt the following plain rules ; bear with us while we explain them : their usefulness will be shown later.

When we get several expressions, such as $10 + j$, $120\,000 + j$, $\frac{1}{6 - 3j}$, etc., to deal with, we must always keep apart the "j" quantities, as shown below.

$j^2 (j \times j)$ is equal to -1 (from which it follows that $\frac{1}{j} = -j$).

To add (say) $6 + 4j$ to $8 - 3j$, we add 9 and 8, and then add 4 and -3, getting $14 + 1j$.

To multiply the same two, multiply separately by each part :—

$$\begin{array}{l} 6 + 4j \\ 8 - 3j \\ \hline 48 + 32j \\ \quad - 18j - 12j^2 \\ \hline 48 + 14j + 12 = 60 + 14j. \end{array}$$

The $+12$ follows, for we have already stated that $j^2 = -1$,

therefore $-12j^2 = -12 \times -1 = +12$.

To divide, it is necessary to get rid of the j in the denominator. We do this by a neat trick. Take, for instance, the undoing of the last sum: divide $60+14j$ by $8-3j$. We multiply both top and bottom by $8+3j$, *i.e.*, the bottom with one sign changed. Thus

$$\frac{(60+14j)\ (8+3j)}{(8-3j)\ (8+3j)}=$$

$$\frac{480+112j+180j-42}{64-24j+24j+9}=\frac{438+292j}{73}$$

$=6+4j$, by simple division.

The full Reactance Expressions.

Now to employ the magic j in circuit calculations we must make a slight addition to our expressions for reactance. Instead of the values already given, which were called "numerical values" ($X_L=\omega L$, $X_C=\frac{1}{\omega C}$) use the following, which we will call, for want of a better name, "full expressions."

THE FULL EXPRESSION FOR INDUCTIVE REACTANCE is

$$X_L=j\omega L.$$

THE FULL EXPRESSION FOR CAPACITY REACTANCE is

$$X_C=-\frac{j}{\omega C}.$$

Lastly, these full expressions, either alone or when combined with resistances to form

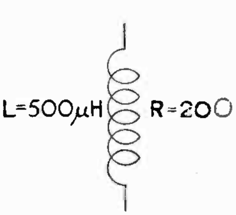


Fig. 1.

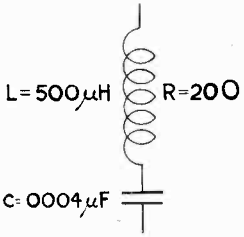


Fig. 2.*

impedances, can be combined in series or parallel just as simple resistances: thus if we have several impedances Z_1, Z_2, Z_3, etc., all in series, the total impedance Z is given by

$$Z=Z_1+Z_2+Z_3, \text{etc.},$$

and if they are in parallel,

$$\frac{1}{Z}=\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3}, \text{etc.}$$

Thus, take Fig. 1, at a wave-length of 942 metres ($\omega=2\times10^6$)

$$X_L=j\omega L=1\,000j.$$
$$Z=20+1\,000j.$$

Now add a condenser of $.000\,6\mu F$, in series, as in Fig. 2,

$$X=-\frac{j}{\omega C}=-\frac{10^{10}j}{2\times10^6\times6}=-833j$$

total $Z=20+1000j-833j=20+167j$.

What does this mean? A resistance of 20O with a reactance of $+167j$. Since this is positive, it represents an inductance. We have, then,

$$X_L=j\omega L=167j, \text{ or } L=\frac{167}{\omega}=88\mu H.$$

Thus *at this wave-length* this combination of $500\mu H$, 20O, and $.000\,6\mu F$ could be replaced by an inductance of $88\mu H$ with a resistance of 20O; as we should expect, the condenser has partly neutralised the inductance.

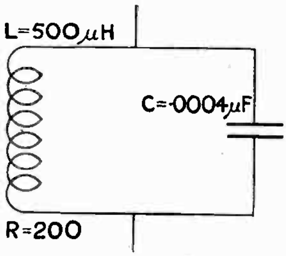


Fig. 3.*

If we wish to find the total impedance of the circuit, combining the resistance and reactance, we do it thus: square the resistance, square the reactance (neglecting j), add the squares, and take the square root. In this case—

$$Z=20+167j.$$
$$Z^2=400+27\,900=28\,300.$$
$$Z=168{\cdot}3 \text{ ohms}.$$

Remember that this can only be done when the impedance has been reduced to its final form of one resistance and one reactance in series. The two squares are always *added*, even if the reactance is a negative one.

Now suppose that with the same coil we added the condenser in parallel, as in Fig. 3. We have

$$\frac{1}{Z}=\frac{1}{Z_1}+\frac{1}{Z_2}=$$

$$\frac{1}{20+1\,000j}+\frac{1}{-833j}=\frac{1}{20+1\,000j}-\frac{1}{833j}$$

Multiplying up the fractions, we have

$$\frac{1}{Z}=\frac{833j-20-1\,000j}{833j\ \ (20+1\,000)}$$

$$=\frac{-20-167j}{833\,000+16\,700j}$$

* Note: the condenser should be ·000 6μF.

Turning it upside down, and multiplying top and bottom by -1,

$$Z = \frac{833\,000 - 16{,}700j}{20 + 167j}$$, dividing top and bottom by 167, to simplify the figures,

$$Z = \frac{5\,000 - 100j}{\cdot 12 + 1j} = 100 \times \frac{50 - j}{\cdot 12 + j}$$

now dodge the bottom j

$$Z = 100 \times \frac{(50 - j)(\cdot 12 - j)}{(\cdot 12 + j)(\cdot 12 - j)}$$

$$= 100 \times \frac{6 + \cdot 12j - 50j - 1}{\cdot 014\,4 + 1} = 100 \times \frac{5 - 49\cdot 88j}{1\cdot 014\,4}$$

$$= 100(4\cdot 93 - 49j) = 493 - 490\,0j.$$

Further Examples.

Take the case of the by-pass condenser, already mentioned. Here we have, in series, the resistance of the valve—say 20 000Ω; the reaction coil, say 200μH, the phones, of an inductance say 5H, and resistance 4 000Ω, and the H.T. battery. The radio frequency is, as before, such that $\omega_r = 5 \times 10^6$, and for an audio frequency of about 1 600 we have $\omega_a = 10^4$.

In practice, the resistance of the H.T. battery can be neglected compared with that of the valve. It is probably in any case shunted by a condenser of low reactance to both H.F. and L.F.

Therefore our condenser must be such that for radio frequency its reactance is negligible compared to the rest. The reactance of the reaction coil is $\omega_r L = 1\,000$, so "the rest" is 20 000 for the valve and $1\,000j$ for the coil.

The impedance is

$$Z_r = 20{,}000 + 1\,000j$$
$$= 1\,000\,(20 + 1j)$$

This can be expressed as,

$$Z_r^2 = (1\,000)^2\,(400 + 1),$$
or $Z = 20\,025$.

It will be found that any capacity reactance up to $-2\,000j$ will make a negligible difference.

This gives, as a minimum capacity (which obviously has maximum reactance),

$$C = \frac{10^6}{2\,000 \times \omega} = .000\,1.$$

On the other hand, looking at the circuit from the audio frequency point of view, the reactance of the phones is $\omega_a L = 5 \times 10^4 = 50\,000$, and their resistance is 4 000. We have

$$Z^2 = (1\,000)^2\,(50^2 + 4^2)$$
$$= (1\,000)^2 \times 2\,516$$
$$Z = 50\,160 \text{ ohms.}$$

Since the condenser is not to rob the phones of current, it must have a reactance considerably higher—say 500 000, or 5×10^5 ohms.

Thus $C = \frac{10^6}{5 \times 10^5 \times 10^4} = \frac{1}{5\,000} = \cdot 000\,2$, and as this is for a *minimum* reactance, it is a maximum capacity. So that the condenser should be between ·000 1 and ·000 2. Obviously, the usual condenser of ·001 will have a reactance of only 100 000 ohms, and will take somewhere about one-third of the current from the phones at this particular frequency.

In actual practice, the larger condenser may be preferred for telephony, for this reason: at frequencies lower than 1 600 the capacity will have higher reactance, and vice versa. It will therefore tend to rob the phones more at high frequencies and less at low, thus giving on the average a deeper and richer tone, which most people prefer.

By applying these principles any circuit, however complicated, can be dealt with.

When dealing with radio frequencies, however, remember these two points :—

1. Every coil has self-capacity, which can be treated as a condenser placed across it. The average value for coils in use at the present day is likely to be, say ·000 025μF, varying from ·000 010 to ·000 050 according to type.

2. The resistance of a coil at high frequencies has little to do with the size of wire or its direct current resistance. The resistance of the same coil goes up with frequency: the best method is to measure it, which is difficult. Barring this, a rough estimate can probably best be made by assuming the resistance to be a fixed fraction of the reactance.

It is not very wide of the mark to assume,

$\frac{X}{R} = 200$ for single-layer coils, or others specially designed for low losses;

$\frac{X}{R} = 100$ for first-class multi-layer coils;

$\frac{X}{R} = 50$ for others.

The Performance and Properties of Telephonic Frequency Intervalve Transformers.

By D. W. Dye, B.Sc., A.C.G.I. [R342-701

PART III.

Herewith the concluding part of this important article, by the head of the Electrical Measurements Department at the N.P.L.

6.—Effective Ratio and Coefficient of Coupling of the Transformer.

The measurement of effective ratio of the transformer is very simple. Referring to Fig. 6 (reproduced in this instalment) the method of observation was to observe the main current as indicated on the thermo-ammeter A. From this, the potential difference on S was readily determined, and hence the primary voltage. The secondary voltage was directly observed by means of the low-reading electrostatic voltmeter. The bridge is so nearly non-inductive that the voltage on S may be computed by means of a simple multiplier from the total current with an inaccuracy much less than 1 per cent. The bridge need not be precisely balanced during this test, and, as will be seen from an examination of the curves of Fig. 21, no appreciable correction need be applied on account of the capacity of the voltmeter except at high telephonic frequency. At frequencies of the order of 3 000 cycles per second, the effective ratio of the transformer is increased by about 2 per cent. as a result of the addition of the capacity of the electrostatic voltmeter.

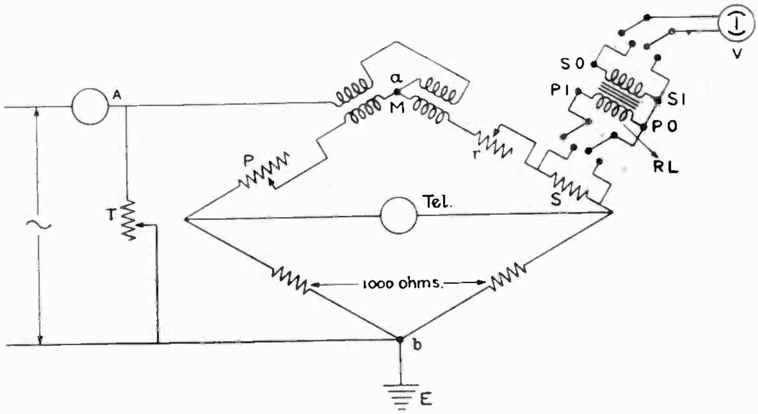


FIG. 6.

Fig. 21 shows the effective ratio of secondary to primary voltage as a function of added capacity. The curves marked A are those obtained when the capacity is added across the secondary terminals. Those marked B are for added capacity between the free ends of primary and secondary, *i.e.*, added mutual capacity. The capacities used in plotting the curves have been corrected to "total effective capacity," in order that the two sets of curves may appear in their correct relation to one another. These results represent "added capacity" + voltmeter capacity + mutual capacity or self-capacity of the winding as the case may be. When the curves are so plotted, they are seen to converge with remarkable accuracy on to the point representing the geometrical ratio of the windings, *i.e.*, 3·5. These curves show that marked increase in effective ratio of a transformer can occur as a result of adding capacity across the secondary winding or of adding mutual capacity, and that well-defined maximum ratios occur having values depending upon the frequency. The value of capacity at which the maximum occurs also depends upon the frequency.

These results were at first puzzling, for it must be remembered that the transformer is being operated in a region of frequency far beyond the resonant frequency. The latter occurs at about 2 000 cycles per second at a total effective secondary capacity of the order of 60$\mu\mu$F (shown by a dotted line near the ratio axis). It will be observed that no marked increase in ratio occurs at the resonant frequency. An insight into this remarkable behaviour is obtained by a simple mathematical consideration of the problem; this is given in a note.[2]

It can be shown that, if σ is the ratio of secondary to primary voltage,

$$\sigma^2 = \frac{k^2\sigma_0^2}{\left[1 + \frac{R_t}{S_2} - L_2C_2\omega^2(1-k^2)\right]^2 + \left[\frac{R_1\sigma_0^2 - L_2C_2\omega^2R_t}{L_2\omega} - \frac{L_2\omega(1-k^2)}{S_2}\right]^2} \quad \ldots (34)$$

where $R_t = R_1\sigma_0^2 + R_2$.

An examination of this equation reveals immediately why σ reaches a maximum value for a frequency or added capacity far beyond the resonant frequency or self-capacity of the secondary circuit. The term $1 - k^2$ is the governing factor. If k is unity there will be scarcely any variation of σ with C_2 or ω, since the other terms involving R_1, R_2 and S_2 are small compared with unity. Owing, however, to the fact that k^2 is not quite unity, $1 - k^2$ is a small positive quantity such as 0·03. At a value of $L_2C_2\omega^2$ equal to about 30, therefore, the first bracket becomes zero, and the voltage ratio is determined only by the resistance terms in the second bracket. These can, theoretically, be made as small as we like, so that a large increase in σ is possible.

It is generally possible to neglect the terms containing S_2, unless a comparatively low resistance shunt is used on the secondary. The expression then reduces to

$$\sigma^2 = \frac{k^2\sigma_0^2}{\left[1 - L_2C_2\omega^2(1-k^2)\right]^2 + \frac{1}{L_2^2\omega^2}\left[R_1\sigma_0^2 - L_2C_2\omega^2R_t\right]^2} \quad \ldots \ldots (35)$$

The corresponding expressions for the case of mutual capacity are somewhat more complicated, but[3] it may be shown that the effect of mutual capacity is similar to that of secondary capacity, and that the maximum value of σ will occur at almost the same frequency or added capacity in the two cases.

It is of interest to find the values of k and R or S_2 which will give values of σ agreeing with the experimental curves of Fig. 21. It will suffice to take the secondary capacity case of (35). Differentiating with respect to C_2 we find that σ (*max.*) occurs when

$$C_2\ (\sigma\ max.) = \frac{\frac{S_2+R_t}{S_2L_2}\left[L_2^2\omega^2(1-k^2)\right] + \frac{R_t}{L_2S_2}\left[R_1S_2\sigma_0^2 - L_2^2\omega^2(1-k^2)\right]}{L_2^2\omega^4(1-k^2)^2 + R_t^2\omega^2} \quad \ldots \ldots (38)$$

In any case except that of a poor transformer this reduces to

$$C_2\ (\sigma\ max.) = \frac{L_2^2\omega^2(1-k^2) + R_tR_1\sigma_0^2}{L_2\omega^2\left[L_2^2\omega^2(1-k^2)^2 + R_t^2\right]} \quad (39)$$

From the curves of Fig. 21 the value of C_2 is known for any particular case, so that, solving for $1 - k^2$, we shall find that

$$1 - k^2 = \frac{1 + \sqrt{1 + \frac{4R_tC_2}{L_2}\left(R_1\sigma_0^2 - R_tL_2C_2\omega^2\right)}}{2L_2C_2\omega^2} \quad (40)$$

In general we can neglect $R_1\sigma_0^2$, so that the expression for $1 - k^2$ reduces to

$$1 - k^2 = \frac{1 + \sqrt{1 - 4R_t^2C_2^2\omega^2}}{2L_2C_2\omega^2} \quad \ldots (41)$$

In order to make our theoretical curve for σ fit the experimental one at, say, the maximum point, we must substitute the value of $1 - k^2$ back into equation (35).

Taking the approximate form of (35)

$$P^2 = \frac{\sigma^2}{k^2\sigma_0^2} = \frac{1}{\left[1 - L_2C_2\omega^2(1-k^2)\right]^2 + R_t^2C_2^2\omega^2}$$

and putting $R_t^2C_2^2\omega^2 = q^2$, we have

$$\frac{1}{P^2_{(max.)}} = \left[1 - L_2C_2\omega^2(1-k^2)\right]^2 + q^2 \quad \ldots (42)$$

From (41) we get

$$L_2C_2\omega^2(1-k^2) = \frac{1 + \sqrt{1 - 4q^2}}{2}$$

which, on substitution in (42) gives

$$\frac{1}{P^2_{(max.)}} = \left(\frac{1 - \sqrt{1 - 4q^2}}{2}\right)^2 + q^2 \quad (43)$$

[2] See Note 2 at end. [3] See Note 3 at end.

whence

$$q = R_t C_2 \omega = \frac{\sqrt{P^2(max.) - 1}}{P^2(max.)} \quad .. \quad (43)$$

Substituting this value of q back into (41) gives

$$1 - k^2 = \frac{1}{L_2 C_2 \omega^2}\left(1 - \frac{1}{P^2(max.)}\right) \quad (44)$$

Equations (43) and (44) enable the effective values of $(1-k^2)$ and R_t to be determined from the co-ordinates of the highest points on the experimental curves of Fig. 21. This has been done in the case of added secondary capacity at a frequency of 2 000 cycles per second (curve A at 2000 on Fig. 21).

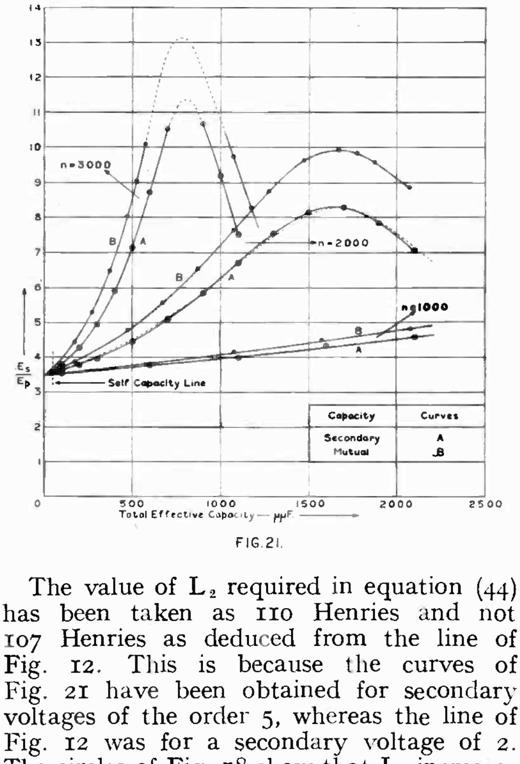


FIG. 21.

The value of L_2 required in equation (44) has been taken as 110 Henries and not 107 Henries as deduced from the line of Fig. 12. This is because the curves of Fig. 21 have been obtained for secondary voltages of the order 5, whereas the line of Fig. 12 was for a secondary voltage of 2. The circles of Fig. 18 show that L_2 increases by about 3 per cent. or 4 per cent. for an increase in magnetisation of the core corresponding to a secondary voltage of 5. Taking, then, $L_2 = 110$ Henries, and, from the curve $C_2 = 1\,650\mu\mu F$ and σ $(max.) = 8{\cdot}30$, we find $1 - k^2 = 0{\cdot}028\,9$, $k^2 = 0{\cdot}971$ and $k = 0{\cdot}985$ and $R_t = 18\,200$ ohms. Now $R_t = R_1\sigma^2_0 + R_2$. This quantity should, theoretically, have been 16 500 using direct-current values of R_1 and R_2. On referring back to Fig. 13, however, it will be seen that an effective value of 1 150 ohms was found for R_1. This value will give almost precisely the value of 18 200 obtained above. There are, therefore, other losses associated with the windings which cause the effective internal primary resistance to rise.

The values of $1-k^2$ and R_t deduced above have been used to calculate theoretically the curve A at $n=2\,000$. The line so obtained is drawn dotted on Fig. 21. The agreement with the experimental curve is remarkably good and shows that the rise in ratio with increase in frequency or with added secondary or mutual capacity is substantially in accordance with the simple theory given.

In consideration of the curves of Fig. 21 we must be careful to keep in mind the effects of added secondary capacity on effective primary impedance as indicated by the circles of Fig. 10. An inspection of these shows that the primary impedance is increased at low frequencies and decreased at high frequencies by the addition of secondary capacity.

It is advantageous to both voltage factor and ratio to add secondary capacity so long as we keep on the right hand of the circle, but for frequencies above the resonant frequency the voltage factor will suffer on account of diminished primary impedance. For example, at a frequency of 3 000 cycles per second and with a zero added secondary capacity the primary effective resistance and reactance are 20 000 ohms and —100 000 ohms respectively. The addition of $100\mu\mu F$ to the secondary winding reduces these quantities to 2 700 ohms and —26 000 ohms respectively. We see, therefore, that above the resonant frequency the effect of secondary (or mutual) capacity is to reduce the primary impedance and hence the primary voltage factor q, where

$$q^2 = \frac{X_p^2 + R_p^2}{X_p^2 + (R_p + R_a)^2} \quad .. \quad (45)$$

On the other hand the presence of secondary capacity increases the voltage ratio of the transformer, unless the capacity is relatively enormous. For small and moderate values of capacity the voltage ratio of the transformer is given by the expression

$$\sigma = \frac{k\sigma_0}{1 - L_2 C_2 \omega^2 (1 - k^2)} \quad .. \quad (46)$$

The amplification of the transformer is equal to the product $q\sigma$; it is of interest therefore to consider now, as the natural application of the whole of the foregoing analysis, how the amplification depends upon all the factors involved, and, in particular, upon secondary capacity and primary inductance.

7.—Voltage Amplification Curves.

The voltage amplification of a complete stage, consisting of a valve and transformer, may be written Eg_2/Eg_1 where Eg_1 is the voltage applied to the grid of the valve in front of the transformer and Eg_2 is the voltage produced on the grid of the valve beyond the transformer when connected to its secondary winding.

We have therefore $Eg_2/Eg_1 = \mu q\sigma$. This is the quantity experimentally determined by the direct method of measurement of amplification, such as that described by Mr. F. E. Smith and H. Napier.* The voltage

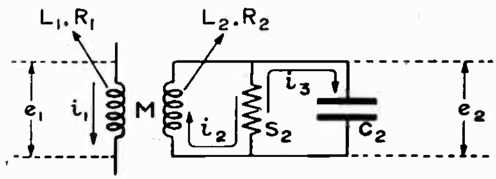


Fig. 22.

factor μ of the valve V_1 is an independent variable and does not enter into our present considerations at all, except as a mere number.

In the case of the transformer investigated here, the amplification has been directly measured using valves having a voltage factor of about 8·3 and an internal anode-voltage anode-current slope R_a of about 24 000 ohms. The curve obtained is given in Fig. 23 as a thin line. The thick line curve has been obtained by calculation of the the product of q and σ from the calculated values of X_p and R_p and the curves of Fig. 21, using the values 8·3 for μ and 24 000 for R_a. In making the calculations allowance was made for the capacity of the leads and valve connected to the secondary winding.

The curves fit one another very well except at the low frequency end, where the experimental curve shows higher amplification than the calculated curve. This is almost certainly due to an increase in effective inductance at frequencies below 500 cycles per second, owing to increased

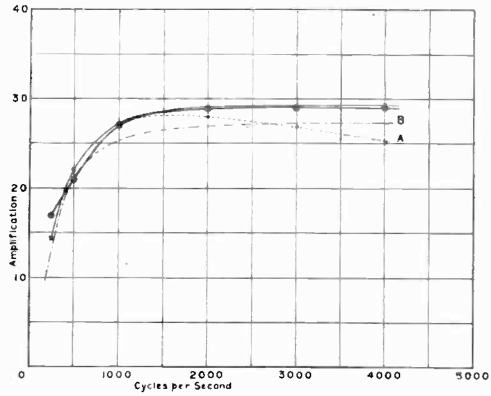


FIG. 23.

effective permeability in the iron. All the measurements become very difficult at frequencies of the order of 300 per second and the accuracy necessarily falls, but measurements of X_p and R_p at 300 indicated that the inductance was several per cent. greater than that at 500 cycles per second. In calculating the curve, the values of X_p and R_p were calculated from the deduced values of L_1, C_2, S and R_1 as obtained by analysis of the circle. For the present case the simple formulæ (8) and (10) are sufficient for the purpose, but when calculating cases in which considerable secondary capacity is present, or assumed, these formulæ are not sufficiently accurate.

It is desirable to be able to calculate various theoretical amplification curves, starting from assumed constants in the transformer, in order to gain some idea as to the desirable values of these for satisfactory performance. As an example, the theoretical case of zero secondary capacity has been taken for the transformer investigated. The curve has been plotted on Fig. 23 as the dotted line B. We see immediately that throughout the whole range of frequency shown, the amplification is lower in the absence of secondary capacity. It is generally considered that secondary capacity is undesirable, but these curves show quite definitely that a certain amount of secondary

* F. E. Smith and H. C. Napier.—"On the Measurement of Amplification given by Triode Amplifiers, at Audible and at Radio Frequencies."—*Proc. Phys. Soc.*, 1920, Vol. 32, p. 116.

capacity considerably improves the performance of a transformer.

We must now consider in more detail the formulæ (21) and (22) for $R_p - R_1$ and $(L_p - L_1)\omega$, corresponding to the case given in Fig. 11 (*b*). In this case we have left out the shunt S on the primary. This quantity, however, is the main factor deciding the diameter of the circle, and must therefore be taken into account in order to obtain approximately accurate expressions for R_p and X_p.

Let R_{p1} and X_{p1} be the effective resistance and reactance of the primary as given by (21) and (22) and let this virtual impedance be shunted by a resistance S.

We then have to a close approximation

$$R_{po} = \frac{SX^2_{p1}}{S^2+X^2_{p1}} \quad .. \quad .. \quad (47)$$

$$\text{and} \quad X_{po} = \frac{S^2X_{p1}}{S^2+X^2_{p1}} \quad .. \quad .. \quad (48)$$

Now, in the expressions for X_{p1} and R_{p1} the term R_2 is the only factor limiting the diameter of the circle in the absence of S across the primary. In a normal case this diameter would be so large, owing to the relative smallness of R_2, that we may neglect the effect of R_2 in substituting the values of X_{p1} and R_{p1} in the equations for R_{po} and X_{po} so long as S has a value not greater than about 10^6 ohms.

In this case $R_{p1}=0$ and

$$X_{p1}=\frac{L_1\omega\left[1-L_2C_2\omega^2(1-k^2)\right]}{1-L_2C_2\omega^2}$$

Substituting these in (47) and (48) we arrive at the final expressions

$$R_{po} = R_1 + \frac{S_1L^2{}_1\omega^2\left[1-L_2C_2\omega^2(1-k^2)\right]^2}{S_1{}^2(1-L_2C_2\omega^2)^2+L^2{}_1\omega^2\left[1-L_2C_2\omega^2(1-k^2)\right]^2} \quad (49)$$

$$\text{and } X_{po} = \frac{S_1{}^2L_1\omega(1-L_2C_2\omega^2)\left[1-L_2C_2\omega^2(1-k^2)\right]^2}{S_1{}^2(1-L_2C_2\omega^2)^2+L^2{}_1\omega^2\left[1-L_2C_2\omega^2(1-k^2)\right]^2} \quad (50)$$

These expressions allow a series of cases to be calculated for variations of S_1, L_1, L_2, C_2 and k. If a shunt resistance S_2 is placed across the secondary, or if the grid-filament circuit of the valve imposes a load on the transformer represented by S_2, then to a close approximation this load may be transferred to the primary as an equivalent shunt resistance in parallel with S_1 and of value equal to $\dfrac{S_2k^2}{\sigma_0{}^2}$[4]

It is obvious that the evaluation of the amplification of the transformer by calculation from its constants involves a considerable amount of arithmetic. Approximations can be made at each end of the frequency scale, but when $L_2C_2\omega^2=1$, and when $L_2C_2w^2(1-k^2)$ is not very small, it is necessary to use the full expressions. Suppose, therefore, we have a transformer of known or assumed constants L_1, R_1, R_2, σ_0, S_1 and k: we wish to find its amplification curve when used with its primary in the anode circuit of a valve whose internal anode resistance is R_a. We calculate R_{po} and X_{po} by means of (49) and (50). Then q is determined from these and R_a, by means of (45). Finally σ is calculated by means of (46).

Note that if $L_2C_2\omega^2(1-k^2)$ is less than about 0·25 it is necessary to use the more exact expression given in equation (35) for σ. The product $q\sigma$ gives the required amplification factor of the transformer. It is convenient to use exact values of ω for these calculations. The following typical case is given in full in order to show a convenient arrangement of the calculations so that they follow one another in a simple manner.

The case taken is one in which the constants have been assumed as follows :—

L_1 = Primary Inductance = 10H.
σ_0 = Turns Ratio = 4.
C_2 = Secondary Capacity = $50\mu\mu$F.
S_1 = Equivalent Primary Shunt Resistance = 5×10^5 ohms.
k = Coupling Coefficient = 0·985.
$1-k^2$ = 0·03.
L_2 = Secondary Inductance = 160H.
R_a = Anode Impedance of First Valve = 25×10^3 ohms.
R_1 = Ohmic Resistance of Primary = 1 000 ohms.

A number of theoretical cases have been worked out in order to show clearly the effect of variation of some of the constants.

The results of these calculations are given in Tables III. to V. below.

In all the cases S_1 has been taken as 5×10^5 ohms, R_1 = 1 000 ohms, $\sigma_0=4$, and $L_2=\sigma_0{}^2L_1$.

Some of these results are plotted in Figs. 24 and 25. The curves of Fig. 24 refer to a theoretical transformer of constant

[4] See note 4 at end of Article.

primary inductance of 20H and show the effect of various secondary capacities and also various coefficients of coupling. The curves of Fig. 25 show the effect of various values of primary inductance, and of secondary capacity. These curves show remarkable variations. It has not been possible to test experimentally the cases worked out theoretically, but a considerable number of various types of transformers on the market have been tested for amplification from time to time, and amongst the curves obtained every type shown on Figs. 24 and 25 has been found.

Amongst the transformers tested for their constants the widest variations in these have been found, thus values of primary inductance between 2 and 15H, of

TABLE II.

Calculation of Amplification Factor.

$\omega \times 10^{-3}$	1	2	3	5	10	15	20	30
$\omega^2 \times 10^{-6}$	1	4	9	25	100	225	400	900
$L_2C_2\omega^2$	0·008	0·032	0·072	0·200	0·800	1·80	3·2	7·2
$1-L_2C_2\omega^2$	0·992	0·968	0·928	0·800	0·200	−0·80	−2·2	−6·2
$(1-L_2C_2\omega^2)^2$	0·984	0·936	0·860	0·640	0·040	0·640	4·84	38·4
$L_2C_2\omega^2(1-k^2)$	0·000 2	0·001	0·002	0·006	0·024	0·054	0·096	0·216
$1-L_2C_2\omega^2(1-k^2)$	1·000	0·999	0·998	0·994	0·976	0·946	0·904	0·784
$[1-L_2C_2\omega^2(1-k^2)]^2$	1·000	0·998	0·996	0·988	0·952	0·894	0·817	0·615
$(1-L_2C_2\omega^2)[1-L_2C_2\omega^2(1-k^2)]$	0·992	0·967	0·926	0·795	0·195	−0·757	−1·985	4·86
$L_1\omega \times 10^{-4}$	1	2	3	5	10	15	20	30
$L_1^2\omega^2 \times 10^{-8}$	1	4	9	25	100	225	400	900
$S^2(1-L_2C_2\omega^2)^2 \times 10^{-10}$	24·8	23·4	21·5	16·0	1·00	16·0	121	960
$L_1^2\omega^2[1-L_2C_2\omega^2(1-k^2)]^2 \times 10^{-10}$	0·01	0·04	0·09	0·25	0·95	2·01	3·2	5
Denom $\times 10^{-10}$	24·81	23·44	21·59	16·25	1·95	18·01	124	965
$SL_1^2\omega^2 \times 10^{-13}$	5	20	45	125	500	1 125	2 000	4 500
$SL_1^2\omega^2[1-L_2C_2\omega^2(1-k^2)]^2 \times 10^{-13}$	5	20	45	124	475	1 005	1 734	2 770
$R_{po} \times 10^{-3}$	1·2	1·8	3·08	8·6	244	57	15	4
$(R_{po}+R_a) \times 10^{-3}$	26·2	26·8	28·1	33·6	269	82	40	29
$R_{po}^2 \times 10^{-6}$	1·4	3·2	9·5	74	59 500	3 250	225	16
$(R_{po}+R_a)^2 \times 10^{-6}$	686	718	790	1 130	72 400	6 730	1 600	835
$S^2L_1\omega \times 10^{-13}$	250	500	750	1 250	2 500	3 750	5 000	7 500
$S^2L_1\omega(1-L_2C_2\omega^2)(1-L_2C_2\omega^2[1-k^2]) \times 10^{-13}$	248	483	695	992	587	−2 840	−9 925	−36 430
$X_p \times 10^{-3}$	10·16	20·2	32·2	61·0	250	157·7	−79·9	−37·7
$X_p^2 \times 10^{-6}$	103·2	407	1 035	3 725	62 500	24 900	6 380	1 327
$Z_p^2 \times 10^{-6}$	104·6	410	1 045	3 800	122 000	28 150	6 600	1 342
$Z_t^2 \times 10^{-6}$	789	1 125	1 825	4 855	134 900	31 630	7 980	2 162
q	0·364	0·603	0·757	0·884	0·952	0·944	0·909	0·788
σ	3·94	3·94	3·95	3·97	4·04	4·17	4·36	5·03
$q \times \sigma$	1·434	2·37	2·9	3·51	3·84	3·94	3·87	3·96

TABLE III.

Amplification Factor.

ω	$L_1=5,\ \sigma_0=4,\ S_1=5\times10^5$					
	$C_2=0\mu\mu F.$		$C_2=50\mu\mu F.$	$C_2=100\mu\mu F.$		
	$k=1·0$	$k=0·985$	$k=0·985$	$k=1·0$	$k=0·985$	$k=0·950$
1 000	0·772	0·762	0·760	0·778	0·766	0·737
2 000	1·440	1·423	1·44	1·476	1·457	1·402
3 000	1·980	1·955	2·02	2·10	2·07	1·990
5 000	2·712	2·68	2·81	2·99	2·97	2·87
10 000	3·416	3·38	3·65	3·79	3·84	3·91
15 000	3·62	3·58	3·87	3·68	3·84	4·20
20 000	3·70	3·66	3·91	3·35	3·57	4·14
30 000	3·75	3·71	3·81	2·67	2·89	3·21

TABLE IV.

Amplification Factor.

ω	$L_1=10,\ S_1=5\times10^5,\ \sigma_0=4$			
	$C_2=0\mu\mu F.$		$C_2=50\mu\mu F.$	$C_2=100\mu\mu F.$
	$k=1·0$	$k=0·985$	$k=0·985$	$k=0·985$
1 000	1·436	1·415	1·425	1·435
2 000	2·40	2·37	2·38	2·46
3 000	2·86	2·92	2·99	3·07
5 000	3·44	3·39	3·51	3·63
10 000	3·73	3·67	3·84	3·88
15 000	3·77	3·71	3·94	3·80
20 000	3·79	3·72	3·97	3·58
30 000	3·80	3·74	3·96	3·03

secondary capacity between 15 and 1 000$\mu\mu$F, of S_1 between $2{\cdot}5 \times 10^5$ and 12×10^5 ohms, of σ_0 between 1 : 1 and 6 : 1, thus indicating

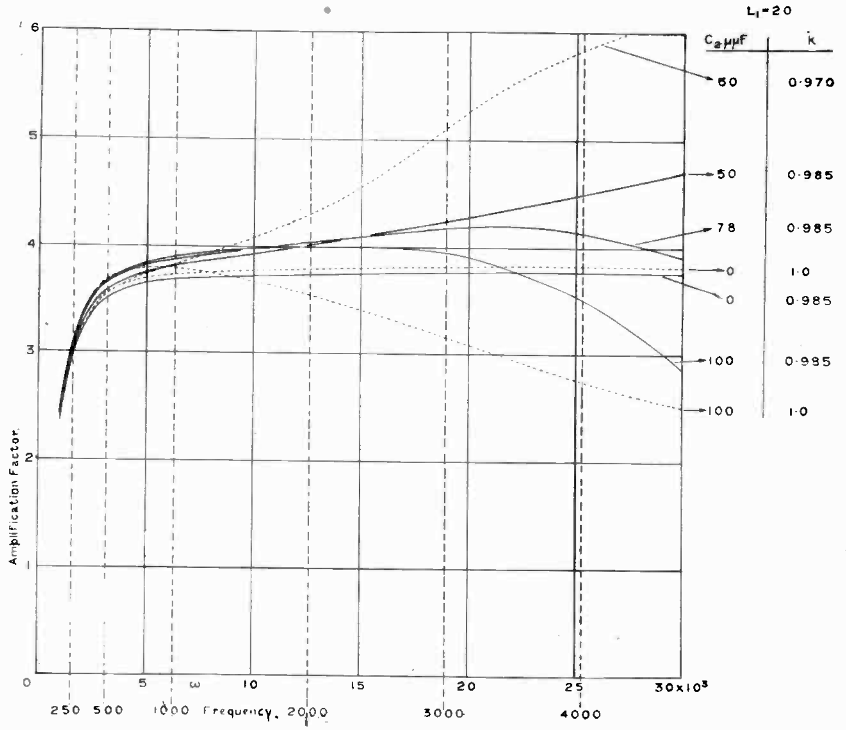


FIG. 24

considerable differences of opinion or lack of knowledge as to what is desirable under various conditions.

8.—Conclusions.

Further experiments are necessary in order to confirm the conclusions stated below, and it is expected that they will be somewhat modified as the result of fuller investigation ; but it is believed that in a general sense the conclusions are true and that they will serve as a basis for further work.

(1) Telephonic intervalve transformers may be considered as possessed of inductance, capacity and resistances which are not very variable with frequency or voltage so long as the latter does not exceed a few volts on the secondary.

(2) The transformer behaves towards the circuit in which its primary winding is connected as though it consisted mainly of an inductance, a condenser, and a shunt resistance in parallel. Such a combination has effective reactances and resistances of which the corresponding values at various frequencies when plotted on rectangular co-ordinates give a curve which approximates very closely to a circle ; this enables a convenient mental picture of the effective impedance over a considerable range of frequencies to be obtained.

(3) The circle diagrams enable the effects of mutual and secondary capacity and a secondary shunt resistance to be clearly visualised in a manner which allows the voltage factor of the primary winding under given conditions to be seen graphically.

(4) The grid-filament circuit of the valve to which the secondary winding of the transformer is connected, may produce profound effects on the primary impedance, according to the conditions prevailing in this circuit. In order to allow the transformer to function properly, it is usually desirable to apply to this grid a steady negative E.M.F. with respect to the filament of such value that the grid potential is never more positive than that which it assumes if left free, *i.e.*, that there can never be a thermionic grid current. Under these conditions the grid-filament circuit becomes of very high impedance, consisting of a small capacity and a resistance in series across the secondary winding ; and does not seriously react on the primary impedance. Under certain conditions the grid-filament resistance may become negative in sign, and so power may be returned to the secondary winding, thus increasing the diameter of the primary impedance circle and tending to cause instability.

The ensuing conclusions assume that the grid-filament circuit connected to the secondary circuit includes means for keeping the grid at a negative potential.

(5) The addition of a moderate shunt resistance on the secondary winding will in general produce greater stability and a flatter amplification curve than would exist in its absence. The amplification will be lowered throughout, but not seriously if the shunt resistance is not smaller than 200 000 σ_0^2 ohms. A turn or two wound over the secondary and short-circuited will produce a similar improvement.

(6) No marked effects occur in either primary voltage factor or ratio of an intervalve transformer as the resonant frequency is passed, but at frequencies above this, marked increases in the ratio of the transformer may occur on account of the fact that the coupling coefficient is slightly less than unity. An effect which may be termed a ratio resonance occurs when

$$L_2C\omega^2(1 - k^2)^2 = 1.$$

(7) The most important single property of an intervalve transformer is the inductance of the primary winding. At low frequencies (below 300 cycles per second) an amplification as great as 75 per cent. of the maximum cannot be obtained on a step-up transformer unless the primary inductance is in the neighbourhood of 20H. This value is not usually attained in practice in the writer's experience, but it should not be impracticable if a somewhat larger iron section is used and if the stampings are carefully annealed after all mechanical treatment is finished.

(8) The effects of secondary and mutual capacity are, with good approximation, interpretable in terms of one another. Thus, from the standpoint of primary impedance (and hence primary voltage ratio), a mutual capacity C_m may be considered as replaceable by a secondary capacity C_2 of such value that

$$C_2 = C_m\left(1 \pm \frac{1}{\sigma_0}\right)^2$$

(the sign depends upon the relative directions of the two windings). From the point of view of ratio, secondary and mutual capacity produce effects which may be interpreted in terms of each other by the relation

$$\sigma_{(C_m)} = \sigma_{(C_2)}\left(1 \pm \frac{1}{\sigma_0}\right)^2$$

where $\sigma_{(C_m)}$ is the value of σ corresponding to a mutual capacity C_m and $\sigma_{(C_2)}$ is the value corresponding to a secondary capacity C_2: it is not correct in this case to consider mutual capacity as replaceable by an equivalent secondary capacity.

At frequencies below that at which $L_2C_2\omega^2 = 1$, the effective primary reactance and resistance are increased by added capacity, and the primary voltage factor thereby improved. Below this limit of frequency, the variation of ratio due to imperfect coupling between primary and secondary is small. The effect of capacity

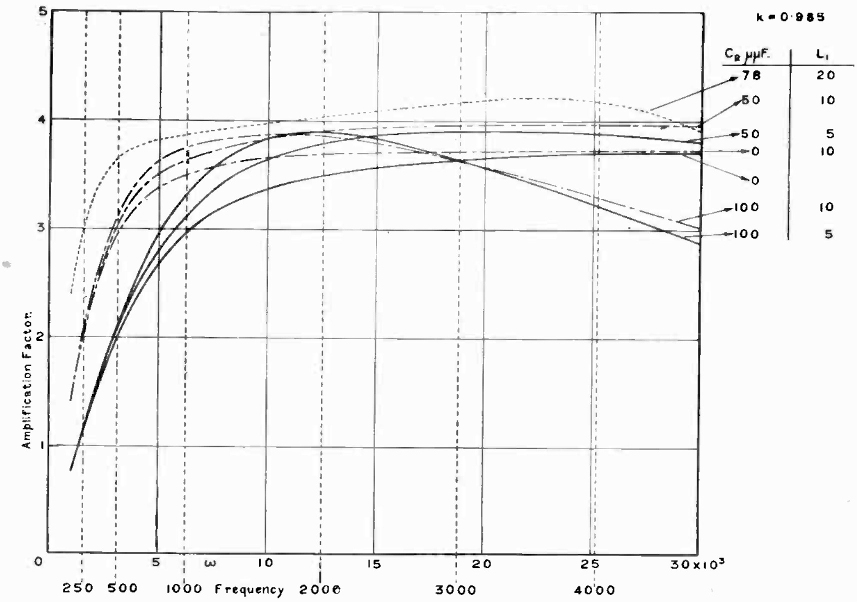


FIG. 25.

on amplification below this region of frequency is therefore always an increase.

At frequencies between that at which $L_2C_2\omega^2=1$ and $L_2C_2\omega^2(1-k^2)=1$ the effects are complicated, and involve all the constants of both windings of the transformer. For all frequencies above that corresponding to $L_2C_2\omega^2=1$ the primary voltage factor steadily falls. A compensation is, however, afforded by the simultaneous rise which occurs in the ratio. The product, giving the amplification factor, may rise or fall or it may keep constant over a considerable part of the region between that where $L_2C_2\omega^2=1$ and $L_2C_2\omega^2(1-k^2)=1$. The amplification factor may exhibit violent fluctuations in the neighbourhood of the point at which $L_2C_2\omega^2(1-k^2)=1$, but above this point it inevitably falls very rapidly and cannot rise again. It is probably desirable to keep this point at a higher frequency than 6 000 cycles per second.

(9) An amplification curve which droops at high frequencies due to the effect of excessive secondary capacity can be improved theoretically by slightly reducing the coupling coefficient. It is not easy to do this in a finished transformer without at the same time reducing the primary inductance, but in the case where an external secondary capacity was used it would be possible to include in the secondary circuit a small external self-inductance. Any reduction in k will cause a corresponding reduction in the ratio at low frequencies. This reduction will in general, however, never be greater than a few per cent.

(10) By a judicious adjustment of k and C_2 to suit each other and the transformer, the amplification ratio can always be improved over that existing in the absence of C_2 or when k=unity. This statement may appear contradictory to the usually accepted ideas on intervalve transformers, but escape from this conclusion appears impossible in the light of the theory developed here. This indicates that a certain amount of secondary capacity is advantageous throughout the whole useful range of frequencies. The desirable value falls within that conveniently obtainable in practice unless the ratio of the transformer is exceptionally high. The higher the ratio or the greater the primary self inductance the smaller becomes the desirable value of capacity. Under these conditions also the coupling coefficient should approach unity more closely. A secondary capacity round about the value $\frac{1\,000}{\sigma_0{}^2}$ in $\mu\mu$F will in general give good results and should bring the resonant frequency to the region between 1 200 and 2 000 cycles per second.

No experiments have been made on the effect of the steady magnetisation of the transformer core as a result of the steady anode current. So long as this magnetisation is not up to the knee of the $\mathscr{HB}$ curve the effect of the superposed steady magnetisation will be to increase the effective alternating

TABLE V.

AMPLIFICATION FACTOR.

ω	$L_1=20,\ \sigma_0=4,\ S_1=5\times10^5$.								
	$C_2=0\mu\mu$F.		$C_2=25\mu\mu$F.	$C_2=30\mu\mu$F.	$C_2=50\mu\mu$F.		$C_2=0{\cdot}78\mu\mu$F.	$C_2=100\mu\mu$F.	
	$k=1$	$k=0{\cdot}985$	$k=1$	$k=0{\cdot}985$	$k=0{\cdot}985$	$k=0{\cdot}970$	$k=0{\cdot}985$	$k=1$	$k=0{\cdot}985$
1 000	2·40	2·37	2·41	2·40	2·39	2·35	2·40	2·46	2·43
2 000	3·24	3·20	3·27	3·23	3·25	3·21	3·29	3·32	3·28
3 000	3·53	3·48	3·56	3·53	3·56	3·51	3·63	3·66	3·64
5 000	3·70	3·65	3·74	3·73	3·76	3·74	3·82	3·80	3·64
10 000	3·78	3·73	3·82	3·87	3·93	4·08	3·98	3·68	3·98
15 000	3·80	3·75	3·80	4·00	4·09	4·55	4·09	3·40	4·00
20 000	3·82	3·77	3·78	4·17	4·28	5·25	4·19	3·08	3·91
30 000	3·82	3·77	3·68	4·67	4·70	6·16	3·91	2·50	2·85

permeability and will be all to the good. This increase may amount to 50 per cent. or 70 per cent. in primary inductance. If, however, the iron is taken up to the bend in its permeability curve or on to the flat portion above the bend, the effects may be serious, both on account of the introduction of harmonics which will result and also on account of greatly reduced effective alternating permeability. The iron will, however, need to be of quite exceptional quality or the anode current be exceptionably large for such a degree of magnetisation to occur. As an example, consider a well annealed sample of Stalloy. To produce a magnetisation of 6 000 gauss will require a value of $\mathscr{H}$ not less than about 2. If we take the total effective length of the core as 8 cms. we shall require about 12 ampère-turns to produce $\mathscr{B}$ =6000. Except perhaps in a loud-speaker stage the product of primary turns and anode current is not likely to reach a value of 12 ampère-turns. If a transformer is required to operate under conditions where such a value of ampère-turns is likely to occur, the transformer should be designed with a large cross section of iron and comparatively few turns on the windings, so as to reduce ampère-turns without sacrificing inductance.

It is, however, not certain what characteristics are desirable in a transformer feeding a loud-speaker stage, since information does not appear to be available concerning the relation between the sound intensity produced and the effective reactance and resistance of loud-speakers under the influence of constant voltage at varying frequencies.

It seems quite certain, however, that intermediate transformers should provide an amplification curve as straight and flat as possible over the longest possible range of audio-frequencies.

Note 2.—The Effect of Magnetic Leakage.

It is not quite certain what is the most accurate theoretical representation of the case, involving the fewest variables, but it becomes very involved if we take more than those shown in Fig. 22, which represents the case for secondary added capacity. It is certain that the properties of the iron must have some effect on the voltage ratio. These cannot be allowed for if the iron losses are represented, as on previous occasions, by a shunt across the primary winding. They have, therefore, been transferred to the secondary winding as the equivalent shunt resistance S_2. This case will also include the case of an external shunt resistance added across the secondary as is sometimes done.

Taking then Fig. 22, we have

$$e_1 = i_1(R_1 + L_1 a) + i_2 M a$$

$$i_2(R_2 + L_2 a + S_2) + i_1 M a - i_3 S_2 = 0$$

$$i_3\left(S_2 + \frac{1}{C_2 a}\right) - i_2 S_2 = 0$$

$$e_2 = i_3 \frac{1}{C_2 a}$$

This will be found to give for the instantaneous ratio the expression

$$\frac{e_2}{e_1} = \frac{S_2 M a}{(R_1 S_2 - R_1 S_2 L_2 C_2 \omega^2 + R_1 R_2 - L_1 L_2 \omega^2 + M^2 \omega^2 - L_1 R_2 S_2 C_2 \omega^2) + (S_2 L_1 - S_2 L_2 C_2 \omega^2 + R_2 L_1 + R_1 L_2 + R_1 R_2 S_2 C_2 + S_2 M^2 C_2 \omega^2) a} \qquad (31)$$

From this we find the ratio of the root mean square voltages to be

$$\frac{E_2^2}{E_1^2} = \sigma^2 = \frac{M^2/L_1^2}{\left[1 - \frac{C_2\omega^2(L_1 L_2 - M^2)}{L_1} + \frac{R_1 R_2 C_2}{L_1} + \frac{R_1 L_2 + R_2 L_1}{S_2 L_1}\right]^2 + \left[\frac{R_1}{L_1 \omega} - \frac{C_2 \omega (R_1 L_2 + R_2 L_1)}{L_1} + \frac{R_1 R_2 - (L_1 L_2 - M^2)\omega^2}{S_2 L_1 \omega}\right]^2} \qquad (32)$$

Let us put $L_1 = L_2/\sigma_0^2$ and $M^2 = k^2 L_1 L_2 = k^2 L_2^2/\sigma_0^2$, where σ_0 = ratio of secondary to primary turns. The equation then assumes the more convenient form

$$\sigma^2 = \frac{k^2 \sigma_0^2}{\left[1 - L_2 C_2 \omega^2 (1 - k^2) + \frac{R_1 R_2 C_2 \sigma_0^2}{L_2} + \frac{R_1 \sigma_0^2 + R_2}{S_2}\right]^2 + \left[\frac{R_1 \sigma_0^2}{L_2 \omega} - C_2 \omega (R_1 \sigma_0^2 + R_2) + \frac{R_1 R_2 \sigma_0^2 - L_2^2 \omega^2 (1 - k^2)}{S_2 L_2 \omega}\right]^2} \qquad (33)$$

Some preliminary calculations show that we can neglect the terms containing the product R_1R_2. Writing also, $R_1\sigma_0^2+R_2=R_t$ we get the more manageable equation

$$\sigma^2=\frac{k^2\sigma_0^2}{\left[1+\frac{R_t}{S_2}-L_2C_2\omega^2(1-k^2)\right]^2+\left[\frac{R_1\sigma_0^2-L_2C_2\omega^2R_t}{L_2\omega}-\frac{L_2\omega(1-k^2)}{S_2}\right]^2} \quad \cdots \quad (34)$$

Note 3.—Leakage with Mutual Capacity.

The full working is similar to that in Note 2 ; the accurate resulting expression is :—

$$\sigma^2=\frac{[\pm k\sigma_0+L_2C_m\omega^2(1-k^2)]^2+[R_tC_m\omega]^2}{\left[1-L_2C_m\omega^2(1-k^2)+\frac{R_1R_2C_m\sigma_0^2}{L^2}+\frac{R_t}{S_2}\right]^2+\left[\frac{R_1\sigma_0^2-L_2C_m\omega^2R_t}{L_2\omega}-\frac{L_2^2\omega^2(1-k^2)-R_1R_2\sigma_0^2}{S_2L_2\omega}\right]^2} \quad (36)$$

which again reduces to the approximate form

$$\sigma^2=\frac{[1\pm k\sigma_0+L_2C_m\omega^2(1-k^2)]^2}{[1-L_2C_m\omega^2(1-k^2)]^2+\frac{1}{L_2^2\omega^2}[R_1\sigma_0^2-L_2C_m\omega^2R_t]^2} \quad \cdots \quad \cdots \quad (37)$$

Note 4.—Transferring Secondary Load to Primary.

In case it is desired to ascertain in any particular case whether this assumption is valid, the accurate expressions for R_{p1} and X_{p1} are here given for the case where a secondary shunt S_2 of any value is present and no primary shunt is included :—

$$R_{p1}=R_1+\frac{M^2\omega^2(R_2+S_2+R_2S_2C_2^2\omega^2)}{(R_2+S_2[1-L_2C_2\omega^2])^2+(R_2S_2C_2+L_2)^2\omega^2}$$

and

$$L_{p1}=L_1+\frac{M^2\omega^2[S_2C_2^2(1-L_2C_2\omega^2)-L_2]}{(R_2+S_2[1-L_2C_2\omega^2])^2+(R_2S_2C_2+L_2)^2\omega^2}$$

The diameter S'_1 of the equivalent primary circle is found by putting $L_2C_2\omega^2=1$. The expression

$$S'_1=(R_{p1}-R)_{max_0}\doteqdot\frac{S_2M^2}{L_2^2}(1-R_2S_2C_2^2\omega^2).$$

When the conditions are such that the second term in the bracket is small compared to unity $S'_1\doteqdot S_2\frac{k^2}{\sigma_0^2}$. This condition will in general be satisfied so long as S_2 is not greater than 5 megohms.

First Ambulance Seaplane.

A NEW Fairey seaplane has been built for service in British Guiana between the plantations of a company and the nearest township, and has been equipped with wireless apparatus by Marconi's Wireless Telegraph Company, Ltd. It has been launched for tests at Hamble, near Southampton.

This machine has been specially designed to carry white men who fall ill with fever on the plantations to the nearest place where they can obtain treatment. Hitherto the journey, though little more than 200 miles, has taken seventeen days owing to the many rapids on the river necessitating porterages, and many sick men have not survived it. The seaplane will accomplish the distance in little more than two hours—the biggest reduction so far obtained on any route.

The Marconi installation will enable telegraphic or telephonic communication to be carried on with both ends of the route. A special wireless ground station has been erected on the estates to work in conjunction with the seaplane.

More about Effective Transmission.

By Hugh N. Ryan (5BV). **[R113**

In this article the author brings up to date, and adds some important facts to, his article on the same subject published last month.

IN my article on "Effective Transmission" in the last issue of E.W. & W.E. there were one or two sentences which probably caused some readers to think that I was suffering from loss of memory. Fortunately, however, this is not the case. The article in question was written eleven months ago, but more important matters crowded it out. It was published last month as a timely warning to those who are about to increase their power in the hope of working America this winter. Unfortunately I was unable to bring it up-to-date before publication, which explains the one or two anachronisms it contains.

During the past year, short wave transmission has developed very considerably, and in this article I can appropriately go straight ahead from the last sentence of the other one, which was "I am wondering if I can span the Atlantic on 4 amps." That was in November, 1923, and the point of the article is well illustrated by the fact that I did *not* succeed in reaching America with this aerial current. I soon began to find that the 4 amps were not "effective." Stations 600 miles away reported signals no stronger than they had been on 1 amp, and not so easy to read. All this work was, of course, on 200 metres, and the set was found to have a very healthy harmonic on 100 metres, which distant stations reported to be as strong as the fundamental.

This was, in fact, the first hint I had of the great carrying powers of the shorter waves, but for the time being I was concerned with 200 metres only, so that harmonic had to go. It was suppressed easily enough, but the aerial current fell from 4 amps to 3.

Here, then, was an adjustment which *apparently* did the wrong thing, and had I not known of the harmonic I should naturally have kept to the adjustment which gave the larger reading on the meter, as, I am afraid, most of us do.

However, since the Danish stations (with whom all these tests were carried out) reported much better signals, I continued to use this smaller aerial current, and was soon rewarded when, on December 2nd, my signals were received in Pittsburg, U.S.A.

Signals were reported to be very weak over there, so I looked for some way of making them stronger. I failed to increase power at all without introducing the harmonic again, but the cause of the trouble was suggested when 2KF politely hinted that a little sharper tuning on my part would make life happier for him (at a distance of two miles !).

Apart from lessening local QRM, it seemed logical that better range might be expected if all the noise was concentrated on one wave instead of being spread out over a band.

The set in use at the time was a direct-coupled Colpitts oscillator, which if not carefully handled is the most broadly-tuned transmitter in existence.

However, the wave was eventually sharpened up by substituting loose- for direct-coupling, and using a tuned plate-supply choke instead of the usual untuned one.

The aerial current with this arrangement was only 2·5 amps, but as soon as I started using it the signals were reported as very strong in Springfield, U.S.A., and also in Northern Africa.

I am afraid that this article has, so far, dealt only with my own work, but I have quoted it to show how a rather carelessly adjusted transmitter can be more or less useless with 4 amps in the aerial, and yet, with careful adjustment and only 2·5 amps, be one of the longest range transmitters in the country. Therefore, "don't worship the amp."

All the foregoing, though actually written in reference to 200-metre work, applies with equal force on 100 metres and thereabouts, but in addition to this there are a few other little difficulties to be met on the shorter waves.

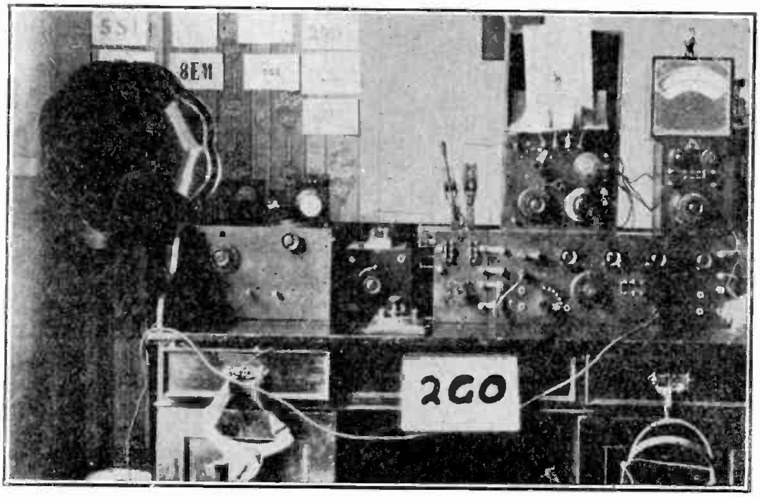
There are, at present, probably a number of experimenters who are transmitting on the 115-130 metre band for the first time, and at first they may be disappointed with the small aerial currents they obtain. Most of us were last year—until the reports started to come in. In the average amateur aerial ·5 amp on 115 metres will give as great a range as four or five amps on 200 metres.

But the chief source of trouble on these waves is the fact that the aerial ammeter hardly ever shows the true current in the aerial. Most stations still use hot-wire ammeters, usually of the ex-Army type, for financial reasons. These meters usually have a metal back through which the terminals pass, and from which they are insulated by mica washers. There is, therefore, a large capacity shunted across the meter, and the higher the frequency the more current goes through this capacity city and the less goes through the hot wire.

Another common trouble is that many people use a low-reading ammeter with a shunt across it, and re-calibrate it. The closed circuit formed by the hot wire and its shunt is often within the field of one of the oscillating coils, when, of course, it has a considerable current induced in it, giving the appearance of a large aerial current. One of the Danish stations was badly "had" in this way last year. I recommend the point to those who think they obtain efficiencies of over 100 per cent.!

Lastly, keep the aerial and counterpoise leads clear of everything, and of each other. I know quite well the smug and complacent feeling that results from seeing the needle of the biggest meter you've got hit the other side of the case, but, believe me, an even more pleasant feeling is obtained when you get a long-distant report, and *then*, the less the current was at the time, the happier the feeling!

I will conclude with one more experience at my own station, this time on the shorter waves. Throughout last year's Transatlantic season I used between 1·5 and 1·8 amps on the short wave. When the year had advanced so far that work with America had practically ceased, I dismantled most of the transmitter for various repairs. At the same time, my aerial came down.



A view of the transmitting and receiving apparatus of amateur British station 2GO, operated by Mr. L. Bland Flagg, 61, Burlington Road, Bayswater, London, W2.

I rigged up a small transmitter for local work, putting under half an amp into a very low temporary aerial (30 ft. high one end and 15 ft. the other).

The signals from this were received *very strongly* in Kentucky, U.S.A., as late in the year as June 2nd, some time after the high power set on the big aerial had ceased to be received in America!

The half amp in a low aerial was thus much more "effective" than 1·5 amps in one 80 feet high. The only difference was that the high-power set used A.C. C.W. and the low-power one pure D.C., which does not seem likely to account for it.

I cannot explain it, so I leave it at that, "stalled" on my own pet subject!

How to Use up Old Gramophone Records.

By Harry A. Gaydon, A.M.I.A.E., A.F.Aer.Inst. [R380

IT is now generally known that the material used in the manufacture of most gramophone records has excellent insulating properties, and can be effectively, used for many purposes for wireless apparatus. [*Not* in H.F. circuits.—Ed. E.W. & W.E.] In their normal state records are somewhat brittle, and the material does not readily lend itself to manipulation, although it can be cut with a saw, filed, and even drilled when carefully done, and finished by means of emery cloth. If, however, a record be subjected to the right amount of heat it at once becomes easily workable, and can be cut with scissors and moulded into various shapes with the greatest of ease. On cooling it again becomes hard and will retain whatever shape it happens to be in, indefinitely. It will be as well to mention, however, that all records may not be suitable for this purpose. For instance, "Columbia" and "Regal" are built up as it were, a coarse material being used as a base, and a much finer material covering both sides on which the sound waves themselves are imprinted. Practically all other records, however, are uniform throughout and well suited for the purpose.

One way of heating the material is to place the record in a shallow pan of boiling water for a few seconds and it will then be found that it becomes plastic, almost of the consistency of dough. Under this condition it is easy to cut into any shape by means of a pair of scissors or a penknife (and it is well to warm the scissors or knife first to avoid local cooling) and can be moulded with the fingers as desired. Another method is to carefully heat it in front of a fire, taking care that the heat is uniformly applied. Still another way is by means of a hot metal plate which can be heated over a gas ring to the desired temperature, which will be readily found by experiment. Care must be taken to avoid overheating, otherwise the material itself may catch alight. After cutting to shape, it can be laid on a flat surface such as a piece of plate glass, to cool.

Holes can be cut with a small knife or punch whilst in the plastic condition, and if extra thin material is required it can be rolled down on a hot plate to the desired thickness by means of a length of metal tube, or even a rolling pin. Tubes may also be made by first cutting a rectangular piece to the required dimensions, and rolling round a rod: if necessary a join may be made along the length where the two ends meet by means of a heated metal rod, after the manner of a soldering iron. This however, will require a little patience. Other shapes of tubes may also be made by the same method, such as square, rectangular, etc.

It will be readily seen that many small useful articles can be made, such as small terminal boards, detector blocks, control knobs, insulating washers, lead-in tubes, bobbins, aerial insulators, it being quite easy to mould a shell insulator by first cutting a disc of the desired size, and shaping by means of the forefinger and thumb of either hand, holes being pierced in the required position to accommodate the wire. It can be also used for filling up unwanted holes in ebonite.

In cases where an internal thread is required, it should not be difficult to mould the substance round a screw of the size chosen, and screwing same out when cold, the knurled edge can be readily formed with the blade of a knife when plastic, or filed when cold. After cooling, the articles may be finished by means of a fine file and emery cloth, a good sound job resulting.

It is not suggested that the articles will compare favourably in appearance with those now purchasable for quite small sums, but to those who take a pride in making all their own apparatus as far as possible, as undoubtedly many do, the above should prove of considerable interest and utility.

The most serious disadvantage, however, is a comparatively high power factor (compared with ebonite). But there are many parts and accessories (especially in L.F. circuits) where this is not of importance.

Some Measurements on a Broadcast Receiver.

By G. W. Sutton, B.Sc. **[R220—240**

Lecturer in Electrical Measurements, C. & G.(Eng.) College.

In this article the author describes some measurements of received voltage, amplication, etc., on a broadcast receiver.

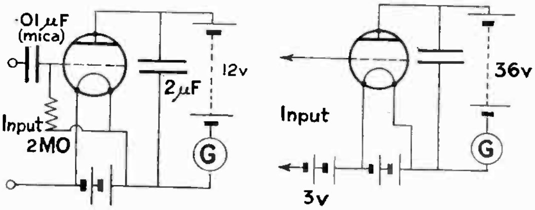
THE following simple measurements of received voltage, amplification, etc., on a broadcast receiver were carried out largely for the purpose of ascertaining the usefulness and limitations of the rectifying valve voltmeter under "amateur" conditions. It was also hoped to gather a little useful information as to the magnitude of the voltages and power employed when operating a small loud-speaker. Owing to limitation of time the results have not been checked and many interesting points have only been partially investigated.

Although facilities were available for carrying out the work under the best conditions as regards apparatus and power supply, they were actually conducted, for the purpose mentioned above, in a small private workroom where the only source of electrical energy consists of 2-volt accumulators (of not too large a capacity) and a limited number of H.T. units.

The most convenient starting point for the amateur about to undertake voltage and current measurements is a thermo-ammeter. The heater and thermo-junction are easy to construct, and, when used in conjunction with a 10s. Weston relay galvanometer, provide a suitable laboratory standard. This may be calibrated on D.C. (by direct comparison with a reliable moving coil voltmeter or ammeter) and may then be used on A.C. of almost any frequency.

Following a suggestion of Prof. Mallett, the author made use of a Weston relay in constructing his valve voltmeters and found it invaluable for the purpose. Owing to its high sensitivity and critical damping it is possible to read rapidly fluctuating voltages, and no difficulty is experienced in levelling or from mechanical vibration. A D.E.R. valve was used and gave very consistent results provided the accumulator was of sufficient capacity to maintain a steady output. A well-charged 20 amp-hour cell in good condition was found suitable.

In the valve voltmeter an A.C. voltage is measured by applying it between grid and filament, employing either cumulative grid rectification (G.R.) or anode rectification (A.R.), and noting the consequent change in mean anode current on a D.C. moving coil milli- or micro-ammeter.[1] The circuits



Grid Fig. 1. *Anode.*

employed in the two types are illustrated in Fig. 1. It is essential in many radio measurements that a voltmeter should take negligible current from the circuit to which it is applied. Some measurements of the voltage-ratio of an intervalve transformer given below illustrate this point. Such current may be due to the inter-electrode capacity of the valve, to grid-filament conduction or, in the case of the grid-rectification instrument, to direct leakage through the grid-condenser and leak. The last may be eliminated by use of a good mica condenser. The second is inherent in the G.R. method and forms one of its draw-backs, but may be eliminated from the A.R. by use of suitable anode battery and grid bias; while the first is avoided by use of the large shunting condenser shown in the anode circuit in each case in Fig. 1. These

[1] See E. B. Moullin. "A Direct Reading Thermionic Voltmeter." *I.E.E.*, Vol. 61, p. 295.

points are important and neglect of suitable precautions may lead to very erroneous results.

The instruments must, of course, be calibrated on A.C. In the writer's case this was obtained from a valve oscillator arranged as in Fig. 2. (If 50~ A.C. is available from the lighting mains this difficulty may be avoided.) The calibration circuit is also shown in Fig. 2. A P.O. box was employed as potential divider, it being considered sufficiently non-inductive at the frequency used, which was approximately 100~.

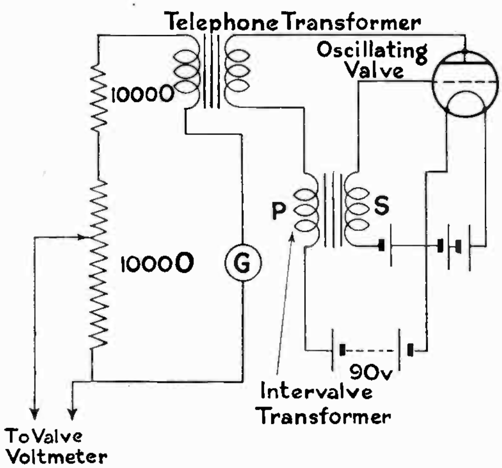


Fig. 2.

The circumstances of the experiment dictate which of the two types of instrument is more suitable for a particular measurement. The G.R. type may introduce an undesirably large amount of damping into a circuit, but on the other hand will read quite small voltages (down to ·02 volt with above arrangement), and is unaffected by D.C. voltages across its terminals. It may be used to measure the voltage on one of two condensers in series (this is not possible with the A.R. type, of course), and so may be employed with a condenser shunt, as shown in Fig. 3. The A.R. type may be adjusted to avoid the introduction of any appreciable damping (up to 2·5 volts in the above case), but is affected by D.C. voltage and must have a closed circuit across its terminals.

It may be mentioned that the galvanometer (only one was available and switching arrangements were adopted so that it might be used in either type of voltmeter circuit) was fitted with a mirror, a spot of light from a 2-volt lamp focused by a 4 in. lantern condenser lens, being reflected on to a 2 ft. scale. There is no reason why a pointer should not be fitted, as suggested by Mr. Sayce in E.W. & W.E., September, 1924. There would, of course, be some sacrifice of sensitivity but a gain in convenience.

One of the most important parts of this experiment was the calibration and checking of the voltmeters. It was found that, so long as the anode, and in the case of the A.R. type, the grid, voltages were fairly closely repeated, and the original zero readings were reproduced by adjustment of the filament current, successive calibration curves coincided as closely as could be read on a graph of foolscap size. Taking all factors into account, it appeared that the instrument could be relied upon to within 1 per cent.

The calibration curves are reproduced in Fig. 4. Zero reading in the case of A.R. was adjusted to 6·0 divisions by means of the filament rheostat whenever a measurement was made, while in the case of G.R., since a *reduction* of mean anode current takes place, a zero of 60.0 was used. These curves illustrate in a qualitative way the conditions under which it is more efficient, from the point of view of signal strength, to employ G.R. or A.R. It must be remembered, however, that the voltages and grid-condenser used are exceptional.

The set upon which the experiments were conducted is a crystal detector and 3-valve resistance-coupled amplifier, which has been giving very satisfactory service for some months in operating a home-made loud-speaker at a distance of some five miles from 2LO on an aerial of moderate efficiency. The loud-speaker consists of two 60-ohm Brown reed-type earpieces with paper cones attached to the reeds and suspended from the ceiling. Using the three valves the intensity of sound is unnecessarily great, speech being audible all over the house, though distortion is scarcely noticeable. In fact, reproduction compares very favourably with any that the writer or his friends have heard. Two valves are normally sufficient for "comfortable" audibility.

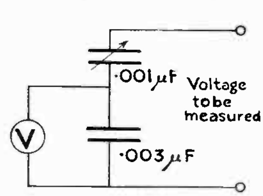


Fig. 3.

Like Mr. Colebrook,[2] and for the same reason, the writer adopted 47 S.W.G. single silk Eureka wire for anode resistances some time ago. It seems unfortunate that an even smaller size is not manufactured, since Eureka is mechanically stronger than copper and would give no trouble in winding; 47 gauge is of more than sufficient carrying capacity for the current it is called upon to carry in these cases. Only 40 000 ohm units were in use when these measurements were made, but another 40 000 ohm bobbin has now been added to each, with consequent increase in amplification.

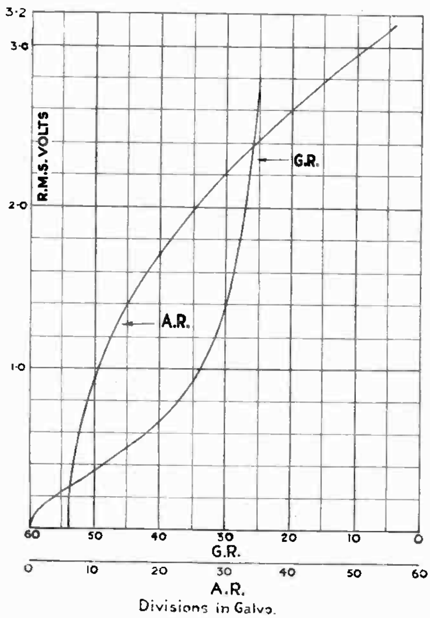


Fig. 4.

The arrangement of the set was largely dictated by the fact that the writer already possessed 2 Wecovalves and a M.O. D.E.R. which he wished to employ. In addition it was considered financially desirable to work on not more than 90 volts or so (three 36-volt units give from 90 to 96 volts for the major portion of their useful lives), if distortionless results could be achieved on that. Thus allowing 30-40 volts drop in the anode resistances of the Wecovalves there remains 50-60 on the plate, which is a suitable value for these small valves. The whole 90 would be available for the D.E.R. since its anode circuit only contains the telephone transformer. It was hoped that this would be sufficient to enable a suitable negative grid bias to be used, so preventing grid current from flowing during any part of a cycle, while working on the straight part of the characteristic. It has since been ascertained that considerable grid current must flow when 3 valves are used, the reason for the comparative freedom from distortion being, doubtless, that the flow produces little effect on the total charge in the 0·1μF coupling condenser, whereas with transformer coupling it would be sufficient practically to short-circuit the secondary.

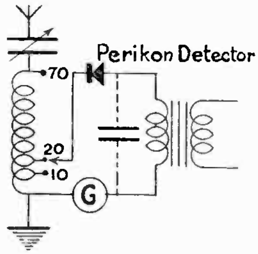


Fig. 5.

A few measurements were first carried out by means of the A.R. voltmeter on the voltage induced in the A.T.I. by 2LO's carrier wave. A 70-turn solenoid, tapped every 10 turns, was employed as shown in Fig. 5. Experiments had previously been carried out along the lines suggested by Mr. Colebrook,[3] and it was found that the maximum value of mean rectified current, 30·3μA, was obtained on the 40th turn, whereas with the crystal circuit connected between turns 70 and 0 only 25·8μA were obtained.

TABLE I.

Radio Frequency.	Voltages. (All in R.M.S. Volts.)			
A.T.I. Tapping.	(a)	(b)	(c)	(d)
70	1·50	·40	·71	·97
40	·90	·27	·48	·70
30	·68			·55
20	·44			·35
10	·21			·15

(a) Detector disconnected.
(b) ,, connected to 70th turn.
(c) ,, ,, ,, 40th ,,
(d) Valve detector (grid rectification) in place of crystal.

[2] E.W. & W.E., September, 1924.

[3] *Wireless World*, April 30th, 1924.

The most interesting of these figures is the ·40 volts column (B) and ·48 volts column (C), which show a 20 per cent. increase in voltage on the detector circuit by placing it across the 40 instead of the whole 70 turns. A 20 per cent. increase of mean rectified current was brought about at the same time. A drop of 0·06 volts across the primary of the intervalve transformer was observed even when there was no modulation of the carrier wave. This was eliminated by shunting a ·0002μF condenser across the winding. This ·06 volts thus represents an appreciable and avoidable loss.

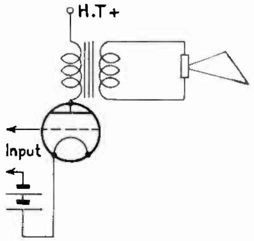


Fig. 6.

Audio-Frequency Voltages.

Attention was now directed to audio-frequency voltages. The writer was surprised to find that the maximum voltage produced during half-an-hour's concert was only 0·1 volt (approx.) across the primary of the intervalve transformer, although the H.F. voltage under rectification was 0·48. Thus the modulation would appear not to exceed 20 per cent.

It was desired to ascertain fairly accurately what the maximum grid swing was on each valve with the loudest received signal,

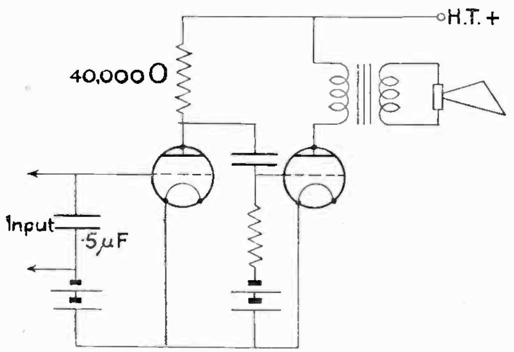


Fig. 7.

and with this purpose the voltage across the secondary of the telephone transformer used with the loud-speaker was observed for some time. With all three valves in circuit this was 2·1 volts. (This could be observed more accurately on the A.R. voltmeter than could the 0·1 volt mentioned above even on the G.R. voltmeter.) Unfortunately the rapid fluctuations made observation very difficult on the normal 2LO transmission.

A 700-cycle oscillator was therefore set up and connected to the input of the amplifier. This led to some extraordinary results which were found to be due to the oscillation of the set at some radio-frequency, possibly due to the fact that the anode resistances were by no means non-inductive. This trouble was eliminated by connecting a large (·5μF) condenser across the input terminals, and so earthing the first grid so far as H.F. voltages were concerned.

The maximum signal voltage at the output end of the set being known it was necessary to measure the voltage ratios at each succeeding stage of amplification. That on the third valve was attempted first, the circuit being as shown in Fig. 6 and the results in Table II.

TABLE II.

Input Volts.	Volts on Secondary of Transformer.	Ratio
·24$_5$	·11$_5$	×·47
·58$_5$	·24	×·41
·82	·37	×·45
1·37	·60	×·44
		mean ×·44

Then the amplification due to the second Wecovalve was measured, the circuit being as shown in Fig. 7. From the static characteristics of this valve μ appeared to be 5·6 and R_a 21 000 ohms. Thus, using an anode resistance of 40 000 ohms, the maximum step-up would be ×3·7. Table III. gives the results of this test.

TABLE III.

Input Volts.	Volts on Grid of D.E.R.	Ratio.
·12$_5$	·43$_5$	×3·5
·21$_5$	·74	×3·4
·32$_5$	1·09	×3·4
·41$_5$	1·36	×3·5

As a check on Table II. and Table III. the results in Table IV. were obtained.

Connections as in Table VI.

TABLE IV.

Input Volts.	Volts on Secondary of Telephone Transformer.	Ratio.
·12$_5$	·19	×1·52
·25	·38	×1·52
·37	·55	×1·49
·60	·92	×1·53

The agreement is very close :—

·44 (Table II.) × 3·45 (Table III.) giving 1·52.

The step-up ratio of the intervalve transformer was now measured, the G.R. voltmeter being employed. The results obtained are given in Table V.

TABLE V.

Primary Volts.	Secondary Volts. Grid of Voltmeter to "O."	Secondary Volts. Grid of Voltmeter to "I."	Ratio.
·08	·29	·35	×3·6 ×4·4
·12	·40	·48	×3·3 ×4·0
·18$_5$	·58	·66	×3·1 ×3·6
·23	·69	·80	×3·0 ×3·5
·37	·89	1·02	×2·4 ×2·8

This test was repeated at several different frequencies with much the same results. Two interesting facts emerge from this. Firstly it illustrates the marked effect of damping due to grid current taken by the voltmeter. This is negligibly small at ·3 volts but rapidly increases. Secondly it shows that under such conditions the direction in which the transformer secondary is connected in circuit is important. When the test was repeated, using the A.R. voltmeter, neither of these effects was noticeable, a typical reading being :—

P 0·8 volts. S (either way) 3·37; ratio 4·2.

Finally, the loud-speaker consumption was noted. The loudest signal so far recorded, and then only for an instant, produced a drop of 2·6 volts across the phones. When this voltage was reproduced by the 700-cycle oscillator the current flowing in the phones was found to be 1·7mA. Thus the maximum consumption was 4·5 milliamp volts. It is obviously not justifiable to consider this to be the power input in milli-watts and time did not permit the measure ment of the P.F. of the circuit. It is sufficient to give an idea of the approximate consumption however.

All the voltages so far recorded are in R.M.S. or effective values. In Fig. 8 these have been converted where necessary into amplitude of grid swing on the assumption of sinusoidal A.C. wave. The voltage on "d" has been taken as 2·1 (corresponding to a loud signal), and, employing the ratios as determined above, that on P. is found to be 0·09—in close agreement with the directly observed value of 0.1.

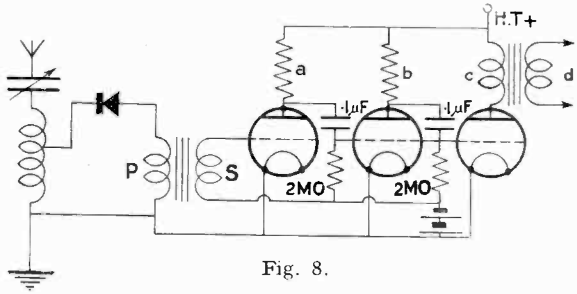


Fig. 8.

	P.	S.	a	b	c	d
R.M.S. volts.	·09	·39	1·36	4·8	25	2·1
Grid Swing.		1·1	3·8	13·5		

S/P = 4·2 : 1. d/c = 1 : 12.

From these figures it is seen that the grid swing is only 3·8 volts on the second Weco-valve. Thus, these two valves could be run on a V_a of only 35 volts and V_g – 1·0 without causing appreciable grid current to flow or moving off a fairly straight portion of the characteristic. One peculiar point noticed with these little valves is that no grid current flows till about 1·6 volts positive is reached on the grid. Operating thus a mean anode current of 0·4 milliamps would be used, and if R_a were raised to 150 000 ohms only 96 volts total H.T. would be required.

The difficulty is the third valve. One allowing for a grid excursion of about 15 volts without moving off the straight part of the characteristic or producing a grid current, when operating with a V_a of 95 volts, is called for. The D.E.R. would fulfil this if provided with 150 volts V_a.

The Perfect Set.

Part II: The One-Valve Set. [R343

Below will be found the second of a series of articles dealing very thoroughly with a subject of great importance both to the advanced experimenter and the ordinary listener.

In considering the design of a one-valve set, we are confronted by a problem singularly different from that of the crystal set dealt with last month. In that case we were dependent entirely upon the energy supplied from the transmitter *via* the aerial, and our main effort was to conserve it. The avoidance of losses became by far the most important point.

In the valve set, on the other hand, we are utilising a local source of energy—the high tension battery—and the problem is rather to ensure that the incoming signals release this energy to the maximum extent consistent with an exact control. Further, the use of reaction affords a method of compensating for many losses, so that the design of the aerial circuit for low resistance is not of such importance.

This last point, be it noted, is one about which there has been much discussion: is it or is it not true that reaction can make up for inefficient circuits? Recent investigations all tend towards the answer "Yes," as regards certain kinds of inefficiency. Reaction will compensate for high resistance. The oft-mentioned "negative resistance" effect is a real one, so that an aerial circuit of 50 ohms with a reaction effect of —30 ohms behaves, as regards strength and selectivity, just like an aerial of 20 ohms. But reaction apparently will not compensate for bad design in the valve circuits themselves, the use of unsuitable voltages, bad telephones, etc.

In the long run, then, successful design in the one-valve set depends on having the valve circuits suited to the valve. Just as a reminder, Fig. 1 shows the standard circuit.

The Aerial Circuit.

In this part of the set our efforts must lie in the direction of getting the biggest possible voltage between the valve grid and filament. In the case of a crystal, as shown in our last issue, it is correct to design the circuit on the principle of equal losses in aerial and crystal: for a high impedance crystal a high-voltage circuit and vice versa. The same applies here. But the input circuit of a valve (at broadcast wave-lengths) has a very high impedance compared with a crystal: it may be, according to the type of valve and the circuit arrangements, 10 000 ohms to perhaps 200 000. Hence the aerial circuit should be designed to have

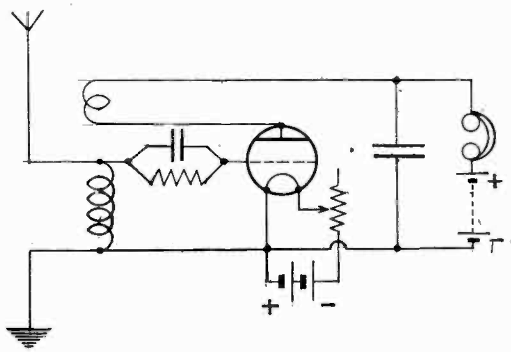


Fig. 1.

as large a voltage as possible across its inductance; and this means a large inductance. To enable a large inductance to be used, while still tuning down to the neighbourhood of 300 metres, means putting an aerial condenser in series with it. So that our typical aerial circuit uses a tuning condenser and fixed coil.

The same idea as last month of transforming up or down to suit the load, may be embodied. It will be remembered that in the crystal circuit this led to a design like Fig. 2A, in which the crystal was tapped off part of the coil, to prevent excessive damping. With the high resistance valve circuit, however, we work in the opposite way: we wish to transform *up*, so we arrange the circuit as in Fig. 2B. Since in this case the high voltage is obtained by transformer effect, it is not so necessary that the voltage between A and B should be large, hence we can include only the actual inductance required to time, and the condenser may be omitted. In actual practice, however, this circuit is not a favourite, for it does not lend itself so well to getting long waves as well as short, since one cannot use the favourite plug-in coils. But if one wishes only to cover the "broadcast band" of 300—500 metres it is hard to beat.

The Valve Circuits.

In considering the valve circuits, we must study detector action a little, and we are presuming throughout that the standard method of grid rectification will be used.

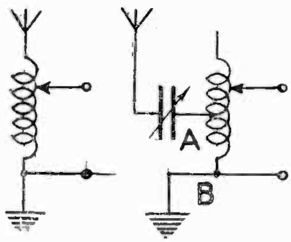


Fig. 2A. Fig. 2B.

As we all know, this depends on having the grid kept, by the grid-leak, at such a steady potential that a very slight grid current flows from filament *via* leak to grid and thence through the valve back to filament. When the incoming signals impress an alternating voltage on the grid, a larger current flows every time the grid becomes more positive, but no current flows as it becomes more negative each cycle. Hence there is an accumulation of charge on the grid and its condenser, which can only leak away slowly through the grid-leak. Let us look into the quantities.

Obviously we are here dealing with a characteristic of the valve which is not often enough given to us by the valve-maker, and which is, unfortunately, not very easy to measure: the relation between grid volts and grid current.

Valves naturally vary greatly on this point, but the sort of relationship likely is shown in Fig. 3. The grid current is *nil* below about —0·5 volt, and then rises, slowly at first and then rather rapidly. Now on studying this particular curve, we can see that the best steady grid voltage is obviously about +0·2V, where the curve is sharpest (the point marked A). The grid is to be maintained at this voltage by the leak, and we must now find how to arrange the leak to do this. Consider Fig. 4.

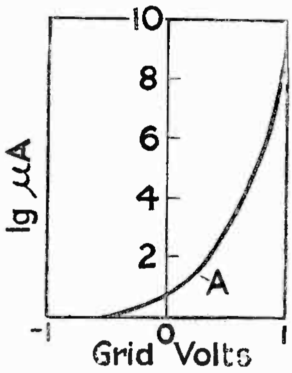


Fig. 3.

The point 0 volts corresponds to the negative side of the filament, which we take as our zero. If we take a 2MO grid-leak, connected to the negative side, we can say that the grid volts and current must correspond to some point on the line OB. For the leak follows Ohm's Law: for every one volt on it there must be

$$\frac{1 \text{ volt}}{2 \text{ Megohms}} = \tfrac{1}{2}\mu A,$$

which is true for the line OB. If we were using a 1MO leak, the line OC would represent it, for in this case 1 volt must give $1\mu A$.

Suppose we connect to the positive side of the filament, say at 4 volts positive. Then the grid current and voltage must be represented by lines such as 4D, 4E in Fig. 4, 4D being for a 2MO leak, and 4E for 1MO.

But we know that the grid volts and current are already represented by the curve of Fig. 3. If now we draw both Figs. 3 and 4 together, as in Fig. 5, we see that (taking the line 4E as an example) there is just one way in which the grid volts and current can fulfil the conditions of Fig. 3 and also of Fig. 4: the grid will set itself at the point represented by F: about 0·6

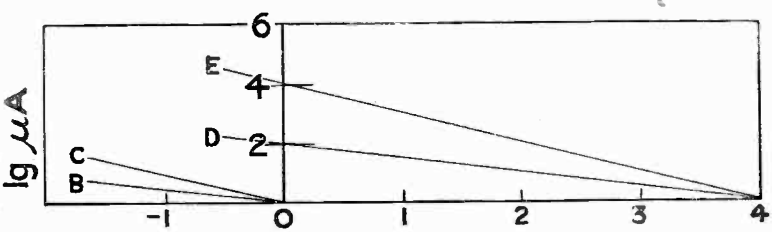


Fig. 4.

volt positive, with a grid current of about 3μA. Now, referring back to Fig. 3, it will be remembered that it was desired to keep the grid steady at the point A. This can

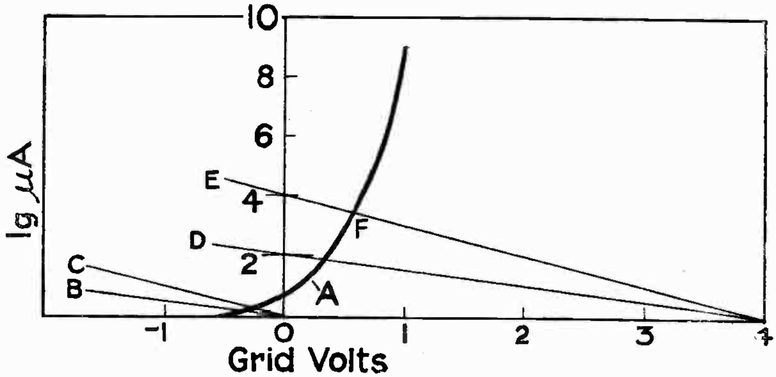


Fig. 5.

obviously be done, as shown in Fig. 6, by a 1MO leak connected to a point at about +1·3 volts (line GH) or a 2MO leak connected at +1·8 volts (line KL) or by other values of leak, provided the leak is connected to the correct voltage. In practice, the best value of leak must be governed by various high frequency considerations, two complicated to be set out here. Generally speaking, a leak of anything between 1 and 3MO will do almost equally well, provided the lower end is connected to a point at the right voltage. What this right voltage is depends entirely on the valve, and in practice the simplest method of finding and keeping it is by using a potentiometer across the filament. For even if we get from the valve makers a curve showing grid current, it must be remembered that a change of anode volts makes quite a difference to the grid current curve. There is, however, one little catch in adjusting grid potential by just listening to signals. Suppose we set the grid a little too negative for best rectification, we are losing signal strength; but we are also decreasing grid currents and we are decreasing the damping effect of the valve on the aerial circuit. The reaction has less loss to work against, we get nearer to oscillation point, and the increase due to this may hide the decrease due to not getting the best rectification. In other words, after each adjustment of grid potential re-adjust the reaction to just off oscillation; then judge the signal strength.

We have now dealt with the size of leak and the connection of the filament end of the grid circuit. There remains the grid condenser. Here again the question of its value is a complicated matter. But, as in the case of the leak, quite a large departure from the theoretical value does not make a large difference in efficiency. Anything between ·000 05 and ·000 2 will serve well with ordinary valves. The use of a variable leak and condenser may sometimes help a little, but it is our firm belief that the use of a potentiometer, connected as in Fig. 7, is much more important, and that if it is adopted variable grid-leaks and condensers are not necessary.

One point, however, is important: the use of a really good grid-condenser, especially from the point of view of high insulation. Since a resistance of 1 to 3MO constitutes the working circuit, the condenser should have an insulation of at least 50MO. Luckily, there are many such available.

The Anode Circuit.

First, perhaps, one should deal with the question of the H.T. battery and its proper voltage. This, luckily, is an easy problem,

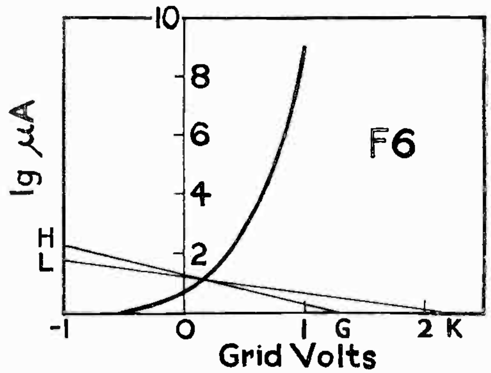


Fig. 6.

if we have available the ordinary characteristic curve of the valve. We know, from previous considerations, that the lower end of the grid-circuit will be held at, say, 2 to 4 volts positive, and that the grid itself will be in the neighbourhood of zero—say between -1 and $+1$ volts steady potential.

We know also that the invariable effect of signals will be to make the grid more negative. We want this change of grid volts to produce the largest possible change of plate current. Therefore, the anode voltage must be such that the top of the "straight" part is at say $+1$ or $+2$ volts—in other words, if the characteristic curves are like those of Fig. 8, the correct voltage would be 60, though if the incoming signals are weak, so that the change of grid-volts is only small, one could use 40 volts.

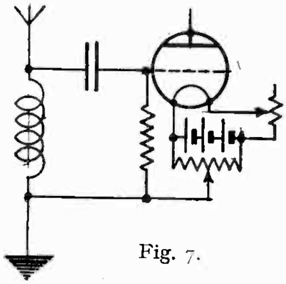


Fig. 7.

This, however, should be the steady voltage on the anode itself. It must not be forgotten that part of the battery voltage is taken up in driving the current through the phones, etc. If for example the steady plate current is $2\mu A$ and the phones have a direct current resistance of 4 000 ohms, there will be eight volts lost in them, and the battery should be this amount higher than the required actual anode volts.

Next, as to the various items in the anode circuit. First, their order. This is fairly well standardised by now, but to prevent any misunderstanding one may as well repeat that the reaction coil must come nearest the anode, then the phones, and lastly the battery. This is for the obvious reason that if the battery or phones were put next the anode, their capacity to earth would shunt much of the H.F. current out of the reaction coil.

The necessary size of reaction coil depends on the size of aerial coil, the efficiency of the circuits, and the type of valve. Less is needed if the valve has a high magnification, etc., if the circuits are of small H.F. resistance, or if the aerial coil is large. It will be found a great convenience to use a fairly large coil, so that the amount of action wanted can be got with the coils some way apart; for if it is necessary to bring them close together, one is confronted with the annoying feature that the slightest change of position has a quite large effect on wavelength and necessitates re-tuning. There may also be difficulty owing to the capacity-coupling between the coils, which may or may not assist in producing oscillation. For the same reason, it is wisest to choose a coupling arrangement in which the coils move quite widely apart. In a type sometimes used, in which one coil moves across the other, there are sometimes surprising fluctuations of coupling at certain points; the coupling may change from positive to negative and back again within a few degrees of movement. The one important point is a really delicate adjustment.

The next item in the anode circuit is the telephone with its shunting condenser. The resistance of the phone must be considered. It is, of course, its impedance to alternating current of audio-frequency that matters, and, unfortunately, this is a very variable quantity. However, one will not be far wrong in using the usual "4 000 ohm" phones. These have a low-frequency inductance, as a rule, of about 5 Henries, or thereabouts, but their self-capacity usually causes them to resonate within the audible range (often at about 1 000 cycles), and in this neighbourhood their impedance varies rapidly. The shunting condenser (which should be across the H.T. battery as well)

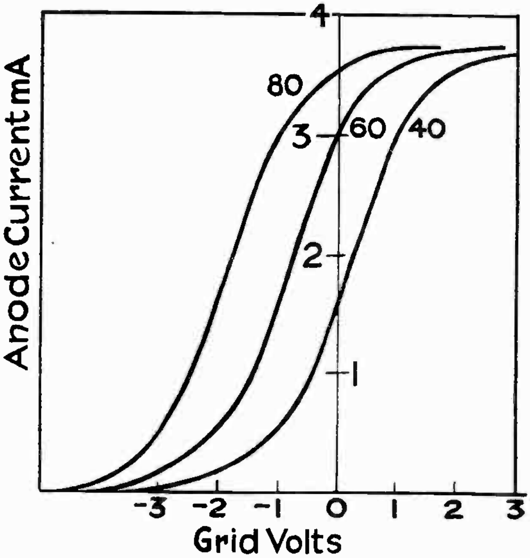


Fig. 8.

has to pass the H.F. component of the anode current. Its value is considered in part of an article elsewhere in this issue (" A Simple Way to Calculate Circuits," p. 69), and reasons are there discussed indicating that its best value is nearer ·000 1 than the usual value of ten times that amount.

A Neon Lamp Method of Comparing Capacities and High Resistances.

By W. Clarkson, M.Sc., and J. Taylor, B.Sc. [R220-240

In the following article, which is a simplified version of their original paper, the authors consider the use of the Neon Lamp for comparing capacities and high resistances and describe some of the methods employed.

I.—General.

READERS will be familar with the glow discharge of the Neon lamp, and with the fact that when a fairly large capacity is placed in parallel with the lamp the discharge becomes regularly intermittent. A circuit for demonstrating this phenomenon of "flashing" is indicated in Fig. 1, in which L is the lamp, E the battery (of about 200 volts), driving the lamp, R, is a resistance of the order of a megohm, and C is the capacity.

Using such a circuit it has been found that the relations between the period of flashing T and the capacity, and between T and the resistance are linear, being expressed by the relation

$$T \propto RC.$$

Figs. (2) and (3) respectively show the relationship between T and R when C is constant and between T and C when R is constant. In obtaining these graphs E was kept constant at approximately 190 volts, C and R were varied as indicated and the times T for one hundred flashes were measured by a stop-watch. As will be seen, the graphs are linear and intersect the C axis at a point not far removed from the origin. These relations hold with C as great as 7·0 microfarads, and were also obtained with E of values ranging from 180-260 volts. We may say then that,

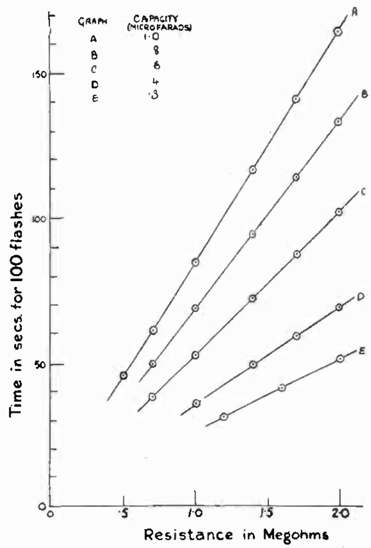


Fig. 2.

the other factors being constant, T is a measure of R in one case and of C in the other. The application of this to the comparison of capacities and high resistances is obvious.

It is not necessary, however, to limit oneself to values of C and R which permit countable flashes. If headphones are included in the circuit of Fig. 1 and C is steadily decreased it will be found that the frequency of the flashes is increased correspondingly, and finally a musical note is heard in the telephones. On further decreasing the capacity the note can be made more and more shrill, until it becomes a faint hiss. This final state indicates a frequency of 20-30 thousand periods per second and even this by no means the limit of obtainable frequencies. Obviously

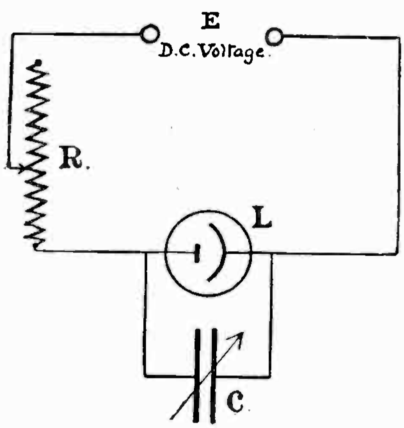


Fig. 1.

timing is impossible in these cases, but by utilising the sensitiveness of the ear to the change in pitch of a note or alternatively by producing "beats" between two frequencies, several delicate methods of comparing resistances and capacities have been developed.

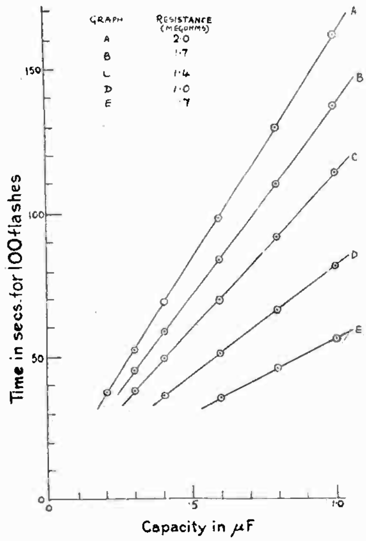


Fig. 3.

The method may be placed in two groups: "Timing" methods, involving the use of countable flashes, and "Note and Beat" methods.

Using such methods, capacities of from 0·000 2 to 7·0 microfarads have been measured, these purely virtual limits being fixed solely by the condensers available. In the case of resistances, however, both experiment and theory show that there is a lower limit to the value of R, below which no "flashing" is possible. Since this limitation can be overcome in a simple manner, as will appear later, it scarcely affects the range of resistances which can be employed.

II.—Apparatus.

Before discussing the details of the various methods advanced, a few remarks about the apparatus are essential. The lamp used in the experiments was an ordinary "Osglim" trade-sign lamp, letter "O" pattern, from which the ballasting resistance (included in the cap) had been removed. Before regular use the lamp was "aged" by being overrun for some time. The high tension battery was composed of small Leclanché cells, voltages greater than 170 volts being necessary. The fluctuations of voltage prevented consistent results from being obtained when the 240 D.C. mains were employed. Whenever possible the action of the battery was steadied by a large condenser being placed across the battery terminals. Since the currents never exceed one or two milliampères, no decrease in voltage due to polarisation occurred, even when the battery was run continuously for long periods. This small current permitted the use of telephones in all circuits without fear of damage.

If possible the lamp should be kept running throughout the experiment, so that the conditions are kept as unvarying as possible. After varying the circuit a short interval should be allowed to elapse before timing is attempted. Time periods greater than 2-3 seconds are not recommended, as it is our experience that they give inconsistent results. Headphones were used in timing, as the sharp clicks in the telephones were easier to time than the corresponding flashes of the lamp.

III.—Comparison of High Resistance.

The apparatus for comparison of high resistances is indicated in Fig. 4, the key

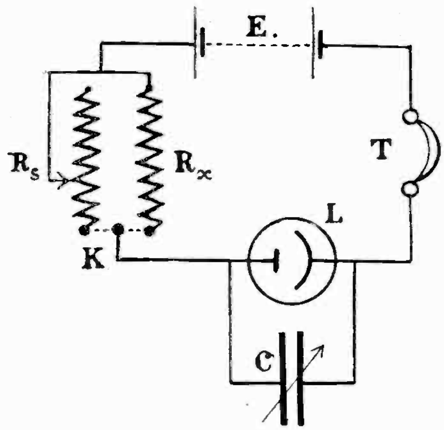


Fig. 4.

K being arranged so that either R_s the known variable resistance or R_x the unknown resistance can be introduced into the circuit at will.

Both an approximate and an accurate method are given below :—

(A) With R_x in the circuit, E and C are adjusted until the lamp is flashing at a suitable rate, the time T_x for one hundred flashes is found, and the standard R_s is then introduced and adjusted until T_s is of the same order as T_x. If we assume that the T, R graphs pass through the origin, then R_x is given by

$$R_x = \frac{R_s T_x}{T_s}.$$

Though the result is sufficiently accurate for many purposes the procedure must be modified as below if exact results are required.

(B) This method is based on the fact that though the T, R graphs do not pass through the origin, yet they are straight lines. Two values of R_s are taken, R_1 and R_2, giving timings T_1 and T_2 respectively. R_x is then obtained from the relation

$$R_x = \frac{R_2(T_x - T_1) - R_1(T_x - T_2)}{T_2 - T_1}$$

IV.—Comparison of Capacities.

Fig. 5 gives the arrangement for the comparison of capacities, C_x being the unknown capacity, C_s the variable standard, and K a switch by which either C_x or C_s can be placed in parallel with the lamp. The methods employed are similar to those just described, as are also the calculations.

Note Methods.

The circuit given in Fig. 5 is also employed in the note method for the comparison of capacities.

With C_x in the circuit, R_2 and E are adjusted until a clear note is heard in the telephones T. The key is now thrown over rapidly, C_x thus being replaced by C_s, and C_s is varied to reproduce the same note in the headphones as given by C_x. By quick reversals of the key the capacities are rapidly interchanged and each time C_x can be varied until finally on substituting C_s for C_x no change in the pitch is detected. The value of C_s now equals that of C_x, for the frequencies of the two arrangements are identical.

The method has the advantage of simplicity and gives very accurate results if the observer possesses a sensitive ear.

Beat Methods.

Beat methods, though more complex, are less liable to errors of personal observation and permit still more exact correspondence between frequencies to be made. The methods are based on the fact that if both C_x and C_s are such that they produce frequencies giving the same number of beats per second when combined with a standard frequency, they must be equal. Since high-pitched notes are used and very slow beats are produced, small differences in frequencies are easily detected, and thus fine adjustments of C_s are possible.

In practice, a circuit arranged as in Fig. 1 was used to produce the standard frequency, C_x and C_s being arranged as in Fig. 5.

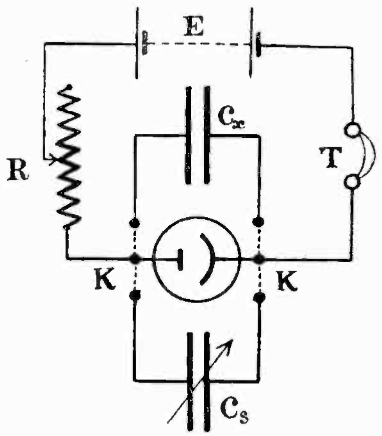


Fig. 5.

In order that beats may be heard the coupling of these circuits must be by telephones and by the battery also if two batteries are not available. This is the arrangement given in Fig. 6. It is best to have C a variable condenser with a value of the same order as C_x, and R_1 and R_2 therefore approximately equal, with a value of about 4 megohms.

With C_x in the circuit, R_2 and E are adjusted to give a high-pitched note and then C altered until slow countable beats are obtained. C_s is now inserted and adjusted to give the same number of beats per second as given by C_x. With this adjustment, C_s is evidently equal to C_x. It is, of course, necessary to see that *both* C_s and C_x are giving frequencies above that given by C, or *both* below. When using this arrangement, it is not convenient to adjust the condensers so critically that no beats are obtained, as the forced interaction of the circuits due to their close proximity and to their coupling causes this to occur over a relatively wide range of capacities. This difficulty is overcome, in a great degree, by methods to be given later.

The 240V D.C. supply was utilised in this method with success, though sometimes the voltage varied sufficiently to alter the beats from time to time. When two batteries are obtainable, forced interaction between the circuits is greatly reduced by using suitable coupling and by keeping the circuits some distance apart. It is possible to reduce the "no beat interval" to very small proportions and to obtain slow distinct beats even when using faint hissing notes. Diagrams of the arrangements are not given here, as many efficient methods are possible. Very delicate measurements have been effected by means of some of these.

All the circuits given as suitable for comparing capacities can be used, with appropriate modifications, for the comparison of resistances, though they are not so sensitive to small changes in resistance as to small changes of capacity. The circuits are modified in the following way: Though the circuit giving the standard frequency is unaltered, the second circuit is like that in Fig. 4, instead of that in Fig. 5 as previously. The procedure is analogous to that of the corresponding method for capacities.

Since the value of R below which no "flashing" is possible is generally about 0·4 megohms, resistances less than these cannot be used alone, but must be included in series with another of suitable size. If this latter resistance, easily made by pencilling on ebonite, is also included with R_s, the latter will record R_x directly when adjusted.

In a similar manner, a capacity giving frequencies too great for timing can be placed in parallel with another capacity, the time period being thus reduced to a convenient value.

Intercalibration.

In cases where it is desired to intercalibrate variable condensers and note or beat methods can be used, the two variable condensers should be placed in parallel with, say, C_x as large and C_y as small as possible. The settings of C_x and C_y are recorded and C is adjusted as in previous methods. C_x is now decreased and C_y increased until

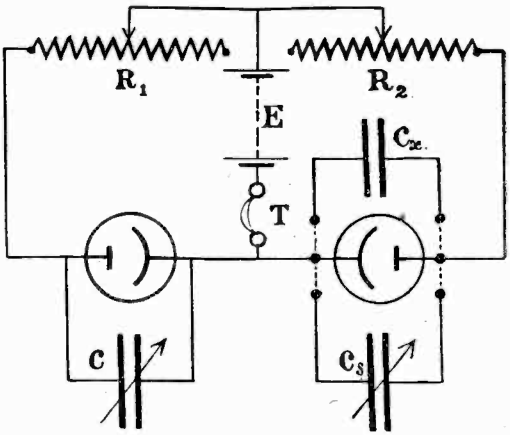


Fig. 6.

the same note is heard or the original beat frequency is obtained, when, of course, the decrease in C_x is equal to the increase in C_y. This progress can be continued until C_x is calibrated in terms of C_y. Their relation can be recorded graphically if a handy record is desired.

If C_x is greater than C_y, it is necessary, after the range of C_y has been covered, to restore C_y to its original value without re-altering C_x, and to reset C so that in time the whole of C_x will be calibrated. The same principle can be applied to the calibration of variable resistances.

(For a more theoretical discussion of the methods, the reader is referred to the original paper in the *Journ. Scien. Inst.*, below.)

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Duplex Telephony.

By P. P. Eckersley, M.I.E.E. [R460

Capt. Eckersley needs no recommendation from us. In this article he outlines the problems of Duplex Telephony and describes a few methods of achieving and operating it.

THE Duplex Wireless Telephone possesses certain undeniable advantages. In the usual system of Wireless Telephony a certain formality has to be studied in the exchange of messages; like the waiter who blows down the speaking tube to give his order, and has to change over to receive to find if the *chef* has interpreted "Adam and Eve on a raft, and wreck 'em" as scrambled eggs on toast. It is doubtful whether the waiter finds his job the more arduous on account of this formal interchange of messages, or if he finds the difficulty of not being able to send and receive simultaneously a serious one; but the waiter is an expert on the speaking tube. One has only to listen to the conversations between ground and air on the London-Paris airway communications to realise that with skilled participants the ordinary simplex system lacks nothing in efficiency. Thus the wireless telephone's inferiority to the wired system is not in many cases so pronounced as might at first be feared, and it has even this supreme advantage, that it discourages "chatting." With unskilled participants, however, the system is provedly hopeless.

The wireless telephone, apart from its commercial value in broadcasting, has an aspect of real usefulness inasmuch as it will, and in certain cases does, provide a long-sought-for link in the wired system. It is a common error among *hoi polloi* (the wireless *hoi polloi*, I mean—so numerous a class now that every up-to-date house has its aerial) to suppose that the wireless telephone will oust the wired; but to readers of this more scientific wireless paper I need hardly point out that the future of the wireless telephone for commercial purposes is to supplement, and not to supplant the older system of voice communication. Thus a real need for Duplex is apparent, whether it be to bridge the Atlantic for the ordinary telephone subscriber on the one hand, or to allow business men on ship, in the air or the train to keep in touch with their offices, on the other.

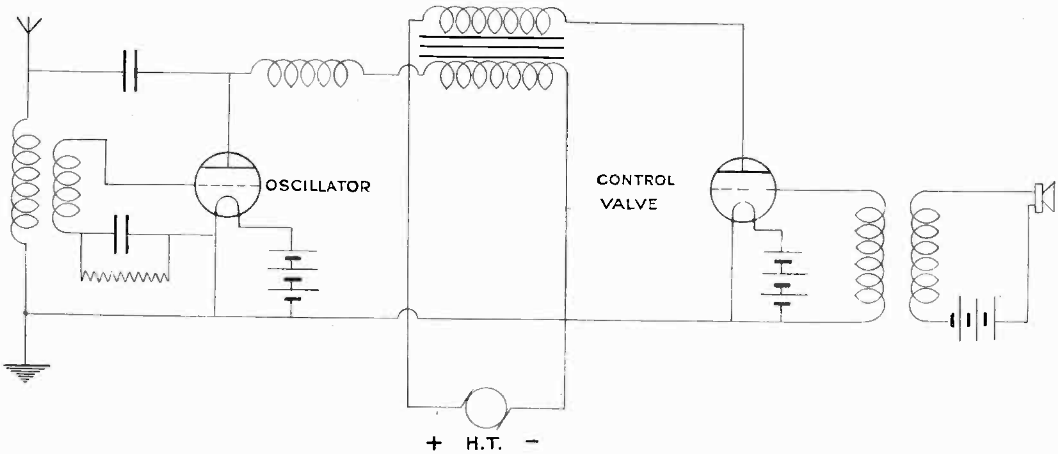


Fig. 1.

The writer may claim to have studied Duplex Telephony in its ground to aeroplane aspect perhaps more deeply than most, but as the problems of the aeroplane contain the lesser problem of ground communication, it might be interesting to go over in part the work done in 1918-19 in co-operation with other wireless experimental officers of the R.A.F. If the reader is curious to know details of some painstakingly abortive experiments, he might care to read a paper delivered by the writer before the Institution of Electrical Engineers in 1919.*

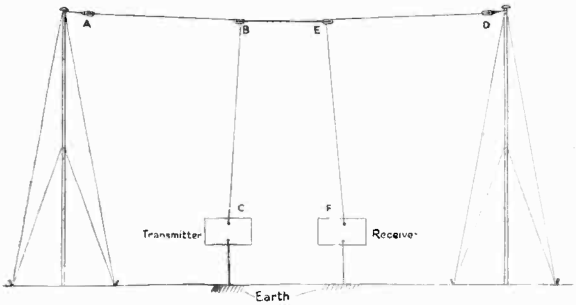


Fig. 2.

The aeroplane problem practically resolved itself into devising a system whereby the operator might be able simultaneously, or as a compromise without moving switches, to send and to receive.

The first experiments aimed at a compromise wherein the voice of the speaker automatically switched on the transmitter. The voice on ceasing automatically restored the receiver to sensitivity, and the reply came to the listener without the need of his moving switches. As a matter of scientific rather than practical interest, the reader may be interested to know that in this method the high tension for the oscillator was supplied entirely by the microphone acting through a powerful voice amplifier, so that only when the operator spoke could the set oscillate. The connections are shown in Fig. 1; really the system is no more than the common choke control arrangement, the steady high tension from the generator being only applied to the control valves, the "voice voltages" not being superimposed upon a steady D.C. potential, but existing alone. It will be immediately apparent that negative swings of the voice variations were ineffective, but theoretically this would seem no bar to intelligibility. It is well known that one can remove a great many components of speech frequency and still retain a recognisable original. In the case of this quiescent aerial system, however, the speech was almost unrecognisable as such, and in spite of ensuring that the valve would oscillate at the least application of H.T. voltage so that was no "threshold," the poor quality, nay! the unrecognisable jumble, remained.

It was Captain Round (it often is!) who pointed out that the jumble was probably due to the phases of the high frequency in one part of the energised periods not being in time with the phases of the next—at least, there was no assurance that such would be the case—and only by a system of double rectification wherein the set was continuously maintained in oscillation, and both halves of the speech wave were employed, would good speech result. I was able to prove the truth of his forecast, but the arrangement was too complicated to permit of consolidation into a robust apparatus, remembering that even were this done the problem would but be half solved. Truly it would be better to change over a switch, and I only have given a passing reference to the experiments to prevent others following a path that leads to a *cul de sac*.

It soon struck me that the solution to the problem lay in devising some method whereby the transmitter remained unchanged while the receiver was protected against the influence of the powerful near-by oscillations . . . the problem resolved itself into the question of obtaining a really selective receiver.

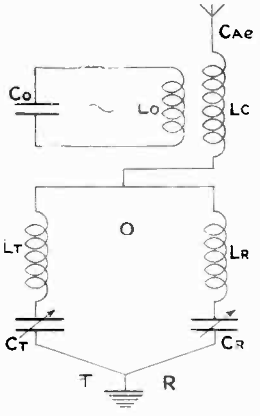


Fig. 3.

As a first step I concentrated on using two aerials side by side, one energised by a transmitter of purely standard design, the other connected to a sensitive receiver working on a slightly different wave from the transmitter, and so selective as to respond only to the one wave and be uninfluenced by the local transmitter either by forced oscillation or low frequency induction. The method of slinging the aerials was simple, and is illustrated in Fig. 2. This method uses but two masts; in fact, the complication of the aerial

* P. P. Eckersley—"Duplex Telephony for Aircraft."—*Proc. I.E.E.*, Vol. 58, p. 555.

system is hardly greater than if a single system were used.

I found a Navy type rejector properly tuned gave me Duplex by this method. With a 10 per cent. difference of wave-length and a transmitter of from 10 to 20 watts power, provided I took great trouble to screen *all* leads in the receiver, I was able to accomplish Duplex over practical distances. I devised and adapted all the well-known selective circuits, and even invented some that (to me, at any rate), were new; but the essence in all the experiments was the same, to protect the receiver by elaborate shielding and selective circuits. I was partially successful, but never wholly so. The experiments showed that the arrangements for unskilled handling would never develop into anything practical.

I had tried in the meanwhile, and up to a point successfully worked, a single aerial system which relied upon the same principle of protecting the receiver, but did it with one aerial. As this forms the basis for a really successful system afterwards developed, it merits a full description. In Fig. 3 an ordinary tuned circuit is branched into two tail circuits T and R, each containing capacity and inductance. The product L_TC_T is equal to L_CC_{Ae} where C_{Ae} is the aerial capacity, so that if a powerfully oscillating circuit L_0C_0 is introduced as shown and is tuned to L_CC_{Ae} strong currents are set up in the path $L_CL_TC_T$. O becomes a node of potential, and except for potentials introduced by ohmic resistance (as apart from reactive impedance) all the current flows through L_TC_T and none through the differently tuned path L_RC_R.

Again, however, the device was not practical. The transmitting current did from a transmitting point of view confine itself to one leg, but the small component that flowed in the leg C_RL_R was often quite enough, without painstaking balancing, to swamp the received component. Added to this, I had all the troubles of direct "wipe out" and the shielding had to be made painfully elaborate. At one time I thought that the only solution was to clothe the operator in copper gauze! It worked at times, and I was able to signal with a 10 per cent. difference of wave-length over practical distances, but obviously there was no hope of a practical realisation of Duplex Telephony.

It was at this disheartening stage of the proceedings that I left the work, and did not pick it up again for perhaps a year. Meanwhile, Mr. C. E. Franklin had perfected a device for Duplex Telephony (using two aerials) that opened up a new principle, which has proved amazingly useful for medium-powered sets for Duplex working where transmitter and receiver must necessarily be close together. Mr. Franklin's system is briefly as follows: One aerial oscillates at a frequency N_T. A near-by aerial is tuned to receive a frequency N_R. Due to the powerful oscillations N_T in the near-by aerial, the receiving aerial has created in it oscillations N_T and N_R, N_T

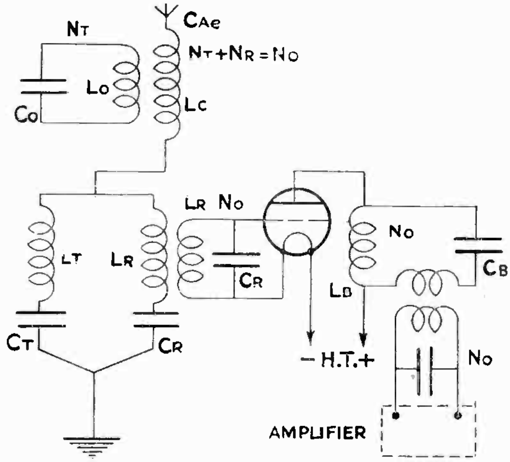


Fig. 4.

being forced from the near-by transmitter, N_R being received from the distant station. These two frequencies beat together and produce a lower frequency N_0, which can be detected and amplified without fear that the amplifier will suffer wipe out from N_T, it being adjusted only to deal with frequencies of the order of N_0, which are far removed from those of N_T or N_R.

Applying this principle to Fig. 3 we see that in the leg L_RC_R we have two components of oscillating current, one of frequency N_T and the other of N_R. A coupled circuit is applied as in Fig. 4, and a rectifying valve produces beat frequency oscillations N_0 in the circuit L_BC_B. Coupled to L_BC_B is another circuit tuned to N_0 and this forms the input to any low frequency or long-wave amplifier. This amplifier, since it deals with beat frequencies N_0

(or long waves) is immune to the forced or induced effects due to the transmitter.

The system works, and works well, with one aerial, and I have received with perfect clarity telephone signals from 100 miles on an aerial which is oscillating with five ampères current at a 10 per cent. difference in frequency from the received signal.

More simply, one can use two aerials on the same mast as in Fig. 2, when the tail circuits of Figs. 4 and 5 are unnecessary; but for ship and more particularly aeroplane work this arrangement is sometimes impossible, and it is at any rate interesting

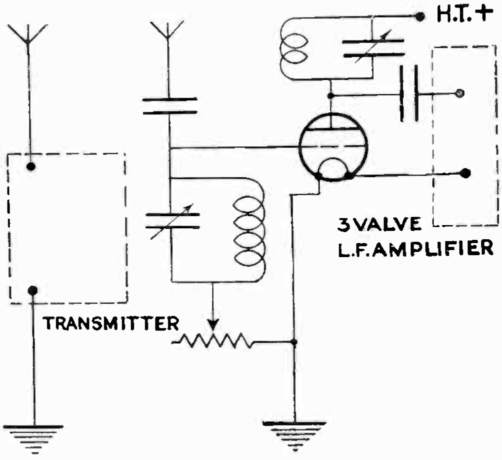


Fig. 5.

to know that my system of the tail circuit can be used. Although one always has a great leaning towards one's own ideas, I think the two-aerial system is better where it can be used.

Mr. N. Ashbridge, my late colleague in an experimental section of the Marconi Company, and now in charge of that section, has devised other and even simpler methods of doing Duplex Telephony for comparatively small power work. Essentially his methods rely upon using two aerials hung as in Fig. 2, but making the receiver so selective as to be uninfluenced by the local transmitter; going back, in fact, to the protected receiver system, and so perfecting the selectivity of the circuits, and so shielding the amplifiers, that with small powers (a few watts) no wipe out is experienced.

The object in view when designing this set was to produce a receiver of ultra simplicity which at the same time was capable of cutting out a small local transmitter.

One circuit adopted is illustrated in Fig. 5. The object in view when designing this set was to produce a receiver of ultra simplicity which at the same time was capable of cutting out a small local transmitter. By this means he was able, working on short wave-lengths, to develop a set which was commercially guaranteed for ranges up to 20 miles. (This means that probably at night, with real pains and a very weak signal, the device might communicate over 200 miles. There is a great deal of difference between an occasional R_3 signal and guaranteed range!)

Further work on similar lines by Mr. Holdridge of the Marconi Company has resulted in a set which is capable of dealing with much larger powers. In this case, however, a really simple circuit is inadequate, and it has been necessary to take special precautions to obtain the necessary degree of selectivity and at the same time obtain a circuit capable of receiving *undistorted* speech.

Turning now from sets in which it is essential to have one operator and both transmitter and receiver side by side, one at once realises that where space is available Duplex presents no serious problem. Captain Round in 1920-21 established two-way communication by telephone over the North Sea, using wave-lengths of 3 per cent separation. His method relied upon frame reception using Armstrong receivers, enabling him to cut out the local station on the frame, and to amplify, thanks to the beat method of reception, at frequencies far removed from those of the transmitter. The receiving and transmitting stations were about 200 yards apart, which further helped to receive without wipe out.

It is obvious that a multiplicity of methods are open to the designer of Duplex systems where large space is available, but the real interest lies in those systems where a single aerial or two aerials close together are a *sine qua non.* I have attempted to outline some few methods of achieving Duplex above, and hope they may have been of interest to readers.

Notes on Power Transformer Design.

By A. Castellain, A.C.G.I., B.Sc. **[R356**

THESE notes are intended for the amateur who has A.C. mains, and who wishes to obtain fairly large voltages for transmitting purposes. One of the simplest ways of doing this, of course, is to transform up to the required voltage, or half the required voltage, as the case may be, and rectify by means of small chemical rectifiers with the aid of condensers. It is proposed to deal here with a transformer designed for use with a voltage doubling rectifier system, and intended to deliver 200 milliamps at 1 100V and 10 amps at 11V from 220V 50 cycle mains.

It is possible to pick up old transformers which have been used for house lighting for quite a moderate sum and in fairly good condition. This constitutes the cheapest method of obtaining a core of reasonable size. A common size of core is shown in Fig. 1. The cross-section of the core shown in the illustration is 2 in. by $1\frac{1}{3}$ in., giving an area of $3\frac{1}{2}$ sq. in.

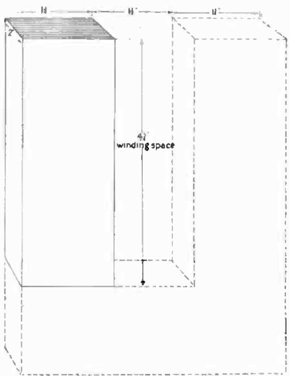


Fig. 1.

Now the fundamental transformer equation is as follows :—

E.M.F. induced per turn $= 4{\cdot}44\, f A\, B\, 10^8$ volts where f is the periodicity of the supply $=50$.

A ,, *effective* core area.

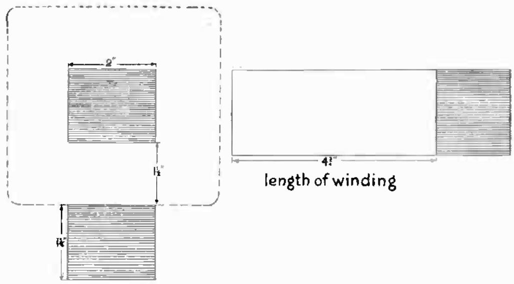
B ,, flux density at which the transformer is worked.

The effective core area is taken as 0·9 times the actual core area to allow for insulation between the core plates.

$$\text{Hence, } A = 0{\cdot}9 \times 3\tfrac{1}{2} \text{ sq. in.}$$
$$= 0{\cdot}9 \times 3{\cdot}5 \times 2{\cdot}54^2 \text{ cm}^2 = 20{\cdot}4 \text{ cm}^2.$$

A suitable value for the flux density B is 10 000 lines per sq. cm., whence E.M.F. per turn $= 4{\cdot}44 \times 50 \times 20{\cdot}4 \times 10^4 \times 10^8$ volts
$$= 0{\cdot}45 \text{ volts.}$$

This means that for every turn we put on



Winding depth $1\frac{1}{2}''$.

Fig. 2.

the core (assumed to be working at a density of 10 000 lines/cm²) we shall obtain a voltage of 0·45. Therefore the primary turns will be

$$\frac{\text{Primary volts}}{\text{volts per turn}} = \frac{220}{0{\cdot}45} = 488.$$

This may conveniently be rounded off to 500 turns, which means that the core will be worked at a flux density slightly lower than 10 000 lines/cm².

The secondary turns will be

$$\frac{\text{Secondary volts}}{\text{Primary volts}} \times \text{Primary turns}$$
$$= \frac{1\,100}{220} \times 500 = 2\,500 \text{ turns.}$$

The turns for the 11V winding will be

$$\frac{11}{220} \times 500 = 25.$$

We now know the number of turns in the winding, so the next thing to be done is to get them into the space available.

It is very convenient to sectionalise the windings, as the experimental value of the transformer become smuch greater—*i.e.*, various different voltages can be obtained from the same transformer. If we make the primary (500 turns) five coils of 100 turns each; the secondary (2 500 turns) five coils of 500 turns each; and the tertiary (25 turns) —say, one coil 12 turns and one coil 13 turns, we can obtain voltages of 5, 6, 11; 44, 88, 132, 176, 220; 220, 440, 660, 880, 1100.

Again it is wise to alternate primary and secondary coils so that, in this case, five coils for each is quite suitable. Hence the winding length will be occupied as follows :—

5 secondary coils each — wide total	x
5 primary coils ,, — ,, ,,	y
2 tertiary coils ,, — ,, ,,	z
13 thicknesses of insulation each 30 mils....... (approx.) total	0·4 in.
Total	4·75 in.

The 11V winding has to supply 10 amps without undue heating. From the London Electric Wire Co. and Smith's tables it is seen that gauge 12 wire will carry 12·868 amps at the 1 000 amp per sq. in. rating. Two thicknesses of gauge 12 D.C.C. wire come to 0·23 in., leaving 4·75—0·4—0·23 in. =4·12 in. for the primary and secondary coils.

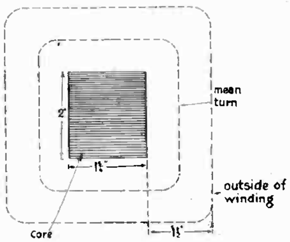


Fig. 3.

Length of mean turn of coils=

$$2\left[(1\tfrac{3}{4}+1\tfrac{1}{2})+(2+1\tfrac{1}{2})\right] \text{ ins.} = 13\tfrac{1}{2} \text{ in.}$$

$$\text{Total length of primary wire} = \frac{500 \times 13\frac{1}{2}}{3 \times 12} \text{ yds.}$$

$$= 188 \text{ yds.}$$

Total length of secondary wire is

$$5 \times 188 \text{ yds.} = 940 \text{ yds.}$$

The secondary has to deliver 200 milliamps. Referring again to the wire tables, it is seen that gauge 27 or 26 is suitable.

The primary current may be taken as

$$\frac{\text{Secy. current} \times \text{secy. volts}}{\text{Primary volts}} + 25\% \text{ for losses;}$$

i.e., in this case it is $0{\cdot}2 \times 5 + 25$ per cent. $= 1{\cdot}25$ amps, for which 19 gauge wire is suitable.

Diameter of	19	gauge wire,	D.C.C.	0·048	ins.
,,	27	,,	,, ,,	0·0246	,,
,,	26	,,	,, ,,	0·026	,,

Gauge 26 is to be preferred from the point of view of ease of obtaining it.

Winding depth available 1·5 in. Allowing for core and winding insulation we will allow a maximum depth of coil of 1·4 in.

Dealing with the secondary winding first :—

No. of turns of 26 gauge wire in 1·4 in.=

$$\frac{1{\cdot}4}{0{\cdot}026} = 54.$$

Hence the secondary coils may have 54 layers, and since 2 500 turns are required, there must be

$$\frac{2\,500}{54} = 46{\cdot}3 \text{ turns per layer.}$$

Having judged what the secondary winding should be, we may now round off the number of layers to 50, thus making the turns per layer 50 also, or the turns per coil per layer 10, which is most convenient. The total width of the secondary winding is $50 \times 0{\cdot}026$ in. $= 1{\cdot}3$ in.

Similarly for the primary winding, the number of layers possible is

$$\frac{1{\cdot}4}{0{\cdot}048} = 29.$$

Taking 25 layers we get

$$\frac{500}{25} = 20 \text{ turns per layer or 4 turns}$$

per layer per coil.

Total width of the primary winding= $20 \times 0{\cdot}048 = 0{\cdot}96$ in.

Combined width of primary and secondary $= 1{\cdot}3 + 0{\cdot}96 = 2{\cdot}26$ in.

Combined width of primary, secondary and tertiary$= 2{\cdot}26 + 0{\cdot}23 = 2{\cdot}49$ in.

We actually have a maximum of 4·75—0·4 =4·35 in. of winding space at our disposal.

Hence the number of turns may be increased in the ratio

$$\frac{4{\cdot}35}{2{\cdot}49} = 1{\cdot}74.$$

We will therefore increase the number of turns by half as much again, and make up the remaining winding length with insulation. This increase in the number of turns on the three windings does not alter the voltage ratios between them, but it lowers the flux density and hence the iron losses at which the core works to $\frac{1}{1{\cdot}5}$ of its original value, *i.e.*, to about 6 700 lines/cm^2. This method of first designing the winding using a high flux density and then increasing the number of turns so as to fit the winding space available, and thus lowering the flux density, will be found very useful when it is desired to fit a winding on to a given core.

The final design of the transformer windings is thus as follows :—

Primary.—Total turns *750*. Made up of five coils of 25 layers, each having 6 turns per layer. Gauge of wire S.W.G. 19.

Secondary.—Total turns *3750*. Made up of five coils of 50 layers, each having 15 turns per layer. Gauge of wire S.W.G. 26.

Tertiary.—Total turns *38*. Made up of three coils, 13, 13, 12 turns of 12 gauge wire. Centre coil tapped 5th turn.

Flux density in core.—6 700 lines/cm^2.

Total length of primary wire $188 \times 1{\cdot}5 =$ 282 yds.

Yards per lb., gauge 19=68 yds.

$$\text{Weight required} = \frac{282}{68}\ \text{lb.} = 4{\cdot}15\ \text{lb.}$$

Total length of secondary wire 5×282 yds. = 1 410 yds.

Yards per lb., gauge 26=340 yds.

$$\text{Weight required} = \frac{1\,410}{340}\ \text{lb.} = 4{\cdot}15\ \text{lb.}$$

Total length of tertiary wire

$$\frac{38 \times 13\tfrac{1}{2}}{36}\ \text{yds} = 14\tfrac{1}{2}\ \text{yds.}$$

Yards per lb., gauge 12=10 yds.

Weight required=$1\frac{1}{2}$ lb.

Total insulation space$=4{\cdot}75-(1{\cdot}5\times 2{\cdot}49)$ =1 in. (very nearly).

Total number of thicknesses of insulation required=14. (The extra one is necessary as there are now three tertiary coils instead of the two previously allowed for.)

Hence thickness of insulation may be

$$\frac{1}{14} = 0{\cdot}07\ \text{in. approx.}$$

The approximate cost of the windings is as follows :—

					s.	d.
$4\frac{1}{4}$ lb.,	19 gauge,	at	1/11	per lb.=	8	2
$4\frac{1}{4}$,,	26	,,	3/4	,,	14	2
$1\frac{1}{2}$,,	12	,,	1/3	,,	1	$10\frac{1}{2}$
					24	$2\frac{1}{2}$

It is quite possible to improve on this cost—especially in the matter of the 26-gauge wire, which can be obtained very cheaply at present.

If this article has shown anybody how to design a transformer to suit his own needs, then it has served its purpose.

Radio in New Zealand. [R090·9

ALTHOUGH New Zealand is far away around the other side of the globe from the great centres of population and the huge factories and laboratories for manufacturing and research, still the fascinating science of radio has taken a great hold on the people of this country, and enthusiastic "fans" of various ages and occupations are numbered by the thousand.

There are several radio stations in New Zealand, erected by the Government and operated by the Post and Telegraph Departments for the conduct of radio communication to and from New Zealand, and between the stations themselves. The Awanui station is situated in the "far north," and Awarua in the south and spaced between these extremes are the four large cities—Auckland, Wellington, Christchurch and Dunedin—each with its own station. These Government stations confine themselves to morse, leaving wireless telephony to the broadcasting stations.

In most towns of any size in New Zealand, broadcasting stations have been erected. None, however, are of considerable power, 100 watts probably being a maximum, and the majority being under 10 watts. All the broadcasting stations in New Zealand are owned and operated by private individuals, or by combinations of dealers in various centres. This service is gratuitous, the only recompense these enterprising enthusiasts receive being that feeling of satisfaction that comes from having done something for the good of the science one is interested in; and to the dealers, the impetus that good programmes properly broadcasted give to the sales of radio parts.

The Government issues licences to those who apply, pass a test, and pay a fee, but there is a very large number of listeners who so far have not registered. Everyone realises that these haphazard conditions cannot long continue; but in the past there has been a holding off, due no doubt to a feeling that what may be decided on to-day may be obsolete by the time the plan is put into operation, consequent on the rapid development during the last year or so.

Latest reports, however, indicate that an arrangement has been effected between the Government, the dealers and the amateurs by which a big broadcasting company is to be formed to control and operate broadcasting in New Zealand. The proposed scheme provides for the installation of a 500-watt broadcasting station at each of the four New Zealand main cities—Auckland, Wellington, Christchurch, Dunedin. These stations will operate simultaneously, but on different wave-lengths, and will commence broadcasting in the early afternoon and continue till 11 p.m. One "silent night" will be observed in each week to permit amateur transmitters to work. When the scheme materialises, listeners possessing up-to-date sets will have an excellent choice of programmes and it is anticipated the number of devotees will be greatly increased. It is expected the licence fee will be about 25s. per year, payable to the Government, and registration will be compulsory. Of this amount, three-quarters will go to the Broadcasting Co., and it is anticipated this will afford sufficient revenue for a really first-class service. Professional talent will be engaged and arrangements made for these artists to tour the circuit of the four stations.

New Zealanders are taking a keen interest in the new stations recently erected in Sydney, Australia—1 000 miles due west of New Zealand—by Farmer & Co., and by Sydney Broadcasters, Ltd., the former sending on 1 100 metres and the latter 350 metres. Both stations have been picked up, but owing to 1 100 metres being beyond the usual broadcasting band of wave-lengths, many owners of receiving sets cannot "tune in" Farmer & Co.

The more experienced amateurs are having considerable success in the reception of long-distance music and speech, particularly from California. One man at Hamilton, an inland New Zealand town, using a 3-valve reflex set, recently heard a number of instrumental items, one song and the announcement "6XJ, General Electric Co., 555, 14th Street, Oakland, California."

Our regulations allow of latitude in regard to the circuits we may use, but not so much as is permitted in U.S.A. For instance, we may use the three-coil regenerative circuit—in fact, this is the one most generally used—but we may not connect "grid" direct to "aerial." In consequence of these differences in allowable circuits, many arrangements recommended in English and American radio journals are not available to us. A very popular circuit in New Zealand is the "Cockaday DX Bringer-in," a desirable feature of which is the provision for changing the inductances, enabling the tuning in of Farmer & Co., the 1 100 metre Sydney station. In this respect this circuit is more suitable than the famous "Cockaday Four Circuit Tuner."

New Zealand is well supplied with radio literature, and the leading radio magazines from America, England and Australia are in evidence in every radio-dealer's shop. In addition, there is a good assortment of text-books, but, naturally, dealers are chary of carrying a heavy stock of these, as they are apt to become obsolete so quickly.

The Auckland Radio Association has under consideration the formation of a technical and research branch, and should this materialise and the members devote themselves seriously to the work, much useful information should result.

Radio instruments and material used in this country are practically all imported, the bulk coming from U.S.A., Canada, and England, and in a lesser degree from France. Dull emitter valves have received an enthusiastic welcome, as they render unnecessary the use of accumulators required with the older types, which were always a source of anxiety, particularly to country users, owing to the inconvenience of getting them recharged.

As some of our readers will be aware, direct two-way amateur communication has now been established between New Zealand and this country. Up to the day of writing, the results are, briefly :—

Oct. 16, 6.30 a.m., 2OD (E. F. Simmonds, Gerrard's Cross) heard Z4AG.

Oct. 17, early morning, Z4AA heard 2OD.

Oct. 18, 2FZ (C. W. Goyder, Mill Hill) worked Z4AA.

Since then, 2NM (G. Marcure, Caterham), 2OD, and 2KF (J. A. Partridge, Collier's Wood) have worked with one or more of Z4AG, Z4AA, Z4AK.

Radio 5US. An Amateur Station.

By J. Croysdale, B.Sc. [R612

THOUGH placed rather at a disadvantage as regards geographical position and availability of public supply mains, a considerable amount of experimental work has been carried out at 5US. Judging by the distances which have been covered and reports on transmissions received from other stations, a fair degree of efficiency may be claimed.

5US is located at Burley-in-Wharfedale, Yorkshire, 250 feet above sea level. The surrounding district is very hilly, and the station, situated in a valley, is badly shielded by the hills of the Pennine Range, which lie to the west. This fact, coupled with the immediate neighbourhood of the station, render the aerial site far from the ideal for transmission purposes.

A great deal of time has been spent on experiments with different forms of aerials on the short waves. The single wire, "sausage," fan, and flat-top have been tried in turn, and the conclusion arrived at so far is that the flat-top gives the best all-round results, expense being an important consideration. The aerial in use at the moment is a twin wire inverted L. The dimensions are given in Fig. 1, which should suffice without further description.

As in the case of the aerial, many forms of counterpoise have been tried. Tests in this case have been governed by the exigences of garden space and the risk of upsetting domestic arrangements. However, an erection which gives fair results has been made.

The wires of the counterpoise, four in number, pass very near earthed objects at irregular distances. Two of the wires pass through small shrubs and on this account they are made of insulated lighting cable. A source of much annoyance is a 30-ft. fir tree which sprouts through the centre of the counterpoise and does its best to reach the aerial; consequently, some dielectric losses are to be expected!

In addition to the counterpoise, an earth connection is utilised in the transmitter. This earth is a soldered connection to the water main which runs up under the garden parallel with the counterpoise.

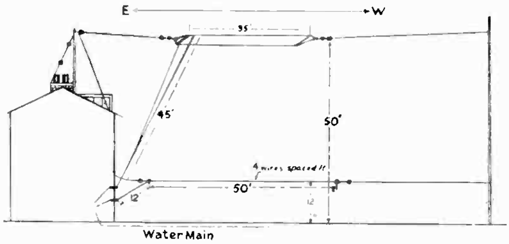


Fig. 1.

The transmitting circuits are continually altering, and the changes have been rung on "Colpitts," "Meissner," "Hartley" and the rest, with innumerable modifications. The circuit now being used is the ordinary "reversed feed back," as it is often called. This appears to be as efficient as the others, particularly when used in the form shown (Fig. 2).

Owing to the aforementioned fact that there is no electric main available, also the expense of a generator being prohibitive, an ex-Government T.V.T. unit was tried as a source for long-distance C.W. work. This has given quite a satisfactory performance, as a result these notes have been written mainly for the information of those who may be interested in this form of high tension supply.

The construction and mode of operation of the T.V.T. unit will be known to most experimenters. The current as delivered from the secondary winding is, of course, a semi-A.C. and applied direct to the valve gives an I.C.W. note. This note, though carrying very well and clear to read was found to give considerable jamming to weak amateurs on account of the flatness of tuning. Means were then sought whereby this "blotting out" of local receivers might be eliminated. Methods of rectification were tried with a view to obtaining pure c.w. Neon tubes and valve rectifiers were tried but did not warrant the power absorbed. It was decided to stick to the original I.C.W. but to try to sharpen up the emitted wave.

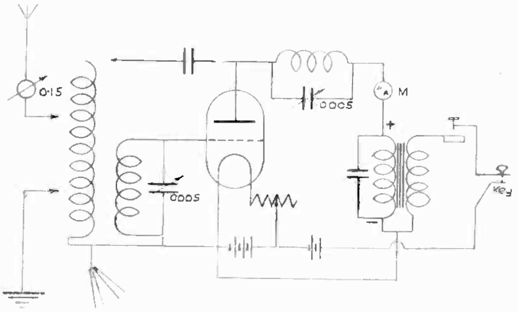


Fig. 2.

This was achieved by using shunt supply to the valve and including a radio-frequency choke in the plate lead; this choke to be tuned with a variable condenser to syntony with the wave-length of the aerial circuit.

The wave was considerably sharpened; to such an extent, in fact, that stations a few miles away who before were helpless over 15° of A.T.C. were now able to cut out the signals sharply with 2° condenser.

Trouble might be expected, perhaps, from the interrupter of the T.V.T. not keeping a steady frequency. But this rarely occurs if the contacts are kept reasonably clean and the valve in use is bright enough to absorb all the current from the secondary.

The transmitting apparatus is shown at the left hand end of the bench (Fig. 3). The aerial inductance may appear somewhat cumbersome. This consists of 32 turns 7-22's stranded aerial wire, spaced ¾ in., wound on a cylinder 6in. diameter. In order to limit the absorption losses due to earthed objects in its field the A.T.I. is supported well away from the wall and bench. The grid-coil, 20 turns of 18 S.W.G., is tapped and moves inside the A.T.I.

The T.V.T., is under the bench in a padded cradle to reduce to a minimum the buzz of the contact breaker. One has to fit a silencer like this when working in the small hours of the morning,

The tuned radio-frequency choke is wound with 30 turns 24 S.W.G. on a 3-in. tube, and tuned with a ·0005 mfd. condenser. The anode stop condenser was made in the conventional way from copper foil and old photographic plates. It has a capacity of ·002 mfd.

On considering the transmitting circuit, it will be noticed that a combination of direct ground and counterpoise is used. The earth tap is set approximately at the voltage node in the aerial inductance. The method of adjusting for the nodal point is as follows: The transmitter is tuned up for maximum aerial current at the required wave-length. The earth tap is then applied to the bottom of the A.T.I., and in steps moved towards the aerial tap, and each time the aerial current increase or decrease noted. A point will be found, at either side of which there is a decrease in current. The point varies, of course, for different wave-lengths.

Before going on to details of the receiving side it might be mentioned that little telephony has been carried out; and this only on very low power. Using a simple "tickler" circuit with grid modulation and 50 volts on an Ediswan A.R. valve good speech was received by 2VO on two valves at 12 miles.

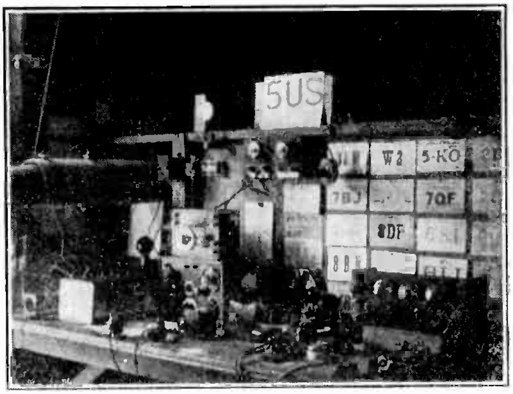


Fig. 3.

To the immediate right of the transmitter will be seen a receiver. This is a single valve "super" and has been used off and on for the last two years for DX work. Quite a few American amateur stations have been logged using only a 4-ft. frame. For general reception and comparative purposes the orthodox reaction circuit is used. A super-heterodyne is now being built for working Australia.

Although 5US has not so far been logged the other side of the Atlantic, some long distance transmissions have been made which show that, at any rate in some directions, the signals should be good for a few thousand miles. Two-way working has been carried out with Finnish 1NA, 3NB, and 2NM and each has reported R-6. The aerial current at this end was 0·25—0·3 and the distance 1 200 miles.

Interesting phenomena have been observed in relation to the shielding effect of the local hills. In particular, signals have been exchanged with 7QF, Copenhagen, at 3.30 p.m. G.M.T., signal strength, R-6. Yet, later the same night, reports from a station to the west were R-3 to R-4; the distance being only 70 miles as against 500. This weakness to the west is always prevalent while signals at the same time anywhere east up to 500 miles are R-7 or so. Whether this shielding is purely local and that the waves are merely deflected or not would be interesting information.

The directional effect of such an aerial as described above may account to some extent for these variations. The combination of aerial and counterpoise with earth tap at the potential node would tend to give directive properties, particularly to an aerial worked in the neighbourhood of its fundamental.

Some details regarding aerial currents obtained with varying inputs to the T.V.T. may be of interest. A Mullard 0-30 A valve is used on the transmitter. Taking the efficiency, input to output, of the T.V.T. to be approximately 33 per cent., with an input of 10 volts, 3 amps to the primary, an input of 10 watts is obtained. This gives an aerial current of 1 amp on 170 metres. Using 6 volts at 2 amps to the T.V.T., *i.e.*, 4 watts to the valve, the current is 0·5 to 0·6 amps.

Reports are always welcome from anyone who hears transmissions from 5US.

Short Wave Receiver Notes.

By R. A. Farmery. **[R402**

Another contributor here expresses a view in favour of L.F. amplification for short-wave work.

SINCE the phenomenal successes which attended the use of very short waves in the Transatlantic tests of 1923-24, more and more attention has been given by experimenters to the design of short-wave receivers. The building of a successful receiver to work on a wave band of say 75 to 250 metres is by no means a simple task, and the writer makes no apologies for offering a few practical notes on the subject.

Before commencing a more detailed examination it is perhaps as well to ascertain the fundamental requirements of such a receiver as we propose to build. In the first place then, since the set is presumably to be used for DX work, it *must* be easy to handle, secondly, it must be sensitive, thirdly, it must be selective, and, lastly, it must be as free as possible from parasitic noises. Whilst this by no means exhausts the list of desirable features it covers the ground fairly well, and at the same time provides us with a quite sufficiently difficult task.

If we omit "super" (?) circuits we have five possible means of achieving our object: (1) Detector alone; (2) H.F.—Detector; (3) Det.—L.F.; (4) H.F.—Det.—L.F.; and (5) Supersonic Heterodyne.

Of these five methods the last is, undoubtedly, the best, but as only relatively few of us can afford to use it, it is not proposed to deal with it in this article.

The question of high frequency amplification on short waves is one which has raised considerable controversy in the United States, but the general opinion over there seems to confirm the writer's own impression that below 300 metres high frequency amplification is a waste of time, money and valves. Whilst this statement may appear to be somewhat sweeping, it is based on several years' short-wave experience; and, although efficient amplification at these high frequencies is possible, it is undoubtedly gained at the cost of so complicating the apparatus as to render it useless for quick changes of wave-length.

The addition of one or two stages of note magnification can be made without any sacrifice in simplicity, and in this way a very considerable increase in the effective range of the station may be made.

It may be pointed out, in passing, that it is quite fallacious to assume that low frequency amplification does not increase range. It is quite possible for a signal to be of sufficient strength to produce rectification and yet to be insufficient to produce an audible movement of the telephone diaphragms. In this case the addition of L.F. valves renders the signal audible and so increases the range of the station. Five minutes' experimenting with a Det.—L.F. receiver fitted with switching for the L.F. valves is sufficient to convince one of this.

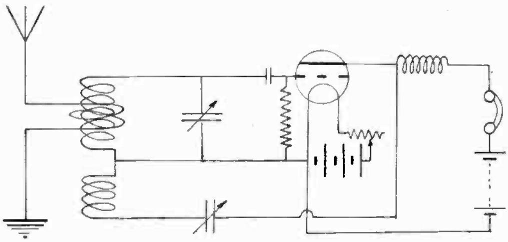


Fig. 1.

It is very questionable, however, whether, for all ordinary purposes, it is worth while to use more than one stage of note magnification since to do so not only makes most signals unnecessarily loud, but also appears to amplify static and inductive disturbances to a much greater extent than the desired signals. Moreover, on the grounds of selectivity, it is not advisable to make signals too loud since the human ear is better able to differentiate between two weak sounds than two loud ones. If it is decided to use more than one stage of low frequency, switches should certainly be incorporated in the set to cut the additional stages in or out as may be required.

Since it is somewhat difficult to make a directly-coupled receiver oscillate at frequencies of the order of 4×10^6 ($75m$) it is almost essential to use some form of loose coupling. The simultaneous adjustment of two tuned circuits is, however, rather a difficult task on these very short wave-lengths, and, in order to keep the receiver as simple as possible the author is strongly in favour of making the aerial coil aperiodic. This is a point however which everyone may best decide for himself, and in districts where "mush" is bad it would be advisable to try out both systems with a view to ascertaining which is least susceptible to this form of interference.

The ordinary loose-coupled receiver works quite well down to the lowest wave-length on which we wish to receive, *i.e.*, $75m$. It is advisable that reaction should be taken to the aerial coil and not the secondary as this has a great effect both on the stability and ease of control of the receiver.

The inductances may in this case consist of a set of purchased extra-short-wave coils, but more efficient results are generally obtainable with homemade coils. It will be remembered that the present type of plug-in coil was originally designed to provide a compact inductance for long-wave work, and that no special care was taken to keep the capacity of plugs and mountings as low as possible. The consequence is, that the capacity in the coil plug, together with that of the coil holder and its attendant leads, is very considerable, and is, in fact, far too great to be really efficient on short and very short waves. If maximum efficiency is aimed at, the single layer coil wound with turns slightly spaced cannot be improved on.

A circuit which has given excellent results is shown in Fig. 1. This is a sort of loose-coupled Reinartz, with aperiodic aerial coil. Whilst no claims are made as to the novelty of this arrangement, the writer does not recollect seeing it described elsewhere.

Although some difficulty was at first experienced in obtaining a smooth control of reaction, this arrangement has proved to be the most satisfactory yet tried. It should be noted, however, that at wave-lengths near the fundamental of the aerial it is decidedly bad to make oscillate. This was overcome in the present case by erecting a special 45 ft. aerial from the operating cabin to the top of the mast. Using this aerial splendid results have been obtained, and it appears to be quite large enough for short-wave work.

Valves Tested. [R330-09

This month we have had a most interesting and diverse set of valves for testing.

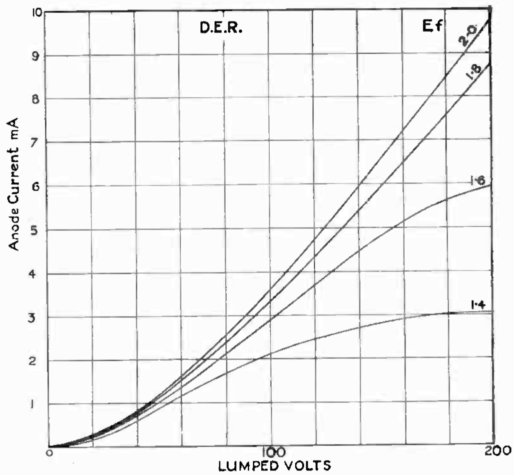
OWING probably to the fact that there was already rather a heavy batch of work in the test room this month, seven valves came along. However, we have struggled against fate, and here follows an account of their characteristics.

We will deal first with a whole bunch of Marconi-Osram valves: the D.E.R., D.E.6, D.E.4, D.E.5b, and D.E.7.

D.E.R.

This is, of course, by no means a new valve, but, curiously enough, we have not previously had one available for taking accurate characteristics.

It was one of the first, if not *the* first, British dull emitter, and is described as a general purpose valve, rated at 1·8—2·0V, 0·4A, anode 30—50V. It will be remembered that the earlier types had vertical electrodes. This is now changed, the electrodes being arranged as in the old "R," but a little smaller.



The valve was tested at 1·4, 1·6, 1·8 and 2·0V, on the filament, and its constants will be gathered from the accompanying table. The first exceptional point is the very large output, this being 10mA at the lower rated voltage, and no less than 19 at 2·0V. In fact this valve should be just large enough to handle a small loud-speaker.

The anode impedance is satisfactorily low, especially in view of the magnification, which is quite high (8·5). The combination leads to a very good figure (3—4) for the power amplification.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	A.	mA.	Ω.			
1·4	·35	3	61 000	8·5	1·2	6·1
1·6	·375	6·1	30 000	8·5	2·4	10
1·8	·4	10	21 500	8·5	3·4	14·
2·0	·45	19	18 500	8·5	3·9	19

The "filament efficiency," *i.e.*, mA of output per watt input, is about half that of the maximum obtained with "super-efficient" valves.

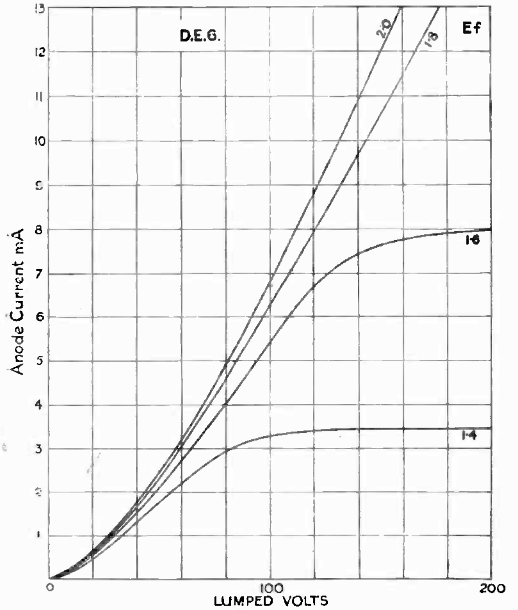
From the set of curves shown we see that the valve should be worked at a steady current of 2mA at least for small input, and say 4 for loud-speaker work; this would correspond to 80V anode and —1V grid for ordinary work, and say +120V anode and —3V grid for a small loud-speaker. Price, 21s.

D.E.6.

This is quite a new valve, being designed as a small dull-emitter power valve to operate off a two-volt battery in conjunction with the D.E.R. The electrodes are apparently quite similar, but the performance gives a clue to the probable differences, as will be seen.

The valve, like the D.E.R., was tested at 1·4, 1·6, 1·8, and 2·0V on the filament. The filament current is almost exactly the same, the difference being no greater than that often found between specimens of the same type. The saturation current is greater, rising to 26mA, with a corresponding increase in filament efficiency. This might be due to running the filament hotter, but is not as far as the eye can judge.

The anode impedance is considerably lower, as will be seen, as is also the magnification: this combination inclines us to



believe that the valve is substantially the D.E.R. with a rather more open grid. The curves show a most satisfactory extent of

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	A.	mA.	Ω.			
1·4	·37	3·4	28 000	5·1	·9	6·6
1·6	·39	8	16 500	5·1	1·6	13
1·8	·41	14	12 500	5·1	2·1	19
2·0	·43	26	11 000	5·1	2·4	30

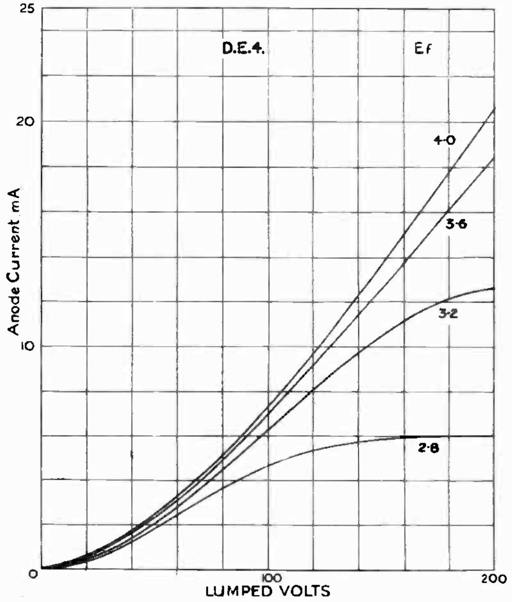
"straight." It would appear that first-class tone for moderate loud-speaker strength would be got with about 90 volts anode, —3V grid, giving a steady current of about 4·5mA. This low voltage is a great convenience.

Price, 25s.

D.E.4.

This is a modification of the well-known D.E.5, being essentially a dull-emitter power valve of large output, but differing from the D.E.5 in its filament, which is designed to operate off a 4-volt battery in conjunction with valves of the 60mA type. It is rated at 3·6V, ·32A, anode 60—120V.

In general appearance it is exactly similar to the D.E.5, with the same hairpin filament and flat grid and anode. We tested it at



2·8, 3·2, 3·6, and 4·0V, and the results appear in the table. It will be seen that the output is fully up to that of the D.E.5, reaching 50mA at 4·0V. The anode impedance, on the other hand, is rather higher, though still very low. It falls to 9 300 ohms at 4·0V, the D.E.5 falling to 6 000 at 5·5. The μ is similar in both valves—about 7.

In the last column we see that the mA per watt of filament input reaches 36, about the same value as in the most efficient 60mA valves.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampl. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	A.	mA.	Ω			
2·8	·29	6	15 500	7	3·1	7·5
3·2	·31	12·5	11 000	7·05	6·5	12·5
3·6	·33	25	10 000	7·1	7·2	20
4·0	·35	50	9 300	7·15	7·7	36

Our curves show a very satisfactory performance. For a large loud-speaker, allowing 5V amplitude on the grid, it would be advisable to allow a lumped voltage of 115, or say 140V anode and —5 grid.

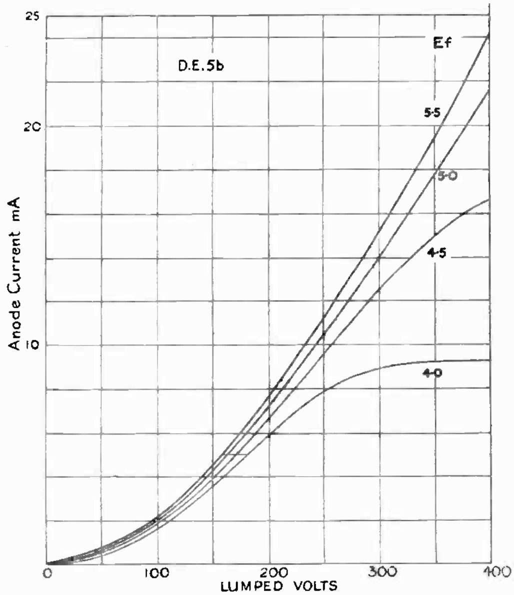
Price, 30s.

D.E.5b.

Here we have another modification of the D.E.5. In this case the change is in the grid, the valve being specially designed to give very high magnification, for use in resistance-coupled amplifiers, in which the consequent rather high impedance (for a large power valve) is of little importance.

It is built like the D.E.5, except for the grid, and, like it, is rated 5 to 5·5V, ·22A, anode 100—120V.

We tested it at 4·0, 4·5, 5·0, and 5·5V, with the results shown. As regards the saturation current at 5·5 filament volts, it is probably a little more; but owing to the large output and close grid, we reached the limit of available battery power before definitely saturating.



The anode impedance is seen to be of the amount usually associated with an ordinary small valve (30,000—20,000); but it is extraordinarily low in view of the μ of over 20. The filament efficiency is of the usual order for the D.E.5 filament.

We give the "power amplification," which is very high. But when we examine the curves we see that the valve is essentially designed for resistance amplification. Special steps would have to be taken for transformer work. The curves, as they stand, do not begin to straighten till the point corresponding to about 200 lumped volts. Owing to the high μ, an input of 3V grid amplitude would necessitate the total voltage being 320V or thereabouts, with —3V grid: the steady current would be about 11mA.

But for the purpose for which it is designed, we can reckon that the resistance coupling before it will only give 1 to 2 volts amplitude, and the "straightening" effect of a resistance

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts}}\right)$
V.	A.	mA.	O.			
4·0	·2	9·5	28 500	22·6	18	12
4·5	·21	18	22 500	21·2	20	19
5·0	·225	32	20 500	20·6	20·5	27
5·5	·24	45*	19 500	20·4	21	34

* Doubtful.

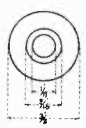
in the anode circuit will also come into play. Under these circumstances, the makers' rating of 120V anode, —1·5V grid would probably suffice; this would give about 2mA steady. But we would prefer 120V on the anode itself, giving 3mA. Allowing for the external anode resistance (say 50 000 ohms) this would necessitate about 200 volts in all. Tested in this way the valve gave most excellent results.

Price, 35s.

F.E.3.

Great interest is now being taken in the 4-electrode valve, and the Marconi-Osram Co. have naturally developed a type to meet it. It will be remembered that they have long had such a valve in use on their reflex ship set. This, however, was designed for a special fitting on V24 lines. The F.E.3, on the other hand, fits the usual 4-pin holder, the inner grid being brought out to the cap, to which a terminal is fitted.

The electrodes are horizontal, and their dimensions are shown approximately in our sketch. We have not the exact sizes, and, needless to say, do not propose to break the valve to measure them! The two grids, within 1/32 in. or less from one another, are a splendid example of skill in valve making. The filament is a normal bright one.



In default of any better method of trying out a four-electrode valve, we tested it for performance, firstly as a "low H.T."

valve, with the inner grid at a constant positive potential; and second as a reflex valve; input to inner grid, or output from outer

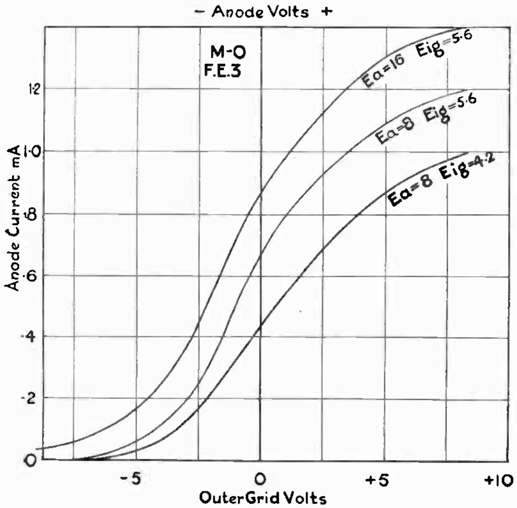


Fig. 1.

grid, and plate as a rectifier. The filament was worked at 3·8V throughout.

Tested first for low anode volt working, we obtained the curves of Fig. 1. These

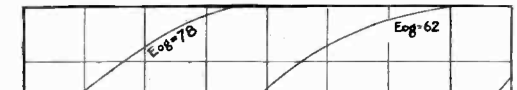


Fig. 2.

show the normal effect of increasing the IG volts—similar to more filament heat. The upper two curves, at the same IG volts, but different anode volts, show an increased saturation. It is probable that the correct

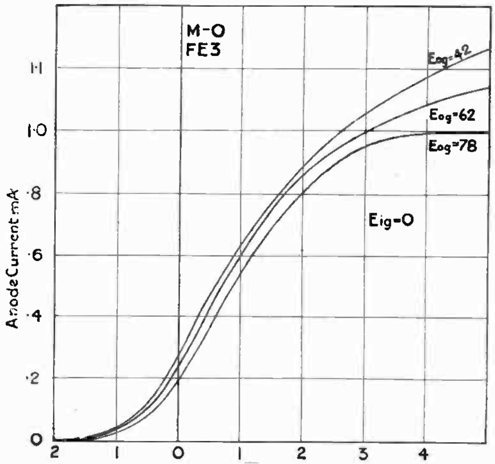


Fig. 3.

anode voltage under these conditions is rather higher than 16. From the curves we find $\mu = 5{\cdot}5$, $R_a = 42\,000$.

Next, we took the two sets of curves needed for the Marconi dual circuit. Fig. 2 shows the effect of using OG as output and IG as input. Owing to the fact that the two grids are close together, the magnification is low—it is equivalent to having grid close to anode in a three-electrode valve. The actual values found from Fig. 2 are: $\mu = 2{\cdot}8$, $R_a = 19\,000$.

As is well known, in this layout the anode circuit is the rectifier, with only a small voltage. Fig. 3 shows its behaviour. Obviously there will be good rectification with about —1V on the anode.

Altogether, however, it is doubtful whether either of these circuits is best suited to the F.E3. We are inclined to think that it might function best as a dual with H.F. input on one grid, L.F. on the other, and output from the anode.

Price, 27s. 6d.

We are informed that a similar valve with dull-emitter filament is also available, known as the D.E.7. We hope to report on this later.

A Mullard Four-electrode Valve.

Another interesting valve just to hand is the D.G. (Double Grid) of the Mullard Co. This, like the F.E.3 mentioned above, uses the four-pin holder. A short lead is soldered to the cap, which is connected to inner grid.

The electrodes are of the new ∩ shape just adopted by the company, their approximate dimensions being shown in Fig. 5.

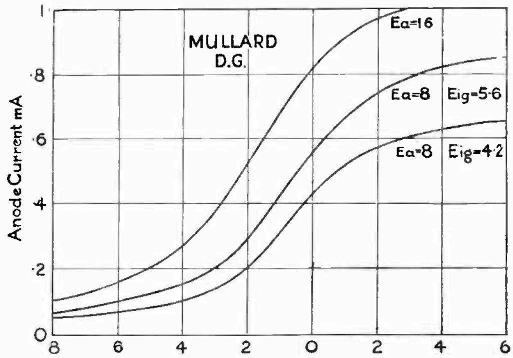


Fig. 4.

The input rating is that usual for bright filaments. It was tested at 3·8V.

Tested for work with low anode volts, the results were as shown in Fig. 4. The curves are normal, except for the curious way in which a small anode current still passes even at quite low grid volts. The "saturation" of 1mA is about that usually given under these conditions. The constants worked out for the two curves with IG at 5·6V are $\mu=5$, $R_a=33\,000$.

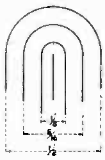


Fig. 5.

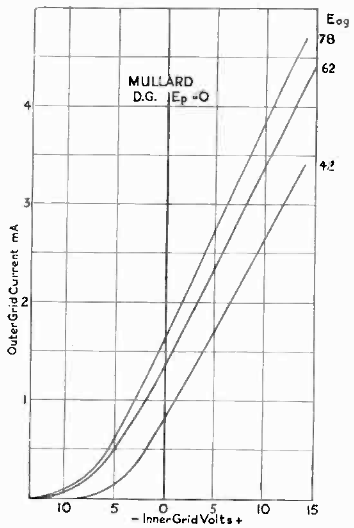


Fig. 6.

With the anode held at oV, input to IG and output from oG, the valve behaved exceedingly well, as will be seen from Fig. 6. The constants found from these curves are $\mu=6$, $R_a=30\,000$.

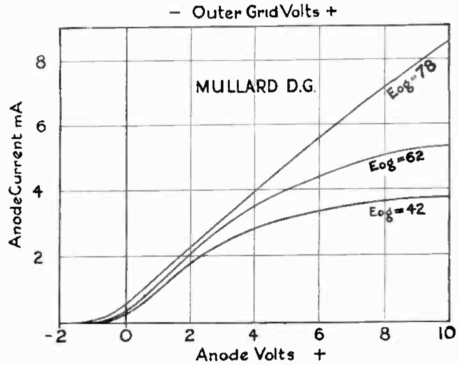
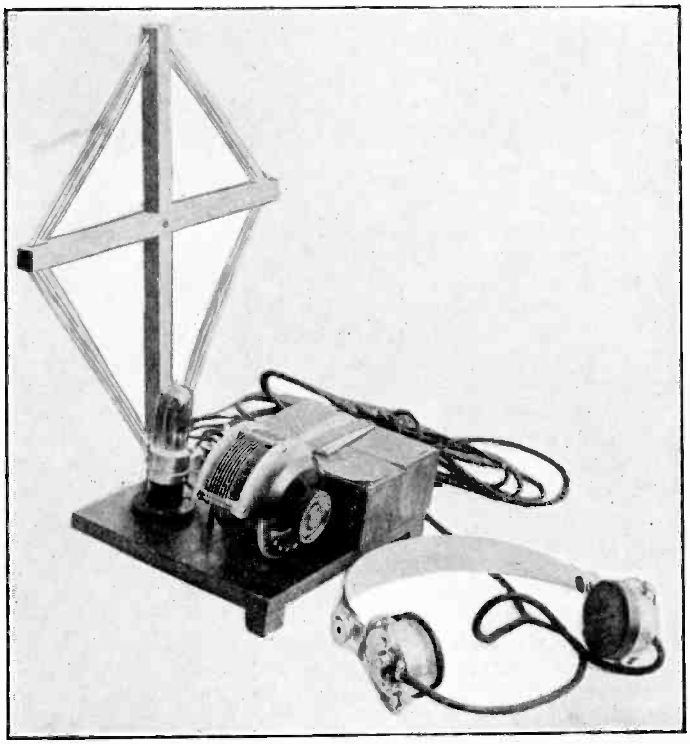


Fig. 7.

Lastly, the anode circuit, tested for rectification, gave the curves of Fig. 7, showing quite good results at about $-\frac{1}{2}$V.

Price, 27s. 6d.



A "High-tensionless" Receiver: range 20 yards on 5XX! It is used at Chelmsford as a test set.

A Compact High-power "Super-Het." [R343

THE accompanying photographs show an attempt to build a portable nine-valve super-heterodyne.

The objects aimed at were, first, to condense a nine-valve set into small compass and second, to make it as simple as possible to "deliver the goods."

I have even removed the ·0005 variable and replaced it with a fixed condenser of ·0001 with equally good results.

Once the rheostats and potentiometers are properly adjusted all stations between, say 300 and 500 metres wave-length (depending on the coils used), can be brought in by the manipulation of one dial. All other supers which I have ever seen built or on paper require the simultaneous adjustment of at least two condensers.

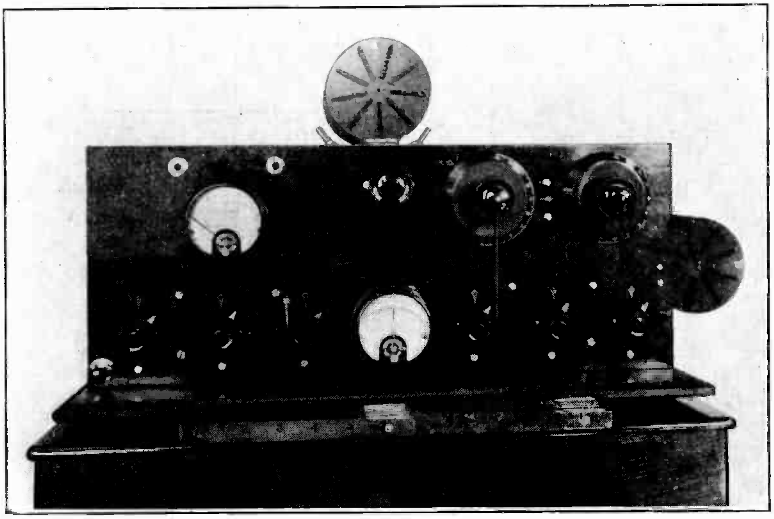


Fig. 1. *General Appearance of the Set.*

The diagram shows several departures from general practice. In the first place I have suppressed grid-leaks in the oscillator and detector circuits, after experiment, and find better all-round results are obtained by working on the lower bend of the characteristic with the assistance of a potentiometer.

The plate-voltage on all valves is the same: 100 volts.

The front and back panels are 20 in. × 8 in., spaced 9 in. apart, and with coils removed fit into a box 21×13×9 in., thus fulfilling the first object fairly well.

The second I achieved by suppressing all H.F. amplification ahead of the oscillator, and using the tuning design which, so far as I know, was first given to the public in the August number of *Radio News*.

It consists essentially in applying the incoming signal, through a small fixed condenser, to the centre or nodal point of the grid-coil of the oscillator.*

The remarkable feature of this "hook up" is that all tuning can be done on either one of the two variable condensers, though I get better results by using the one in the oscillator circuit: the other, across the secondary tuning coil, being set and left almost anywhere. My procedure is to set the latter at 50 on the dial and tune in with the former.

*Query: is this really a nodal point?–Ed. E.W. & W.E.

The intermediate H.F. amplification consists of 4 iron-cored transformers, built to work around 30 K.C. (10 000 metres), preceded by an input transformer made up of 2 Gambrell coils, both tuned to 10 000 metres wave-length by condensers.

The first L.F. stage is followed by a stage of Push-Pull, though the latter is practically never required.

I have found a condenser and variable grid-leak across the secondary of the first L.F. stage of considerable advantage.

A Weston voltmeter, reading 15 on either side of zero, is shown in the centre of the front panel; and under each rheostat and potentiometer a small switch-point connected into the proper circuit. Contact between the end of the flex and one of the points enables one to read the filament-voltage of any valve, or how much negative-bias the potentiometer is putting on the grid—an unnecessary refinement, perhaps, but one which increases one's knowledge of the behaviour of valves in various parts of the circuit.

Another refinement shown is the milliammeter, connected in the plate circuit of the oscillator valve — at least it shows whether the oscillator valve *is* oscillating.

No switches have been allowed anywhere near an H.F. circuit; and on the L.F. side jacks have taken their place. The writer has always looked upon a switch as a trap to catch elusive electrons.

No comprehensive list of the components used has been given; the same results could be obtained with different parts, provided they are the best obtainable: that is a *sine qua non*. Another important point is to take the characteristic of every valve before use, and pick out well-matched ones for the intermediate H.F. and Push-Pull stages.

As to results, I cannot speak from great experience, as the set has only been built a short time. So far English, Dutch, German, French and Spanish stations have been tuned in on the loud-speaker—Radiola and some of the home stations with both aerial and ground disconnected: the chief charm of the set being to my mind the use of one condenser only when operating.

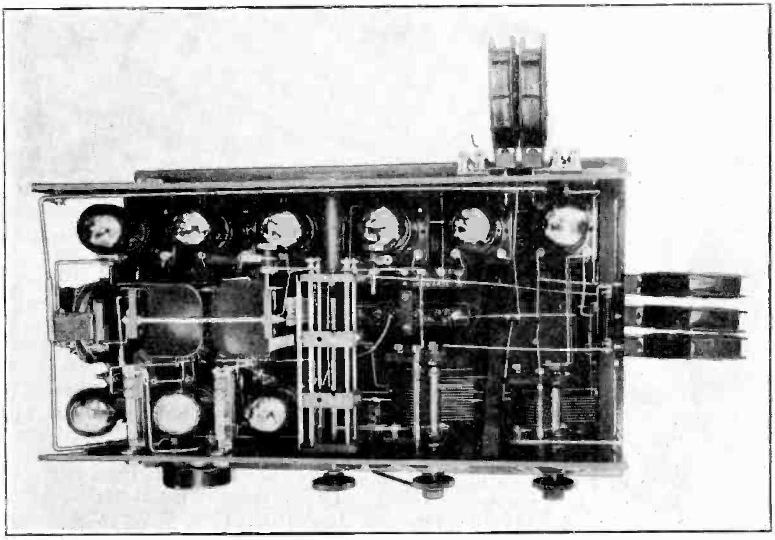


Fig. 2. *Uncovered View, showing the Construction.*

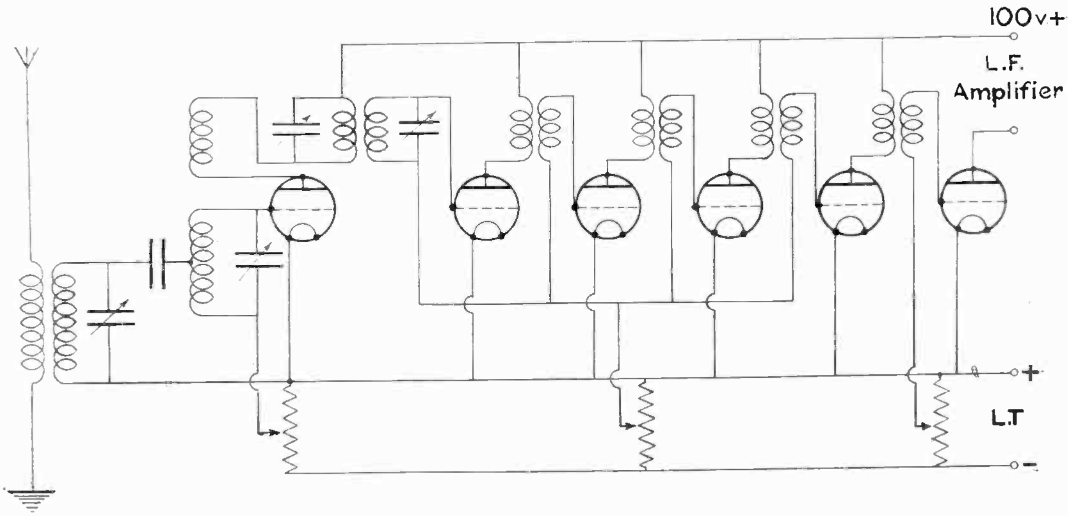


Fig. 3. *The Circuit, which contains several unusual Features.*

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Electrolytic Rectifiers.

The Editor, E.W. & W.E.

SIR,—I read with great interest the communications from Dr. Corret and M. de Bruyne occasioned by my article in the August issue of EXPERIMENTAL WIRELESS. I have read the paper of Gunther-Schulze and Alberti referred to by these correspondents. The fact that fused salts may be used in place of an aqueous electrolyte and that the undesirable capacity effect is less in the fused salts is certainly of scientific interest, but the practical application of this fact presents obvious difficulties.

I have considered the subject chiefly from the point of view of the wireless experimenter who may desire to rectify a high-periodicity, high-voltage supply for a valve transmitter. Many amateurs complain about the messiness of the usual high-tension electrolytic rectifier, and I think that the limit of indulgence would be passed if we asked them to use fused potassium nitrate in each cell. The idea would be more acceptable if a maximum voltage of 500 or so were obtainable per cell; one could reasonably use one or two cells arranged compactly to be heated over one Bunsen burner or gas ring. But Gunther-Schulze and Alberti state definitely that the maximum voltage is only 90 for a cell employing fused potassium nitrate, which is no greater than for an aqueous solution of ammonium phosphate. Further research along these lines might, however, lead to practical results. For instance, it might be possible to use a eutectic mixture of two or more different salts with a very low melting-point.

With regard to the probability of the action of the electrolytic rectifier being an electronic phenomenon as against ionic, I am not prepared to contradict anyone who has conducted precise work on this point. Gunther-Schulze and Alberti only conclude that it is probable at the high frequencies at which they worked, and they do not state in what manner they expect the action to be wholly electronic.

Dr. Corret's remarks about the use of borax rather confirm my own experience. My original condemnation of borax was based on repeated experiments both with the commercial quality of salt and the pure salt obtained from a reputable firm of chemical dealers. Recently I bought some more pure borax from the same firm and gave it another trial in my high-tension rectifier. This time the results were quite good; the rectifier stood full voltage perfectly well and the aluminium plates kept in quite good condition. The only disadvantage was that the rectifier seemed to have a high impedance which increased with time, and it was difficult to get sufficient current through. Borax seems to work much better in high voltage rectifiers than low voltage ones such as are used for charging accumulators. Borax is excellent for electrolytic condensers, but for rectifiers of any kind I still maintain that pure ammonium phosphate is much superior and more reliable. With regard to the "20 Mule Team" borax so frequently referred to in American journals, this has puzzled me for a long time. It is typical of the unscientific method of the typical "ham" that he should inquire into the nature of what he is using no further than its irrelevant trade name.

London. E. H. ROBINSON.

Effective Transmission.

The Editor, E.W. & W.E.

SIR, — *Re* Mr. Hugh N. Ryan's article on "Effective Transmission," in the October issue of E.W. & W.E., I myself have been experimenting on the ratio of aerial current to signal strength, on a wave-length of 120 metres, and the reports I have received confirm the statement made by Mr. Ryan, "that an increase in aerial current does not always increase the signal strength." Mr. Corsham (2UV) and Mr. S. K. Lewer (6LJ) acted as report stations. As the aerial current was increased the signal strength increased up to a certain value, then as the aerial current was increased further the signal strength either remained constant or decreased. On the face of these reports the results are quite contrary to what one would expect from the theoretical standpoint; for instance, consider the following report:—

Aerial current at 5BH ·2A, signal strength at 2UV, R4.

Aerial current at 5BH ·4A, signal strength at 2UV, R3.

One would expect an increase of signal strength of about four times with the point four aerial current over the point two, in view of the fact that the power radiated varies as the square of the

RMS value of the aerial current, measured at the base of the aerial.

It should be pointed out that the wave-length was kept constant during these tests, otherwise the reports would be of no value.

Mr. Ryan mentions a station "5CX" of Colne, this station is very near to mine. He reports that the signal strength fell away as the aerial current was increased. Would Mr. Ryan kindly inform me if the wave-length was kept constant throughout the test, also if he has noticed the effect from any more stations? Information on this point would be welcome.

One more point before concluding. Have any readers given any thought to this effect, that is, "change of note with wave-length," it being very noticeable on stations using direct current for H.T. supply? On some wave-lengths their note is pure CW, on others a harsh hissing sound. Why is this so? Any readers having views on this point might communicate with me at my address, or through this paper.

ALEX. V. SIMPSON, A.M.I.R.E. (5BH).
28, Westgate,
Burnley,
Lancashire.

L.T. Discharge Tubes.

The Editor, E.W. & W.E.

SIR,—The following notes, in the light of further work on the "Osglim" lamp and low-tension discharge tubes, may prove of use in supplementing the article by Clarkson and myself on "A Neon Lamp Method for the Comparing of Capacities and High Resistances."

It is stated there that "time periods greater than 2 to 3 seconds are not recommended, as it is our experience that they give inconsistent results." This inconsistency is, of course, due to the "lag" of the discharge behind the voltage producing it, and may be overcome by having a bright light, radio-active substance, or another continuously-running neon lamp, in the vicinity of the experimental tube. One of the last two agents is recommended, since no appreciable temperature effects are involved, such as might disturb the conditions of experiment; nevertheless sufficient ionisation in the "flashing" tube is provided to overcome the "lag."

The linearity of the "flashing" relations depends upon the equation,

$$T = CR\log_{\epsilon}\frac{E-V_c}{E-V_b} + C\Delta,$$

(see Taylor and Clarkson, *Journ. Scien. Instrs.* Vol. 1, No. 6, p. 751) where T is the total time period, C is the value of the capacity across the tube terminals (in microfarads), R is the resistance in the circuit (in megohms), E is the charging voltage of the battery employed, V_b and V_c are the lower and upper critical voltages respectively (see E.W. & W.E., Vol. II, No. 13, p. 41), and Δ is approximately a constant.

It will be evident, that the accuracy of possible measurement of C and R depends upon the constancy of V_b and V_c, with C and R.

In some recent work (not yet published), in collaboration with W. Stephenson of Armstrong College, we have found, in the case of all the "Osglim" lamps investigated (including many of different patterns), that V_b decreases almost linearly with C from the highest capacities used (about 8 microfarads), down to 0·5 or 0·25 (according to the type of lamp used), but the graph slope is very small, there being a difference of a few volts only in some 130 or so over the whole range. Further, for these capacities, V_b is independent of E, the charging voltage, over a wide range, and of the external ionising agent.

For smaller capacities V_b decreases more and more rapidly, until with very small capacities of the order of 10^{-2} microfarads or so, it attains a minimum value, and probably increases with further diminution of C. V_b is consequently sufficiently steady in value to ensure that the results for C and R measurement, by the method of interpolation, are quite reliable. It would further appear from our results that V_c is, within the limits of experimental error, constant and independent of the nature of the external ionising source.

Newcastle-upon-Tyne. JAMES TAYLOR.

H.F. & L.F. Amplification.

The Editor, E.W. & W.E.

SIR,—With reference to Mr. Hogg's letter concerning my article on "The Use of Low-frequency Amplification for Long Distance Reception," I cannot see why he is disappointed that I should choose L.F. in place of H.F. Would he have me use H.F. because it should give better results from the theoretical point of view? The results I have obtained are in every way satisfactory.

H.F. amplification may be possible on the very short waves, but is the use of such methods justified by the increase (?) in range or signal strength? A supersonic-heterodyne (which may be termed a "brute-force" H.F. amplifier) will certainly give good range and audibility, but in the general opinion it is ruled out because of the very high ratio of cost of manufacture and maintenance to efficiency, *i.e.*, the very poor overall efficiency. When the number of H.F. amplifiers is reduced to one it becomes much less efficient—the overall efficiency is extremely small—and it is doubtful whether the results obtained with one H.F. and detector are any better than those obtained with a single valve.

Mention was made in your Editorial Views of the similarity of selectivity and "extra difficulty in tuning," which occurred in my table. The extra difficulty in tuning comes directly from the increased number of adjustments. It is generally understood that short-wave H.F. amplifiers are tuned. This means that there are three adjustments to make—the tuning of the aerial circuit, the tuning of the H.F. anode circuit, and the reaction coupling. The last named is extremely important—some people don't think so, but let them try it and see—the susceptibility of the receiver to really weak signals is increased enormously when it is only just oscillating. Any person whose DX reception is good will agree to this. Unless the operator is lucky enough to have three hands, something has got to suffer—it is the efficiency. A set which is hard to tune need not be selective; and a selective set is not necessarily hard to tune.

Apparently Mr. Hogg thinks that selectivity is an advantage when searching for weak signals, and advises the use of a much smaller tuning condenser with a fine adjustment. Now, how can anybody search rapidly for weak signals over a large band of wave-lengths with a vernier condenser complete with a fine adjustment of one in umpteen thousands? It is utterly impossible. Therefore selectivity becomes a disadvantage.

Mr. Hogg is probably looking at H.F. and L.F. from the theoretical point of view. In dealing with the use of L.F. for DX work we are dealing with the practical side. What is the DX record of an H.F.-and-detector set compared with that of even a single valve? It is hopelessly in the background.

Perhaps a few notes on my results would be of interest to Mr. Hogg and others. Since writing the article in question the total number of Yanks I have heard has risen to 715. They were comfortably audible on a single valve right through the summer. On the 12th October, I logged 92 of them on one valve only while listening on a wave-band of 5 metres, and through interference from a transmitter, 200 yards away, putting 4½ amps into the aerial on that wave. The list included amateurs in all of the nine districts. WGY, on the 104 metre wave, came in comfortably on a single valve while the aerial and earth were disconnected, the former being lowered to the ground to eliminate re-radiation. Incidentally, about 9.30 one evening during the early summer I logged the call SQ from JMJK, followed by lingo which makes one wonder whether one has forgotten the code. Presumably, the station was in Japan, judging by appearance of the call-sign. I am awaiting confirmation. But that is by the way.

I have received confirmation of my reception from six Pacific Coast amateur stations. CB8 was received R6 on a single valve in a non-oscillating condition—simply by reading the beat note caused by a local heterodyning receiver also receiving CB8.

If these things can be done on one valve, why use an H.F. amplifier? It means another valve and another knob, to say the least; and even then the results are no better. My receiver is open to Mr. Hogg's personal inspection, and I am willing to make a comparison of the two types if it is desired.

S. K. Lewer.

32, Gascony Avenue,
West Hampstead, N.W.6.

[Our correspondent seems to have missed the point of our comment, as also of Mr. Hogg's.—Ed., E.W. & W.E.]

The Editor, E.W. & W.E.

Sir,—I am particularly interested in the discussion going on in E.W. & W.E. regarding the type of apparatus most useful for the reception of short waves.

I am convinced that the popular "Rectifier and single note magnifier" boosted by a large section of "Radio hot-gospellers" is a compromise brought about by their inability to make any receiver which incorporates high frequency amplification function properly. The first mentioned receiver also appeals to the great majority of alleged experimenters, as it is tolerably immune from the effects of "spaghetti" wiring and the like.

As stated by some of your correspondents, H.F. amplification is of real use up to three million cycles and more, but if people use even efficient reactances tuned by armour-plated condensers (by the way, *who* invented variable condensers with metal end-plates?), and wired on the lines of the "shortest way is the quickest," it is no small wonder that they give up the investigation in disgust.

Personally, I do not use high frequency receivers for short waves in the ordinary sense, being a stanch upholder of the super-heterodyne, but I may say that the addition of a single H.F. stage previous to the first rectifier can be made of very real use in this type of receiver.

I also venture to suggest that in the case of the rectifier and note magnifier, there is a definite psychological effect of highly efficient loud reception just because there is a large amount of noise (signal, atmospheric and parasitic) emanating from the phones.

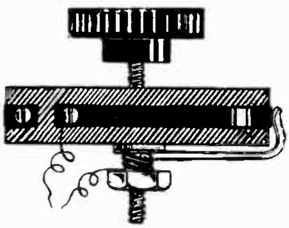
W. Kenneth Alford (2DX).

Rosedene,
Camberley, Surrey.

A Novel Grid-Leak.

The Editor, E.W. & W.E.

Sir,—The following hint may be of value to experimenters in wireless.



A piece of *passe-partout* makes an excellent grid-leak, and gives constant results. This material can be obtained from any good class stationers or photographic dealers at a very small cost.

I have a leak made up of dimensions indicated in the sketch. This I can vary from zero to 4 megohms, the material is three inches long by one-eighth inch wide, and is mounted as shown. I trust this will be of value to your readers.

C. W. H. Bennett.

"Southcote,"
King Street,
Wokingham.

The Winter's Work Begins.

The Editor, E.W. & W.E.

Sir,—I beg to advise you of two-way working between American 1AAC—Framlingham, Conn., U.S.A. and G.2KF in the early hours of September 23rd. Contact was maintained for about one hour on short waves.

I believe this is the first two-way communication this autumn.

J. A. Partridge (G.2KF.)

22, Park Road,
Collier's Wood,
London, S.W.19.

Work in S. Africa.

The Editor, E.W. & W.E.

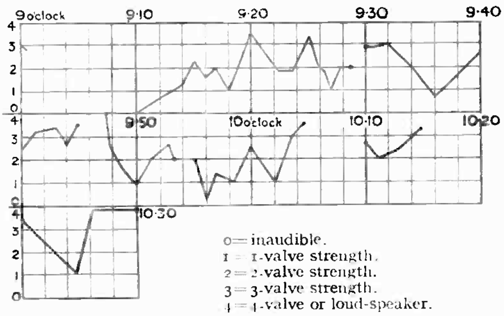
SIR,—In your August number I notice you have a request to readers asking them to inform you of the types of articles that interest them.

I suppose you have a number of readers in this country who are keen experimenters, like myself. We are handicapped in the one sense that a transmitting licence only allows one to transmit for a radius of five miles, although there are a number of amateurs broadcasting on 200λ some of whom are heard 600-700 miles away. I do not understand how they keep within the regulations

Transmission, therefore, interests us more from the theoretical point of view.

The distances out here being so great compared with the old country, most of our experiments are carried out with a view to obtaining clear reception at a distance of, say, 500 or 600 miles from the broadcasting station. The set must not be too large, must be practically dustproof, and be economical in working; for battery charging costs 12s. 6d. a time in this town.

A set as described in your last issue, or, rather, a circuit for a three-valve set, which the author says gives loud-speaker results at five miles from 2LO, is of little use to us. There is, of course, much satisfaction to oneself on reading that article knowing one gets loud-speaker results on a four-valve set of home manufacture 500 miles from J.B.



Long-distance reception over the earth's surface has problems of its own. Take, for example, fading, one of the bugbears apparently little is known about. Some nights fading is very pronounced from loud-speaker strength to inaudibility in, say, two minutes.

I put it down to a more or less run-down L.T. battery, but have noticed it on a battery up to full strength. I am enclosing a rough chart taken one Sunday night which gives some idea.

Next month extensive experiments are being carried out in this country both by *Radio*, our South African magazine, on the Lourenço Marques time signal and also by the Johannesburg Broadcasting Company.

The results of these should be interesting and instructive provided data, such as nature of country, etc., is noted as well.

Our other bugbear is atmospherics. On August 19, for instance, these were so bad and so continuous as completely to blot out all signals, morse as well as telephony. As atmospherics are aperiodic I do not see how they can be eliminated. They are as bad on 200 metres as 600, culminating at their worst, curiously enough, at 450, which is J.B.'s wave-length.

We are also very worried by interference from shipping. Lourenço Marques sometimes nearly blots out the telephony from J.B., and the former is a hundred miles farther away. If the tuning for the commercial stations was as fine as for telephony we should have no difficulty, so an article on interference eliminaters, theory, practical construction, etc., would be appreciated; the author remembering that some of us have no reference library within 100 miles and no one to go and discuss things with.

To sum up, the subjects from a practical point of view useful to us out here, are long-distance reception, elimination of interference, and the subjects of fading and atmospherics.

GEO. K. MALLORY.

P.O. Box 22,
Cathcart, C.P.,
South Africa.

A Reader's Wishes.

The Editor, E.W. & W.E.

SIR,—Congratulations on your journal. The paper, printing, photos, and especially the fact that the advertisements are kept separate, are quite what one could expect when looking forward to the binding of such a volume from the purchaser's point of view. The arrangement is ideal.

The articles, too, are of such a variety as to give everyone some article of interest dealt with in a substantial way by experts.

I was much interested in the article on the "Old Vic" Relay. Will you please give articles from time to time on valve transmitters using "Master Oscillator" and other systems, with diagrams and photographs of the sets used? Could you give us some photographs of the apparatus used by the B.B.C. for transmitting (not the 2LO microphone)?

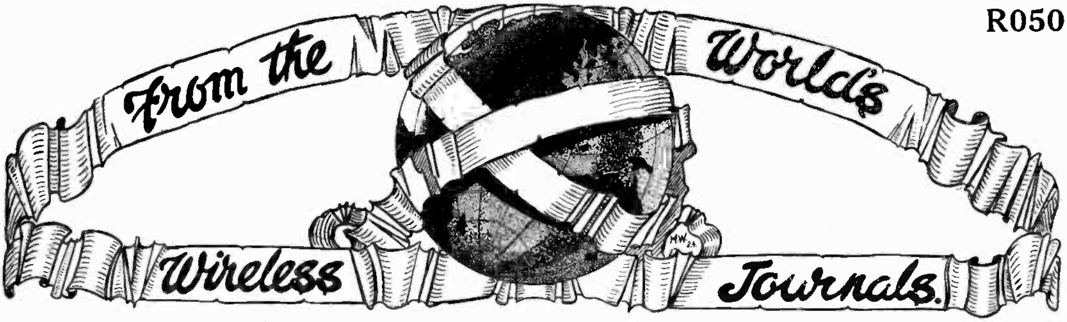
Being a commercial radio "fan" I appreciated article on p. 224 and that on the Devizes Station and manufacture of valves. Page 387 was also interesting and the two articles on selectivity in No. 7.

I am looking forward to receiving some more issues from home. Trusting your journal will have the wide circulation it merits, and wishing you every success, I remain,

"ANTENNA."

[This letter is dated many months ago.—Ed., E.W. & W.E.].

R050



R000.—GENERAL.

R025·4.—THE ARRANGEMENT OF WIRELESS BOOKS AND INFORMATION.—(*Exp. W.*, Oct.).

Explanation of Dewey system of classification and the Bureau of Standards extension of it, with special reference to its application to press cuttings, books, papers, etc., referring to wireless matters.

R100.—GENERAL PRINCIPLES AND THEORY.

R110.—SOME EXPERIMENTS CONFIRMING THE NEW THEORY.—Prof. G. W. O. Howe, D.Sc. (*Electn.*, Oct. 10.)

Prof. Howe gives some experimental data derived from measurements made on the signal strength of Nantes by the vessel *Aldébaran*; these experiments in some measure confirm Prof. Howe's new theory of the propagation of radio waves over long terrestrial distances.

R110.—PORTÉE DES ONDES ; ACTION DE L'ATMOSPÈRE.—M. J. Guinchant (*Onde Elec.*, Sept.).

Discussion on the various attenuation formulæ that have been put forward. It is shown that the purely theoretical formula of Watson always predicts weaker field strengths at a distance than the empirical formula of Austin does; whereas the older Hertz-Blondel formula indicates larger values than the Austin formula. The writer states that if the Hertz-Blondel formula is corrected for the effects of the atmospheric medium then the modified Hertz-Blondel values come into closer agreement with observed values.

R110.—ETUDE SUR LES IRRÉGULARITÉS DE PROPAGATION DES ONDES COURTES.—P. Lardry (*Onde Elec.*, Sept.).

Some experiments on the intensity of signals on short waves. Variations in intensity were too rapid to allow measurement of field strength so that the shunted-telephone method of measuring audibility was used. The data obtained are represented by a number of curves. Measurements over an extended period were taken during the day under various weather conditions.

R113.—EFFECTIVE TRANSMISSION.—H. N. Ryan (*Exp. W.*, Oct.).

Some notes on points which count in operating a valve transmitter to produce effective signals at a distance.

R149.—VALVE *v.* CRYSTAL FOR DETECTION.—P. K. Turner (*Exp. W.*, Oct.).

The *modus operandi* of the valve and crystal rectifier is summarised and the two are compared for distortion effects, much to the disadvantage of the valve, which latter cannot fail to give distortion on telephony when the grid-condenser and leak method is used.

R200.—MEASUREMENTS AND STANDARDISATION.

R240.—HIGH-FREQUENCY RESISTANCE.—J. H. Reyner, B.Sc. (*Exp. W.*, Oct.).

Description of a simple method of testing coils for high-frequency losses.

R260.—THE VACUUM TUBE VOLTMETER.—J. H. Turnbull (*Q.S.T.*, Oct.).

A method employing a three-electrode valve to measure high voltages at any frequency.

R300.—APPARATUS AND EQUIPMENT.

R320.—TRANSMISSION EXPERIMENTS AT 8AQO.—S. Kruse (*Q.S.T.*, Oct.).

Second part of a description of experiments to determine relative merits of earth and counterpoise on various wave-lengths as indicated by field strength measurements at a short distance from the transmitting station.

R342.701.—THE PERFORMANCE AND PROPERTIES OF TELEPHONIC FREQUENCY INTERVALVE TRANSFORMERS.—D. W. Dye, B.Sc. (*Exp. W.*, Oct.).

Second instalment of a paper on some original research work on the impedance of intervalve transformer windings and the general electrical properties of these transformers. This is perhaps the most complete investigation of the subject that has been yet undertaken.

R343.—COMMENT J'AI REÇU OC9.—Capt. Ancelme (*Onde Elec.*, Sept.).

Practical description of a receiver for wavelengths of 9 metres.

R343.—A STUDY OF SUPERHETERODYNE AMPLIFICATION.—H. A. Snow (*Q.S.T.*, Oct.).

Some considerations of the conditions governing the operation of supersonic heterodyne receivers.

R344.—WORKING AT 5 METRES.—S. Kruse (*Q.S.T.*, Oct.).

Some practical circuits for short-wave transmitters; also methods of measuring these short waves.

R344.—A PROPOS DES ONDES COURTES.—P. Girardin (*R. Elec.*, Sept. 25).

Some notes on circuit arrangements for valve sets operating on wave-lengths of the order of two or three metres.

R344.—LOCAL OSCILLATION GENERATORS.—(*Electn.*, Oct. 10).

A description of recent patterns of Marconi local oscillators.

R350.—THE CRYSTAL AS A GENERATOR AND AMPLIFIER.—Victor Gabel (*W. World*, Oct. 1 and Oct. 8).

An English account of the work of the Russian engineer, O. Lossev on crystals as amplifiers and oscillators. A number of circuits are illustrated in which crystals are used for these purposes and a complete crystal regenerative receiver is described.

R350.—LES DÉTECTEURS GÉNÉRATEURS.—M. Vinogradow (*Onde Elec.*, Sept.).

An account in French of Lossev's work on oscillating crystals. The mathematical theory is dealt with, as well as the practical circuit arrangements.

R355.—A METHOD OF OBTAINING A.C. FOR TRANSMISSION.—J. K. Jennings, B.Sc. and B. L. Stephenson (*Exp. W.*, Oct.).

How a D.C. motor may be adapted to act as a rotary converter of D.C. to A.C.

R370.—THE PERFECT SET; PART I.: THE CRYSTAL SET.—P. K. Turner (*Exp. W.*, Oct.).

The first of a series of articles dealing with points of fundamental importance in the design and operation of receiving sets, which are frequently overlooked in constructional articles.

R381.—THE REMOTE CONTROL OF VARIABLE CONDENSERS.—Leonard A. Sayce, M.Sc. (*Exp. W.*, Oct.).

Short note on a method of actuating variable condensers at a distance.

R382.—THE RECEIVING COIL PROBLEM.—G. W. Pickard (*Q.S.T.*, Oct.).

The defects of spiderweb and cylindrical coils are discussed.

R400.—SYSTEMS OF WORKING.

R410.—LE CODE DU GÉNÉRAL O. SQUIER.—W. Sanders (*R. Elec.*, Sept. 10).

A description of Squier's morse system in which dots and dashes have same duration but different amplitudes.

R800.—NON-RADIO SUBJECTS.

STUDIES OF ELECTRIC DISCHARGES IN GASES AT LOW PRESSURES.—Irving Langmuir and H. Mott-Smith (*Gen. El. Rev.*, July, Aug. and Sept.).

Series of articles on the phenomena of gaseous discharges in low-pressure discharge tubes such as mercury arc rectifiers, etc. The theory of plane, cylindrical and spherical collectors, with retarding and accelerating fields, is presented.

RECTIFIER WAVE FORMS.—D. C. Prince (*Gen. El. Rev.*, Sept.).

A technical article dealing with the various factors influencing the wave form of the outputs of single and multiphase rectifiers.

POWER CIRCUIT INTERFERENCE WITH TELEGRAPHS AND TELEPHONES.—S. C. Bartholemew (*Journ. I.E.E.*, Oct.).

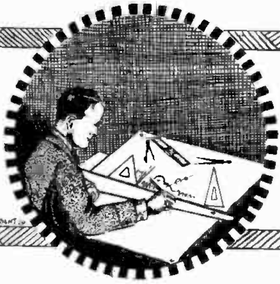
This paper deals mainly with interference with line work by power circuits, but the subject is of interest to the wireless worker under certain circumstances. The questions of harmonics in A.C. supplies, noises from D.C. supplies, electric railways, etc., are dealt with.

SOUND IN RELATION TO WIRELESS.—Prof. E. Mallet, M.Sc. (*W. World*, Sept. 17 and Sept. 24).

The composition of various sounds is considered and the presence of upper harmonics in everyday sounds is shown to be essential to their particular characteristics. Some interesting oscillographs of various sounds are given.

ON SOME PROPERTIES OF LOW-TENSION DISCHARGE TUBES.—J. Taylor, B.Sc. (*Exp. W.*, Oct.).

Article dealing with the volt-ampère characteristics of discharge tubes of the Neon, or "Osglim" type. The properties of these tubes as oscillators and rectifiers is described. The "short-path" principle used in certain types of rectifier is explained.



Some Recent Patents

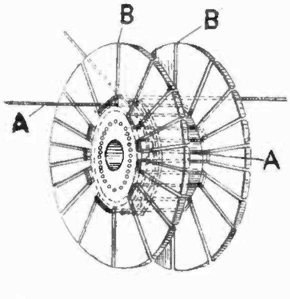
(*The following notes are based on information supplied by Mr. Eric Potter Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.*)

[R008

DURIC COILS.

(*Application date, June* 12, 1923.)

An extremely neat form of tuning coil is that described in respect of Patent No. 217,045 (J. D. Dunthorne, of Ladywell, and W. J. Rickets, of Brixton). In this coil consecutive layers of wire are separated by string in order to provide an air space between them. A former for use in constructing the coil is shown in the drawing.



The dotted lines show the disposition of the string and the beginning of a layer of wire, the turns of which should be preferably spaced.

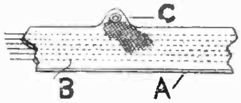
By tuning one disc in one direction to throw the slots in the discs out of alignment and adjusting its perforations over different pins in the core of the former, subsequently completing a layer of string and superimposed layer of wire, and then turning the disc in the opposite direction the string can be laid in layers disposed diagonally in opposite directions.

When the winding is completed the string loops on the outside of the former are cut and the discs removed. The coil is then treated with insulating varnish to make it rigid and the projecting ends of the string trimmed off.

LOOP AERIAL TO FIT WALLS OF ROOM.

(*Convention date, January* 11, 1923.)

The figure illustrates A. N. Goldsmith's Patent No. 209,758. Instead of the ordinary small frame aerial a strip of flexible material A is used in which run a number of parallel wires B, sufficient length of this strip being used to run along walls, ceiling and floors to form a closed loop.

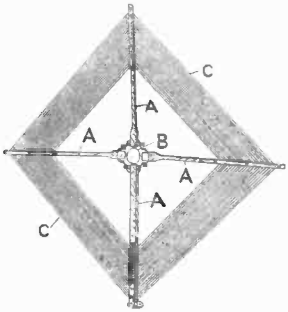


The wires B are joined where the ends meet so as to constitute a large multi-turn inductive loop which can be used for the reception of radio signals. Tabs C may be provided to facilitate fixing the strip in position.

COLLAPSIBLE FRAME AERIAL.

(*Application date, February* 28, 1923.)

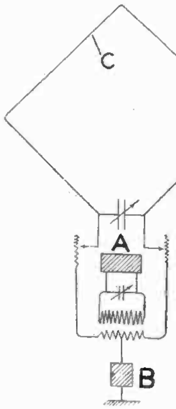
Certain features of the collapsible frame illustrated form the subject of Patent No. 216,578 of the British Thomson-Houston Co., Ltd., and R. C. Clinker. The arms A of the frame are pivoted at their junctions to the central boss B so that they can be folded together when the frame is out of use. The mounting of the arms is so arranged that they open out a little beyond the position where they are in the same plane when the tension of the wires C maintains them in this position. It is stated that when the frame is closed the wires show no tendency to get muddled, but hang in natural folds. A special tripod stand (not shown) for use with the frame is described in the specification, which is so constructed that the downward pressure of the frame due to its weight causes the vertical shaft to be gripped.



AERIAL SYSTEM FOR DUPLEX.

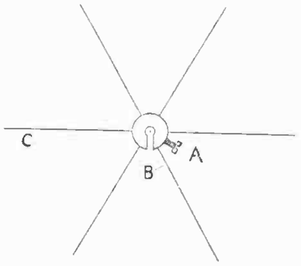
(*Application date, June* 25, 1923.)

An ingenious scheme for simultaneous transmission and reception on the same aerial forms the subject of Patent No. 217,060 of E. Boselli. An elevated loop C is used in such a manner that the receiver A utilises its frame-aerial properties while the transmitter B energises the loop as an ordinary open capacity aerial. Various means are described in the specification for balancing out interaction between transmitter and receiver.



STATIC CHARGE ON AERIALS.

(*Application date, August* 4, 1923.)

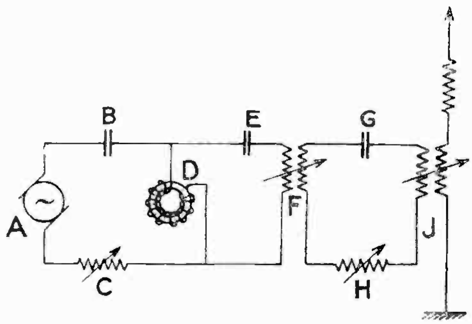


A boss B, adapted to be fixed on to an aerial wire by means of a set-screw A, carries a spike or number of spikes C, which act as discharging points to dissipate any electrostatic charge which may accumulate on the aerial. The patentee is Mr. C. H. Woodward, and the number of the patent 219,185.

ELIMINATION OF HARMONICS.

(*Convention date, November* 29, 1922.)

It is difficult to run transmitters at high efficiency without the radiation of harmonics. In Patent No. 207,781 W. Doring covers the use of an intermediate resonant circuit G F H J between the oscillation generator A and the aerial circuit to filter out undesired harmonic components. In the illustration A is the initial high-frequency generator



and D a frequency multiplier such as is common in long-wave high-power stations. Condenser E and transformer 6 form a system resonant to the desired frequency which serves to transfer the output of D at this frequency to the intermediate circuit and aerial system. We do not quite see where the novelty lies, however, in the mere use of an intermediate circuit.

UNITS FOR RECEIVING SETS.

(*Application date, August* 2, 1923.)

Patent No. 220,161 of Stockall, Marples & Co. covers a wireless set comprising a panel having two connectors and a filament resistance and being wired up so that any number of such panels can, by a mere interchange of plug-in units, be adapted for addition to a foundation panel so as to produce receiving sets of different nature at will. The foundation panel is adapted to be used by itself as a crystal set and is fitted with all the battery wires necessary for the addition of valves.

NEW DEPARTURE IN COATED FILAMENTS.

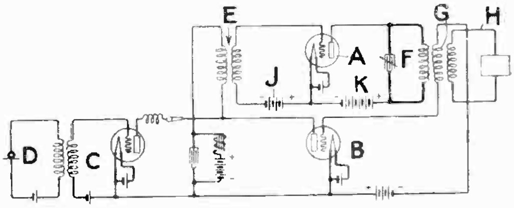
(*Application date, April* 25, 1923.)

Patent No. 219,396 of the Edison Swan Electric Co., Ltd., P. Freedman and E. Greetham covers the use of electron-emitting coatings such as lime, thoria, etc., not in actual contact with the filament itself but as a narrow tube surrounding the filament and free from any metallic supporting base. A method of preparing this non-integral coating or tube is described in the specification. The filament is coated electrolytically with a base metal such as copper; over this is coated electron-emitting substance and the copper is subsequently removed by electrolysis or other suitable means. How this coating remains supported the patentees do not say.

EFFICIENCY IN VALVE OSCILLATORS.

(*Convention Date, March* 31, 1923.)

It is impossible for an oscillating valve to give a pure sine wave at an efficiency greater than 50 per cent. Oscillations produced at higher efficiencies are more in the nature of series of impulsive kicks, there being only a comparatively small D.C. component of the space-current. From a practical point of view it is preferable to work with these high-efficiency but distorted oscillations, as the energy wasted in the valve itself is greatly reduced. A method of generating oscillations of this type has been patented by the Western Electric Co., Ltd., and H. W. Nichols (Patent No. 213,562) and is illustrated herewith. A is the main power valve



fed from a D.C. source K through the main oscillatory circuit F. By means of the bias battery J the grid of A is made so negative that A normally passes practically no current. Reaction coupling between input and output circuits of this valve is effected through the coil G and the H.F. transformer E. It will be noticed that this reaction circuit contains a relay valve B which acts as a "distorter" of the grid excitation of A in such a manner that the latter consists of high positive potential impulses of very short duration compared with the periodic time of the oscillations to be generated in the load-circuit H. Telephonic modulation may be effected by choke-controlling the distorter B with another valve C. The inventors state that with this system they can attain a higher efficiency than has been previously known.

THORIATING TUNGSTEN FILAMENTS.

(*Application date, March* 19, 1923.)

In Patent No. 217,646, Dr. L. A. Levy covers a method of electrolytically thoriating tungsten wires for use as low-temperature electron-emitting filaments. The tungsten wire is made cathode in a cell containing a solution of a thorium salt as electrolyte. The chloride or perchlorate may be used. The wire may be passed through the solution continuously, each part being submerged for about half a minute.

THE GRIMES DUAL CIRCUIT.

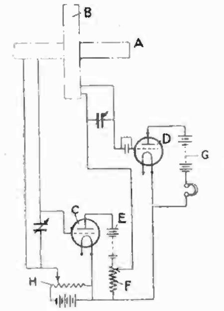
(*Convention date, September* 19, 1922.)

D. Grimes of America has patented the well-known reflex circuit in which a number of valves act simultaneously as H.F. and L.F. amplifiers, the circuit being characterised by the fact that the valves are made to act as L.F. amplifiers in an order different from that in which they act as H.F. amplifiers. Thus the last H.F. valve is made the first L.F., while the first H.F. valve functions as the final L.F. stage. The object is to keep the load on the various valves as uniform as possible. (Patent No. 204,301.)

D.F. RECEIVER.

(*Application date, May* 1, 1923.)

The diagram illustrates a directional receiving scheme covered by Patent No. 220,029 of Dr. J. Robinson and G. J. R. Joyce. Two frame aerials, A and B, are fixed at right-angles with respect to each other and rotate together about a vertical axis. The detecting valve D is associated with frame B. Frame A is connected to another valve C whose function is to paralyse the detector D except when frame A is at minimum with respect to the station being received. In order to effect this a resistance F is connected in series with the battery E in the anode circuit of the valve C. The positive potential derived across part of this resistance F is applied to the grid of D. The grid of C is biased negatively by means of H so that the arrival of signals in A increase the conductivity of the valve C and hence the positive potential applied to the grid of D by the resistance F. Since this positive potential will always exist to a greater or less extent, except when there are no signal currents in A, it follows that the detector will be sensitive only when A is in the minimum position and B in the maximum position.



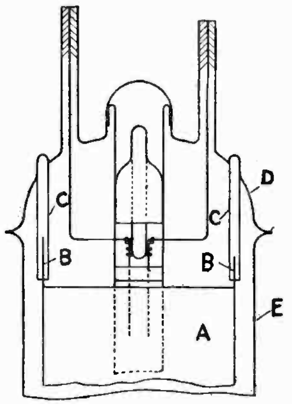
APPLYING COATINGS TO FILAMENTS.

(*Convention date, January* 12, 1923.)

Patent No. 209,730, held by the Dutch firm of Philips, covers a process of applying alkaline earths to electron-emitting cathodes in such a way as to be firmly adhesive. The body to be coated has at least its surface covered with some metal which will form an alloy with the alkaline earth metals. A layer of alkaline earth metal is applied to this surface and the whole is heated in a reducing atmosphere to allow the alloying action to take place. The body thus coated is then heated in an oxidising atmosphere so that a layer of the alkaline earth oxide is formed at the surface.

VALVE CONSTRUCTION.

(*Application date, March* 1, 1923.)

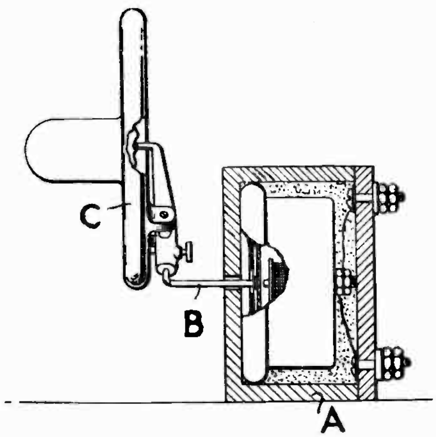


Patent No. 216,585 of C. Seymour, H. G. Hughes and T. E. Goldup deals with the construction of power valves of certain types in a manner to facilitate assembly. The anode supporting wires B are made of unequal length in order to facilitate their fitting into the supporting tubes C when the cap D of the envelope is being fitted to the main body E.

GRAMOPHONE AS LOUD-SPEAKER.

(*Convention date, April* 5, 1923.)

The diaphragm of a telephone receiver A is connected through a member B to the needle holder of



a gramophone sound-box C. Thus telephonic vibrations produced in A are reproduced in the gramophone system. (Patent No. 213,936, R. E. B. Wakefield.)