EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

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A Personal Note.

WITH this issue, EXPERIMENTAL WIRELESS enters upon a new phase of its career: it has undergone change of proprietors, change of editor, and amalgamation. As EXPERIMENTAL WIRELESS AND THE WIRELESS ENGINEER it will try to serve the interests of its readers even better than heretofore. Perhaps it will not be out of place to say a few words as to the change of editors. Mr. Paul D. Tyers, who has so ably conducted the journal since its beginning; to whom, in fact, the idea of a serious wireless journal is due, has been badly overworked in carrying his idea to fruition, and has been ordered by his doctor to take a long holiday. We are sure his many friends and, in fact, all our readers will join us in our sympathy and in wishing a speedy return to full health and strength.

On our own behalf, we must beg the indulgence of our readers if by any chance they miss a tone and outlook to which they are accustomed. It is no light task to take over the control of an existing journal without the active help and advice of its prior editor.

For the Future.

As regards the future of E. W. & W. E., our readers may be assured that we shall maintain the high quality of its contents. At the same time, it is proposed to widen its scope somewhat.

Probably few of our readers have been in touch with THE WIRELESS ENGINEER, which has hitherto been available only to those actually engaged in the wireless trade. Its aim was to appeal to the professional wireless engineer, engaged in the scientific design of apparatus; and in future issues of E. W. & W. E. we propose to devote a certain amount of space to articles of this nature: an example is the treatise on L.F. Transformers, by Mr. D. W. Dye, which commences in this issue.

While we are thus extending our ground in the direction of scientific theory, it is proposed also to appeal to another type of reader: the new hand who is, shall we say, just graduating from the B.C.L. stage into a full-blown experimenter. These amateurs have usually a very fair *surface* knowledge of wireless, but often suffer from insufficient acquaintance with fundamental principles, particularly as regards alternating currents; and we propose to offer them the chance to overcome any such ignorance.

Our calibration department will continue its work on the same lines as at present. Later, perhaps, it will be possible to enlarge the service, but just at the moment our staff is fully occupied in dealing with arrears of work in hand.

We have in mind several new features, which will, we believe, add both to the attraction and the usefulness of E. W. & W.E.

A Subject-Index.

Those of our readers who, as is so often the case, wish to make frequent reference to articles or papers on one department or another of wireless work, must often realise how unsatisfactory it is to try and arrange their extracts in alphabetical order, or to look them up in an alphabetical index.

It may not generally be realised that the Bureau of Standards of America has already got out a fairly complete subject classification of wireless matters, which is, in fact, an extension of the Dewey decimal classification of all knowledge, on which most libraries are arranged to-day. In a future issue we hope to give a sketch of the Dewey system, together with the main lines of the Bureau of Standards extension. It will be found that an index to articles and other sources of information, arranged in the numerical order thus arrived at, is a very great help when seeking for information, for it automatically brings together all references dealing with one subject and, moreover, places references to allied subjects close together, thus arranging the whole in a logical scheme. Thus, for example, useful references for transmitter design might in an alphabetical index be found under all sorts of headings: Valves, Hartley, Meissner, High Tension, Reaction, are only a few of the many.

According to the Dewey scheme, all references on the theory of valve transmitters are together, and so is everything dealing with design and construction.

Accordingly, we are making the preliminary arrangements to enable our readers to deal in this manner with all the information we can put before them. In our next issue, we hope, will appear an article on the subject, and we propose also to give the Dewey reference number not only of every article in the future, but also of abstracts, patents, etc. To the best of our knowledge, the only existing wireless periodical in which this is done is the *Radio Service Bulletin* of America, to which we make our acknowledgments.

5XX.

Although few of our readers are likely to build stations quite like 5XX, the detailed description which we publish this month should be not only of interest, but of use to all transmitters. For although the actual station itself is still an experimental layout, still in its design it is in many ways a model. It is interesting to note the great decrease in smoothing arrangements in the three-phase supply as compared with the single-phase, although the former is of a much lower frequency. Unfortunately, the low-power transmitter will probably be unwilling to use six rectifiers for an amount of power that he can handle with one.

Another notable point is the efficiency of the modulator as an amplifier. There is no sign of the usual series of sub-control stages of gradually increasing power: an input of 10-30 watts, corresponding to, say, 100 watts in the H.T. supply to the previous stage, is used to control directly the four 10 kW valves of the modulator, and does so to such an extent that there is 3000 volts of A.C. across the speech choke.

The free use of "tank circuits," *i.e.*, inductively-coupled closed output circuits is also interesting.

Both the drive oscillator and the magnifier feed into such circuits, the stability of which, as compared with the aerial and magnifier grid circuits into which the valves would otherwise feed, is a very useful help in steadying the set. It will be seen that in both cases the input circuits are tuned, although their tune is kept well away from that of the oscillations to be dealt with. Of course, it may well be the case that on the extremely short wave-lengths on which our amateurs are now doing such wonderful work, the losses in such circuits might be unduly heavy. One point we might mention: the values of the radio-frequency chokes in the anode supply circuits are those given to us by the Chelmsford staff; but we think it just possible that they may be incorrect; both on the appearance of the actual coils and on what we should expect from their function in the circuits we should expect higher values.

Transformers.

It is a curious fact that when someone with a nice machine shop decides to become a wireless manufacturer, in two cases out of three he starts off by making an L.F. Transformer. The article by Mr. Dye, which commences in this issue, shows the rashness of such an attempt. He shows that it is by no means a simple matter to find out how an actual transformer will behave when set to do its duty, and it is obvious that the inverse problem, of designing a transformer to give a required performance, is one that may well occupy the most highly skilled electrical engineer for many weeks.

L.F. Transformers.

A non-mathematical abstract of the important article appearing elsewhere in this issue.

ELSEWHERE in this issue will be found the first part of a most important and masterly article by Mr. D. W. Dye, B.Sc., A.C.G.I.

This article will be read with the greatest interest by the professional wireless engineer, for it is the first published thorough investigation into the design of these transformers. For the benefit of the amateur, who is more interested in getting the best performance out of purchaseable transformers, or in designing his own with a minimum of mathematics, we reproduce below some of Mr. Dye's conclusions, in the simplest of language.

The experiments on which the article is based were directed to finding the true resistance and inductance of the transformer windings, and their self and mutual capacities; also the *apparent* resistance and reactance of the primary when the secondary was loaded. From these values can be found the two factors which control the voltage step-up: first, the ratio of the total (alternating) anode voltage which reaches the transformer primary, and, second, the ratio of primary to output voltage. It is obvious that the product of the two factors gives the total step-up from one valve to the other.

Another most important point is the variation of these factors with frequency. It is obvious that for undistorted telephony reception all frequencies should be amplified alike, while for DX telegraphy it is advisable to sacrifice everything else to a high step-up at about 1000 frequency.

In the article itself, it is shown how, starting from assumed values for the windings, etc., the performance can be predicted, and examples are shown of the accurate agreement between prediction and the measured values. But without mathematics one cannot do more than state some general conclusions, some of which, as will be seen, are already well known as the result of practical experience.

It appears, firstly, that the inductance, self-capacity, etc., of transformers are fairly constant, and do not change with frequency or voltage, except perhaps for particularly high voltage such as may occur in high-power loud-speaker work. The effect of the transformer on the rest of the input circuit is that of a large inductance, a small condenser, and a high resistance, all in parallel. Under certain conditions (see below) the apparent shunt resistance is not so high, which means diminished efficiency. A circuit of this type is, of course, a "rejector," and shows a very high apparent resistance at its resonant frequency. But as regards the all-important matter of "step-up," little or no special effect (curiously enough) is shown at resonance, which in ordinary transformers occurs at from, say, 1000 to 3000 cycles. There is, however, a strong *apparent* resonance effect—increased step-up—at a higher frequency, due to magnetic leakage effects. Steps may be taken to counteract this, as will be shown later.

If the grid of the following valve is ever allowed to become positive—that is, if its grid bias is less than the amplitude of the voltage applied by the transformer, the resulting grid current puts on such a load that the step-up falls away. In such conditions the transformer is wasted; it may give no better amplification than a choke or resistance coupling. On the other hand, the "load" of a valve grid circuit *properly adjusted* will sometimes give a better step-up than would be got with no load at all. This is due in part to its capacity, and in part to the fact that, if this second valve has an inductive load in its plate circuit, its input may have "negative resistance," *i.e.*, there is regeneration, which makes up for some of the iron and copper losses in the transformer.

This fact of regeneration may, however, lead to instability, with the possible result of distortion or even howling. It is common practice to use a shunt resistance, of a megohm or so—a "grid leak" in fact—across the secondary, to avoid these effects. It is shown that the effect of this is to give a flatter curve of step-up for different frequencies. For high and low frequencies the loss is very small, but any "hump" in the curve, which would mean distortion, is considerably reduced. Such resistance loading is therefore beneficial. Mr. Dye gives a value of $\cdot 2 \times$ (turns ratio)^2 megohms as suitable, and points out that the same result is obtained by winding a few turns of wire, say, one to five turns of 18 or 20 S.W.G., over the coil of the transformer, and shorting it.

It was implied in the last paragraph but one above, that the capacity load of a valve *improved* the step-up. This is an undoubted result of the experiments. It was shown that mutual capacity and self-capacity both produced results of the same kind; that, in fact, all the capacities could be represented by one across the secondary. On adding further loading capacities of various values the performance was distinctly improved. Generally speaking, at frequencies below resonance (say up to 1500 cycles) both the factors referred earlier to in this article—primary voltage ratio and step-up—are increased. At higher frequencies, up to the "false resonance" mentioned already, the primary voltage ratio falls, but the step-up of the transformer itself rises: the net effect may be either a rise or a fall. For higher frequencies still, over say 6000 cycles, the loading capacity diminishes the performance.

But it is shown that this may sometimes be improved in another manner, by increasing the magnetic leakage. In a complete transformer this is not practicable directly. But an equivalent change may be made by putting on an inductive load. To reduce the "*k*" of an ordinary transformer by 1 per cent.—the order of change required—would need a load coil of 1 Henry.

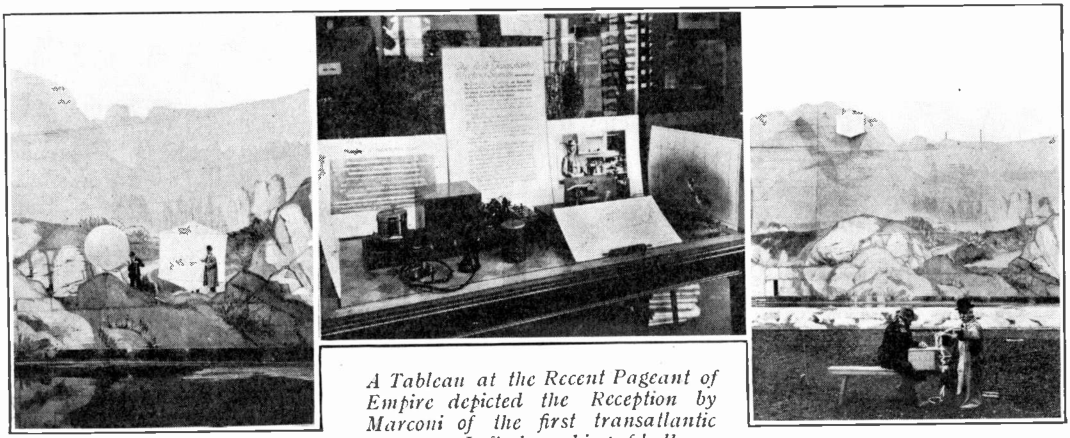
It seems quite certain that by proper adjustment of this kind, a loading capacity will always give improved performance, except in the case of transformers with high ratio or very large primaries. A *total* capacity of about

$$\frac{\cdot 001}{(\text{turns ratio})^2}\ \mu\text{F}$$

seems suitable, but the loading capacity to add can only be found by test: in some cases of not too well designed transformers, the self-capacity is already more than this.

In connection with the loading *inductance* suggested above, to go in series with the capacity, it would be interesting to try the effect of transferring it to the primary, using say 40 000 μH, or, if the "one or two turns of thick wire" is being used, to try the effect of inserting an inductance of 3 or 4 μH (say 5 or 10 turns), *not* round the transformer coils, in series with this.

Lastly, in Mr. Dye's own words, "the most important single property of an intervalve transformer is the inductance of the primary winding." The lower frequencies will not be properly amplified unless this is sufficient. Mr. Dye recommends a primary of the order of 20 Henries, and points out that few commercial transformers have large enough primaries.



A Tableau at the Recent Pageant of Empire depicted the Reception by Marconi of the first transatlantic message. Left: launching of balloons bearing aerials; right: reception of signal; centre: the original apparatus.

The Use of Low-frequency Amplification for Long-distance Reception.

By S. K. Lewer (6LJ).

IT is not the purpose of this article to describe some means of receiving Honolulu on a crystal set or how to make a special H.F. amplifier, but to show how to increase the efficiency of a receiver of the detector and note magnifier type, which is generally considered to be incapable of covering a distance of more than about 3000 miles except under very favourable conditions.

Of course, the aerial should be high and as free from screening as possible, but much can be done with poor aerials; the writer has obtained very satisfactory transatlantic reception with an aerial whose effective height is about five feet! Care must be taken to reduce the losses due to leakage and capacity to earth to a minimum. Every little helps. As everyone knows, the earth lead should be short and thick in order to reduce the resistance.

If the tuning inductance in the aerial circuit is to be efficient it should be designed very carefully. The wire must be thick, but not too thick—about 20 S.W.G.—because eddy-current losses will probably occur. The turns should be spaced and wound on, say, six ebonite strips in which slots have been cut, so that dielectric losses will be at a minimum.

The condenser in the aerial circuit should preferably be of the low loss type and of about ·0005 μF capacity. Condensers with thin plates generally have high losses, necessitating tighter coupling of the reaction coil. If the whole aerial circuit has a high resistance it will be necessary to "couple up" very closely to obtain oscillations. Now this is a disadvantage which is not generally realised. Any slight adjustment of the reaction coil when it is close to the A.T.I. will vary the wavelength very considerably, and this increases the difficulty in searching for a very faint station, because in order to obtain the greatest sensitivity the set should be only just oscillating and this condition varies with the wavelength. Hence, if the aerial circuit has a low resistance and little reaction is needed, searching is made easier. The set may be made to oscillate more readily by taking the lead from the grid to a point higher up than the aerial tap on the A.T.I.

As regards the valves to be used, it may be said that ordinary "R" valves are quite suitable, but a soft rectifier may give better results. The chief point to observe in adjusting the set is that a quiet circuit is absolutely necessary. It is utterly impossible to read a faint signal through the multitude of "rushing" noises which is inherent in some sets with two or more valves. The noise is reduced by cutting down the filament and anode voltages. The H.T. voltage on the rectifier should be in the vicinity of 25 volts if it is a soft valve, and that on the amplifiers about 20 volts. Three volts on the rectifier filament, and perhaps 2½ volts on the amplifiers should suffice. In most cases not more than one note-magnifier will be needed. This method of reducing the filament-to-anode current also limits the jamming caused by "mush," etc.

Naturally the efficiency of the set will vary if the voltages are varied, and tests should be made to counteract this by finding the best grid potential. The simplest way to do this is to use a potentiometer, but much can be done by trying the effect of taking the lead from the grid to various points on the filament circuit. These tests must be made on faint signals, as in all probability loud signals, such as those emanating from the local B.B.C. station, will be horribly distorted due to the overloading of the valves. Another point of which care must be taken is "overlap." To detect if overlap is present proceed in this way:

gradually tighten the reaction coupling: if the set bursts into oscillation with a click and remains in this condition when the reaction coil is withdrawn beyond the point at which oscillation began, then overlap is present. Obviously this must be eliminated in order to obtain maximum sensitivity. This is most easily done by connecting the direct grid lead to a different point on the filament circuit. At the same time the efficiency will be improved. Varying the H.T. voltage or the size of the reaction coil often assists in smoothing out the oscillation point. A variable grid leak is sometimes useful, but some of those on the market are variable only once when they are first screwed up, after which they remain fixed.

It is a good plan to control the normal grid potentials by means of a potentiometer, but this is not absolutely necessary in order to obtain the highest efficiency if care is taken to connect each grid lead to the best position on the filament circuit. The sensitivity of the valve is due to the presence of the grid, and hence the utmost care must be used in its control.

The grid condenser and leak should have the usual values, but it is advisable to try soft rectifiers without them.

The intervalve transformer must be of the high-ratio type, and preferably of well-known make. Cheap transformers are often inefficient because they are not wound with sufficient wire. The usual shunting condenser of about ·001 mfds. should be used. The telephones should be of high resistance, as there is bound to be some loss in the transformer if low resistance telephones are used.

At the writer's station, unfortunately, an efficient aerial cannot be erected, and the one in use at present is 10 to 20 feet below the neighbouring housetops. Within 15 feet of the aerial there are about 500 square feet of metal in the form of roofs. A soft Dutch valve is used for rectifying and an "R" valve for amplifying. The transformer is an ex-W.D. one, and the telephones are Brown's "A" type of 8000 ohms resistance.

Regarding the results obtained with this set, it may be mentioned that the writer has on several occasions listened for American amateurs, and has logged 308 of them at a rate of about 12 per hour on the average. Six American Broadcasters have been heard, WGY and KDKA being easily audible 15 feet from the home-made loud-speaker on a good night. Three amateur stations on the Pacific Coast of U.S.A. have been read on one valve only, but the writer admits that these were "freaks." However, such stations as 1XW, 1BQ, 3OT, 4BZ, 9BL can be heard several feet from the loud speaker almost any morning. All of the above stations can be read on one valve with an indoor aerial.

In conclusion, perhaps it would be of interest to compare the relative advantages and disadvantages of H.F. and L.F. amplification for DX work.

Comparison of the relative advantages and disadvantages of H.F. and L.F.

Advantages.	*Disadvantages.*
H.F.	
1. Selectivity. 2. Sensitivity.	1. Extra difficulty in tuning. 2. No reduction of aerial circuit resistance. 3. Extra capacity in detector grid circuit. 4. Body-capacity effects.
L.F.	
1. Very easy tuning. 2. Reduction of aerial circuit resistance.	—

The first advantage of H.F. in the table tends to become a disadvantage in practice, because it is so very difficult to find a really faint station if the receiver is selective. It is true that an H.F. valve increases the sensitivity, but some of this is lost by the extra capacity which is involved in the detector grid circuit. If an H.F. amplifier is used reaction is generally coupled to the tuned-anode coil or the transformer, as the case may be. This means that the resistance of the aerial circuit is not reduced; but when reaction is coupled to the A.T.I. the effective resistance may be decreased to and below zero if necessary, so that the strength of signals is increased. If "double-reaction" is used, that is, if the three coils are coupled together, adjustments become very critical, and quick tuning is by no means easy.

This article does not take into comparison the multi-valve super-heterodyne set, which is undoubtedly the most reliable of all sets for distant reception.

The Performance and Properties of Telephonic Frequency Intervalve Transformers.

By D. W. Dye, B.Sc., A.C.G.I.

This important article, by the head of the Electrical Measurements Department at the N.P.L., will be studied with great interest by all technical readers. An abstract, in non-mathematical language, will be found elsewhere in this issue.

Summary.

Methods are described for measuring the effective primary inductance and resistance of telephonic frequency transformers.

It is shown that when reactance and resistance are plotted in a convenient manner the result is a circle diagram.

The analysis of the effective components of inductance, capacity and resistance corresponding to the circle diagram is then shown and is developed to include the effects on primary effective reactance and resistance of mutual and secondary capacity, shunt resistance on the secondary and the attachments of a valve grid-filament circuit.

The means of evaluating secondary inductance and self-capacity are shown. The effects of the foregoing quantities on the ratio of the transformer are then examined experimentally and theoretically and the close relationship of ratio to the coefficient of coupling shown.

The results of the complete analysis are applied to the determination of the amplification factor of the transformer and a number of conclusions are drawn therefrom.

1.—Introduction.

Intervalve transformers are a very commonly used means of coupling the stages of amplifiers used for various purposes in which it is required to magnify weak currents of telephonic frequency.

Very little information has been published on the properties of such transformers or on the methods of testing their operation and determining the qualities that are desirable in them in order that they may best suit the circuits to which they are applied. One test which is commonly applied is to measure the effective amplification of voltage given by a valve and transformer. This may be expressed as the ratio of the secondary voltage produced by the transformer, when connected to the grid of another similar valve, to the voltage applied to the grid of the first valve in whose anode circuit the primary of the transformer is connected.* This test is very valuable and is a direct measure of the overall performance of a transformer. As a means of comparing various types of transformer also it is probably indispensable. Such a test, however, has very small power of analysing the various factors entering into the overall performance.

It was thought that more insight into the behaviour of such transformers would be obtained by carrying out direct measurements of the effective inductance, resistance and other inherent properties of the windings. The present investigation is an attempt to analyse the transformer experimentally and theoretically under the conditions of use. The results have proved highly interesting and somewhat remarkable, and although it has not been possible to separate completely all the quantities involved, a sufficiently complete analysis has been obtained in a manner which is capable of giving much guidance in design.

2.—General Considerations.

Statement of the case.

The function of an intervalve transformer is to receive on its primary winding as large a fraction as possible of the alternating voltage set free in the anode circuit in which it is connected. It should then develop at its secondary terminals—connected to the grid circuit of the ensuing valve—as high a voltage as possible. Further, the ratio of the input voltage to the first valve to that given by the transformer to the ensuing valve should be invariable with regard to frequency and amplitude. It is, of course, realised in making the above statement that the most perfect transformer from this point of view may fail by its very perfection on account of the instability which may be produced and which will result in the self-generation by the system of oscillations of audible frequency constituting one form of the troublesome malady known as "howling."

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* 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.

In the present investigation, however, no account is taken of this possibility in any part of the discussion or conclusions.

Referring now to Fig. 1, representing a typical use of an intervalve transformer T, we have, applied to the grid of valve V_1, an alternating voltage, e_g, the source of which, for the moment, does not concern us. As a result of this voltage, a voltage e_g is produced in the anode circuit ABCF ; of this voltage a fraction e_p is applied to the primary of the transformer, resulting in a secondary voltage e_s which is applied to the grid-filament circuit of the valve V_2. The duty of the transformer is to give a ratio e_s/e_p as large as possible and to keep this ratio independent of amplitude and frequency. Now the essential electrical quantities involved can be represented as in Fig. 2, in which the valve V_1 and its batteries have been replaced by a resistance R_a assumed constant and pure and a source of alternating voltage of value μe_g. The valve V_2 is assumed to be replaced by an impedance Z_g consisting of a capacity C_g and a series resistance r_g. A variety of quantities enter into the electrical representation of the transformer, but for the moment, as regards the current i_p entering at the terminals, the primary winding can be represented by a simple impedance Z_p and the secondary winding can be represented in a like manner.

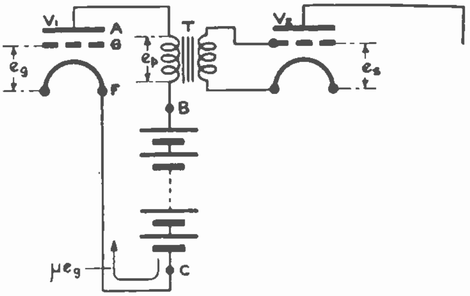

FIG. 1.

The ratio $\frac{e_s}{\mu e_g}$ may now be considered as the product of the two quantities q and σ, where q is the primary voltage factor and σ the ratio of e_p to e_s. We have

$$q^2 = \left(\frac{e_p}{\mu e_g}\right)^2 = \frac{Z_p{}^2}{X_p{}^2+(R_p+R_a)^2},$$

in which X_p and R_p are the reactance and resistance components of Z_p, while σ depends mainly upon the ratio of the numbers of turns of primary and secondary windings. If therefore we measure X_p and R_p under various conditions and over a considerable range of frequencies, we can determine the performance of the transformer under these conditions. It is to be anticipated also that a separation of the internal constants of the transformer can to a considerable extent be made by observation of the change in effective primary impedance and in ratio when various external conditions are varied. Since an intervalve transformer contains thousands of turns in its windings, in a confined space, it is to be further expected that the distributed capacities of the windings will play an important part in its behaviour.

The transformer may therefore be considered as a mutual inductance possessing all the parts indicated in Fig. 3, in which R_t and L_t represent a tertiary closed circuit imitating the hysteresis and eddy current effects due to the iron core and C_m represents distributed capacity between primary and secondary windings. The meanings of the other quantities are obvious.

The complete solution of this case can be expressed as a determinant, but the reduction of any part of it to a working equation becomes too complicated to enable the bearing of the various factors to be visualised ; in addition L_t and R_t are variable with frequency and current, and the effective mutual capacity C_m will depend upon the potential differences between any chosen points on primary and secondary circuits as determined by the complete electrical system including the external circuit. As regards this latter point, in practice the transformer is commonly connected as shown in Fig. 4. The impedance of the anode battery between the points A, B is small compared with the rest of the circuit, even without the con-

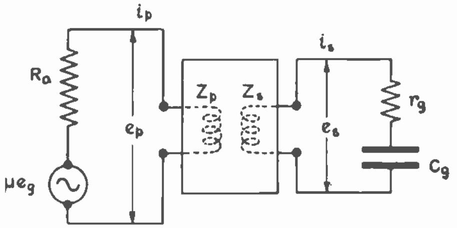

FIG. 2.

denser C. When this is used, as is common, and has a value of the order 1 or 2 μF, it virtually amounts to connecting the terminals P O, S I together so far as the alternating voltages are concerned. This results in a simplification of the equivalent circuits of the transformer to those shown in Fig. 5, in which also the iron losses have been transferred as a load Z_s (not necessarily invariable with frequency) on the secondary winding. The equivalent grid capacity and resistance have been merged into the secondary capacity and impedance. This diagram represents the simplest form and possesses the smallest number of variables to which an intervalve transformer can be reduced. Before giving the evaluation of the equations connecting the various voltages and currents, it is convenient to describe the methods and some results of the experiments on the measurements of effective inductance and resistance of the primary winding and of the effective ratio of transformation.

3.—Measurement of effective primary impedance and of voltage ratio of transformer.

The measurement of an inductance of many Henries having a resistance of many thousands of ohms is not very easy, especially when these measurements are required at small voltages. Variable mutual or self-inductances of range expressed in Henries are not easily available, and, further, if one arm of a bridge is allowed to be of several hundred thousand ohms in impedance, the effects of stray capacities become very troublesome, and the measurements are uncertain unless great precautions are used.

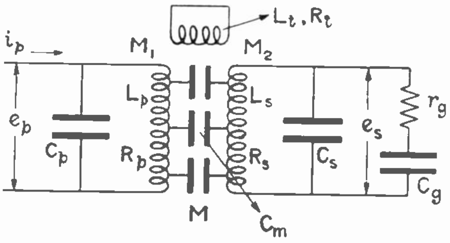

FIG. 3.

In the light of previous experiments, the method finally adopted consisted of a mutual inductance bridge with four equal arms of 1000 ohms each. The arrangement is shown in Fig. 6. The measurements consist in observing the change in effective inductance and resistance of the non-inductive resistance coil S when shunted by the primary of the transformer. A definite voltage is conveniently applied to the ends of S by the help of the thermoammeter A, and a shunt resistance T across the bridge. The whole bridge resistance between a and b is almost invariable under all experimental conditions, and is nearly 1000 ohms. The mutual inductometer is of 10 mH range : the variable resistance r requires to be known to 0·01 ohm, and may reach values somewhat greater than 10 ohms. The point b of the bridge is directly earthed, and greatly stabilises it ; doubtless a Wagner earth would be superior from the point of view of rendering capacities of the transformer to earth of no consequence, but these effects are of no particular importance in the present investigation, since less than 1 per cent. uncertainty is produced by them.

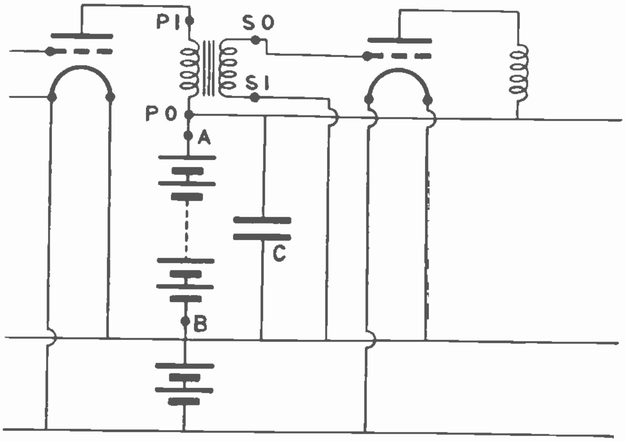

FIG. 4.

An Ayrton-Mather low-reading electrostatic voltmeter serves to read or to see the secondary voltage of the transformer. This voltmeter must be disconnected when the observations are made, because of the large effects produced on the effective primary inductance and resistance by the capacity of the voltmeter. As will be seen later, the voltmeter capacity has a negligible effect on secondary voltage. The low-reading voltmeter is rather a luxury in such experiments, but if desired a valve instrument of the Moullin type could doubtless be used instead.

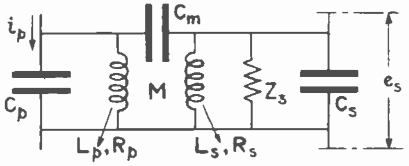

FIG. 5.

The procedure consists in observing the values of M and *r*, first with the transformer disconnected from S, and then after shunting it across S. Before making the second observation, the voltmeter is connected to the secondary of the transformer and the bridge current adjusted so as to give the desired primary or secondary voltage. The effective resistance and inductance of a shunt circuit in terms of the change in effective resistance and inductance of the resistance S is given as follows : if the pure resistance S is shunted by R and L in series, and then has an apparent resistance and inductance S_0 and L_0, then

$$R = \frac{SS_0(S-S_0)-SL_0^2\,\omega^2}{(S-S_0)^2+L_0^2\,\omega^2}$$

$$= \frac{S^2\Delta S}{\Delta S^2+L_0^2\,\omega^2} - S$$

in which $\Delta S = S - S_0$ and

$$L = \frac{S^2 L_0}{\Delta S^2+L_0^2\,\omega^2}$$

In the equal arm bridge here used L_0 is equal to 2 $(M-M_0)$ where M_0 and M are the readings on the inductometer before and after connecting the transformer primary across S, and ΔS is equal to the difference between the values of *r* before and after connecting the transformer.

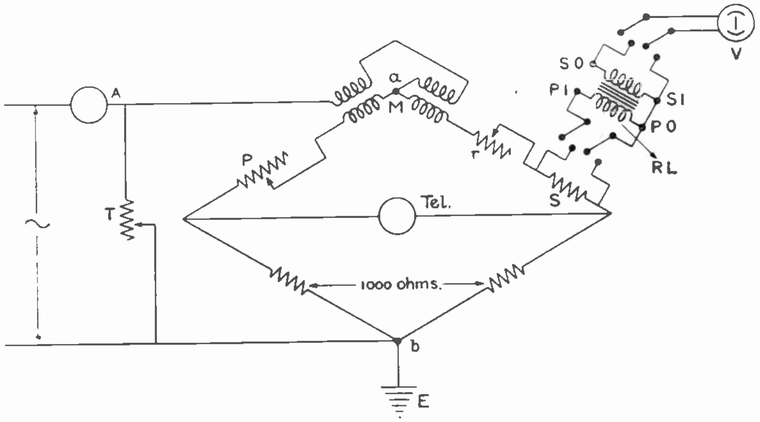

FIG. 6.

We have therefore

$$R = \frac{S^2\Delta R}{\Delta R^2+(2\Delta M)^2\,\omega^2} - S \quad .. \quad (1)$$

and

$$L = \frac{S^2 2\Delta M}{\Delta R^2+(2\Delta M)^2\,\omega^2} \quad .. \quad (2)$$

By choosing S equal to 1 000 ohms we get a very convenient multiplier of 10^6, thus enabling the readings to be taken on the 10mH inductometer. In a poor transformer, however, M may become larger than 10mH. In this case S may be conveniently chosen as 500 ohms.

When the current through the bridge is reduced to such a value that the secondary voltage across the transformer is less than 2, favourable external conditions are required in order to obtain good sensitivity, since there is not then more than about 1 volt on the whole bridge. As will be seen later, a typical transformer may have an effective primary reactance of no less than 500 000 ohms in certain regions of frequency, so that the change in *r* representing change in S is only about 2 ohms. For an accuracy of 1 per cent. therefore *r* must be observed to 0·02 ohm, and this is an arm of 1 000 ohms resistance. Since, however, practically the whole of the bridge consists of 4 manganin coils of 1 000 ohms each, the balance is remarkably stable.

When observing the effects of added capacity across the secondary or as added mutual capacity, a standard low range variable air condenser was used. The effects of resistance across the secondary were also studied, and for this purpose grid leaks previously calibrated at telephonic frequencies were used.

A typical series of observations is given in Table I below, together with the reduced values of R_p, L_p and X_p, the effective resistance, inductance and reactance of the primary winding.

TABLE I.

EFFECTIVE PRIMARY RESISTANCE, INDUCTANCE AND REACTANCE OF INTERVALVE TRANSFORMER WITH P O AND S J COMMON AND NO CONNECTIONS ACROSS THE SECONDARY.

Frequency. cycles per sec.	Observed r Difference.	Observed M Difference.	R_p	L_p.	X_p.
	Ohms.	μH.	Ohms.	Henries.	Ohms.
500	4·49	5 010	3 450	9·93	31 200
800	2·73	1 794	7 200	10·82	54 300
1 000	2·22	1 014	12 500	12·23	77 000
1 200	1·93	565	24 300	14·82	111 800
1 400	1·88	319	54 500	18·54	163 000
1 500	1·85	+225	85 000	21·07	198 500
1 600	1·81	+156	135 300	23·84	239 600
1 700	1·78	+102	224 000	25·85	276 000
1 750	1·76	+64	345 500	25·10	276 000
1 800	1·74	+42	442 000	21·36	+241 600
1 850	1·74	+13	557 000	8·36	97 000
1 900	1·71	—10	569 000	—6·54	—78 000
1 950	1·71	—30	493 000	—17·31	—212 000
2 000	1·71	—46	400 000	—21·56	—271 000
2 100	1·74	—85	216 000	—21·14	—279 000
2 200	1·75	—116	130 000	—17·43	—241 000
2 500	1·76	—187	51 000	—10·37	—163 000
3 000	1·75	—256	17 000	—5·33	—100 500

The curves corresponding to R_p and L_p are shown in Fig. 7. The changes in them are very great as the frequency passes through the resonant region. In this region, therefore, frequencies near one another must be used if accurate delineation is required; the frequencies must also be known with considerable precision.

It will immediately be seen that these curves are those corresponding to a system having a well-defined resonant frequency. Now one of the properties of such a system is that if we plot effective resistance against the corresponding effective reactance the points should lie approximately on a circle. In Fig. 8 are shown the corresponding values of resistance and reactance plotted—as dots in circles—in this manner. It will be seen that the points lie upon an astonishingly good circle. It is of interest to consider the simplest kind of circuit which can produce a circle when its properties are treated in this manner.

4.—Circle diagram and its relationship to the properties of a circuit.

If we take the simple circuit shown in Fig. 9 (a), we shall find that the equivalent R_0 and X_0 with respect to the external current i_0 have such values as to give a perfect circle when plotted in the manner shown in Fig. 8. Thus—

$$i_0(R_0+L_0a)=e_0=i_1La=i_2S=i_3\frac{1}{Ca}$$

where $a=j\omega$,

and $i_0=i_1+i_2+i_3$

$$\text{whence } R_0=\frac{SL^2\omega^2}{S^2(1-LC\omega^2)+L^2\omega^2} \quad .. \quad (3)$$

$$\text{and } \quad L_0=\frac{S^2L(1-LC\omega^2)}{S^2(1-LC\omega^2)+L^2\omega^2} \quad .. \quad (4)$$

Now if we let $a^2=(\text{Radius of circle})^2=(R_0-\tfrac{1}{2}S)^2+(L_0\omega)^2$

we get $a^2=$

$$\frac{S^2\left[\{L^2\omega^2-S_2(1-LC\omega^2)^2\}^2+4S^2L^2\omega^2(1-LC\omega^2)^2\right]}{4\{S^2(1-LC\omega^2)^2+L^2\omega^2\}^2}$$

$=S^2/4$.

For all values of ω therefore the points lie on a circle of diameter equal to S, and with its centre on the axis at the point $R_0=\tfrac{1}{2}S$. Now such a circle, although approximately representing the transformer primary, cannot quite do so, since the inductance L_1 has in practice a resistance R, which is shown by the relatively very small R_0 at the point O

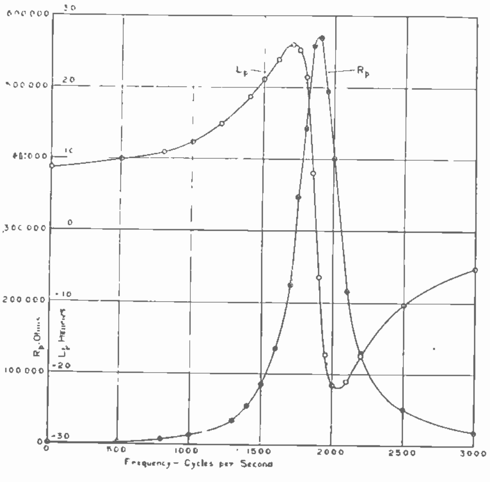

FIG 7

on Fig. 8, corresponding to a frequency 0. Now this resistance R, although of little consequence at frequencies corresponding to the lower portion of the circle, has a considerable influence on the diameter of it. A further effect is to cause the circle to be displaced horizontally by a small amount, so that its centre lies to the left of the R axis. The experimental results are sufficiently accurate to show this, as will be seen by close inspection of the points. A closer approximation to the experimental and the actual case is given by (*b*) of Fig. 9, where an R term is included, and the shunt resistance S now has a different value from that corresponding to Fig. 9(*a*).

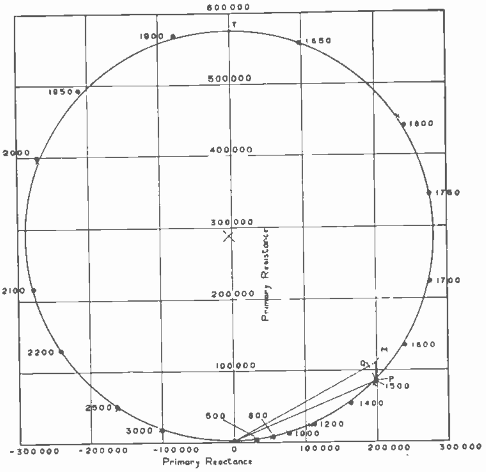

FIG. 8

Calculating the effective values of R_0 and L_0 for case (*b*) the accurate expressions are

$$R_0 = \frac{S(R^2+SR+L^2\omega^2)}{(R+S[1-LC\omega^2])^2+(L+RSC)^2\omega^2} \quad .. \ (5)$$

and

$$L_0 = \frac{S^2\{L(1-LC\omega^2)-R^2C\}}{(R+S[1-LC\omega^2])^2+(L+RSC)^2\omega^2} \quad .. \ (6)$$

When $LCw^2=1$, these become to a very close approximation

$$R_0 \max = S - \frac{RS^2C}{L+RSC}$$

$$= \text{Diameter of circle} = \frac{SL}{L+RSC} \quad .. \ (7)$$

$$L_0 = 0$$

It is seen that the introduction of the R term has considerably complicated the expressions for R_0 and L_0, so that the diameter of the circle is no longer equal to S, and the exact evaluation of the four constants L, C, S and R from a series of observed values of R_0 and L_0 is not quite so easy. It would, in any case, obviously be unwise to attempt to separate L and C at a region of frequency near that at which $LC\omega^2=1$. We will, therefore, consider the case where $LC\omega^2$ is not nearly unity, *i.e.*, the lower portion of the circle. Terms containing R^2 become negligible, and the expressions reduce to

$$R_0 = R_p = \frac{S(L^2\omega^2+RS)}{L^2\omega^2+2RS+S^2(1-LC\omega^2)^2} \quad .. \ (8)$$

and

$$L_0 = L_p = \frac{S^2L(1-LC\omega^2)}{L^2\omega^2+2RS+S^2(1-LC\omega^2)^2} \quad .. \ (9)$$

or

$$X_p = L_p\omega = \frac{S^2L\omega(1-LC\omega^2)}{L^2\omega^2+2RS+S^2(1-LC\omega^2)^2} \quad (10)$$

in which R_p and L_p represent the effective resistance and inductance of the primary of a transformer.

The separation of the quantities L, C, S and R will now be considered.

Equation (10) may be written

$$\frac{1}{X_p} = \frac{1-LC\omega^2}{L\omega} + \frac{1}{S^2} \times \frac{L\omega}{1-LC\omega^2} + \frac{2R}{SL\omega(1-LC\omega^2)} \quad (11)$$

Let $\dfrac{1-LC\omega^2}{L\omega} = P$

we then have

$$\frac{1}{X_p} = P + \frac{1}{S^2} \times \frac{1}{P} + \frac{2R}{SL\omega(1-LC\omega^2)}$$

We can treat the term $\dfrac{2R}{SL\omega(1-LC\omega^2)}$ as a separate correction to be applied afterwards, as will be seen later.

Taking then, $S^2P = S^2P^2X_p + X_p$

we have

$$P = \frac{1}{2X_p}\left(1 \pm \frac{1}{S}\sqrt{S^2-4X_p^2}\right)$$

If, therefore, we choose points having observed values X_1 and X_2 of X_p at known values of ω equal to ω_1 and ω_2 as given by the circle, we can write down two equations,

$$P_1 = \frac{1}{2X_1}\left(1 \pm \frac{1}{S}\sqrt{S^2 - 4X_1^2}\right) \quad \ldots (12)$$

and

$$P_2 = \frac{1}{2X_2}\left(1 \pm \frac{1}{S}\sqrt{S^2 - 4X}\right) \quad \ldots (13)$$

The significance of the ± sign in the bracket is that, for points on the circle below the horizontal diameter the sign is +, and for values above this diameter the sign is —. At the two points on the circle where the horizontal diameter cuts it, the expression under the square root becomes zero.

$$\text{Now } P_1 = \frac{1}{L\omega_1} - C\omega_1 \text{ and } P^2 = \frac{1}{L\omega_2} - C\omega_2$$

$$\text{so that } L = \frac{\omega_2^2 - \omega_1^2}{\omega_1\omega_2(P_1\omega_2 - P_2\omega_1)}$$

$$= \frac{n_2^2 - n_1^2}{n_1 n_2(P_1\omega_2 - P_2\omega_1)} \quad \ldots (14)$$

$$\text{and } C = \frac{P_1\omega_1 - P_2\omega_2}{\omega_2^2 - \omega_1^2} = \frac{P_1 n_1 - P_2 n_2}{2\pi(n_2^2 - n_1^2)} \quad \ldots (15)$$

It has been noted above in equation (7) that the diameter of the circle does not equal S, so that we cannot use the experimentally known diameter in equations (12) and (13) in order to determine P_1 and P_2.

But if we choose suitable values of X_1 and X_2, an uncertainty in S can be made of little consequence. The best procedure is first to calculate L and C assuming S to be equal to the diameter of the circle, and then, assuming these values of L and C in the equation

$$S = \frac{LR_p\,(max)}{L - CRR_p\,(max)} \quad \ldots \quad \ldots (16)$$

—deduced from equation (7)—we can find a more accurate value for S. This new value is then used in equations (12) and (13) in determining P_1 and P_2. One such stage of successive approximation will give results for L and C which are not in error by ½ per cent.

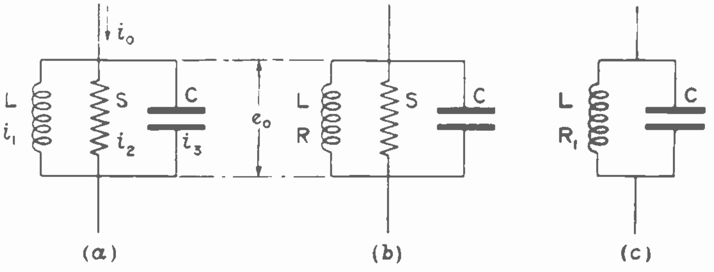

FIG. 9.

Suitable points to choose for X_1 and X_2 are, one on either side of the R axis, at which they have values of the order of one quarter of the diameter of the circle.

An example taken from Fig. 8 will illustrate the procedure.

Let the points chosen be

$n_1 = 1500(\omega = 9424)$ and $n_2 = 2500(\omega = 15700)$.

The corresponding values of X_1 and X_2 are $X_1 = 198\,500$ ohms and $X_2 = -163\,000$ ohms. Using first the value $S = 576\,000 =$ (dia. of circle), these give for P_1 and P_2 the results

$$P_1 = \frac{1}{397000}\left(1 + \frac{1}{576000}\sqrt{576000^2 - 397000^2}\right)$$

$$\text{and } P_2 = -\frac{1}{326000}\left(1 + \frac{1}{576}\sqrt{576^2 - 326^2}\right)$$

whence $P_1 = 4{\cdot}35 \times 10^{-6}$ and $P_2 = -5{\cdot}60 \times 10^{-6}$ so that $L = 8{\cdot}81$ henries.

Also C, by formula (15), is equal to

$$\frac{4{\cdot}35 \times 10^{-6} \times 9426 + 5{\cdot}60 \times 10^{-6} \times 15700}{15700^2 - 9424^2} = 814\,\mu\mu F$$

Using these values of L and C in equation (7a), and assuming the d.c. value of 1000 ohms for R, we get for S the corrected value, $S = 608\,000$ ohms. The revised values of P_1 and P_2 become $4{\cdot}43 \times 10^{-6}$ and $-5{\cdot}66 \times 10^{-6}$ respectively, giving for L and C the corrected values

$L = 8{\cdot}68$ H.
and $C = 825\ \mu\mu F$.

The analysis yields therefore the following effective values for the primary winding :—

$L = 8{\cdot}68$ H; $C = 825\ \mu\mu F$; $S = 608\,000$ ohms; and R (assumed equal to the d.c. value) = 1000 ohms.

Returning now to the term $\frac{2R}{SL\omega(1-LC\omega^2)}$, which was neglected in equation (11), we should have used terms of the form

$$\frac{1}{X}-\frac{2R}{SL\omega(1-LC\omega^2)} \text{ instead of } \frac{1}{X}$$

in equations (12) and (13) when determining P_1 and P_2. If the values already determined for S and L are inserted in the correction term we shall see that a value of P_1 about 0·8 per cent. smaller and a value of P_2 about 0·4 per cent. greater should have been used in calculating L and C. If these corrections are applied, it will be found that L will only be increased by 0·3 per cent. and C will be increased by a completely negligible amount. We can therefore safely take the simplified form of equation (11) when calculating L and C.

Using the values of L, C and S thus determined, values of R_p and L_p have been calculated by formulæ (5) and (6) for a number of frequencies. These points are marked by crosses on the circle in Fig. 8, and will be seen to give very good agreement with the observed values at these same frequencies. This agreement indicates that L, C and S do not vary much with frequency at the small magnetisation necessary to produce a secondary voltage of 2.

The circle diagram affords a very convenient graphical means of observing the voltages and their phase relations in the primary winding and the associated valve circuit. Thus, at any frequency, such as that given by P on the circle corresponding to $n=1500$, we may draw PM equal to the anode resistance R_a of the valve; if now we join OM we have a triangle in which we may consider OM equal to the total voltage μe_g in the equivalent circuit of Fig. 2. PM is the voltage drop in R_a and OP is the voltage e_p across the primary of the transformer. The phase relationships of these voltages is also shown, and the ratio OP/OM gives the fraction q of the voltage μe_g which is acting on the primary winding of the transformer.

The circle diagram will be found a very clear and simple method of visualising at a glance the behaviour of a mesh circuit possessing any parallel combination of resistance, capacity or inductance towards another circuit in which it is placed. The locus of the end of the impedance vector travels round a circle when any one of the four quantities S, L, C or ω is continuously varied. The circuit need not contain both capacity and inductance, but in such a case only a semi-circle will be obtained; also, for the particular case where $S=\infty$ the circle becomes of infinite diameter and the vector impedances all lie on one line. If we take a common oscillatory circuit with series resistance and infinite shunt resistance, the circle is not quite perfect, since the vector is not zero at zero frequency, but in most cases the diameter is so large compared with the resistance vector that the want of perfection is inappreciable. There would appear to be room for the development of this method of studying the relationship of one circuit to another.*

Returning now to Fig. 9, the quantities L, R, S and C require examining. L as analysed above is clearly the true effective self-inductance of the primary winding. R is a term depending upon the copper losses in primary and secondary, and probably has a value in the neighbourhood of $R_1+R_2/\sigma_0{}^2$, where R_1 and R_2 are the d.c. resistances of primary and secondary windings and σ_0 is the ratio of the turns. C, however, is an equivalent capacity, involving the three capacities of Fig. 5 and also σ, where

$$\sigma=\frac{M}{L_1}$$

The meaning to be attached to the shunt resistance S was, at first, not at all clear. Before the system 9(*b*) was tried, it was expected that the various losses in the system would manifest themselves as an augmented R, and a system such as Fig. 9 (*c*), in which a single resistance R_1 replaced S and R of (b) was at first tried. But the value of R_1 would then need to be variable with frequency, otherwise the value necessary to give the diameter of the circle would be of the order of 20 000 ohms, and the circle would become a spiral starting at 20 000 ohms at frequency=0 and finishing at $R_0=0$ at frequency$=\infty$. When the system (b) was discovered to fit the circle so closely, it became clear that the shunt resistance S must have a physical meaning representing a constant loss in the system for a constant

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* A variety of applications of the circle diagram will be found in Dr. Eccles' "*Continuous Wave Wireless Telegraphy,*" Vol. I., Chaps. iii. and iv

terminal voltage, irrespective of frequency. It is believed by the author that the explanation lies in the nature of the iron losses. The circle has been obtained under the conditions of constant induced voltage of 2 volts on the secondary winding. Now the flux density will therefore be inversely as the frequency, and will in any case be very small. Many measurements made by the author on the total losses in silicon iron at low flux densities and at telephonic frequencies have shown that the main portion of these losses, in the case of sheet material of the usual thicknesses, are eddy current losses. These losses are proportional to n^2 and to $\mathscr{B}^2$. Now, for a constant induced voltage under variable frequency, $n \times \mathscr{B}$ will be constant, and hence the eddy current losses will be constant. The hysteresis losses, however, vary as a power of $\mathscr{B}$ which is greater than 2 at low flux densities (below 100), so that this portion of the losses is not invariable but will increase with diminishing frequency, and it is possible that they appear as an augmented R in the primary winding, or that (together with the small secondary losses) they make up a small total not very variable with frequency or small enough not to be separable from the S term. It must be remembered that in the foregoing analysis R has been tacitly assumed equal to 1000 ohms, *i.e.*, the primary direct current resistance, and then the appropriate S has been determined to make the diameter of the circle come right. If, however, a value of R of 1200 or 1300 ohms had been taken, and the appropriate new S calculated, the new circle would be almost indistinguishable from the old one. The methods under examination cannot therefore separate hysteresis and eddy current losses in the core of the transformer, but they do give an indication of the value of the total losses.

(*To be continued.*)

React... ?

By F. Youle, B.Sc., A.C.G.I.

THERE is a growing tendency amongst wireless men to say "reactance" when they mean "reaction." This, although perhaps permissible to the tyro, is a mistake no one who really knows his subject should make, even through carelessness. The novice, accustomed to hearing the two terms used synonymously, is often puzzled when he comes across "reactance" used in its correct sense.

"Reaction," as we all know, is the return of energy from the output of an amplifier (in the wide sense), to the input, where it can be of use in overcoming resistance and increasing apparent efficiency. "Reactance," on the other hand, is the effect of capacity and inductance in a circuit, owing to which an EMF is necessary for the passage of an alternating current.

The man with electrical experience knows that the total opposition to the current in a circuit, called the Impedance, is given by

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} \text{ Ohms,}$$

where :

R = Resistance in the circuit, in Ohms,
C = Capacity " " " in Farads,
L = Inductance " " " in Henries, and
ω = $2\pi \times$ frequency.

The portion $\left(\omega L - \frac{1}{\omega C}\right)$ is the "Reactance" of the circuit, and is usually denoted by the letter X.

When we tune a circuit, we alter L or C until $X=0$. It is obvious that for any given values of L and C there is only one value of the frequency which will make X equal to zero, so that for all other values X is a factor which reduces the current, since it increases the values of Z. Hence, when we tune to a station, we are really making the reactance of the circuit zero for that particular frequency, while at the same time it offers opposition to currents of any other frequency. As the value of X at radio frequencies is large compared with R, since ω is then large, this means that signals from other stations will not produce currents great enough to give audible sounds unless they happen to be on approximately the same wavelength.

It is not necessary, therefore, to add anything to a set to enable one to use "reactance." It is there already in the tuning circuits, and it is only by making use of the fact that its value depends on the frequency of the current in the circuit that we are able to tune at all.

To say "reactance" for "reaction" is thus almost as absurd as substituting "black" for "white."

British 2SH.

By F. L. Hogg.

In these notes it is proposed to give, instead of the usual station details, a résumé of how the particular set in use at present was built, more especially emphasising the methods which were adopted to gain the various ends, and the process of evolution. Special attention will be paid to the mistakes which were made, and similar points. It is hoped that this may be of practical help to those who are rather at a loss to know how to approach the problem of a set which is not behaving itself. I do not mean to say that the methods adopted are the best—in many cases better ideas followed—but they are merely an account of what was done while the set was in construction. What was required was a set capable of operating on any reasonable wave-length from, say, 220 metres downwards, on powers of from 1 kW. to a few watts, which could be adjusted fairly easily for a wave-length change in a short time, for some transatlantic test working at a very reasonable cost. It had to be of a constancy equal to that of the average American relay station, and yet be instantly available for testing almost in any conceivable direction of experimental work. How far these conditions have been fulfilled will be seen.

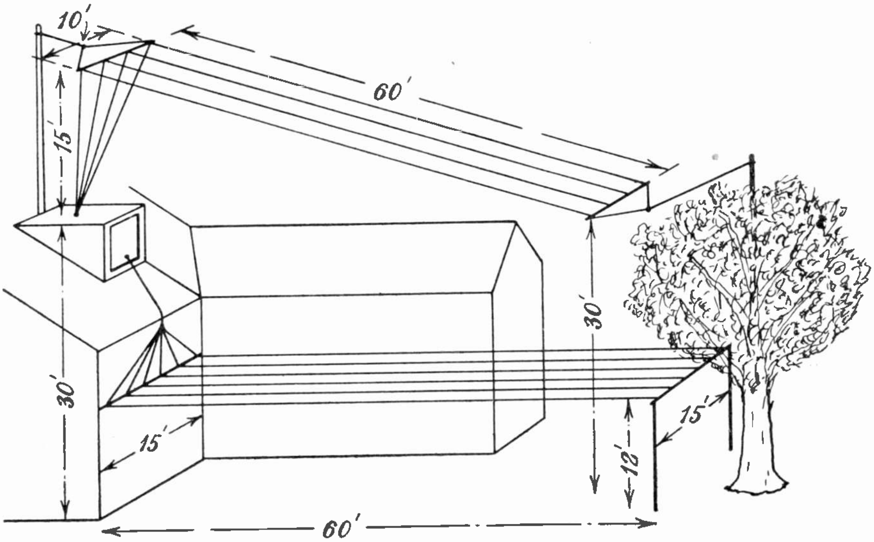


Fig. 1.

Firstly, a description of the aerial system will not be out of place. Unfortunately, this is extremely bad. Fig. 1 shows a sketch of it, giving its main dimensions. At no part of the aerial is it more than 15 ft. from the side of the house or the tree, and the free end is just below the top of the tree. It is impossible to raise either end any further. There is a 20-ft. mast in the tree, but owing to the perversity of the tree the mast only projects five feet above the top, and even then it is none too steady in bad weather. It was also found essential to allow at least five feet sag in the aerial to prevent the wave changing due to the variation in capacity on swinging in the wind. Arranged thus, complaints of wave alteration, even on the shortest waves, have ceased, whereas previously a great deal of trouble had been experienced in this direction. The only redeeming feature is that the station is situated quite near the top of one of the highest points in London. This must account for the extraordinary way in which signals get out. The counterpoise is not at all well fitted up, but limitations of time have prevented this being attended to. It is all right if it doesn't get covered with snow. The lead-in used to consist of a most efficient arrangement. A hole about 4ft. square was cut in the flat roof, and the wire led in through this. When it rained a bath was put underneath—affording great diversion to visitors walking across the room. Owing to ultimatums received from the powers-that-be, a 2-ft. porcelain tube, 2″ diameter, was fitted in, and this has all the advantages in efficiency without the attendant disadvantages of the old method. Large size Buller insulators are used on the aerial and are perfect in wet weather.

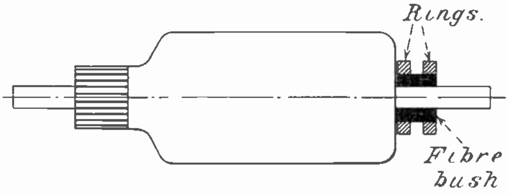


Fig. 2.

To come down to the set proper, the first question was that of H.T. supply Only 240 volts D.C. was available in the house, and it was immediately obvious that the only solution was to use A.C. In considering this, the fact that the set was to be used at night had to be noted, and ultimately it was decided to use a rotary converter of a rather little-used type.

If in any D.C. motor we tap off to two slip rings from two opposite commutator segments, we can take A.C. off these rings on running the motor on D.C. The A.C. voltage is, theoretically, line voltage × ·707, and the frequency, number of pairs of poles on motors × revolutions per second. It will be seen that for a reasonable frequency a high-speed motor must be obtained, and obviously, it must be shunt wound.

After some trouble, a 1 h.p. Siemens 2,700 revolution two-pole motor was obtained and was fitted with rings as follows: At the end of the armature, opposite to the commutator, a fibre sleeve was fixed, about $\frac{1}{4}''$ thick and $\frac{3}{4}''$ long, quite close to the windings, Fig. 2. On this were pinned two rings $\frac{1}{4}''$ square section, hole 1″, $\frac{1}{4}''$ apart. It was then found on replacing the end plate on the motor that the slip rings had taken up room to the extent that the plate had to be spaced $\frac{1}{8}''$ from the frame for clearance. Four $\frac{3}{16}''$ spacing plates were then fitted to the end plate very carefully to give the required extension, Figs. 3 and 4. This made a very satisfactory job of it. The brush holders were fixed in insulating bushes in two adjacent "spokes" of the end plate (see Fig. 5). The brushes are copper-carbon, about $\frac{3}{16}''$ square. The connections to the slip rings were made from two opposite segments of the commutator. Incidentally, it should be noted that while you can get any number of phases A.C. by using the correct number of rings, the number of segments on the commutator must be exactly divisible by the number of rings. The commutator in question had forty segments. The connecting wires were carefully inserted under the binding wires on the armature, and one passed through a hole in the inside ring to the outer, to which it was carefully soldered, the other being soldered direct to the inner ring. Very soon the insulation burnt off where the wire passed through the other tube, so a small micanite tube was fixed instead. Also the brushes, as originally made, were not quite so strong as those shown in the sketch, and because of the heat developed the sweated part melted and broke off. This was rectified as shown. In practice, on loads up to 100 watts the voltage curiously is about 190 volts, falling on very heavy load to 140. Theoretically, it should only be 170 maximum. A quite comfortable load is 600-700 watts at 160 volts, and up to 1 kW. can be obtained without making the machine labour. Above 1 kW., though, things begin to happen. It is a very good plan to keep the commutator clean—it makes a big difference to the H.T. voltage. For some time this machine was used during the night just resting on two cushions in the operating room, but now, due to a little wear, etc., it has had to be removed to the cellar owing to complaints! The frequency given by this machine in practice is about 55. This is a most excellent method

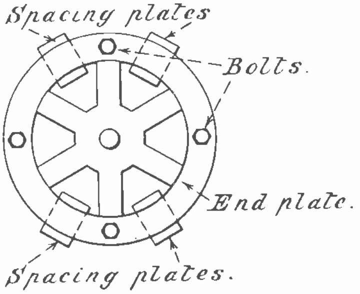


Fig. 3.

Fig. 4.

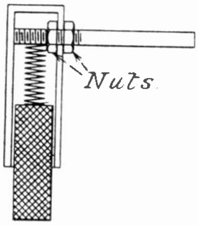


Fig. 5.

for getting a supply of power, for it costs a ridiculously small amount compared with a similar capacity D.C. generator. A small fan motor will comfortably give 50 watts if well made. The next thing to be decided was the valve, and it was obvious that at least one rated at 250 was necessary. Also the question of life had to be considered for obvious reasons. Finally, a Mullard O.250.C was decided upon. The filament consumption is quite high for the emission, and also it has the enormous advantage of being refilamentable for a small portion of the original cost. It takes 12·5 volts 5·5 amps., and has already been in hard use for about six months. It is rated at 2000 volts, but this goes not mean, of course, that that is the required voltage for full output. It was considered that about 3500-4000 volts would be necessary, and the transformer was procured for this purpose. After a lot of trouble an old 90-cycle 2-kW. lighting transformer of the box type was obtained, and was subsequently rewound. The primary was carefully designed and made up to suit—by whom is a question over which there has been some argument, for it was discovered three months later that it was just two and a half times the right size! A secondary was designed and wound by a professional to give 4000 volts, in four sections. The first time the key was pressed the troubles began there. It had broken down from the bottom layer to the core. It did not occur to me that I had earthed the outside (no rectifier was being used). However, after some time the three bottom layers were removed. The set was started up without any rectification to begin with. A filament transformer was made from an old Foster 60-cycle 220-110 volt auto-transformer by removing a few turns to make it suit the line voltage of 160 volts or so, and winding on a secondary of enamelled 7/22 wire to give 15 volts, to allow for any loss of voltage on mains. This was rigged up at first using the inductance shown in the Colpitts (Fig. 6) circuit for a start, and using full transformer and no rectification: about 200 watts input only was obtained. The water bottle grid leak and anode tap were carefully adjusted for maximum output, and it was found that the coil, which had seventeen turns spaced 1 cm.

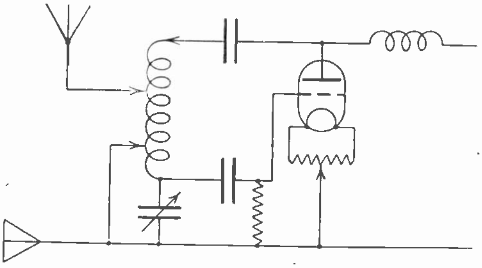


Fig. 7.

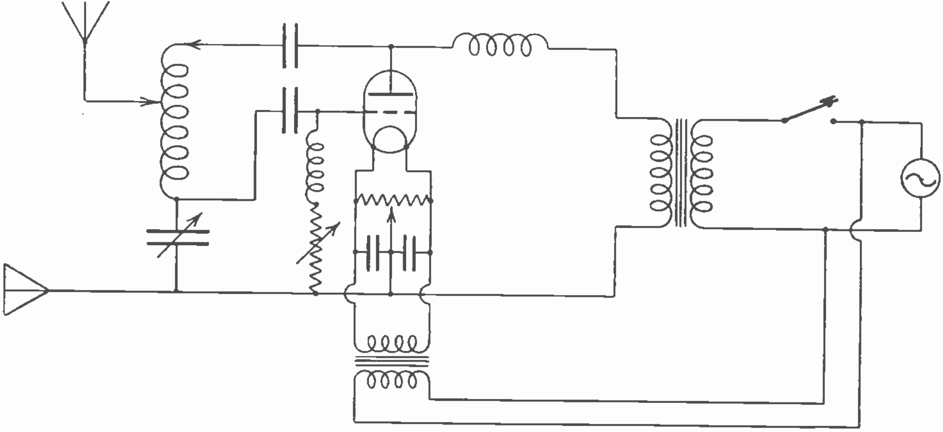


Fig. 6.

on a 45 cm. diameter was not large enough, because the best position was when all the coil was in. Adding a couple of turns made a large difference. The series condenser was a ·0005 set of parts in paraffin, which actually has lower losses than anything else I have succeeded in getting for the voltage !

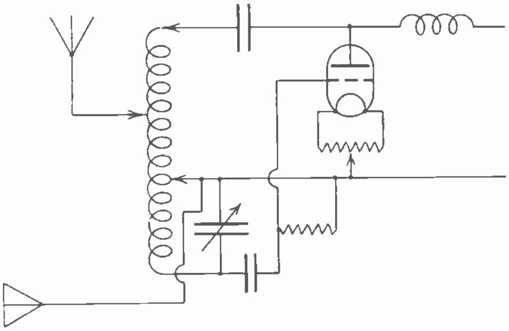


Fig. 8.

The next thing was to try other circuits. The reversed feed-back was tried, but for some reason or other we struck an unlucky patch, for it refused to oscillate on any wave below about 120, and the less aerial coil one used the higher went the wave. This is a phenomenon that happens sometimes, and the best thing to do is to try something else ! So we tried what U1CMK called a modified Colpitts circuit, which gave fine results (Fig. 7). This had been tried on low power before, with a resulting higher input over the normal, so the natural conclusion was that it might help here. The modification consists in taking another connection from the coil between grid and aerial to the counterpoise. It was not noticed for some time that this is really only a Hartley oscillator (Fig. 8) with a tuned grid circuit when it is drawn straightforwardly, and not made to look like a freak arrangement. However, expectations were fulfilled, and the radiation was greatly increased and the input rose to about 300 watts. It was found found that a grid leak was sensitive on radiation to a movement of $\frac{1}{8}''$ either way, and an inch either way would often drop the current one amp. This shows the importance of a finely variable leak. The aerial currents could only be guessed at, as a reliable meter could not be obtained at a reasonable price. The system was to use an old Marconi 0-7 amp. shunted hot wire meter, and add another shunt every time it went off the scale. Now 60 cycles unrectified A.C. is the next worst thing to 25 cycles to read, so a rectifier was started on.

Large numbers of 1-lb. jam jars and a few pounds of lead, aluminium and sodium phosphate were obtained. A bridge rectifier was built with 30 cells in each arm (Fig. 9). The aluminiums were 5″ × 1″ × 20 gauge, and the leads 6″ × 1″ × 18 gauge. These were bolted together at the top with iron bolts. The aluminiums were well cleaned with caustic soda and nitric acid, and fixed up in a semi-saturated solution of pure sodium phosphate. Each cell was formed by placing 240 volts D.C. in series with a radiator lamp across it in the wrong direction. This forms the cells very rapidly. We found with 120 volts on a cell it would pass only about 25 milliamps. reverse current, and this was thought to be all right. It thought differently, for the first time we tried it all the fuses came out. After a bit, by using 1800 volts from the transformer, instead of 3800, we got nearly the same output as before, with a vastly better note. However, the rectifier was really no good, for it took a colossal load even on 60 volts per cell—anything above this brought the fuses out. It was obvious something had to be done about it, so many days were spent forming and reforming the 120 cells without success. The circuit was altered from the bridge to the voltage-raising circuit (Fig. 10), using two 1-μF condensers with improved results. Here 60 cells altogether were used, but it wouldn't take full voltage, even with 120 cells. The only result was that the aerial current went down, and the load up on increasing voltage. Soon commercial ammonium phosphate was tried, and turned out far worse—having got rid of about ten gallons of the old stuff—and ultimately we got pure phosphate with improved results for a couple of days. Just here came the eventful night of December 8. I had had to test for a couple of hours to get things going

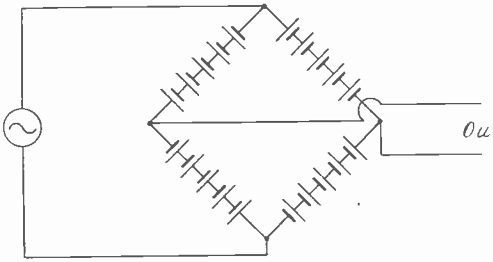


Fig. 9.

after some changes, mostly on artificial aerial circuit, and when 8AB told 1MO to stand by for 2KF and 2SH, all was bliss and joy—for about ten seconds. Then it all blew up. The rectifier took such a load—about 12 kw., I think—that one of the brushes got completely unsweated and fell off. Just so as not to be unsociable, the transformer blew up again, as it did every few days. That was just about the last straw. It took about four days to get the rectifier to work again, as every one of the 60 cells had to be gone over about umpteen times. The brushes were also reconstructed, as mentioned above. It was by now certain that the trouble was not, as was thought, due to the solution but to the aluminium, so, although what had been in use was bought as the best obtainable commercially, another maker was tried. For all this, results were just as bad as before, so Messrs. Mullard were appealed to and they kindly lent two U250 rectifiers for the job. Incidentally I have recently found that Messrs. Griffin, the chemical suppliers, sell pure aluminium, which is far better than what we used, and at a very reasonable price. Having two perfectly good valves, the next thing was a filament transformer. It was decided to make one, while about it, to stand about 10 000 volts between each of the two secondaries and the primary, so that the voltage doubling circuit could be used if desired.

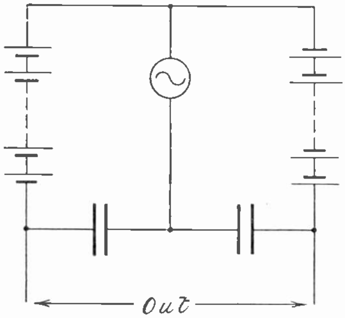
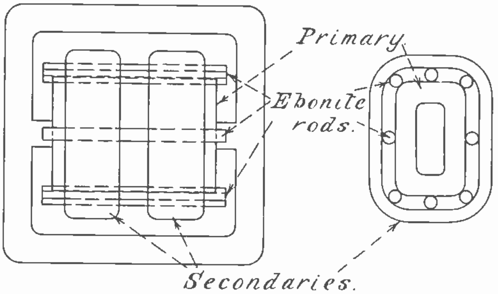


Fig. 10.

This was the method adopted: An old G.E.C. 220-volt transformer, 300 watts capacity, was picked up. The turns were counted and reduced to the required number, found by multiplying original number by $\frac{160}{220}$, and the secondaries wound side by side over this, spaced from the primary by eight $\frac{1}{8}''$ ebonite rods at the corners and middles of the sides. This is shown in Figs. 11 and 12. The secondaries had to supply 10 v. 3·5 a., but because of the spacing between primary and secondaries they are designed for 16 volts, which is just enough. There have been many attempts to blow this up, but all have been unsuccessful. It was clamped up with ever-useful Meccano strips instead of the usual shell, for safety's sake. It can be seen between the rectifying valves. These were mounted roughly close at hand and put on instead of the chemical rectifier with exactly the same voltages, etc. (Fig. 13). The radiation went up a little, which was a good sign. It was found using this doubling circuit that it was essential to adjust the filaments to a very fine degree. The usual split transformer circuit was tried, but results were absolutely no use, as the two halves of the transformer were unequal. It was also found that the wave was extremely sharp owing to the smoothing the condensers provided, so this circuit was kept in use despite warnings that surges would be troublesome. Now the transformer voltage was increased—for a few minutes only. The radiation went off the map, but so did the transformer. However, this was put right soon; and then the condensers began. It was found disastrous in many ways to have large slabs of condenser flying around the room, accompanied by a colossal noise in the middle of the night, so four were placed in series instead of two. Well now, the input, despite the greatly reduced primary turns, could on occasions reach 400 watts or so, and 350 or so could be got always when required. However, the good work was carried on by reducing the primary turns. Result—more condensers and turns off the secondary till we arrived just where we started! It was highly amusing—for everyone but the owner—when every time a condenser blew a surge was produced which



Figs. 11 and 12.

made a large flash inside the vacuum of the oscillating valve between one of the plate supports and the filament spring. It at any rate showed that the insulation was excellent elsewhere, as about 15 000 volts are necessary to do this! Thus things went on until one of the rectifier filaments went—due to overrunning it, as no maker will put an A.C. filament voltmeter on the market at a

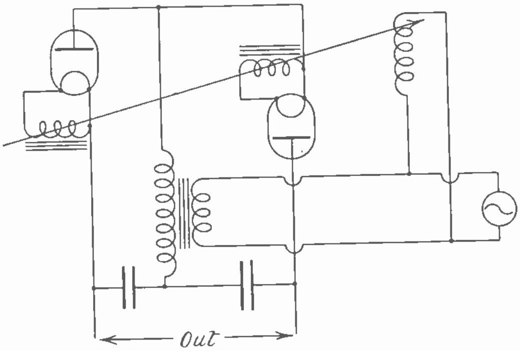


Fig. 13.

reasonable price. Then the set was worked again unrectified. The result was not so much a lost radiation but a terrible note to read through any interference, and all Americans came back "QSA BT QRM QRN," so one-third of the radiation was lost by putting in a single-valve rectifier and a bit of a choke and $\frac{1}{4}$ mfd. across the line—in the correct way so as not to build a filter. However, this improved results to an extraordinary degree. Here the transformer finally turned over and died, so an old Marconi pack set spark transformer, 75 volts 175 cycles 500 watts, was re-wound on the primary and put in for want of anything better. Apart from taking a no-load current of about 3-4 amps. this works very well if more than 100 watts is not wanted! What is in use at present is this transformer with the two rectifier valves paralleled. This gives a radiation of quite reasonable value with a passable note. This completed the H.T. episodes! The voltage obtained on a load of 120 milliamps. or so was just about the transformer voltage. That is, the doubling device had made up for all losses in the rectifier. The H.T. maximum obtained for any time worth considering was 3200 volts, and it became obvious that a 6000-volt transformer would be necessary to get full output. This will be done when a little time is available!

During this time many circuits, freak and otherwise, were tried. Always, however, best output was obtained on the tuned-grid Hartley. It was found, as others have discovered, that at a point of maximum radiation the set is liable to flop over on to another wave-length. This was found to be due to the fact that almost invariably best results are obtained on this circuit when the grid circuit is tuned to the second harmonic of the aerial circuit. Incidentally this circuit puts out a large harmonic anyway if care is not taken. By adjusting taps very carefully this can be avoided and the flopping-over reduced to a great extent. This circuit is by no means easy to adjust, and so a few details will be given. Suppose you have a coil which, using Colpitts, requires for a given wave plate and grid to opposite extremities and aerial at the mid point between the two. Now take the wire from the earth and tap this on a turn about one-third of the way between grid and aerial. Then tune the condenser and note results. If the radiation is best on minimum condenser, decrease turns between grid and earth, and so on. Then, supposing you are aiming at 200 metres, you, having got things fairly tuned up, find you are on about 101 or 370 metres. The next thing is to start again with less aerial turns, and so on. One can amuse oneself for hours this way until one gets used to the set. Having discovered an efficient point, try altering the grid-leak—it helps a lot and probably will alter all the tappings you have laboriously found. However, having found

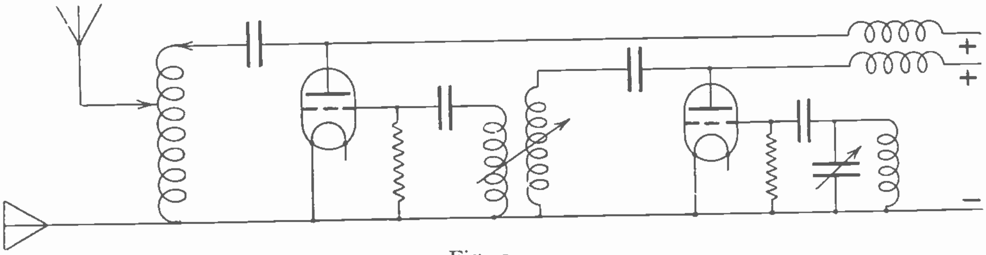


Fig. 14.

good results, make a careful note of the settings for future reference.

Best results as regards output on a given voltage were obtained from the master oscillator, but unfortunately the H.T. troubles stopped much in this way for permanent use (Fig. 14).

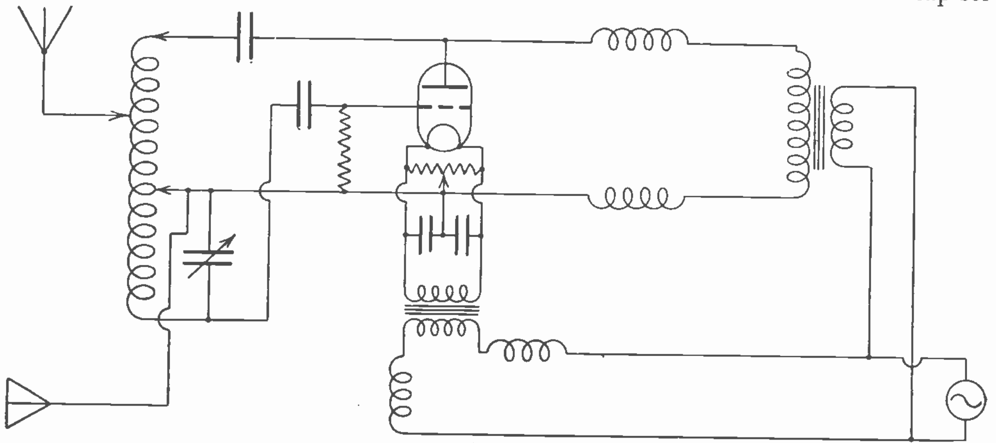


Fig. 15.

During this time, of course, it had become necessary to drop to 100 metres, and here further fun began. The taps on the tuned-grid Hartley were carefully lowered by slow degrees from 180 to 135 metres. All was beautiful, radiation exactly what was expected, but—just a touch more and nothing would happen, in comparison. On 134 metres the radiation dropped to about one-fifth of the previous value. Colpitts was then appealed to. Results were exactly the same. It soon became obvious that absorption somewhere was the trouble. After nearly every imaginable absorbing body had been searched for, a radio-frequency choke was placed in the negative H.T. lead. The result was that it would now go down to about 132 metres, which indicated that we were on the right lines. The brain-wave was then conceived of trying chokes in all power leads, so two were placed in the filament transformer leads. The result was that immediately we got down to 100 metres easily. (Fig. 15). It was found no joke using the tuned-grid Hartley on that wave (of course a series aerial condenser was used below 160 metres), so Colpitts was tried. Results here were good up to a point, but it was not very good below 120 metres, so a little dodge was tried. The difficulty was mainly that altering the aerial turns did not alter the wave-length as it should. The connection from the condenser to the grid was removed and made variable on the coil. This gave better working at once. Then a series aerial condenser was tried (another ·0005 set of parts, now immersed in paraffin). This helped further and it was found that the two condensers and the aerial tap served more as fine adjustments for wave-length and governed radiation while the condenser tap altered the wave-length. After a lot of juggling about the expected results were obtained and this circuit is still used. (Fig. 16.) Now next time we went up to 200 metres the set was all over the place. The r.f. chokes spoilt everything. On the low wave the trouble was that the capacity between the windings of the transformers was serving as a series condenser in between the counterpoise and the earthed mains forming a tuned earth very much out of tune.

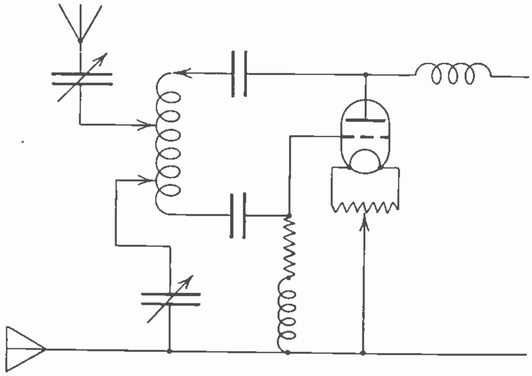


Fig. 16.

Still, this did not explain the extraordinary results, and many hours were spent trying to tune the mains; but they wouldn't be tuned anyhow. Many days after it was discovered that an old buried earth—or rather three—had been connected to the mains through a 2-mfd. condenser under the table. This of course explained the extraordinary effects. All these five earths happened to more or less "fit" round 200 metres, one compensating for the other, but on the lower waves this was not so. This has been shown to be true, but due to the usual reason it has been impossible to rig up a proper arrangement as yet, for this is sure to improve results. Beyond these points there was no difficulty in getting down quite low—even to 90 metres. The anode tap is most critical, however, and must be carefully watched, for one turn too few will sometimes stop the set oscillating. The troubles of about 90 per cent. of amateurs in getting down very low are due to some effect in supply wires and I can thoroughly recommend attention to this point. This about completes all the adventures with the transmitter.

The receiver uses the ordinary tuned anode circuit with ORA valves normally, but on 100 metres a C300 soft detector (which survived a journey by post from California) is used. This valve gives marvellous signal strength, but it is useless on 200 metres if there is any QRM at all, owing to the damping produced by grid current. Signals on 200 metres are half the strength and ten times in number from the States on an ORA! If the soft detector gets better distant signals they are always jammed out, and if a sufficiently more selective set, to make up for the loss in selectivity, is used the advantage in distance is lost. A super-heterodene is available, but has not been used greatly for several reasons. It gives marvellous results on many signals: the Tate sugar box under the receiver is the motor starter. A 50-ohm resistance with tappings is hung across inside. All other parts need no comment. As is obvious no trouble has been spent on appearance—all the available time has been taken up in making things work.

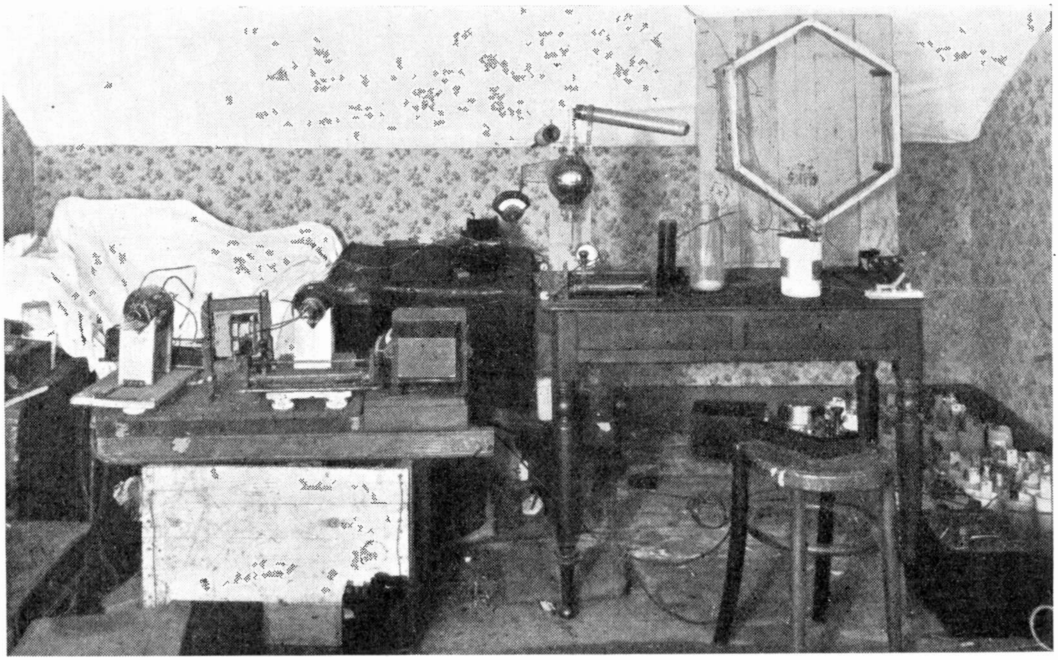


Fig. 17.

As to results, the first report of signals from the States was received only fairly recently, referring to September 21 last when a temporary set using 500-cycle I.C.W. was in use for a couple of days putting out only 1·5 amps. on 185 metres. This was heard by 8OX, and reported by card to American 2SH, who after some time replied that he had no set. Suddenly 8OX realised who it was, and the report has now been confirmed properly. This seems the first occasion on which any British station has got across using a power which was really less than 1 kW. The next report was from 2BL on November 25, at about 0030 GMT. Next came the best ever—one from 5XD, New Mexico, 500 miles from the Pacific coast, who heard signals for several minutes and read what was sent, on December 1. Since this little has been done on 200 metres. In the organised tests only six 10-minute schedules were transmitted. One of these was heard in Georgia. Interference from GKB has now stopped any serious 200-metre work, as he rarely closes down now except for a few minutes during the night. The radiation in these cases was 3·5 amps. on 100 watts input. This was only measured a few weeks ago by a borrowed meter, but results had been noted as readings on the meter used. This applies also to the following readings. On 100 metres 1XW was worked on December 12 with about 75 watts and ·65 amp. in the aerial! This was heard by 9CD of Chicago and probably even further inland. The small current was of course due to the troubles already mentioned above. Since then, radiation gradually improving, a number of stations have been worked. 2AGB was worked a very large number of nights, and almost invariably received without aerial or earth. At the times at which really high power has been used, the strength was reported to be greater than that of 8AB; but, not so much because of the H.T. troubles, but because the P.O. graciously permitted a lengthy transmission on over 100 watts for 15 minutes per night, it was not felt to be worth while to use high power to any extent. No useful results of the kind which are being worked for can be obtained with such a ridiculously short time limit, it being far better to keep things constant at 100 watts. Finally, almost 2 amps. were obtained on 100 watts and 3·5 to 4 on maximum power (that is maximum in use for any time. Sometimes 700-800 watts were obtained until that loud noise you heard happened!) The efficiency is not

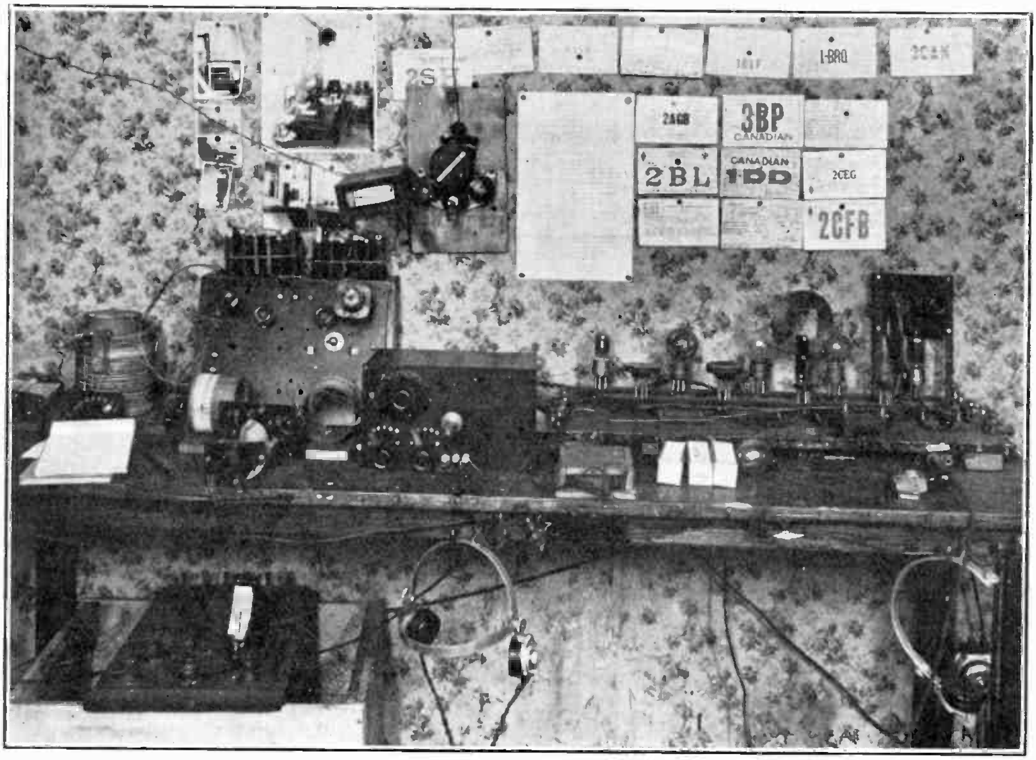


Fig. 18.

nearly so high as it should be, but the work has had to be done in very short periods and work can only be done on very few days per week, so the set could be greatly improved in detail. Altogether 16 stations have been worked, including 4BZ of Atlanta (on 1·2 amps.), the best distance, and 9AZX of Indiana, half an hour after daylight here. Now considering this carefully, we have a terrible aerial system and a medium power set and yet the results are astounding. It all goes to demonstrate how little is really known about 200 and 100-metre working. No credit can be claimed for results at all, and considering the time of operation which has been only about a quarter of that of many others, results would not be bad for a real 1 kW. on an aerial worth the name. The only thing seems to be the undoubtedly favourable situation of the station. Anyhow, the whole thing seems rather contradictory; for on 100 watts, say, signals are the same on the coast or inland and on higher powers the strength is only greater at the coast. Which all goes to show what has already been said, that the sooner we learn something about 200 and 100 metres the better!

I hope these notes will help some of those who have written to me as regards the methods to be adopted to get things going. It is, of course, a matter of opinion always, and this merely gives things as they appealed to me, whereas they will appeal to others in different ways. But when one has not had sufficient experience to have formulated opinions it is extremely bewildering. If these notes stop a few writing and asking "why won't it work," by helping them to see their difficulties, it is quite sufficient.

I should like to acknowledge my indebtedness to Mr. Robinson, 2VW, well known to EXPERIMENTAL WIRELESS readers, for his most valuable help—for many pleasant (?) hours spent over rectifiers and the like!

Amateur Wireless in Australia.

It is thought that a few notes on experimental activities in this part of the world may be of interest to British experimenters, particularly in view of the excellent DX work that is now being achieved.

From the earliest days of wireless telephony there has been a limited number of experimenters in Australia, but only during the last three or four years has this science achieved any measure of success. In particular, the advent of the valve, together with the issue of experimental transmitting and receiving licences, has done much to stimulate amateur activities. Shortly after the conclusion of the war the issue of receiving licences recommenced; one or two amateur transmitters were also allowed to operate on low power under special licence. However, it is only during the last two years that amateur transmission has been allowed on any considerable scale.

Under the present regulations, experimental licences (as distinct from those for broadcasting) are granted either for transmission and reception, or for reception only, the fee being £1 for the former, and 10s. for the latter, payable annually. Applicants have to state the nature of the experiments it is proposed to conduct, produce evidence of satisfactory technical qualifications and, if necessary, must submit to a technical examination in writing; they must also pass an examination in Morse transmission and reception at 12 words per minute.

Transmitting licences are not easy to obtain; they are granted only after careful investigation by the Government officials, and definite experimental work of value to the science must be undertaken. Within five miles of a commercial or defence station, no spark transmission is allowed, and the input of valve transmitters must not exceed 10 watts. Up to 50 miles from commercial stations, any system of transmission is allowed on power not exceeding 25 watts, and at greater distances 250 watts is permitted. Each experimental transmitter is allotted a definite wave-length, in the band ranging from 100 to 250 metres, and may not deviate from this wave without special permission. There are about 300 licensed amateur transmitters in Australia at the present time, and a considerable number in New Zealand.

Conditions for reception and transmission in Australia and New Zealand are, generally speaking, very good—better, it is thought, than around the British Isles, though in the summer atmospherics are much stronger and more prevalent than in England. In fact, X's often becomes so severe that ship and shore traffic is paralysed for hours at a time; but, as usual, less trouble is experienced on the shorter amateur waves.

Reception in New Zealand is remarkably good, equalling if not excelling that in any other part of the world. The leading New Zealand amateurs, with comparatively straightforward receivers, have repeatedly copied signals from every American amateur district in a single night, although the distance involved may be anything from 6000 to 9000 miles; American amateurs have been frequently copied on a single valve. One New Zealand experimenter claims a world's record for broadcast reception on one valve, having heard and verified a transmission from WHAZ at Troy, New York. The distance is some 9,000 miles.

In general, circuits and apparatus used follow British practice in reception, and lean rather towards American methods in transmission. The majority of the more successful receiving stations employ one or two stages of H.F. amplification, using either tuned transformer or tuned anode coupling, and English valves are very generally used. It is noticeable that H.F. transformers for amateur waves are usually wound with much heavier wire than is commonly used in England, 22 gauge wire on a three or four inch former being common. Tuned anode receivers are frequently stabilised by the introduction of a variable high resistance in series with the plate circuit, or a lower variable resistance in series in the rejector circuit itself. Australian practice differs from British in one notable respect, much greater use being made of the soft and semi-soft valves as rectifiers; and much of the unusual reception must be attributed to this. Valve receivers capable of oscillating the aerial are not permitted.

The long distance single valve receptions previously referred to were all accomplished with soft valves. It has often surprised the writer that British valve manufacturers do not pay attention to this type of valve, for good specimens would have a great sale among experimenters once their remarkable capabilities became known. Undoubtedly the very critical adjustments of filament and plate voltage necessary for good results deter many people, but such difficulties can easily be surmounted. The American Audiotron, a tubular valve no longer manufactured, was probably the most sensitive valve ever commercially produced, and a few Australian experimenters still have carefully preserved specimens, which are highly prized, as much as £5 being offered for one. It is understood that the reception of WHAZ previously mentioned was accomplished with one of these valves. One soft valve of fair quality is manufactured in Sydney, and is used extensively in commercial service; the semi-soft American, UV200, is also much used by amateurs.

In transmission, the American 5- and 50-watt Radiotrons are used more extensively than any others, and the 5-watters in particular have accomplished some remarkable D.X. work. Using only one of these valves, experimenters carry on excellent two-way communication between the capital cities of Australia, on both c.w. and voice, though the distance is never less than 500, and often in the neighbourhood of 1,000 miles. Reliable communication is also obtained on similar power between Australia and New Zealand, the distance varying from 1,200 to 2,000 miles, and complete musical programmes have often been successfully received under these conditions. Good communication has actually been established between Australian 2CM and New Zealand 4AA on an input power of ·0037 watt. The input was checked and certified by independent witnesses, and on this power complete messages were received in New Zealand, a distance of over 1,200 miles. It will be seen that the Australian transmitting amateur has little to learn from other countries in point of efficiency; it should be noted, however, that no restriction is laid upon the dimensions of our aerials.

Tuned counterpoise is almost universally used in conjunction with the usual earth, and the reversed feed-back circuit is very popular. Filament supply is usually A.C. and plate supply rectified A.C. or, less often, high-voltage D.C. Constant-current (choke-control) modulation is usual, but much excellent work has been done on grid modulation; many have also had great success with absorption modulation, obtained by connecting a microphone in series with a loop of one or two turns, and placing the loop in inductive relation with the A.T.I.

A unique experiment has just been carried to a successful conclusion and has provided data of great value to Australasian experimenters. Mr. Maclurean, of Sydney, who operates 2CM, obtained permission to instal a duplicate of his transmitter and receiver on a trans-Pacific liner, and make the voyage to America, in order to ascertain how far it was possible to maintain communication on amateur wave-lengths and power; and incidently to discover why American amateurs are unable to receive Australia, while Australians log innumerable American stations.

With 8 watts input at the Australian end, messages were copied up to a distance of 5,380 miles—two days' voyage from San Francisco. On the same set, using 4 valves, music was received clearly at 4,300 miles on a loud speaker—not bad for 8 watts input! Closer to America, indescribable QRM from American amateurs rendered consistent reception from Australia impossible; nevertheless, messages were copied from a 100-watt transmitter in Sydney at a distance of 5,900 miles, and calls from both the 8-watt and 100-watt sets were actually heard at good strength whilst lying in 'Frisco, over 6,000 miles away. Code messages could not be deciphered through the local jamming.

The 10-watt transmitter on the liner was unfortunately put out of action early in the voyage, so that two-way communication at extreme ranges was impossible. KGO was heard strongly on a loud speaker at 5,600 miles, being audible all over the ship's afterdeck. KGO is, of course, the American broadcast station at Oakland, California.

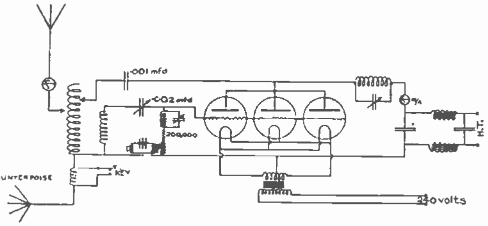


Fig. 1.

The receiver employed was a four-valve set, employing 1 stage tuned anode and 2 stages L.F. amplification, and a three-coil tuner. The H.F. valve was a Marconi QX, the other three being American 201A Radiotrons, which closely resemble the B.T.H. B4 type. No grid-leak was used on the rectifier. Fig. 1 is the circuit diagram of the 8-watt set which was used at the Australian end (I am endebted to "Radio," for this). It will be seen that a counterpoise only was used. The aerial was a 100 ft. T-type on an 80 ft. mast; a 6-wire 4 ft. cage construction being used. The transmitter was supplied with 7-8 watts of rectified and smoothed A.C. and gave an aerial current of 1·8 amps. at 235 metres. For music, speech and I.C.W. grid modulation was used.

[NOTE.—There seems something doubtful here. Even assuming an efficiency as high as 83 per cent. for the transmitter, only 6·5 watts are available for output. With 1·8 amps. this gives 2 ohms as total effective aerial resistance, which seems to us extraordinarily low. In view of the ranges covered, we are inclined to believe that the input quoted (7·8 watts) is under-estimated.—ED. E.W. & W.E.]

In conclusion, it may be mentioned that the regulations under which experimenters have hitherto worked are now being entirely recast, and if, as is hoped, greater latitude is given in the matter of power and wavelength, and the American amateurs can learn to handle H.F. amplification properly and to control their local QRM, two-way working between Australia and America can confidently be expected in the near future; direct communication with England also seems quite possible under favourable conditions. May it be soon!

Further Notes on Resistance-capacity Amplification.

By F. M. Colebrook.

Giving details as to the design of such amplifiers for L.F. work, for which they are becoming increasingly popular.

THE resistance-capacity type of inter-valve coupling appears to be gaining steadily in popularity, both for high frequency and low frequency amplification. Its characteristics have been the subject of a considerable amount of research work during the last few years and the following references may be of interest.

In an article by the present writer, published in EXPERIMENTAL WIRELESS in March, 1924, it was shown that the howling effect frequently experienced with resistance-capacity coupled amplifiers is probably due, not to a genuine low frequency oscillation, but to the periodic starting and stopping of radio frequency oscillations in the input circuit. It was further shown that this troublesome tendency could be eliminated with very slight loss of efficiency in operation by the use of grid leaks of lower resistance than had hitherto been customary, about ¼ megohm being a suitable magnitude in most practical cases.

A very complete analysis of the inherent reactive effects and the stability conditions of radio-frequency resistance amplifiers was given in two articles by M. Léon Brillouin published in *L'Onde Electrique* in January and February, 1922. It is there shown that the phase relationships of the various potential changes occurring in different parts of the amplifier are the vital factor in determining the stability or instability of the input circuit—amplifier combination. The limitations of amplifiers of this type for short wave-lengths were considered by the same writer in association with M. Beauvais in an article published in *L'Onde Electrique* in May, 1923. It was shown in this paper that by the careful constructional minimisation of accidental capacities and the use of valves of low inter-electrode capacity, the useful range of a resistance amplifier could be extended very considerably in the short wave direction, even down to wave-lengths of only a few hundred metres.

Recently a certain amount of attention has been paid to the question of low frequency amplification by means of resistance coupling. It is generally agreed that a purer reproduction can be obtained by this method than by any of the available alternatives.

On the occasion of the opening of the British Empire Exhibition at Wembley, the writer was able to make an interesting direct comparison between the results obtained by resistance-capacity and low frequency transformer amplification. At either end of a fairly large hall two receiving sets were working simultaneously, operating two loud-speakers of the same make. The distance from 2LO was about twelve miles, and each set was connected to its own aerial. One of the sets was a straightforward arrangement of detector valve and two low frequency transformers, the transformers used being of very high quality judged by present standards. The other set consisted of a crystal detector and a three stage resistance-capacity coupled amplifier, the circuit being as shown in Fig. 1.

The difference between the two reproductions was very marked indeed. The transformer set gave very much greater intensity, but the quality was poor. It is no exaggeration to say that the following of the speeches called for considerable concentration on the part of the listeners. The resistance set, on the other hand, gave very clear articulation and a reproduction that was easily intelligible.

Simplicity of operation and purity of reproduction are very desirable features in any arrangement intended for the reception of telephony. The circuit shown in Fig. 1 possesses both these characteristics, and it may therefore be of interest to consider in fuller detail some of its special features.

The input circuit is worthy of note. It will be seen that the aerial is tuned by means of a series condenser and an inductance, the crystal detector being in shunt to a part only of this inductance. A simple experimental account of this point was given by the writer in an article in the *Wireless World* on April 30th.

A perikon detector was used, since, as shown elsewhere by the writer[1] this is superior to galena for use in connection with valves or with circuits of very high impedance.

It will be noticed that the low frequency impulses in the crystal circuit are stepped-up on to the input of the amplifier by means of a low frequency transformer. This may appear to be wasting the distortionless character of the amplifier by introducing distortion right at the outset. Such is not the case, however. It is well known[2] that the principal cause of the distortion produced by a low frequency transformer is the variation with frequency of the ratio of the primary impedance of the transformer to the internal resistance of the valve in the anode circuit of which it is used, the greatest magnitude of this ratio being, in most practical cases, in the region where its variation is most likely to be harmful. The conditions under which the transformer is used in the present circuit are quite different from this. The impedance of the transformer winding is so much higher than the resistance of the crystal that the case approximates to that of pure potential rectification and this type of rectification is practically free from distortion.[1]

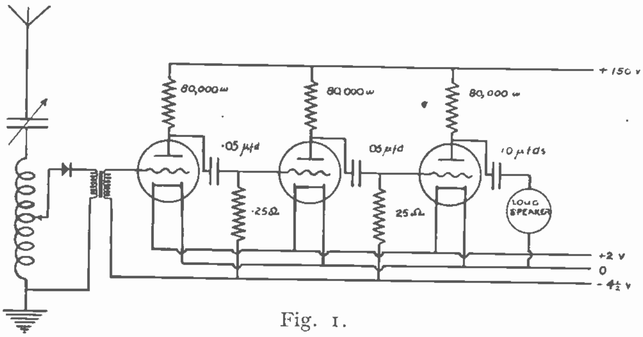


Fig. 1.

The only distortion likely to be produced by the transformer in the circuit illustrated is that due to the variation of its transformation ratio with frequency, which variation is, in general, too small to cause any noticeable effect. It is here assumed that there is no appreciable load on the secondary of the transformer. This condition is essential,[3] and is easily ensured by applying to the grid of the valve a negative potential of such magnitude that the oscillating signal potential will not at any time make the resultant grid potential positive, the anode potential being of a suitable value to correspond to this applied mean grid potential. With the D.E.R. valves used it was found that a total high-tension of 150 volts with a negative grid potential of 4½ volts appeared to be quite satisfactory. It should be pointed out that the transformer is not essential to the circuit. Under suitable conditions of distance, aerial resistance, etc., quite sufficient intensity can be obtained without it, the detector being connected directly to the grid as shown in Fig. 2. The writer made these two arrangements interchangeable by means of switches, and found that the transformer gave a marked increase in intensity without apparent detriment to the quality.

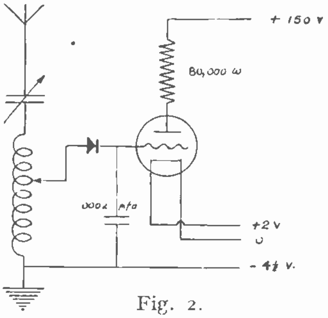


Fig. 2.

The method of connecting the loud-speaker to the last valve should be noted (see Fig. 1). It has two advantages. In the first place, it avoids what would otherwise be the necessity for a separate high-tension tapping for the last valve, allowing for the difference between the d.c. resistance of the loud-speaker windings and that of the anode resistances in the preceding valves. The second advantage is that in the arrangement shown the continuous anode current does not flow through the loud-speaker.

In any type of resistance-capacity coupled amplifier the suitability of the anode resistances used is a very important factor. Of the various types at present on the market, some, no doubt, may be quite satisfactory. The writer, however, has not been altogether fortunate in his experiences with such products. In spite of every care with contacts he found it impossible to eliminate entirely a certain crackling or rushing noise in the telephones. The anode resistances then being used were therefore examined by being inserted in a Wheatstone bridge circuit with a very sensitive galvanometer. It was found that, even when the potential differences across the resistances were considerably less than those which would occur in practice, the galvanometer indicated not only a steady decrease in resistance, but also slight spasmodic variations in resistance such as might arise from contacts of a microphonic character. It seemed probable that this might be the cause of the extraneous noises heard in the telephones. It was decided, therefore, to substitute resistances made with high resistance wire. When this change was made the stray noises disappeared and the amplifier was absolutely silent in operation.

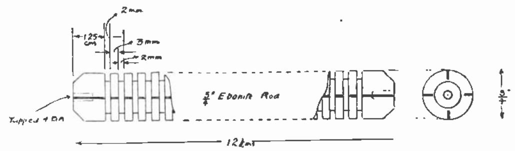


Fig. 3.

For the special experimental purposes to which the amplifier was originally applied it was necessary that the resistances should be non-inductive. For general purposes this may not be quite so essential, though in most cases it will be desirable, in order that the resistance shall not vary appreciably with frequency. Further, for high frequency amplification it is essential, and for low frequency amplification desirable, that the self capacity of the resistances shall be as low as possible. Judging by the results obtained the type of construction now to be described fulfils both these requirements in a satisfactory manner.

The former on which the resistance wire is wound is as shown in Fig. 3. It consists of a length of ¾in. diam. ebonite rod cut with 20 equal and equidistant grooves. This, of course, can be done quite easily on a lathe. In addition, there are four narrow longitudinal slots, equally spaced round the diameter and cut to the same depth as the grooves. These were put in with a milling cutter, but they could be made with a fine hack-saw without much difficulty. Finally, the ends are chamfered and the centre of each end drilled and tapped with a 4 B.A. hole.

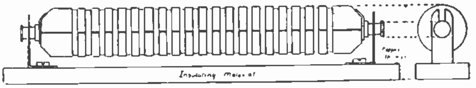


Fig. 4.

The wire used is 47 S.W.G. double silk covered Eureka. The method of winding is as follows: the former is mounted in a lathe between a chuck and a back centre, and 50 turns are wound into the first groove, the end of the wire being left projecting for connection. The wire is then led through one of the longitudinal slots into the next groove and 50 more turns wound on in the same direction. It is again led back through another slot into the first groove and 50 turns wound in the reverse direction, then back into the second groove for 50 more turns, also in the reverse direction. The process is continued until 300 turns have been wound into each of the first two grooves. The wire is then led through a slot into the third groove, and this and the fourth are filled in precisely the same manner. The process is continued until the whole of the grooves have been filled with 300 turns each, there being in each groove 150 turns in either direction. Finally, the ends of the wire are soldered on to small copper tags held in position by 4 B.A. terminals screwed into the ends of the former, as shown in Fig. 4 (which also illustrates a convenient method of mounting the finished resistances).

The resistance of a single unit made as described above will be found to be about 60 000 ohms. Any other desired value can be obtained by a suitable modification of the dimensions. The constants of the wire are as under :—

Diameter over insulation ..	·004 inches.
Resistance/1000 yds. ..	214 000 ohms.
Weight/1000 yds. ..	·036 lbs.

The wire is, of course, expensive, the present price being about seven shillings an ounce. As will be seen from the above figures, however, only about an ounce and a half are required for a 60 000 ohm unit, so the total cost compares favourably with that of a low-frequency transformer.

No special merit attaches to the figure 60 000 ohms, and where high-tension is not a limitation this can with advantage be increased to 80 000 or so. Resistances of this value can easily be made with the same overall dimensions as described above. A set of resistances of this magnitude was in fact constructed by the writer, and was used in the circuit illustrated in Fig. 1.

The proper choice of the value of the intervalve condensers is a matter of considerable importance, for on this will depend the uniform behaviour of the amplifier with respect to frequency. This condenser serves no useful purpose in the amplification process proper, and its only function is to prevent the continuous anode potential of any one valve from acting directly on the grid of the succeeding valve.

It is obvious that there is a certain loss of voltage over this condenser and that this loss is greatest at low frequencies. It may be shown (see Appendix) that if f is the lowest frequency we wish to consider, and that we decide on a maximum loss of voltage to be allowed, *i.e.*, a minimum ratio of E_g to E_a in Fig. 5, then the smallest capacity which we may use is

$$C = \frac{n}{2\pi f R}\,\mu F$$

where R is the grid-leak resistance in megohms, and n is derived from the curve in Fig. 6.

Suppose, for instance, that the variation with frequency over the whole audible range, from 50 cycles upwards, is not to exceed 3 per cent. The curve of Fig. 6 shows that in order to fulfil this requirement the lowest value of n shall not be less than 4. We have, therefore,

$$C = \frac{n}{2\pi f R} = \frac{4}{2 \times \frac{22}{7} \times 50} \times \frac{1}{R}$$

$$= \frac{{\cdot}0128}{R}\,\mu F$$

The requisite value of C depends on that of R. For reasons already given, a suitable value for R is about ·25 megohms. In this case we have

$$C = \frac{{\cdot}0128}{R} = \frac{{\cdot}0128}{{\cdot}25} = {\cdot}05\ \mu F \text{ approx.}$$

With intervalve capacities of this magnitude, the overall variation of the amplification with frequency for a three stage amplifier will not exceed 6 per cent. over the whole range of audible frequencies from 50 cycles upwards, and from 100 cycles upwards the variation will not exceed 2 per cent. This degree of constancy is superior to anything obtainable with low-frequency transformer coupling.

It may be argued that since a larger value than ·05 μF for the intervalve capacity would give an even greater constancy with respect to frequency, there is no reason why a larger valve should not be used. In practice, however, there is really nothing appreciable to be gained by doing so, and the use of capacities larger than are actually necessary is undesirable for reasons of economy, low dielectric losses, high insulation, quickness of response, etc.

There is one other detail in connection with intervalve condensers, whether for high or low frequency amplification, the great practical importance of which is not sufficiently realised; namely, the necessity for very high insulation resistance. The consequence of any imperfection in this respect is that a certain proportion, not necessarily the same in each stage, of the continuous battery potential on the anode of any one valve is passed on to the grid of the succeeding valve. Suppose, for instance, that the continuous anode potential of one valve is 50 volts, that the grid leak resistance is 2 megohms, and that the insulation resistance of the coupling condenser to the next valve is 25 megohms. It is easily seen that the insulation resistance of the condenser and the resistance of the grid leak form a sort of potential divider, and that a positive potential of approximately 4 volts is added to the applied negative grid potential of the succeeding valve. This is quite sufficient to modify its behaviour very considerably. It is an additional advantage attaching to the use of grid-leaks of comparatively low resistance that they will greatly reduce the detrimental effect of defective condenser insulation. Thus, in the case considered, if the grid leak resistance is only ·25 megohms instead of 2 megohms, the positive potential passed on to the grid will only be a half of a volt instead of 4 volts.

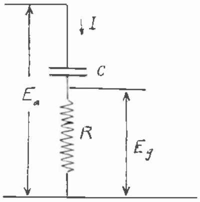


Fig. 5.

Due attention being paid to the matters of detail enumerated above, it will be found that resistance-capacity low frequency amplification is exceedingly satisfactory from the point of view of ease of operation and purity of reproduction.

APPENDIX.

The principal requirement to be fulfilled by the capacity is that its impedance at the lowest important audible frequency, say 50 cycles per second, shall be small compared with the resistance of the

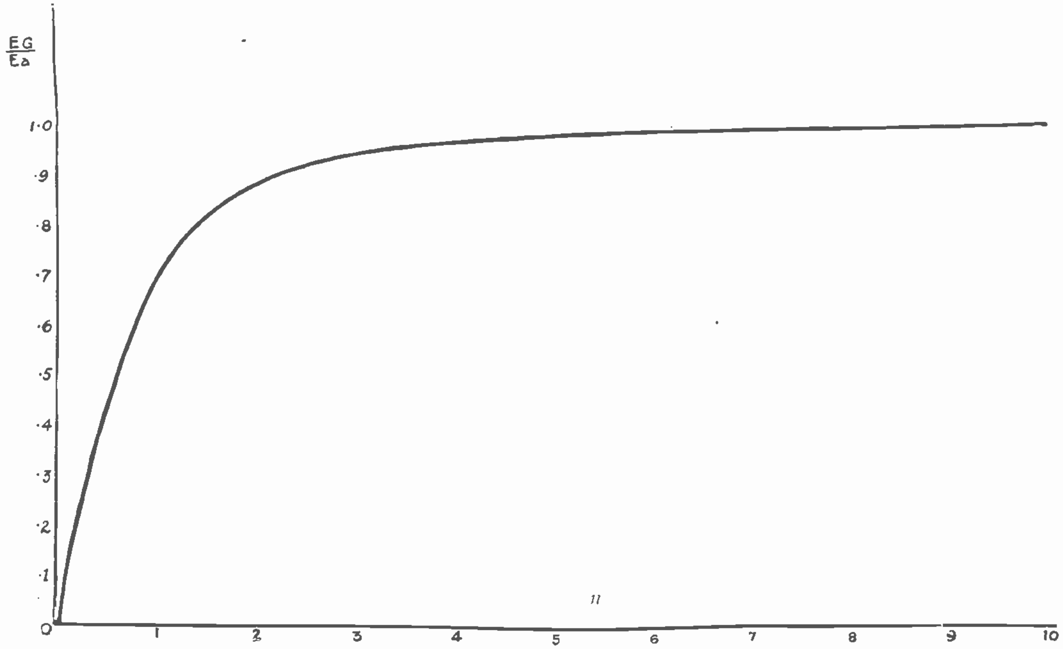


Fig. 6.

grid-leak. Referring to Fig. 5, if $\mathbf{E}_a$ is the vector alternating signal potential difference produced at the anode of any valve of the amplifier, its frequency being $\omega/2\pi$, then there will flow in the circuit consisting of the grid condenser and the grid-leak of the next valve a current given by $\mathbf{E}_a/Z$, Z being the impedance operator of the capacity and resistance in series, *i.e.*,

$$Z = R \times \frac{1}{j\omega C}$$

$$= \frac{1+j\omega CR}{j\omega C}$$

The vector representing the current is therefore given by

$$\mathbf{I} = \frac{j\omega C\mathbf{E}_a}{1+j\omega CR}$$

If $\mathbf{E}_g$ be the vector representing the alternating potential difference produced across the grid leak, *i.e.*, the potential difference which is applied to the grid of the next valve, then

$$\mathbf{E}_g = R\mathbf{I} = \mathbf{E}_a \frac{j\omega CR}{1+j\omega CR}$$

The corresponding equation relating to the amplitudes or root-mean-square values of these potential differences is therefore

$$\frac{E_g}{E_a} = \frac{\varpi CR}{\sqrt{1+\omega^2C^2R^2}}$$

or, putting n for ωCR,

$$\frac{E_g}{E_a} = \frac{n}{\sqrt{1+n^2}}$$

This expression, $n/\sqrt{1+n^2}$, is clearly a factor by which the theoretical voltage amplification given by any particular valve is multiplied in consequence of the coupling conditions. It is important, therefore, that this factor should vary as little as possible with frequency. This is particularly the case where multi-stage amplification is concerned, for a little consideration will show that an $m\%$ variation with frequency of this factor in each stage of an r stage amplifier will cause an overall variation of $(r-1)m\%$ with frequency in the total amplification. This is a feature common to all multi-stage amplifiers and its importance is not always realised.

The variation of $n/\sqrt{1+n^2}$ with n is shown is Fig. 6. Its chief characteristic is its extreme flatness for the higher values of n. This means that the variation of $n/\sqrt{1+n^2}$ with frequency can be reduced to any desired extent by fixing a suitable minimum value for n.

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[1] "The Rectification of small Radio-Frequency Potential Differences." F. M. Colebrook, *Wireless World*, April 30, p. 122.

[2] "The Conditions for Distortionless Low-Frequency Amplification." F. M. Colebrook, EXPERIMENTAL WIRELESS, May, 1924.

[3] "Grid-Filament Conductivity: Its Effect on Amplification." F. M. Colebrook, *Electrician*, November, 1923.

A Combined Test and Broadcast Receiver.

Details of a receiver designed to fulfil a stringent specification : there are many ingenious points of arrangement and construction.

RECENTLY I have had the chance to examine, and I now have permission to describe, a set which has some most interesting features. I believe that some of these features could be imported with advantage into many experimental sets.

The builder is a friend of mine who is actually engaged in the industry, and is constantly faced with the necessity of testing sets, components, and circuits. He built this set specially for this work, to fulfil (so he tells me) the following requirements :—

(1) Good reception of broadcasting ;

(2) Must work on all wave-lengths except the very shortest (100 metres, etc.) with equal efficiency ;

(3) Must be adaptable to new circuits ;

(4) Must work with any good components and have facilities for testing the most varied ones ;

(5) Must be variable in power to match any set to be compared with it ;

(6) In view of (2), must have a minimum of switchgear.

Perhaps the most striking points about the general design as actually carried out are : the complete abolition of terminals throughout the set, in favour of "Clix" ; the use of valve type four-pin sockets for both H.F. and L.F. intervalve couplings ; and the provision of separate filament, grid bias, and H.T. supplies for each valve.

Practically all changes of connections are dealt with by these plugs. The only switches are for the filaments, in the aerial tuning, and two for use with crystal detectors.

Provision is made for three valves, any or all of which can be worked as H.F. or L.F. or Reflex in the simplest manner. The first can be used as detector also very simply ; and by special outside connections so can the others. It is also possible, by outside changes, to use any valve as a separate oscillator, to use the set as a superheterodyne, and so forth. Provision is also made for crystal detection.

What the builder calls his "normal" circuit is a reflex with crystal detector, the number of valves varying according to need.

With these preliminaries I will proceed to the actual set. Fig. 1 is a general view to give some idea of the proportions. Fig. 2 is a composite photo of the top and front, stripped of components ; and Fig. 3 is a schematic diagram. It should be noted that the set itself works from right to left, not left to right as in Fig. 3.

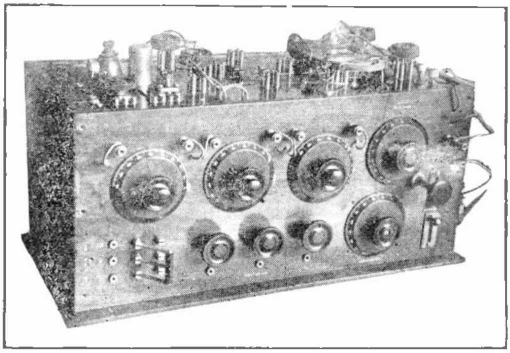


Fig. 1.

A general view, without valves and intervalve couplings.

Turning attention first to the aerial circuit (not shown in Fig. 3), this comprises a ·001 condenser with s.p. switch, a Sterling variometer with s.p. switch for the two windings, and a pair of sockets for leads to a loading coil. The condenser and variometer alone give a range from about 200 to 3,000 metres. Each side of the condenser, the loader, and the variometer are accessible for tapping in if required—in fact, such accessibility of "strategic points" is carried out right through the set.

The connection between aerial circuit and the remainder of the set is made by "Clix," so that either part can be used independently, thus leaving the way open for experiment with various types of aerial circuit.

Looking now at the intervalve circuit, the most striking point is the simplicity of the arrangement, in spite of its wide scope. The two coupling sockets are in series, the H.F. being on the valve side: by-pass condensers can be plugged in across the L.F. windings if wanted. Referring to the general diagram, Fig. 3, the H.F. input from the aerial circuit goes via flex leads (two separate leads, not twin flex) to the H.F. input plug. This is shown in Fig. 2. Note that the two left-hand pins are shorted. Hence it can be plugged into any of the H.F. sockets, and the valves before it (to the right in the actual set which works from right to left) are still available for L.F. work if desired.

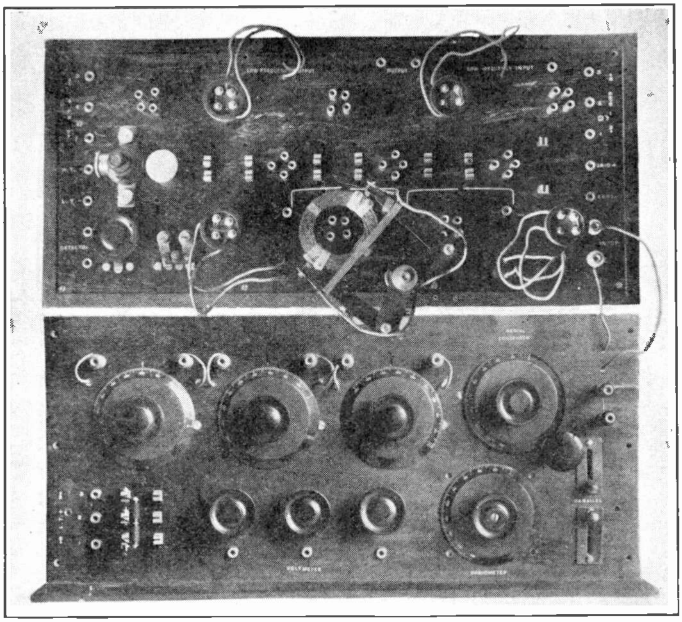


Fig. 2.

The top and front, showing the sockets for valves and couplings, and the use of Clix.

A similar device is adopted for the H.F. output plug, the flex leads from which go to the detector circuit.

For normal work crystal detectors are used, and the detecting circuit is shown at the upper right-hand corner of Fig. 3. The coil-holder is mounted so that it can be coupled for reaction to either H.F. intervalve transformer: the rectified currents pass to a socket taking an L.F. transformer, and from the secondary go flex leads to the L.F. input plug. As in the H.F. side, anything from one to three L.F. valves can be used, an L.F. output plug taking off the final result and leading it to the output terminals. To provide for the case where the H.F. or L.F. side of any particular valve is out of use, short-circuiting plugs are used.

Three minor points may be noted here: grid leads are brought out to take neutrodyne condensers if required; the crystal detectors may be reversed (often an advantage when used after H.F. valves); and there is a 3-way selector switch for two detectors in the set, with connections for attaching a separate one to be tested.

In view of the fact that valves of new types are often being tested, three low tension positives are provided, each of which can, if desired, be connected to 2, 4, or 6 volts. A 3-arm switch breaks all three circuits together: the negative is common. Separate rheostats are provided, microstats being used. I asked the builder of the set whether these were satisfactory, and he was very pleased with them. As to whether they would last he could express no opinion, having had them in use only about six weeks. A useful point is that a tapping is taken from the filament side of each rheostat to a Clix, for plugging in a voltmeter. The voltmeter negative being permanently connected to the common L.T. –, this enables the filaments to be adjusted accurately to rated voltage—quite an important matter with strange valves.

A somewhat similar refinement exists in the H.F. transformer primary circuits (the primaries are tuned). Instead of taking leads direct from the transformer socket to the condenser, flex leads are brought out through the front of the cabinet to Clix, and the condensers themselves are connected to Clix set in the front, so that the condensers can be used in other circuits if desired.

About the H.T. and grid battery circuits there is not much to remark, except that a 15-volt unit, tapped every cell, is used as grid battery. This adjustment, in steps of 1·4 volt, is found quite fine enough, I am told.

A separate coil-holder is arranged to give variable coupling with the aerial loading coil: this is used for a separate heterodyne when required for long waves, or for super-heterodyne working. It should be noted that the coils used are all gimbal mounted, those for long waves being Igranic "slabs," and the short wave ones home-wound duolaterals of a rather unusual shape which the builder swears by and which certainly seem efficient. They are quite narrow, only $\frac{1}{4}$ in. instead of the standard 1 in., and carry 5 turns per layer of 28 D.C.C. wire.

To fit the L.F. transformers, those in most common use are mounted on small ebonite bases carrying four valve pins.

The whole set looks rather frightening at first sight—Fig. 4 shows it with transformers and all accessories—but it does not appear difficult to handle on its normal circuit, at any rate by the man who built it, who is by way of being a pretty old hand.

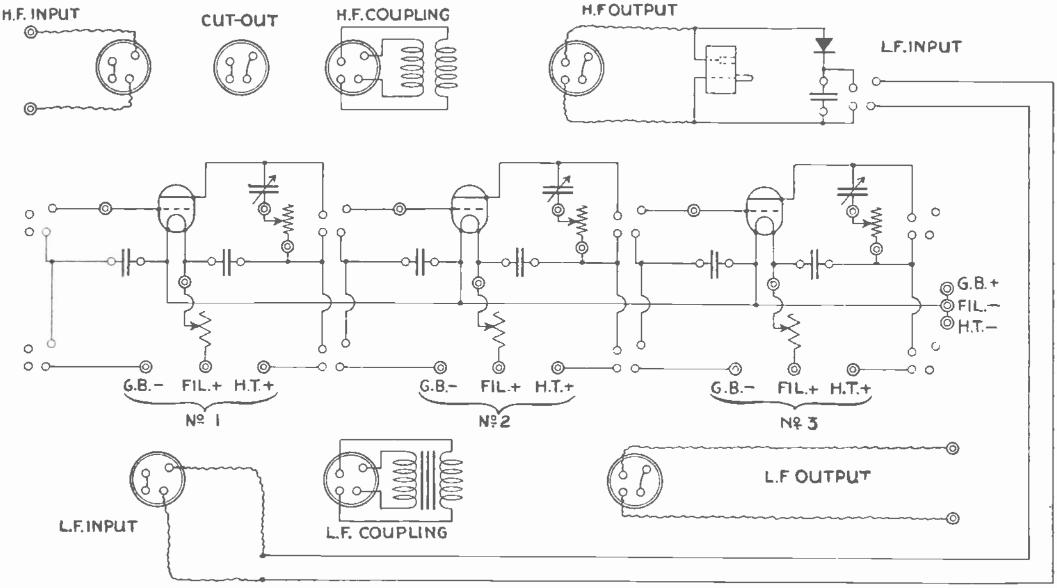


Fig. 3.

Schematic diagram. Double circles signify Clix, small open circles plug-in connections. Above and below are the different types of 4-pin plugs.

For distant broadcast stations he has usually, when I have been there, worked on three valves, 2 reflex (*i.e.*, 2 H.F., crystal, 3 L.F.) with which he has no difficulty in getting all B.B.C. stations at what I consider excessive loud-speaker strength and excellent tone. Above 400 metres, he gets them through London easily, but below this, *i.e.*, Newcastle down to Cardiff, he has been using a simple series rejector tuned on London. He told me that with three stages H.F. (giving four tuned circuits), he could just dodge London and get Bournemouth, but not Manchester, so he then installed the trap, after which the only difficult one was Cardiff.

This made the circuit much more prone to oscillate. Without it, the set was (whenever I have been with him) beautifully controllable with 2 H.F., but needed negative reaction with 3. He said that with the rejector he needed negative reaction with 2. This led to a new fitting, shown in Fig. 4, of which the wiring is shown in Fig. 3. This damps down the intervalve transformers: it consists of a 500-ohm potentiometer used simply as a series resistance. My friend considers stabilising by positive grid bias a barbarous method, as the grid adjustment should be governed by considerations of distortion. He does not control the last tuned circuit, as it is already damped by the crystal. He now uses fairly strong positive reaction and then puts in damping resistance till each valve is as near oscillation as he wants, afterwards controlling entirely on the resistances. This control works so admirably in his hands that I am fitting it on my own set. It will be noted that the L.F. amplification (if the valves are working reflex) is quite unaffected.

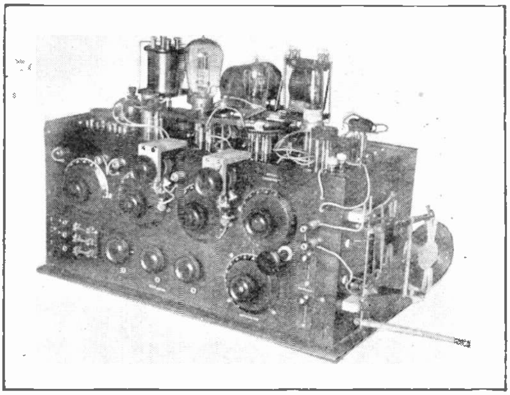
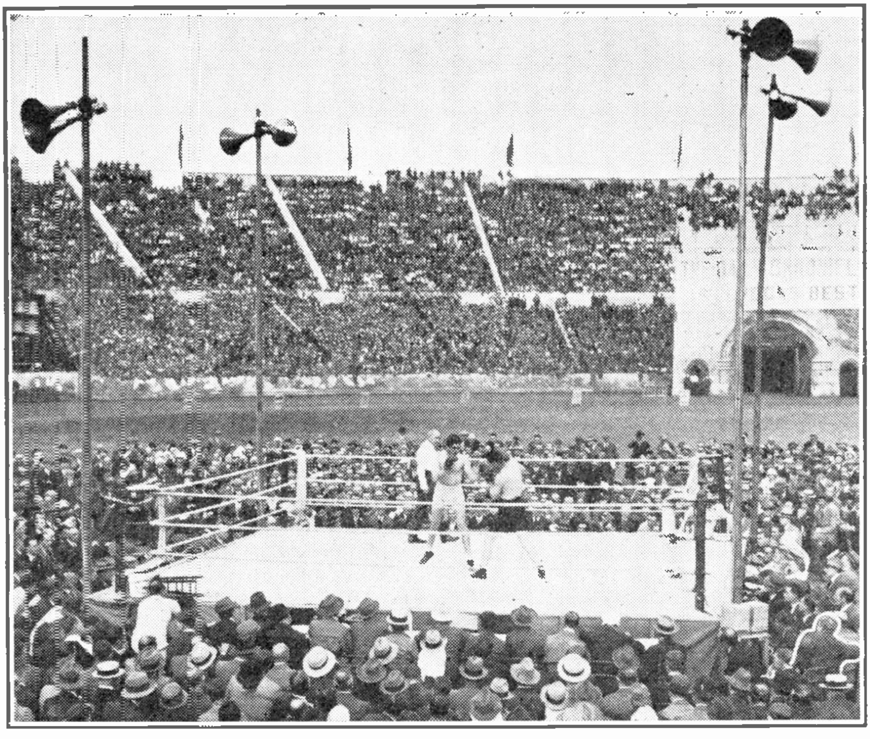


Fig. 4.

A general view complete with accessories.

Altogether, the set is an interesting one, and I am taking several of the ideas into use on my own set. The builder desires to remain anonymous, but has expressed his willingness to give further particulars to anyone interested: I shall be delighted to pass on any inquiries.



The advantage of being a great inventor: Capt. Round at the ring-side at the big fight at Wembley, watching over his microphones and loud-speakers. He is in the right lower corner, outlined in white.

A Simple Method of making Direct Current Measuring Instruments.

By Leonard A. Sayce, M.Sc., A.I.C.

THE high cost of accurate measuring instruments is one of the greatest obstacles that the amateur experimenter has to face. It is because of this that so much work has to be done by "rule of thumb" methods, and the predominance of the personal element in tests that should be quantitative leads to many conflicting reports of various devices. It is thought, therefore, that a short account of the principles upon which these instruments depend and of a simple means of making them may meet the needs of many.

Most sensitive voltmeters and ammeters for direct current measurements are of the Moving-Coil type, that is to say, they contain a rectangular coil of wire free to turn against the restraining action of a spring in a powerful magnetic field. If a current is flowing through the coil, the amount that the coil is rotated is proportional to the current, if the magnetic field is uniform and the controlling spring uniform in action. To obtain great sensitivity, the coil is pivoted between jewel bearings (like the balance-wheel of a watch) and is wound with many turns of fine wire. If this were all, the instrument would not be aperiodic (or dead-beat), but when in use the pointer, which is attached to the coil, would oscillate backwards and forwards for some time before coming to rest at the right place. The delay and unnecessary wear that would be caused in this way are prevented by winding the rectangular coil upon a metal frame or former. When the coil moves, eddy currents are induced in this frame and these eddy currents produce a magnetic field which, reacting with that of the permanent magnet, opposes the motion of the coil. This form of damping can be made so effective that the coil moves to its final position without any delay or over-shooting the mark.

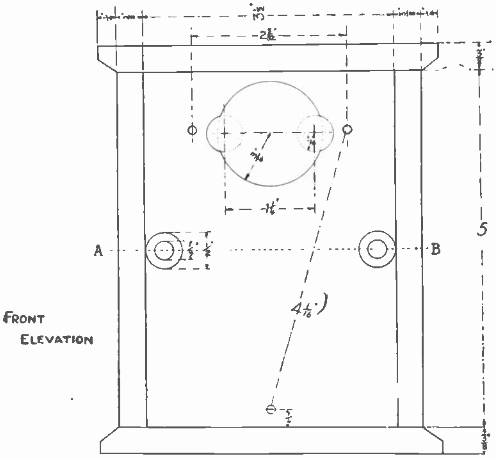


Fig. 1.

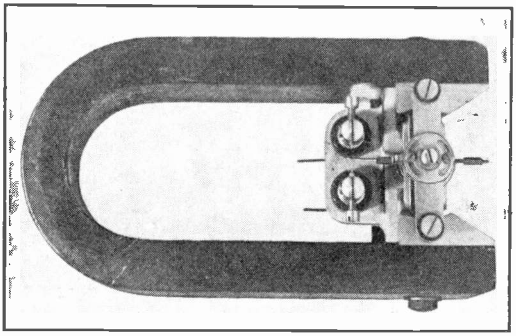


Fig. 2.

The "Weston Moving-Coil Relay" is an instrument of this type, and it can readily be converted into either a sensitive galvanometer for indicating currents or into a meter for measuring them. It can now be obtained for about half-a-guinea from vendors of ex-Government stores. The moving coil is wound to a resistance of approximately 350O* and current is conveyed in and out of

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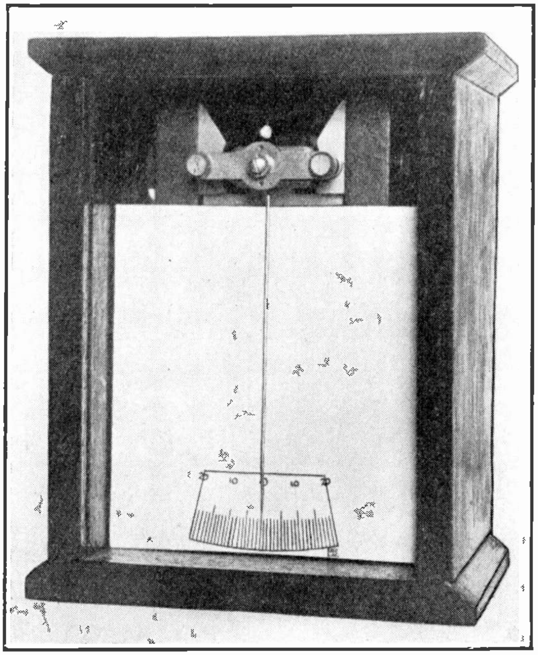
* The coils for three relays were found to have a resistance of 337O, 343O and 360O respectively.



the coil by two fine hair-springs. The coil turns in agate bearings between the curved pole-pieces of a powerful permanent magnet and consists of a rectangular aluminium frame wound with many turns of fine wire. The local current is led through a third hair-spring to a brass wire carrying a platinum strip which, when the coil moves, completes a local circuit by touching one or other of two platinum-tipped screws. A current of ·000 015 amp. is sufficient to work the relay.

Very few modifications are required to make the relay into a satisfactory galvanometer for bridge work or into an ammeter or voltmeter of any required range. A mahogany box is required, whose dimensions are shown in Fig. 1. The back of the box should be of $\frac{3}{4}$ in. wood, having a tongue at each side to enable it to slide in groves in the sides of the box. It should also be provided with a hole of the size and shape shown and be fitted with two terminals in ebonite-bushed holes.

The relay is modified as shown in Fig. 2. The marking and spacing contact-screws are removed entirely. The platinum contact-strip, attached to the moving coil, is removed by touching it with a miniature soldering-iron made from thick copper wire, as also is the hair-spring by which the current is led to the moving contact. The removal of this spring renders the instrument much more sensitive. Upon the stump of brass wire, from which the contact was taken, a light pointer is now attached. This pointer should be $3\frac{5}{8}$ in. long and must be very light but rigid. Such a pointer may be made by cutting a strip of thin aluminium foil $\frac{5}{64}$ in. wide and about 4 in. long. One end is cut to a point and threaded through a wire draw-plate. By drawing the strip through successively smaller and smaller holes the edges are bent round to form a tube that is rigid but extremely light. (The weight of such a pointer of the dimensions given need not exceed 0·02 gm.) One end is flattened out into a fine blade, cut off obliquely and dipped into indian ink. When the ink has dried, the tube is cut to a length $3\frac{5}{8}$ in. The un-flattened end is slipped over the stump of brass wire and fixed in place with a little shellac. The tip of the pointer will then move in an arc of a circle of 4 in. radius.

It is now necessary to balance the weight of the pointer. Three little balance-weights will be found near to where the pointer is attached. The balance-weight lying diametrically opposite to the pointer is screwed out until it is balanced, and it will usually be found necessary to increase the mass of

the balance-weight by a small globule of solder. The relay may now be fitted to the back of its box. This is done by means of the three attachment screws that are provided with the relay. The heads of these screws require to be deeply countersunk. The large hole in the back of the box takes the back bearing of the coil and gives access to the two hair-springs for zero adjustment. Two rubber-covered leads are connected to the terminals and to the hair-spring supports respectively and, after the zero adjustment has been made, the hole in the back of the box is closed by a brass disc 2 in. in diameter.

The scale may be drawn on Bristol board with a very fine drawing-pen, but the writer has found it easier to draw the scale three times its proper size and then reduce it photographically. The divisions of the scale must be fine, for the Weston relay has one disadvantage as a measuring instrument: the movement of the coil is limited to about 25° and this corresponds to 40 mm. at the end of the 4 in. pointer. For a nul instrument this is no disadvantage, but for a measuring instrument we must get over the difficulty to some extent by using a very fine pointer (made as described above) and a finely divided scale. The available 4 cms. should, therefore, be divided into millimetres and, seeing that with practice it is easy to read correctly to one-tenth of a division, the scale may then be read to one part in four hundred. If the relay is for use merely as a nul galvanometer the scale is marked with a central zero, but if it is required as a measuring instrument the zero should be at the left-hand end of the scale. If the instrument is now tested the pointer will be found to move one scale division when a current of from 4 μA to 8 μA (0·000 008 amp.) is passed through the coil.* It can therefore be used as a microammeter if the scale is first calibrated by reference to a standard instrument. In the absence of such a standard the converted relay may be connected in series with a reliable 1Ω grid leak and a variable high tension battery. For every volt used from the battery a current of 1 μA will traverse the circuit.

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* The exact sensitivity depends upon the adjustment of the hair-springs and the care taken in balancing the pointer.

Nodal Points and Aerial Tuning.

By P. K. Turner.

In response to a request from an amateur transmitter, the question of the nodal points and natural frequencies of a loaded aerial working on its harmonics is dealt with by simple calculation.

NOT long ago I was discussing, with a serious and very successful amateur transmitter, the question of Nodal Points in the Aerial, when working on short waves. On my stating that the approximate position of the voltage nodes could be derived from "the old ql equation," I found that he had somehow not come across the fundamental equation of aerial tuning.

In case there are others doing work on the same problems, I give a few notes on the matter.

The problems are: What is the required loading (coil and condenser) to tune an aerial of known capacity and inductance to a given wave-length; and what is the current or voltage distribution over the aerial. The latter problem obviously gives the nodes, which are defined as points where the voltage is zero.

To simplify matters, I shall neglect the aerial resistance, which would complicate the calculations enormously. Although it greatly affects the *amplitude* of the current, it does not greatly affect the tuning or the distribution. Secondly, I shall assume that the aerial has a constant capacity and inductance per foot run over the whole of its length. This is more nearly true for short amateur aerials than for big "roof" commercial, long-wave aerials. The result of an uneven distribution would be a shifting of any nodes that exist up in the aerial itself. The point will be taken up later. Lastly, only the case of an earthed aerial is dealt with in detail. At the end of the article I show how to apply the results to a counterpoise.

It is not proposed to give the derivation, by calculus, of the main current and voltage equations: the reader must take my word for it that they are correct. They are as follows*:—

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* See any standard work such as Fleming, Morecroft, etc.

Let e_x be the voltage x feet from the bottom.
i_x the current x feet from the bottom.
L_0 the aerial inductance (Henries).
C_0 the aerial capacity (Farads).
l the aerial length (in feet if x is in feet).

then
$$e_x = A \cos \overline{ql - qx} \cos \omega t \quad \dots \quad \dots \quad (1)$$

$$i_x = A\sqrt{\frac{C_0}{L_0}} \sin \overline{ql - qx} \sin \omega t \quad \dots \quad (2)$$

where ω is the impressed frequency × 2π
A a constant depending on the amplitude of the impressed voltage (see below)
and q is given by the equation

$$ql = \omega\sqrt{L_0 C_0} \quad \dots \quad \dots \quad (3)$$

Pausing just for a moment to consider the physical meaning of these equations, we see that both voltage and current are of the usual alternating sine-wave form as regards tune. But the amplitude—the value when $\cos \omega t$ or $\sin \omega t$ is 1—itself depends on the distance up the aerial.

Confining ourselves to the amplitudes, we have

$$E_x = A \cos q(l-x)$$

$$I_x = j A\sqrt{\frac{C_0}{L_0}} \sin q(l-x)$$

where $j = \sqrt{-1}$ and signifies that the current is 90° out of phase with the voltage.

Now the voltage impressed on the aerial is that at the foot. If we call it E, we have

$$E = E_0 = A \cos ql$$

$$A = \frac{E}{\cos ql}$$

So that
$$E_x = \frac{E}{\cos ql} \cos q(l-x) \quad \dots \quad (4)$$

$$I_x = j\frac{E}{\cos ql}\sqrt{\frac{C_0}{L_0}} \sin q(l-x) \quad (5)$$

From these we can find the values at the foot and the extreme end :—

$$E_e = \frac{E}{\cos ql} \cos 0 = \frac{E}{\cos ql} \quad \dots \quad (6)$$

$$I_e = j\frac{E}{\cos ql}\sqrt{\frac{C_0}{L_0}} \sin 0 = 0 \quad \dots \quad (7)$$

$$E_0 = \frac{E}{\cos ql} \cos ql = E \quad \dots \quad \dots \quad (8)$$

$$I_0 = j\frac{E}{\cos ql}\sqrt{\frac{C_0}{L_0}} \sin ql$$

$$= jE\sqrt{\frac{C_0}{L_0}} \tan ql \quad \dots \quad \dots \quad (9)$$

The impedance of the aerial to the impressed voltage (which, as we are neglecting resistance, is equal to its reactance) is obviously the ratio of voltage to current at the foot. Calling it X_0, we have from (8) and (9)

$$X_0 = -j\sqrt{\frac{L_0}{C_0}} \cot ql \quad \dots \quad (10)$$

The Voltage Nodes.

Now it is obvious that the " Nodal Points " (a better term is " Voltage Nodes ") are the points where $E_x = 0$. Looking at equation (4), we see that the condition for this is

$$\cos q(l-x) = 0 \quad \dots \quad \dots \quad (11)$$

As we all know, the cosine of an angle is zero when the angle is 90° ± (180° × any whole number), or, using the usual radian measure,

$$q(l-x) = (2n+1)\frac{\pi}{2} \quad \dots \quad (12)$$

where n is any whole number.

We will express this in terms of wave-length. If q_0, λ_0, f_0, ω_0, refer to the fundamental frequency or wave-length of the unloaded aerial, then λ_0 is given by the condition that the reactance of the aerial at this frequency is zero, or (from equation (10))

$$\cot q_0 l = 0$$

or
$$q_0 l = (2n+1)\frac{\pi}{2},$$

or, for the fundamental,

$$q_0 l = \frac{\pi}{2}, \quad n \text{ being } 0 \qquad \ldots (13)$$

Thus we have, for the nodes (from (12))

$$ql - qx = (2n+1)\frac{\pi}{2} = (2n+1)q_0 l$$

or, dividing by ql,

$$1 - \frac{x}{l} = (2n+1)\frac{q_0}{q} = (2n+1)\frac{\lambda}{\lambda_0},$$

since q varies as ω (see (3)), hence varies as f, and therefore varies inversely as λ.

Rearranging, we have

$$\frac{x}{l} = 1 - (2n+1)\frac{\lambda}{\lambda_0} \qquad \ldots \quad \ldots (14)$$

This gives at once the positions of all the nodes in the aerial itself. Take, as an example, an aerial 100 ft. long in all, of 200 metres natural wave, being worked on 45 metres.

$$\frac{x}{l} = 1 - (2n+1)\frac{45}{200}$$

Now the possible values of n are limited by the facts that $\frac{x}{l}$ must be positive and less than 1. (We are not investigating nodes in the ground or beyond the end of the aerial !)

We have the following table of results :—

n	-1	0	1	2
$2n+1$	-1	1	3	5
$(2n+1)\frac{45}{200}$	$-·225$	$+·225$	$+·675$	$+1·125$
$\frac{x}{l}$	$1·225$	$·775$	$·325$	$-·125$
x	——	77′ 6″	32′ 6″	——

There are, therefore, two nodes, at 32 ft. 6 in. and 77 ft. 6 in. from the foot of the aerial. As mentioned above, deviations from our original assumption as to even distribution of capacity and inductance will shift the positions somewhat. If there is a single lead-in and multiple top, for example, the nodes will be shifted upwards. But their number will not be changed : further, their position is independent of loading and tuning (provided the frequency is kept constant by forced oscillations) : *the nodes depend only on the ratio of the frequency in use to the fundamental of the unloaded aerial.*

Loading and Wave-length.

Next, as to the loading required for a given wave-length. As we are dealing with short waves, we will consider only a load of capacity and inductance in series : the parallel case can be taken up in a later article if desired.

Suppose we insert an inductance L_s henries, and a capacity C_s farads, the inductance having negligible self-capacity and the condenser and its leads negligible self-inductance. Then we have placed between aerial and earth a reactance X_s, given by

$$X_s = j\left(\omega L_s - \frac{1}{\omega C_s}\right) \qquad \ldots \quad \ldots (15)$$

If now the aerial and load are tuned as a whole to the frequency of $f\left(=\frac{\omega}{2\pi}\right)$, then the total reactance is nil, *i.e.*, $X_s + X_0 = 0$, or $X_s = -X_0$, whence, from (10) and (15)

$$\omega L_s - \frac{1}{\omega C_s} = \sqrt{\frac{L_0}{C_0}} \cot ql \qquad \ldots (16)$$

Remembering that $ql = \omega\sqrt{L_0 C_0}$, and that by supposition L_s, C_s, L_0, and C_0 are known, it is obvious that this equation will give us ω, and hence the wave-length. But it cannot be solved directly. However, a graphical solution is easy, and we will carry it out.

To simplify matters, we will take a concrete case ; that of an aerial of ·0004 μF, with 64 μH of inductance. First we will plot a curve of cot ql for various frequencies. As an example, if f is 159 000 cycles, ω is 1 000 000, or 10^6. Now $ql = \sqrt{L_0 C_0}$, and is easily found to be $\frac{·155\omega}{10^6}$: for this case it equals ·155. Now to find *cot ql* from ordinary tables, we must convert to degrees by multiplying by $\frac{180}{\pi}$, which gives us 89°. From any table of cotangents, cot $ql = 5·67$, and as $\sqrt{\frac{L_0}{C_0}} = 400$, we have $(-X_0) = 2270$ ohms approx.

Calculating for other frequencies in the same manner, we arrive at the heavy lines marked X_0. in Fig. 1. The points where these lines cross the horizontal axis are the frequencies of zero reactance, *i.e.*, the natural wave-lengths of the aerial alone. Expressing them in terms of the fundamental (point A) as a unit, their frequencies are 1, 3, 5, 7, 9 . . . etc. These lines are always the same for the same aerial, whatever the loading.

Now imagine the aerial loaded by an inductance of 50 μH. The reactance of this is given by $X=50\omega$, and is easily drawn as the straight line B. Now at the points where line B cuts lines X_0, we have $X_s=-X_0$, or the aerial and coil are tuned. Therefore the natural frequencies of the loaded aerial are the points marked by circles on line B. It is interesting to note their frequencies in terms of the fundamental A. We observe

$$\frac{f}{f_0} = \cdot 85,\ 2\cdot 4,\ 4\cdot 3,\ 6\cdot 27,\ 8\cdot 25,$$

corresponding to harmonics of the free aerial at 1 3 5 7 9

As would be expected, the loading coil lowers the natural frequency in every case (*i.e.*, increases the wave length). But, expressing the harmonics of the loaded aerial in terms of *its own* fundamental, we have

1 2·8 5 7·4 9·97

The harmonics are not even multiples of the fundamental.

If we remove L_s and substitute C_s, of ·0001 μF, its reactance $\left(=\dfrac{1}{\omega C_s}\right)$ is given by curve C. The natural frequencies, in terms of the free fundamental A, are

1·8 3·65 5·55 7·5 9·5

showing increased frequency. In terms of the loaded fundamental,

1 2·03 3·08 4·16 5·27,

a very great divergence from the 1, 3, 5, 7, 9 of the free aerial.

Lastly, suppose both the condenser and the inductance to be inserted. The curve of X_s will then be the (algebraic) sum of curves B and C. It is shown as curve D, and the natural frequencies are shown by the points marked by triangles. We now strike a particularly interesting feature. The frequencies, in terms of A, are

1·7 2·9 4·4 6·3 8·25

or in terms of the loaded fundamental,

1 1·7 2·6 3·7 4·8

an even greater divergence than before from the harmonic series for the free aerial.

The fundamental frequency is increased in the ratio 1·7 by this loading; *i.e.*, the wave-length is decreased in this ratio. But the next harmonic is hardly altered, while all the higher ones are *decreased* in frequency!

By the simple method of drawing other X_s lines on the same diagram, any combination of loading may be investigated. We have drawn (dotted) lines for 20 μH inductance (marked E) and ·0002 μF capacity (marked F).

Hours might well be spent on studying such curves. We will just note three important points:—

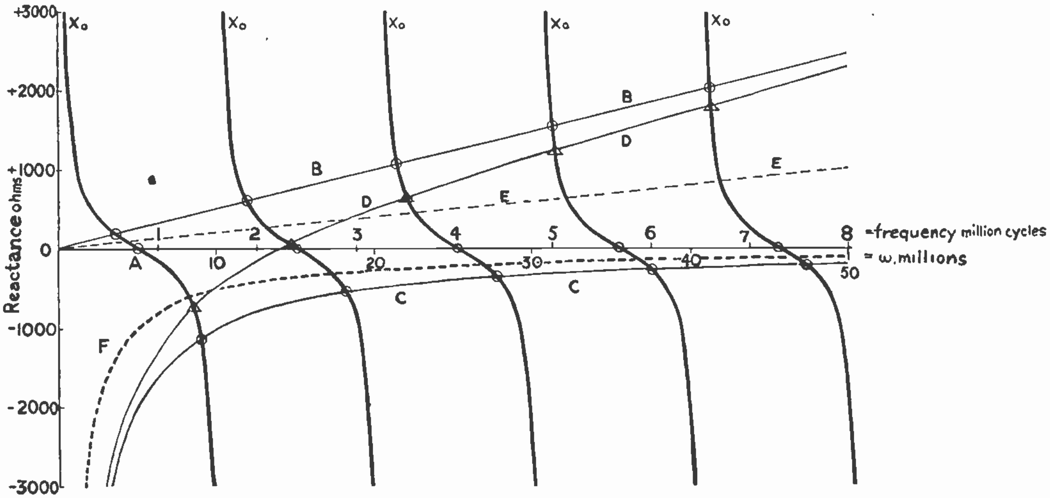


Fig. 1.

(1) No loading of any kind can make one harmonic "trespass" on the space of another. For example, the fourth X_0 curve covers frequencies giving between 31 and 41 million for ω. No loading can increase this harmonic to 42 or reduce it to 30.

(2) The effect of inductive loading is greatest in the harmonics.

(3) The effect of capacity loading is greatest on the fundamental.

Nodes in the load.

A question asked in the original conversation which led to this article was: "Can one have a node in the loading coil or condenser?"

This can be decided as follows:—

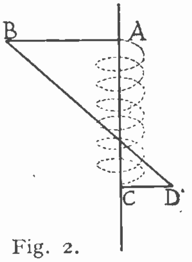


Fig. 2.

If we have a loading coil L_s above a condenser, and the voltage set up in it is E_L, then

$$E_L = j\omega L_s I_0 = -\omega L_s \sqrt{\frac{C_0}{L_0}} \tan ql. \; E_0 \text{ from } (9).$$

Now the voltage at the foot of the inductance is

$$E_0 - E_L = E_0\left(1 + \omega L_s \sqrt{\frac{C_0}{L_0}} \tan ql\right) \quad .. \quad (17)$$

If this difference is negative (*i.e.*, $E_l > E_0$) there will be a change of sign between the voltage above and below the inductance, so that there must be a node at some point on it. This will be the case if *tan ql* is *negative*, and of value greater than

$$\frac{1}{\omega L_s} \sqrt{\frac{L_0}{C_0}}$$

Since tan ql varies from $-\infty$ to $+\infty$ in quite a small range of ω, this is obviously possible at certain frequencies. Further, if it is found that at a certain frequency there is a node, its position on the coil is easily found. Suppose that in Fig. 2 the voltage at foot is found to be $\frac{1}{3}$ of E_0, we can draw lines AB, CD, making $\frac{AB}{CD}$ in the ratio $\frac{E(\text{foot})}{E_0}$ ($=\frac{1}{3}$ in this case).

The line BD cuts the centre of the coil at the node. This, of course, is only an approximation, for it assumes that every turn has equal inductance. Without this assumption, we can say (calling L_N the inductance of that part of the coil *above* the node,

$$\frac{L_N}{L_s} = \frac{E_0}{E_L},$$

from which L_N, and hence the proportion of turns, can be found.

In the case of the condenser being above the inductance, it can be proved in the same way that there will be a node if *tan ql* is *positive*, and of value greater than

$$\omega C_s \sqrt{\frac{L_0}{C_0}}$$

There can obviously never be a node in a pure inductance or condenser next to the earth connection, as its bottom end is itself a node.

The Counterpoise.

Hitherto, we have worked on the basis of an earthed aerial, but the results can be extended in a simple manner (see Fig. 3). Here we have a circuit consisting of aerial A, tuning condenser C_s, coil L, counterpoise condenser C_c and counterpoise C. The circuit is earthed at E. Now if we consider the coil to be split at E, forming an aerial coil L_a and a counterpoise coil L_c, we have obviously two circuits, AC_sL_aE and CC_cL_cE, each of which can be dealt with as indicated.

One important point is instantly shown by this. We have already proved that for a given impressed voltage the current is proportional to $\frac{C_0}{L_0}$, or, in another form, to pass a given current we must impress a voltage proportional to $\frac{L_0}{C_0}$. Now this fraction will probably be different for the aerial and the counterpoise. So if, as is usual, we want the earth lead to be simply a stabiliser carrying no current, we must adjust the impressed voltage on the counterpoise accordingly, so that the currents in A and C are equal. This will probably be done by varying L_c— of course C_c must be varied in turn to bring the counterpoise back to the right tune.

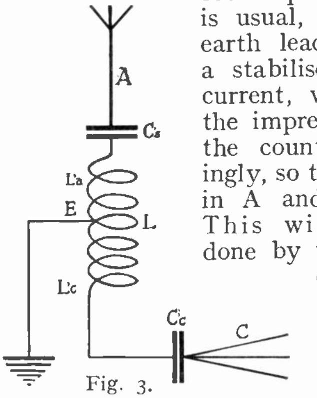


Fig. 3.

A Full Wave Rectifier.

By Herbert H. Dyer, A.M.I.E.E.

In the following article the author describes how he constructed a full-wave rectifier from an ex-W.D. D III. buzzer, and also details the operation of this novel piece of apparatus.

A NUMBER of experiments have been carried out by the writer, when time could be spared from purely "wireless" work, with the object of designing a really satisfactory rectifier for charging filament batteries from alternating current mains. A tuned reed rectifier had been used previously, but although this, on the whole, gave satisfactory results, it was found that slight variations in frequency or sudden changes in the voltage of the supply caused some sparking at the contacts. As it was desired occasionally to leave the charging in unskilled hands, it was decided to design a rectifier that would not be affected by these changes in the supply. The aim was to obtain something that would run absolutely sparklessly without adjustment for many months, using both halves of the wave. After a gratifying amount of success with various arrangements, the writer was fortunate enough, in one of his periodical searches amongst ex-W.D. apparatus, to discover what appeared to be the very thing for the purpose. This was a buzzer from a D III field telegraph set, and it actually exceeded expectations. It is safe to say that a better rectifier could hardly be designed for the purpose, and no alteration at all was required except in the connections.

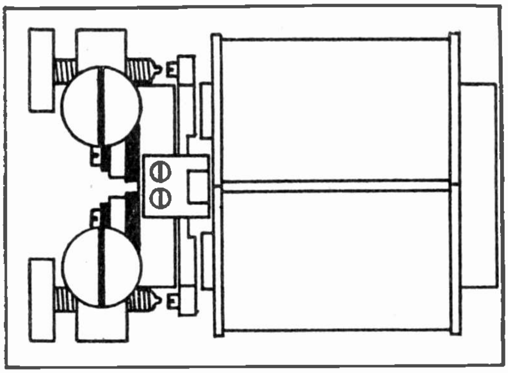


Fig. 1.
The D III Polarised Buzzer.

It is proposed to describe the arrangement and to give the results of tests carried out with it.

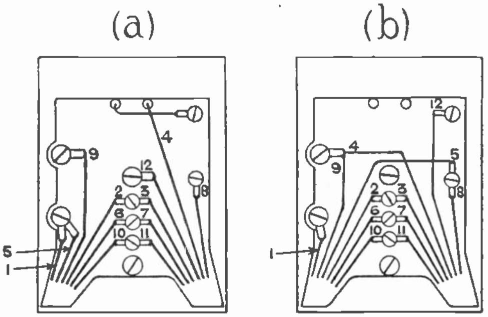


Fig. 2.
Back connection of D III Buzzer.

For the benefit of those unfamiliar with the D III buzzer, the following short description is given. A pair of coils with iron cores are fixed on a **U**-shaped magnet, forming an almost closed magnetic circuit. In the gap and across the ends of the two cores is the armature, which is fixed at the centre to a flat spring. Screwed on each side of the armature is a short contact spring. The contact screws are fastened to the magnet and, of course, insulated from it. Fig. 1 shows the buzzer in plan.

Each coil consists of three separate windings, the resistances being approximately 1·6 ohms, 1·6 ohms and 32 ohms respectively. The vibrator is fixed on an ebonite base $3\frac{1}{8}$ in. × $2\frac{1}{4}$ in. × $3\frac{1}{2}$ in. thick, the overall height of the vibrator being $1\frac{5}{8}$ in.

On the first buzzer the writer obtained the magnet was demagnetised, in fact it was quite soft and could be readily filed. Consequently the 32 ohm windings were used for polarising the armature, the windings being connected in such a way as to produce similar poles at the open ends of the two cores. The other four windings (two on each core) were joined in series and connected to the A.C. supply. The connections must be such that a current in either direction produces opposite poles at the open ends of the two cores.

Fig. 2 (*a*) shows, from the back, the original connections of the buzzer, and 2 (b) shows the connections altered for use as a rectifier. The operating windings are from 1 to 12, *i.e.*, four coils, each about 1·6 ohms, connected in series. The magnetising windings are from 6 and 7 to 5 and 8, *i.e.*, two coils, each about 32 ohms connected in parallel. The operation will now be obvious, the flux due to the alternating current acting on the polarised armature causes it to vibrate at exactly the same rate as the frequency of the supply. As the armature is not tuned, the operation of the buzzer is equally satisfactory at all ordinary supply frequencies.

A transformer is necessary, not only to step down the voltage to the required value, but to provide a centre point for full-wave rectification. The secondary winding of the transformer has a tapping at the centre. The outside ends of the secondary are connected to the contact screws of the buzzer, and the centre tapping of the secondary is connected through the battery to the armature of the buzzer. The transformer used was of the "Hedgehog" type, the core being of soft iron wire. The diameter of the core was about two inches, and about five and a half pounds of iron wire was used. The primary consisted of 2000 turns of No. 30 D.C.C. wire, each layer being carefully wound on the lathe and well shellacked, with, shellacked paper between the layers. The secondary was wound with 140 turns of No. 18 D.C.C. wire in two layers, with a tapping at the centre and tappings at 60 and 65 turns each side of the centre. The shellac was dried out by passing a direct current through the primary for about twenty-four hours. The supply is rated at 200 volts but is rather higher and varies considerably. The secondary voltage was arranged for charging four-volt batteries only at from three to five ampères.

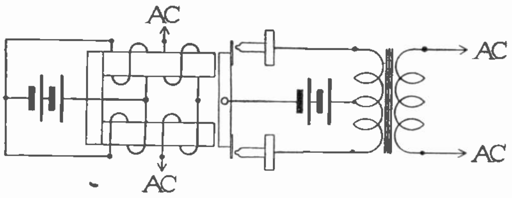


Fig. 3.
Connection of Buzzer for use as Rectifier.

OPERATION.

Having briefly described the construction and connections of the rectifier, the operation can be discussed. Referring to Fig. 4, the sine wave represents the secondary terminal voltage. In order to get sparkless rectification the "make" and "break" must occur exactly at the points A and B, where the secondary voltage just balances the battery voltage. Unless the movement of the armature is precisely in step with the secondary voltage, sparkless rectification is impossible. If the operating coil of the vibrator is connected directly across the secondary, the movement of the armature will lag considerably behind the secondary voltage, owing to the highly inductive nature of the winding. The operating coil was consequently connected to the mains through resistances and condensers in order to ascertain the best arrangement. It was eventually found that a 4 μF condenser connected in series gave absolutely sparkless rectification. The contact screws are provided with a very fine thread, and adjustment is thereby considerably simplified. The best method of adjusting for full-wave rectification is to draw one of the contact screws right back and adjust with the other for half-wave; then gradually bring up the first contact screw until the sparkless point is reached. It will be found that this does not upset the original half-wave adjustment, and the ammeter should give the same reading with either side disconnected. The writer's rectifier has been running for about a year without giving any trouble, and no spark at all is visible, even in the dark, at full load. In the arrangement actually used the magnetising current is provided by the battery on charge.

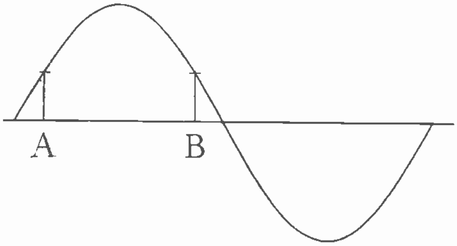


Fig. 4.
Showing conditions for sparkless rectification.

TABLE I.

Secondary Voltage		Battery Voltage V3	Charging Current		Input from Mains			Output Watts V3A2	Efficiency
Open Circuit V2+V2	Closed Circuit V2+V2		P.N. Inst. A2	H.W. Inst. A3	Volt-Amps V1A1	Watts W	Power Factor		
									Per cent.
—	—	—	No Load		53	8	·15	—	—
			Amps.	Amps.					
6·5+6·5	5·6+5·6	4·5	3·1	5·5	66	40	·61	14	35
7·3+7·3	6·1+6·1	4·5	4·5	7·0	73	54	·74	20	37
7·8+7·8	6·4+6·4	4·6	5·0	7·5	80	61	·76	23	38

A number of tests were made to ascertain the efficiency. Fig. 5 shows the connections for the test, where it will be noticed that a separate battery was used for magnetising. V1 is an A.C. voltmeter, W a wattmeter, A1 an A.C. ammeter, V2 A.C. voltmeters, A2 a D.C. ammeter, A3 a hot-wire ammeter, and V3 a D.C. voltmeter. A selection of the figures is given in the table. The vibrator itself took about 8 watts, the power factor being only ·15. The difference between the readings on the D.C. ammeter and the hot-wire instrument is interesting. To prove that the reading given by the moving coil instrument indicated the effective current for charging the battery, a batch of new cells was charged several times from the D.C. supply and a discharge test made after each charge. Readings were taken every hour, both during charge and discharge. Four of the cells which gave identical results hour by hour were then selected, and two of them charged from the D.C. mains and two from the rectifier simultaneously. It was found that when the rectified charging current indicated on the D.C. instrument was the same as that indicated on the instrument in the D.C. charging circuit the two batteries came up together. This test was repeated several times at different charging rates, with exactly the same result.

The small current used for magnetising the buzzer has not been taken into account when reckoning the efficiency. The writer believes that the rectifier would operate equally well when using a permanent magnet, but has not, up to the time of writing, been able to give this an extended trial. The advantage of magnetising from the cell on charge is that it does not matter which way the battery is connected to the charging terminals. With power at one penny per unit it will be seen that eighty ampère-hours can be put into the battery at a cost of one penny.

The rectifier can be used satisfactorily without the transformer for charging secondary H.T. batteries, the current being regulated by means of a lamp resistance.

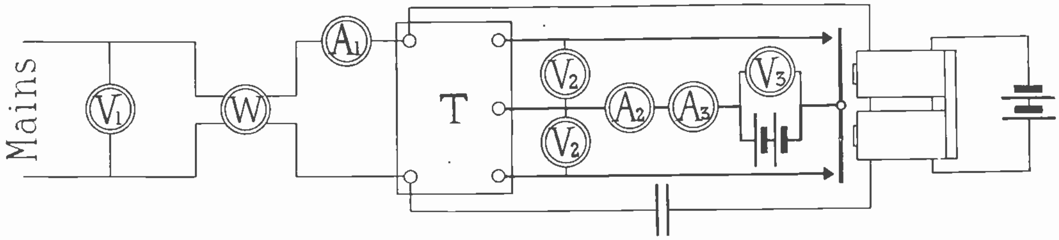


Fig. 5.
Connections for Efficiency Test.

5XX.

A technical description of the first British high-power station designed throughout for distortionless telephony.

IN attempting to describe such a station as 5XX, one is confronted with various difficulties. First, where does the "station" begin? Inasmuch as the microphone and the A and B amplifiers are of the usual B.B.C. type, we have decided (somewhat arbitrarily we fear) to keep to the transmitter itself, beginning with the leads coming into the transmitting house from the sub-control.

These carry a power (pure A.C. power) in the neighbourhood of 10 to 30 watts. They go to the primary of the control input transformer, which is of 10 : 1 ratio, the primary having 2040 turns.

Another difficulty is that, although casual inspection of the set has been fairly freely allowed, one finds when detailed and expert inquiry is made that various details are highly confidential.

By courtesy of the B.B.C. and the Marconi Co., we were able to make a detailed investigation, and our notes and results have very kindly been checked by Capt. Round; but it will be understood that certain details are of necessity omitted.

Dealing now with the apparatus in the main transmitting house, the set may be, for purposes of description, divided into three clear-cut parts, though in the actual experimental station in use it is not so clearly divided. There is, first, the drive oscillator, next the magnifier or main power amplifier and aerial circuit, and third the modulator.

The Drive Oscillator.

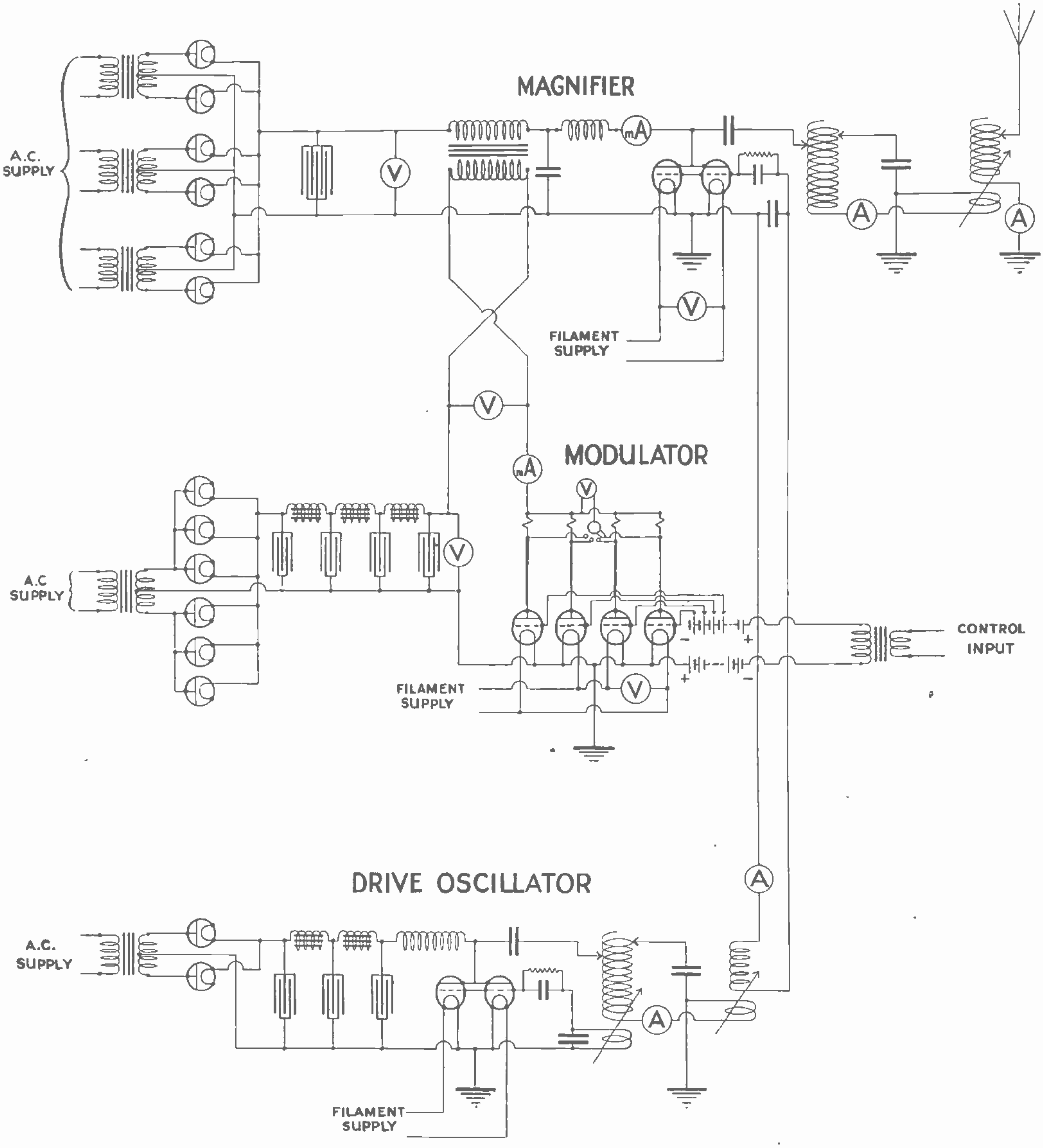
The circuit of this, as will be seen from our diagram, is simplicity itself—as, in fact, are all the circuits. It is an ordinary back-coupled oscillator with branched H.T. circuits, employing two M.T. 7a valves. These are of the ordinary "Bottle" type, one of them being illustrated. They are rated to dissipate about 1 kW if necessary. Their main characteristics are $\mu=72$, $R_a=30\,000$; the filaments each take about 25A at 12V. The filaments are supplied by the same D.C. generator that feeds the magnifier and modulator valves (see below).

The grid circuit comprises first a condenser-leak combination, the leak having a value of 15 000 O, and the condenser ·0046 μF. The D.C. grid current is given as 80mA, from which we see that the leak will depress the mean grid potential to −1200V. This large value is not surprising in view of the large H.T. supply, as will be noticed presently. The anode circuit being tuned, the grid circuit would be normally aperiodic, but it is found that the coupling may be weakened and a smaller coil used by partially tuning the grid circuit. The grid coil of 700 μH. is therefore shunted by a condenser of ·0005 μF, giving a natural wave-length 0·7 of that of the anode circuit.

Of the two branches of the anode circuit we shall deal first with the H.T. supply. This is derived primarily from a 6 kW alternator, giving single-phase current at 500V, 300∼. This is transformed up to 10 000V, and applied to a full-wave rectifier consisting of two M.R.7a. valves, these being two-electrode valves of power corresponding to the M.T.7a's used as oscillators. Their filaments are fed *via* a transformer from the same supply as those of the other rectifiers, as described below.

The rectified output is smoothed by two 45H chokes and three condensers (of ·25, ·125, and ·125 μF.). It is then applied to the anodes *via* a radio choke of 4200 μH, consisting of three single-layer coils wound on porcelain. This obviously offers a reactance of 5 000O to currents of 1600 meters wave-length. The current amounts to 180mA on the two valves, or a total input of 1·8 kW.

The output anode circuit commences with a stopping condenser of ·000 6μF. of the Moscicki tube type, offering a complete stop to D.C. currents and a reactance of 10 000O to the high frequency.



THE CIRCUITS OF 5XX.

In this drawing, in order to keep that simplicity which makes for ease in reading, the power supply circuits, which are of quite a normal type, are cut out, as are also the filament circuits for the rectifiers. Certain small omissions have been made, as there are one or two confidential points of design. The constants of the various items have not been inserted, as their inclusion is somewhat confusing. They are given in the accompanying description.

Next to this comes the main coil of heavy litz wire on a skeleton former. It is of 300 μH, with separate tappings for the anode and for the output circuit. In series at the lower end of it is the coil coupling to the input of the magnifier, and across the two is the tuning condenser, of ·002 μF. This is an open condenser with air dielectric and is fixed, adjustments being made by the taps on the coil and by a small variometer (not shown in the diagram). The H.F. current in this circuit is normally 25A. The lower end of the condenser is earthed, thus providing the filament connection for the anode circuit.

The Magnifier.

The coil coupled to the circuit last described forms part of the grid circuit of the magnifier, which we will now consider in detail.

It consists of a bank of two water-cooled valves in parallel. These valves, made by the M-O Valve Co., have not yet received their final nominal rating. It is believed, however, that they will stand up to an anode dissipation of 20kW each. At present they are being used at lower power, on a basis of 10kW. Their main characteristics are $\mu=30$, $R_a=10\,000\Omega$: the filaments take 40A at 20V each. In common with the modulator and drive oscillator filaments they are supplied in this set by a 10kW D.C. generator, the power actually taken for the whole being about 7·5kW.

As in the case of the Drive Oscillator, the anode circuit is branched, and we will deal with the input or H.T. branch before considering the H.F. circuits.

The source of supply in this case is a 3-phase generator delivering about 30kW at 440V. This is transformed to 10 000V and a bank of M.R.7a valves used to give full wave rectification on each phase. All the rectifier filaments for the whole set are supplied by transformers from a 15kW. 200 ~ 500V. alternator in this experimental set. Actually only about 5kW is taken. As a result of the 3 phases, the resulting D.C. has a comparatively small ripple, and no smoothing choke is necessary, only a 0·9 μF. condenser being used. The negative lead now goes direct to the magnifier filaments.

The positive lead would, in a normal choke control set, go through the speech choke and then divide into two branches for the main and modulator supplies. It is, however, a peculiarity of 5XX that separate H.T. supplies are used for the two branches. The two supplies are led through equal coils on a 1:1 transformer instead of a choke, and obviously the effect produced is identical; an audio frequency change in the modulator anode current will induce a corresponding variation in the magnifier supply. It is, however, a useful feature that by winding the two coils in opposite directions on the core, the steady D.C. components of the two currents may be made to produce fields in opposition, so that their effects on the core cancel out. This absence of D.C. polarisation effects a considerable saving in iron. For a large set, such as 5XX, this is no small matter: even now the core of the choke is 5 in. × 5 in. cross section, the whole instrument being about 2 ft. × 3 ft. × 3 ft. over all. Each winding has an inductance of 24H so that a voltage of 3 000 is set up in it by an A.C. component of 24mA at 1000 ~

Across the valve side of the choke winding in the magnifier circuit is a condenser of ·0025 μF. capacity. The anode supply next passes through a radio choke of 3000 μH., consisting of single-layer coils on porcelain. The reaction of this to the radio-frequency current is 3 500Ω. The total current to the two valves is 2 400mA, giving an H.T. input of 24kW.

Turning now to the high frequency circuits; to the grid is connected a condenser-leak combination consisting of a ·0046μF condenser paralleled by a leak of 7000Ω. This leak is rather interesting, being constructed of cloth woven with asbestos warp and wire weft. The D.C. component of the grid current being 200mA, we see that the leak depresses the mean potential to − 1 400V. Next follows the tuned input circuit. This comprises a condenser of ·000 55 μF consisting of one Moscicki tube, across a coupling coil of 1280 μH. The H.F. resistance of this circuit is kept fairly high, the normal current in it (H.F. component) being 3A.

The Output Circuit.

The H.F. anode circuit commences with a stopping condenser of ·005μF. Next comes the main coil, common to the H.T. and output circuits. This is a large coil of litz wire on a skeleton framework. It is provided with anode and output taps, the latter including 450 μH. In series with it at the lower end are a variometer for fine adjustment (not shown in the diagram), and the aerial coupling coil, which is of 30 μH. The whole of the inductance is bridged by a large condenser of ·001 5 μF, consisting of plates about 6 ft. × 8 ft. hung about 8 in. apart in air. The lower end of the parallel circuit thus formed is earthed, providing the return circuit to the filaments for the anode circuit.

The Aerial Circuit.

As will be known to our readers, the aerial at 5XX consists of a single sausage about 450ft. long and 400ft. high, with a similar lead-in. Its capacity is ·0035 μF, and the inductance of the order of 20-30 μH. (it has not been measured accurately). The resistance of the aerial circuit at 1600 metres is 12·5O, a rather high figure, due to the fact that (the aerial being actually over the works) a rather inefficient earth has to be used instead of a counterpoise.

The only loading is a coil of 280 μH, coupled to the output coil already mentioned; the aerial current is 40A, corresponding to an output of 20kW, the magnifier input being 24kW of D.C.

The Modulator.

This consists of a bank of four special water-cooled valves,. They differ from the valves used in the magnifier by having more open grids, their μ being 8 and R_a 2800O. The filament input is the same as that of the others. The filaments are fed from the same supply as those of the magnifiers.

The grid circuit comprises a dry battery of 150 volts, with individual tappings for the four valves. Next comes the secondary of the input transformer. This is of 10 : 1 ratio, the secondary having 20 400 turns. The remainder of the grid bias battery comes next, amounting to 850V, 1000 being provided in all. The D.C. grid current is nil, so that ordinary receiver 100V batteries are used.

The anode circuit gets its supply from a single-phase 300~ generator, giving 1000V. This is transformed to 10 000V and rectified by a full-wave rectifier, each half of which consists of three M.R.7a valves in parallel. The filaments are supplied in common with those of the other rectifiers. The resulting D.C. is smoothed by a bank of 21H chokes combined with one ·36 μF. condenser and three of ·18 μF. The anode lead then passes through the second winding of the transformer or double speech choke already described, and divides to the four valves.

An ingenious point here is the method of indicating separately the anode current of each valve. This is necessary, because no two valves are absolutely identical—hence the individual grid battery trappings. To avoid the necessity of four individual expensive milliammeters, only used when making adjustments on rare occasions, each anode lead has a 2-ohm resistance inserted in it, and an ordinary voltmeter can be switched across each, thus showing the current. The anode current to the four valves is the same as that for the magnifiers: 2400mA, or 24kW of power.

General Design.

It must, of course, be understood that the general arrangement of the set is purely experimental. In particular, the division of the power has been governed not so much by design considerations as by the generators available in the Marconi Co.'s research laboratory, in which the set is located. In fact, we believe that the one and only piece of apparatus specially made for the set was the double speech choke. This seems to function so well that it may be adopted as a final design, even if both modulators and magnifiers should be fed from the same supply. It is interesting to note the total power input to the set (the efficiency of conversion from A.C. to D.C. for the anode supplies is estimated at 80 per cent.):—

		kW.
Filaments:	6 10kW valves at 20V 40A ..	4·8
	2 M.T.7a at 12V 25A ..	·6
,,	A.C., 14 M.R.7a at 12V 25A ÷ ·8 ..	5·2
Anodes:	Drive, 180mA	
	Magnifier 2400mA	
	Modulator 2400mA	
	4980 at 10 000V ÷ ·8 ..	62.0
		72·6

An Experimental Determination of High Frequency Resistance.

By *W. G. White.*

The high frequency resistance of copper wires is a matter of considerable interest to experimenters. In this article, Mr. White describes some experiments on its measurement.

THE following notes describe an attempt to evaluate the high frequency resistance of straight, round, copper wires. The temperature rise of a wire carrying direct current is compared with the temperature rise when carrying alternating current; thermo-junctions being employed for measuring the temperature.

The wire being tested was enclosed in an ebonite tube sealed at the ends as shown in Fig. 1. At the middle of the wire a thermo-junction was attached with the minimum of solder and brought out to a second junction, kept at a constant temperature, and connected in series with a galvanometer.

The circuit shown in Fig. 2 was employed to supply the test wire with current at radio frequencies. It was found that the circuit L_1, L_2, C_1, oscillated on a large number of different wave-lengths, and by adjusting the resonating circuit C_2, L_3 to any one of these frequencies currents of sinoidal wave form could be obtained in this circuit. The wave form was checked by means of a cathode ray oscillograph.

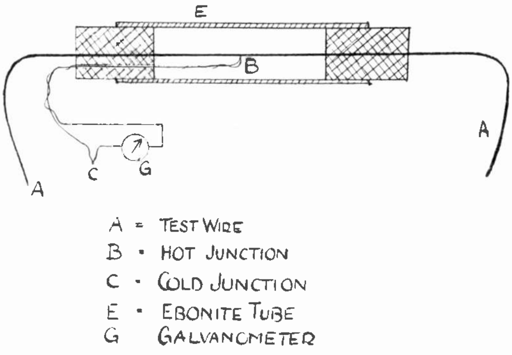


Fig. 1.

It was found essential to "anchor" the galvanometer to earth by means of condenser C_3 to prevent the instrument attaining a high potential and also to eliminate trouble from body capacity.

With a steady alternating current passing through the wire, readings of deflection and time were taken and the results plotted as shown in Fig. 3. Similar curves were also obtained using direct current. If, now, an ordinate be drawn up from, say, the five minute mark, the points at which the curves are intercepted represent the deflection of the galvanometer after carrying a certain current for five minutes, and these deflections are a measure of the temperature rise of the wire :

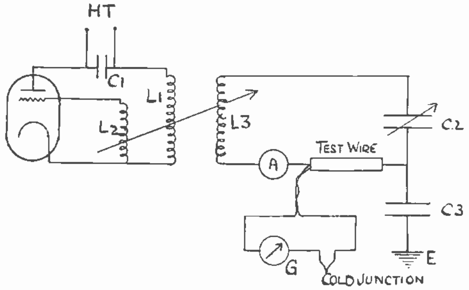


Fig. 2.

If d = deflection of galvanometer
θ = corresponding temperature rise
R = resistance of wire under test, then
d is proportional to θ
Then $d \propto \theta$. But $\theta \propto I^2$, so that $d \propto I^2$.

Fig. 4 is typical of the results obtained with different gauges of wire and shows that the method gives reliable readings.

Referring now to Fig. 4, we see that any particular deflection of the galvanometer (say 4·2) can be obtained both with alternating current and with direct current, the actual values in Fig. 4 being 4·3 amps. and 6·45 amps respectively, and from these values we can compare the resistance of the wire to alternating current, with the resistance to direct current, thus :—

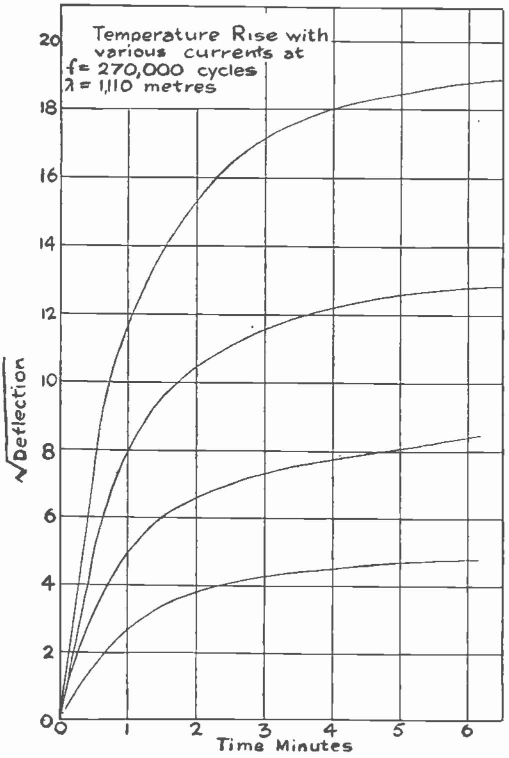


Fig. 3.

Let R_{dc} = resistance of wire to direct current.

R_{ac} = resistance of wire to alternating current.

I_{dc} = direct current producing the same temperature rise in a given time as an alternating current I_{ac}.

t = time, taken as 5 minutes in Fig. 4.

Then $I^2_{dc}\ R_{dc}t = I^2_{ac}\ R_{ac}t$

$$\therefore \frac{R_{ac}}{R_{dc}} = \left(\frac{I_{dc}}{I_{ac}}\right)^2 = m \text{ (say)}$$

The value of m obtained from Fig. 4, is :—

$$\left(\frac{6{\cdot}45}{4{\cdot}3}\right)^2 = \underline{\underline{2{\cdot}25}}.$$

Hence, at a frequency of 270 000 cycles, corresponding to a wave-length of 1 110 meters, the resistance of a straight wire of No. 18 gauge is 2·25 times its resistance as measured with a Wheatstone bridge.

Curves similar to those in Figs. 3 and 4 were also obtained with three other frequencies, and the whole series were repeated with three other sizes of wire.

The Table shows the range of frequencies and wires tested, together with the results obtained from the graphs.

TABLE SHOWING VALUES OF m.

Wave-length λ		1740	1110	510	335
Frequency f		172 400	270 000	589 000	896 000
$\sqrt{f}$		415	520	769	946
SWG.	Diam.				
22	0·711	1·37	1·5	2·125	2·44
20	0·915	1·58	1·88	2·59	3·0
18	1.22	1·96	2·25	3·2	3·7
16	1·63	2·6	2·94	4·23	5·15

The next point is to determine the connection between the results obtained and the values of diameter and frequency, and with this end in view the factor m is plotted against the square root of the frequency, Fig. 5. These graphs are linear in form over the range tested although they must bend somewhere lower down so as to pass through the value of $m=1$ at zero frequency, *i.e.*, the resistance is never less than its direct current value. From the figure it appears that the factor m is a function of the square root of the frequency and further the amplitude of the graphs appear to be a function of the diameter of the wire. This latter point is brought out more prominently in Fig. 6, where the factor m is plotted against the diameter of the wire in millimetres. These graphs must also pass through the value of $m=1$.

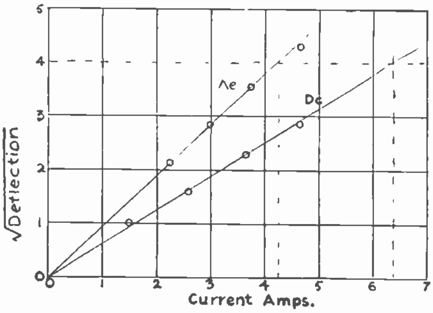
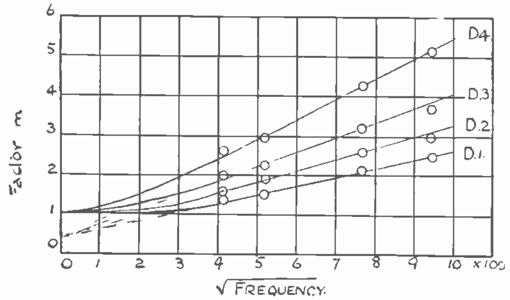


Fig. 4.



$D_1 = 0{\cdot}711$mm ; $D_2 = 0{\cdot}915$mm ;
$D_3 = 1{\cdot}22$mm, and $D_4 = 1{\cdot}63$mm.
Fig. 5.

From Figs. 5 and 6 it appears therefore that for the range tested the factor m may be defined by a simple expression of the form—

$$m = Kd\sqrt{f} + A, \text{ with } d \text{ in mm.}$$

Where K and A are constants.

The results of Figs. 5 and 6 are combined in Fig. 7 (full line), from which the value of A is found to be 0·4 and K = ·0309.

The subject of high frequency resistance has been investigated by Professor Morecroft but the results obtained by him do not appear to be quite consistent. For this reason it is hoped that although the results given here differ a little from those of Professor Morecroft, they may still be of some interest.

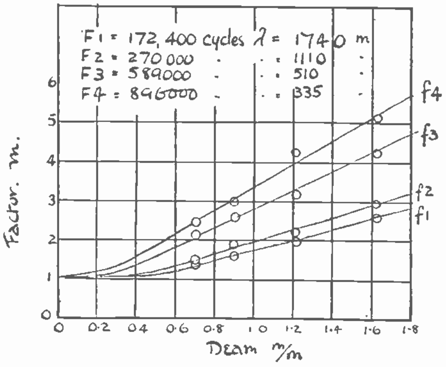


Fig. 6.

The copper and Eureka wires used for the junctions were of No. 36 S.W.G., but smaller wires would have been more suitable. These wires were carefully twisted together so that the e.m.f. induced in them by the oscillating circuit was neutralised as completely as possible. Without this precaution the galvanometer might easily have come to grief. The test wire was enclosed in an ebonite tube in order to eliminate variations in air temperature in the vicinity of the wire. It was found that if the small wires tested were exposed to the air, movements of the hand or body were sufficient to cause the galvanometer "spot" to swing about over a wide range.

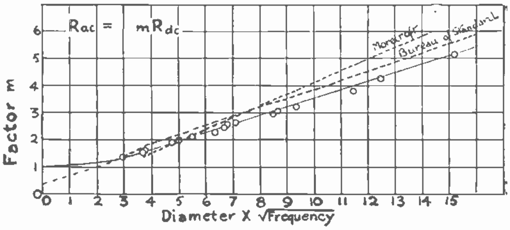


Fig. 7.

The method described above appears suitable for determining the high frequency resistance of heavy conductors used for transmitting inductances.

SUPPLEMENTARY NOTE.

(*By the Editor,* EXPERIMENTAL WIRELESS.)

It is interesting to compare Mr. White's experimental figures, and the empirical equation he derives from them, with the standard theoretical results and equations.

The complete equations for the ratio m are extremely complicated, but for values of $d\sqrt{f}$ (d=diameter in mm., f= frequency) greater than, say, 30, there are various approximations. Thus Fleming gives

$$m = {\cdot}033d\sqrt{f} + {\cdot}3 \quad \ldots \quad \ldots \quad \ldots \quad (a)$$

Morecroft does not give an equation, but from his curves one may find, for $d\sqrt{f}$ greater than 25 to 30

$$m = {\cdot}041\ d\sqrt{f} - {\cdot}55 \quad \ldots \quad \ldots \quad \ldots \quad (b)$$

While in the admirable Circular No. 74 of the Bureau of Standards of the U.S.A., "Radio Instruments and Measurements," we find a set of tables from which we can derive, for $d\sqrt{f}$ greater than about 30

$$m = {\cdot}033\ d\sqrt{f} + {\cdot}5 \quad \ldots \quad \ldots \quad \ldots \quad (c)$$

To Fig. 7 of the paper we have added dotted lines showing the results to be expected from formulæ (b) and (c). As would be expected from the equations in both cases, the values are higher than those obtained in Mr. White's experiments. Not knowing in exact detail the precautions adopted in the tests, we cannot say why.

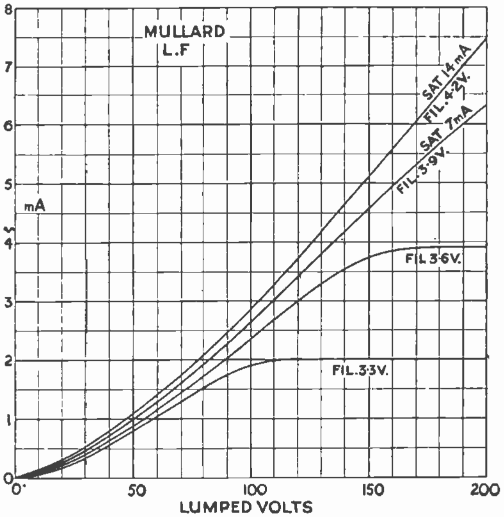
It will, of course, be realised that these equations apply only to straight wires, not coils, and only to copper wires. In the case of wires of other metals, not only is the resistance changed, but also the value of m, the ratio of H.F. to D.C. resistance.

Valves and Valve Testing

With three new productions as examples.

IN describing the results of one's tests on valves, one is naturally anxious to give the fullest possible information, while at the same time the information must be conveyed in a concise form. The usual series of curves, showing current in terms of grid bias for various H.T. voltages, is insufficient, as they do not give any idea of the effect of filament current. A series of three or four such sets would take too much space.

What then is needed ?



Direct information as to the μ, or voltage amplification, is useful for obvious reasons. But the anode impedance, R_a, is also highly important, as the choice of intervalve transformers or resistances to use depends on it. It is easily proved that the performance of a valve for transformer-coupled L.F. work, *with a transformer chosen to suit it,* is proportional to $\frac{\mu^2}{R_a}$, so this figure is useful. Also, for L.F. work, especially for use with the loud-speaker, it is necessary to know the saturation current, from which one can estimate the amount of power which can be handled without noticeable distortion. Since this varies with the filament heat, it is useful to have it (and the other constants mentioned) for various filament voltages. The filament current is also an obvious necessity. Lastly, in order to get the proper H.T. and grid voltages to use, one needs a characteristic for each filament voltage. But the usual set of several is not necessary. The result can be shown in *one* curve of the Eccles "lumped" type, if the μ is given. The Eccles lumped characteristic gives anode current for various values of *combined grid and anode voltage,* got by taking the anode voltage and adding μ times the grid volts (subtracting if the grid volts are negative).

It follows that if the lumped curve shows 2mA, say, for 100 lumped volts, then if $\mu = 8$ this current will be got by 0 on grid and 100 on anode, or $+2$ on grid and 84 $(100 - 2 \times 8)$ on anode, or -3 on grid and 124 on anode. So that from each lumped curve the reader can make, if he wishes, a complete set of either anode-volt or grid-volt curves.

Lastly, it is interesting to know, for comparison with other valves, what one may call the "filament efficiency" : milliamps of output per watt input to the filament.

This method then will be adopted in E. W. & W. E. (until some even better one is found) of giving maximum information in minimum space when describing new valves. Here follow the results on three recently to hand.

The New Mullard H.F. and L.F. Values.

These are put forward in the belief that the bright valve, with its robustness and comparatively low price, has still a long life before it. As regards the filament input they resemble the old type of R and similar valve ; but the electrodes have been redesigned in the light of later knowledge, and a considerably increased performance obtained.

A free arched filament is now employed, with U-shaped grid and anode. In the actual valves it is hard to see any difference between the L.F. and H.F. grids, owing to the magnesium deposit. Presumably the H.F. grid is of heavier wire. The "open" end of the U, below the filament, is also partly closed up in the H.F. The two are distinguished externally by a narrow coloured band round the bulb, red for H.F. and green for L.F. Another new point in construction is the use of a moulded ebonite cap without metal, said to give considerably less capacity.

As regards performance, the accompanying curves show lumped characteristics. In both cases the saturation current at 3·9 volts is about the same as that of a good "R," while at 4·2 volts it is much better. The H.F. valve has, throughout, a lower μ and R_a and a higher output than the L.F.: it has also a very slightly higher power amplification co-efficient. In fact, it would be the better valve of the two for L.F. but for the fact that for L.F. work one needs a fairly straight characteristic. It will be seen that the L.F. curve for 4·2 volts straightens out nicely at about 4mA, 100V., while the H.F. only begins to straighten at 200V, 8·6mA.

H.F.

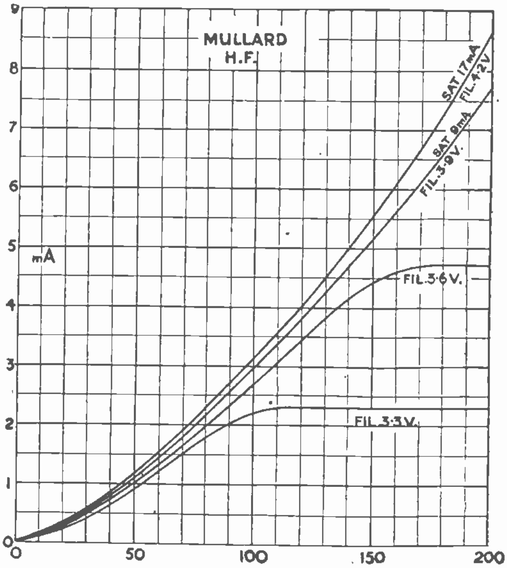
Fil. Volts. E_f	Fil. Cur. I_f	Sat. Cur. I_a	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. $P\left(=\frac{\mu^2}{R_a}\right)$	Filament Efficiency $=\frac{I_f}{\text{Watts.}}$
V.	A.	mA.	O.			
3·3	·66	2·3	31 500	7·7	1·88	1·05
3·6	·69	4·7	28 500	7·5	1·97	1·9
3·9	·73	9·0	25 500	7·3	2·08	3·15
4·2	·76	17·0	23 500	7·0	2·09	5·3

L.F.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Cur. I_a	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. $P\left(=\frac{\mu^2}{R_a}\right)$	Filament Efficiency $=\frac{I_f}{\text{Watts.}}$
V.	A.	mA.	O.			
3·3	·66	2·0	38 000	8·3	1·80	·92
3·6	·69	3·9	34 000	8·1	1·94	1·58
3·9	·72	7·0	30 000	7·7	2·00	2·5
4·2	·75	14·0	27 000	7·3	2·00	4·32

The Performance of the New Mullard Valves.

The H.F. valve is recommended as a detector, on account of its larger grid current at zero grid volts. This would hardly seem so very important, as detector performance would appear to depend really on the sharpness of curvature at the bend of the grid current curve. This was not tested, but judging by the makers' curves both valves would seem likely to do well. About 60-70V on the plate brings the steep part of the anode current curve well over the bend of the grid current curve. A 3-MO grid-leak is recommended.



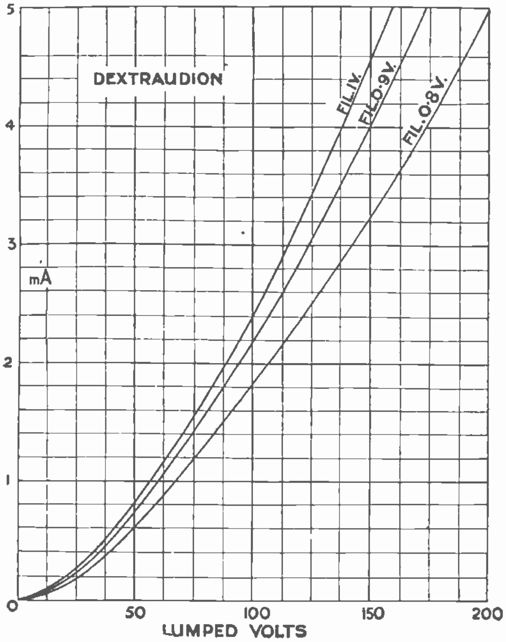
For loud-speaker work, reckoning on a grid swing of, say, 3V each way, the L.F. valve should do well if kept up to 4V or over on the filament. One might use the 4·2 volt curve from 3mA upwards, from which point it is fairly straight. The swing of 3V on the grid equalling 21V on the anode, we could use the 120-volt point to work on (=3·8mA). To allow for 3V of grid swing, 4V of bias would be advisable. As the lumped voltage is to be 120, this gives us $120+4\times7=148$, or, say, 150 volts as a good working voltage. This was found correct on test: we do not agree with the makers' suggestion that the L.F. valve will allow of L.F. amplification without grid bias.

Taken altogether, the two valves are well worthy of the makers' high reputation.

The Dextraudion.

The race to decrease the filament consumption of receiving valves is producing some surprising results, considering that it is only about a year or two since the dull emitter was only an experimental proposition. All that is wanted now is a valve with negative consumption, which will return energy to its filament circuit as well as to its input.

This has not yet arrived, alas! But we have just been testing a valve rated to consume ·1 watt, or just about half the power of the standard 60mA type. This is the Dextraudion, marketed by The Economic Electric Co. It is an oxide-filament valve, apparently—at any rate the filament works at the same dull red as in that type. It is to be noted that it costs only 21s.



The electrodes are of the same type as in the earlier E.E.C. valve, forming the top and sides of a rectangular box. They are, however, smaller.

On actual test, we found the filament consumption rather above the rating: as will be seen from our Table, it varies from ·125 to ·155. However, the valve works quite well at ·8 volt, so that the watt rating is correct.

The voltage magnification is curious in being, as far as we could tell, constant over the whole range tested. We found, however, quite a difficulty in testing, as the anode current showed a tendency to "creep." On increasing the anode voltage, for example, the current would jump to a higher value and then go on increasing slowly for some time.

	Fil. Volts. E_f	Fil. Cur. I_f	Sat. Cur. I_s	Voltage Ampli. μ	Anode Impedance. R_a	Power Ampli. $\frac{\mu 2}{R_a}$
	V.	A.	mA.		O	
DEX-TRAUDION	·8	·125	—	7·4	45 000	1·2
	·9	·135	—	7·4	35 000	1·56
	1·0	·145	—	7·4	30 000	1·8
	1·1	·155	—	7·4	29 000	1·85

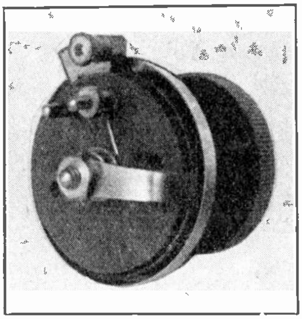
This is connected, we believe, with the fact that the valve is distinctly soft. We could find no signs of a saturation current: but on raising either the grid or the anode volts so that the current rose much above about 5mA, the valve blued up distinctly: the space is so small that it was hard to say exactly. Since any ionisation is likely to damage a coated filament very quickly, we did not like to force the valve.

It is likely, on this account, to make a good detector, but as we have not yet found a quantitative method of expressing the detecting properties of a valve, we cannot express an opinion, except that it seemed to work very well.

The curve for 1·1V on the filament was practically coincident with that for 1V.

A GOOD VARIABLE GRID-LEAK.

Our readers frequently inquire whether we know of a satisfactory variable grid-leak, and we have pleasure in reporting on one which, at any rate on a preliminary test, gives excellent promise.



This is made by J. Anderson, 60, Garfield Street, Watford, and the general arrangement is that of a miniature filament rheostat, with the coil replaced by a stick about $\frac{1}{16}$ in. diameter of some black substance—nature unknown. We tested it at the extremes of its travel, and at three other points about equally spaced, with the following results in megohms:—

Position:	min.	¼	½	¾	max.
Resistance:	·18	1·35	3·25	6·5	9·7 M O.

Results consistent to 2 per cent. were obtained the next day; but whether tests over a long period would be equally good we cannot, of course, say. We are inclined to recommend our readers to try.

The Problem of High-tension Supply.—IV.

By R. Mines, B.Sc. (Eng.).

(*Continued from August issue, page* 652.)

Impulse Generators.

IN view of the requirement of a supply of power at a steady high potential, it would appear that apparatus coming under this heading would be the last kind to use if this result is to be secured. As the name implies, such generators produce successive pulses or peaks of potential, which with a suitable load are followed by corresponding rushes of current. These impulses follow one another usually at a steady rate, the frequency depending upon the design of the apparatus.

Nevertheless under the heading, "Use of an A.C. Supply," have been described methods in which the uni-directional power supply is in the first instance available only in pulses of short duration relative to their time period; therefore although the impulse generator as a source of high-tension power may prove to be a degree worse than the "rectified alternating supply," the difficulties involved in its use are of the same nature and are not insurmountable.

The Induction Coil.

Most experimenters will have had personal acquaintance with this piece of apparatus, so there will be no need to describe its construction here. In the common method of using the device (invented by MASON and improved by RUHMKORFF) power from a D.C. source, usually a battery, is applied to the primary winding, and in the primary circuit is included an essential auxiliary device, the Interrupter, which alternately makes and breaks this circuit. As a result of the periodic interruption and re-establishment of the primary current, there are alternations of growth and decay of the magnetism in the iron core, and this by ordinary induction, as in a transformer, gives rise to pulses of electromotive force in the secondary windings; these pulses correspond to the alternate making and breaking of the primary circuit and therefore occur alternately in opposite directions. Further, due to the inductance of the primary winding with its iron core, the growth of the current on making the circuit is necessarily comparatively slow, whereas the stoppage of the current on breaking the circuit can with a suitable design of interrupter be made exceedingly sudden.

We thus arrive at the characteristic feature of the Induction Coil as an impulse generator, that the pulses in one direction are very intense and of short duration, while those in the opposite direction (known as "inverse") last for a considerable portion of the cycle and are comparatively weak.

Evidently the induction coil constitutes a simple and useful source of power at a high potential, and since early days it has proved its utility for exciting discharge tubes and similar experimental work. In its modern powerful forms it is still one of the important means of supplying large X-Ray tubes; but in this work it is found advisable to combine it with a rectifier device, unless a "self-rectifying" tube is being used, because in the X-Ray tube, "inverse current" involves heating of the tube without any corresponding useful production of X-Rays.

If such an apparatus is to be used for feeding power against a steady P.D. then a rectifier becomes an essential part of the equipment, just as with the A.C. transformer previously considered; otherwise power would flow backwards all the time that the varying P.D. of the generator falls below the steady P.D. of the load circuit, and especially while the inverse pulse is occurring. The simplest arrangement is to use a single rectifier, as shown in Fig. 1A of our Part II. in the July number, in which case the connections will be arranged so that it is the intense pulse (due to breaking of the primary circuit) that is utilised. (It would be possible, but uneconomical, to use the inverse pulse instead.) We have seen also how by using two or four rectifiers (see Figs. 2A and 3, July number) it is possible to use both the half-waves of the A.C. input ; for with a true A.C. supply the half-waves are similar in magnitude and duration. On the other hand, the induction coil, as above described, does not permit the use of both pulses, because of their dissimilarity.

Modifications of the Induction Coil Method.

In the classical method above described, the essential desideratum is always to make the breakage of the primary circuit as sudden as possible, as this gives the maximum peak value of the secondary potential for a given size of coil. Now a heavy current flowing through an inductive circuit is the most difficult kind to interrupt, and much research has been devoted to the development of interrupters to perform this task.

This problem may be attacked however from quite a different point of view—for example, by controlling the cyclic variation of the inductive energy in the primary circuit. Wilson's* first attempt in this direction was along the following lines :—

Energy from the supply was stored in a separate inductance ; this inductance was coupled to an oscillatory circuit of long periodic time, so that when the supply circuit was interrupted, the inductive energy was transferred to a condenser relatively slowly. Subsequently a third brush on the interrupter short circuited the inductance, so that the condenser discharged with extreme rapidity through the primary winding of the induction coil. This rapid discharge entails a very sudden growth (instead of decay) of the primary current and so a high peak of potential on the secondary, combined with an almost sparkless interruption on the primary, two conditions which with the old method were incompatible.

This system had the disadvantage of giving a very low pulse frequency, due to the complicated cycle of operations that had to be controlled by the interrupter switch, and in addition the operation of the switch was by no means sparkless. A new method* was evolved therefore, one of the aims of which was to reduce the inductive energy to zero at the instant of rupture of the primary circuit, so that there would be no current to "interrupt" and hence little tendency to spark. This time the energy from the supply is stored in a large condenser ("C" in Fig. 1A). The rotary interrupter, when properly adjusted for timing, breaks the supply circuit at the instant when the charging current flowing from the supply through the primary p of the spark coil, and so the inductive energy in this primary, is zero. The condenser has shunted across it an auxiliary inductance L, and through this it begins to discharge as soon as the supply is disconnected. The discharge overshoots itself, due to the fly-wheel effect of L, in other words, the circuit LC oscillates at its own natural frequency. The interrupter reconnects the supply as soon as the condenser has reversed its polarity, so that a further pulse of current flows from it in the correct direction to "boost up" the oscillation in the circuit LC. The action is exactly similar to the building up and maintenance of the swing of a clock pendulum by the "impulse" delivered through the escapement.

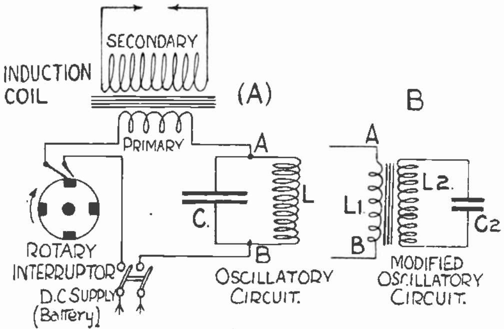


FIG. 1.
[WILSON, 1922]

Obviously it is necessary for the interrupter to be driven at a constant speed, which must be closely adjusted to give the required condition of resonance with the circuit LC. The drive may conveniently be an electric motor, running from the battery supply ; but if instead a synchronous motor is used, drawing power from the oscillatory circuit (preferably through a miniature transformer), then this circuit fixes the speed to suit itself, thus eliminating the necessity for a critical

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* W. H. Wilson. *Jour Röntgen Soc.*, p. 64 (1911).

* W. H. Wilson. *Jour Röntgen Soc.*, 18, 143 (July, 1922).

speed control, requiring adjustment with every change of battery P.D. or other condition (such as heating of the apparatus). There is the difficulty of starting the synchronous motor (running up to the synchronous speed), but with a small machine it is possible to arrange for this to be done by hand.

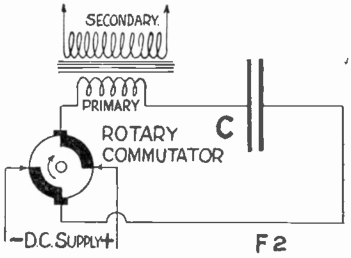
As a result of the resonance established in the circuit *LC*, a high value of alternating P.D. appears between the points *A* and *B* (Fig. 1A); and during the period of connection of the supply by the rotary interrupter, this P.D. is in such a direction as to help the supply P.D. in sending pulses of current through the primary *P*. These pulses are, therefore, many times larger than would obtain if the circuit *LC* were absent, or were not resonating with the interrupter frequency.

The more intense pulse of E.M.F. on the secondary occurs at "make" of the interrupter and not at "break," since as a result of the resonant P.D. of the circuit *LC* the growth of the primary current is more sudden than its decay: for the same size of coil this pulse is of the same order of magnitude as, but lasts much longer than, the intense pulse obtained at "break" of the primary current with an ordinary interrupter. Thus with Wilson's arrangement an induction coil gives much more power, while the moving part of the auxiliary equipment, the interrupter switch, is simpler and trouble-free; the apparatus is no improvement in the matter of "inverse current," a rectifier must still be used to suppress it if a steady D.C. output is required.

One should note here, however, that in practice a modification is made to the primary circuit. Owing to mechanical limits to the speed of the interrupter and the number of segments it may be fitted with, the frequency at which the circuit must oscillate is necessarily low, and so both the inductance *L* and the condenser *C* must be large. It is found more convenient to substitute a step-up transformer for the inductance as shown in Fig. 1B, and the condenser, which now need be of only a small capacity, is connected across its secondary. With this arrangement it is the secondary circuit that oscillates; but due to the close coupling with the primary, the effect on the induction coil primary is the same.

The Induction Coil as a Transformer.

We see that in the methods so far described the high-tension output consists of two dissimilar pulses, only one of which is useful; it is natural to inquire whether it is possible to secure symmetry in the output wave-form, *i.e.*, to make the two pulses alike as with an A.C., for by this means an increased power output is obtainable from the same size of apparatus. A suggestion for securing this result, is that the input current should be reversed in direction through the primary winding of the coil, instead of being merely started and stopped by the rotary switch. The amplitude of the change of magnetic flux in the iron core which occurs at each operation of this switch is therefore double its previous value, and it should be possible to obtain twice the energy from the secondary at each pulse; further, the symmetry of the pulses enables both to be used, so the actual gain should be four-fold.

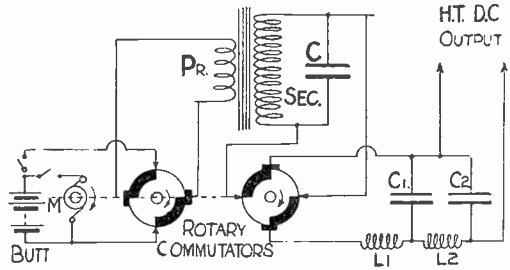


F2

THE INDUCTION COIL AS A TRANSFORMER

Now the problem of reversal of the primary current may be attacked in a manner similar to the problem of its interruption. Fig. 2 shows a condenser connected in series with the primary winding of an induction coil, the combination being connected to a D.C. source of power through a rotary reversing switch or commutator instead of an interrupter. This switch is preferably driven at constant speed by an electric motor.

With the commutator in the position shown, a charging current flows from the supply until the primary and the left-hand condenser plate are charged to the potential of the positive pole of the supply, and the right-hand plate is at the potential of the negative pole. After a quarter of a revolution, however, the commutator reverses the connections; the condenser therefore discharges and then recharges in the opposite direction. The corresponding current rush is in the opposite direction in the primary and condenser circuit, but due to the reversed connections at the commutator it is in the same direction in the supply circuit. Similarly, when the commutator has completed half a revolution, the condenser charge reverses, again accompanied by a current rush through the primary winding, and so the cycle repeats itself. Now in this method again we have an oscillatory circuit, composed of the inductive primary and the condenser; and if the speed of the rotary switch is adjusted so that the frequency of reversal is equal to the natural frequency of this circuit a condition of resonance will be established.



F.3

R. BARTHÉLEMY'S Stato-Mechanical Converter

Under this condition the electrical oscillation builds up to a maximum, and approximates to a sinusoidal wave-form; thus an amplified alternating P.D. appears across the primary terminals, which may be regarded as assisting the small supply P.D. to pump large current pulses through the primary, as occurs with Wilson's apparatus. The current drawn from the D.C. supply is of course uni-directional, but is in pulses corresponding to each half-wave of the primary oscillation. The output P.D. appearing at the secondary terminals of the induction coil is a symmetrical alternating P.D., and the problem of its use for providing a steady high-tension supply may be attacked on the lines laid down in the section on "Use of an A.C. Supply." In this connection it may be remarked that the method invites the use of a mechanical rectifier (rotary type), for this may be mounted on the same shaft with the commutator in the primary circuit.

As with Wilson's apparatus, there is a mechanical limit to the frequency that may be attained, involving an unduly large condenser, especially since the inductance available in the primary is a fixed quantity. A similar way out of the difficulty presents itself in this case, with the added advantage, however, that there is no necessity for a separate step-up transformer to be used—the small condenser may be connected direct across the induction coil secondary. With this arrangement therefore the two stages of amplification of the P.D. occur both in the same circuit—the one due to the stepping-up by the induction coil functioning as a transformer, the other due to resonance in the secondary circuit.

This modified arrangement, combined with a mechanical rectifier, is the "Stato-Mechanical Converter" recently developed by R. Barthélemy.[*] Fig. 3 shows the complete apparatus, as designed for supplying the high-tension power for a 3-valve radio transmitter. The complete converter (built in 1918) was contained in a rectangular box occupying about 1/9 cubic foot. It was operated from a 12-volt storage battery, and supplied 50 to 60mA. at 350V with an overall efficiency of about 60 per cent. The electrical conditions necessary to secure sparkless operation of the commutators are dealt with in detail in the original paper. With 25A being drawn from the battery, there was no sign of current flow at the low-tension brushes except some rise in temperature. The filter shown had inductance of 100H. and condensers of 1μF., and was stated to render the P.D. wave sufficiently pure for use on radio telephony.

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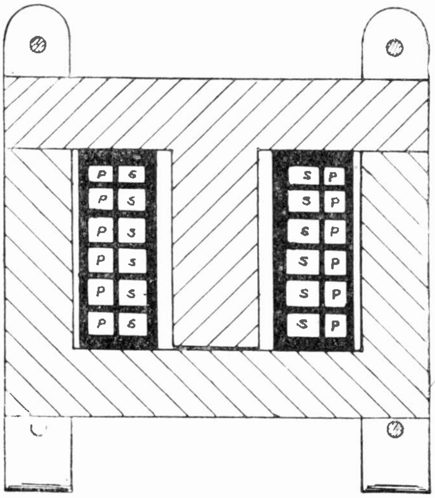
[*] *Rev. Gén. d'Elec.*, 10, p 659 (Nov. 12, 1921), *R. Barthélemy* . . .

A New R.I. Transformer.

The new L.F. Intervalve transformer which has just been put on the market by Messrs. Radio Instruments, Ltd., is interesting, apart from any other things, because it has been designed to supersede a type of which 250,000 have been sold with satisfaction during the last two years.

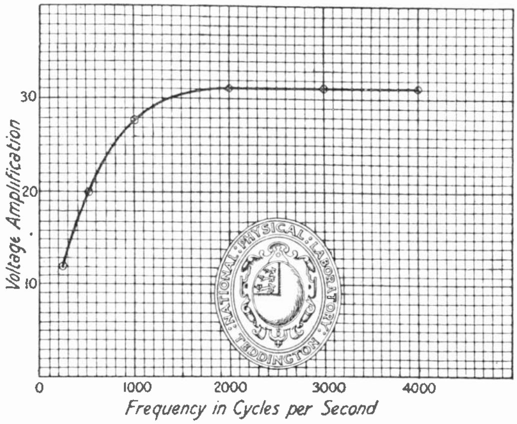
According to the information supplied by the maker, much trouble has been taken in the new type to get the best performance possible consistent with robustness and a reasonable selling price. There must necessarily be a compromise here, for theoretical design calls for larger windings than can be put on if fairly heavy wire is to be used. According to Messrs. Radio Instruments, the primary, of 3,000 turns, gives 11H, and the secondary, of 12,000 turns, 160H. (It is curious that there should be such a distinct divergence between the ratio of inductance and the square of the turns ratio.)



The performance, both as regards amplification and distortion, is well shown by the N.P.L. curve reproduced. Presuming that, as usual, the N.P.L. tested on a valve with a μ of about 8·3, we see that at all frequencies above 2,000 the step-up is 3·75, while there is less than 20 per cent. falling off—about the smallest that can be noticed—at frequencies over 800.

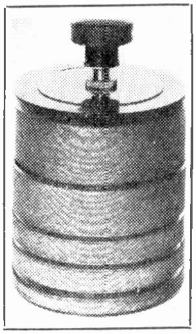
It is to be noted that a special effort to reduce self-capacity has been made, by winding both primary and secondary in sections, the arrangement being according to the sketch reproduced. By this means the (presumably total) self-capacity has been reduced to $18\mu\mu F$, a quite exceptionally low figure.

Tested on actual telephony, the results were very good. We have adopted as standards on our set various transformers of well-known commercial makes which represent first-class current design, and the R.I., when tested against these for strength, showed the following results: after a crystal 1·2 × standard; after an ordinary valve of 30,000 ohms anode impedance, equal; after a power valve of 6,000 ohms, 1·2 × standard. The tone was excellent throughout. Two points needed care: first it is important to find the right connections by trying the windings reversed; they are made unusual by the fact that the secondary is inside the primary: second, owing to its very low self-capacity, it is very sensitive to capacity across the secondary, and can be given any desired tone in this manner. We found a small condenser an improvement.



A Ready-made Tapped Coil.

Those amateurs who at any time want a neat tapped coil all ready for panel mounting may care to remember the "Success Tuner" of Messrs. Beard & Fitch. Our illustration shows the general design; it is of the one-hole fixing type. An 11-point switch is fitted at the back end, operated by a central spindle: the switch is a good mechanical job.



Only the extremes of the inductance were tested: on stop 11 it was $5800\mu H$, on stop 1, $80\mu H$. In the latter position the self-capacity was approximately $45\mu\mu F$, so that the instrument with a ·001 variable condenser, will tune from 135 metres to 4750. H.F. resistance was not measured, but should be low; the wire appears to be 28 S.W.G. D.C.C.

The instrument is priced at 21s., which seems high. There is, however, a good deal of work in it.

Correspondence.

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.

MONSIEUR LE REDACTEUR D' " EXPERIMENTAL WIRELESS,"—Faisant actuellement une étude détaillée des redresseurs électrolytiques, j'ai lu avec un intérêt particulier l'article de Mr. E. H. Robinson, dans le numéro du mois d'Août, sur le fonctionnement de ces redresseurs aux fréquences élevées.

Je puis vous signaler que cette question a été étudiée par Zenneck (*Elektroteknische Zeitschrift*, 24 mai 1923, t. XCIV., p. 501), ainsi que par A. Gûnther-Schulze, R. Lindeman et E. Alberti, qui ont trouvé que l'effet de soupape se manifeste encore à la fréquence 3.10^5 et qui ont conclu que, puisque l'effet redresseur existe encore à ces fréquences élevées, c'est qu'il ne s'agit pas de séparation ou de formation d'ions, mais seulement de phénomènes électroniques.

Dans un précédent article, Mr. E. H. Robinson a trouvé tout à fait " hopeless " l'emploi du borax comme électrolyte pour ces redresseurs. Des essais que j'ai faits à ce sujet il résulte que *certains* borax ne donnent, en effet, *aucun* redressement ; *certains autres* donnent un redressement médiocre ; *d'autres* enfin donnent un redressement *excellent.* Ces différences dans les résultats sont probablement dûes à divers degrés de pureté du sel employé. Il faut remarquer, à ce sujet, que la plupart des Américains qui emploient avec succès le borax, spécifient qu'ils se servent de " 20 *Mule Team Borax,*" ce qui est probablement une marque de borax particulièrement purs.

Recevez, Monsieur le Rédacteur, mes bien sincères salutations.

DR. PIERRE CORRET (8AE).

(*Translation*)

As I am actually engaged in a detailed study of electrolytic rectifiers, I have read with particular interest the article by Mr. E. R. Robinson, in the August issue of EXPERIMENTAL WIRELESS, on the performance of these rectifiers at high frequencies. It may be noted that this question has been studied by Zenneck in *Electrotecknische Zeitschrift* of May 24th, 1923, Vol. XCIV., page 501, also by A. Gunther-Schulze ; R. Lindeman ; and E. Alberti ; who find that rectification is still possible even up to frequencies of 300 000. They conclude that in view of this fact, rectification cannot be due to the separation or the formation of ions, but is essentially an electronic phenomenon.

In an earlier article Mr. Robinson has found the use of Borax " hopeless " as an electrolyte in these rectifiers. My own experiments on the subject show that certain samples of borax certainly give no rectification. Others, however, give fair results ; and others again perform excellently. These differences are probably due to the varying degree of purity of the borax employed. It should be noted that the majority of the successful users of borax in America use the brand known as " 20 Mule Team " Borax. Presumably this is a particularly pure brand.

SIR,—I was very interested in E. H. R.'s account of his experiments with electrolytic rectifiers at high frequencies, but although I have never worked at this branch of the subject myself, I must confess to a difference of opinion with him about the operation of the rectifier.

That the efficiency of an electrolytic rectifier falls off with increase in the frequency of the alternating current is an established fact, but I cannot agree with E. H. R. in explaining this fact by the time taken, or the work done, in forming or destroying an oxide film. In the light of modern work such an explanation is untenable ; the reasons for this are too long and numerous to be given here, I can only refer those who are interested to the *Transactions of the Faraday Society,* Vol. IX, p. 266, or to my book on the Electrolytic Rectifier.

The decrease in efficiency with increase in frequency can only be explained by the capacity of an aluminium anode, and as E. H. R. has pointed out, this capacity is considerable. Therefore the capacity must be kept down; E. H. R. has accomplished this by using very small anodes, but there is another method of reducing the capacity. An aluminium anode has a smaller capacity in fused electrolytes than in aqueous electrolytes, therefore a rectifier with a fused salt as electrolyte should be more efficient on high frequencies than one with a solution. A. Gunther Schulze and E. Alberti (*Phys. Zeits.* 23, p. 188-191, 1922) by using fused potassium nitrate as electrolyte, have rectified currents of 300 000 cycles per second.

N. A. DE BRUYNE.

Charges on Aerials.

SIR,—I noted with interest the correspondence in your August issue *re* the charging of aerials from atmospheric electricity.

Mr. Bligh suggests the use of steel points for a spark gap, but I should like to point out the disadvantage of these. My experience has been as follows. A *steel* point gap was installed and adjusted with a very narrow gap, a very small fraction of a turn of the threaded rod being required to short-circuit the aerial to earth. The gap was then left unattended for some months. One evening signals were noisy and intermittent and eventually ceased. A fault in the receiver was immediately expected and looked for but a long search failed to reveal any loose connection. On inspection it was found that the steel points had rusted and shorted across, thus effectually stopping reception. Brass is also liable to corrosion, although not so fast. Nickel seems the best metal; in fact, high-class work which calls for similar conditions is always done in solid nickel.

As mentioned by Mr. Bligh, spark gaps *do not* lead to inefficiency if properly constructed, and they are the only satisfactory way of protecting the aerial, especially when experimental work is being carried out on atmospheric effects which calls for the use of an aerial when in the normal way it should be left alone! Another interesting point in connection with the leakage of the charge from points. It is a well-known fact that a pointed conductor will soon lose its charge by leakage and it occurred to me that a well-insulated aerial with all the ends tucked away and finished off will be a greater source of danger than one in which loose ends are left, or one such as is occasionally seen with wire "spider-webs" attached to it from which the charge would rapidly leak, particularly if there are any wet trees, etc., in the vicinity.

H. A. CLARK.

Telephony Reception.

SIR,—I was particularly interested in Mr. H. J. Neill's "Telephony Reception" in your this month's issue, the subject being one in which I am—it is not too much to say—engrossed. Quantity—with *quality*.

I would esteem it a favour to have a little further information on one point. In the matter of air-space inductance, the superiority of which is easily demonstrable, on page 632, col. 1, Mr. Neill speaks of "the *closed* circuit inductance . . . wound on a hexagonal frame 6 ins. across. . . ." I have used a similar A.T.I. (on the "broadcast" wave-band of course) for a long time now, but—my difficulty is a practical one—I am still seeking a really good method of working a loose-coupled circuit with inductances of the type mentioned. Without occupying too much of your space, would Mr. Neill tell us—I feel others would be interested—how he arranges the coupling between primary and secondary and the proportions of the two coils, and if possible the shape and nature of the reaction coil shown associated with the C.C.I. in the diagram? I can only express my sincere thanks for the article as a whole—thoroughly worthy of the character of your publication. That is saying, in my humble opinion, a very great deal. Thanking you both in anticipation.

H. MASON.

"A Universal Meter."

SIR,—With reference to the article on "A Universal Meter" in the July issue, I am afraid Mr. Dyson has neglected an important consideration in stating that the instrument has an even scale. The condition for this desirable feature is that the field in which the coil swings shall be uniform and *radial*. This is secured in commercial instruments by the use of curved pole-pieces on the magnet and by fixing a cylinder of soft iron inside the coil, which is necessarily wound on a hollow framework instead of a hollow former. Incidentally this decreases the air-gap and makes the instrument more sensitive.

In the arrangement described by Mr. Dyson the field would be parallel, and the law of the instrument :—

$$C = K \times \frac{\theta}{\cos\theta}$$

Instead of :—

$$C = K\theta$$

If the latter law is assumed, an error of about 13 per cent. will be introduced at each end of the scale, if the middle is correct, assuming the whole scale to be 60°, while if it extends to 120°, as the writer appears to indicate, the error will be as high as 50 per cent. This presumes that the control is torsional: actually a bifilar suspension is employed which tends to modify further the calibration, but owing to the closeness of the two wires, the control is almost entirely torsional.

I do not wish to suggest that such a meter is useless, but it would need calibrating at more than one point.

E. LESTER SMITH.

A.D. Cells.

SIR,—We note that in your issue of August, on page 647 (dealing with High-Tension Supply), it is stated that our A.D. Cells were invented by Fery, and are being marketed in this country under the name of A.D. Cells.

May we point out to you that A.D. cells were invented by us, and that they will shortly be manufactured in large quantities at our new works at Portslade, Sussex.

Will you kindly correct this wrong impression in your next issue.

LE CARBONE.

Spark Jamming.

SIR,—In your remarks concerning the reply of the Post Office officials about the question of spark jamming of broadcasting, I believe you lay rather too much emphasis on the poor selectivity of broadcast receivers. I would venture to say that very little can be done to eliminate spark jamming if retroaction is already in use. It is well known that the decrement of a receiving circuit approaches zero when the set is on the point of oscillation, as it usually has to be when reception is over a long distance. In such a case, any jamming will be due almost entirely to the transmitting stations large decrement.

The writer recently tested a super-heterodyne receiver at 3½ miles from 2LO, and using a good indoor aerial and low resistance earth 2LO could be cut out if the receiver was detuned to a frequency differing by 5 kilocycles. That is to say, it was possible to receive Le Petit Parisien on a loud-speaker without trace of 2LO when that station was working on a wave-length midway between 5WA and 2LO.

This same receiver was later used in Cornwall and found no more selective than a standard set with two stages tuned H.F. and simple circuit tuning. FFU working on ±600 could be read when 6BM or 5WA were tuned in and all the French trawlers (who are responsible for 80 per cent. of the spark jamming in this region) interfered just as much as on the standard set operated just off point of oscillation.

The only way we have available for increasing selectivity is to be found in the conjoint use of a frame and an open aerial to give heart-shaped reception.

I hope this letter is not too long, but I feel that those who pride themselves on being able to cut out their local station at 3 or 4 miles should realise that this is not the same thing as eliminating a flatly tuned spark station.

R. H. P. COLLINGS.

A French Short-Wave Transmission.

SIR,—I have been asked by F8ÉK to inform the English Wireless Press that he transmits telephony and CW every Wednesday from 9 p.m. till midnight on a power of 50 watts and on wave-lengths between 80 and 150m. His QRA is, Mons. Ateliers Lemouzy, 42, Avenue Philippe-Auguste, Paris (XI^{e}).

I trust the above is quite clear and will be of interest to you.

C. L. WARD.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the early issues of "Experimental Wireless."

I.—TRANSMISSION.

Emission sur Ondes Courtes par Antennes Dirigées.—H. Chireix (*R. Elec.*, 5, 64).

Essais d'Emission et de Réception sur Ondes de 35 Metres.—A. Vuibert (*Onde Elec.*, 31).

Third Harmonic Transmission.—F. D. Bliley. (*Q.S.T.*, 8, 1).

Fixed Condensers for Sending Sets.—H. F. Mason (*Q.S.T.*, 8, 1).

Telephony and C.W. Transmitters for 100 Metres.—G. E. Alinvalla, A.C.G.I. (*Exp. W.*, 1, 11).

Notes on Systems of Modulation Employed in Radio Telephony.—H. S. Walker (*Exp. W.*, 1, 11).

The Poulsen Arc.—D. G. Bower (*Exp. W.*, 1, 11).

Rundfunksender. —W. Schäffer (*Telefunken-Zeitung*, 37).

II.—RECEPTION.

La Réception à la Station de Sambeek.—N Koomans (*R. Elec.*, 5, 64).

Les Amplificateurs à Résistances pour Basse Fréquence.—L. Brillouin (*R. Elec.*, 5, 64).

Générateur-Amplificateur Sans Lampe.—I. Podliasky (*R. Elec.*, 5, 64).

More About Crystal Reception.—F. M. Colebrook, B.Sc. (*W. World*, 258).

Loud-Speaker Horn Design.—H. J. Round, M.C. (*W. World*, 258).

Coil Design for Crystal Reception.—F. M. Colebrook, B.Sc. (*W. World*, 259 and 260).

Étude Expérimentale de quelques Procédes de Détection des Oscillations de Haute Fréquence.—R. Dubois (*Onde Elec.*, 31).

A One-Control Neutrodyne.—J. L. McLaughlin (*Q.S.T.*, 8, 1).

Building Superheterodynes that Work.—(*Q.S.T.*, 8, 1).

The Prevention of Radiation from a Radio Receiver.—Dr. L. M. Hull (*Q.S.T.*, 8, 1).

Receiving Aerials of Low Resistance.—N. W. McLachlan, D.Sc. (*Exp. W.*, 1, 11).

Telephony Reception.—H. J. Neill (*Exp. W.*, 1, 11).

Transatlantischer Rahmen-Schreibempfang.—O. Schade. (*Jahrb. d. Drahtl. Tel.*, 23, 4-5).

Long Distance Radio Receiving Measurements at the Bureau of Standards in 1923.—L. W. Austin (*Proc. I.R.E.*, 12, 4).

The Marconi Four-Electrode Tube and its Circuit.—H. de A. Donisthorpe (*Proc. I.R.E.*, 12, 4).

The Performance and Theory of Loud-Speaker Horns.—A. N. Goldsmith and J. P. Minton (*Proc. I.R.E.*, 12, 4).

III.—MEASUREMENT AND CALIBRATION.

Methods of Wavemeter Calibration.—Maurice Buchbinder (*W. Age*, 11, 11).

A Résumé of Modern Methods of Signal Measurement.—J. Hollingworth (*W. World*, 258, 259 and 260).

Plotting Valve Curves Automatically.—W. Baggally (*W. World*, 259).

An Accurate Wavemeter.—E. L. White (*Q.S.T.*, 8, 1).

Uber ein Empfindliches Röhrenvoltmeter fur Kleine Wechselspannungen.—L. Bergmann (*Telefunken-Zeitung*, 37).

IV.—THEORY AND CALCULATION.

Theory of Thermionics.—H. A. Wilson (*Phys. Rev.*, 24, 1).

On the Calculation of Inductances and Capacities for Multi-Range Tuned Circuits. —J. Erskine-Murray (*Proc. I.R.E.*, 12, 4).

V.—GENERAL.

Sound in its Relation to Radio.—John P. Minton, Ph.D. (*W. Age*, 11, 11).

Building a Rectifier.—(*W. World*, 260).

Etablissement des Avant-Projets d'Emetteurs à Triodes.—Lieut.-Blanchard (*Onde Elec.*, 31).

More About Low Loss Coils.—(*Q.S.T.*, 8, 1).

A Simple Rotary Rectifier.—A. Butement (*Exp. W.*, 1, 11).

Some Experiments with Electrolytic Rectifiers at High Periodicities.—E. H. Robinson (*Exp. W.*, 1, 11).

The Effect of the Earth in the Transmission of Electromagnetic Waves in Radio-Telegraphy.—Prof. G. W. O. Howe (*Electn.*, 2412).

The Energy of Atmospherics.—T. L. Eckersley (*Electn.*, 2412).

Some Radio Direction—Finding Observations on Ship and Shore Transmitting Stations.—R. L. Smith-Rose, Ph.D. (*J. Inst. Elec. Eng.*, 62, 332.)

Method of Producing a Square Wave of Radio Frequency.—J. L. Bowman (*Phys. Rev.*, 24, 1).

Experimentelle Untersuchungen über Schwingungskreise mit Eisenkernspulen.—L. Casper, K. Hubmann and J. Zenneck (*Jahrb. d. drahtl. Tel.*, 23, 4-5).

Wellentelegraphie und Vorgänge in der Atmosphäre.—K. Stoye (*Jahrb. d. drahtl. Tel.*, 23, 6).

Distribution of Radio Waves from Broadcasting Stations over City Districts.—R. Bown and G. D. Gillett (*Proc. I.R.E.*, 12, 4).

The Limit of Regeneration.—N. C. Little (*Proc. I.R.E.*, 12, 4).

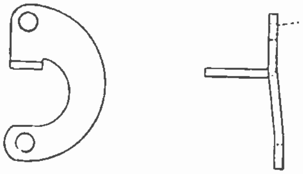
Some Recent Patents.

The following notes on interesting new wireless inventions are supplied by Mr. Eric Potter, Patent Agent, 27, Chancery Lane, W.C.2.

STERLING TELEPHONE MAGNETS.

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

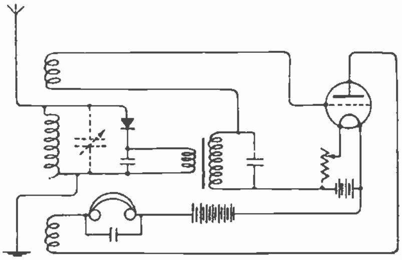
The Sterling Telephone Co. patent a particularly neat magnet for telephone receivers under No. 215,850. There are two identical stampings, each having a portion bent at right angles which constitutes the pole-piece. The yokes extend over more than a semi-circle, and are bent in their length to the extent of their thickness, so that they overlap, and can both be fixed by the same screws.



REFLEX RECEIVERS.

(*Application date, November* 10, 1922.)

In Patent No. 215,799, Mr. J. Scott Taggart and the Radio Communication Company cover various dual amplification circuits. The first of them, Fig. 1 of the specification, is distinctly interesting, although it is not quite a reflex circuit in the usual sense of the word. In the main, it is a circuit comprising a crystal detector and one low frequency valve, but the main defect of such a circuit in respect of strength of signals—absence of reaction—is got over by providing the L.F. valve with input and output coils, both of which are coupled to the aerial. This circuit appears to have considerable possibilities.

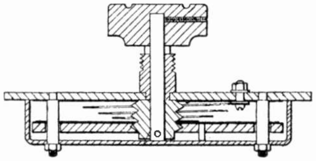


The second diagram in the specification is an ordinary dual amplification circuit with reaction and using a crystal detector, and we really cannot understand its inclusion in any modern specification. The diagram No. 3 is substantially that of Fig. 1 with an H.F. valve in front of the detector, and should have all the advantages of that already described with the addition that, with care in use, it should not cause any interference by radiation.

NEW TYPE VARIABLE CONDENSER.

(*Application date, March* 22, 1923.)

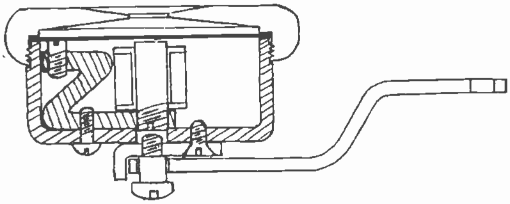
Mr. A. E. Chapman, who may perhaps be known to our readers through his previous inventions, such as the 3 E.V.C. condenser, Filtron grid-leak, etc., covers in Patent 215,906 a new type of variable condenser which will be exceedingly compact. The sketch herewith makes the construction so clear that there is hardly any necessity for us to describe it. It would seem likely that this condenser would have the advantage of giving a nice open scale over the whole of its range, especially if care is taken in the design of the spiral plate.



TELEPHONE EAR-PIECE CONSTRUCTIONS.

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

In Patent No. 215,973, J. W. Hobley covers the construction of what he claims to be a simple and efficient type of ear-piece. The distinguishing point is the " Z "-shaped permanent magnet. The receiver is of the single-pole type, one end of the " Z " making contact with the central pole carrying the coil, while the other end carries an adjustable screw which makes contact with the diaphragm. The construction is shown clearly in our drawing. A separate claim is made that the particular design of cap shown is more comfortable to the ear than other designs.



CAPACITY AERIALS.

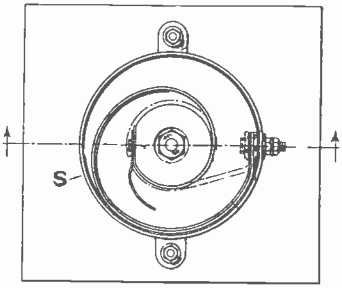
(*Application date, March* 12, 1923.)

In Patent No. 216,247, J. C. Round tries to cover the use of what have usually been known as capacity aerials, consisting simply of a single metal plate elevated. It would appear that the patent is not likely to be valid.

COILED PLATE CONDENSERS.

(*Application date, October* 5, 1923.)

The Telephone Manufacturing Company are responsible for an improvement in coiled plate condensers, one of the chief points of interest being the non-resilience of the flexible plate.

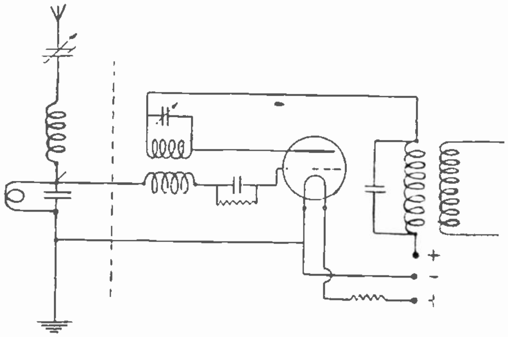


In other respects the construction represents little departure from earlier patents, a spring as at S being utilised for keeping the plate in close proximity to the outer wall as it is unwound. Patent No. 216,038 has just been granted for this invention.

HETERODYNE RECEPTION.

(*Application date, April* 30, 1923.)

To prevent oscillations generated by the local detector valve of a heretodyne receiving system from being impressed on the aerial, it is proposed to use a grid circuit such as that in the drawing, so sharply tuned to the incoming waves that it offers a high impedance to them (so that they are impressed on the grid) while at the same time offering only a small impedance to the local oscillations, which are of a different wave-length. For this purpose the capacity-inductance ratio is made large and the ohmic resistance very low. As an alternative the grid circuit may be coupled to the aerial.



The inventor in this scheme is Mr. T. H. Kinman of the Royal Aircraft Establishment, to whom Patent No. 216,308 has just been granted.

METAL PANELS.

(*Application date, March* 10, 1923.)

The general principle of construction of the well-known Sterling broadcast sets is covered in Patent No. 216,246 to the Sterling Company and Mr. T. D. Ward-Miller. This, as is well known, consists mainly in the employment of a metal panel instead of the more usual ebonite or other insulating material. Various details of the construction are given in the specification, but the most interesting point is the first claim, which reads as follows: "Apparatus for wireless telephony or telegraphy comprising a box cabinet or like enclosure, a metal deck completing said enclosure, and tuning devices or like components supported directly or indirectly upon the said deck and having their handles projecting through it."

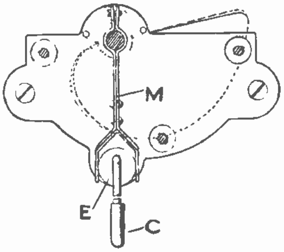
It appears to us that the validity of this claim is really open to question.

FINE CONDENSER ADJUSTMENT.

(*Convention date* (*U.S.A.*) *November* 28, 1922.)

Simple means for providing fine adjustment of condensers of the usual air dielectric type forms the subject of Patent No. 207,797 to Mr. L. A. Hammarlund of U.S.A.

In addition to the usual knob for rotating the movable plates a fine adjustment control is provided at C. Rotation of C produces displacement of the lever M through the medium of eccentric E. This member M is in frictional engagement with the shaft carrying the moving plates, so that operation of C produces a small angular movement of the plates.



Apart from its simplicity, a material advantage of the construction resides in the ability to locate the fine control outside the immediate sphere of electrical influence.

HIGH TENSION CONDENSERS.

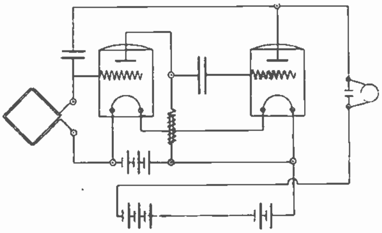
(*Convention date* (*U.S.A.*), *October* 25, 1923.)

An interesting point in the design of condensers for high voltages is dealt with in Patent No. 206,107 to W. Dubilier. It has been realised of late years by the designers of insulators for the extremely high voltages now used in commerce, that one of the main reasons why, for example, a layer of mica 1/10 in. thick has not ten times the dielectric strength of a layer 1/100 in. thick, is that when the dielectric is subjected to a high voltage, as in the case of a condenser, the electric stress is not equal at all points of the thickness, *i.e.*, the voltage drop between the plates does not follow a straight line law. The consequence is that some parts of the dielectric are more severely stressed than others and may fail. The usual means adopted for getting over this difficulty in the design of high voltage insulators is to divide the dielectric into many layers by placing metal plates between the layers. This, in effect, converts the whole condenser into a set of condensers in series, and if the areas of the various metal plates are alike the voltage drops over the separate layers of dielectric will be equal to one another. This principle was first utilised in the well-known condenser bushings for high-tension insulators. Its application to the case of condensers is covered by Mr. Dubilier in his Patent.

SEALED RECEIVING SETS.

(*Convention date* (*Germany*) *August* 8, 1923.)

A rather interesting design which we fear would not greatly appeal to the advanced experimenters of this country is that covered by Patent No. 202,978 of the Funktechnische Gesellschaft, m.b.H, an Austrian Company. The set is designed to make any adjustment absolutely impossible. The aerial is a frame, and is wound round between the inside and outside shells of a double case so that it is quite ungetatable. The two valves and all connections, except the battery plug, are all within the cabinet, which is of itself sealed up. It is interesting to note the peculiar wiring diagram employed. No particulars as to the operation of a set connected in this manner are given in the specification.



AN S.-T. CIRCUIT.

(*Application date, November* 10, 1922.)

An S.-T. circuit forms the subject of Patent No. 215,798 to Mr. J. Scott Taggart and the Radio Communication Co. The principal feature consists in arranging the valves, say one H.F. and one detector, so that the output of the detector reacts both with the input of the detector and the input of the H.F. valve.

The coupling between the coils should, of course, be variable and it would seem that very fine adjustment will be a distinct advantage.

In the Specification several modifications are described at length.

ELECTROLYTIC CONDENSERS.

(*Application date, March* 14, 1923.)

Mr. T. F. Wall adds to his earlier specification (215,129) dealing with electrolytic condensers in which the electrodes are of varying oxides of lead, some fresh details covered under Patent No. 215,897. In this latter specification he states that these oxides of lead are sensitive to the chemical changes involved when the condenser is in operation. To ensure their retaining their characteristic properties without deterioration, he now proposes to add a certain amount of oxidising substance to the electrolyte, and states that nitric acid is found to be a suitable agent. He, therefore, adds a small amount of it to dilute sulphuric acid normally used.

TELEGRAPHIC RECEPTION.

(*Convention Date* (*France*), *August* 24, 1922.)

The Société Française Radio-Electrique give some most interesting circuits for telegraphic reception, with particular application to cases where the messages are to be recorded. All the circuits mentioned in the specification (which is No. 202,998) are based on reception from stations which send out a spacing as well as marking wave, and the general idea is not only to use the marking wave to give a deflection of the indicating instrument in one direction as usual, but also to make the spacing wave give a negative deflection. This can be accomplished by a circuit of the type shown in Fig. 1, where the two frame aerials A and B with their associated receiving sets are tuned to the marking and spacing waves respectively. It is obvious that the voltage between the points C and D will be twice as great as if only set A were in use and the indicating instruments were connected to C and E. The essential point of the present patent is the application of this arrangement to work with relays. Our second diagram shows the corresponding modifications in the circuit. It will be seen that the anode resistances of the previous circuit are now replaced by the relay R with two windings. The steady current from the battery E traverses the relay and cancels out the field produced by the spacing wave in aerial B. It is obvious that when there is neither marking nor spacing wave, there will be a certain definite pulling force on the armature of the relay, due to the current from E. When the set A is energised by the arrival of the marking wave, this force will be further increased, so that the sensitivity of the whole installation is very high; further, in so far as atmospherics may be considered to affect both sets A and B alike, they will not produce any effect on the relay. Various modifications are shown on the specification, including its application to telephony.