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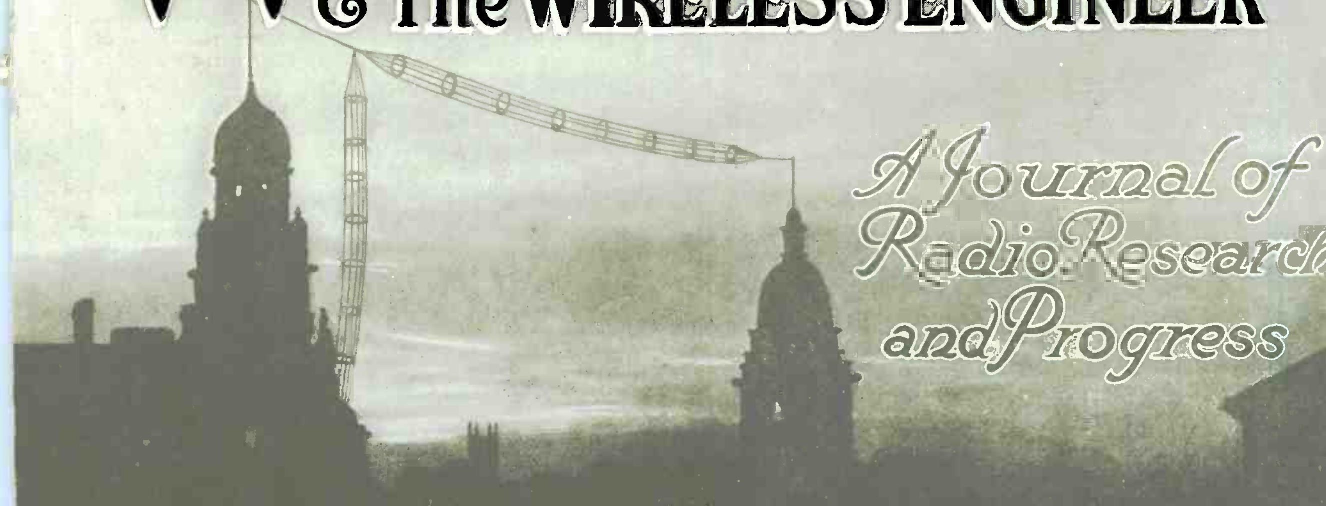

A Journal of Radio Research and Progress

Vol. IV
No. 45.

IN THIS ISSUE

JUNE
1927.

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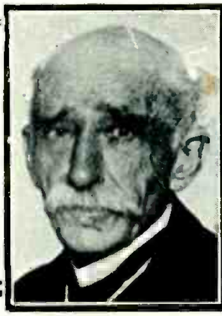

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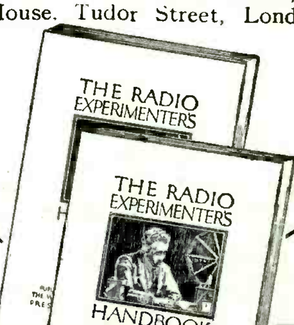

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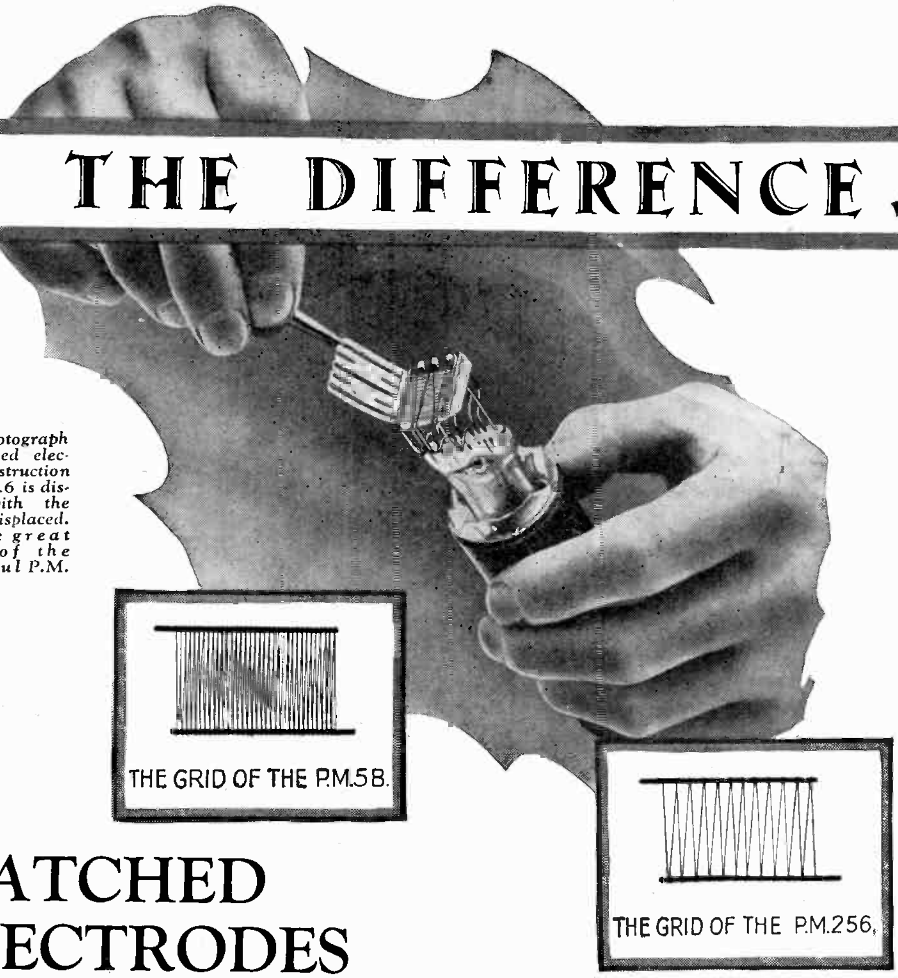

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A Journal of Radio Research and Progress

Technical Editor: Prof. G. W. O. HOWE, D.Sc., M.I.E.E.
Editor: HUGH S. POCOCK.
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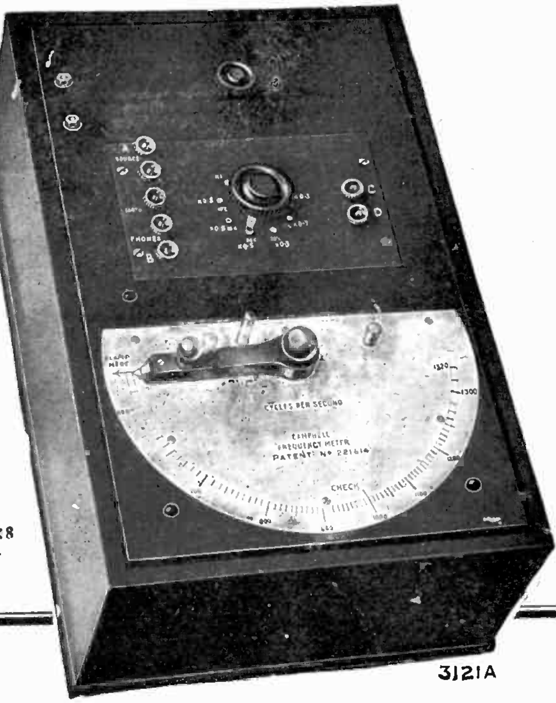

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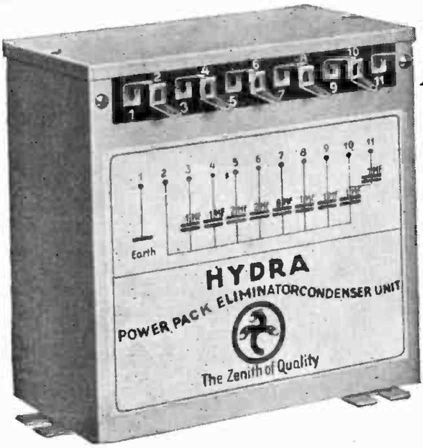

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. IV. JUNE, 1927. No. 45.

Editorial.

The Eclipse.

ON the morning of 29th June a total eclipse of the sun will occur and will be visible in England. Such an event has not occurred since the eighteenth century and will not occur again until the last year of the present century. To most people in this country it will appeal as a unique opportunity—given favourable weather conditions—of watching a rare natural phenomenon, but to scientists it will appeal in many different ways, depending on the branch of science in which they are specially interested. To wireless experimentalists it offers an opportunity of making measurements of the strength or direction of signals with a view to determining any special variation due to the eclipse. It is impossible to say exactly what measurements it would be best to make, but there is one thing which should be emphasised above all else and that is, that unless the greatest care be taken to obtain accuracy and reliability, the results obtained will be worthless.

It will be necessary for each observer to decide on which transmitting station he will concentrate his attention. Arrangements are being made for certain of the broadcasting stations to send out steady signals for the purpose. Particulars of some of the observation work to be carried out by the Radio Research Board under the direction of Professor E. V. Appleton, F.R.S., are published on page 381. These stations will send out the signals in exactly the same way on several days before and after the 29th and it will be essential to make the measurements on these days as well as on the day of the eclipse, as it will only be by comparison of this kind that any effect of the eclipse will be detected.

In deciding the transmitting station on which he will concentrate his attention, the observer will be guided by his position with respect to the track of the shadow, but he must not be misled by maps showing the shadow track sweeping across the country from North Wales to Sunderland, for these maps refer to the shadow on the ground. If the eclipse has any effect on wireless signals it will be due to changes produced in the upper atmosphere and the shadow which interests the wireless observer is that cast on the ionised layer at a height of about 50 miles. As the eclipse occurs so soon after sunrise the sun's rays make a small angle with the surface of the earth and will therefore pass through the ionised layer at a point about 150 miles south-east of the point where they strike the ground. Hence for wireless purposes the track of the shadow across the country lies perhaps 100 miles to the south of the observational track, the exact position depending on the height assumed for the ionised layer. Wireless observers in Yorkshire and Lancashire are therefore well to the north of the shadow track which will have any effect on signal strength.

The Exact and Precise Measurement of Wavelength in Radio Transmitting Stations.

By RAYMOND BRAILLARD Engineer A. & M., E.S.E., Advisory Engineer of Radio-Belgique, President of the Technical Commission of the Union Internationale de Radiophonie; and EDMOND DIVOIRE, Engineer A.I.Br., in charge of classes at Brussels University, Secretary of the Technical Commission of the Union Internationale de Radiophonie.

Part A.—THE BROADCAST PROBLEM.

General Considerations.

RECEPTION of broadcast transmissions of good quality, using a properly designed set, may be more or less seriously affected by four main classes of stray radiations—

(*a*) Strays of natural origin, generally called "atmospherics";

(*b*) Strays of an industrial origin: induction caused by tramways, electric trains, lifts, X-ray appliances, luminous signs, telegraphic equipment, high power transmission lines, electric motors, etc.;

(*c*) Stray radiations from neighbouring receiving sets badly adjusted;

(*d*) Jamming by other transmissions—on the same or on neighbouring wavelengths or by harmonics of long wave stations.

We will not deal, in the course of the present study, with the three first causes of reception trouble, forming as they do the subject of constant research on the part of technical experts of all lands, but will confine our attention to the fourth.*

Radio-Electric Interferences.

Incessant increases in the number and power of radio-electric stations involve, by way of consequence, an increase in reception interference capable of seriously compromising the legitimate development of wireless applications.

It is necessary to recognise the fact that the law "Lex talionis" which has, for a long time, worked as a moderating agent, shows itself definitively as being inoperative because it conduces, in the absence of any rational international organisation of wireless, to a chase after power.

The last international meeting* regulating the conditions of the use of wireless in various domains dates back, as a matter of fact, to 1912.

The forthcoming universal congress, which is to meet at Washington in October, 1927, and of which the heavy task of organisation is incumbent on the American Government, has been adjourned from year to year for various reasons.

Owing to these adjournments the prodigious evolution of broadcasting and the multiplication of telegraphic, naval, aircraft and meteorological services, etc., have ended up by creating a state of things such that the responsible technical experts consider with real anxiety the announcement of the erection of other new transmitting stations as the prospect of a new source of interference.

International Agreements for Wavelength Allotment.

While waiting for the new organisation, which has been promised us at Washington, and of which the results will not be perhaps either so efficacious or so rapid as one is pleased to hope,† the technical experts have sought, under the urge of necessity, to work in as well as possible within each radio-electric branch, wavelengths which have been occupied *de jure* and *de facto* in order to derive therefrom the best possible benefit.

It is this which gave rise to an organisation

---

* The Union Internationale de Radiophonie in particular is actively occupied in the study of the problem of strays of industrial origin, under its twofold technical and juridical aspects.

* The London meeting.

† As a matter of fact, months and even years have passed between the closing of such meetings and the date of putting into force, by the various interested Governments, the resolutions adopted. Furthermore, the rules admitted or enacted, very often at the end of numerous compromises, are not always suitably rigorous to bring about a definite remedy for the defects which one desired to avoid.

such as the Union Internationale de Radiophonie, whose original purpose, since considerably enlarged in the juridical and artistic domains, was to find a remedy for growing interference which was compromising the development of European broadcasting. As we have said, the London Convention, which regulated wireless from the international point of view, dates from 1912. The case of broadcasting has not been provided for, and no international agreement has correlated national regulations of various countries which may have been contradictory or inadequate. The Union Internationale de Radiophonie, created in March, 1925, groups together at Geneva the majority of European broadcasting organisations.

After a series of studies and tests carried out by a technical committee appointed to this end* a first "European" plan for allotment of wavelengths between 200 and 600 metres was adopted at Geneva in March, 1926, and applied to the great majority of European broadcasting stations on the 15th November of the same year. The result obtained was remarkable in its entity and would have been complete were it not for several causes of trouble arising from stations which have not rallied to the plan, or which are working under defective technical conditions.

A similar allotment plan, dealing with long wave stations, is now being studied.†

* This Committee consists of :—

President: M. RAYMOND BRAILLARD, Engineer A. and M.—E.S.E.—Advisory Engineer of Radio-Belgique (Brussels).

Members: M. CESARE BACCHINI, Administrator of the Unione Radiofonica Italiana (Milan). Capt. P. P. ECKERSLEY, Chief Engineer of the B.B.C. (London). M. PIERRE GENDRON, Technical Director of *Petit Parisien*. Dr. HARBICH, Director of P.T.T. (Reichs Rundfunk, Berlin). M. SIFFER LEMOINE, Engineer at the Direction Générale des P.T.T. Suédois (Stockholm). M. ERNST STEINBACH, Engineer Radio E.S.E.; Chief Advisor of Postes et Télégraphes (*Radio Journal*), Prague. Dr. B. VAN DER POL, Director of the Research Laboratory, Philips (Eindhoven).

Secretary: M. EDMOND DIVOIRE, Engineer, Radio E.S.E., in charge of classes at University of Brussels.

† International Conference of Broadcasting Engineers organised at Brussels, 28th and 29th of January, 1927, by the Technical Committee of the U.I.R.

Technical Qualifications which Broadcasting Stations must Satisfy.

All tests for regulating wavelengths with a view to suppressing interference will be illusory if broadcasting stations do not satisfy the three following conditions :—

1. The length, or rather the frequency of wave emitted, should correspond exactly with nominal wavelength allotted.
2. The emitted wave should remain stable; no matter what kind of manipulation or modulation be adopted.
3. The emitted wave must be free from appreciable harmonics.

The strict observance of these conditions is indispensable for safeguarding wireless progress. It nevertheless does not appear, on the whole, that builders of broadcasting stations have sufficiently borne this in mind, as can easily be seen by listening to the majority of radio-telegraphic or radiophonic transmissions.

The accuracy of the frequency of the emitted wave depends mainly on the technical value of the wavemeter used to regulate a station.

The stability and suppression of harmonics are obtained, thanks to the aid of equipment which is well known to-day, and which we will not deal with in the course of the present study.

It should be noted, however, that a good wavemeter at a broadcasting station not only enables one to obtain an accurate adjustment of wavelength, but furthermore to control its stability.

The Problem of Wavemeters.

The exact and precise measurement of wavelengths constitutes a delicate problem which in the minds of many technical experts appertains solely to the laboratory.

In the very great majority of stations, we find, as a matter of fact, wavemeters which offer none of the characteristics suitable for obtaining the accuracy and precision desired. Very often these appliances are of an obsolete model, and their present standardisation corresponds only very roughly with their initial standardisation, which in itself afforded only a very approximate accuracy.

Thus, it is not infrequent to find that the wave transmitted by a telegraph or telephone station differs by 3 to 4 per cent. or even more from the nominal wave appearing in official lists.

As we have said above, the present situation will no longer allow of such a degree of inaccuracy, which some years ago did not present any inconvenience.

Let us consider the class of radiophonic transmitters :—

It has been found necessary to observe separation of 10 kilocycles between the frequencies of stations on neighbouring wavelengths, in order to avoid, on one hand, the heterodyning of modulation bands, and on the other hand the production of a permanent audible note arising from interference on carrier waves by the well-known heterodyne effect.

Now in the waveband of 200 to 600 metres a margin of 10 kilocycles between frequencies corresponds to a comparative margin as follows :—

2 per cent. in wavelength for a wave of 600 metres.

1 per cent. in wavelength for a wave of 300 metres.

0.66 per cent. in wavelength for a wave of 200 metres.

It is, therefore, very obvious that an accurate wavemeter, affording an accuracy of the order of 1 per cent., which is normally considered as remarkable for commercial sets, would be quite inadequate, seeing that its absolute error would correspond to a margin of frequencies of two stations on neighbouring wavelengths.

It is for these reasons that the Technical Committee of the Union Internationale de Radiophonie foresaw, as a condition indispensable to the success of all international wavelength allotment plans, the necessity of keeping each station on its normal wave with an accuracy achieving the order of several ten thousandths.

There is no doubt that this condition, which might at first sight appear draconian, will be imposed with a more or less brief delay in all branches of the applications of radio-electricity.

Faults of Ordinary Wavemeters.

The best ordinary wavemeters always show the following faults :—

1. Their waveband is too extensive, as manufacturers seek to turn out sets which are more or less universal and as such can adapt themselves to no matter what station. The result is that the reading of wavelengths offers a great degree of inaccuracy, especially at the beginning of the scale, for condensers are generally of the semi-circular moving plate type. Thus, for instance, we frequently find that the wavelength band of 200 to 600 metres is represented by 100° or less on the scale. Errors in reading may, therefore, easily reach or exceed the value of the margin separating two neighbouring stations.

2. Standardisation is not constant. This is due to mechanical deformations in the constituent elements. Especially in variable condensers with parallel blades and great capacity, the wearing away of pivots and stops involves comparatively important variations in the air gap and consequently in capacity. We have often found that good sets had, after several months of use, suffered variations in standardisation rising to 1, 2 or even 3 per cent., which one had to attribute mainly to variations in condenser capacity.

3. Damping is generally very high because in sets with an extensive band the multiplication of control or working parts, the grouping together of constituent elements of the oscillating circuit within a reduced space, the abundance of connections, etc., involve important losses. The result is on the one hand a greater inaccuracy in ascertaining the point of resonance and on the other hand the necessity for tight coupling between the wavemeter and the transmitter, which may give rise to a temporarily varying of wave during measurement when dealing with low power stations.

4. The appliances are not protected against electrostatic effects. The approach of the hand, head or body of operator during measurement may also cause large errors in the value of such measurement.

The Solution of the Technical Committee of the U.I.R.

After having first prescribed the general restandardisation of wavemeters in service in all stations in a single laboratory provided with a single frequency standard, the Technical Committee of the U.I.R. turned down this solution on account of its uncertainty.

Another solution which was at first sight very alluring consisted in using resonant piezo-electrical quartz crystals, carefully calibrated on stationary waves.

Such appliances, generally of very great accuracy, are in use in several important stations, especially in Germany. Unhappily, their use is fairly delicate, and they suit only very modern stations, with a very stable transmission and provided with a selected technical staff; but their use could not be generalised at the present without risk of abuses.

Finally, the Technical Committee of the U.I.R. decided on the following scheme :—

(*a*) To study a new wavemeter, accurate, precise, stable, covering a very narrow frequency band around the operating frequencies and to equip each broadcasting station with one.

(*b*) To mass produce these wavemeters with a view to reducing in so far as possible the cost price so as to permit of their being widely distributed.

(*c*) To standardise all wavemeters according to the most modern methods of absolute frequency measurement in one and the same laboratory equipped with a single frequency standard.

These various operations were carried out at Brussels in the wireless laboratory of the University under the care of the authors and in complete and constant agreement with all members of the Technical Committee of the U.I.R.

Starting in August, 1926, they were carried through very rapidly and in December of the same year more than 60 European stations, amongst them the most important, were already permanently controlled by these sets, which we are going to describe more in detail.

Part B.—DESCRIPTION OF WAVEMETER.*

Conditions to be Realised.

In the construction of the wavemeter, we have imposed on ourselves at the outset the three following conditions :—

(*a*) To reach an accuracy of reading as high as possible. This will mean, on the one hand, a careful study of the different elements, so as to lower damping to a minimum in circuits, and on the other hand, a reduction of the waveband which the instrument will cover.

(*b*) To get a perfect constancy of standardisation, and to this end, to build each instrument particularly robustly and rigidly so as to avoid all ulterior geometrical deformation involving a modification of the electrical characteristics of the instrument.

(*c*) To limit the cost of manufacture to a comparatively low value, in order to enable, no matter what broadcasting station, to acquire the wavemeter; it was therefore necessary to eliminate all expensive meters, and generally to have recourse to industrial processes of mass production without compromising indispensable accuracy in manufacture.

The three above considerations lead us to work out a combination comprising :—

1. A resonant circuit reduced to its essential elements, viz., a fixed inductance and a big fixed and a small variable condenser, mounted in parallel (see Fig. 1)

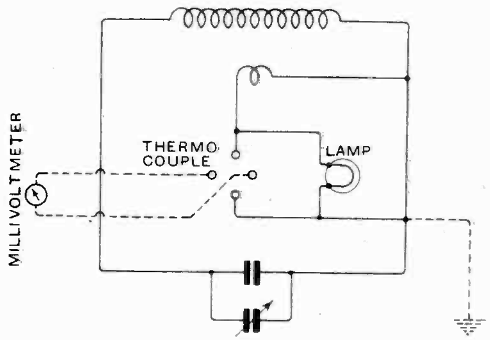

Fig. 1.

M the capacity of this latter being calculated so as to ensure a total band of frequencies equal to a small percentage of the total value.

2. An indicator circuit loosely coupled up to the resonant circuit and consisting essentially of a simple incandescent lamp as a measuring instrument.

Make-up of Instrument.*

As we have shown above, we have deliberately abandoned the principles on which

* Registered Patent.

* See photo, Fig. 2.

instruments of the kind ordinarily are based, such as doing away with important metallic masses, general use of ebonite and other insulators, etc.

On the contrary, we have adopted, after study, a metallic construction very robust wherever possible: parts of well finished cast metal, solidly fixed to a very thick aluminium panel — the use of insulating material being strictly limited where it was indispensable. (Further, the adoption of a very narrow waveband: about 30 kilocycles).

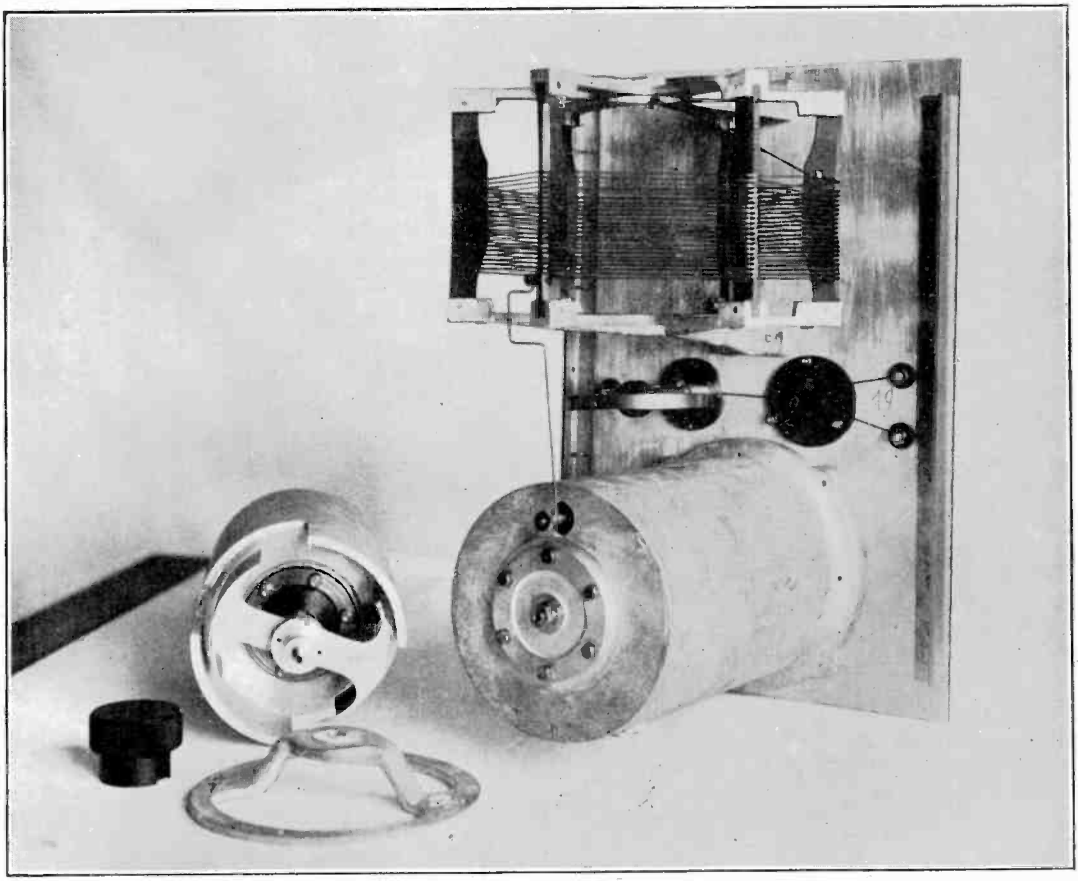

Fig. 2.

The advantages resulting from this particular construction are, first of all, the rigidity and indeformability of the separate parts, and thence, constancy of standardisation; next an almost radical way of avoiding unwanted electrostatic and other effects, due to the presence of observer, which effect might alter this standardisation.

Lastly, we had recourse, as much as possible, to cast metal so as to reduce ulterior deformations resulting from molecular action. This is difficult to avoid when using welded metal, such as plates, cylinders, etc.

Condensers.

We have seen that the condenser is made up of :—

(*a*) a fixed condenser;

(*b*) a variable condenser, covering a frequency band slightly above 30 kilocycles.

It is easy to calculate that the variable section of the capacity is comprised between 5 per cent. and 11 per cent. of the total capacity for waves between 200 and 600 metres. This considerably reduces errors arising from mechanical deformations of moving parts.

To reduce damping, it was thought to be essential to use air dielectric condensers.

After studying the matter, we rejected the multiple parallel plate condensers of the well-known type, to adopt condensers made up in the main by two concentric cylinders.

It would be interesting to develop mathematically the reasons.

Let us first consider a condenser element made up of three parallel plates, separated by an air gap equal to C, the central plate forming one side, and the external plates the other side, and let us find the capacity variation resulting by shifting E, the central plate, towards one of the other plates (see Fig. 3 (a)).

The initial capacity per square centimetre of surface is :—

$$C_0 = \frac{1}{4\pi} \cdot \frac{2}{C}$$

After displacement it becomes :—

$$C_1 \cdot = \frac{1}{4\pi(e+\varepsilon)} + \frac{1}{4\pi(e-\varepsilon)} = \frac{1}{4\pi} \cdot \frac{2e}{(e^2-\varepsilon^2)}$$

Whence

$$\Delta C = C_1 - C_0 = \frac{1}{4\pi}\left(\frac{2e}{e^2-\varepsilon^2} - \frac{2}{e}\right)$$

$$= \frac{1}{4\pi} \frac{2}{e} \frac{\varepsilon^2}{e^2-\varepsilon^2}$$

We easily derive

$$\frac{\Delta C}{C_0} = \frac{\varepsilon^2}{e^2-\varepsilon^2}$$

and as ε is small compared with e

$$\frac{\Delta C}{C_0} = \frac{\varepsilon^2}{e^2} \qquad \ldots \qquad \ldots \quad (1)$$

The effect of compensation is obvious, seeing that a small variation of air gap corresponds to a variation $(\varepsilon/e)^2$ of capacity and $\frac{1}{2}(\varepsilon/e)^2$ of frequency.

Thus, the variation of 1/100 of air gap would correspond to a variation of 1/10,000 of capacity, or 1/20,000 of the frequency.

But in practice it is different, because it is extremely difficult to construct such a condenser with an initial air gap e constant.

We can find, as a matter of fact, that the *mean value* of this air gap is equal to e, but there are always two different air gaps, e_1 and e_2.

$$e_1 = e\,(1 + K)$$

$$e_2 = e\,(1 - K)$$

$$e_1 + e_2 = 2e$$

Under these conditions the initial capacity is :—

$$C_0 = \frac{1}{4\pi} \cdot \frac{1}{1 - K^2} \cdot \frac{2}{e}$$

A further displacement of central plate gives, taking the most unfavourable case

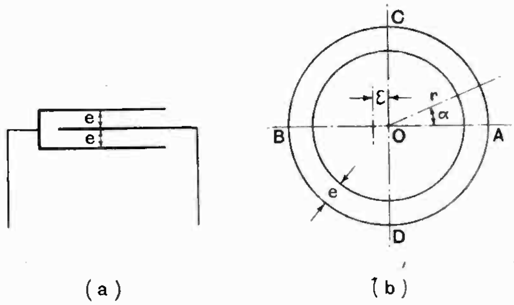

Fig. 3.

for which a difference of air gap is accentuated,

$$e_1 = \frac{1}{4\pi} \cdot \frac{1}{1-K^2} \cdot \frac{2(e+K\varepsilon)}{e^2-\varepsilon^2}$$

We thus easily derive :—

$$\frac{\Delta C}{C_0} = \frac{K\frac{\varepsilon}{e} + \left(\frac{\varepsilon}{e}\right)^2}{1 - \left(\frac{\varepsilon}{e}\right)^2}$$

and as $(\varepsilon/e)^2$ is small compared with 1

$$\frac{\Delta C}{C_0} = K\frac{\varepsilon}{e} + \left(\frac{\varepsilon}{e}\right)^2 \quad \ldots \qquad \ldots \quad (2)$$

Comparing this formula with the corresponding formula in the initial theoretical case, we at once see that the inevitable initial mechanical imperfection leads to the introduction of a term of variation of the first degree which may become very quickly preponderant when K increases.

Taking $K=0.10$, which is very difficult to realise industrially, we find $\varepsilon/e = 1/100$:

$$\frac{\Delta C}{C_0} = 0.1 \times \frac{1}{100} + \frac{1}{10{,}000} = \frac{11}{10{,}000}$$

Variation, therefore, is eleven times greater than in the theoretical case corresponding to air gaps strictly equal in construction.

The difficulty of keeping equal air gaps increases, moreover, rapidly when we increase the number of plates and it becomes almost insurmountable when we desire to realise variable condensers rotating on this principle.

On the other hand, the welded plates usually employed are liable to gradual deformations, which are nevertheless important and are due to variation in molecular stresses in the metal even in the absence of major temperature variations.

The foregoing considerations alone explain all the faults which have up till now been encountered in the construction of wavemeters, no matter how much care be given to the mechanical design of variable or fixed condensers with multiple blades used in industrial equipment.

They explain moreover the extent to which the standardisation of wavemeters carried out on receiving sets comprising such condensers is unreliable.

We will now consider a condenser formed of two concentric cylinders, separated by a constant air gap, small in regard to the radius (see Fig. 3(b)).

The capacity per unit of length of cylinder is equal to $1/2e$.

Let us now seek, as formerly, the comparative variation of capacity produced by a displacement ε of one of the armatures, ε being small in comparison with e. In A, the gap becomes $e+\varepsilon$. In B it is reduced to $e-\varepsilon$. In C and D the gap is constant. Taking CA as a basis we may admit that the air gap varies according to the law :—

$$e + \varepsilon \cos \alpha$$

Let us seek the value of capacity of a semi-cylinder ACB.

The initial value is :—

$$C_0 = \varepsilon/4e$$

The new value becomes :—

$$C_1 = \frac{1}{4\pi}\int_0^{\pi}\frac{\delta\alpha}{e+\varepsilon\cos\alpha}$$

being greater than C_0

the general integral is given by

$$\int\frac{\delta\alpha}{e+\varepsilon\cos\alpha} = \frac{2}{\sqrt{e^2-\varepsilon^2}}\arctan\frac{\sqrt{e-\varepsilon}\tan\frac{\alpha}{2}}{\sqrt{e+\varepsilon}}$$

Proceeding to limits we find

$$C_1 = \varepsilon/4 \cdot \frac{1}{\sqrt{e^2-\varepsilon^2}}$$

whence

$$C_1 - C_0 = \varepsilon/4\left(\frac{1}{\sqrt{e^2-\varepsilon^2}} - \frac{1}{e}\right)$$

We derive

$$\frac{\Delta C}{C_0} = \frac{e-\sqrt{e^2-\varepsilon^2}}{\sqrt{e^2-\varepsilon^2}}$$

or after reduction and allowing for $(\varepsilon/e)^2$ being small in comparison with 1 :—

$$\frac{\Delta C}{C_0} = \frac{1}{2}\left(\frac{\varepsilon}{e}\right)^2 \quad \ldots \quad \ldots \quad (3)$$

In comparing this value with the corresponding value given in (1) for parallel plate condensers, we see that the capacity variation with equal air gap and displacement is twice as small.

We may assume that in construction an eccentricity existed from the start.

Without developing the calculation, let us point out that in this case we find :—

$$\frac{\Delta C}{C_0} = K\frac{\varepsilon}{e} + \frac{1}{2}\left(\frac{\varepsilon}{2}\right)^2$$

a formula which it is well to compare with (3).

To sum up, we see that in all cases the subsequent accidental variation of the capacity depends principally on the accuracy of initial performance, that is to say, on the value of K. Now it is very easy to attain an extremely low value for the term K with well made and perfectly concentric cylinders. The advantage of cylindrical condensers is, therefore, considerable from the standpoint of stability of capacity value. If we take care, moreover, to form the cylindrical plates out of cast and turned pieces of metal, and not out of drawn tubes, we avoid all deformations due to internal molecular tension.

The above considerations lead us to design wavemeters in the following manner :—

(*a*) *Condensers.*—Fixed and variable condensers are formed in one and the same organ, the plates being concentric cylinders mounted on a fixed axis and held at both ends by conical bushes. The external cylinder forming a cover is joined to the case while the internal cylinder is insulated from the axis at both ends by means of extremely thin pieces of ebonite moulded in the form of opposing cones at the base. This special arrangement ensures perfect rigidity of insulating material and at the same time gives conditions suitable for perfect insulation, *i.e.*, minimum section, minimum volume and maximum length of leakage path. The moving electrodes are supported on the same axis, centring being ensured by a truncated conical bush. The moving electrodes comprise two quadrants of cylinders spaced 180° apart, and have the same polarity as the mass of the external cylinder. Variations of capacity are given by a movement of these electrodes in front of two other quadrants, which are fixed on the shell, being in fact prolongations of the internal cylinder which is insulated and therefore of inverse polarity (see Fig. 2).

The above method of condenser design not only assures a unit of great robustness, but also has for its object the securing of accurate mounting of the electrodes with respect to one another, and furthermore reduces to an insignificant value not only risk of eccentricity and accidental deformation, but also that of initial eccentric mounting.

(*b*) *Inductance.*—The inductance is formed by a coil of bare copper wire supported by six insulating strips forming the facets of a hexagonal prism. The two bases are formed by aluminium supports in the form of six branch stars and rendered perfectly rigid by stays.

The diameter of these bases is constant for all models of wavemeters; the pitch of winding and section of wire have been specially studied so as to reduce high frequency resistance.

For the insulating material chosen for the strips, measurement showed that its choice was of little account in regard to loss. As a matter of fact, in such a coil the copper loss was preponderant compared with dielectric losses.

Nevertheless, the necessity of keeping a strictly indeformable winding has led us after tests with strips of ebonite and bakelite of the best quality to consider the use of pyrex glass or fused quartz.

We will revert later on to the values of resistance on which we have decided.

(*c*) *The indicator circuit* is made of a single turn of thick brass strip which is perfectly rigid and is mounted on a brass base. The loop is directly connected to the resonance indicator which is either a small incandescent lamp of the 3.5-volt type, or a thermoelectric couple of the Allochio and Bacchini type used in conjunction with a D.C. millivoltmeter.

Obviously both systems of measurement cannot be used simultaneously.

Study of Instrument's Characteristics.

A. Inductance and Capacity.

The first question which arose was to fix the value of the ratio Inductance/Capacity to be adopted for the series of wavemeters that had to measure the wavelengths in the 200 to 600 metres waveband.

In defining this we were at first guided by considerations of the accuracy to be obtained. This ratio fixes in fact the circuit decrement for each wavelength, and consequently the degree of accuracy.

What was the problem ?

In the present case it was to measure between 200 and 600 metres a series of frequency intervals of 10 kilocycles each, with as much accuracy as possible, involving an error lower than one kilocycle.

The result is that for a 600-metre wavelength (500 kilocycles) this accuracy should be at least 2/1,000, while for 200 metres (1,500 kilocycles) it should be 0.66/1,000.

Consequently, the problem was not to obtain a constant value of comparative accuracy over the whole waveband, but really a constant value of absolute frequency accuracy.

Which in other words means that it would be necessary to make the condition Δf=constant for all decrements.

Now, we have δ appreciably proportional to $\Delta f/f$.

It was therefore necessary to get

$$\delta = K \frac{1}{f}$$

Or, again, by replacing δ by its value $\frac{R}{2L} \cdot \frac{1}{f}$

$$= \frac{R}{2L} \cdot \frac{1}{f} = K \frac{1}{f}$$

Giving therefore, $R/2L$ the constant for all instruments.

Such was the desideratum; but was it possible?

Let us roughly estimate R and L as a unction of the number of turns of inductance and the frequency, the condenser resistance being regarded as negligible compared with that of the inductance (which is nearly true in our case).

In a coil of the type adopted we may assume that the H.F. resistance is proportional to the D.C. resistance and to the square root of the frequency

$$R_{HF} = KR_{DC}\sqrt{f} = K'n\sqrt{f}$$

(n. representing the number of turns).

On the other hand, our experiments have shown that we got the ratio $L = K'n^2$ approximately.

Whence, finally, the condition

$$R/2L = \text{constant}$$

works out at

$$L = K \times f = K'/\lambda$$

The inductance, therefore, instead of increasing with wavelength, should diminish.

It is easy to see that this condition would rapidly lead to inadmissible capacity values for the two extremities of the waveband required.

We have, therefore, confined ourselves to a *comparatively* constant accuracy taking care that this accuracy should suffice for the most unfavourable case, that is to say, for the shortest waves.

This meant that the condition

$$\delta = \frac{R}{2L} \cdot \frac{1}{f} = \text{constant}$$

was realised, or, taking into consideration once more the above approximations in the evaluation of R and L, the adoption of a constant ratio L/C for the different instruments.

Experience shows, as a matter of fact, subsequently, that in this way the decrement of different wavemeters falls regularly between 0.016 and 0.018 for the ratio L/C=0.5 *circa* (L expressed in microhenries and C in microfarads).

(To be concluded.)

Slope Inductance.*

A Note on the Effective Inductance of Iron-Cored Chokes or Transformers.

By C. R. Cosens, M.A.

THE *Inductance* of an air-core choke is a constant quantity, independent of the current through the choke, and it may be defined as the "flux-turns per unit current."

It is well known that the inductance of a choke having a closed, or nearly closed, iron core is not a constant,† because the permeability of the iron varies with the flux-density; but it is not generally realised that the extent of this variation may be as much as ten or twenty to one.

A.C. Inductance and Slope Inductance.

The quantity $\frac{\text{"Total flux-turns"}}{\text{Current}}$ as calculated from the reactance of the choke to a sine-wave A.C. current will be referred to as the *A.C. Inductance.* (This is the quantity which is required for ordinary A.C. work, other than wireless.)

The quantity $\frac{\text{"Change of flux-turns"}}{\text{Change of current}}$ (where the change of current is small, and is superimposed on a relatively large D.C. current through the windings), will be referred to as the *Slope-inductance*. This is the effective inductance of the choke when used in an amplifier where the windings carry a steady D.C. anode current upon which is superimposed a relatively small A.C. component, referred to as the "Signal current."

Frequency adopted for Tests.

In pursuance of the principle of measuring one thing at a time, it is desirable to eliminate, as far as possible, the effects of the self-capacity of the coil windings, this points to the use of a comparatively low frequency for the test. The commercial 90 cycle A.C. supply was therefore used, which is practically convenient.

Test of A.C. Inductance.

The impedance Z of the choke is easily measured by noting the currents passed with various applied alternating potentials. In practice the current-measuring device is conveniently an adjustable non-inductive rheostat across which a Moullin voltmeter is connected.

If R is the resistance of the adjustable rheostat, and r the effective A.C. resistance of the choke (including iron losses), the reactance X of the choke is then obtained from

$$Z^2 = X^2 + (R + r)^2 \quad .. \quad (1)$$

In practice, we do not know the effective resistance r, but fortunately it will be found that if we assume the iron losses are of the same order as the copper losses, we can neglect r altogether as small compared with X. (For proof see Appendix I.)

We have, then, approximately,

$$X = \sqrt{Z^2 - R^2} \quad .. \quad (1A)$$

and if f be the frequency of supply,

$$L = X/2\pi f \quad .. \quad .. \quad (2)$$

A.C. Inductance of Commercial Choke.

The results of such a test of A.C. inductance of a commercial choke of well-known make are plotted (on semi-logarithmic paper) in Fig. 1, against the A.C. current through the choke (R.M.S. value). Strictly speaking, there is a source of error here, in that if the applied E.M.F. is sinusoidal the current will show a pronounced third harmonic, but the test will still be suitable for comparison of different chokes; the error is probably small, as the effect of the adjustable resistance in series with the choke is to reduce the error.

* M.S. received April, 1926.

† If the iron core has an air-gap so large that the reluctance of the gap is much greater than that of the iron part of the magnetic circuit (a few millimetres may suffice where the iron is worked at a high permeability) the inductance is for practical purposes nearly constant, within a few per cent.

In the actual test the current was carried up to 12 milliamperes; the P.D. across the choke was then about 500 volts R.M.S. (a peak value of at least 700 volts). It speaks well for the insulation of the choke that it stood up to this for over five minutes without any sign of breakdown.

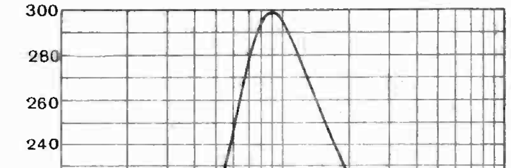

Fig. 1.

An inspection of the curve of Fig. 1 shows that the A.C. inductance is of the order of 60 henries for a very small current (found by extrapolation from a curve drawn on ordinary, not semi-log., paper), rising to 300 henries for a current of about 1 milliamp of A.C. (This is not of much practical use, as it needs a P.D. of about 160 volts across the choke to drive 1 milliamp through the winding, even at so low a frequency as 90 cycles.)

Above 1 milliamp A.C. the inductance drops, until at about 14 milliamps it becomes about the original 60 henries; and if a larger A.C. current could be passed without damaging windings and insulation, the inductance would presumably decrease indefinitely.

It will be noticed that the shape of the curve of Fig. 1 is similar to that of the permeability-curve of iron, in actual fact this is exactly what it is; with a knowledge of the number of turns on the winding and the dimensions of the core we could draw new scales on the axes to show the μH relationship for the iron. Incidentally this is a method of measuring permeability with a single winding only on the core. (For proof see Appendix II.)

Conditions of Operation of a Choke in an actual Amplifier.

The results of the test just given do not show anything like the actual effective inductance of the choke when employed in the anode circuit of a valve, for in such a position we have a small A.C. "signal E.M.F.," of a few volts at most, across the choke, and superimposed on the small A.C. "signal current" due to this E.M.F. a comparatively large D.C. current, the anode current of the valve.

In this connection, it may be noted that the signal E.M.F. on the grid of the last valve of an amplifier adjusted to give comfortable volume on a medium-sized loudspeaker, is of the order of 5 volts R.M.S. This was measured on the tuning-note of 5XX (corresponding, the B.B.C. state, to about 80 per cent. modulation), the measurement being made with a Moullin voltmeter.

In order to obtain comparative results, it was decided to use a constant signal E.M.F. of 3 volts R.M.S. at 90 cycles; the "slope-inductance" of the choke was then calculated as before, from the impedance, but with different D.C. currents flowing in the windings. This to some extent reproduces the average conditions of operation in an actual amplifier.

Connections for Test of Slope-Inductance.

The principle of the test is as follows: If the choke is connected in series with a non-inductive rheostat, so adjusted that the A.C. potential difference across the rheostat is equal to that across the choke, the impedance of the choke will then be numerically equal to the resistance of the rheostat, thus saving calculation. To do this we require two things. Firstly, we must supply the choke and rheostat with both D.C. and A.C. without the supplies mutually interfering, and so that the D.C. current can be accurately measured. Secondly we require a means of measuring the small A.C. potentials across the choke and rheostat, which shall be unaffected by the comparatively large D.C. potentials present, and which shall take no appreciable current from the circuit. The latter requirements are admirably met by a Moullin voltmeter of the grid-rectifying type, provided that the insulation resistance of the grid-condenser is sensibly infinite. The "Type B" of the Cambridge Instrument Co. would probably be very suitable, but the instrument actually used was one employing a four-electrode valve, which has been described elsewhere.* The difficulty encountered, owing to low insulation resistance of the grid condenser, and the means of overcoming it, are described in a later section of this article.

A simplified diagram of connections of the test is shown in Fig. 2. L is the choke under test, R the non-inductive rheostat. D.C. is

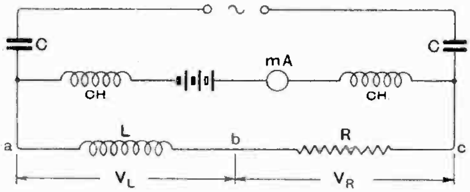

Fig. 2.

supplied by the battery shown, through the moving-coil milliammeter mA, and the small chokes CH. The latter are to prevent the A.C. supply from sending a heavy current through the battery and milliammeter and damaging them, or affecting the reading. The battery is provided with tappings, and an adjustable resistance arranged as a potentiometer so as to be able to regulate the D.C. current; these are omitted from the diagram to simplify it.

A.C. is supplied to L and R from a small transformer (not shown in figure), with a potentiometer adjustment to the primary for regulating purposes; the A.C. supply passes through the condensers C ($2\mu F$ paper condensers). This prevents the D.C. supply being short-circuited through the secondary of the transformer, and ensures that all the D.C. passing through the milliammeter mA passes through the choke under test.

(It may be suggested that if a transformer is being tested, it is unnecessary to make these elaborate arrangements to separate the D.C. and A.C. supplies, for the D.C. can be passed through the secondary while the slope-inductance of the primary is being tested with A.C., and *vice versa*.)

The points marked a, b, and c in Fig. 2 are connected to a change-over switch, so that the Moullin voltmeter can be connected either across ab or across bc, so as to measure the alternating potentials V_L and V_R across L and R respectively.

Method of taking a Reading.

The D.C. supply being adjusted to give approximately the number of D.C. milliamps required, the A.C. supply is switched off and the Moullin voltmeter switch tried in both positions. There will be a large kick on closing the switch, but the reading should then return to zero. Probably it will not quite do this, for unless the insulation resistance of the grid condenser is sensibly infinite compared to the grid-leak resistance, the combination forms a potential divider and applies a D.C. voltage to the grid. Thus, supposing we have 100 volts D.C. across the voltmeter, if the insulation resistance of the condenser is 200 megohms, and the grid-leak 2 megohms, we shall have 1 volt D.C. applied to the grid. In the case of a temporary arrangement rigged up for the purpose, a good mica condenser should be used, or, preferably, several in series (the value is unimportant, as it will merely affect the calibration, but the larger the capacity the better). If the instrument is contained in a box, and it is inconvenient to change the grid condenser, a good well-insulated condenser, of as large a capacity as possible, should be connected in series with the grid terminal of the voltmeter, or, if necessary, several in series may be used. It will then be necessary to recalibrate the voltmeter, but as only one point on the scale (that corresponding to 3 volts) is required, this is not a serious inconvenience.

The A.C. supply is now switched on, and by adjustment of the rheostat R and the supply to the primary of the transformer, the Moullin voltmeter is made to read the

* See "A Valve Voltmeter with Self-contained Batteries."—*Journal of Scientific Instruments*, March, 1926, p. 181.

same value, namely 3 volts, for either position of the switch. The D.C. may then need a final readjustment, but the process does not take as long as it sounds, for the exact value of the D.C. is not important as long as it is read accurately on the milliammeter mA. Having noted the reading R' of the rheostat R, we have the impedance (say Z') of L numerically equal to R', for choke and rheostat carry the same current, and have the same 3 volts P.D. across them.

We may again neglect the effective resistance r' of the choke as small compared with the reactance X', and write

$$X' = Z' \text{ (nearly)} \quad .. \quad (3)$$

and we have the slope-inductance

$$L' = X'/2\pi f \quad .. \quad .. \quad (4)$$

Errors from Leaks.

Trouble is often caused through the presence of stray earths, to which the grid-rectifying type of Moullin voltmeter is peculiarly sensitive. If the conditions of supply allow, this source of trouble can be avoided by arranging that the filament of the Moullin voltmeter valve is always connected to earth. In this case it is convenient to arrange the change-over switch so that this terminal of the voltmeter is always joined to the point b in Fig. 2.

Results of Test.

The results of this test for the same commercial choke as Fig. 1 are plotted in Fig. 3, the slope-inductance for a 3-volt 90-cycle signal as ordinates, the D.C. current through the choke as abscissæ. Note the steady fall of inductance from about 60 henries with no D.C. to about 14 henries with 14 milliamps D.C.

With the anode currents usual in an amplifier, it will be seen that the effective inductance is of the order of 30 to 40 henries.

Tests at one or two points, for low D.C. currents, were made on other chokes and transformers that happened to be available, but if large D.C. currents flow, the test is rather a strenuous one, and may cause damage. It was found that transformers gave very similar results to chokes, and that the higher values were not given by the best transformers in every case! The effects of self-capacity have, of course, a large influence, and this test is designed to eliminate them.

For comparison purposes, a similar test was made on an ex-Government choke, a Post Office "1,000 ohms telephone switchboard indicator" such as were obtainable a year or so ago at 6d. or 1s.

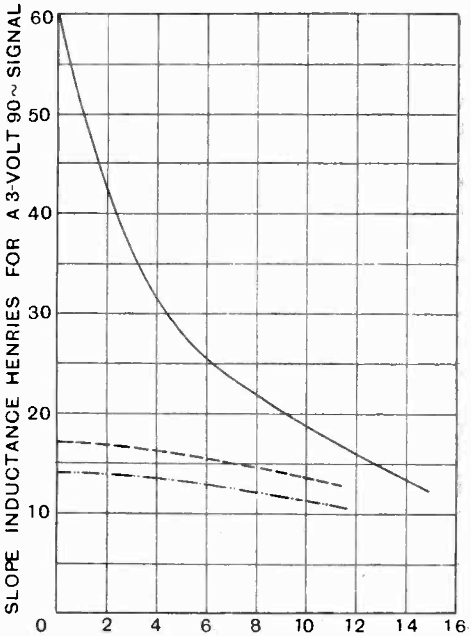

Fig. 3.

Two tests were made, one with the adjustable lid removed, so as to leave a large air-gap, and one with the lid closed as tightly as possible. The results are plotted on Fig. 3 in dotted lines.

Owing to the air-gap, the drop in inductance is much less than in the case of a choke having a closed iron core, and at about 10 milliamps D.C. the inductances of the two are very similar, and one might suppose that they would be equally suitable for use in an amplifier. The two chokes were therefore tried in the anode circuit of the last valve (a D.E.5), the loud-speaker being connected across them through a condenser. The reproduction with the closed-core choke was as good as with the loud-speaker connected in the anode circuit of the last valve, and no decrease of volume was noticeable, but with the small "indicator" choke the volume was much reduced, and quality bad, probably due to large self-capacity.

APPENDIX I.

Discussion of Error made in neglecting Effective Coil Resistance.

Let the true reactance of the choke be X, where :

$$X^2 = Z^2 - (R + r)^2 \quad \ldots \quad \ldots \quad (5)$$

Let the calculated reactance, neglecting the resistance r be Y

where $$Y^2 = Z^2 - R^2 \quad \ldots \quad \ldots \quad \ldots \quad (5\text{A})$$

Then $$X^2 = Y^2 - (2rR + r^2)$$

or $$X = [Y - (2rR - r^2)]^{\frac{1}{2}} \quad \ldots \quad (5\text{B})$$

Expanding the square bracket by binomial as far as the second term,

$$X = Y - \frac{1}{2Y}(2Rr + r^2)$$

$$= Y - \frac{r}{Y}(R + \tfrac{1}{2}r) \quad \ldots \quad \ldots \quad (5\text{C})$$

and the error e is then :—

$$e = (Y - X) = \frac{r}{Y}(R + \tfrac{1}{2}r)$$

or $$e/Y = \frac{r}{Y^2}(R + \tfrac{1}{2}r) \quad \ldots \quad \ldots \quad (5\text{D})$$

Now, if the iron and copper losses are about equal, the effective A.C. resistance will be about twice the D.C. resistance, which is about 1,965 ohms ; say $r = 4{,}000$.

e/Y will clearly be greatest when Y is smallest, and for given Y will be greatest when R is a maximum.

The value of R must then be kept as small as possible without obtaining too small a P.D. across it to be read on the voltmeter.

The worst case actually occurring was $Y = 40{,}000$, $R = 1{,}000$, for which

$$e/Y = \frac{4{,}000}{(40{,}000)^2}\left(10{,}000 + \frac{4{,}000}{2}\right) = \frac{1{,}200}{40{,}000}$$

or 3 per cent.

This is less than the probable error of the readings, which may amount to 5 per cent., and we may therefore say that our results for A.C. inductance are too large by an amount which may be about 5 per cent. at most (the error from neglecting r for greater values of Y is of course much less).

In the test of effective or slope-inductance, the error is different, but the process of obtaining it is similar.

Let X be the true reactance of the choke, and Y the calculated reactance, neglecting the effective resistance r of the choke. Y is then really the impedance of the choke, and—

$$Y^2 = X^2 + r^2 \quad \ldots \quad \ldots \quad (6)$$

We adjusted the resistance R of the rheostat so that $$R = Y \quad \ldots \quad \ldots \quad (6\text{A})$$

whence $$X^2 = Y^2 - r^2 = R^2 - r^2 \quad \ldots \quad (6\text{B})$$

or $$X = (R^2 - r^2)^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (6\text{C})$$

Expanding the bracket by binomial, as before, as far as the second term :—

$$X = R - \frac{r^2}{2R} = Y - \frac{r^2}{2R}$$

and the error $e = Y - X = r^2/2R$

or $$e/Y = \tfrac{1}{2}(r/R)^2 \quad \ldots \quad \ldots \quad (6\text{D})$$

In the worst case here, we have, assuming $r = 4{,}000$ as before, $R = 16{,}000$,

whence $e/Y = \frac{1}{2}(4{,}000/16{,}000)^2 = \frac{1}{2}(\frac{1}{4})^2 = \frac{1}{32}$

or 3 per cent.

The error is then about the same as before.

APPENDIX II.

Proof that the curve of Fig. 1 is, to suitable scales, the μH curve of the iron (plotted on log. paper).

Let L = A.C. inductance.
l and a = length and cross-section of the iron flux-path.
T = number of turns.
I = maximum current.
B = maximum induction.
H = maximum magnetising force.
ϕ = maximum flux.

$$4\pi IT/10 = Hl \quad \ldots \quad \ldots \quad (7)$$

whence $$H = \{4\pi T/10l\}I \quad \ldots \quad \ldots \quad (8)$$

so that H is proportional to $\mathfrak{I}$.

Further $$L = \frac{\phi T}{I} = \frac{BaT}{I} = \mu \cdot \frac{H}{I} \cdot aT$$

or $$\mu = L \times \frac{1}{aT} \times \frac{I}{H} = L \times \frac{1}{aT} \times \frac{10l}{4\pi T}$$

$$\mu = \{10l/4\pi aT^2\}L \quad \ldots \quad \ldots \quad (9)$$

so that μ is proportional to L.

Now if we assume a sinusoidal current, $\mathfrak{I} = \sqrt{2}I$, where $\mathfrak{I}$ is the R.M.S. current,

thence $$H = \frac{4\pi}{10\sqrt{2}} \; \frac{T}{l} \cdot \mathfrak{I}.$$

L.T. & H.T. Supply from D.C. Main.

THE accompanying diagram, Fig. 1, shows a three-valve receiver connected to an arrangement for obtaining H.T. and grid bias from a D.C. 250-volt town main supply, where the + side of the system is earthed.

The arrangement is similar to that described in my article on "L.T. and H.T. from a 250-volt D.C. Supply" in the February number of *E.W. & W.E.* A 60-ohm resistance provided with tappings connected to wander plug sockets supplies a range of grid bias voltage. This resistance consists of several 12-ohm M.F. lamps in series and is connected in circuit between the choke coil and negative battery terminal. It gives every satisfaction with entire absence of hum.

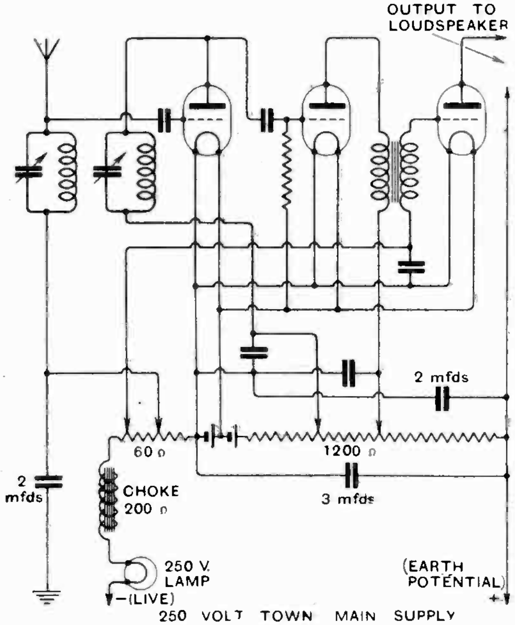

Fig. 1.

If grid bias is desired for only the last valve, this resistance may take the form of a rheostat.

Care must be taken that the reservoir condensers are connected directly to the L.T. busbars. A slight modification in this circuit may cause these condensers to bring in a considerable hum from town main supply, when, with direct connections, they should slightly contribute towards smoothing of ripple.

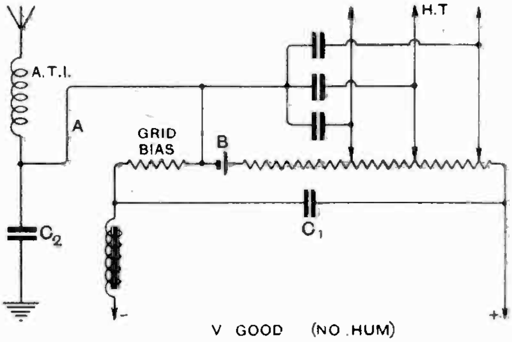

Fig. 2. *Arrangement for obtaining H.T. and grid bias from 250 volt D.C. town main supply.*

Figs. 2 to 6 show several possible arrangements together with a brief account of their behaviour in actual use.

The following explanation for presence of hum in circuits shown in Figs. 4 and 6 is deduced from the experimental results obtained. The ripple passing through the choke coil thereafter splits up into two main

Fig. 3. *Another arrangement also giving excellent results.*

portions, one of which is by-passed, through condenser C_1, to the positive supply terminal; the other portion travels via leads B and A (Fig. 2) to earth via condenser C_2. There are also two other very small components, one of which travels through the 1,200-ohm resistance to the positive supply terminal. The other goes up through the anode

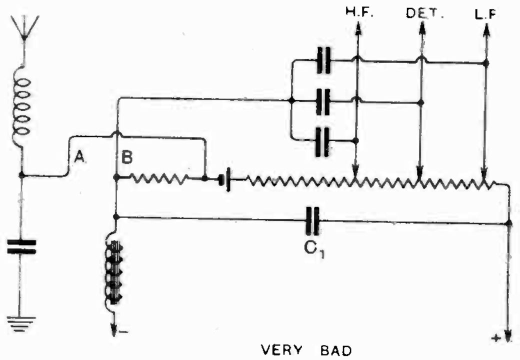

Fig. 4. *Showing an arrangement with which the hum is very bad indeed. This arrangement is similar to that in Fig. 5, but the reservoir condensers are connected up. In this case the reservoir condensers cause considerable hum, owing to position of connection B in circuit.*

reservoir condensers and back through a portion of the 1,200-ohm resistance to the positive supply terminal. Both these components are harmless and only the component which takes the path through condenser C_2 will at present be discussed.

In Fig. 4 the ripple passing through the choke coil would, if there were no resistance in circuit, travel direct to earth through condenser C_2. The presence of the grid bias resistance causes a small portion to be

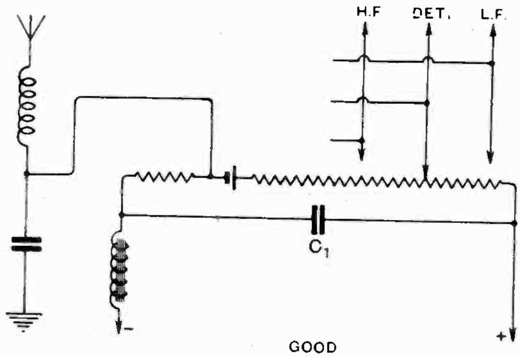

Fig. 5. *Showing same arrangement as Fig. 2, but reservoir condensers are disconnected. This arrangement gives quite good results but there is a slight trace of hum which indicates that the reservoir condensers slightly assist smoothing.*

diverted through lead *B* to the anode condensers returning through the valve to the battery and to earth through condenser C_2.

This theory is supported by the fact that the hum ceases when the circuit is broken at either *A* or *B* and also when the 60-ohm resistance is shorted.

The conditions in circuit shown in Fig. 6 are somewhat more complicated.

This circuit is similar to that shown in Fig. 5, but in this case the L.F. anode reservoir condenser is connected up and the L.F. wander plug is inserted in an anode supply socket. The anode circuit is, however, broken at the L.F. valve holder, and the L.F. valve filament unlighted. The reservoir condenser, on detector anode supply, is disconnected.

It will be gathered from the data obtained

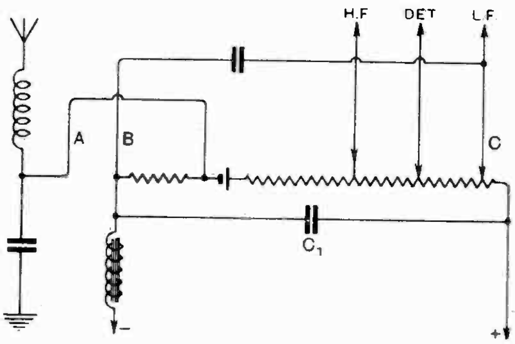

Fig. 6. *An arrangement in which there is no hum when L.F. valve wander plug is at the extreme positive end of resistance. The hum becomes evident as the plug approaches the detector wander plug. Hum is very bad when LF. wander plug lies between detector and battery but it disappears when L.F. plug is directly connected to the battery.*

(see note below Fig. 6) that the ripple, diverted by means of the 60-ohm resistance, passes up through the L.F. anode reservoir condenser, down the L.F. wander plug, thence along a portion of the 1,200-ohm resistance to the detector wander plug to the detector valve and back via battery and thereafter to earth through lead *A* and condenser C_2

In support of this theory the hum ceases when circuit is broken at *A*, *B* or *C*. It also ceases when the L.F. wander plug is inserted at the extreme positive end of the 1,200-ohm resistance (owing to ripple having a direct return path through the positive supply terminal).

It also ceases when the L.F. wander plug is directly connected to the battery terminal as the circuit then becomes shorted to earth via lead *A* and condenser C_2.

The operation of the circuit, shown in Fig. 6, has been dealt with in some detail as it serves to demonstrate the important part an apparently trivial detail may play in the working of a piece of apparatus. It was on such a circuit that the writer made his preliminary experiments, although it was ultimately intended to adopt that shown in Fig. 3. It so happened that the arrangement as shown in Fig. 6 could be experimented with without interfering with the wiring inside panel. The tests were carried out, in the first instance, with the detector valve only and the L.F. wander plug was simply pushed into a vacant socket to be out of the way. Tests were made with various types of resistance such as filament rheostat, wire wound resistance, non-inductive resistances and lamp resistances. A hum was experienced in the first three cases and no hum in the last test. An inductive resistance would, of course, accentuate the hum, but in this instance the improvement noted was not due to any difference in the characteristics of the different resistances but to a change in the position of the L.F. wander plug. This happened to be moved down one socket at the same time as the change was made from wire resistances to lamp resistances. This change, it afterwards transpired, altered the position from that of maximum hum to that of minimum hum. The arrangement shown in Fig. 3 is that adopted by the writer and it gives every satisfaction with all three valves in operation.

A. Robertson.

Design and Construction of a Superheterodyne Receiver.

By P. K. Turner, A.M.I.E.E.

(Continued from page 292 of May issue.)

A SIMPLE modification of the circuits of Figs. 8 and 9 (p. 292 May issue) makes negligible the objections to these circuits there referred to. This modification, as shown in Fig. 10, is based on substituting a double condenser, C_2C_3, for C_2, and connecting the centre point to the valve filament. In this way our bridge is completed by two condenser arms, of low impedance compared to the previous ones. C_2, of course, is shunted by the valve impedance, but as this is considerably higher than the reactance of C_3 it exercises only a small effect on the total impedance of the C_3 arm, and this effect can be largely balanced out by putting a corresponding load across

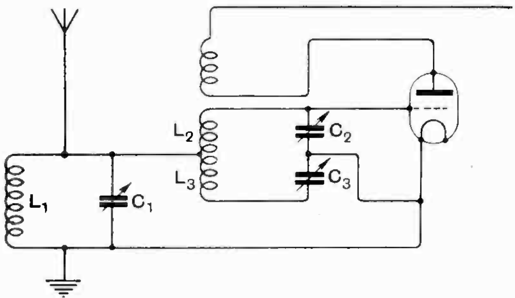

Fig. 10. *The split condenser* C_2C_3, *shown here, is the real solution of the difficulties met with in the previous three circuits.*

C_3. For those who are not accustomed to think in impedances, perhaps the analogous case in Figs. 11 and 12 will be clearer.

In Fig. 11 the upper resistance is variable, and it is obvious that at either extreme of its variation there is a 1 : 2 or 2 : 1 ratio between the two resistances. Now suppose that we have, as in Fig. 14, arms of low resistance (100 ohms), with the high resistance arms across them. Working by the well-known formulæ for parallel resistances, we find 99 ohms for the net resistance of the fixed arm, while the upper one varies from 98 to 99.5 ohms, or a change of only $1\frac{1}{2}$ per cent. in the balance, instead of a change of 4 : 1 in Fig. 13.

This type of circuit was eventually adopted, as shown in Fig. 13. It was desired to be able to use a frame or an open aerial, but the arrangements for this, as well

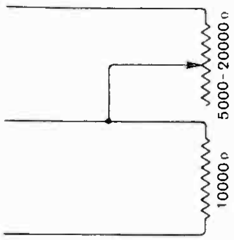

Fig. 11.

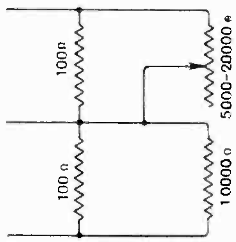

Fig. 12.

Figs. 11 and 12. *The article shows how these resistance circuits are analogies of Figs. 9 and 10.*

as the values of the various components, will be dealt with later, after the theoretical diagram has been completed. It will be noted that a grid-leak and condenser have been included. At the time, I was still not sure whether it would pay to sacrifice the increased efficiency of the grid current detector for the lessened harmonics of the anode current type; it was obviously simpler to include the condenser, and short it afterwards if necessary.

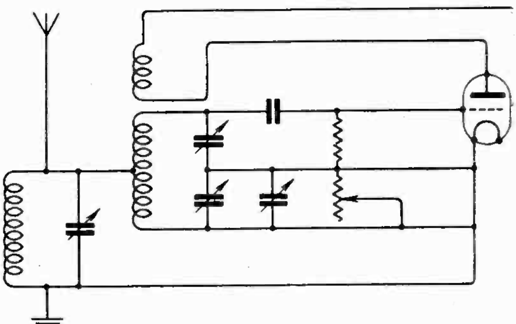

Fig. 13. *The final circuit arrangement, in which errors of balance are negligible.*

The rest of the set, as regards preliminary design, is simple enough, and is shown in Fig. 14—it may be said that the filling-in of the details is not so simple. There is a choice of two alternatives at the point A, where the rectified output from the second detector is thrown back to an earlier valve. These are shown in Fig. 15(a) and 15(b). There are two points that might influence one's choice; the effect of the necessary by-pass condenser on the audio-frequency tone, and the possibility of getting the I.F. component

(b) needs an extra component (the choke). However, it was eventually decided to include the choke and use (b).

We thus have the first theoretical diagram —except for the filament circuit—as shown in Fig. 14. Before we begin to consider the detail of this, one important question must be settled: What is to be the intermediate frequency?

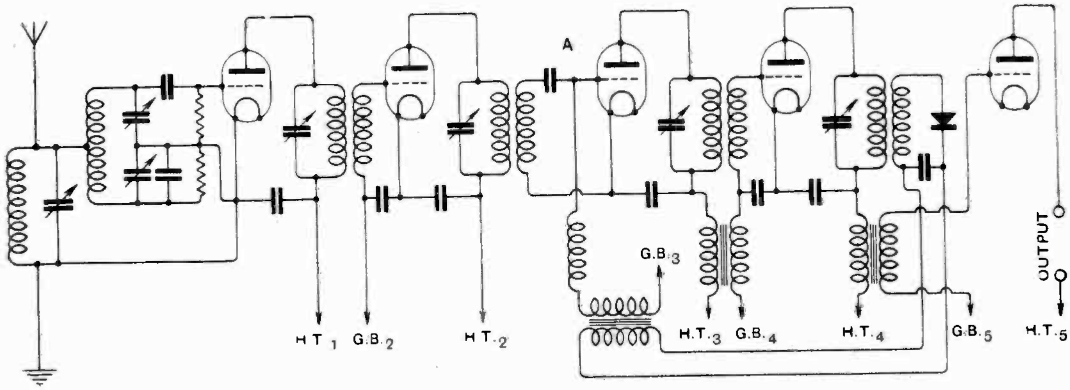

Fig. 14. *Here we have a preliminary sketch of the complete circuit of the set, with non-essentials and details omitted for simplicity.*

in the second detector output thrown back with the audio, which would lead to instability. As regards the first point, there is no choice; but as regards the second point (b) is the better, for the I.F. choke *Ch.* not

Fig. 15. *Two alternative arrangements for the throw-back transformer; (a) is the most economical, (b) probably the better.*

only stops the normal I.F. from leaking down to the L.F. transformer, but also stops the reverse action. On the other hand, the effect is not usually an important one, and

If there were no question of Daventry and similar stations, it would be easy. Our preliminary consideration of the question has shown that there is a wide latitude. But if we want to receive up to, say, 2,600 metres (Paris) the intermediate wavelength must be not less than, say, 6,000 metres, or 50kC. Now, in many cases it would make little difference whether we used 6,000 or 10,000 metres. But in this set it is proposed to use two of the valves for both I.F. and L.F., and this makes things just a bit more difficult. For, in this case, both the primaries and secondaries of the L.F. transformers need by-pass condensers These should be large enough not to offer too much reactance at the intermediate frequency; at the same time, if they are large, they will upset the performance of the L.F. transformers at the higher end of the audio-range.

Now, the lower the intermediate frequency the larger these condensers must be; so we desire to keep the I.F. high. Further, there is a great advantage in having a choice of I.F.s available. Any one station, as we all know, can be recevied at two settings of the oscillator. By the same token, any one setting will beat with two stations, and if (like the writer) one happens to live only two miles from a station, one is likely to find that it interferes on the second setting.

For example, with an I.F. of about 3,000 metres London and Birmingham will very likely clash,* and it may be a great convenience to be able to change the I.F., when they are separated at once.

These two points decided me to try something that I believe to be new. I decided to use an I.F. of about 3,000 metres, or 100kC, and to put *variable* condensers on all the I.F. transformers, the condensers being all operated from one knob. Then for the long wave stations the first valve is stopped from oscillating, and the I.F. amplifier used direct and tuned to the signal. I may as well confess here and now that this device, in spite of its obvious advantages, is by no means free from "crabs." It is expensive and needs a lot of room, and it is not so easy to get stability *and* efficiency at various settings of the I.F. tuning condensers.

At first I designed some rather intriguing switch-circuits to put the incoming signal through to the second valve and simultaneously cut off the filament voltage of the first. It was not till the set had been actually built and tried out that I suddenly perceived the error of my ways. Of course, it was only necessary to stop the first valve from oscillating and tune the aerial circuit to the long wave to be all in order. True, the first valve probably works rather inefficiently, but every little helps.

The next question was as to valves, because this affected the filament circuit. I wanted freedom to use different valves, but obviously all the I.F. valves had to be alike, if the I.F. circuits were all to be tuned together. I therefore designed the circuit for 6 volts, but provided rheostats. As, however, the set would not always be handled by myself, I decided to provide safeguards against excessive filament heat, so that the circuits contain provision for screw-in fixed resistors as well as the rheostats.

By changing these, it is always possible to ensure that, even with the rheostats cut right out, no valve can be heavily overloaded, while there is still the ability to control the filaments, if it is really necessary. For example, the first valve is separately controlled. If one wishes to use a 306 valve, a 45-ohm fixed resistor is used, which puts a limit of about 3.2 volts on the filament even with the rheostat cut right out. The rheostat is a 30-ohm, and can be used to control the valve when needed.

In view of the fact that the three I.F. valves should always be of the same type, they are all controlled from one rheostat, a third control being fitted for the final power valve.

Since I expected to use different valves from time to time, I desired to have a filament voltmeter always available—for it is pretty useless to try to judge the voltage on dull emitters by their appearance. I was also quite determined to have a milliammeter in circuit, as it is such a useful guide to adjustment and also for fault-finding, apart from its being a sure indicator of distortion due to the valves. As will be shown later, I was able to use the same meter for both purposes.

It was at this stage that I began to consider what tappings I should need on the grid and anode batteries. Again, in view of the fact that I wished to experiment with various valves, I decided to run one anode tap for the "detoss," one for the three I.F.s, and one for the power valve. The same was done for the grid battery. Since this was to be inside the set, it would obviously be just as easy to connect the earth point of the "detoss" grid circuit to a flexible tap as to make a permanent connection to either side of the filament, and I decided on this.

At last, then, I was ready to design out the final theoretical diagram, and, as usual, I started with the filament circuit. I always find it best to neglect this in preliminary work, to begin with it in the final schematic diagram, but to leave it to last again in the layout.

It was decided at once that all the rheostats must go on the positive side of the filaments. It is one of the advantages of fixed resistors that they may be inserted in the negative leg, and thus in many cases enough grid bias may be got, without a special battery, for all except the last valve.

* At the time of writing, Birmingham was on its old wave of 480 metres or thereabouts.

But this is quite unjustifiable with variable filament rheostats, since every adjustment of the resistance alters the grid bias. It was further decided that L.T.— should be the "bus-bar," to which should be connected all by-pass condensers, earth (when used), screens, etc., and also H.T. — and G.B.+.

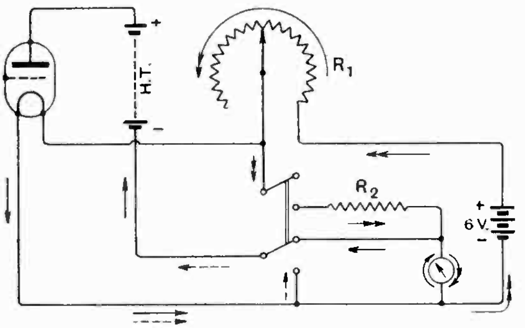

Fig. 16. *In order to show anode mA or filament volts on the same meter, a switch is arranged (as shown).*

A little thought had to be expended on the arrangement for switching the meter to register either filament volts or H.T. milliamps. One or two arrangements which worked admirably for one valve had the disadvantage that when extended to deal with several the slightest error in operating the switches led to a short. That finally adopted is shown in its simplest form in Fig. 16. Here R_1 is the filament rheostat and R_2 a suitable high resistance to make the milliammeter work as a voltmeter. It is clear from the diagram that with the switch in its present position the return current from filament to — of the H.T. battery follows the line of the plain arrows through the meter. On switching over, this H.T. current flows according to the dotted arrows and does not affect the meter, while the latter, with R_2 in series, is placed across the filament and thus indicates filament volts as shown by the double-headed arrows. Since the two currents flow in opposite directions, a central zero instrument must be used.

The resistance R_2 may be found as follows: Suppose the full deflection of the meter is 10mA, and we want this to mean 6 volts, Ohm's Law ($R=E/C$) tells us that the resistance of R_2 and the meter together must be $6/.01=600$ ohms. The makers will always state what is the resistance of the meter, and R_2 can be found approximately from any wire tables, and checked and adjusted by comparing the milliammeter and R_2 against a voltmeter—or the calibration department of *E.W. & W.E.* would undertake the work.

For use with several valves, one slight modification must be made: "R_2" must go to the arm of the switch and "Fil.+" to the contact: the reason for this will be appreciated on studying Fig. 17, which shows the full filament circuit for the set. The switches are, of course, Dewar keys, which are most effective and convenient for such work.

It will be seen that four such keys are included in Fig. 17, of which one is simply a switch for the H.T. and L.T. — leads, thus forming the main on-off switch for the set. The other three are connected as in Fig. 17, the left-hand contacts of each key being for filament voltage and the right-hand ones for the H.T. current circuit. In the position shown, the main switch is off. On pressing the key, the centre contacts rise into contact with the top bars. There is then a complete circuit from the right-hand contacts of this switch *via* the middle and bottom right contacts of all the keys, and the meter, thus connecting H.T. — to Fil.—. On pressing

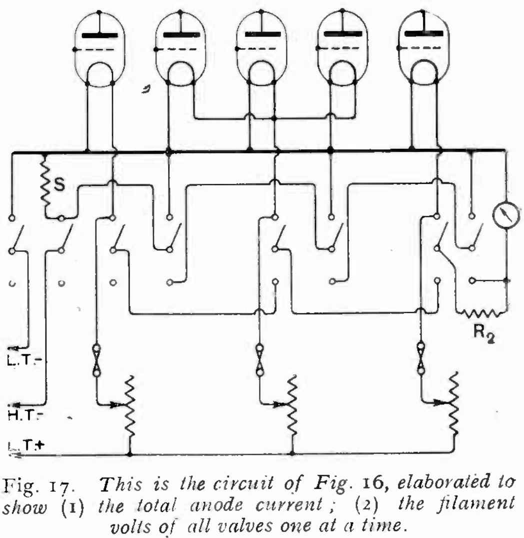

Fig. 17. *This is the circuit of Fig. 16, elaborated to show* (1) *the total anode current;* (2) *the filament volts of all valves one at a time.*

any key, the right centre contact rises and makes contact with the upper bar, thus disconnecting H.T.— from the meter and putting it straight to the Fil.—. At the same time, the left centre contact of the key pressed rises and connects the meter through R_2 to the corresponding Fil.+. If by accident two keys are pressed at once, nothing happens except that the meter reads the voltage of the nearest filament.

In the actual set, S had to be included. This is a shunt which comes across the meter whenever it is being used as a milliammeter, and was put in because the only available instrument was a 10mA meter, and it was desired to read up to 20mA.

When this part of the circuit had been wired up, the glass of the meter was removed, and the existing scale covered by a paper one, of which one side was marked in black to read 20mA, and the other in red to read volts: the graduation was done against outside meters known to be fairly accurate.

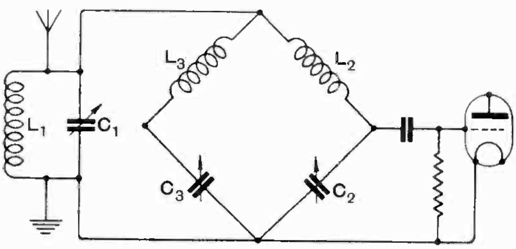

Fig. 18. *In the detailed design of the input circuit, it must not be forgotten that the oscillator coils and condensers come across the aerial circuit and affect its tuning.*

To avoid confusion, this filament circuit will not be shown in later diagrams, it being understood that the grid and anode circuits are connected (for H.F. and audio currents) to the Filament negative busbar shown as a heavy line in Fig. 17.

The next task was to think out in detail the arrangements for the grid and anode circuits. It had already been decided that the I.F. should be 100kC (3,000 metres) or thereabouts; and it was desired to have the transformers of a plug-in type, with a view to test and experiment. It was decided to install McMichael air-cores as a commencement, as they were compact, and also lent themselves conveniently to the use of reaction if desired. This led naturally to the McMichael "Autodyne Unit" for the twin coils of the oscillator. As it was desired to get a fairly wide wave-length range, it was decided to use a twin .0005 condenser across these coils.

It was realised that the presence of these coils and condensers would have a distinct effect on the aerial tuning, for, as will be seen from Fig. 18 (which is Fig. 13 drawn differently) they come across the frame or A.T.I. whichever is used. It must be remembered that $L_2L_3C_2C_3$ control the *oscillator* frequency and are therefore out of tune with the aerial to the amount of 100kC (the intermediate frequency). If they are tuned to a longer wave than the aerial the condensers will be too large to tune with the aerial, they will offer too little reactance, and the whole of $L_2L_3C_2C_3$ will act as an inductance in parallel with L_1. If, on the contrary, $L_2L_3C_2C_3$ is tuned to the shorter wave than the aerial, they will act as a capacity across C_1. The matter is further complicated by any mutual inductance between L_2 and L_3, and the precise calculation of the effects is quite tricky. It leads to the important feature that if connected up as shown, and arranged so that L_2 and L_3 form one coil in Fig. 13, signals will be stronger when the oscillator is tuned to a shorter wave than the signal. This is a valuable feature in diminishing interference. If it is desired to work permanently on the other "channel," with the oscillator set to a longer wave than the signal, the following changes should be made: (1) L_2 and L_3 should have more turns—probably about twice as many; (2) they should be wound in opposition, *i.e.*, *one* of them should be reversed; (3) probably several turns will have to be taken off the frame.

Connected as shown, the McMichael unit, nominally 300-600 metres, gave a range of 200-700 with the two .0005 condensers across it. The smaller unit, nominally 150-300, gave about 120-350 metres.

In order to cope with a wide range of experimental conditions the aerial condenser C_1 was made large (0.001) and a special arrangement of plugs was used for connecting up the frame. This is shown in Fig. 19. Sockets are provided for an outside aerial and earth when desired. To use the frame, F is plugged in. To use a tuning coil, C is plugged in. For short waves on the frame both plugs are inserted, putting the coil socket in parallel with the frame, when a short wave coil may be inserted to cut down the wave length. If one wants a long wave, beyond the range of the frame, the two plugs (which are Clix) are connected together, which puts coil and frame in series.

Between this arrangement and $L_2 L_3$, however, there is another device: the long wave switch. The connections of this are shown in Fig. 20. All it does is to cut a long-wave coil clear out of circuit or bring it in; it also shorts the oscillator reaction coil on long waves.

Everything has now been decided up to the first grid except the grid and balancing condensers and leaks. It was decided to make the leaks variable, and as we had previously had good results with the Bretwood, we used these. The grid condenser was made 0.0001. Probably an even smaller value would have been an improvement. From the point of view of detection, this condenser should be large enough to offer

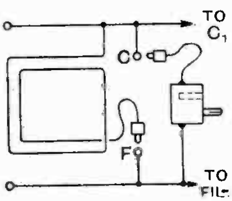

Fig. 19.

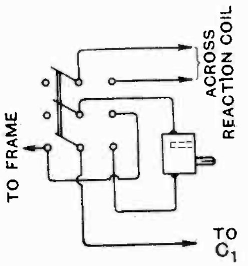

Fig. 20.

Fig. 19. *Two plugs and sockets enable us to use frame and loading coil either alone, in series, or in parallel.*

Fig. 20. *This 3-way switch, thrown to the left, puts aerial to set. On the right, it throws in a series coil for long waves, and at the same time shorts out the oscillator reaction.*

not too great a reactance to the radio frequency input, but at the same time small enough to offer a high reactance to the rectified output. Since in this case the output is at 100,000 cycles as compared with audio frequency for an ordinary detector, the condenser should be kept smaller than usual, provided this does not interfere with the valve's performance as an oscillator. Since only low-power oscillations are needed, this latter point is not of great importance.

Lastly, as to the balancing condenser. This has to balance out the apparent working capacity of the valve, and should be made variable, with a maximum capacity of 50-100$\mu\mu$F. One of the single-plate neutrodyne or "vernier" condensers on the market will be suitable.

As already explained, it is simplest to leave the filament connection variable, so that the grid battery can be used to give a volt or so + or — potential. The reason is that this valve has, firstly, to oscillate with as few harmonics as possible, and secondly, to rectify with as few harmonics *of the rectified frequency* as possible; and to meet all these requirements it is best to have a free hand with both grid and anode voltages. Do not imagine that the adjustment is difficult; the set will work, and work well, with any reasonable voltages; but if it is to be used within a mile or so of a 3kW station, that station may tune in in more than two places on the scale if these harmonics are not kept down. In actual practice, I have found that, for M-O D.E.3B, Mullard H.F. 06, and Burndept H. 310, about 90 volts on anode, and grid circuit straight to filament negative, gave the best results, while with Burndept H.L. 512, one cell negative grid bias was an improvement. Unfortunately, one cannot very easily forecast the requirements in advance, for it is very difficult to calculate what will be the mean grid potential of a valve with condenser and leak when that valve is oscillating. Finally, therefore, we have Fig. 21 as the circuit as far as the output of the first valve. As regards the values of components not already decided, we have found that a small frame about 2 ft. × 1 ft. needed 8 turns, and a large one, 3ft.×3ft., needed 5 turns. These were tapped once (the 8-turn at 5 and the 5-turn at 3), and in this way each would tune from 200 to 600 metres without troubling to use a plug-in coil. The long-wave coil will probably need to be 150 or 200 turns. For the 300-600 twin coil a reactor marked "30" proved the best, and for the 150-300 a "20," or better still, a "20" rewound with only three-quarters of its original turns. The condenser C_1 is simply to by-pass the grid battery and if the flexible plug lead (as in our case) is only a few inches long, it can be safely omitted. If included, it may be anything from .001 to .005.

It may quite possibly be desirable to modify the arrangement of the anode circuit. There are two obvious possibilities, and the choice will depend on whether it is desired to tune the primaries or secondaries of the I.F. transformers. For equal "goodness" of design, it will probably be most efficient to tune the secondaries, but it is often more convenient (and gives a longer range of wave-lengths, if desired) to tune the primaries. If the latter is done—and as will be seen later, it is especially convenient with a crystal detector—then Fig. 21 gives the correct wiring, the tuning condenser across the primary also acting as a of the I.F. stages. A point which needs consideration straight away is that of reaction, or on the contrary, stabilising. If transformers of fairly high step-up are used, it is quite likely that stabilisation will be called for, especially if the tuning condensers are small—these are both points making for high amplification per stage, and compara-

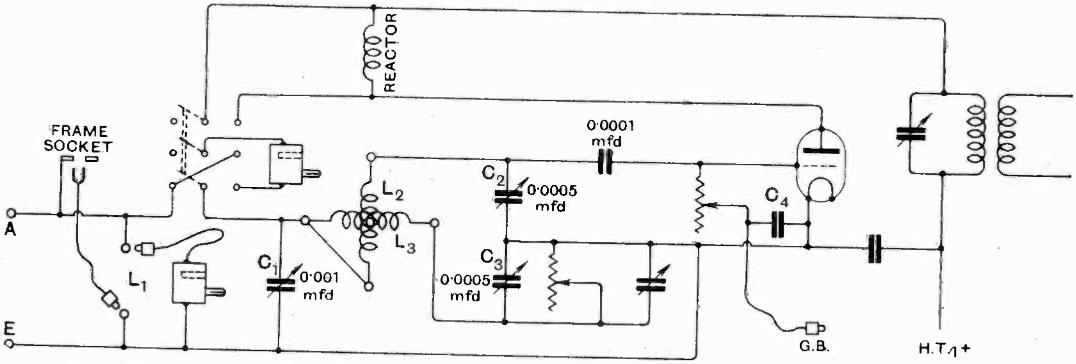

Fig. 21. *Here we have, with all frills, the complete circuit from aerial as far as the output of the first valve.*

by-pass for the H.F. components in the detector output. If, on the other hand, the secondary is to be tuned, and the primary is of low self-capacity, Fig. 22 shows the best method. The primary acts as an H.F. choke, and the .0001 condenser in the lead to the reaction coil, as an I.F. stopper. It may be advisable to reduce the latter to

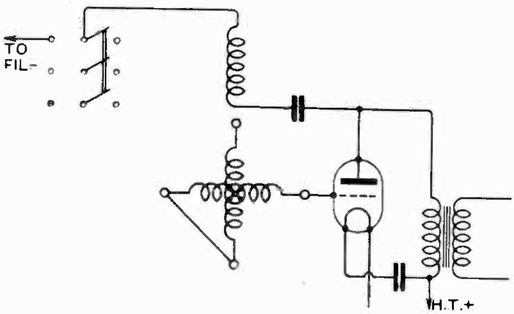

Fig. 22. *If the I.F. transformers have* NOT *got tuning condensers across their primaries, this form of oscillator reaction circuit must be used in place of that in Fig. 21.*

.00005. Also, it will be noted that the long-wave switch connections are changed so as to open-circuit the shunt reaction coil path on long waves.

Now we must begin to consider the design tively low selectivity. On the other hand, if the transformer step-up is kept low—say $1\frac{1}{2}$ to 1—and if the I.F. is such that the transformers tune to it with a fair amount of capacity (these points giving extreme selectivity but lower amplification), then with good design the I.F. amplifier will be so stable as to stand quite a lot of positive reaction.

These two points perhaps need a little further treatment. That of selectivity was treated by the writer in a recent issue of *E.W. & W.E.** This dealt primarily with amplifiers of the tuned anode type; but since a "tuned anode" circuit is essentially a 1 to 1 transformer of zero magnetic leakage, and since the tuning conditions of any tuned transformer may be reduced to those of a 1 to 1 transformer by working on "equivalent capacities," the principles of that article will apply. It was there shown that small windings and large capacities give great selectivity, but a certain reduction in strength. If the condensers are *too* great, one may easily, with several stages, get excessive selectivity and cut down the strength of the side-bands giving the higher notes.

* "Selective Amplifiers," *E.W. & W.E.*, October, 1925, pp. 801 *et seq.*

It will be noted that on p. 805 of the article just referred to, there is given the example of finding the right values of the condenser for "amplifying at 3,000 metres, to give a drop of not more than 20 per cent. in the strength of the side-bands at 5,000 cycles audio-frequency with valves of 30,000 ohms anode impedance." It may perhaps be a matter for surprise that the conditions there specified fit in so aptly with our present requirements. To be perfectly frank, that article was inspired by the actual calculations made for this receiver, the writer finding to his disgust that no one else had written an article from which he could crib the necessary data.

The example shows that a capacity of 0.0002 is called for across the primary of the transformer, which is what we wish to do here. Had it been desired to use transformers of higher step-up, we should use the same capacity across the primary. Strictly, a correction should be made, because the step-up ratio makes the load on the secondary (due to the next valve) more important; but the correction is not large (see p. 803 of "Selective Amplifiers," *re* the ratio R_a/R_e). If, on the other hand, we had proposed to use step-up transformers of ratio 1 to 4, and tune the secondaries, we should have divided the .0002 already found by the *square* of the ratio (*i.e.* $4^2=16$), thus getting 0.000012 for the best capacity.

As regards the correct ratio of a tuned transformer for the highest amplification, this is a much more complicated matter. The writer has worked out the analysis fairly completely, but the difficulty is that the best ratio depends essentially on the input impedance of the valve which follows the transformer, and this is quite a difficult thing to forecast. Under average conditions, it is probable that the ratios given in the following little table are about correct:—

TABLE II.

Wavelength.	Ratio.
200—400	1 : 1
400—800	1 : 1½
800—1,600	1 : 2
1,600—3,200	1 : 3
3,200 upwards	1 : 4

In every case, of course, if the transformers are to be home-built, the inductance of the tuned winding is to be calculated from the maximum tuning capacity as found above and the desired maximum wavelength. In practice, the winding should be made slightly larger than calculated in this way, to allow for the "demagnetising" effect of the other winding. This correction is practically negligible if the secondary is to be tuned; but if the primary is to be tuned, and there is a fairly high ratio, so that the secondary is large, then it may be found advisable to increase the primary inductance by say 20 per cent. (or the turns by 10 per cent.) above the value calculated as just shown.

In the particular set we are describing, it had been decided to tune the primaries. To allow for any unexpected effects, it was decided to fit condensers of 0.00025μF, and the No. 3 air-core barrel-type transformers of L. McMichael, Ltd., just filled the bill, giving about 3,000 metres with all the capacity across.

This having been settled, it was noted that these transformers are practically 1 to 1 ratio, so it was expected that the amplification would be fair, the selectivity good, and the amplifier pretty stable. So provision was made for reaction. This, as a matter of fact, is exceptionally convenient with these transformers, as they can be fitted with reactors as desired.

In cases where stability is not expected—or where, though expected, it has not been achieved—one must consider whether to use reverse reaction or whether to stabilise by control of grid potential. I must confess to a strong distaste for this latter method. For a commercial act, to be handled by the unskilled, it has many advantages. But for a set for myself, I prefer magnetic reaction, positive or negative, as may be found necessary. It should be emphasised that this is simply a personal preference: I know of various excellent sets which use potentiometer control.

I am surprised that so many builders of supersonics neglect the importance of this control. On many sets the "stabiliser" is an "occasional" control, not intended to be used frequently. But it is extremely useful. It gives a most powerful control of volume for getting very distant stations, and is also of great assistance in getting increased selectivity when absolutely necessary. Of course, this may cause loss of high notes from excessive selectivity, so it is equally necessary to avoid its use when best possible tone is needed from a station fairly near.

After all this preliminary thought, one can get down to the details of the I.F. circuits. The first stage is partly shown in Fig. 21; but we give it in full in Fig. 23. It is that part to the left of *AB*. The circuit is typical, and needs no explanation except for the by-pass condensers. It is usually used, 100V on the anodes is the sort of voltage called for.

In putting up these suggestions, of course, I have an eye to the requirements of the later I.F. stages, which are doing L.F. work as well. For the first stage, which is pure I.F., one can neglect distortion to some extent, and if desired use less H.T. and bias. But it seems simpler to run all the I.F. valves alike.

The next stage is that included between the dotted lines *AB* and *CD* in Fig. 23. The first part, the anode circuit, is similar to the previous anode circuit except for the omission

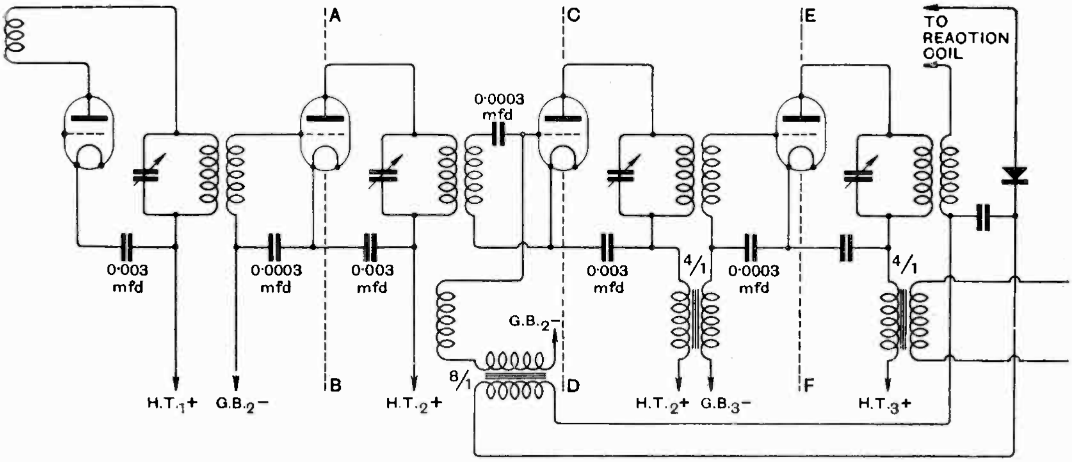

Fig. 23. *Here we have, complete except for battery connections, the circuits of the I.F. amplifier and detector, including the reflexed L.F. circuits.*

considered sufficient to put in a condenser across the battery, and leave it at that. But, as will be seen shortly, we *must* use these condensers in later stages, and it is always sound practice to have a short H.F. path straight to the filament, so they are included in this stage as well. The reason for the difference in their values is the increased impedance of the grid circuit as a whole, which allows a correspondingly high reactance or low capacity for a by-pass. As to values of H.T. and grid bias, they should be arranged for pure amplification: a bias of 1 cell (say 1.5V) is probably sufficient for all these stages, though I prefer myself to put on 3V as a precautionary measure, as some valves start grid current some way below zero volts. With most valves of μ from 10 to 20, such as will probably be of the reaction coil. It therefore needs no remark. The second part, however—the grid circuit of the third valve—has some points needing consideration. We have already gone into the reasons which led to the choice of parallel circuits for the I.F. and L.F. currents. We must now choose values for the splitting choke and condenser.

The condenser presents the old problem: it must have a low reactance to the I.F. (100kC), but a high reactance to the audio (say 2kC), both "low" and "high" being in comparison with the input impedance of the valve. As will be seen from Fig. 23, we have given this the same value as the grid by-pass condensers in other stages. These are based on the following empirical rule: "To separate audio-frequency from 300 metres, use 0.0001 in grid circuits and

0.001 in anode circuits: if either of the limit frequencies is n times these values, divide the capacity by $\sqrt{n}$." Thus, since your actual limits in this case are 3,000 metres and audio, we have *divided* one frequency by 10, and we therefore *multiply* the 0.0001 by $\sqrt{10}$, getting approximately 0.0003μF.

As another example, take the grid condenser of the first detector. Here the frequencies are (say) 300 metres and 3,000 metres. The latter is 100kC, or say 50 times audio-frequency, so the condenser should be divided by $\sqrt{50}$, or 7, giving 0.000,015. Actually, we used a larger condenser, to help the valve as an oscillator, but on a future occasion, we should try a smaller value.

With regard to the I.F. choke, it is hard to give any definite rule—apparently almost anything will do—provided, of course, it is not *too* small. Ordinary coils of various makes from 400 turns upwards all did fairly well. We finally chose a coil which seemed just a little better than most for this particular purpose, and had the merit of cheapness. It was an Igranic "slab" of 1,800 turns, rated at about 200,000μH, self-capacity about 11$\mu\mu$F. Probably a coil of 2,000 turns of fine wire wound solid in a slot, say 1½ in. bottom diameter, ⅛ in. wide, and not less than 1 in. deep, would do as well; for in this instance we are not interested in H.F. resistance: low self-capacity is the great factor.

The next stage, between *CD* and *EF*, is again slightly different. Here both the anode and grid circuits are combined L.F. and I.F. The series arrangement was adopted, merely on the ground of saving chokes; for the particular reasons which made the parallel method preferable in the first or "throw-back" stage now no longer apply. There is also a real disadvantage about having several H.F. or I.F. chokes in the same set. Although the I.F. current flowing in such chokes is extremely small if they are efficient, yet it does exist; and their large inductance makes even a small current quite powerful in creating unwanted stray fields. If several are in use, it is quite surprisingly difficult to keep them from picking up from one another, which promptly leads to instability.

The by-pass condensers, transformer, and main tuning condenser are all just as described for previous stages, so that there is really little to say about the I.F. part of this stage: the L.F. part will, of course, be dealt with later.

(*To be continued.*)

Mathematics for Wireless Amateurs.

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C.

(*Continued from page 285 of May issue.*)

8. The Circular Measure of Angles.

AN isosceles triangle is one having two sides equal. It is easy to show from the results of Sect. 5, that the angles opposite these sides will be equal, and therefore that all such triangles with a given angle included between the equal sides will be similar. n such triangles of equal size and with vertical angle $360°/n$ can obviously be combined into a figure such as that shown in Fig. 15. Such a figure is called a regular n-sided polygon.

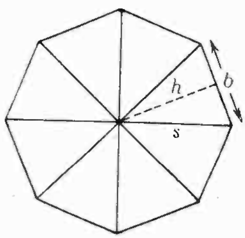

Fig. 15.

(That illustrated is an octagon.) From the preceding discussion of similarity it follows that for any given number of sides n the ratio b/s, and therefore nb/s is constant, *i.e.*, independent of the size of the figure, *i.e.*,

$$nb/s = k_n$$

where k_n depends only on n. Now by sufficiently increasing n the figure can be made to differ by as little as we please from a circle. A circle is in fact the limiting case when n is made infinite, nb then becomes the periphery or circumference of the circle, and s its radius. Thus the ratio

$$\textit{circumference}/\textit{radius} = k_\infty$$

is constant for all circles. The constant is the number 6.2831 . . . . . , usually written 2π. The symbol 2π is used both for shortness and because π is what is called an incommensurable number, *i.e.*, it cannot be completely represented by any decimal. It follows that the ratio of any given fraction of the circumference to the radius is also constant for all circles. Thus in Fig. 16,

$$\frac{\textit{length of arc } a_1}{r_1} = \frac{\textit{length of arc } a_2}{r_2}$$
$$= \text{constant for all circles}$$

the magnitude of the constant depending only on the angle θ. The ratio *arc/rad.* is therefore a natural measure of the angle and is in fact called the circular measure of the angle. Unit angle on this basis will be that for which

$$\textit{arc}/\textit{rad.} = 1$$

i.e., the angle subtended by an arc formed by bending the radius round the circumference. This angle is called one radian, and all angles in this system are expressed in terms of radians. Thus an angle 1.3, *i.e.*, 1.3 radians, is one subtended by an arc 1.3 times the radius in length.

The relation between the two sets of units is obvious, for half the circumference subtends 180°, and the ratio of this arc to the

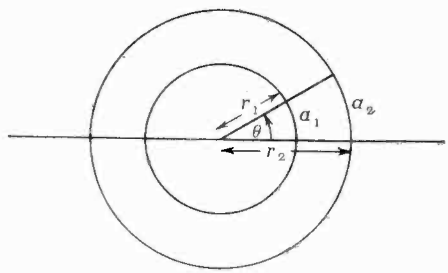

Fig. 16.

radius is as shown above, π, or 3·14159 . . . . , so that

$$180° = \pi \text{ radians},$$

which gives 57° 17′ 44·8″ as 1 radian. This is a cumbersome sort of relationship, but conversion is very rarely called for so it does not really matter. In general terms we have

$$\theta \text{ radians} = \left(\frac{180}{\pi}\theta\right)^\circ$$

A right angle is clearly $\pi/2$ radians, and the angles of a right-angled triangle can therefore be expressed in circular measure as $\pi/2$, θ, and $(\pi/2-\theta)$. Complementary angles (Sect. 2) are defined by

$$\theta + \theta' = \pi$$

and in practice the definition is extended to the case in which either of these angles is numerically greater than π, the other being correspondingly negative. In the familiar group of symbols *sin* $2\pi ft$ or *sin* ωt, where $\omega=2\pi f$ (f being the frequency in cycles per second), ωt is an angle which increases at the rate ω, or $2\pi f$, *radians* per second.

9. (A) Area.

Area, or amount of surface, is a fundamental conception or thing of its own kind, which cannot be described in terms of anything else, as one soon discovers by trying to do so. Like all the fundamental physical quantities, its magnitude can only be expressed in terms of itself, *i.e.*, in terms of its own unit. Thus an area of ten units means an area having ten times as much surface as some area which it is has been agreed to call a unit area. Humanity has always been vitally concerned with area and a multiplicity of practical units has arisen in consequence, but they all have this feature in common—they are expressed in terms of the amount of surface of a square having a side of specified length, and for this reason they nearly all bear names, such as square mile, square centimetre, etc., which indicate the length of the side of the square. This choice of the unit shape is quite arbitrary—a circle of specified radius would serve the same purpose, but the accepted shape has the advantage that the area of a rectangle of sides a and b units of length is arrived at by the simplest possible calculation on this system. It is in fact ab units of area, as can easily be demonstrated by a little simple drawing, the unit of area being the square unit of length, whatever that may be. This, however, must not be taken to mean that "area is length multiplied by length" a statement which is completely unintelligible except as a conveniently abbreviated expression of the ideas which have just been described. (Compare this with the discussion in Part I on the physical aspect of multiplication.)

(B) Area of a Triangle.

Referring to Fig. 17, the area of the triangle ABC is $\frac{1}{2}ah$ where a is the length of the side BC. This can be demonstrated by completing the rectangles $EBDA$, $AFCD$. It can be shown, as in Sect. 5, that the lines AB, AC divide these rectangles into equal triangles, whence the above result follows.

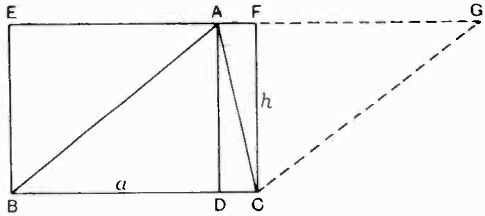

Fig. 17.

(C) Area of a Parallelogram.

In a similar manner it can be shown that the area of the parallelogram $ABCG$ is ah, for the diagonal AC divides it into two equal triangles.

(D) Area of a Circle.

Referring to Fig. 15, the area of each of the isosceles triangles into which the polygon is divided is $\frac{1}{2}bh$, so that the area of the whole polygon is $\frac{1}{2}nbh$. If the number of sides is increased indefinitely the figure becomes a circle, nb becoming the circumference, and h the radius. The area of the circle is therefore half the product of the length of the circumference and that of the radius. As already shown, the circumference is 2π times the radius, so that the area of the circle is $\frac{1}{2}(2\pi r)r$, *i.e.*, πr^2.

10. Vectors.

The idea "vector" is still hedged about with that vague apprehension and dislike that attaches to the unfamiliar; but the shyness, if it exists, must be fought down, for one cannot get far in electrical theory nowadays without it. The trouble is that although the essential idea itself is simple enough, its application calls for new habits of thought, a new mental technique. That means hard thinking, and hard thinking is the hardest of hard work. The technique, however, is worth all it costs in that way, and there can be no doubt that the vector notation will play a large and increasing part in the mathematics and mathematical physics of the future. Even to-day it is unusual to find any analysis of alternating current circuit problems which is not expressed in terms of the symbol "j", and that symbol, as the following sections will show, is very intimately connected with the vector idea, though it is admittedly open to more than one interpretation (and a few misinterpretations).

It was pointed out in Sect. 2 that a single straight line in an infinite plane cannot in any useful sense of the word be said to possess direction, for direction is essentially a relation to some other straight line. We will therefore take as the domain of our present thinking an infinite plane and an infinite line in that plane. By the direction of any other

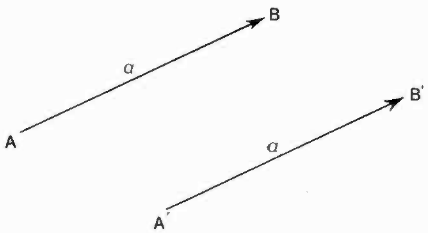

Fig. 18.

line in the plane will then be meant its direction relative to this given line. For practical purposes, the infinite plane can be taken as that of the paper one is writing on, and the reference line can be any line parallel to the bottom edge of the paper.

On this understanding any line in the plane of the paper will have direction, and any finite segment of the line will have both magnitude and direction. The name "vector" is given to any line regarded in this way as a combination of magnitude and direction. In general, any physical quantity whatever which possesses both magnitude and direction is called a vector quantity. Thus velocity, force, acceleration, etc., are vector quantities, and as such are capable of representation by means of vectors (not necessarily co-planar in any given system). Most of the quantities with which physics, and more particularly electricity, is concerned are of this character, whence the fundamental importance of the vector idea and of its technique. As distinct from a vector quantity, any quantity which has magnitude only is called a scalar quantity, or, shortly, a scalar. Density, temperature, energy, etc., are examples. The distinction is well marked in the case of weight and mass. The latter is a scalar, and the former, being the gravitational force associated with the mass, is a vector.

For the present, however, we shall not be concerned with vector quantities in general, but simply with the co-planar line vectors defined as above. It should be noted that no mention is made of position in the definition. Position plays a secondary part in vector analysis, and where it does enter into any given problem it will arise as a consequence of the other two attributes or will be otherwise specified. In general any two lines such as AB, $A'B'$, in Fig. 18, which are equal in magnitude and direction (the latter being indicated by an arrow head as shown) are vectorially identical. Following a well-established typographical practice, a line of length *a* will be printed in bold face type (**a**) if it is being considered as a vector. Alternatively, $\overrightarrow{AB}$ will be taken to mean the line AB considered as a vector. The magnitude of any given vector **a** will be indicated either by using the same letter in ordinary type, or by $|\mathbf{a}|$.

(B) The Addition of Vectors.

A vector can be regarded as a displacement or step of specified amount and direction. The obvious interpretation of the addition of two vectors is the combination of the two displacements as shown in Fig. 19, the *sum*,

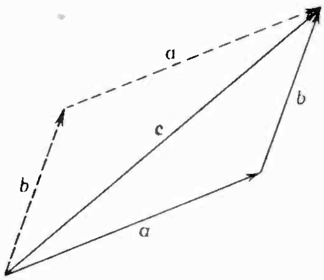

Fig. 19.

as distinct from the *process* of addition, being the single displacement which has the same total effect as the two displacements made in succession. Thus the sum of **a** and **b** is **c**. From the properties of a parallelogram it follows that **b** + **a**, shown by the dotted lines in Fig. 19, is the same as **a** + **b**, so that the process of addition of vectors obeys the commutative law, which brings it into line with the same process in ordinary algebra. The extension of the above, and of the commutative law, to the addition of any number of vectors is obvious. Notice that in general

$$|\mathbf{a}+\mathbf{b}| < |\mathbf{a}| + |\mathbf{b}|$$

which is Euclid's proposition about two sides of a triangle being greater than the third.

(C) Vector Interpretation of the Negative Sign.

As far as possible the symbolism of vector algebra will be made analogous to that of scalar algebra. Since therefore

$$a + (-a) = 0$$

in scalar algebra, let us use the same form vectorially and interpret $(-a)$, at present undefined, to suit this condition. If

$$\mathbf{a} + (-\mathbf{a}) = 0$$

then $-\mathbf{a}$ is a displacement which cancels the displacement **a**, *i.e.*, $-\mathbf{a}$ is a vector of the same magnitude as **a** but opposite to it in direction. The subtraction of vectors then becomes an operation of essentially the same character as addition, for

$$\mathbf{a} - \mathbf{b} = \mathbf{a} + (-\mathbf{b})$$

The process is illustrated in Fig. 20. Notice that $\mathbf{a}+\mathbf{b}$ and $\mathbf{a}-\mathbf{b}$ are the diagonals of a parallelogram having **a** and **b** as sides.

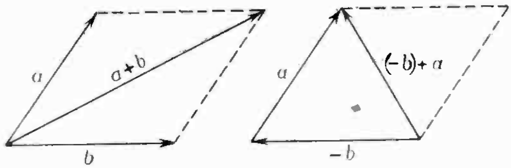

Fig. 20.

(D) The Multiplication of a Vector by a Number.

By analogy with the corresponding scalar operation

$$\mathbf{a}+\mathbf{a}+\mathbf{a}+\mathbf{a}+ \text{ etc. } \ldots\ldots\ n \text{ terms}$$

will be written $\mathbf{a}\times n$, or more conveniently $n\mathbf{a}$. Thus $n\mathbf{a}$ is a vector of the same direction as **a** but n times as long.

(E) The Idea of Operator and Operand.

The group $n\mathbf{a}$ can be regarded as symbolising a definite operation on the vector **a**, which in this relation can be called the "operand." If n is a positive number or fraction, the operation consists of the multiplication of the magnitude of **a** by n without changing its direction. If n is a negative number or fraction, say, $-m$ where m is positive, then $n\mathbf{a}$ represents the somewhat more elaborate operation of multiplying the magnitude of **a** by m and reversing its direction. Regarded in this way, the symbol n is called an "operator." It is an essential feature of an operator that its effect shall be independent of its operand, *i.e.*, the relation of $n\mathbf{a}$ to **a** does not depend in any way on **a**. This idea is more than a mere pedantic elaboration of terminology. Other forms of operator, which play a very large part in alternating current theory, will be introduced in later sections.

(F) Unit Vectors.

A unit vector is a vector of unit length. It follows from paras. (D) and (E) above that any vector whatever can be expressed in terms of a positive or negative number and some unit vector. Thus the vector **a** can be expressed in the form $a\,\mathbf{a}_1$, where $\mathbf{a}_1$ is the unit vector in the direction of **a**. Thus $m\mathbf{a}_1$ and $n\mathbf{a}_1$ are vectors of magnitudes m and n and of the same or opposite direction according as m and n are of the same or opposite sign. Notice that

$$m\mathbf{a}_1 + n\mathbf{a}_1 = (m+n)\mathbf{a}_1$$

In all that follows the symbol ν will be used for the unit vector in the direction of the bottom edge of the page from left to right.

11. The Scalar Product of Vectors.

In the arithmetical sense of the term, the multiplication of two vectors is not an intelligible process at all, but there is a quantity which involves two vectors in a manner similar to multiplication, and to this the name scalar product is given. It is defined in this way. The scalar product of two vectors **a** and **b** is the scalar quantity $ab\cos\theta$, a and b being the magnitudes of the vectors and θ the angle between their positive directions. It is written $\mathbf{a}\cdot\mathbf{b}$, so we have

$$\mathbf{a}\cdot\mathbf{b} = ab\cos\theta$$

The character of this product will be made clear by an inspection of Fig. 21(A). If BP

is drawn perpendicular to OA, then

$$\frac{OP}{OB} = \cos\theta$$

i.e., $OP = OB\cos\theta = a\cos\theta$

so that $\mathbf{a}\cdot\mathbf{b} = ab\cos\theta = OA\cdot OP$

The scalar product is thus the product of the magnitude of one vector and of the "projection" of the other on it.

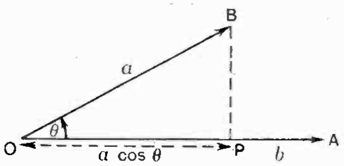

Fig. 21 (A).

Notice that a scalar product has sign as well as magnitude. This is because $\cos\theta$ has sign. Thus the scalar product of the vectors **a** and **b** shown in Fig. 21 (B) will be a negative quantity, for in this case θ is in the second quadrant and its cosine is therefore negative.

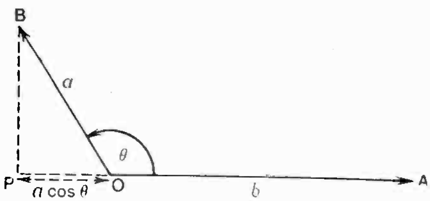

Fig. 21 (B).

Notice further that there is no question of extending this notation to more than two vectors. $\mathbf{a}\cdot\mathbf{b}$ is a scalar quantity, so there is no scalar product of $(\mathbf{a}\cdot\mathbf{b})$ and a third vector **c**.

This conception of scalar product may at first sight seem rather arbitrary, but it has as a matter of fact a very definite physical significance. To take one of the many instances of its physical interpretation, if **a** represents the displacement of a body under the action of a force represented by the vector **b**, then $\mathbf{a}\cdot\mathbf{b}$ is the work done by the force on the body. Another application of a rather different character is of particular interest to wireless amateurs. Let **e** be a vector of magnitude $\hat{e}$, making with ν an angle θ. Further, suppose that θ is proportional to time, increasing at ω radians per second, its magnitude being ϕ when $t = 0$,

i.e., $\theta = \omega t + \phi$

Then $\mathbf{e}\cdot\nu = \hat{e}\cos(\omega t + \phi)$

Thus a sine wave of E.M.F. can be represented as the scalar product with a fixed unit vector of another vector of constant length rotating with constant angular velocity (ω).

It will now be shown that scalar multiplication obeys the same formal laws as ordinary multiplication. It follows from the definition that

$$\mathbf{a}\cdot\mathbf{b} = \mathbf{b}\cdot\mathbf{a}$$

so that a scalar product obeys the law of commutation.

Further it is easy to show that scalar multiplication of vectors obeys the distributive law, *i.e.,*

$$\mathbf{c}\cdot(\mathbf{a}+\mathbf{b}) = (\mathbf{a}+\mathbf{b})\cdot\mathbf{c} = \mathbf{a}\cdot\mathbf{c} + \mathbf{b}\cdot\mathbf{c}$$

The demonstration is illustrated in Fig. 22. We have

$$\begin{aligned}(\mathbf{a}+\mathbf{b})\cdot\mathbf{c} &= OQ \times OC\\ &= (OP+PQ)\times OC\\ &= OP\times OC + PQ\times OC\\ &= \mathbf{a}\cdot\mathbf{c} + \mathbf{b}\cdot\mathbf{c}\end{aligned}$$

It follows directly from this that

$$(\mathbf{a}+\mathbf{b})\cdot(\mathbf{c}+\mathbf{d}) = \mathbf{a}\cdot\mathbf{c} + \mathbf{a}\cdot\mathbf{d} + \mathbf{b}\cdot\mathbf{c} + \mathbf{b}\cdot\mathbf{d}$$

and similarly for the scalar products of vectors expressed as the sums or differences of any number of component vectors. Operations of scalar multiplication of vectors can

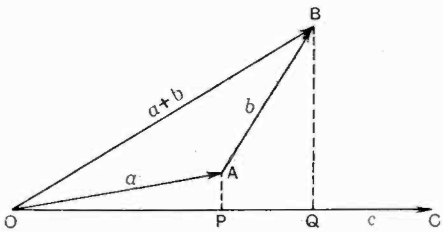

Fig. 22.

therefore be carried out in just the same way as the ordinary multiplication of similar number groups.

Two Important Special Cases.

(*i*) $\mathbf{a}\cdot\mathbf{a} = a \times a \times \cos 0 = a^2$

This can be written

$$\mathbf{a}^2 = a^2$$

Thus the scalar square of a vector is the square of its magnitude.

(*ii*) If **a** and **b** are perpendicular to each other, then

$$\mathbf{a}\cdot\mathbf{b}=a\times b\times \cos \pi/2=a\,b\times 0=0$$

The converse of this is also true with a reservation.

If $\mathbf{a}\cdot\mathbf{b}=ab\cos\theta=0$
then $a=0$
or $b=0$
or $\cos\theta=0$
i.e., $\mathbf{a}=0$
or $\mathbf{b}=0$

or the vectors are mutually perpendicular.

This will prove to have an important application to alternating current theory in the following form. Suppose that i_1, i_2, i_3, etc., be a number of alternating currents

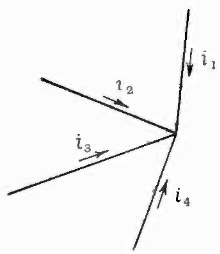

Fig. 23.

which meet at a branch point of a network of conductors as shown in Fig. 23. Then by Kirchhoff's first law, the sum

$$i_1+i_2+i_3+\text{etc.}=0$$

at every instant. Now as shown in above, each of these currents can be represented in the form $\mathbf{i}_1\cdot\nu$, $\mathbf{i}_2\cdot\nu$, etc., where $\mathbf{i}_1$, $\mathbf{i}_2$ are vectors of constant magnitude rotating with constant angular velocity. Therefore

$$\mathbf{i}_1\cdot\nu+\mathbf{i}_2\cdot\nu+\mathbf{i}_3\cdot\nu+\text{etc.}=0$$

i.e., $$(\mathbf{i}_1+\mathbf{i}_2+\mathbf{i}_3+\text{etc.})\cdot\nu=0$$

Therefore the vector $(\mathbf{i}_1+\mathbf{i}_2+\mathbf{i}_3+\text{etc.})$ is zero or else is perpendicular to ν at every instant. The second condition cannot be fulfilled at every instant, for the vectors are assumed to be rotating with constant angular velocity. Therefore

$$(\mathbf{i}_1+\mathbf{i}_2+\mathbf{i}_3+\text{etc.})=0$$

so that Kirchhoff's law applies not only to the instantaneous values of the currents which meet at a branch point, but also to the rotating vectors which, as described more fully later on, are used to represent these currents.

Examples.

1. Take 22/7 as a sufficiently close approximation for π. Find in degrees and minutes to the nearest minute

   i. $1\frac{1}{21}$ radians.

   ii. $\frac{1}{7}$ radian.

   Find the magnitude in radians of

   iii. 10°.

   iv. 1260°.

2. Find the area of

   i. A regular octagon with side 10 units in length.

   ii. A sector of a circle or radius 5 cms., length of arc 10 cms.

3. If the unit of area were defined as that of a circle of unit radius, what would be the area of the figures described in (2)?

4. The vectors **a** and **b** are of length 5 and 10 cms. respectively, and make with some other vector angles of 60° and 30° respectively.

   Find graphically *i.* $|\mathbf{a}+\mathbf{b}|$; *ii.* $|\mathbf{a}-\mathbf{b}|$; *iii.* Calculate $\mathbf{a}\cdot\mathbf{b}$; *iv.* Measure the angle between $\mathbf{a}+\mathbf{b}$ and $\mathbf{a}-\mathbf{b}$, and calculate $(\mathbf{a}+\mathbf{b})\cdot(\mathbf{a}-\mathbf{b})$. Show by calculation *v.* $(\mathbf{a}+\mathbf{b})\cdot(\mathbf{a}-\mathbf{b})=\mathbf{a}^2-\mathbf{b}^2$;

   vi. $(\mathbf{a}+\mathbf{b})^2=\mathbf{a}^2+2\mathbf{a}\cdot\mathbf{b}+\mathbf{b}^2$;

   vii. $(\mathbf{a}-\mathbf{b})^2=\mathbf{a}^2-2\mathbf{a}\cdot\mathbf{b}+\mathbf{b}^2$

Answers to Examples in May Issue.

1. 80°.

2. Figure divides into five triangles. Therefore sum of internal angles is 5×2 right angles, minus the sum of the angles at the centre, *i.e.*, minus four right angles. Therefore sum is six right angles.

3. *e* is $4\frac{1}{9}$, *f* $5\frac{5}{9}$, both in inches.

5. $\tan 50^\circ=1.191$; $\sec 50^\circ=1.555$; $\operatorname{cosec} 50^\circ=1.305$; $\cot 50^\circ=.840$; $\sin 140^\circ=\sin(90+50)^\circ=.643$; $\cos 220^\circ=\cos(270-50)^\circ=-.766$; $\tan 320^\circ=\tan(270+50)^\circ=-.840$; $\tan -50^\circ=-1.191$; $\sin 40^\circ=\cos 50^\circ=.643$; $\sec -40^\circ=\sec 40^\circ=\operatorname{cosec} 50^\circ=1.305$.

   $(\sin 50^\circ)^2+(\cos 50^\circ)^2=1.000$.

Self-Inductance of Straight Wires.

By R. M. Wilmotte, B.A.

(Of the National Physical Laboratory.)

THE design of an effective choke circuit for extra high frequencies of the order of 10^7 or 10^8 cycles per second and higher is one of growing importance and the common practice applicable to lower frequencies must be considerably modified as the frequency reaches these high values.

As the frequency rises, the effect of the self-capacity of the choke becomes of increasing importance, until at extra high frequencies it is necessary to space the wires forming the choke so that the distance between wires is never less than some 200 times the diameter of the wire, as will be seen below. When such spacing is kept throughout the design of a choke, one obtains the remarkable result, that the self-inductance of the choke is little affected by the way in which the wire is coiled. That is, if the choke is made of a given length of wire, it does not matter whether the wire is stretched out in a straight line or coiled in the ordinary way, the self-inductance will be nearly the same in both cases. The main requirement for large self-inductance is length and thinness of wire.

That the self-inductance of a wire is not very much affected by being coiled up may seem against common sense and an altogether improbable view, yet that this is so can be readily understood.

The self-inductance of a circuit is equal to the total magnetic flux (due to the current in the circuit) threading this circuit when a unit current is passing. Now the magnetic force at a point, due to a long length of wire carrying a current, is inversely proportional to the distance of that point from the wire. In the case of a very thin wire, the magnetic field at or near the surface of the wire will be very large and practically independent of the rest of the circuit, if the distances of all other parts of the circuit from the portion considered are large compared to the diameter of the wire.

In such a case, then, practically the whole of the flux linking the wire will be within a small imaginary cylinder surrounding the thin wire of the circuit. So long as this cylinder does not cut itself, the self-inductance of the circuit will be practically independent of its shape. This will, of course, hold, if the wire is very thin and the distance between the various parts of the circuits is large compared with the diameter of the wire.

In order to give quantitative basis to these conclusions, we shall deal with a few formulæ and put numbers into them, but before doing this, the meaning of the self-inductance of a straight wire must be explained. This point was raised in the Editorial of the January, 1926, number of the *E.W. & W.E.*, and it may be useful to explain the exact meaning and application of the terms.

The E.M.F. induced by a magnetic field in a wire is, by Faraday's law, proportional to the rate at which lines of force cut it. When the magnetic field is produced by a current in the wire itself, we obtain the idea of self-inductance, which is the total number of lines of force which collapse on to the current when this current is reduced from a value of one ampere to zero. Now, consider a small length of wire $A\ B$ and imagine that it is carrying a current of one ampere. In order to make this possible, we must suppose the circuit to be completed, but, since we are dealing only with the portion $A\ B$ of the circuit, we shall suppose that there is a mutual inductance M between $A\ B$ and the rest of the circuit, the value of M being dependent on the shape of the circuit outside $A\ B$.

If L_{AB} be the self-inductance of the portion, $A\ B$ and L that of the rest of the circuit, then the self-inductance L_0 of the whole circuit will be given by

$$L_0 = L_{AB} + L - 2M \quad .. \quad (1)$$

Now, consider the magnetic field produced by the current in the part $A\ B$ of the circuit (Fig. 1).

It is evident that we have cylindrical symmetry about the axis $A\ B$. Thus the line of force through any point P will be a circle having $A\,B$ produced as axis. When the current in $A\,B$ is decreased how will this line of force move? The idea that it moves is purely arbitrary and is only to allow us to visualise the process. We can make it follow any path we like, such as the line $O\,P$ or $P\,R$, but having once decided on a definite path we must keep to it in all our calculations of self and mutual inductance.

Suppose we consider the line of force at P to collapse along the cone $O\,P$, we can calculate the total number of lines of force

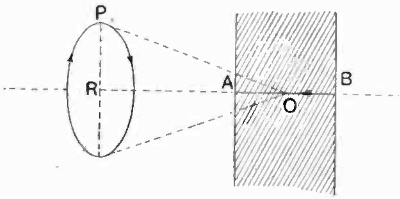

Fig. 1.

that collapse on to $A\,B$ when the current is reduced to zero. Unfortunately, this calculation leads us to the most unsatisfactory result that the self-inductance of the wire $A\,B$, according to this definition, is infinite, which is of very little practical use. We must try to look for a definition which will give a finite result. Such a definition is obtained by considering that these lines of force collapse radially along lines such as $P\,R$. According to this, only the lines of force which are in the area shown shaded will be effective in creating self-inductance, the rest of the field will collapse on $A\,B$ produced and this will not be a cause of creating an E.M.F. in $A\,B$.

It may seem definitely wrong to assume that part of the flux produced by the current in $A\,B$ is neglected as far as the self-inductance of $A\,B$ is concerned but this is not so, for $A\,B$ must be considered as part of a circuit and the flux, which we have neglected in considering $A\,B$, will, on collapsing on to $A\,B$ produced, cut other parts of the circuit and will therefore be included in the mutual inductance M between $A\,B$ and the rest of the circuit.

We thus see that the meaning of the self and mutual inductance of a portion of a circuit is dependent on the arbitrary notion, which we have regarding the motion of the lines of force, but, having once fixed our ideas, the meaning becomes quite definite, though it may well be argued that, owing to the special meaning applied, the terms of self and mutual inductance used in this connection are misleading.

However, since the terms are now fairly universally used and the reader does, or at any rate should, now understand the special meaning implied, I will continue to use them, hoping that my previous explanation will be sufficient in preventing errors.

I shall give a few formulæ, which refer to wires of circular cross section, and for lengths which are large compared to the radius of the wires. The values of L and M in the following formulæ are in microhenries, all linear dimensions being in cms.

The self-inductance L of wire of length l and radius r for direct current is given by

$$L=2l\left[\log_e(2l/r)-1+\frac{\mu}{4}\right]\times 10^{-3} \quad .. \quad (2)$$

where the permeability of the substance of the wire is μ and that of the dielectric is unity.

For H.F. current the self-inductance is given by

$$L=2l\left[\log_e(2l/r)-1\right]\times 10^{-3} \quad .. \quad (3)$$

The difference between equations (2) and (3) is caused by the difference of magnetic field within the wire in two cases. Equation (2) refers to uniform distribution of current across the section of the wire, which occurs when the wire is thin and the frequency not too high, while the equation (3) gives the case when the magnetic field within the wire is zero, that is, all the current flows on the surface of the wire. This occurs in thick wires and at very high frequencies. It will be seen that the difference between equations (2) and (3) will in general be quite small.

The mutual inductance between two equal parallel wires of length l, which is large compared with their distance d apart, is given by

$$M=2l\left[\log_e(2l/d)-1+\frac{d}{l}\right]\times 10^{-3} \quad .. \quad (4)$$

The self-inductance of a circuit, made of two long, equal, parallel wires distant d apart, is obtained from equations (3) and (4) giving

$$L'=2L-2M$$

$$=4l\left[\log_e(d/r)+\frac{\mu}{4}\right]\times 10^{-3} \quad .. \quad (5)$$

The mutual inductance between two contiguous linear conductors of lengths l_1 and l_2 in the same straight line is given by

$$M=\left[l_1 log_e\left(\frac{l_1+l_2}{l_1}\right)+l_2 log_e\left(\frac{l_1+l_2}{l_2}\right)\right]\times 10^{-3} \quad (6)$$

The mutual inductance between two parallel linear conductors of lengths l_1 and l_2 distant d apart (Fig. 2) is given by

$$M=\left[l_1\, log_e\left\{\frac{l_1+l_2+\sqrt{(l_1+l_2)^2+d^2}}{l_1+\sqrt{l_1^2+d^2}}\right\}+l_2\, log_e\left\{\frac{l_1+l_2+\sqrt{(l_1+l_2)^2+d^2}}{l_2+\sqrt{l_2^2+d^2}}\right\}+\sqrt{(l_1+l_2)+d^2}-\sqrt{l_1^2+d^2}-\sqrt{l_2^2+d^2}\right]\times 10^{-3} \quad (7)$$

When d is small, this reduces to equation (6).

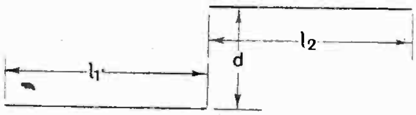

Fig. 2.

It should be noticed that the mutual inductance between two perpendicular wires is zero.

From these formulæ, the self and mutual inductances of any circuits, the sides of which are parallel and perpendicular to each other, can be calculated.

Now, to return to our original inquiry on chokes, we shall require one more formula giving the capacity C between two long parallel wires of radius r distant d apart (d is large compared to r),

$$C=\frac{l}{3.6\, log_e\,(d/r)}\,\mu\mu F \quad (8)$$

From equations (4) and (8) the following table has been calculated for the constants per unit length of two parallel wires.

d/r	Self-inductance (microhenries.)	Capacity. ($\mu\mu$F.)
5	0.0075	0.179
10	0.0102	0.121
20	0.0130	0.093
50	0.0167	0.071
100	0.0194	0.060
250	0.0231	0.050
500	0.0259	0.045
750	0.0275	0.042
1,000	0.0286	0.041
5,000	0.0331	0.033
10,000	0.0378	0.030

These values are plotted in Fig. 3. It will be at once evident how quickly the capacity decreases as the ratio (d/r) increases and reaches an almost constant value. At the same time, the self-inductance is rapidly increasing to a sensibly constant value also.

Now at extra high frequencies, it is all-important that the self-capacity should be low. A capacity of $3\mu\mu$F, at a wavelength of 15 metres, has an impedance of approximately 2,500 ohms. It is not much use having a coil of very large impedance if it is to be shunted by 2,500 ohms. It becomes evident that we must reduce the self-capacity first of all and consider the self-inductance afterwards.

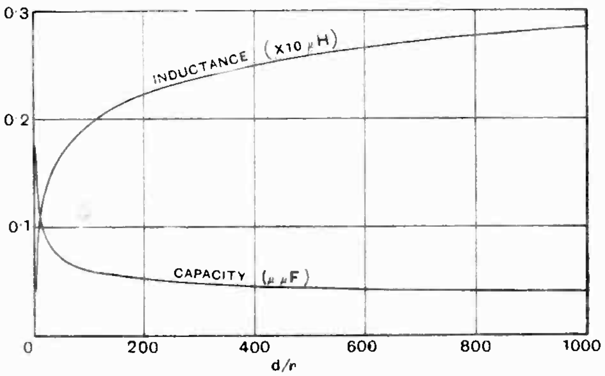

Fig. 3.

The curve of Fig. 3 shows that d/r must be large, that is the distance of various parts of the circuit must be some 200 times the diameter of the wire, and to do this within a reasonable space we must use thin wire such as 47 S.W.G.

When d/r is large, the mutual inductance between the various parts of the circuit will be small (see above formulæ) and the inductance of the circuit will be nearly equal to the self-inductance given by equations (2) or (3), in which l is the total length of wire irrespective of its shape.

At very high frequencies corresponding to wavelengths of a few metres it will be found very convenient to use simply a straight length of number 47 S.W.G. wire as choke. This is often quite sufficient and at the same time keeps the terminals far apart, which is important, for it must be remembered that the choke may become quite ineffective, if it has large terminals close together at its ends, owing to the capacity between them.

At longer wavelengths, between 10 metres and 100 metres, the spacing between wires need not be so large.

A single layer solenoid of number 47 S.W.G., having the distance between its turns about 20 times the radius of the wire, will be found to produce a very good choke. The above formulæ will not hold, however, for this case, and we have to return to the simple formula which applies with very good accuracy for this spacing. The formula is

$$L = \frac{\pi^2 d^2 n^2}{l \times 10^3} \times k \text{ microhenries}$$

where d is the diameter of the solenoid, n the number of turns and l the length.

k is an end effect correction factor depending on the ratio of the length to the diameter of the solenoid. Its value is given by the graph Fig. 4.

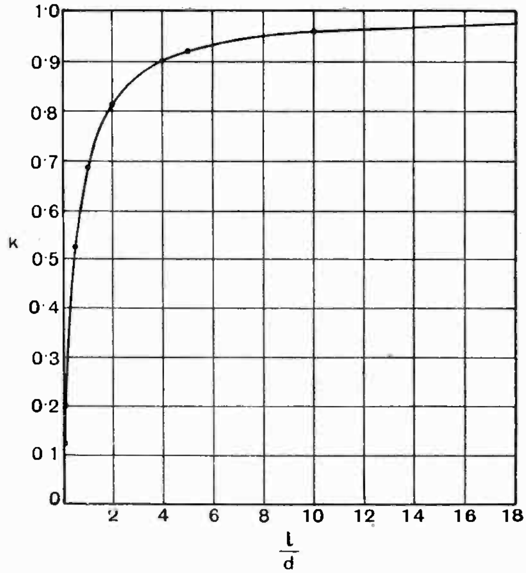

Fig. 4.

Wireless Transmitting Valves.

The meeting of the I.E.E. Wireless Section on 4th May was devoted to a wide discussion of transmitting valves. Three papers were read, each dealing with the type of valve stated below, while a general discussion on the whole subject followed the reading of the papers. Abstracts of the individual papers and of the general discussion are given below.

The Holweck Demountable Type Valve.

By C. F. Elwell, M.I.E.E.

ABSTRACT.

THE paper first describes briefly the Holweck molecular pump, used in conjunction with the demountable valve. It consists (Fig. 1)* of a smooth light cylinder

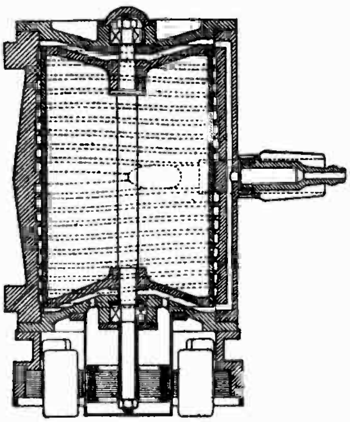

Fig. 1.

mounted on ball bearings inside and very close to a heavy casting upon the inside of which a 7-turn right- and left-hand spiral groove of diminishing cross section has been cut. The cylinder is driven at 4,500 r.p.m. by means of a rotating field, rendering it unnecessary to bring the shafts supporting the rotating portion through the body of the pump. A small passage in the body serves as a connection to a rough vacuum pump, and a large orifice connecting the two spiral grooves serves as a connection to the vessel (*i.e.*, valve) to be evacuated. The cylinder thus revolves in the rough vacuum, so that less than 10 watts is necessary to drive it at the high speed stated. When the current is cut off the cylinder continues to rotate for upwards of an hour. In practice the pump has proved capable of maintaining the vacuum on demountable valves with 8,000 volts on the anode.

The valve, which is mounted directly on the top of the pump, is shown in Figs. 2 and 3. It comprises :—

1. Lower glass or quartz insulating piece for connecting the valve to the pump.

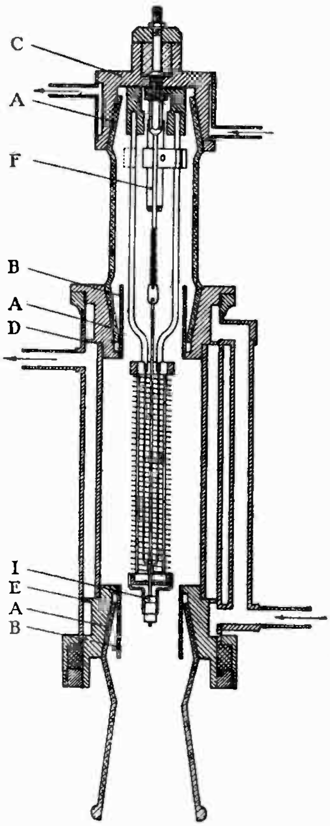

Fig. 2.

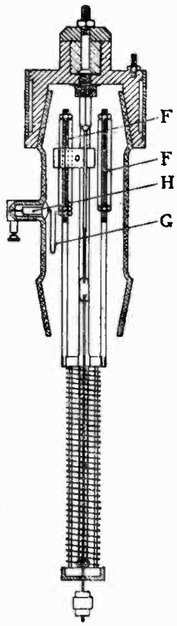

Fig. 3.

* The authors' original figure numbers are adhered to throughout these abstracts.

2. Water-cooled anode.

3. Upper glass insulating piece with grid connections.

4. Water-cooled head carrying grid and filament.

These valves are made in 10kW and 30kW sizes and a sufficient number is now in service to warrant their serious consideration as a rival to the sealed-in variety. Against the need for a pumping system must be balanced the advantage of being able to renew the filament at the cost of a few pence.

Each of the types is capable of considerable overload and it is stated that on trial one of the 30kW valves took 100kW. This suggests the feasibility of making single units of 100kW, which in turn might only be stepping stones to the building of single units capable of handling 200, 500 or 1,000kW.

It is also stated that at the Malmaison Station a 10kW valve has been used down to 37.5 metres, signals of strength 7 being received in Shanghai, and of strength 9 in S. America.

Silica Valves in Wireless Telegraphy.

By H. Morris Airey, C B.E., M.Sc., M.I.E.E. G. Shearing. B.Sc., M.I.E.E., and H. G. Hughes, M.Sc.

ABSTRACT.

THIS paper deals with silica valves as used in British Naval wireless transmitters.

In discussing the properties of silica as an envelope for high-power valves, the authors point out that it has the advantages of: (i.) very high softening point; (ii.) low coefficient of thermal expansion; (iii.) ease of manufacture and of opening for repair; (iv.) high insulating properties; (v.) high diathermancy; (vi.) low dielectric loss at high frequencies.

Silica valves are divided into two classes according to the method of cooling the anode :—

(A) Valves in which the heat is removed by radiation through the silica envelope.

(B) Valves in which the heat is removed by direct contact of the anodes with a cooling fluid.

An important point in the silica valve is the seal through which electrical contact is effected. The basis of the seal is a lead plug in a short length of thick-walled silica tubing. The lead is melted *in vacuo* in the silica tube, under which conditions the molten lead adheres firmly to the silica, forming a vacuum tight joint. For ratings up to 50 amperes the conductors to the interior and exterior are embedded in the lead plug. For larger seals, up to 100 amperes, the plug is modified so that the current is conveyed independently of it. The two types of seal are shown in Figs. 1A and 1B.

The silica envelope consists of a cylindrical body with domes welded on the two ends.

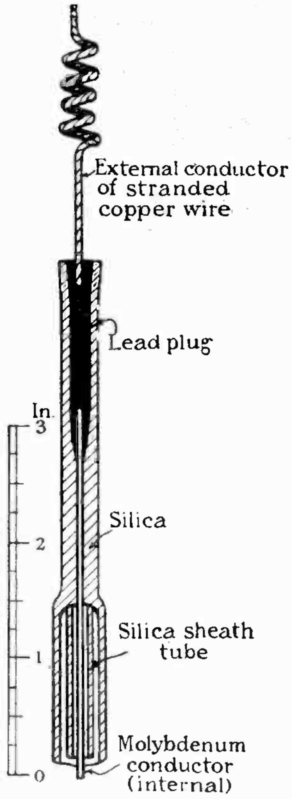

Fig. 1A.

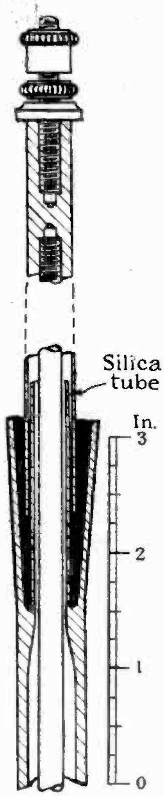

Fig. 1B.

The electrode seal tubes are fused into the domes in a direction which is usually parallel to the axis of the cylinder. This form is

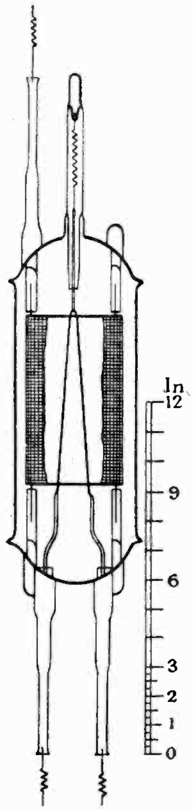

Fig. 2.

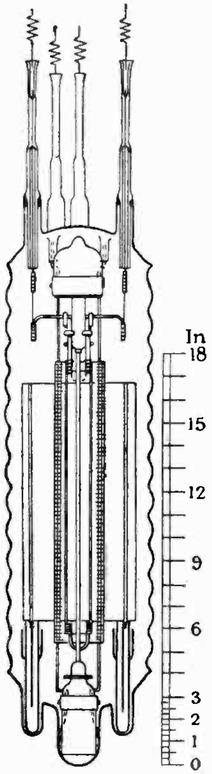

Fig. 5.

convenient for baking processes during evacuation.

Typical constructions are illustrated in Figs. 2 and 5. The grid usually has a framework of molybdenum and a spiral or mesh of either tungsten or molybdenum. The anode of the radiation types is now of cylindrical form of molybdenum strip, woven basket fashion.

The construction of naval silica valves is such that they can be readily repaired. One of the domes may be cut off the body by means of a carborundum wheel and the electrode system removed. Any reconstruction necessary can thus usually be effected at a fraction of the cost of a new valve.

For sets of power up to the order of 15kW the heat energy from the anodes is dissipated by radiation from the bulb. For higher powers provision has been made for cooling by a circulatory system.

A method of external cooling is illustrated in Fig. 6. This employs a double-walled cylinder containing the circulating water and surrounding the valve, which is thus not in direct contact with the fluid. The seals of the valve are on the top dome and are air-cooled. In another method of external cooling the valve is totally immersed in a tank containing oil, which is circulated by a pump through a radiator system.

The introduction of the type of seal in which the conductor is independent of the lead plug has enabled valves to be constructed in which the anode is an internal spiral tube of metal as shown in Fig. 7.

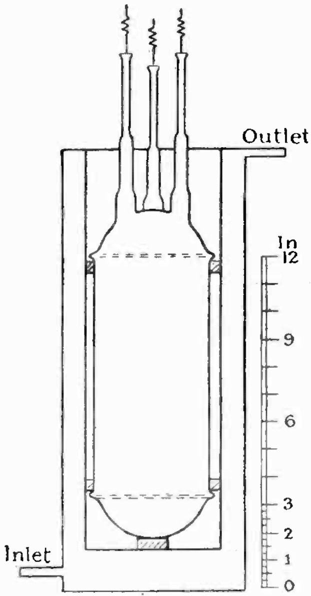

Fig. 6.

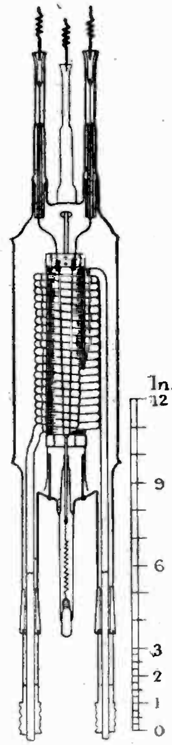

Fig. 7.

The cooling of the anode is effected by the circulation of oil or water through this tube. This arrangement permits the use of smaller silica envelopes than for the equivalent power rating of the radiation type of valve. This type of valve is, at present, in its development stage, and none has been standardised for production.

Failure of the majority of defective valves has been due to burnt-out filaments, 90 per cent. having been known to fail from this cause. For burnt-out filaments the repair cost is from 15 to 20 per cent. of initial cost, while the average cost of repairs for all kinds of defects is from 20 to 25 per cent. of the initial cost of the valve.

Cooled Anode Valves and Lives of Transmitting Valves.

By W. J. Picken, A.M.I.E.E.

ABSTRACT.

THIS paper is of much greater length than the other two. The first part of the paper deals with cooled anode valves, and the latter part with the lives of transmitting valves; the life data quoted by the author being mostly for radiation-cooled glass valves.

The term "cooled anode" is used to cover valves in which the anode forms part of the envelope and is capable of being cooled by water, oil or other liquid applied directly to it.

In the introductory paragraphs the author refers to the advantages of the cooled anode type, particularly in the considerable increase of power which they have rendered possible. He then proceeds to describe valves of this type made for Marconi's Wireless Telegraph Co., Ltd., by the M.O. Valve Co., Ltd.

The types of valve described are :—

Cooled Anode Transmitting Valves, C.A.T.1, C.A.T.2, C.A.T.5.

Cooled Anode Modulating or Absorbing Valves, C.A.M.1, C.A.M.2, C.A.M.3.

Cooled Anode Rectifying Valves, C.A.R.1, C.A.R.2, C.A.R.3.

The first valve of the type developed was C.A.T.1 shown in Fig. 1. The anode is of copper tube 5 cm. diameter and 23 cm. long. On one end is brazed a ring of nickel iron on which a large glass cylinder of 7 c.m. diameter is sealed. By the choice of a suitable nickel-iron alloy it is possible to obtain the same coefficient of expansion as for glass. Details of construction, evacuation, etc., are given, and processes of manufacture were illustrated by photographic slides displayed during the reading of the paper. This valve is capable of standing a dead-loss test of 7.5kW at 15,000 volts without

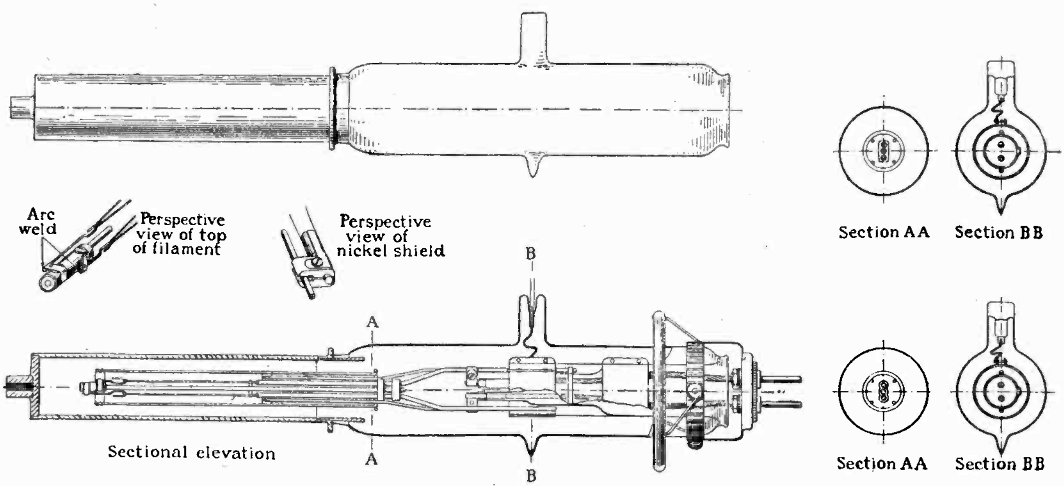

Fig. 1.

impairing the vacuum. On oscillatory tests it has been taken up to an input of 30kW at 15,000 volts. The general practice of the Marconi Co. is to rate valves conservatively so that the "life expectation" may be high. The C.A.T.1 valve is therefore usually rated at 10-15kW input at 10-12,000 volts, with a maximum loss of about 3kW in the anode when used normally as a high frequency magnifier or self oscillator.

consistent with good characteristics. The interelectrode insulation is increased, and the construction allows easy fitting to all electrodes of conductors capable of standing heavy high frequency currents with very low I^2R losses. Oil is sometimes used instead of water for cooling this valve on short wavelengths in order to avoid dielectric losses in the water. Inputs of 10kW at about 15 metres wavelength are handled

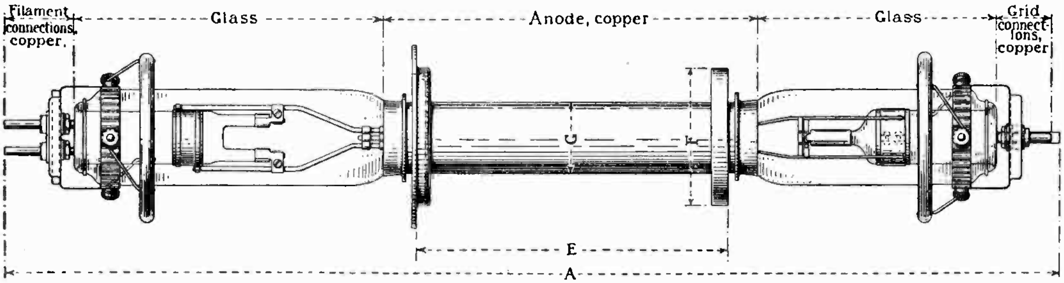

Fig. 9.

by this type acting as a high frequency magnifier.

The author then briefly discusses the conditions under which valves are operated. It is pointed out that the ratio of peak space current (*i.e.*, the peak value of instantaneous anode and grid currents) to mean anode current is generally taken as 5 to 1. Thus for 10kW input at 10kV the mean anode current is 1 ampere, and 5 amperes total emission is required. In telephony the conditions are more arduous. With a modulation of 80 per cent., the anode voltage swings at audio frequency up to 18kV when the anode current is 1.8 amperes. Taking a 5 to 1 ratio as before a total emission of 9 amperes is required. The H.F. peak potentials will be of the order of 34,000 volts. Protective devices in the form of Corona rings, etc., are therefore incorporated.

General methods of applying the water cooling are then discussed, especially with reference to hardness of the water.

C.A.T.5 valve, which is then described, is of similar general design to C.A.T.1, but rated at 15 to 20kW at anode voltages up to 12kV.

The C.A.T.2 valve, next described, and shown in Fig. 9, was produced especially for use on short wave beam transmitters. The grid and filament are mounted on glass-work at opposite ends of the anode, thus giving the minimum grid-filament capacity consistent with good characteristics.

Amongst the modulators, Type C.A.M.1 is similar to C.A.T.1 but with an open spiral grid, giving a low anode impedance and amplification factor to avoid distortion.

Type C.A.M.2 is particularly suitable for use as an absorption modulator for keying a wireless telegraph transmitter. The system is shown in Fig. 14. During spacing intervals a positive potential is applied to the "absorber" grid. Anode current flows, causing current to traverse the resistance X, which absorbs power during the "spacing" period. On "masking" a suitable negative potential is applied to the grid, reducing the anode current to zero and no power is absorbed in the resistance. This lessens the fluctuations of load and consequent voltage variations which would otherwise occur. A convenient method of keying is obtained by simultaneously varying the anode voltage of the "drive" at Y.

For use as an absorber it is necessary that (1) with suitable negative potential, the grid should completely cut off anode current at the highest anode voltages, and (2) the grid must be capable of standing for long periods losses incurred by a relatively high positive grid voltage at the same time as the anode voltage is at a maximum. To keep the requisite grid voltages at reasonable values, the amplification factor is 25.

Type C.A.M.3 is a modulating valve of greater power than C.A.M.1, generally approximating to C.A.T.5 in physical dimensions.

The simplest type of rectifier valve is similar to a transmitting valve with the grid omitted. Thus C.A.R.1 resembles almost exactly C.A.T.1. It is capable of handling 1 ampere at 10,000 volts when used as in Fig. 14.

In full wave rectification, during the non-conductive half cycle the valve has almost twice the A.C. peak potential difference between anode and filament. This powerful field tends to bow the filament, which difficulty is overcome in the C.A.R.2 type (Fig. 23). The anode is compressed into two cylindrical upper chambers, as shown, with one leg of the filament in each. This "binocular" construction makes it possible to reduce the anode diameter without fear of filament distortion. A connection to the centre of the filament allows the return anode current to be led into the filament at several points. The construction has led to a valve of only 150 ohms anode/filament resistance.

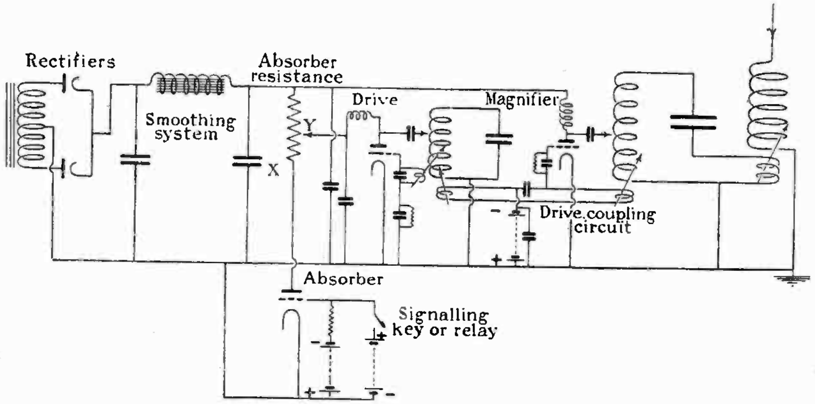

Fig. 14.

Type C.A.R.3 is of similar construction capable of supplying A.C. voltages up to 25,000, and has a total emission of 10 amperes.

A variety of the valves described were on exhibition at the meeting.

The latter part of the paper deals with the lives of transmitting valves. The factors governing valve life are given as :—

1. Diameter of filament.
2. Effective area of filament.
3. Total emission required of filament.

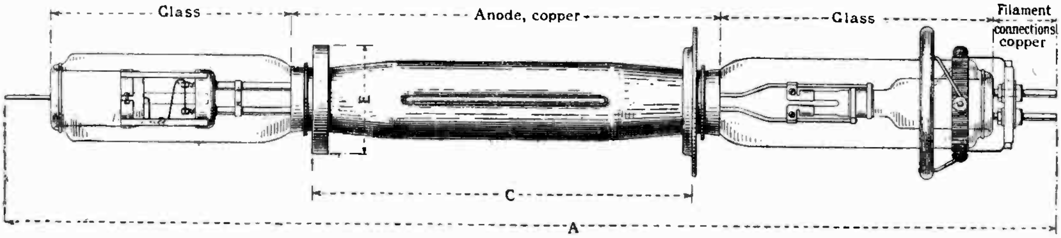

Fig. 23.

Unless the filament is very short, when end-cooling becomes serious, the life of a filament increases in direct proportion to the increase of its diameter. The tendency is therefore towards filaments taking heavy currents at low voltages.

Fig. 26 shows the variation of the life of a filament and the total emission with temperature and the corresponding changes in (1) watts per ampere emission, (2) filament voltage and (3) filament current. It will be observed that life and emission vary enormously with small changes of filament voltage. As a well-known phrase has it: "A 5 per cent. increase or decrease of filament voltage halves or doubles the life."

The author then discusses details of total emission, etc., with reference to various characteristics given for the different types of valve.

It is pointed out that in telephony it is usual to light the valve filaments by direct

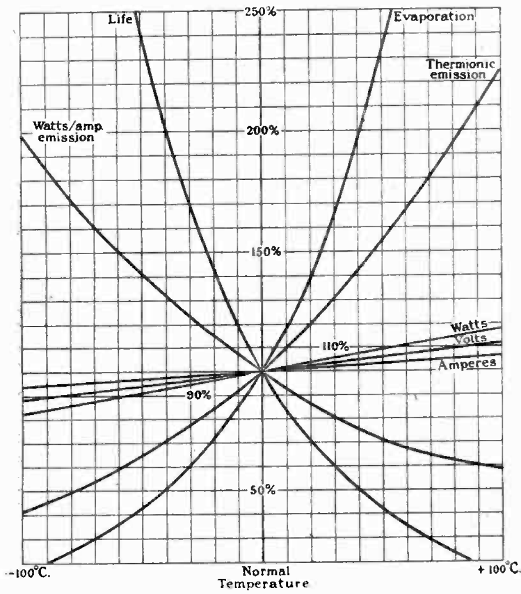

Fig. 26.

current in order to avoid hum. The emission current will return to the filament at its negative end, and if the filament polarity is never reversed this will cause greater evaporation and ultimately premature fracture near the negative end. The ideal method of reversing filament polarity is by heating it with alternating current. It is essential, however, that this current should not be synchronous with the alternating voltage applied to the anode. Various arrangements of phase to obtain this are discussed.

The life expectation of a valve—as for an electric lamp—is usually given as an average life.

If a batch of valves is taken of sufficient quantity to be representative, it will be found that filament burn-outs will begin at about one-half the average life, and that

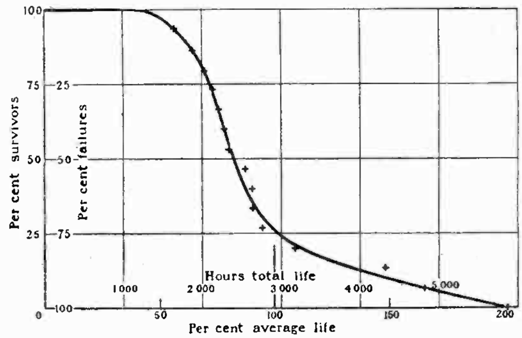

Fig. 36.

others will occur only after the valve has lived for twice its "life expectation."

Radiation cooled valves have now been in commercial use for sufficient time to enable adequate life data to be collected. These data are presented in the form of survivor curves. Various curves are given for such stations as Glace Bay, Munchenbuchsee (Berne), Ongar, Deutsch Altenburg (Austria), Barcelona, etc. Typical curves are given in Figs. 36 and 43.

In general survivor curves conform to three general types as shown in Fig. 45:—

The narrow.
The wide.
The linear.

The "narrow" type would appear to be normal for valves used under steady conditions as regards load, filament voltage, etc.,

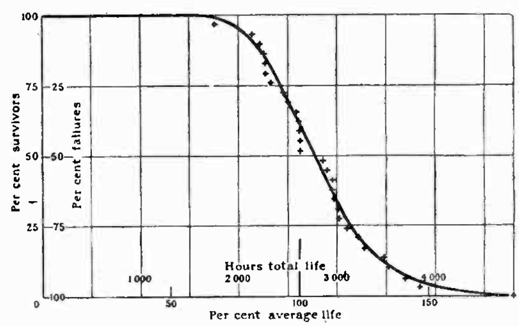

Fig. 43.

and at a loading well within the capacity of the valve.

The "linear" type results from variable conditions, overloading, excessive filament voltage, etc.

The "wide" type is probably a compound of several batches each giving narrow curves.

A table is also given showing the lives of cooled anode valves in use at Daventry, two valves having already given lives of upwards of 5,000 hours. The Carnarvon Station valve record for December, 1926, also shows several lives (at the end of the month reviewed) of nearly 4,000 hours.

Survivor curves can be used for two general purposes :—

To study the conditions under which valves are being used.

To study the behaviour of valves under given conditions.

The former assists in correcting wrong conditions of operation.

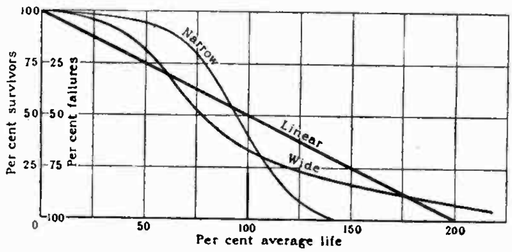

Fig. 45.

The latter assists in the calculations in valve design, and allows the effect of alterations and improvements in manufacturing processes to be watched.

It is too soon yet to give similar data regarding cooled-anode valves, but from the foregoing it will be seen that certain standards as regards average life have been established by radiation-cooled valves, and it is already evident that cooled-anode valves will not fall short of these standards.

DISCUSSION.

Dr. R. V. Hansford said the papers covered present-day practice in transmitting valves. The idea of a demountable valve was very useful, but he did not feel that it would become a serious rival until valves of 100-200kW were developed. Had these valves been used in parallel with common or with separate pumping ? With reference to the cooling of silica valves he thought that this necessity would make the ordinary cooled type of valve as useful. The silica type was not a serious rival for large powers. He made further reference to the discharge effect (referred to in his paper with Mr. Faulkner at the December meeting, abstracted in *E.W. & W.E.*, January, 1927) and described more recent tests made on the subject. In discussing life curves he showed a slide of performance of valves at Rugby. The need for the future was, he thought, for a fewer number of valves of greater power.

Mr. B. S. Gossling spoke of the apparent overlap in the three papers, but said that this was less than at first appeared because of the difference of functions mentioned. Development was limited by the conservative rating, and the comparison of valves for life and service was like the comparison between a motor bus and a high-speed racing car. In the cooled anode type the cathode was designed for long life.

Mr. J. R. Mullard asked if the Holweck valve had been used on short wavelengths. He did not agree that the silica valve had reached the limit of development. The cooling method (described in the second paper) was very important and helped in the process of manufacture to get a stable vacuum.

Mr. W. Gibson expressed particular interest in the second paper. He dealt especially with the survivor curves and said that the shape of the curve depended on the conditions of operation.

Mr. H. L. Kirke said that the cooled anode type had been successful in operation at Daventry. Discussing the peak/mean ratio of anode current, he pointed out that this ratio affected life and depended on the system of working. With reference to the second paper he asked for information of the power dissipated under oscillatory conditions.

Dr. Drane dealt with the desirability of keeping the valve as a discrete unit, free from cooling attachments. He suggested an air blast for this purpose, and discussed fragility, and asked for information as to the behaviour of silica valves under gunfire. He also dealt with X-radiation with silica valves and asked for information on the effects of this.

Mr. B. P. Dudding discussed survivor curves, and showed a slide illustrating the differences of survival according to the numbers of groups of valves working under different conditions of over-run, under-run, etc. He also asked for information as to the variation of vacuum during operation. Differences between glass and cooled anode valves suggested that this was important.

Mr. H. G. Hughes said that metal-glass valves cost two or three times as much as silica valves, while the latter were cheaper to repair. In tests of robustness silica valves had proved very satisfactory, and they had had no trouble due to gunfire. They had also had no trouble with X-radiation. With reference to the discharge, mentioned by Dr. Hansford, he attributed this to metallic deposits.

Dr. Bryan asked was there any difficulty in starting up the Holweck valve ? He had found such difficulty in starting up another type on pumping. Was there any information as to the weight of the filament after burning ?

The authors replied briefly to the discussion.

Mr. C. F. Elwell agreed with the need for fewer and more powerful valves. He felt that there was no trouble in getting 100kW in a single Holweck valve. Two valves could be used in parallel on one pump with a *Y* feed. These valves had been used on wavelengths down to 37.5m., as mentioned in the paper. The filament was renewed when it had dropped by 10 per cent., and after a filament renewal, four or five minutes' preliminary pumping was necessary.

Mr. G. Shearing said he thought the limits of silica valves were above requirements and that in comparison they had proved the cheaper type. As regards the question of oscillating power, the anode dissipated that power when generating oscillations. Silica valves had been used down to 10 metres. He thought the demountable type might prove best for large powers.

Mr. W. J. Picken said that the survivor curves were desired to show that a law applied to failures according to the theory of possibilities. The curves were intended to help in determining the conditions of operation. His conservative estimate excluded Naval, Military and Air conditions, being limited to commercial conditions. 100kW valves were not now visionary but were near accomplishment. As regards X-ray transparency he had found that with a hard-glass valve at 15,000 volts D.C. X-ray effects were considerable.

On the motion of the Chairman (**Major B Binyon**) the authors were cordially thanked for their papers.

Abstracts and References.

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PROPAGATION OF WAVES.

SUR LA PROPAGATION DES ONDES ELECTROMAGNÉTIQUES AUTOUR DE LA TERRE (On the propagation of electromagnetic waves around the earth).—H. Gutton and J. Clément. (*Comptes Rendus*, 184, 14th March, 1927, pp. 676-678.)

In a preceding article (*C. R.*, 184, 1927, p. 441; these Abstracts *E.W & W.E.*, May, 1927, p. 312) experiments on the dielectric properties of ionised gases were described which led to the conclusion that the mutual actions between the electrified centres acted on these like quasi-electric forces and consequently determined the existence of an average oscillation period of the ions. As the mutual actions increase with the number of ions, this period must be the shorter the more ionised the gas, and in a periodic electromagnetic field resonance phenomena can be produced for frequencies that are the higher the greater the ionisation. In order to verify this latter point, the previous experiments were repeated employing shorter waves. It was found that for equal pressures the ionisation corresponding to resonance between the ionic oscillations and those of the field is much greater when the frequency of these latter is higher, also that the pressure beyond which no further apparent diminution of the dielectric constant is observed is higher. From the phenomena of resonance that exist in a gas and taking account of the fact that the period of resonance is the longer the weaker the ionisation, conclusions can be drawn as to the propagation of waves around the earth.

There is a mean ionic oscillation frequency corresponding to the ionisation of the lower part of the Heaviside layer. When short waves are propagated, the frequency of the electromagnetic field is higher than that of the ionic oscillations. The convection current produced by the movements of the ions is then in phase opposition with the displacement current and brings about an apparent diminution of the dielectric constant. As predicted by Eccles' theory, reflections and refractions send the waves back to the ground. For larger waves, the resonance period is reached. The convection current becomes in quadrature with the displacement current and no longer causes variation of the dielectric constant; it has the phase of a conduction current and effects marked absorption of the waves. Waves longer still have a frequency below the resonance frequency; the convection current is then in phase with the displacement current and produces an apparent augmentation of the dielectric constant. Refraction phenomena are no longer possible, but the waves are then sufficiently large for the conductivity of sea-water to assure long-distance propagation, in the conditions which are those of Austin's formula.

The phenomena happening on the two sides of the wavelength for which there is resonance in the ionised gas, when radio signals are transmitted, are thus very different. For frequencies close to resonance, distant transmission is not assured by the upper atmosphere which absorbs the waves. On the other hand, they are too short to be propagated along the ground without great attenuation. Thus is explained the fact often found, that waves in the neighbourhood of 200 metres are unserviceable for wireless telegraphy. Further, the reception of signals on these wavelengths is irregular and subject to marked fading. Indeed, in the vicinity of resonance, small changes of ionisation produce very large variations in the phase of the ionic oscillations and, consequently, considerable variation of the dielectric constant.

These experiments were made employing waves of 2 and 4 metres and large ionisations. The frequency of waves of 200 metres being much lower, the ionisation corresponding to resonance is weaker and can be reached in the upper atmosphere.

EXPÉRIENCES SUR LA PROPAGATION DES ONDES RADIOTÉLÉGRAPHIQUES EN ALTITUDE (Experiments on the propagation of radio waves at an altitude).—P. Idrac and R. Bureau. (*Comptes Rendus*, 184, 14th March, 1927, pp. 691-692.)

In order to make a preliminary study of the propagation of short waves as a function of the altitude at which they are emitted, sounding balloons with transmitting equipment attached were sent up from Trappes Observatory. The signals, whose wavelength was about 42 metres, were heard at several meteorological stations as well as by different amateurs. Waves of the same length were also sent out on the ground, so that the conditions of propagation of the waves emitted in the air and at the earth's surface could be compared. The experiments showed that these can be entirely different: certain stations hearing the wave at the ground without that in the air, while others heard the wave in the air but not that at the ground. Several stations were able to follow the emission both ascending and descending with certain gaps for which the cause will only be able to be determined in subsequent experiments. In one ascent an altitude of between 13 and 14 kilometres was reached, which was probably the first time that waves were emitted in the stratosphere. The authors now intend to make a systematic investigation of the influence of altitude and that of the structure of the atmosphere on wave propagation.

A COMPARISON OF THE VARIATION OF INTENSITY AND DIRECTION OF RADIO SIGNALS.—H. Reich. (*Journ. Franklin Institute*, April, 1927, pp. 537-48.)

An account of experiments undertaken for the purpose of recording and comparing simultaneous changes of direction and intensity in the broadcast band, particularly at the time of dawn and sunset; also simultaneous direction changes of signals from two or more stations.

The apparatus employed is described and the data obtained are shown graphically.

The conclusions drawn from the experiments are expressed as follows :—

1. Rapid and pronounced fading is usually accompanied by rapid direction changes of large amplitude throughout an evening, but there seems to be no correlation as to the exact time at which the changes occur for the two phenomena, or between the amplitudes of fluctuations over a short interval.

2. The two phenomena frequently begin and end almost simultaneously, but not always.

3. There is no correlation between direction changes in the signals from two different stations.

4. Although there almost always seems to be a pronounced deflection of fairly long duration shortly after sunset and shortly before sunrise, this is not always in the right direction to verify the theory of refraction at the border between day and night.

5. A display of the Northern Lights appears to result in an absence of directional minima on all stations.

THE SHORT-WAVE ECHO EFFECT.—(*E.W. & W.E.*, May, 1927, pp. 257-258.)

A brief article giving the new results on the propagation of short waves described by Herr Quäck in the December number of the *Zeitschrift für Hochfrequenztechnik* (these Abstracts, *E.W & W.E.*, March, 1927, p. 176). Assuming that the waves are propagated with the velocity of light *in vacuo*, the height at which they had travelled is worked out to 182 kilometres. In a note in the *Wireless World* of 23rd March, p. 356, a Berlin correspondent makes the height come to 350 kilometres, instead of 182 kilometres, on the same assumption.

In a letter to the *Wireless World* of 20th April, p. 505, and in the May number of *E.W & W.E.*, p. 259, Prof. Howe points out that this assumption giving the ionised layer a height of some hundred kilometres, is false. He shows that since the waves travel in an ionised medium they have a phase velocity higher and a group velocity lower than that of light, and that when this correction is made, the German observations are consistent with a height of about 90 kilometres, which agrees well with the value deduced from other experiments.

PHASE AND GROUP VELOCITIES IN AN IONISED MEDIUM.—G. W. O. HOWE. (*E.W & W.E.*, May, 1927, pp. 259-260.)

EAST OR WEST?—(*Electrician*, 15th April, 1927, p. 403.)

The following paragraph appears among "Current Topics" :—

The number of times that the beam wireless system of signalling to Australia is reported upon in terms of East and West, is legion. One report even goes so far as to say that there are "two paths; one goes over Europe and Asia, and the other West over the Atlantic, South America and the Pacific Ocean." While appreciating the fact that light and dark bands have to be considered, and that the "Heaviside layer" may give rise to some distortion of the actual route, we still see no reason why beam wireless waves should not be regarded as taking the shortest route, rather than following, more or less, the course steered by the Australian mail boat! The fallacy of the argument of East and West is fully realised when the relative positions of England and Australia are studied on a globe, when it will be seen that for either the daylight or darkness bands, the most probable route for beam, or other radio waves, is one almost passing over the North Polar regions.

THE INTENSITY OF THE RADIATION FROM A SOURCE OF ELECTRIC WAVES WHEN THE ELECTRIC CONSTANTS OF THE MEDIUM IN THE NEIGHBOURHOOD OF THE SOURCE ARE DIFFERENT FROM THE ELECTRIC CONSTANTS AT A DISTANCE FROM IT.—H. Macdonald. (*Proc. Roy. Soc.*, 114, April, 1927, pp. 367-375.)

A mathematical discussion leading to the conclusion that in wireless telegraphy the amplitude of the oscillations is practically unaffected by differences in the electric constants of the atmosphere at a distance from the earth's surface.

THE SOLAR ECLIPSE AND ITS EFFECT ON RADIO.—H. de A. Donisthorpe. (*E.W. & W.E.*, May, 1927, pp. 293-300.)

A lecture delivered before the Radio Society of Great Britain on 23rd March, 1927.

HOLLAND—SHORT-WAVE TELEPHONY.—(*Electrical Review*, 25th March, 1927, p. 477.)

Telephone communication has been established between Holland and the Dutch East Indies constituting, it is claimed, a world's record for long-distance wireless telephony. The transmitter was constructed by Dr. B. van der Pol and Mr. Numans for experimental purposes, the antenna consisting of a single wire attached to a pole only 22 ft. from the ground. The wavelength was 30.92 metres.

ATMOSPHERIC ELECTRICITY.

THE MECHANISM OF A THUNDERSTORM.—G. Simpson. (*Proc. Roy. Soc.*, 114, April, 1927, pp. 376-401.)

The article is summarised as follows :—

A detailed description is given of the mechanism of a thunderstorm according to the theory in which the separation of electricity is brought about by the breaking of raindrops. The orders of magnitude of the meteorological and electrical quantities involved are investigated and shown to be in accordance with observations. The observations made by Schonland and Craib in South Africa of changes of electrical field-strength produced by lightning discharges are examined in the light of the theory and found to be in complete accord.

ATMOSPHERIC POTENTIAL AT VARYING ALTITUDES. —(*Electrician*, 1st April, 1927, p. 347.)

At the Aerodynamic Observatory at Trappes, sounding balloons have been employed to record the change of atmospheric potential with altitude. In general, the electric field becomes less with increasing altitude. The mean results were 10.4 V. per metre at 4,000 metres, 5.6 V. per metre at 6,000 metres, and 2.3 V. per metre at 8,000 metres. From the three balloons that entered the isothermal layer, the results at the lower limits reached a considerable value, amounting to from 30 to 40 V. per metre. The one balloon that reached an altitude of 20,000 metres showed that at heights above 16,000 metres there is a comparatively regular decrease, *e.g.*, 12 V. per metre at 16,000 metres, 5 V. per metre at 17,000 metres, and 1 to 2 V. per metre at 19,000 metres.

PROPERTIES OF CIRCUITS.

INFLUENCE ON THE AMPLIFICATION OF A COMMON IMPEDANCE IN THE PLATE CIRCUITS OF AMPLIFIERS.—J. Anderson. (*Proc. Inst. Radio Engineers*, 15, 3, March, 1927, pp. 195-212.)

It is pointed out that the common impedance in the plate circuits of two or more valves in an amplifier will affect the output, and under certain conditions cause distortion and oscillation. A theory is developed to explain this phenomenon. Several typical amplifier circuits are analysed with the theory and some experimental evidence is adduced in support of it. Methods of avoiding oscillation and distortion are suggested.

ON THE VARIATION OF FREQUENCY OF A GENERATING VALVE CIRCUIT DUE TO THE VARIATION OF FILAMENT CURRENT.—J. Obata. (*Proc. Physico-Mathematical Society of Japan*, January, 1927.)

It is well known that the frequency of the oscillation generated by a valve circuit does not absolutely correspond to the simple formula $n = \frac{1}{2\pi\sqrt{LC}}$, but is affected by various factors such as the resistance in the oscillatory circuit, voltages of the various batteries in use, temperature of the filament, coupling between portions of the circuit associated with the grid and anode, etc. The effects of these factors have been investigated by a number of authors (including Eccles and Vincent, *Proc. Roy. Soc.*, 96 and 97, 1920) with the result that of these various factors the filament current is found to play the principal part.

According to Vincent the frequency of oscillation in a generating circuit, maintained by a B valve with grid-coil coupling, has a minimum value for a certain filament current. This minimum would be useful, since in its neighbourhood change of filament current would have little effect on the frequency. Testing several valves, however, the author obtained no minimum in the frequency for any of them within the limit of the normal working value of the filament current. The experiments showed that the change in frequency decreases the looser the coupling. Of the various valves tested the change in frequency was found to be the smallest with the Radiotron 201A, employing loose coupling, but even with this arrangement it was by no means easy to obtain constant frequency for a long period of time.

THE THEORY OF A TUNED R.F. TRANSFORMER.—G. Browning and F. Drake. (*Q.S.T.*, March, 1927, pp. 20-22.)

The mathematics given apply to any tuned radio-frequency transformer, whether for frequencies included in the broadcast band or some frequency chosen for the intermediate transformer; but the theory has only been checked with experimental curves over the broadcast band.

DISCUSSION ON THE OUTPUT OF CHARACTERISTICS OF AMPLIFIER TUBES (WARNER AND LOUGHREN).—(*Proc. Inst. Radio Engineers*, 15, 3, March, 1927, pp. 249-251.)

COUPLING CONDENSERS AND LEAKS.—A. Sowerby. (*Wireless World*, 20th April, 1927, pp. 481-483.)

An article showing how to calculate the correct values for any frequency.

THE APPLICATION OF A GENERATING VALVE CIRCUIT TO THE MEASUREMENT OF PULSATORY OSCILLATIONS, MICRO-TREMORS AND TILTINGS.—J. Obata. (*Proc. Physico-Mathematical Society of Japan*, January, 1927.)

FRAGEN DER ANTENNENKOPPLUNG (Questions of antenna coupling).—E. Zepler. *Telefunken Zeitung*, 8, December, 1926, pp. 79-84.)

Considerations of the problems of intensity and selection in the cases of the tuned and the aperiodically coupled antenna, dealing in the latter case also with the question of the detuning of the tuned circuit by the antenna.

The current distribution in the antenna is taken throughout the discussion to be quasi-stationary as in practice is almost always the case.

TRANSMISSION.

MESSUNGEN IM STRAHLUNGSFELDE EINER IN GRUND-UND OBERSCHWINGUNGEN ERREGTEN STABFÖRMIGEN ANTENNE (Measurements in the radiation field of a linear antenna excited in its fundamental oscillation and harmonics).—L. Bergmann. (*Annalen der Physik*, 82, 4, 1927, pp. 504-540.)

The construction is described of a valve transmitter for generating undamped oscillations on a wavelength of 172 cm. that will excite a linear antenna in any odd or even number of harmonics. Measurements were made with a specially constructed receiver of the field radiated by the antenna excited in the fundamental oscillation and in different harmonics up to the sixth. When excited in the fundamental the whole radiation is sent out at right angles to the antenna in its equatorial plane, but when excited in the harmonics, radiation takes place in several directions: in fact, there are always as many directions of radiation as there are current antinodes along the antenna. Between the radiation diagrams obtained by measurement and the curves calculated according to Abraham, there is very good agreement as concerns the different directions of radiation. With regard to the amplitude of the energy sent out, however, there was at first a divergence between calculation and measurement. The reason for this was when calculating hitherto it was always assumed that the current amplitude in the different oscillation antinodes along the antenna had the same value, whereas actually the amplitude of the current in the antinode where excitation is effected is considerably greater than in the neighbouring current antinodes: when this is taken into account in the calculation, theory and measurement agree also as concerns the amplitude. In various cases, the radiation of individual oscillation antinodes is prevented by the insertion of coils, producing a particular radiation diagram, which likewise agrees with calculation.

The results obtained are of value for short wave telegraphy in that, by exciting the transmitting antenna in harmonics, one is in a position to send out the largest part of the radiated energy not, as previously with long waves, perpendicular to the antenna, *i.e.*, parallel to the earth's surface, but making a more or less acute angle with the antenna and consequently sloping upwards, thereby sending the radiation from the outset into altitudes that are particularly favourable for the propagation of short waves.

There are 25 figures and 2 plates showing photographs of the apparatus.

Discussion on Radiation Resistance of a Vertical Antenna (Levin and Young).—S. Ballantine. (*Proc. Inst. Radio Engineers*, 15, 3, March, 1927, pp. 245-247.)

The Constancy of B.B.C. Transmissions.—W. Griffiths. (*Wireless World*, 20th April, 1927, pp. 497-500.)

Enumeration of factors governing the strength of received signals.

Crystal-Controlled Transmitter.—R. Bloxham. (*Wireless World*, 13th April, 1927, pp. 449-451.)

Practical details of a 50-watt installation working on 45 metres.

Some Possibilities and Limitations in Common Frequency Broadcasting.—De L. Martin, G. Gillett, I. Bemis. (*Proc. Inst. Radio Engineers*, 15, 3, March, 1927, pp. 213-223.)

Discussion of the nature of the problems involved in common frequency broadcasting where two cases call for consideration: two or more stations attempting to use the same frequency (*a*) with their own separate programmes, and (*b*) for sending out a common programme which is transmitted to them from a single source.

Die Rückwrikung bei fremdgestenesten Röhrensendern (Back action in externally modulated valve transmitters).—W. Kummerer. (*Telefunken Zeitung*, 8, December, 1926, pp. 20-25.)

It is explained how back action in externally modulated valve transmitters is brought about and the different methods for getting rid of it are discussed.

The Insulation of a Guyed Mast.—H. Miller. (*Proc. Inst. Radio Engineers*, 15, 3, March, 1927, pp. 225-243.)

Theoretical and experimental examination of the question as to the advisability of insulating the masts and guys employed to support the antennæ of high power transmitting stations. Under certain conditions this will increase the effective height and efficiency of the antenna giving a power saving that is worth more than the cost of the insulation and the increase in mechanical hazard, while under other conditions the increase in antenna efficiency may be insufficient to make the insulation worth while. No fixed rules can be given since each design of antenna and mast system presents a different problem. An attempt is made, however, to point out with the help of a characteristic example certain fundamental considerations and experimental methods that will assist in the economical insulation of guyed masts.

RECEPTION.

A New Receiver.—(*Electrician*, 1st April, 1927, p. 368.)

A series of receivers which are guaranteed for aural reception of any long wave C.W. station at the extreme limit of its range, has recently been developed by Marconi's Wireless Telegraph Co., Ltd. A comparatively small loop is used as an aerial, which helps to secure the desired degree of selectivity and eliminate atmospheric interference. The set itself is a seven-valve instrument comprising two tuned stages of high frequency amplification, followed by an "anode bend" rectifier, two low frequency filter systems with valve-coupled tuning circuits designed for a note frequency of 1,200 cycles, and a transformer coupled stage of note magnification. A "phasing unit" is incorporated in the set, which, consisting of a single valve and a simple inductively coupled circuit, gives greater selectivity should circumstances demand a higher standard than that given by the frame and receiver alone.

Electric Dust Precipitators and Radio Reception.—F. Muller. (*Siemens Zeitschrift*, January, 1927.)

Serious interference of radio reception has been observed in the previously occupied zones of Western Germany from the many electric dust precipitators installed in the surrounding mining districts. The trouble in all cases was found to be due to the synchronously driven rectifying spark gap, which changes the high voltage A.C. into approximately 50kV D.C. The secondary of the feeding transformer, together with the spark gaps and the capacity of the precipitators, forms an excellent oscillating circuit, emitting waves of 200 to 300 metres. Three ways of remedying the interference are suggested in this article: (1) Increasing the capacity by placing high-voltage condensers parallel to the precipitators. (2) Inserting ohmic resistance into the high-voltage connections at properly selected points. (3) Replacing the synchronous rectifiers by valve rectifiers.

SOURCES OF DISTORTION IN RESISTANCE AMPLIFIERS.—M. von Ardenne. (*Wireless World*, 30th March, 1927, pp. 395-399.)

Discussion of the influence on quality of anode resistance, grid leak, and coupling condenser valves.

LA RÉCEPTION PAR DOUBLE CHANGEMENT DE FRÉQUENCE (Reception by double change of frequency).—A. Cazes. (*Radio-Revue*, March, 1927, pp. 321-322.)

Description of a method of reception permitting the employment of the "bireflex" device patented by the author, discussed in *L'Onde Electrique* of August, 1926, p. 425.

QUELQUES OBSERVATIONS PRATIQUES SUR LA RÉCEPTION DES ONDES COURTES (Some practical observations on the reception of short waves).—*Radio-Revue*, April, 1927, p. 345.)

SUR LES CONTACTS RECTIFIANTS (On rectifyng contacts).—H. Pélabon. (*Comptes Rendus*, 184, 7th March, 1927, pp. 591-593.)

An instrument is described for studying the influence of the distance between the two conductors of a detector or the pressure they can exert on one another.

Employing a steel needle point and a galena crystal, two values for the detection were found corresponding to the interior and exterior regions for which the contact resistance assumes such different values. Measuring the rectified current when a small difference of alternating potential was set up between galena and point gave not only different current intensity for the two regions, but variations that were not comparable. The greatest intensity corresponds to the region offering the greatest resistance to continuous current. All the metals tested behave like steel when associated with galena, but the curves obtained differ sufficiently from one conductor to another for them to be considered as characteristic of the metal in question.

LOCATION OF RADIO INTERFERENCE.—B. Ellsworth. (*Electrical World*, 16th April, 1927, pp. 810-811.)

A list is given of 47 causes of radio interference due respectively to secondary lines, set noises, and power company's equipment. The procedure followed in tracing source of trouble is described and the equipment used.

DIRECTIONAL WIRELESS.

SUR LES PROCÉDÉS DE RÉPÉRAGE, D'ALIGNEMENT PAR LES ONDES HERTZIENNES ET SUR LES RADIOPHARES D'ALIGNEMENT (On methods of taking bearings and direction finding employing Hertzian waves and directive radio-beacons).—A. Blondel. (*Comptes Rendus*, 184, 7th March, 1927, pp. 561-565.)

It is known that, with the aid of antenna systems joined by one or two horizontal connections so as to make open or closed frames, we can effect the concentration of Hertzian waves in certain directions in space and, by means of interference, produce nodal planes, *i.e.*, planes in which no wave is propagated, in certain azimuths.

The author has already described three types of such frames, presenting different particulars :—

(*a*) A frame in which the two vertical antennæ are traversed by currents of opposite phase spaced at most a half wavelength apart : the nodal plane at some distance away is a plane perpendicular to the plane of the antennæ.

(*b*) A frame in which the two preceding antennæ are excited in the same phase, when the nodal plane coincides with the plane of the antennæ.

(*c*) A frame in which the difference of phase between the antennæ is equal to the phase lost by a wave travelling from one antenna to the other, when the nodal plane again passes through the antennæ but, differing from the two previous cases, the radiation distribution is unsymmetrical, the nodal plane existing only in a single direction.

Bellini has taken up the same subject in a more complete manner (*Jahrbüch*, 1909, p. 381). Frames of type (*a*) or (*b*) can be employed on short waves of 20 to 100 metres for indicating directions over sea or in the air corresponding to the nodal plane : exciting the frame by means of a suitable oscillation generating system producing musical waves being all that is necessary to establish a directive radio-beacon.

Details are given of a new system and also of the employment of very short waves of 5-10 metres with two directional curtain antennæ placed one above the other at an angle of 20°-30°, excited alternately, the plane bisecting the two curtains giving an accurate determination of the direction sought.

SUR LES RADIOPHARES TOURNANTS (On rotating radio-beacons). — A. Blondel. (*Comptes Rendus*, 184, 21st March, 1927, pp. 721-724.)

The double curtain arrangement for directive radio-beacons can also serve to construct rotating beacons giving more accurate readings than the devices tried hitherto (in particular the Marconi installation at Dover and Mesny's Greek-patterned rotating curtain). The two curtain antennæ are mounted on a trolley turning at constant speed and excited alternately at intervals sufficiently rapid to enable the navigator, knowing the speed of rotation, to read off his position. This he does by noting the moment when he hears the sounds equally, and referring it to the instant when he picks up a special signal, emitted automatically by an independent antenna when the plane bisecting the two rotating curtains passes through a cardinal landmark.

LA BOUSSOLE HERTZIENNE (The Hertzian compass).—H. Busignies. (*Radio-Revue*, March, 1927, pp. 309-319.)

Preliminary description of this compass, which appears to have advantages over the ordinary radiogoniometer principally for aeronautical use. It is understood that, from analogy with the ordinary compass which indicates the direction of the terrestrial magnetic field, the name Hertzian compass is intended to denote an instrument indicating the direction of the electromagnetic field of Hertzian waves, or the direction, at right angles, of the transmitter of these waves, installed at the aerodrome. The apparatus, two forms of which are described, consists essentially of two similar receiving frames, perpendicular to one another, from which the currents induced by the transmitter are conveyed to two equal ordinary galvanometric frames pivoting round the same vertical axis, to which a pointer moving over a graduated scale is attached, indicating the deviation of the direction in which the craft is travelling from that of the transmitting station. The obvious advantage of the device is that no wireless operator is required, the pilot having merely to guide his craft so that the pointer keeps at zero on the dial in order to arrive at his destination. The compass is discussed here chiefly from the theoretical viewpoint, a commercial form of the instrument being under development, particulars of which the author hopes to give later.

DER NEUE TELEFUNKEN-PEILER E358N (New Telefunken bearings-finder E358N).—(*Telefunken Zeitung*, 8, December, 1926, pp. 41-44.)

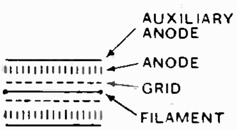
VALVES AND THERMIONICS.

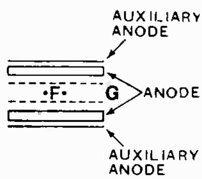
ON THE APPLICATIONS OF VARIOUS ELECTRONIC PHENOMENA TO THERMIONIC VACUUM TUBES WITH PROPOSED NEW VACUUM TUBES.—K. Okaba. (*Journ. Inst. Elect. Eng. Japan*, No. 463, February, 1927, pp. 174-195.)

A paper with 25 figures showing applications to three and four electrode valves of various electron phenomena, especially electron reflection and secondary emission.

(*a*) A negative-resistance valve which utilises magnetic field only. This valve consists of filament, anode and auxiliary anode, with magnetic field applied. The effect of secondary electrons from the anode is negligible since a large proportion of the secondary electrons cannot be attracted by the auxiliary anode. If the voltage of the plate increases, the current through it decreases, on the other hand, if its voltage decreases, all of the thermoelectrons from the filament can be caught by the plate as there is no effect of secondary emission (including electron reflection). Thus this valve has negative resistance of very small value, which is a desirable characteristic for the generation of short waves.

(*b*) Excited four-electrode valve. This valve consists of filament, grid, anode and auxiliary anode as shown below:





The auxiliary anode is made of special material from which the secondary emission is very large. In this new valve the anode current consists of the secondary electrons from the auxiliary anode, which is a few times larger than that of the thermoelectrons from the filament, and its characteristics are quite similar to those of the triode. Experiment showed that the internal resistance of this valve is $\frac{1}{2}$—$\frac{1}{3}$ that of the triode under the same conditions, giving the same amplification constant.

Lastly it is shown that oscillations of the Barkhausen and Kurz type may be maintained by the action of reflected and secondary electrons at the surface of the grid, assuming that the grid voltage is high enough and the plate voltage negative.

UNE NOUVELLE LAMPE PERMETTANT L'ALIMENTATION DIRECTE DE TOUS LES RÉCEPTEURS DE T.S.F. SUR LES RÉSEAUX À COURANT ALTERNATIF (LAMPE EURÉKA) (A new valve permitting the direct supply of all radio receivers from alternating current mains (Eureka valve)).—Lejeune and Givelet. (*Radio-Revue*, April, 1927, pp. 339-341.)

Lecture given to the Radio-Club de France, 24th February, describing the Eureka valve.

In this valve the filament heated by alternating current is distinct from the electron producing filament, but not as is usual under these circumstances a small distance away from it so that the emitting filament is heated by radiation; instead, the two filaments are in contact one being rolled round the other. Owing to the difference in resistance of the two filaments, only one-tenth of the alternating current passing through the emitting filament, and the supply tension being very low, the tension variations in this filament relatively to the grid are said to be altogether negligible.

The principal constants of this valve are given as:—

Heating tension: 1V. 4 to 1V. 6.
Heating current: about 1.5 amps.
Saturation current: 10 milliamps.
Amplification coefficient: 9 to 12.
Internal resistance (between filament and plate): 20,000 to 35,000 ohms.

A diagram of the circuit arrangement is shown.

THE ALIGNMENT METHOD IN LINEAR VALVE CHARACTERISTIC FIELDS. — W. Barclay. *E.W. & W.E.*, May, 1927, pp. 261-270.)

VACUUM-TUBE NOMENCLATURE.—E. Chaffee. (*Proc. Inst. Radio Engineers*, 15, 3, March, 1927, pp. 181-194.)

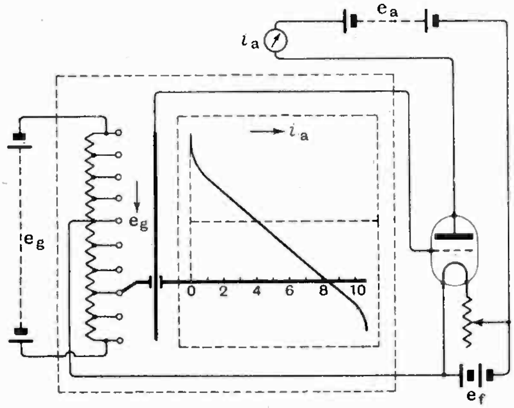
A scheme of symbols, for which no claim to completeness is made, is presented in the hope that it may serve as a step towards the early standardisation of a system of valve nomenclature.

The proposed scheme is discussed by G. Metcalfe on pp. 253-254.

EINE EINFACHE RÖHREN-MESSPLATTE (Simple method of obtaining valve characteristics).—E. Römhild. (*Elektrotechnische Zeitschrift*, 3rd February, 1927, pp. 139-140.)

Usually the determination of the electrical characteristics of a valve requires complicated connections between batteries, resistances, instruments, etc., calling for the services of a skilled operator. In this article a semi-automatic valve measuring instrument is described, of particular value for routine testing work by unskilled persons.

A diagram of the circuit-arrangement is shown below:



The slider of a potentiometer is mechanically connected to a movable straight edge, and readings from a directly indicating instrument are plotted along the straight edge while it is moved over a piece of co-ordinate paper. The whole apparatus is combined in a portable set.

La Bigrille à Reaction (The four-electrode valve with reaction).—E. Weil. (*Radio-Revue*, April, 1927, pp. 346-349.)

Account of experiments with the double-grid valve which is of interest at the moment owing to the employment of frequency changers in wireless telephony.

Modern Valve Manufacture.—J. Gracie. (*Wireless World*, 6th April, 1927, pp. 406-413.)

Electric Lamps and Valves.—(*Electrical Review*, 25th March, 1927, p. 494.)

Abstract of Mr. Paterson's lecture at the Royal Society of Arts on 16th February.

The nature is indicated of some of the problems encountered by manufacturers who seek a reduction of empiricism in process operations, efforts to solve them leading to fundamental questions which so far remain unanswered.

Choosing the Right Valve.—P. K. Turner. (*Wireless World*, 6th April, 1927, pp. 417-421.)

Characteristics required for the various stages in a multi-valve receiver.

How to Test your Valves.—W. James. (*Wireless World*, 6th April, 1927, pp. 425-428.)

Thermionic Properties of the Rare-Earth Elements.—E. Schumacher and J. Harris. (*Bulletin*, Reprint B-226, Bell Telephone Laboratories, January, 1927.)

Data are given showing that rare-earth metals of the cerium and yttrium groups are much more active thermionically than the commonly occurring metals, the electron emission from some being a million times as great as that from clean tungsten at the same temperature. The paper describes two methods of determining the thermionic activity of substances obtainable in powdered form.

GENERAL PHYSICAL ARTICLES.

Photo-Electric Emission as a Function of Composition in Sodium-Potassium Alloys. —H. Ives and G. Stilwell. (*Bell Telephone Laboratories Reprint*, B-238, March, 1927.)

The Characteristics of Gas-filled Photo-electric Cells.—N. Campbell. (*Philosophical Magazine*, 3, April, 1927, pp. 945-959.)

Beiträge zur Untersuchung des Nachhalles (Contributions to the study of the echo).—E. Meyer. ((*Elekt. Nachr.-Technik*, 4, 3, 1927, pp. 135-139.)

Description of a qualitative method of investigating echo phenomena, employing a Reiss microphone, an amplifier and oscillograph.

Experiments on Highly Penetrating Radiation from the Earth.—L. Bogoiavlensky and A. Lomakin. (*Nature*, 9th April, 1927, p. 525.)

Measurements of penetrating radiation from the earth carried out at Piatigorsk (in the Caucasus) by means of a portable electrometer covered with lead 1 cm. thick, show that the intensity fluctuates according to the observing station where the measurements are made. Differences of as much as 100 per cent. are observed between stations separated by a few metres only at places rich in radium. The intensity at the same station is found to be constant and independent of meteorological conditions. The radiations are found to be directed from below, their source lying apparently in radio-elements diffused in upper strata of the soil.

The full report of this work will be published in the *Bulletin* of the Institute of Practical Geophysics, Leningrad.

Measurements of the Amount of Ozone in the Earth's Atmosphere and its Relation to other Geophysical Conditions—Part II.—G. Dobson, D. Harrison and J. Lawrence. (*Proc. Royal Society*, 114, April, 1927, pp. 521-541.)

The article is summarised as follows :—

A method of measuring the amount of ozone in the upper atmosphere having been described in a previous paper, results of simultaneous measurements made at various places in N.W. Europe are given. As previously found, there is a marked connection between the amount of ozone and the meteorological upper-air conditions. The possible reasons for this connection are briefly discussed. Connections with terrestrial magnetism and possibly with sunspots are also indicated.

Water Vapour in the Atmosphere.—E. Gold. (*Nature*, 30th April, 1927, pp. 654-655.)

STATIONS: DESIGN AND OPERATION.

NEW WIRELESS STATION FOR CROYDON AERODROME. — (*Electrician*, 8th April, 1927, p. 396.)

The new station, which is to be erected for the Air Ministry by the Marconi Company, will consist of a group of four 3kW transmitters operated in conjunction with a wireless direction finding receiver. The transmitters will be capable of telephonic, C.W. and tonic train telegraphic transmission, the wavelength range being from 800 to 2,000 metres. Independent drive circuits will be incorporated to maintain constancy of frequency and wavelength. Energy for the transmitters is to be supplied by a common motor alternator group, the power from which may be switched on to any of the transmitters. The new D.F. apparatus will incorporate the latest filtering and amplifying devices. It is to be arranged so that, if required, two or more circuits can be operated on different wavelengths for the reception of telephony and telegraphy on the same aerials.

In order to keep the neighbourhood of the aerodrome as free as possible from obstruction, the wireless masts and transmitters will be erected two or three miles from the Air Port and operated by the "remote control" system.

DIE FLUGHAFEN-FUNKSTELLE HOF IN BAYERN (The air-port radio station Hof in Bavaria). —*Telefunken-Zeitung*, 8, December, 1926, p. 19.)

Brief description of the aerodrome radio station, 4 kilometres to the west of Hof in Bavaria, recently constructed by the Telefunken firm for the Imperial Ministry of Communications. The site is 140 metres above Hof and 550 metres above sea level. The two lattice masts, which are 45 metres high and 70 metres apart, support the 3-wire T-antenna 64 metres long and 4 metres broad having a natural wave of about 550 metres and capacity 1,100 cm. The earth system has an area of 4,000 sq. cm. and is buried in the ground 30 cm. deep. The transmitter is a self-excited intermediate circuit valve transmitter of about 1.5kW resultant antenna output for distances of from 800 to 1,800 metres and is arranged for both unmodulated and modulated (note transmitter) telegraphy and for telephony.

IRISH FREE STATE—CORK STATION.—(*Electrical Review*, 1st April, 1927, p. 519.)

The new broadcasting station at Cork of the Department of Posts and Telegraphs, constructed by Standard Telephones & Cables, Ltd., London, has almost completed its tests. It is located at Sunday's Well, and occupies the site of the old prison. Two 120-ft. masts support the aerial, which consists of four wires each 156 ft. long; an earth mat, composed of a network of copper wires, has been buried in the ground covering an area of approximately 20,000 sq. ft. The station is rated at 1.5kW, and with 100 per cent. modulation a "peak" power of 4kW can be handled without distortion, assisted by the use of a condenser microphone. The frequency of the carrier wave is maintained constant within 0.01 per cent. The power required to operate the complete station is about 9kW, obtained from the local supply mains and used to drive motor generators. It is hoped that this station will cover the south and west of the Free State. The wavelength is 400 metres.

BROADCASTING DEVELOPMENTS IN THE IRISH FREE STATE.—(*Electrician*, 29th April, 1927, p 480.)

Particulars are given of the equipment of this new broadcasting station which was opened formally on 25th April.

SHORT-WAVE BEAM TRANSMISSION.—(*Electrician*, 8th April, 1927, pp. 378-379.)

Continuation of the description of the Grimsby Station begun in the *Electrician* of 25th March. The present article considers the masts and aerial equipment, feeder system and special earthing arrangements.

On p. 396 it is stated that a second beam station is now being completed in Australia to give a direct service between that country and Montreal. The Montreal service will also be available, if required, as an additional channel of communication with London, linking up with the Anglo-Canadian Beam. Wireless feeder stations have been erected at all the Australian capital cities to work in conjunction with the beam service, and additional accepting and delivery offices in the State capitals will be opened as occasion demands.

AUSTRALIAN BEAM SERVICES.—(*Wireless World*, 30th March, 1927, pp. 378-379.)

Description of the Grimsby and Skegness Stations.

AUSTRALIA—NEW RECEIVING STATION.—(*Electrical Review*, 1st April, 1927, p. 519.)

The La Perouse radio receiving station was opened recently by Amalgamated Wireless (Australasia), Ltd. It is capable of receiving messages from Tilbury Docks, London, as well as from the docks in Vancouver and San Francisco, and has also kept in communication with ships fitted with short-wave sets between these terminal ports. It will be the official receiving centre for Sydney, and will be in direct communication with all the "beam" feeder stations in Australia, and automatically relay the messages received direct to the head office of the Company. The same procedure will be followed regarding messages received from the Federal Government stations in New Guinea and the Pacific Islands, which are controlled by Amalgamated Wireless, Ltd. The aerial system at La Perouse consists of four 72-ft. tubular steel masts in the form of a square, with one 99-ft. mast in the centre. All transmitting will be done from the Pennant Hills, about 30 miles distant.

DER RHEINLANDSENDER (The Rhineland transmitter).—W. Meyer. (*Telefunken Zeitung*, 8, December, 1926, pp. 8-19.)

Detailed description of the Langenberg broadcasting station with 25 diagrams and illustrations.

SUBSIDIARY APPARATUS.

GRUNDLEGENDES ZU UNTERSUCHUNGEN AN MIKROPHONEN (Principles of microphone investigation).—G. Schubert.

The difficulties of studying microphones are considered in detail and methods of making objective tests suggested.

LOUD-SPEAKER DESIGN.—N. McLachlan. (*Wireless World*, 30th March and 13th April, 1927.)

BATTERY ELIMINATORS.—(*E.W. & W.E.*, May, 1927, pp. 271-278; *Wireless World*, 27th April, pp. 535-538; *Electrician*, 29th April, p. 466.)

Abstracts of a paper read by Messrs. P. Coursey and H. Andrewes before the Wireless Section, I.E.E., on 6th April, 1927.

A NEW FREQUENCY TRANSFORMER OR FREQUENCY EXCHANGER.—I. Koga. (*Journ. Inst. Elect. Eng. Japan*, No. 463, February, 1927, pp. 146-156.)

Description of a triode arrangement that will not only multiply the frequency of an alternating current, but will also obtain such frequencies as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{3}{2}$, $\frac{4}{3}$, etc., of the given frequency. The behaviour of the apparatus is shown to be due to the non-linear characteristics of the triode.

MISCELLANEOUS.

SUCCESSFUL TELEVISION DEMONSTRATION OVER 200 MILES.—(*Electrician*, 15th April, 1927, p. 420.)

Television was successfuly demonstrated on 7th April by the American Telephone and Telegraph Co., Ltd., to a group of newspaper representatives at its Bell Laboratories, New York. They saw Mr. Hoover, Secretary of Commerce, leaning over the telephone in Washington, 200 miles away, and watched his image on a screen as he spoke.

In this connection it is interesting to note that Mr. Baird claims to have established television between London and New York, proposing to give a public demonstration shortly. The tests are expected to show the commercial practicability of television, and if they are successful, televisors will be placed on the market at a cost of £30.

TELEVISION BECOMES AN ACTUALITY.—(*Electrical World*, 16th April, 1927, pp. 824-825.)

Account of the demonstration on 7th April given by the American Telephone and Telegraph Company, when speakers at Washington were seen in action on a screen in New York. The transmission was effected by wire, but the fact that radio will serve equally well was proved by the audience being shown, at the same time as hearing, a performance from the Whippany studio transmitted by wireless. In the method developed a minute spot of very bright light is projected upon the object to be transmitted and moved to and fro so that the details of the entire surface are successively illuminated. This light is reflected back upon the photo-electric cell which generates a current in direct proportion to the amount of light falling upon it. This current, amplified many million million times, is that which is transmitted. Previous experimenters had tried to secure complete illumination of the object by pouring a tremendous flood of light upon it. The use of the new scanning method makes it possible to employ a very small quantity of light instead of an amount that would be unbearable to performers.

COMMERCIAL PICTURE TRANSMISSION.—A. Dinsdale. (*Wireless World*, 27th April, 1927, pp. 510-516.)

A technical description of the methods and apparatus used in America.

DIE FORTSCHRITTE DER BILDTELEGRAPHIE TELEFUNKEN-KAROLUS-SIEMENS (Progress of picture telegraphy on the Telefunken Karolus Siemens method).—F. Schröter. (*Telefunken Zeitung*, 8, December, 1926, pp. 5-8.)

Illustrated description of this method which was successfully used last autumn to send pictures between Nauen and Rio, a distance of about 10,000 kilometres, on a wave of 25 metres.

DIE UMWANDLUNG EINES BILDES IN ELEKTRISCHE TELEGRAPHIERZEICHEN (Converting a picture into electrical signs for telegraphing). —O. Schriever. (*Telefunken Zeitung*, 8, December, 1926, pp. 35-40.)

FRANCE—NEW REGULATIONS.—(*Electrical Review*, 1st April, 1927, p. 519.)

BRITISH EXPORT FIGURES OF RADIO APPARATUS, INCLUDING VALVES.—(*Electrician*, 1st April, 1927, p. 368.)

From recent export figures Japan appears to be the biggest importer of radio apparatus and instruments of British manufacture, in that during the last recorded month (January) goods valued at £14,096, together with valves valued at £588, were shipped to that country. Russia imported goods to the value of £11,032, and valves to the value of £91. Australia absorbed apparatus to the value of £10,618 and valves to the value of £2,362. Sweden's import of apparatus and instruments was £5,270 and of valves £1,122. New Zealand imported apparatus with £3,820 and valves £640. Canada's figures were £1,228 and £922. France took apparatus and instruments valued at £3,543 and valves £1,385. Germany's totals were £1,519 and £2. The Irish Free State bought apparatus of British make valued at £2,488 and valves at £256. The Netherlands bought almost £5,000 worth of apparatus, as well as valves to the value of £300.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

PROPAGADO DE ONDOJ.

EĤA EFEKTO DE MALLONGAJ ONDOJ.

Redakcia artikolo pritraktanta la konatan fenomenon de "eĥa" efekto, kaŭze de ondoj, kiuj transiras longan distancon laŭ malsamaj vojoj. Oscilogramoj estas donitaj por ilustri la efekton, kun frapanta ekzemplo, kie la ĉefa signalo estas vojaĝinta nur kelkajn kilometrojn kaj la eĥa signalo estas ĉirkaŭinta la terglobon.

FAZAJ KAJ GRUPAJ RAPIDECOJ EN IONIZITA MEDIO.—Prof. G. W. O. Howe.

La artikolo diskutas eksperimentojn faritajn en Berlin por determini la tempon uzitan de mallonganda signalo ĉirkaŭi la terglobon, per kio oni faris deduktojn pri la longeco de la vojo, kaj alteco de la vojo super la tero. Oni atentigas, ke du aferoj devas esti konataj—la tempa intervalo kaj la rapideco de la ondo. La prelego tiam diskutas la rapidecon de la ondgrupo kiel tuto, kaj la "faza rapideco," kaŭze de la moviĝo de individua ondo en la grupo. Oni montras, ke ĉi tiuj estas respektive malpli kaj pli grandaj, ol la rapideco de lumo, kaj estas funkcioj de la elektrona denseco en la medio. La aŭtoro poste traktas pri korektoj aplikataj al la Germana takso pri alteco, laŭ diversaj valoroj de grupa rapideco kaj elektrona denseco.

LA SUNA EKLIPSO KAJ ĜIA EFEKTO JE RADIO.

Raporto pri lekcio antaŭ la Radio-Societo de Granda Britujo, de Kapitano H. de A. Donisthorpe, je 23a Marto 1927a.

La lekcio traktis pri la efektoj de la suna eklipso je 24a Januaro, 1925a. Li priskribis radio-observadojn en Nova Jorko, kaj diskutis kelkajn efektojn, kun ilustraĵoj de la observadoj laŭ la pozicioj de la stacioj rilate al la tuteklipsa regiono.

Sugestoj por la radio-observadoj je la okazo de la okazonta eklipso je 29a Junio estas fine donitaj, kune kun raporto pri la diskutado, kiu sekvis la paroladon.

RICEVADO.

DESEGNO KAJ KONSTRUO DE SUPER-HETERODINA RICEVILO.—P. K. Turner.

Kvankam la prelego pretendas esti "Priskribo," la teorio kaj principoj de supersona funkciado estas ankaŭ klare pritraktitaj.

La aŭtoro unue konsideras la efekton de la loka oscilatoro kaj la diversaj frekvencoj, kiuj ekzistas ĉe la enmeto kaj elmeto de la unua detektoro. Li poste traktas pri la Intera frekvenca amplifikatoro, diskutante la tipon de resonanco bezonita ; de tio al la dua detektoro kaj malaltfrekvenca amplifikatoro. Li poste revuas eblajn ŝparojn per kombino de valvaj funkcioj, kiel ĉe refleksaj cirkvitoj, kaj priskribis eksperimentojn je konstruado de supersonaj riceviloj. La unua ricevilo havis 4 valvojn, kombinita detektoro-oscilatoro (laŭ la dua harmonika principo), 3 valvoj je inter frekvenco, dua detektoro-kristalo, kaj du el la I.F. valvoj ankaŭ funkciantaj kiel malaltfrekvencaj. La malfacilaĵoj renkontitaj estas priskribitaj, ĉefe harmonikoj en la oscilatoro, kaj ĝenoj okazantaj pro refleksado de la elmeta valvo. Dua ricevilo estas poste priskribita, al kiu estis aldonita elmeta altpotenca valvo. La "Tropodina" cirkvito por la oscilatora-detektora pozicio estas diskutita, kaj modifaĵoj por plibonigi la ekvilibron estas sugestitaj. La artikolo estas daŭrigota.

BATERIAJ FORIGILOJ, aŭ Instrumentoj por la Funkciigo de Radio-Ricevilaj Cirkvitoj per Energio ricevita el Elektraj Ĉef-tuboj.

Resumo de prelego legita de S-roj. P. R. Coursey, B.Sc., M.I.E.E., kaj H. Andrewes, B.Sc., antaŭ la Senfadena Sekcio, Instituto de Elektraj Inĝenieroj, Londono, je 6a Aprilo 1927a.

La prelego diskutas la provizon de Alta-Tensiaj, Malalta-Tensiaj, kaj Krad-Potencialaj voltkvantoj pere de la publikaj elektraj ĉeftuboj. La aŭtoroj sugestas la nomon "Radio-Proviziloj," anstataŭ la pli kutima termino "Bateriaj Forigiloj."

La prelego traktas pri ĝeneralaj principoj, poste pri Alta-Tensia provizo, inkluzive alĝustigo de elmeta voltkvanto, funkciigo kaj desegnado de A. T. filtrilo, permesebla ondeta voltkvanto, takso de A. T. proviziloj kaj mezurado de elmetaj karakterizoj. Oni donas kurvojn montrantajn la efekton de l'elektraj konstantoj de la filtrila aranĝo, kaj tabelo kaj kurvoj montras mezuritajn elmetajn koeficientojn de diversaj komercaj A.T. Proviziloj. La prelego poste pritraktas aranĝojn por krada potencialo, malalta-tensia provizo, kun filtrilaj aranĝoj, rektifikatoroj por A.T. kaj por M.A.T. provizo, k.t.p. Fina sekcio traktas pri antaŭzorgoj necesaj je la uzado de tiaj aranĝoj.

Mallonga raporto aperas ankaŭ pri demonstracio donita dum la lekcio kaj pri la diskutado, kiu sekvis la legadon de la prelego.

VALVOJ KAJ TERMIONIKO.

LA ALLINIIGA METODO ĈE LINIAJ KARAKTERIZAJ KAMPOJ.—W. A. Barclay.

Plua kontribuaĵo de ĉi tiu aŭtoro pri l'uzado de la alliniiga principo ĉe la kalkulado de senfadenaj problemoj. Je nuna okazo la metodo estas aplikita al la linia regiono de valvaj karakterizoj.

Oni montras, ke la anoda kurento estas esprimita de

$$i_a = \frac{v_a + \mu_0 v_g - v_0}{R_0}$$

kaj ke la aktuala voltkvanta pligrandiga μ obtenita kiam rezistanco R estas enmetita en la anodan cirkviton estas esprimita de $\mu = \mu_0 \frac{R}{R + R_0}$

Alliniiga grafikaĵo por la determino de unuj el ĉi tiuj kvantoj estas poste montrita. La metodo de konstruado de la grafikaĵo laŭ eksperimentaj informoj estas plene klarigita, la diversaj paŝoj estante ilustritaj diagrame, kaj pruvitaj kiam necese. La praktika funkciado de la diagramo estas fine priskribita, kun etato pri ĝiaj multaj utilecoj.

DIVERSAĴOJ.

RESUMOJ KAJ ALUDOJ.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

MATEMATIKO POR SENFADENAJ AMATOROJ.—F. M. Colebrook.

Daŭrigita el antaŭaj numeroj. La nuna artikolo komencas Parton II de la serio, kaj traktas pri Geometrio kaj Trigonometrio, la Rekta Linio, Anguloj, la Triangulo, Paraleloj, Egaleco de Trianguloj, Geometria Simileco, la Trigonometriaj Proporcioj, k.t.p.

LIBRA RECENZO.

Recenzo de L. Hartshorn pri la libro "Elektraj Kondensatoroj," de Philip R. Coursey.

Book Review.

WIRELESS LOUD-SPEAKERS. A PRACTICAL MANUAL DESCRIBING THE PRINCIPLES OF OPERATION, PERFORMANCE AND DESIGN. By N. W. McLachlan, D.Sc., M.I.E.E., F.Inst P. Pp. 139, with 86 illustrations and diagrams. Published by Iliffe & Sons, Ltd., London. Price, 2s. 6d. net, by post 2s. 8d.

Perfection in component parts of receiving apparatus is the aim of all those engaged in the design of wireless apparatus for broadcast purposes and it is probable that no individual component has of late attracted more thought and attention than the loud-speaker. Designers will, therefore, welcome a practical manual by Dr. N. W. McLachlan, describing the principles of operation, performance and design of loud-speakers, with a special reference to the type which has come to be known as the "coil drive."

The preliminary chapters of the book are devoted to a discussion of the general acoustic principles involved in the design of sound reproducing apparatus, showing how the quality of sound is determined largely by the number and nature of the overtones, with clear, practical observations on the sensitivity of the human ear at different frequencies, the effect of resonance on complex sounds, and the influence of loudness on the quality of reproduction.

The author next deals with the problems involved in the design and construction of the horn type of loud-speaker, the length of horn theoretically required for proper reproduction, and descriptions of various standard types already on the market. A short chapter on the principles of hornless or large-diaphragm loud-speakers leads us to a more detailed exposition of the action of the diaphragm, its shape and size, and the object of baffles.

Probably the most interesting section of the book is that which is devoted to a description of the author's design of a hornless loud-speaker of the coil drive type. The author has appreciated the fact that the design of the amplifier to be used with the loud-speaker is of equal importance with the design of the speaker itself, and further chapters are devoted towards the end of the book to the design of amplifiers where volume can be obtained without a sacrifice in quality.

The book is the only work of the kind devoted to the subject and probably there is no one better acquainted with the subject than the author. He has the further advantage of being free to discuss and give details of the experimental work he has carried out, whereas others who may be working on the same problem both here and abroad, are mostly prevented from disclosing their work on account of their associations with commercial companies.

The book is well illustrated both with photographs and detailed drawings.

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.

The Audio-Transformer Problem.

To the Editor, E.W. & W.E.

SIR,—I have followed with interest the correspondence on this subject, but cannot help feeling that the very divergent opinions held by the opposing schools of thought are due to the fact that each side is neglecting certain factors of the problem. May I therefore state it in the simplest form ?

Fig. 1 shows the circuit, e_1 being generated in the anode circuit and R_a the anode slope resistance. The turns ratio is s, and the leakage is taken as zero, so that the mutual reactance is sX_1. The transformer ohmic resistance and core losses are neglected.

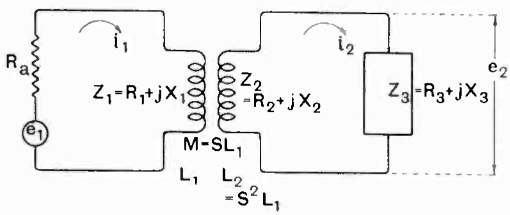


Fig. 1.

We then have, for any definite frequency,

$$i_2 = \frac{jsX_1}{js^2X_1 + Z_3} i_1 \quad \ldots \quad \ldots \quad (1)$$

As will be shown later, the most critical conditions are at low frequencies, and we will therefore consider such frequencies. This means that the capacity load on the secondary will be of very high impedance, as will also be the resistive load. The apparent input impedance is then $Z' = R' + jX'$, where

$$\left.\begin{aligned} R' &= R_1 + \frac{s^2X_1^2}{Z_3^2}.R_3 \\ X' &= X_1 - \frac{s^2X_1^2}{Z_3^2}.X_3 \end{aligned}\right\} \quad \ldots \quad \ldots \quad (2)$$

Equations (1) and (2) are well-known transformer expressions, correct beyond any doubt.

Thus, under these conditions,

$$Z' \doteqdot Z_1 \doteqdot R_1 + jX_1 \quad \ldots \quad \ldots \quad (3)$$

Then

$$i_1 = \frac{e_1}{R_a + jX_1} \quad \ldots \quad \ldots \quad (4)$$

(neglecting R_1). From (1) and (4),

$$i_2 = \frac{sX_1}{Z_3} \frac{e_1}{R_a + jX_1} \quad \ldots \quad \ldots \quad (5)$$

(neglecting s^2X_1 in comparison with Z_3)

Hence

$$e_2 = Z_3 i_3 = \frac{sX_1}{R_a + jX_1} e_1 \quad \ldots \quad (6)$$

Putting $e_2/e_1 = \eta$, we have

$$\eta^2 = s^2 \frac{X_1^2}{R_a^2 + X_1^2} \quad \ldots \quad \ldots \quad (7)$$

This is (except for the factor s^2) the well-known form of expression for choke coupling. It seems to indicate that the "Duff" school—high primary impedance—is correct. But the tale is not yet told.

Equation (7) includes as factors both s and X_1, and these are not independent. For η to be large, we want *both* these factors to be large. But both practical considerations of space and cost, and theoretical considerations of capacity and leakage effects, place a limit on the amount of secondary winding which can be accommodated. In fact, we can put $s^2X_1 = A$ where A is a constant determined by these considerations.

We then have

$$X_1 = \frac{A}{s^2} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

and (7) becomes

$$\eta^2 = \frac{A^2/s^2}{R_1^2 + A^2/s^4} = \frac{A^2 s^2}{s^4 R_a^2 + A^2}$$

or

$$\frac{1}{\eta^2} = \frac{1}{s^2} + \frac{R_a^2}{A^2} s^2 \quad \ldots \quad \ldots \quad (9)$$

There is, then, an optimum value for s, and it is easily found that $1/\eta^2$ is a minimum for

$$s^2 = \frac{A}{R_a} \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

from which and (8) we have

$$X_1 = \frac{A}{s^2} = R_a \quad \ldots \quad \ldots \quad (11)$$

So that, when we remember that the secondary cannot be made indefinitely large, the "Fowler-Clark" school appear to be in the right !

But still we have not finished with the subject. The above analysis is for a fixed frequency, and since X_1 varies with frequency while R_1 does not, we must obviously find what happens for other frequencies. Suppose that Equation (11) holds for the frequency $\omega_0/2\pi$, so that

$$L_1 = \frac{X_1}{\omega_0} = \frac{R_a}{\omega_0} \quad \dots \quad \dots (12)$$

then, for any frequency $\omega/2\pi$

$$X_1 = \omega L_1 = \frac{\omega}{\omega_0} R_a \quad \dots \quad \dots (13)$$

Hence, from (7),

$$\eta^2 = s^2 \frac{X_1^2}{R_a^2 + X_1^2} = s^2 \frac{\frac{\omega^2}{\omega_0^2} R_a^2}{R_a^2 + \frac{\omega^2}{\omega_0^2} R_a^2} = s^2 \frac{\omega^2}{\omega_0^2 + \omega^2} \quad (14)$$

and the latter part of this expression shows that as ω increases beyond ω_0, η rapidly tends towards s, while for $\omega < \omega_0$, it falls off rapidly. Hence ω_0 must be the lowest frequency to be dealt with. Since, as a rule, we wish to deal with very low frequencies in musical reception, we usually make ω_0 as low as we can, which means that L_1 $(= R_a/\omega_0)$ will be as large as we can make it.

If, when we have made L_1 and L_2 as large as we can, ω_0 is still higher than we should like, it can be reduced by decreasing R_a since (from (12))

$$\omega_0 = \frac{R_a}{L_1}$$

According to the above analysis, η would be constant and equal to s for values of ω well above ω_0. But here we meet with the factors that we have neglected. Self and mutual capacities make a load on the secondary, and leakage becomes important: equation (3) no longer holds, and the whole problem becomes much more complicated.

Summing up :—

1. Mr. Clark is correct in that *if X_1 is the only variable*, η is a maximum for $X_1 = R_a$.

2. But since X_1 should $= R_a$ for the lowest frequency to be received, then for musical work L_1 will probably be limited simply by the wire that can be got on.

3. To extend the range of low frequencies, L_1/R_a should be increased, if necessary, by reducing R_a.

4. At high frequencies, the effects are much more complicated, and both self capacity and leakage must be allowed for.

P. K. TURNER.

New Eltham.

A New Development in Resistance Amplification.

To the Editor, E.W. & W.E.

SIR,—In reply to the letter from Mr. Scroggie in your issue for May :—

The best condition for efficiency of anode bend rectification with a valve coupled to the next valve by means of a resistance in the anode circuit, is that the effective anode circuit impedance shall be small for the radio-frequency currents in the anode circuit and as high as possible compared with the internal resistance of the valve for the low frequency components. The use of very high anode resistances of the order suggested in my paper fulfils both these conditions as far as the broadcast range of wavelengths is concerned. In connection with the first condition it should be remembered that the effective internal impedance of the valve under these conditions of operation is considerably higher than that corresponding to the straight line region of the valve characteristics.

If grid rectification is employed the second condition still applies, but the first need not be fulfilled except in so far as it is desirable to prevent radio-frequency currents passing into the low-frequency stages of the amplifier. This point is alluded to again below.

In connection with anode-bend rectification it is important to realise that the effective rectilinearity of the anode current characteristic is maintained only with respect to grid voltage changes of low frequency; and the shape of the working characteristic as far as radio-frequency grid potential is concerned will show pronounced curvature owing to the fact that the external anode circuit impedance is not high compared with the internal impedance of the valve. This fact is difficult to realise in the absence of a detailed analysis which would be out of place in a letter, but it explains why quite satisfactory high-frequency rectification is obtained with a grid voltage that corresponds apparently to a straight region of the D.C. working characteristic; while the low frequency rectification will be negligible under the same conditions. These deductions are confirmed by practice.

Finally, I would like to take this opportunity of emphasising a very important matter relating to multi-stage amplification by the high resistance method.

A recent paper by Mr. L. Hartshorn, "The Input Impedances of Thermionic Valves at Low Frequencies" (*Proc. Phys. Soc.*, Vol. 39, Part 2, pp. 108-122) makes it clear that the effective grid-filament capacity of a valve may reach quite large values—100$\mu\mu$F or more—when the anode circuit contains a high resistance. Further, the higher the voltage factor of the valve, the larger this input capacity is likely to be. Such capacities will have a material shunting effect at high audio frequencies and undoubtedly constitute the real limiting factor as far as uniformity of frequency response is concerned. The analysis of the coupling conditions given in my paper is quite valid under the conditions stated, *i.e.*, that the shunt effect of grid-filament capacity shall be unimportant. It appears, however, that with high voltage factor valves of relatively high internal impedance this shunt effect may not be unimportant at the higher audio frequencies, and may result in a falling off of amplication at the high frequency end. This fact is recognised by Von Ardenne, who originated this method, and is confirmed by the character of some of the curves published by him in his descriptive article in a recent number of the *Wireless World*, though the full explanation of the effect is more explicitly given in the paper by Mr. Hartshorn referred to above.

The satisfactory quality of the reproduction given by amplifiers using high anode resistances and high voltage factor valves seems to indicate that the effect is not so detrimental as one might imagine at first sight. Nevertheless it calls for a rather more careful consideration of the effect of the input capacity of the succeeding valve than is given in my paper (which, by the way, was written more than a year before Mr. Hartshorn's paper was published). I have called Mr. Hartshorn's attention to the matter and there is a possibility that he will at some future date complete the analysis given in my paper in this respect.

As far as Mr. Scroggie's last query is concerned—it should now be clear that radio-frequency amplification through a multi-stage high resistance amplifier is not likely to be appreciable, at least as far as shorter wavelengths (3,000 metres or less) are concerned. Any residual voltage transference could possibly be minimised by connecting a radio-frequency choke between the anode and the anode resistance, the coupling capacity being connected to the common point of the choke and the resistance, but this arrangement I have not had any occasion to try.

F. M. Colebrook.

Radio Research During the Eclipse.

A NUMBER of important tests will be conducted by the Department of Scientific and Industrial Research under the auspices of the Radio Research Board during the solar eclipse on 29th June, the main details of which were arranged at a conference at which representatives from most of the wireless interests were present.

The main observations will be carried out under the supervision of Prof. E. V. Appleton, F.R.S., with the aid of photographic recording apparatus installed in the experimental station of the Department at Peterborough.

The B.B.C. has promised to co-operate as regards transmissions to be sent out, on a wavelength within the ordinary broadcasting band, either from Daventry or Birmingham, while simultaneously observations will be made at Liverpool on their Newcastle station.

It is expected that the eclipse will afford a valuable opportunity for studying the variation in directional effects which take place at sunrise and sunset and will serve to enable those conducting research in connection with these phenomena to check and verify the data already obtained. D.F. observations will be taken from the B.B.C. station at Manchester, at Slough, and at Bristol University. It is also hoped that this work will be supplemented by observations at the experimental stations of the G.P.O.

The variation in signal strength of long-wave stations will also be the subject of special tests. Transmissions from a Continental station will be measured at Slough and with special apparatus installed at Aberdeen University, while checking observations will be made at Rugby. Similar long-wave tests will be made independently by Prof. Marchant, using his own method for the measurement of signal strength with apparatus, in the Liverpool University. The observed station in this case will probably be a high-power Scandinavian station in the line of totality.

The intensity measurements of the strength of atmospherics is another contemplated series of tests. Observations from Slough and a station in Scotland are expected to afford valuable information regarding the range of atmospheric disturbances and to indicate whether those heard are mainly local or from a distance. The cathode ray D.F. apparatus will be used to determine the direction whence the X's originate.

All the above observations will be duplicated for two days before and the two days following the eclipse, in order to separate as far as possible those effects which normally occur at sunrise and sunset from those peculiar to the eclipse, and for this reason the experiments on all five days will continue for $2\frac{1}{2}$ hours.

The R.S.G.B. is also arranging for a series of tests by its members on 90 metres, unmodulated, from a $1\frac{1}{2}$kW station at Caterham, and for transmissions on other wavelengths from amateur stations in the South and North of England and probably from Iceland. Dr. W. H. Eccles, F.R.S., is also organising a series of observations by amateurs on the Continent.

The B.B.C. will announce later the special arrangements they propose making with regard to time signals, etc.

All these bodies of organised observers join in an urgent entreaty to listeners generally, and to amateur transmitters who are not actively engaged upon this special work, to avoid all risk of interference with the tests. Listeners are advised to confine their attention to their local station and not endeavour to reach out for distant stations, however interesting they may be. It is essential that oscillation should be avoided if full use is to be made of this rare and exceptional opportunity to conduct a series of important tests in the very short time available and the organised observers will be ever grateful to other wireless enthusiasts if they will show the true sporting spirit by leaving them in peace during the critical period.

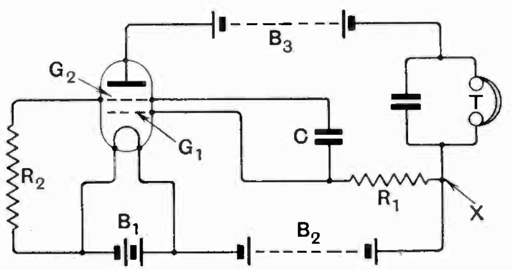
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each

A MULTIVIBRATOR.

(*Application date, 9th February*, 1926. *No.* 267,279.)

A multivibrator circuit incorporating a four-electrode valve is described in the above British Patent by N. V. Philips' Gloeilampenfabrieken. The invention relates to the type of multivibrator circuit in which two three-electrode valves are

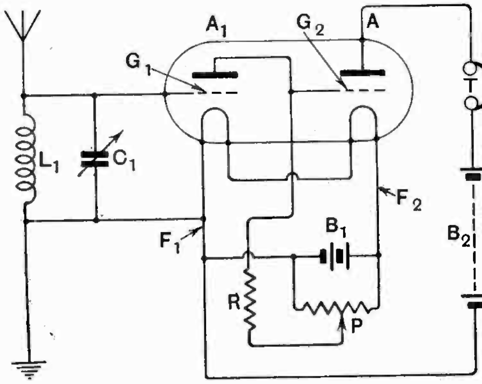


coupled together by means of a resistance, a retroactive effect being obtained by coupling the anode of the second valve to the grid of the first. Current impulses of large intensity are obtained in a circuit of this type due to the periodic charge and discharge of the coupling condenser, the frequency of the charging operation being determined by the time constant of the circuit constituted by the coupling condenser and the grid resistance. The present invention utilises a four-electrode valve in a somewhat similar manner, the method of connection being indicated in the accompanying diagram. Here the filament of the valve is heated by a battery B_1 while the anode circuit is supplied by a battery B_2 the anode being connected through telephones T or other indicating or coupling devices. Additional anode voltage is shown supplied by another battery B_3. At a point X in the anode circuit, that is, on the lower side of the telephones, connection is made to the inner grid G_1 through a resistance R_1. This grid is coupled through a condenser C to the other grid G_2, which is connected to the filament through a resistance R_2. The value of the coupling condenser may be of the order of 2,000 $\mu\mu$F, but may be made as large as one microfarad. The resistance R_1 is of the order of a few thousand ohms, while the resistance R_2 is approximately a megohm. The explanation of the operation of the device as given in the specification is as follows: The condenser C is charged first rapidly, and then gradually more slowly until a certain potential difference exists between its terminals. At this moment a rapid discharge will occur, accompanied, of course, by a reversal of the current. The condenser is then charged again in this manner, but in the opposite sense. It is stated that the low self-induction present in the connecting wires maintains this sequence of operations in somewhat the same manner as the flywheel allows the piston in a reciprocating engine to be carried just over top dead centre. The smaller the self-induction, the greater will be the tendency for the current curves of the discharge to differ from a sinusoidal wave form, and it will accordingly be more easy to sift out the higher harmonics and even, it is mentioned, those of radio frequency.

A LOW POTENTIAL AMPLIFIER.

(*Application dates, 3rd December*, 1925, *and 4th January*, 1926. *No.* 267,198.)

A low potential amplifier is described in the above British Patent by A. H. Midgley. The invention relates to a type of amplifier in which the anode of the first valve is given a very low positive potential, the grid of the next valve being connected to the anode. One form of the invention is shown in the accompanying diagram, in which the two valves are sealed together in one envelope, this being an additional feature of the invention. The illustration shows an ordinary aerial tuning circuit L_1 C_1 connected between the grid G_1 and filament F_1 of the first valve or, in this particular case, the first set of electrodes of the common valve. The anode A_1 is connected through a resistance R to a source of positive potential which is obtained through a potentiometer P from the filament heating battery B_1. The anode A_1 is connected to the grid G_2 of the second valve or second set of

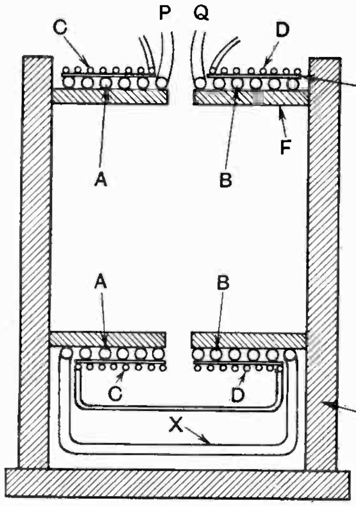


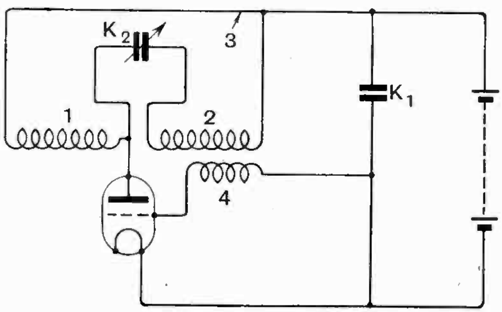
electrodes, while the anode A is connected through the telephone receivers T to a normal anode battery of reasonable voltage B_2. The value of the resistance R may be between a half and two megohms, while the positive potential communicated to the anode A_1 and grid G_2 through this resistance may be of the order of three or four volts. The specification states that the value of the resistance R may be increased to about five megohms, in which case the potential should be increased to about forty volts. It will be noticed that the two filaments F_1 and F_2 are shown connected in series. The specification also claims the use of a special valve incorporating two filaments, two anodes, and two grids, and details of this are given.

INDUCTANCE CONSTRUCTION.

(*Application date, 30th November, 1925. No. 267,196.*)

A type of inductance particularly useful for wavemeters is described by K. E. Edgeworth in the



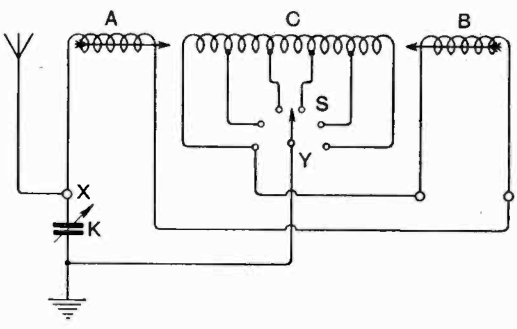


above Specification. The broad idea of the invention consists in winding the inductance in two portions, the extremities of which are connected together, while the inner ends are brought out for connection to the circuit with which it is to be used. This system can further be employed for coupling inductances or for transformer construction. The accompanying illustration shows two inductances coupled together, and constructed according to the invention, and also a wavemeter or generator circuit employing this type of coil. In the upper figure the first inductance comprises two portions A and B, wound on an insulating former F. The extremities of the winding are connected together by a wire X, while the adjacent ends P and Q are brought out for connection to the circuit. An insulating layer L is placed over the two windings A and B, while another inductance consisting of two portions C and D is wound over the layer L, being connected in a similar manner. The whole is arranged in a framework R. The lower illustration shows an inductance of this type connected in a wavemeter or valve generator circuit, the advantage of the arrangement lying in the fact that the earth connection to the inductances renders the system less liable to the influence of capacity effects. In the circuit the upper ends of the anode coil 1 and 2 are connected together at 3, and earthed through a blocking condenser K_1. The anode circuit is taken across the inner connections of the inductance by a condenser K_2. The grid coil 4 is shown coupled to the Section 2 of the anode inductance.

A TUNING ARRANGEMENT.

(*Convention date (France), 29th June, 1925. No. 254,338.*)

Compagnie pour la Fabrication des Compteurs et Material d'Usines a Gaz describes in the above British Patent an arrangement of mutually associated and electrically connected inductances, suitable for tuning over a large wavelength range, the novelty of the invention lying in the manner in which they are arranged so that the short wave sections are not appreciably influenced by the long wave sections. The accompanying drawing should make the invention quite clear. The short wave tuning coils are divided into two equal portions A and B, and are connected in series, but are spaced some distance apart. The two sections A and B are further so arranged that the directions of the windings are opposite. The longer wave tuning coil C is connected in series with the two short wave coils A and B, and is placed between them as indicated. The aerial and earth terminals are shown at X and Y, and the tuning condenser is shown at K, while a multiple switch S enables various tappings to be obtained on the longer wave portion. The specification states that the

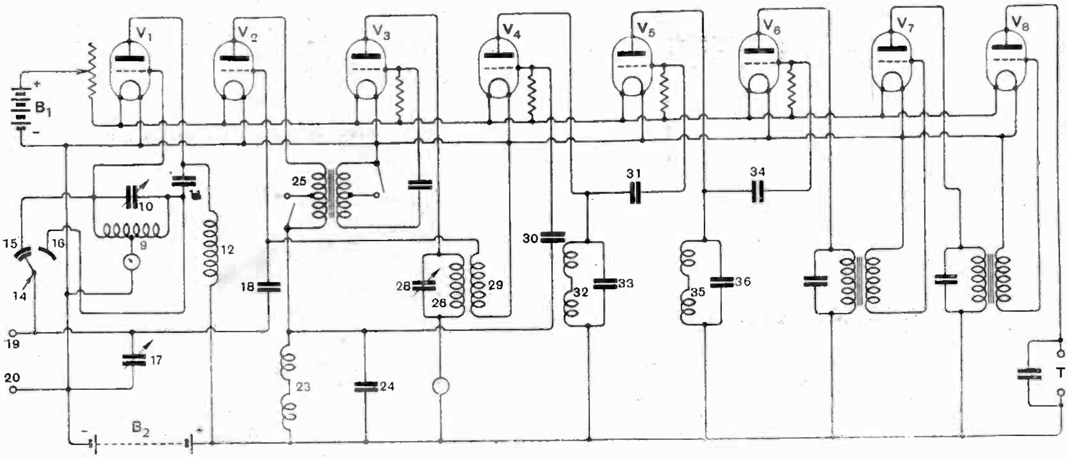


effect of the flux of the coil A upon C will be equal and opposite to the flux of the coil B upon the coil C, and, therefore, since the two coils A and B constitute the short wave portion the coil C will have no appreciable effect upon them.

STABLE SUPERHETERODYNE.

(*Convention date* (*France*), 12*th December*, 1924. *No.* 244,484.)

The above Specification gives details of a superheterodyne receiver which has been produced by L. Levy. The accompanying diagram shows an eight valve set, the most important portions of which will be referred to in detail, but those components not mentioned may be taken as being quite normal; or simply a repetition of those in a preceding stage. The valves are shown as V_1 to V_8. V_1 is a local oscillator, V_3 and V_6 are detectors, while V_7 and V_8 are audio-frequency amplifiers, the output circuit of the last valve operating telephone receivers, or a loud-speaker *T*. Common batteries B_1 and B_2 are shown for the filament and anode supply respectively. The local oscillator is a shunt feed arrangement, and consists of a tuned circuit 9 10, and stopping condenser 11 and high frequency choke 12. A coupling condenser is provided with two fixed electrodes 15 and 16, and a movable electrode 14, the function of which will be described subsequently. A valve V_2 is arranged as a high and intermediate frequency amplifier. A frame aerial is used, and is connected at terminals 19 and 20, and is tuned by a condenser 17. The input is in series with the grid circuit of the valve V_2 together with a condenser 18 of small value and an air core inductance 29. The anode circuit of the intermediate amplifier V_2 contains the primary of a high frequency iron-cored transformer 25, and an intermediate frequency tuned circuit 23 24. The secondary of the iron-cored transformer 25 is connected between the grid and filament of the detector valve V_3. The anode circuit of the detector valve V_3 contains an intermediate circuit 28 26, coupled to the inductance 29. This tuned circuit 29 18 is tuned to a frequency which is considerably higher than the intermediate frequency, and is very tightly coupled to the intermediate circuit 28 26. The oscillatory circuit 23 24 is coupled through a condenser 30 to the grid of the amplifier V_4, a similar arrangement being employed in the subsequent amplifying valves. The specification states that the circuit operates in the following manner: The coupling condenser 14 15 16 enables the effect of the local oscillator upon the grid of the valve V_2 to be made as weak as may be necessary, since the potentials across the electrodes



15 16 are 180 degrees out of phase with respect to the common filament. The valve V_2 amplifies the radio-frequency oscillations, and the valve V_3 transforms them into beat frequency oscillations where they are returned by means of the coupling of 26 and 29 to the valve V_2 for amplification at intermediate frequency. The intermediate frequency voltages in the anode circuit of the valve V_2 are applied to the grid circuit of the valve V_4, and amplified by the valves V_4, V_5, and are finally detected by the valve V_6, after which low frequency amplification is carried out. Since the circuit 29 is tuned to a frequency which is high relative to the tuned circuits 23 24, 32 33, 35 36, the intermediate frequency amplification system is stable, and does not give rise to the production of continuous oscillations. A further refinement consists in placing the whole arrangement in a screened compartment to prevent the amplifier being influenced by stray fields.

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