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Editorial.

A Chapter in the History of Radio Measurements.

AT an international conference in connection with the accurate determination of time held in Paris in October, 1912, Prof. Schmidt of Halle, and Dr. Robert Goldschmidt, of Brussels, proposed the formation of an organisation to co-ordinate the efforts which were being made in various countries to investigate the propagation of radio waves and to develop radio measurements. Dr. Goldschmidt not only placed his powerful transmitting station and laboratories at Laeken, near Brussels, at the disposal of the organisation, but gave 50,000 francs to cover the preliminary expenses. In October, 1913, a meeting was held in Brussels at which Mr. Duddell was elected President, Prof. Max Wien vice-president, and Dr. Goldschmidt secretary; the other members of what became known as the International Scientific Radiotelegraphic Commission were as follows:—Abraham (Paris), Ferrié (Paris), Benndorf (Graz), Schmidt (Halle), Vanni (Rome), and Wulf (Holland).

A provisional programme was drawn up and consisted of four items, viz.: (1) To determine the best means of ensuring constancy in the signals sent out from Laeken; (2) to make relative measurements of the variation in signal strength from day to day at different receiving stations and with different wavelengths; (3) to compare signal strengths in different directions and at different distances; (4) to make simultaneous measurements of atmospheric disturbances.

In each country represented on the Commission a national committee was set up, the British National Committee being constituted as follows: Mr. Duddell, Dr. Eccles, Prof. Howe, Sir Oliver Lodge, Prof. Marchant, Sir Henry Norman, Prof. Thompson. This committee met several times during 1913-1914, and discussed, among other things, the efforts of several of the members to measure the strength of the signals emitted by Laeken and by the Eiffel Tower. The Commission met for the second time at Brussels on the 6th, 7th and 8th of April, 1914; the writer was unable to be present, but England was represented by Messrs. Duddell, Eccles and Marchant. In June, 1914, was published the first Bulletin of the Commission containing an account of the proceedings at the two meetings. This first Bulletin was destined to be the last, and its ambitious plans for international co-operation in radiotelegraphic measurement were completely shattered by the outbreak of war within two months of its publication. On the approach of the German army the transmitting station at Laeken was completely destroyed. When conditions once again permitted the resumption of such schemes of international co-operation in radiotelegraphic measurement, the sub-

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ject had developed in a way which could not have been foreseen in 1914.

As very few of our readers will have seen a copy of the Bulletin, or even have heard of the Commission and its short-lived activities, we thought that it would be of interest to recall this pre-war organisation and to devote a few pages to describing what was done by the members of the British National Committee during the spring of 1914.

The transmitter at Laeken employed a spark gap consisting of a copper tube with its axis normal to a copper plate; the spark jumped from the end of the tube to the surface of the plate. The tube formed a nozzle for a powerful air blast which played directly on to the plate and escaped radially. The oscillatory spark-gap circuit was loosely coupled to the aerial which was tuned to the same frequency. The wavelength employed was 3,500 metres. The results obtained from this station were not so good as those obtained from the Eiffel Tower spark transmitter, which worked on a wavelength of 2,200 metres and which sometimes, thanks to the co-operation of General Ferrié, sent out a succession of 10-second dashes. Measurements were made by Mr. Duddell at his laboratory in Victoria Street, London, by Prof. Marchant at Liverpool University, and by the writer at South Kensington. Whereas the two former members, in common with all the other observers, used some form of detector in combination with a delicate galvanometer—Prof. Marchant obtained photographic records by means of an Einthoven galvanometer—the writer measured the high-frequency current set up in the receiving aerial by means of a thermo-galvanometer, and thus made a direct measurement of the energy collected by the receiving aerial from the passing wave.

The aerial employed consisted of a single No. 14 copper-coated steel wire suspended from the tower of the Imperial Institute, 260 feet above the ground and carried in a single span of 530 feet to a chimney stack on the City and Guilds Engineering College. It had a fundamental wavelength of 900 metres, and was connected to earth through several tuning coils wound with 27/36 multiple-stranded silk-covered wire. These coils formed the primary winding of a variable mutual inductance, the secondary of which was wound with similar wire; the object of this will be seen in a moment. When the aerial is tuned to exact resonance with the received wave it acts as a non-inductive resistance R_a; R_a is the equivalent resistance of the aerial. If now the heater of a thermo-galvanometer is inserted between

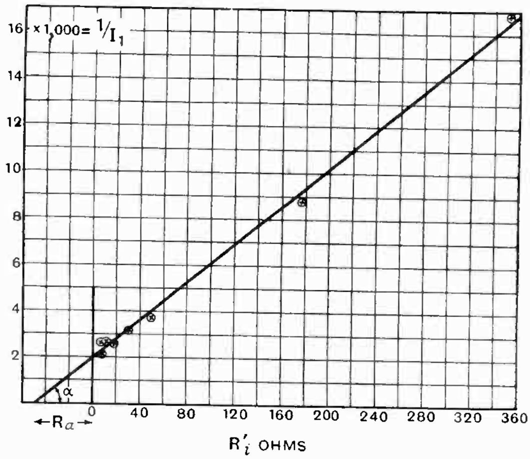

Fig. 1.

the aerial and earth the aerial current is reduced from E/R_a to $E/(R_a+R_i)$, where R_i is the heater resistance. Although the total energy $E^2/(R_a+R_i)$ abstracted from the wave is reduced, that supplied to the heater increases as R_i is increased until it reaches a maximum when $R_i = R_a$. As R_i is still further increased, I^2R_i decreases.

Although the writer was fortunate in possessing a very sensitive Duddell thermo-galvanometer, the resistance R_i of its heater was 1,175 ohms, which made it quite unsuitable for inserting directly in the aerial. The heater was therefore coupled to the aerial by means of what was really a current transformer; it was connected between the terminals of a coil of inductance L_2, which was coupled to the aerial tuning coil. If the mutual inductance is M it is easy to show that this is equivalent to inserting a resistance R_i' directly in the aerial, where

$$R_i' = R_i \frac{\omega^2 M^2}{R_i^2 + \omega^2 L_2^2}$$

We neglect the resistance of the coil in comparison with that of the heater, and we neglect the error due to the wave being damped and not continuous. Any effect

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of the coupling on the tuning of the aerial can be corrected by retuning. It will be seen that by varying M, that is, by varying the coupling between the coils, the equivalent resistance inserted in the aerial can be varied. By adopting this arrangement we were enabled to determine not only the power, and thus the E.M.F. induced in the aerial, but also the equivalent resistance of the aerial. To determine the latter, it was only necessary to vary R_i' until the maximum power was absorbed by the heater; that is, until the deflection was a maximum; this occurs when $R_i' = R_a$.

We shall illustrate the method by giving the results of a test made on long dashes sent out from the Eiffel Tower at a wavelength of 2,200 metres, with about 45 amperes in the transmitting aerial between 7 and 10 p.m. on Thursday, 26th March, 1914. The calibration of the thermo-galvanometer gave the result $I = 5.78\sqrt{\theta}$, where θ is the deflection in mm. and I is in microamperes; a deflection of 50 mm. was thus obtained with a current of 41 microamperes. The results of the measurements are given in the table; L_1 is the

L_1	L_2	M	θ	R_i'	I_2	I_1	P
μH	μH	μH	mm	ohms	μA	μA	μW
184	211.6	112	42	7.65	37.5	465	1.65
184	1,850	285	65	18.0	46.7	377	2.55
184	1,850	365	75	29.5	50.1	316	2.96
184	1,850	175	24.5	6.77	28.8	379	0.97
1,600	1,850	1,260	31.5	352	32.5	59.5	1.24
1,600	1,850	890	58	176	44.1	114	2.28
1,600	1,850	470	88.5	48.8	54.5	267	3.48
1,600	1,850	228	42	11.54	37.5	377	1.64

self inductance of the primary coil; that is, of the part of the aerial tuning inductance which was used for coupling; L_2 the self inductance of the secondary coil, and M the mutual inductance between them; the value of M was read off a calibrated scale. I_2 is the current in the secondary circuit as determined from the deflection θ, and I_1 the corresponding aerial current. This can be calculated from the equation $I_1^2R_i' = I_2^2R_i$, the right-hand side being the actual power dissipated in the heater and the left-hand side its primary equivalent. The last column gives this power P in microwatts.

Since $I_1 = E/(R_a + R_i')$ where E, the E.M.F. induced in the aerial, and the resistance R_a may be regarded as constants, a straight line should be obtained on plotting $1/I_1$ against R_i'. Fig. 1 shows that although the observations cannot be regarded as very accurate they enable R_a to be determined fairly accurately by producing the line

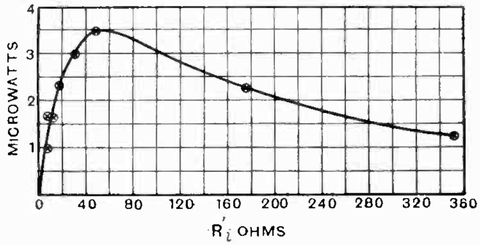

Fig. 2.

backward to meet the base; the value obtained is about 49 ohms. The ordinates of Fig. 2 represent the power supplied to the heater of the thermo-galvanometer and it is seen that this reaches a maximum of about 3.5 microwatts when the equivalent resistance inserted in the aerial is equal to the equivalent aerial resistance.

Since

$$E = I_1(R_a + R_i') = \frac{R_a + R_i'}{1/I_1} = \text{cotan}\ \alpha \text{ (Fig. 1)},$$

the E.M.F. induced in the aerial could be determined to a high degree of accuracy; in the present example it was 24.4 millivolts. It must be remembered, however, that, although the current in the Eiffel Tower aerial was always adjusted to 45 amperes, the observations on Fig. 1 were spread over about three hours; the relatively small deviations from the straight line indicate that the transmission conditions remained fairly constant during this period. These measurements were made on the evening of 26th March, the results were worked out and sent to Mr. Duddell on 3rd April, and communicated by him to the Commission at Brussels on 7th April. In a letter Mr. Duddell said: "They created considerable interest as they were the only results in which an actual measurement of the power received in the aerial had been made." We fear that it would be practically impossible to use the same method at the present day, as the receiving aerial was very flatly tuned and susceptible to

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interference. In 1914 the ether was comparatively empty, and few of the 10-second dashes were missed owing to interference; when it did occur it was usually due to the Admiralty station in Whitehall, and one immediately switched off to prevent the heater of the thermo-galvanometer being burnt out.

The following extract from the Bulletin of the Brussels meeting is of historical interest: "A la fin de la séance, M. Drumaux, dans un exposé remarquable, décrit le renforçateur 'von Lieben-Reiss,' avec lequel il a fait d'intéressants essais, en vue de la résolution du problème de la téléphonie avec fil à grande distance. Cet appareil est certainement appelé à rendre de grands services également en télégraphie sans fil."

This was the thermionic valve amplifier just appearing on the horizon.

G. W. O. H.

A Direct-reading Valve Tester.

By Marcus G. Scroggie, B.Sc., A.M.I.E.E.

IT is quite a simple matter, given a generous array of multi-range instruments, to measure the characteristics of a valve. The usual methods, however, are not ideal unless time is no object and great precision is required. There are many circumstances in which a comparatively rough measurement is all that is required, provided it can be performed in a few seconds and without the risk of bad errors due to mental calculation. When this can be done, and with equipment that is not unduly lavish, then the method can be considered useful to those persons who wish to check the characteristics of more than a very few valves.

Before going on to describe an instrument which fulfils these requirements, let us be perfectly clear as to what one wants to measure. The most important characteristic of a valve is the relation between anode current and anode and grid voltages. There are innumerable other characteristics which it would be possible—and doubtless very interesting—to observe, but for rapid tests they cannot be considered. This fundamental relation between the three abovementioned variables is represented graphically by a surface in three dimensions, but as it is not generally convenient to employ a sculptor for the purpose of portraying one's valve characteristics, a quicker but less expressive method is adopted by drawing the profiles of various cross-sections of such a surface, which then appear as the valve curves of commerce. By drawing a number of these curves on a sheet of paper, a clever person is able to fill in the gaps mentally and get quite a clear picture of the electrical behaviour of the valve. If the cross-section is taken at right-angles to the anode voltage axis (which is equivalent to considering the anode voltage to be constant at some amount represented by the distance of the section from the origin of that axis), then the profile of the section takes the familiar form of a grid voltage/anode current curve. Other such curves are formed by taking sections representing other fixed anode voltages. If, on the other hand, the sections are taken at right-angles to the grid voltage axis, then one obtains the outline of anode current/anode voltage curves; a less familiar but more useful type than the previous one. The curves obtained by taking sections at right-angles to the anode current axis are not commonly drawn out, but are indirectly used, as will be explained later.

Though more practical than a solid model, even a set of curves involves some labour, and is out of the question for rapid testing, because even if an automatic curve tracer is used for speeding up the job, it is not always immediately obvious which of two curves refers to the better valve, particularly if they are plotted to different scales. So it has become customary to specify three so-called constants; anode impedance or slope resistance, magnification ratio and mutual conductance. There is an unfor-

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tunate lack of standardisation regarding these cumbersome terms and the symbols used to represent them, but in this article they will be referred to as R_a, μ, and G respectively, and the three important variables related in the characteristic surface, namely, anode amperes, anode volts, and grid volts, as i_a, v_a, and v_g.

The three " constants " are in reality very far from being constant for a given valve, a fact which is often obscured when ascribing figures to a particular type of valve. Of the three, μ is the most nearly constant. R_a decreases as v_a and v_g increase ; while G, which is not independent but is equal to μ/R_a, consequently increases. A useful amount of information is, however, provided by measuring two of these quantities (from which the third follows) at some known setting of v_a and v_g. The fact that μ is so nearly constant over a wide range of v_a and v_g makes it possible to simplify matters somewhat. The anode current i_a is a function of $(v_a + \mu v_g)$; hence it is convenient to consider the " lumped voltage " $v_l = (v_a + \mu v_g)$, for whatever the values of v_a and v_g, within limits, a given value of v_l will result in very nearly the same values of R_a and G. So it is not necessary to specify all the possible settings of v_a and v_g corresponding to a certain R_a and G ; a single v_l covers them all.

It has already been mentioned that there are three main types of valve curves, and the three " constants " are derived one from each of these types. R_a is the slope of the v_a/i_a curve ; G is the slope of the i_a/v_g curve, and μ the slope of the v_a/v_g curve. The slopes would, of course, only be constant if these curves were straight lines throughout their lengths, whereas that is far from being the case. It is necessary, therefore, to measure them at the particular points corresponding to the settings at which the valves are to be worked. A valve used as an anode rectifier, for example, has a higher R_a than the same one used as an amplifier, because it is worked at a bend where the slope is less. This makes it necessary to apply some thought to the common cases where the same valve is used for both purposes, and not to fall into the error of applying the figure for R_a measured under normal amplifying conditions to a valve worked at the lower bend.

There are various methods of measuring R_a, μ, and G. The subject offers splendid scope to the theorist for applying the differential calculus, but for practical purposes it is sufficient to measure two points on the curve, one a little below and the other a little above the point of reference, and to assume that the slope of the straight line joining these points is the same as the slope of the curve at the point of reference. An example will make this clear. A valve is to be used as an amplifier with a lumped voltage of 60. To find the R_a at this voltage, the v_a/i_a curve at $v_g = 0$ may be drawn from readings, as in Fig. 1. (Note that it is more usual to plot it as an i_a/v_a curve, which means that the slope has to be considered relative to the ordinate instead of the abscissa). Then R_a is the slope of the tangent to the curve at the point where v_a is 60. On the other hand, it is much quicker and nearly as accurate to measure i_a at 50 and 70 volts and divide the difference in voltage by the difference in current, say, 0.70 mA or 0.0007 amp.

$$R_a = \frac{20}{0{\cdot}0007} = 28{,}600 \text{ ohms}$$

The same applies to the measurement of μ and G. It is obviously not necessary to measure more than two, as the third follows from $\mu = GR_a$. It is also clear that these

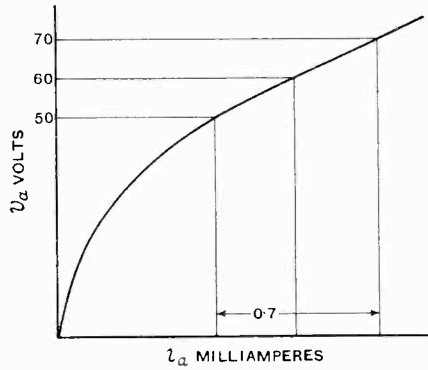

Fig. 1.

three quantities are arbitrary, in that one might equally well consider their reciprocals ; thus the anode conductance might be used instead of the anode resistance, being the

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slope of the i_a/v_a curve, which is the more usual form for expressing this relation.

The most important of the three for purposes of design is R_a, as it largely determines the correct anode load or amplifier coupling. Of a number of valves equal as regards R_a, the choice then falls on the one having the largest G. A convenient form of test measures R_a primarily and G secondarily; μ may then be derived if desired.

The straightforward test consists, as has just been described, of four readings, two subtractions, and a division. It would be much simpler to boil this down to one reading and no calculations. With a view to exploring this possibility, the i_a and R_a at a fixed v_l of a very large number of valves were measured; valves of almost every type—tungsten, thoriated and coated filaments of 2, 4 and 6 volts; power valves and extra high resistance-coupling valves; old French Rs and LS5A's. R_a and the reciprocal of i_a for all these were plotted on logarithmic paper; three sets of points corresponding to v_l of 50, 100, and 150 volts. Some of the low resistance valves were omitted in the 150-volt set as they showed signs of saturation. As had been hoped, the points in a given set were grouped fairly close to the best straight line through them, and the three lines corresponding to the three sets were practically parallel. The most extreme cases could be covered by a band of about $\pm$ 10 per cent. about the central line, and the majority were much closer. Hence to obtain a measurement of R_a to this accuracy (which is sufficient for most purposes) it is only necessary to measure i_a at the v_l in which one is interested.

An attempt to differentiate between thoriated and coated filaments, and between 2 and 6 volt filaments, did not lead to very definite results, but there are indications that for a given v_a/i_a coated filament valves have a somewhat lower R_a than thoriated.

If V_L is the lumped voltage chosen and I_a the corresponding anode current, then the best lines arrived at experimentally can be defined very closely by the empirical relation

$$R_a = \frac{0.6\ V_L}{I_a}$$

It must be confessed that it was not until an attempt was made to reconstruct the generalised valve curve from this equation that it was realised that the foregoing work amounted to an experimental verification of the familiar expression for the anode current of a valve—

$$i_a = A\ (v_a + \mu v_g)^{\ B} = A v_l^{\ B}$$

where A and B are constants. The latter is often assumed to be 1.5, but has been placed by various investigators at values between 1.5 and 2. It is not in actual fact

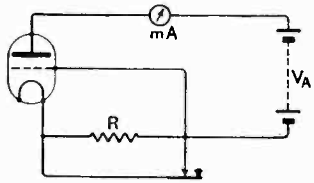

Fig. 2.

a constant, but is itself to some extent a function of v_l; hence the disagreement. Assuming our experimental equation, we have

$$\frac{dv_l}{di_a} = \frac{0.6 v_a}{i_a}$$

and solving $i_a = C v_a^{\frac{1}{0.6}}$, thus giving an index for average valves of 1.67. This result, though perhaps outside the scope of this article, has been included as being of some general interest.

The general scheme of an instrument for giving direct readings of R_a on these lines is obvious, and a convenient practical arrangement will be described shortly, but in the meantime let us consider an extension of the method for the purpose of indicating G also. It would be possible to provide means for impressing a known negative bias on the grid of the valve (which has been held at zero potential for the measurement of R_a), say one volt, and the resulting drop in anode current would be a measure of G. This method necessitates a voltmeter for ensuring that the correct bias is applied, and also a special biasing battery. Both these extras are dispensed with by utilising the principle of automatic grid bias, which also carries with it the important advantage that the amount of the bias is always suited to the type of valve being tested. The principle of this method is illustrated in

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Fig. 2, where a resistance R, which is normally short-circuited by a push-button switch is shown interposed between negative H.T. and filament. The grid of the valve is connected to negative H.T. A milliammeter indicates the anode current at zero grid potential, and can if desired be made to read R_a direct in ohms. A better method will be described further on. If now the push-button be pressed, putting R in circuit, the grid will be biased negatively, and the anode current will consequently be reduced. The drop in current is related to the G of the valve, as will now be shown. Let I_1 be the anode current with the resistance R shorted, and consequently with an anode voltage V_a (say) and a grid voltage of zero. When the resistance R is inserted, the current falls to I_2 and the anode voltage is then $V_a - I_2R$ and the grid voltage is $- I_2R$. Now, from the definition of μ it follows that the drop in anode volts I_2R is equivalent to a drop in grid volts of I_2R/μ. The effect, therefore, is the same as that due to a grid voltage of $- I_2R\ (1 + 1/\mu)$, the anode voltage being maintained at V_a. G is defined as the change in anode current divided by the change in grid voltage responsible, at constant anode voltage. (To the mathematician this is an inexcusably loose statement, as it only gives a rough average over a portion of the characteristic curve instead of the more elegant $\dfrac{di_a}{dv_g}$, but is nevertheless well suited to practical requirements).

$$\text{Thus } G = (I_1 - I_2)/I_2R\ (1 + 1/\mu)$$
$$= (I_1 - I_2)/I_2R\ (1 + 1/GR_a)$$
$$1 = (I_1 - I_2)/I_2R\ (G + 1/R_a)$$
$$\text{and } G = \frac{I_1 - I_2}{I_2R} - \frac{1}{R_a}$$

If $1/R_a$ is neglected and the milliammeter (Fig. 2) is controlled by a variable shunt, so that for every valve the needle is brought to a fixed mark by the current I_1, then the scale can be marked off to read G directly when the button is pressed. For example, if R is 1,000 ohms and on pressing the button the current is reduced to two-thirds of the original value, then $G = 1/2{,}000$, or in more usual units 0.5 milliamps per volt. A table can be drawn up in this way connecting $(I_1 - I_2)/I_2R$ and G, and the instrument calibrated accordingly. The error due to the neglect of $1/R_a$ obviously is most serious when R_a is small. Thus if in the above example, R_a is 4,000 ohms, the correct value of G is only 0.25 mA per volt. As R_a is presumed to be already measured, it is not a difficult matter to make this correction.

Having now discussed the matter theoretically, a practical form of apparatus will be described in which the foregoing calculations are made absurdly simple. The gear involves only one measuring instrument, apart from any that may be used for testing filament consumption, etc. The circuit diagram is shown in Fig. 3, and the numerical values of the components are those suitable for testing almost any type of receiving

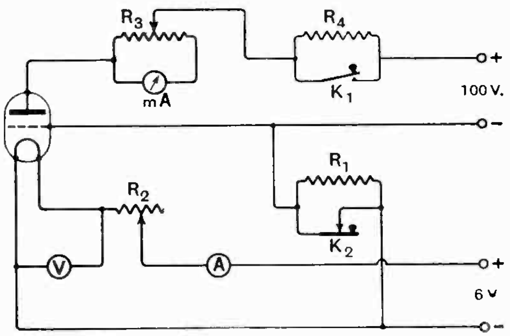

Fig. 3.

valve, ancient or modern. V and A are low consumption meters, Weston type 301 reading up to 6 volts and 1 ampere respectively for setting to the correct voltage and checking the current. The filament rheostat R_2 is of the Burndept dual type with a graded element; maximum resistance 60 ohms. mA is a milliammeter reading up to 1 mA full scale when the potentiometer shunt R_3 is at its maximum. It can easily be shown that when connected as illustrated the full scale current of the meter is inversely proportional to the resistance to the left of the slider, and hence if the resistance is uniformly wound the scale of the shunt when calibrated to read R_a direct in ohms is linear. "Full scale" need not necessarily be what is usually understood by that term, but any convenient mark. Thus Fig. 4 shows a suitable form of calibration for the meter and shunt. The latter is a Burndept rotary potentiometer uniform with the filament rheostat, especially wound to 64

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ohms, and is calibrated 0–60,000 ohms. The outer concentric scale is the reciprocal of the inner, so gives the correction to be subtracted from the value of G indicated by the meter. When the shunt is adjusted so that the milliammeter needle is brought to the prominent mark towards the right of the scale, then R_a can be read off directly in ohms. The procedure in testing a valve is first to adjust the filament to the correct voltage; then if the valve is to be tested for normality the shunt is set to the normal R_a (the scale may be marked with the names of various types of valves according to this

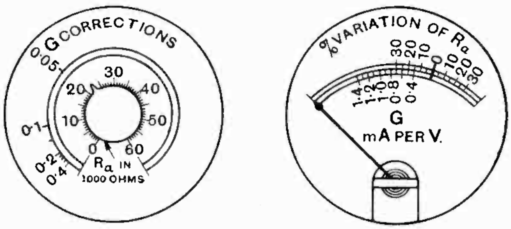

Fig. 4.

value), and the pointer indicates the variation from normal. Before actually taking the reading the safety resistance R_4 is shorted out by the key K_1, after it has been noted that the anode of the valve is not touching the grid or filament, which would be indicated by an unduly high reading on the milliammeter. The needle is then brought to the central mark (the shunt pointer then reads actual R_a) and the key K_2 pressed, putting resistance R_1 of 1,000 ohms into action. The needle of the milliammeter will then take up a new position indicating G on the lower scale. Finally this value of G is corrected by subtracting from it the amount indicated by the pointer of the shunt. It will be noted that a disconnection or misconnection of any of the elements of the valve will be shown up by one or other of these tests. μ if desired is obtained by multiplying R_a and G already found, being, of course, in *amperes* per volt for this purpose.

A little refinement that is useful concerns the value of R_4. The accuracy of the instrument obviously depends on the anode battery being maintained at 100 volts (or whatever figure is chosen). R_4 is therefore made of such a value that with anode and filament valve sockets joined and shunt slider at maximum (right), the milliammeter reads full scale, or any convenient mark, when the battery is correct. It is inadvisable to press K_1 when making this preliminary test.

It is possible for a relatively unskilled operator to test valves very rapidly using this apparatus, which is not by any means costly, and its convenience outweighs, for many purposes, its limitations as regards accuracy. For example, if it is desired to pick a particularly good valve out of a dozen samples, it would be quite tedious to do so by the more usual methods. Or if one does a large amount of experimental work with apparatus involving valves, it is extremely irritating to find one's results vitiated by the presence of a valve past its prime. The test-gear just described is so rapid that it is no hardship to make a practice of testing all valves before each experiment. The details of construction may, of course, be adapted to the particular requirements of the situation.

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Loop Permeability in Iron, and the Optimum Air Gap in an Iron Choke with D.C. Excitation.

By A. A. Symonds, M.A.

I.
LOOP PERMEABILITY.

In view of the frequent use of iron-cored chokes and transformers with a direct current through the winding, there seems some need for considering the appropriate properties of iron used in such instruments.

As explained in a recent Editorial,* when, in addition to the applied alternating fluctuations, there is a direct current through the winding producing a constant flux through the core, a cyclic curve representing the alternating fluxes must be drawn about some point on the B—H diagram given by the magnetic condition of the iron.

This part of the paper is concerned with the property of the iron when there is a direct current maintaining a constant H in the

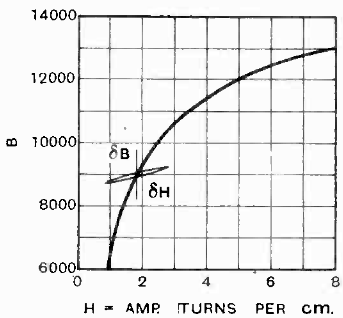

Fig. 1.

iron. The complete solution of the problem requires knowledge of all the cyclic curves and local loops in the iron over the range of operation, and the previous history of the iron with respect to the D.C. component of induction, and, in addition, the phase and magnitude of the A.C. component. This is not attempted. The problem is limited by taking the D.C. component of induction as being defined by the reversal curve for the iron, and the amplitude of the alternating component of induction, denoted here by δB, as being considerably smaller than the D.C. component. In the experimental work to be described the R.M.S. value of δB never exceeded 20 per cent. of the D.C. induction.* With values of δB nearly equal to or larger than the D.C. component of induction, extraordinarily shaped curves occur,† but these are not dealt with here.

Ewing has shown‡ that loops of the sort we are dealing with are always lenticular in shape, very narrow, and materially independent of the frequency, and that their mean slope is far less than the slope of the reversal curve at the point where they are taken. Also the form of the loops assumed for relatively small amplitudes of δB is nearly obliquely symmetrical with respect to local axes of B and H, see Fig. 1, so that if δB is a simple harmonic variation of induction with time, then the corresponding variations of magnetic force, δH, will have only odd harmonics, and one can assume that the current is a simple harmonic function of time with a maximum given by the appropriate value of δH. Thus to a degree of accuracy which the above simplification allows, the only important quantity is the slope of the major axis of the loop, $\delta B/\delta H$. This is the loop or incremental permeability of the iron, and is written μ'.

With this view of the loops they will appear to differ only in the slope of their axes, and as is shown by Ewing,‡ this decreases from a maximum in the neighbourhood of $B = 5{,}000$ lines per cm.^{2} roughly as the slope of the reversal curve decreases. Below this value of B μ decreases, and μ' is certain to decrease also, for it is obvious that if δB is considerably smaller

* *E.W. & W.E.*, Feb., 1928.

* The experimental work was carried out at the Cambridge University Engineering Laboratories.

† "Hysteresis Loss in Iron taken Through Unsymmetrical Cycles of Constant Amplitude," M. Rosenbaum, *J.I.E.E.*, Vol. 48, pp. 534–545.

‡ "Magnetic Induction in Iron and Other Metals," by J. E. Ewing, 3rd Ed., Sections 77 and 78.

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than B, μ' cannot be greater than μ. No quantitative measurements were, however, made at these low inductions. Spooner has given a method of calculating μ' very approximately,* and a few experimental figures† ; but his method of measuring

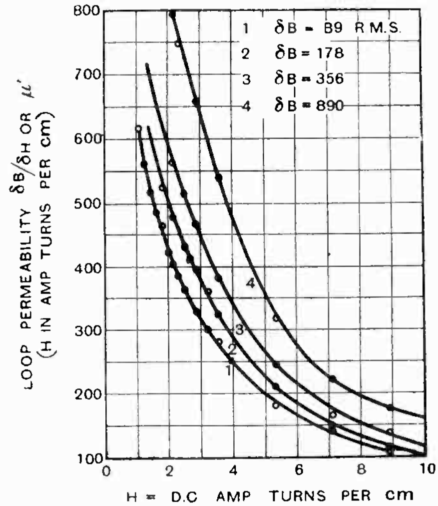

Fig. 2a.

$\delta B/\delta H$ is complicated by other objects in view, and the accuracy attempted is not great.

In connection with the above simplification it is interesting to note that the slope of the axes of local loops is not much changed when the induction in the iron is very far from being defined by the reversal curve. In the experiment to be described a reading for μ' was taken for a certain value of D.C. induction which, since the iron had been demagnetised by reversals, would be as defined by the reversal curve. The direct current was then increased by 50 per cent. and reduced again to its original value, and the resulting μ' was inappreciably changed when the induction for which the measurements were made was less than 11,000 lines per cm.^{2} Since the moment of closing, the switch, and hence the transient conditions of current, had no apparent effect on μ', it is reasonable to suppose that the A.C. loops in the iron do not follow any rigorously defined paths till after some cycles of A.C., and in evidence of this is the fact that the mean slope of a small change of induction varies, falling off in value after the first change till it finally takes up some constant value. T. Spooner has given quantitative measurements of this falling off in value of μ', showing the change to be some 20 per cent., and to become constant after about 50 cycles. Thus $\delta B/\delta H$ has different values—one for the case of a single reversal of a small current and another for the case of a continuously applied A.C.

The values of $\delta B/\delta H$ for Stalloy, with the meaning and limitations already discussed, are given in curves in Fig. 2, (*a*) and (*b*), where, to facilitate their use in practical design, the units of magnetic force used are ampere turns per cm. of iron. These units are used in the curves throughout the paper ; the change to absolute units is easy as one has only to use the factor $4\pi/10$.

The loop reluctivity ρ' corresponding to the loop permeability μ' is shown in Fig. 3.

These curves were taken by measuring the alternating current necessary to produce a selected virtual voltage across the terminals of a transformer, through one winding of which a known direct current C was passing. The circuit used is shown in Fig. 4.

The iron was 27.9 cm. in length and 4.97 cm.^{2} in cross section. Two windings were

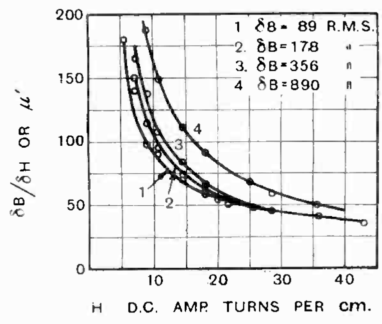

Fig. 2b.

employed, a primary of 1,000 turns and a secondary of 200 turns, tapped at convenient stages.

A winding of sufficient section to carry both the alternating and direct currents necessarily occupied a considerable space. When there is a direct current in the winding $\delta B/\delta H$ is not very large, so that the in-

* *J.Am.I.E.E.*, 1923, pp. 42–47.
† *Physical Review*, 1925, pp. 527–539.

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ductance is appreciably affected by stray fluxes, and thus it was necessary to measure the fixed alternating P.D. (V_2, Fig. 4) across a separate secondary. This secondary was wound as close to the iron as possible.

TABLE A.

Showing the method of deriving $\delta B/\delta H$ from experimental data.

C	V_2	N_2	δB	R	V_1	δI	$\delta(IN/l)$	CN/l	$\mu' = \frac{\delta B}{\delta H}$	μ'' (see note)
.1	1	40	890	21.3	.96	.0451	1.61	3.58	552	440

NOTE.—In the last column but one, as throughout this paper, δH is in ampere-turns per cm. ; in the last column μ'' gives the corresponding value if δH is in the usual absolute units.

The value of the alternating current δI producing the δH was obtained by measuring the voltage across a known resistance R by means of a thermionic voltmeter V, a condenser of 4 μF. capacity being included in the circuit to exclude the D.C. drop across R.

A D.C. ammeter, as shown at C, and a reversing switch (not shown) for the purpose of removing residual magnetism from the iron when so desired, were included.

The D.C. ampere turns per cm. in the primary of 1,000 turns are known, and δB was obtained from V_2 since we have,

$$V_2 = A\ \delta B\ N_2\ 2\pi n \times 10^{-8},$$

where A = cross section of the iron,
and n = cycles per sec.

Table A gives a sample of the reduction of results, where the experimental readings were collected and the conversion to $\delta B/\delta H$ carried out. The A.C. supply was at 90 cycles.

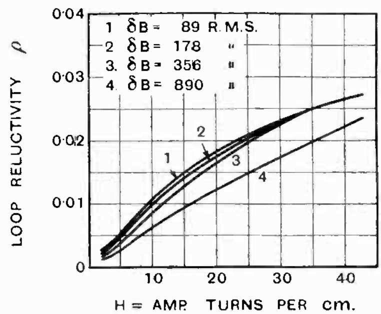

Fig. 3.

The values of δB given in the curves I, II, III, and IV correspond to selected applied E.M.F.'s of .56, 1.12, 2.2 and 5.6 volts R.M.S. per 1,000 turns per cm.[2] of iron cross section, at 100 cycles. This method of giving the results provides a convenient means of determining the δB that will occur for any given values of dimensions, turns, applied E.M.F. and frequency.

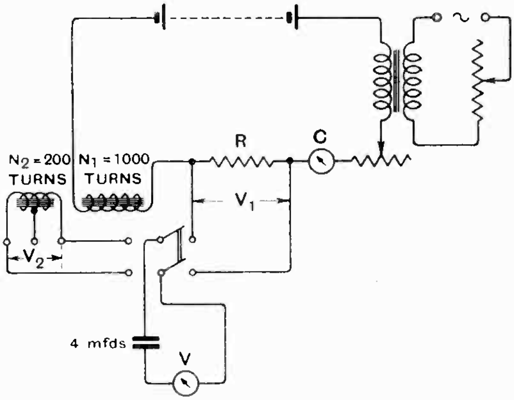

Fig. 4.

II.

THE OPTIMUM AIR GAP.

It will be seen from Fig. 2 how μ' decreases as the D.C. excitation increases, and this explains the falling off in inductance of iron cored chokes and transformers, as is shown in a paper recently published by L. B. Turner.* It is the object of this part of the present paper to consider the application of the experimentally determined specific properties of the iron in the determination of the optimum air gap for a core, and the value of the consequent inductance. This inductance will be the maximum obtainable from the iron core for the assigned conditions of turns and direct current. Conversely, given any fixed direct current, the number

* "Measurement of a Stalloy Core with D.C. and A.C. Excitation," L. B. Turner, *E.W. & W.E.*, Oct., 1927.

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of turns for any required inductance can be found, and the correct air gap.*

Suppose we apply a direct current to an iron cored choke with a small air gap cut in the iron. Consider any fixed value of induction B throughout the magnetic circuit; we have,

$$M = H_i l + Ba$$

where M = the M.M.F. required.
H_i = the magnetic force in the iron.
l = the length of the iron.
a = the length of the air gap.

H_i is given by the reversal curve for the iron for the value of B considered, so that the consequent loop reluctance of Stalloy with this induction can be found from Fig. 3. Thus for a change of induction δB,

$$\delta M = \rho' l \delta B + a \delta B$$

and hence, writing $M/l = m$,

$$\delta B/\delta m = 1/(\rho' + a/l) \quad \ldots \quad \ldots \quad (1)$$

This $\delta B/\delta m$ obviously depends on the value of m, and curves between $\delta B/\delta m$ and m are shown in Fig. 5 for various constant ratios of air gap length to iron length a/l. These curves are obtained by the use of Fig. 3 and equation (1), since for any B we know the value of H_i from the reversal

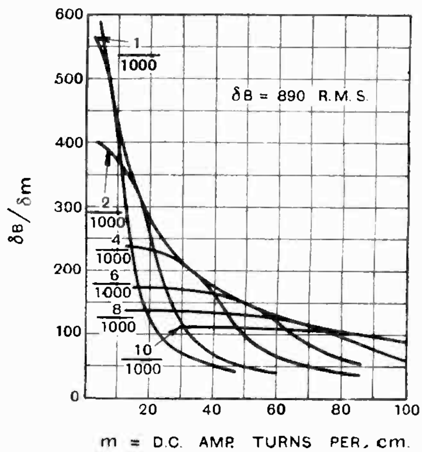

Fig. 5.

curve. As would be expected, these curves begin more or less flattened at low values of m when the loop reluctance in the iron will be small and the constant air gap reluctance relatively large.

Considering any constant m, Fig. 5 shows what value $\delta B/\delta m$ will have for any of the air gap ratios for which curves are drawn,

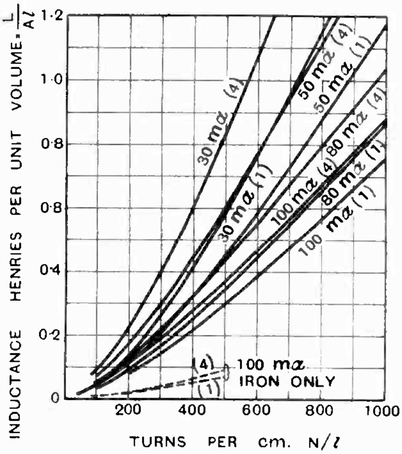

Fig. 6a.

Curves (1), δB = 89 *R.M.S. lines per cm.*[2]
Curves (4), δB = 890 *R.M.S. lines per cm.*[2]

and by drawing the envelope to the curves shown in Fig. 5 we get a derived curve showing the maximum $\delta B/\delta m$ that it is possible to obtain for any given m.

On the assumptions made with regard to local loops on the $B-H$ curve we can define the inductance of a coil with an iron core as the rate of change of flux turns with current.

$$L = d(\phi N)/dI$$

so that for a composite iron and air gap core

$$L = Al\frac{N^2}{l}\delta B/\delta m \times 10^{-8} \text{ henries} \quad \ldots \quad (2)$$

where A = cross-section of the core.
N = total number of turns.
m = M.M.F. per cm. of magnetic circuit length, in amp. turns per cm. units.

Now with the aid of the envelope of Fig. 5, obtained for the appropriate value of δB, it is a simple matter to take any constant direct current and with the help of (2) to plot inductance per unit area of cross-section and length of core, against number of turns per cm., for Stalloy. This is done in Fig. 6 (*a*) and (*b*) for cases where δB = 89 and 890,

* The method employed for obtaining the maximum $\delta B/\delta H$ is similar to one given in the Editorial, *loc. cit.*, from a paper, "The Design of Reactances and Transformers with Superposed D.C.," C. R. Hanna, *J.Am.I.E.E.*, Feb., 1927.

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for a number of direct currents between 10 and 100 mA.

In Fig. 5 any point where one of the curves touches the envelope is a point of maximum possible $\delta B/\delta m$. Thus from Fig. 5 can be derived a curve connecting air gap ratio a/l and m. This curve is shown in Fig. 7 for $\delta B = 89$ curve I, and for $\delta B = 890$ curve IV.

It can be seen from the curves of Fig. 5 that the loss of inductance due to an air gap ratio erring on the large side is less than the loss due to an air gap ratio erring on the small side. For instance, in Fig. 5 take the point where $m = 52$ amp. turns per cm. The maximum $\delta B/\delta m$ given by the envelope is 143, and this for an air gap ratio 6/1,000. If the ratio had been 8/1,000 $\delta B/\delta m$ would have been 129, whereas if the ratio used had been 4/1,000 the $\delta B/\delta m$ would have been 89.

So far only constant known applied A.C. voltages have been considered, which is by no means likely to be the only practical condition; in fact, this case seems to be confined to A.C. rectifiers designed for a constant output.

If instead of plotting $\delta B/\delta m$ against m, as in Fig. 5, we plot $\delta B/\delta m$ against B, we get

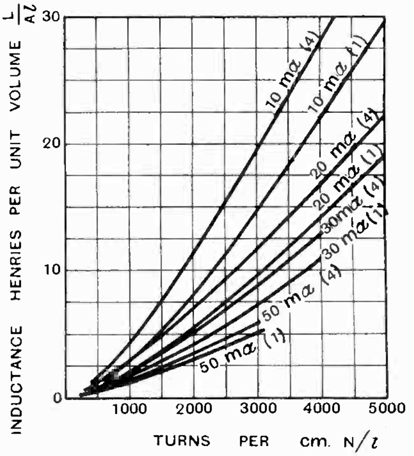

Fig. 6b.
Curves (1), $\delta B = 89$ *R.M.S. lines per cm.*^{2}
Curves (4), $\delta B = 890$ *R.M.S. lines per cm.*^{2}

another series of curves, each curve being drawn for a particular ratio a/l. Selecting a value for B we can compare the $\delta B/\delta m$ obtained with this B and some particular air gap ratio, as found from this curve, with the maximum $\delta B/\delta m$ shown in Fig. 5 for the value of m giving the selected B, and thus we can find the diminution of $\delta B/\delta m$ resulting from using conditions other than the optimum. By this means an air gap cut to allow an induction of 9,000 lines throughout

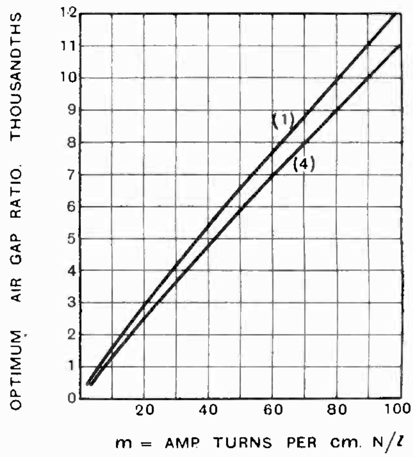

Fig. 7.
Curves (1), $\delta B = 89$ *R.M.S. lines per cm.*^{2}
Curves (4), $\delta B = 890$ *R.M.S. lines per cm.*^{2}

the core will be found to cause a diminution of possible $\delta B/\delta m$ of only 9 per cent. over the range of D.C. excitation and applied voltages considered here. This is about the best average value possible and should be used whenever the applied A.C. volts are known to vary in amplitude or frequency to any considerable extent.

The stray flux is now an important consideration. Most of the stray flux is in the neighbourhood of the air gap, and the effect of this is to reduce the effective reluctance of the air gap.

Consider an air gap of length a'. Let a be the length of the air gap which, with no stray flux, would have the same reluctance as the gap a'. Let q be the dispersion coefficient. Then, since the flux crossing the gap a is the same as the flux crossing the gap a' plus the stray flux,

$$qa = a' \quad \ldots \quad (3)$$

The dispersion coefficient depends on the configuration of the iron, and on the air gap, and its value is best found experimentally. Two specimens of the iron core to be used, made up with different air gaps of about the expected length, will give a short curve

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between q and a', by means of which, with the aid of equation (3), a graphical solution for q is obvious.

An example of the use of the curves follows.

A smoothing choke was required for an A.C. rectifier giving 60 mA. D.C. at full load output. Considerations of ohmic drop and space available for winding led to 8,100 turns being the maximum that could be wound on the core, 28 cm. long and 5.6 cm.^{2} in cross-section. The A.C. fluctuations were calculated to produce 40 volts R.M.S. across the choke at full load, the worst conditions, and at 100 cycles. The corresponding δB in the iron will be 78, for which curves (1) will be near enough.

The D.C. excitation is $\frac{.06 \times 8{,}100}{28} = 17.4$ amp. turns per cm.

From Fig. 6 (a) curve (1) for 50 mA. and 290 turns per cm. the inductance is .20 H. per unit cross-section and length. For 80 mA. the inductance is .16 H. For 60 mA., therefore, the inductance will be approximately .19 H. Hence the inductance of the choke should be $.19 \times 28 \times 5.6 = 29.8$ H., and from Fig. 7 curve (1) the optimum air gap ratio for 17.4 amp. turns per cm. is 2.5/1,000, hence the air gap length should be $28 \times 2.5/1{,}000$ cm. $=$ .7 mm.

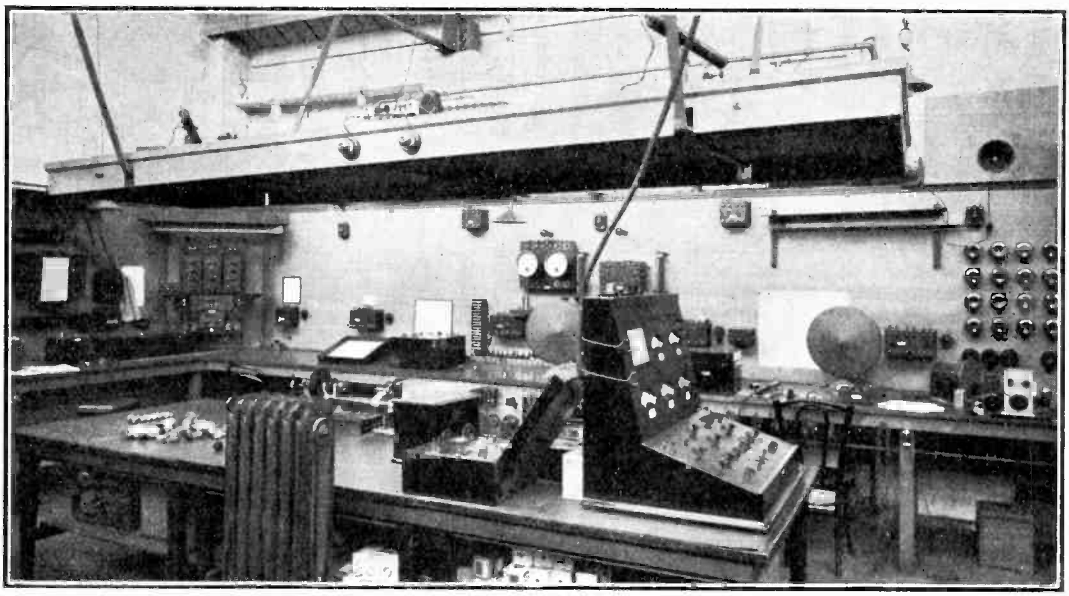
The dispersion coefficient for the iron core was 1.41, and since the equivalent air gap a required is .7 mm. we have from equation (3) that $a' = .99$ mm. This is the air gap to be cut in the iron core.

With the object of comparing actual with predicted results an applied voltage was adjusted to give a δB of 78, and the inductance measured. This was found to be 31.2 H. The winding itself had a small inductance of about 1 H. not associated with the iron core, and this added to the predicted inductance gives 30.8 H., which should be compared with the actual inductance of 31.2 H.

The close tallying of the predicted with actual figures is, no doubt, partly fortuitous, as in fact the actual air gap was 1.5 per cent. smaller than specified; but the figures show the practical utility of the method.

With a plain iron core and no air gap, the nductance of the choke would have been 6.8 H., from which it can be seen that the gain in inductance due to suitable air gap is nearly 400 per cent.

I have been privileged in having the kind assistance of Mr. L. B. Turner in the preparation of this paper.



A view of the Burndept research laboratory. A valve-testing set is seen on the right. The platform over the bench is mounted on rubber cushions and carries a mirror galvanometer.

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Some Output Power Measurements on a Moving Coil Drive Loud Speaker.

By H. A. Clark and N. R. Bligh.

1. Introduction.

DURING the course of some experimental work in which a moving coil cone loud speaker was employed the instrument was suspected of having a very pronounced resonance at a low frequency. Some measurements were made therefore at these frequencies. It was also decided to make a complete test on the instrument over the acoustical range.

Owing to the increasing use of this type of reproducer it is thought that the results and the method of obtaining them will be of general interest, particularly by showing, as they do, the weak points in the design of this particular instrument.

2. Description of Loud Speaker.

The instrument on which the measurements were made is representative of a large number now in use. It consists of a 7in. diameter right-angled conical diaphragm of stiff drawing paper varnished to prevent moisture absorption and carrying a moving coil wound on an extremely thin ebonite former. The diaphragm is suspended at its periphery only by means of a $\frac{1}{2}$in. width of

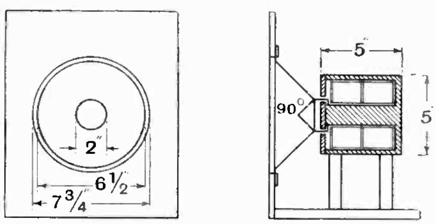

Fig. 1.—*Illustrating type of loud speaker on which measurements were made.*

oiled silk attached to a wooden ring which is screwed to a vertical wooden panel containing a 7$\frac{7}{8}$in. circular opening. The coil is free to move in a $\frac{1}{8}$in. annular gap in the usual form of cylindrical field magnet excited by 0.6 ampere at 6 volts.

The moving coil consists of 100 turns of No. 38 S.W.G. enamelled copper wire, the leads being brought down the diaphragm to

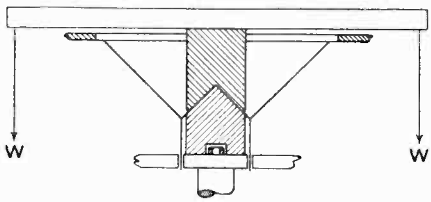

Fig. 2.—*Method of clamping diaphragm.*

the edge, where they are joined by a pair of spiral fine wire leads to the input terminals. The instrument was used with a 6ft. square baffle.

Measurements Required.

It was required to find the resistance and reactance of the instrument over the audible range of frequencies both with the loud speaker in its normal operating condition and also with the diaphragm rigidly clamped in order that the acoustical output may be reduced to zero. In doing this care has to be taken that the moving coil remains in the same position as when the diaphragm is free to move. It was found that the most satisfactory method of ascertaining this was to use a pair of wooden cylinders, one having an external cone and the other an internal cone turned on their ends to fit the re-entrant cone of the diaphragm perfectly and of such a diameter that one will just enter the former of the moving coil. Its length must be such that when resting on the surface of the pole piece of the field magnet the diaphragm is closely in contact with it when the moving coil is in the correct position. A recess must be made to accommodate the bolt head securing the pole piece. When the inner cone was thus fitted the instrument was arranged with its axis vertical and then the

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upper cone put in position. A cross bar of wood was laid across the end of this and weights hung from the ends to hold the diaphragm perfectly rigid. A total of 8 lbs. was found sufficient. It is important to note that the connection between the coil and the diaphragm must be sufficiently rigid to prevent the former moving independently of the latter.

3. Principle of Method.

As the reactance to be measured may change from positive to negative at some frequencies, a method of measurement in which this may be accommodated without change in circuit connections, etc., was required. The Heaviside equal ratio inductance bridge was therefore decided upon. This is illustrated in the accompanying schematic diagram (Fig. 3).

R_1 and R_2 are two identical resistances. R is a variable known resistance of very low or known inductance. M is a variable standard of mutual inductance.

The apparatus under test is put in circuit at will at X. The bridge is supplied at *ac* with an alternating voltage and some form of detecting device placed across the points *bd*.

Now suppose X to be short-circuited and that the bridge is balanced with settings of

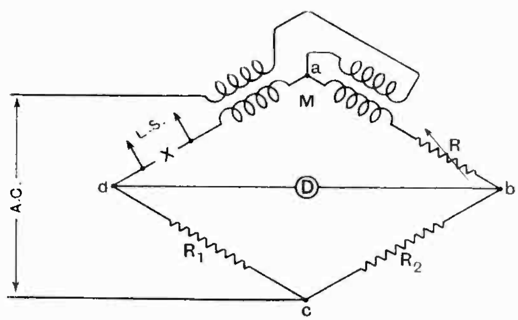

Fig. 3.—*Theoretical Circuit of Bridge.*

M' and R' respectively on the mutual inductometer and R. Now let X be put in circuit and the bridge rebalanced to give values of M'' and R''. Then it may be easily shown that the inductance added at $X = L = 2(M'' - M') + \theta$, where θ is a small correction due to unbalanced residual reactances in the balance arm and due to the reactance of the resistance R, and the resistance added at $X = r = R'' - R' + 2\rho'' - 2\rho' + \theta'$, where ρ is an impurity in the mutual inductance and is due to an E.M.F. induced in phase with the primary current and θ' is an error due to inequality in the bridge arms which can be eliminated by interchanging them.

Now, for the order of accuracy required in this work both the impurity of the mutual inductance and the reactance of the resistance R may be neglected, giving the simple results

$$L = 2(M'' - M')$$

and

$$r = R'' - R'.$$

If now the effective inductance L becomes negative, the arm of the mutual inductometer will swing on to the negative part of the scale. For large negative values it is only necessary to reverse the connections to the primary of the inductometer.

4. Practical Arrangement of Apparatus.

In practice a number of additions were required to the simple bridge circuit shown above. To render the arrangement sensitive a two-stage amplifier was used at the output terminals to supply a pair of telephones in which the balance of the bridge was judged. It was found desirable to earth the bridge at the point C and also to enclose the resistances R_1 and R_2 in earthed screens to reduce direct pick-up. The source of AC and the amplifier were also earthed, and to prevent throwing large capacity loads across the bridge screened and balanced transformers were used for both input and output. Owing to the fact that the mutual inductometer was not screened, it caused considerable pick-up by induction. As screening would probably alter the calibration rather seriously this was put at some feet from the rest of the apparatus. The inductance and capacity of the leads are of no moment as they produce an error which cancels out owing to the difference method explained above.

The loud speaker was put in an adjoining room owing to the acoustical output making balancing in the telephones difficult. The inductance of the long flex leads produces another error which cancels out as the short-circuiting device was put at the loud speaker terminals. This consisted of a copper link making contact in mercury pools in a block of paraffin wax.

For frequencies above 200 cycles per second a valve oscillator was used. This was of the

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ordinary feed-back type, and produced a reasonably good wave-form. The amount of harmonics present was not sufficient to render balance difficult. The whole oscillator was placed in a heavy brass screen which was earthed. To measure the frequency a Campbell frequency bridge was used.

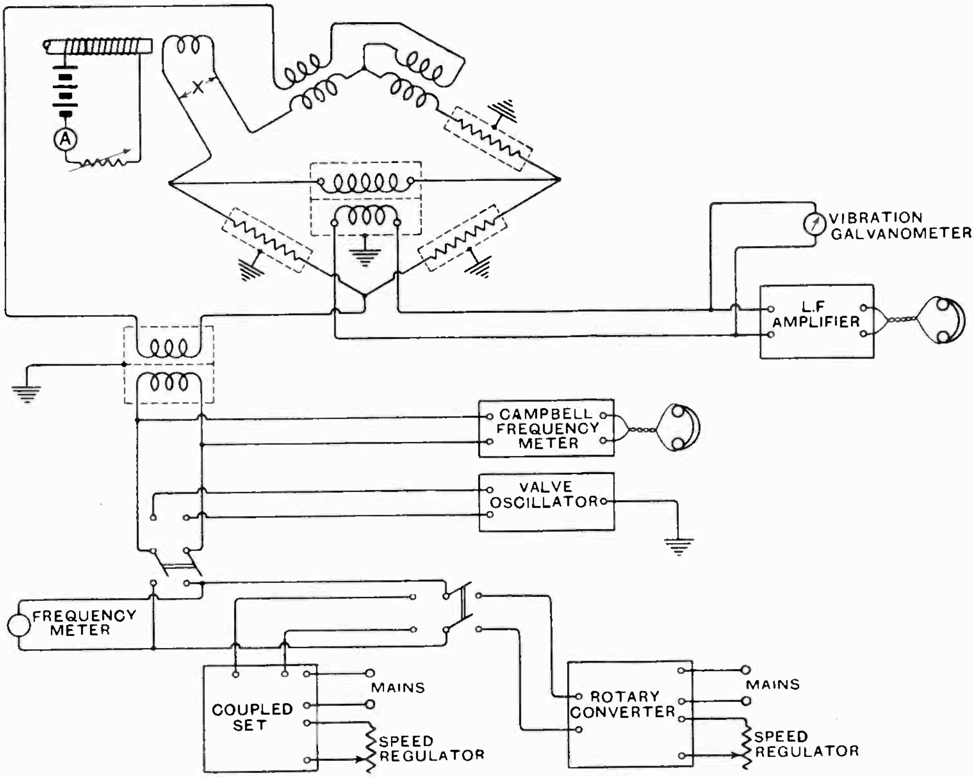

Fig. 4.—*Practical Arrangement of Apparatus.*

Below 200 cycles the oscillator was unsatisfactory as the output at the fundamental frequency was found to decrease considerably, also aural balancing was found to be of increasing difficulty. The supply was therefore taken from a coupled set consisting of a D.C. shunt motor with a field regulator for speed variation and a single phase alternator with a transformer with a number of tappings for various voltages.

A Campbell type of vibration galvanometer was used as a detector below 200 cycles. The amplifier was also left connected, however, and it is interesting to note that quite a fair degree of accuracy could be obtained by aural balancing as low as 70 to 80 cycles. It should be mentioned that high-class components were used in the amplifier to enable this to be done. Greater accuracy was obtainable, however, with the galvanometer. The only disadvantage of this instrument for this type of work is that it has to be tuned for every frequency used; this is a tedious operation when numerous readings are required.

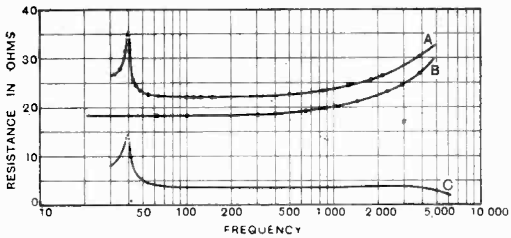

Fig. 5.—*Curve A—Resistance with diaphragm free. Curve B—Resistance with diaphragm clamped. Curve C—Motional Resistance.*

The frequency was read on a direct reading frequency meter by the Weston Electric Instrument Co. Below 60 cycles the coupled

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set had to be run at such a slow speed that the frequency was not constant. A rotary-convertor capable of covering a range of 30 to 60 cycles was therefore used, together with an L. C. Wild type of direct-reading frequency meter, made by R. W. Paul. On these very low frequencies the Campbell galvanometer was found to be unsatisfactory and a Drysdale type, by Tinsley, was substituted. As will be seen from the results which follow it was of the greatest importance to keep the frequency very constant while taking measurements at low frequencies. The complete layout of apparatus is shown in Fig. 4.

5. Experimental Results.

The figures obtained for the effective resistance both for clamped and free diaphragm have been plotted and are shown in Fig. 5. The difference between these is due to the acoustical work done* and is represented by so many ohms. The reactance has also been plotted as found by taking $2\pi f$ times the effective inductance. It is quite obvious that the suspicions entertained were justified. A very sharp resonance was undoubtedly present at about 40 cycles.

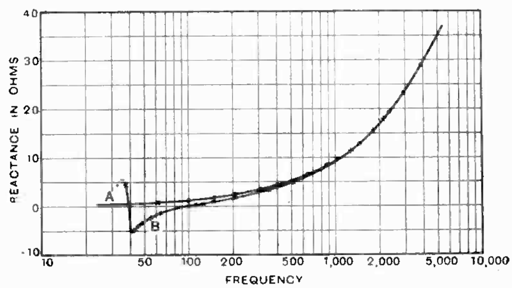

Fig. 6.—*A—Reactance diaphragm clamped. B—Reactance diaphragm free.*

Now, the power in any circuit is given by the effective resistance multiplied by the square of the current in the resistance. Hence, if the current through the moving coil $= I$ amp. (R.M.S.) and effective resistance with the diaphragm free $= R_1$ ohms, then the total power supplied to the loud speaker $= I^2R_1$.

If the resistance with diaphragm clamped $= R_2$ ohms, then the output or acoustical radiated power $= I^2(R_1 - R_2)$, assuming no losses in moving the diaphragm other than the load produced by the air.

Hence, if the current through the moving coil were constant at all frequencies, the output power characteristic would have the shape shown by the output resistance curve.

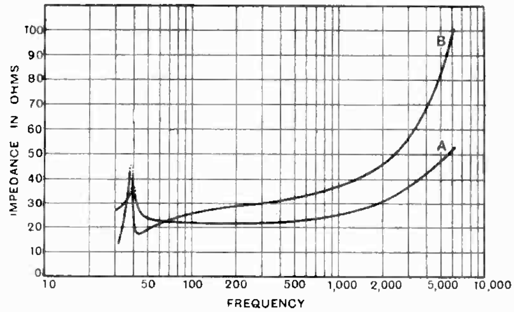

Fig. 7.—*A—Impedance of loud speaker alone. B—Impedance of loud speaker, transformer and valve.*

This, however, is not the case. Assuming a constant voltage across the loud speaker terminals, the current will vary inversely as the impedance. Now both the effective resistance and reactance vary very largely with frequency, and hence the output will vary within very wide limits.

The impedance of the loud speaker at various frequencies has been calculated from the resistance and reactance figures. This is shown in Fig. 7. Assuming a constant voltage supply, the current and hence output power can be calculated. The curve shows

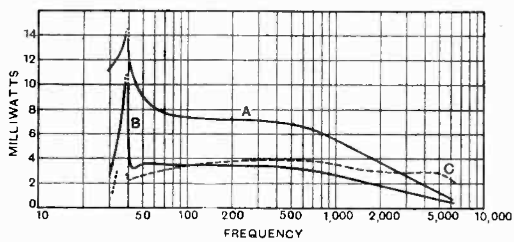

Fig. 8.—*A—Output for 1 volt across loud speaker. B—Output for 24 volts across primary of transformer. C—Overall characteristic for loud speaker and amplifier.*

that the output power varies from 13.3 per cent. at 6,000 cycles to 230 per cent. at 40 cycles, taking the power at 100 cycles at 100 per cent.

Neglecting small iron and eddy current losses, the force on the diaphragm will be in

* *See* Appendix.

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phase with the current. The phase of the current relative to the E.M.F. across the terminals can be calculated, and hence the " phase distortion " of the loud speaker can be found.

6. Effect of Step-down Transformers and Valve Impedance.

In actual practice the loud speaker is used in conjunction with a step-down transformer the primary of which is in the anode circuit of the output valve of an amplifier. It can be shown that this transformer has a very considerable influence on the performance of the loud speaker. The constants of the transformer being known, it is possible to calculate its effect at any frequency by using an equivalent circuit. This equivalent circuit is shown in Fig. 9.

The values for the step-down transformer normally used with the loud speaker are as below :—

Primary inductance with normal polarising current (L_1) = 25 henries.

Equivalent self-capacity of primary (C) = 700 μFds.

Total leakage inductance referred to primary (l) = 0.25 henry.

Secondary resistance (R_s) = 0.455 ohm.

Primary resistance (R_p) = 800 ohms.

A.C. anode impedance of valve (R_a) = 4,700 ohms.

Step-down ratio of transformer (σ) 24 to 1.

All these values have been referred to the secondary for the purpose of the equivalent circuit.

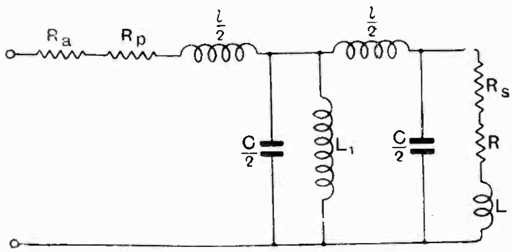

Fig. 9.—*Equivalent circuit of loud speaker, transformer and valve.*

It has been found that this circuit may be considerably modified for various frequencies with sufficient accuracy, thus making calculations much more simple. These circuits are shown in Fig. 10.

The total impedance of the circuit was calculated, and hence the total current assuming 1 volt across the terminals. This

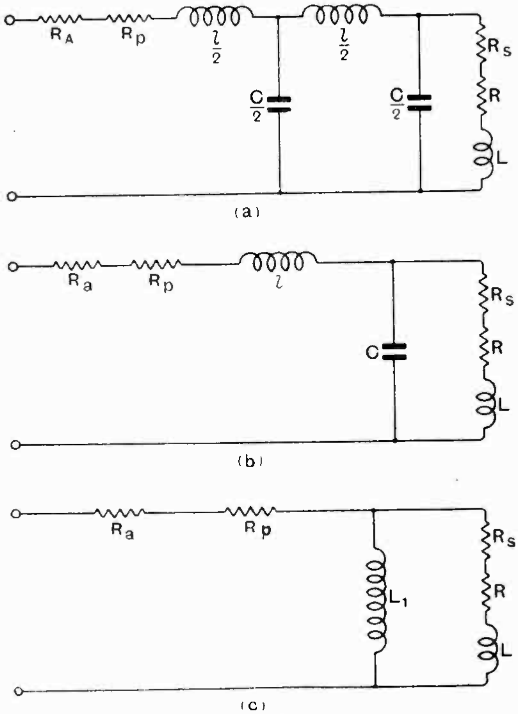

Fig. 10.—*Simplified Equivalent Circuits.*
(a) For frequencies above 4,000 cycles.
(b) For frequencies below 4,000 cycles and above 400 cycles.
(c) For frequencies below 400 cycles.

corresponds to $\frac{\sigma}{\mu}$ volts on the grid of the last valve, where σ = step-down ratio of the transformer and μ = amplification factor of the valve.

From the total current the current passing through the moving coil was found and hence the output power. The phase angles were calculated as before. Fig. 8, curve *B*, shows the output power with the transformer in circuit. It will be seen that the overall effect of the transformer and valve is to flatten the characteristic particularly at the lower end.

7. Effect of the Amplifier Characteristic.

If the overall voltage amplification characteristic of the amplifier is known, the overall performance of the loud speaker and amplifier may be found. As the loud speaker

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had a falling characteristic the amplifier was made to have a rising curve in an effort to compensate for this. The resulting overall characteristic for a uniform input to the amplifier is shown as a dotted curve which approximates to a horizontal line over the useful frequency range.

8. Conclusion.

The results are instructive in that they show two faults in the design of the speaker. First, there is a serious resonance in the order of 40 cycles. This undoubtedly is due to the diaphragm, as when it was tapped and the ear placed close there was a definite very low-frequency note produced. This resonant frequency could be lowered by increasing the effective mass of the diaphragm or reducing the elastic control of the suspension. The latter is by far the more favourable method. To find this resonant point more exactly the resistance was plotted against reactance for clamped and free diaphragm. By joining points of equal frequency on the two curves the motional impedance is found for any frequency. The maximum motional impedance occurs at the resonant frequency. The frequency scale is very open round the loop of the curve, enabling the resonance point to be found with great accuracy.

The other undesirable feature is the falling off of output power at the higher frequencies due to the increased reactance. Less inductance in the moving coil would decrease this effect at the expense of overall efficiency.

It should be noted in passing that the

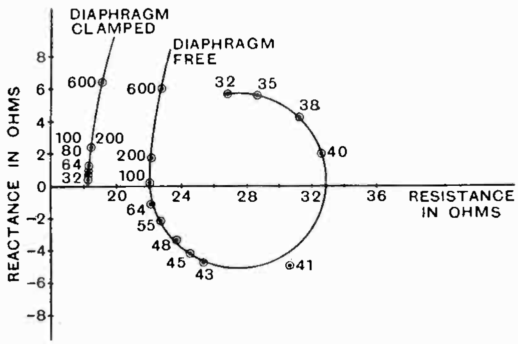

Fig. 11.—*Reactance-resistance Diagram.*

output resistance divided by total resistance will give a figure for the efficiency of the instrument alone. This is about 16 per cent. at 100 cycles, and falls to 6.4 per cent. at 6,000 cycles. This rather high figure is, of course, reduced in practice owing to the losses occurring in the rest of the resistance in circuit.

In conclusion, therefore, a much better instrument would result by reducing the

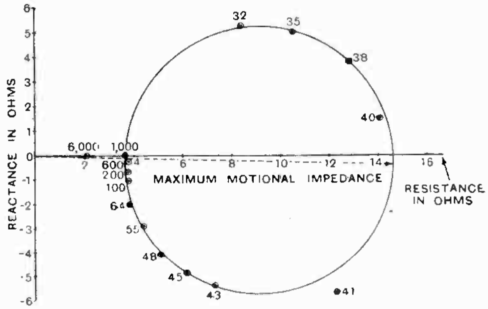

Fig. 12.—*Motional Impedance Circle.*

elastic control on the diaphragm and using fewer turns on the moving coil.

The authors are indebted to the Northampton Engineering College, London, for the experimental facilities provided and to Mr. A. C. Jolley for his keen interest throughout the work.

APPENDIX.

Equations of Motion for a Moving Coil Loud Speaker.

In deriving the equations of motion for the diaphragm we have a force F acting on the moving coil. Three assumptions are made, as follows :—

1. The actual distributed mass can be considered as a concentrated mass intimately associated with the moving coil.

2. The elastic restraint produces a force proportional to displacement and can be considered as concentrated and fixed to the equivalent mass.

3. The output power can be considered as a frictional force, concentrated and acting on the moving coil, and its magnitude is proportional to the velocity of movement. This seems to be substantiated by previous investigators, and it is of interest to note that some output power is absorbed by the air viscosity and the viscosity of the diaphragm and suspension materials, and that such viscosity produces a force proportional to the velocity of relative displacement. We therefore write

$$F = (MD^2 + KD + K_1)x$$

where M is the equivalent mass and has dimensions $MLT^{-2} \div LT^{-2} = M$

K is the equivalent resistance and has dimensions $MLT^{-2} \div LT^{-1} = MT^{-1}$

K_1 is the equivalent elasticity and has dimensions $MLT^{-2} \div L = MT^{-2}$

x is the displacement in the direction of the force.

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The greatest difficulty is to decide the magnitude of the various components. Since the edge of the disc is only semi-free it does not vibrate as a plane disc, but bends in a manner similar to the prong of a tuning fork, and the effective mass will be some fraction of the static mass which will vary with frequency, while at low frequencies the inertia of the air must also be allowed for.

The resistance component is only approximately an equivalent output resistance, as at the higher frequencies especially losses take place in the diaphragm material itself. For losses other than those proportional to the velocity of movement the effect will be to modify the reactance components as well as to increase the losses.

The effective elasticity, though probably given correctly by a static test for the lower frequencies, is not correct at the higher frequencies, when the disc probably vibrates in a complex manner, dividing into various resonating sections at various frequencies (*see E.W. & W.E.* Editorial, Dec., 1927). The elasticity thus varies with frequency, and since the efficiency is so high some allowance must be made for the air elasticity.

To find the force on the moving coil let B be the flux-density, l be the active length of wire in the coil and $I \cos \omega t$ the current flowing.

$$F = lBI \cos \omega t = (MD^2 + KD + K_1)x$$

On solving for the steady state, *i.e.*, neglecting all transient effects,

$$x = \frac{\frac{lB}{M}\left(\frac{K_1}{M} - \omega^2\right) I \cos \omega t + \frac{K}{M} \cdot \frac{lB}{M}\,\omega I \sin \omega t}{\left(\frac{K_1}{M} - \omega^2\right)^2 + \frac{K^2}{M^2}\,\omega^2}$$

Let $$\left(\frac{K_1}{M} - \omega^2\right)^2 + \left(\frac{K}{M}\right)^2 \omega^2 = Z^2.$$

The coil movement induces into itself a back E.M.F. given by $e_1 = lB\,\frac{dx}{dt}$.

If the coil circuit has inductance L and resistance r and letting current flowing in it be $I \cos \omega t$ as above, we have that

$$-\omega LI \sin \omega t + rI \cos \omega t = e - e_1$$

where e is the applied E.M.F.

$$\text{Now } e_1 = \frac{(lB)^2}{M^2}\,\frac{K_1}{Z^2}\,\omega I \sin \omega t + \frac{(lB)^2}{MZ^2}\,\omega^3 I \sin \omega t + \frac{(lB)^2}{M^2Z^2}\,K\omega^2 I \cos \omega t$$

or $e_1 =$ " A " $+$ " B " $+$ " C "

Consider K and K_1 non-existent, then $e_1 =$ " B." Therefore

$$-\omega LI \sin \omega t + rI \cos \omega t + \frac{(lB)^2}{\omega M} \sin \omega t = e.$$

Hence term " B " represents a condenser and has a capacity $C = \frac{M}{(lB)^2}$. This gives dimensionally $\frac{M}{\mu MLT^2} = \frac{1}{\mu LT^2}$, which are the dimensions of a capacity.

The dimensions of K are MT^{-1}, of K_1 are MT^{-2} and of Z^2 are T^{-4}

Now consider the term " A."

Dimensionally we have $\frac{\mu MLT^{-2} \cdot MT^{-2}}{M^2T^{-4}} = \mu L$, which are the dimensions of an inductance and since the term has a multiplier $\omega I \sin \omega t$ we can consider this term as having a positive reactance given by an inductance of value $l_1 = \frac{(lB)^2}{M^2}\,\frac{K}{Z^2}$.

Considering term " C " we have dimensionally

$$\frac{\mu MLT^{-2} \cdot MT^{-3}}{M^2T^{-4}} = \mu LT^{-1},$$

i.e., the dimensions of a resistance, and this is also shown as the impedance gives an E.M.F. in phase with the current. We can therefore write

$$\left(L + \frac{(lB)^2K_1}{M^2Z^2}\right)\omega I \sin \omega t - \left(r + \frac{(lB)^2}{M^2Z^2}\omega^2\right) I \cos \omega t - \frac{l^2B^2}{MZ^2}\,\omega^3 \sin \omega t = e.$$

Hence we can represent the arrangement by the equivalent circuit as shown

L = Loud speaker static inductance.

$l_1 = \frac{(lB)^2}{M^2Z^2}\,K_1$ or reflected inductance due to motion.

r = Loud speaker static resistance to A.C.

$R = \frac{(lB)^2}{M^2Z^2}\,\omega^2 K$ or reflected resistance due to motion.

$C = \frac{MZ^2}{(lB)^2\omega^4}$ or reflected capacity due to motion

$$Z^2 = \left(\frac{K_1}{M} - \omega^2\right)^2 + \left(\frac{K}{M}\right)\omega^2.$$

Thus the reflected impedance components vary with frequency especially about the region of $\frac{K_1}{M} = \omega^2$.

Consider three frequency bands :—

1. When ω is small,

$$\frac{K_1}{M} \gg \omega^2 \text{ and also} \gg \frac{K}{M}\,\omega \qquad \therefore Z = \frac{K_1}{M}$$

$$l_1 = \frac{(lB)^2}{K_1}, \qquad R = \frac{(lB)^2}{K_1^2}\,K\omega^2,$$

$$C = \left(\frac{K_1}{lB}\right)^2 \cdot \frac{1}{M\omega^4}.$$

Thus at very low frequencies the output resistance is proportional to $\left(\frac{\omega}{K_1}\right)^2$ and the advantage of reducing the elastic control is easily seen. For very low frequencies the reactance due to the condenser will decrease at a rate proportional to ω^3, but this only occurs at very low frequencies.

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2. When $\frac{K_1}{M} = \omega^2$, i.e., $Z^2 = \left(\frac{K}{M}\right)^2 \omega^2 = \frac{K^2 K_1}{M^3}$.

Now considering the reactance components, we have

$$\left\{L + \left(\frac{(lB)^2}{MZ^2}\frac{K_1}{M} - \frac{(lB)^2\omega^2}{MZ^2}\right)\right\} \omega I \sin \omega t.$$

This reduces to $\omega LI \sin \omega t$ when $\frac{K_1}{M} = \omega^2$. The added reactance is zero and the effective reactance is given by ωL. If ωL is very small the mechanical resonance is at the same frequency as the electrical resonance which was confirmed by tapping the diaphragm.

The resistance at resonance is given by $R = \frac{(lB)^2}{K}$.

3. At high frequencies where

$$\omega^2 \gg \frac{K^2}{M^2} - \frac{2K_1}{M}, \quad Z = \omega^2$$

$$l_1 = \frac{(lB)^2}{M^2} \frac{K_1}{\omega^4}$$

$$C = \frac{M}{(lB)^2}$$

$$R = \frac{(lB)^2}{M^2} \cdot \frac{K}{\omega^2}.$$

At such frequencies the addition of l_1 is negligible, and the reactance of C is also negligible. This confirms the experimental results, as at high frequencies the motional and static reactance were the same.

The greater the frequency the smaller the output resistance, but it is independent of the elasticity. It is plain that the mass of the diaphragm seriously curtails the output at higher frequencies. Owing to the disc vibrating in various modes at these frequencies, however, other resonances take place, and the effective mass is probably reduced.

The assumption has been made that the driving force is in phase with the coil current and that the induced back E.M.F. is in phase with the coil motion. If the eddy current losses and hysteresis losses are low this should be so, and as the circle diagram gives a very small or inappreciate dip below the resistance axis these assumptions are probably justified.

National Physical Laboratory Annual Visit.

Matters of Wireless Interest.

THE annual inspection of the National Physical Laboratory, Teddington, was held on Tuesday, 26th June, and was, as usual, largely attended by visitors interested in every branch of science. As in former years, all departments of the laboratory were open to visitors, who were afforded an excellent idea of the extent and variety of the work carried out, and of the highly useful function which the establishment serves in industrial science.

While many exhibits of great interest were on view in every department, we are compelled by space to limit ourselves to those of more or less direct wireless interest, especially in the different sections of the electricity department.

Wireless Section.

In the wireless section many items of interest were to be seen.

A short-wave transmitter for wavelength range of 2 to 100 m. was on view, working in conjunction with a Lecher wire system for measurement of the wavelength. This was demonstrated in operation by the location of voltage nodes. A small portable transmitter for use with experimental direction-finding receivers was also shown, as was apparatus for the transmission of standard calibration waves. Wavemeters on view included the oscillator (described by Colebrook), suitable for the generation of C.W. or of modulated oscillations from 5 to 20,000 m., while a wavemeter more especially for the short waves was also shown in operation.

Amongst receivers was one for waves of 5 to 100 m., while a complete D.F. receiver (with its frame aerial electrostatically screened for the elimination of vertical) was shown in operation in conjunction with its supersonic amplifier.

Another interesting exhibit was of apparatus for electric and magnetic screening. This comprised boxes (of commercial production) made of plywood covered with metal, suitable for the housing of receiving apparatus, oscillators, etc., while another group included coupling coils suitable for measuring purposes, electrostatically screened from each other, and boxed for screening from external fields.

In this section also, were exhibited high-grade variable air condensers. using quartz pillars (commercially produced to N.P.L. model and specification) and apparatus for measuring capacity and losses in condensers by a quick and sensitive method.

In another section, there was on view a Cathode ray oscillograph apparatus for the study of wave-forms from amplifiers, oscillators, etc. A linear time-base permits the ready examination of the wave form of the voltage applied to the plates of the tube producing vertical deflection of the fluorescent spot. Arrangements for the measurement of amplification were features of considerable interest. These comprised a high-power amplifier for the fundamental study of amplifier operation under various conditions. Apparatus for receiver measurements generally comprised a large screening chamber for radio and audio-frequency oscillators, the whole chamber being closed by a mercury seal. The output was led through careful screening to another screened room where the receiver was located, and where accurately known values of modulated or unmodulated H.F. voltage could be injected into the receiver under test.

Standards Division.

In the Electrical Standards and Measurements Division, were to be seen many exhibits of the high degree of precision associated with this division.

Amongst these was the standard harmonic wavemeter for the accurate measurement of radio-frequencies from 10 k.c. to 50 megacycles (30,000 m. to 6 m.). A novel exhibit was an inter-ferometer for examination of the modes of vibration of quartz crystal plates. this being shown in operation.

Apparatus for dielectric measurements included a method for the measurement of the permittivity and power factor of dielectrics in the form of thin sheets, and apparatus for the measurement of power factor and permittivity of dielectrics at radio-frequencies, and at known temperatures and conditions of humidity.

Several interesting A.C. bridge methods were also on view. Amongst these was a Schering bridge, shown in operation in conjunction with a screened input oscillator, for the measurement of inductance, capacity and effective resistance at radio-frequencies. A bridge method of measuring the mutual conductances of valves was also on view, while a form of Hay's bridge permitted measurement of the effective inductance and resistance of iron-cored chokes carrying both D.C. and A.C., each component being adjustable to any desired amount.

In this section, also, was apparatus for measuring the amplification and phase relationship in amplifiers at frequencies from 25 to 6,000, while, among magnetic tests, was equipment for measurement of the total power losses at power and at telephonic frequencies in magnetic sheet materials.

One Million Volts.

Although not directly of wireless application, a demonstration of extraordinary interest was shown in the High Voltage Laboratory. Three transformers in cascade, capable of developing up to about 1,000,000 volts were shown in operation, the voltage being gradually built up until it flashed over an insulator of about 6 feet. The transformers are specially designed to facilitate research measurements at extra high voltage, and the display is believed to be the highest voltage so far used in this country. The copious brushing from the conductors during the building up of the voltage was itself spectacular, but the final flash over was a sight unique to those accustomed to more modest voltages.

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A Graphical Construction for Resistance Amplifiers.

By W. A. Barclay, M.A.

In a recent issue of this journal Mr. A. L. M. Sowerby deduced a series of equations from which the best values of anode resistance, grid bias, etc., to secure maximum output for a particular amplifying valve might be calculated. [*E.W. & W.E.*, April, 1928, "Calculations for Resistance Amplifiers," by A. L. M. Sowerby, M.Sc.] A simple graphical method of solving these equations will now be described by means of which not only the external resistance R to be used, but also the various other quantities dealt with in Mr. Sowerby's article may be readily obtained. The method depends on the properties of the parabola, but one curve having been set out once for all as described below, the same diagram may be made to serve for any number of valves. The symbols employed and the numeration of the equations are those of the article in question, to which readers are referred.

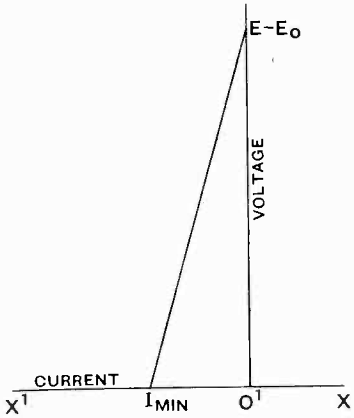

Fig. 1

In the diagram of Fig. 1, let current in milliamps. be measured along $O'X'$ to the left of O' to any convenient scale of representation, while voltages are measured upwards from O' on the vertical line, again to any desired scale. Then, if v be the voltage drop across a resistance R due to the passage of a current i, a measure of R will be afforded by the slope of the line joining v to i on their respective scales. We shall seek on this diagram the points corresponding to the voltage $E - E_0$ and to the current $I_{min.}$ for our particular valve, and shall refer to the gradient of the resulting slope line as G.

We now prepare another diagram, Fig. 2, whereon the x-axis is graduated linearly in resistances to any convenient unit, while vertically above each resistance graduation a point P is taken such that the slope OP is identical with the slope of the same resistance taken on the diagram of Fig. 1. It is easy to show that the locus of these points is a parabola to which the x-axis is tangential at the origin, and that the ordinates to the curve are proportional to the squares of the corresponding resistances.

If, now, a line of slope G meets this parabola at a point P whose abscissa is $R + R_0$, the ordinate PQ will be $(R + R_0)^2$. But from equation (3) of Mr. Sowerby's article

$$\frac{(R + R_0)^2}{R_0} = \frac{E - E_0}{I_{min.}} = G = \frac{PQ}{NQ}.$$

so that NQ will represent R_0. Hence ON will measure R, the value of external resistance to be used.

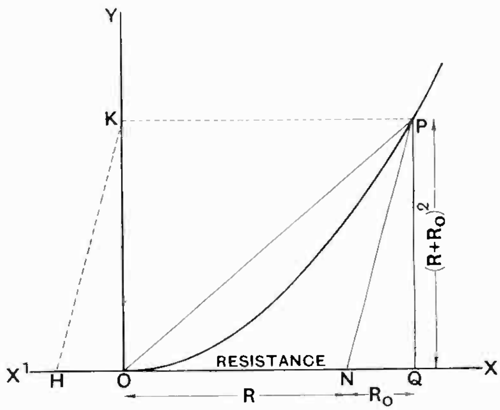

Fig. 2

This property is made use of practically as follows. From O in the reverse direction OX' set off OH equal to R_0 and through H draw a line of slope G to meet OY in K.

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Draw KP parallel to OX to meet the curve in P, PN being then drawn of slope G to meet the x-axis in N.

Consider now the diagram of Fig. 3, in which the position of P and the value of $ON = R$ have been obtained by the above construction. Draw NV to meet the curve in V, and join OV to meet PQ in M. Then from Mr. Sowerby's equations (2) and (3) and the properties of the parabola it may be shown (see Appendix I) that

$$PQ : MQ : VN :: E - E_0 : -2\mu E_g : 2V.$$

This leads to the following simple construction to obtain these quantities, as well as I_a and I_aR of Mr. Sowerby's equations (5) and (6).

Whence, by subtraction,

$$E_a = E - I_aR.$$

APPENDIX I.

Mr. Sowerby's equations (2) and (3) may be re-written :—

$$2V = R\left\{\frac{E - E_0}{R + R_0} - I_{\text{min.}}\right\} \quad .. \quad (2)$$

$$\frac{E - E_0}{R + R_0} = \frac{R + R_0}{R_0} \cdot I_{\text{min.}} \quad .. \quad (3)$$

whence $\qquad 2V = \frac{R^2}{R_0} \cdot I_{\text{min.}}$

Therefore, $\qquad \frac{E - E_0}{2V} = \frac{(R + R_0)^2}{R^2} = \frac{PQ}{VN}$

Again, since $\qquad I_{\text{min.}} = \frac{E - E_0 + 2\mu E_g}{R + R_0}$

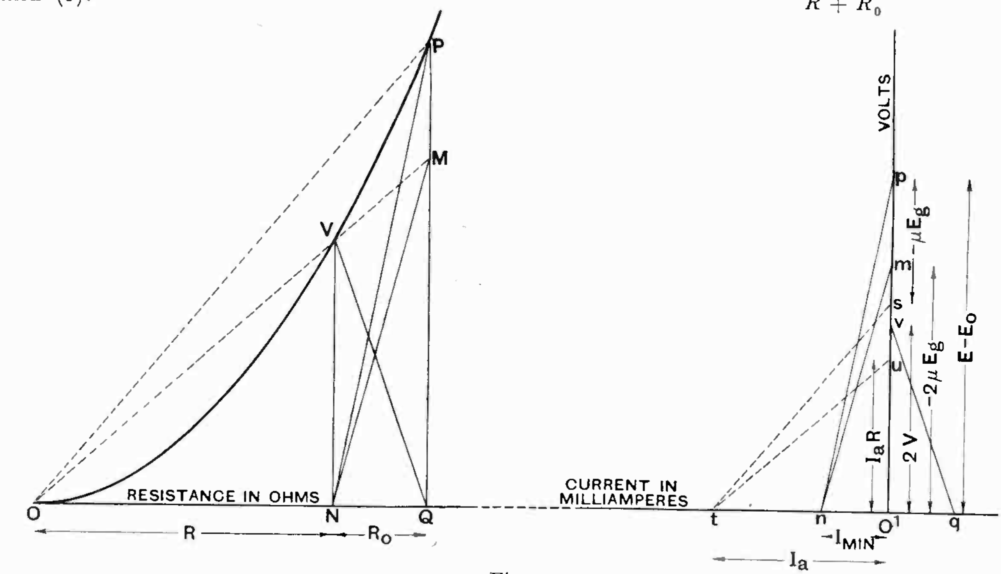

Fig. 3

In Fig. 3 let $O'p$ and $O'n$ represent $E - E_0$ and $I_{\text{min.}}$ as in Fig. 1, and let P be the point on the parabola found as in Fig. 2 so that PN is parallel to pn and $ON = R$.

Join VQ, NP, NM, OM and OP.

Take a point q on the opposite side of O' so that $O'q$ is equal to $O'n$.

Draw qv parallel to QV. Then $O'v$ represents $2V$.

Draw nm parallel to NM. Then $O'm$ represents $-2\mu E_g$. From p measure down $ps = \frac{1}{2} O'm$.

Draw st parallel to OP. Then $O't$ represents I_a.

Draw tu parallel to OM. Then $O'u$ represents I_aR. (For proof, see Appendix II.)

we have from (2) :

$$\frac{2V}{R} = -\frac{2\mu E_g}{R + R_0}$$

Therefore, $\qquad \frac{-2\mu E_g}{2V} = \frac{R + R_0}{R} = \frac{MQ}{VN}$

APPENDIX II.

From construction :

$PQ : MQ : VN :: O'p : O'm : O'v$

But, $\qquad O'p = E - E_0.$

Therefore, $\qquad O'm = -2\mu E_g$ and $O'v = 2V.$

Again, $\qquad O's = O'p - \frac{1}{2} O'm$

$\qquad\qquad = E - E_0 + \mu E_g.$

But gradient of st = gradient of $OP = R + R_0$.

$\therefore \qquad O't = \frac{E - E_0 + \mu E_g}{R + R_0} = I_a$

Also, gradient of tu = gradient of $OM = R$.

$\therefore \qquad O'u = I_aR.$

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Fading Measurements in India on the Short-wave Station PCJJ (Holland).

By T. S. Rangachari, M.A.

(Indian Institute of Science, Bangalore, India.)

THE phenomenon of fading is well known to a large number of listeners and in recent years it has been a subject of systematic study by quantitative measurements. These measurements are made in almost all cases on the broadcast band of wavelengths. The idea of Empire Broadcasting extends the importance of fading observations to the short-wave band.

There is a common belief that short-wave broadcasting is subject to no fading. Some while ago a listener in India wrote in the *Wireless World* (Feb. 29th, 1928, p. 235) that no fading was present. But the experience of the author is not the same on PCJJ, the Dutch station, on a wavelength of 30.2 metres, which is regularly listened to, at the Indian Institute of Science, Bangalore. A quick fading was evident and it was decided to make a more quantitative observation than listening could provide. The results of measurement, though they are not extended enough to draw general conclusions, yet were capable of giving some interesting information.

Method of Measurement.

The usual method of using H.F. amplification and measuring at the detector is difficult in the case of short waves. Therefore recourse was made to measuring on the L.F. side of the receiver. The method adopted is shown in Fig. 1. The H.F. part of the receiver is used in an oscillating condition to get a steady audible beat with the incoming carrier wave and a crystal detector is used to rectify the resulting alternating L.F. current. In series with the crystal a micro-ammeter is connected to read the D.C. current.

The circuit of the receiver is shown in Fig. 1. It consists of a detector with reaction and two L.F. stages. The detector and the coils on the H.F. side are enclosed in an aluminium case which is connected to the negative of low tension and earth. The aerial is a taut vertical wire, 30ft. high, stretched between the work table and the roof inside the laboratory. Any error that may occur due to the swinging of

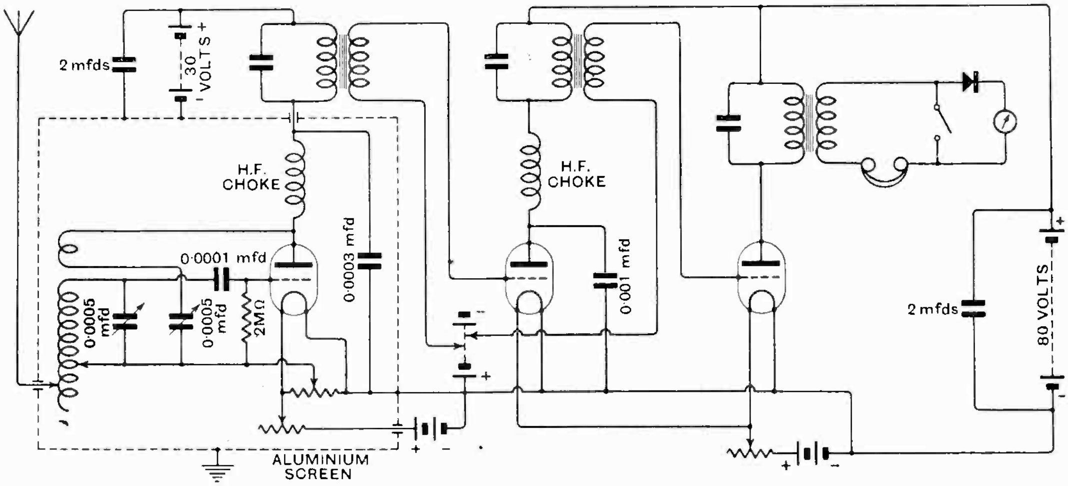

Fig. 1.—*Circuit of the receiver used.*

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the aerial if erected outside, exposed to the wind, is thus minimised. Since the measurements are made on the L.F. side, it is important to avoid low frequency and "threshold" oscillations by careful wiring and by using a separate battery for the detector. The valves used are P.M.5X. the exact relation of the micro-ammeter reading to fading as perceived by the ear is complicated, one can say that the readings do correspond to the fluctuating effect in the ear which one recognises as fading. It is seen from the results that the intensity of the signal is subject to violent fluctuations

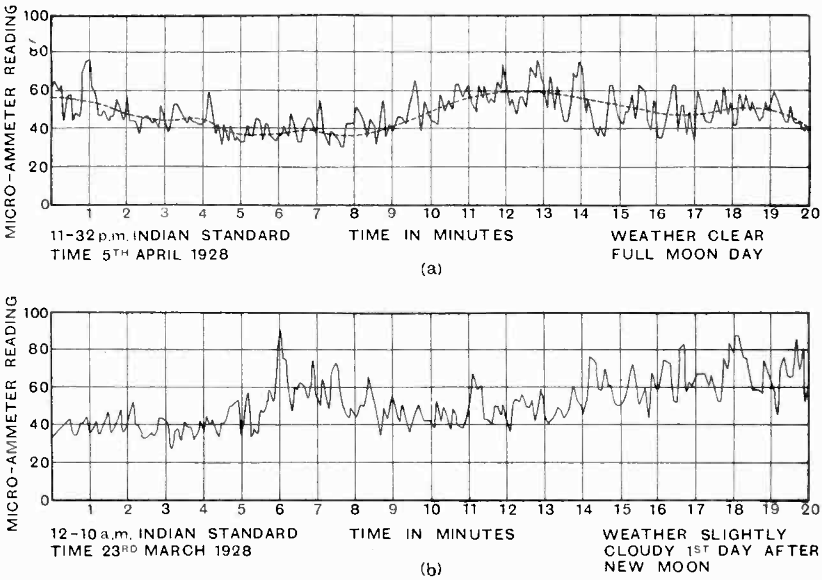

Fig. 2.

This receiver gives comfortable phone strength with absolute silence of background. The crystal, which is fused silicon and silver catswhisker, is found to work satisfactorily for hours together.

Results.

Measurements are taken for periods of 20 minutes at a stretch at intervals of every 5 seconds. In Fig. 2 are given some observed experimental curves. The ordinate represents the deflection of the micro-ammeter, while the abscissa represents time in minutes. These curves are only typical of a number of similar curves obtained during the course of observations for about two months. Though of very short period of the order of a few seconds. Also the mean value of this fluctuating signal strength is not constant but varies as shown by the dotted curve in Fig. 2(a). This variation is slow, of the order of 10 minutes. The observations so far made do not indicate any definite period, but the presence of this variation of a longer duration is evident. Thus two kinds of fading effects appear to be present, a quick fading superimposed on one of a longer duration. Further, it is also observed that at no time is the fading so severe as to make the station go out of hearing. The phases of the moon appear to have no effect on the nature of fading.

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Some New Applications of Short Radio Waves.

By James Taylor, D.Sc., Ph.D., A.Inst.P., and Wilfrid Taylor, Ph.D., M.Sc.

Introduction.

IT is a curious and striking fact that the scientific toy of to-day is the commercial product of to-morrow. Nowhere has this been so well illustrated as in the development of short electrical waves which, largely neglected by the professional, were investigated by the amateur, but when their scope and usefulness were demonstrated, were applied to such diverse uses as transmission of signals, and high-frequency furnaces for the making of fine ingots. Recently, an entirely new and remarkable property of these waves has been discovered, namely, their property of causing bright luminous electrical discharges in highly rarefied gases. The new field thus opened out offers great interest for the scientist, and merits careful consideration from short-wave wireless enthusiasts.

The Electric Discharge in Gases.

It has always been assumed as a result of extensive experience that gases at very low pressures (say, less than 1/1,000th of a millimetre of mercury, and below the degree of vacuum of a soft X-ray bulb) do not permit of the passage of an electric discharge except at very high voltages. All hard electronic devices, including thermionic valves, are based upon this fundamental property. But within the last few years our ideas upon this matter have been radically altered, and it has been found possible by applying alternating voltages of radio frequency (short waves) to produce luminous discharges at extremely low pressures, and to maintain them with relatively small voltages.

The first experiments along these lines were made by Gutton.[1] At a later date, Kirchner[2] in Germany set himself the task of investigating the potentials required to maintain glow discharges in different gases at various pressures and at radio frequencies. The voltage alternations were produced by commercial transmission valves (Telefunken RS 55), and the oscillations sent out from the transmitter were picked up by another circuit coupled inductively with it by means of Lecher wires, and containing the discharge tube. Frequencies down to 3.5×10^7 were obtained, and luminous discharges appeared in the tube. For the first time, therefore, the possibility of creating the beautiful and interesting phenomena of electrical discharge through gases had been placed in the hands of an amateur owning a few Geissler tubes (which may be purchased very cheaply) without any more elaborate means than his short wave set, and eliminating the very costly induction coil or other elaborate device for producing high voltages.

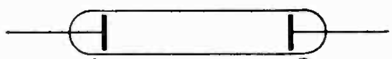

Fig. 1.

Let us consider two metal electrodes *A* and *B* (Fig. 1), mounted in a vessel which is first evacuated and then filled with a known gas at a definite (low) pressure. If now a gradually increasing voltage is put across the electrodes, then at a definite potential, called the sparking potential, a glow or visible discharge begins; an example of this form of discharge is afforded by the well-known neon lamp, now so extensively used for advertising and other purposes. We know, of course, that the discharge is caused by the motion of the electrons in the field between *A* and *B*. When the electrons can acquire a certain minimum velocity and collide with a gas atom, the latter originally neutral atom is dissociated (ionised) into one electron and one positive ion, and by repetition of this process large numbers of electrons and ions are produced. The ions in turn produce more electrons when they strike the cathode, and thus if the potential is sufficiently high, a discharge

[1] Gutton, Mitra, and Ylostalo, *Comptes Rend.* 176, 1871, 1923; also Gutton, *C.R.*, 178, 467, 1924.
[2] Kirchner. *Ann der Physik*, 77, 287, 1925.

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is maintained. With regard to the luminosity, it is now well known that according to the modern physical picture, the atom consists of a positively charged nucleus surrounded by rotating electrons like a miniature solar system. A certain number of orbits are permissible for each electron, and when the latter jumps from one outer orbit to another inner orbit, light is emitted. Hence light is produced when, as a result of a collision with an electron, electrons are made to change orbits.

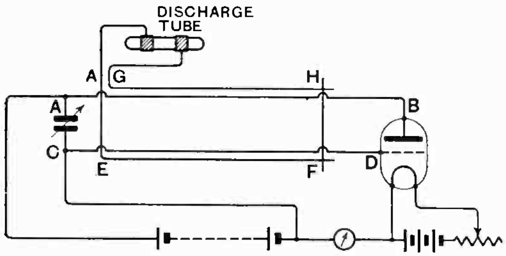

Fig. 2.

Kirchner found that when the frequency of the alternations across the electrodes attained radio values the potential required to maintain the discharge began to fall, and attained, in some cases, extremely low values. Thus, in the case of neon at pressures between 1.5 and 2.0 mms., the discharge could be maintained at a potential of 15 volts with a frequency of 3.5×10^7 cycles. These high-frequency undamped oscillations were capable of maintaining the discharges at low potentials and pressures, in certain circumstances, even at pressures less than those in cold cathode X-ray bulbs. This is a surprising result, for it is well known that for ordinary low-frequency voltages the potentials required to maintain a discharge become progressively higher with decrease of pressure; thus at X-ray stages they are of the order of many kilovolts.

Professor R. W. Wood and A. L. Loomis[3] in America have applied the new discharges to excite spectra in various gases. They used tubes provided with external tinfoil electrodes, and obtained brilliant discharges in hydrogen (blue) and make the remark that, judging from the appearance, they would have estimated the gas pressure at 1 mm., yet with internal electrodes no discharge could be obtained from an induction coil giving a 2-inch spark in air. Effects of fluorescence and red glows on the glass walls were also obtained.

More recently, the present writers have studied the electrical conditions of these discharges.[4] The oscillating circuit was of the type introduced into this work by Gill & Donaldson[5], and is shown in Fig. 2. An Osram L.S.5 valve, the plate and grid being connected as shown to two parallel copper wires about 1½ yards in length and about 3 inches apart. It is not possible to place the discharge tube in this circuit directly on account of its disturbing effect, hence the oscillations radiated from the "transmitter" are picked up by the tuned system *EFGH* coupled to the first by the familiar Lécher wire method. Across the ends *AC* of the first pair of wires a condenser is shunted, the magnitude of which is not of very great importance providing it is of the order of a milli-microfarad. The point *A* is connected to the positive of a high-tension battery of about 400 volts, and the grid wire *C* to the negative. It has since been found possible to use 220-volt direct supply mains in place of the high-tension battery, a resistance being inserted for safety. Experiments were carried out with tubes containing internal electrodes (see Fig. 1), but it was found on the whole to be much easier to maintain the discharge with external electrodes. Consequently, such tubes as shown in Fig. 3 were frequently employed.

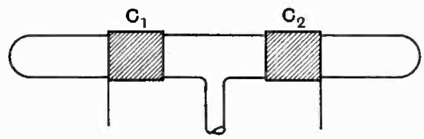

Fig. 3.

The electrodes took the form of annular rings of copper foil wrapped round the outside of the glass tube. The discharges obtained in this way are usually referred to as "electrodeless discharges." If we require a rough gauge of the pressure in such a tube, we may employ an internal electrode tube of the form shown in Fig. 1, and connect the electrodes to the terminals of an in-

[3] Wood and Loomis, *Nature*, 120, 510, 1927.

[4] *Proc. Cambridge Phil. Soc.*, 24, 259, 1928.

[5] Gill and Donaldson, *Phil. Mag.*, 2, 129, 1926.

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duction coil, adjusting the spark gap until a discharge just fails to pass in the tube. This alternative spark-gap distance then gives a rough measure of the hardness of the vacuum, although for precise measurements, of course, a proper gauge must be used.

General Form of the Discharges.

If we take a typical case of the tube of Fig. 3, and pump it down from atmospheric pressure, then the following phenomena are observed. Air, which is a mixture of nitrogen and oxygen, does not begin to conduct in these circumstances until pressures of 1 mm. or so are obtained. At 0.1 mm. the discharge was of a pink colour (band spectrum of nitrogen), and often took the curious form of a sharply defined egg of bright glow bathed in a faint pink luminosity. The walls of the tube meanwhile glow with an apple-green fluorescence, and the whole appearance, when observed in a dark room, is a most beautiful spectacle. If the pressure is still further decreased, the length of the discharge increases in the tube, and at the same time the luminosity increases, until at a certain stage the colour changes to a dirty blue, dull at first but brightening up later, when it exhibits the characteristic colour of a positive column in mercury, and, in fact, the blue colour marks the stage at which the air has been so far pumped out that the discharge passes in the mercury vapour which diffuses in from the pump. The mercury vapour may be frozen out by immersing the tube in liquid air; nevertheless, faint luminosity still persists. Exact measurements have shown us that even below pressures of 0.00005 mms., these faint glows may be obtained.

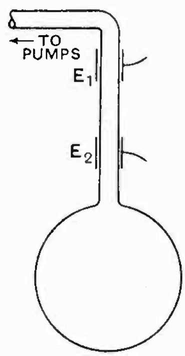

Fig. 4.

Problems of the High-frequency Discharges.

We may perhaps at this stage indicate briefly the nature of the problems which confront experimenters studying the effect of high-frequency waves in vacuum tubes. Four questions arise naturally: (1) What are the carriers of the discharge? (2) Why are the discharges so strongly luminous? (3) What phenomena take place on the walls of the tube? and (4) Why are the discharges so readily obtained at low pressures? It is easiest to take these questions in the reverse order, and to consider first why it is that similar luminosity cannot be obtained by direct potentials, *e.g.*, by an induction coil. The reasons are to be found in the following facts: (1) The scarcity of collisions between gas atoms or molecules and electrons which prevents accumulation of ionisation by collision. (2) Large quantities of electricity are lost to the electrodes. (3) The positive and negative charges are separated by the field and form "space charges." Now, in the high-frequency discharge, we can overcome all these difficulties. Considering again the tube of Fig. 1, in which the high-frequency voltage is applied between A and B, there is little difficulty in imagining what takes place in the gas. There are always some free ions and electrons in any gas, and these oscillate in the alternating electric field. If the distance travelled by the electron in one-half cycle of the wave is insufficient to take it to one of the electrodes, then there will be very little loss of charge. Most of the electrons remain in the gas and are available to build up more ionisation by collision. Also, since the frequency is so high, there will be no permanent separation of the charges, and as many electrons will vibrate one way as another. Thus there is no effective space charge to destroy the field, and instead we have a cloud of both types of charge. This gives the necessary condition for recombination and the emission of luminosity. It is easy to see also that by using external electrodes even the small loss of charge to the electrodes may be avoided, and the discharge maintained with greater ease.

Discharges in Narrow Tubes.

We pass on to describe more of the effects observed in the tube of Fig. 3, when the discharge was passing in mercury vapour at a pressure of 0.001 mm. Several different types of glows were obtained; in some the luminosity was confined between the electrodes, but in others this space was quite dark and the glows appeared on both sides of it. Sometimes the whole tube was lit up

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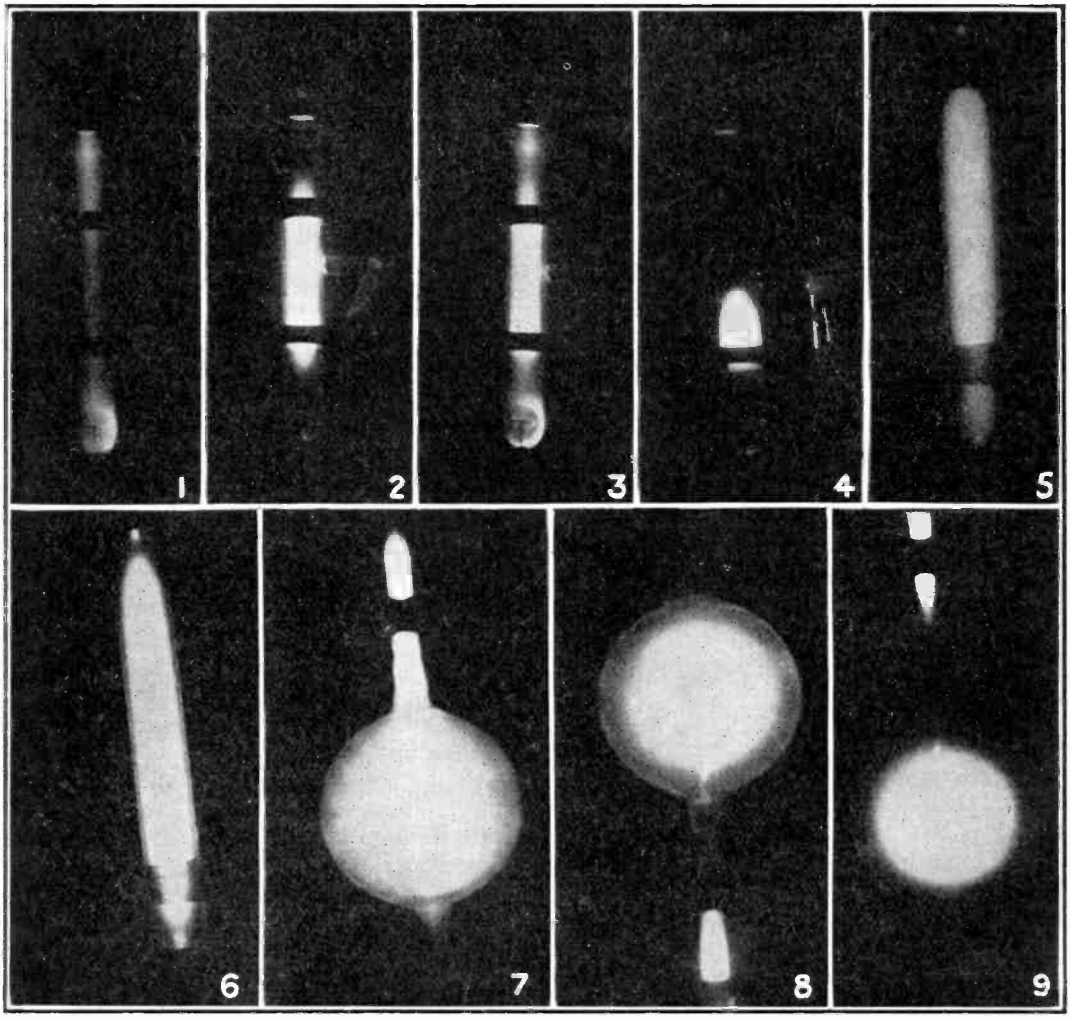
from end to end. All these effects depended upon the distance apart of the electrodes. A strange fact was that even if one electrode was completely taken off the tube, a glow still remained.

If the tube was stroked by the hand (or earthed conductor) on the outside, the glow could be induced to follow the motion of the hand in a most remarkable fashion, and on favourable occasions it was possible to lead the glow round two right-angled bends in the tube and on removing the hand, to leave the whole path still glowing. At other times the glow could be extinguished by pointing the finger at it and touching the outside of the tube.

The discharges pass more readily in wide than in narrow tubes, and there is always a dark space between the glow and the wall.



Photographs of discharges obtained by the methods described.

Such dark sheaths are doubtless to be explained by a theory of Langmuir given for similar ones met with in ordinary positive columns. The theory deals with very important considerations of space charge, and has, of course, vital application to thermionic valves. According to this theory, any

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surface immersed in a cloud of negative and positive charges will tend to charge up negatively in consequence of the swifter motion of the electrons. The surface then repels all but the fastest moving electrons, and creates a sheath in which there is a strong concentration of positive ion space charge. Owing to the lack of electrons for recombination, this sheath will be relatively dark and will moreover serve as a perfect reflector for most of the electrons striking it. Photographs were taken of discharges in a tube of the form shown in Fig. 1, but external electrodes as in Fig. 3 were added, thus the tube was a composite one, including the two forms, Figs. 1 and 3. The filling gas was pure helium at the pressure of about 1/50th mm. Plate 1 shows the discharge obtained on connecting the inside electrodes (A and B) to the terminals of an induction coil working at over 1,000 volts. Plate 2 shows the high-frequency electrodeless discharge produced when the external ring electrodes (C_1 and C_2) were connected to the oscillating set (Fig. 2). Plate 3 gives the combined effects of the induction coil and the high-frequency voltage. It is at once seen that the electrodeless discharge is much more intense than that given by a direct voltage of 1,000, and it is very remarkable to find that the superposition of a steady voltage of this magnitude across an electrodeless discharge is relatively without influence. The photographs give but a poor idea of the beauty of the actual discharges and their fascinating colour effects. The dark sheaths at the glass walls are well developed, as can be seen very clearly.

Plate 4 shows the same type of discharge after the helium became contaminated with traces of air. The luminosity was confined to a cone of light at one of the electrodes.

Plate 5 is a photograph with a tube of the form shown in Fig. 3 (no internal electrodes). The pressure was very low (residual gas after pumping out thoroughly and maintaining the vacuum by means of charcoal immersed in liquid air) certainly less than one-thousandth of a millimetre, the gas being probably hydrogen. In order that some of the phenomena we have described should be visible within the circular external electrodes, the latter were made of fine wire gauze. The gas pressure was so low that ordinary discharges could only have been produced at many thousands of volts. The electrodeless discharge, however, started without difficulty and, as the photograph shows, was extremely intense. The dark sheaths at the walls, and the constrictions within the annular electrodes are beautifully exhibited. Plate 5 shows a similar discharge in the same tube, with the striking condition that one electrode of the high-frequency voltage feed has been entirely removed from the tube. It may be of interest to mention that the photographs were taken on ordinary Ilford Special Rapid Plates with a large portrait lens, and exposures of only about two seconds.

Discharges in Bulbs.

Still more interesting effects were found to occur when a large glass bulb was used for the experiments. The bulb was about 20 cms. in diameter, and fitted with a side tube upon which the external electrodes were mounted as shown in Fig. 4. The filling gas was mercury vapour as before.

The first type of discharge has been termed "Type A," the side tube was filled with the same luminosity as described previously, and this extended right down into the bulb in the form of a luminous streamer. The streamer was surrounded by a diffuse and fainter glow which completely filled the bulb. There was no dark space round the walls. [Plate 7. Unfortunately the streamer cannot be obtained in a photograph.]

This appearance was, perhaps, what might have been expected, but on reducing the power in the oscillating circuit, the whole discharge underwent a sudden change and collapsed into a perfectly different form, which we shall call Type B. The luminosity in the side tube disappeared entirely, and with it the bright streamer. The glow in the bulb took the form of a perfect sphere floating in the centre of the bulb, but separated from it everywhere by a dark space of uniform thickness. [Plate 8. Plate 9 shows Type B in nitrogen at low pressure.] This glow was largely unaffected by external agencies; for example, moving an earthed conductor about the outside of the bulb produced no effect, and a magnetic field which bent the streamer of Type A into a semi-circular arc merely caused the sphere to brighten slightly.

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It is striking that these discharges lend themselves very well to photography. With an F/4.5 portrait lens, the photographs reproduced in this article were obtained after an exposure of 3 seconds, even though it was necessary to darken the room to exhibit the discharges properly to the naked eye. The radiations from the high-frequency discharge are, therefore, of a high actinic power.

From many points of view we may regard the glowing sphere as an enclosure of positive and of negative ions at a uniform high temperature. It might seem strange at first sight to talk of temperature in connection with electric charges, but it is a perfectly justifiable usage. We know that temperature merely measures the kinetic energy with which atoms and molecules are actuated in bulk whilst suffering mutual collisions. In the same way ions may move and collide. We have in fact by the high-frequency electric field a method by which their speeds and therefore their energies may be very greatly increased. Langmuir has estimated the temperature of the electrons in a positive column of mercury at the enormous figure of 600,000 degrees Centigrade, and considerably less than this for the positive ions. Thus, when a gas molecule is shot into the glow, there is a chance that it will be struck by a body at a "temperature" of thousands of degrees, and the result will be that the molecule will emerge from the encounter with properties appropriate to the high temperature, *e.g.*, different chemical activity, or even in the form of fragments. The molecule of hydrogen, for example, might be expected to be dissociated into two atoms and the new discharge may thus be a means of producing that striking substance, atomic hydrogen. Finally, it may be remarked that the sphere discharge bears a most striking resemblance to the solar corona seen during a total eclipse, and there is reason to suppose that the conditions may in some ways be indeed very similar. It can well be that a near approach to celestial phenomena may be reached in the laboratory.

Of more pertinent application of the new phenomena to radio, there seem to be several possibilities. Thus, the theory and practice of valve functioning at very high frequency is not entirely known, and it is possible that discharge effects of the type we have described may play an important part in certain valves if the voltage fluctuations are sufficient. It is also tempting to think that new light may be thrown upon the nature of the Heaviside layer now that demonstration of the absorption of Hertzian waves in highly rarefied gases has been made. It is interesting to speculate that high-frequency waves of celestial origin may produce sufficient ionisation in the upper layers of the earth's atmosphere.

Applications.

The application of short-wave discharges has already led to results of interest and importance.

It is an extremely powerful tool for studying certain chemical actions that are of vital importance in industry, and it supplies possibilities of working under the extreme conditions of refinement and purity which are the ideal of scientific investigation.

Further, it has yielded information on the obscure problem of what part the glass walls play in "softening" and "hardening" of valves, electric lamps and the like. "Softening" or "hardening" of an electronic device means change of the gas content and this is frequently fatal to repeatability and constancy of performance. It may be of interest to state that it is found that glass must be regarded as a sort of viscous, stiff liquid containing particles of matter charged some with positive, some with negative electricity. These charged particles sometimes break down under electrical influence and give off gas, on the other hand they can, under favourable conditions, seize gas molecules that come up to the walls and hold or fix them.

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The Harmful Effects of Inter-electrode Capacity.

By Manfred von Ardenne and Wolfgang Stoff.

IN all amplifiers, whether for high or low frequencies, the capacities between the electrodes of the valves stand in the way of making the fullest use of the amplifying action of the valves. On this account the amplification per stage cannot be increased to the theoretical maximum, but only as far as a certain limit. This limit is fixed by the magnitudes of the stray capacities themselves, but in addition the feed-back effects caused by these capacities between the electrodes must be taken into account. In amplifiers with tuned couplings the reaction between the various circuits caused by the valve capacities nearly always has self-oscillation as its consequence; the capacities themselves, so long as they do not give rise to reaction, can in such a case hardly be termed harmful, for their sole effect would then be an alteration in the tuning of the circuits connected between successive stages. In contrast to this stand amplifiers with aperiodic couplings, in which the shunting effect of the capacities results in a decrease of the amplification per stage with increasing frequency, so that in low-frequency amplifiers there arises an unwelcome variation with frequency, while at radio-frequencies the amplification attained per stage is very small.

The Capacities in a Single Stage.

In order to give a numerical idea of the magnitudes of the stray capacities it may be stated that in the modern high-amplification valves the capacities between the individual electrodes amount to about 1 to 4 $\mu\mu$F., and do not vary greatly in magnitude. To these electrode capacities must be added the parallel capacities of the leads and the parts of the circuit connected to them. In a reasonably carefully constructed instrument the additional capacities so caused will have a value of about 2 to 6 $\mu\mu$F. The measurement of these small capacities is not altogether easy, and requires specially accurate measuring equipment. Moreover, the individual capacities cannot be directly measured on account of the arrangement of the electrodes, but must in all cases be found from the sum of the partial capacities with the help of several measurements and a simple calculation.

For the discussion of the stray capacities and their effects one stage of an amplifier will be isolated and discussed in detail. In Fig. 1, in which this amplifying stage is shown, the three capacities within the valve are indicated by dotted lines. All circuit elements of the grid circuit are included in the impedance $\mathbf{Z}_g$, and those of the anode circuit in $\mathbf{Z}_a$. It hardly needs to be specially mentioned that $\mathbf{Z}_g$ and $\mathbf{Z}_a$ represent complex operators, and include not only the couplings but also the capacities due to the *preceding*

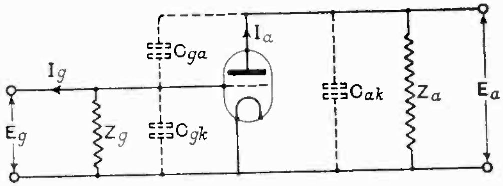

Fig. 1.

and *following* stages. The network of Fig. 2 corresponds to the amplifying stage of Fig. 1, and may be substituted for it. The valve is here replaced in the usual way by an A.C. generator with the E.M.F. $\mu\mathbf{E}_g$ and an internal resistance R_i. From this network there follows at once the well-known equation:

$$\mu\mathbf{E}_g = \mathbf{I}_a . R_i + \mathbf{I}_a\mathbf{Z}_A \quad \quad (1)$$

Taking as positive the direction of $\mathbf{E}_a$ shown by the arrow in Fig. 2, there follows also:

$$\mathbf{E}_a = -\mathbf{I}_a\mathbf{Z}_a \, * \quad \quad (2)$$

The diagram of Fig. 3 is drawn on the basis of these equations. In this diagram there is shown not only the magnitude of the various voltages, but also their phase-angles ϕ or $180 - \phi$ and ψ relative to the anode current $\mathbf{I}_a$. There has been selected the special case in which the impedance $\mathbf{Z}_A$ in the anode circuit consists of a pure resistance shunted

* In this article the symbolic notation is adopted; bold-faced letters represent complex quantities or vectors.

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by a capacity. It can be seen from the diagram that the voltage $\mathbf{E}_a$, which from Equation (2) is opposite in direction to the voltage-drop $\mathbf{I}_a\mathbf{Z}_A$, and the voltage $\mu\mathbf{E}_g$, or $\mathbf{E}_g$ itself, are *not* in exactly opposite sense. For further discussion, therefore, $\mathbf{E}_a$ is resolved into two components, of which one, $E_a.\cos\ (\phi - \psi)$, is exactly opposed to $\mathbf{E}_g$ while the other, $j.E_a \sin(\phi - \psi)$, is at right-angles to $\mathbf{E}_g$.

Feed-back Effects across the Grid-anode Capacity.

As Fig. 2 shows, the three valve capacities are so arranged that the capacities C_{gk} and C_{ak} are directly in parallel with the grid and anode circuits respectively. The third capacity C_{ga}, on the other hand, effects a coupling between these two circuits. In consequence of this the alternating voltage $\mathbf{E}_a$ on the anode can reach the grid through the capacity C_{ga}, so producing reaction from the anode circuit to the grid circuit. As the result of this reaction part of the alternating current in the anode circuit flows to the grid, and its effect on the grid circuit is as though there had been connected in parallel with that circuit an additional impedance. The direction of the current flowing to the grid can be seen from the vector diagram of Fig. 4; this part of the anode current corresponds to a grid current of the value:

$$\mathbf{I}_g \text{ react.} = j\omega C_{ga}(-\mathbf{E}_a) = -j\omega C_{ga}.E_a.\cos(\phi - \psi) - j\omega C_{ga}.jE_a \sin(\phi - \psi) \quad .. \quad (3)$$

As the foregoing considerations show, this formula only includes the reaction from the anode circuit. Only the voltage $\mathbf{E}_a$ on the anode resistance reacts back into the grid circuit; in setting up the formula for the

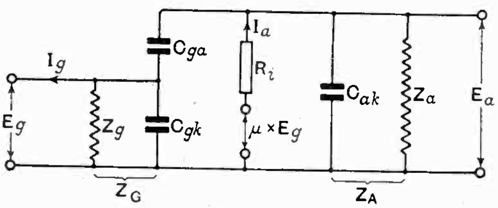

Fig. 2.

total current flowing in the grid circuit it would be necessary to consider the voltage difference $-(\mathbf{E}_a - \mathbf{E}_g)$. As will be shown below, and as can easily be seen from Formula 5, this means no more than that in addition to the impedance due to the feed-back effect the capacity C_{ga} itself is to be regarded as permanently connected in parallel with the grid circuit.

On the assumption that C_{ga} is a pure capacity, without losses, the current $\mathbf{I}_g$ react. must be at right-angles to the voltage $\mathbf{E}_g$ (see Fig. 4). The admittance of the corresponding additional impedance just mentioned in the grid-circuit has the value:

$$\frac{1}{\mathbf{Z}_g \text{ react}} = \frac{\mathbf{I}_{g1}}{\mathbf{E}_g} + \frac{\mathbf{I}_{g2}}{\mathbf{E}_g} = -j\omega C_{ga}.\frac{E_a}{E_g}.\cos(\phi - \psi) + \omega C_{ga}\frac{E_a}{E_g}\sin(\phi - \psi) \quad .. \quad (4)$$

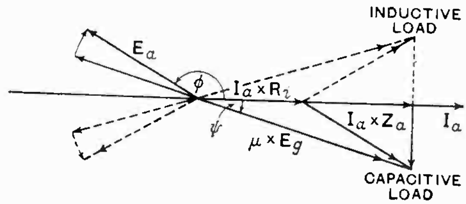

Fig. 3.

As the diagram of Fig. 4 also shows, this part of the current can be resolved into two components, one of which, $\mathbf{I}_{g1}$, is at right-angles to the voltage $\mathbf{E}_g$, while the other component falls along $\mathbf{E}_g$. The additional impedance parallel to the grid circuit can be resolved in a corresponding way into a capacity with a pure resistance in parallel with it; it may therefore be regarded as a condenser with losses. The sign of this resistance depends upon the sense of the voltage-drop $\mathbf{I}_a\mathbf{Z}_A$, and therefore upon the sign of the loading in the anode circuit. In the diagram (Fig. 3) a capacitative loading of the anode circuit is assumed. If this were inductive the diagram would have to be raised above the axis; in this case the voltages shown dotted in the figure would arise. As before, the additional impedance in the grid circuit would be made up of a capacity and a resistance in parallel. This resistance, however (corresponding to the component of current $\mathbf{I}_{g2}'$, in contrast to the case already discussed), is negative; if this negative resistance is numerically greater than the positive resistances of the grid circuit, self-oscillation will occur. In conclusion, it should be mentioned that in

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addition to the extra impedance caused by feed-back from the anode circuit, the grid-anode capacity itself is *always* present as a load on the grid circuit, even when the anode circuit is short-circuited ($\mathbf{Z}_a = 0$); but as there is in this case no alternating voltage $\mathbf{E}_a$ on the anode, there can be no reaction into the grid circuit. From the equations deduced above and the circuit diagram of Fig. 2 there follows for the total admittance of the grid circuit this equation:

$$\frac{1}{\mathbf{Z}_G} = \frac{1}{\mathbf{Z}_g} + j\omega C_{gk} + j\omega C_{ga}\left(1 - \frac{\mathbf{E}_a}{\mathbf{E}_g}\right)$$
$$= \frac{1}{\mathbf{Z}_g} + j\omega C_{gk} + j\omega C_{ga} - j\omega C_{ga}\cdot\frac{E_a}{E_g}\cos(\phi - \psi)$$
$$+ \omega C_{ga}\frac{E_a}{E_g}\sin(\phi - \psi) \quad \ldots (5)$$

From this equation, and from what has been said above, there follows the well-known and important fact that the magnitude of the feed-back depends on the ratio $\frac{E_a}{E_g}$, or, in other words, upon the voltage amplification of the stage.

In cases where the assumption made above, that the insulation-resistances parallel to the valve capacities can be neglected, does not apply, the admittance $\frac{1}{R_{ga}} + j\omega C_{ga}$ must be substituted for the admittance $j\omega C_{ga}$ in the formula. Formula (5) then takes the form:

$$\frac{1}{\mathbf{Z}_G} = \frac{1}{\mathbf{Z}_g} + j\omega C_{gk} + \left(j\omega C_{ga} + \frac{1}{R_{ga}}\right)\left(1 - \frac{E_a}{E_g}\cos(\phi - \psi) - j\frac{E_a}{E_g}\sin(\phi - \psi)\right)$$
$$= \frac{1}{\mathbf{Z}_g} + j\omega C_{gk} + j\omega C_{ga} - j\omega C_{ga}\frac{E_a}{E_g}\cos(\phi - \psi)$$
$$- \frac{1}{R_{ga}}\cdot j\cdot\frac{E_a}{E_g}\sin(\phi - \psi) + \frac{1}{R_{ga}}$$
$$- \frac{1}{R_{ga}}\cdot\frac{E_a}{E_g}\cos(\phi - \psi)$$
$$+ \omega C_{ga}\frac{E_a}{E_g}\sin(\phi - \psi) \quad \ldots (5a)$$

Since for capacitative loading of the anode circuit the angle $(\phi - \psi)$ lies between 90 deg. and 180 deg., for this case the ohmic resistance appearing in the grid circuit will be considerably increased on account of feed-back over the insulation resistance Z_{ga}; the capacity appearing in the grid circuit will, however, be slightly decreased. If the load in the anode circuit is inductive $(\phi - \psi)$ lies between 180 deg. and 270 deg., and the sine becomes negative, so that there results on the one hand a reduction of damping, and on the other an increase in the added capacity of the grid-circuit.*

Besides the reaction from the anode circuit already discussed, there exists a similar transference of energy from the grid circuit to the anode, which also takes place through the grid-anode capacity. This effect will not be gone into more deeply here, for it behaves in a manner exactly opposite to the feed-back from anode to grid, and therefore decreases as the voltage amplification of the stage increases. Even when the voltage amplification is comparatively low the effective capacity introduced into the anode circuit by transference of energy from the grid can be neglected in comparison with the capacity C_{ak} between anode and cathode.

Effect of the Feed-back from the Anode in Different Types of Amplifier.

In considering the effect of the feed-back from the anode in the various types of amplifier we shall have, according to the considerations just advanced, three different cases to distinguish, each case corresponding

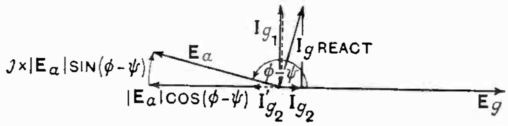

Fig. 4.

to a different type of load in the anode circuit. If the total impedance $\mathbf{Z}_A$ in the anode circuit is purely resistive, the additional impedance in the grid-circuit is capacitative only, for in this case no additional resistance enters. In practice, however, a purely resistive load is very difficult of realisation. It is true that in tuned amplifiers the anode impedance may be regarded as purely resistive when the circuits are exactly in resonance, but this ideal case is no longer realised when these circuits are detuned to even the slightest

* *See* L. Hartshorn, "The Input Impedances of Valves at Low Frequencies," *Proc. Phys. Soc.*, Vol. 39, Part 2, 15th Feb., 1927.

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extent. The direction of the detuning decides which of the two remaining cases applies. In amplifiers in which the coupling is by resistance only the ideal case only occurs at very low frequencies. Here, however, the harmful capacities no longer play any part. At high frequencies we at once have the case of a pure resistance shunted by a capacity, which will now be considered.

If the anode circuit consists of a pure resistance shunted by a capacity, or, more generally, if the anode circuit can be regarded as capacitative, then, in addition to the capacity already mentioned, there is introduced into the grid circuit by the feed-back from the anode a positive real component; that is to say, a positive ohmic resistance. This case is of importance for the calculation of the effects of frequency in resistance-coupled low-frequency amplifiers.* In this calculation it must be remembered that the additional capacity in the grid circuit, which here generally outweighs the static capacities, always behaves as an extra capacity in the plate circuit of the preceding stage; the load in the anode circuit of any stage is therefore dependent on the anode circuits and amplifying properties of subsequent stages. On this account it is only possible to work out the exact conditions by starting with the anode circuit of the *last* valve and calculating *backwards* stage by stage. This is especially true for resistance amplifiers, but really applies to amplifiers of all types.

The feed-back from the anode is clearly of extreme importance also in designing resistance-coupled high-frequency amplifiers. *The appearance from this cause of a resistance in the grid circuit is of very special importance in the design of circuits containing an aperiodic high-frequency amplifier.* If there is a tuned circuit on the input side of such an amplifier, as is the case in the majority of the circuits so far published, then the damping of this circuit will be very considerably increased by this additional resistance. To give a numerical idea of the magnitude of this effect, it may be mentioned that in an aperiodic high-frequency amplifier designed to operate on the broadcast band of wavelengths, the real component has a value of the order of 10,000 ohms or less. The realisation of this fact has a very important bearing on the improvement of the selectivity of receivers with aperiodic high-frequency amplifiers, and this point will be gone into in a later communication.

There often occurs in practice the case of an inductive load in the plate circuit. In this case the feed-back from the anode results in the appearance in the grid circuit of a negative real component; that is, a negative ohmic resistance. This leads to self-oscillation as soon as it outweighs the total positive resistance in the grid circuit. This case of inductive load is especially prominent when working with a sharply tuned high-frequency amplifier, for here, as already mentioned, detuning to a very small extent suffices to make the anode circuit inductive. When self-oscillation occurs in these amplifiers as a result of the inductive load it is on this account not possible to obtain stability by an apparently accurate adjustment to resonance. The tendency to oscillation can only be overcome when the feed-back from the anode is cancelled by applying one of the well-known neutralised circuits. The same considerations hold, as need hardly be remarked, for low-frequency amplifiers, in which self-oscillation can also occur as a result of inductive anode impedances.

Further Effects of Stray Capacities.

So far the stray capacities have only been considered with reference to an amplifying stage embodying a three-electrode valve. In the case of the four-electrode valve we must take into consideration, besides the three capacities mentioned, the capacities between the second grid and the other electrodes. It is possible, with the help of these extra capacities to introduce further effects into the grid circuit and thus, by using special circuits, to attain a partial or complete compensation of the effects already discussed. Alternatively, it is possible to make use of the screening-grid arrangement to reduce considerably the anode-grid capacity. The self-capacities of the windings in choke and transformer-coupled amplifiers

* *See* M. v. Ardenne and W. Stoff, "Die Berechnung der Scheinkapäzitaten bei Widerstandsverstärkern," *Jahrbuch*, Part 3, Vol. 30, 1927; and M. v. Ardenne and W. Stoff, "On the Values and the Effects of Stray Capacities in Resistance-coupled Amplifiers," *Proc. I.R.E.*, No. 11, Nov., 1927.

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must be regarded as really harmful, for their chief effect is to increase the grid-cathode capacity of the stage to which they are connected.

Capacities which arise, as the result of unsuitable wiring, between the grids of valves which do not follow one another directly, must be regarded as especially dangerous, on account of the marked reaction effects to which they give rise. These effects are stronger than those derived from a single stage on account of the much higher alternating voltages that are carried back. Owing to the addition of successive phase-displacements self-oscillation can arise in this way even from capacitative anode circuits; in multi-stage amplifiers especially capacities which amount to no more than a fraction of a micro-microfarad but which act as the coupling between the input and output sides of the amplifier, may often lead to a self-oscillation. In amplifiers with the stages built as separate units stray capacities of the last-mentioned type can easily be avoided by screening.

These capacities cause special difficulties in the construction of multiple valves, where great care must be taken on this account in the construction of the different stages. On the other hand, the compact construction of the circuit in multiple valves offers the advantage that the capacities, and with them the feed-back from the anodes, can be enormously reduced.

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.

Screened Grid Valves.

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

SIR,—May I thank Herr Von Ardenne for so courteously calling my attention to the reference made in his book to the possibility of utilising the *negative slope* of screen grid valves in amplifiers. Unfortunately, I have not had an opportunity of reading the book in question, but I gather from the quotation given that, at the time of writing, Herr Von Ardenne was more concerned with avoiding the region in question than with its utilisation.

As regards the latter part of his letter, I am glad to find myself in agreement with so distinguished a worker. More recent experiments of mine, which were confined to low-frequency conditions, bring out the fact that quite uniform amplification is obtainable when rather high resistances are employed. There are, indeed, other valuable applications of the method to which, however, this letter is hardly the place to refer.

JOHN J. DOWLING.

Short-wave Aerial Systems.

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

SIR,—In the Editorial in the June issue, the expression for the sending end impedance of an aerial is given as

$$\sqrt{\frac{L}{C}} \cdot \frac{1}{j \cdot \tan wh\sqrt{L \cdot C}}$$

This expression can be derived very simply by the method given in the article on "Short-wave Aerial Systems" in the same issue.

Thus, if Fig. 8(*d*), page 310, represents the conditions at a distance h from the free end of the aerial, we have

$$D_2\hat{B}_2A_2 = \frac{1}{2} D_2\hat{C}_2A_2 = \frac{1}{2} \cdot \frac{4\pi h}{\lambda}$$
$$= \frac{wh}{v} = w \cdot h \cdot \sqrt{L \cdot C}$$

The sending end impedance is

$$\frac{V_2}{I_2} = R_0 \frac{A_2B_2}{A_2D_2} = \sqrt{\frac{L}{C}} \frac{1}{j \tan wh\sqrt{L \cdot C}}.$$

E. GREEN.

Poldhu, Cornwall.

On the Equivalent Inductance and Capacity of an Aerial.

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

SIR,—It is evident from Prof. Howe's July editorial that we are at cross purposes. I have found an approximate value for the equivalent inductance and capacity of an aerial which, when any loading inductance is added, will give approximately the same resonant frequency as when the same loading inductance is added at the foot of the aerial. Prof. Howe, after stating this test of equivalence in his June editorial, deduced a theoretical value which is applicable when the aerial is not loaded, and in his July editorial he obtains, for a loaded aerial, a value which is a function of the loading inductance and not a characteristic of the aerial itself.

I realise a fixed value which is exact for all values of loading inductance cannot be obtained, and I have no quarrel with Prof. Howe's results as deduced from the definitions he uses, though I am not convinced that his definitions would be universally accepted.

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My standpoint, however, is simply this: that the formula

$$\omega_1 L_x = \sqrt{L/C} \cot \omega_1 h \sqrt{LC} \quad .. \quad .. \quad (1)$$

can be replaced by an approximate formula of the type

$$\omega_1(L_1 + L_x) = 1/\omega_1 C_1 \quad .. \quad .. \quad (2)$$

where L_1 and C_1 are *constants*, and functions of L and C only. If, for a given frequency ω_1, the necessary added inductance as calculated from equation (1) is L_x, and as calculated from equation (2) is (say) L'_x, then by making

$$L_x \doteq L'_x \text{ when } \omega_1 \longrightarrow 0 \text{ (\textit{i.e.}, when } L_x \longrightarrow \infty)$$

and by making the equations have the same root when L_x and $L'_x = 0$, we deduce the values

$$L_1 = hL/2.46 \text{ and } C_1 = hC.$$

Furthermore, these values of L_1 and C_1 make L'_x approximately equal to L_x for *all* values of ω_1: it can be shown that the maximum absolute error in L'_x is only $0.073\ hL$, and this occurs when ω_1 is zero or when the resonant wavelength is infinite.

The fact that Prof. Howe said there is "no special merit" in the above value of L_1 "beyond the fact that the corresponding value of the equivalent capacity is simply hC" and the fact that Prof. Howe continues to advocate values of L_1 and C_1 which are of little use for practical calculations, seemed to make these further comments desirable.

L. S. PALMER.

The College of Technology,
Manchester.

[Dr. Palmer's statement that formula (1) can be replaced by an approximate formula of type (2) where L_1 and C_1 are constants was not only disproved but a curve was given on page 359 showing how greatly L_1 and C_1 varied. Moreover, we showed that the value $L_1 = hL/2.46$ was only deduced by assuming that $C_1 = hC$,—admittedly a very convenient assumption, but with no more scientific basis than the assumption that $C_1 = 0.9\ hC$ or $1.1\ hC$. As, however the letter raises no point which was not completely answered in our July editorial we do not propose to pursue the matter further. We have just received for review a copy of Hund's "Hochfrequenz Messtechnik" (2nd edition) in which we find 18 pages (403 to 421) devoted to this subject. We commend them to Dr. Palmer and feel sure that after studying them he will alter his opinions as to the general acceptance of our definitions and as to the practical utility of the formulæ based on them.—ED.].

BOOK REVIEW.

AN INVESTIGATION OF A ROTATING RADIO BEACON. By R. L. Smith-Rose and S. R. Chapman, pp. vii.+45. H.M. Stationery Office. Price 2/3 net.

This is issued as Special Report No. 6 of the Radio Research Board, and consists of an account of experiments carried out on an experimental rotating loop beacon transmitter erected at Fort Monckton, near Gosport. The beacon was of the type used by the Air Ministry and consists of an ordinary valve transmitter with a loop aerial, the loop being rotated at a uniform rate. Any receiver can be used to pick up the signal which will vary in strength between a maximum and zero as the loop rotates; a characteristic signal is emitted when the direction of the loop is north and south, and by carefully observing the time which elapses between this signal and the zero or minimum the observer can determine his direction with respect to the beacon. The object of the investigation was to determine the reliability of the bearings under various conditions, especially for marine navigation purposes. The system has the great advantage that one only requires an ordinary wireless receiver and a suitable watch; it is, therefore, of special interest to know that as the result of a series of observations carried out in ships under sea-going conditions, it has been found that the results are as accurate as those given by the other methods under the most favourable conditions.

Difficulty was experienced in maintaining a uniform speed of rotation, due to fluctuations in the supply voltage. This was overcome by a somewhat elaborate system employing an electrically maintained tuning fork driving a phonic motor geared to the beacon spindle. This was found to exercise sufficient control to maintain the speed constant provided the supply voltage did not vary too much from the normal value. Any variation was indicated by a stroboscope employing a Neon lamp operated from the tuning fork.

A great amount of experimental work was done with the object of discovering and, if possible, removing the cause of the lop-sidedness of the figure-of-eight polar radiation curve. The maxima were unequal and the zero on one side was replaced by a minimum value.

Although a metal wire screen around the transmitter equalised the minima it did not make them sharp, and the improvement was doubtful. It seems probable that the defects were due to some extent to the site on the edge of a sheer drop of 25 feet to the sea.

The beacon had a 6-turn frame 5 feet square, carrying a current of 40 amperes at a wavelength of 525 metres. Oversea reliable bearings can be obtained up to 50 miles by night and up to 100 miles by day, but bearings can be obtained at longer ranges with an accuracy depending on the care of the observer, who should take the mean of a number of observations to minimise the effect of night and observational errors.

In an appendix the authors give a theoretical analysis of the effect of currents set up in a tuned aerial in the neighbourhood of the transmitter. There appears to be something wrong with formula (2), however, which makes the current set up in the aerial depend only on the field strength and resistance, without any reference to the height of the aerial.

The pamphlet should be studied by everyone interested in the applications of wireless telegraphy to navigation. Its results hold out every promise that the rotating beacon will prove of great practical utility.

G. W. O. H.

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A New Idea for a Detector Valve.

Y. B. F. J. GROENEVELD, Balth. v.d. Pol and K. Posthumus have shown that the grid current detection properties of a receiving valve depend almost entirely upon the grid current characteristics and the constants of the grid circuit. Measurements have shown that the anode voltage has but little influence.

The grid current characteristics can be represented substantially by an exponential function of the form

$$i_g = i_{go}\epsilon^{\frac{V_g - V_{go}}{V_T}}$$

where i_g = grid current,
V_g = grid voltage,

i_{go} and v_{go} = constants, which depend on each other, and V_T = the voltage increase required for a multiplication of the current by ϵ. The authors call this voltage the *temperature voltage*.

It thus appears that the slope of the grid current curve, logarithmically plotted, is exclusively determined by the temperature voltage. This temperature voltage is indicated by

$$V_T = \frac{kT}{e}$$

where k = constant of Boltman,
T = absolute temperature,
e = charge of electron.

The slope of the grid current curve, logarithmically plotted, is thus entirely determined by the temperature of the filament. With equal filament temperatures the nature of the material used for the filament has no influence on the detecting properties.

The experimental shape of the grid current characteristic, as described by the authors, is based on Maxwell's law of velocity distribution.

For oxide filaments the temperature voltage has a value of about 0.1 V. For thoriated filaments the average temperature voltage is 0.18 V. and for tungsten 0.25 V.

It can be calculated that the detection

$$\Delta V = \frac{1/4\, E_0^2}{V_T}$$

where E_0 = amplitude of the A.C. voltage applied.

This formula only applies for small values of E_0 $\left(\frac{E_0}{V_T} \ll 1\right)$ and for large values of the grid leak resistance $\left(\frac{1}{R} \ll \frac{di_g}{dv_g}\right)$.

From this it follows that for the *detection of weak signals* valves with a small temperature voltage, *i.e.*, with a low filament temperature, are an advantage, as the detection will be strongest with slowly moving electrons.

A filament emits electrons, partly with large, partly with small velocities. If it were possible to separate the electrons with small velocities and use them for detection, a device possessing considerably more sensitive detecting properties than a normal valve would be obtained.

Mr. K. Posthumus, of Messrs. Philips' Laboratories, Eindhoven, has suggested the idea of effecting this separation of electrons by means of a magnetic field. Under the influence of such a field the slow electrons will be deflected to a greater degree than the swift ones and by conducting these slow electrons through a separate grid, it will be possible to increase materially the detecting properties of a valve.

THE NATIONAL RADIO EXHIBITION, OLYMPIA,
SEPTEMBER 22nd to 29th, 1928.

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Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

A TRANSMITTER-MODULATING DEVICE FOR THE STUDY OF THE KENNELLY-HEAVISIDE LAYER BY THE ECHO METHOD.—Tuve and Dahl. (*Proc. Inst. Rad. Eng.*, June, 1928, V.16, pp. 794–798.)

The importance is emphasised of very short duration and proper spacing for the peaks, and objections to the original modified A.C. modulations are pointed out. The method now described for modulating the transmitter depends on the very sharp, widely and non-uniformly spaced pulses produced in a " multivibrator " two valve circuit (Abraham and Bloch), when this is used in an unbalanced condition. Examples of reflections obtained by this method are given. The non-uniformity of spacing is useful in the identification of the separate peaks.

NOTE ON TOTAL REFLEXION OF ELECTRIC WAVES AT THE INTERFACE BETWEEN TWO MEDIA.—H. M. Macdonald. (*Proc. Royal Society* July, 1928, No. A, 783, pp. 523–525.)

In a previous communication (*ibid*, A, Vol. 108, p. 386) it was assumed that when total reflexion takes place at the interface between two media, the electric force in the disturbance in the second medium is in the plane of the wave-front ; it may be shown that it is impossible in this case to satisfy the condition that the electric and magnetic forces are both in the wave-front in the second medium.

The object of the present communication is to investigate the disturbance in the second medium, and to obtain the changes of phase in the reflected waves in the first medium.

ZUR THEORIE DER AUSBREITUNG ELEKTROMAGNETISCHER WELLEN LÄNGS DER ERDOBERFLÄCHE (The Propagation of Electromagnetic Waves over the Earth's Surface).—R. Weyrich. (*Ann. d. Phys.*, 19th March, 1928, V. 85, pp. 552–580.)

Propagation from a vertical Hertz dipole is considered, in a parallel slab of dielectric between perfectly conducting planes. The dielectric slab is assumed to have S.I.C., permeability and conductivity.

SUR LES PROPRIÉTÉS DIÉLECTRIQUES DES ÉMULSIONS GAZEUSES (Dielectric properties of gaseous emulsions).—C. Pawlowski. (*Comptes Rendus d.l. Société Polonaise de Physique* No. 6, 1926, pp. 44–55 ; abstracted in Phys. Berichte, 15 June, 1928.)

By gaseous emulsions are meant suspensions of small drops of liquid in a gas. If these drops have no electric charge, the dielectric constant can be calculated by Wiener's formula. Actual dielectric tests on artificially produced mists (including a water mist) show that the formula does not then apply : it allows neither for the structure of the mist nor for the influence of the frequency of the A.C. field used for the measurement. The dielectric constant decreases with increasing frequency and with increasing amplitude.

LA PRÉCISION DES MESURES ET SON CONTRÔLE DANS L'OPÉRATION DES LONGITUDES MONDIALES (The Precision of Measurement, and its Control, in the Determination of World Longitudes).—A. Lambert. (*Comptes Rendus*, 21st May, 1928, V. 186, pp. 1425–1427.)

Curves are given which suggest variations in the time of long distance, long wave wireless communication amounting to as much as 0.001 sec. over distances of the order of 12,000 kms. The author says however that the value for velocity of propagation derived from these observations is so low (mean $V = 247{,}000 \pm 9{,}000$ km./sec.) as to suggest some systematic error in registering the arrival of the waves.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

SOME ELECTROPHYSICAL CONDITIONS DETERMINING LIGHTNING SURGES.—H. Norinder. (*Jour. Franklin Inst.*, June, 1928, V. 205, pp. 747–765.)

A paper describing recent work done in Sweden, and the conclusions drawn from it. Subheadings, with extracts, are as follows :

(1) Distribution of charge and calculation of field force. Certain assumptions have to be made : with these, the calculated field force, with the earth's surface insulated, becomes about 60 kV/m. If the surface is supposed to be quite conducting, Kelvin's method of images leads to a doubling of this value. Direct observations have led the writer to find gradients of 100 to 150 kV/m.

(2) Dimensions of the field regions. The writer concludes that the thunder-cloud is formed of a few large regions of different polarity rather than of a great number of smaller regions. It has been proved that the greater number of discharges take place within the internal parts of the thunder-storm atmosphere, only a small proportion passing from cloud to earth or from earth to cloud. Lightning surges in transmission lines are generally positive, though some discharges can cause double polarity.

(3) The regions discharged by lightnings. A very pronounced limitation has been found to the size of these regions, agreeing with the high values found for the field force.

(4) Research on the discharging rate of lightning : by the use of a special cathode-ray oscillograph, time variations of an order of magnitude of microseconds can be recorded. The ray only records when a suitable voltage or current is applied to the

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deflecting circuits, the instrument thus being independent of the time of arrival of the phenomenon to be recorded. This is attained by a special device which makes the ray itself act as a relay. Lightning discharges in an aerial have thus been recorded, and examples are given. Two types of discharge are recognised, one very slowly discharging (probably taking place mainly between internal parts of the cloud) and one rapidly discharging (earth-to-cloud or *vice versa*); but sometimes the rapid may occur within the cloud itself. This may especially be the case for secondary lightning initiated by the ionisation processes of primary slowly moving lightnings. Sometimes a super-imposed high frequency (of an amplitude of only a few per cent. of the total field variation) is observed on the usual non-oscillatory discharges. The main part of the statics produced in a wireless receiver is due to this high frequency, whose period is estimated to vary between 10 and 30 microsec.

Sur L'Ionisation Intense de l'Air dans les Lieux Fréquemment Foudroyés (Intense ionisation of the air in spots frequently struck by lightning).—Dauzère and Bouget. (*Comptes Rendus*, 18 June, 1928, V. 186, pp. 1744-1746.)

In a former paper (*C.R.*, 4 June, 1928), the authors described tests made by them concerning the predilection of lightning for certain spots, and showed that these spots are not necessarily prominent points, but that the choice depends on the geological composition of the ground. They found that compact, chalky soils enjoy a very great security from lightning, whereas siliceous rocks and soils enclosing minerals are often struck. In the present paper, the authors mention tests to support their derived theory—that the chosen places are those where the air near the ground is more ionised than elsewhere. These tests (with the Elster and Geitel apparatus) showed that spots exist where the ionisation of the air near earth is *constantly* greater than in neighbouring spots at the same altitude and under the same physical conditions; that this depends on the geological constitution of the soil; and that the more highly ionised spots are particularly liable to be struck by lightning. Among the suggested practical applications of this knowledge is the proposal that the use of the electrometer should help in geological exploration.

The Upper Atmosphere.—J. Bartels. (*Naturwissenschaften*, 4th May, 1928.)

A summary of our present knowledge, based on observations of meteors, luminous high clouds, auroræ, ozone, long distance propagation of sound, terrestrial magnetic variations, and radio propagation.

Étude des Fluctuations Nocturnes de l'Ozone Atmosphérique (Night fluctuations in atmospheric ozone).—D. Chalonge. (*Comptes Rendus*, 25th June, 1928, V. 186, pp. 1856-1858.)

The author's measurements lead him to the following conclusions: The higher atmosphere never contains less ozone at night than by day; the thickness of the ozone layer at night varies little from a mean value which (at Paris) is 335 hundredths of a millimetre (reduced to N.T.P.): *i.e.*, it presents no seasonal variation, at any rate for the period studied (October 1927—April 1928); and the author's final conclusion is that to account for the creation and the fluctuations of the ozone at high altitude, other causes besides ultra-violet solar radiation must be looked for.

Observations on the Height of the Ozone in the Upper Atmosphere.—Götz and Dobson. (*Nature*, 14th July, 1928, p. 79: from Royal Society Meeting.)

Measurements of the height over Arosa (Switzerland) show that it is greatest when the amount is large and least when the amount is small. There is also evidence of an increase of height from autumn to spring. The average height seems to be between 35 and 40 km.

On the Quantity of Electricity Discharged in a Lightning Stroke.—A. W. Simon. (*Proc. Nat. Acad. Sciences*, June, 1928, V. 14, pp. 458-460.)

Calculations based on the experimental work of Norinder lead the author to conclude that the order of magnitude is probably 10 coulombs.

The Raman Effect and the Spectrum of the Zodiacal Light.—L. A. Ramdas. (*Nature*, 14th July, 1928, V. 122, p. 57.)

The Raman effect, originally found in the case of liquids, has been obtained by the writer for the vapour of ether. The same special spectrograph also photographed the spectrum of the zodiacal light, no trace being found of light of wave-lengths longer than about 5,000 A.U. This indicates that the scattering material producing the zodiacal light is diffused in atomic or molecular condition, and the writer suggests that the production of modified frequencies by the Raman effect may account for the observed weakness of polarisation of the light.

Carriers of Electricity in the Atmosphere.—A. M. Tyndall. (*Nature*, 7th July, 1928, V. 122, pp. 16-17.)

Substance of a recent lecture on the study of ion-motion in an electric field.

The Correlation of Solar and Terrestial Magnetic Phenomena.—S. Chapman. (*Nature*, 23rd June, 1928, V. 121, pp. 989-991.)

Sur la Loi de Variation de Densité de L'Atmosphère en Fonction D'Altitude (The Law of Variation of the density of the atmosphere as a function of the altitude).—Esnault-Pelterie. (*Comptes Rendus*, 2nd July, 1928, V. 187, pp. 55–56.)

The author derives a formula which he claims allows for the first time the accurate determination of altitude by simple measurements of temperature and pressure, at any rate for layers of sufficient height.

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La Prévision des Cyclones de la mer des Antilles et du Golfe du Mexique (Forecasting cyclones).—Laforest Duclos. (*Comptes Rendus*, 2nd July, 1928, V. 187, pp. 17–19.)

The author claims that all the phenomena of our atmosphere are due to the *combined* action of solar heat and the attraction of Sun and Moon. He arrives at a simple formula for f (daily cyclone-tendency); if this exceeds a certain value, a cyclone occurs.

Radioaktive Niederschläge auf Hochantennen (Radioactive deposit on high antennæ.)—F. Schindelhauer. (*Phys. Zeitschr.*, 15th July, 1928, V. 29, pp. 479–487.)

Über die Hypothese, dass die Höchsten Atmosphärenschichten Durch Beta-Strahlen Erwärmt Werden (The hypothesis that the highest layers of the atmosphere are heated by β-rays.)—H. Petersen; reply by W. Anderson. (*Phys. Zeitschr.*, 15th July, 1928, V. 29, p. 492–493.)

PROPERTIES OF CIRCUITS.

Sur une Nouvelle Méthode d'Amplification des Courants Alternatifs à Haute Fréquence (A new method of amplifying H.F. currents).—J. Bethenod. (*L'Onde Élec.*, June, 1928, V. 7, pp. 261–262.)

The method described was patented by the author in 1924. Since then, he says, somewhat similar proposals have been made by the younger Van de Pol (*cf. E.W. & W.E.*, June, 1926). The method depends on the fact that if an oscillating circuit is made up of a condenser C and inductance L both varying periodically but in such a way that always $CL = C_oL_o$, it must behave as if it were a circuit with constant capacity C_o, constant inductance L_o and an apparent resistance

$$\frac{L_o\left(R + \frac{dL}{dt}\right)}{L},$$

where R is the constant ohmic resistance. Now, if L varies periodically with a frequency $\frac{\omega}{2\pi}$ (much less than the natural frequency of the circuit) and if the quantities are chosen suitably, the apparent resistance will periodically take on a negative value during a certain fraction of the period; so that impressed waves tuned to the natural frequency of the circuit will grow indefinitely during this part-period, and an important effect of amplification will be obtained.

The Impedance Adjusting Transformer.—C. T. Burke. (*Rad. Engineering*, May, 1928, V. 8, p. 18.)

"A little consideration will show that if the primary impedance of this transformer is equal to the tube impedance and if the secondary impedance matches the load impedance, one-half the voltage existing in the plate circuit will be expended in heating the plate. It is obvious, then, that the primary impedance should be several times that of the tube." Perusal of the above statement (which he says is typical of the mental haze surrounding the subject) prompts Mr. Burke to write, with an amusing touch, an explanation of the function of transformers designed to match impedances: deriving first the equation for maximum energy transfer:—Turns Ratio = square root of the ratio (Primary Impedance) to (Secondary Impedance): and then showing how this must be combined with other factors in designing the transformer.

The Theory of Wave Filters containing a Finite Number of Sections.—H. A. Wheeler. (*Phil. Mag.*, July, 1928, V. 6, pp. 146–174.)

The Phenomenon of Blocking of Potential of an Insulated Grid.—S. A. Obolensky. (*Teleg. i. Telef. b.p. Nichny-Novgorod*, June, 1928, V. 9, pp. 259–273.)

TRANSMISSION.

Complex Transmitting Antennæ.—Turlygin and Ponomarev. (*Teleg. i Telef. b. prov., Nichny-Novgorod*, June, 1928, V. 9, pp. 281–303.)

Röhrengenerator grosser Leistung für sehr kurze elektrische Wellen (A Power Valve Generator for very Short Waves).—H. Wechsung. (*Zeitschr. f. Hochf. Tech.*, June, 1928, V. 31, pp. 176–183.)

The circuit on which these theoretical and experimental investigations are based was described by A. Esau (E.T.Z., V. 47, No. 11, 1925). On the information thus obtained, two short wave transmitters have been constructed. The smaller delivers 150 watts to the aerial for telegraphy, 60 watts for telephony, with an efficiency of about 38 per cent. The larger gives 700 and 300 watts respectively, with an efficiency of 35 per cent. Both sets work on 2.8 to 6 metres. Telephony is by grid control, which was found to be the best method. Reception at a distance was by the short-wave receiver described by O. Cords (same journal, January and February, 1928).

Technical Considerations involved in the Allocation of Short Waves (frequencies between 1.5 and 30 megacycles).—L. Espenschied. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 773–777.)

The paper begins with a chart which is believed to represent the consensus of present knowledge as to the approximate relation of Optimum Frequency to Distance of Communication, for Short Waves ranging from 10 to 200 metres, and distances 0—7,000 miles; curves for night, day and intermediate periods are shown. For tabulating purposes, the following three bands can be derived from this chart: 200—50m., for distances up to 1,000 miles at night; "regional" in its service range: the shorter waves may cause interference over intercontinental distances at night; 50—20m.,

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"regional" for the daylight portion of the globe but may include practically the entire hemisphere in darkness; and 20—10m. (the shorter limiting wavelength being somewhat uncertain), appearing to be world wide, extreme distances being reached especially over the daylight hemisphere. The International Frequency Allocation (starting 1st January, 1929) is tabulated, and on the same table appear the ideal limiting numbers of channels for telegraph and telephone (channel spacings 1,000 and 10,000 cycles respectively) and also estimated figures based on present general practice. The ratio ideal/present varies from 70 for the shortest wavelengths to 5 for the longest (telegraph), for reasons which are briefly outlined.

BEAM TRANSMISSION OF ULTRA-SHORT WAVES.—H. Yagi. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 715–741.)

Part I. of this paper is devoted to a description of various experiments on wavelengths all below 5 metres and the majority below 2m. Curves are given to show the effect of the earth (the energy transmitted increases when the height of receiver *and* transmitter is increased, no limit having been yet found for this effect; but when either receiver or transmitter is kept fixed, the energy transmitted has a maximum when the other reaches about that height) and of various types of inductively excited antennæ called "wave directors" which can be combined with wave reflectors to give a very sharp beam. Such a wave "director" is an oscillating system of frequency higher than that of the wave to be transmitted; the field converges upon it, and radiation in a plane normal to it is augmented. Part I. concludes with the beam projection of horizontally polarised waves, first parallel to the surface of the earth and then with high-angle radiation. Part II. is devoted chiefly to the magnetron valves used for the production of very short wavelengths down to 12 cms. and the circuit arrangements employed (*c.f.* July Abstracts, paper by K. Okabe). With the shorter waves dealt with in this Part, sheet metal parabolic reflectors may be used. A Barkhausen single valve receiver was employed successfully as a detector on wavelengths of about 150 cms.

On 41 cms. the maximum distance at present covered was reached—1 kilometre: here a crystal detector with a 3-stage note amplifier was used. In the discussion following, the Bureau of Standards Chief of Radio Division assigns considerable importance to the work by his concluding words "I have never listened to a paper that I felt so sure was destined to be a classic."

ALLOCATION OF EUROPEAN BROADCAST WAVELENGTHS (Some New Points of View.)—S. Lemoine. (*E.W. & W.E.*, July, 1928, V. 5, pp. 386–396.)

RECEPTION.

LE PHÉNOMÈNE DE MILLER DANS L'AMPLIFICATION HAUTE FRÉQUENCE (The "Miller" effect in high frequency amplification.)—G. H. d'Ailly. (*Q.S.T. Franç.*, July, 1928, pp. 12–19.)

The writer disapproves of the mathematical treatment which Miller has given to the phenomenon which bears his name, and proceeds to give his own analysis of the effect. The article is to be continued.

LES "SUPER-RÉACTIONS" (Super-regeneration).—P. David. (*L'Onde Élec.*, June, 1928, V. 7, pp. 217–259.)

This paper may be divided as follows:—(I) Definition. (II) Study of an oscillating circuit in function of its resistance-values; (*a*) resistance constant and not zero; (*b*) resistance zero; (*c*) resistance variable as a function of time. (III) Application. Method of action. Three varieties:—(1) Super-regeneration *A* or telephonic (the original "Armstrong circuit.") (2) Super-regeneration *B* or stroboscopic: negative resistance is large to obtain maximum amplification but without reaching saturation point: the free oscillations are not extinguished entirely between two periods, their residue causing beats with the signal: these beats are themselves supersonic, but the stroboscopic effect produces audible whistles. This method is therefore applicable to continuous wave reception, and is particularly useful for short wave working because of its ease of adjustment compared with heterodyne or autodyne methods. (3) Super-regeneration *C* or anti-jamming; negative resistance reaches very high values, giving saturation; incoming continuous waves produce silence undisturbed by interference; signals produced by cutting up the continuous waves become audible together with the interference. Each of these varieties *A*, *B* and *C* is considered and illustrated by curves. The author then deals with the influence of length of wave (showing that increased frequency facilitates the action, but contradicting Armstrong's idea that the amplification grows as the square of the frequency) and then with the question of sensitivity and selectivity. Finally, he verifies his theoretical explanations of the processes involved by cathode-ray records taken with each of the varieties *A*, *B* and *C*. A bibliography of 23 items is attached.

NOTICE SUR LE RÉGULATEUR ANTI-FADING.—(*Rad. Revue*, June 1928, v. 7, p. 692.)

The de Bellescize Anti-fading regulator depends on a relay (working, for example, by the rectified detector-current) which controls the amplification by adjusting the grid voltages.

ENDVERSTÄRKERPROBLEME.—B. D. H. Tellegen. (*Zeitschr f. Hochf. Tech.*, June, 1928, V. 31, pp. 183–190.)

A complete translation into German of the original Dutch paper (see July Abstracts).

SOME CORRELATIONS OF RADIO RECEPTION WITH ATMOSPHERIC TEMPERATURE AND PRESSURE.—G. W. Pickard. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 765–772.)

Night reception and temperature at the receiver are found to be directly related, maximum reception being associated with maximum temperature. This is the reverse of the relation previously found by Austin for day reception, where falling tem-

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perature improved reception; and is therefore another case of the already-established inverse relation of night to day reception. The temperature effect appears to be local to the receiver, for no definite relation was found between temperature at the transmitter and reception.

A correlation between night reception and pressure was also found, signal strength increasing as areas of low pressure passed over the receiver, and decreasing with the passage of high pressures. All these relations do not hold over long periods during which seasonal changes can intervene; and the author points out that as both temperature and pressure are related to solar activity, it is not safe to assume that the correlations are purely those of cause and effect.

ON THE DISTORTIONLESS RECEPTION OF A MODULATED WAVE AND ITS RELATION TO SELECTIVITY.—(*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 848–850.)

Further discussion on the Vreeland paper (see May abstracts). It is mentioned that if the coupling is made to increase at a rate slightly less than as the first power of the frequency, not only is the selectivity improved, but the amplifications at high and low frequencies are equalised. This can be done by employing combinations of capacitive and inductive couplings. Such an arrangement is believed to be more nearly ideal than that discussed by Vreeland.

LOOSE COUPLING (Some notes on two-circuit receivers.)—" Radiophare." (*Wireless World*, 4th June, 1928, V. 23, p. 10.)

A defence of the "old fashioned" variably coupled and separately tuned aerial circuit, on the grounds of its increased signal strength for a given selectivity.

THE OUTPUT STAGE AND THE PENTODE.—N. W. McLachlan. (*Wireless World*, 11th, 18th and 25th July, 1928, V. 23, pp. 30–33, 77–80, and 113–115.)

Will the pentode replace its 3-electrode predecessors as a loud-speaker valve?

SWITCH-OVER THREE.—H. F. Smith. (*Wireless World*, 4th and 11th July, 1928, V. 23, pp. 2–6 and 34–37.)

Full constructional details of an efficient switching scheme giving continuous tuning from 250 to 2,200 metres. It is stated that the loss due to switching, compared with a fixed band receiver and in terms of H.F. voltage across detector grid circuit for a steady input, is only 10 per cent.—which from the point of view of audibility is negligible.

THE PENTODE.—W. I. G. Page. (*Wireless World*, 4th July, 1928, V. 23, pp. 7–9.)

The working principles of the screened grid power output five-electrode valve are explained and its advantages illustrated by curves (*cf.* "Eindversterkerproblemen" in July abstracts).

SYSTEM FOR COMBATING EFFECTS OF STATIC.—E. A. Tubbs. (*E.W. & W.E.*, July, 1928, V. 5, pp. 378–379.)

THE USE OF ALTERNATING CURRENT FOR HEATING VALVE FILAMENTS.—C. W. Oatley. (*E.W. and W.E.*, July, 1928, V. 5, pp. 380–384.)

VALVES AND THERMIONICS.

FREQUENCY VARIATIONS OF THE TRIODE OSCILLATOR.—D. F. Martyn. (*Phil. Mag.*, July, 1928, V. 6, pp. 223–228.)

The writer refers to his paper with the same title in Phil. Mag., November, 1927, and maintains that his mathematical theory there developed (which takes account of the flow of grid current) is the only one which satisfactorily accounts for the large frequency variations observed by various workers, and on a particularly large scale by the writer himself; provided, at least, that the resistances present are not large and the frequency is not too high. To obtain constant frequency, grid-current is to be eliminated; this cannot be done merely by increasing the negative grid bias; other optimum conditions must be observed, and a small condenser in series with the grid coil (automatically adjusting the grid bias) is an advantage. Stringent tests on such an oscillator showed that the frequency remained constant to one part in 100,000 even when the filament current was deliberately varied, and to a much higher degree when the filament current remained steady.

AN EMPIRICAL THERMIONIC EMISSION FORMULA.—V. I. Volynkin. (*Phys. Berichte*, 15th June, 1928, from the Russian.)

The author proposes, for practical use, to modify the formula $J = A \,.\, T^{a} e^{-\frac{b}{T}}$ (where a lies between -1 and 2 according to the various theories) by putting $a = 0$. The formula then becomes $J = A_0 \,.\, 10^{-\frac{a}{T}}$, which gives the same accuracy as the original. For Tungston, $A = 1.48 \times 10^9$ Amp./cm.^{2} and $a = 24{,}400$ abs.

VERY SHORT UNDAMPED WAVES IN A RECEIVING VALVE.—D. Rozanskij. (*Phys. Berichte*, 15th June, 1928, p. 1093, from the Russian.)

The author obtains waves down to 10 cm. by the application of moderate grid potentials, in ordinary receiving valves. Still shorter waves can be produced by enclosing the oscillating inductance inside the valve container (*cf.* July Abstracts, paper by E. Pierret—who however only got down to 14 cms.).

DIE STROMVERTEILUNG IN DREIELEKTRODENRÖHREN . . .—H. Lange. (*Zeitschr. f. Hochf. Tech.*, June, 1928, V. 31, pp. 191–196.)

Final part of the paper abstracted in July and August numbers. Section E deals with practical applications: (1) double-grid valves; (2) transmitter valves, and (3) investigation of secondary

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emission. Section F deals with contact-potentials, which by the help of current-distribution measurements can be determined with an accuracy (± 5 mV.) far greater than by Schottky's method using the starting current, and with much greater ease. The author however admits that complete absence of space charge is essential, so that very small currents (about 10^{-7} amp.) and very high vacuum must be used. Section G is devoted to this latter point.

FOUR-ELEMENT TUBE CHARACTERISTICS AS AFFECTING EFFICIENCY.—D. C. Prince. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 805–821.)

In this work the fourth electrode was only used to eliminate secondary emission in order that the variation in the ratio grid current to plate current in 3-electrode valves might be studied to ascertain the laws of current division. It was thus found that in a tube having symmetrical electrodes, *i.e.*, straight wire filament, concentric cylindrical anode and cylindrical grid (made up of wires parallel to the axis) the ratio was a function of the valve geometry and quite different from that usually found in commercial design. This discrepancy appears to be due to a combination of secondary emission from the anode and unsymmetrical arrangements of grid wires and supports.

DETECTION WITH THE FOUR-ELECTRODE VALVE.—J. R. Nelson. (*Ibid.*, pp. 822–839.)

A mathematical analysis of plate rectification is given and the results applied to a screen-grid valve of type Cunningham CX.322. The screen-grid detector under proper conditions will efficiently utilise the high radio-frequency voltage obtained with the screen-grid valves used as radio-frequency amplifiers. The square law holds for large input voltages, making it practical for the detector to work power valves of the type Cunningham CX.371.

THE SCREEN-GRID TUBE.—N. H. Williams. (*Ibid.*, pp. 840–843.)

Radio-frequency amplification by means of the 3-electrode valve is usually disappointing; in resistance coupling, owing to the phase-relation of the feed-back reducing amplification, and in inductive coupling the feed-back causing self-oscillation for conditions of best amplification. In the shielded grid valve the feed-back is reduced to a negligible amount and the current through the valve is very nearly independent of the plate voltage over the working range. Under these conditions, the voltage amplification becomes the product of the mutual conductance and the load impedance. High impedance in the plate circuit is obtained by using a sharply tuned parallel circuit. With proper shielding such a circuit may be used without producing self-oscillation. At a wavelength of about 400m., amplifications of 80-fold per stage may be obtained, and more at lower frequencies. An overall amplification of more than two million-fold has been measured for a 5-stage amplifier so built that each stage was in a separate compartment of a metal box. As an example of the simplicity of calculation with the screen-grid amplifier in research, mention is made of the measurement of the charge of the electron by the shot effect. Electrons produced by thermionic emission, by photo-electric emission and by ionisation of gases were all measured in this way.

SECONDARY ELECTRONS FROM COBALT.—M. N. Davis. (*Proc. Nat. Acad. Sciences*, June, 1928, V. 14, pp. 460–465.)

The secondary emission from cobalt for low velocity primary electrons was studied. It proves to be much greater than that from any other metal yet investigated.

DIE ABGESCHIRMTEN RÖHREN (Screen-grid Valves). M. v. Ardenne. (*Rad. f. Alle*, July, 1928, pp. 290–297.)

X-ray photographs of screen-grid valves by various makers are included, and characteristic curves of the Telefunken RES.044. These various types are compared in the text. Other types are also described in a paper by N. Werner ("Modern Screen Grid Valves") in the same number.

ÜBER DIE ERREGUNG SEHR SCHNELLER ELEKTRISCHER SCHWINGUNGEN IN DER DREI-ELEKTRODENRÖHRE (The Excitation of very Rapid Oscillations in the 3-electrode Valve). —O. Pfetscher. (*Phys. Zeitschr.*, 15th July, 1928, V. 29, pp. 449–478.)

More work on the "Gill-Morrell" oscillations.

DIRECTIONAL WIRELESS.

AIRPLANE RADIOBEACON VARIATIONS OVERCOME. —(*Tech. News Bull., B. of Stds.*, June, 1928, No. 134, p. 82.)

The errors at night (*cf.* August Abstracts) have been largely overcome by replacing the slanting, trailing aerial by one consisting of a vertical 10ft. metal pole, a special new receiver enabling such a short aerial to be satisfactory. But it is said that on some of the airways the beacons will probably be spaced closer together (power being reduced) so as to allow the short range undistorted directional effect to be used.

AIRCRAFT RADIO AND NAVIGATION.—R. Gunn. (*Journ. Franklin Inst.*, June, 1928, V. 205, pp. 849–863.)

The essential engineering features of aircraft radio and the associated difficulties are discussed. Solutions of these problems are given, although no attempt has been made to describe particular equipment. Two outstanding radio aids to aerial navigation are discussed (the equi-signal radio beacon—see August Abstracts—and a "homing" device which is an application of the same principle to the aircraft receiver) and a method is described whereby these may (with sacrifice of range) be made to operate a visual indicator. A modification of the equi-signal beacon is also mentioned, in which the possible 180 degrees error is avoided by combining an aerial effect with the loop effect and altering the angle between the loops from 135 degrees to about 90 degrees. A heterodyne beacon

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is finally described, in which two crossed loops or other directive systems, quite uncoupled, are fed with H.F. differing by, say, 1,000 cycles. The intensity of the received beat frequency depends within limits on the product of the intensities of the two impressed oscillations, and the system produces a sharp zero signal on either side of a narrow maximum—very suitable for timing. The beacon rotates, sending a non-directional timing-signal when the sharp maximum is directed N. Complications are rather expected when an attempt is made to avoid the 180 degrees error by combining with an aerial.

ÜBER DIE VON LEITERGEBILDEN IN DER UMGEBUNG EINES FUNKPEILERS RÜCKGESTRAHLTEN STÖRFELDER UND DIE VERFAHREN ZU IHRER KOMPENSIERUNG (The error-producing field re-radiated by a conducting structure in the neighbourhood of a direction-finder, and its compensation).—F. A. Fischer. (*E.T.Z.*, 12th July, 1928, V. 49, pp. 1043–1045.)

The basis of this paper has already appeared (*E.T.Z.*, 1925–26–27) in articles dealing with the correction of errors on board ship; but as the further building up of the theory and practice of such compensation is buried in nautical journals *Ann. d. Hydrographie*, 1926–27), the present paper reproduces a general survey of these articles, dealing first with the theory of the re-radiated field and then with its compensation. The paper deals throughout with a D.F. using a loop with associated vertical aerial.

MEASUREMENTS AND STANDARDS.

THE STATUS OF FREQUENCY STANDARDISATION.—J. H. Dellinger. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 579–592.)

A paper by the Chief of Radio Section, Bureau of Standards, Washington.

The measurement of frequency has become of first-rank importance in reducing radio interference. This has come about through the increasing use of all available radio channels, particularly at broadcasting and higher frequencies.

While an accuracy of one half per cent. was satisfactory five years ago, accuracies a thousand times as good are now sought. Nor is it only a question of measurement; frequencies of transmitting stations must actually be held constant with very great accuracy.

The piezo oscillator is meeting the needs of this situation in large part; but commercially available oscillators, without temperature control, are generally reliable only to about 0.03 per cent.—just barely enough to meet the present U.S.A. requirement of one-half kilocycle. The Bureau and other organisations are engaged in a co-operative programme to attain an accuracy and constancy of 0.001 per cent. for the national primary standard, and it is hoped that this, and simultaneous work in other countries, will lead to a corresponding improvement in the agreement between international standards from its present value of about 0.003 per cent. Even this value is in advance of requirements for the present degree of accuracy in general practice; but it is hoped that this will be improved to a value of the order of 0.003 per cent. (*i.e.* a tenfold improvement).

Both aspirations depend very largely on the new possibilities opened up by the temperature-controlled piezo-oscillator carefully used. As regards short-wave transmission (*e.g.*, 30 metres), such H.F. channels cannot at present be spaced closer than 0.1 per cent., but it is likely that for C.W. work under the hoped-for conditions, the channel-width could be narrowed to about 0.01 per cent., and as regards longer waves, several stations could broadcast on the same frequency without heterodyne interference. A point made is that it is *not* true that highly accurate comparisons can be made by sending a quartz plate from one laboratory to another; the complete piezo-oscillator must be sent.

Another point is that even the highest accuracy is less urgent than high constancy.

A short discussion follows the paper.

DAS MASS DER ABWEICHUNG EINER WELLENFORM VON DER SINUS-WELLE (The Measurement of the departure of a waveform from the sine-wave form).—(*E.T.Z.*, 17th May, 1928, pp. 776–778.)

An argument between Benischke and Hammerer over proposals for the establishment of a "deformation coefficient" which shall serve the purposes both of Power Engineering and of Telephony, etc.

SUR LE CHAMP MAGNÉTIQUE ET L'INDUCTANCE D'UNE SPIRE CIRCULAIRE (The Magnetic field and the inductance of a circular helix).—P. Bunet. (*Rev. Gén. de l'Elec.*, 19th May, 1928, V. 23, pp. 853–860.)

The primary object of this paper is to expose as inexact the conclusions of C. Hering relative to the self-inductance of a circular circuit. In addition, however, it investigates the various well-known formulæ to find with what approximation they give their numerical values.

MESURE DE L'INDICE DE RÉFRACTION DE L'EAU POUR LES ONDES ENTRETENUES COURTES (Measurement of the index of refraction of water for short undamped waves).—Martey and Jones. (*Revue Scientifique*, 25th February, 1928, V. 66, pp. 119–120.)

The index of refraction is deduced from the phase-difference between two parts of the same ray, the one having travelled in air and the other through water. Each part has its own receiving circuit, and the induced E.M.F.s in these are used to obtain Lissajous' figures in a cathode oscillograph. The wavelengths used were from 3 to 7 metres, and the values obtained for the index of refraction varied between 8.4 and 9.4.

A DESCRIPTION OF INDUCTANCES AND THE CALCULATION OF THE VALUE OF INDUCTANCES OF THE AIR CORE TYPE.—F. F. Rider. (*Rad. Engineering*, May, 1928, V. 8, pp. 24–27 and June, pp. 50–53.)

The usual formulæ of Lorenz and Nagaoka are supplemented by special ones for spider-web, honeycomb and toroid windings. Mutual inductance is briefly dealt with. The second instalment gives curves and tables for the construction of various types of inductances.

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DIE SCHEINBARE ÄNDERUNG DER DIELEKTRIZITÄTSKONSTANTE TECHNISCHER ISOLIERSTOFFE (Apparent variation in specific inductive capacity of insulating materials in practical use.)—P. Böning. (*Zeitschr. f. Tech. Phys.*, June, 1928, pp. 212–214.)

The theoretical S.I.C. is a constant varying only with temperature and (mechanical) pressure. In the case, however, of the most important dielectrics in practical use, there appears (sometimes very markedly) a dependence of S.I.C. on the voltage applied. The object of this paper is to show that this arises from the same facts which led the writer to propound his "Relation between Breakdown Voltage and Thickness of dielectrics" ("Breakdown Function") in 1908: namely, that conductivity in liquid and solid insulators is of an electrolytic nature; that at the surface between two media, one of which contains dissociated ions, a part either of the kations or the anions is absorbed; and that consequently there must be present in the material inter-communicating, electrolyte-filled canals. The writer derives the following equations for the relation between ϵ (the theoretical constant) and ϵ' (the actual variable value of S.I.C.) where d is the thickness of dielectric, and V the applied voltage:

$$\epsilon' = \epsilon + \frac{A}{V} \qquad (d \text{ constant})$$

$$\epsilon' = \epsilon + Bd^2; \qquad (V \text{ constant})$$

Experimental tests appear to confirm these theoretical results; at low voltages discrepancies occur which however fit in with the assumptions on which the calculations are based.

DATA ON THE VOLTAGE AMPLIFICATION OF RADIO FREQUENCY TRANSFORMERS.—B. K. Osborn. (*Rad. Engineering*, May, 1928, V. 8, pp. 13–15.)

Analysis of the results obtained with testing apparatus outlined in a previous article. The transformers tested are classed as "continuous winding" if the direction of rotation keeps the same as one proceeds from the plate of the amplifier valve, through the primary, to the filament end of the secondary and through the secondary to the grid of the output valve; and as "reversed" if the direction of rotation changes as one passes from primary to secondary. Curves are given showing that the "reversed" winding gives the higher amplification at the maximum point on the curves; moreover, it gives greater selectivity. These effects are not produced in transformers so wound as to have very low capacity between the two windings. Other effects of variation in ways of winding, etc., are shown.

GROUND RESISTANCE TESTING.—W. B. Craigmile. (*Elec. World*, 28th April, 1928, V. 91, pp. 861–862.)

A method of test requiring two auxiliary earths and employing a special "megger"-type ground resistance tester reading directly the required resistance.

The D.C. hand-generator provides current which after passing through the ohmmeter is transformed into A.C. for the test by means of a commutator. The P.D. across the ground under test is used to produce an A.C. which is rectified by a similar commutator and supplies the "potential" coil of the ohmmeter. Readings are independent of the speed of rotation.

THE (U.S.A.) NAVY'S PRIMARY FREQUENCY STANDARD.—Worrall and Owens. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 778–793.)

This constant frequency source is a crystal-controlled oscillator of special design employing a circuit which is particularly rich in harmonics, over 200 of which can be used as fixed standard frequencies. After describing this, the paper gives in detail the method by which the fundamental frequency of this standard is determined in terms of Naval Observatory time to an accuracy of about one part in 100,000. The ultimate standard of frequency is therefore the mean solar day.

A METHOD OF WAVELENGTH MEASUREMENT BY MEANS OF PIEZO-QUARTZ.—V. S. Gabel. (*Teleg. i. Telef. b.p., Nichny-Novgorod*, June, 1928, V. 9, pp. 323–329.)

THE MEASUREMENT OF CHOKE COIL INDUCTANCE.—Wright and Bowditch. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 844–847.)

Discussion of the paper abstracted in June number. The authors are accused of various errors, and defend themselves.

SUBSIDIARY APPARATUS AND MATERIALS.

A MODERN PHOTOGRAPHIC ELECTROGRAPH.—R.E. Watson. (*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 145–152.)

The author summarises his article as "describing a new installation for obtaining continuous photographic records of atmospheric electrical potential, in which, owing to the unique construction of the insulators, uncertainties due to defective insulation are reduced to a negligible amount. The capacity of the system is small, and rapid changes of potential are well registered, while the sensitiveness is capable of variation through fairly wide limits."

THE QUADRANT ELECTROMETER.—J. F. Sutton. (*World Power*, June, 1928, V. 9, pp. 319–326.)

The author classifies the various kinds of measurements for which the instrument is specially suitable by reason of its characteristics, and investigates the degree of accuracy which may be expected.

DEUX EXEMPLES DE MONTAGES QUI FONT INTERVENIR LA VARIATION DES CHARACTÉRISTIQUES D'UN APPAREIL RÉCEPTEUR OU DE MESURE (Two examples of methods of connection which introduce variation of the characteristics of a receiving or measuring instrument).—L. Cagniard. (*L'Ode Élec.*, April, 1928, pp. 162–166.)

The author proposes to show how a quadrant electrometer, which when used idiostatically is an instrument of very mediocre sensitivity, can be

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made into one of enormous sensitivity by using the fact that its capacity increases with its deflection. In the present article, however, he only leads up to the subject by describing how this property can be used to convert a quadrant electrometer into a "clock" driven by high frequency currents.

FLEXIBLE POWER OPERATED AMPLIFIER.—W. H. Fortington. (*Rad. Engineering*, May, 1928, V. 8, pp. 30–33.)

A full description, with schematic diagram, of an amplifier suitable for use in addressing small audiences: it will handle a few watts of modulated energy and will deliver sufficient undistorted power to handle a quarter kW. modulator in a transmitter. Supply is entirely A.C., and the input conditions are flexible so as to allow coupling to all kinds of circuits. Ultra-high quality is not expected for the purposes in view, low cost and compactness being more considered.

AN ECONOMICAL 171 B-ELIMINATOR (An Economical power-mains adaptor for anode supply of Receivers).—J. R. Francis. (*Rad. Engineering*, May, 1928, V. 8, p. 35.)

The cost of the adaptor is reduced by getting rid of all choke-coils by the use of an electrolytic condenser; the unit thus consisting of the power transformer, a socket, the electrolytic condenser and two small resistances. The condenser utilises an aluminium oxide coating upon an aluminium sheet.

THE DEVELOPMENT OF THE HOT CATHODE X-RAY TUBE.—(*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 170–172.)

A description of new types of tube whose containers are largely of metal; this development being made possible by improved methods of glass-to-metal sealing. As an illustration of the mechanical strength of such joints, it is mentioned that by using a corrugated cylinder of chromium iron to which glass insulating cylinders were sealed, the distance between two electrodes could be varied by several millimetres by applying mechanical pressure to the outside.

BESCHRIJVING VAN EEN TOONGENERATOR. . . . (Description of a L.F. generator).—B. F. J. Groeneveld. (*Physica*, May, 1928, pp. 157–164.)

The generator gives sinusoidal oscillations continuously variable from 25 to 25,000 kc. per sec. The form of condenser plate is shown, giving a logarithmic frequency scale.

CONSTRUCTION PRATIQUE ET UTILISATION DES SOUPAPES AU TANTALE (Practical Construction and Use of Tantalum Rectifiers).—Chardon. (*Rad. Revue*, June, 1928, V. 7, pp. 685–689.)

Since the recent Paris Fair, these rectifiers (ribbon of tantalum, lead sheet or wire, electrolyte of iron or nickel sulphate in sulphuric acid) have come into considerable favour.

AN EXPERIMENTAL INVESTIGATION OF SOME CHARACTERISTICS OF LOUD-SPEAKERS.—A. Kharkevitch. (*Teleg. i. Telef., b.p., Nichny-Novgorod*, June, 1928, V. 9, pp. 305–316.)

A COMPENSATED ELECTRON-TUBE VOLTMETER.—H. M. Turner. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 799–801.)

To eliminate the errors caused in valve-voltmeter readings by changes in the filament current, this method arranges that the grid bias changes with the filament current. Examples are given: in one, the resulting calibration is exact for filament current variations which would have caused 10.6 and 4 per cent. errors by the uncompensated method.

"MAINS" RADIO APPARATUS.—(*Nature*, 7th July, 1928, V. 122, p. 30.)

Regulations for the design and installation of this class of apparatus have now been issued by the I.E.E. with the approval of the Radio Manufacturers Association (*cf.* several recent "Abstracts" concerning the need for such regulations). The paragraph summarises about eight of these rules.

SOME FURTHER USES FOR THE NEON GRID-GLOW TUBE.—Wilkins and Friend. (*Journ. Opt. Soc. Am.*, May, 1928, V. 16, pp. 370–373.)

A two-electrode neon lamp ("Osglim") if connected in a suitable circuit will oscillate at regular intervals. The period of flashing is directly proportional to resistance R and capacity C; therefore the tube has been very usefully employed for the comparison of capacities or high resistances. A somewhat similar tube, but with a grid, has now been brought out under the name "Grid-Glow Tube" and two applications of this device are here described: for the registration of alpha rays, and as a sensitive voltmeter (1 volt through 15 megohms causing an easily measurable effect).

SOME NEW METHODS OF LINKING MECHANICAL AND ELECTRICAL VIBRATIONS.—W. H. Eccles and W. A. Leyshon. (*Nature*, 30th June, 1928, V. 121, p. 1042.)

A short notice of a paper read before the Physical Society on 25th May.

THE DESIGN OF THE FIELD MAGNET. FIELD STRENGTH AND LEAKAGE FLUX IN MOVING COIL LOUD SPEAKERS. A. P. Castellain. (*Wireless World*, 20th June, 1928, V. 22, pp. 665–668.)

THE PROBLEM OF RADIO SET POWER SUPPLY.—G. B. Crouse. (*Rad. Engineering*, May, 1928, V. 8, pp. 19–22, and June, pp. 42–44.)

Parts V. and VI. of a series, covering "Design Problems and the Application of Condensers and Inductance Coils to Socket Power Units" and "The Power Supply of the Future." In the first article the author details the eight points involved in a complete specification of condensers for such a filter circuit and proceeds to describe how the necessary values are to be determined. Inductances

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are then treated in a similar way. In the second article, the probable trend of development of power supply is considered. The author advocates the use of screen-grid valves with filaments in series, and gives diagrams of a 7-valve receiver on these lines.

DRY CELLS AND BATTERIES, U.S. GOVERNMENT MASTER SPECIFICATION FOR.—(*Bureau of Standards*, Washington, Circular No. 139.)

A full specification of construction, types, sizes, tests and required performance of cells of the salammoniac type with depolariser.

LABORATORY CURVE TRACER.—(*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 167–170.)

A simple graphically recording instrument for recording the deflection of mirror instruments, without the elaboration entailed by photographic methods, and with greater accuracy than by readings at intervals entered in a note-book. The pen which records on a moving cylinder is provided with a cross-wire which is kept continually coincident with the mirror-image on the scale, by the manipulation of a controlling handle turning a leading-screw. Provision is made for more rapid movement, but from the description it would appear that some difficulty might be encountered in records involving large sudden changes.

MICROPHONE AMPLIFIERS AND TRANSFORMERS.—H. L. Kirke. (*E.W. & W.E.*, July, 1928, V. 5, pp. 361–370.)

L'EXTENSION DES APPLICATIONS DE L'OSCILLOGRAPHE CATHODIQUE DE DUFOUR (The extended application of the Dufour Cathode-ray Oscillograph).—K. Berger. (*Bull. de l'Assoc. Suisse des Elec.*, 7th May, 1928, V. 19, pp. 292–301.)

A description of an oscillograph so modified as to operate only in time for the phenomena to be recorded. It would seem to be based on the lines suggested by Gabor in 1927 (*cf.* also these Abstracts, under "Atmospherics," article by Norinder).

AMERICAN SOCIETY FOR TESTING MATERIALS: REPORT OF COMMITTEE D. 9 ON ELECTRICAL INSULATING MATERIALS.

Various revisions of standard methods, and new tentative methods, are proposed. It is noted that research at short wavelengths (15 to 30 m.) is being done by the collaboration of several firms and the Naval Research Laboratory.

ON THE "MISTUNING" OF WEIGHTED FORKS.—W. R. Miles. (*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 152–154.)

Weighted tuning-forks are frequently used for their several advantages, *e.g.*, adjustability to different frequencies. In general, the weights cannot be adjusted with very great exactness, so that unequal adjustment of the two prongs is liable to occur. The author proves photographically that such inequality produces no error, since the two prongs always vibrate alike so far as rate is concerned, though the "slower" prong presents a lesser amplitude. Therefore in tuning a fork to a very specific rate (*e.g.*, for a phonic-motor chronograph) the fine adjustment may be done by only one weight.

STATIONS, DESIGN AND OPERATION.

SHORT WAVE MULTIPLEX SYSTEM OF RADIO COMMUNICATION.—Marconi - Mathieu. (*Nature*, 7th July, 1928, V. 122, p. 31.)

A paragraph describing experiments at the Bridgwater beam station, when music was sent from Montreal using the same apparatus and aerials as those through which two simultaneous Morse telegraph messages were being sent. The music was received at full strength, the quality was excellent, and there was no hint of Morse interference. It is also claimed that with the new apparatus the effects of "fading" are considerably diminished.

GENERAL PHYSICAL ARTICLES.

SUR L'EFFET VOLTA (on the "Volta" Effect of Contact Potential).—A. Cotton. (*Comptes Rendus*, 25th June, 1928, V. 186, pp. 1832–1833.)

The author had previously announced variations in the Volta Effect caused by heating in vacuo one of the two electrodes. In the present paper he describes how the effect of water vapour on several metals (including Iron, Nickel and Copper) is to make them more positive; on the precious metals no appreciable effect is noted. The author points out that in the usual measurements of Volta Effect, the metals contain a certain amount of water, so that very different values may be expected if the tests are repeated with anhydrous metals.

A NEW METHOD OF DETERMINING THE MOBILITY OF IONS OR ELECTRONS IN GASES.—Van de Graaff. (*Phil. Mag.*, July, 1928, V.6, pp. 210–217.)

Fizeau's rotating toothed wheel (used as a periodic shutter for determining the Velocity of Light) is here represented by an oscillating potential in combination with grids, producing a shutter effect for the ions or electrons whose velocity is to be measured.

ZUR ELEKTRONEN THEORIE DER METALLE NACH DER FERMISCHEN STATISTIK (The Electron Theory of Metals according to the Fermi Statistics).—A. Sommerfeld. (*Zeitsch. f. Phys.*, Nos. 1/2, V. 47, 1928, pp. 1–32 and 43–60.)

Part I. General, current and emission processes: Part II., thermo-electric, galvanometric and thermo-magnetic processes.

THE EMISSION OF SECONDARY ELECTRONS AND THE EXCITATION OF SOFT X-RAYS.—O. W. Richardson. (*Proc. Royal Society*, July 1928, No. A, 783, pp. 531–542.)

The particular point dealt with here is the origin of that part of the secondary electron emission which does not result from reflection.

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On the Kinetic Method in the new Statistics and its Application in the Electron Theory of Conductivity.—L. W. Nordheim. (*Proc. Royal Society*, July, 1928, No. A. 783, pp. 689–698.)

The dynamical theory of gases, developed by Maxwell and Boltzmann, is here successfully applied to the electron theory of conductivity.

Experiments on the Diffraction of Cathode Rays. G. P. Thomson. (*Proc. Royal Society*, July, 1928, No. A. 783, pp. 651–663.)

A continuation of the author's work on the diffraction patterns produced on a photographic plate by a beam of cathode rays passing normally through a very thin film of metal. These are now shown to be in complete agreement with those which can be predicted on the de Broglie wave theory, the atoms of the metal crystals being the diffracting system. The velocity of the diffracted electrons differs by less than 1 per cent. from that of the main beam. The electrons must be accompanied by a train of not less than about 50 waves.

The Piezo-electric Resonator and its Equivalent Network.—K. S. Van Dyke. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 742–764.)

The paper deals first with the piezo-electric effects as first known, the quantitative results obtained by the Curies fifty years ago, and the complete theory worked out by Voigt; it then shows how the introduction of resonance (about 1919) altered the whole importance of the phenomenon, magnifying the effects several thousandfold. The author shows that the functions of the quartz as dielectric and as vibrator are separable and replaceable by a condenser in parallel with an electric resonator, *i.e.*, a series chain of inductance, resistance, and capacity. Illustrative values for the elements of the network are given: for a plate of a size commonly used in oscillators, L = 0.33 henry, R = about 5,500 ohms, $C = 0.065\ \mu\mu F.$, $C_1 = 1.0\ \mu\mu F.$ (C_1 being the parallel condenser). The paper concludes with a description of experiments, with a cathode-ray oscillograph, on the nature of the variations in the crystal impedance as the frequency is varied through resonance.

Evidence for the Continuous Creation of the Common Elements out of Positive and Negative Electrons.—Millikan and Cameron. (*Proc. Nat. Acad. Sciences*, June, 1928, V. 14, pp. 445–450.)

A full and authoritative account of the author's latest work on cosmic rays and the conclusions drawn from it. It is stated that the results cannot be explained by a step-by-step process of building up, but only by creation in a single act. The tone of the authors is much more confident than in the paper abstracted in the August number: they conclude with the following sentence: "This whole work constituted, then, very powerful evidence that the sort of creative, or atom-building processes discussed above, are continually going on all about us, possibly also even on the earth, and that each such event is broadcast through the heavens in the form of the appropriate cosmic ray."

Radiation and Relativity.—G. Y. Rainich. (*Proc. Nat. Acad. Sciences*, June, 1928, V. 14, pp. 484–488.)

The first part of a paper in which the author proposes to study systematically from the relativity point of view a particle moving with the velocity of light, following the methods by which a material particle is studied.

The Negative Absorption of Radiation.—Raman and Krishnan. (*Nature*, 7th July, 1928, V. 122, pp. 12–13.)

Earlier work of the writers showed that when a liquid (*e.g.*, benzene) is irradiated by monochromatic light, the radiation scattered by the molecules contains several spectral lines of modified frequencies, each equal to the incident frequency less one of the characteristic infra-red frequencies of the molecule; so that the process of modified scattering involves the absorption of radiation by the molecule. They now find that in addition to these modified (longer) wavelengths there are present two modified *shorter* wavelengths (less bright) whose frequencies each exceed that of the existing wave by one of the infra-red frequencies of the molecule. The presence of these lines proves simultaneously the existence in the liquid of molecules at levels of energy correspondingly higher than the normal, and the fact that the incident radiation induces a return to a lower state of energy; in other words, that there is a negative absorption of the radiation, a hitherto unproved phenomenon characteristic of Einstein's derivation of the Planck radiation formula and also figuring prominently in the Kramers-Heisenberg theory of dispersion.

Theory of the Kerr and Faraday Effects in Gases. Part II. Quadratic Effects.—R. de L. Kronig. (*Zeitschr. f. Phys.*, V. 47 No. 9–10, 1928, pp. 702–711.)

The Waves of an Electron.—G. P. Thomson. (*Engineering*, 20th July, 1928, V. 126, pp. 79–80.)

An account of the paper read before the Royal Institution on June 8th.

The Reflection of X-Rays from Glass and Quartz.—Laby, Shearer and Bingham. (*Nature*, 21st July, 1928, V. 122, pp. 96–97.)

It is well known from the work of Compton and others that X-rays can be reflected at glancing angles up to about 40 mts., and Holweck claims to have observed reflection at 16.2 deg. The writers have obtained reflection of X-rays of about 50 A.U. from glass and quartz up to glancing angles of 45 deg. The ratio of intensity of incident to reflected beam is about 2 to 1 up to 35 deg.; above that angle the intensity of the reflected ray decreases. It appears that the reflected radiation is X-radiation, and not cathode rays or ultra-violet. The results do not seem to be reconcilable

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with the Lorentz dispersion formula. If these preliminary observations have been correctly interpreted, X-rays can be reflected from spherical surfaces and brought to a focus.

STOSSSPANNUNG UND DURCHSCHLAG BEI GASEN (Shock-voltage and Discharge through Gases) —W. Rogowski. (*Archiv. f. Elektrotech*, 11th May, 1928, V. 20, pp. 99–106), and BREAKDOWN OF SPARK GAPS.—J. Slepian. (*Elec. World*, 14th April, 1928, V. 91, pp. 761–765.)

Both authors point out the failure of the classical Townsend theory under conditions of very transitory applications of potential, and propound their ideas as to how that theory should be modified. The second writer formulates a theory which gives much shorter times for the breakdown process, depending on thermal ionisation; at a gradient just sufficient for breakdown, an electron starting from the cathode will cause thermal ionisation to appear near the anode. With larger voltages, this ionisation sets in much closer to the cathode, the positive ions at the cathode-end of the thermally-ionised trail need to move a shorter distance and are driven by a stronger field, so that the time is greatly reduced by a slight over-voltage.

STATISTICAL EXPERIMENTS ON THE MOTION OF ELECTRONS IN GASES.—R. d'E. Atkinson. (*Proc. Royal Soc.*, 1st June, 1928, V. 119, Series A, pp. 335–348.)

Prof. Townsend's Oxford experiments have been considered by him to show results irreconcilable with the theories generally accepted. The object of the present paper is to show that this is not really the case: it suggests that the apparent contradiction depends largely on the fact that the term-systems of the principal gases studied contain metastable states among their lowest excited levels —a fact relatively unimportant in the critical-potential work, but effecting an enormous and apparently quite unsuspected disturbance when statistical high-pressure methods are employed, as is always the case in the work of Townsend.

UNTERSUCHUNGEN UBER DEN MECHANISMUS DES LICHTBOGENS (Investigation of the Mechanism of the Electric Arc Discharge).—R. Seeliger. (*E.T.Z.*, 7th June, 1928, V. 49, pp. 853–857, and "Discussion," pp. 880–881.)

INFLUENCE OF WEAK MAGNETIC FIELDS ON THE DEGREE OF POLARISATION OF THE LIGHT EMITTED BY HYDROGEN CANAL RAYS.—v. Traubenberg. (*Phys. Zeit.*, 1st December, 1927, pp. 856–857.)

PHÉNOMÈNES D'IONISATION DES GAZ (Phenomena of ionisation of gases).—— Abadie. (*Génie Civil*, 12th May, 1928, V. 92, p. 472.)

Summary of a paper read before the Société Française des Électriciens, dealing with luminescent vacuum tubes in which the residual gas may be an ordinary or a rare gas. The author points out that such a tube supplied with alternating current does not absorb the whole of the current; it produces watt-less current and plays the part of a self-inductance; therefore, instead of supplying high-tension A.C. it is better to use high frequency, these tubes having a natural frequency corresponding to wavelengths between 300 and 400 m. The efficiency of a tube excited at H.F. is considerably increased. Its life is limited by the absorption of the residual gas, and this the author overcomes by regenerating the atmosphere by the dissociation of a salt; as a result, he has obtained a tube lasting more than 12,000 hours. He has also succeeded in reducing the cathode drop (usually 150–300 volts) to 12 volts.

THE ELEMENTS OF WAVE MECHANICS.—L. M, Milne-Thomson. (*Nature*, 2nd June, 1928. V. 121, pp. 885–886.)

An article based on Prof. Schrödinger's lectures at the Royal Institution last March.

REPORT OF WORK OF BARTOL (RESEARCH) FOUNDATION.—W. F. G. Swann. (*Journ. Franklin, Inst.*, June, 1928, V. 205, pp. 767–829.)

Continued from August "Abstracts."

(8) The variation of dielectric constant of a solution with concentration of the dissolved salt.

(9) The nature of the processes occurring in certain electric arcs. (Incidentally, a photo-electric cell is mentioned which will detect the light of a match at one-third of a mile).

(10) The reflection of hydrogen atoms from crystals. Dr. Johnson has obtained reflection of a beam of atomic hydrogen characterised by equality of angles of incidence and reflection.

(11) A device for obtaining high potentials (it is hoped, of the order of a million volts) based on the "water-dropper" idea, but in a vacuum, and with the water replaced by a steel ball.

(12) The variation of residual ionisation of a gas with pressure as a function of the altitude.

MISCELLANEOUS.

ANALOGY BETWEEN THE CRYSTAL DETECTOR AND A VACUUM TUBE.—W. Ogawa. (*Phil. Mag.*, July, 1928, V. 6, pp. 175–178.)

According to the writer's theory, the rectification by a crystal detector is brought about by the difference of electrons emitted from each electrode. He finds experimental verification in a test made with a crystal detector couple (galena and copper rod) sealed in a glass tube with a small space between metal and crystal. On exhausting the tube and applying A.C. potential of the right value, a glow discharge starts up and rectified current results in the same direction as in the corresponding contact rectifier.

EIN EINFACHES VERFAHREN ZUM MAGNETISIEREN VON PERMANENTEN MAGNETEN (A simple method of magnetising permanent magnets). —E. Schulze. (*E.T.Z.*, 28th June, 1928, V. 49, pp. 969–974 and 993–994.)

This patented method uses the large surge in the almost short-circuited single turn secondary of a transformer excited by D.C., at make or break of

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the primary current. With a transformer rated at less than 12 kVA., surges of 10,000 A. and more can be obtained.

ÜBER DEN EINFLUSS DER NICHTLINEAREN EISEN-VERZERRUNGEN AUF DIE GÜTE UND VERSTÄNDLICHKEIT EINES TELEPHONIC-ÜBERTRAGUNGSSYSTEMES (The influence of non-linear iron-distortion on the quality and intelligibility of telephone transmission).—G. V. Békésy. (*E.N.T.*, June, 1928, V. 5, pp. 231–246.)

This paper includes a method for measuring the strength of the overtones of a loud-speaker. The apparatus includes a Quincke interference-tube, and each overtone is adjusted in turn to be as loud as the fundamental: the amount of adjustment required to produce this equality gives a measure of the overtone.

ZUR ANWENDUNG DER KURZEN WELLEN IM VERKEHR MIT FLUGZEUGEN: VERSUCHE ZWISCHEN BERLIN UND MADRID (The use of short waves for communication with Aircraft: Tests between Berlin and Madrid).—Krüger and Plendl. (*Zeitschr. f. Hochf. Tech.*, June, 1928, V. 31, pp. 169–176.)

Transmission was from ground sets at Berlin and from aeroplane sets in the neighbourhood; reception was at Madrid (distance about 2,000 kms.). Previous tests over Germany had shown that for distances up to 1,000 kms. the wave-band 40–50 m. was particularly effective, a power in the aerial of only 1 watt giving good telegraphic communication particularly at night. The present longer range tests showed that the 46 m. wave with 2 watts in the aerial gave moderate communication up to 1,400 kms., but would not reach the 2,000 kms. range by day even with power increased 150 times. On the other hand, a 30 m. wave gave "news" communication with either 0.5 (aeroplane) or 300 watts (ground) in the aerial. The best waves for day and night were found to be 27–30 m., while 16–19 m. was only slightly inferior.

GEOPHYSICAL METHODS OF PROSPECTING.—Eve and Keys. (*U.S. Bureau of Mines*, Tech. Paper 420, reviewed in *Nature*, 7th July, 1928.)

The methods described are the magnetic, gravitational, electric and seismic; other methods, which have as yet been "inadequately tested," are only enumerated.

DEMONSTRATION OF A PORTABLE ELECTRIC HARMONIC ANALYSER, SHOWING THE MEASUREMENT OF HARMONICS IN VOLTAGE AND CURRENT WAVES.—R. T. Coe. (*Proc. Phys. Soc.*, 15th June, 1928, V. 40, p. 228.)

The determination of each harmonic only takes a few minutes; the amplitudes of small harmonics in voltage waves are found correct to at least 1-20th of 1 per cent. of the fundamental. The method embodies the mathematical principle of obtaining the nth harmonic by multiplying by Sin npt and integrating over a complete period.

TELEVISION BY CATHODE RAYS.—A. A. Campbell Swinton. (*Modern Wireless*, June, 1928.)

The writer carried out experiments in 1903–1904, and in 1908 published what is believed to be the first published suggestion of the use of cathode rays for television, both at the transmitter and at the receiver. Since then numerous patents have been taken out. Recent demonstrations of television have depended on mechanically moving devices, and the writer urges the abandonment of such clumsy methods and the development of methods in which the only moving parts are imponderable electrons.

FOCUSSING ELECTRONS REFLECTED OR EMITTED AT EQUAL ANGLES FROM A PLANE SURFACE.—D. A. Wells. (*Journ. Opt. Soc. Am.*, May, 1928, V. 16, pp. 355–356.)

ÉMISSION ET RÉCEPTION PAR UN RÉCEPTEUR À SUPER-RÉACTION (Transmission and reception by a super-regenerative receiver).—G. Beauvais. (*l'Onde Élect.*, May, 1928, V. 7, pp. 206–209.)

The writer obtains inter-communication by making use of the fact that when two stations are using super-regenerative receivers on very short waves, they often hear each other. The necessary wave-change at each end is accomplished by short-circuiting a loop of wire coupled to the self-inductance of the oscillating circuit, when switching over from transmission to reception.

CRUISE VII OF THE "CARNEGIE," 1928–1931.—(*Nature*, 2nd June, 1928, V. 121, pp. 871–873.)

A programme of the new cruise, which should amount to 110,000 miles. Among the great mass of work to be done may be mentioned: determinations of changes in the values of the atmospheric electric elements with geographic position (a photographic recorder to record continuously variations in atmospheric potential gradient; ionic-content apparatus); measurement of the penetrating radiation and the radio-active content; dust-count observations; measurement of marine electric currents; investigation of variations in transmitting and receiving conditions, skip-distance and signal-intensity (short wave radio signals).

DIE RADIOTECHNIK AUF DER LEIPZIGER FRÜHJAHRSMESSE, 1928 (Radio technics at the Leipsic Spring Fair, 1928).—(*E.T.Z.*, 17th May, 1928, p. 749.)

Improvements in detail, rather than actual novelties, are prominent. Multiple valves, combining several systems in one valve, have won a good place. In the design of adaptors to the public mains supply, elimination of noises is attended to and special attention is given to the use of filters in the attempt to make distant reception faultless; apparently complete success has not yet been attained. Quality of reproduction in loud speakers shows improvement; a particular make is named as giving perfect reproduction of the very deepest bass without detriment to the high frequencies.

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One example of electric reproducers for gramophone is highly commended. Coil units covering 180–5,000 m. in three stages which are controlled by a barrel-switch mounted on the unit, and various forms of indoor aerial, are mentioned; a thermo-electric battery to replace the filament-accumulator (requiring about 100 watts for a supply of 0.4 amp. at 2 v.) is described, also a practical accumulator-tester composed of a glow-lamp and two resistances so mounted that one of these takes the full working current while the other combines with the lamp to form a sensitive voltmeter.

DIFFERENTIAL INTENSITY SENSIBILITY OF THE EAR FOR PURE TONES.—R. R. Riesz. (*Phys. Review*, May, 1928, V. 31, pp. 867–875.)

The ratio (Minimum perceptible increment in sound intensity): (Total Intensity) was measured as a function of frequency and intensity, over practically the entire range of both variables for which the ear is capable of sensation. The method is described and results are given in curves. The ratio is a minimum at about 2,500 p.s. frequency, corresponding to the region of greatest absolute sensitivity of the ear. At 1,300 p.s., it is calculated that the ear can distinguish the maximum number (370) of tones as being of different intensity.

UN NOUVEAU SYSTÈME DE TÉLÉVISION ET DE TÉLÉCINEMATOGRAPHIE (A new system of Television and Telekinematography).—L. Thurm. (*Q.S.T. Franç.*, July, 1928, pp. 55–57.)

The system described, which has already been demonstrated, differs from the usual systems in that transmission does not take place synchronously with the scene-events, the currents derived from the exploration of the latter being temporarily stored up in "magnetic spirals." This is done by passing the current derived from each photo-electric element of the exploring "retina," after amplification, through an electromagnet before which passes a steel band; each retina-element exploring only a portion of the scene and each having its electromagnet and band. Thus the rate of the actual wireless transmission is rendered independent of the rate at which the scene itself moves.

Practical details are promised in the next instalment.

PERSONAL AND IMPERSONAL STYLES IN SCIENTIFIC COMMUNICATIONS.—N. R. Campbell. (*Nature*, 30th June, 1928, V. 121, p. 1021.)

A protest against the present "stylistic fad" encouraged by some editors against the use of the first person in scientific writings: not as part of a more general crusade against the egotism which leads to squabbles over priority and the assignment of credit, but merely as an isolated, clumsy, and artificial fashion. The writer suggests that writers should learn from Faraday, Rayleigh, Huxley and many others how to say "I" freely, naturally, with elegance and with dignity.

AT THE SCIENCE MUSEUM: SOME RECENT ADDITIONS TO THE RADIO SECTION.—R. P. G. Denman. (*Wireless World*, 11th July, 1928, V. 23, pp. 49–53.)

Among other interesting items may be mentioned the three dimensional valve characteristic models for various types of valves.

LE GRAND ÉLECTRO-AIMANT DE L'ACADÉMIE DES SCIENCES.—A. Cotton. (*Comptes Rendus*, 9th July, 1928, V. 187, pp. 77–89.)

This magnet has just been completed. It is explained that whereas Kapitza (*cf.* August Abstracts) has attained fields of hundreds of thousands of gauss, these fields are very transient and very small in volume. With the French magnet, a steady field, between pole-pieces 4 cm. in diameter and 2 cm. apart, has been obtained up to 46,400 gauss. More powerful fields of smaller volume are in process of being measured.

EUROPEAN PROGRESS IN TELEVISION.—W. J. Brittain. (*Science Progress*, January, 1928, V. 22, pp. 493–494.)

A short but comprehensive survey of the various different systems.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPRECOJ DE CIRKVITOJ.

INTER-ELEKTRODAJ KAPACITOJ KAJ REZISTECA AMPLIFADO.—L. Hartshorn.

Oni atentigas, ke la kutima analizo de rezisteca-kapacita amplifado supozas, ke la sunta efekto de elektrodaj kapacitoj ĉe la diversaj rezistecoj estas malgranda, sed la aŭtoro asertas, ke ĉi tiu efektiva kapacito povas facile esti 100$\mu\mu$F. aŭ pli.

Li poste diskutas enmetan impedancon, admitancon, kaj kapaciton, rilate al la ekvivalenta retaĵo por unu aŭ por du ŝtupoj, kaj montras ke, kaŭze de la tuta amplifado, la efektiva krada kapacito en unu ekzemplo estas 110$\mu\mu$F. Ponta metodo estas priskribita kaj ilustrita por la mezurado de enmeta admitanco kaj kapacito, tabeloj donantaj eksperimentajn rezultojn por enmeta kapacito kaj enmeta konduktanco.

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La aplikado de ĉi tio al la rezisteca-kapacita amplifikatoro estas poste diskutita sub la rubrikoj (*a*) Kradanoda kapacita efekto ; (*b*) Anodimpedanca termino ; (*c*) Kupla termino, k.t.p. La efekto de mem-kapacito en la kutima formo de anoda rezisteco estas ankaŭ diskutita.

Tre utila fina resumo estas verkita laŭ la konsideradoj de la antaŭiranta teksto.

La Resonancaj Kurvoj de Kuplitaj Cirkvitoj.—Prof. E. Mallett.

La aŭtoro unue aludas al antaŭaj artikoloj (*E.W. & W.E.*, Feb.–Marto, 1927a) pri l'uzado de vektoraj metodoj por obteni la resonancajn kurvojn de unuoblaj oscilaj cirkvitoj, post kio li paŝas al simila traktado pri kuplitaj cirkvitoj, kiam la frekvenco estas variigita. La ekzemplo de du agorditaj cirkvitoj kuplitaj per komuna indukteco estas unue konsiderita, la fundamentaj esprimoj estante donitaj kun vektora konstruado kaj la rezultanta kurvo por Z kaj i_2. La rezonado estas etendita al aliaj metodoj de kuplado, ekzemple, iu formo de komuna impedanco, kaj ankaŭ al cirkvitoj iomete malagorditaj. Etendado al tri (indukte kuplitaj) cirkvitoj estas ankaŭ donita, kaj la etendado al kvar aŭ pli da cirkvitoj mallonge indikita.

RICEVADO.

Kvalito Kontraŭ Selektiveco je Malproksima Brodkasta Ricevado.

Redakcia artikolo, super la ĉefliteroj de Prof. Howe. Oni aludas al lastatempa prelego ĉe la Institucio de Radio-Inĝenieroj, de Vreeland, kaj al la efektiva bezono por rektangula responda kurvo, tiel ke ĉiuj frekvencoj, ekzemple, 10 k.c. sur iu flanko de la portondo povas esti egale ricevita. Metodoj por larĝigi la respondan kurvon estas mallonge diskutita, ĉi tiuj estante amortizado, frekvenca interspacado de kaskadaj ŝtupoj, kaj la uzado de du agorditaj cirkvitoj rigide kuplitaj por doni kurvon kun du ĝiboj.

La teoria esplorado pri la relativaj meritoj de ĉi tiuj metodoj estas sugestita kiel interesa problemo.

MEZUROJ KAJ NORMOJ.

La Mezurado de Malgrandaj Varieblaj Kapacitoj je Radio-frekvencoj.—W. H. F. Griffiths.

La aŭtoro unue atentigas, ke malgranda aerkondensatoro ne estas normigebla, krom se ĝiaj konduktoroj kaj skrenaj kondiĉoj (uzotaj post normigado) estas konataj kaj starigataj dum normigado. La malfacilaĵoj de tiaj mezuroj estas diskutitaj detale kaj bone ilustritaj per skizoj. La aŭtoro sugestas, ke estas pliigo de kapacito laŭ skalo, kio estas plej grava dum praktiko kaj, ke oni povas aranĝi, ke ĉi tiu metodo de normigado certigu, ke nur la linia porcio de l'skalo estas uzata. Li poste komencas diskuti precizan metodon de ĉi tiu " dekliva kapacita " normigado.

La metodo estas priskribita multdetale, kun tipaj rezultaj tabeloj, kaj notoj estas donitaj pri eblaj eraroj, utilaj proksimumaĵoj, mezurado de falsa nulo, la korekta determino de mem-kapacito en la cirkvito, k.t.p.

HELPA APARATO.

Mikrofonaj Amplifikatoroj kaj Transformatoroj.—H. L. Kirke.

Findaŭrigita el lasta numero.

La nuna parto konsideras la rezistec-kapacitan kaj ŝok-kapacitan ŝtupojn. La dimensioj de intervalvaj kondensatoroj estas unue diskutitaj, kaj la reakcio kaŭze de interelektroda kapacito. La efekto de Kontinua Kurento ĉe transformatoroj estas poste pritraktita, kaj la ŝok-kapacita kuplo al transformatora primario estas diskutita. Oni opinias, ke ŝoka kuplo al la elmeta transformatoro estas avantaĝa. Rezistanca kaj ŝoka kuplo estas poste diskutita kvante, kaj ĝenerala komparo donita pri transformatora, ŝoka, kaj rezistanca kuplo. Por bona entuta kurvo per multŝtupa amplifikatoro, rezistanca kuplo estas la sola formo, kiu estas uzebla ĉe mikrofonaj amplifikatoroj por brodkastaj celoj.

La aŭtoro poste diskutas distordadon sub la rubrikoj de l'Amplitud-Pligrandiga Karakterizo kaj de Fera Distordado. Laste, li traktas pri la Pligrandigo bezonita ĉe Amplifikatoroj, faktoro de sendanĝereco, mekanika desegnado de amplifikatoroj (aparte por eksterdoma aŭ teatra brodkastado), kaj la skalo de volumen-kontrolo necesa.

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.

La Operatoro " Heaviside " a kaj la Operatora Kalkuluso.—W. A. Barclay.

Ĉi tiu artikolo grandparte naskiĝis pro la lastatempa kontribuaĵo de S-ro J. A. Ratcliffe (*E.W. & W.E.*, Majo, 1928a), kaj la Redakcia kritiko kiu estis donita.

La nuna aŭtoro diskutas simbolajn sistemojn kaj paŝas al la Operatoro Heaviside'a $D = \frac{d}{dt}$. Li poste traktas pri la Operatora Ekvacio, kondukante al la Impedanca Operatoro, kun ekzemploj koncerne seriaj kaj paralelaj L.C.R. (Indukteco, Kapacito, & Rezisteco) cirkvitoj. La agadmaniero uzi la Operatoron estas mallonge resumita, kaj la aŭtoro finas per kritiko de la Diferenciala Operatoro, kaj de la Heaviside'a Operatora Kalkuluso.

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Some Recent Patents.

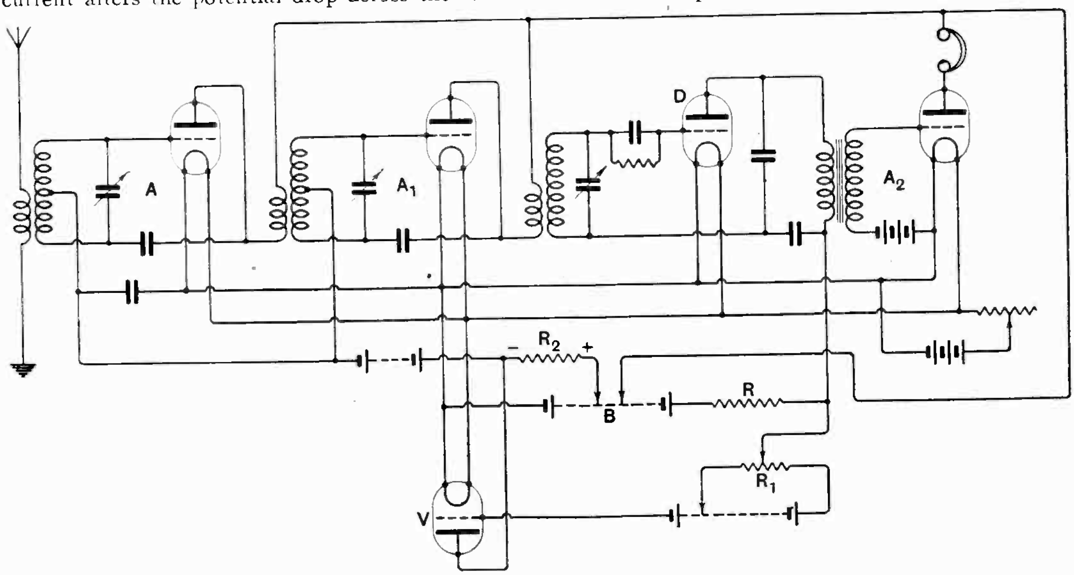
The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

MINIMISING FADING EFFECTS.

(*Convention date* (*U.S.A.*), *3rd January,* 1927. *No.* 283,120.)

In order to ensure a uniform overall strength of reception, irrespective of fluctuations in the intervening medium due to atmospheric conditions, means are provided for automatically adjusting the grid-bias of the receiving valves in accordance with the volume of the rectified signals. The Figure shows two neutralised high-frequency amplifiers, A, A_1, feeding a detector valve D and a subsequent stage A_2 of low-frequency amplification.

The rectified current from the detector D flows through a resistance R, which regulates the effective voltage across the grid and filament of an auxiliary amplifying valve V. A resistance R_2 in the plate circuit of the latter valve is, in turn, included in the input circuit of the first amplifier A and serves to regulate its operative grid-bias. When the signals rise above normal strength, the voltage across the resistance R falls, and this allows the battery B to throw the grid of the amplifier V more positive. The resulting increase in plate current alters the potential drop across the resistance R_2 in the sense that the end of the resistance connected to the grid of the first amplifier becomes more negative, thus tending to cut down the initial amplification. Should the received signals be too weak, the grid of the first amplifier is thrown more positive.

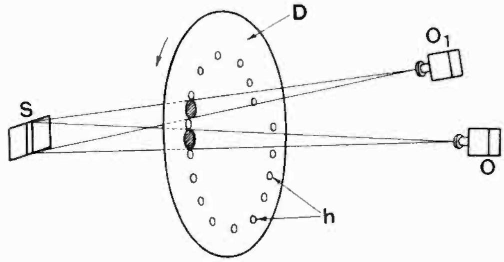


Patent issued to British Thomson-Houston Co., Ltd.

TELEVISION APPARATUS.

(*Application date,* 30*th November,* 1926. *No.* 291121.)

Relates to a viewing-screen for the reception of moving-picture effects in which the surface is



phosphorescent in character, *i.e.*, in which the semi-permanent image persists for a certain length of time depending upon the nature of the surface coating, as distinct from a fluorescent screen where the luminescence ceases as soon as the activating light is cut off.

In order to prevent undue persistence in a screen of phosphorescent material, such as calcium sulphide, means are provided for obliterating each image by projecting over the surface a ray of light of longer wavelength than that emitted by the screen. As shown in the Figure a rotating disc D having a spirally-arranged series of holes h traverses the phosphorescent screen S with light from a source O, which is controlled by the incoming

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"television" signals so as to build up a visual image on the screen.

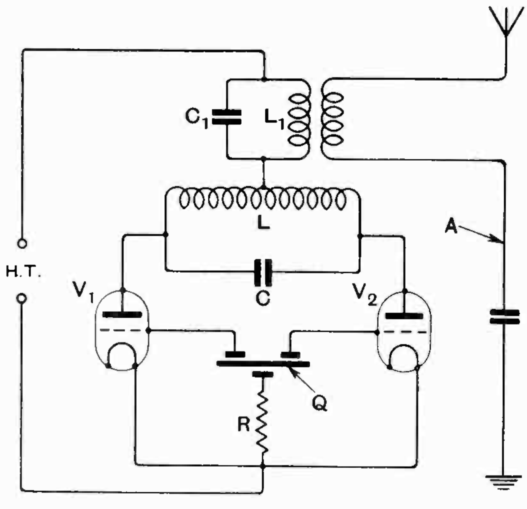
An obliterating ray, say of infra-red wavlength, derived from a second source O_1 after passing through a suitable filter, is swept over the screen by the same disc D, either immediately before or immediately after a new image has been projected from the source O. The method is stated to be also applicable to an arrangement where the phosphorescent screen is replaced by a bank of lamps fitted with shutters, the opening of which is controlled by the activating light-ray and the shutting by the infra-red ray.

Patent issued to Television, Ltd., and J. L. Baird.

FREQUENCY-DOUBLING.

(*Convention date* (*Germany*), *13th January*, 1927. *No.* 283549.)

In order to generate short-wave energy, two valves V_1, V_2 are fed in parallel through a circuit L, C, the high-tension supply being tapped to a potential node along the coil L. The grid-filament connection comprises a piezo-electric oscillator Q provided with split electrodes to ensure a symmetrical connection to the common leak resistance R. Oscillations corresponding to the fundamental crystal frequency are thereby produced in the resonant circuit L C.



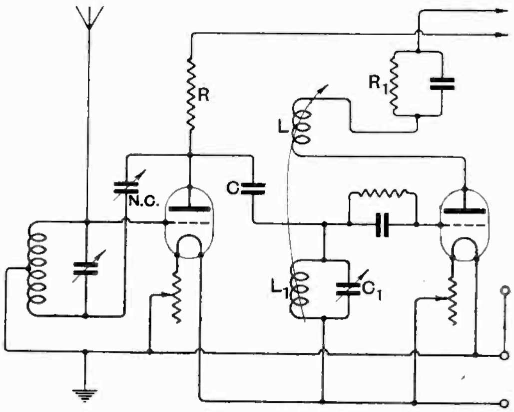
During each half-period of oscillation, energy passes first through one valve V_1 and then through the other V_2, producing in each complete oscillation two current impulses, which is equivalent to an alternating current of double the main oscillation frequency. The latter frequency is absorbed by the loop circuit L_1, C_1 and is then fed to the transmitting aerial A. In the limiting case, the tuned circuit L C is replaced by a plain connecting wire which co-operates with the interelectrode capacities of the valves to form a resonant circuit of very short wavelength. The H.T. supply is taken to the centre of the plain wire, which is a potential node, and the doubled frequency is tapped off to the aerial by a direct metallic coupling at another point of zero potential variation.

Patent issued to C. Lorenz Co., Ltd.

REACTIVE RESISTANCE-COUPLINGS.

(*Application date*, *15th March*, 1927. *No.* 291.894.)

The ordinary resistance-capacity coupled amplifier tends to fall off in efficiency on the shorter



wavelengths owing to the increasing shunt effect of the internal valve capacities. Again, special provision is necessary in order to utilise reaction to a beneficial extent. The figure shows a circuit designed to operate efficiently on the higher frequencies, with reaction, the first valve being arranged to protect the aerial from any feed-back sufficient to cause reradiation.

The coupling condenser C between the resistance R in the plate of the first valve and the tuned input L_1, C_1 in the grid of the second is chosen so that it has a comparatively low impedance compared with R and with the internal plate-filament capacity of the first valve. When R is 100,000 ohms a suitable value for C would be 0.01 mfd. By tuning the grid condenser C_1, the output and input impedances can be brought to a maximum and the reactive coupling correspondingly controlled. In the second valve an inductive winding L is coupled to the input coil L_1, the value of the resistance R_1 being less than that of R in order to allow an appreciable current to flow in the plate circuit of that valve. A neutralising condenser NC prevents the aerial from being energised through the first valve.

Patent issued to H. J. Stenning and the Edison Swan Electric Co., Ltd.

VOLTAGE REGULATION IN H.T. ELIMINATORS.

(*Application date*, *27th January*, 1927. *No.* 289,530.)

One drawback to the use of H.T. eliminators lies in the difficulty of maintaining a constant voltage-drop across the shunt resistance R from which tappings to the various plate circuits are taken. Any alteration in the output current, caused by changing the number of valves in circuit, or otherwise, affects the terminal voltage and so gives rise to bad regulation.

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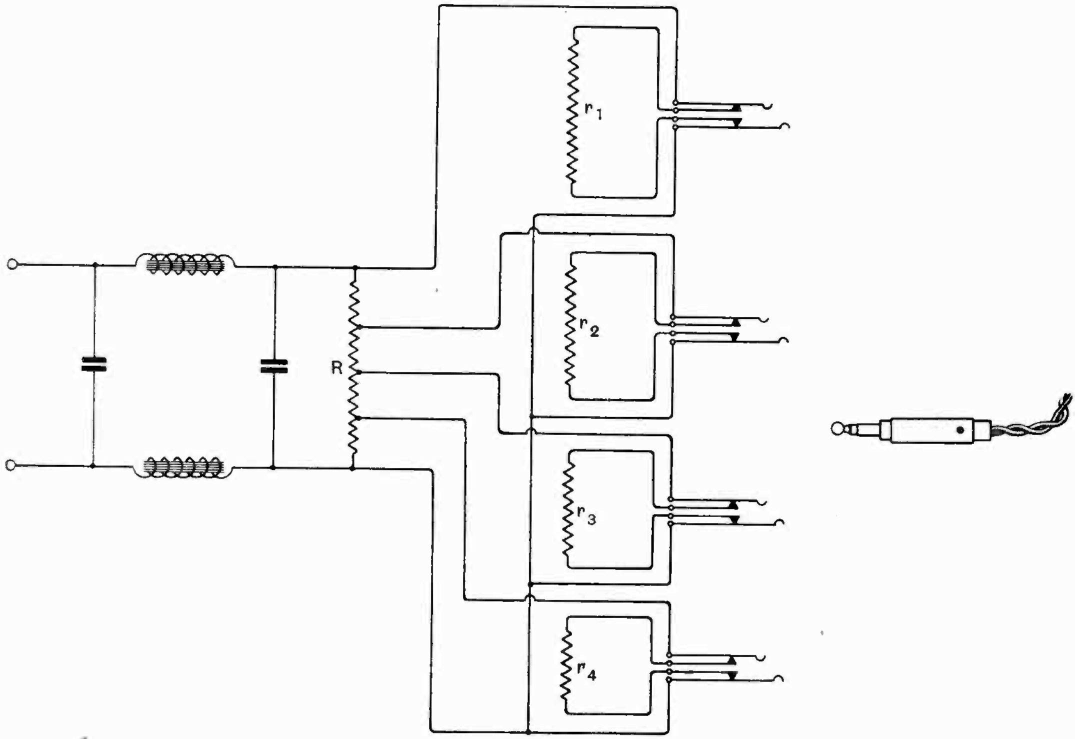
In order to overcome this defect separate compensating resistances r_1, r_4 are arranged to be automatically bridged across any section of the potentiometer R not actually in use. Each resistance should be approximately equal in value to the external circuit which would under normal circumstances be connected across the section in question. In this way the current-flow across each section of the potentiometer R is kept substantially constant, so that the voltage of each tapping point remains steady no matter how many valves are switched in or out of circuit.



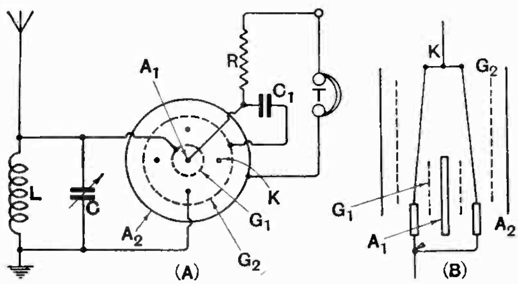
Patent issued to The British Thomson-Houston Co., Ltd.

MULTI-STAGE VALVES.

(*Application date*, 11*th March*, 1927. *No.* 292,218.)

Relates to valves of the type on which several stages of amplification are housed inside the same bulb. As shown in Figs. A and B, a central anode A_1 is surrounded first by a grid G_1, then by a filament K, next by a second grid G_2, and finally by an outer cylindrical anode A_2. The relative spacing of the various electrodes is such that the effect of the grid G_1 on the electron stream flowing between K and A_1 is greater than the effect of the grid G_2 on the stream between K and A_2.

When connected up in the manner shown in Fig. A, the overall amplification is stated to be greater than that obtainable from two separate valve stages coupled in series. The input circuit LC is connected across the grid G_2 and the negative end of the filament K. The central anode A_1 is connected through a 5-megohm resistance R to a high-tension supply of about 30 volts, and also through a blocking-condenser C_1 to the outer grid G_2. The telephones are inserted between the outer anode A_2 and the high tension. The amplified voltage variations on the central anode are transferred through the condenser C_1 to the outer anode



A_2, the combined action of the two grids and anodes on the common electron stream giving rise to a reaction effect which increases the magnification factor.

Patent issued to A. H. Midgley.

PHOTO-ELECTRIC RELAYS.

(*Application date*, 14*th February*, 1927. *No.* 290367.)

If light falls suddenly upon the active electrode of a photo-electric cell, the resulting current does

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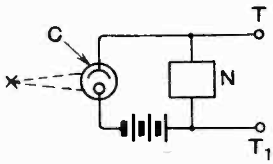
not rise instantaneously to its maximum value, but is subject to a lag analogous to that observed in the case of selenium though smaller in magnitude and more complex in character. The lag is due partly to the time necessary for ionisation to set in between the cell electrodes, and partly to the fact that the internal resistance is, in effect, shunted by the inherent capacity of the cell itself including the external leads, and that a time interval occurs before this capacity is charged up to a steady potential.



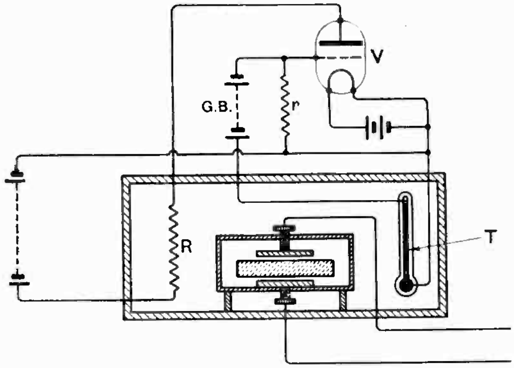
In order to correct for any distortion due to this sluggishness in high-speed picture telegraphy, or in television, the photo-electric cell *C* is inserted in series with an impedance network *N* which "matches" the cell impedance over the range of working frequencies. The output *T*, T_1 is tapped off across the impedance *N* so that the system constitutes a balanced wheatstone bridge. Variations in the input are accordingly repeated across the conjugate output points independently of any time-lag effect in the respective arms of the bridge.

Patent issued to G. M. Wright.

FREQUENCY-STABILISING DEVICES.

(*Convention date* (*U.S.A.*), 15*th January*, 1927. *No.* 283596.)

It has been found that the fundamental oscillation frequency of a piezo-electric crystal varies with temperature as much as 30 cycles per second for every degree centigrade when set to a normal frequency of one million cycles per second. In order to remove this source of fluctuation a master-control crystal is housed inside a suitable covering which is maintained at a uniform temperature by the device shown in the figure.



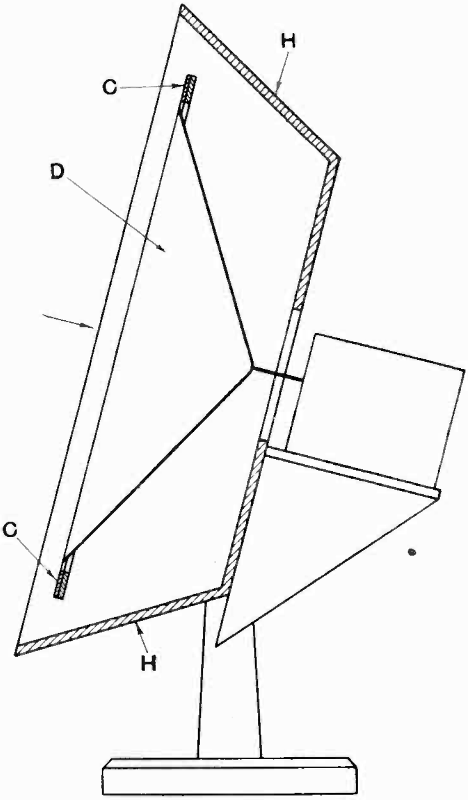
The plate circuit of a valve *V* contains a heating-resistance *R* located inside the crystal casing, whilst the grid circuit comprises a thermometer *T* so arranged that when the temperature falls below a given point, a paralysing negative potential from the battery *GB* is removed from the grid, so that a plate current flows through the resistance *R* to heat the casing until the temperature falls to a point at which the mercury column connection between the grid and filament is broken, whereupon the heavy negative bias from *GB* is reimposed upon the valve.

Patent issued to The Marconi Co., Ltd.

LOUD SPEAKERS.

(*Application date*, 9*th February*, 1927. *No.* 290344.)

A diaphragm *D*, mounted so that it vibrates with a combined piston and flexure action, is located inside a shallow horn or resonance chamber *H* so that sound waves are propagated both from



the front and rear surfaces of the diaphragm. The diaphragm *D* is constructed of a shallow cone of paper having an angle of about 120 degrees. It is supported from a rigid peripheral ring *C* by means of three lugs (not shown) which impose very little axial restraint upon the vibrating surface though they impart considerable radial rigidity.

In this way the central portion of the conical diaphragm is able to vibrate by simple piston action, *i.e.*, to move bodily to and fro without flexure, whilst on the other hand the outer portion of the diaphragm vibrates mainly by flexure about the peripheral supporting-ring *C*. This mounting is distinguished from the standard "free-edge rigid-diaphragm" type, and is stated to reproduce music with a high degree of fidelity.

Patent issued to Charles Mahé de Chenal de la Bourdonnais.

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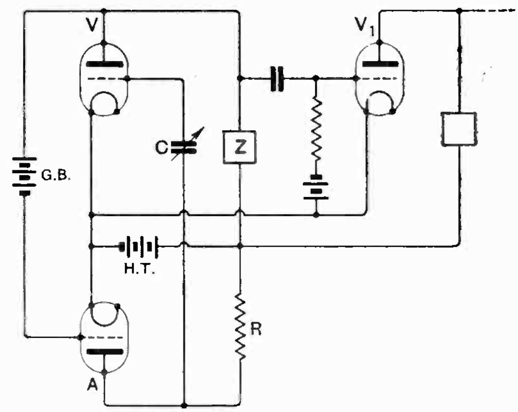
BALANCING INTER-ELECTRODE CAPACITY.

(*Application date*, 10*th February*, 1927. *No.* 290,351.)

In a cascade amplifier, the inherent grid-plate capacity constitutes an input impedance on the grid, the effect of which depends, among other things, upon the nature of the impedance in the plate or output circuit. In order to provide a balancing arrangement which is independent of the nature of the plate impedance, whether inductive or otherwise, an auxiliary or compensating valve is cross-coupled to the amplifier in the manner shown in the figure.

The first amplifier V is coupled to a subsequent stage of amplification V_1 in any suitable manner. In series with the plate impedance Z is a pure resistance R which is also included in the plate circuit of the special compensating valve A, the plate of which is also variably coupled through a condenser C to the grid of the amplifier V. Conversely the plate of the latter is connected through a grid-biasing battery GB with the grid of the compensating valve. Both valves are fed from a common L.T. supply, the H.T. being connected to a point between the impedance Z and resistance R.



In operation the condenser C transfers potential variations to the grid of the valve V which neutralise the effect of the inherent plate-grid capacity of that valve.

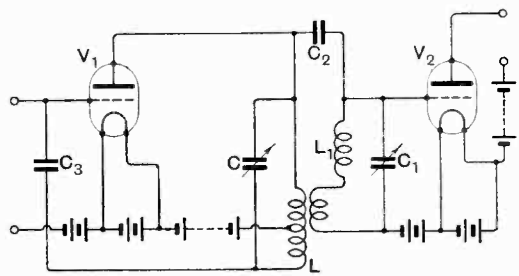
Patent issued to W. S. Smith and N. W. McLachlan.

A CONSTANT-COUPLING CIRCUIT.

(*Convention date*, (*U.S.A.*), 28*th January*, 1927. *No.* 284,587.)

Tuned intervalve couplings, although highly selective, suffer from the disadvantage that as the resonant frequency is decreased the coupling-factor is progressively increased until self-oscillation sets in. Although means have already been suggested for ensuring a constant coupling over a range of signal frequencies, the effect of the inter-electrode valve capacities still remains to be provided for. According to the invention a combined inductive and capacity coupling is provided for each valve stage, whilst the inherent valve capacities are neutralised either by using screened grids or by means of additional balancing condensers.

As shown in the figure, two H.F. valve amplifiers V_1, V_2 are connected in cascade through a step-down magnetic coupling between the coils L, L_1, and through a coupling condenser C_2. The amplification factor through the inductive coupling rises



as the frequency is increased, whilst that due to the condenser C_2 decreases, the result of the combination giving an approximately constant ratio. In addition the effect of the inter-electrode capacity of the amplifier V_1 is eliminated by means of a neutralising condenser C_3 in series with the coil L.

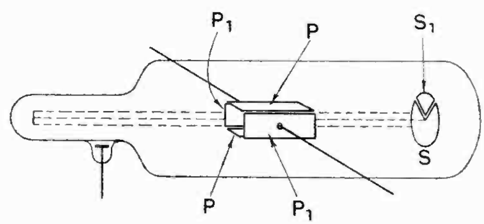
Patent issued to the British Thomson-Houston Co., Ltd.

DIRECTIONAL WIRELESS.

(*Convention date* (*Germany*), 5*th November*, 1926. *No.* 280,235.)

In order to increase the directional effect in reception, a cathode-ray tube provided with two pairs of mutually perpendicular control plates is used in combination with two directional aerials, and a cut-off segment limiting the area over which signals can be recorded on a luminescent screen. As shown in the figure, the cathode-ray stream passes through two pairs of plates P, P and P_1, P_1, to which the signal voltages from a pair of directional aerials are applied.

So long as the received signals come from stations inside, say, an angle of 14 deg., the corresponding messages are indicated by the ray striking against a luminescent sector S at the end of the tube. For any wider angle of incidence the control voltages



throw the cathode stream off the sector S and on to a non-recording sector or screen S_1. The luminescent effect of the received signals on the active sector S may energise a photo-electric cell, adapted, in turn, to actuate a suitable indicator or recorder.

Patent issued to the Telefunken Co., Ltd.

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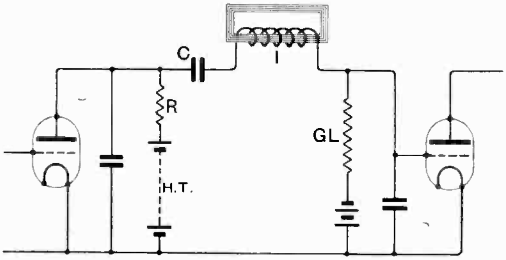
LOW-FREQUENCY AMPLIFIERS.

(*Application date*, 23*rd February*, 1927. *No.* 291,143.)

In resistance-coupled amplifiers the use of high magnification valves in combination with high anode resistances results in a strong tendency for the amplification to fall off, particularly in the neighbourhood of 2,000 cycles and over. In order to counteract this defect, an inductive reactance is



inserted in the intervalve coupling circuit, and is of such value that in combination with the valve-grid capacity it forms a resonant circuit which increases the voltage across the grid and filament of the succeeding valve and so neutralises the previous loss in amplification.

As shown in the figure the reactance I is in the form of an iron-cored choke inserted between the coupling condenser C and the grid leak resistance GL of the next valve, the ordinary anode coupling resistance being shown at R. The resonant circuit may be arranged to have a comparatively sharp cut-off for frequencies above, say, 5,000 to 6,000 cycles so as to shut out unwanted high-note sounds.

Patent issued to H. J. Round.

SINGLE-WAVE BROADCASTING.

(*Convention date* (*Germany*), 3*rd February*, 1927. *No.* 284,665.)

Relates to broadcasting networks of the kind in which a number of stations are so distributed as to serve a large area at crystal-reception strength, each station transmitting on the same wavelength under the control of a central or master station. To work such a system efficiently, it is essential to maintain the common wavelength at an absolutely constant value, otherwise intolerable heterodyning will occur. Even when this condition has been attained it is noticed that certain local zones occur, usually about midway between two stations, where owing to mutual interference between the two sets of waves, reception falls off very noticeably.

In order to prevent the formation of such " dead " areas, the carrier wave of one or more of the transmitting stations is periodically varied either as regards frequency, phase, or amplitude in a supersonic cycle, so as not to give rise to any disturbing note in the phones. Preferably the phase of the carrier-wave is varied in this manner, either by means of a constantly rotating coil or condenser or by using iron-cored chokes supplied by a variable source of saturating current.

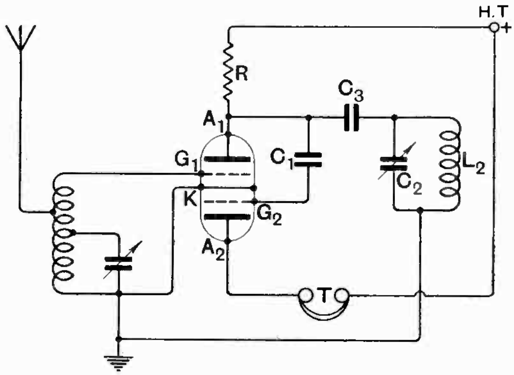
Patent issued to the C. Lorenz Co., Ltd.

HIGH-RESISTANCE COUPLINGS.

(*Application dates*, 24*th February and* 14*th October*, 1927. *No.* 291,493.)

The inventor advances a theory of valve detection and amplification based upon the use of a high plate resistance of the order of 3 to 5 megohms. He points out that in such circumstances the reactance of the external plate circuit is much greater than that of the inter-electrode capacity of the valve. The electron current through the valve may therefore be considered as divided into two parts, one passing through the plate resistance and the other charging-up the capacity of the valve electrodes. If the latter current predominates, the resultant potential variations on the plate will be approximately only 90 deg. out of phase with the grid potentials, instead of 180 deg. as is the case with a normal plate resistance of the order of 100,000 ohms. There is accordingly no appreciable feed-back to cause undesirable self-oscillation. It is stated that rectification takes place owing to the H.F. component of the plate current being smoothed out by the valve capacity, the resulting L.F. component of the modulated wave setting up potential variations across the coupling resistance.

The figure illustrates the arrangement as applied to a valve with a central filament K, two grids G_1, G_2, and two plates A_1, A_2. A resistance R of 3 megohms connects the plate A_1 to the H.T. supply, whilst a condenser C_1 connects it to the opposite grid G_2. A tuned circuit L_2, C_2 is shunted



across the resistance R to increase the voltage variations on the plate, and hence the effective amplification, a blocking condenser C_3 preventing the electron current from being short-circuited across the inductance L_2. Incoming signals are applied across the grid G_1 and filament, whilst the telephones T are inserted across the second plate A_2 and the H.T. supply.

Patent issued to A. H. Midgley.

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