EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial Views.

The Paris Conference.

THE conclusions reached at the International Conference of Amateurs, held just after Easter at Paris, will, we are sure, be of great interest to our readers. In a later issue we hope to reproduce at some length the actual resolutions expressed; here we propose to give just a short *résumé* of the work done.

Five matters were put up for discussion :—

A. A proposal for an International Amateur Radio Union;

B. Arrangements for International tests, etc.;

C. Allotment of definite wave-bands for international amateur work;

D. An international auxiliary language for amateurs;

E. Arrangements for the use of definite intermediate letters to indicate country.

Each of these questions was considered by a separate sub-committee, containing delegates from the countries represented at the Conference, except question A, which was considered by the whole. The resolutions of the sub-committees were reported to and considered by the whole Conference.

The I.A.R.U.

A complete draft organisation for this was submitted by the A.R.R.L., and after considerable modification many parts of it were adopted. One or two of the outstanding points of the final scheme are: Membership will be open to any person seriously interested in amateur experimental wireless work. If there are not less than 25 members in a country, a national section will be formed. Each such section will have a "national president." There will also be a President, Vice-President, and Secretary-Treasurer at headquarters, also an Executive Committee. For the present, headquarters will be the headquarters of the A.R.R.L., and "Q.S.T." will be the official organ. The annual subscription will be \$1. Twenty-one countries were represented in the voting.

International Tests.

The sub-committee on this question considered that the matter needed more detailed investigation than could be given in the time available. They therefore only gave general recommendations. They suggested that a representative should be appointed to go into the question in each country, and report to headquarters. They suggested a definite scheme for arranging the time for scheduling tests, this being to specify G.M.T., and give the time in the four-figure form, from 0000 to 2359. They also hoped for a definite scheme for rating signal-strength. Lastly, they suggested a definite schedule of times permanently allotted for communication with headquarters.

Wave-bands.

This sub-committee devoted much thought to getting out a schedule of wave-lengths which should be (*a*) within the licensed bands for each country's transmitters;

(*b*) suitable for International work. They finally specified the following :—

Country.	Usual Band	Extra short band
	Metres.	Metres.
Canada and Newfoundland ..	120-115	43-41.5
Europe	115-95 75-70	47-43
Other parts (except as below)	95-85	37.3-35
U.S.A.	85-75	41.5-37.3

They suggested that amateurs should use other waves within their licensed bands for near communication, reserving these exclusively for International work. They hoped that the I.A.R.U. would be able to set up an International standard.

International Language.

This sub-committee recommended Esperanto as a standard auxiliary for telephony, for abstracts and/or translations in periodicals, and for congresses. It suggested the same for telegraphy where the two workers had no common national language. The Congress also adopted it as its own auxiliary language, besides the national languages used. The Committee very thoroughly considered the claims of the languages proposed to it for the purpose (English, Esperanto, Ido and Interlingua), but was definitely in favour of Esperanto.

Intermediate Call Letters.

The sub-committee on this subject got out a complete list of letters to replace the official DE and give the countries called and calling. We do not give these *in extenso* at present, as in any case their use is illegal in Great Britain.

They also quoted the initial figures of call-signs in various European countries (*e.g.*, 2, 5 and 6 for Great Britain ; 8 for France, etc.) and asked the I.A.R.U. to persuade governments, if possible, to consent to numbers on a consistent scheme thus :—

1	Italy
2, 5, 6	Great Britain
3	Finland
4	Germany
5	(See 2)
6	(See 2)
7	Denmark
8	France
9	Switzerland
0	Luxemburg.

Power Loss in Coils.

We are very pleased, and we are sure our readers will be also, to have, in the article by Mr. R. M. Wilmotte in this issue, some definite information as to the relative importance of various points in the design of coils. It is true that the question of power loss in coils is so complicated that one cannot give absolutely simple, easy and definite instructions on avoiding them while at the same time making a reasonably cheap and compact coil.

But there is room for improvement on the lines indicated. It is only a few months ago that we saw a commercial set in which, for compactness, the variable condensers were put inside the coils !

It is evident from the results obtained in Mr. Wilmotte's tests (conducted with the facilities of a great laboratory) that the question of the insulation between turns is of paramount importance. He found especially that cotton covering was to be avoided, and in cases where the turns are in contact the increase in resistance will be even greater than in the case quoted by him. It is obvious that the general lines of design for short-wave coils—including those for broadcast wave-lengths—must be : increase of air-space between turns, even at the cost of using thinner wire ; use of the minimum amount of "building" material (*i.e.*, solid insulating formers, etc.), near the wires ; choice of good insulating materials.

Detectors.

In this issue we conclude the article by Mr. F. M. Colebrook on the crystal detector. We hope that even those of our readers who are not disposed to journey with him through the by-ways of mathematics will none the less note carefully his conclusions, especially those showing that under proper conditions the crystal detector is a distortionless rectifier of high efficiency. We have in hand a further article by the same author, in which similar methods are applied to the consideration of the valve detector ; and we may say at once that this article confirms our own opinion that the crystal is superior, at any rate for telephony. It would seem likely that the most efficient combination of all is that of an H.F. valve with reaction, followed by a crystal, with a separate heterodyne for C.W. work. Of course, for many purposes this is too complicated, so a less efficient design must be used.

A Calibrator's Day. [R2083

Some of our sorrows. Perhaps a careful perusal of them will persuade readers to help us more in future

WE wonder whether a few readers might derive some useful lessons from the simple report of a day's work in the calibration department!

Anyhow, we are going to inflict it on them, for we ourselves have feelings, and at the moment of writing they need relief. It had happened that our calibration work, which is usually done in the evening, had been getting in arrears, so we decided that two of us should put in a full day at it and clear some of it off. So at 9.30 a.m. we started, full of hope, and rigged the standard valve wavemeter in one corner of the room and the buzzer in the other. And these were the first 15 instruments we handled :—

1. A valve wavemeter.—Two ranges, claimed to be 40-250 metres. Its appearance was not hopeful, for the coils were wound on cardboard formers, so that their inductance could not be depended on to remain constant nearer than, say, 2 per cent. It had the favourite but horrible scheme of connections shown in Fig. 1, which is very liable to change of wave-length owing to the phones and H.T. battery being inserted at a high-potential point. However, we connected it up, and spent half an hour trying to get in touch with it. Finally, having proved that not even the substitution of 100 volts for the specified 30 would make it oscillate on the short range, we turned it down.

2. A variable condenser.—The owner had had a good idea in using a protractor as a 180 deg. scale, with a pointer on the spindle. This was soon done.

3. Another variable condenser, this time with transparent celluloid housing. The job was soon done, but we wonder whether the user will realise that (owing to the absence of shielding) the act of putting the condenser within a foot of the rest of any circuit will upset all the readings we gave him? Metallic cases are essential for condensers to be used in quantitative work.

4. A similar job to No. 3.

5. A valve wavemeter, obviously made on the same design as No. 1 (from an article that appeared in a well-known wireless periodical some months ago). For results, re-read above paragraph, except that we gave it up after a quarter of an hour instead of half.

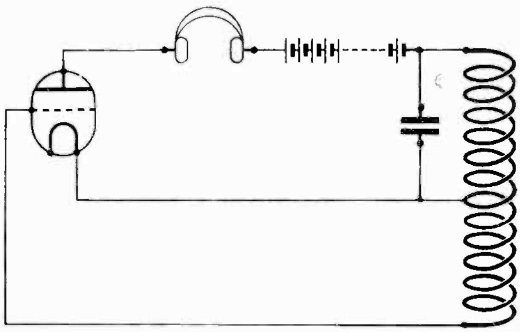


Fig. 1.

6. A different type of valve wavemeter, and, to our joy, preliminary tests showed oscillation over both its ranges! A few tests with the standard at 5 000 metres or so (see "Harmonics," E.W. & W.E., April, 1925, page 390) established the fundamental, and this job was soon done.

7. Two plug-in coils, for inductance and self-capacity. Soon done. They were of a good type for measurement, being single-layer coils on good rigid formers.

8. A buzzer wavemeter.—Quite O.K., and soon done.

9. Another buzzer, but this time of the more usual type, *i.e.*, with non-buzzing buzzer. However, 20 minutes' work put this right, and the meter itself was not unduly flat. But why do people wind buzzer shunts of wire on matchsticks, when a miniature lamp is such a superior alternative?

10. A set of boxed condensers, including one variable.—Why, oh, why, do people pick

out, for standardising purposes, a variable condenser of the varying-distance type, with a characteristic curve like Fig. 2? Especially when it is practically certain that in a few months said condenser will develop backlash and be subject to 10 per cent. error in the all-in position!

A curious point about this test was that one of the fixed condensers (rated .000 5) showed .000 004. Was it, we wonder, a dud condenser? Or did the builder forget to connect that one? Or can't he solder?

11. A beautifully-built buzzer wavemeter. Gave quite good results on its first range, but exactly the same wave-length on the

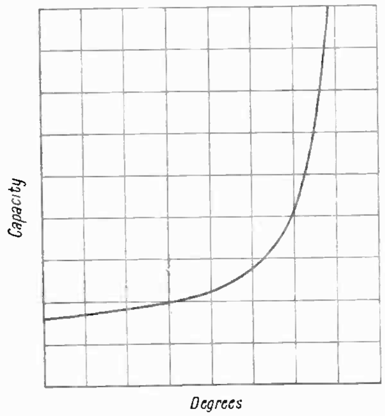


Fig. 2.

second, third and fourth ranges. Evidently the builder forgot something—or was it, perhaps, a practical joke? If it was, we failed to see the point.

12. A valve wavemeter, built by a wireless firm for a customer, to whose design it is not stated; anyway, it would only oscillate on the middle one of its three ranges, so was turned down. We hear that the firm who built it has gone out of business. This causes us neither sorrow nor surprise.

13. Three small fixed condensers, for a commercial firm. An easy job.

14. A valve wavemeter, of similar design to Nos. 1 and 5. This has a history. It first arrived with some of the components and most of the tin-foil shielding in a sort of salad loose in the case. We sent it back. This time it was more or less in one piece. But a fixed condenser was designed to be held in place only by its connecting wires, and the maker was no artist with the soldering iron. Result may be guessed. We were preparing to repair this, to avoid having to return it again, but just then we noticed that turning the condenser knob had no effect on the plates. So that was turned down. Two useful notes: (*a*) If apparatus has to be sent by rail or post, fix the components. (*b*) For an instrument to be calibrated, pin the knob or pointer through the spindle; lock-nuts are not good enough.

15. A buzzer wavemeter. Quite all right in design, as far as we could tell. But we could not be sure, for the variometer had ten degrees backlash between rotor and knob, and there were three disconnections in the circuit.

At this point our feelings overcame us. We adjourned for tea, and deferred further calibration to a later date.

The Lesson.

We have tried to treat of our day's work in a spirit of resignation tempered by mild humour. But there is a serious side to it. Out of 14 instruments for readers, 7 (50 per cent.) could not be calibrated on account of glaring faults. Of the remainder, 4 (28 per cent.) were calibrated, but were not really suitable, and probably will not maintain their accuracy; leaving 22 per cent. (3 out of 14) really satisfactory. Out of eight hours' work, about four and a half hours was wasted—for it takes longer to "mess about" with a bad instrument than completely to calibrate a good one.

May we beg readers who are making instruments for calibration to adopt the following hints:—

1. Get a decent design to start with.

2. Use reasonably good components; *especially spend all you can afford on a good condenser.*

3. Put just a little care into construction.

4. Test the instrument, and *prove* that it works properly before sending it.

5. Pack it properly for transport.

6. Give us the information asked for in the page containing the coupon.

The Rectifying Detector.

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

Part III and Last.

[R149

An exhaustive investigation, theoretical and experimental, into one of the most difficult problems of the Wireless Engineer.

9. Efficiency in the Rectification of a Modulated High-Frequency E.M.F.

We are now in a position to consider the variation of the modulation frequency power obtained, with the magnitude and character of the load. From equation 8·13 the amplitude of $\mathbf{I}_n$ is

$$I_n = \frac{K_c R_{cm} M}{\sqrt{(R_{cm}+R_n)^2+X_n^2}} \quad .. \quad (9·1)$$

It will be convenient to assume some constant mean value for the ratio of M to E. Calling this μ we have

$$I_n = \frac{\mu K_c R_{cm} E}{\sqrt{(R_{cm}+R_n)^2+X_n^2}} \quad .. \quad (9·2)$$

Expressing this in terms of Z_n and θ

$$I_n = \frac{\mu K_c R_{cm} E}{\sqrt{Z_n^2+2R_{cm}Z_n\cos\theta+R_{cm}^2}} \quad (9·3)$$

An obviously important factor is the ratio of Z_n to R_{cm}. Calling this ν then

$$I_n = \frac{\mu K_c E}{\sqrt{\nu^2+2\nu\cos\theta+1}} \quad .. \quad (9·4)$$

The modulation frequency power is therefore

$$P_n = \frac{\nu\cos\theta}{\nu^2+2\nu\cos\theta+1}\;\frac{\mu^2 K_c^2 E^2 R_{cm}}{2} \quad (9·5)$$

For the sake of simplicity we will consider first the case in which the amplitude E can be considered constant. This will correspond approximately to any case in which, by valve retroaction or other means, the damping effect of the detector load can be neutralised. In all such cases the most important factor will be

$$\Psi(\nu,\theta) = \frac{\nu\cos\theta}{\nu^2+2\nu\cos\theta+1} \quad .. \quad (9·6)$$

The form of this function for $\theta = 0$ and $\theta = 60^\circ$ is shown in Fig. 28. For any constant value of θ it reaches a maximum when $\nu = 1$, its value being then

$$\Psi(\nu,\theta)_{(max)} = \frac{\cos\theta}{2(1+\cos\theta)} \quad .. \quad (9·7)$$

Again, the expression on the right hand side of equation 9·7 reaches a maximum value when $\theta = 0$, its value being then $\frac{1}{4}$. This, therefore, is the maximum-maximum value of $\Psi(\nu,\theta)$. The corresponding value of P_n is

$$P_{n\,(max)} = \frac{\mu^2 R_{cm} K_c^2 E^2}{8} \quad .. \quad (9·8)$$

On the assumption of a constant input potential, therefore, the proper basis for the comparison of detectors is $K_c^2 R_{cm}$.

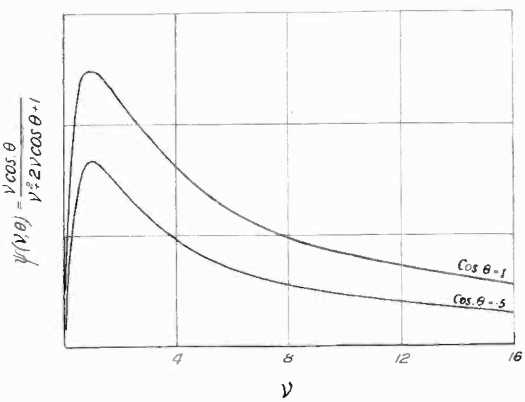


Fig. 28. *Variation of audio-frequency output power with load, for constant input volts.*

The determination of this quantity is considered further on.

The discussion of the condition for the maximum efficiency of conversion of high-frequency power into modulation frequency power, which is the more important characteristic in relation to the direct reception of modulated continuous waves with a crystal detector, is very much more complicated. In the first place, it must be remembered that the E.M.F.

$$e = (E + M \sin nt) \sin \omega t \quad .. \quad (9\cdot 9)$$

is really equivalent to three continuous waves having frequencies $\frac{\omega}{2\pi}$ and $\frac{(\omega \pm n)}{2\pi}$ respectively. Thus, even in the case of a single pure tone modulation the expression for the high-frequency power will be a complicated one. However, since M is in general very small compared with E, the high frequency power consumed will only differ very slightly from that in the case where the E.M.F. is unmodulated and of frequency $\omega/2\pi$ and amplitude E. The power P_1 can therefore be calculated on this basis and expressed in the form

$$P_1 = \frac{E^2}{2R_1} \quad .. \quad (9\cdot 10)$$

where R_1 is the effective high-frequency resistance of the detector circuit under any given load condition. The efficiency of conversion can therefore be put in the form

$$\eta = \frac{\nu \cos \theta}{\nu^2 + 2\nu \cos \theta + 1} \mu^2 K_c^2 R_1 R_{cm} \quad (9\cdot 11)$$

As has been shown in an earlier part of the paper, R_1 will vary considerably with R (the D.C. resistance of the modulation frequency load), increasing rapidly as R increases. This increase of R_1 may, and in most practical cases actually will, more than compensate for the decrease in $\Psi(\nu,\theta)$ due to the consequent increase of ν, the ratio of Z_n to R_{cm}. The matter cannot be very usefully discussed without reference to actual values, and will therefore be considered more fully when discussing experimental results. It may be stated, however, that in general the best load resistance will be in excess, in some cases very greatly in excess, of the value apparently appropriate to the internal resistance of the detector. This is probably the reason for the greater sensitivity obtained by the use of high resistance telephones in the direct crystal reception of modulated continuous waves, in spite of the fact that the impedance of such telephones at audible frequencies will be greatly in excess of the apparent internal resistance of the detector.

Experimental Results with Modulation Loads.

It has been shown that the modulation power developed in a load of magnitude Z_n and phase angle θ_n due to the rectification of an E.M.F. E, where

$$e = (E + M \sin nt) \sin \omega t = E(1 + \mu \sin nt) \sin \omega t,$$

will be

$$P_n = \frac{\nu \cos \theta_n}{\nu^2 + 2\nu \cos \theta_n + 1} \frac{\mu^2 K_c^2 R_{cm} E^2}{2}$$

where $\nu = Z_n / R_{cm}$.

It was further shown that

$$\frac{1}{R_{cm}} = F_1(E) - v_0 F_2(E) + \frac{v_0^2}{2!} F_3(E) - \ldots$$

$$+ (-1)^n \frac{v_0^n}{n!} F_{(n+1)}(E) + \ldots = -\left(\frac{\delta i_0}{\delta v_0}\right)_E$$

and that

$$\left(\frac{\delta i_0}{\delta E}\right)_R = \frac{K_c R_{cm}}{R_{cm} + R}$$

where

$$K_c = F'(E) - v_0 F_1'(E) + \frac{v_0^2}{2!} F_2'(E) - \ldots + (-1)^n \frac{v_0^n}{n!} F_n'(E)$$

The values of the quantities K_c and R_{cm} can thus be determined either from the known form of the characteristic or, if this cannot be expressed in mathematical form, from the measurement of the slopes $(\delta i_0/\delta E)$ and $(\delta i_0/\delta v_0)$. It is clear that the values will depend primarily upon E, and for a given value of E will vary somewhat with R, the D.C. resistance of the modulation frequency load. If R is very small, v_0 will be small, and we shall have

$$K_c = F'(E)$$

$$R_{cm} = R_c = \frac{1}{F_1(E)}$$

For finite values of v_0, K_c will in general decrease in value, while R_{cm} will increase, the product $K_c R_{cm}$ varying less than either of them in consequence. The values of R_{cm} for a constant load of 1 000 ohms are shown in Fig. 29 for the two types of detector. It will be seen that the curves are very similar to those showing the variation of

R_c with E. The values of R_c, which are very simply determined in the manner already described, can, in fact, be taken as an indication of the values of R_{cm} with the understanding that for moderately large carrier wave amplitudes R_{cm} may increase with R up to something like twice its no-load value. The following table will give a general idea of the order of magnitude of R_{cm} and $K_c R_{cm}$ and the nature of their variation with R.

GALENA.

E	R =	0	200	400	600	800	1 000
·9	R_{cm} =	90	140	150	95	60	50
·9	$K_c R_{cm}$ =	1·1	1·1	1·1	·97	·86	·80
·5	R_{cm} =	120	143	228	270	274	250
·5	$K_c R_{cm}$ =	1·1	·80	·87	·87	·92	·99
E	R =	0	1 000	2 000	3 000	4 000	5 000
·1	R_{cm} =	3 200	3 800	4 300	4 800	5 200	5 600
·1	$K_c R_{cm}$ =	1·17	1·26	1·36	1·45	1·54	1·61
·05	R_{cm} =	7 060	7 160	7 200	7 250	7 260	7 300
·05	$K_c R_{cm}$ =	·665	·650	·640	·630	·620	·610

PERIKON.

E	R =	0	500	1 000	1 500	000	3 000
·9	R_{cm} =	380	540	650	700	760	790
·9	$K_c R_{cm}$ =	·76	·95	·98	·98	·97	·94
·5	R_{cm} =	560	640	730	920	1 080	900
·5	$K_c R_{cm}$ =	·80	·70	·80	·85	·80	·67
E	R =	0	1 000	2 000	3 000	4 000	5 000
·1	R_{cm} =	12 000	12 500	13 000	13 500	14 000	14 800
·1	$K_c R_{cm}$ =	·77	·79	·81	·83	·86	·88
·05	R_{cm} =	17 200	17 400	17 600	17 700	17 800	17 900
·05	$K_c R_{cm}$ =	·4	·4	·4	·4	·4	·4

THE CHOICE OF TELEPHONES.

Coming now to the discussion of the most suitable telephone resistance for use with the above detectors, we shall have, as before, two cases to consider. The matter is somewhat complicated by the fact that the impedance of the telephones will vary very greatly with frequency.

If a constant input potential can be assumed, then the best telephone load will be that for which the impedance over the most important part of the audible range of frequencies is equal in magnitude to the apparent internal resistance of the detector under the given conditions of amplitude. This would indicate the use of very low resistance telephones for large signal amplitudes, and high resistance telephones for small signal amplitudes.

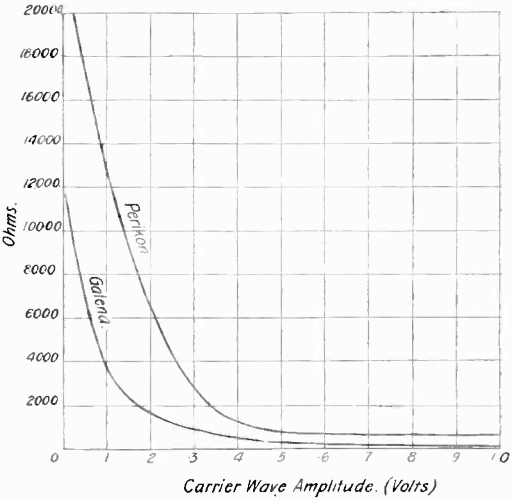


Fig. 29. *Values of R_{cm}, the apparent internal resistance to audio-frequency output, for varying H.F. input and constant external load of* 1 000 *ohms.*

It has already been pointed out, however, that under most practical conditions of direct crystal reception a more suitable basis of comparison would be the efficiency of transformation of high-frequency power into modulation-frequency power. This cannot be very satisfactorily discussed without reference to exact figures for the variation of telephone impedance with frequency, a matter on which information is scarce. To obtain some idea of actual conditions we will assume the following data:—

$$E = 1 \text{ volt.} \qquad \mu = 15\%.$$

It will further be assumed that at some given audio-frequency the impedance will be about four times the D.C. resistance, and that the phase angle will be 45°. The high-frequency power consumed in the detector can be calculated in the same way as for the continuous wave rectification already considered. The curves of Fig. 30 show P_n (the modulation-frequency power) and P_n/P_1 calculated for a galena detector under these conditions.

It will be seen that whereas P_n reaches a very pronounced maximum for a very low value of R (about 100 ohms), P_n/P_1 reaches a maximum for a considerably higher value of R (about 450 ohms) this maximum being much less pronounced than the former. It seems probable that where a galena detector is used with moderately large signal amplitudes there is nothing to be gained by using telephones of very high resistance. It must be remembered, however, that if low resistance telephones are used, steps should be taken to reduce the damping imposed by the detector circuit on the aerial by some such means as those described in the article by the present writer on the subject of crystal reception in the *Wireless World* of July 23, 1924.

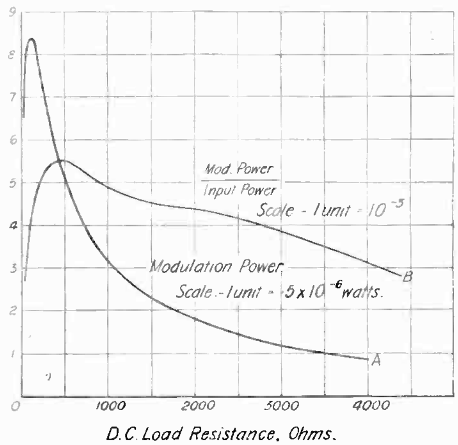


Fig. 30. *For one set of conditions (E=1V, μ=15 per cent.) the output power and power efficiency have been worked out for galena.*

It will be seen from the above table that the telephone resistances appropriate to a perikon detector will be in all cases three or four times as large as those most suitable for galena.

For small signal amplitudes (about .25 volts or less), the maxima of P_n and P_n/P_1 will be associated with more nearly equal values of R, for reasons already given. For these smaller amplitudes it appears that high resistance telephones are likely to be more efficient than low resistance telephones.

It should be noted that under equally favourable load conditions galena should give a very much greater signal strength than perikon. In practice the superiority is less marked than the above discussion would indicate, but this is probably due to the fact that the usual conditions of operation will be less inefficient for perikon than for galena.

The above statements are admittedly no more than roughly approximate generalisations. The very variable character of the quantities involved will not permit of any greater exactitude.

10. Distortion in the Rectification of Modulated Currents.

Whether or no distortion is produced in the rectification of a modulated continuous wave, and the degree of such distortion, if any, will depend not only on the characteristic of the rectifier but also on the conditions under which it is used, more particularly the load conditions.

We have seen that an ordinary crystal detector with no modulation-frequency load will give a modulation-frequency current which is, to a high degree of approximation, a faithful reproduction of the modulation E.M.F. To this extent crystal reception can be regarded as distortionless. Again, if the modulation-frequency load be constant with respect to frequency, equation (8·13) shows that the modulation-frequency current will be a faithful reproduction of the modulation. In practice, however, the modulation-frequency load will be one which varies very greatly with frequency. Consider, for instance, the case in which a detector of internal resistance 500 ohms is used in conjunction with a pair of telephones of which the impedance varies from about 10 000 ohms to 40 000 ohms, with a phase angle of about 60°, over the important audible range of frequency. From equation (9·6) it will be seen that the efficiency factor $\Psi(\nu,\theta)$ will vary from ·024 to ·006 over the same range, i.e., a variation of 400 per cent. with frequency. This variation will undoubtedly cause a very pronounced distortion of the wave form of the modulation, but the effect that this distortion will produce on the ear is further complicated by the response characteristic of the telephones.

The whole subject is at present so little understood that no definite assertion can be made. All that can be said at present is that any distortion present in the telephone reception of modulated continuous waves with crystal rectification will be due almost entirely to the variation of the impedance and the acoustical efficiency of the telephones, and not to the crystal itself.

11. The Influence of Contact Conditions.

(a) Galena.

During the experimental work, rough comparisons of the efficiency of rectification were made with various metals as the contact wire or "cat-whisker." The impossibility of reproducing exactly equal conditions for the various cases makes it very difficult to draw a definite conclusion, but no very marked differences were observed. It appeared that differences attributable to a variation of the contact metal were considerably less than those which would arise from variation of the actual point of contact. The suitability of the metal is probably decided by other considerations, such as immunity from surface oxidation. For the measurements described a finely pointed silver wire was used.

An attempt was also made to investigate the effect of contact pressure, but, for the same reasons, no very definite conclusion could be reached. It seemed, however, that provided a finely pointed wire is used, the detector is not very sensitive to contact pressure. In practice a moderately firm pressure can be used without apparent loss of sensitivity and with a gain in stability.

(b) Perikon.

In this case, quite definite conclusions were obtained. It was found that a heavy contact gave a very much greater no-load sensitivity, with a constant input potential. An increase up to 500 per cent. was obtained by increasing the contact pressure. With a high resistance load, however, the effect went the opposite way, but to a much less extent, the sensitivity decreasing by an amount up to about 30 per cent. with increased contact pressure. These apparently contradictory results can be explained very simply in terms of the apparent rectified E.M.F. and the apparent internal resistance. The decrease of sensitivity with a high resistance load indicates that there is a decrease of the rectified E.M.F. with pressure; the increase of sensitivity at no-load indicates that this slight decrease in the rectified E.M.F. is more than compensated by a considerable decrease in apparent internal resistance.

In confirmation of this, it was found that the open circuit rectified E.M.F. was decreased by an amount up to about 30 per cent. by increase of contact pressure. An examination of the static characteristics corresponding to a light and a heavy pressure revealed the cause of these changes. It was found that the increase of contact pressure resulted in a considerable increase of conductivity in both directions. Under practical conditions of operation, this would have the effect, not only of decreasing the rectified E.M.F., but also of reducing very considerably the effective high-frequency resistance of the detector circuit. Both of these changes will result in a lower efficiency. These conclusions are confirmed in the practical application of this type of detector to the reception of telephony. It may be concluded that the holder for perikon crystals should be designed on comparatively massive lines, for the sake of rigidity, and should permit of very fine and smooth adjustment of the contact pressure.

12. The Variation of the Sensitivity with Wave-length.

All the measurements described were carried out at a constant wave-length of

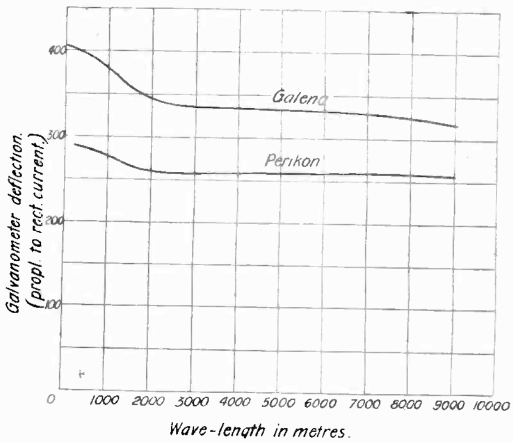


Fig. 31. *The effect of input wave-length on output is not very great.*

about 400 metres. The effect of variation of wave-length is exhibited in the curves of Fig. 31. It will be seen that in each case the sensitivity decreases slightly as the wave-length increases, but that the change is comparatively small.

13. Summary of Results with Simple Crystal Rectifiers.

(i) The apparent dynamic characteristic of a crystal detector may differ by as much as 80 per cent. or so from its static characteristic. The dynamic conductivities of the galena specimens tested appear to be higher, and those of perikon lower, than the static conductivities.

(ii) The important features of a crystal detector are :—

(*a*) The apparent rectified E.M.F. This appears to vary from about 25 per cent. to 80 per cent. of the signal amplitude with variation of D.C. load and amplitude for both types of detector examined. In general, it increases with the load.

(*b*) The apparent internal resistance. This varies very greatly with the signal amplitude and to a less extent with the load. Probable limits for large and small amplitudes are : For galena, 50-100 ohms to 10 000 ohms ; for perikon, 300-500 ohms to 20 000 ohms. The apparent internal resistance increases very rapidly as the amplitude decreases from about ·3 volts.

(*c*) The effective high-frequency resistance of the complete detector circuit. For a constant signal amplitude this varies greatly with the D.C. load in series with the detector. At large amplitudes it will increase from a comparatively low value at no-load to a magnitude comparable with that of the D.C. load at higher load resistances. At infinite loads (*i.e.*, open circuit rectification) it will probably be very high, of the order of tens of thousands, being comparable with the reverse direction conductivity of the detector. For small signal amplitudes the high-frequency resistance will vary comparatively little with the D.C. load, and will be in general between 10 000 and 100 000 ohms.

(iii) For comparatively large signal amplitudes (greater than ·4 volts) a crystal detector of either type will give under ideal conditions a very faithful reproduction of telephony or other modulation. In practical crystal reception some distortion is present, but this is almost entirely due to the nature of the modulation-frequency load. The purity of the reproduction of modulation given by a rectifier is decided chiefly by the straightness of the rectification characteristic over the range of signal amplitude represented by the modulation.

(iv) The most efficient loads for use with a crystal detector will depend not only on the apparent internal resistance of the detector, but also on the input energy conditions. If we assume constant input *power*, the best load will be that giving the highest efficiency of transformation of high frequency into continuous or modulation-frequency power. Such loads will in general be of considerably higher impedance than those which would be appropriate to the detector if a constant input *potential* could be assumed.

(v) The apparent internal resistance of a crystal detector for the modulation-frequency components of the rectified current will vary considerably with the carrier wave amplitude, and to a less extent with the D.C. load. It will in all cases be comparable with and of the same order of magnitude as the no-load internal resistance of the detector for continuous current.

(vi) With either type of detector the rectified modulation-frequency E.M.F., with carrier wave amplitudes greater than about ·4 volt, will be from ·5 to 1 times the mean modulation percentage times the carrier wave E.M.F. acting in the detector circuit. For very small signal amplitudes the modulation-frequency E.M.F. produced in the detector circuit will be proportional to the square of the carrier wave E.M.F. acting in the detector circuit.

This concludes the application of the general theory of the rectification of small radio-frequency potential differences to typical crystal rectifiers. For the sake of completeness, we go on to consider one or two special cases in which the similar methods of analysis are useful.

It might be stated that the author has in preparation the extension of the general theory to include valve rectification, and has developed a method by means of which the quantitative behaviour of any small receiving valve can be predicted to a fairly high degree of accuracy from its static characteristics.

14. Crystal-Valve Combinations.

One very simple crystal-valve combination has already been mentioned and was illustrated in Fig. 22. It was shown that the application of a continuous wave E.M.F. $E \sin \omega t$ to the terminals of the detector would produce a change v_0 of potential across the condenser, v_0 being the solution of equation (6·2). In the general case v_0 will of course be a function of E, and it will be seen from the curves given among the experimental results that in the case of a galena or a perikon detector the function is such that its change of slope over a small variation of E is exceedingly small. Expressing v_0 in the form

$$v_0 = \chi(E) \quad .. \quad .. \quad (14·1)$$

it follows that the variation of E due to the modulation m will result in a change of potential v_m of the modulation frequency and wave form superimposed on v_0, where

$$v_m = m\chi'(E) \quad .. \quad .. \quad (14·2)$$

It is here assumed that the condenser will not introduce any appreciable time-lag in the potential changes, a condition which can be satisfactorily realised by making its capacity no larger than is necessary to provide a path for the high-frequency currents of low impedance compared with that of the crystal, i.e., about ·000 3μF for the broadcast range of wave-lengths. This modulation frequency change of grid potential will of course give rise to an exactly corresponding component of anode current in the usual way. The purity of the reproduction given by this method of rectification will clearly depend on the straightness of the function $\chi(E)$ over the range of variation m. It will be seen later that either of the ordinary types of crystal detector will probably be quite satisfactory in this respect.

Another very common crystal-valve combination is that illustrated in Fig. 32. It would appear at first sight that this arrangement would not be free from distortion on account of the use of a low frequency transformer. It can easily be shown that this is not necessarily the case. If $\dot{Z}_n$ be the operative impedance of the primary winding of the transformer at the frequency $n/2\pi$, then, from equation (8·11), using the abbreviations which have already been introduced,

$$\mathbf{I}_1 = \frac{K_c \mathbf{M} R_{cm}}{R_{cm} + \dot{Z}_n} \quad .. \quad (14·3)$$

The p.d. across the primary winding will therefore be

$$\mathbf{V}_n = \frac{\dot{Z}_n}{R_c + \dot{Z}_n} (K_c\mathbf{M}) R_{cm} \quad .. \quad (14·4)$$

In nearly all practical cases $\dot{Z}_n$ will be so large compared with R_{cm} that $\dot{Z}_n/(\dot{Z}_n + R_{cm})$ will only differ very slightly from unity, i.e.,

$$\mathbf{V}_n = K_c\mathbf{M}R_{cm} \quad .. \quad .. \quad (14·5)$$

to a close approximation. Putting this in scalar form,

$$v_n = R_{cm}K_cM \sin nt \quad .. \quad (14·6)$$

If σ_n be the voltage step-up ratio of the transformer at the frequency $n/2\pi$, then the potential difference operating on the grid of the valve will be

$$\sigma_n v_n = R_{cm}P_nK_cM \sin nt \quad .. \quad (14·7)$$

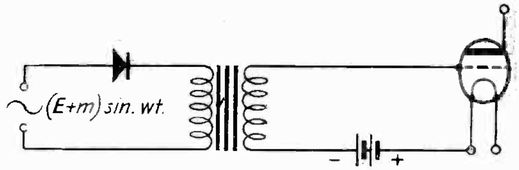


Fig. 32. *The most usual type of crystal-valve circuit.*

In this case, therefore, the purity of the reproduction will depend, not on the variation of the impedance of the transformer, which is the usual cause of transformer distortion in valve circuits, but on the constancy of the ratio of transformation. For a full account of this last factor the reader is referred to the series of articles by Mr. Dye on the subject of low-frequency transformers, commencing in the September (1924) number of E.W. & W.E. It can be said that in general the variation of σ_n with frequency is relatively unimportant as a cause of distortion, and can be made very small indeed by suitable design. With a good transformer, therefore, the above combination should be free from any appreciable distortion. It is, moreover, a very effective arrangement, since it provides a multiple of the rectified E.M.F. for the operation of the valve.

It might be mentioned that the writer has actually compared the two arrangements described above (the direct connection of the crystal to the grid and the transformer connection), by means of a change-over switch, a resistance-coupled amplifier being used to avoid subsequent distortion. It was found that the transformer gave a very marked increase of intensity without any apparent modification of the quality, this result being consistent with the above discussion.

It should be noted that a transformer intended for use with a crystal need not have so high a primary impedance as one intended for use with a valve, and can therefore be wound to a higher transformation ratio with advantage.

15. Heterodyne Reception.

In heterodyne reception the signal E.M.F., which we will express in the form

$$e_1=E_1\sin(\omega_1 t+\theta_1) \quad \ldots \quad \ldots \quad (15\cdot1)$$

is combined with another E.M.F.,

$$e_2=E_2\sin(\omega_2 t+\theta_2) \quad \ldots \quad \ldots \quad (15\cdot2)$$

before the process of rectification, the second E.M.F. being induced in the receiving circuit by any suitable means. The E.M.F. acting in the rectifying circuit will therefore be of the form

$$e=E_1\sin(\omega_1 t+\theta_1)+E_2\sin(\omega_2 t+\theta_2) \quad \ldots \quad (15\cdot3)$$

Let

$$\omega_1=\omega+n \quad \ldots \quad \ldots \quad (15\cdot4)$$

and

$$\omega_2=\omega-n \quad \ldots \quad \ldots \quad (15\cdot5)$$

i.e.,

$$n=\frac{\omega_1-\omega_2}{2} \quad \ldots \quad \ldots \quad (15\cdot6)$$

$$\omega=\frac{\omega_1+\omega_2}{2} \quad \ldots \quad \ldots \quad (15\cdot7)$$

Then

$$e=E_1\sin[(\omega+n)t+\theta_1]+E_2\sin[(\omega-n)t+\theta_2] \quad (15\cdot8)$$

$$=E_1\sin\omega t\cos(nt+\theta_1)+E_1\cos\omega t\sin(nt+\theta_1)+E_2\sin\omega t\cos(nt-\theta_2)-E_2\cos\omega t\sin(nt-\theta_2) \quad (15\cdot9)$$

i.e.,

$$e=[E_1\cos(nt+\theta_1)+E_2\cos(nt-\theta_2)]\sin\omega t+[E_1\sin(nt+\theta_1)-E_2\sin(nt-\theta_2)]\cos\omega t \quad (15\cdot10)$$

Now let

$$E_1\cos(nt+\theta_1)+E_2\cos(nt-\theta_2)=E\cos\alpha \quad (15\cdot11)$$

and

$$E_1\sin(nt+\theta_1)-E_2\sin(nt-\theta_2)=E\sin\alpha \quad (15\cdot12)$$

i.e.,

$$E^2=(E_1^2+E_2^2)+2E_1E_2\cos(2nt+\beta) \quad (15\cdot13)$$

where

$$\beta=\theta_1-\theta_2 \quad \ldots \quad (15\cdot14)$$

The E.M.F. acting in the circuit can therefore be reduced to the simple form

$$e=E\sin(\omega t+\alpha) \quad \ldots \quad (15\cdot15)$$

where E has the value determined above, and where

$$\tan\alpha=\frac{E_1\sin(nt+\theta_1)-E_2\sin(nt-\theta_2)}{E_1\cos(nt+\theta_1)+E_2\cos(nt-\theta_2)} \quad (15\cdot16)$$

It will be seen that α is not a constant with respect to time. The nature and extent of its variation can be judged from the facts that if E_1 is small compared with E_2, which is frequently the case in practice, α approaches the limit $(nt-\theta_2)$, i.e.,

$$\omega t+\alpha=(\omega-n)t-\theta_2 \quad \ldots \quad (15\cdot17)$$

while if $E_1=E_2$

$$\alpha=\frac{\theta_1+\theta_2}{2} \quad \ldots \quad \ldots \quad (15\cdot18)$$

In the general case the fact that α is not a constant can be regarded as equivalent either to a slow variation of the phase of the oscillation $E\sin(\omega t+\alpha)$ or as a periodic very small variation of the frequency. In any case it will have no appreciable effect on the magnitude of the continuous or low-frequency components of the rectified current.

To an E.M.F. of the form given in equation (12·15) the whole of the preceding analysis can be applied, with the following simple modification:—

The expression for the "no-load" continuous current given by the rectification of an E.M.F. $E\sin(\omega t+\alpha)$ by means of a rectifier having the characteristic $i=f(e)$ was stated in the form

$$i_0=\frac{1}{T}\int_0^T f(E\sin\overline{\omega t+\alpha}).dt \quad (15\cdot19)$$

$$=F(E) \quad \ldots \quad \ldots \quad \ldots \quad (15\cdot20)$$

the graph of $F(E)$ being obtained by plotting i_0 against E. It would, of course, be equally simple to plot i_0 against E^2, giving

$$i_0=F(E)=H(E^2) \quad \ldots \quad (15\cdot21)$$

It is the latter function, $H(E^2)$, and its various derivatives which are of importance in connection with heterodyne reception. From the form of the amplitude E in equation (15·13) it is clear that there will be, in addition to the continuous component i_0, a number of low frequency currents which can be represented by the general symbol i_m, i.e.,

$$i_0+i_m=H(E^2) \quad \ldots \quad \ldots \quad \ldots \quad (15\cdot 22)$$

$$=H\left[(E_1^2+E_2^2)+2E_1E_2\cos(2nt+\beta)\right] \quad (15\cdot 23)$$

$$=H(E_1^2+E_2^2)+$$
$$2E_1E_2\cos(2nt+\beta)\,H'(E_1^2+E_2^2)+$$
$$\frac{4E_1^2E_2^2}{2!}\cos^2(2nt+\beta)\,H''(E_1^2+E_2^2)+\ldots$$
$$+\frac{(2E_1E_2)^m}{m!}\cos^m(2nt+\beta)H^m(E_1^2+E_2^2)+\ldots \quad (15\cdot 24)$$

where

$$H^m(x)=\frac{d^m}{dx^m}H(x) \quad \ldots \quad (15\cdot 25)$$

Now $E_1^2E_2^2$ will in general be a very small quantity. Further, it will be seen from the curve of Fig. 33, which shows $H(E^2)$ plotted against E^2 for a typical crystal rectifier, that $H''(E_1^2+E_2^2)$ will also be relatively small, i.e., over the small range of variation represented by $2E_1^2E_2^2$ the $H(E^2)$ line is sensibly straight. The principal component of i_m will therefore be a current of frequency $2n/2\pi$, the amplitude of which is given by

$$i_{2n}=2E_1E_2H'(E_1^2+E_2^2)\cos(2nt+\beta) \quad (15\cdot 26)$$

The case is thus seen to be very similar to that of the rectification of a modulated continuous wave, with the difference that whereas in the latter process the important factor is the slope of the $F(E)$ line, in the former it is the slope of the $H(E^2)$ line. The equations for the behaviour with respect to load will be similar to those applying to the modulated continuous wave, and need not be restated in detail.

It should be noted that if the $H(E^2)$ line is appreciably curved over the range of variation involved, the third and subsequent terms of equation (11·24) may become appreciable. This will result in the introduction of currents of frequencies $4n/2\pi$, $6n/2\pi$, etc. This will not matter in the case of morse reception, where purity of tone is unimportant, but it may have significance in the case of superheterodyne reception of telephony, and will be referred to again later.

It will be of interest to compare the amplitude of the audible-frequency current with the magnitude of the continuous current which would have been produced by the same rectifier under the action of the same signal but without heterodyne. The latter is given by

$$i_0=F(E) \quad \ldots \quad (15\cdot 27)$$

The ratio is therefore

$$\frac{I_{2n}}{i_0}=\frac{E_1E_2H'(E_1^2+E_2^2)}{F(E)}$$

For the typical crystal rectifier illustrated in Fig. 15, and assuming the values

$$E_1=\cdot 1 \text{ volt}$$
$$E_2=\cdot 5 \text{ volt}$$

the actual value of this ratio is 19·7, which illustrates the great gain in reception sensitivity obtainable by heterodyning. The gain is particularly marked in the reception of very weak signals. Thus, in the above case, if $E_1=\cdot 025$ volt the ratio is about 80.

16. The Supersonic Heterodyne.

The principle and objects of superheterodyne reception are too well known to need description. As applied to the reception of continuous waves, the first process is that described in the preceding paragraph, with the difference that the beat frequency, instead of being in the audible range, is adjusted to some fairly low radio-frequency suitable for efficient amplification.

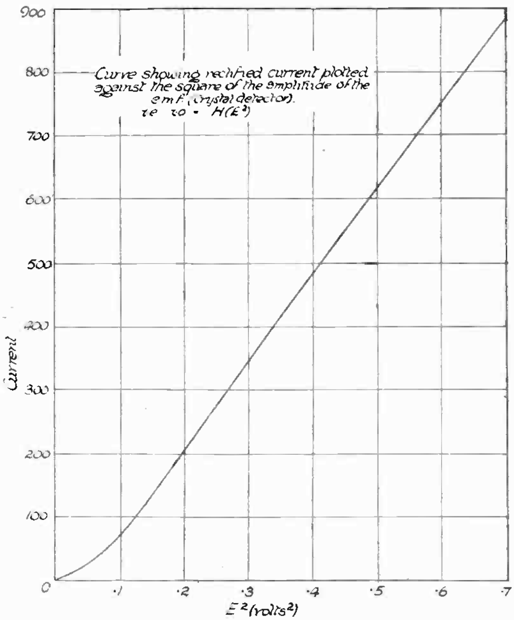


Fig. 33. *For heterodyne work. the connection between output current and the square of H.F. voltage is important.*

A valuable feature of this method, and one which, at first sight, seems very remarkable, is that it can be applied to the reception of speech- or music-modulated continuous waves of very short wave-length without apparently modifying the wave shape of the modulation in any way. The reason for this can be made clear from the preceding analysis.

If $\omega_1/2\pi$ be the carrier wave frequency of the signal, and $\omega_2/2\pi$ that of the local heterodyne E.M.F., then it was shown that the predominant component of the rectified current would be one whose magnitude is proportional to the amplitude E_1 of the original signal and whose frequency is, say, $p/2\pi=(\omega_1-\omega_2)/2\pi$. In the case of valve rectification this will give rise to a grid potential of the same character, i.e., putting e for this rectified radio-frequency signal operating on the grid of the first intermediate-frequency amplifying valve, we have

$$e = kE_1 \cos(pt+\beta) \quad .. \ (16\cdot1)$$

The steps in the argument leading to this conclusion will not be affected in any way if the amplitude E, instead of being a constant, is of the form

$$E = E_c+m.. \quad .. \quad .. \ (16\cdot2)$$

where E_c is the constant carrier wave amplitude and m an audible-frequency modulation of more or less complex wave form. Assuming therefore that the process of high-frequency amplification does not produce distortion, a matter which is outside the scope of the present discussion, the E.M.F. which is finally available for rectification will be of the form

$$e = k'E_1 \cos(pt+\beta') \quad .. \ (16\cdot3)$$

$$= k'(E_c+m)\cos(pt+\beta').. \ (16\cdot4)$$

The transformation of this by rectification into a current of modulation frequency and modulation wave form will be exactly as already shown in the preceding sections of the paper.

It was shown in paragraph 15 that any appreciable curvature of the $i_0=H(E^2)$ characteristics of the initial rectifier would result in the production of currents of frequencies which were multiples of the beat frequency. Even if such parasitic frequencies are produced, however, it does not follow that they will be present in the E.M.F. which is finally rectified. They can, in fact, be very effectively eliminated by the use of an intermediate amplifier having a selective characteristic. The superheterodyne method is thus capable of giving a high degree of purity of reproduction of the original modulation.

Wireless Engineering in American Universities.

Professor Charles L. Kinsloe, the head of the electrical engineering department at Pennsylvania State College, was interviewed recently in New York in order to obtain his views with regard to whether or no American Universities would institute a course of wireless engineering.

He stated that he did not think it was the purpose of the more important colleges to include wireless engineering in their curricula; the greater necessity is an absolute knowledge of the fundamental principles of the science of electrical engineering. Companies and manufacturers, he said, of the type who would employ such students on their completion of the course, recommend that specialisation should be avoided and that a general basic foundation should be concentrated upon.

The World's Highest Station.

What is claimed will be the highest wireless station in the world is being erected by the French Government in connection with the observatory on the summit of the Pic du Midi, at a height of approximately 9 430 feet above sea level.

Amateur Broadcasting in Switzerland.

The amateur transmitters of Switzerland are forbidden by their governmental authorities to employ a power of over fifty watts in their stations. Their wave-length regulations conform to the general boundaries enforced in other countries: amateurs must utilise a wave lying between 180 and 200 metres. Thus it is necessary that anyone working above or below the wave-length limits, or using a greater power than 50 watts, should obtain a special licence.

The various sections of the Swiss Radio Club are already planning to awake greater interest in the science of wireless telephony and telegraphy, and to encourage the erection of amateur stations in Switzerland.

An Australian Association.

According to news lately received from Sydney, the Institution of Radio Engineers of Australia has been formed to advance the interests of those engaged in wireless telegraphy and telephony, and to promote the science and practice of the profession throughout the Commonwealth.

The Perfect Set.

Part VIII: Stability in H.F. Amplifiers. [R132

This instalment completes our treatment of H.F. Amplification, and we shall next consider some special circuits.

IN our last article we discussed generally the favourite couplings for H. F. amplification. It is now proposed to devote some attention to stability. As it happens, we are spared much of the explanation which would otherwise have been necessary, for the subject was treated admirably in our last issue by Mr. O. F. Brown, M.A., B.Sc., whose article was largely based on a special memorandum prepared by him for the Radio Research Board.

In this article, Mr. Brown devoted special attention to what we may call "compensating" methods. We, however, will first deal with "stabilising" methods. The distinction is that the former try to effect a radical cure, by compensating out the fundamental cause of the trouble—the Miller effect—while the latter are really palliatives, to avoid inconvenience by treating the symptoms only. One might justly compare them to the two methods of treating a bad complexion, by ointment or by blood medicine.

None the less the palliative methods are extremely useful, provided they are used intelligently. The great point to be remembered is that the trouble is due to regeneration which tends to cause some closed capacity-inductance circuit to oscillate. If we add resistance to this circuit we can kill this tendency, and, in the author's opinion, without loss of efficiency, for we *want* each circuit to have a small definite positive resistance. On the other hand, some of the methods which have been suggested aim at producing stability by lowering the effective amplification of the valves, which spoils the effectiveness of the set.

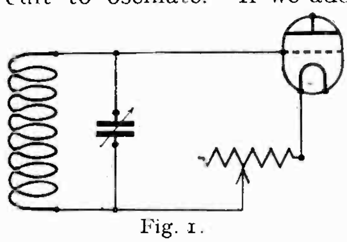


Fig. 1.

Two favourite methods fall into this category, and will therefore only be given as examples of what to avoid. The first is that of taking the grid leads to a potentiometer, and making them sufficiently positive to stop oscillation. One is usually told that this is effective because the resulting grid currents make the valve act as a comparatively low resistance across the input circuit, and so cause damping. This, in itself, is a legitimate method. But the trouble is that in doing it we are almost certainly spoiling the amplification. The method is most decidedly not one to be adopted.

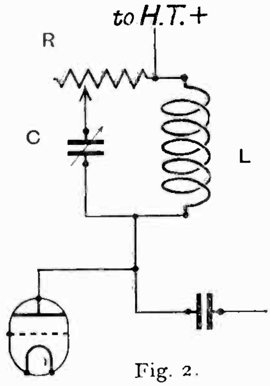


Fig. 2.

An even worse alternative is that in Fig. 1, of inserting a series resistance in the input lead. If this resistance is large enough to be effective, it is simply cutting down the proportion of the input voltage which gets to the valve. It thus cuts down the effective amplification. At the same time, as will be noticed, it offers no hindrance whatever to oscillations in the input circuit *A*, which it does not stabilise at all. It is merely quoted here as an awful example.

The limit offered in the last paragraph leads us to the solution. It is not the *valves* that want stabilising, but the *circuits*, especially those parts forming closed inductance-capacity loops. A valve cannot oscillate without oscillating circuits.*

The device shown in Fig. 2 is a practical embodiment of this idea. It consists simply of inserting, in the "tuned anode" circuit, an ohmic resistance. Note that the same

* Always true, though in some cases the closed circuit may contain only a foot or two of wire and the valve's own capacities.

connection can be used if L is the primary of a transformer. Observe that R is not in the D.C. anode supply circuit, so that even if its value is high it in no way affects the steady anode voltage. It is simply a damper for oscillating currents within the closed circuit LC. Incidentally, besides being a stabiliser, it is to some extent a compensator. Calculation shows that it may have quite an appreciable effect in diminishing the Miller effect from the start as well as in helping to mitigate the results.

It might be thought that the waste of energy in R would lead to low amplification, but that is not the case. We are trying to cope with a set which has *superabundant* energy. Provided that no more resistance is inserted at R than is necessary to stop free oscillation, the *net* H.F. resistance of our circuit remains nearly zero. The author has at present in use a set with 2 or 3 stages of H.F. controlled in this way. Without the stabilisers, a fair amount of negative reaction is needed. With about 200 ohms of resistance in, considerable positive reaction is used, the final reaction control being entirely on the stabilisers. It is an especially useful point that this final control has only the faintest perceptible effect on the tuning. The resistances R are actually potentiometers of the usual 400-ohm type, one end being left disconnected. They are, of course, inserted on the battery side of the condenser.

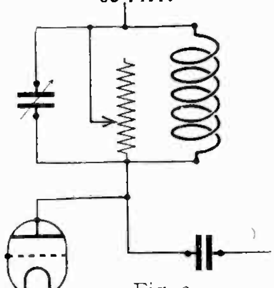


Fig. 3.

An equally good alternative depends on the fact already mentioned in this series, that a low series resistance in such a circuit as Fig. 2 is equivalent to a high resistance across it. This leads to a circuit such as Fig. 3, where R is a variable anode resistance of say 20 000 to 500 000 ohms. The choice between the two depends mainly on the following consideration: the circuit LC will be required to cover a certain range of wavelength. Now at the shortest waves covered—with condenser all out—the reactance of each side of the circuit will be at its maximum, and as the effect of R in Fig. 2 increases with its amount *compared with the reactance*, it will be least effective on the short end of the wave-range. But usually this is where it is most needed. In fact, as C is decreased, R must be considerably increased to keep stability. In the case of Fig. 3, however, the reverse is the case. R is more effective as it decreases compared with the reaction, hence it is more effective as C is decreased. It would appear, therefore, that Fig. 3 would need less adjustment than Fig. 2.

At the time when we built the set mentioned, there was not a really reliable variable anode resistance. Lately, however, we have temporarily connected some in, and although we have not yet had them in long enough to make definite statements, it certainly appears that Fig 3 is the better.

Of course, the action of this stabilising arrangement in no way depends on the LC circuit being in the anode lead. If transformers are used with the secondaries tuned, it may just as well be applied there.

Coming now to the compensation methods, the best known of these is almost certainly the "Neutrodyne." It is necessary, in considering this, to draw a clear distinction between the Neutrodyne principle in general, and the Neutrodyne set as a detailed design.

The main principle of the Neutrodyne is shown by Fig. 4. The trouble is, that when there is an alternating voltage at A, not only is this voltage impressed on L_1 as desired, but it also sends a current through C_1 L_2 (C_1 being the valve capacity), thus impressing a definite voltage on G, leading to regeneration. Now suppose we add the circuit L_3C_3, and by some means or other arrange to induce a voltage on L_3. Take, for example, the instant at which the voltage at A is sending a current through L_1 and C_1 as shown by the arrows I_1, I_2. Normally, I_2 would pass through L_2, but if the voltage in L_3 is at this instant such as to require a current I_2 going downwards, as shown by I'_2, then this can only be got by a current I_2 going up through C_3. No current from A can therefore flow through L_2, there will be no voltage at G due to that at A, and regeneration is avoided.

In practice, we apply the requisite voltage to L_3 by making it the transformer secondary, the voltage being induced in it from L_1. The amount of current is controlled by varying C_3. The most important point is to make sure that the voltage in L_3 is in the right direction; and it must be noted that this must be controlled by the actual direction (left-hand or right-hand) of the windings—*it cannot be got by simply reversing the connections.*

There is a real relation of principle between Neutrodyne and "Bridge" circuits, the idea in the latter being to turn the circuit into some sort of Wheatstone bridge which is balanced at all frequencies. These will not be treated here, as they were so admirably dealt with in the article already dealt with.

Unfortunately, the same trouble arises with both Bridge and Neutrodyne circuits, which prevents their being entirely perfect. This is the variability of the valve capacity itself; every change in frequency affects this somewhat, and it is therefore impossible to put up a fixed arrangement which will ensure complete stability at varying wave-lengths. None the less, they are extremely valuable.

One last word: The peculiar arrangement

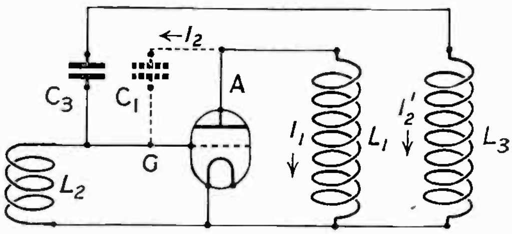


Fig. 4.

of tipped-up transformers adopted in the complete Neutrodyne set is introduced simply to avoid coupling from one transformer to another. *Verb. sap.*: it is useless to adopt elaborate circuits to avoid trouble due to valve capacities unless one takes every precaution, as a first step, to avoid casual coupling *outside* the valve.

Short-Path Discharge Rectifiers.

By Gerald R. Garratt (5CS). **[R336**

IN America, "short-path" rectifiers have received considerable attention, and much time and money has been spent in research work in connection with them; but in this country they have received little attention, and they are certainly not in common use as is the case in America, although the "S" tube of the Amrad Co. is available here. The theory underlying the operation of these rectifiers depends on the "mean free path" of an electron in a gas. It has been discovered that it is possible to design and locate two electrodes close together in gas at certain pressures in such a way that almost perfect insulation exists between them, except under certain conditions dependent on a magnetic field, while, if the electrodes are further apart, there is the usual gaseous conduction.

The separation of the electrodes, which usually take the form of concentric cylinders, is of the order of the mean free path of an electron in the particular gas in which the electrodes are located.

This mean free path may be defined as the distance an electron may travel in any gas, at a given pressure, without colliding with a molecule gas. The value of the mean free path is obtained by multiplying the mean free path of a molecule of the gas by $4\sqrt{2}$. The mean free paths of a molecule of oxygen, hydrogen and nitrogen are given in the following table, which is taken from Kaye & Laby's *Physical and Chemical Constants*, and it should be noted that the mean free path varies inversely as the pressure of the gas. The values below are at normal pressure—760 mm.

Oxygen	.. 9.95×10^{-6} cm.
Nitrogen	.. 9.44×10^{-6} cm.
Hydrogen	.. 18.3×10^{-6} cm.

From these values the mean free path of an electron at any gas pressure may be calculated. For instance, at a pressure of .2 mm. of mercury the mean free path of an electron in hydrogen is :—

$$18.3 \times 10^{-6} \times 4\sqrt{2} \times \frac{760}{.2} = .39 \text{ cm.}$$

of the electrons leaving the outer cylinder, and this increase is sufficient to cause a large number of collisions between the electrons and the molecules of the gas, with the result that ionisation and gaseous conduction at once commence ; while the path of the electrons leaving the inner cylinder seems either to remain unchanged, or, as is more probable, the path is actually shortened and hence ionisation and gaseous conduction are not set up.

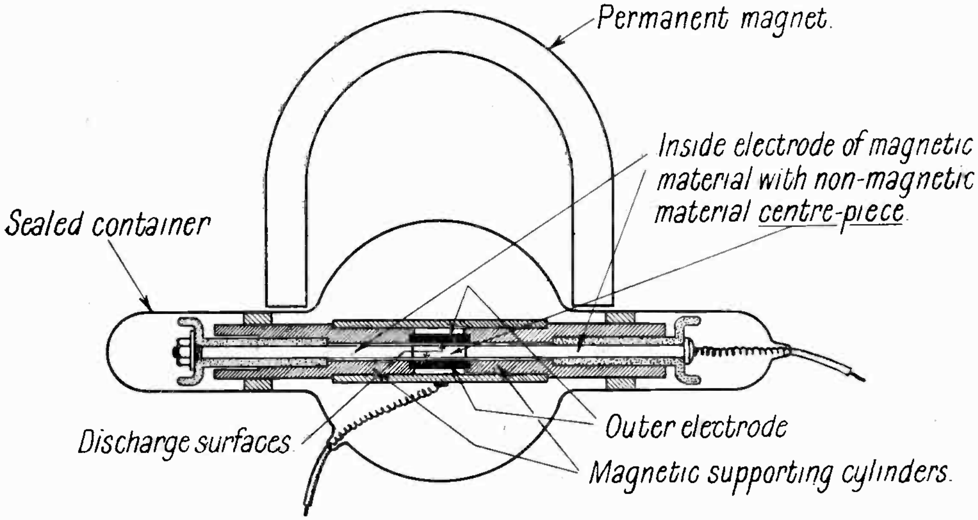


Fig. 1.

The actual spacing of the electrodes is not critical within certain fairly small limits, but if the spacing is increased too much ionisation will at once commence with the result that the insulation breaks down.

If however a constant magnetic field is suitably impressed upon the space separating the two electrodes, it is found that there is little or no insulation in one direction, while if the E.M.F. is applied in the reverse direction it is found that almost perfect insulation still exists.

The exact theory of this rectification is not at present fully understood, but it is believed to be due to a change in the length of the mean free path of an electron under the influence of the magnetic field.

The magnetic field, in some way, seems to cause an increase in the length of the path

From this it might be thought that the rectification would improve with an increase in the strength of the magnetic field, but for some reason this is not the case. When no magnetic field at all is present, almost perfect insulation exists up to potentials of the order of 10 000 to 15 000 volts, but when a magnetic field is impressed upon the gap the device is found to rectify provided that the strength of the magnetic field is between certain limits, which although not critical to any large extent depends on the actual design of the gap. If the magnetic field is too weak the gap will not conduct in either direction, and if it is too strong the gap conducts readily in both directions.

The conductivity of a gas at any moment can be said to depend on the number of ions present, but although there are always a few stray positive ions present, their number is too small to have any appreciable effect on the conductivity provided that their number is not increased by collision.

If the electrons given off from one electrode have normally only a short distance to go before reaching the other electrode, they will collide with only a very few atoms of the gas, and the number of positive ions produced to bombard the cathode and liberate electrons for the initiation of the gaseous discharge will be too small for practical consideration.

Fig. 1 shows a diagram of the rectifier as described in a patent specification by the American Radio and Research Corporation.

As may be seen from Fig. 1, it consists of two concentric electrodes of some non-magnetic material such as molybdenum. The electrodes are subjected to a potential difference, and when the tube is in an operating condition, current will be conducted from the outer to the inner electrode across the gap The electrodes are sufficiently close to prevent conduction in both directions even when subjected to very high potentials. The magnetic field, which is applied so that the lines of force are almost entirely parallel to the axis, causes conduction in one direction and insulation in the other. The magnetic field is set up by a permanent magnet external to the sealed container, but co-operating with the permanent magnet are two cylinders of magnetic material which serve to localise the magnetic field and which also serve to support the outer electrode.

In order to allow the heat generated in the gap to escape, the outer electrode and the connecting sleeve are perforated. The connecting sleeve itself is made of non-magnetic material, and serves only to support the magnetic cylinders.

The inner electrode consists of a small rod of non-magnetic material, which is fastened at both ends to magnetic rods of similar diameter which serve to support it in position. The rod is fastened at its ends to the magnetic cylinders but is insulated from them by glass or other insulating material.

The author regrets that, at the moment, only a small amount of practical data is available but it may be stated that a tube constructed as described above with a radial spacing of .085 inches filled with hydrogen at a pressure of .233 mm. of mercury will rectify with a magnetic field of from 112 to 150 gauss.

A rectifier of this description possesses many advantages over the usual type of valve rectifier which uses an incandescent filament or over the chemical " stew " which is a terrible trouble and a beastly mess!

1. Its life is not dependent upon any one element and hence the life of the tube is determined chiefly by its treatment and with careful use it will last several thousand hours.

2. It will rectify high voltages without the supply of energy to it in the form of filament current, etc.

3. It is extremely simple to use.

4. Owing to its special construction it is able to withstand short periods of excessive overloads.

(Overload is liable to cause heating with the consequent liberation of gases.)

5. It has comparatively low internal losses and the voltage drop across it is not excessive.

In conclusion, the author does not wish to imply that this short article is intended to be a complete treatise on discharge rectifiers, but it was written in the hope that amateurs may be encouraged to experiment in this direction as there is still much to be discovered in connection with them and there is probably a very large future for such tubes for such uses as the rectification of high voltage A.C. for transmission purposes for which service they are admirably suitable.

It should be noted that the " S " tube (see E. W. & W. E., December, 1924), while operating on the short path principle, does not utilise a magnetic field, the unilateral conductivity being achieved in another way.

VALVES FOR SALE.

Do any of our readers want 50-watt. Mullard transmitting valves?

An experimenter, living in London, has been forced to give up the work, and has for disposal two, stated to be new and unused.

We shall be pleased to forward any offers.

Radio 2OA. An Amateur Station.

By E. A. Anson. **[R612**

THERE appear to be very few data available to anyone about to carry out C.W. transmission tests on low power. Diagrams there are in profusion, but actual results obtained with a given power, aerial and circuit are almost non-existent in the various papers devoted to wireless. Each experimenter has to do quite an amount of spade work, and personally

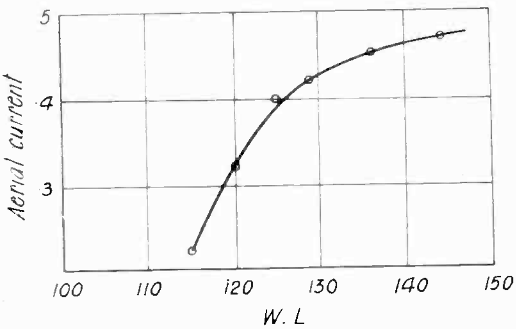


Fig. 1. *Aerial current plotted against wave-length.*

I felt quite cut off from reliable information on what to expect. This article is an attempt to give results with one of the most used circuits, and it is hoped it will be useful to those who are just taking up low power transmission on the amateur wave-lengths.

The locality of these tests is on the Firth of Forth, the site being open and flat, with no masses of houses within half a mile. Spray from the sea breaks over the room on rough days, and there are no trees near.

Wave-length tests were carried out first with an R valve (180 volts H.T. from dry cells), the aerial transmitting coil being a Burndept low-wave receiving coil, the aerial a single 7/22 wire 35 feet high and 100 feet long. The earth was a water pipe. Under these conditions an aerial current of ·05 amp was obtained. When an LS5 valve was substituted this was increased to ·18 amp.

A counterpoise—a 10-foot high duplicate of the aerial—was then substituted for the water pipe, which, using an LS5 valve, increased the radiation to ·28 amp. The circuit was a standard reversed feed back, and the actual circuit, aerial and counterpoise were not altered subsequently, an anode tap being the only addition.

A few remarks about the anode tap may be of use to others. It consisted of a 3s. 6d. broadcast variometer, and except for a tendency to melt under the influence of H.F. currents, it worked well. Of course a better-class variometer would have been more suitable. The importance of the anode tap cannot be emphasised too strongly, since in this case a half-turn of the variometer reduced the aerial current from ·8 to ·1 amp.

At this period transmission took place at the bottom of the garden in an outhouse amid a mass of wires and dry cells ; reception, on the other hand, took place in the house on another aerial, necessitating a 50-yard walk

L.T. Volts.	H.T. Volts.	Milliamps with T15
12	388	18
14	474	27
16	550	35

Fig. 2. *Showing average output of Mackie generators.*

carrying the one and only filament accumulator! Change over switching was apt to be slow—taking five minutes with luck. However, 5JX was very patient.

Having obtained sufficient data, a wave of 125 metres was selected as a result of the curve in Fig. 1 (probably quite wrongly), and a Mackie generator was obtained as advertised in all the wireless papers. Fig. 2 is a table showing what may be expected from these generators.

The L.T. current did not vary much, and at 16 volts was 8 amps, fed from self-starter accumulators. Although this generator ran warm no serious overheating was noticed. The revs. at 16 volts on H.T. load were 2 300 per minute. In order to raise the note of the hum as high as possible a 10-ohm resistance was inserted in series with the field shunt coils, and the revs. rose to 3 200, giving a commutator hum of 1 000 p.p.s. I do not know the size of the mica condenser supplied across the H.T. terminals, but it must be about 2μF, and the commutator ripple is very small even without a filter coil. (The makers informed me that the full output of 600 volts 80mA would be obtained with an L.T. input of 19 volts 10 amps, but that serious overheating would result if used for any but very short runs).

The transmitter circuit at present in use is shown in Fig. 3. Battery grid bias is used in place of the more usual grid-leak, because it is not only very much cheaper, but gives excellent results. A bias of 4½ volts negative on the grid appeared to be correct. Steadiness of wave, even in a gale, was much improved by earthing the filament negative. (Do not mix this with the counterpoise, which is well insulated from earth.)

An H.F. current of ·25 amp flows from L.T. negative to earth, and the aerial current increases by this amount. All combinations of counterpoise and earths proved unsatisfactory except in this manner. Incidentally, the earthing of L.T. negative removed all capacity effects when adjusting in the vicinity of the helix.

The grid coil is not rotatable, but has been adjusted to give maximum results on 125 metres without a tuning condenser. For high waves a ·000 25 variable air condenser is required.

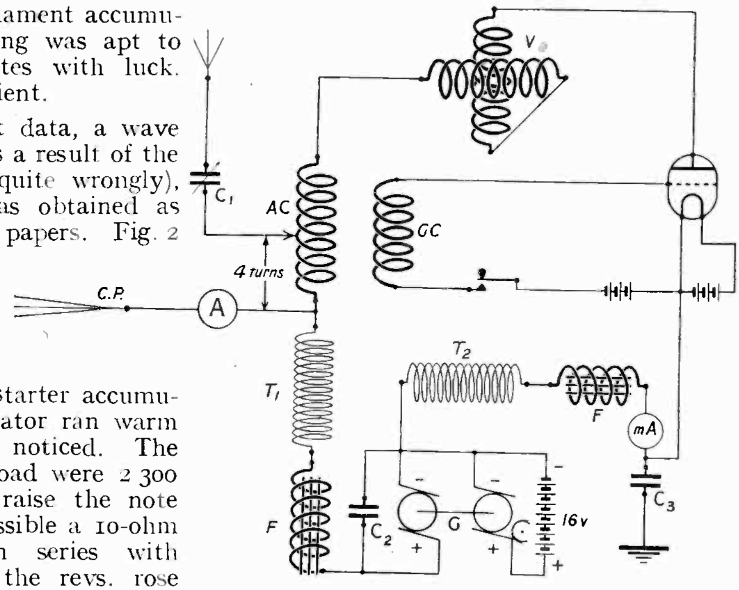


Fig. 3. *The transmitter circuit.*

All my variable condensers on the transmitter are good quality receiving condensers and they seem to function very well. The 500-turn H.F. chokes—Igranic coils—on the H.T. increased the aerial current by ·1 amp. The filaments are lit from my 6-volt car battery, leads being led to the garage for this purpose. Fig. 1 gives aerial current

10 in. Octagonal Helix.
¼ in. Copper Strip spaced ¾ in.
Bottom turn to counterpoise.

Aerial tap from Bottom.	Series Condenser .001 5 max. Ex-WD.	W.-L.
1 turn	12°	115
2 turns	20°	120
3 ,,	22°	122
4 ,,	30°	125
5 ,,	40°	129
6 ,,	41°	132
7 ,,	48°	136
8 ,,	52°	137
9 ,,	59°	140
10 ,,	62°	144

Fig. 4. *Coil and condenser settings for various wave-lengths.*

against wave-length at a constant input. Fig. 4 gives coil and condenser settings for

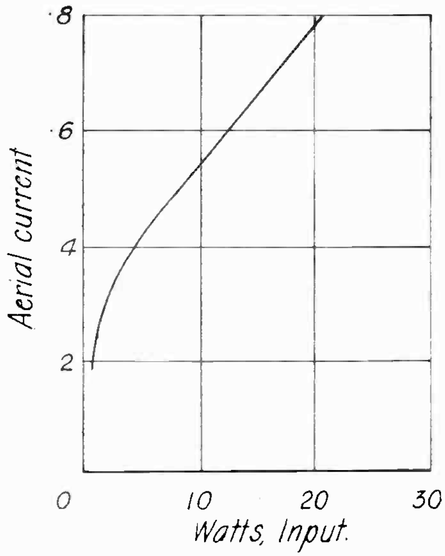


Fig. 5. *Aerial current against watts input.*

various wave-lengths, and may help those feeling their way to radiation. Fig. 5 gives aerial current plotted against watts input to the valve. I do not suppose for a moment that any of these curves are what they ought to be; they are what have resulted from taking ordinary care, and using good instruments.

A switching refinement has been installed lately. It consists of a Lucas Aero dynamo cut-out, connected as in Fig. 6. When the generator is switched on and is "revving" up, this cut-out operates as the starting load lessens and the valve filaments light. On switching off the generator this cut-out turns off the filaments. Two T15 valves are used in parallel at a filament voltage of 5·4. (One T15 will give the same results at 5·8 volts, but the life is shorter.)

The receiver consists of one H.F. detector, and—at will—one L.F. stage. R valves are used, and C.W. reception is possible down to 35 metres. The aerial coil is aperiodic, and untuned for all waves below 150 metres. A Burndept concert coil No. 4 is used, but any coil above this size will work, provided the long-wave stations do not come in. The tuned anode is the only tuned circuit. Although H.F. amplification is almost nil on low waves, the H.F. circuit is capable of extremely fine tuning, and for this reason alone is worth its filament current. The reaction is in the anode coil.

This is by no means a millionaire station, and, like 5KO, radiation and efficiency

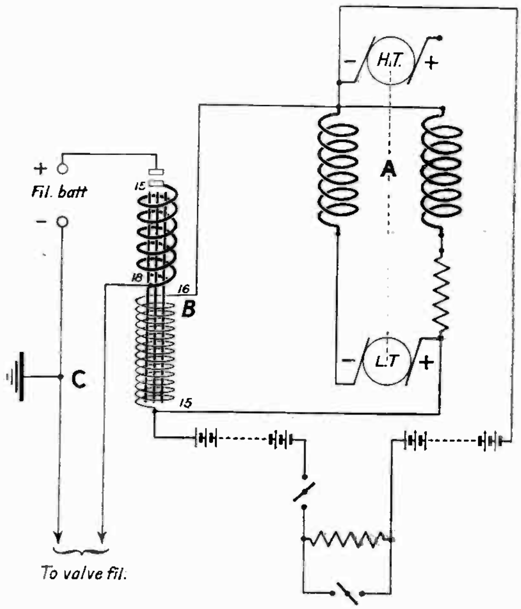


Fig. 6. *Showing the connections of the generator cut-out.*

have been the results of much thought and experimenting. DX results are no more than the average low-power amateur station. France, Sweden, Norway, all the British Isles, and—thanks to 2OD—C1AR have been received.

Parasitic Losses in Inductance Coils at Radio-Frequencies.

By Raymond M. Wilmotte, B.A. **[R382·1**

Suggestions on the really important matters in low-loss coil design.

THE losses in inductance coils at radio-frequencies can be divided into two classes; first the loss in the wire of the coil itself, and second the losses in the surrounding medium. It is the latter that I term parasitic losses. They include losses produced by eddy currents in any neighbouring metallic object, such as screws, terminals, etc., and the losses in the surrounding dielectric.

1.—Loss due to surrounding Metallic Objects.

We shall first consider the losses in the surrounding metallic objects. Imagine a closed circuit of resistance R and inductance L, through which an alternating flux ϕ is passing, so as to thread through the circuit once only. The E.M.F. induced in the circuit is then

$$\frac{\phi}{\sqrt{2}}\omega.10^{-8}\text{ volts}$$

where the frequency is $\omega/2\pi$.

The power loss is, therefore,

$$\frac{R\phi^2\omega^2.10^{-16}}{2(R^2+L^2\omega^2)}\text{ watts.}$$

If L is small this becomes

$$\frac{\phi^2\omega^2}{2R}.10^{-16}\text{ watts.}$$

Thus we see that the loss is proportional to the square of the frequency and inversely proportional to the resistance.

A metallic object, placed near a coil in which alternating current flows, is subjected to an alternating magnetic field. The object can be considered made up of a large number of closed circuits similar to the one just considered. At low frequencies, when $L\omega$ is small, the power loss in the object will be proportional to the square of the frequency, but at high frequencies $L\omega$ may not be small compared to R; the loss will vary with the frequency, but not as quickly as its square.

At all frequencies and for all sizes of objects, the loss will be greater the lower the specific resistance of the material. Thus, a copper screw will produce a greater loss than a brass one. The case of magnetic materials is different, as the value of the flux passing through them is greatly increased; an iron screw will produce a greater loss than a brass one, although the specific resistance of brass is less than that of iron.

The loss is, of course, dependent on the position of the metallic object relatively to the coil, since it is a function of the magnetic field at the position considered. The calculation of the magnetic field produced by a straight uniformly-wound coil is extremely laborious. It is necessary to differentiate the usual formulæ for the mutual inductance between a coil and a circle. The results obtained are complex formulæ involving complete elliptic integrals of all three kinds. For the present purpose, I have roughly calculated the axial and radial components of the magnetic field of a single layer coil having its length equal to its diameter (Fig. 1). The curves in Fig. 2 represent the square of the magnetic force at various radial distances along a diameter AB passing through the centre of the coil (the dotted curve) and for various positions along the axis CD of the coil. The lines MN and $M'N'$ represent the limits of the coil, and the letters Q, A, B, C, D, in Fig. 2, represent the same points as in Fig. 1.

It will be noticed that the dotted curve goes to infinity at the surface of the coil. This assumes that the wire is infinitely thin. In practice the finite size of the wire and the spacing of the turns alters slightly the magnetic field at points in close proximity to the wires themselves. Apart from this small difference the field is identical with that shown in Fig. 2, which is worked out for the ideal case of a uniform current sheet.

The curves show how quickly the magnetic field decreases just outside the coil.

Since the loss varies as the square of the

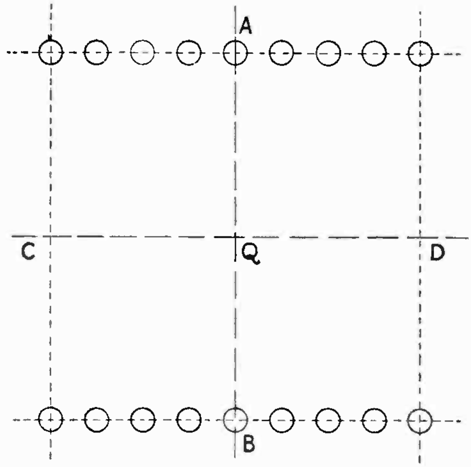


Fig. 1.

flux, it will be seen that the loss produced in a metallic object outside the coil will be very much less than if the object were placed anywhere within the coil. Thus the loss produced by placing a small metallic object in the centre of the coil would be about 10 times the loss in the same object placed on the axis at a distance equal to a quarter the diameter from the end of the coil.

To gain an idea of the magnitude of the quantities involved, a low resistance coil of 20 turns of No. 16 S.W.G. copper wire, having both its diameter and its length equal to 9 cms., was made. The effective resistance of the coil at a frequency of 1 500 kilocycles was about 0·6 ohm, and its self-inductance about 25 microhenries. By inserting in the centre of the coil a copper tube of 1 cm. side, the effective resistance was increased by 0·10 ohm, that is about 15 per cent.

The resistance of the coil was particularly low, but the intensity of the field was small owing to the comparatively large size for the number of turns used—since, for a given shape of coil, the intensity of the field is inversely proportional to the linear dimensions of the coil.

When a circuit containing a coil is tuned and a metallic object brought near the coil, the current decreases considerably. This is due primarily to the reduction of the inductance of the coil and but little to the increase of the resistance. The object usually affects the reactance of the circuit far more than its resistance. To obtain a true comparison of the effect on the resistance of the circuit, the latter must be retuned.

It will have been seen from the foregoing that, if care is taken to place all screws, terminals, etc., in suitable positions relative to the coil, their effect on the effective resistance of the coil will be very small and should not be greater than 1 per cent. or 2 per cent. of the total resistance, even at very high frequencies of the order of 2 000 kilocycles or thereabouts.

2.—Loss due to the Dielectric.

I have laid much stress on the effect of small metallic objects. This is not because the loss due to their presence is large, but because there exists a considerable variety of ideas on the magnitude of the loss produced by them. The effect of the dielectric is of greater importance. Unfortunately it is impossible to make coils commercially with only air as dielectric, and when a solid support is necessary it must be placed in contact with the wire, where the gradient of the electrostatic field is greatest.

A coil can be replaced by an equivalent circuit (Fig. 3) containing a resistance R in series with a self-inductance L, the two being in parallel with a capacity C in series with a resistance r. C is the effective self-capacity of the coil and L the effective self-inductance found by the ordinary methods. The losses are represented by the resistances R and r. R represents the loss in the metallic portion of the wire, as well as that due to eddy currents in the surrounding metallic objects, while r represents the dielectric loss, that is the loss due to the electrostatic field alone.

If P is the average power factor of the dielectric, we have $P = rC\omega$ .. .. (1)

It can be shown (see appendix) that the circuit shown in Fig. 3 is equivalent to a pure resistance R_0 in series with a pure self-inductance L_0, where

$$R_0 = \frac{R + rC^2\omega^2(L^2\omega^2 + R^2 + Rr)}{(1 - LC\omega^2)^2 + C^2\omega^2(R+r)^2} \quad .. \quad (2)$$

and

$$L_0=\frac{L(1-LC\omega^2)-C(R^2-r^2LC\omega^2)}{(1-LC\omega^2)^2+C^2\omega^2(R+r)^2}$$

We are only concerned here with R. When C is small and the frequency does not approach the natural frequency of the coil, we can write

$$R_0=R(1+2LC\omega^2)+PL^2C\omega^3 \quad .. \quad (3)$$

in which we have eliminated r by means of equation (1). Thus if the worst material used in a coil has a power factor P, the increase in the effective resistance due to the dielectric cannot be greater than $PL^2C\omega^3$.

In a practical case, taking the following values :—

$$L\omega = 1\,000 \text{ ohms}$$

$$\frac{1}{C\omega} = 2\times 10^4 \text{ ohms}$$

$$P = 0.02$$

we have

$$PL^2C\omega^3 = 1 \text{ ohm}.$$

It should be noticed that for a given shape of coil the value of C depends on the dielectric constant of the dielectric used. If C_0 is the self-capacity of the coil with air as the only dielectric and K is the average dielectric constant of the materials used the second term in equation (3) becomes :—

$$PKL^2C_0\omega^3 \text{ (approximately).}$$

For coils or panels then, the true criterion for a dielectric is not the power factor P but the product PK of the power factor and the dielectric constant. This fact does not seem to have been sufficiently realised, for in the little available data of losses in dielectrics at radio-frequencies, I have never seen this product mentioned.*

One more point is to be noticed ; that is that the equivalent series resistance due to the dielectric increases rapidly with frequency, namely as the cube, if the power factor is constant.

It has been assumed that the actual resistivity of dielectrics used is sufficiently high to ensure that the eddy current losses produced in them by the magnetic field are negligibly small. This may not always be the case, and it is possible that in very poor dielectrics, such as celluloid, this form of loss occurs. These dielectrics should, of course, never be used in conjunction with apparatus for radio-frequencies.

* See end of article.

In coils two forms of dielectrics are used : one must have suitable mechanical properties, and is used to support the wires in position ; the second is used as an insulating covering direct on the wire. This may be silk, cotton, enamel, etc. There should be the minimum quantity of the former necessary for a solid construction, while the latter should be dispensed with wherever possible. It is the latter, since it is placed where the potential gradient is greatest, which generally produces most of the dielectric loss in the coil.

Let us consider now the various insulating materials available. The data relating to dielectric loss at radio-frequencies are far from abundant. Furthermore, the values given must be very carefully used. It is not possible to see from colour and general appearance, even after considerable experience, whether one given example of material has the same properties as another. Considerable variations occur between similar materials sold by various manufacturers—ebonite is particularly at fault in this respect. Some samples may be extremely good, while others are so bad that one wonders whether it is really meant to be insulating material or merely high resistance. Owing to the high cost of the principal material,

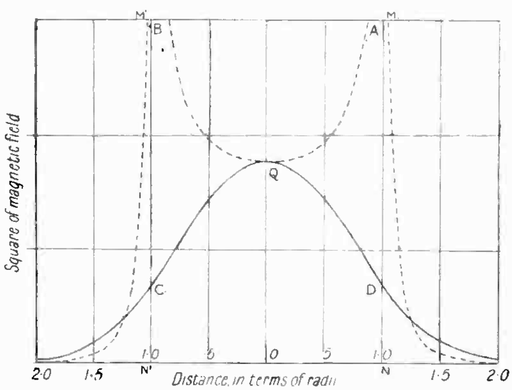


Fig. 2.

rubber, most manufacturers load their ebonite with some inorganic compounds. Ebonite thus loaded loses many of its exceedingly good qualities for radio work. Some manufacturers have also the habit of improving the appearance of their products by imparting on it a high surface polish, which is hardly suitable since this polished surface is usually very appreciably conductive.*

In the March number of the E.W. & W.E. (page 325) a list is given of the power factors of various materials taken from papers of R. V. Guthrie and of Preston and Hall. Unfortunately the dielectric constant is not stated, and a true comparison of the relative merits of the materials for coils and panels cannot be made. There are a few other sources of data. In this respect special mention should be made of the excellent papers of G. E. Bairsto (†), E. Schott (‡), and J. H. Dellinger and J. L. Preston (§).

G. E. Bairsto measured the power factor of a number of materials over a very large range of frequency. The materials tested were blotting paper, crown glass, vulcanised indiarubber, guttapercha, marble and slate; the frequency ranging from 1 to 3 000 kilocycles per second. Bairsto carried out this work just before the war, and the apparatus then available did not allow a high degree of accuracy. He obtained definite maxima near 600 kilocycles for all the materials he tested with the exception of marble and slate. It should be noticed that his values for marble show that this material is quite good, if the frequency is high enough, as the

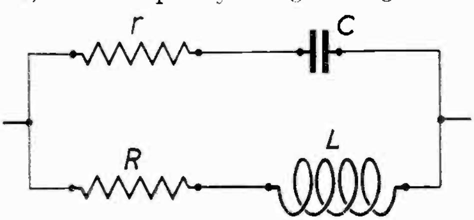


Fig. 3.

power factor decreases fairly rapidly with increasing frequency.

E. Schott, with more accurate apparatus, found the power factor of a large number of glasses of different composition and compared them with mica, ebonite, presspahn and amber. He also studied the effect of temperature in a range from —70°C. to 450°C., showing a rapid increase in the dielectric loss of glass above 100°C. or thereabout. His paper shows that he took considerable care over the measurements and his figures should be reliable. It should be noticed that, though he worked over a range of frequency from 200 to 1 000 kilocycles, he failed to obtain the maxima which G. E. Bairsto found.

We now come to the excellent paper of J. H. Dellinger and J. L. Preston. They investigated the properties of moulded and laminated phenolic insulating materials and compared them with those of ebonite and vulcanised fibre. In their paper of 125 pages they give the results of measurement of the power factor and dielectric constant over a range of frequency from about 100 to 500 kilocycles, depending on the sample. The insulating resistance, as well as the mechanical properties, effect of temperature, moisture, machining qualities, thermal expansivity, and the action of various chemical reagents were also investigated. It is not possible to give a *résumé* of their results.

Another paper on dielectric losses at radio-frequencies is one by W. Steinhaus* who investigated resin and waxes and the effect of temperature on them. It shows how remarkably small the losses in good waxes may be, the power factor being of the order of 0·002.

We have now to consider the effect of the insulation wound direct on the wire. It is not difficult to understand why no values have been published of the power factor of silk and cotton. The results would hardly be reliable if the usual methods of measurement were used.

In order to compare them, I made a small single layer coil of square section having approximately 7·5 cms. side. There were 30 turns with 1·5 mm. pitch, so that by using No. 22 S.W.G. wire, the turns were far from being in contact. Three types of insulation were used: double cotton, double silk and enamel. The effective resistance of the coil was measured by the variation of resistance method at a frequency of 1 000 kilocycles. The coil was then left in water for half an hour, wiped so that it just felt damp, and the resistance again measured; it was next dried by placing on a radiator for a quarter of an hour and further dried, if necessary, by placing in an oven. The results, which are considered reliable to within 0·02 ohm, are given in the table in the next page.

*It is to be noted that Mr. Wilmotte apparently intends these remarks to apply to *bad* ebonite. As will be seen further on, *good* ebonite remains, in spite of these disadvantages, still the best "building" insulator.—Ed. E.W. & W.E.

†. *Roy. Soc. Proc., A.*, Vol. 96, page 363, 1920.

‡. *Jahrb. d. Draht. Tele.*, Vol. 18, page 82, 1921.

§. *Tech. Papers of the Bureau of Standards*, No. 216, Vol. 16, page 501, 1922.

*·*Jahrb. d. Draht. Tele.*, Vol. 18, page 29, 1921.

From these results it is seen that no difference can be detected between bare wire and silk-covered wire within the limits of accuracy of measurement. The effect of moisture is the same on bare wire as it is on enamel, due presumably to a thin film of moisture forming on the wires. The effect of moisture is more apparent on the silk insulation, but this is easily removed; while with cotton, the first measurement immediately after dipping in water shows that the resistance has increased $2\frac{1}{2}$ times. Most of this disappears, however, on first drying over a steam radiator, but even on a second drying in an oven, the resistance of the coil does not quite return to its original value.

The case considered is not a very drastic one from the point of the dielectric, for the self-capacity of the coil is small, it being a single layer coil, having the turns between which there is a big difference of potential far apart.

Unfortunately, I have not the time at present to consider other cases, but it would undoubtedly be of much value should tests similar to the one given here be carried out for various shapes of coils.

3.—Conclusion.

It is evidently too much to ask the mathematician at present for a solution of the problem of the parasitic losses in coils, with odd shaped metallic objects and insulation of varying qualities. The problem is best attacked by direct measurement.

We have seen that, except for high grade coils having very low decrements, the effect of screws, terminals, etc., is very small, if care is taken in placing them where the magnetic field is small.

The problem of the dielectric is more complicated, as it must necessarily be placed where the potential gradient is greatest. We saw that, for a given power factor, the resistance due to the dielectric increased as the cube of the frequency and as the self-capacity of the coil. The latter should therefore be kept small. This is usually done by winding the wire so that there is no large difference of potential between adjacent turns. That this has considerable effect on the self-capacity is well shown by the fact that, in a set of coils for receiving sets, the smaller coils usually have a larger self-capacity than the larger ones. This is because in the small coils the first and last turns are much closer together than in the bigger ones. The size of the wire is also of considerable importance, for the potential gradient at the surface of the wire increases as the diameter of the wire diminishes, thus increasing the dielectric loss.*

Effective Resistance of Coil.

Insulation.	Effective resistance.	D.C. resistance.
	ohms.	ohms.
Bare	1·58	0·245
,, wet	1·68	
,, first drying ..	1·58	
D.S.C.	1·58	0·245
,, wet	2·09	
,, first drying ..	1·58	
Enamel	1·61	0·245
,, wet	1·71	
,, first drying	1·61	
D.C.C.	1·64	0·245
,, wet	4·19	
,, first drying ..	2·01	
,, second drying	1·64	

Table showing results of effective resistance measurements with various coils.

In comparing the various insulating materials for supporting the coils, the mechanical properties become important. So far as the electrical qualities are concerned, micanite and ebonite are extremely good; but both are expensive. The former cannot be machined with any hope of regular results, while the latter is affected by sunlight, begins to soften at about 100°C., warps and deteriorates slowly and, more important still, blunts with extraordinary rapidity all tools with which it comes in contact.

Next in electrical properties come glass, marble, varnished papers, the phenolic

* If, however, the distance between centres of wires remains constant, the use of smaller wire may give an improvement, as a larger proportion of the dielectric between wires will be air.—Ed. E.W. & W.E.

insulating materials, and wood. Glass and marble are hardly suitable for coils. The power factor and dielectric constant are probably of the same order of magnitude for good varnished papers and phenolic insulating materials, but some samples of the former are extraordinarily bad, and they have a further defect in absorbing moisture, which has a very detrimental effect on their electrical properties. The phenolic insulating materials have a power factor varying from 0.03 to 0.07, while the dielectric constant varies from 4.5 to 6 for the laminated materials and from 5 to 7.5 for the moulded. Age does not appear to affect them, and they absorb but little moisture. The laminated products resist shocks, but the moulded material is brittle and difficult to machine; it can, however, be moulded accurately to shape. I have no figures of the electrical properties of wood, but from personal experience I can say that most kinds of wood appear to be good, especially when dry and waxed.

It is a remarkable fact that the power factors of most insulating materials do not vary very much over a large range of frequency. The results of G. E. Bairsto seem an exception to this rule, but the papers of Schott and Dellinger and Preston of the Bureau of Standards show this very well. Some samples have a power factor which increases with frequency; in others it falls, while in others there appears either a maximum or a minimum: but on the whole the variation of power factor is comparatively small. With regard to the dielectric constant, all the results show a very small and regular decrease with increasing frequency.

From the test described above, the best insulation to be put directly on the wires appears to be silk, with enamel as a good second. With enamel, however, there is a tendency to place the wires in very close proximity to each other, and this will increase the self-capacity. Cotton is the worst of the three and is appallingly bad when moist. Further tests are necessary before a more definite judgment can be passed on these materials.

There is one more point I wish to emphasise: that the true criterion of a dielectric is not its power factor but the product of the power factor and the dielectric constant. This does not appear to be generally recognised; although the value of the power factor and the dielectric constant are often mentioned together, it appears to be due more to the fact that, when measuring the power factor of a dielectric at radio-frequency, it is very easy to measure the dielectric constant, than to the thought that the product is necessary in order to compare the relative merits of the samples under test. (*See end of article.*)

For high class work, then, silk covered, or if possible bare wire, wound on an ebonite frame kept away from sunlight can safely be used. The wires should also be well spaced in order to reduce the self capacity of the coil. (The spacing of the turns will incidentally reduce the resistance of the coil for other reasons.) For many coils, however, phenolic insulating materials or even wood could replace ebonite without causing an undue increase in resistance.

APPENDIX A.

EQUIVALENT RESISTANCE AND INDUCTANCE OF A COIL REPRESENTED BY THE CIRCUIT OF FIG. 3.

The impedances of the two parallel branches are

$$R + La \text{ and } r + \frac{1}{Ca}$$

where $a = j\omega$

Hence the impedance Z of the circuit is given by

$$\frac{1}{Z} = \frac{1}{R + La} + \frac{1}{r + \frac{1}{Ca}} = \frac{(1 - LC\omega^2) + (R + r)\,Ca}{R - rLC\omega^2 + (RrC + L)a}$$

$$\therefore Z = \frac{[(1 - LC\omega^2) - (R + r)\,Ca]\,[R - rLC\omega^2 + (RrC + L)a]}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

$$= \frac{(R + rC^2\omega^2)\,(L^2\omega^2 + R^2 + rR) + [L\,(1 - LC\omega^2) - C\,(R^2r^2LC\omega^2)]\,a}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

Hence, if R_0 and L_0 are the equivalent effective resistance and inductance of the circuit, we have

$$R_0 = \frac{R + rC^2\omega^2 (L^2\omega^2 + R^2 + rR)}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

and

$$L_0 = \frac{L(1 - LC\omega^2) - C(R^2 - r^2LC\omega^2)}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

APPENDIX B.

By the Editor.

In accordance with Mr. Wilmotte's suggestion, we have obtained such information as we can as to the dielectric constants of the dielectrics given in the table in E.W. & W.E., Mar. 1925, p. 325, and we reprint the greater part of the table herewith, having added approximate electric constants, and also the product called KP, by Mr. Wilmotte, which we prefer to call $K\psi$ as ψ is used generally for phase difference (which equals power factor when both are small). For notes on these materials, refer to the original table.

Material.	Power Factor. ψ	Dielectric Constant. K.	Wilmotte Factor. $K\psi$.
Bakelite ..	·046	5	·230
Celeron ..	·057	5*	·285*
Celluloid ..	·035	6*	·210*
Ebonite ..	·010	2.5	·025
Fibre	·050	4*	·200*
Formica ..	·050	5	·250
Glass	·008	6*	·048*
Mica	·000 4	8*	·003 2*
,, built up	·016	6	·96
Paper, waxed	·020	3·5	·070
Sulphur ..	·006	3	·018
Varnish ..	·004	3*	·012*
Wax, paraffin	·00016	2	·00032
Wood, dry ..	·040	5*	·200*
,, baked and waxed ..	·020	5*	·100*

* Variable.

A Transmitting Circuit for Short Wave-Lengths. [R423·0124

By E. H. Robinson.

THE object of the present article is to put before readers who are interested in short-wave working a circuit which the writer has devised for energising an aerial below its fundamental wave-length. It is only fair to state at the outset that the fundamental idea was used several years ago in certain ship spark sets, but the possibility of its application to modern valve transmitters seems to have been overlooked.

The original spark transmitter arrangement is shown in its simplest form in Fig. 1. The aerial is a large ship's aerial, having a natural wave-length of perhaps 400 metres. The loading inductance L_1 tunes the aerial up to the 600-metre wave, the condenser C remaining disconnected for this wave-length. L_1 is the coupling coil from the closed circuit which is tuned to the desired wave-length in the usual way. Now, to get down to 300 metres the switch S is closed, *thus putting the condenser C in parallel with the A.T.I.*, the closed circuit being, of course, re-adjusted to 300 metres. It seems at first very much of a paradox that the introduction of a parallel condenser should cause the aerial to resonate at a lower wave-length than the fundamental, but the fact remains that it does, provided, of course, that C and L_1 are of suitable values. The explanation which has been suggested is illustrated in Fig. 2. Consider the parallel shortening condenser made up of two smaller ones, C_1 and C_2 in parallel; this will be admitted as perfectly permissible. One condenser C_1 may be considered a series condenser straight

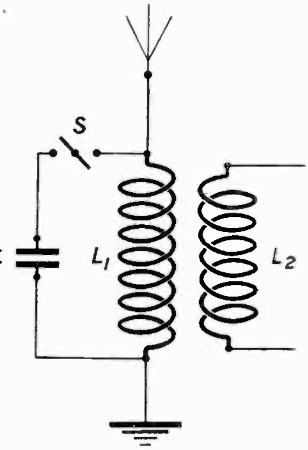


Fig. 1.

in a plain aerial, thus reducing the wave-length below the fundamental, while the other condenser C_2 forms a closed circuit with L_1, which is tuned to the aerial and conductively coupled to it across the terminal of C_1. We thus have a circuit for working an aerial below its fundamental which differs from all others in that the aerial circuit virtually consists of an aerial with a condenser in series and no series loading inductance at all. This would seem to be the most logical way of working on wave-lengths shorter than that of the aerial itself. What we usually do is to insert a series condenser to get the wave-length down, and then, in order that the aerial may be coupled to some source of oscillations we proceed to load it up again with a coupling inductance which to some extent defeats the purpose of the series condenser.

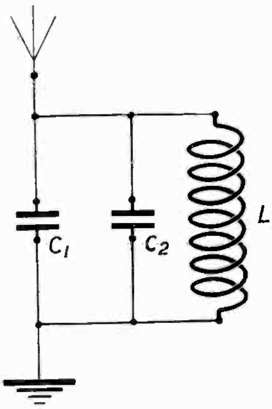


Fig. 2.

The practical circuit adopted for valve transmission is shown in Fig. 3. There is actually no great departure from the usual valve transmitter employing a grid reaction coil. It is essential, however, to tune the grid circuit to the wave-length on which the set is required to function. The reason, apart from the maintenance of a steady wave, is that there are two wave-lengths to which the aerial circuit will respond, namely, the obvious one well above the fundamental which is normally to be expected with a parallel tuned aerial circuit, and the paradoxical wave-length below the fundamental which has been referred to in the preceding paragraph. The grid circuit may contain a small cylindrical inductance with a variable condenser across it. It is well to calibrate the grid circuit roughly against a wave-meter and set it at the required short wave-length and then to adjust the other circuits accordingly. These other adjustments consist mainly in getting the right number of turns of the inductance L in the aerial circuit and adjusting the condenser C. The position of the anode tap is of importance as in any other valve oscillator circuit. By varying the grid tuning condenser without altering any other part of the transmitter it will be found that there are two settings at which maximum aerial current is obtained, and care must be taken to work on the lower one.

The right values of condenser and inductance in the aerial exciting circuit depend so largely on the individual aerial and the wave-length on which it is desired to excite the aerial, that no definite figures can be given here to meet all cases. The following details, however, apply to the experiments made by the writer and may serve as a guide. The aerial itself was about 120 ft. long, consisting of a single length of 7/22 stranded copper wire with an average height of 40 ft. The natural wave-length of the aerial when connected straight to the earth was about 140 metres. It was desired to transmit on a wave-length of 100 metres, and the circuit in Fig. 3 was adopted. The condenser C in the aerial circuit was a .001μF variable condenser at about half setting

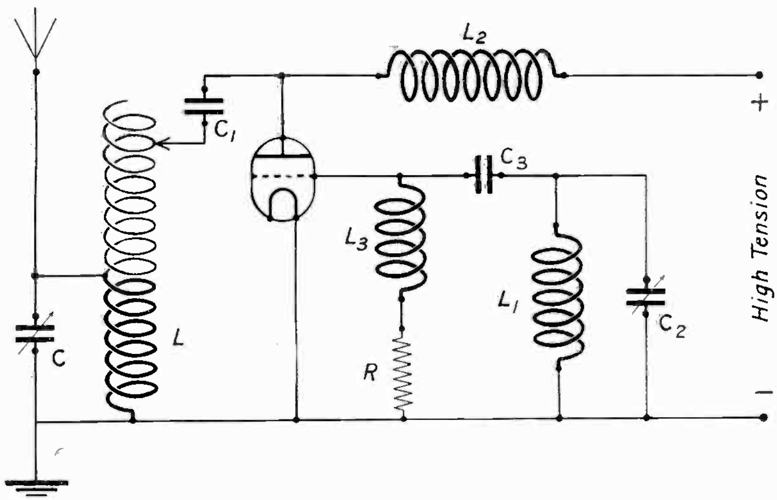


Fig. 3.

The potentials set up across this condenser are not excessive, and an ordinary receiving variable condenser serves quite well on powers below 50 watts. The part of the inductance L included in the aerial circuit consisted of nine turns of No. 12 copper wire wound on a cardboard cylinder 4 ins. in diameter, the turns being spaced from each other by a distance equal to the diameter of the wire. The anode tap portion was wound with about a dozen turns of 28 D.C.C. wire so as to form a continuation of the thick-wire part; there is no object in using heavy gauges of wire for anode tap or ratio tap windings as they do not have to carry large currents. It is important to have just the right amount of anode tap; this amount can only be found by trial and usually consists of quite a large number of turns. Other components in the circuit, such as the blocking condenser C_1, the grid condenser C_3, the grid choke L_3 and the grid-leak R need no special mention as they were the same as would be required in any other circuit. In the actual experiments made it was found that there was no need to couple the grid circuit to the anode circuit. When the two circuits were brought into resonance, the inter-electrode capacity of the valve was sufficient to maintain oscillations, and nothing was gained by further coupling. The best results were obtained on about 110 metres, although the circuit worked well over quite a wide range of wave-lengths. Obviously the optimum wave-length for such a circuit depends on the dimensions of the aerial. Roughly speaking, its useful range is from somewhat above half the natural wave-length of the aerial to a little below the natural wave-length itself.

A further slight modification shown in Fig. 4 allows additional flexibility in wave-length adjustment. This consists in taking the aerial tapping a turn or two below the upper tapping to the condenser instead of at the same point as in Fig. 3. The effect of taking this lower aerial tap is to *increase the wave-length*; and if the aerial tap were taken from the very bottom turn of the inductance the wave-length would be brought practically up to the fundamental or natural wave-length of the aerial.

It should be remembered that the circuit is not intended to work above the fundamental. The fact that the parallel-tuned aerial circuit is capable of responding to two different frequencies, as stated, might give rise to the suggestion that two waves would be radiated at once. This, fortunately, is not the case. It was found that only one wave was radiated, this being on the wave-length to which the grid circuit is tuned. There is, of course, the possibility of producing feeble higher harmonics on shorter wave-lengths, but this depends on the working conditions of the oscillator valve just as in any other regenerative circuit.

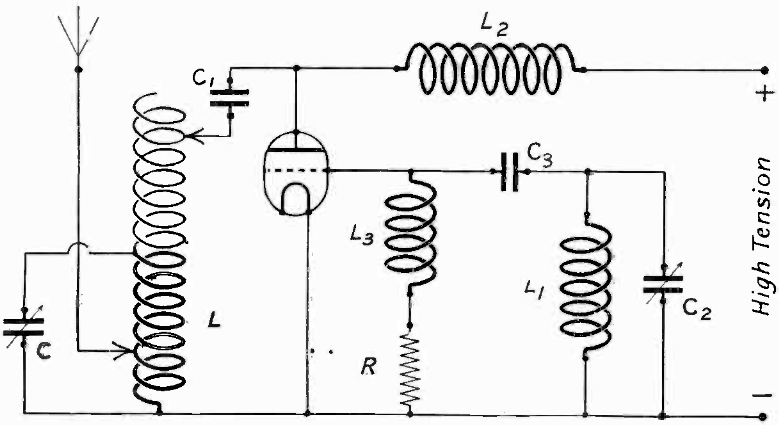


Fig. 4.

Comparative tests showed that the circuit described was quite as good as the more ordinary circuits, and with the aerial used it was distinctly better. In a long high-resistance aerial, at any rate, the measured H.F. current for a given power input was at least 20 per cent. greater than could be obtained with other circuits. Continental stations were worked with quite low power. Whether this method of exciting an aerial can make a general claim to superiority remains to be decided by such other members of the experimental fraternity who care to give it a trial.

The Testing and Measurement of Wireless Components. [R201·060

A paper read before the Radio Society by Mr. P. K. TURNER, at the Institute of Electrical Engineers, on March 25th.

AN Ordinary General Meeting of the Radio Society of Great Britain was held at the Institute of Electrical Engineers, Victoria Embankment, London, W.C., on Wednesday, March 25th, 1925. Dr. W. H. Eccles presided.

After the minutes of the previous meeting had been taken as read, and signed,

The CHAIRMAN said: The first business is to present the prize to the successful exhibitor at the recent Schools Wireless Exhibition. A great many schools competed for the prize, which was offered by Mr. Reeves (one of the Members of Council). The Broadwater Road School obtained highest marks, and a clear majority over any other school, and, therefore, the prize has been awarded to them by the judges, who were Mr. Maurice Child, Mr. G. G. Blake, and Mr. Fogarty. The prize selected is a loud-speaker with a special winding, and, as the winding is unusual, we are not able to present the instrument to-night. I suppose the apparatus exhibited was made more or less collectively, and not by a single individual.

Mr. FOGARTY: It was the collective work which really gained the marks.

The CHAIRMAN: Is there any spokesman here to represent the School?

There being no representative present,

The CHAIRMAN said: That being the case, all I have to do is to announce that the loud-speaker will be sent, as soon as it is ready, to the Broadwater Road School.

The CHAIRMAN: I will now call upon Mr. P. K. Turner to deliver his lecture, entitled "The Testing and Measurement of Wireless Components."

Mr. P. K. TURNER: This subject, of course, is much too large to cover in a single talk, and I propose just to describe some of my own work. The testing and measurement of wireless components at the present moment is more or less in the making, and one has, in a sense, to invent one's own methods as one goes along.

Of course, one has to face from the beginning some rather large problems in the general idea of measurements. Roughly speaking, there are some measurements that can only be carried out in a highly equipped laboratory—such work, for example, as the measuring of the power factors of dielectrics—but there are other tests which are susceptible to a varying degree of accuracy, according to the conditions under which they are carried out. There is also a third class of measurements which cannot under any conditions be made accurately.

In our own work, of course, we are testing from a particular point of view. My office is constantly receiving commercial apparatus which is intended to be sold to the public, and I am asked to report in the columns of various papers as to whether it is suitable, in one case for the experimenter to use, and, in the other, as to whether it is suitable for the trader to sell; and, of course, reports on the tests vary according to the papers in which they are going to appear.

We have set up as a basis of testing that we will find out what the constants of the article actually are so far as possible before we begin to say whether we think it is to be recommended or not, and the first question that confronts one in considering some component which has arrived for test and report is, "What is it supposed to be or to do?" That is quite a difficult question to answer in some cases. Assuming that we have found out what the component is supposed to do, the next question is, "What are the particular qualities that are desirable in order that it shall do that?" Having solved that question, we have to pass on and say, "How can we measure these qualities ? " In some cases the methods are well known and obvious, but in others they are not. Before we report we have to answer the question, " How do the results obtained from our tests compare with the results obtained with similar components ? " I propose to deal to-night with a few of the most prominent components that we deal with, and to try to put forward my ideas —my personal ideas, and not official ones— as to the answers to these questions.

Naturally, the first accessory that we take up is the valve. In answer to the first question, as to what the valve is for, there are obviously two purposes ; namely, amplification and detection. The second question, as to what are the desirable qualities of a valve for L.F. amplifying, is surprisingly difficult to answer. You are tempted to say at first that what you want is amplification—high μ—but high-μ valves are sometimes quite undesirable for that purpose. The valve must be capable of amplifying without distortion, or with not more than a certain maximum of distortion, and it must, for most purposes, be so designed that one can amplify under distortionless conditions with reasonable convenience—that is, without demanding excessive inputs to the valve in the way of high tension, low tension, and so-forth. The first essential of all, amplification, obviously calls for reasonably high μ, but it must not be forgotten that it also involves its anode impedance. The factor μ^2/R_a, the square of the amplification factor divided by the anode impedance, appears to be one that gives a true measure of what the valve will do when it is coupled with transformers designed for it. The absence of distortion calls for a fairly large portion of the characteristic curve of the valve to be reasonably straight, though there can be a certain amount of deviation before the resulting distortion is perceptible. Another most important requirement, and one which is very badly neglected at the present day, is sufficient output, so that the straight portion of the curve should be obtainable at fairly low anode voltages.

Fig. 1 shows a typical curve of the type that I usually work with. I very rarely use the grid voltage characteristic at all, as I find that this is a much more satisfactory method of dealing with the matter. This characteristic is obtained in the simplest possible way, by simply putting instruments into a valve circuit, gradually increasing the anode voltage, and observing the resulting anode current. The first thing about it is the direct measurement it gives of the anode impedance. You have here a certain change of current ΔI_a produced by a given change of anode voltage ΔE_a. If you are on a substantially straight portion of your valve curve, by dividing one by the other you get the anode impedance. There

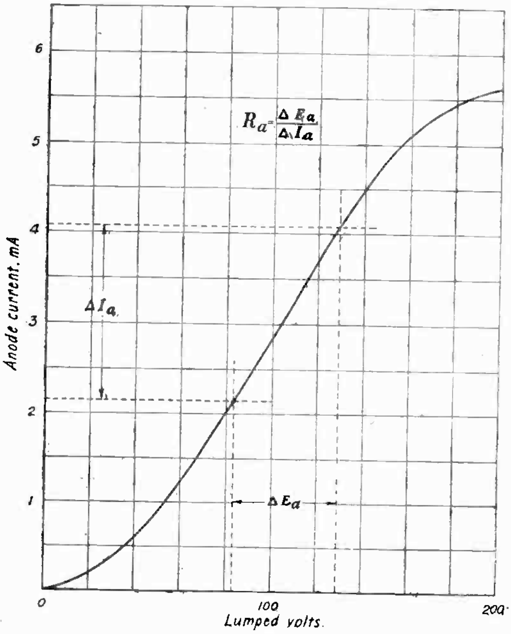


Fig. 1.

is quite an important point there, and that is the question as to on what part of this curve are you going to take the measure of anode impedance ? That is a point I shall return to later, but at the moment I might just say that, where the valve gives a curve which begins to rise fairly gently, and goes on gently for a long time, and perhaps does not begin to straighten out until the 100-volt point, it means that, in order to work on the straight part of the curve you must have 150 volts, or something of that sort, and this must be the volts on the *anode* and not necessarily the *battery* volts. In average use the valves of the present day seem to have rather lower voltages than that. The temptation is to use a 60-volt battery unit, and it is quite probable that the valve will be used on some point down on the curved part in that case, and the valve maker will usually measure the anode impedance down there. He claims that he is justified in doing so because it is where the valve is to be used. Personally, I give the anode impedance about the centre of the straight part, because I say that is where the valve *ought* to be used. Each has an entirely different point of view, and on one or two occasions that has led to considerable discussion.

Fig. 2 shows characteristic curves for the same valve, but at different filament heats, and this is a point which is badly neglected in the makers' usual characteristic curves of valves. The point, I think, is sufficiently obvious. There is a change in the anode impedance with change in filament heat. The slope of the curve is less with lower filament heats, and the result is a higher figure for anode impedance. But, much more important than that, is the fact that you cannot get the same amount of power output with low filament heat. The instructions so often issued for the use of valves are: "In order to get long life, reduce the filament heat until you begin to lose signal strength." Consideration will show, however, that before there is any perceptible loss of signal strength, you will be working

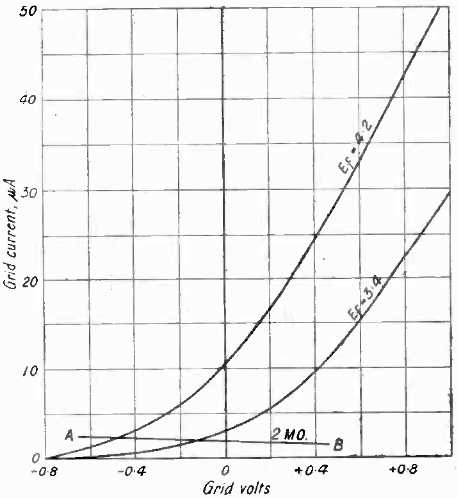


Fig. 3.

right on to the bends of the curves, getting distortion. Distortion becomes perceptible before signal strength begins to fall, and hence that suggestion to cut down the filament heat to that extent is a faulty one from the point of view of first-class reception.

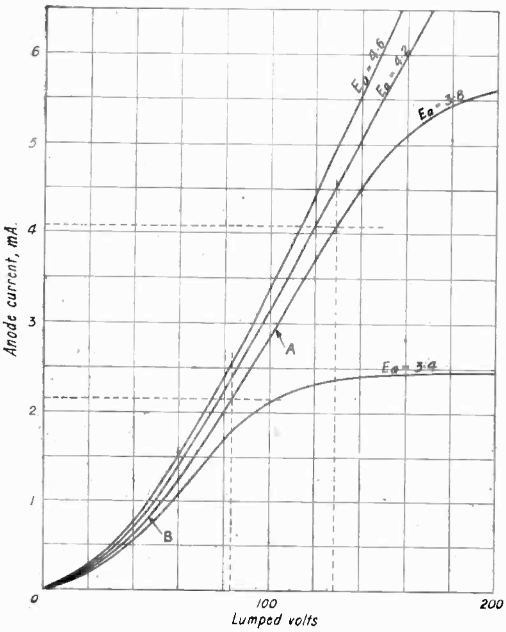


Fig. 2.

The next constant of the valve cannot be got from this curve, but it is got from the usual grid voltage curve. In our case, having taken these curves—say we take the one for 3.8 volts in Fig. 2—the centre point is at *A*, and we see what the current is. In this case it is 3 milliamperes. With that filament heat and 3 milliamperes, we know we are operating as far as possible on the best portion of our curve for amplification. I then put in 1 volt of negative grid bias, and increase the high tension to come back to the same point, where I am still reading 3 milliamperes. I then first take off the 1 volt and then put on 2 volts grid bias, to get the change of anode current per grid volt. That is, of course, the mutual conductance. The anode impedance is defined as the change of anode voltage per milliampere; or, strictly speaking, per ampere. When one considers that, it is fairly easy to see that the product of those two factors gives us the magnification of the valve. In one case you are measuring the change of anode volts necessary to give a certain change of anode current, and in the other case you are measuring the amount of grid volts necessary to give a certain change in anode current. One is expressed as the impedance, and the other is placed the other way up as a conductance. Multiplying the two gives us the change of grid volts which is equivalent to a given change in anode volts, and thereby gives us the magnification.

Then we come to another point. Suppose that this valve, measured at A, gives an anode impedance of, say, 20 000 ohms, and that, multiplied by a certain mutual conductivity, gives a certain μ. If you measure the anode impedance down at the point B, it will appear much higher, and on multiplying that by the mutual conductivity, you will get a magnification twice as large as before. It appears that this valve is a very fine amplifier, simply because you have measured anode impedance at what I consider to be an unjustifiable point; so that when somebody says that a certain valve has an anode impedance of so much and a μ of so much, the first question to be asked is: at what filament heat did they measure it? and the second, was it measured in the middle of the curve? The middle of the curve seems to be the only point of the curve which you can define accurately. You can take a simple approximation by saying half saturation current.

The question of output I have already dealt with.

For valves for high frequency amplification the conditions are rather different. It is probable that the valve will not be used with a coupling which steps up; hence, a high μ in the valve itself is important. But it is important also to remember that a high magnification in the valve leads to a high input capacity, other things being equal. The effective input capacity of a valve at high frequencies is, to a first approximation, equal to the actual measured low frequency capacity of the valve multiplied by μ. If you have a valve of twice the magnification, the effective input capacity will be somewhere about twice as much, even with the same electrodes. That input capacity has an important effect upon amplification, and it may be that the high μ valve will give less amplification over the whole stage than one of lower μ.

Another point we take into account in getting these characteristics is grid current. Fig. 3 shows a couple of typical grid current curves taken at different filament heats. You are probably aware of the method of finding what is going to be the actual grid voltage of the detector valve when it is in

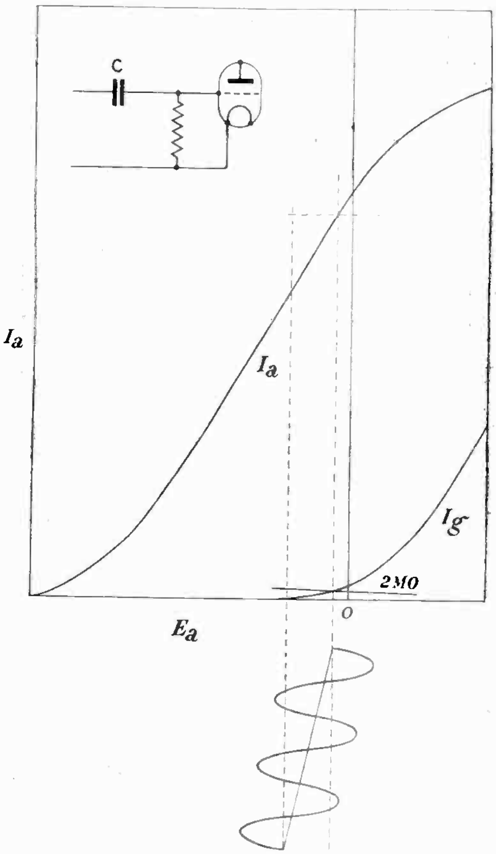


Fig. 4.

use. We all know that it is possible to draw a line AB in Fig. 3 on the curve sheet, representing the current and voltage conditions across the grid-leak, while the curve represents the current and voltage conditions across the grid space inside the valve. The point where they meet is the voltage at which the grid will set itself when no signals are coming in. Fig. 4 is the circuit we all know. We have to think what are the desirable qualities in the valve in order to get the best results. First the question arises as to how quickly the potential of the grid will fall. It seems likely that it will eventually fall to an amount equal to the input voltage, or very nearly so. But the speed at which it will follow the changes in incoming potential is governed by two things. It is mainly a question of how quickly the condenser C charges up, and that depends upon the size of the condenser, and on how much current is passed during a positive swing. A quick rise in grid current would appear to be an advantage. Then the question arises—granted you have got so much voltage drop on the grid—how much change in anode current is that going to give ? and that is a function

TYPICAL VALVE CONSTANTS AT RATED FILAMENT VOLTS						
Class No	Description	Satur'tn. Current I_s (mA)	Anode Impedance R_a (Ω)	Voltage Amplific'n μ	Power Amplific'tn $\frac{1000\,\mu^2}{R_a}$	Filament Efficiency $\frac{I_s\,(mA)}{W}$
460	"R"	8	25 000	7	2	3
460,560	New Bright General Purpose	15	20 000	7	$2\frac{1}{2}$	6
306	"06" Type	7-8	18 000	7	$2\frac{1}{2}$-3	30
235	"Semi-dull"	15	18 000	7	$2\frac{1}{2}$-3	15
245	2 Volt. Power	25	15 000	$5\frac{1}{2}$	2	26
606	".06." Power	40	7 000	8	9	60
625	Power	50	5 000	7	10	30
625 b	"High μ"	40	20 000	20	20	30
435	4 Volt, Power	40	10 000	7	5	30

Fig. 5.

of the slope of the curve marked I_a. I think we can say that a quick rise of grid current is an important thing, and that the other important thing is the ratio of μ to the anode impedance.

In addition to these measurable points, there are a lot of other things affecting the quality of the valve. We have to consider whether it is robust, regular—are alleged duplicates really duplicates?—to what extent it is microphonic, what it costs, and so on. These are not capable of measurement, and I do not propose to deal with them to-night.

I will give a few typical results. (See Table, Fig. 5.) These are mostly the average of two or three valves of that general nature. The first column is a little personal fad of my own, namely, a class number for a valve. Different makers have initials for different types of valves, and they also have numbers. One maker calls a given type of valve one thing, another maker another, and yet another maker another, and so forth, and one gets them very badly mixed. I propose to give all valves of a certain description a number, of which the first figure gives the approximate rated filament volts, and the others the approximate rated filament amps.

You can say roughly that, since the straightness of curves of valves do not vary a very great deal, the undistorted output is proportional to the saturation current. Therefore it gives a very good idea of what any valve will do. In the sixth column we have μ^2/R_a multiplied by 1 000, and in the seventh a rather useful figure, the filament efficiency. It is the milliamperes of saturation current given by 1 watt applied to the filament. The old R valve gives 3 milliamperes per watt, but modern bright valves give more, about 6, and new dull emitter valves about 30. The "semi-dull" valve runs to 15, and the "606" type of power valve runs to 60. If the filament is of a new type altogether this figure gives you an idea of its comparative efficiency from the point of view of emission. If, on the other hand, the filament is one of a known type, and you find it gives an extra high value of filament efficiency, you can guess that it is being run rather hot. If somebody gives me an ordinary R valve with an ordinary bright filament, and says that the filament efficiency comes to 10, I should say that while this is very nice, the life of the valve will be about 150 hours, and I should not recommend it. Thus, that is a point quite worth watching.

Inductance Coils.

I will now break away from valves and come to the question of coils—a rather neglected component. Hundreds of them are made, but very few appear to be tested. The first question is, "What is it for ?" It is a pure inductance in theory—or it is supposed to be. What are the desiderata ? The first one, apart from efficiency, is that it should be fairly rigid and fairly constant. How rigid and constant you want it depends upon its use. If for use in an ordinary receiving set it does not much matter, but in a wavemeter you must go out for those two factors, even at considerable cost. Another feature about which a great deal is said in advertising matter is low self-capacity. My own opinion is that low self-capacity is nothing like so important as it is often claimed to be.

People talk of the apparent resistance of a coil going up enormously with high self-capacity. If you have a circuit like B in Fig. 6 in which you induce from a source into another circuit, and in series with the inducing coil you have another coil L, then the coil L naturally has a self-capacity, represented by the dotted condenser C. When you happen to strike the natural frequency of the circuit LC, obviously that is a rejector circuit, and its apparent resistance will go up. But it is a comparatively rare thing, and in a case like that of A in Fig. 6, where you are inducing into the coil itself, it does not arise at all. It is only under the conditions of circuit B that self-capacity is a hindrance from that point of view. Of course, it is always a hindrance, in diminishing the range with which you can swing with a given condenser, but even that may be over-rated. Remembering that most condensers have a capacity, when set at zero, considerably greater than that of good coils, you still have to combat the self-capacity in the rest of the circuit, however good the coil.

Now we come to resistance, and this, I think, is probably the most important quality. The subject was dealt with so admirably by Prof. Fortescue at the last meeting of the Society that there is not much to be said about it, except that I propose to describe some methods of measurement.

Our standard third question is: How are we going to measure these things? Of course, there are dozens of ways of measuring an inductance, but I think it will be generally

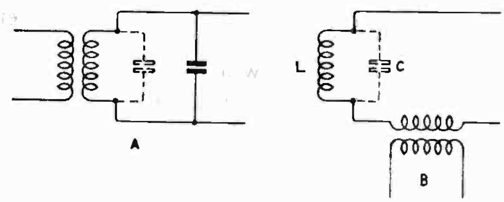


Fig. 6.

agreed that inductances, for our purposes, should be measured at or about the frequency at which they are going to be used.

We all know the fairly simple method of measuring the true inductance and self-capacity of a coil. You place across the coil a variable condenser, of which you know the capacity. From the old formula we know that the product of the inductance and the total capacity across it is proportional to $\lambda^2/3\,550$, the wave-length being obtained by testing with the wave-meter. You measure the wave-length with a varying amount of capacity added, plot the results as shown by dots in Fig. 7, and, if you are in a hurry, you draw what appears to be the best straight line through them, and then the distance AO represents the self-capacity of the coil. The alternative, and superior method, is to make equations and work them out by the method of least squares, to get the most probable values and the probable errors. That, unfortunately, means a lot of work, and I do it on my own standard coils, but I do not mind admitting that I do not do it for anybody else's. (Laughter.)

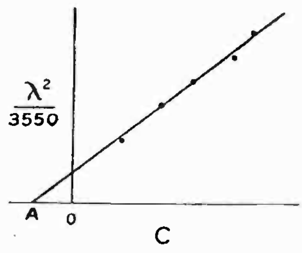


Fig. 7.

That brings me to another point, and that is the lack of information—and I must try to remedy it—on the interpretation of results of this sort of work, and on computation. There are dozens of fine books on calculus, advanced and elementary, and books on the theory of wireless, but I do not know of a single book dealing with methods of numerical computation, in reducing results to a practical form. If anybody has done any of that work, I beg and pray him to write a book, or some articles on it.

As to measuring the high-frequency resistance of coils, the methods, I think, are pretty well known. I described two or three recently. The difficulty is that as a rule you cannot measure the high-frequency resistance of a coil as such. You can find the apparent high-frequency resistance of a circuit, but, of course, as Professor Fortescue pointed out, that apparent resistance includes all sources of power loss. Recently some measurements were made at the National Physical Laboratory, in which they did find the resistance of a coil as an individual thing by itself, and in rather an ingenious manner. They made the coil of glass tubing, and filled it with mercury, and used the mercury inside the tube as the coil. They then put the coil into an oven, and calibrated it as a thermometer against a standard thermometer. Then they put it in a circuit and found what increase of temperature resulted in the coil from a definite amount of power going in, and hence found its resistance by itself. It was

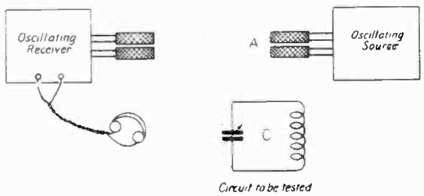


Fig. 8.

interesting to note that when they came to check these results they did not check at first.

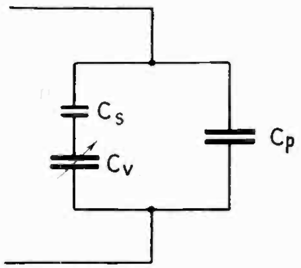
Previously they had had a circuit consisting of one or two wires, the coil and a condenser. They thought they had measured the condenser resistance fairly accurately, and they had found this method of measuring the coil resistance fairly accurate. Eventually they ran a blowpipe flame over the plates of the condenser, and they did then get a check. The running of the blowpipe flame over the plates of the condenser reduced the resistance by between 1/20th and 1/10th of an ohm in that instance. What they did actually was to burn the dust off the plates. They came to the conclusion that under the repeated input and output of power these dust particles were moving; they were standing to attention and then lying down again, and the power taken to pick them up and lay them down again was being registered as the apparent resistance. That was the discrepancy.

Coming to the actual subject, you put a given coil in a circuit and you measure the H.F. current induced in it. You then insert in the circuit a known resistance, and measure the current. Obviously, if the circuit itself already has 10 ohms resistance, then the adding of 1 ohm will not make much difference to the current; if it has only 1 ohm resistance, the adding of 1 ohm makes a considerable reduction in the current. That is the whole essence of the resistance variation method. The well-known alternative method is that commonly known as reactance variation. That consists simply of measuring the sharpness of the resonance curve. There are two rather interesting new methods which you may not all have come into contact with. I will mention particularly one which has rather special advantages. This is the invention of P. W. Willans. You put up an oscillating source, as in Fig. 8, and you put near it your circuit to be tested, so that you couple it to the two coils. Some distance away you put up an oscillating receiver. That also has two coils. The coils *A* and that to be tested form a transformer. When you tune *C* through the wave-length to which the source is set, you alter the current in *C*. But it is always the case that when you alter the load on the secondary of the transformer you alter the apparent impedance of the primary. But if you are altering the apparent impedance of coils *A*, which govern the frequency of the source, then you are altering the emitted wave-length, and if you have the receiver beating with it, you alter the audible note. As *C* swings through resonance, your note suddenly gets higher, and then gets lower, and as you get further away from resonance it again becomes normal. Willans showed that if you measure accurately the condenser adjustments of *C* at which the note is at its highest and its lowest in pitch, you can find quite easily the resistance of the circuit *C*.

There is practically no calculation required. You can do it in various ways. You can either work from a known frequency, and have the condenser of *C* calibrated, or you can insert resistance into the circuit and use this beating arrangement instead of the meter in the resistance variation method I have already described. I have been able to show that you need not even have a calibrated condenser at *C*, provided you have a *good* condenser. So far as my knowledge goes, Mr. Willans is the first man to describe a method of high frequency resistance measurement which does not require any calibrated condenser or any high frequency ammeter or voltmeter. It is a method which can be handled by practically any ammeter.

There is another method, susceptible of considerable accuracy, which is allied to this. It is the Mallet-Blumlein method, which has been described before the Institute of Electrical Engineers. Instead of having the coil of *C* coupled to both the coils of the source, it is coupled to an extra coil in the anode circuit, so that the reaction from it would not interfere with the frequency. But it did affect the impedance of the coil to which it was coupled, and by measuring that impedance, and by adopting a certain graphical construction, you can come to a very accurate measurement indeed of the resistance. That is essentially a laboratory method, and, as such, is rather beyond the scope of my paper to-night.

There are one or two little points I should like to mention. In these and the reactance variation methods the total changes are about 2 or 3 degrees on the average condenser scale, and that makes it awkward: the accuracy required is of the order of accuracy of the scale itself. There is a very old method of getting over that, and that is by a group of condensers. You want to be able to alter condenser *C* in Fig. 8 by 1 per cent. or less. You simply put in parallel with it a small condenser, about 1/10th its capacity, and in series with that you put your variable, a big variable, as in Fig. 9*a*.



$$C = C_p + \frac{1}{\frac{1}{C_s} + \frac{1}{C_v}}$$

$$= C_p + \frac{C_s C_v}{C_s + C_v}$$

Fig. 9*a*.

When you reduce C_v to zero, C_s is cut out, and the capacity is simply the capacity of C_p. However big C_v may be, the capacity of C_s and C_v in series can never be greater than that of C_s, and therefore the total change you can make by varying C_v from 0 to infinity is, you can say, not more than 10 per cent. That is a very old tip, of course.

As to high frequency resistance units, Fig. 9*b* shows the ones I am using. You probably know that Messrs. Burndept make a little gadget for use with dull-emitter valves; a fixed resistance which screws into a socket.

The standard method of use is to lead a wire in at the base and up the groove to the top, and then wind it round and round the outside and finish it off. That struck me as having possibilities. I have obtained a few of these through the courtesy of Mr. Phillips, of the Burndept Company. I set in at *A* a piece of 40-gauge copper wire, join it at *B* to anything from ½ to 2 in. of 47 Eureka, follow this with 40 copper again, solder at *C*, and cover the whole thing up.

These have a great many of the special properties required in a resistor for high frequency resistance. I should say that the inductance is probably less than 1/100th of a microhenry, and the capacity is of the order of one or two centimetres. In any case, the change in reactance from one resistance to another is extremely small. I assume they make no change in the inductance or capacity. The weak point is that there is contact with red fibre, which is, for these purposes, not a first-class dielectric. Owing to the power loss in the dielectric, you cannot be certain that the high frequency resistance will be absolutely the same as the measured D.C. resistance.

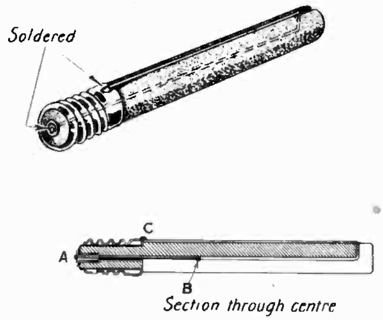


Fig. 9*b*.

The next thing, unless you adopt the Willans method of measuring high frequency resistance, is the measuring instrument—the ammeter. That is quite a difficult question. A thermo-junction is obviously indicated, but if one is using a rather insensitive measurer of current in the circuit one must either couple closely to the source or use a high power source, in order to get sufficient current in the circuit to get readings.

But on no account must one couple closely to the source, because the whole theory of that method of measurement is based on the fact that the source of supply is unchanged. If we couple closely the reaction of the change in current induced in the circuit affects the source. Thus we must have a large source. A large source is not convenient, especially in the drawing-room where I usually work, so that I came down from the ordinary hot-wire meter to a delicate thermo-junction. But on connecting up the circuit you are likely to get a little surge of current, and before the pointer of the galvanometer has begun to move and show the surge, the thermo-junction has burned out. Besides, delicate thermo-junctions have quite high resistances. Eventually I fell back on the Moullin voltmeter. It is quite easy to show that the measurement with a Moullin voltmeter of the volts across the coil ora condenser in a resistance circuit is exactly equivalent to measuring the current in the circuit. Moullin voltmeters are of two kinds.

Each is simply a calibrated valve detector —there is the type with grid-leak and condenser, and the type without. In measuring high frequency resistance the first thing I wanted to ensure was that the load put on by the detector itself (the voltmeter), should be the smallest possible, and therefore I plumped for the anode rectification type. That is usually made up something like *A*, Fig. 10. There is a small grid bias caused by the drop across the resistance, and there is no high tension battery beyond the six volts of the accumulator. It appeared to me that we have not got to the lowest power absorption. With the source I had at my disposal I got a deflection of 3 or 4 volts. I therefore put in a $4\frac{1}{2}$-volt grid battery, and, to get readable current in the galvanometer, I had to put on some anode voltage, the circuit then being as *B*, Fig. 10. Rough measurements I have taken indicate that that voltmeter, very roughly made, throws into the circuit about 9 micromicrofarads of capacity, and it increases the apparent series resistance of the circuit by about 0.6 ohms. I am pretty well sure that one fairly well designed will come down to considerably less than that. It is important to make sure that the condenser *C* is very large. The point about the condenser is that (owing to the well-known Miller effect), if the valve has a load in the anode circuit, its input capacity and resistance depends upon that load. By making *C* a very large condenser you practically short-circuit that load, and, for any reasonable frequency, you can say there is no load. The reactance of the condenser is so low that there is no anode load. There is a useful test for that, and that is to measure the apparent input capacity with the valve alight, and with it out. You put two such instruments across the circuit, and use one to take the readings while you connect and disconnect the other, and see what effect it has on the circuit. The first thing to do is to see how much capacity you have to add to the tuning condenser, and secondly, to measure the high frequency resistance of the circuit with and without the extra meter. I am glad to say that in my own instrument I have not found any difference whether the valve was alight or not ; hence the capacity was not increased by the load in the anode.

There is another little point. The two input leads in the actual arrangement were of stiff copper wire, about 8 inches long, 6 inches apart, and about 5 inches above the table, and, having made the above test, I disconnected at the meter, leaving those two leads on the tuning condenser, and measured again. Then I took them off at the condenser end and measured again. The two grid leads

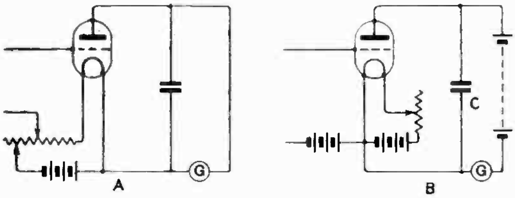


Fig. 10.

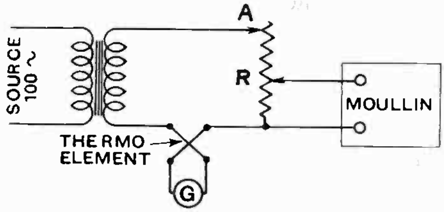


Fig. 11.

threw .1 ohm into the circuit. Whether it was dielectric loss to the table, or whether it was actual radiation, I do not know. Experts have given me opposite opinions. It is interesting to realise that a few inches of copper wire disconnected at one end throw quite a large resistance into the circuit.

As to calibrating the voltmeter, I rigged a local oscillator with a low frequency intervalve transformer across it, and with a condenser across the secondary got about a 100 cycles source. The circuit was as in Fig. 11. What one does is to move *A* up and down until one gets a convenient current which you know. *R* is calibrated, and you know exactly what resistance it is; therefore, you know the voltage applied to the Moullin voltmeter. You then measure what deflection the Moullin voltmeter is giving, and, unless something goes wrong, you have it calibrated.

In finding the resistance of a coil you have to correct for the resistance in the rest of the circuit. The resistance of the condenser is the sort of thing with which you must start. I threw the onus of that on the National Physical Laboratory, and they gave me the resistance of my condenser at various settings.

Having found the resistance of a coil, you are confronted with the question of how to express this. It is very variable. The higher the frequency the higher the resistance.

There is a certain confusion between "power factor," "phase angle" and "phase difference." In any case, I think the soundest method is to measure the resistance-reactance ratio of the coil, which is the difference of the phase angle from 90 degrees. The resistance of a coil at high frequency is composed partly of a more or less constant element, the resistance of the wire; partly of skin effect, which I believe varies as the square root of the frequency; and partly of dielectric loss, which probably varies as the square of the frequency. In any case, the resistance is a rather complicated function of frequency. The phase difference, or R/X depends upon the resistance divided by frequency. The resistance is expressed, as in Fig. 12, and if you divide it by frequency, you get an expression for ψ, the phase difference, and it is obvious that this is a minimum when the frequency is $\sqrt{C/A}$. Expressing the same thing in another way, a coil in which the dielectric losses are high is bad for high frequencies, but not so bad for low frequencies, while the reverse is the case for a coil of high ohmic resistance.

I have noticed in the report of Professor Fortescue's paper, that he speaks of coils of 3 ohms per millihenry. I am going to try to get some of those coils, because—I do not know at what frequency he measured them—at broadcast wave-lengths a millihenry has reactance in the neighbourhood of 5 000 ohms. If you put resistance over reactance you get 3 ohms over 5 000 ohms, a phase difference, or whatever you like to call it, of .000 6. Personally, I have never come across any coil like that yet. Typical results for commercial coils sold for amateurs in this country show power factors of about .01—the resistance is 1/100th of the reactance. I worked with some 50 and 35-turn coils not long ago which showed power factors of about .005, and I was very pleased with them until I read this report. At the National Physical Laboratory they have some very fine coils used on the multivibrator wavemeter. The lowest power factor there was .001 8, so that either the resistances of Professor Fortescue's coils must have been measured at very much lower frequencies, or else they were extraordinarily good.

POWER FACTOR OF COILS

Apparent Resistance of coil, including dielectric losses = R

Frequency = f

$$R = af^2 + bf + c,$$

$$\psi = \frac{R}{\omega L}, \text{ or, } \psi \propto Af + B + \frac{C}{f}$$

This is a minimum for $f^2 = \frac{C}{A}$

Fig. 12.

One interesting case cropped up the other day. A coil arrived, of which I thought the design was extraordinarily good. It was of bare wire, with a minimum of supporting matter, and it gave every prospect of being excellent. But when I tested it I found its resistance, at broadcast wave-length—377 metres—was in the neighbourhood of 12 ohms

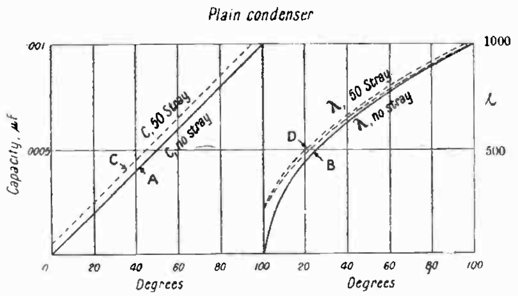


Fig. 13*a*.

as compared with 5 for the very ordinary coil I put against it. I found that in order to hold the outside turn down, they had soldered it to the next previous turn, so that there was one short-circuited turn. I notice that all the makers advertise the self-capacity of their coils, but, unfortunately, they do not tell us much about the high frequency resistance.

Condensers.

The condenser is another all-important component. Here again the answer to the question as to what it is for is a simple one. It is pure capacity, fixed or variable. I suppose one of the first desiderata in the case of a condenser is that it should be constant. I am talking primarily of variable condensers, and I do not think many people realise how difficult it is to get anything like constancy in a variable condenser. I was told the other day, at one of the biggest testing institutions in the country, that although they are prepared to pay £200 or £300 for a condenser, they cannot get one that will remain accurate for six months within 0.1 per cent., and in fact, whenever they are doing a job which requires a calibrated variable condenser, they calibrate one for the job. The trouble appears to be largely due to the fact that the plates sag. Of course, one also wants low loss, and, if possible, a low zero, and one also wants, for ordinary listening purposes at any rate, a convenient scale-law—by which I mean a reasonable and comfortable change of capacity in relation to the change of angle which you effect by turning the knob. I am now going to ride another hobby-horse.

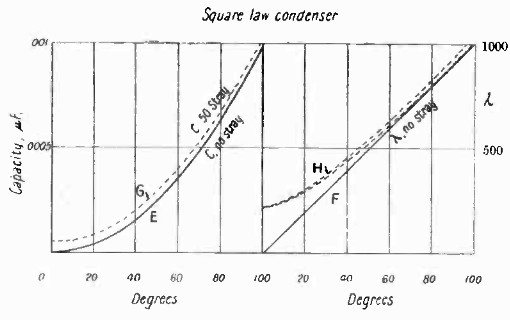


Fig. 13*b*.

Fig. 13*a* shows curves for an ordinary condenser, with semi-circular plates. If it were a perfect condenser, you would have the capacity varying directly with the degrees, as indicated at *A*. When one puts such a condenser with a perfect coil, and works out the resulting wave-length, one

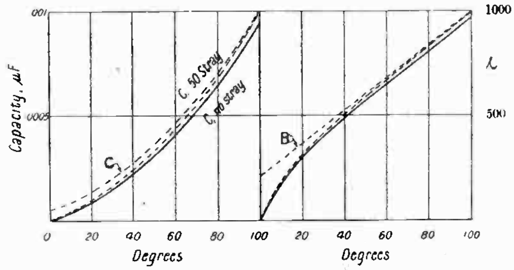


Fig. 14*a*.

gets a curve such as *B*. But actually there is stray capacity, so that *C* and *D* represent actual conditions. Great efforts have been made in the alleged "square law" condenser to get over the curvature of *D*. But in practice they do not.

Fig. 13*b* shows the capacity curves of a "perfect" square law condenser, *E* and *F* being those for no stray capacity. But the effect of stray is to give curves such as *G* and *H*. I have had about a dozen of these to calibrate, and the makers were annoyed when I said the curve looked like *H*. I had to explain why a square law was not a square law. The simple way of getting over it is that we allow for (say) 50 cms. stray capacity, and we say that we know what our wave-length will be—like *B* in Fig. 14*a*—

and we draw a straight line and then build the condenser to deal with it, and the curve comes out like C. Fig. 14*b* shows capacity

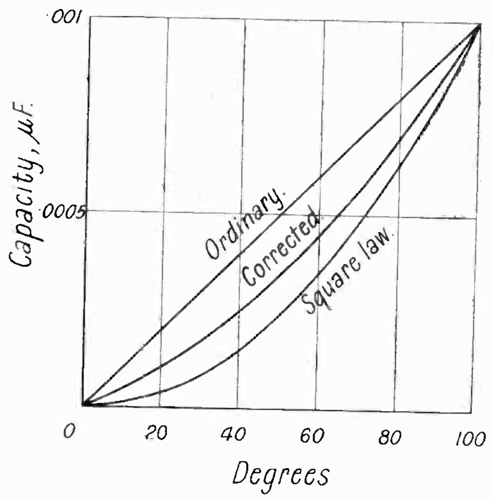


Fig. 14*b*.

curves for the ordinary, the square law, and the corrected square law condenser. Apparently nobody has had the nerve to build a condenser of the corrected type yet, but I hope it will come.

For fixed condensers, which are, as a rule, not air-dielectric, the requisites are of a sufficiently high voltage limit, compactness, low losses, accuracy and constancy. There again one is entirely in the hands of the condenser maker, but there are one or two condenser makers who know how to make condensers, and who fulfil those needs to a considerable extent.

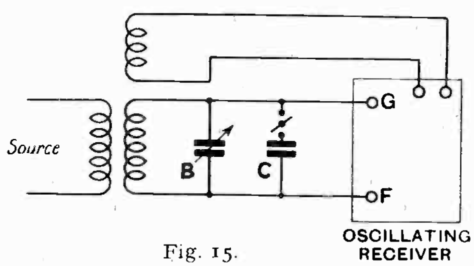


Fig. 15.

I think Fig. 15 shows the simplest and by far the least troublesome method of measuring condensers. We arrange an oscillating receiver, and tune it to the source, then switch in the condenser C to be tested, and see how much has to be taken out of the calibrated condenser B. That has the advantage that you are making only the very smallest alteration in the circuit. The usual method of detecting resonance is to listen for the silent point between beats: that is sufficiently accurate for most work provided you balance the strength of oscillation in the receiver and the source. If it is found that the silent "point" is too wide, then it is not sufficiently accurate, and the best way out of that is to put up an audio-frequency oscillator, make sure that the telephones are in the output circuit of that audio-oscillator, and adjust the condenser B, not to silence, but until the note itself beats with the audio-frequency note.

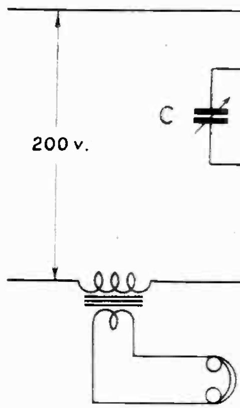


Fig. 16.

A standard method of condenser testing, of course, is to use the alternating current bridge, but an accurate alternating current bridge is extraordinarily expensive, and I prefer to measure large condensers by the "neon tester" method. The method is probably well known to you. If the condenser is sufficiently large it is simply a question of counting the flashes in a neon or "Osglim" lamp with a condenser and high resistance in its circuit (see Fig. 16). The method only compares against a standard, and is not an absolute method. As a general rule, one adopts the same principle as before, putting the unknown condenser in parallel with a calibrated one. For small variable condensers the flashes are so rapid that you get a musical note, and by switching quickly from one condenser to another one can match those notes to a surprising degree of accuracy. But the more accurate method is to put up two complete neon tubes in circuits, as in Fig. 17.

Here *A* represents one set with a small condenser. You adjust that circuit until it gives a musical note which beats with the one from *B* and produces slow countable beats in your ear, and, after diminishing the capacity of the unknown condenser and increasing that of the calibrated one, to compensate; again count the slow beats between the musical note of *A* and that of *B*.

The high frequency resistance of a condenser is again a very variable thing. I am told that with a fixed condenser of good quality it is justifiable to assume that the phase difference—the ratio of resistance to reactance—is more or less constant. In the case of a variable condenser the phase difference is inversely proportional to the amount of capacity in; that is to say, if the phase difference is 1 part in 1 000 at 180 degrees, it will be, to a first approximation, 1 part in 100 at 18 degrees.

As to typical results, the zero capacity of most ordinary variable condensers on the market appears to be between 20 and 30$\mu\mu$F. Values of ψ (phase difference)

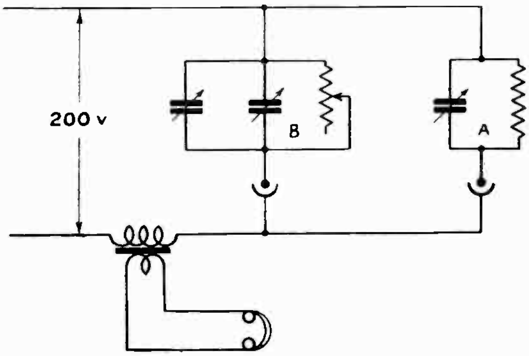


Fig. 17.

seem to be, on the average, in the neighbourhood of .000 2 when the condensers are all in.

The constancy of the ordinary aluminium plate condenser is 2 per cent., if that. Brass plate condensers, possibly, are better, but not much. I distinguish between constancy and accuracy. The constancy is the maintenance of the definite capacity at any given reading at any time, and the accuracy is the approach of the all-in capacity to its rated value. If a .001 condenser measures .001 all in, it is accurate. If, at the end of six months, it was still .001 within 1 per cent., I should think I had a marvellous condenser.

Crystals.

I should like to make a short reference to crystal testing. I cannot give a history of the various methods adopted to try to get

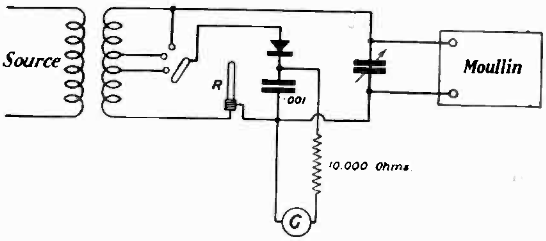


Fig. 18.

some idea of whether a crystal was a good one or not, but finally we decided to measure the high frequency input power on continuous wave and the D.C. output power, and call the ratio the efficiency. I will show the circuit we tested on (Fig. 18).

You are going to measure the high frequency input power of the crystal. That crystal has a resistance, very often, in the neighbourhood of 50 000 ohms, and, to get results of any value you must measure at the signal voltages it is likely to be used on. We are confronted with the job of putting an H.F. voltage of 0.1 to 1.0 volts on to 25 000 ohms, thereby getting a matter of 5 microamperes, and you have to measure 5 microamperes at broadcast wave-length. That cannot be done, so we built up a high frequency resistance testing circuit. Instead of using a thermo-junction, we used the Moullin voltmeter to measure the voltage across the condenser, which is an indication of the current through the circuit. First of all we leave the switch as shown, and insert a little high frequency resistance at *R*, and measure the resistance of the whole circuit. Then, if you put the switch right up on the top stud, you put the crystal in circuit. The effect of that is a power absorption which can be represented as an increase in the equivalent series resistance of the circuit, and, of course, a decrease in voltage. But one has to re-tune. The re-tuning must be allowed for, because you are measuring the voltage across a certain reactance. If you vary the reactance you have to allow for the variation. Actually it is so small that the correction is of the order of 1 part in 1 000. We put two tappings on to the coil and calibrated them, so that when we had two or three volts across the whole thing, with a crystal on an intermediate stud, we had exactly 1 volt on the crystal. We calibrated it simply by measuring the volts. So that in that way, while measuring the whole voltage across the circuit, we can apply a definite fraction of that voltage to the crystal, and, of course, measure the resulting current. Now we have the input load expressed as series resistance. It is easy to work out the equivalent high frequency resistance *across* the circuit, and that tells us the apparent high frequency resistance of the crystal, and by multiplying that by the current squared we find the input power. In the same way we find the output power, by multiplying the square of the crystal current by the load in the circuit, 10 000 ohms.

There are one or two results I might show. I do not definitely say that such and such a crystal is magnificent on the basis of the small amount of testing done on one sample. Our tests on these crystals gave the results shown in Fig. 19.

I assume that the average voltages on a crystal in action are .1 to 1. I have actually found one point on one crystal in which the efficiency was 94 per cent. I thought there was something hopelessly wrong with it, and checked it again, and got results varying between 90 and 96. The last column shows the apparent high frequency resistance, and this value may be a useful guide in designing the circuit across which the crystal has to be used. Of course, the power loss in that circuit should be designed in relation to the power loss in the crystal itself. There is always a considerable increase in the high frequency resistance at low voltage. I have also got some results which were obtained last night with a Zincite - Bornite detector. Taking the average of 5 points, with an input of 1 volt, the efficiency was 12 per cent., and the average high frequency resistance was 95 000 ohms. I then found a good point, and at 2 volts input the efficiency was 52 per cent., and the high frequency resistance 25 000 ohms. At .2 volts the efficiency was 5.8 per cent., and the high frequency resistance 220 000 ohms. I cannot guarantee the accuracy of the last figure, because I was on the limits of measurement of my meters, but it is perhaps within 15 per cent.

TESTS OF CRYSTALS AT APPROX. 800 kC

Name	Input Volts	Efficiency	H.F. Resistance
"EXOLO"	·5 *	29 %	25 000
	1·0	20	13 000
	·3	24	34 000
"RADIOLYTE"	·5 *	45	15 000
	1·0	40 – 50	5 400
	·1	40 – 50	25 000
"DEARNITE"	·5 *	67	14 000
	1·0	70	10 000
	·2	70	27 000
"ETHITA"	·5 *	75	24 000
	1·0	50	7 100
	·1	80	47 000

* Average of 5 contacts

Fig. 19.

The Discussion.

The CHAIRMAN: The lecture is an especially interesting one to old experimenters like myself, who were working on these things 20 years ago, and doing very imperfectly the very measurements that Mr. Turner has described—with damped waves because there were no continuous waves and with very imperfect measuring appliances. I remember measuring the efficiency of crystals, I think about 1908, which is 17 years ago, with spark transmission, and getting efficiencies of from 5 to 15 per cent. It seems that these modern crystals, especially when used with continuous waves, have better efficiencies, or perhaps the methods of measurement are now more accurate. Every item discussed by Mr. Turner was intensely interesting, and I have no doubt, if you would allow me, I should ramble on for a very long time talking about each item, but, unfortunately, I have another appointment, and have to leave. I will therefore ask Mr. Coursey to take the Chair.

Mr. P. R. COURSEY, B.Sc. then occupied the Chair for the remainder of the meeting.

Mr. MAURICE CHILD: The measurements I have made in the past have not been of a very high standard of accuracy, and I have rather fallen out of the method of measuring things with the latest arrangements. I was particularly impressed with the interesting method which the lecturer described of comparing condensers for measuring the capacity of the condensers. He mentioned the very simple device of the neon tube. It is very curious that one of the earliest high frequency measuring instruments ever produced utilised the neon tube as the detector, but, of course, in a different manner from that indicated by the lecturer, although not very different. I refer to the well-known cymometer of Dr. Fleming, in which he employed a neon tube, and I believe that was one of the first applications of that gas in practical service. I think the neon detectors which Mr. Turner referred to were probably the same devices that one sees nowadays adapted for advertising people's goods. I am not quite happy as to whether that method is altogether satisfactory. It seems to me, from observations I have made in connection with the neon tube, that there is a risk of the tube itself failing to operate properly at just the critical time when you want it to operate properly. The characteristics of these neon detectors or lamps are not, I think, well understood at the present time. It seems to me that at some critical voltage they burst off, but before you get that bursting off you get apparently a very weak current, which is not obvious at all. Mr. Turner seems to have got over that difficulty by using the aural method, but I should like to know whether he is absolutely satisfied with the use of these neon detectors for practical purposes, and whether he finds that in the middle of his measurement there is a variation which necessitates his starting all over again. The other points in connection with coils are very interesting, but I am sure other speakers can deal with them better than I. I do think, however, that Mr. Turner has served us very well in bringing out one important thing. He mentioned the test on one coil which he thought was going to give very good results and, fortunately for us, he measured it and found that he did not get good results. The reason he gave was that one turn was short-circuited by another. To members here who have not taken up the study of wireless very long, and whose knowledge of the subject may be comparatively elementary, that is a most interesting thing. because it shows the futility of expecting to get reliable results when you have a coil consisting of a wire wound on a piece of cardboard and finished off or having contact made to it, in such a manner that it short-circuits, not one turn, but sometimes four or five at a time. If the publicity which this lecture will get will have the effect of stopping the manufacture of these inefficient devices, then Mr. Turner will have done us and the public generally a very good service.

Mr. R. E. H. CARPENTER: I was interested in the figure for what Mr. Turner called the "power amplification" μ^2/R_a. It appears to be the product of the mutual conductance and the voltage factor. I take it that is why it is called the power amplification, but I should like to hear more about that from this point of view. One index figure which would give a general indication of the performance of a valve is a very desirable thing. One might compare it with the single figure you give for the horse power of an engine. Looking at the figures which Mr. Turner has given us, I notice very wide discrepancies indeed between the values of μ^2/R_a given for different valves which one has not observed in practice to give such vastly different results in the amplification one gets; and I should like to know whether in fact this index figure he has given does give an indication of the relative performance of valves when they have a load in their anode circuits. He did not show us the effect of the anode load in straightening the curve, altering its slope, and in some cases turning a straight line characteristic into a loop when the load is reactive. There is just one point I should like to raise with regard to the method of testing crystals, and that is, that apparently, in order to get the low voltages, one finds it necessary to use a tapped inductance, and to assume that one can rely on the proportional voltage across the tapped piece being unaffected by the connecting up of the crystal across that piece. Is that so? A large ratio of diameter to length for the coil would help to keep the voltage ratio constant no doubt.

Mr. G. G. BLAKE: In the first place, I think the method that Mr. Turner suggested for classifying valves—putting the characteristic figures in the first column to indicate the different types of valves—is most useful. I have never seen it before, and I believe it is his own suggestion. If so, I think it might usefully be adopted. When one picks up the wireless papers and sees the different valves advertised, one is quite at a loss to know the characteristics of the many different valves, and with a notation such as that suggested we should know which valves were which. With regard to the measuring of the resistance of a coil composed of a tube filled with mercury, that method seems to me to be most interesting, and, I should say, very accurate. As to the Moullin voltmeter, do you know what difference there is in sensitivity as between that and the Lippmann capillary voltmeter, which was used by Roussel in France a little while ago? He carried out some measurements on the resistance of crystals and the rectified currents in crystal detector circuits, and he used a Lippmann capillary voltmeter.

Mr. J. H. REEVES, M.A.: There is one point on which I differ somewhat from Mr. Turner. He treated the capacity of a coil entirely as a shunt capacity which went in parallel with any tuning condenser. I was writing on the subject, and I pointed out that, suppose one began with a coil of, say, 20 gauge enamelled wire with turns touching, and then, keeping exactly the same pitch, wound with smaller and smaller gauge wire, one would have two effects. The self-capacity of that coil, or, as I prefer to call it, the distributive capacity, becomes very rapidly less at first, whereas the direct current resistance, and presumably the high frequency resistance, would increase somewhat slowly, and I had an idea that the actual efficiency of that coil as a receiving instrument ought to be improved. A 20 gauge enamelled wire coil with turns touching would not be so efficient a coil as one wound at precisely the same pitch, but with a somewhat smaller diameter wire. It came prominently before me this evening when Mr. Turner somewhat curtly dismissed the question of the distributed capacity of the coil as being merely a shunt capacity, and the whole tendency of the day seems to be to pay more and more attention to the elimination of the distributed capacity of the coil. As I said then, and I think still to-day, that distributed capacity has very much the same sort of effect on the coil as that of the oscillation in a submarine cable.

Mr. E. C. ATKINSON : Mr. Turner referred to the Willans method of measuring high frequency resistance, and it might be worth while to refer to a snag which I came across only the other day to be avoided in making measurements by that method. In an oscillator with two coils closely coupled, we are all familiar with the phenomenon of howling ; that is to say, there are two high frequency currents, of slightly different frequency, flowing simultaneously in the circuits. If you uncouple to some extent the howling ceases, and apparently one of the high frequency oscillations has disappeared altogether. I notice, in attempting to measure resistance, that conditions may prevail in which the tuning of the circuit under test determines whether the other circuit oscillates with one or the other of two frequencies.

In this case the measure for the raised pitch of the heterodyne note is made at one frequency and that for the depressed note at another, the deduced value for the resistance being, of course, quite incorrect. I found those experiments exceedingly fascinating. So far I have only reached a stage at which I can consider results as being approximate. Perhaps my ear is not very critical, but I require a good deal of training to arrive at the exact point at which the pitch is highest, and it is dangerous to determine that point by swinging the condenser backwards and forwards unless you limit yourself as much as possible, because the curve slopes steeply on one side and gently on the other, and consequently, with a large swing the value deduced for the resistance will be too high.

Mr. P. R. COURSEY, B.Sc. : With regard to the self-capacity of coils as affecting the high frequency resistance of the coils, I think I am correct in saying that, although when the E.M.F. is induced into the coil, the C_0—the self-capacity—as has been stated, adds to the tuning condenser as far as tuning goes, yet if you make any attempt at measuring the effective resistance of that coil by anything connected externally to measure the current which must necessarily pass between the coil and the tuning condenser, then in both cases, whether the E.M.F. is induced into the coil or outside, the self-capacity will increase the effective resistance of the coil, because its effect is to shunt off some of the current that should otherwise go through the measuring instrument. I think, as a matter of fact, the formulæ work out the same in both cases for the increase in the effective resistance of the coil due to self-capacity.

Again, if the self-capacity of the coil is large, then it means that some of the current in the oscillating circuit which should be going through the tuning condenser—which has presumably an air dielectric, and consequently very small losses if reasonably constructed—will be passing through a distributed capacity in and around the coil and coil supports, which capacity may have in its circuit relatively poor dielectrics. In consequence, there may be a type of secondary increase of the resistance of the circuit, due to the self-capacity of the coil, and the fact that the electrostatic field of which that self-capacity is an expression is passing through poor dielectrics.

The Willans method of measuring high frequency resistance is very interesting, and is one on which I have done a little work recently. With the assistance of Mr. H. Andrewes, at the last informal meeting of the Society, I gave an experimental demonstration of how it could be used for measuring resistance. The accuracy of it can be considerably improved by using a double heterodyne or audio-frequency oscillator, but that, of course, introduces a lot of complications. I think also, the method we used then might overcome the difficulty Mr. Atkinson referred to. We used a 4-electrode valve oscillator instead of a 3-electrode one with a reaction coil. The result is that there are not two coupled circuits, and there is not the tendency for a frequency jump. I certainly agree with him that, as regards measuring capacities in general, the substitution methods are always the best, not only for radio-frequencies but for audio-frequencies as well, as even in the latter case it is quite possible to get considerable errors due to stray capacities.

There is one other point to which I should like to draw attention. Mr. Turner referred to the constancy of variable air condensers and probably the 2 per cent. he referred to is the average figure, but I have known aluminium-vane condensers which, when used in oscillating circuits, will give much greater accuracy than 2 per cent. over very long periods.

Mr. TURNER, replying to the discussion, said : Dr. Eccles raised a most interesting point in his reference to crystal efficiency tests in comparatively early days. I wish to goodness I had known about it, because I should have been spared many hard-working hours in evolving the methods described. He found efficiencies very much lower than mine—5 and 10 per cent.—and he was doubtful whether that was due to increased accuracy of measurement or improvement of crystals. I am inclined to think it is not due to either, but is due to the fact that measurements are now made on continuous waves. The efficiency of the crystals I have tested goes up rapidly with the amplitude. When applying a spark generator with heavily damped waves, a considerable amount of the input is of very low amplitude, and the efficiency of the crystal is pulled down by that fact, I think.

Mr. Child mentioned the neon tester, and asked whether there was any irregularity in the tubes. There is an interesting point there. If one is working in the evening, as most of this work has to be done, then with large condensers and high leaks (so that the nominal time of flash is of the order of several seconds) you sometimes get great irregularity. By daylight you do not, the whole secret being in the degree of ionisation in the gas within the neon lamp before the flash commences. In order to get extreme regularity, you must see that that is maintained constant. You can do it by experimenting in daylight or strong ultra-violet light, or by a chunk of radium, if you have it handy. (Laughter.)

As to the "omnibus" figure of merit for valves, I think the main difficulty there is a difficulty that runs through the whole of this testing, the fact that one wants different qualities for different circumstances of use. If one neglects that, one is liable to say that a certain component is a fine component, because it happens to suit the circuit you test it on. Many a casual test is merely a test of *tout ensemble*, of whether a component is matching the rest of the circuit, not whether it is itself good.

As to the question of proportional voltages in the crystal tester.

You have a main oscillator circuit, and you are shunting a portion of the coil by a resistance R (Fig. 20), and the question is whether a change in R changes the voltage ratio between E_1 and E_2. Well, of course it does, but if R is high enough in proportion to the reactance across which it is connected the change is not appreciable. The same question crops up in a simpler form in the potentiometer. In practice, for anything over about 1 000 ohms for R, in the circuit used, the correction is negligible as compared with the natural variability of the crystal.

With regard to the valve type numbers, that was an idea I was very proud of. In fact, I was so proud of it that I put it up to the Valve Makers'

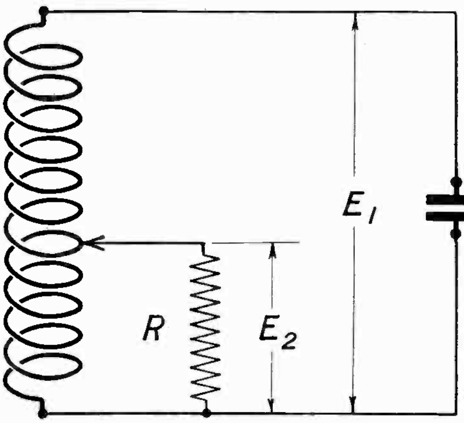


Fig. 20.

Association, and they replied in quite enthusiastic terms—for an association—"that it was worthy of very serious consideration." Apparently the consideration they have given it is so serious that nothing has transpired. After a month I wrote and said I hoped something might be transpiring, for that unless I heard it was transpiring pretty quickly I should go ahead and publish it, the implication being that the association were not (shall we say) progressive. Nothing transpired, and I did publish it, and the implication remains. (Laughter.)

As to the question of whether the Moullin voltmeter is affected by the D.C. component, the question can be avoided altogether by using for that job the other type of Moullin voltmeter, which, if you supply it with a mixed A.C. and D.C. voltage, will only measure the A.C.

The matter is, however, not serious for (see Fig. 21) the crystal is of a resistance of say, 20 000 ohms, and the load 10 000 ohms, so that there are 30 000 ohms in circuit. Now the Moullin is across the coil L, which has a D.C. resistance of only a few ohms, so that of the total D.C. voltage only 1/10 000 comes on to the voltmeter.

Both Mr. Reeves and Mr. Coursey raised the question of the efficiency of coils. Perhaps I was too hurried in speaking of self-capacity. The point I was trying to make is that the importance of self-capacity, as self-capacity, is somewhat overestimated. There is no doubt that self-capacity is a very serious disadvantage, for the reason quoted by Mr. Coursey, that the condenser formed by the distributive capacity is such a bad condenser. The point is that with every effort that you make in designing a coil to cut down the H.F. resistance due to dielectric losses also cuts down self-capacity. I was mentioning some coils I tried to wind for low losses. I wound them indifferently with 24 or 28 gauge wire. I am convinced that the use of heavy wire for coils is a complete mistake for high frequencies or low wave-lengths, because all the figures tend to show that for such work ohmic resistance and skin effect combined are unimportant compared with the dielectric losses, in the average design of coils. If you space your turns, say, 10 to the inch, use small wire so as to get more air between them. There must be, obviously, an optimum gauge of wire, which will depend on the design of the individual coil.

Mr. Atkinson described some of his troubles with the Willans method of resistance measurement. Undoubtedly, high frequency resistance measurement on accurate lines is quite a tricky job at first. It is necessary to make two measurements to get a high frequency resistance, one with and one without an added resistance. I usually make five or six, and as a rule I can work within .5 per cent. I have had no trouble with that change of oscillation in the Willans method. I am using an oscillator in which the coils are very closely coupled. The nearest point of the circuit to be measured is usually about six or seven inches away, and I have not had that change, but have found trouble in pitching on the exact adjustment at which the note is highest or lowest. It is simplest to use an extra audio-frequency oscillator and get slow countable beats.

As to the accuracy of condensers, the 2 per cent., as a matter of fact, was not my own estimate. It was the estimate given me by somebody at the National Physical Laboratory as the result of a lot of tests carried out there. The main difficulty with aluminium plates is that it is very hard to anneal them so that there is not a stress left in them. That stress comes out after a time and the plates warp. It is easier to flatten brass plates, but if you know a manufacturer who knows how to flatten aluminium, and is prepared to take the trouble there is nothing to choose between the two.

Mr. Fogarty: It is a great pleasure to me to have the opportunity of proposing a vote of thanks to Mr. Turner for his very interesting paper. I did not take part in the discussion because I think that, to a large extent, his lecture was clear, except for one or two points. These, however, came out in the discussion, and he has given satisfactory answers. I think we might take this paper as an example of the kind of which we want a great many more, because they are extremely useful to us, who are, for the most part, interested on the experimental side, and want to get down to measurements. The whole principle of science depends upon making measurements, and making them accurately, and our thanks are due in a particular measure to Mr. Turner.

The vote of thanks was accorded with acclamation.

The CHAIRMAN: There is suspended in the hall a list of candidates for membership, and of societies for affiliation. No comments have been raised, and I have to declare that 8 more members and 5 societies have been elected.

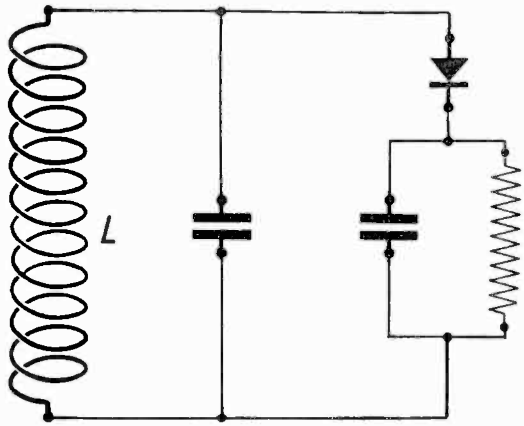


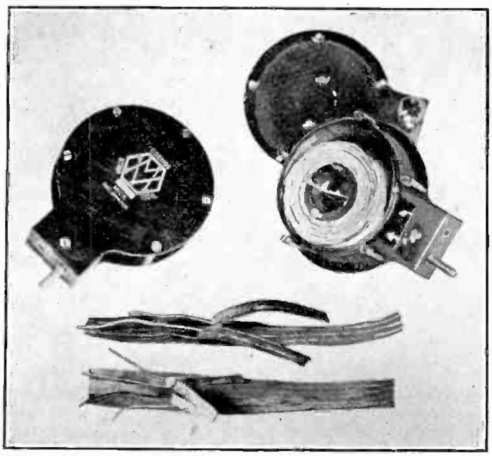
Fig. 21.

Two Low-Loss Tuning Coils. [R382·009

The "Cosmos."

METRO-VICK SUPPLIES CO. are the makers of a plug-in type of high efficiency and interesting construction.

In this coil use is made of a roll of paper in which a number of spaced wires are fixed, whose ends are linked through to form a continuous winding.



Above can be seen the general appearance (left) and the interior construction (right) of the "Cosmos." The wire "tape" is shown below.

The inductance, self-capacity and H.F. resistance were calculated using a wave-length of 377 metres.

In order to give some idea of the comparative value of the figures found, it was tested against another coil consisting of the same number of turns, 40, of a well-known make.

The inductance of the "Cosmos" was 92μH, while the other coil possessed 62μH. The self-capacity (including stray capacities of leads and our apparatus) amounted to $12\mu\mu$F, as against $48\mu\mu$F for the other coil.

It will be seen from this that the "Cosmos" has an extremely low self-capacity; the value of the stray capacities in our apparatus amounts to $9\mu\mu$F, so that the net self-capacity of the "Cosmos" is only $3\mu\mu$F, compared with $39\mu\mu$F for the other coil.

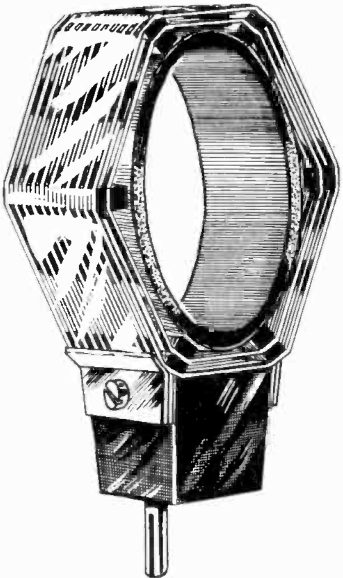
The net resistances, measured at the same frequency, were found to be 4·5 and 3·91O for the "Cosmos" and the other coil respectively. In spite of this higher resistance, the "Cosmos" must be regarded as the better coil in view of its higher inductance.

The power-factor amounted to ·009 8 for the "Cosmos" and ·001 26 for the other.

The coils are supplied in a range marked 20-400, and cost 4s. 9d. to 9s. 9d.

The "Airmax."

Another coil lately tested by us is known as the "Airmax," made by Airmax, Ltd., of Sheffield. Its appearance is probably familiar to most readers.



The "Airmax" coil.

It is wound with bare tinned copper wire, and spaced with insulating spacers. It is in fact a "Morecroft" coil, wound tightly and without external covering, or cheeks. It was tested after the same fashion as the "Cosmos."

The "Airmax" tested was a 50-turn coil, and it was compared with a similar size coil of a well-known make.

The inductance of the "Airmax" was found to be considerably greater owing to its larger diameter; it had a value of $203\mu H$, against $131\mu H$ for the other coil.

The net self-capacities were approximately 21 and $31\mu\mu F$ (at 377 metres). The net H.F. resistances, measured at the same frequency, were 12·20O and 9·0O respectively.

Like the "Cosmos" it has a slightly higher resistance, but the power-factor was ·012 against ·014 for the other coil, thus proving the "Airmax" the better coil of the two.

These coils are made in nine sizes covering a wave-length range of 120-3 080 metres with a $·001\mu F$ condenser.

The prices are 5s. to 9s.

The Leicester Radio Society.

We are asked to announce that Joseph W. Pallett, the Hon. Secretary of the Leicester Radio and Scientific Society, has been forced to resign owing to ill-health. His position has been filled by Mr. A. E. Walker; all future communications therefore should be addressed to his residence—"Glen Burn," Ashleigh Road, Leicester.

Mr. Godfrey Isaacs. [R·097

THE death of Mr. Godfrey Isaacs, which occurred after a short illness at Virginia Water on April 17th, deprives the world of commercial wireless telegraphy of a great personality. For some time past his state of health had been a cause of anxiety to those closely connected with him, and it was for this reason that last November he resigned the position of managing director of the Marconi Co. With this company his name will always be coupled by those who watched the growth of wireless from infancy to sturdy youth, for it is largely due to his ability and acumen that the Company occupies its present position.

Mr. Godfrey Isaacs, whose retirement, last November, was unfortunately too long delayed to save his health.

In 1910 he became associated with Marconi and later the control of the Marconi Company passed into his hands. Under him, its development proceeded apace.

Thorough in all things, he had an unbounded zeal for work and did not always appreciate the fact that the structure must be strong enough to support the driving machinery. As a result, he worked without intermission and never spared himself. It has, indeed, been stated that for over 40 years he had not taken a holiday. His death at so early an age—he was only 59—will be deeply regretted by all who served under him, for he was popular alike with associates and subordinates.

The Aerial-Earth System.

By E. Simeon. [R320

The results of experiments with various types of aerial and earth arrangement.

SOME years ago the writer erected a 45 ft. pole and hung from it a single wire aerial with three shell-type insulators at each point of suspension. It was about 60 ft. long and had about 40 ft. of down-lead, the receiver being on the ground floor, and the usual waterpipe earth being employed.

The aerial system gave what were thought to be satisfactory results, and no further trouble was taken over it for a time. As it stood, it was probably at least as good as the average receiving aerial; yet by various small improvements, and without increasing its height or length, the received strength on a standard set was subsequently increased to about four times its original value.

For the comparison of results given by various arrangements, a leaky grid-condenser detector without reaction was used. An "R" valve was employed on 90 volts, with which it gave 40 per cent. greater strength than with 60 volts. The efficiency of any given system was taken to be indicated by the maximum drop in anode current caused when passing through resonance. The drop caused by 2LO was found to be very constant, rarely altering by 5 per cent.

This method of testing aerial efficiency is more reliable than by measuring aerial current given by a constant input transmitter, since false impressions might be caused through increase in capacity, etc.

No reliance could be placed on judging strength by telephone, it being found difficult with music to notice any change in volume when the current drop was altered by 30 per cent., though with a pure note it was much easier.

The first thing done was to get the receiver reasonably efficient, so that measurable readings could be obtained. The circuit which had been used for 360 metres consisted of an 80-turn honeycomb coil with a ·001mF series condenser, about ·000 1mF being actually employed. When a valve was used as detector, this arrangement was found to be about the best, the drop reading about 150 microamps.

As a matter of interest, this tuning circuit was tested against others when a crystal was used as rectifier, and totally different results obtained. Here the current delivered was only 15 microamps, using the series circuit. This astonishingly small current gave a telephone strength just lost at a few inches from the ears. Probably most crystal users have under 10 microamps of D.C. flowing.

When, however, a 45-turn coil was substituted with a small parallel capacity, a current of 40 microamps was delivered, and finally, by the use of the 80-turn coil as secondary with loose coupling (45° apart) an increase to 54 was obtained. No improvement by using a secondary was obtained if more than .000 2mF was allowed across the coil. Tuning was also very considerably sharpened. Of course, we all know that an improvement can be obtained by using a secondary, yet how many B.C.L.'s use one?

Coming back to the valve detector, alterations in tuning coils were tried, but at this stage did not give substantial improvement, due to large losses elsewhere. That there were losses was obvious from the fact that a non-inductive resistance of 20 ohms could be inserted in the aerial lead without any appreciable drop in strength!

For raising the aerial wire, a stranded-steel, ex-Government signalling cable, being handy at the time, had been used. The cable was also used to fasten together the groups of insulators at either end. It was thought that a certain amount of capacity leakage might be taking place through the porcelain, and a short length of whipcord was substituted for the cable. This resulted in a slight increase—about 15 per cent.—and noticeably sharpened tuning.

It was not thought safe, however, to leave the cord to withstand the weather, as its breaking would mean that the pole would have to be lowered in order to obtain the end again. The cable was attached to a weight of a pound or two at the point where it joined the cord, so that in the event of the latter breaking, the weight would then bring down the end over the pulley on paying out cable from below.

The copper wire itself was renewed and the insulators cleaned after two years of London smoke. No noticeable change occurred, however, showing it to be unnecessary continually to overhaul the aerial. The oxide which soon forms on the wire is practically an insulator, so that it does not affect the resistance.

The next thing tried was to substitute a twin wire aerial. To lessen sagging, the 7 ft. spreaders were made of small section ash ½ in. square. With this aerial, a drop of 220 microamps was obtained, an increase of over 25 per cent. A large increase in aerial capacity was noted, a 50-coil now being used with about the same series capacity. This is, of course, an advantage when higher wave-lengths are to be reached, though for getting down to low wave-lengths it would be better to keep to the singlewire. Some tests were next made on the earth connection. It is perhaps not always ealised that a connection to a water main—giving a D.C. earth of utterly negligible resistance —is often unsatisfactory for short-wave work. Suppose connection to be made directly to the main itself, running away underground for an indefinite distance. In any case, a wave of, say, 360 metres can only possibly travel 180 metres along it during a half-cycle, so that for this or lower wave-lengths the rest of the pipe may be absolutely neglected. Obviously, the shorter the earth lead the better, since the effective buried length is proportionately greater.

It is, therefore apparent that a water-main connection to earth has a very definite H.F. resistance, which becomes serious with shorter wave-lengths. On the other hand, it is possible to have a good H.F. earth connection, yet one with a high D.C. resistance; for instance, a buried enamelled iron plate, where the glaze would act as a dielectric between the plate and the surrounding soil.

It was found that to get a reasonably low-resistance earth connection by means of a buried iron plate, a very large surface must be offered before a better connection

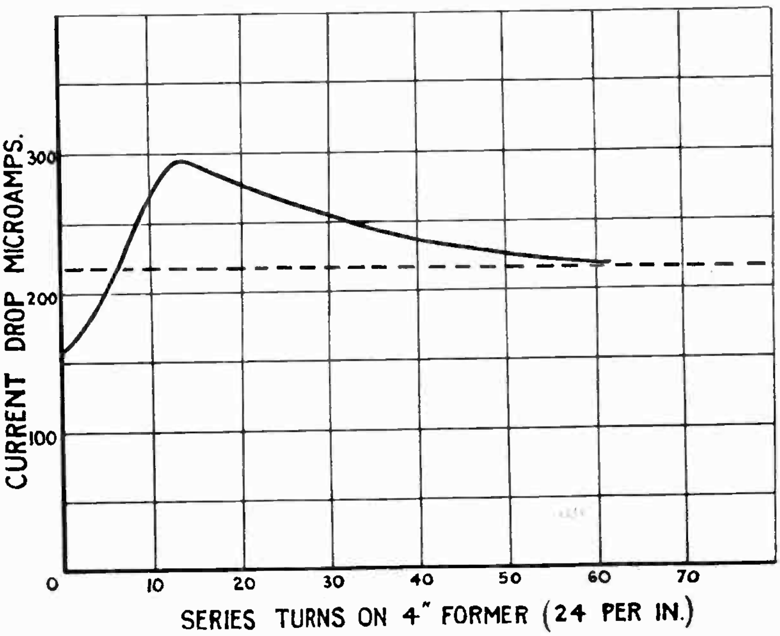


Fig. 1. *Showing the effect of using two earths in parallel.*

can be made than a water-main will give at 360 metres. An iron plate was buried in damp soil, with a total contact area of 34 sq. ft., and this, when used with the aerial, gave about 60 per cent. of the strength from the water-pipe earth. This roughly indicated, therefore, that the latter was acting as if it were a length of only about 75 metres of pipe, all concentrated at the foot of the aerial.

In all probability, in a case where a long earth lead would have to be employed to reach a water-pipe, a similar plate would give better results.

The next thing which obviously suggested itself was to use both earths in parallel. This led to some curious results, caused by the fact that the two earth leads were of different lengths. It was found that with the water-main earth the signal was tuned in some 10 to 15° lower, showing the latter lead to have an appreciable inductance.

The curve of Fig. 1 shows the effect of using the two earths in parallel. The dotted line shows the current drop with the water-pipe earth alone. On joining the plate earth to it, the output dropped by about 30 per cent. When, however, a small inductance was placed in series with the lead to the plate, a well-defined optimum point was found, at which the resistance was considerably below that of either earth singly. The insertion of this coil had only a very slight effect on the wave-length.

It is not thought that this inductance would need changing on other wave-lengths, though it was not possible for the writer to test this point, no other station being close enough to give measurable readings.

In the writer's case, too, it was not possible to have a counterpoise permanently in use, owing to the objections of the domestic authorities. It was, however, tried as an experiment—to see whether it was worth while bringing pressure on the latter—and interesting results were obtained.

A three-wire counterpoise was employed, about four-fifths the length of the aerial and 7 ft. above ground level. The wires were parallel, and spaced 4 ft. apart. With this an increase over the combined earths of 30 per cent. was obtained—the drop now measuring 385 microamps. With the two outer wires only 375 microamps, and with the centre one only (the others being cut away) 365 microamps were indicated. It does not, therefore, seem probable that much would be gained by the use of more than three wires.

Little difference was shown whether the wires were arranged parallel or fan-fashion, or whether they were slightly longer or shorter than the aerial. The counterpoise system required considerably more series-capacity to tune in on the same coil, almost .0001mF extra being needed.

Finally, some trials with various coils were made. A 5 in. diameter solenoid, with a skeleton former and wound with 16 S.W.G. wire, used in place of the duolateral coil, increased the output by another 40 per cent. —the final reading being 540 microamps. The latter coil was wound with 26 D.C.C., and might be taken as a typical one of its kind. It was held together with a minimum of wax, though for this purpose celluloid would probably be more suitable, both from the point of view of distributed capacity and mechanical strength. The coil could be soaked in a solution of celluloid in amyl-acetate, and then gently dried off.

Some further tests were carried out on the tuning condenser, but they showed that even with one of the cheapest makes, results were substantially the same as those given by a first-class instrument. This is, of course, a rough comparison of efficiency only, and does not mean that a well-made condenser would not be preferable for constancy and reliability.

As a matter of interest, the effect of inserting a series resistance in the aerial lead was tried again, and 5 ohms caused a large enough drop in strength to be detected with the phones (some 30 per cent.), showing the ohmic resistance now to have been reduced to a reasonable figure. When using such an aerial, the effects of oscillation will be rendered more serious, necessitating more care when searching.

In conclusion, it is thought that many amateurs might profitably spend a little time on that part of their apparatus on the outdoor side of the aerial and earth terminals. It is of little use, say, to use thick wire for coil winding, if the earth used consists of a 3-ft. iron rod driven into the ground.

More Valves Tested.

With a Note on our Methods. [R333·009

JUST lately one or two cases have occurred in which our values for the R_a and μ (anode impedance and voltage amplification) of valves have not agreed with those of the makers, and questions have been raised as to which was correct.

It seems advisable, therefore, that we should give definite information on the way in which these values are found. First, we must emphasise the fact that, in spite of every effort on the manufacturers' part, sister valves do differ somewhat between themselves, and we can never state definitely that the sample tested by us is actually an average one. Secondly, as we will show, there are possibilities of quite wide divergence in finding R_a and μ, even with the same valve.

We will start by describing just how we proceed. First, the filament is lit, and adjusted to a definite voltage. Then, with the grid connected direct to filament negative, the anode voltage is gradually increased from 0 to 200, or saturation, whichever occurs first, and the anode current noted at various voltages. The corresponding curve is then drawn. If the curve shows a well-defined straight part, we find ΔI_a and ΔE_a across the straight, as shown in Fig. 1, p. 487, and from them get R_a by simple division. In the valve shown on that page this is approximately 23 000 ohms.

Next, we apply one cell—say, 1.4 volts, in any case we measure it carefully—of negative bias, and adjust the anode volts until we get an anode current well on the straight part of the curve—we used 2.5mA in this case. Then, without touching the anode volts, we make the grid volts in succession 2.8 and 0. In this case the resulting anode currents were 1.9 and 3.1mA, making ΔI_a .6, for $\Delta E_g=1.4$. This, by division, gives G_m $\left(\text{mutual conductivity}; =\frac{\Delta I_a}{\Delta E_g}\right)$ equal to $\frac{\cdot 43}{1000}$

Now to find μ, we have only to multiply G_m by R_a—

$$G_m \times R_a = \frac{\Delta I_a}{\Delta E_g} \times \frac{\Delta E_a}{\Delta I_a} = \frac{\Delta E_a}{\Delta E_g}$$

and in this case we find 9.86.

It will be noted that, with the same change produced by a given grid voltage, *i.e.*, the same G_m, a lower anode impedance gives a lower μ, which is why in many cases the μ of a valve falls off at higher filament volts (note the S.P.18 valve, reported below). Now suppose, however, that instead of measuring R_a in the way we suggest, over the straight part of the curve, we were to measure it somewhere about *B* in Fig. 2, p. 488, without actually drawing a curve, we should find that to get a ΔI_a of .5mA (1 — .5) needed a ΔE_a of 17V (53 — 36), giving $R_a = 34\,000$. If the mutual conductivity came to $\frac{\cdot 43}{1\,000}$ as before, we should find $\mu=14.6$.

Now in one particular case we were testing a valve of rather high μ, and the straight part of the curve centred about a value of 200 anode volts. We accordingly gave R_a and μ for this value. The makers had done the very thing shown above. They had measured R_a at about 100 volts, and the μ they got was much larger than our value. They made the excellent point that the general public would use about 100 volts, so that their values were those that would obtain in practice. Our reply is that anyone so unwise as to use a valve for amplification while working on a curved part of its characteristic would not appreciate the meaning of R_a or μ at all: and that our values were for the only portion of the valve characteristic at which it *ought* to be used for amplification.

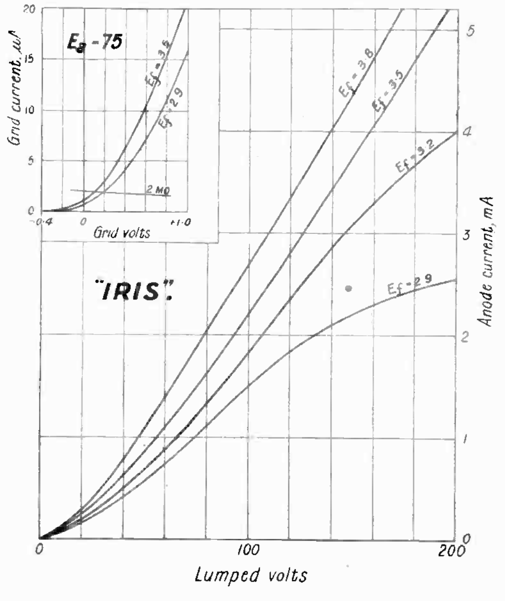
A somewhat similar difficulty arises in the case of certain valves of which the characteristic tends to get steeper and steeper all the time. This is especially likely to be the case if there are signs of softness. In this case one can only measure at some reasonable value, and state at what value. In the absence of any such details, it can be taken that the values given by us are those measured on the straight portion of the curve.

Iris ·06.

This is a French valve of the 60 milliamp type, supplied by Messrs. Anglo-Franconia, Ltd., Baltic House, 27, Leadenhall Street, E.C.3. Like most French valves, it is designed for a rather higher magnification than is the common practice in England: as is seen from our table,

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency F $\left(=\frac{I_s}{\text{Watts.}}\right)$
2.9	.059	3	55 000	12	2.6	17.3
3.2	.064	6	42 000	12.5	3.7	29
3.5	.069	10	35 000	13	4.8	41
3.8	.075	15	28 000	13	5.6	53

the μ varies between 12 and 13, and it is notable that it actually increases with the filament heat. Another point it shares with most French valves of this type is that it is designed for a distinctly higher filament voltage than the English 60 milliamp valve. It is in fact a ·406 rather than a ·306 valve. The curve sheet for this valve shows that while there are no points of exceptional interest,



the valve shows every prospect of being thoroughly efficient, and it should be noted that it is sold at the comparatively low price of 9s.

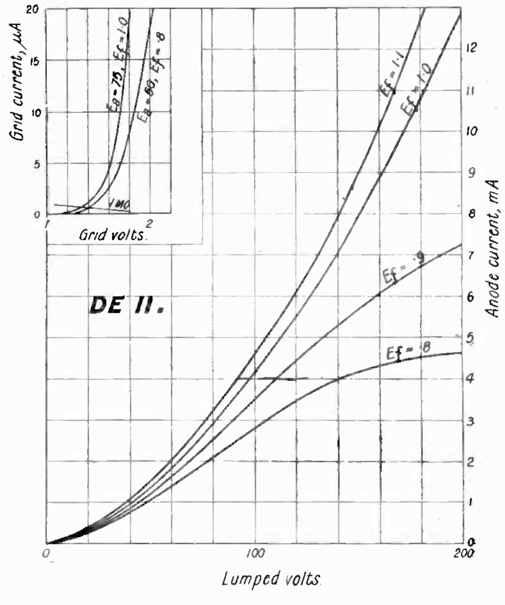
Two Metro-Vick Valves.

Two interesting valves have been received for test from Messrs. Metro-Vick Supplies, Ltd., 3, Central Buildings, Westminster, S.W.1, these being the D.E.11 and the S.P.18. The D.E.11 is what we ourselves should call the 125 type, using a coated filament and designed to be run on a single large dry cell. In common with most valves using oxide-coated filaments, there are traces of softness: it will be seen that at the full rated voltage of 1.0 or more on the filament it is impossible to find a saturation current, as ionisation takes place. None the less, the valve possesses excellent qualities, showing an average magnification with a low anode impedance.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
.8	.20	5	31 000	8	2.1	30
.9	.22	10	25 000	7.5	2.2	50
1.0	.235	—	15 500*	6	2.1	—
1.1	.25	—	14 000*	6	2.8	—

* At 120V.

An interesting point arises in connection with the grid current curve. It will be seen from our illustration that there is no trace of grid current until a positive voltage of slightly more than 1 volt is applied to the grid. From this point onwards the rise in grid current is very rapid. It would thus appear that the valve has a distinct field for use

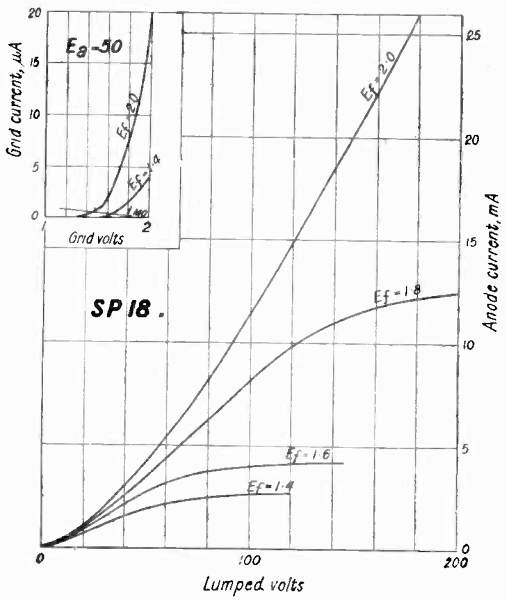


in the early stages of a note magnifier without grid bias, provided that it is not subjected to an input of more than 2 volts grid swing. At the same time, the very rapid rise of grid current once it has started indicates that the valve should possess useful properties as a detector.

An even more interesting valve from the same house is the S.P.18, in which we are informed the letters S.P. stand for "short path" and the 18 designates the filament voltage. We should refer to it as a 235 valve. This valve also uses an oxide filament, but is most remarkable for the design of the electrodes. The ruling idea of the construction has been to get the filament, grid,

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.25	3	40 000	12	3.6	5.4
1.6	.27	6.5	25 000	11.3	5.1	9.3
1.8	.30	15	12 500	7.3	4.3	28.0
2.0	.33	—	6 200	3.7	2.4	—

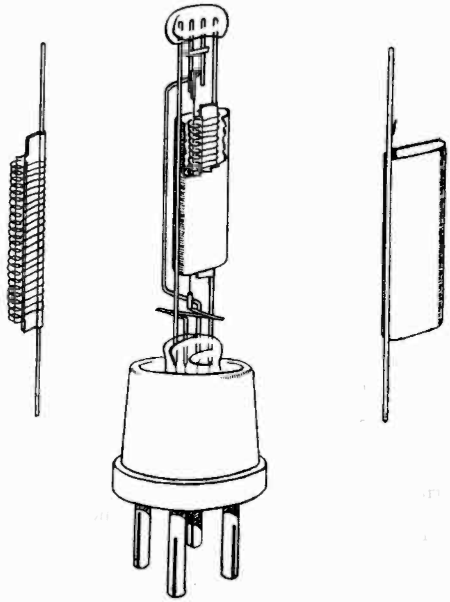
and anode very close together in order to obtain a very low anode impedance, while maintaining the magnification large—which is, of course, the idea behind the construction of many modern power valves employing flattened plate and grid. In the S.P.18 the grid is cylindrical, employing the usual helical winding, but in order to provide a solid support the grid is extended as shown in our sketch. It must be borne in mind, however, that the extension is merely a support, not part of the working grid. Its construction has involved a rather peculiar design of anode, which at first sight resembles that of the flattened type already mentioned. This, however, is not actually the case, for the working portion of the anode is simply



that part surrounding the working portion of the grid, the remainder of the anode merely being made of this particular shape as a convenient practical construction.

On test the valve showed up extremely well, although here again there were signs of softening at full grid filament heat. The value of 15 milliamps for the saturation current at 1.8 volts was in fact somewhat indefinite, as a further increase in the voltage applied tended to cause ionisation and a rush of emission.

It is obvious from the values given for anode impedance that the design has been completely successful from this point of view, the impedance falling to a figure as low as 6 200 at 2 volts on the filament. The mutual conductivity, however, did



The interior construction of the S.P.18 valve.

not increase in the same proportion, with the result that the value of μ falls considerably. Bearing in mind that both the anode impedance and the voltage amplification are involved in arriving at the best figure of power amplification, we find that the valve is most efficient from this point of view at quite a low filament heat. It would appear from the values obtained, which were confirmed by actual test, that the valve should have great scope in the early stages of a note magnifier, for, as in the D.E.11, grid current does not start until more than one volt positive has been applied to the grid. It must be noted that there is sufficient output to handle a loud-speaker at full filament heat, but under these conditions the magnification is not so high. It is an important point that practically distortionless amplification, even for loud-speaker work, can be got with not more than 100 volts or so on the anode, which is an exceptionally useful property. The grid current curves show exceptionally efficient rectification provided that the filament is kept fairly bright. The prices of the D.E.11 and S.P.18 are 21s. and 18s. respectively.

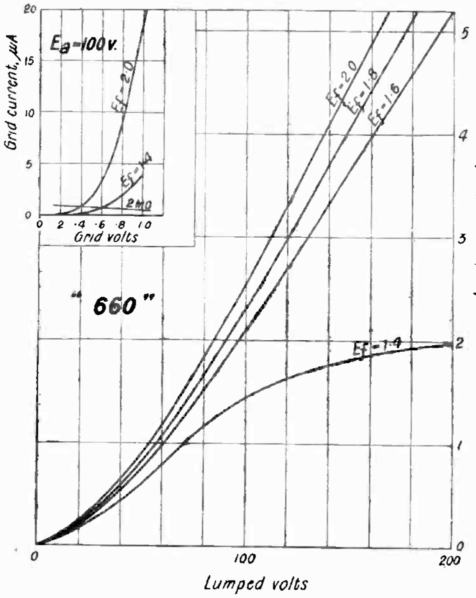
The "Six-Sixty."

We have seen some interesting claims made for the "Six-Sixty" valve employing a special filament, which we believe is of molybdenum wire.

In view of the rating of the valve (1.8 volt, .3 amp) it appears probable that the actual emission is due to the filament being thoriated, in which case, of course, the substitution of molybdenum for tungsten as a filament material would not be extremely important from this point of view. This opinion appears to be justified by the results of actual test, for as regards performance the valve behaves in a manner essentially similar to that of the ordinary thoriated type, although it must be said that the results were in many ways exceptionally good.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.33	2.5	50 000	11	2.4	5.8
1.6	.36	6.5	36 000	11	3.2	11.4
1.8	.385	10	31 000	11	4.0	14.5
2.0	.42	15	28 000	14	7.3	18

In appearance the valve is very neat, the bulb being quite small and cylindrical, and the cap being of some insulating material mottled in red and black. The table and curves reproduced here show its performance in a smaller compass than an extended description could do. A particularly notable point is the rather high magnification, which is obtained with a comparatively low anode impedance. The magnification also is maintained at comparatively high filament heats, owing to a considerable increase in the mutual conductivity. This results in an excellent value for the power amplification at full filament heat, although we still do not think the output quite sufficient for the satisfactory operation of a loud-speaker. An examination of the curves shows that they have the useful feature of straightening out at comparatively low voltages, thus ensuring distortionless amplification without the use of large batteries. The grid current curves are normal, but, as will be noted, the increase in



grid current in increasing filament heat is very rapid, indicating that the valve would probably function most satisfactorily as a detector if the filament is maintained fairly bright. The valve is supplied by Messrs. The Electron Co., Ltd., Triumph House, 189, Regent Street, W.1, at the price of 18s.

USES OF THE SUPERHET.

Owing to continual interference from an uncertain source, members of the Plate and Grid Club, of Stamford, Conn., U.S.A., an organisation of listeners and amateurs of the American Radio Relay League, decided to take the matter into their own hands. With the co-operation of the *Stamford Sentinel*, it was found that trouble was being caused by the local lighting company's high power lines. With the aid of an eight-valve superheterodyne set and a frame aerial, mounted in a car, the interference was found to be coming from several leaks in the cables.

It was also observed that the decrease in signal strength was not so pronounced while the car was travelling parallel to the wires as it was when the car passed through side streets at right angles to them.

THE PROGRESS OF WIRELESS IN RUSSIA.

Strange and contradictory reports are constantly received from Russia with regard to the progress being made in wireless telephony and telegraphy in that country. There is, however, some information that may be relied upon. One of Russia's finest engineers, M. A. Boutsh-Brujewitsh, is at present at work at Nijni-Novgorod on a water-cooled valve, which he hopes will furnish a power of 100 kilowatts. The valve will be constructed in the same manner as one previously made by the same engineer, and which gave a power of 81kw.

The laboratory at Nijni-Novgorod was officially founded by the Soviet Government for their own use in October, 1918. It is now under the Directorship of Professor Lebedinsky, who has just returned there after a tour of Eastern Europe.

More about Errors in Measurement.

By P. K. Turner. **[R800:519·8**

A simplified treatment of the Method of Least Squares, by which experimental results are treated to find the most accurate possible values

IN a short article on "Errors in Measurement" (E.W. & W.E., March, 1925), the author dealt with the best value and probable error of a directly observed quantity, and also showed the graphical construction for less simple cases, where we are trying to find one quantity by measuring others.

It was then stated that the most satisfactory method of dealing with such work is the "Method of Least Squares," and the author tried to get out of describing this. However, quite a surprising number of readers have asked for it, so. . . . . . .

The problem is this, to give a typical example: We wish to find the self-capacity and true inductance of a coil, by measuring the wave-length given by the coil with various condensers across it. (This is the same example as already dealt with.) We know that the quantities are connected by this equation:—

$$L\,(C+C_s)=\frac{\lambda^2}{3\,550} \qquad .. \quad (1)$$

Where L is the inductance, C the added capacity, C_s the self-capacity, and λ the wave-length.

Now this equation can be made simpler in appearance as follows. Obviously,

$$LC+LC_s=\frac{\lambda^2}{3\,550} \qquad .. \qquad .. \quad (2)$$

Now, of these letters, L represents a constant unknown quantity (call it x), C is a varying known quantity (call it a), LC_s is a constant unknown (call it y), and $\frac{\lambda^2}{3\,550}$ is a varying known (call it m).

The equation thus becomes—

$$ax+y=m \qquad .. \qquad .. \quad (3)$$

where x and y are to be found.

Obviously we cannot find them from one equation, but we can from two. Thus: If for one observation $a=2$, $m=8$, and for another $a=3$, $m=10$, we have

$$\left.\begin{aligned}2x+y&=8\\3x+y&=10\end{aligned}\right\} \qquad .. \qquad .. \quad (4)$$

from which any schoolboy will give us $x=2$, $y=4$.

Now suppose we take three observations, the third being $a=1$, $m=7$.

We have

$$x+y=7 \qquad .. \qquad .. \quad (5)$$
$$2x+y=8 \qquad .. \qquad .. \quad (6)$$
$$3x+y=10 \qquad .. \qquad .. \quad (7)$$

and now we run up against the distressing fact that no values of x and y can be found which will satisfy all three equations. In this case, (5) and (6) give $x=1$, $y=6$; (5) and (7) give $x=1\frac{1}{2}$, $y=5\frac{1}{2}$, and, as before, (6) and (7) give $x=2$, $y=4$. The reason, of course, is that the quantities a and m have not been observed with absolute accuracy; and the problem is: What values of x and y are the nearest we can find to their unknown true values; and what is the probable error in our estimate?

Various methods might be suggested, such as taking the equations two by two, solving them, and averaging the results, etc., etc. But the mathematicians have shown us what is by far the best.

If we re-write the three equation as

$$\left.\begin{aligned}x+y-7&=0\\2x+y-8&=0\\3x+y-10&=0\end{aligned}\right\} \qquad .. \qquad .. \quad (8)$$

and then substitute some definite values of x and y in them, they will not all reduce to zero. Thus, taking $x=2$, $y=4$

$$\left.\begin{aligned}2+4-7&=-1\\4+4-8&=0\\6+4-10&=0\end{aligned}\right\} \qquad .. \qquad .. \quad (9)$$

Again, if we put $x=1$, $y=6$,

$$\left.\begin{aligned}1+6-7&=0\\2+6-8&=0\\3+6-10&=-1\end{aligned}\right\} \qquad .. \quad (10)$$

Note the figures on the right of these equations (0, 0, and -1 in (10)). The mathematicians tell us that if we square all these, and add them together, then the best values of x and y are those that give the smallest sum.

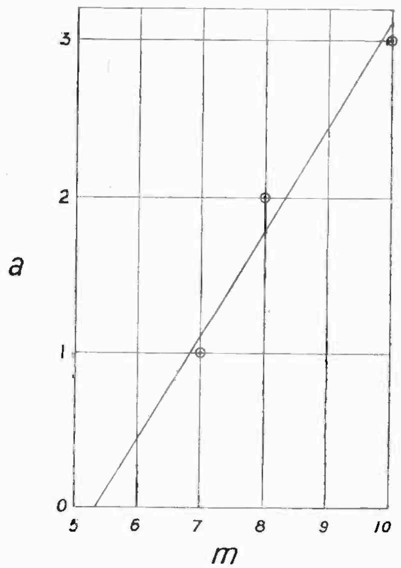
Now, how do we find these values? The method, carried out in a general way, is complicated and laborious. But by taking only a restricted class of equations we can simplify it enormously, and the author now proposes to give definite instructions applicable to most cases that readers will come across, without going at all into principles.

The first thing is to write down the governing equation. In the case quoted above (self-capacity and true inductance)

$$L(C + C_s) = \frac{\lambda^2}{3\,550} \quad \ldots \quad \ldots \quad (11)$$

Then convert this into the standard form

$$a'x + y = m'$$



The three readings of Example 1, *with the "best" straight line among them.*

where $a'x$ is a compound term containing a varying known term a' and a fixed unknown one x,

y is a fixed unknown term,

m' is a varying known term.

Thus we can set out (11) as

$$LC + LC_s = \frac{\lambda^2}{3\,550} \quad \ldots \quad \ldots \quad (12)$$

Where LC corresponds to $a'x$, a' being C' and x being L;

LC_s corresponds to y

and $\frac{\lambda^2}{3550}$ corresponds to m',

or we can change (11) to

$$C + C_s = \frac{\lambda^2}{3\,550}\,\frac{1}{L} \quad \ldots \quad \ldots \quad (13)$$

here C corresponds to m'

C_s corresponds to y,

$\frac{\lambda^2}{3\,550}$ corresponds to a'

and $\frac{1}{L}$ corresponds to x

In this latter case the result is

$$m' + y = a'x \quad \ldots \quad \ldots \quad (14)$$

$$\text{or } a'x - y = m' \quad \ldots \quad \ldots \quad (15)$$

so that we will say $y = -C$.

If one of the two known quantities can be more accurately observed or measured than the other, make that one m'.

If the equation cannot be thrown into this general form, the following procedure is not correct. But usually there is little difficulty.

In the following procedure, certain items are concerned with the sum "s." These calculations are not *necessary* to get the result; they are *checks*, to prove correctness. Having had considerable experience of such work, the author strongly advises that they should be used.

First, set out Table I., fill it in, and do the arithmetic indicated. (Note, n is the number of observations.)

TABLE I.

Observation No.	a'	m'
1	....	....
2	....	....
3	....	....
.	.	.
.	.	.
n	.	.
	$n = ..)$ .... = Sum.	$n = ..)$ .... = Sum
	$a_0 =$ ______ = Av.	$m_0 =$ ______ = Av.

It will be seen that we are simply finding average values for a' and m', which we call a_0 and m_0.

Next we have the largest job of all—to make out and fill in Table II. This introduces us to several new quantities, of which the first three are a, m, and s, given by

$$a = a' - a_0 \quad \ldots \quad \ldots \quad \text{I.}$$

$$m = m' - m_0 \quad \ldots \quad \ldots \quad \text{II.}$$

$$s = a + m + 1 \quad \ldots \quad \ldots \quad \text{III.}$$

The values for a, m, and s for each observation are set out in their respective columns, and the first check on the accuracy of working

TABLE II.

	$a = a' - a_0$			$m = m' - m_0$		$s = a + m + 1$		
Observation.	a	m	s	a^2	m^2	am	as	ms
1	....	....	....	....	....	....	....	....
2	....	....	....	....	....	....	....	....
3	....	....	....	....	....	....	....	....
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
n	.	.	.	.	.	.	.	.
Sums.	.... O	.... O	....$=n$	.... A	.... B	 C	.... P	.... Q

is that the sums of the a and m columns shall be zero, and that of the s column n:—

FIRST CHECKS: $\Sigma a = \Sigma m = O$ .. .. IV.

$\Sigma s = n$ .. .. V.

Now comes the task of filling the other columns, the squares and products being got from tables, logs, or slide-rule (but see below as to slide-rule working).

SECOND CHECKS: $A + C = P$ .. .. VI.

$B + C = Q$ .. .. VII.

Then $x = \dfrac{C}{A}$ .. .. .. VIII.

$y = m_0 - a_0 x$ .. .. .. IX.

give the best values for x and y.

Next, to find the probable errors.

Find D, from the equation

$D = B - xC$ .. .. X.

and R, from

$R = Q - xP$ XI

THIRD CHECK: $D = R$ .. .. .. XII.

Note here that D should be small, and it is usual to find that B and xC are large numbers nearly equal. It would, for example, be by no means unusual to find $B=100$, $xC=99.99$, whence $D=.01$.

Hence, a very small percentage error in calculating B, x, or C might give a very large percentage error in D. If, for example, we got $xC=99.98$, this is an error of 1 part in 10 000 approximately. But it would give $D=\cdot 02$, an error of 100 per cent! Hence, if D is wanted accurately, it is advisable to go to some trouble with Table II. Five-figure, or if not too much labour, seven-figure logs should be used.

Having found D, we have, calling r_x the probable error of x,

$$r_x = \sqrt{\frac{\cdot 455 D}{(n-2)A}} \quad .. \quad \text{XIII.}$$

and

$$r_y = a_0 \times r_x \quad .. \quad .. \quad \text{XIV.}$$

As a last check (though it is seldom that one is enthusiastic enough to carry it out), make out and fill in Table III.

TABLE III.

Observation.	a'	$a'x$	$a'x+y$	$v = a'x+y-m'$	v^2
1	....	....	......	......	......
2	....	....	......	......	......
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
n					
			Sums	0	$D=\ldots=R$

As a first example, in easy figures, it is proposed to take that already given—the three equations

$$x+y=7$$
$$2x+y=8$$
$$3x+y=10$$

(*To be concluded.*)

Long-Distance Work.

By Hugh N. Ryan (5BV). **[R545·009·2**

SINCE last month's report was written, interest has centred chiefly around the development of much shorter waves than those lately employed for DX work. Most of the winter's work was done on waves between 70 and 100 metres, and these were by far the most useful we had ever used.

More recently, however, considerable attention has been given by a number of well-known experimenters to shorter waves, chiefly those around 40 and 20 metres.

Most of the 40-metre work has been conducted in America, and the results, though interesting, are not startling. A wave-length of 40 metres apparently behaves very much as one of 90 metres, except that it possibly travels rather farther, in bad weather conditions, than does the higher wave.

The 20-metre wave, however, on which considerable work has been done on both sides of the Atlantic, has been found to behave in a way quite its own. Its most apparent—and to us all-important—property is that it travels very much better by day than by night.

All the longer waves, from the 1 000 metres with which we started many years ago, to the 80 metres which we now use most generally, are only useful for long distances at night. Each of the successively-shorter waves which we have used have extended the period during which we could work America, until now, on 80-90 metres, we can work under good conditions from about 10.30 p.m. to 8.30 a.m.

The 20-metre wave does much to fill in the "dead" gap, as it enables us, at this time of the year, at any rate, to work across the Atlantic from about 9 or 10 a.m. until about 7 p.m. These figures are not exact, but indicate roughly the large portion of the day during which the short wave is useful. With the fall of darkness the signals fade away, just as longer wave signals fade out in the morning. The only other notable characteristics of 20-metre signals are the violent fading to which they are subject and the very unusual distribution of signal strength over various distances.

Signals on this wave are audible up to about 25 miles from the transmitting station, and then absolutely inaudible until about 400 miles from it. At distances greater than 400 miles a fairly steady strength is found, up to considerable distances. (About 7 000 miles as observed so far.) The most obvious, and probably correct, explanation is that the direct waves from the transmitting aerial are absorbed before they have travelled far (in this case about 25 miles), as would be expected of very short waves; and the reflected waves (from the ionised layer) do not become effective until about 400 miles from the aerial. There are two possible explanations of this last fact, as will be readily apparent, and the whole question should provide an extremely-interesting line of discussion and investigation.

The leading station in this work on the American side is NKF, a naval station which has for a long time co-operated with American and European amateurs in short-wave investigations. He is using 1.5 kilowatts on 20 metres, and his signals are very strong at all times of the day, both here and in France.

The pioneer American amateur on these waves is John L. Reinartz, 1XAM, an old friend on the longer waves. Other Americans often heard are 1CMP and 1CKP, both also old friends.

Most of the work on this side has been done by 5LF, who has worked NKF daily for long periods. 2SH and 2KF have worked 1CCX and 1CMP respectively.

The only Frenchman at present on 20 metres is 8BF, who has worked 1CKP in daylight with only 90 watts input. He is receiving, by the way, on a new kind of 5-valve set, which he calls a "superheterodyne without heterodyne." It appears to work very well.

Although 20-metre work has provided so much of the interest this month, only a few stations are at present working on it, and many are still busy on the longer waves.

As was to be expected, the volume of work on 90 metres decreased considerably with the approach of summer, but it is still far from ceasing entirely. 6NF has worked some 20 Americans during the month—a small number compared with those he has worked during previous months. He has also received a number of reports from Australia.

5LF and 2SH have only been on the shorter waves. 6QB has spent the month working stations all over Europe in daylight on less than one watt. He has also worked American 2ZB on 4 watts.

Mr. E. J. Martin, of Cobham, whose work in reception figured in several of these reports last year, is now known as 2BAW. He has heard a considerable number of Americans this month on 20 metres.

6UV worked 26 Americans during March, bringing his total to 52. He is still in regular touch with the States. 2XV of Shelford, Cambs, has worked over 200 miles in daylight, and 300 miles telephony at night, all on 9 watts.

Very low power DX seems to be fashionable around London this month.

5TZ, in the Isle of Wight, whose European work has been well known for a long time, is now in touch with America at last. As is usual in transatlantic work, the "first contact" proves to be the difficult one to achieve, and he now works large numbers of Americans. He and 6NG, of Manchester, are both receiving Americans on 20 metres.

Although a large number of Americans are working on 40 metres, I have very few reports about this wave. Presumably, 90 metres is thought more interesting, on account of the two-way work there; but I have one report from Mr. S. F. Evans, of Northumberland, who has received over 50 Americans on 40 metres in a period of three weeks.

5SI, of Shrewsbury, is, I believe, back in action again now after his illness, and is working all Europe and a few Americans on a very small power.

5UQ recently blew his big valve, and celebrated the occasion by working 13 Americans in one night on a small one. The continued use of the small one would seem to be indicated.

There are at least two active stations, 6TD and 6US, in Wales, although the former is soon moving into England. Both of them have worked every European country and a number of Americans.

I should be glad if those sending me reports next month would remark specially on how they find the relative strengths of 90-metre and 20-metre signals as the season advances. I personally expect 90-metre American signals finally to fade out about the end of May, and 20-metre signals to last through the summer.

I also want reports of any Australian or New Zealand signals heard from now onwards, in order to try to establish the seasonal "cycle" in which they appear.

I rather expect a return of these signals in the early summer, for about a fortnight. They are, of course, very occasionally heard now, but by a "return" I mean a period during which they can be heard almost daily, as when we first worked them.

Reports by May 10th, please.

A NEW DUBILIER CONDENSER. [R381·009

A rather novel condenser, the "Duwatcon," has been received for inspection from The Dubilier Condenser Co., Ltd.

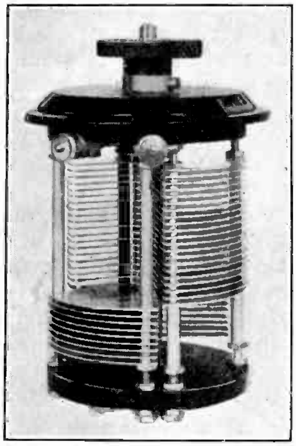
It is specially designed to overcome the usual gap in the wave-length range covered between series and parallel positions of an ordinary aerial condenser.

For this purpose two sets of vanes are provided. The main set extends over 120° of angle, and gives a capacity varying from ·000 028 to ·000 59. Just before this is all in the second small set (which extends over 90° only) begins to enter. This set is always connected across the aerial coil, and when all in amounts to ·000 16.

As a parallel condenser, the range is ·000 028 to ·000 75.

Calculation shows that on any aerial up to ·000 35 capacity there will be an overlap between the maximum wave-length, with this condenser in series and the minimum wave-length with it in parallel.

It is priced at 30s.



The "Duwatcon."

For the Esperantists.

Extracts from E.W. & W.E., April, 1925.

Resumaro de Artikoloj en E.W. & W.E.

Aprilo, 1925. [R800

HARMONIKOJ. [R146

PROVO korekti unu-du erarojn, kun noto pri uzo de ondmetroj. Ĉu la harmoniko estas beno aŭ malbeno dependas tute de la vidpunkto. Oni povas priskribi harmonikon kiel kurenton aŭ tension de frekvenco, kiu estas ekzakta oblo de iu fundamenta frekvenco.

Unu eraro estas, ke fermita cirkvito, "agordita" al frekvenco de, ekzemple, 1000 kilocikloj (1000 kc = 1000000 cikloj = 300 metroj) estas ankaŭ agordita al la harmonika frekvenco, 2000 kc aŭ 150 metroj. Simpla agordita cirkvito estas bona *filtrilo* por harmonikoj.

La artikolo enhavas kelkajn diagramojn de karakterizaj kurvoj de valvoj. Unu kurvo estas de valvo kun preskaŭ pura sinusa kurvo, kies harmonikoj estas malgrandaj. Estas tamen pli probable, ke la krado havos pligrandan balanciĝon, kiel montrite en alia diagramo, en kiu okazo, la elmeto estas reprezentita de kurvo kun plata supro, enhavanta interalie fortan trian harmonikon. Se la valva kurvo estas simetria ĉirkaŭ la linia mezo de la konstanta krada tensio, devus esti nur neparaj harmonikoj ; tio estas, se la fundamento estas de 1 000 kc., la elmeto estos miksaĵo de 1 000, 3 000, 5 000 kc., k.t.p., aŭ 300, 100, 60 metroj, k.t.p. *ne* la aliaj harmonikoj de 2 000, 4 000 k.c., k.t.p. Sed se la krado ricevus tension aŭ la alta tensio estus ŝanĝita, la pozitiva kaj negativa duonondoj de l'elmeto estus ne-egalaj, kaj la paraj kaj neparaj harmonikoj ambaŭ ĉeestos ĉe la elmeto.

La aŭtoro tiam citas la antenan cirkviton. Oni agordas la antenon al kelkaj frekvencoj samtempe, sed, kun unu aparta escepto, la plialtaj frekvencoj *ne* estas harmonikoj. La naturan harmonikon el la valva sendilo oni aŭdas je ondlongo kiu estas ĝusta suboblo de la fundamenta, ne el la anteno.

Kiam li uzas valvan ondometron la amatoro plej ofte renkontas harmonikojn. La aŭtoro priskribas kio okazas, kiam oni uzas ondometron por kontroli valvsendilon aŭ oscilantan ricevilon. Oni fiksas unu instrumenton kaj varias la kondensatoron de l'alia, kaj oni aŭskultas por pepo audebla kiam ajn la frekvenco de la varianta cirkvito transiras tiun de la fiksita cirkvito ; ankaŭ se la varianta cirkvito emisias harmonikojn kaj unu el ili transiras la "fiksitan" frekvencon. Sed krom tio, la fiksita instrumento ankaŭ emisias harmonikojn, kaj tiel oni aŭdas pepon kiam ajn *iu* harmoniko de unu "transiras" *iun* harmonikon de l'alia.

Diagramo ilustras, kio okazas kiam ambaŭ instrumentoj emisias harmonikojn, en la okazo de varianta metro, kiu registras nur ĝis la 20a harmoniko, batanta kontraŭ fiksita oscila ricevilo, kiu emisias nur ĝis la 10a. La diagramo montras nombron da "pintoj" je cititaj frekvencoj, ĉiu el kiuj okazigas pepon. La alteco de la pinto montras la laŭtecon de la peko.

LA PERFEKTA APARATO. [R132

Serio de artikoloj pritraktanta la kvalitojn necesajn en perfekta aparato. La nunmonata parto traktas Altfrekvencan Amplifadon, kaj enhavas detalojn pri la diversaj metodoj de altfrekvencaj kuplecoj.

La tri ĉefaj postuloj por maksimuma efikeco rilate al la valvo estas : 1. Longo de "rekta" karakterizo sufiĉa por ricevi la kradan balanciĝon ; 2. Neniom de krada kurento ; 3. Funkcio sole ĉe la rekta parto de la kurvo.

La kuplecoj uzataj por altfrekvenca amplifado venas sub du ĉefaj klasoj. La rezistance kuplita amplifikatoro estis multe uzita kiam la amatoroj pli okupis sin pri longonda telegrafado ; sed ĉar tiu speco de kupleco ne taŭgas por mallongaj ondlongoj, oni malofte uzas ĝin por altfrekvenca funkciado. La ŝok-amplifikatoro estas ankaŭ uzita, sed estas malfacilaĵoj rilate al ĝia desegno por mallongonda funkciado. Oni donas detalojn pri desegno de ŝokamplifikatoro patentita de Miller antaŭnelonge, kiu, li pretendis, estas efektiva por ĉiuj radio-frekvencoj, kvankam ĝi ne bezonas agordon.

Alia speco de kupleco ofte uzata estas la transformatora, kiu, oni ordinare kredas, estas tute malsama je la "agordita anodo," sed ĉar plej multaj transformatoroj uzas rigide kuplitan l-krontraŭ-l proporcion, kun la primario agordita, ĝi estas preskaŭ identa kun la agordita anodo. Tiu ĉi lasta kompreneble havas nur unu volvaĵon, sed bezonas kradrezistancon kaj kondensatoron, dum la transformatoro havas du volvajojn kaj ne bezonas rezistancon aŭ kondensatoron, kaj oni povas uzi proporcion malsaman je la l-kontraŭ-l, se oni deziras.

Koncerne la meritojn de la du metodoj, se la dua valvo estas kradkurenta detektoro, la agordita anoda cirkvito estas la pli simpla. Kontraŭe, se la dua valvo ne estas krada detektoro, la transformatoro estas certe preferinda, ĉar oni ne nur povas ŝanĝi la proporcion de la volvaĵoj, sed la kradrezistanco kaj kondensatoro, kiuj neniam povas helpi la amplifadon kaj eĉ ofte malhelpas ĝin, ne estas bezontaj.

Aparte de la speco de transformatoro jam priskribita, oni povas uzi nerigide kuplitan transformatoron. Kvankam ĝi posedas grandan selektivecon, ĝi ne estas vere praktika por ordinara funkciado, ĉar ĝi bezonas tri alĝustigojn: la du kondensatoroj kaj la kuplo de la bobenoj. Oni ankaŭ povas uzi rigide kuplitan neagorditan transformatoron, ku posedas sian propran naturan ondlongon kaj sufiĉe akutan agordon. Tiu speco tamen postulas la posedon de granda aro de interŝanĝeblaj transformatoroj.

Laŭ opinio de l'aŭtoro, la ŝoko Miller estas la plej bona por neagordita aŭ neakute agordita aparato, sed se oni deziras la selektivecon, la rigide kuplita agordita transformatoro estas multe pli bona ol aliaj kuplecoj. Li ankaŭ preferas enŝtopajn transformatorojn ol la speco kun tapaĵoj. Li finas per priskribo pri du specoj de transformatoro, kiuj tute kontentigis lin.

PRI TERMO-KUNIĜOJ.

W. Gordon Edwards. [R251.2

Se oni varmigas aŭ malvarmigas la kontaktpinton de du malsimilaj metaloj, potenciala diferenco okazas, kaj kiam oni fermas la cirkviton, elektra kurento fluas.

Kvankam la rezultanta kurento estas malgranda, ĝi estas grava rilate al la desegno de sentivaj elektraj instrumentoj, kaj estas utiligita komerce, ĉar, kune kun milivoltmetro, oni povas utiligi ĝin kiel tre sentivan miliampermetron. Duddell enkorpigis en unu instrumenton la termo-kuniĝon kaj movadon per sia termo-ampermetro, kie la finoj de la mova bobeno estas solditaj al du pecetoj de speciala alojo, fermitaj per arĝenta plato.

Estas du fenomenoj konsiderendaj, nome, la efektoj Peltier'a kaj Thomson'a, kiuj estas :—

1. La efekto ĉe la termo-kuniĝo estas perfekte inversebla ; se la varmigo de la kuniĝo produktas elektromovan forton, tial elektromova forto produktas varmigon.

2. La kvanto de elektro, kiu pasas trans kuniĝon havas sian propran specifan varmecon.

Diversaj specoj de termo-kuniĝoj kun varmigiloj de nesamaj rezistancoj estas fabrikitaj de bone konataj firmoj, sed la aŭtoro konsilas al la eksperimentisto, ke li fabriku sian propran pro malkareco, sed oni bezonas multan zorgon kaj paciencon.

Estas du metodoj porti varmecon al la kuniĝo :—

1. Terma konduko, t.e. ; efektiva kontakto ; aŭ

2. Radiado kaj konvektado.

La unua havas kelkajn malavantaĝojn, pro la malebleco konstrui la matematikan pinton, kio kreas inversecan eraron kaj alportas kapacitajn ĝenojn. La dua metodo estas preferinda, kvankam ĝi forigas sentivecon, kio ne estas tre grava, escepte se oni entreprenas esploradon au normigadon.

Termo-kuniĝoj estas speciale utilaj por mezuri temperaturojn en neatingeblaj lokoj, kiel ekzemple en transformatoro aŭ je lego de longa distanco. Aŭ la du- aŭ trivoja speco estas uzebla, la konektaĵoj por ambaŭ montrataj sur diagramoj. Tabelo montras la termo-elektromovajn fortojn de diversaj metaloj kontraŭ platinumo je mikrovoltoj.

La aŭtoro donas konsilojn pri la konstruado de instrumento, kiel ankaŭ pri la uzo de la termo-kuniĝo kune kun galvanometro.

RESISTANCO EN SENFADENAJ CIRKVITOJ.

Lekcio al la Radio-Societo de Granda Britujo de Prof. C. L. Fortescue, je 25a Februaro 1925a.

Tre interesa parolado traktanta la praktikan gravecon de rezistanco. Rilate al valvo, kiu provizas potencon al la cirkvito anstataŭ absorbi ĝin, la rezistanco estas negativa.

Ĉe altfrekvencaj agorditaj cirkvitoj, estas necese malgrandigi la rezistancon, ĉar la selektiveco de riceva cirkvito dependas de la proporcio de la rezistanco al la induktanco, speciale kiam, kiel ofte okazas, signalo interferanta estas multe pli forta ol signalo ricevata ; ankaŭ pro tio, ke la efikeco de senda anteno kiel radianto de elektromagnetaj ondoj dependas de la relativaj valoroj de la efektiva rezistanco.

La lektoro tiam klasifikis jene la perdojn de potenco ĉe induktanco : (A) Konduktoraj perdoj, (B) Dielektrikaj perdoj, (C) Perdoj ĉe ĉirkaŭantaj konduktoroj, (D) Perdoj ĉe bornoj kaj kontaktaĵoj, (E) Perdoj ĉe fadenfinoj.

Li komparis diversspecajn konduktorojn, inter ili rekta cilindra fadeno, kaj la sama speco volvita ; dividita fadeno (kun ĉiu fadeno izolita de la aliaj) ; maldika strio volvita laŭ plata bobeno. Bobenoj unukaj mult-tavolaj estis komparitaj, sed oni ne povis alveni al definitivaj rezultoj laŭ ĉiuj eblaj cirkonstancoj. Sub la 300-metra ondlongo oni trovis, ke unutavola bobeno estas la plej bona, mult-tavola bobeno estas plitaŭga por la pli altaj ondlongoj.

Rilate al dielektrikaj perdoj, la lektoro akcentis la gravecon de efika izoligo. Li priskribis ekzemplojn de grandaj perdoj trovitaj ĉe certaj bobenoj kaj variometroj kiujn li provis.

Rilate al perdoj ĉe ĉirkaŭantaj konduktoroj, oni pruvis, ke la apudeco de latuno apenaŭ havis efekton je la rezistanco de l'induktanco, sed ke ŝtalo multege pligrandigis la rezistancon. Aliaj flankoj de la temo pritraktitaj estis la altfrekvenca rezistanco de kondensatoroj ĉe kuplitaj cirkvitoj, kaj reakcio.

LONG-DISTANCA INTERKOMUNIKADO.

H. N. Ryan (5BV).

(R545.009.2

Raporto pri dumonta interkomunikado inter britaj kaj aliandaj sendistoj. Jam dum sufiĉe longa tempo kunlaborado kun Usonaj amatoroj estas ĉiutaga afero ; lastatempe Britaj amatoroj celas plimalproksimajn kampojn.

Ekzemple, dum la dua duono de Januaro kaj unua duono de Februaro, kelke da Britaj stacioj komencis komunikadon kun diversaj landoj en Sudameriko, precipe kun Brazilio. Dum longa tempo nombro da amatoroj aŭdis la voksignalon WJS, sed povis nek trovi la sendanton nek komuniki kun li. 2NM (tre konata brita amatoro) tamen sukcesis, kaj trovis, ke ĝi estas la voksignalo de la Ekspedicio Hamilton-Rice en la sovaĝejoj de Brazilio. 2MN ankaŭ sukcesis interkomuniki kun la ekspedicio, informante al ili la novaĵojn de la ekstera mondo. Tiu faro estas unu el la plej laŭdindaj en la historio de amatora radio.

Oni ankaŭ povas aŭdi signalojn ĉiunokte el Arĝentino, Ĉilio, kaj Meksikujo, kvankam regula interkomunikado ankoraŭ ne komenciĝis.

Rilate al progreso sur la Kontinento, du Hispanaj stacioj komunikis kun Ameriko, kaj GHH (Brita stacio en Mosul) sukcesis atingi Aŭstralion. Estas interese scii, ke 6TM, brita amatoro, tenas la rekordon pro la nombro de Amerikaj stacioj aŭditaj unu vesperon, 150 dum 5 horoj. 2IL de Southampton estas aŭdita telefone en Finnlando. 5OV faris interesan provon kun la ĉeĥoslovaka OKI.

Je la fino de lasta jaro, kiel oni nun tre bone scias, Britaj amatoroj sukcesis establi du-vojan interkomunikadon per Morso kun Nov-Zelando, tiutempe la plej mirinda faro atingita. Granda nombro da amatoroj interkomunikis kun Nova Zelando dum kelkaj semajnoj, sed poste la signaloj forvelkis pro sezonaj kaŭzoj. Oni tamen atendis aŭdi signalojn denove en Februaro, kaj tiu kredo efektiviĝis, kvankam la signaloj ne daŭris longe, nek ili estis tiel fidindaj. Tamen estas notinde, ke 2OD efektivigis *telefonan* interkomunikadon kun Nova Zelando kaj Aŭstralio, plua rekordo.

En Londono, 6NF kunlaboris kun 160 Amerikaj stacioj kaj aŭdiĝis en Cachar (Hindujo) kaj sur la Pacifika marbordo de Ameriko. 5DN, bone konata en Sheffield, faris provojn per malgranda potenco kun Usono. Kvankam lia potenco estas malpli ol 20 vatoj, liaj signaloj atingis eĉ Kentucky.

Entute la Britaj amatoroj jam faris laboron, pri kio ili povas senti fieraj !

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.

Aerial-Earth Potentials due to Thunderstorms.

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

SIR,—The following is my reply to Mr. Desmond Fitz-Gibbon in response to your letter on his behalf.

J. C. JENSON.

Department of Physics,
Nebraska Wesleyan University,
Nebraska.

February 24, 1925.

DESMOND FITZ-GIBBON, ESQ.

DEAR SIR,—A letter has been received from the Editor of E.W. & W.E., stating that you are interested in the voltage obtained across low resistances placed in series between the antenna and the earth. The galvanometer used has a sensitivity of 13·7 mm. per microvolt. In thunderstorm weather, before the storm reaches the immediate vicinity of the apparatus, it is not at all unusual to have deflections of 20 or 30 cm. on the scale. Such deflections for this galvanometer would make a constant difference in potential between the deck and the earth of about 20 microvolts. The resistance of the galvanometer is 18·2 ohms. The resistance of lead wires and ground connections may be disregarded.

When thunderstorms are directly overhead, potentials reaching a magnitude of 5000 volts or more are induced in the deck, causing rapid throws of the galvanometer. These are built up for a short time before a lightning discharge, and then suddenly reduced to nearly zero values. In other words, the steady potential between the deck and the earth is of the magnitude of a small fraction of a volt, but when a thundercloud is overhead, potentials amounting to thousands of volts are induced in the deck or in the antenna, causing violent electrical surges between the antenna or deck and the ground.

Trusting that this answers your question.

I am,
Yours very truly,
J. C. JENSON.

Nebraska.

Call Signs.

The call sign 6DO has been allotted to P. M. Dorté (6CV) at "Lynwood," Oatlands Park, Weybridge, Surrey.

We are asked to state that Mr. W. H. Coombs, who owns stations 6KL (fixed) and 5OS (portable), has not been working since Christmas, but hopes to commence again at the end of this month, on wave-lengths of 150-200, 110-115 and 20-40 metres, and would be glad to receive reports on his transmissions. His address is: 29, Alexandra Road, West Park, Chesterfield.

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

SIR,—The call sign 2BI has been allotted to me. Any reports on transmissions will be welcomed. Wave-length at present in use is 195 metres.

W. S. PALMER,
Lt.-Col.

Elm Field,
Calne, Wilts.

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

SIR,—I should be glad if you would oblige me, as a new but most certainly permanent reader, by publishing the information that my call sign has been changed from 2AUL to 2XY, and that reports of reception from distances over 30 miles would be very welcome

I should also be glad to get into touch with another one of the "gang" who would be willing to conduct tests with me, while all QSL cards will be gladly answered.

GERALD A. JEAPES
(G2XV).

"Chandos,"
Great Shelford,
Cambs

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

SIR,—Please note I have been issued the call 2BAK. 10 watts. C.W. or phone.

C. R. JEFFRIES.

25, King's Avenue,
New Malden, Surrey.

Short-Wave Work.

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

SIR,—I should be grateful if you could find space in your journal to give notice that the station here, operating under the call sign 2DX, will be working on 24 metres wave-length each day at 12.00 G.M.T. (mid-day). Reports of reception will be particularly welcome. I shall be glad if you can publish this notification and wish you every success in your efforts to advance the best interests of Wireless Science.

W. KENNETH ALFORD (2DX).

"Rosedene,"
Camberley, Surrey.

Power Factor Measurements.

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

SIR,—With reference to the table of power factors of various insulating materials which you quote in your March issue, I note that you deplore the non-existence in England of a body similar to the Institute of Radio Engineers. I would, however, remind you of the existence here of the Electrical Research Association, which has this advantage, that it studies the method of test before turning out results.

Further, I would venture to suggest that the values which you quote are most unreliable and misleading. It has been shown that in testing for power factors or permittivity at high or low frequencies, it is most necessary to use mercury electrodes in order to obtain good contact with the material, otherwise the results may be 100 per cent. or more out in some cases. If you will refer to the article from which you took your table, you will see that plain flat metal (solid) electrodes were used, and the results obtained are, therefore, of little value, except perhaps to American engineers. As a matter of fact, I believe the values of permittivity and power factor for nearly all insulating materials are very little different at high or low frequencies.

In accepting American figures, the following should be noted: "In research, the British spend £50 on apparatus and £1,000 on thinking, and get results; the Americans spend £1,000 on apparatus and £50 on thinking, and get lost."

D. V. ONSLOW, A.M.I.E.E.

11, St. Cuthbert's Road,
Cricklewood, N.W.2.

[While we agree with our correspondent that the precise conditions of test have a great influence on the figures obtained for the power factor of insulators, we feel obliged to comment on that part of his letter in which he compares the Institute of Radio Engineers of America and the Electrical Research Association in England, and makes some very disparaging remarks about American research. His remarks may or may not be true, but American research departments at any rate appear to have one useful characteristic, which is that *their results are available*. On writing a letter to our correspondent to this effect, he replied that the results of experiments done at the instance of the Electrical Research Association were published to the members of that Association, and also as papers in the Proceedings of certain learned Societies. We repeat that it is our opinion that to distribute results to the members of the Association is not publication, and that for our purposes all the work done by the Electrical Research Association is actually useless, because it is not available to the public.—E.W. & W.E.]

A Wireless Museum.

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

SIR,—The Milwaukee Radio Amateurs' Club has started a collection of modern, obsolete and unique radio parts and equipment which is being assembled at the Milwaukee Public Museum where it will be permanently exhibited. This idea has met with the hearty co-operation of everybody and with the help of the "gang" we hope to have an exhibit which will really be an asset to the radio game.

We are asking you for any material whatsoever which would be of interest or value in such a collection. We all have old time "doohickies" and "whatnots" that the club would most certainly appreciate having. Due credit is given to contributors by placing a card on each of the exhibits.

Send along whatever you have and it will be greatly appreciated. Address all packages to Sam Snead, 805, 63rd Avenue, West Allis, Wis.

SAM SNEAD.

The Milwaukee Radio Amateurs' Club, Inc.,
601, Enterprise Building,
Milwaukee, Wis.

A South African Amateur.

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

SIR,—It may interest some of your readers to listen for my transmissions, which will take place as follows:—

April. Every evening 17.15 to 17.45—95 metres.
Every Saturday at 20.05 to 21.00—95 metres.

May and June. Every Saturday 20.05 to 21.00.
Every Thursday and Sunday morning 00.15 to 00.30. (Thursday and Sunday transmission calling Argentine CB8.)
All times are G.M.T.

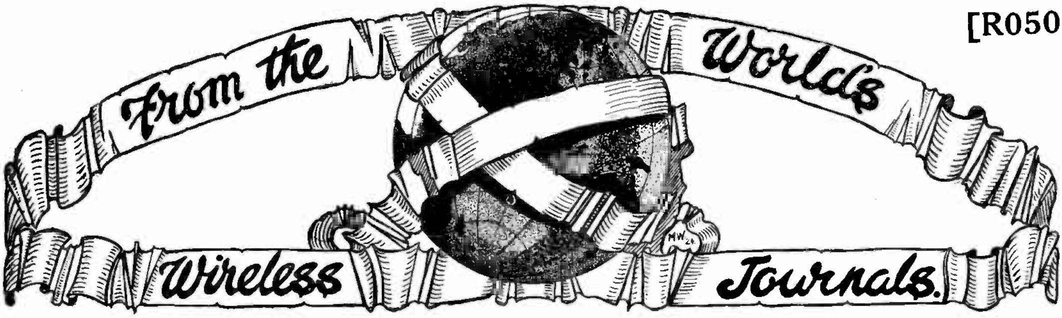
The May and June transmissions will be on 95 metres up to and including Wednesday, May 13th, when, if two-way working has not been established with Argentine CB8 my wave-length will be reduced to 70 metres for all transmissions.

The transmitter is a four-coil Meissner using a Phillip's type ZY valve. Input 1 500 volts, 70 milliamps. Aerial current is 1 ampere on 95 metres. Aerial is a single wire "L" (8 gauge wire), 50 ft. high, top portion 38 ft. long. Fan counterpoise of six wires each 55 ft. long is used, no earth being employed. The wave is pure C.W., filament current being supplied from a battery and high tension from a motor generator.

My telegraphic address is "Streeter, care Sidleth, Cape Town." Call letters A4Z.

J. S. STREETER.

Myrtle Grove,
Irwell Street, Observatory,
Cape Town.



[R050

R000—WIRELESS IN GENERAL.

R000—A PROPOS DE LA PROPAGATION DES ONDES TRÈS COURTES DANS LES TISSUES VIVANTS.—A. Chaulard (*Onde Elec.*, Feb., 1925).

The possibilities of the therapeutic use of very short electromagnetic waves for the treatment of malignant growths within the body are discussed. The suggestion is that stationary waves could be set up within the tissue to produce effects localised at points normally inaccessible. It is pointed out that the velocity of electric waves in living tissue is much less than in air owing to the semi-conducting nature of the tissue, hence the wave-length of the stationary waves produced would be less than the corresponding nominal wave-length in air. Experiments carried out by M. Lakhowsky are cited in which a certain plant affected by a cancerous growth was treated in the manner indicated. The tumour disappeared and the healthy tissue was left unaffected.

R1000.—GENERAL PRINCIPLES AND THEORY.

R113.7—DIE AUSBREITUNG DER ELEKTRISCHEN WELLEN ÜBER DIE ERDE.—A. Meissner (*Jahrb. d. drahtl, Tel. Vol.* 24, *No.* 4).

An article dealing with the problem of the propagation of radio waves over the earth's surface. The author does not hold with the overworked Heaviside layer theory and discredits the attempts of radio engineers, especially the British ones, to explain everything by the assumption of a condition of the upper atmosphere which may not exist at all. It is pointed out that two kinds of radiation can take place from an aerial. There is "surface radiation" due to half-waves just above the surface of the ground which are completed by mirror images below the surface; these waves are always earth-bound. There is also "space radiation," such as is produced by a Hertzian double completely isolated from the ground; this radiation is free to go off on its own in space. The longest wave stations (10 km.) send out only surface radiation while the shortest waves (2 or 3 ms.) are sent out almost entirely as space radiation. The reason for the latter fact is that on short wave-lengths it is usual to operate the aerial on harmonics of its fundamental wave-length, there being a series of nodes and anti-nodes of potential. The aerial wire between two consecutive anti-nodes acts as an isolated Hertzian double. On intermediate wave-lengths (50-2 000 ms.) aerials radiate both surface radiation and space radiation. It is the interference between these two types of radiation which gives rise to night effects and fading. The shorter the wave-length the more rapidly is the surface radiation attenuated by absorption, so that long distance communication on short wave-lengths (below 100 ms.) may be attributed to space radiation alone. No definite explanation of the bending of waves round the curvature of the earth is offered but it is pointed out that light is refracted by the atmosphere when the sun is at low altitudes. It is also suggested that the different gases composing the atmosphere have different specific inductive capacities and that the S.I.C. of a gas is modified by ionisation. In homogeneity of the atmosphere in these respects might account partly for the bending of the path of electromagnetic waves.

R114.—ONZE MOIS D'OBSERVATION DES ATMOSPHERIQUES.—R. Bureau (*Onde Elec.*, Feb., 1925).

Concluding portion of account of some extended observations on atmospherics in particular relation to meteorological conditions. A good deal of experimental data is given in this respect. The writer states that his observations lend no support to the idea held by some investigators that atmospherics have a long range of hundreds or even thousands of kilometres. He concludes that the range of an atmospheric is quite small.

R142.3.—ERZWUNGENE SCHWINGUNGEN IN ZWEI ABGESTIMMTEN SCHWINGUNGKREISEN, DIE DURCH EISENKERNSPULEN GEKOPPELT SIND. —L. Casper, K. Hubmann and J. Zenneck (*Jahrb. d. drahtl. Tel. Vol.* 24, *No.* 4).

An experimental study of the resonance curves of two oscillatory circuits coupled through an iron-cored transformer.

R200.—MEASUREMENTS AND STANDARDS.

R290.—DÉTERMINATION DU RENDEMENT D'UN GÉNÉRATEUR À LAMPES PAR LA MÉTHODE THERMOMÉTRIQUE.—J. Groszkowski (*Onde Elec.*, Feb., 1925).

A thermometric method of determining the efficiency of valve generators is described. If we can measure the energy dissipated per second as heat in the valve as well as the total input power we can arrive by simple subtraction at the high-frequency power output and hence the efficiency of conversion. To measure this dissipation the bulb of a thermometer is placed in a fixed position near the valve under examination. The thermometer will receive heat from the valve and when the steady state has been attained the temperature indicated by the thermometer will be some function of the rate at which heat is produced in the valve. The apparatus is first calibrated with the thermometer in position by applying a known input power (H.T. volts × H.T. current) to the valve when not oscillating; under this condition all the input power goes to heating up the valve and by varying the input power and noting the corresponding thermometer readings a curve may be plotted showing the relation between thermometer readings and the power expended within the valve. This curve may now be employed when the valve is oscillating under normal conditions to deduce from the thermometer readings how much power is being dissipated in the valve. In spite of the extreme simplicity of this method it is stated that the accuracy may be made within 1 to 2 per cent.

R300.—APPARATUS AND EQUIPMENT.

R374.1.—THE RECTIFICATION OF ALTERNATING CURRENTS BY CRYSTALS.—A. C. James (*Phil. Mag.*, April, 1925).

Various theories of the unilateral conductivity of contacts with certain crystals are discussed. A number of determinations of electrical conductivity were made on a galena-steel contact immersed in paraffin at various temperatures. Galena was found to have a transition point at 160°C., there being an increase in conductivity at this temperature. The addition of silver sulphide was found to increase the rise of conductivity at the transition point. It is concluded that the passage of direct current through galena is accompanied by the formation of metallic threads; this effect being increased by the addition of silver sulphide and decreased by the addition of stannous sulphide. An electrolytic explanation of the rectifying action is favoured. The variation of rectifying properties at different points on the crystal surface can be explained by the fact that the metal ions can move without collision in some planes of the crystal but not in others.

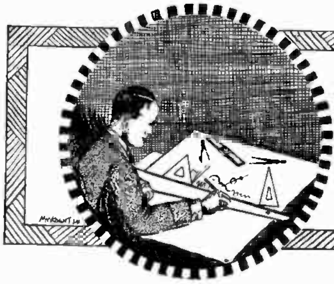
R386.—THEORIE DER KURZEN SIEBKETTEN.—H. Backaus (*Jahrb. d. drahtl. Tel. Vol.* 24, *Nos.* 2 *and* 3).

The theory of short filter circuits is dealt with mathematically. Resonance curves are derived for different types of filters and some experimental results are also given.

R400.—SYSTEMS OF WORKING.

R470.—LA TÉLÉGRAPHIE LE LONG DES RÉSEAUX DE DISTRIBUTION DE LA LUMIERE ET DE L'ENERGIE.—S. and A. Hattowski (*Onde Elec.*, Feb., 1925).

From time to time suggestions have been made for utilising electric supply mains for purposes of telegraphic and telephonic communication without interfering with the normal duty of such mains. This article gives some interesting practical methods of accomplishing this. One method depends upon the fact that the nominally earthed side of a D.C. main is only officially earthed at certain definite points, such as the generating station or distribution centres. There is a small but distinct resistance (0.1 to 0.5 ohn) between the earthed main and a true local earth. Hence if an audio-frequency E.M.F. from a small alternator is applied between this main and earth a voltage is established which can affect a receiver at a distant point on the same supply which is also connected between the main and earth. It is necessary to insert large blocking condensers as it is not permissible to earth an "earthed" main at unauthorised places. A number of practical working arrangements are described. It is said that the distance between the stations has practically no effect on the signal strength. Modifications are described whereby A.C. supply circuits may be used for communication. Particular mention is made of the difficulties encountered in the use of three-phase high-tension lines and how these difficulties can be overcome.



Some Recent Patents

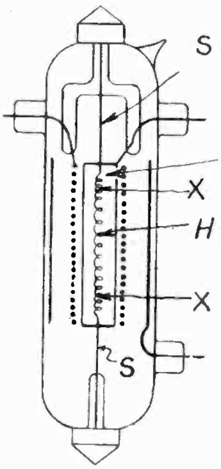
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

[R008

Cathode Construction.

(*Application date, March 14th*, 1924. *No.* 225,584.)

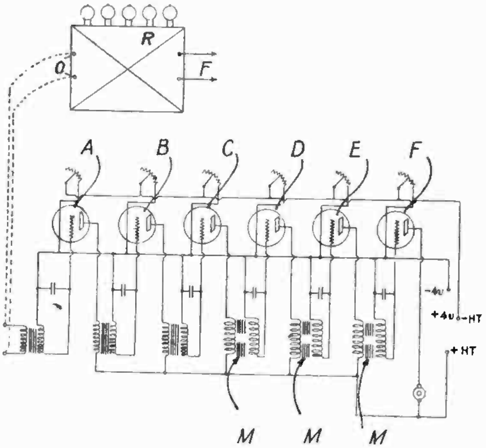
BRITISH Patent No. 225,584 granted to G. C. Beddington, describes a form of equi-potential cathode construction which is illustrated by the accompanying diagram. The object of the invention is to provide a means for heating the cathode equally. It has been found that when an equi-potential cathode takes the form of a cylinder containing a heating element that the cylinder cools rather rapidly towards the ends owing to conduction through the supports. Thus in the accompanying diagram the cathode C is supported at each end at S, and contains a heating coil H. This is of spiral formation, and it will be seen that at V the turns are very much closer together. This results in a greater heating at the ends of the cylinder, and consequently an equal temperature is obtained over the whole surface. It appears, however, from the specification that the heater is simply held in the centre of the cylinder, and the use of a filling of nitrogen between the filament and the inside of the cathode is suggested. We should imagine that some difficulty might arise owing to the diffusion of gas through the heated metal.



Selective Reception.

(*Application date, December 4th*, 1923. *No.* 225,704.)

British Patent No. 225,704 has been granted to Y. Marrec for a selective system of reception. Readers will no doubt remember that Marrec demonstrated his system some little while ago. The specification, however, is rather vague and it is really not quite clear exactly how the scheme functions. Referring to the illustration, the signals are received on an open or closed aerial and are applied to the terminals F of the receiver R. This receiver comprises an ordinary radio frequency amplifier, a rectifier and a few stages of audio frequency magnification. The signals

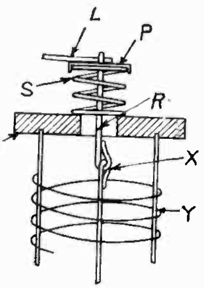


are obtained by beat reception and the output terminals Q deliver an audio frequency signal to the input I of the eliminating device. It is stated that the first three valves, A B and C, act as aperiodic repeaters, and that the amplification obtained therefrom is substantially nil. The last three valves, D E and F, are coupled by iron core transformers having movable cores M. It is stated that the valve D acts as a limiter, the limiting action being controlled by adjusting the filament rheostat. The valve E acts as a selector, and the valve F acts as an autodyne relay. Apparently the last valve generates audio-frequency oscillations, and is controlled by the incoming signals, or in other words, the incoming signals cause continuous oscillations to be produced, which beat with it. It is a pity that the specification is not clearer, as it is almost totally impossible to determine the manner in which each valve is supposed to function.

A Filament Support.

(Application date, August 30th, 1923. No. 225,293).

C. Seymour, D.S.O., and H. G. Hughes describe in British Patent No. 225,293 a form of filament mounting which is illustrated by the accompanying diagram. The invention relates to the familiar filament tension spring. A wire strip or ribbon R is fixed to the end of the filament at X, the other end of the ribbon being attached to a plate P. An insulating disc D is provided with a hole through which the ribbon R can pass, and a spring S is placed between the under side of the plate and the top of the disc D. A filament lead L, of course, is attached to the top of the plate, while the insulating disc D, which may be made of silica or similar material, can be attached to the grid Y.



Maintaining Vacua.

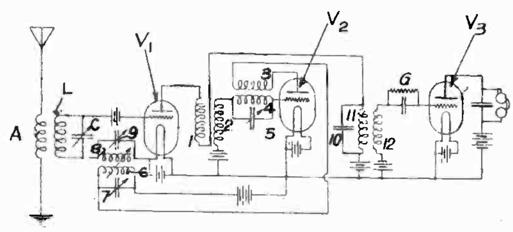
(Application date, November 12th, 1923. No. 225,694.)

L. A. Levy describes in British Patent No. 225,694 a method of maintaining a vacuum within a hard valve. This consists of placing within the bulb a small quantity of highly absorbent material, such as silica gel or highly activated charcoal. A further feature of the invention is the impregnation of the charcoal with a substance such as magnesium, lithium, or red phosphorus. The valve is roughly pumped in the ordinary way and the use of ordinary getting methods may be employed. It is stated that in practice it is convenient to place the absorbent material in a side tube connected to the side of the bulb. The use of absorbent material of this nature has been known for some considerable time in connection with devices other than hard valves.

The Latest Armstrong Superheterodyne.

(Application date, May 9th, 1924. No. 215,785.)

The Westinghouse Electric and Manufacturing Company describe in British Patent No. 215,785 a superheterodyne receiving system which is illustrated by the accompanying diagram. It will be seen that the circuit really amounts to an

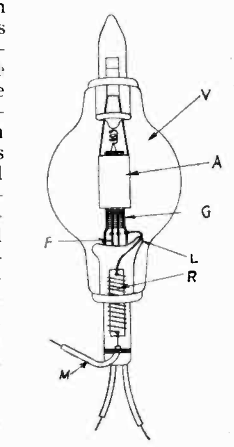


ordinary super-heterodyne system in which the intermediate frequency is reflexed from the first valve. The aerial circuit A is coupled to a circuit L.C, which is tuned to the incoming frequency This secondary circuit is applied to the grid and filament of the valve V1. The anode circuit of the valve V1 contains a radio-frequency transformer 1 2 which also amplifies at the incoming frequency. The secondary of the transformer 1 2 is applied to the grid and filament of the valve V2. The grid circuit of this valve contains a tuned circuit 4 5, and the anode circuit contains the circuit 3. The coil 3 is coupled to the coil 4, causing oscillations to be generated, and the circuit 4 5 is tuned to a frequency equal to half the frequency of the incoming signals plus half the frequency of the desired beat frequency. In this way it will be seen that the first harmonic of the oscillator will differ from the frequency of the incoming signal by the desired intermediate frequency. The anode circuit of V2 also includes the tuned circuit 6 7, which is tuned to the beat frequency, and this is coupled to the circuit 8 9, which is also included in the grid circuit of the valve V1. The grid of the valve V1 therefore has impressed upon it oscillations of beat frequency, and the anode circuit, it will be noticed, also includes a tuned circuit 10 11 tuned to the beat frequency. This is coupled to the coil 12 which is connected across the grid circuit of the valve V3, which includes the grid condenser and leak G and functions as the second rectifier. Considerable details are contained in the specification regarding adjustment and arrangement of the various tuned circuits for the prevention of self-oscillation of the system and other undesirable conditions. The specification also claims the use of a bye-pass filter for this purpose.

Stabilising Valves.

(Application date, July 12th, 1923. No. 225,899.)

An interesting form of valve construction is described by N. Lea and the Radio Communication Company, Limited, in British Patent No. 225,899. It is well known that when using three-electrode valves there is frequently a considerable tendency for the production of undesirable oscillation, due to the existence of capacity between the electrodes. Various means have been devised for overcoming this difficulty, such as the connection of various external condensers and ohmic resistances. In such cases, however, there is still the possibility of self oscillation occurring, since the external connections of the valve possess inductance which may form oscillatory circuits when combined with the electrode capacities.

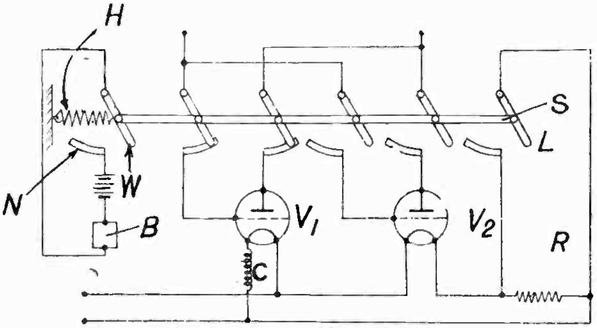


According to this invention, this difficulty is overcome by the inclusion of an ohmic resistance within the valve itself. Thus, in the accompanying illustration, the valve V contains a normal anode A, grid G and filament F. The lead L from the grid G contains a resistance R, which in this case is housed within a re-entrant tube, the ordinary lead M being brought out in the usual manner. Several forms of construction are described in the invention, and consist, for example, in breaking one of the grid supports and including a strip of insulating material, round which the resistance is wound. The specification also claims the use of a number of resistances connected in parallel from several points on the grid. The resistance varies with the type of valve, as well as with external conditions. For example, in a 500-watt valve, the grid leak resistance may be of the order of 100 ohms, while in other cases it may be as low as 10 ohms, or even less.

Maintaining Constant Operation.

(*Application date, October 8th,* 1923. *No.* 226,306.)

E. Y. Robinson, W. J. Brown and Metropolitan-Vickers Electrical Company, Limited, describe in British Patent No. 226,306 a system for maintaining the constant operation of a station which is to be uninfluenced by the sudden burning out of the cathode of one of the valves. The accompanying diagram illustrates the operation of the scheme, which consists essentially in running a main valve on full load, and either running a subsidiary valve with it on a small load, or running a subsidiary valve on no load, and providing a means for instantaneously putting the full load on this valve. Thus in the accompanying illustration valve V1 is connected to its normal radio-frequency circuit by means of a six-pole two-way switch S, which is normally maintained in the position indicated by a spring H. The filament circuit of the valve V1 contains the coil C, which controls the operating mechanism of the switch S.

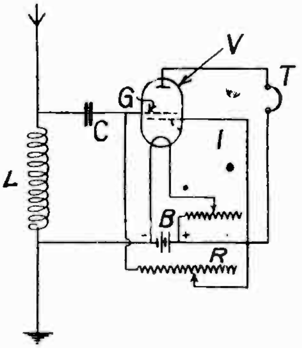


Normally, when the current is passing through the coil C, the switch is in the position shown, but should the filament burn out, the current through the coil C will cease, and cause the switch to move over into the other position. This automatically connects the valve V2 in circuit and the arm L of the switch S short circuits the resistance R, which is in the filament circuit of the valve V2, thereby applying full voltage to the filament. It will be noticed that the switch S is provided with an arm W which makes contact with the segment N and completes a circuit through a warning device B. As soon as the valve V1 fails, it will be seen that the valve V2 is brought into circuit, and this effect is immediately made known by the operation of the warning device.

The "Unidyne" Circuit.

(*Application dates, April 4th,* 1924 *and April 11th,* 1924. *No.* 226,417.)

Readers will no doubt remember that about twelve months ago the popular press boomed the use of a four-electrode valve which operated without the use of a separate anode battery. In particular, readers will no doubt remember the "Unidyne" circuit, which is due to K. D. Rogers and G. V. Dowding, and is described in British Patent No. 226,417. In the accompanying illustration the aerial circuit is simply shown as an inductance L for some reason or other. This is connected through a grid condenser C to the outer grid G of an ordinary four-electrode valve. The grid-leak R is connected, of course, between the grid and the positive side of the filament. The anode potential is obtained from the positive pole of the heating accumulator B, telephones T being included in the anode circuit. The inner grid I is also connected to the positive end of the filament, and the positive potential of the inner grid with respect to the filament tends to neutralise the effect of the space charge. Thus with an anode voltage of the order of 4 to 6 volts the anode current obtained is something of the order of that which is usual with the ordinary three-electrode valve. We are under the impression that the use of a positive potential on the inner grid of a four-electrode valve was known somewhat earlier than April, 1924.



Filament Construction.

(*Application date, November* 12th, 1923. *No.* 226,654.

An interesting form of filament construction is disclosed in British Patent No. 226,654, which is granted to L. A. Levy. The object of the invention is to provide a valve which has a very small current consumption, but at the same time is comparatively robust. Accordingly, instead of making the filament of wire, an infusible core of relatively non-conducting material is employed. This is coated with platinum, or some other metal, upon which is deposited a layer of barium, strontium or thorium compound in any known manner. One method of manufacturing the filament is described, and consists in using a filament core of fused silica which is coated with platinum by treating with a mixture of platinous chloride with oil of rosemary and oil of lavender. Once the first coat has been formed it can be thickened by electrolytic deposition. After this the conducting layer is coated in the normal way.