EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. III. NOVEMBER, 1926. No. 38.

Editorial.

The German Radio Exhibition—General Impressions.

VISITORS to the two preceding Annual Exhibitions in Berlin reported that manufacturers in England had nothing to fear from German competition. In this connection it must be remembered that economic conditions in Germany have been and still are such that the development of broadcasting is likely to be slower than in this country. Until recently, moreover, the Government adopted an unfavourable attitude to the new development. All this is changing very rapidly and the wireless industry shows every sign of healthy development. The broadcasting industry is established on lines somewhat resembling our own, the Post Office collecting the licence fee of two shillings per month and handing over a part of it to the Company. The studios at Vox Haus in Berlin are well equipped and the performers are drawn from the best talent in Germany; the orchestra is one of the best in Berlin and is conducted by one of the leading conductors.

On the technical side they draw on the whole resources of the Telefunken Company, Siemens and Halske and the A.E.G., and no effort is being spared to obtain the best results that modern science can produce. The number of listeners is at present small compared with the number in this country, but this will doubtless change as the struggle for existence becomes less intense among the great mass of the population, and the possession of a receiving set comes to be regarded as something to which an ordinary individual may aspire.

Several of the leading makers exhibited well designed and beautifully constructed neutrodyne and heterodyne sets at prices which seemed to be lower than those ruling in this country for similar sets. Even although most of the stalls are provided with sound-proof rooms for demonstrating their sets with loud-speakers, the conditions were not suitable for making critical tests and was largely dependent on appearance and the naturally somewhat rosy accounts of performance given by those in charge of the stalls. One could have no doubt, however, about the quality of the sets now being exhibited by such firms as Telefunken, Lorenz, Seibt and Huth, the latter of which we understand has been absorbed by the Berliner Telephone Co.

The firms exhibiting simple crystal sets numbered thirty-six, whilst thirty-seven firms showed valve sets. Between them they covered the whole range from sets costing a few shillings to superheterodyne sets at from £30 to £40. The superheterodyne was not nearly so popular as the neutrodyne type of receiver. The Telefunken Co. was showing a new five-valve neutrodyne—the Telefunkon-Gamma with three tuned neutralised circuits, controlled by a single knob, the three condensers being mechanically coupled. The only other controls were a wave-change switch and a loudness regulator. A somewhat similar set by the Magnophon Co. of Dresden had the dial marked with the names of the leading European broadcast stations so that one could tune any of these stations in without bothering about their wavelength. No fewer than forty-eight firms exhibited variable air condensers and among them were many ingenious slow motion devices. One manufacturer stated that they experienced considerable competition from England in this component, one English firm in particular doing a large business in Germany. Many of the better class receiving sets had the coils enclosed in removable trays or shallow drawers, which could be simply taken out and another drawer inserted to obtain a further range of wavelength, thus obviating the handling of the coils themselves. Although about twenty firms were showing rectifiers and apparatus for charging batteries or supplying anode current from the mains, much of the apparatus seemed to be only just emerging from the experimental stage. As was to be expected, headphones and loud-speakers were shown on a great many stalls; there was little novelty among the former but among the latter there was every conceivable construction. Of the forty-one firms showing loud-speakers many had several types and several sizes of each type. In some the sound passed through a trumpet of massive wood, all metal being avoided, whereas in another the sound passed through two turns of 1-in. brass tubing about two feet in diameter before emerging from a brass trumpet. The highest priced loud-speaker was of the hornless type with a cone of thin aluminium foil, made by Seibt and listed at £7 10s. The efforts of some makers in the direction of ornamentation would find little appreciation in this country. Valves were shown by fourteen manufacturers but the only outstanding novelty was the multiple valve of Loewe. Although forty makers exhibited intervalve transformers, few of them could give curves or particulars of performance; generally speaking they were smaller and cheaper than those employed in this country.

There were, of course, a large number of stalls filled with minor accessories, such as terminals, plugs, insulating materials, cabinets, etc., into which we need not enter.

As an example of the prices ruling and the way in which business is being done, the following is a translation of an advertisement in an amateur wireless weekly magazine:—

"We deliver an A1 two-valve set made by Messrs. Schuchhard, for all wavelengths, complete with valves, accumulator, anode battery, cord, and Hallophon Loud-speaker, erected complete with aerial. Six months' guarantee. Reception of foreign stations for 6 monthly payments of £1 or 26 weekly payments of 5s. Representative will call without charge. Demonstrations daily. The entrance price of the Exhibition refunded to every purchaser of a set."

It suggests good value for £6.

In the same magazine is an article on Loud-speakers from which we translate the following paragraph: "In loud-speakers with diaphragms the tone is produced by the vibration of the diaphragm. In loud-speakers without diaphragms, there is no diaphragm to vibrate, but its place is taken by carbon granules which vibrate backwards and forwards." This is from the weekly wireless supplement to the *Berlin Morgenpost* which was distributed at the Exhibition. It is only fair to say, however, that this is far below the standard of the bulk of German popular wireless literature.

The Berlin Wireless Exhibition. [R064

Enterprising Methods of German Radio Manufacturers.

THE third annual German Wireless Exhibition was held in Berlin from 3rd to 12th September. The exhibits were confined to German manufacturers, no goods of foreign manufacture being admitted. The exhibition was organised jointly by the State, the City of Berlin, and the " Verband der Funk-industrie," an association of wireless manufacturers. The official opening of the exhibition was made the occasion of the dedication of the new tower which is to carry the Berlin broadcasting aerial and which stands in the exhibition grounds.

The City of Berlin has taken a large tract of land—an old parade ground about five miles from the centre of the city—and set it apart as an exhibition ground. On this land there are now three large exhibition halls, the first of which, " Das Haus der Funk-industrie," was erected two years ago for the purpose of holding the first German wireless exhibition. The idea of the wireless industry of any country erecting their own exhibition buildings as a permanent structure on the outskirts of the capital is so striking, and the actual building presents so many points of interest, that we feel sure our readers will welcome a brief description of the undertaking.

After some discussion it was decided to avoid the use of iron as much as possible and to erect a wooden building. Except for the brickwork of the lower walls the building is almost entirely of wood; but

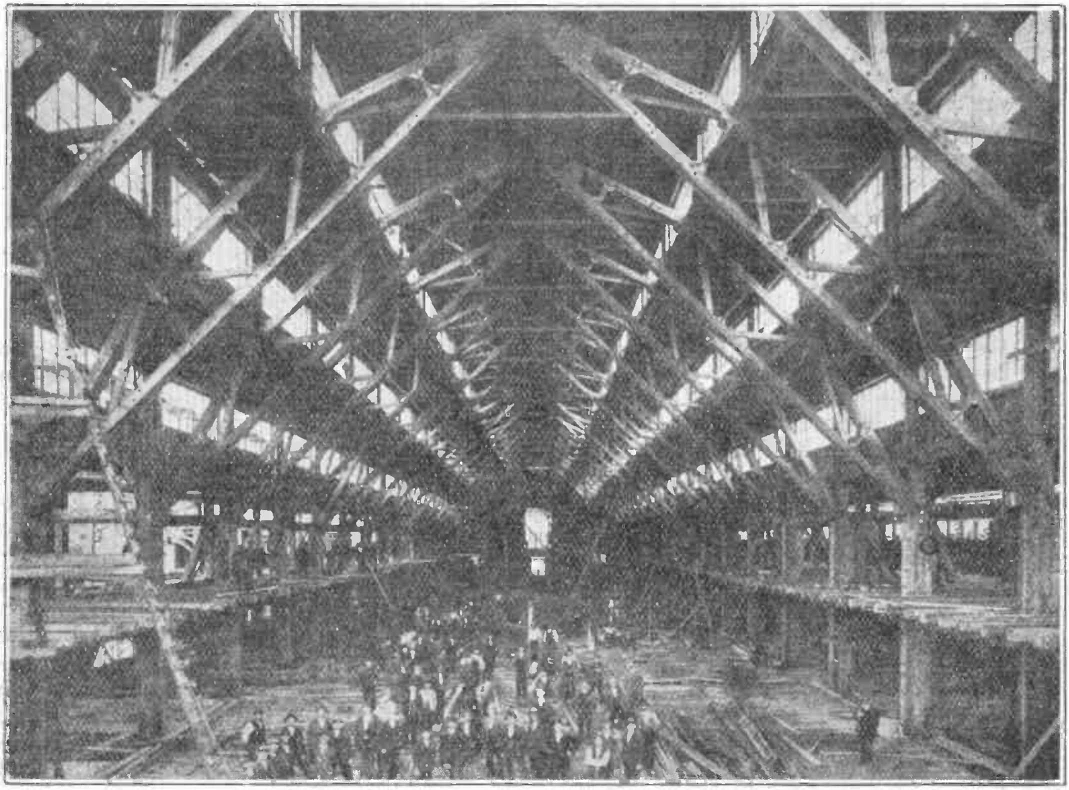

Fig. 1. *The Wireless Exhibition Hall in course of construction.*

owing to the wood being encased in fire-proof material, it has the appearance inside of a concrete building. The external appearance is very striking. As the building also houses the Berlin Broadcast Transmitter, an extensive system of earth wires was buried in trenches under the building before putting in the foundations. The main hall is rectangular, 430 ft. long and 136 ft. wide, with a gallery all round. Behind most of the stands, both on the ground floor and on the gallery, are sound-proof cubicles for demonstrating headphones and loud-speakers. During the wireless exhibition the local transmitter is not used, the Berlin broadcast being given from another aerial in a different part of the city. Two wires were stretched from end to end high up under the roof, and from these were hung a large number of receiving aerials, one for each stand if necessary. This hardly commends itself as an ideal arrangement for demonstrating the qualities of receiving apparatus and loud-speakers, although several exhibitors stated that it worked much more satisfactorily than one might have anticipated. We certainly heard many loud-speaker demonstrations without any sign of interference.

One of the most striking things about the exhibition building is the fact that it was completed in three and a half months from the commencement of the work.

The New Berlin Wireless Tower.

The tower has a total height of 453 ft; like the Eiffel Tower, it is self-supporting, but is only about half the height and has not the widely spread base. It has been designed to answer a double purpose, for in addition to supporting the broadcasting aerial, it is to be used as an outlook tower and as an aerial restaurant. At the top is a revolving searchlight which will act as a useful guide to aircraft approaching Berlin. Just below the searchlight is a platform to which visitors are taken by a lift for ten persons; from this platform a very fine view is obtained, the city on one side, the Havel and Grunewald on the other. At a height of 150 ft. a restaurant has been built into the tower with two floors, the upper one being the restaurant proper and the lower one the kitchens, etc. It was intended at one time to insulate the tower from the earth and this would have necessitated special arrangements, but we understand that it has not been decided to work with the tower earthed; we noticed that the careful insulation of the feet of the tower was short-circuited by copper strip running to earth.

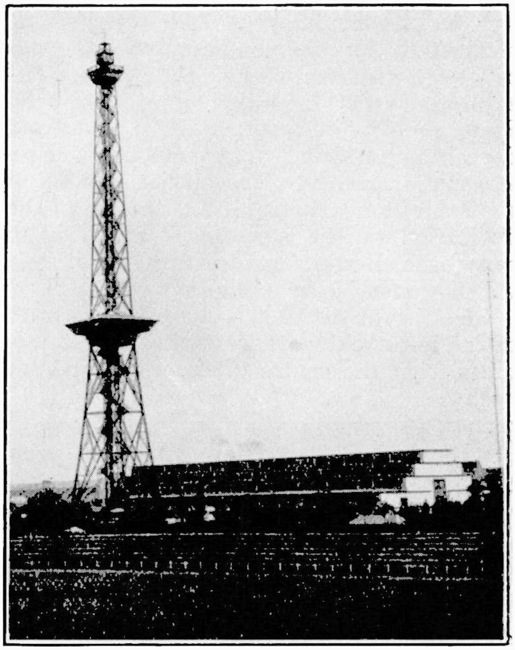

Fig. 2. *The new Berlin wireless tower.*

The Exhibits.

No attempt will be made to review the exhibits in detail, but mention will be made of certain products which seemed of special interest.

The Loewe-Radio Company's Exhibit.

The greatest novelty at the Berlin Exhibition was undoubtedly provided by the Loewe-Radio Company, who made a strong point of their multiple valves. Interest was stimulated first by the low price at which the valves were offered; secondly, by the offer of the company to repair any burnt-out valve for 8s., replacing not only the burnt-out filament, but also the others at the same time; and thirdly, by the announcement that the company had ceased to manufacture their previous types of single valves. The low frequency 3-fold valve type 3NF, containing 3 valves together with the anode resistances, condensers and grid-leaks, all in a single bulb with a six-pin

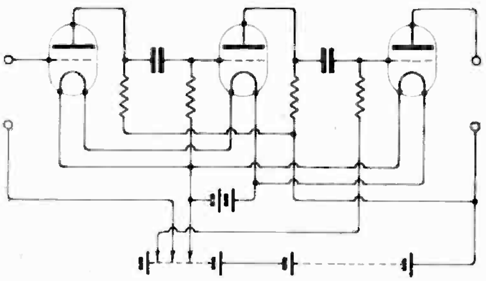

Fig. 3.

socket is listed at 17s. 6d. plus a licence fee of 7s. 9d. The high frequency double valve type 2 H.F., containing two valves and the necessary anode resistance, condenser and grid resistance is listed at 15s. plus 5s. The special six-terminal bayonet sockets for these multiple valves cost 2s. 3d. each.

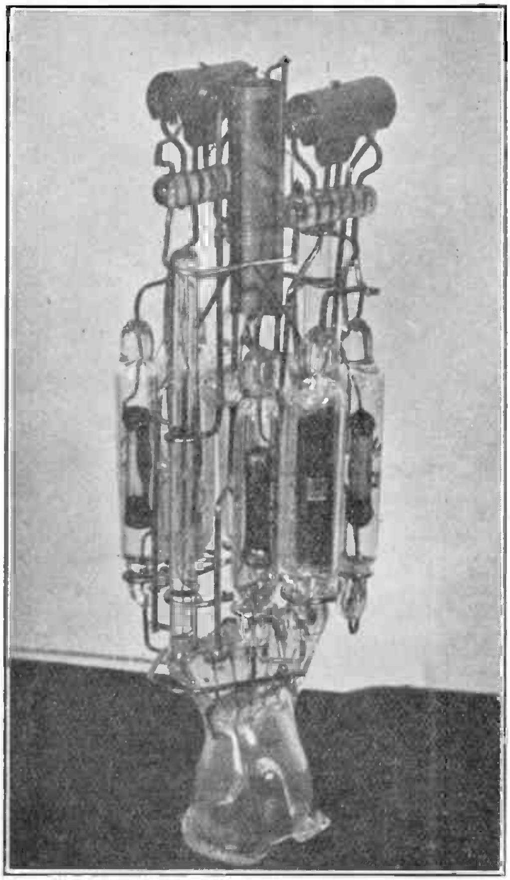

Fig. 4.

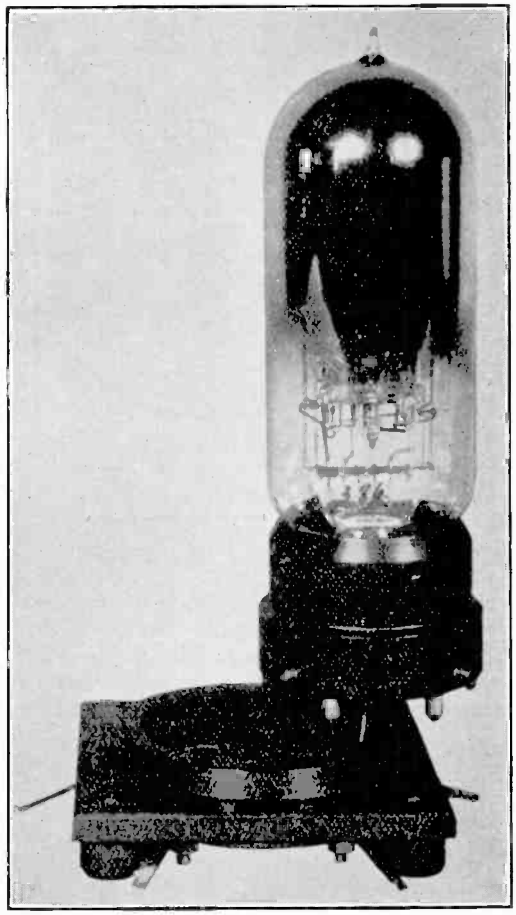

Fig. 5.

These multiple valves are a development from the work of M. von Ardenne and Heinert, who, instead of using an anode resistance of the order of 50,000 ohms in resistance-coupled amplifiers, used resistances of several megohms with valves specially designed to have a very large amplification ratio, viz.: 25 to 35.

To obtain good results with such an arrangement it is essential that the resistances should be non-inductive and of as small a capacity as possible. The Loewe Company developed a valve with suitable characteristics—their LA77—and a special type of resistance sealed in an evacuated glass tube, and put on the market a three-valve set employing these components. The

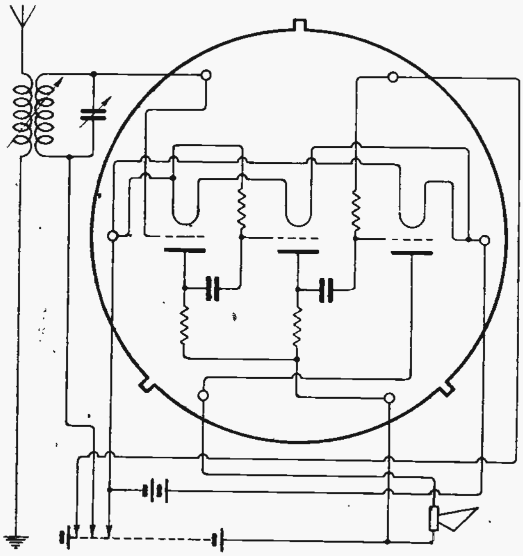

Fig. 6.

connections of this set, which was intended to give loud-speaker results from a local station, were as shown in Fig. 3.

The four resistances and two condensers were so small that they suggested the

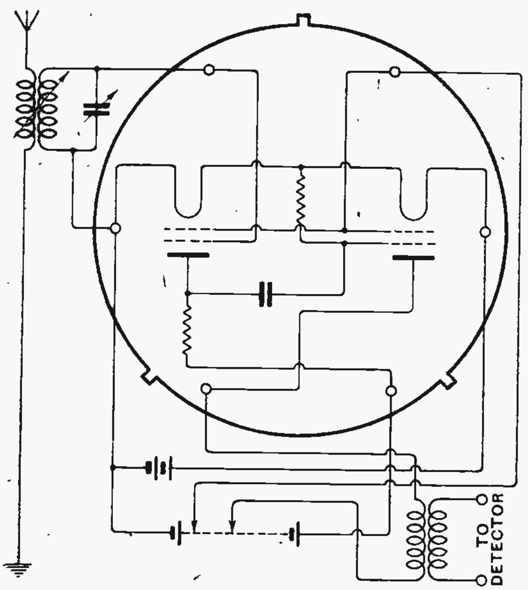

Fig. 7.

possibility of putting them all in a single bulb which might also contain the elements of the three valves. This would have the advantages of reducing stray capacities to a minimum, of screening all parts from atmospheric influences and of extreme compactness. Fig. 4 shows how the various elements are assembled in the bulb, whilst Fig. 5 shows the external appearance of the

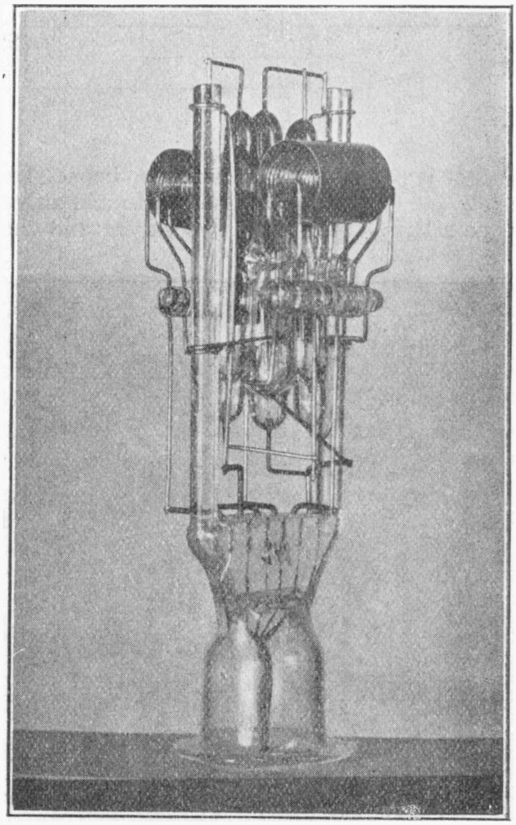

Fig. 8.

bulb and the specially-designed socket. From Fig. 6 it will be seen that the connections are the same as in Fig. 3; it will be seen moreover that the only apparatus outside the bulb is the aerial tuner, the batteries, and the loud-speaker. The filament battery should be one of 4 volts without series resistance, small voltage changes due to the battery running down having no appreciable effect; the current taken is 0.3 ampere. With an anode voltage of 90 the total current taken by the three valves is only from 3 to 5 milliamperes, but to obtain volume enough for a large room the voltage should be increased to 150 volts.

From a local station, loud-speaker strength can be obtained with an indoor or frame aerial. With an outdoor aerial a number of distant stations can be heard on the head-phones.

The H.F. Double Amplifier Valve.

The same principles have been applied to the design of a high frequency resistance-coupled unit consisting, however, of only two stages. The necessity of avoiding all stray capacities increases with the frequency, and the Loewe arrangement is therefore very suitable for high frequency resistance-

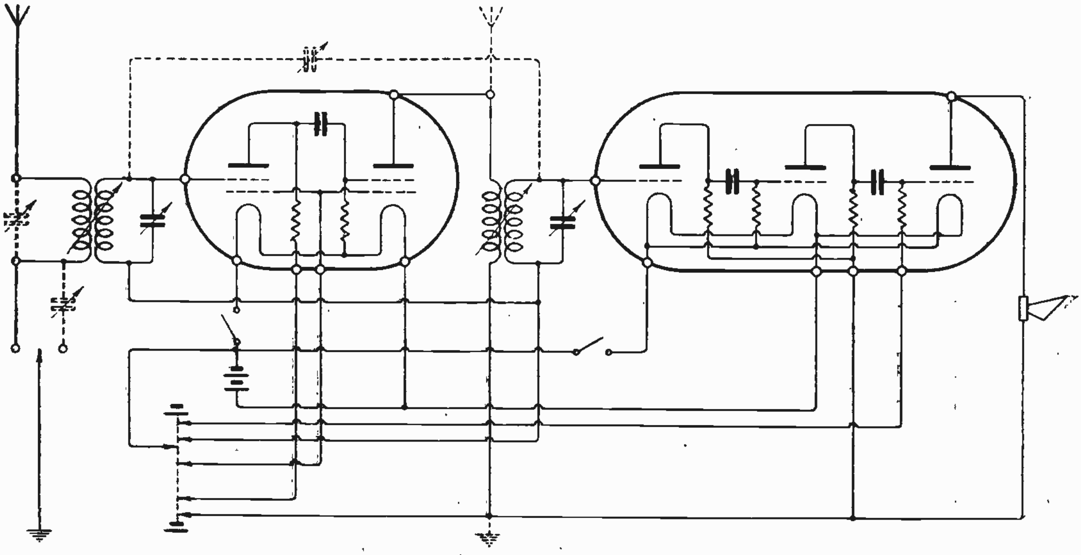

Fig. 9.

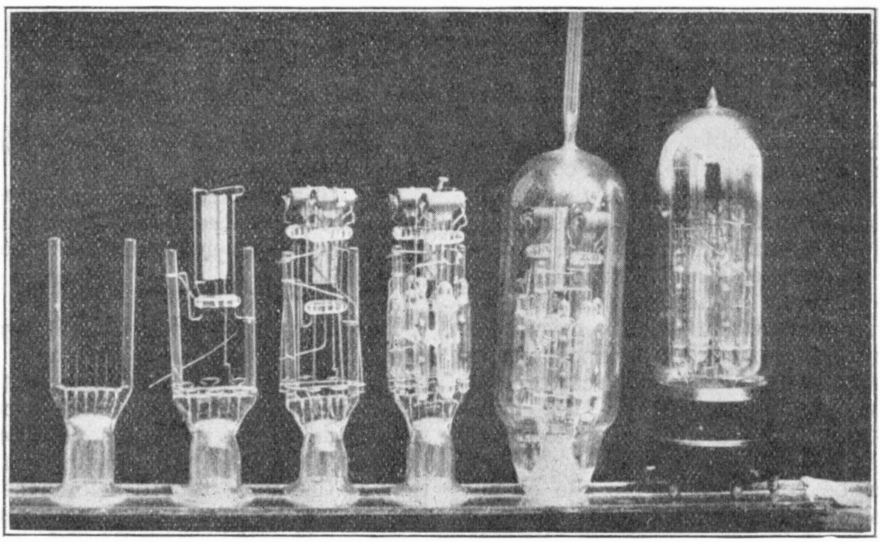

Fig. 10.

coupled amplifiers. The connections are shown in Fig. 7, and the arrangement of the various elements in the bulb in Fig. 8. The design has been carefully worked out by Dr. Loewe in collaboration with M. von Ardenne, with the result that appreciable amplification is obtained down to wavelengths of less than 200 metres. In Fig. 8, are to be seen the two valves, the anode resistance of the first valve, the grid condenser, and the grid-leak of the second valve. In outward appearance the two bulbs are similar, each has a six-pin cap fitting into similar sockets. In the H.F. amplifier double grid valves are employed, the inner grids being connected to a point on the anode battery about 15 volts positive with respect to the filament; the total space-charge current will then be about 5 milliamperes. The filaments are designed for direct connection to a four-volt battery, the current being about 0.17 ampere.

The makers emphasise the importance of screening to obtain the best results, and advise wrapping tinfoil round the bulbs and earthing it to the filament terminal. They also recommend that a 5,000 cm. condenser be connected across the output terminals on the socket of the detector amplifier unit in order to avoid H.F. oscillations being set up.

Fig. 9 shows the combination of the two units in a receiver. The Loewe Company supply receivers made up in this way at a list price of £6 15s. inclusive of licence fees but exclusive of the four plug-in coils.

To increase the amplification at short wavelengths, capacity reaction is provided by a very small condenser, shown dotted, which has a maximum capacity of 2 or 3 cm.

Such an aperiodic amplifier is not in itself selective; sufficient selectivity must be obtained by the tuning and loose coupling of the aerial and grid circuits. We presume that one will have to make the usual compromise between selectivity and quality of reproduction.

Figs. 10 and 11 show various stages in the manufacture of the detector-amplifier unit and the high frequency amplifier respectively.

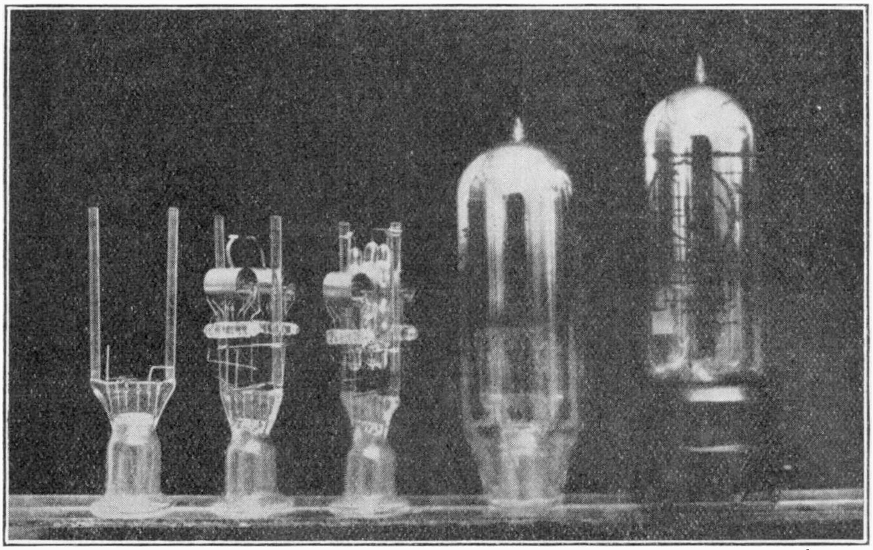

Fig. 11.

Radio-Frequenz G.M.B.H.

This company, which is a Loewe-Radio subsidiary, specialise in luminous quartz resonators. As oscillation generators were not allowed within the Exhibition Hall they could not be shown in operation there, but the writer was given a striking demonstration of this important development at the Reichsanstalt, where the discovery was made by Dr. Giebe and Dr. Scheibe. It is now generally known that if a bar of quartz cut in a certain direction with relation to the crystal axes is compressed, it becomes electrically polarised and conversely, if placed in an electric field it becomes mechanically strained. These so-called direct and

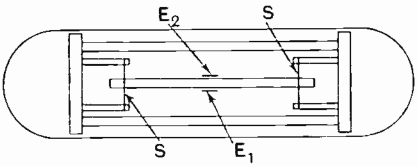

Fig. 12.

reciprocal piezo-electric effects were discovered in 1880 by J. and P. Curie. In 1922 W. J. Cady described how the natural mechanical frequency of vibration of such a quartz bar enabled it to be used as a very accurate standard of frequency of electrical oscillations. Giebe and Scheibe in 1925 mounted the quartz bar in a vacuum tube with a mixture of helium and neon at a pressure of a few millimetres and found that the electric polarisation set up when the bar vibrated caused its surface to be covered with a luminous glow. This serves as a very sensitive indicator of resonance without the aid of any measuring instrument. Fig. 12 shows a bar of quartz suspended by silk threads *SS* at each end, the electrodes E_1 and E_2 being close to the bar at its centre but not touching it. When placed in the rarefied gas with a high frequency P.D. applied between E_1 and E_2, nothing happens unless the frequency is adjusted to agree exactly to within about 1 part in 20,000 with one of the natural frequencies of the quartz bar. Fig. 13 shows photographs of the effects produced on a bar 8 cm. long when vibrating in its 3rd, 9th, 15th and 21st harmonic. The vibrations are not transverse, but longitudinal, and the luminous effects occur at the points of maximum compression; thus the luminous patches cannot occur at the ends, and with the electrodes symmetrically at the centre only the odd harmonics can be produced. This will be clear from Fig. 14, which shows the conditions existing *in the quartz bar at* successive quarter cycles when vibrating at its 3rd harmonic. In 14(*a*) there are no differences of pressure, but the arrows show the movement of the quartz at different parts of the bar; in 14(*b*) a quarter period later the movement has ceased, but the preceding movements have left it strained with a central region of compression and two side regions of rarefaction; a quarter period later the strain is relieved and we have the velocities shown in 14(*c*), to be succeeded a quarter period later by the compressions and rarefactions shown in Fig. 14(*d*).

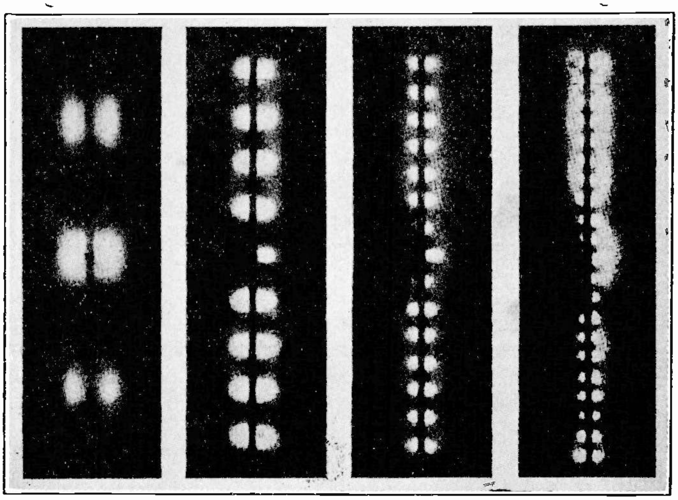

Fig. 13.

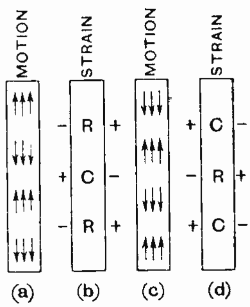

Fig. 14.

The longitudinal compressions and rarefactions cause transverse electrical polarisation as indicated by the + and — signs, and if these are strong enough they produce luminous effects in the neighbouring gas.

If it is only desired to work at the fundamental frequency of the quartz rod a simpler arrangement is possible, especially for wavelengths of a few hundred metres. The frequency of the broadcast transmitter at the Berlin Exhibition Hall has been controlled for some months by a quartz rod 4–6mm. long 3mm. broad and 1.5mm. thick, lying loosely in a small metal holder with the other electrode a few millimetres above it. The fundamental frequency corresponds to a wavelength of 505 metres.

Fig. 15.

The newest type made by the Radio-Frequenz Co. are mounted in bulbs resembling small electric lamps; in these the quartz bar is held between the electrodes as shown in Fig. 15. These respond to a P.D. of 30 volts if the frequency is within one part in 10,000 of the resonant value. Fig. 16 shows a cabinet with five resonators each differing from the next by one part in a thousand, the middle one being adjusted to the standard frequency required. In this way one can watch the variation of frequency and see at once whether it is too high or too low. Above the quartz resonators is a neon lamp for rough adjustment, it is in parallel with the resonators and goes out when they respond; it also serves as a safety valve to protect the resonators. In the lower part of the cabinet is a crystal detector and galvanometer which can also be used as a resonance indicator.

The connections are as shown in Fig. 17. Prof. Giebe has made the interesting discovery that there is a low frequency periodicity in the luminous phenomenon. If a detector-amplifier unit be connected up to a loud-speaker and the input grid terminal be connected to a piece of wire brought near the quartz resonator, a note is emitted whenever the resonator glows. The pitch of the note depends on the gas pressure and on other things; it is highest at resonance, and lowers in pitch on either side of the resonant point, ceasing abruptly when the luminosity ceases. As the loud-speaker or

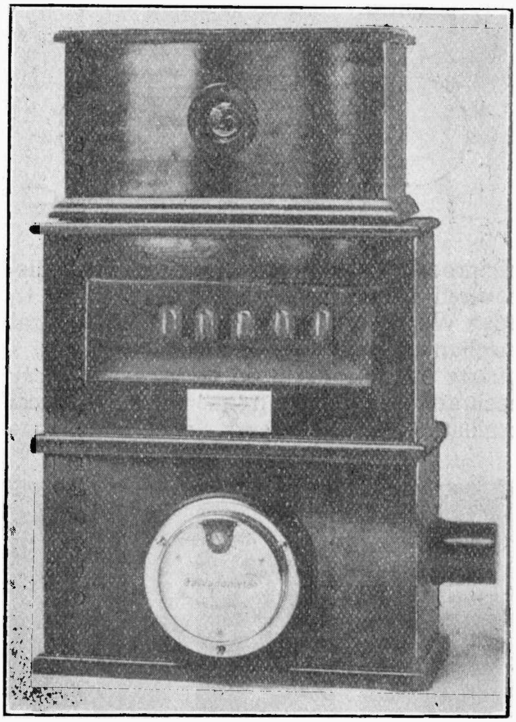
Fig. 16.

several loud-speakers can be situated at any convenient points this gives a very convenient acoustic method of distant control of the frequency. Fig. 18 shows the arrangement.

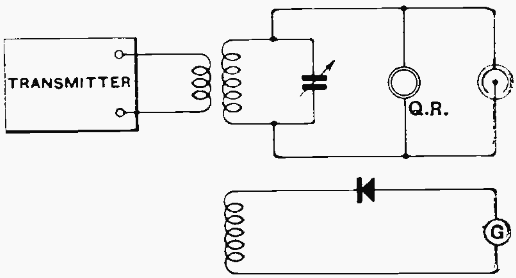

Fig. 17.

Siemens Halske's "Protos" Loud-Speaker.

This loud-speaker excited much interest because one of the same type but of a large size was mounted on the top of the kiosk in the centre of the Hall and added to the general hubbub of the Exhibition by giving musical items. The volume was no doubt enormous and the quality remarkably good considering the conditions, but it was, we fear, generally regarded as a nuisance by those in its immediate vicinity. A similar apparatus in the grounds sounded better, probably due to the absence of

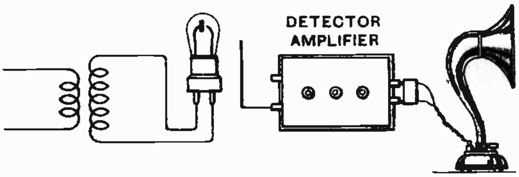

Fig. 18.

reverberation, especially in items of the military band type. The principle of this loud-speaker is simple; two sheets of Pertinax are secured at their outer edges and curved round so that their adjacent edges lie together, where they are stiffly sewn together as shown in Fig. 19. The magnet system acts horizontally on this stiff edge as shown by the arrow.

Fig. 20 shows the interior, with the ornamental perforated front plate removed.

This model is listed at £3 15s.

Apparently the same loud-speaker is made by the Telefunken Company under the name "Arcophone."

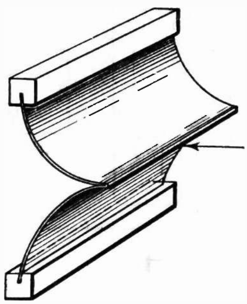

Fig. 19.

Fig. 21 shows the large model referred to above. It will be noticed that the curved sheets are placed vertically in this case. It is operated on the moving coil principle but the coil is replaced by a straight aluminium band about 20 inches long running along the stiff edge where the two curved sheets are fastened together. This is situated in the gap of a magnet and consequently moves backwards and forwards under the influences of the amplified speech currents.

C. Lorenz A.-G. of Berlin.

This firm is one of the oldest and largest in the Radio Industry; they manufacture everything connected with wireless from

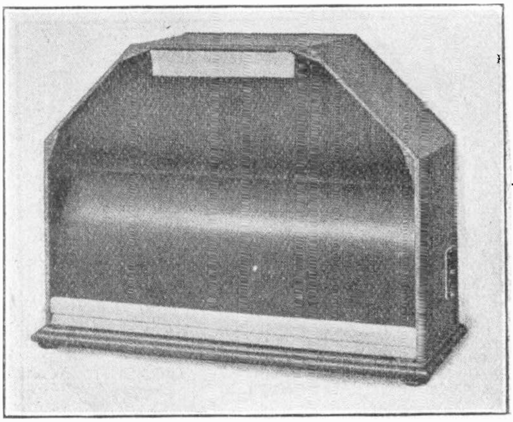

Fig. 20.

crystal detectors to high-frequency alternators. They exhibited a wide range of apparatus, including complete broadcasting

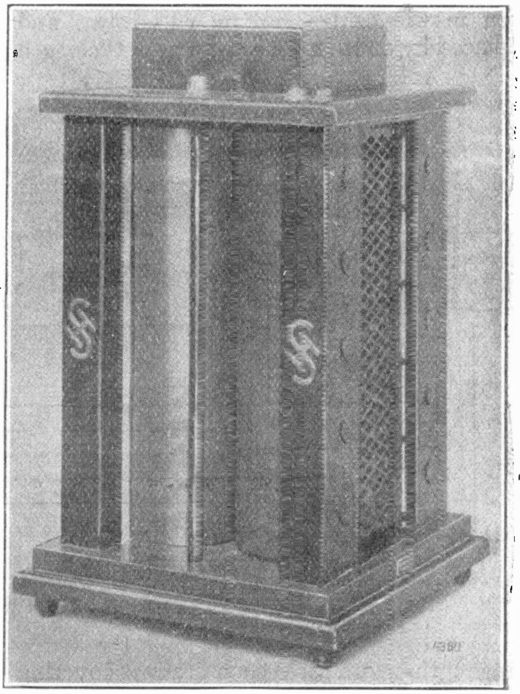

Fig. 21.

panels as supplied to many of the continental stations. Among the receiving sets was a small but well-made crystal set with variometer tuning listed at 10s. At the other end

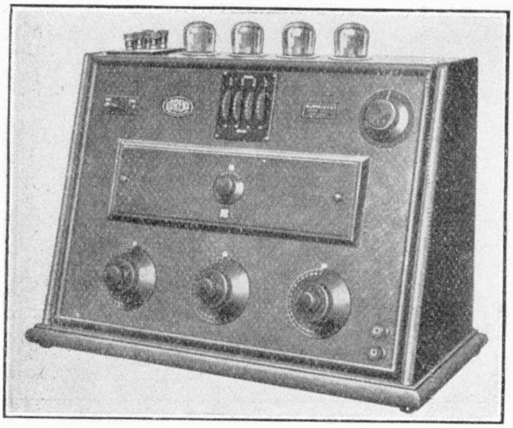

Fig. 22.

of the scale was their " Neutro " 4-valve receiver shown in Fig. 22, the connections of which are shown in Fig. 23. The drawer seen in the centre can be withdrawn and replaced by another for a different wavelength range; there are three such drawers covering 200-600, 600-1,700, and 1,700-4,000 metres respectively. The three variable condensers are seen at the bottom, the reaction adjustment at the right; the four filament rheostats are operated by the four discs mounted edgewise at the top of the case. The set is

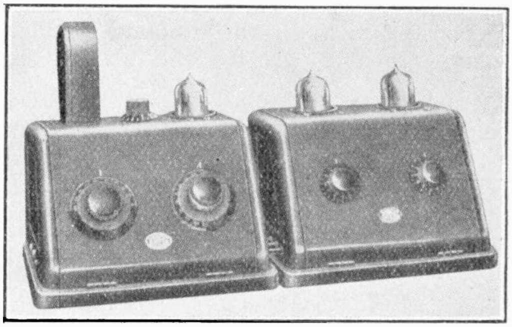

Fig. 24.

listed at £14 10s. with a single wavelength range; the additional ranges cost 35s. each.

Their " Universo " set consisted of a single-valve receiver which could be coupled up to a two-valve amplifier in a separate case. This set is shown in Fig. 24 and the connections in Fig. 25. On the left is seen the massively mounted plug-in coil by which the range can be changed, four coils covering the range from 200 to 4,500 metres. Each half of the set is listed at 57s. 6d. and the coils at 5s. 6d. each.

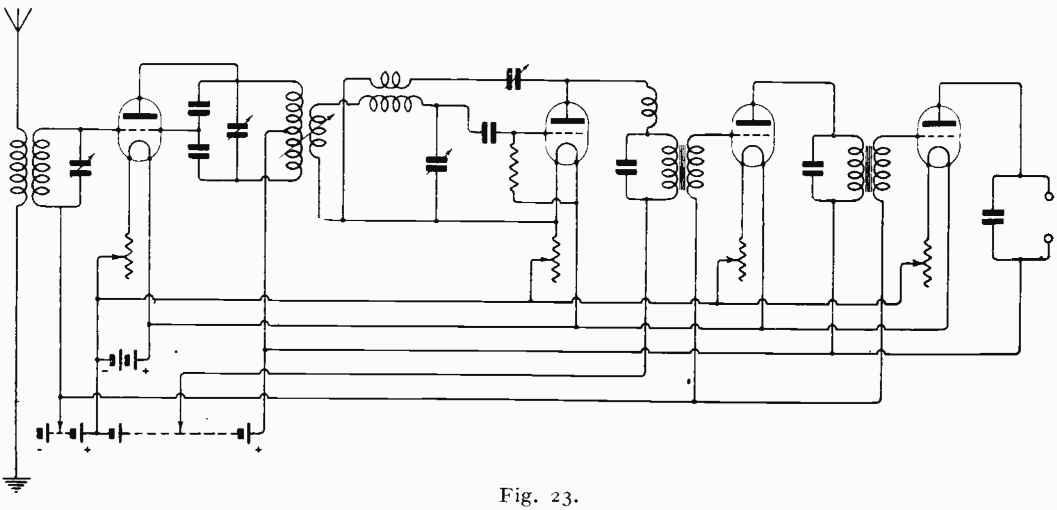

Fig. 23.

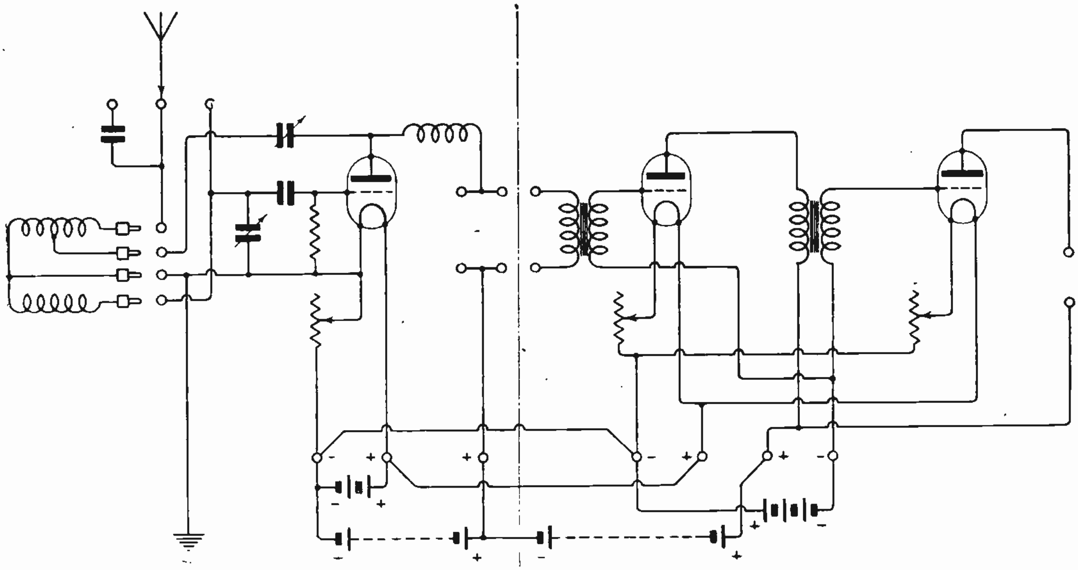

Fig. 25.

Push-Pull Valves.

Two firms exhibited valves with a single filament but with a grid and anode on either side of it. These valves were fitted with six-pin caps, and could be used in place of two separate valves in any ordinary two-valve arrangement; they could also be used with central-tapped transformers on the well known push-pull system, as shown in Fig. 26, which is reproduced from the pamphlet issued by Dr. Nickel G.m.b.H. of Charlottenburg, one of the firms making these valves under the name of "Dustron."

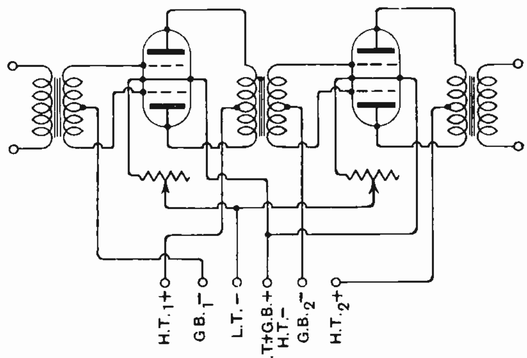

Fig. 26.

The Thermionic Voltmeter.

By W. B. Medlam, B.Sc., A.M.I.E.E., and U. A. Oschwald, B.A.

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(*Concluded from page 589 of October issue*).

Type III.—Direct Grid Slide Back Type.

THIS type, as shown in Fig. 24, is rather more complicated than Types I. and II., but has important advantages. To measure a voltage applied across the input terminals the grid potential is adjusted by means of the potential divider A (fine control) and the cells B_1 (coarse control) until the anode current is reduced to a definite fixed value, say $1\mu A$. The D.C. grid voltage is then a measure of the applied voltage. A separate D.C. voltmeter to measure the grid potential is not essential, as this may be measured on the anode microammeter by a simple change of connections. An arrangement for this purpose is shown in Fig. 25. With the switch in position 1 the instrument is connected in the anode circuit, and in position 2 the instrument is connected in series with the necessary resistance R across the steady grid voltage to be measured. The resistance R may be tapped, or the galvanometer may be shunted, to give a series of D.C. voltage ranges.

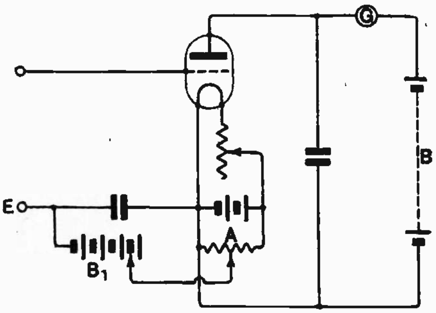


Fig. 24. *Connections on the slide back voltmeter, Type III.*

The connections in Fig. 24 are similar to those used in the earliest forms of voltmeter in which the grid voltage was slid back until the anode current was just reduced to zero. The difference between the slide back voltages with the signals on and off gives the peak value of the A.C. voltage. Owing to the indefiniteness of this zero setting and the low sensibility in the region of zero anode current the authors prefer to modify the operating conditions so that the slide back

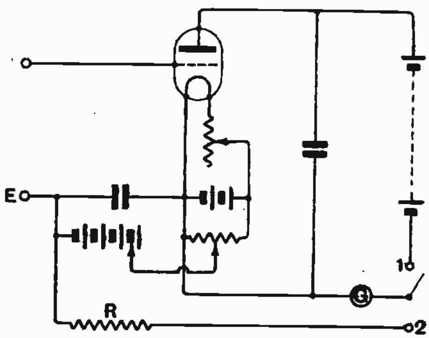


Fig. 25. *Connections for measurement of the grid bias on the anode microammeter.*

is to a false instead of to a true zero of anode current. In this case the calibration, except for very low voltages, may be made practically linear over a long range.

(*a*) *Sensibility and Range.*

With this type the range extends from about 0.1 volt to the highest voltage it is safe to apply to the grid of the valve. The whole range is covered by a single calibration and the voltmeter can be made highly sensitive throughout its range. Specimen calibration curves are given in Fig. 26 for a series of values of the constant anode current. For the nearly linear part the calibrations may be expressed in the form $E = aV - b$, in which

E = the R.M.S. value of the A.C. voltage to be measured.

V = D.C. slide back voltage required to reduce the anode current to the given value.

a and *b* are constants the values of which, derived from the curves in Fig. 26, are given in Table V. As the constant anode current is reduced the value of *a* approximates more nearly to $1/\sqrt{2}$, *i.e.*, the increment in bias voltage becomes more nearly equal to the increment in peak value of the A.C. voltage. A calibration for zero anode current is not given owing to the indefiniteness of the

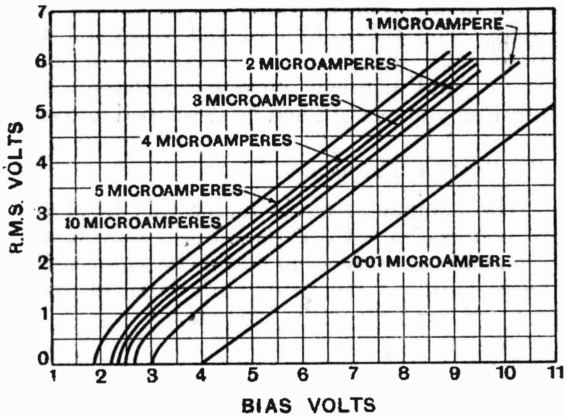


Fig. 26. *Calibration curves of the slide back voltmeter, Type III.*

zero setting. The apparent setting depends entirely on the sensitivity of the galvanometer used. This point is well shown by the curves in Fig. 27, showing the relation between bias and anode current for two slightly different A.C. voltages applied to the grid. As the bias is increased the slope becomes

TABLE V.

Constant anode current.	*a*	*b*
0.01	0.73	2.87
1.0	0.75	1.72
2.0	0.76	1.42
3.0	0.76	1.26
4.0	0.76	1.05
5.0	0.77	0.96
10.0	0.77	0.66

less and less, and zero anode current is approached asymptotically. One might estimate that the zero is reached by the lower curve at about —9.8 volts bias, but if the values in this region were measured with an instrument ten times more sensitive, some anode current would probably still be measurable with, say,—11 volts bias. If one works to a definite constant anode current, however small this may be within reason, the bias setting is perfectly definite. The difference in bias for the given difference in A.C. voltage is practicly constant over the range covered by the two curves in Fig.

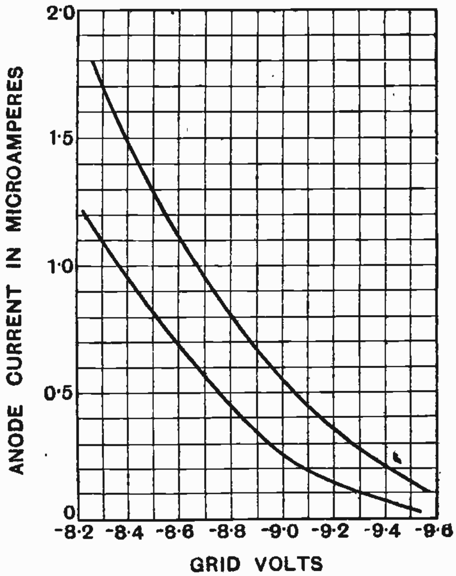


Fig. 27. *Anode current—grid bias curves, in the region of zero anode current, for two slightly different A.C. voltages.*

27, *i.e.*, the horizontal separation of the curves is nearly constant, being .27 volt at .1μA and .30 volt at 1μA, *i.e.*, a change of only .03 volt when the current is increased tenfold. However, the curves are steeper at the higher value of anode current, indicating a rather more sensitive adjustment of the bias with a given galvanometer. With a microammeter the sensitivity of the bias setting (for small A.C. voltages of the order of .2 volt) increases with the anode current; but there is little gain for currents above 5μA. On the other hand, the change in bias volts due to a given A.C. input actually increases as the anode current is decreased, as shown by the values of the constant *a* in Table V. Of course, one wants this change in bias to be as large as possible, and in this respect there is a real gain in working to $1\mu A$ rather than to $5\mu A$, especially on very low inputs. Further information on this point is given in Table VII., later. However, the sensitivity of the bias adjustment at $1\mu A$ is ample to make this value preferable to any greater value, when all things are taken into consideration. Before leaving the curves in Fig. 27, it may be noted that although their horizontal separation is nearly constant, their vertical separation decreases as the bias increases, indicating continued decrease in sensibility if the voltmeter is used as the deflection Type I.

TABLE VI.

(A) SINE WAVE.

R.M.S. volts.	Bias to slide back to:			A.C. peak volts.	Increment in bias to slide back to:		
	.01μA.	1.0μA.	5μA.		.01μA.	1.0μA.	5μA.
0	4.80	4.40	3.42	0	—	—	—
0.5	5.51	5.00	3.65	0.71	0.71	0.60	0.23
1.0	6.21	5.60	4.20	1.41	1.41	1.20	0.78
1.5	6.92	6.20	4.75	2.12	2.12	1.80	1.33
2.0	7.63	6.85	5.40	2.83	2.83	2.45	1.98
2.5	8.34	7.45	6.05	3.54	3.54	3.05	2.63
3.0	9.04	8.05	6.72	4.24	4.24	3.65	3.30
3.5	9.75	8.60	7.40	4.95	4.95	4.20	3.98
4.0	10.46	9.20	8.10	5.65	5.66	4.80	4.68

The effect of H.T. on the sensibility of the Type III. voltmeter is quite different from its effect on the deflection types. If the H.T. is increased more negative bias must be used in order to pull down the anode current to its given value if the filament current is kept constant, or alternatively, if the bias is kept constant the filament current must be reduced. In either case the sensibility is very little affected by large changes in H.T., and any value, say between 4 volts (from L.T.—) and 20 volts is suitable from this point of view. If the H.T. is very low one cannot use as much negative bias as is desirable unless a large filament current is used. Alternatively, with large values of H.T. and a safe value of the bias the filament current has to be so low that the sensibility falls owing to early saturation produced by the low filament emission. The best value of H.T. to use in any particular case may be determined as follows: With no A.C. input, set the bias to about −3 volts and raise the filament current to its normal working value, then adjust the H.T. until the required anode current of, say, $1\mu A$, is obtained. This gives the lowest value of H.T. which should be used. Then lower the filament a little and increase the H.T. until the required anode current is again obtained Finally vary the bias in order to see that there are no signs of saturation at zero (or any negative) grid potential. When the filament current has to be reduced to such a value that saturation occurs near zero grid potential, the corresponding H.T. is the highest value which should be used. The calibration of the voltmeter is practically identical for all values of the H.T., (and filament current) between the limiting values obtained as described above.

(b) Possible Frequency Error.

The comments made under this heading in connection with Type I. apply here also. Calculations made from static characteristics agree within 1 per cent. with experimental A.C. calibrations with Type III.

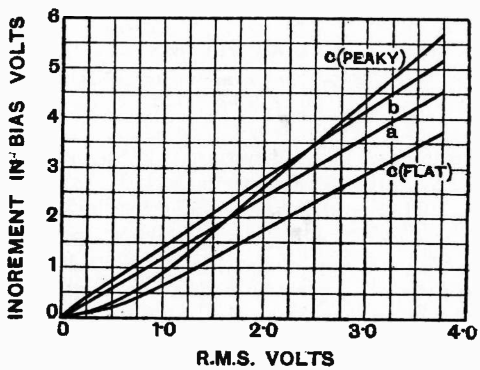


Fig. 28. *Calibration curves of the Type III. voltmeter on wave forms (a), (b), (c).*

(c) Wave Form Error.

From the principle of operation of this type of voltmeter one would expect its readings to follow the peak value of the input voltage unless the constant anode current is large. This view was confirmed on test with the same wave forms (Figs. 7, 8, and 9) on which the other voltmeters were tested. The results are given in Tables VI., VII. and VIII. for *(a)* the sine wave, *(b)* the third harmonic wave, and *(c)* the second harmonic wave, respectively. The increment in bias is plotted against R.M.S. volts in Fig. 28, for a slide to $1\mu A$, in all cases. The errors referred to the corresponding sine calibrations as before, are given in Table IX. They will be seen to be greater than for Type I. and less than for Type II. The errors decrease as the anode current is increased.

TABLE VII.

(B) THIRD HARMONIC WAVE.

R.M.S. volts.	Bias to slide back to:			A.C. peak volts.	Increment in bias to slide back to:		
	.01μA.	1.0μA.	5μA.		.01μA.	1.0μA.	5μA.
0	4.80	4.40	3.42	0	—	—	—
0.5	5.64	5.15	3.68	0.915	0.84	0.75	0.26
1.0	6.47	5.85	4.25	1.83	1.67	1.45	0.83
1.5	7.31	6.50	4.83	2.74	2.51	2.10	1.41
2.0	8.14	7.20	5.50	3.66	3.34	2.80	2.08
2.5	8.98	7.90	6.20	4.57	4.18	3.50	2.78
3.0	9.82	8.55	6.90	5.49	5.02	4.15	3.48
3.5	10.65	9.15	7.60	6.40	5.85	4.75	4.18
4.0	11.49	9.80	8.33	7.32	6.69	5.40	4.91

(d) Input Load.

The power factor of this type is about the same as for the deflection Type I. (operated with proper grid bias in relation to the input voltage). With very large input voltages (exceeding say 20 volts) the load may become a little greater unless the initial bias is at least 3 volts with no input. The reason for this is that the increase in bias is not quite as great as the increase in A.C. volts.

TABLE VIII.

(C) SECOND HARMONIC WAVE.

R.M.S. volts.	Bias to slide back to 1μA.		A.C. peak volts.		Increment in bias to slide back to 1μA.	
	Peaky half. +	Flat half. +	Peaky half. +	Flat half. +	Peaky half. +	Flat half. +
0	4.60	4.60	0	0	—	—
0.5	4.91	4.80	0.88	0.52	0.31	0.20
1.0	5.53	5.25	1.77	1.05	0.92	0.65
1.5	6.34	5.80	2.65	1.57	1.74	1.20
2.0	7.20	6.36	3.54	2.10	2.60	1.76
2.5	8.08	6.92	4.42	2.62	3.48	2.32
3.0	8.94	7.48	5.31	3.15	4.34	2.88
3.5	9.80	8.04	6.19	3.67	5.20	3.44
4.0	10.65	8.60	7.08	4.20	6.05	4.00

(e) Stability of Calibration.

A great advantage of this type of voltmeter is the permanence of its calibration. When operated very close to zero anode current, say .01μA, the increment in bias becomes nearly equal to the peak value of the A.C. voltage, and is almost entirely unaffected by change in the values of the H.T. steady bias and filament current. In addition, this calibration is the same for any valve. As the constant anode current is increased the calibration becomes dependent, to an increasing extent, on the values of the H.T. bias and filament current and also on the valve used.

TABLE IX.

R.M.S. volts.	Per cent. error with slide back to:				
	1μA.			.01μA.	5μA.
	b	*c*		*b*	*b*
		Peaky half +	Flat half +		
0.5	+20	—48	—68	+20	+5
1.0	+23	—22	—47	+18	+7
1.5	+16	—3	—34	+18	+3
2.0	+15	+7	—26	+18	+3
2.5	+16	+16	—23	+18	+5
3.0	+15	+21	—21	+18	+5
3.5	+14	+25	—19	+18	+4
4.0	+14	+28	—16	+18	+5

The results of a test with a 235-type valve to show the effect of changes in the H.T. filament current and steady bias are given in Table X. for a constant anode current of 1μA. In test *A* the bias was kept constant at —2 volts and the filament current and H.T. were varied together to give 1μA with no input. The bias values with 2.2 volts R.M.S. are shown in column 4, and the change in bias due to this input in column 5. The calibration is seen to vary, but it must be taken into consideration that the

TABLE X.

CONSTANT ANODE CURRENT 1μA.

Anode volts.	Filament current.	Negative bias with		Increment in bias.	Conditions of test.
		No volts.	2.2 volts R.M.S.		
18	.236	2.00	3.67	1.67	A
16	.242	2.00	3.97	1.97	
14	.26	2.00	4.13	2.13	
12	.282	2.00	4.21	2.21	
10	.302	2.00	4.24	2.24	
8	.330	2.00	4.21	2.21	
6	.370	2.00	4.19	2.19	
4	.438	2.00	4.17	2.17	
12	.245	0.93	2.70	1.77	B
12	.260	1.41	3.61	2.20	
12	.290	2.18	4.39	2.21	
12	.318	2.69	4.89	2.20	
12	.378	3.44	5.62	2.18	
2	.35	0.78	3.20	2.42	C
6	.35	1.77	4.00	2.23	
12	.35	3.15	5.34	2.19	
18	.35	4.50	6.60	2.10	

filament current range between the first and last values (.236 and .438A respectively) is enormous. With .236A the saturation current did not greatly exceed 1μA, and with .438A it was greater than 40 milliamps. In the region of normal filament current a change of 1 per cent. in the calibration does not occur until the H.T. changes about 30 per cent. In test B the H.T. was kept constant, and the filament current and bias were varied together to give 1μA, with no input. The change in calibration does not much exceed 1 per cent. over a range of filament current from .26 to .378, and of initial bias from 1.41 to 3.44 volts.

In test C the filament current was kept constant and the H.T. and initial bias were varied together over a very wide range. If an H.T. of nominal value 12 volts drops to half this voltage the calibration only changes 1.8 per cent. under these conditions.

Type IV.—Deflection Type, Curvature Rectifier with Grid-Leak and Condenser.

This type operates in the same manner as the Type I. voltmeter but it does not require a closed input circuit and is not affected by D.C. voltages across its input terminals. The connections are shown in Fig. 29. These are the same as for Type II. except that negative bias is applied to the grid-leak so as to enable the valve to operate on the

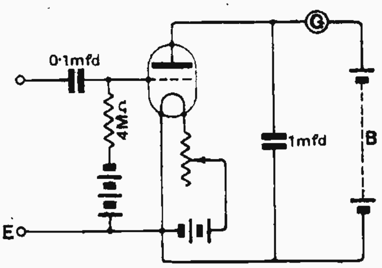


Fig. 29. *Connections of the deflecting voltmeter, Type IV., rectifying on curvature of the anode characteristic but using a grid condenser and leak.*

lower bend of its characteristic and to prevent the flow of grid current. The voltmeter will operate without the extra anode voltage *B* if the galvanometer lead is taken to L.T. +, but this extra voltage is an advantage as in the case of Type I., and for the same reasons.

(*a*) *Sensibility and Range.*

The general comments made under this heading for the Type I. voltmeter apply equally here. If the voltmeter is operated so that no grid current flows during any part of the cycle of the input voltage, *i.e.*, the grid bias exceeds the peak value of the A.C. voltage by a volt or so, then the calibration is

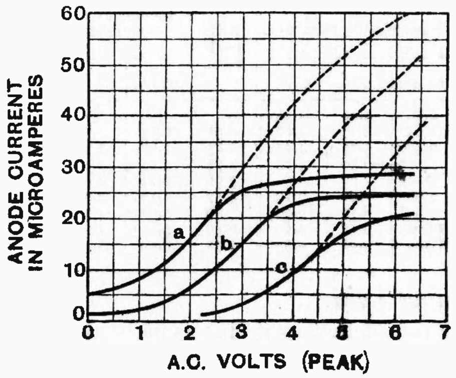


Fig. 30. *Calibration curves of the Type IV. voltmeter.*

identical with that of Type I. operated under any given conditions. Thus the numerical results previously given for Type I. also apply to Type IV. in this case. But if the grid bias is insufficient to prevent grid current the calibrations of the two types are not the same. This is shown by the calibration curves in Fig. 30. The full line curves are the calibrations for Type IV., the dotted lines are those for Type I. These results were obtained with the following steady biases: (*a*) — 2.27 volts, (*b*) — 3.17 volts, and (*c*) — 4.27 volts. Vertical lines cutting the three calibration curves *a*, *b*, and *c* at these voltages respectively, will be seen to mark the point on each curve at which the calibrations for the two types become different. Beyond this point the divergence increases rapidly with increased input and correspondingly increased grid current. The reason for this divergence is that grid current through the leak sets up a P.D. across it in such a direction as to make the grid more negative. Thus with grid current the negative potential on the grid is greater than the steady bias, giving a reduction in anode current which does not occur in the case of Type I. unless the voltmeter is used on a very high resistance input circuit.

However, this divergence is really outside the normal working range of the voltmeters over which the calibrations are identical.

By arranging the input connections as shown in Fig. 31, using a single pole switch, a rapid change over from one type to the other may be effected. With the switch in position 2 the voltmeter operates as Type IV. on open input circuits or where there is a D.C. through the input circuit; with the switch in position 1 the voltmeter operates as Type I. in cases where it may be desired to cut out the load due to the leak.* The calibration and operating conditions are all unaffected by the change over, unless there is grid current. The bias must be connected as shown in Fig. 31, and not in series with the leak, as in Fig. 29.

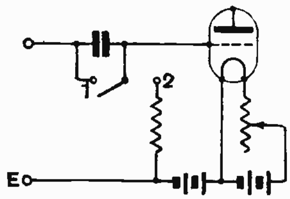


Fig. 31. *A method of effecting a change over from the Type IV. voltmeter to Type I.*

(*b*) *Frequency Error.*

See remarks under this heading for Type II.

(*c*) *Wave Form Error.*

The wave form error is the same as for Type I. over the range where no grid current flows. When there is grid current the reading will be less with a peaky wave than with a sine wave, and the errors will be less positive than shown in Table I. We do not present experimental results for this case, as it is outside the proper working range of the voltmeter.

(*d*) *Input Load.*

The power factor of Type IV. will be higher than that of Type I. by an amount depending on the A.C. qualities of the grid-leak. From the results given in Tables II. and IV. one may expect that the losses will be about doubled by the presence of the leak, unless this happens to have unusual losses. In this connection it may be noted that with the switching arrangement shown in Fig. 31, the total capacity between the switch contact 2 (with its wiring to and the capacity of the leak terminal) and the centre contact (with its wiring to the grid) must be reduced to a fraction of $1\mu\mu F$ if the leak losses are to be much reduced when the switch is in position 1. For instance, with leak *F* (Table IV.), a wiring capacity as low as $0.4\mu\mu F$, will only reduce the leak losses to half what they would be with the leak in direct connection to the grid. It may also be noted that, although the material used between the plates of the grid condenser must have a high insulation resistance in order, as has been previously pointed out, to prevent direct leakage of D.C. potentials to the grid, this material may be a very inferior dielectric without affecting the A.C. losses of the voltmeter, as there is practically no voltage drop on this condenser.

Although the losses with Type IV. will be greater than with Type I., they will be less than with Type II., using the same leak in both cases.

(*e*) *Stability of Calibration.*

If the operating conditions are such that there is no grid current the results previously given for Type I. apply here in detail. A change of leak resistance has no effect on the calibration. But when there is grid current there will be a change in calibration if the leak resistance alters.

Type V.—Grid Slide Back Type with Grid-leak and Condenser.

This type of voltmeter is the similar modification of Type III. that Type IV. is of Type I. It is operated in exactly the same way as Type III. The connections are shown in Fig. 32. The variable bias required to reduce the anode current to its constant value is applied to the grid through a high resistance leak, instead of directly as in Type III.

The performance of this type under headings (*a*), (*c*) and (*e*) is identical, qualitatively and quantitatively to that of Type III., the calibration being independent of the leak resistance.

The power factor will be increased due

* See also the comments under heading "Input Load," Type IV.

to the A.C. losses in the leak, even if the D.C. resistance is made high enough to prevent any appreciable load on this account. The magnitude of the increase may be estimated from what has been stated above in connection with other types of voltmeter.

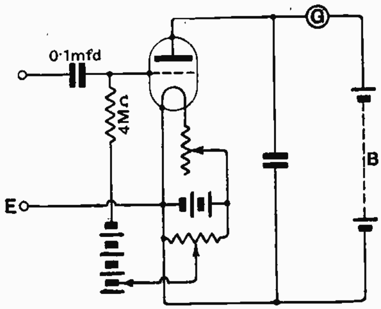


Fig. 32. *Connections of the slide back voltmeter, Type V., using a grid condenser and leak.*

The frequency error will be determined by the conditions given in connection with Type II.

Type VI.—The Reflex Voltmeter.

The great disadvantage of the direct deflection voltmeter, Type I., for general purposes, is the shortness of its range. If one maintains the grid bias at 1 volt more than the peak value of the maximum A.C. voltage, then the difference between the highest and lowest voltages readable (on the scale of a microammeter) will not exceed

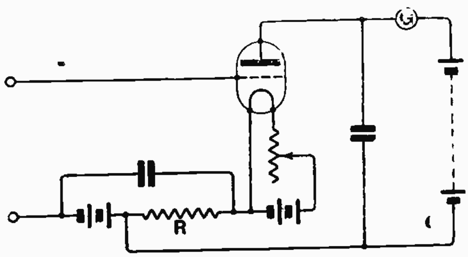


Fig. 33. *Connections of the reflex voltmeter, Type VI.*

3 volts under the most favourable conditions. Usually the range covered is nearer 2 than 3 volts. Thus many different calibrations are necessary to cover a wide range without a break. We have recently been experimenting with a modification of this type in which the above disadvantage is overcome. This new voltmeter we have termed the reflex type. The connections are shown in Fig. 33, from which it will be seen that a high resistance *R* is connected in such a way that the voltage drop on it, due to the anode current flowing through it, acts as an additional negative bias. If the A.C. voltage on the grid is increased, the anode current increases, and the negative

TABLE XI.

H.T. = 60 volts. *R* = 160,000 ohms.
Steady bias — 12 volts.

R.M.S. volts.	Anode current.
0	8.
1	9.5
2	12.0
3	15.3
4	20.
5	25
6	30
8	40
10	50
12	60
14	70
16	80
18	90
20	100

bias is also automatically increased in proportion. Thus much greater voltages may be applied to the grid before grid current occurs than is the case with the Type I. voltmeter with the same steady bias. In addition the sensibility with low inputs is

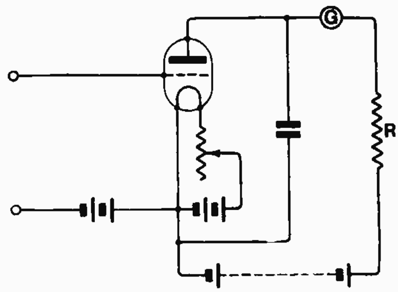


Fig. 34. *The usual method of improving the degree of linearity of the scale of the Type I. voltmeter.*

unaffected, as under these conditions the anode current, and drop on the resistance is very small. It is possible with this type to calibrate the scale of a microammeter from, say, 1 to 10 volts, or from 2 to 20 volts. In the second case the scale may be made perfectly linear from 4 to 20 volts, as shown by the specimen calibration in Table XI.

It is well known that the scale of the deflection voltmeter (Type I.) may be made more linear by insertion of a high resistance in the anode circuit as shown in Fig. 34,* but this resistance does not increase the useful range of the voltmeter as it does not affect the grid circuit conditions, on which the maximum safe input voltage depends. The voltage drop on the resistance in this case has the sole effect of reducing the anode potential so that the anode current rises more slowly as the A.C. grid voltage is increased. In the reflex voltmeter this resistance has the additional

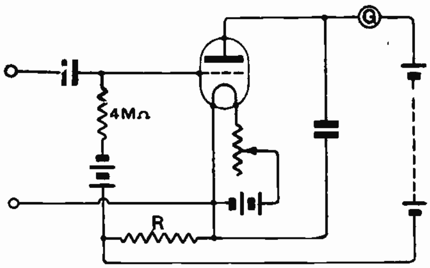


Fig. 35. *Connections of a reflex voltmeter, using grid condenser and leak.*

effect, as mentioned above, of increasing the negative bias when the A.C. grid volts increase. This second effect also slows down the increase in anode current. Thus a given degree of linearity of the scale is obtained with a lower resistance with the reflex connection.

We are at present attempting to make a linear microammeter scale serve for several voltage ranges having exact multiplying factors of, say, 2, 5 and 10, by simply changing the resistance and bias according to the range required. As our experiments in this direction are not yet completed we are leaving quantitative information on this voltmeter for a later paper.

It will be evident that the reflex action may be applied usefully to the Type IV. voltmeter, as shown in Fig. 35.

* *Loc. cit.*

Conclusion.

Each of the voltmeters described above is more suitable than any of the others for some particular purpose, and it may be useful to indicate briefly the scoring points of each type. The deflection voltmeter, Type I., is the simplest of all. This type and its modified form, Type IV., are the most suitable for use in cases where small changes in comparatively large voltages have to be read as accurately as possible, as in certain resistance measurements. By suitably biasing the grid the voltage scale may be expanded in the region where it is desired to work, and these voltmeters will be the most sensitive of any to voltage changes over this restricted range. These types also show less wave form error than any other type. The broken D.C. input circuit of Type IV. makes this type more generally useful than Type I., and it would completely replace this type of the effect of the A.C. losses in the leak could be made negligible.

Regarding the leaky-grid voltmeter, Type II., we can only show it to advantage in cases where voltages below 0.1 volt have to be measured directly: no other type can be used at or below this voltage. But in order to make use of this extra sensitivity it is necessary to balance out the large steady current. For all other purposes this voltmeter is inferior to some other type. Its broken D.C. input circuit can be met with Types IV. or V.; its losses and wave form errors are much greater than for any other type, and its calibration is the least stable.

The slide back voltmeters, Types III. and V., are useful where voltages of widely differing values have to be measured. A single calibration covers a range from 0.1 to 100 volts, and the calibration is much more stable than in any other type (in the sense that a given change in operating conditions affects its calibration least). Of the two slide back voltmeters, Type III. is preferable where the losses have to be kept down to the absolute minimum. However, these types have the very serious disadvantage of taking a comparatively long time to make a measurement, as the bias has first to be adjusted before the actual reading is taken. This disadvantage rules these types out as general purpose voltmeters.

As the general purpose voltmeter we have no hesitation in advising the reflex Type VI., with grid condenser and leak (Fig. 35). About 70 per cent. of its voltage scale can be made as linear as in a D.C. moving coil instrument, and the microamps per volt over this part of the scale may be adjusted to any desired value. Thus two such ranges, say from 25 to 5 volts, 10 to 2 volts, together with a low range from .1 to 2.5 volts, would suffice for most purposes.

APPENDIX.

The A.C. calibration of any of the voltmeters described above is calculable from static characteristics. The calculated and observed values invariably agree within the limits of error of the instruments used for the A.C. measurements. The more exact calculations are rather tedious, and only one example—applied to the Type I. voltmeter—will be given in detail, in order to illustrate the method.

First the instantaneous values of the A.C. voltage are tabulated at, say, 10° intervals from 90° to 270°, and the corresponding instantaneous values of the grid potentials are obtained by subtracting the steady negative bias from each reading. Then the anode current for each of these grid voltages is obtained from the static characteristic, which is assumed to be given. These currents are then integrated and the mean value is calculated. The result is one point on the calibration.

TABLE IA.

Grid volts.	Anode current	Grid volts.	Anode current.	Grid volts.	Anode current.	Grid volts.	Anode current.
+1.8	417.6	—0.1	175.0	—2.0	34.1	—3.9	2.18
+1.7	403.8	—0.2	164.0	—2.1	31.0	—4.0	1.7
+1.6	390.0	—0.3	152.6	—2.2	28.15	—4.1	1.3
+1.5	376.3	—0.4	142.0	—2.3	25.25	—4.2	1.0
+1.4	362.5	—0.5	132.5	—2.4	22.5	—4.3	0.7
+1.3	348.8	—0.6	122.	—2.5	20.0	—4.4	0.55
+1.2	335.0	—0.7	114.0	—2.6	17.5	—4.5	0.4
+1.1	322.5	—0.8	105.0	—2.7	15.5	—4.6	0.3
+1.0	310.0	—0.9	97.0	—2.8	13.5	—4.7	0.2
+0.9	295.0	—1.0	89.0	—2.9	11.75	—4.8	0.1
+0.8	283.0	—1.1	82.5	—3.0	10.0	—4.9	0.0
+0.7	270.0	—1.2	76.0	—3.1	8.8		
+0.6	257.5	—1.3	69.5	—3.2	7.6		
+0.5	245.0	—1.4	63.0	—3.3	6.5		
+0.4	232.5	—1.5	57.3	—3.4	5.6		
+0.3	220.0	—1.6	51.6	—3.5	4.75		
+0.2	210.0	—1.7	46.6	—3.6	4.0		
+0.1	200.0	—1.8	41.6	—3.7	3.33		
0.0	186.0	—1.9	37.8	—3.8	2.65		

For the numerical example the static characteristic is given in Table IA. To simplify the calculations a sine wave of applied E.M.F. was assumed with a peak value of 2 volts. The steady bias was taken as —3 volts. The instantaneous values e of the alternating input, for each 10° from 90° to 270°, are shown in the second column of Table IIA. The instantaneous grid potential, e_g, is given in this case by the expression $e_g = e - 3$. The anode currents (from Table IA) corresponding to these grid potentials are given in the last column of Table IIA.

A little consideration will show that the anode current wave from 0° to 90° is the same as from 90° to 180°; and also the part from 180° to 270° is identical to that from 270° to 360°. Thus it is only necessary to tabulate values for the half cycle from 90° to 270°, as is done in Table IIA. The average anode current I_a read by a microammeter in the anode circuit is given by the expression

$$I_a = \frac{I - \frac{1}{2}(I_{90} + I_{270})}{n - 1}$$

in which

I represents the sum of all the instantaneous anode currents.

I_{90} represents the anode current for the first reading at 90°.

I_{270} represents the anode current for the last reading at 270°.

n represents the total number of readings (including the first and last reading).

TABLE IIA.

Angle (degrees).	e	$e_g = e - 3$	Anode current.
90	2.000	—1.00	89.0
100	1.97	—1.03	87.05
110	1.88	—1.12	81.2
120	1.732	—1.27	71.45
130	1.532	—1.47	59.0
140	1.286	—1.71	46.1
150	1.00	—2.00	34.1
160	0.684	—2.32	24.7
170	0.347	—2.65	16.5
180	0	—3.00	10.0
190	—0.347	—3.35	6.05
200	—0.684	—3.68	3.46
210	—1.00	—4.00	1.7
220	—1.286	—4.29	0.73
230	—1.532	—4.53	0.37
240	—1.732	—4.73	0.17
250	—1.88	—4.88	0.02
260	—1.97	—4.97	0
270	—2.00	—5.00	0

TABLE IIIA.

Peak volts.	Anode current.		
	A.C. test.	Calculated at 10° intervals.	Very approximate calculation.
0	10.0	10.0	10.0
0.425	11.0	—	10.9
0.85	13.0	—	13.0
1.0	14.0	14.2	13.9
1.4	18.0	—	18.0
2.0	27.0	27.06	27.2
2.77	44.0	—	45.1
3.0	50.8	50.7	51.5

In this case I, the sum of all the currents in the last column of Table IIA, is 531.6. The value of $\frac{1}{2}(I_{90}+I_{270})=\frac{1}{2}(89+0)=44.5$, and $n=19$.

Thus

$$I_a = \frac{531.6-44.5}{19-1} = 27.06\mu A.$$

In a similar manner the mean anode current was calculated for A.C. peak inputs of 1 and 3 volts. The results, together with the corresponding values from an A.C. test with a sine wave of applied voltage, are given in Table IIIA. In this test the supply was at 40 cycles; the H.T. 18 volts, and the steady bias —3 volts. An approximate calculation giving results within 2 or 3 per cent. at every point may be rapidly obtained in a very simple manner, as follows:—

From the static characteristic find the anode current corresponding to the following grid potentials:—

(*a*) The steady bias.

(*b*) The steady bias + peak value of the A.C. voltage.

(*c*) The steady bias — peak value of the A.C. voltage.

The mean anode current is then given approximately by

$$\frac{(a)}{2} + \frac{(b)+(c)}{4}$$

For example, consider an A.C. of 1.4 volts peak, with bias —3 volts. Then from Table IA we have

(*a*) for —3 volts the anode current is 10.

(*b*) for —3+1.4=—1.6 volts the anode current is 51.6.

(*c*) for —3—1.4=—4.4 volts the anode current is 0.55.

The mean current is

$$\frac{10.0}{2} + \frac{51.6+0.55}{4} = 18.04\mu A$$

against an A.C. test value of 18.0μA.

Other values calculated by this approximate method are given in the last column of Table IIIA.

With reference to the article by Messrs. Medlam & Oschwald, we are asked by the Cambridge Instrument Co., Ltd., to state that they are the makers of the Moullin Thermionic Voltmeter.

We are also asked to state that they are the makers of the Duddell Oscillograph employed by Mr. Baggally in the experiments described in our October issue.

Mathematics for Wireless Amateurs.

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C. [510

(*Continued from page 618 of October issue*).

6. (A) The Solution of Equations.

THE solution of equations is a sort of mathematical detective work. One is given a sufficiency of clues and instructed to find the body, as it were. More prosaically, equations are statements embodying information about certain un- the known numbers (usually represented by symbols x, y, or z) and various other known numbers (a, b, c, etc.), and from this information it is required to find what numbers are represented by the x, y, or z symbols. This is more generally expressed as finding the "values" of the unknown numbers. The use of the word "value" in this connection is sanctioned by general practice, but one has only to speak of x being "more valuable" than y to realise that this special application of the term "value" does violence to the ordinary meaning of the word, which is rather a pity. It is, however, a convenient word to use for the full algebraic significance of a symbol, *i.e.*, magnitude and sign.

The simplest equations are those in which only one unknown number, x, has to be determined, and these will first be considered.

(A1) Equations for One Unknown Number.

This subject is best approached as one might approach some new and unexplored city. Having first seen it as a whole from overlooking high ground, one enters and gets to know its main thoroughfares and as many of its byways as one has occasion to use.

The meaning of the word "function" and of the notation

$$y=f(x)$$

was explained in the preceding section. It was shown that $f(x)$ is a number the magnitude and sign of which depends in some specified manner on the value assigned to x. For instance the form of the function might be specified as

$$y=f(x)=3x^2+5x+7$$

The value of y for some particular value of x, 8 for instance, is written $f(8)$, so that for this value of x

$$y=f(8)=3\times 8^2+5\times 8+7=239$$

In general, if $f(x)$ is specified as

$$y=f(x)=ax^2+bx+c$$

the value of y corresponding to some particular numerical value of x, α for instance, would be

$$y=f(\alpha)=a\alpha^2+b\alpha+c$$

It was further shown that in general the relation between y and x where

$$y=f(x)$$

could be exhibited graphically in the form of a picture drawn in accordance with certain agreed rules. The relation is shown in the form of a line which may be a straight line (see Fig. 8, October issue) but which will in general be a curved line which may assume an infinite variety of shapes according to the type of the function. (See for instance Fig. 9, October issue.)

In most cases the curve representing the function will cut the axis of x (*i.e.*, the line OX in Fig. 8). If it is a straight line it will cut it in one point only, but if it is a curved line it may cut it in several places or perhaps not at all. Thus for some assumed function $y=F(x)$, the curve of which is as shown in Fig. 10, the axis of x is crossed at three points, the x co-ordinates of these points being, say, α, β, and γ. For all points on the x axis, the y co-ordinate is zero, *i.e.*, $y=0$. For all points at which the curve $y=f(x)$ cuts the x axis, the value of x is such that

$$y=f(x)=0$$

Thus for the function $y=F(x)$ shown in Fig. 10,

$$F(\alpha)=F(\beta)=F(\gamma)=0$$

Any value of x for which

$$f(x)=0$$

is called a "root" of the equation $f(x)=0$, so that α, β, and γ are the roots of $F(x) = 0$. (One would like to know why this curious name is used. The name "solution" can also be used, and is preferable in some respects.)

Generally speaking, for any specified function

$$y = f(x)$$

the value of y corresponding to any desired value of x can be determined by simple arithmetic. We are concerned now with the reverse process, *i.e.*, given some particular value of y, *i.e.*, zero, to find the corresponding value or values of x. This may be and usually is a rather more difficult matter. One perfectly general

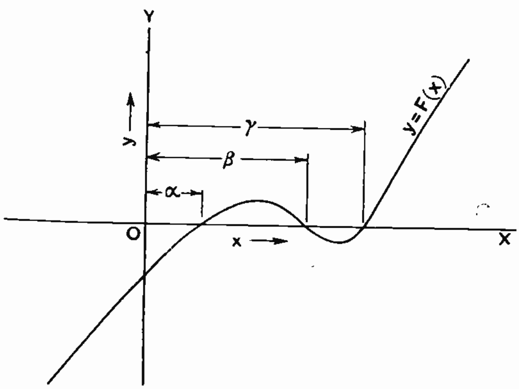


Fig. 10.

method is obvious from the above discussion, and was illustrated in the preceding section for the case of the function

$$y = a^x.$$

The method is to draw the curve of the function and find the points at which it cuts the x axis. This, however, is likely to be laborious. Moreover, the accuracy of the solution will depend on one's skill in drawing, the sharpness of one's pencil, and various other non-mathematical factors. Nevertheless, it is in many cases the only available general method and one that is quite often used. Further consideration will be given to it later on, but for the present we shall be concerned with simpler and more accurate methods which can be applied to certain common types of equation.

(A2) The Linear Equation for One Unknown Number.

The simplest kind of function is that of which the picture is a straight line. (See Fig. 8, October issue.) All such functions can, by appropriate manipulation, be reduced to the form

$$y = ax + b.$$

Corresponding to such functions is the linear equation

$$ax + b = 0$$

the characteristic of which is that it contains only known numbers and the first power of the unknown number. As already explained, the solution of this equation is the x co-ordinate of the point in which the line

$$y = ax + b$$

cuts the x axis. Except in the case in which the line is parallel to the x axis (a case of no practical importance) it will always cut the x axis at one point and one point only. Thus there is always one solution to the equation. Once the equation has been reduced to the standard form its solution is simple. Since the numbers $ax+b$ and 0 are equal, the addition of the number $-b$ to each side will not disturb the equality, *i.e.*,

$$ax + b - b = 0 - b$$

or

$$ax = -b$$

Notice that in effect the b is taken over to the other side of the equation, its sign being changed on the way. In practice one speaks of taking the number or symbol over to the other side. Actually the process consists of the addition of the corresponding number or symbol with the sign reversed to each side of the equation. Since the numbers ax and $-b$ are equal, the division of each by a will leave the resulting numbers or fractions equal, *i.e.*,

$$ax/a = -b/a$$

or

$$x = -b/a$$

Thus $x=-b/a$ is the solution of the equation $ax+b=0$, and the whole art of solving a simple linear equation consists of reducing it to the standard form, after which its solution can be written down at once. For instance, given

$$4(3x - 8) = 7 + 4x$$

then $12x - 32 = 7 + 4x$

and taking the 7 and $4x$ over to the left

$$12x - 4x - 32 - 7 = 0$$

$$8x - 39 = 0$$

and comparing this with

$$ax + b = 0$$

the solution is seen to be

$$x = 39/8 = 4\tfrac{7}{8}$$

Taking a rather more difficult example :—

$$\frac{2}{5x+7} = \frac{3}{8x+2}$$

Multiply each equal fraction by the number $(5x+7)$ $(8x+2)$. Then

$$\frac{2(5x+7)(8x+2)}{(5x+7)} = \frac{3(5x+7)(8x+2)}{(8x+2)}$$

and cancelling out the common factors in the numerator and denominator of each fraction (see para. E2, p. 495, August issue)

$$2(8x+2) = 3(5x+7)$$

from which point the solution proceeds exactly as in the first example.

Notice that in general, if

$$a/b = c/d$$

$$ad = bc$$

This is known as "cross multiplication," but it really consists of multiplying each equal fraction by the number bd.

This is all that need be said about the simple linear equation. No perfectly general rules can be laid down for the reduction to the form

$$ax + b = 0$$

but a little common sense and ingenuity are all that is required.

(A3) The Quadratic Equation.

Next in order of complexity to the linear equation comes the quadratic equation, in which the unknown quantity appears in the second power as well as the first. The general type of this equation is

$$ax^2 + bx + c = 0$$

corresponding to the function

$$y = ax^2 + bx + c.$$

The reader is recommended to plot out roughly some such function, *e.g.*,

$$y = 2x^2 - 5x + 2.$$

It will be found that in every case the curve obtained will resemble one or other of the two curves shown in Fig. 11. Such curves are called parabolic and are of great importance in geometry and in applied science. The equation

$$ax^2 + bx + c = 0$$

is sometimes called parabolic also, but the other name is more generally used.

One general characteristic of this sort of equation appears at once from the picture of the typical parabolic function. The curve of such a function will either cut the x axis in two points or not at all. This means that a quadratic equation will either have two real roots or no real roots at all.

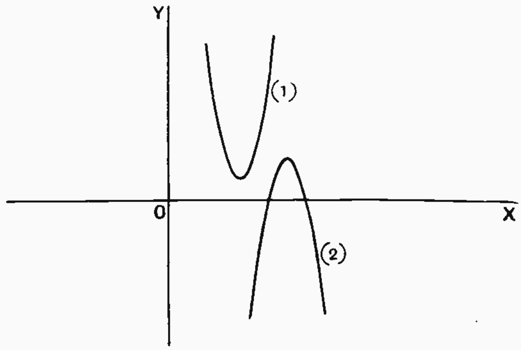


Fig. 11.

As in the general case one method of solving such an equation would be to plot the curve of the function

$$y = ax^2 + bx + c$$

and find where it cut the x axis, but fortunately there are in this case simpler and more accurate methods available.

The easiest method is one for which the way was prepared in paras. D2 and D3 of Section 3 (p. 449 of July issue). The multiplication of any two numbers $(x - \alpha)$ and $(x - \beta)$ gives

$$(x - \alpha)(x - \beta) = x^2 - (\alpha + \beta)x + \alpha\beta$$

Now suppose the numbers α and β are such that

$$\alpha + \beta = -b/a$$

$$\alpha\beta = c/a$$

Then $$(x - \alpha)(x - \beta) = x^2 + \frac{b}{a}x + \frac{c}{a}$$

and multiplying each of these equal numbers by a gives

$$a(x-\alpha)(x-\beta) = ax^2 + \frac{ab}{a}x + \frac{ac}{a}$$
$$= ax^2 + bx + c.$$

If therefore we can find two numbers α and β such that

$$\alpha + \beta = -b/a.$$
$$\alpha\beta = c/a$$

then

$$a(x-\alpha)(x-\beta) = ax^2 + bx + c = 0$$

Now there are two values of x for which $a(x-\alpha)(x-\beta) = 0$. The first is α for putting $x = \alpha$,

$$a(x-\alpha)(x-\beta) = a(\alpha-\alpha)(\alpha-\beta)$$
$$= a \times 0 \times (\alpha-\beta)$$
$$= 0$$

and in a similar manner putting $x = \beta$ will also make the number zero. Therefore α and β are the solutions or roots of

$$ax^2 + bx + c = 0.$$

For example

$$3x^2 + 54x + 96 = 0.$$

Here $\qquad -b/a = -18$

$\qquad c/a = 32$

Also $\qquad (-2) + (-16) = -18$

and $\qquad (-2) \times (-16) = 32$

so that $\qquad \alpha = -2$

and $\qquad \beta = -16$

will satisfy the condition

$$\alpha + \beta = -b/a = -18$$
$$\alpha\beta = c/a = 32.$$

Therefore the roots of this equation are -2 and -16, and

$$3x^2 + 54x + 96 = 3(x^2 + 18x + 32)$$
$$= 3\{x - (-2)\}\{x - (-16)\}$$
$$= 3(x+2)(x+16).$$

This, however, is inspired guesswork, and inspiration is notoriously erratic and capricious. For everyday purposes we need something more certain, a method which, though neither as speedy nor as exhilarating as the flying leap, can always be relied upon to get there. However the equation is solved, whether by flying or walking, the solution will be the same, so that the roots of the equation are α and β where

$$\alpha + \beta = -b/a$$
$$\alpha\beta = c/a.$$

If α and β cannot be guessed from these clues, is there any other way? Yes, there is another way, depending on a trick which is well worth learning for other purposes also. Since

$$\alpha + \beta = -b/a$$

the squares of these equal numbers will also be equal, *i.e.*,

$$(\alpha+\beta)^2 = \alpha^2 + 2\alpha\beta + \beta^2 = b^2/a^2$$

Also $\qquad 4\alpha\beta = 4c/a.$

Since these pairs of numbers are equal, the differences between the pairs will be equal, *i.e.*,

$$\alpha^2 + 2\alpha\beta + \beta^2 - 4\alpha\beta = b^2/a^2 - 4c/a$$

i.e. $\qquad \alpha^2 - 2\alpha\beta + \beta^2 = b^2/a^2 - 4ac/a^2$

$$= (b^2 - 4ac)/a^2.$$

But $\qquad \alpha^2 - 2\alpha\beta + \beta^2 = (\alpha - \beta)^2$

Therefore $\qquad (\alpha-\beta)^2 = (b^2 - 4ac)/a^2$

and since these numbers are equal their square roots will also be equal,

i.e., $\qquad \alpha - \beta = \sqrt{(b^2 - 4ac)/a^2}$

$$= \sqrt{(b^2 - 4ac)}/a$$

Now we know both the sum and difference of α and β, and from these both can be determined, for if

$$\alpha + \beta = -b/a$$

and $\qquad \alpha - \beta = \sqrt{(b^2 - 4ac)}/a$

the addition of these pairs of equal numbers will give

$$(\alpha+\beta)+(\alpha-\beta) = 2\alpha = -b/a + \sqrt{(b^2 - 4ac)}/a$$
$$= \frac{-b + \sqrt{b^2 - 4ac}}{a}$$

Therefore

$$\alpha = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

The subtraction of the pairs gives

$$(\alpha+\beta) - (\alpha-\beta) =$$
$$(\alpha+\beta) - \alpha + \beta = 2\beta = \frac{-b - \sqrt{b^2 - 4ac}}{a}$$

Therefore

$$\beta = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

Thus the roots of $ax^2 + bx + c = 0$ are α and β, where these numbers have the values given above in terms of the known numbers, a, b, and c.

Writing it out in full

$$ax^2+bx+c=a\left(x-\frac{-b+\sqrt{b^2-4ac}}{2a}\right)$$
$$\left(x-\frac{-b-\sqrt{b^2-4ac}}{2a}\right)=0$$

For brevity, the two roots are usually combined into one expression by writing

$$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

which means that

$$x=(-b+\sqrt{b^2-4ac})/2a$$

and $$x=(-b-\sqrt{b^2-4ac})/2a$$

are the solutions of the equation. The reader is recommended to confirm the fact that the sum of these roots is $-b/a$ and their product c/a.

As an example, suppose

$$6x^2+5.4x-19.32=0$$

i.e.,
$$a=6$$
$$b=5.4$$
$$c=-19.32$$
$$b^2=29.16$$
$$4ac=-463.68$$
$$b^2-4ac=492.82$$
$$\sqrt{b^2-4ac}=22.2.$$

Therefore the roots are

$$x=(-5.4+22.2)/12=1.4$$
$$x=(-5.4-22.2)/12=-2.3$$

and it can be confirmed by actual multiplication that

$$6x^2+5.4x-19.32=6\,(x-1.4)\,(x+2.3)$$

It was stated above that in certain cases the equation would have no real roots at all. If the general solution given above is really general, this fact should be implicit in it; and so it is, for the roots contain the term $\sqrt{b^2-4ac}$, and this will not always exist as a real number. Suppose a and c are of the same sign so that $-4ac$ is a negative number. Then, if $4ac$ is greater than b numerically, b^2-4ac will be negative, and b^2-4ac will be "imaginary." (See p. 563 September issue). Under these conditions there will be no real roots to the equation. For instance

$$29x-4x+1=0$$

has no real solutions for

$$b^2-4ac=16-116=-100$$

and $$\sqrt{b^2-4ac}=\sqrt{-100}=10\sqrt{-1}$$

Subject to finding some interpretation for $\sqrt{-1}$ the roots can be left in the form $(4\pm10\sqrt{-1})/58$, *i.e.*, $(2/29)+(5\sqrt{-1}/29)$ and $(2/29)-(5\sqrt{-1}/29)$. It should be noted and confirmed by actual multiplication and addition that though these are "complex numbers," *i.e.*, numbers consisting of two parts one of which is imaginary, their product and sum are real, being respectively 1/29 and 4/29.

For the solution of a quadratic equation, therefore, it is only necessary to reduce it to the form

$$ax^2+bx+c=0$$

and the roots can then be found either by guesswork or by means of the formula: The roots of the equation are the numbers $(-b\pm\sqrt{b^2-4ac})/2a$. (Whether these numbers are real or complex or imaginary, they are still called the roots of the equation.)

As in the case of the linear equation, however, some little ingenuity may be required for the reduction of any given equation to the standard form, but this is only a matter of practice and experience. To take an example, suppose

$$3(x+10)=1/(1+x).$$

Multiplying each equal number by $(1+x)$ gives

$$3(x+10)(1+x)=(1+x)/(1+x)$$

i.e., $$3(x^2+11x+10)=1$$

or $$3x^2+33x+29=0.$$

Again,

$$7\left(x+\frac{1}{x}\right)+3\left(1+\frac{1}{x}\right)=-16.$$

Multiplying each equal number by x and rearranging the terms will give

$$7x^2+19x+10=0$$

and a practised eye would see the roots of this to be $-5/7$ and -2.

(A4) Equations Reducible to Quadratics.

Before leaving the subject of quadratic equations it will be well to point out that an equation that looks forbidding and unapproachable at first sight may prove on closer inspection to be quadratic, not in x, but in some simple function of x. An equation

$$ay^2 + by + c = 0$$

can be solved for y, whatever the nature of y may be. If the roots are α and β then

$$y = \alpha \text{ or } y - \alpha = 0$$

and

$$y = \beta \text{ or } y - \beta = 0$$

will satisfy the original equation.

If, now, y is some function of x, say $f(x)$, then these become

$$f(x) - \alpha = 0$$

and

$$f(x) - \beta = 0$$

two further equations in x, which may or may not be solvable but which will in any case be more manageable than the original equation in x. To take a very simple example :—

$$ax^4 + bx^2 + c = 0.$$

This can be written

$$a(x^2)^2 + b(x^2) + c = 0$$

or, writing y for the function x^2

$$ay^2 + by + c = 0$$

If the roots of this equation are α and β, then the original equation is satisfied by

$$y - \alpha = 0$$

and $$y - \beta = 0$$

i.e., $$x^2 - \alpha = 0$$

and $$x^2 - \beta = 0$$

The factors of the first are

$$(x - \sqrt{\alpha})\ (x + \sqrt{\alpha}) = 0$$

and of the second

$$(x - \sqrt{\beta})\ (x + \sqrt{\beta}) = 0$$

so that the four roots $x = \pm\sqrt{\alpha}$ and $\pm\sqrt{\beta}$ will satisfy the original equation. Notice that the linear equation containing the first power of x was found to have one root. The quadratic, containing the second power of x, was found to have two roots. The above equation, containing the fourth power, has four roots. This suggests, but does not of course prove, that an equation containing the nth power of x will have n roots. This is so in fact and will be proved later.

The recognition of the quadratic form will not be always so simple as in the above example. Take, for instance,

$$x^2 + \frac{1}{x^2} + x + \frac{1}{x} = 4$$

This can be written

$$\left(x^2 + 2 + \frac{1}{x^2}\right) + \left(x + \frac{1}{x}\right) - 6 = 0$$

Now

$$\left(x^2 + 2 + \frac{1}{x^2}\right) = \left(x + \frac{1}{x}\right)^2$$

so that the equation is really

$$\left(x + \frac{1}{x}\right)^2 + \left(x + \frac{1}{x}\right) - 6 = 0$$

and writing y for $(x + 1/x)$, this becomes

$$y^2 + y - 6 = 0$$

of which the solutions can be seen to be

$$y + 3 = 0$$

and

$$y - 2 = 0$$

i.e.,

$$\left(x + \frac{1}{x}\right) + 3 = 0$$

and

$$\left(x + \frac{1}{x}\right) - 2 = 0$$

The multiplication of each side of each equation by x will convert these into two simple quadratics in x which can then be solved for x in the ordinary manner. Here again it is the insight born of practice and experience that sees the essential simplicity at the heart of the apparent complexity.

(A5) The General Equation of the *n*th Degree.

Having disposed of the linear equation and the quadratic equation, the next in order is the cubic, which contains up to the third power of x or, another way of saying the same thing, is of the third degree in x. The typical equation is

$$ax^3 + bx^2 + cx + d = 0.$$

Then comes the quartic, *i.e.*,

$$ax^4 + bx^3 + cx^2 + dx + e = 0$$

and so on indefinitely.

Unfortunately, however, there are no general solutions for these equations. This is specially unfortunate from the point of view of electrical theory, for the analysis of the behaviour of two coupled circuits involves a quartic, or as it is sometimes called, a bi-quadratic equation, and for this reason practically all textbooks fight shy of it, confining the full discussion to the simpler case of resistanceless circuits, when the bi-quadratic becomes a quadratic in x^2.

Although there are as stated no perfectly general solutions for equations of higher degree than the second, such cases are by no means hopeless. Certain form of higher degree equation can be solved. (Two bi-quadratics were solved in the preceding paragraph.) Also there are certain general considerations relating to equations of any degree which will sometimes point the way to a solution, and which are intrinsically interesting and useful apart from this application. We will therefore discuss briefly the general equation of the *n*th degree, typified by

$$ax^n + bx^{n-1} + cx^{n-2} + dx^{n-3} + ex^{n-4}, \text{etc., etc.} + k = 0.$$

Example. — Equations for One Unknown Quantity.

1. Solve the equations :—

(*a*) $3(x + 27) = 2(x + 4) + 7(x - 9)$

(*b*) $\dfrac{2}{x + 3} = \dfrac{5}{7(x - 1) + 2(x + 3) + 1}$

(*c*) $ax + b = cx + d$

(*d*) $\dfrac{m}{ax + b} = \dfrac{n}{cx + d}$

2. Find where the line

$$y = 3x + 4$$

cuts the axis of x.

Find the co-ordinates of the points on this line for which $y = -5$ and $y = 4$

3. Solve by inspection the equations :—

(*a*) $x^2 - 5x + 6 = 0$

(*b*) $x^2 + 5x + 6 = 0$

(*c*) $x^2 - x - 6 = 0$

(*d*) $x^2 + x - 6 = 0$

4. Solve the equations :—

(*a*) $\dfrac{1}{x - 1} = x\left(1 + \dfrac{1}{x}\right)$

(*b*) $(x - 5) + \dfrac{1}{(x - 2)} = \dfrac{1}{(2 - x)}$

(*c*) $x^2 - 2ax + a^2 - b^2 = 0$

(*d*) $x^2 - 2bx + b^2 - a^2 = 0$

5. Solve the equation

$$x(1 + x) + \frac{1}{x}\left(1 + \frac{2}{x}\right) = 0$$

(Convert to an equation in $x + 1/x$)

6. Solve the equations :—

(*a*) $(x^2 - 4)(x^2 - 5x + 4) = 0$

(*b*) $(x - a)(x - b)(x - c)(x - d)(x - e) = 0$

(*c*) $(ax^2 + bx + c)(dx^2 + ex + f) = 0.$

Erratum.

In Examples, p. 618, October issue, *for* $1 + x$ in Example No. 5 *read* $1 + \log x$.

(*To be continued.*)

Recent Developments in Short-Wave Wireless Telegraphy.

By H. Rukop [R401

(*Telefunken Company*).

(*Concluded from page 612 of October issue.*)

III.—Nauen–Buenos Aires Transmitting Experiments.

THE Telefunken Company, directly news was received regarding the striking results that had been obtained with short wavelengths, directed its whole attention to this important fact and forthwith decided to carry out with all speed a trial transmission from Nauen to Buenos Aires, where long-wave transmission, in spite of the employment of the most powerful electric equipment, had shown itself to be unreliable.

The experimental apparatus for short-wave transmission will probably be generally known, so that I need not describe it very minutely. It is obvious that the valve transmitter was the only one suitable for the purpose, and I do not believe that serious results could now be anticipated from any other type. If it is desired to use large outputs, special valves are generally required which, in the first place, must not contain in their connecting leads any considerable self-induction, and, secondly, are arranged for the heavy load which results from the capacity charging current of the electrodes, the sealed leading-in wires being dimensioned for currents up to about 20A. Such special valves for short waves are shown in Figs. 4 and 5. Fig. 4 represents a valve in a glass bulb for a high-frequency output of about 1.5kW with 4,000 volts anode direct current voltage, which works excellently for waves down to 10 metres. Fig. 5 shows types of valves with water-cooled anode, which generally give outputs of 10 and 20kW high frequency, but which in the special short-wave construction are to be reckoned at about 6-8 and 12-16kW.

The first short-wave transmitter, which we manufactured for the contemplated large scale series of experiments, is shown in Fig. 6. This shows in parallel the two valves of the glass bulb type represented in Fig. 4. They are worked in self-excitation and are fed on the cathode side by an accumulator battery, and on the anode circuit by a 4,000 volt direct current dynamo. Special precautionary measures had to be taken to keep the frequency of the transmitter sufficiently constant, so that a pure transmitted note could be received in Buenos Aires. This method, namely, to transmit

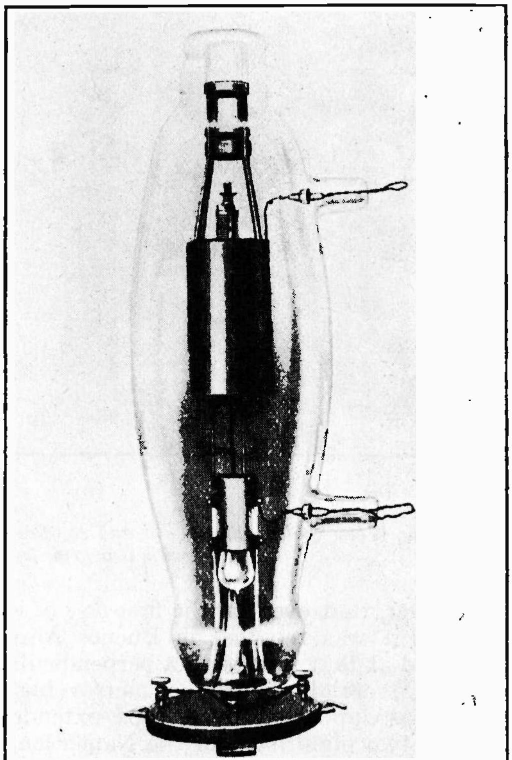
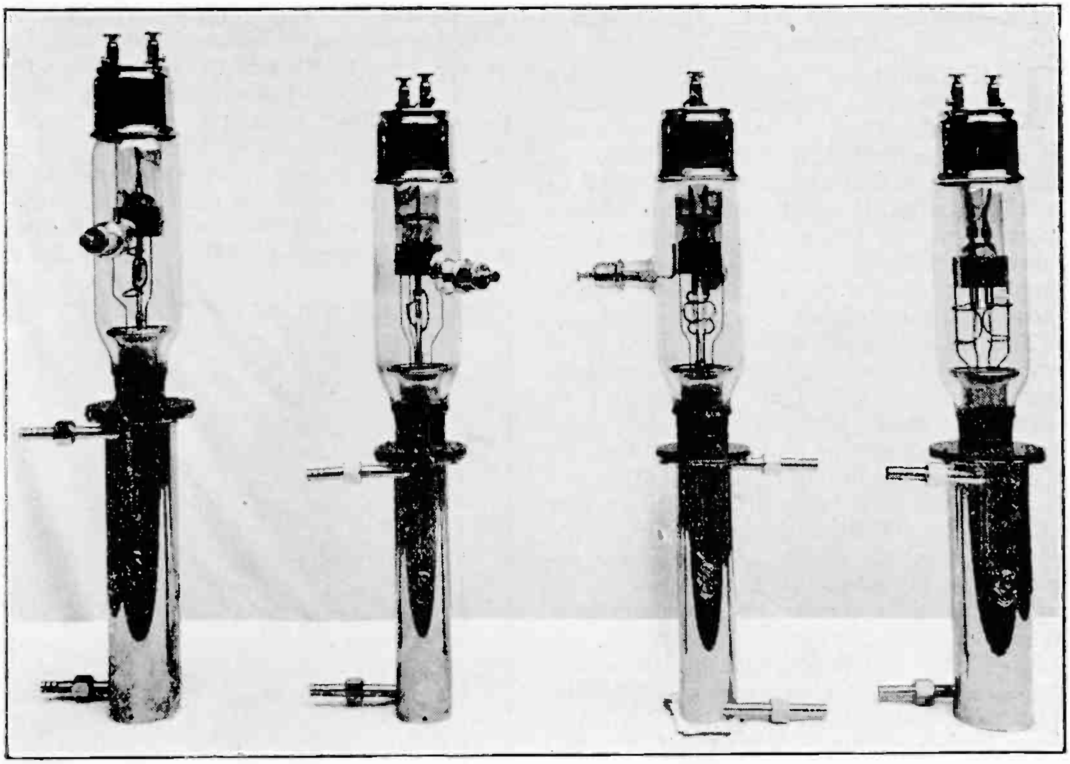


Fig. 4. *Short-wave transmitting valve for about 1.5kW.*

unmodulated undamped waves with a frequency of the greatest possible constancy and to receive with heterodyne and pure note, was found to be superior to all others for receiving conditions in Buenos Aires. The transmitter, which originally had the call signal POX, and became later AGA, was housed in a very provisional hut (Fig. 7). The very excellent working of this transmitter was quite unexpected. The fact the telegram traffic and, moreover, we could not effect by its means the experimental variations we desired to make in the transmission to Buenos Aires. We therefore constructed forthwith a second transmitter of approximately the same dimensions, and this was made specially light and transportable, so that its location could be changed with the greatest possible speed. This transmitting station, which was given the



(a) (b) (c) (d)

Fig. 5. *Water-cooled valves. (a and b) Transmitting valves. (c) Short-wave transmitting valve with two grid terminals. (d) Rectifier.*

is, however, that even on the first day of its working, it was received in Buenos Aires. It worked at that time with a perpendicular single-wire aerial about 100 metres high, which was supported by a rope extended between two high masts of the Nauen long-wave aerial.

Of course a merely make-shift transmitter did not meet our requirements, as in the first place it had at once to undertake call signal POF, consists of two vehicles (Fig. 8), one of which, a motor lorry, contains the machines and other sources of power, and the other, a furniture van of small type, the high-frequency part of the transmitter. This latter can be seen separately in Fig. 9. Fig. 8 shows the whole transmitter erected in the grounds of the long-wave station at Nauen. In the background can be seen the large machine transmitter house of the

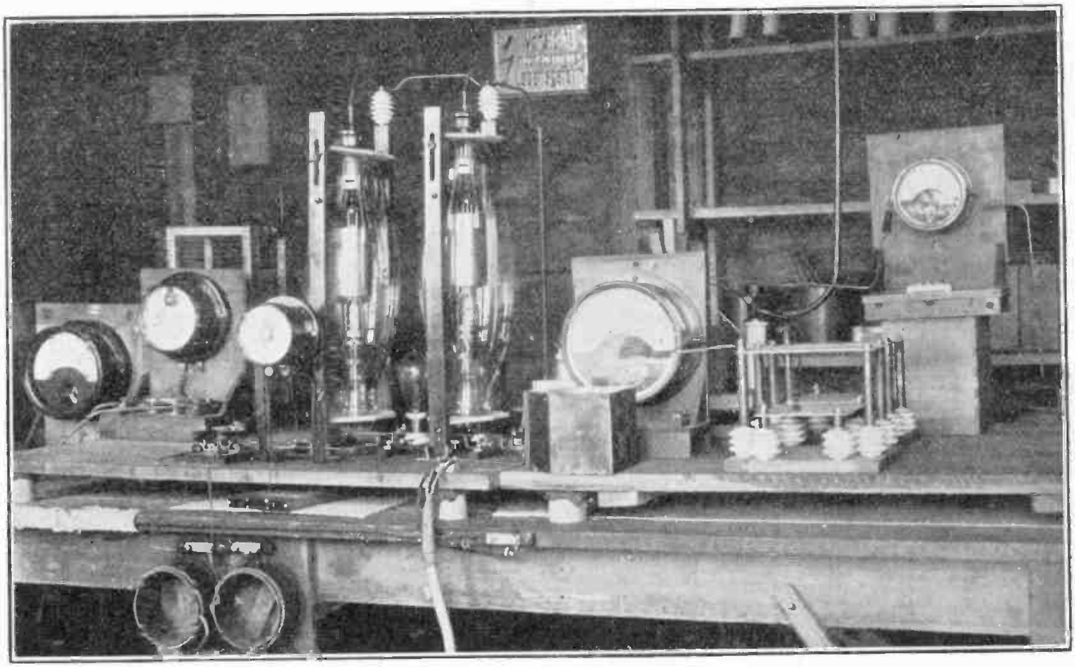


Fig. 6. *Short-wave transmitter AGA.*

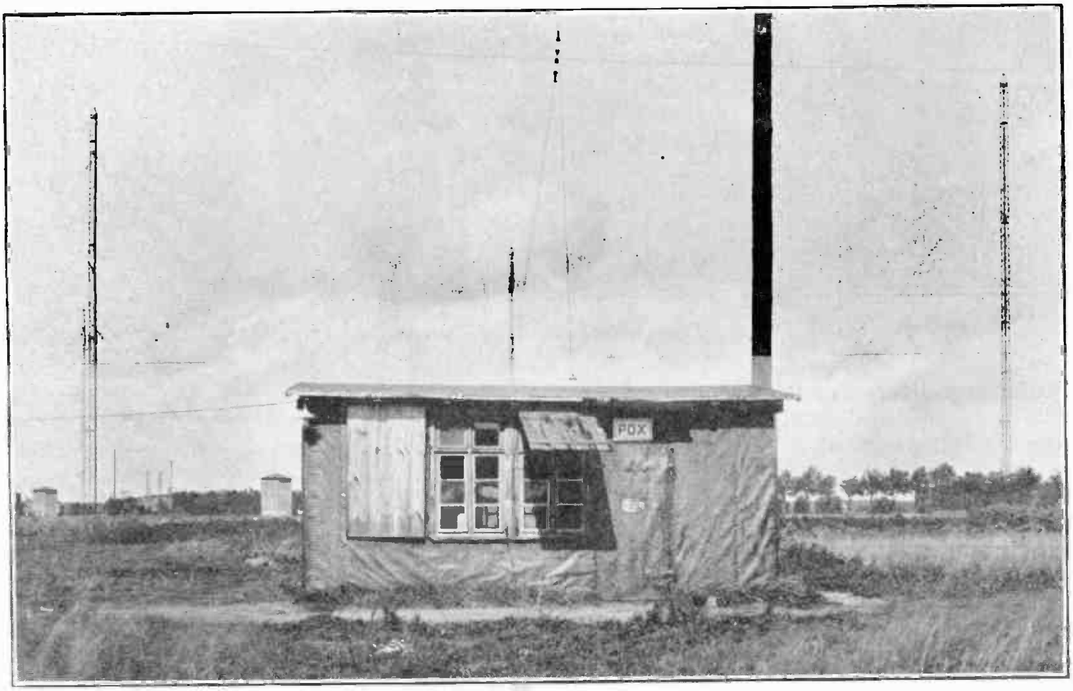


Fig. 7. *Short-wave transmitter AGA.*

Transradio Company. The POF transmitter was able, on the one hand, to work on an aerial similar to that of the AGA transmitter, namely, a perpendicular wire of about 100 metres in height, on the other hand it had, as shown in Fig. 8, a special wooden mast about 20 metres in height, with a perpendicular copper tube aerial, which was generally excited in its third harmonic, but often, however, was shortened to 5–6 metres for the purpose of working at a quarter wavelength. Fig. 10 shows the obtain up to about 16kW high frequency in the aerial. It contained (see Fig. 11) one or two water-cooled valves of the types shown in Fig. 5 and for a long time was installed in the large machine transmitter building of the Transradio Company, until it was finally removed from there to another small building, because the vibration of the building, in consequence of the machines, exercised a harmful influence on the purity of the oscillations emitted by the set, with the result that the oscillations continually

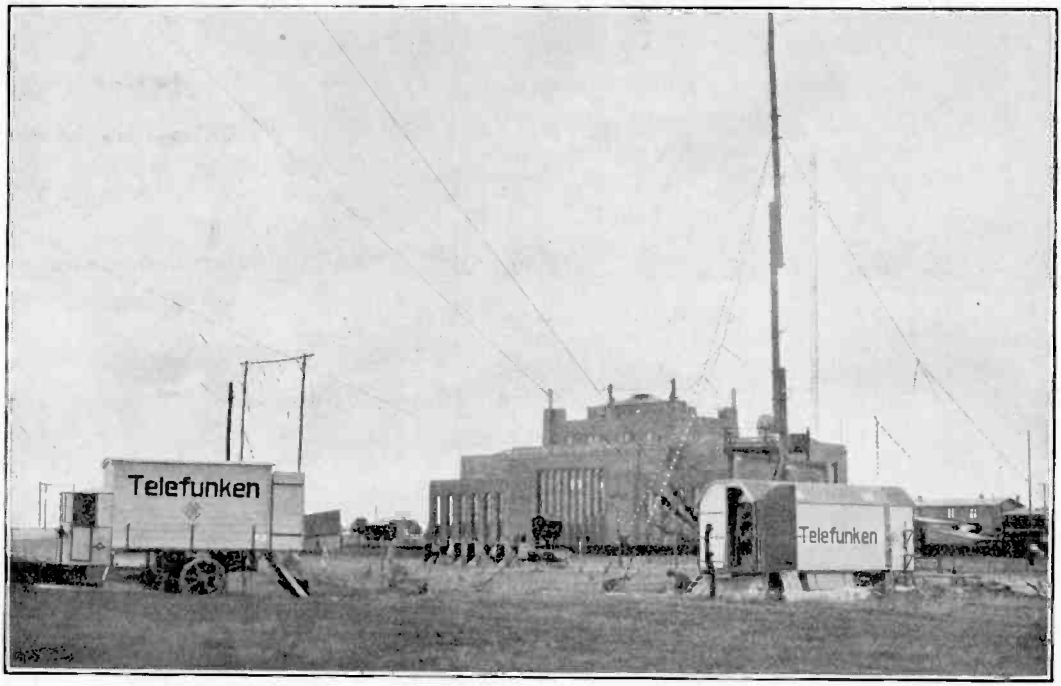


Fig. 8. *Transportable short-wave transmitter POF.*

POF transmitter after being removed to a small hill 20 km. distant from Nauen; the aerial is being erected.

Furthermore, a third transmitter with the call signal POY was occasionally used, and this in its electrical construction was exactly like the transmitters AGA and POF, but was erected in the big machine transmitter building of the Transradio Company. Whilst these three transmitters generally gave 2, or at the maximum 3kW in the aerial, a fourth transmitter with the call signal POW was installed, and by this it was possible to underwent a small modulation, which rendered the heterodyne note impure at the point of reception and thus made the station less suitable for reception at Buenos Aires, which is, as is known, a region subject to unpleasant atmospheric disturbances. At the place to which the station was removed the interference caused by vibration was eliminated to a large extent, so that the heterodyne note became quite pure.

The wavelengths with which the individual transmitters worked were originally about 70 metres, but, after the first trials, they

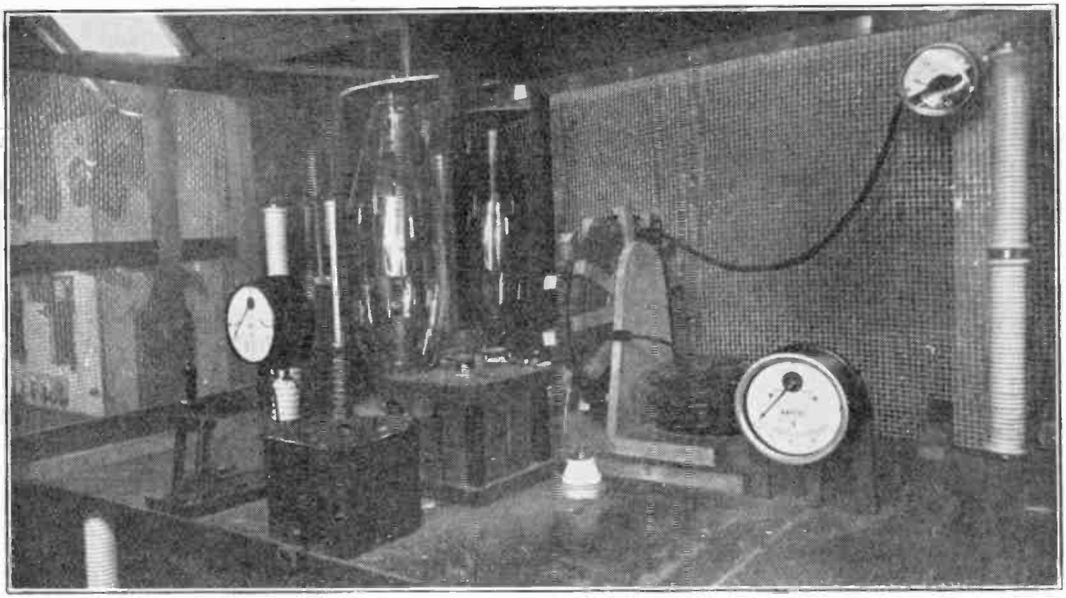


Fig. 9. *Short-wave transmitter POF.*

were very soon lowered in big jumps. Long experimental and working periods were carried out on wavelengths of 40 metres, 25–28 metres, 16–19 metres. At this juncture trials were also made on wavelengths as low as 13 metres. It was very soon found that from the standpoint of atmospheric interference, reception at Buenos Aires was effected very much more favourably on waves of 16–25 metres than with those of about 70 metres the relative intensity of atmospheric interference being in the ratio of about 1 : 10.

A series of separate trial and traffic results will now be shown in curves and definite conclusions, as far as they can be deduced from the various material available, will be given below.

Fig. 12 gives, first of all, by way of example, a typical picture of the effects of fading. The intensity curve represents the reception results obtained at the Geltow receiving station (belonging to Nauen) from transmissions effected by a foreign short-wave transmitting station over 1,000 km. distant, the period of time represented being about 4 minutes. The average constant intensity of reception and likewise the sharp and deep drops which are characterised as "fading" can here be recognised.

There now follows a series of intensity

Fig. 10. *Short-wave transmitter POF.*

curves which were taken chiefly in Buenos Aires (12,000 km.), some also at Bandoeng, Java (11,000 km.) and at Osaka, Japan (9,000 km.) and which have been communicated to us in due course. The results are shown in relation to the times of the day, as may be seen, for example, in Fig. 13, both at the place of transmission and of reception. In Fig. 13 the ordinates are indicative of the signal strength measured on time differ from each other by five hours, and that Buenos Aires time, corresponding to its westerly situation, is behind the former. The shaded region in Fig. 13 and in many of the following ones indicates night at the relative points on the Nauen-Buenos Aires route. If therefore a perpendicular line runs between the axes of the Central European and the Buenos Aires times completely through the shaded region, this means that

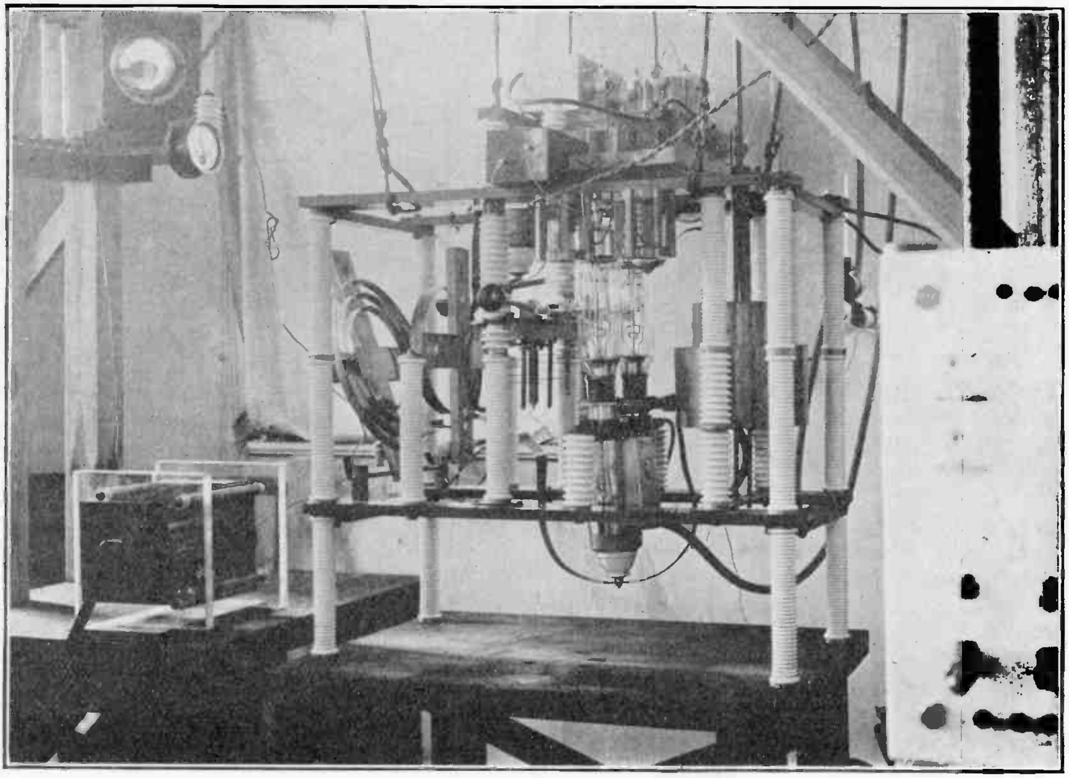


Fig. 11. *Short-wave transmitter POW with two water-cooled valves.*

an arbitrary scale, the abscissæ indicate the times, both the Central European time (upper scale) and the Buenos Aires time (lower scale) being shown. The region lying between these two abscissa axes, each of which corresponds to a place, indicates the route between Nauen and Buenos Aires and is to be regarded as linearly divided. A perpendicular line through the two axes of time therefore indicates objective simultaneity, and from this it will be seen that Central European time and Buenos Aires on the whole route between Nauen and Buenos Aires it is night at that time. The left oblique limiting line of the shaded region consequently indicates sunset, and the right hand line sunrise.

The two intensity curves shown in Fig. 13 show a very striking result, which recurs in many curves of our series of experiments, but by no means in all. They are therefore a definite and frequent type and show that at times of complete daylight over the whole route nothing was to be heard and that the first signals were heard in Buenos Aires when half of the route from Nauen to Buenos Aires was dark after sunset, that the intensiy then increased as darkness came on, remained fairly constant during complete darkness, and later on diminished and completely disappeared when half the route to Buenos Aires was in daylight after sunrise. One

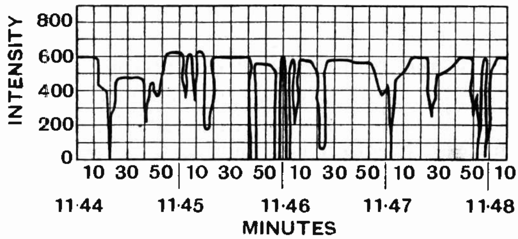


Fig. 12. *Example of reception, disturbed by fading effect.*

must, of course, bear in mind in this connection that the intensity did not remain at an entirely constant level, as is shown in the curves in Fig. 13, but diminished at times in consequence of the fading effect previously described.

Of the two curves shown in Fig. 13, the heavily drawn line indicates the intensity of the AGA transmitter, which worked on a wave of 26 metres and with an output of 2kW, and the dotted line indicates the intensity of

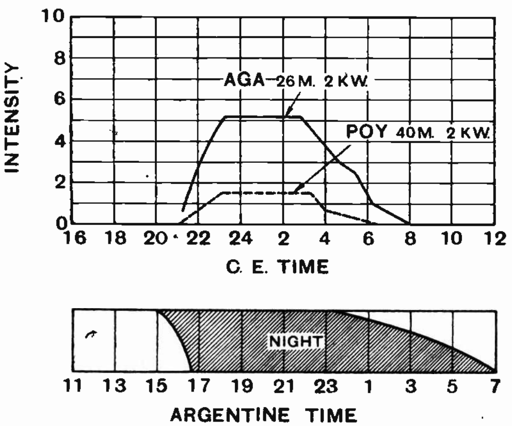


Fig. 13. *Example of receiving results, Nauen–Buenos Aires.*

the POY transmitter, which worked simultaneously with AGA and transmitted on a wave of 40 metres with an output of 2kW. The radiated output should in both cases have been the same, since with such high aerials and such short waves the degree of

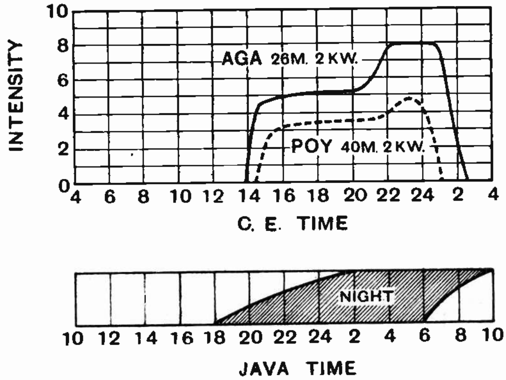


Fig. 14. *Example of receiving results, Nauen–Bandoeng.*

radiation efficiency is extraordinarily high. Nevertheless, the difference in the intensities is very considerable, as the intensity of the 26-metre wave is about four times as great as that of the 40-metre wave—a fact which has almost always revealed itself to us when transmitting over so great distances.

A further interesting example of these circumstances is shown in Fig. 14, which shows intensity curves taken at Bandoeng (Java). The times of favourable transmission are here almost the same as in Fig. 13, namely, from the time of semi-daylight in the evening until semi-daylight in the morning. The differences in intensity between the 40-metre wave and the 26-metre wave are not as large as in Buenos Aires, but they are nevertheless clearly perceptible.

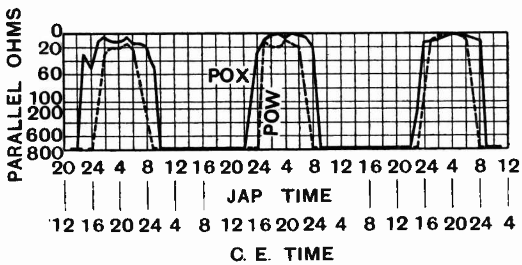


Fig. 15. *Results of a three days' transmission experiment, Nauen–Osaka (Japan).*

Of great interest are the similar conditions shown in Fig. 15, which shows intensity curves which were taken at Osaka (Japan) during an uninterrupted period of transmission lasting three days. In this case POX was transmitting on 26 metres and with 2kW, and POW was transmitting

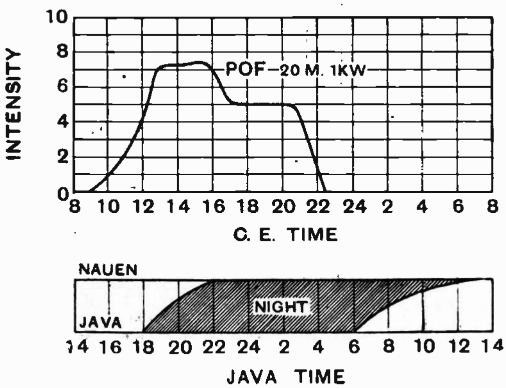


Fig. 16. *Example of receiving results, Nauen–Bandoeng.*

simultaneously on 42 metres and with about 8kW. It is again shown, first of all, that only at the time of complete darkness was good reception obtained. Furthermore, the intensity of the 42-metre wave, notwithstanding the considerably higher output radiated, is almost equal, on the one hand, to that of 26 metres, but, on the other hand, it is clearly seen that in the morning and in the evening the telegraphing period with the 42-metre wave is from 1 to 2 hours

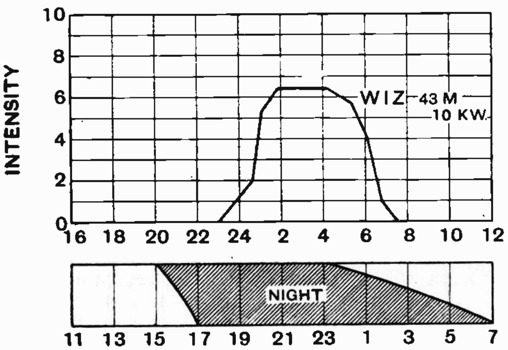


Fig. 17. *Example of receiving results, North America–Geltow.*

shorter, *i.e.*, that the superiority of the 26-metre wave is here very great.

There are, however, very great deviations from these transmission results, which for a long time we were inclined to regard as normal. A type of deviation is shown in Fig. 16: this is a transmission from Nauen to Java on a wavelength of 20 metres. In this case the favourable transmitting time does not extend from the semi-daylight in the evening until semi-daylight in the early morning, but begins as early as the afternoon in complete daylight over the whole distance and ends in a remarkable way at night when there is complete darkness over the whole route. We were unable to discern any system in these deviations.

A deviation similar in principle, but in another direction is shown in Fig. 17; this is a curve taken at Geltow, near Nauen, from the transmissions of a North American short-wave station working on a wavelength of 43 metres. Here, the transmission only

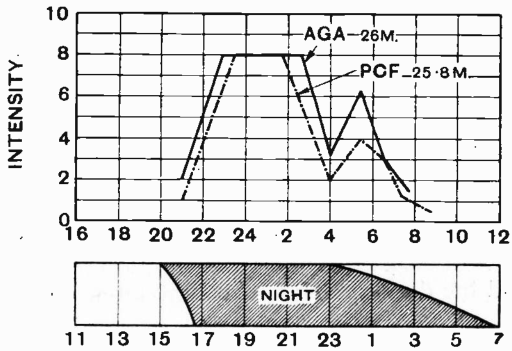


Fig. 18. *Example of receiving results, Nauen–Buenos Aires.*

begins with complete darkness on the entire route, but ends with semi-daylight at sunrise.

A further type of deviation, which, however, is not specially striking, is seen in Fig. 18. In this case, both the commencement and the end of the transmission, as in very many cases, coincide with semi-daylight in the evening and in the morning. Nevertheless, before the end of transmission, namely, at the time when the sun first rises on the route, which in this case was at Nauen, the place of transmission, the signal strength declined greatly, but increased once again considerably before finally dying out. We have experienced a certain number of results of this type also. Fig. 18 is of interest, since, in this case, both the AGA and POF transmitters used two very close wavelengths, namely, of 26 and 25.8 metres. No remarkable differences were, however, found in the quality of transmission.

On the basis of the results shown hitherto, one could easily have taken the view that

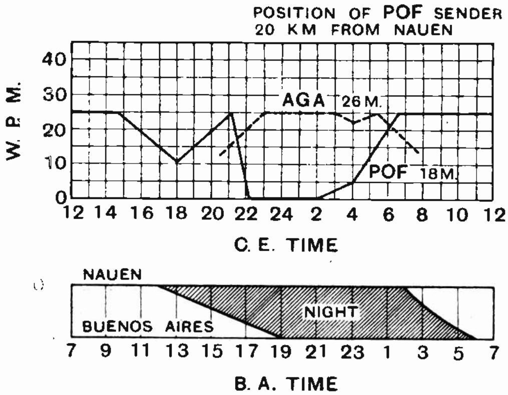


Fig. 19. *Example of receiving results, Nauen–Buenos Aires.*

transmission would only be possible at night, or, in any case, would require during the daytime so enormous an increase of output that in practice it would hardly be possible to attain it. Nevertheless, by numerous series of experiments with different wavelengths down to 13 metres, we have found that there is no general decisive law.

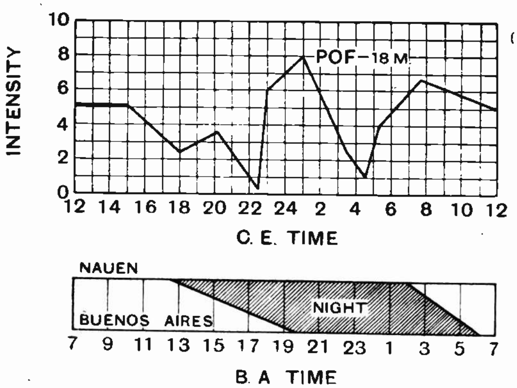


Fig. 20. *Example of receiving results, Nauen–Buenos Aires.*

Some interesting results of day transmissions are shown in Figs. 19, 20 and 21. In Fig. 19 it is a question of two transmitters working simultaneously throughout the day, namely, AGA on a wave of 26 metres and POF on a wave of 18 metres. The POF transmitter was erected on this occasion on a small hill, 20 km. distant from Nauen. Here the remarkable result obtained was that the 26-metre wave could also be heard at the usual time from semi-daylight in the evening until semi-daylight in the morning. On the contrary, the 18-metre wave revealed an entirely different behaviour, in that it was audible throughout the whole day and only died out for a few hours during the time of complete darkness. The same POF transmitter, at the same place and on the same wave, gave a still better result on another day (see Fig. 20). It was in fact audible throughout the whole day, even during the time of cessation during complete darkness, shown in Fig. 19, and even attained its maximum intensity at this time and only

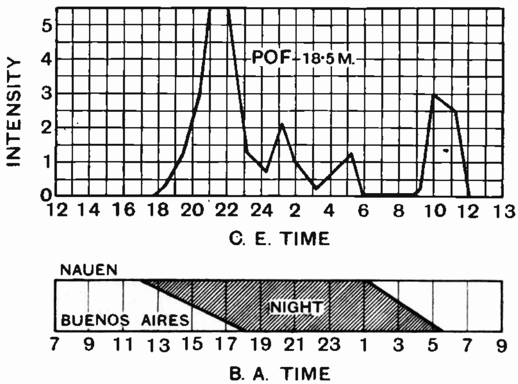


Fig. 21. *Example of receiving results, Nauen–Buenos Aires.*

towards sunset and also before sunrise showed a short but considerable diminution of intensity. Unfortunately, however, such results cannot be obtained every day and on one of the succeeding days a result was obtained as represented in Fig. 21, *i.e.*, adequate transmission occurred from evening until morning and, likewise, during complete daylight for about three hours during the morning. In any case, it would appear that for transmission to Buenos Aires at least, the most favourable conditions result from wavelengths between 18 and 28 metres, and that at certain times the waves round about 18 metres are the best. Numerous attempts were made with still shorter waves, and good results were occasionally obtained with 16 metres, but, in the majority of cases, the results were bad, and nothing or almost nothing was heard in Buenos Aires or Java. With a wavelength of 13 metres signals could, in fact, be perceived at Buenos Aires, but the intensity was nothing like adequate for the handling of telegraphic traffic.

This result, namely, that when the wavelength is reduced to about 15 metres transmission suddenly becomes perceptibly worse, coincides very remarkably with a curve showing the silent zones, which is to be found in the above-mentioned paper of A. H. Taylor and E. O. Hulbert[7]. In this, the authors show, on the basis of observations and extrapolated assumptions, that the silent zones become extremely

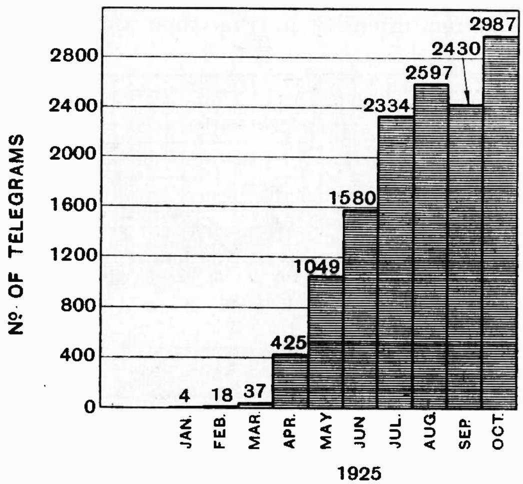


Fig. 22. *Short-wave telegram traffic, Nauen-Buenos Aires from April to October, 1925.*

broad in the region of 10 metres, and that a return of the energy from the atmosphere no longer takes place. Whether the results which we have obtained with waves in this region are a confirmation of the curve, I should not like to affirm at present, as the results are not sufficiently numerous and are not represented so systematically that one could speak of an actual confirmation.

By a suitable searching for wavelengths, by transmitting with several transmitters at the same time, and by using the most favourable hours of the day, etc., we finally succeeded in establishing an almost completely reliable night service with Buenos Aires, which was used throughout by the Transradio Company. Fig. 22 gives a very interesting idea of this; the increase of the telegrams transmitted since the short-wave transmitters were brought into operation can clearly be seen. The traffic worked with so great a reliability that on several days Nauen was the only station in Europe and North America which could get telegrams over to Buenos Aires, so that Transradio had often to undertake the traffic of other transmitting stations in Europe and North America, which it did successfully. It can be said, therefore, that in spite of relatively provisional means when short-wave transmitters were introduced, extraordinarily successful results have been obtained, thanks to frequent variations in the trial conditions and the indefatigable efforts expended upon them.

It will likewise be of interest to point out that in a large number of aerial trials, in which the linear aerial was sometimes perpendicular, sometimes oblique, and sometimes even horizontal, we were never able to ascertain any conclusive influence of the aerial length from $\lambda/4$ (about 5 metres) to an aerial 125 metres long excited in high harmonics. With a tiny aerial of a total height of 5 metres and a 2kW transmitter, the most astonishing transmission results (12,000 km.) were obtained at certain hours of the day. It will nevertheless be seen from these results that transmitters of 2kW are in general too weak for a reliable traffic and that transmitters of 20kW up to perhaps 50kW must, for reasons of reliability, be regarded as normal, especially if it is desired to extend the traffic for several hours in the morning and evening, or in fact throughout the whole day.

IV.—Conclusion.

It will probably be clear to any technical man that it is of extraordinary importance to be able to state which are the most favourable wavelengths at any time and from any place in the world to any other place, and whether and how they vary in the course of the day and with the time of the year, and in what way they are dependent upon atmospheric and other geophysical condition. There is, however, certainly no doubt that the condition of ionisation of the atmosphere must exercise the greatest influence on the whole course of the route of transmission, and that such influence might, in turn, be dependent upon certain contingencies outside the earth, as, for example, the incoming of electrons from the sun-spots, etc. But even if one does not wish to invoke reasons lying outside the earth, we have on the earth itself so enormous a number of variables that it would probably be a herculean task to assemble them systematically for a complete solution of the problem of transmission. If, therefore, I were asked to draw any conclusions at all from the material set forth above, I should have to say that it was not possible to do so. It can safely be affirmed that with all the results we obtained, waves of 40 metres and under showed themselves to be considerably superior to waves between 40 metres and 100 metres and that a clear optimum between 26 and 18 metres can be recognised. In any case it must be stated that the optimum cannot in this case be ascribed purely to the propagation of short waves, but that there is the further favourable circumstance that atmospheric interference has very little effect upon the reception of such short waves.

In order to be able to state which are the favourable day waves and which the favourable night waves, the various results are not sufficiently conclusive and consistent, although one would at times be greatly inclined to regard as general a result that recurred many times. In any case I should prefer to confine myself to communicating the results to all, for their knowledge and use, without drawing any useless or premature conclusions. The experiments will be actively pursued by us. My colleague, Dr. A. Meissner, is especially engaged in investigating the influence of some reflector arrangements and of the position of the electric vector. He will himself make statements regarding them in due course.

In conclusion, I should like to point out that a large number of persons from the laboratories of the Telefunken Company are taking part in the solution of these problems and by their industry and their devotion to the subject have made possible the communication of these results.

I should like to thank especially, in the name of the two Companies above mentioned, those stationed at the foreign receiving stations in Argentina, Japan and Java, who have supported us so kindly and effectively in this difficult and trying series of experiments.

The Relative Values of Long and Short Waves in Wireless Communication. [R040

A Discussion before the Radio Society of Great Britain.

THE Radio Society of Great Britain held the first meeting of its 1926-27 session at the Institution of Electrical Engineers, Savoy Place, London, W.C.2, on Wednesday, 22nd September, when Dr. W. H. Eccles opened a discussion on "The Relative Values of Long and Short Waves in Wireless Communication and their Future Possibilities." Brigadier-General Sir H. Capel Holden, K.C.B., F.R.S., presided.

The CHAIRMAN, opening the proceedings, said: Ladies and Gentlemen, it seems to be hardly necessary for me to introduce Dr. Eccles to you, but I can, I am sure, on my own behalf and on yours, welcome him very heartily. He is going to start a discussion to-night on a subject which at the present time is a very important one, and he has entitled it: "The Relative Values of Long and Short Waves in Wireless Communication, and their Future Possibilities." I will now call upon him to commence.

DISCUSSION.

Dr. Eccles: I hope you will permit me first to read a letter from Sir Oliver Lodge, our President, regretting that he is not able to be with us to-night. He writes:—

"I wish I could attend your discussion of the relative advantages of long and short waves, at the meeting of the Radio Society to-morrow. I feel as if the tremendous radiating power conferred by high frequency has not yet been thoroughly exploited. The shortness of wave may not be an advantage for transmission purposes, though the high radiating power is. But there are so many surprising things which take place in the upper atmosphere that we may discover an optimum wavelength suitable for transmission at different times in the day; and it is to be hoped that the combined activity of the members of the Radio Society may gradually give us the information necessary.

"The work of amateurs may be of the utmost value in this respect. The theory of emission is simple enough; but about the theory of transmission, complicated as it is by the effect of sunlight and all the other atmospheric conditions, we have still much to learn.

"Let me wish all success to the Society in its enterprise and activities during the coming winter."

It is now about five years since the use of short waves for long distances began to attract the enthusiastic attention of amateur investigators. The first amateur transatlantic tests of February, 1921, and those of the following winter, enabled dozens of amateurs on both sides of the Atlantic to get into touch on waves of 200 metres length or less. At the end of 1922, the Pittsburg broadcasting station KDKA was transmitting on a wavelength between 90 and 100 metres and this gave amateurs all over the United States an opportunity of studying short wave transmission conveniently. Before that date the general experience with short waves was that they were only really useful for short distances; when they did get through to long distances the performance was known as freak transmission. During 1923 waves shorter than 150 metres became more and more common as commercial firms and amateurs took up the study in increasing numbers.

We have now had twenty years' experience of long waves and four years of short waves in long-distance radio telegraphy. For very long waves, say over 15,000 metres, the facts are relatively simple; these waves travel almost equally well by day and night and the distance to which good signals can be transmitted depends merely on the power employed. But waves of medium length, say 1,000 metres, are different, they travel much better by night than by day. In both cases the strength of the signals falls off steadily as distance increases, at any rate after the first few hundred miles, and therefore to send signals to the Antipodes for twenty-four hours in the daytime requires 1,000 kilowatts or more and very long waves. As a broad rule the number of hours of service can always be increased by increasing the horsepower.

Our four years' experience of short waves, that is waves shorter than 200 metres, has been crystallised in the recent writings of a number of technical men, chief among whom may be mentioned Hoyt Taylor of the American Navy and Heising, Schelling and Southworth in the Bell Telephone Company of New York. Taylor classified the reports which hundreds of amateurs sent to him about his station. His results for a power of 5 kilowatts may be summarised as follows. In the daytime a wave of 100 metres long can be picked up as far as 200 miles away; a wave 50 metres long at 100 miles, a wave 30 metres long can be picked up at all distances up to 50 miles, and is inaudible at points between 50 miles and 500 miles, yet is audible again at all distances between 500 and 1,500 miles. The space over which signals are inaudible forms a circular silent zone over which the signals jump; this is called the "skip." Shorter waves have a longer skip—for instance, 15-metre waves cease to be audible at 10 miles, skip 1,500 miles, and are then audible with some uncertainty up to 3,000 miles. At night time in winter the 100-metre wave of 5kW output has been heard at all distances up to 8,000 miles; the 50-metre wave up to 10,000 miles; the 40-metre wave skips 500 miles and goes to all distances beyond. The 30-metre wave skips 4,000 miles, the 20-metre wave skips 7,000 miles, and both are heard at all distances beyond. But the 15-metre wave, after travelling a few miles, skips off the earth for good. Similar things happen on summer nights, but the skip is less marked.

The work of Heising, Schelling and Southworth has consisted of actual measurements of strength at various distances. They find it varies from season to season, from hour to hour and even from second to second. Their results are so numerous that I cannot do justice to them. They find that in the daytime the strength of all waves between 111 metres and 16½ metres falls off with increasing distance as fast as, or faster than, the long waves, but at night time short waves of 111 metres and 66 metres travel much farther. What happens to waves still shorter at night, is complicated by the skip distance. As a broad rule, after the skip the signals for a time get stronger the farther you go—an amazing conclusion. It is to be noted, however, that there usually is a time in the middle of the night, say from midnight to 3 a.m., for waves of 33 metres and distances of 1,000 miles, when the signal will not get through. Remembering that midnight occurs at different instants at different places on the globe, we see that the reception of these signals at distances of thousands of miles is complicated very greatly by their midnight vagaries.

The writers of this very valuable paper lay stress on the instability produced by these various conditions. They have made special observations on fading. They find that the rate of fading may be very slow or may be as quick as 100 times a second. Sometimes one wave fades while another of slightly different wavelength increases in strength. Some of these phenomena occasionally make radio telephony impossible because of distortion. Nevertheless very useful service can be rendered in both telegraphy and telephony by short waves; but it is important to choose the wavelengths carefully for any given task. For telephony to 200 miles distance use 100 metres; for 500 miles use 50 metres, and then it may be possible to maintain a 24-hour service. For 1,000 miles use 30 metres in the day and about 60 at night. For transatlantic work the wavelength should be altered between 100 metres and 20 metres from time to time in the endeavour to maintain fairly continuous touch.

From the whole mass of scientific observations now available in the technical literature I conclude that short waves are certainly more useful than long waves for distances up to 1,000 miles. Beyond this distance the relative utility of short and long waves depends upon the kind of work to be done and the time when it is done. Amateur investigators will always find the short waves vastly more interesting and much cheaper to install than the long waves for the purposes of international communication. For commercial purposes countries that need to be in touch only a few hours daily will also adopt short waves. On the other hand, a commercial firm which is running a long distance service in competition with cables will find the long waves more generally trustworthy. In such a service it is often necessary to ensure the delivery of messages within a very limited time of handing them in; in that case, long waves are best during certain hours of the day and will be used even though the plant is more costly. But there is a possibility that in the course of time, methods of changing from one short wave to another exactly as atmospheric variations demand, may be developed, and that will put the short wave on a level with the long wave, but may, of course, at the same time make the short wave plant as costly as the long wave plant.

These are scientific facts that have arisen out of the study of short wave propagation, but I hope we shall hear from some other speakers their impressions gathered from personal experience of short wave and long wave communication. Experience is as valuable, very often, as measurement; I have dealt solely with measurement, and, as you all know, have omitted a great many other considerations.

Admiral Sir Henry B. Jackson: Dr. Eccles has dealt briefly, but fully, with the subject. With regard to the distances he has tabulated, at which various waves are receivable, I think probably some of us here may find that they do not agree with them; I do not personally, and I have taken a great many measurements during the last year or so, and from my own experience I do not quite agree, especially about the 30-metre wave. I have received on 30 metres, or practically 30 metres, very well indeed, and the statement that it is only received up to 50 miles in the daytime is, I think, not always correct, *e.g.*, this afternoon I have received it at 80 miles without any difficulty, so that I think it is open to argument whether or not the figures are right at all times, although I daresay the general trend is perfectly correct, especially the great skips of the various wavelengths, but small changes in wavelengths may make very considerable differences in the strength of signals, and in picking up or losing them; and there is no doubt that we have not got to the bottom of the subject yet, and I fancy it will mean a good many years' practical experience, by commercial companies, the services, amateurs, and others, before we get reliable results, because I am sure we shall find the summer and winter results may be quite different. As our President, Sir Oliver Lodge, says, amateurs can help a great deal in this, and if they will help we shall be very glad indeed, but I think that if they do help they must work systematically. They must not jump from station to station and from wavelength to wavelength, but should work on one wavelength and one station for a week or two, then go to other wavelengths and other stations, and then, after a month or two come back and repeat their previous experiments. Systematic observations as to the distances and times at which they can always receive the different wavelengths will be very useful. Certainly this short wave work is in its infancy. We have had 20 or 30 years with long waves, but only a few years with short waves, and short waves are subject to influences which have very much less effect on the longer ones. Of course, one of the great advantages of short waves is that there is so much less interference generally, and less interference by atmospherics, but I notice that on some short wavelengths, especially between 30 and 50 metres, interference is getting rather troublesome. So many stations use those wavelengths, and if you pick up a receiver and tune to one of them you will find three or four stations within a few metres of it. I have noticed it with 50 metres, and there is a good deal of interference with 36 metres as well, so there will have to be legislation to deal with interference with the short waves as with the long waves. However, the subject is very much in the air at present, but if amateurs will help systematically I am sure the results will be of very great value in settling the point as to at what distances and at what times these different waves are receivable.

Mr. Gerald Marcuse: I am afraid it would take too long to deal with this subject as I should like to, but perhaps I may touch upon one or two points. As Sir Henry Jackson has said, it is necessary to carry out tests with one station for many nights. I have done it for nights on end with stations in all parts of the world, and the signals certainly vary from night to night. There is no doubt about it that, whatever there is above the ether, or if there should be a Heaviside layer, the density of that outer atmosphere does vary, and the waves penetrate deeper into it at certain times than at others, so that the angle of deflection varies. There must be truth in that. Take, for instance, the wavelength of 45 metres; there is very little skip distance. It is a rather curious wavelength, because it seems to be that in very bright sunlight the skip distance is very pronounced. I was carrying out tests at intervals all day long last Sunday, during the bright sunlight, and there is no doubt that there was a skip; it practically skipped the British Isles. At Belfast, for instance, a distance of 300 miles, the signals were weaker in sunlight than on a dull day, and in Gloucester (Dursley) they were practically inaudible. But that is a very rare occurrence, and you rarely get a skip on 45 metres in England. I have worked on 45 metres, and on the 32 to 34 metres wavelength, and with the latter there seems to be always a skip, almost of England. In the evening the 32-metre wave seems to be suitable for distances such as 1,000 miles and over. The distances given by Dr. Eccles do not coincide with the results of our experiments, but we must take into account the fact that these signals vary every day; you could not guarantee a short wave to behave in the same way every day, if you take six months on end. Also, there is no doubt about it, they vary from east to west and from north to south. I have tried a given power, say 500 watts—of course, I am talking in terms of hundred-watts, whereas Dr. Eccles is talking in kilowatts—under different conditions, using the same type of aerial, of course, suitable for both wavelengths, for communicating with the Antipodes, and I find that on some days one wavelength is better than the other, and on the whole I find that 45 metres is more suitable for morning communication, whereas the 30-metre band is distinctly better for evening working with the Antipodes. But it is most difficult to make general comparisons owing to varying conditions at different points. Topographical conditions play such a great part in short waves. It seems to me, if we are considering short *versus* long waves, that the whole point is that of atmospheric conditions. I am not conversant with the long wave records, or how those waves behave, but it seems to me that although high frequency amplification is much easier on long waves than on short waves, the atmospheric conditions must on occasion, especially in the tropics, make it impossible to carry out two-way communication with long waves, whereas with short waves, even if you are on the Equator, on most nights you can use, say, 30 metres with practically no interference at all. Fading is another matter which has been the subject of extensive experiment. Apparently there is something operating between two stations long distances apart which affects communication, although you may have a perfectly steady wave at both of the transmitters; even with crystal control there is some effect between the two stations, which must be atmospherical. Nobody, I think, has yet discovered the real cause of it. I certainly agree with Admiral Sir Henry Jackson with regard to interference, and I think the whole question of interference will have to be dealt with pretty severely, owing to the use of broadly tuned waves and unrectified alternating current. There is no need to have a spreading wave. Yesterday morning, for instance, in the course of receiving, we got a back kicking of a key from 6 o'clock until 9 o'clock. That kicking of the key was spreading over the whole wave gap from 20 metres up to 50 metres. My last point is that, of course, you must consider the relative powers used on short and long wavelengths, and the distances covered.

Mr. H. Bevan Swift: Mr. Marcuse has forestalled me in pointing out that the behaviour of short waves is not consistent; what happens on one night is entirely different on others. I can quite appreciate the position of the radio engineer who has to install a large station. He is not in a position to experiment; he has so much capital put into his hands and must put down a station which will work and immediately produce commercial results. It is obvious, therefore, that he would to a large extent avoid anything of an experimental nature on a big scale, and I can quite understand that this is the reason why so many radio engineers, when installing large stations, have avoided the short wave. They must be able to get signals through to the distant receiving station under all practical circumstances, and communication has to be assured. On the other hand, the fickleness of short waves is a thing which appeals to the amateur experimenter. He is accustomed to a certain percentage of failures and more or less expects them. In fact, the happiness and the pleasure is in looking forward to finding a solution for the various difficulties. No doubt in time we shall have some new principle of short wave working which will put the thing on an entirely different footing, but, unfortunately, we have a long way to go yet. The Heaviside layer is a thing we cannot control, but we may be able to devise some means of beam transmission or some means by which we can actually aim at the station we want to transmit to, and that is a line of investigation which I am sure will appeal to every transmitter. We have got to circumvent in some manner the extreme subtlety of short waves and put them on to a practical and commercial footing. As regards telephony on the short waves, of course there is going to be the one great trouble of modulating the wave properly, and those who have tried to modulate the 45-metre wave have obtained very curious results. The modulation varies from night to night. That alone is against the commercial use of a telephone band at 45 metres, and, I think as Dr. Eccles has said, the 100 metre wave is far more suitable for telephony than the high frequency waves below 50 metres. There is a vast difference between 100 and 45 metres, almost the same difference that we observe between the two bands of 100 metres and, say, 5,000 metres. All the peculiar phenomena of short waves become noticeable down below about 70 metres, so that I think that for telephony, with the added difficulty of avoiding distortion and getting pure speech through, it is more likely that from about 100 metres, say, to 150 metres will be the band that will ultimately come into common use, whereas the low powers required, sharpness of tuning giving narrow peaks and the great advantage that you can crowd so many stations into a few metres, will confine the short wave mostly to C.W. work.

The Chairman: Mr. Shaughnessy is here, and although he has said he is not prepared to speak, I am sure that if I appeal to him on behalf of the members present to tell us some of his experiences he will do so.

Mr. E. H. Shaughnessy (Engineering Department, G.P.O.) : The subject of the discussion which Dr. Eccles has opened is the relative values of long wave and short wave communication. With regard to the former, I think that at our Rugby station we have reached the maximum of power which one can economically apply to a long wave station. Since I gave my lecture on Rugby to this Society* we have been able to use the whole of the aerial, and are now getting 750 amps in that aerial. We get very good and consistent results. If one wants better results, then it is more economical to spend money on the receiving plant, and for long waves certainly one wants very selective and efficient aerials and selective receivers. With regard to the statement that has been made that short waves can be received in the tropics on certain nights, I can assure you that long waves can be received in the tropics on most nights. With regard to the skip distances, our experience with short wave transmission is that it is by no means constant, and from the data available it is not possible to accept any definite figure for definite waves. I do not want to depreciate the value of the experiments carried out by Hoyt Taylor—I think they are very valuable—but he is relying for his results on a number of people co-operating with him: some good and some unreliable, and consequently his results are necessarily approximate. Even if one continues experiments over very long periods between the same places; taking simultaneous measurements of field strength, it is very difficult to deduce any definite law from the results which vary so much from day to day. In connection with some long distance, short wave Admiralty experiments, our station at Banbury and the Admiralty station at Horsea were listening out for signals from a distance of 4,000 or 5,000 miles. We got very good signals at Banbury on one wavelength, whilst Horsea did not get them at all; on the other hand, Horsea got very good signals on another wavelength, and we did not get any at all at Banbury. The distance apart of those two stations in this country is approximately 100 miles, and the distance over which the signals came was something like 4,000 miles, so that I think you will see the difficulties that arise. We have a few short wave, low power stations which are carrying out experimental and commercial work, and they are placed so as to be able to take up traffic during the best hours of the day for short wave work and to enable us temporarily to shut down the more expensive high power stations. I think that a big field for short wave stations lies in that direction. There is one thing I view with alarm in Dr. Eccles' opening remarks, and that is, the suggestion that, having found a wave that can be used at 9 a.m. between here and, say, South America, we use another at 10 a.m., another at 11 a.m., and so on throughout the day. Just imagine all the stations on the Continent chasing each other round like that! For the future short wave commercial stations will, I think, have to be content with not more than two waves per station, one wave for one part of the day and another wave for another part of the day. I can confirm what has been said about the utter unreliability of anything definite in the way of a service for any definite hours of the day so far as short wave, low powered stations are concerned. You will get a lower powered station to work over long distances quite well one day for certain hours, but on the next day it will not work during those hours and may during some other hours. There is no doubt that the large amount of attention which is being given to short waves, both by amateurs and by professional and commercial people, will tend to develop a more stable condition of short wave communications and lead to a more definite knowledge of the law of transmission over various distances and various parts of the globe.

Mr. Philip Coursey: This discussion serves to emphasise that, although we have been carrying out experiments on short waves for some years, we have still a very great deal to learn about them. In fact, in carrying out experiments of this nature—at least, I think so—the more one finds out, the greater is the vista opened out for further exploration. One rather important point occurred to me when Dr. Eccles sketched a diagram on the board showing the various skip distances for different wavelengths for different times of the day. The variation of distances of transmission during the day only emphasises the atmospheric influences of the Heaviside layer, but it seems

* "The Rugby Radio Station," by E. H. Shaughnessy. R.S.G.B., 23rd June, 1926.

to me that it might also be influenced to a very great degree by the nature of the aerials used for transmission, and possibly also, to some extent, by the nature of the waves. I think Dr. Eccles has been an exponent of the consideration of the angle at which the radiation is emitted from an aerial, depending upon what is connected to it, and that might probably also be influenced to some extent at least by the shape of the aerial itself and by the shape of surrounding objects, such as leading-in wire or earth connections, and so on. If there is anything in the idea of the Heaviside layer affecting the directions and distances to which these waves are transmitted, it would seem that the aerial itself must have an important influence upon that transmission also. In other words, if we transmit energy at different angles or in different directions, that must have an important effect on the skip distance. Such a consideration would rather seem to raise the possibility of at least carrying out some experiments—it may or may not prove practicable commercially—with multiple transmitters on different wavelengths at the same time from different but adjacent stations. From the remarks already made it would seem that if two, or probably three wavelengths could be used simultaneously for the same transmission there would be a much better reliability factor than is obtained when only one is used. Such tests, at any rate, would probably give interesting results, particularly if the signal strengths, on two or more simultaneous transmissions, could be measured at the receiving stations. It might tell us a great deal more of the mechanism of transmission that would separate transmiission from different stations on different wavelengths. The larger number of wave bands available in the shorter wavelengths might render such a scheme of transmission possible on a commercial scale, should it prove of any value as compared with the single wave. It might also be more valuable than changing the wavelength at different hours of the day. I do not know whether any such tests have been made, but if not I put forward the suggestion as one perhaps worthy of careful attention.

Mr. Maurice Child : There are several points in connection with both long and short waves which I think it would be useful to bear in mind when we are considering the possibilities of the two forms of transmission. It has been suggested that for commercial work the long waves are probably the most satisfactory, the reason being that we know, after some twenty years' experience, how to generate those waves as efficiently as possible, and we also know probably a good deal more exactly how to receive them. We also know the sort of variations we are likely to expect over the distances at which it is contemplated the stations will work. Mr. Bevan Swift suggested that the wireless engineer, or radio engineer, had to set up his station in accordance with the requirements of the service and the amount of money put forward. I am going to suggest that the radio engineer is almost a non-existent person. The engineer to-day who has to put up a bridge, for instance, has to know every detail connected with the materials he is going to use—the strains and stresses, the sizes of the bars and the girders to carry a definite load—and he can produce with wonderful exactitude the results he is required to produce. On the other hand, we all know that it is a very speculative business to put up a wireless station to get through to certain places at long distances—say, distances of 3,000 or 4,000 miles and over. At any rate, the usual practice has been to put up a station of sufficient power so that under almost the worst possible receiving conditions the signals will, somehow or other, get through. Yet, what do we find ? We find that in some cases—and I am going to cite one in a moment—with all the power we put into our long waves for those stations, strengths vary enormously from day to day in exactly the same sort of way as the short waves vary, and I am not aware of any data available yet which gives us the relative variations in signal strength on the long waves in proportion to the power used, and the relative variations of signal strengths of, say, short waves of below 100 metres in proportion to the power used in transmitting. I think that data on that would be very useful. I was speaking the other day to an old pupil of mine who has been working for a long time on a commercial—600 metre—coast station on the Gold Coast, and I asked him how he found the reception of Press news from Rugby. What I wanted to get at was whether the signals from that station, received on the Gold Coast, were constant, reliable, easy to read, and so on. He said, " Yes, Rugby is a very good station to read ; when it really comes through well, it is extremely good." I said, " What do you mean by ' well ' ? " He replied, " If we want to get really good reception of Press news there on the long wave, we invariably get on to Bordeaux." " But," I said, " Rugby is probably using more power than Bordeaux, or in any case the wavelength is more constant." He said, " It may be, but the fact remains that on the Gold Coast the best reception is always from Bordeaux." The difference in distance between Rugby and Bordeaux in relation to the Gold Coast is not very much, say between 300 and 400 miles, so that there we have the same unreliability with the long wave that we get with the short wave transmission. Perhaps it is not so to the same extent, but nevertheless it exists. It makes one rather careful in speculating as to the future possibilities of the use of the long and the short waves when one still has these enormous variations to contend with. I think that one of the great difficulties we have to overcome with short waves before we can make further and very useful measurements is to make some big improvements in our methods of receiving. The majority of amateur workers, and also some professional workers, have realised that for short wave reception it is necessary to employ as simple detecting arrangements as we can—and, of course, simplicity is always a desirable thing, provided we can also get reliability. It does seem to me that an enormous amount of work has to be done, in connection with the development of the short wave, to make up for the variations in strength that we get in the short wave. If we experiment only on the simple detector and the amplifying valve at receiving stations we shall stick almost where we are, but if we can use a receiver which can be increased in its range of sensitivity, as long wave receivers can be, by high frequency stages, we can get over the difficulties we find at present. That seems to me to be one of the important things. There is one other point I should like to mention. When we put up a comparatively high power transmitting, short wave station, say 20kW or less, the signals come through at the distant station—by "distant" I mean perhaps in the Antipodes—with enormous strength, but there is a difficulty which has arisen, which apparently nobody foresaw at the time when high power was employed, and that is that although you get strong signals you cannot read them—or, at any rate, it is very difficult to read them. It appears that at great distances the wave from the transmitter goes direct round the world to the receiver, it then goes round the world again and comes to the receiver, and then again the third time, so that you never get a quick cut-off, which is necessary when reading the Morse code. The dot ends with a succession of dots, and that makes the reception of high speed signals very difficult. Perhaps the solution would be to cut down the power of the transmitting station.

Mr. Hogg: I am glad that Mr. Coursey mentioned the possibility of the variation in skip distances by altering the constant of an aerial circuit. Some years ago I did a great deal of work, at the suggestion of Dr. Eccles, in getting across the Atlantic on 100 metres, and I found that the variation of skip distance does not apply merely to the short waves, but also to the longer waves of 200 metres; it varies just as much, and if you use a small amount of power you can readily get the same effect. On 100 metres it is possible for a signal to be inaudible on the east coast of America, and to get a powerful signal halfway across America, and vice versa, just as you desire. Another problem is the extraordinary variation in transatlantic signals at quite regular periods of a week or so. I believe that about once every week or ten days you find all the American amateurs transmitting—and there are hundreds of stations—will vanish completely for about a week, and then come back again; they all vanish at the same time and come back at the same time: No other stations in any other part of the world seem to do the same thing; it only happens between England and America, on approximately 40 metres. Results have been obtained by Pickard recently in connection with polarisation, but they have not been based on a very large quantity of experimental work, and it would be interesting to have Dr. Eccles' opinion on them. With regard to Admiral Sir Henry Jackson's remarks on the 30-metre wavelength, I think the general experience of most amateurs has been that the 32 to 34-metre waveband is almost inaudible in England at any time during the day or night from 30 or 40 miles onwards. As to the fading of audio frequency, that has been cured by many amateurs to a great extent by the use of crystal control. That is also the case with KDKA and WGY, and I do not think there has been any distortion since they used crystal control. There is another kind of skip which I have noticed when working over distances of 50 or 70 miles. I have been working with a small transmitter on a car recently, doing some very short wavelength experiments, working on a schedule with a station in London. At times we have both been on and could hardly hear each other, but maybe we hear each other later with terrific strength. We get a sudden cessation of signal strength at such a short distance for no apparent reason. In another case we knew a man was transmitting at a certain time, but his signals were quite inaudible, but in half an hour's time there he was as large as life, and perhaps as strong as usual. There seems to be something unusual to cause all these rather peculiar skips, which require investigation. It seems to me that there is a great deal to be done in the way of polarisation, and that seems to be the most interesting field at the moment. I should like to hear what Dr. Eccles has to say about it.

Dr. Eccles, replying to the discussion, said: Admiral Sir Henry Jackson objected to the sharply defined figures that I gave of skip distances, and other speakers supported him in saying that they did not believe the figures were so hard and fast as I indicated. I think I ought to say that Mr. Hoyt Taylor, in his paper on the subject, says that all he has done is to take the average of a great many rather different figures in deducing, for instance, to get that 50 to 500 miles as the skip distance of the 30-metre wave in the daytime. It is well known that an average, although it occurs sometimes, does not occur often. The things that are not average occur more often than the things that are average. I have often heard it said that the average height of members of the population of the United Kingdom is 5 ft. 9 in. and several decimal points, but probably nobody of exactly that height exists. In the same way, I can quite believe that these skip distances probably are never hit on in actuality. Mr. Bevan Swift has employed the phrase "the fickleness of short waves." That phrase explains excellently why these skip distances are never the same two days running or even two hours running. The other investigators I have quoted actually say that the behaviour of the 66-metre wavelength to-day is very like what that of the 45-metre wavelength was yesterday, so that, you see, these things have to be taken as very rough approximations. All this is supported very strongly by Mr. Marcuse's statement that one cannot guarantee that a short wave will do the same thing every day. He pointed out, too, a thing which I did not mention in my opening remarks, namely, that a very important advantage of short wave over long wave transmission is the portability and smallness of the apparatus. You can have it so small that explorers on the Amazon can communicate with Mr. Marcuse in England, carrying their kit with them, in a way which would be absolutely impossible with long wave transmission without taking a barge. (Laughter.) You will notice, by the way, that the advent of short waves has altered the whole aspect of exploration. The explorer now is in a very different position as compared with five years ago. Wherever he goes, whether it be the North Pole, the South Pole, Central Asia or anywhere else, he can keep in touch with civilisation if he wishes. Mr. Shaughnessy's illuminating remarks, drawn from the experience of the Post Office, I was very glad to elicit from him, as they will go on record in our Proceedings, and will be of great value to the people who take the trouble to read them. It is very remarkable that stations so near together as Horsea and Banbury can record absolutely different experiences on the same signal at the same instant, but again the explanation is the "fickleness" of short waves. Both Mr. Coursey and Mr. Hogg dealt with the effects of the shape of the aerial, the length of the aerial relative to the wavelength, or the inclination to the ground of the aerial, and Mr. Hogg reminded me that Pickard, in a recent paper, had gone very deeply into the question of the polarisation of the waves as affecting propagation. It would take too long to do justice to Mr. Pickard's work to-night, but I think it would form a very good subject for continuing the discussion of short waves on some other evening, either at an informal meeting or a full meeting of the Society. I hope we can make room for that amongst the papers and discussions that are to come. The remarks of Mr. Child, to the effect that the radio engineer does not exist because there is so much guesswork in what he does, and because nature comes up against him and falsifies his prophecies, seem to me to apply just as much to, say, the civil engineer. After all, the structures which the civil engineer builds are intended to stand the test of the elements, but when a tornado, such as that in South Florida comes, all his calculations are falsified and the buildings fall down. I think we are very much in the same boat, and have come to the conclusion that there is no such thing as an engineer at all. (Laughter.) His remarks about the difficulties that must arise in short wave reception at high speeds if the signals go echoing round the world are very apt, and they do indeed constitute a thing that will have to be combated if that echo hypothesis is correct. It resembles the problem of echoing in long telephone cables, and it may possibly be got over by analogous methods. That remains for the future, however. As regards reception on the Gold Coast from Rugby and Bordeaux, it is quite true that sometimes in some places Bordeaux is more legible than Rugby, and vice versa. The configuration of the surrounding country has a great deal to do with it. If a chain of mountains happens to come into the "line of fire" between Rugby and the Gold Coast, and does not come into the "line of fire" from Bordeaux to the Gold Coast, one would expect—and it has been demonstrated again and again—that the signals would be stronger over the clearer path.

The Chairman: I understand that Mr. Marcuse has a very interesting suggestion to make, though it has nothing to do directly with long or short waves, and I should like to call on him to tell the meeting what it is. There will be no necessity for us to come to any decision to-night, but a statement from him now will be an easy and rapid way of letting the members of the Society know what his proposal is, and they will have a certain amount of time to think about it.

Mr. Marcuse: I do not wish it to be thought that I am trying to preach economy to the Radio Society of Great Britain, although there may be times when it is needed and when the Society may not be too flush with funds, but I do feel that the meeting to-night indicates the community of interest between the members of the Society and the members of its T. and R. Section. You may not know that the membership of the T. and R. Section is mounting up, and we shall soon be 1,000 strong, and I do feel that we ought to merge our interests by holding joint meetings. The Radio Society is holding a meeting to-night, and the T. and R. Section may be holding a meeting next week; you are discussing short waves, and we might be discussing short waves. Therefore, I think we might merge the meetings into one. It has been suggested that we hold two meetings one month and one the next, but if we merge our interests we might possibly hold two every month, or, if special circumstances arise, probably three a month. I notice that the meeting to-night includes a good many members of the T. and R. Section—they are all members of the Society itself, of course—and it seems to me that whatever subjects are discussed at the meetings of the Society or of the T. and R. Section, they are allied and of interest to all of us. It will make my work much easier, as well as the work of the gentlemen responsible for arranging the meetings of the Society, and we shall all be happier. I do not know whether you want to discuss the proposal, but if the Council would consider it—and I have the honour to be a member of the Council—perhaps it would be better for them to do so.

The Chairman: You have heard the proposal made by Mr. Marcuse, and I hope you will think over it. To my mind, it is a very generous one, and shows that the T. and R. Section does not want to keep all its knowledge to itself. I feel that the field is one which is so vast and varied that there is any amount of room for any number of experimenters to take it up.

Abstracts and References.

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R100.—GENERAL PRINCIPLES AND THEORY.

R111.—NEW DEDUCTIONS OF THE ELECTROMAGNETIC EQUATIONS.—W. Swann. (*Physical Review*, 28, pp. 531-544, Sept., 1926.)

R112.—ÜBER RAUMSTRAHLUNG (Concerning space radiation).—A. Meissner. (*Zeitschrift für Hochfrequenz.*, 28, 3, pp. 78-82, Sept., 1926.)

On the hypothesis that with space radiation transmission should be directed upwards at an angle of 60-80°, the advantage of employing a horizontal antenna (dipole) follows. For conducting the energy to this antenna, parallel leads were utilised several wavelengths long and 8-10 cm. apart. Tuning was not effected on the antenna, but through a rotary condenser in the transmitter coupling coil. The solution of the antenna problem for the present is a horizontal antenna or combination of horizontal antennæ in conjunction with a metal reflector directing the radiation upwards at an angle of 60-80°. An experimental arrangement carried out at Nauen is described. This arrangement improved reception at Buenos Aires two to fivefold, and reception was often possible, particularly in the daytime, when nothing was heard in the case of the transmitter with the vertical antenna; also with longer waves (up to 300m.) the horizontal antenna was found superior to the vertical.

R113 and R114.—LONG DISTANCE RADIO RECEIVING MEASUREMENTS AND ATMOSPHERIC DISTURBANCES AT THE BUREAU OF STANDARDS IN 1925.—L. Austin. (*Washington Academy of Sciences Journ.*, 16, pp. 398-408, 19th Aug., 1926.)

A résumé of the measurements made by the Bureau of Standards on long-wave, long-distance signal intensities and atmospheric disturbances during 1925, with the addition of some comparisons of the field intensities and disturbances from 1922 to the present time. The results are tabulated and shown graphically. No certain relationship has been discovered between sunspots and abnormal signals, but in many cases there appears to be an undoubted effect of the more severe magnetic storms upon transmission. Further conclusions drawn from these experiments have already been given (these abstracts, Sept., 1926, p. 570). Observations in Washington show that in winter the prevailing afternoon disturbances come roughly from the direction of eastern South America or perhaps partly from Africa. In summer the direction is south-westerly, apparently from Mexico or the south-western United States. This is in accord with the idea that disturbances generally originate over land and are most intense in the afternoon and evening in the regions where the sun passes very nearly overhead.

R113.—TEMPERATURE AFFECTS RADIO SIGNAL STRENGTH.—(*Amer. Inst. Elect. Eng. Journ.*, 45, 9, p. 863, Sept., 1926.)

That temperature influences the strength of radio signals is the conclusion reached from experiments made at the Bureau of Standards. Two years ago, Dr. Austin observed a decided increase in the signals received at Washington from Tuckerton and New Brunswick, during the passage of severe cold waves over the eastern States. Further research now indicates that whenever the temperature rises along the signal path there is a tendency for the signal to drop, and conversely, a falling temperature tends to produce a stronger signal, though these temperature effects are often masked by other unknown influences. It is stated that doubtless temperature changes influence the waves which are reflected or refracted from the Kennelly-Heaviside layer, 60 miles or more above the earth's surface, rather than the waves which glide along the ground, since no marked change is observed in signal intensity due to long continued rain or drought, the presence of snow, or the presence or absence of frost in the ground.

R113.—A SUGGESTED WIRELESS TRANSMISSION THEORY.—C. Snell. (*Electrical Review*, 99, p. 363, 27th Aug., 1926.)

A reply to Mr. Barton's letter (these abstracts, October, 1926, p. 635) stating that the shorter wavelengths are more efficient both by day and by night provided that the transmitting apparatus and its associated aerial system are specially designed for such wavelengths. Mr. Snell also explains that his articles were framed so as to distinguish as completely as possible between the variations in efficiency occasioned by changes in aerial and apparatus design and those exclusively attributable to the characteristics of the media intervening between transmitter and receiver.

R113.—CURVED PATH OF WIRELESS WAVES.—A Mallock. (*Nature*, 118, pp. 443-444, 25th Sept., 1926.)

A letter on the question as to why wireless waves follow the curvature of the earth. The writer states that since with visible light in air the shorter the wavelength the less the velocity, while the refractive index for X-rays is practically unity, there must be a condition in which a decrease of wavelength is accompanied by an increase in velocity, at and after a certain shortness of wavelength is reached. Similarly at the other end of the spectrum it is not impossible that the velocity may drop as the wavelength increases, although at present a physical explanation may be wanting. A case of diminished velocity with increased period would occur in air if the waves were of such great length that the heat due to compression had time to diffuse. If it were found that for wireless waves the velocity increased about one part in four thousand per mile of height above the ground, the writer continues, the reason for such waves following the curvature of the earth would require no further explanation, and until experiment proves that there is no such change, it would be reasonable to impute the observed curvature of path to this kind of cause.

A graphical construction for determining diffraction effects is added.

R113.—RECENT DEVELOPMENTS IN SHORT-WAVE WIRELESS TELEGRAPHY.—H. Rukop. (*E.W. & W.E.*, 3, 37, pp. 606-612, October, 1926.)

A first instalment of a full translation of the Telefunken publication *Neuere Ergebnisse in der drahtlosen Telegraphie mit kurzen Wellen,* also appearing in *Zeitschrift für Hochfrequenz*, 28, 2, pp. 41-50, August, 1926.

R113.—SHORT WAVE EXPERIMENTS.—R. Durrant. (*WirelessWorld*, 19, pp. 331-332, 8th September, 1926.)

An account of tests, between a yacht cruising in the Norwegian fjords and a station in Hampshire, which show that reliable communication can be maintained day and night on low power, over 600 miles, where ordinary long-wave spark and C.W. signalling will not penetrate beyond a few miles.

R113.—CAN WE SIGNAL TO MARS ?—E. Appleton. (*Wireless World*, 19, pp. 359-360, 8th September, 1926.)

The conditions under which short waves penetrate the Heaviside layer are considered, and it is estimated that somewhere between 1 and 10 metres long distance transmission would be found to become impossible, because all the waves leave the earth.

R113.4.—A TEST OF THE EXISTENCE OF THE CONDUCTING LAYER.—G. Breit and M. Tuve. (*Physical Review*, 28, pp. 554-575, September, 1926.)

The following abstract is given :—

A method previously proposed for a test of the existence of ionisation in the upper atmosphere has been developed, and definite proof obtained of the existence of echoes from the upper regions. The echoes are present for 70-metre waves with an 8-mile base near Washington, D.C. The effective height of the layer is between 50 and 130 miles. At times multiple reflections are present. Radio fading is shown to be not only an effect of interference between the ground and the reflected waves, but also to a large extent an effect of the presence or absence of reflected waves. A seasonal variation in the effective height between summer and fall seems to exist. A smaller diurnal effect is also suspected. The height seems greater in the fall than in the summer and greater in the afternoon than in the morning. Effects of wavelength and of location have been studied. A quantitative discussion of the results enables one to eliminate too gradual distributions of electron density. The measured retardation is shown to correspond to a height greater than the actual by amounts differing for various polarisations of the refracted waves.

R113.4.—AUDIBILITY OF EXPLOSIONS AND THE CONSTITUTION OF THE UPPER ATMOSPHERE. —F. Whipple. (*Nature*, 28th August, 1926, pp. 309-313.)

From the reports on the audibility of the experimental explosions arranged by the International Commission, Prof. Maurain has concluded that the high temperature (about 300° F.) postulated by Lindemann and Dobson for the atmosphere at 60 km. and above, is not high enough to account for the recurring of the sound rays, and that Von den Borne's hypothesis of the hydrogen atmosphere must be invoked. He goes so far as to hazard the estimate of 92 per cent. of hydrogen in the constitution of the atmosphere at 116 km. The author shows that Prof. Maurain's hypotheses are at variance with certain deductions from the observations and that reasonable agreement with the observations is obtained by assuming that the rise of temperature begins at 30 km. and increases regularly up to 50 km., at which level and beyond the temperature is 380°. The probability that the transition from the uniform temperatures of the stratosphere to much higher temperatures begins at the comparatively modest height of 30 km. makes it desirable to extend the range of soundings by free balloons to that height, and beyond, which should not be impossible by the proper choice of balloons.

R113.6.—POLARISATION OF WIRELESS WAVES.—S. Hollingworth. (*Nature*, 118, p. 409, 18th September, 1926.)

A brief outline of observations made at Slough and Exeter on the transmissions from Sainte Assise (14,350 m.), from which the two chief facts that emerge are :—

I. Long waves as well as short may be elaborately polarised by refraction in the upper atmosphere during the night. This effect is also present, though to a less degree, during daylight in winter, and occasionally even during daylight in summer.

II. The effect persists during the hours of darkness, remaining fairly steady after the sunset period is over, and consequently it cannot be caused by the mere temporary displacement of the reflecting surface from its normal horizontal position owing to the ionic recombination occurring at sunset, but must be an essential feature of the mode of refraction.

R.113.6.—THE KERR EFFECT IN WIRELESS TRANSMISSION.—E. V. Appleton. (*Nature*, 118, p. 514, 9th October, 1926.)

Evidence is briefly reviewed pointing to the rough generalisation that long wireless waves are deviated by reflection and short waves by refraction. Taking into account the earth's magnetic field on the motion of electrons, a Kerr effect (rotation of plane of polarisation, on reflection from a sharply-defined magnetised surface, through an angle depending on the intensity of magnetisation) would be expected for long waves at night, which prediction seems to find fulfilment in Mr.

Hollingworth's recent observations (*Nature*, 18th September, p. 409). A consideration of the magneto-ionic formulæ for the conductivity and dielectric constant of ionised gas shows that, in cases of reflection, there is a certain critical height in the atmosphere above which the inductivity in the direction of the earth's lines of magnetic force is appreciably different from that in a direction at right angles. This is the height at which the frequency of the electron collisions with gas molecules is equal to the angular frequency with which the electrons normally spiral round the lines of magnetic force. Estimates of mean free paths and air pressures at different altitudes give a value for the critical height somewhere about 70-80 km. When the waves are deviated below this height, practically no abnormal polarisation occurs, but when deviated above, both Kerr and Faraday effects will be produced according to the wavelength. The fact that the Kerr effect is found at night and not by day indicates that the ionised layer passes from or below this critical region to a height appreciably above it at sunset.

R113.8.—AURORA POLARIS.—(*Nature*, 11th September, 1926, pp. 366-368.)

Observations of the aurora and related phenomena, particularly in the regions where the aurora and associated ionisation are most strongly developed, are of considerable radio interest, owing to the connection existing between ionisation in the upper atmosphere and wave propagation. This article reviews the "Records of the Aurora Polaris" by Sir Douglas Mawson, giving the detailed observations from the three stations occupied by the Australian Antarctic Expedition between 1911 and 1914. These records will be followed by two other parts in the same volume—"Records of Magnetic Disturbances" and "Records of the Range of Transmission of Wireless Signals."

R113.8.—VARIATION OF PENETRATING RADIATION ON THE JUNGFRAU.—W. Kolhörster and G. von Salis. (*Nature*, 118, 9th October, 1926, p. 518.)

Recent research with more sensitive instruments appears to confirm Kolhörster's early belief in a cosmic origin for the penetrating radiation. The radiation is found to reach maximum intensity when certain celestial regions culminate, for example, the Milky Way, and specially the regions of Andromeda and of Hercules, which is explicable as a consequence of the minimum length of the path of rays from these regions through our atmosphere at culmination.

R113.8.—SOME ELECTROSTATIC DISTURBANCES UPON THE EARTH WHICH SEEM TO BE CAUSED BY DISTURBANCES UPON THE SUN.—F. Sanford. (*Physical Review*, 28, p. 429, August, 1926.)

Abstract of a paper presented at the June meeting of the American Physical Society in California.

An instrument used for the past five years for measuring daily variation of the surface potential of the earth at Palo Alto shows very great deviations from the ordinary daily range of variation at certain times. These deviations have some of the characteristics of magnetic storms, but they seem to occur most frequently during the forenoon hours, while magnetic disturbances occur at the same time all over the earth. Since very great earth potential disturbances have accompanied some of the great sun spot disturbances, an attempt has been made to find whether the disturbances of earth potential regularly accompany the passage of sun spots across the sun's central meridian. The data given in the paper indicate the probability, but not the certainty, of a physical relation between the two phenomena.

R113.8.—THE RECURRENCE OF MAGNETIC STORMS.—C. Chree. (*Nature*, 4th September, 1926, pp. 335-336.)

R114.—PREMIÈRES OBSERVATIONS RELATIVES AUX PARASITES ATMOSPHÉRIQUES EN AFRIQUE OCCIDENTALE.—First observations on atmospherics in West Africa.—H. Hubert. (*Comptes Rendus*, 183, pp. 368-370, 2nd August, 1926.)

For this investigation at Dakar, a frame receiver was used, similar to that employed by Rothé at Strassburg (*L'Onde Electrique*, 2, 1923, p. 7). The sounds heard in the telephone are the same as those described by Rothé and Lacoste under the names of "décharges" and "craquements et claquements." By discharges, Rothé denotes manifestations that are less frequent and last a fairly long time, up to five seconds, having an intense metallic noise like a gong with a clear high note, and maintaining during their whole duration the same intensity and pitch. Claquements et craquements are the disturbances known as clicks and grinders.

Discharges.—In agreement with Rothé's observations, discharges are in direct relation with lightning flashes. It appears, moreover, that, in W. Africa at least, discharges alone belong to this category. For each wavelength there is an orientation of the frame, towards the east, for which the frequency is a maximum, and another direction, often very comparable, for which there is a maximum intensity of discharge. Except in the case of a very near storm in an azimuth very different from the east, these directions are also very near those observed for clicks and grinders. In practice the azimuth of greatest frequency of discharge is much the same for all wavelengths except one, varying between 6,000 m. and 15,000 m. with the time, for which the frequency is a maximum, with progressive decrease above and below this wavelength. During the period of the year when there are no lightning flashes, no discharges are recorded. In winter they are only observed when there is a flash of lightning within a radius of less than 300 or 400 km. The frequency is in direct relation with that of the lightning flashes. Audibility is far better when the storm is approaching the observer than after it has passed him by.

Clicks and grinders.—These occur at any hour in all seasons, and are not determined by the lightning flash. For these also there is maximum frequency for a certain orientation of the frame (near the east) and a variable wavelength (often about 13,000 m.), with progressive decrease on either side of this orientation and wavelength (atmospherics are relatively rare above 22,000 m. and below 200 m., but one must go well below this latter figure to eliminate them). The azimuth of greatest frequency is not fixed. In general it gradually shifts by a small amount (exceptionally 75°) towards the north from morning to evening. About sunset it shifts suddenly towards the south. It varies further according to the season: in winter it is ordinarily near the east or east-south-east and in the dry season the east-north-east. Apart from any meteorological disturbance, the frequency of clicks and grinders is much greater by night than day, there is a sudden increase from the time of sunset and marked diminution after midnight. It is probable that at nightfall there is no increase, in the absolute sense, of the atmospherics produced, but simply an increase in the atmospherics picked up, owing to the better audibility. For the twelve hours of sunshine each day, the frequency varies with the season. For instance, in winter there are 30 clicks to the minute at 8 a.m., 60 at 2 p.m., 80 at 5 p.m.; in the dry season there are 40 at 8 a.m., 55 at 2 p.m., and 45 at 5 p.m. The frequency does not change with the approach of cold fronts or by horizontal displacements of the atmospheric air, but it systematically increases with vertical displacements of masses of air in the aerial currents, whether rythmical or accidental. Things happen as if the clicks and grinders were due to oscillating discharges of minor importance, emitting neither light nor sound, that occur every moment—at an altitude of at least some thousands of metres and at distances of some tens of kilometres or more from the receiver—between masses of air of very different potential brought into the neighbourhood of one another through an energetic stir up caused chiefly by violent ascending currents.

R114.—LIGHTNING.—(*Nature*, 2nd October, 1926, p. 482.)

Further brief correspondence between Dr. Simpson and Dr. Dorsey concerning their respective theories as to the nature of lightning (see these abstracts, *E.W. & W.E.*, October, 1926, p. 638).

R114.—ATMOSPHERIC ELECTRICITY AND ALLIED PHENOMENA. (*Nature*, 2nd October, 1926, p. 493.)

Announcement of a communication from Profs. H. Benndorf and V. Hess, who are writing a comprehensive treatise on the above subject to be published next year, asking physicists and meteorologists in English-speaking countries to send them reprints of their publications. Papers are required on atmospheric electricity dealing with the electric field of the earth and atmosphere, atmospheric ionisation, electricity of thunderstorms, electric properties of rain and snow, radio-activity of the earth and atmosphere, the aurora, theories of the origin of electro-atmospheric phenomena, and propagation of electric waves round the earth. Any reprints on these subjects would be gratefully received by Prof. Benndorf or Prof. Hess, Physikalisches Institut, Universität, Graz (Steiermark), Austria.

R132.—AN EXAMINATION OF THE PROPERTIES OF AUDIO-FREQUENCY AMPLIFIERS BY MEANS OF THE DUDDELL OSCILLOGRAPH.—W. Baggally. (*E.W. & W.E.*, 3, 37, October, 1926, pp. 628-632.)

R133.—EIN NEUER GRUNDSATZ FÜR DIE ERZEUGUNG VON SCHWINGUNGEN MIT ELEKTRONENRÖHREN (A new principle for the production of oscillations with valves).—F. Kiebitz. (*Elektrische Nachrichten-Technik*, 3, 8, August, 1926, pp. 284-289; *Zeitschrift fur Hochfrequenz.*, 27, 6, July, 1926, pp. 163-167.)

The falling I_a—E_{ga} characteristic of the ordinary commercial valve gives the grid-anode system the properties of a negative resistance, which is able to maintain oscillations when arranged parallel to the condenser of an oscillatory circuit. Experiments with such a circuit-arrangement are described when all oscillations ranging in period from 5 sec.—10^{-8} sec. were successfully produced.

R134 & R149.—NOTES ON WIRELESS MATTERS. L. Turner. (*Electrician*, 10th September, 1926, pp. 288-289.)

A brief review of the actions in the rectifier of a wireless receiver and the relations subsisting between the several types of rectifier.

R138.—SECONDARY EMISSION FROM METALS DUE TO BOMBARDMENT OF HIGH-SPEED POSITIVE IONS.—W. Jackson. (*Physical Review*, 28, September, 1926, pp. 524-530.)

The emission from various metals is measured using different kinds and speeds of positive ions and following a method the results of which are unequivocal. Attempt is made to separate electron emission from the phenomenon of positive ion reflection.

R138.—THERMIONIC AND ADSORPTION CHARACTERISTICS OF CAESIUM ON TUNGSTEN AND OXIDIZED TUNGSTEN.—J. Becker. (*Physica Review*, 28, August, 1926, pp. 341-361.)

R138.—VARIATION WITH TEMPERATURE OF THE WORK FUNCTION OF OXIDE-COATED PLATINUM.—M. Glass. (*Physical Review*, 28, September, 1926, pp. 521-523.)

A series of tests were made with standard Western Electric VT2 valves, in which the filament was held at a higher temperature for a period of five minutes and then returned to a lower reading temperature (950°C.) and the electron current measured with a plate potential of 110 volts. It was found that the previous heating of the filament caused a temporary increase in the electron current over the normal value for that temperature, and that this effect increased with temperature up to about 1130° C., after which point it began to fall off. The results of another series of tests indicate that positive ion emission from the filament begins at a temperature somewhat above that which produced maximum electron current. These results are in agreement with the theory that the thermionic activity of oxide-coated platinum filaments is probably due to a film of metallic barium and strontium produced by reduction of the oxides.

R138.—SCATTERING OF ELECTRONS IN IONISED GASES.—F. Penning. (*Nature*, 28th August, 1926, p. 301.)

A letter referring to Langmuir's paper in the *Physical Review* of November, 1925, where it is stated that in investigations with a tube containing electrons with abnormally high velocities, no oscillations could be found. The writer has made experiments with a tube similar to the one used by Langmuir, however, and has detected oscillations when the velocities became abnormal. With appropriate values of emission, anode voltage and pressure, these oscillations could be brought on a Lecher system, the wavelength varying from about 40 cm. to 100 cm. From his results, which are summarised here, the writer concludes that it is not impossible that the observed "scattering of primary electrons" is always accompanied and caused by these oscillations.

R142.3.—DER EINFLUSS DER DÄMPFUNGEN AUF DIE FREQUENZEN ZWEIER GEKOPPELTEN KREISE. (Influence of damping on the frequencies of two coupled circuits).—B. van der Pol, Jr. (*Zeitschrift für Hochfrequenz.*, 28, 1, pp. 12-15.)

A mathematical discussion with a graphical representation of the results.

R149.—SUR LES CONTACTS RECTIFIANTS.—H. Pélabon. (*Comptes Rendus*, 183, 6th September, 1926, pp. 491-492.)

The detection of electro-magnetic waves can be effected by a system, metal-dielectric-metal, in which the minimum thickness of the dielectric (generally air) is maintained practically constant by the intercalation of insulating granules (*L'Onde Electrique*, 52, p. 411, these abstracts, June, 1926, p. 386). This article deals chiefly with the practical means of making such detectors. Various methods of depositing the intercalating powder on the surface of one of the metals are mentioned and also ways for increasing the electric resistance of one of them, shown to be generally an advantage.

R161 & 162.—THE AMPLIFICATION AND SELECTIVITY OF A NEUTRALISED TUNED ANODE CIRCUIT.—N. McLachlan. (*E.W. & W.E.*, 3, 36, September, 1926, pp. 545-552.)

R200.—MEASUREMENTS AND STANDARDS.

R213.—CALIBRATION OF ULTRA SHORT WAVE-LENGTHS.—F. Aughtie. (*E.W. & W.E.*, 3, 37, October, 1926, pp. 633-634.)

R251.—A VERY SENSITIVE VALVE GALVANOMETER.—Prof. G. W. O. Howe. (*E.W. & W.E.*, 3, 37, October, 1926, p. 634.)

R261.—THE THERMIONIC VOLTMETER.—W. Medlam and U. A. Oschwald. (*E.W. & W.E.*, 3, 37, October, 1926, pp. 589-598.)

A first instalment of a paper giving the results of an experimental investigation of the performance of five different types of thermionic voltmeter from the points of view of sensibility and range, possible frequency error, wave form error, input load, and stability of calibration.

R281.—DIELECTRIC ABSORPTION AND THEORIES OF DIELECTRIC BEHAVIOUR (Whitehead), and THEORY OF ABSORPTION IN SOLID DIELECTRICS (Karapetoff). (*Amer. Inst. Elect. Eng. Journ.*, 45, 9, September, 1926, pp. 888-894.)

The discussion on these papers, which were published in this Journal of June, 1926, p. 515, and of March, 1926, p. 236, respectively.

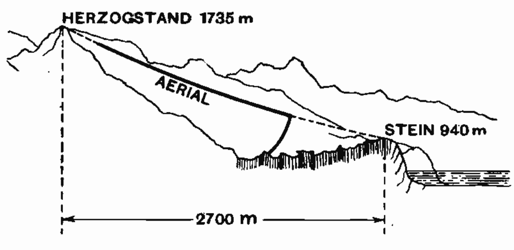
R281.—THE MECHANISM OF BREAKDOWN OF DIELECTRICS.—P. Hoover. (*Amer. Inst. Elect. Eng. Journ.*, 45, 9, September, 1926, pp. 824-831.)

A critical study of existing theories in an attempt to obtain a working hypothesis that more nearly meets the stringent requirements of experimental facts. In a dielectric there is kinetic equilibrium between the ions and the molecules, and breakdown will occur when that equilibrium is disturbed, regardless of whether the disturbance is due to mechanical strain, electrical strain, or to thermal effects. The three-fold nature of the phenomenon must be considered in a complete analysis of the problem, which it is thought has not been sufficiently realised in the past.

R300.—APPARATUS AND EQUIPMENT.

R321.—DER BAU DER BERGANTENNE AM HERZOGSTAND.—O. Scheller. (*Elektrische Nachrichten-Technik*, 3, 7, pp. 241-255.)

Detailed description of the construction of this unique aerial of a new German high-power station for communication with the Far East. Economy is practised by doing without masts altogether and suspending the aerial between two mountain peaks, as shown below :—



Several illustrations of constructional features are shown including the earthing arrangement.

R330.—THE LIFE-TESTING OF SMALL THERMIONIC VALVES.—M. Thompson, R. Dudderidge and L. Sims. (*Inst. Elec. Eng. Journ.*, 64, September, 1926, pp. 967-985.)

A paper discussing the basis of a life specification for thermionic valves and describing their general characteristics in relation to the problems involved. Solutions of these problems are considered and a large installation for testing the life of valves is described. Typical examples of the results obtained are given.

R343.—On the Amplification of Ultra Short Waves by the Thermionic Valve.—H. Ando. (*Journ. Inst. Elect. Eng., Japan*, August, 1926, pp. 899-907.)

If we try to amplify ultra short waves of 50 metres or less with a valve amplifier, the inter-electrode capacity will become important, and the valve tend to oscillate, accompanied by a diminution of the amplification per stage, consequently until recently direct amplification of ultra short waves was considered impossible or impracticable. The author has been engaged on research of a valve high frequency amplifier, particularly of the tuned type, for some years, and devised the method of preventing inter-electrode capacity coupling employed extensively in broadcast receiving apparatus. He has now developed his earlier idea, a first account of which is given in this article. The new method is said to have proved superior to the simple so-called neutrodyne system in the 100-300 metre band and much more effective in the ultra short wave regions. Circuit diagrams are shown, the description of which, however, is in Japanese.

R343.—The Infradyne.—H. Green. (*Radio News*, October, 1926, pp. 356-357.)

Description of a circuit differing from the superheterodyne in that instead of making use of the difference in frequency between the local oscillator and the incoming signal and amplifying this beat, the sum-frequency is utilised. Amplification is thus carried out on the very short wave of 95 metres, instead of between 3,000 and 10,000 as in the superheterodyne. In addition to the total absence of interference from long-wave transmitting stations the advantage is claimed of the complete elimination of harmonics which are so prevalent in superheterodyne receivers.

R343.8.—Neutrodynes.—S. Lwoff. (*Radio Revue*, 5, pp. 137-147, September, 1926; pp. 169-179, October, 1926.)

The first two parts of a well-illustrated article on neutrodyne theory and practice.

R344.9.—Piezoelectrische Resonanzerscheinungen (Piezo-electric resonance phenomena).—A. Scheibe. (*Zeitschrift für Hochfrequenz.*, 28, 1, pp. 15-26.)

A survey of the subject arranged in the following five sections :—

I. Piezo-electricity, comprising the following subsections : history of the piezo effect, piezo-electric crystals, demonstration and theory of the effect, piezo-electric properties of quartz and Rochelle salt.

II. The piezo-electric resonator, comprising the subsections : Langerin's resonator, experimental basis of quartz resonators, establishing resonance, absorption method—normal frequency, rendering the high-frequency longitudinal oscillations of piezo-electric plates visible.

III. The employment of quartz resonators as frequency standards—steel resonators—constancy.

IV. Piezo-electric stabilisors and oscillators.

V. Piezo-electric oscillographs.

Literature consulted.

R376.—On the Condenser-Telephone.—G. Green. (*Philosophical Magazine*, 2, pp. 497-508, September, 1926.)

A preliminary discussion of the mathematical theory of the condenser-telephone when used either as a receiver or transmitter. It is concluded that the instrument has that most important quality of reproducing the vibrations delivered to it uniformly and equally over a very great range of frequency, which has been amply demonstrated by the experiments in progress. Further, condenser telephones of low capacity show decided resonance effects and may be used in bridge-measurements or in heterodyne reception of continuous waves.

R376.3.—Loud-Speaker Efficiency.—C. Balbi. (*Wireless World*, 19, pp. 277-279, 25th August, 1926.)

A brief classification of the sources of energy loss in a loud-speaker, and their relative importance.

R382.—On the Design of an Inductance Coil for Audio-Frequencies which has the Iron Core with the Air Gap.—H. Nukiyama and K. Nagai. (*Journ. Inst. Elec. Eng., Japan*, July, 1926, pp. 734-741.)

It is usual in practice for inductance elements for audio frequencies to employ iron-cored inductances which have an air gap in order to avoid bulky dimensions and to make the ratios of effective resistances to their reactances as small as possible. In this paper the length of the air gap is obtained theoretically by the help of complex permeability, and some relations for the design of the iron-cored inductance are derived taking the leakage into account.

R385.—The Keying of Valve Transmitters.—W. Ditcham. (*E.W. & W.E.*, 3, 36, pp. 526-531, September, 1926.)

R386.—Design of Wave Filter for Absorption of Irregularities of Direct Current Pressure Wave and Application of Aluminium Cell Condenser.—T. Ishiyama. (*Journ. Inst. Elect. Eng., Japan*, August, 1926, pp. 908-935.)

R388.—A Method of Obtaining the Braun Tube Figures in Rectangular Co-ordinates.—I. Yamamoto and K. Morita. (*Journ. Inst. Elect. Eng., Japan*, August, 1926, pp. 945-959.)

R400.—SYSTEMS OF WORKING.

R420.—On the Wireless Beams of Short Electric Waves (III.).—S. Uda. (*Journ. Inst. Elect. Eng., Japan*, July, 1926, pp. 712-724.)

Further experiments in directional transmission on a wavelength of 4.4 metres are described.

According to the author's experience a parabolic reflector is not necessary; a reflector consisting of vertical metal rods arranged along a polygonal base line drawn on the ground is equally effective. The rods were spaced 1.1 m. apart and tuned to a half wavelength. When 19 reflector rods were used and the aperture of the reflector nearly equalled 2.7 wavelength, the radiated power was confined almost to an angle of 30°. The paper also gives various types of directive antennæ, for all of which the field measurements were carried out.

R440.—THE REMOTE CONTROL OF BROADCAST RECEIVERS.—P. Hole. (*Electrical Review*, 99, pp. 339-340, 27th August, 1926.)

The article is discussed by F. Duffield in the issue of 3rd September, p. 402, to which P. Hole replies in the issue of 10th September, p. 443.

R487.—DER NEUE DREHSPULEN-SCHNELLSCHREIBER VON SIEMENS AND HALSKE. (New rotating coil high-speed printer by Siemens and Halske.)—A. Jipp. (*Zeitschrift für Hochfrequenz.*, 27, 6, pp. 175-177.

Description of a new telegraph receiver for which the highest speed yet reached is claimed, also the ability to distinguish between signal and disturbance currents.

Illustrations and specimen records are shown.

R500.—APPLICATIONS AND USES.

R536.—WIRELESS NEWS. (*Electrician*, 97, p. 370, 24th September, 1926.)

Mention is made of recent experiments in the Limburg coal mines when intelligible signals were sent and received by wireless telegraphy through the earth. The wavelengths employed varied from 30 to 50 metres, and it was found that communication was more satisfactory in a lateral than in a perpendicular direction.

R570.—TELEARCHICS.—A. Castellain. (*Wireless World*, 19, pp. 255-262, 25th August, 1926.)

The first of a series of articles dealing with the subject of distant control from both the theoretical and practical point of view.

R580.—WIRELESS AND THE GRAMOPHONE.—A. Dinsdale. (*Wireless World*, 19, pp. 399-405, 15th September, 1926.)

An account of the application of electrical methods to gramophone recording and reproduction.

R582.—PICTURE TELEGRAPHY AS A METHOD OF INVESTIGATING THE PROPAGATION OF SHORT WAVES.—H. Rukop. (*Elektrische Nachrichten-Technik*, 3, 8, pp. 316-318.)

See Abstract under R113.

R592.2.—OVERSEAS RADIO SERVICES.—C. Crawley. (*Wireless World*, 19, pp. 305-310, 1st September, 1926.)

Notes on British stations engaged on imperial and foreign communication.

R600.—STATIONS: DESIGN, OPERATION AND MANAGEMENT.

R616.5.—RADIO-WIEN.—G. W. O. Howe. (*E.W.& W.E.*, 3, 36, pp. 533-543, September, 1926.)

Description of the new high-power Vienna broadcasting station.

R800.—NON-RADIO SUBJECTS.

R000.—THE B.E.S.A. GLOSSARY.—C. L. Fortescue. (*Electrical Review*, 99, p. 523, 24th September, 1926.)

A discussion of the points at issue between Prof. Howe and the B.E.S.A. Panels, showing that Prof. Howe's sweeping criticisms may not be as fully justified as might at first sight appear.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

R000.—SENFADENO ĜENERALE.

R050.—RESUMOJ KAJ ALUDOJ.

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

R064.—LA NACIA RADIO-EKSPOZICIO.

Revuo pri la konstrueroj kaj akcesoraoj montritaj ĉe la lastatempa Nacia Radio-Ekspozicio ĉe Olympia, Londono. La temoj pritraktitaj estas Novaj Valvoj, Plenondaj Gas-Dissarĝaj Rektifikatoroj, Alternkurentaj Bateriaj Elimiloj, Havigo de Filamenta Provizo el Alterna Kurento, Kontinukurentaj Potencialaj Dividiloj, Supersonaj Heterodinaj Desegnoj, Alt-tensiaj Akumulatoroj, Laŭtparoliloj, Simplaj Provaj Ekipaĵoj, kaj Diversaj Ĝeneralaj Desegnoj. En la sekcio pri Novaj Valvoj, oni donas utilajn informojn pri la konstantoj de la novaj tipoj. La artikolo estas bone ilustrita per fotografaĵoj de multaj el la partoj kaj akcesoraĵoj priskribitaj en la teksto.

R100.—ĜENERALAJ PRINCIPOJ KAJ TEORIO.

R132.—Ekzameno de la Proprecoj de Aŭdfrekvencaj Amplifikatoroj pere de la Duddell'a Oscilografo.—W. Baggally.

La aŭtoro priskribas eksperimentojn pri la speco kaj grandeco de ondforma distordo produktita de aŭdfrekvencaj transformatore-kuplitaj amplifikatoroj. Unue oni mallonge priskribas la Duddell'an Oscilografon uzitan por la eksperimentoj. La mezuroj estis faritaj je 480 cikloj, kaj estis desegnitaj por liveri informon pri (1) Indiko pri la speco kaj grandeco de ondforma distordo produktita de la amplifikatoro sub laboraj kondiĉoj, (2) La tuta volta amplifo obtenita per difinitaj elmetaj kondiĉoj, (3) La pinta tensio, ĉe la unua krado, kaj la maksimuma permesita tensio konforme al foresto de troŝarĝo kaj rezulta distordo, (4) La plej bonaj funkciaj alĝustigoj por la amplifikatoro. Oscilogramoj obtenitaj sub diversaj kondiĉoj estas reproduktitaj kaj ĝeneralaj konkludoj tiritaj el la eksperimentaj rezultoj.

R200.—MEZUROJ KAJ NORMOJ.

R213.—Normigo de Mallongegaj Ondolongoj. —F. Aughtie.

Se ondometro kun skalo de 100-200 metroj estas uzita por la normigo per harmonikoj de ege mallonga ondo, ekzemple, 5- aŭ 6-metra, oni renkontas malfacilecon eltrovi la ĝustan valoron de la harmoniko efektive koncernita. En la nuna artikolo, tabula metodo estas priskribita, per kio tiu-ĉi harmoniko estas facile trovita, kaj la mallonga ondlongo decidita kun multa precizeco.

R251.—Tre Sentema Valva Galvanometro.—Prof. G. W. O. Howe.

Priskribo, kun skizo, estas donita de aranĝo de kvar-elektroda valvo kiel valva galvanometro. Rezistanca retro-kuplo estas uzita, posedanta la ekvivalentan efikon pligrandigi la krutecon de la valva karakterizo ĝis dekoble de ĝia originala valoro.

R261.—Termiona Voltmetro.—W. B. Medlam & U. A. Oschwald.

La artikolo pritraktas la ĝeneralan funkciadon de valvaj voltmetroj, kaj diskutas ilian agadon laŭ la vidpunktoj de (*a*) Sentemeco kaj skalo, (*b*) Ebla frekvenca eraro, (*c*) Ondforma Eraro, (*d*) Enmeta Ŝarĝo, (*e*) Stabileco de Normigo. En la nuna parto, la tipoj traktitaj estas de la modelo "Moullin," uzantaj anodkurvan kaj amasigitan kradan rektifadon respektive. La diversaj rubrikoj estas bone ilustritaj per eksperimentaj rezultoj. Oni montras, ke la eraroj ondformaj estas pligrandaj ĉe la plilasta tipo, kiel ankaŭ potencperdoj. La artikolo estas daŭrigota.

R290.—Metodo Normigi Mikrofonojn kaj Laŭtparolilojn.—H. J. Round.

Metodo estas priskribita por normigi mikrofonon. Produktilo de muzika tono funkcias tra sendistorda amplifikatoro sur metalan blokon funkciigantan la mikrofonon kaj ĝian asociitan amplifikatoron. Glitaj voltmetroj provizas por la determino de mikrofona enmeto kaj elmeto. Diagramo de la aparato estas presita, kun priskribo de la muziktona produktilo kaj amplifikatoro. Tio-ĉi uzas du radio-frekvencajn oscilatorojn por produkti heterodinajn batojn de la bezonita aŭdebla frekvenco.

R300.—APARATO KAJ EKIPAĴO.

R355.51.—Alt-Tensia Rektifikatoro por Malalt-Potenca Sendilo.—T. S. Skeet.

Priskribo de transformatoro kaj sinkrona rektifikatoro (kun komutaj kaj glatigaj aranĝoj), funkcianta per provizo de 200 voltoj, 50 cikloj Alterna Kurento, kaj liveranta glatan Kontinukurenton je ĉirkaŭ 620 voltoj kaj ĝis 60 miliampermetroj, por malaltpotenca sendilo. Cirkvita diagramo kaj fotografaj ilustraĵoj estas donitaj, kaj la eksperimenta disvolviĝo de la aparato priskribita por la bono de aliaj konstruistoj.

R400.—APLIKOJ KAJ UZOJ.

R401.—Lastatempaj Progresoj je Mallongonda Senfadena Telegrafio.—H. Rukop. Traduko el la *Telefunken Zeitung* de Januaro 1926A.

En la nuna parto la aŭtoro unue diskutas la antŭan historion de long-distanca interkomunikado, kaj montras ke la optimuma ondlongo, por, ekzemple, Transatlantika funkciado, estis kalkulita kaj eksperimente trovita esti 10,000—20,000 metroj. Li tiam diskutas la neatenditajn distancojn, kiujn oni trovis eblaj per mallongaj ondoj, kaj montras la ekziston de plua optimumo ĉe la mallongonda aro. Eksperimentoj pri la temo estas mallonge priskribitaj. Li poste diskutas kaj ilustras la distribuon de riceva intenseco ĉirkaŭ mallongonda sendilo, kaj transpasas al la funkcio de la ionizita tavolo kaj la diversaj teorioj pri ĝia funkciado, kiuj estas sugestitaj. La klarigo nun plejparte akceptita kiel ĝusta, estas, ke kurbigo de la radioj okazas, kaj ke ĉi tiu kurbiĝo estas efektivigita pro tio, ke la efektiva dielektrika konstanto estas malgrandigita ĉe la supraj tavoloj per kondukiveco, kaj la rapideco de propagado konsekvence pligrandigita. La artikolo estas daŭrigota.

R431.—Noto pri Sistemo de Atmosferaĵaj Eliminoj.—S. Butterworth.

La aŭtoro pritraktas pri lastatempa patenta specifiko de M. L. Levy, priskribanta cirkviton por elimini atmosferaĵojn aŭ alian similan ŝokan ekscitigon. La cirkvito estas unu, ĉe kiu la aŭtoro jam antaŭe eksperimentis, kaj kiu, laŭ opinio lia, ne kapablas je tia elimino. La funkcio de la cirkvito estas diskutita kaj esprimoj derivitaj, laŭ kiuj oni montras, ke la sistemo pligrandigas anstataŭ malgrandigi la relativan gravecon de atmosferaj perturboj.

R800.—NE-RADIAJ TEMOJ.

R510.—Matematiko por Senfadenaj Komencantoj.—F. M. Colebrook.

La nuna parto pritraktas Logaritmojn. La temo estas dividita laŭ la rubrikoj, (A) Antaŭa Noto pri Funkcioj kaj ilia Grafika Reprezentado, (B) La Elmontra Funkcio, (C) Logaritmoj. Naturaj kaj Ordinaraj Logaritmoj estas pritraktitaj. kun ekzemploj.

Correspondence.

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

The Properties of Audio-Frequency Amplifiers.

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

SIR,—As one who has from time to time experimented with L.F. transformers, more particularly in reflex sets, I found Mr. Baggally's article entitled "An Examination of the Properties of Audio-Frequency Amplifiers by means of the Duddell Oscillograph," in the October number of *E.W.& W.E.*, very interesting.

One is immediately struck by the small overall voltage amplification obtained and I cannot help thinking that a very serious degree of reverse reaction must be present. In support of this I would mention that I have found a demonstrable degree of interaction between two transformers of the make used by Mr. Baggally at separation distances up to 4 ft. 6 in. if their core plates are in the same or parallel planes. I also found that by tipping them, after the fashion of the H.F. transformers in a Neutrodyne set, it was possible to bring them so close together as to be almost touching without appreciable interaction occurring. This method of mounting is not, however, generally convenient and I now always have at least one of a pair of transformers iron shrouded.

As a contributory cause of the oscillation experienced under certain conditions, I would suggest that an appreciable amount of capacity reaction might be obtained between the oil-immersed elements of the Duddell Oscillograph since no earths or "anchor points" are shown in the diagrams.

The spurious oscillation apparent in Oscillogram 6 is extremely interesting as it shows the type of voltage wave applied to the grid of a valve in a reflex set. Such a wave is inherently asymmetrical as in this oscillogram. The fact that, in the case of this amplifier, the modulations in H.F. wave are in step with the L.F. wave, indicates that an interference is taking place between the two waves, due to varying slope in that part of the characteristic of one or more valves within the set traversed by them. In a reflex set such interference will produce distortion and under certain conditions a characteristic howl (of which more anon).

Wimbledon. D. KINGSBURY.

Plate-current, Plate-voltage Characteristics.

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

SIR,—Your correspondent, Mr. I. A. J. Duff, in pointing out the erroneous reasoning in Mr. E. Green's article in your August issue, entitled as above, himself falls into error in the statements :—

1. ". . . the greater the voltage across the primary the greater the overall amplification. The greater the primary impedance the greater the fraction of μ that is utilised"; and

2. ". . . . the main law holds good that the transformer should be of the utmost possible impedance and not of equal impedance with the valve as it would have to be for maximum power amplification."

The notion that transformer primary impedance should be equal to that of the valve is *not* an error, and should therefore not be "laid to rest." When a valve is utilised with an anode pure resistance choke or tuned circuit and the potential for operating the next valve is taken, via a condenser, from the anode itself, then it is true that the greater the anode impedance, the greater is the fraction of μ that is utilised. In this case μ, the voltage amplification factor of the valve, is a measure of the ideally obtainable step-up.

When, however, the primary of a transformer constitutes the anode impedance, whether that transformer be an unloaded (nearly) intervalve transformer, a loaded telephone (loud-speaker) transformer, or a loud speaker itself (considered as a transformer), then it is true in a general way that for maximum activity in the primary its impedance should be equal to that (*i.e.*, to the anode A.C. resistance) of the valve.

We say "in a general way" because such a law is meaningless in the exact sense unless the exact manner is specified in which each variable upon which it depends is made to vary,

We use the word "activity" as a name for the quantity measured by volts × amperes, just as power is a name for the quantity measured by watts. "Activity" embraces its particular case of power.

It is not possible in a letter fully to explain this matter—an article on the subject would be necessary. However, when the laws of variation are such, for instance, that the effective resistance R of the winding, the inductance L, and therefore also the reactance X at a given frequency, vary proportionally, as the fineness of the winding is increased, not only do we get the maximum power, viz.: I^2R watts, when the winding impedance is equal to that of the valve, but also maximum "activity," viz.: $I^2\sqrt{R^2+X^2}$ volt-amperes, and therefore also maximum $I^2\times$ effect (wattless volt-amperes). And in this case it is $\mu\times m$, the mutual conductance, and not μ alone that is a measure of the ideal activity amplification.

Though strict proportionality of reactance to resistance would, at any rate if iron is present, never obtain, it does so sufficiently nearly to serve as a basis upon which to build up an approximate law, such as the one in question. It is a fair approximation, not incorrect in principle. Further, it is nearly correct with windings of various degrees of fineness in a given winding space that either quantity, resistance or reactance at a given frequency, is proportional to the square of the number of turns. Hence the I^2X or wattless volt-ampere effect is proportional to the square of the magnetising ampere-turns. At once it follows that the maximum alternating core-flux and therefore the maximum voltage of a given secondary occurs when the impedance of the primary is equal to that of the valve.

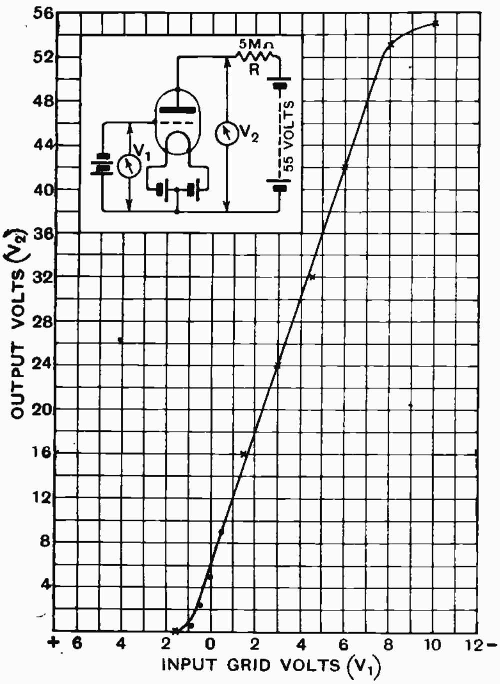
There are various reasons, which cannot be gone into here, why the particular frequency for which the primary impedance of an audio intervalve transformer should be made equal to that of the valve, should be one quite low in the audio scale, after which the primary should be tuned to a low audio-frequency by the addition of a small parallel condenser, as is done in one of the latest and best transformers to be placed on the market; but it is an error of principle to say that because we want volt-amplification, the *primary* of the transformer of the valve-transformer combination must be of the highest possible impedance.

Derby. E. FOWLER CLARK, B.Sc., B.A., A.M.I.E.E.

Resistance Amplification.

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

SIR,—The curve enclosed relates to an earlier experiment with the circuit shown, considerably better results have since been obtained with another



type of valve. The readings denoted by × were taken on an electrostatic voltmeter while those with the circle were taken on a Moullin type voltmeter.

Great care was taken to verify the readings especially those at the extreme ends.

The circuit is by no means a freak one, but it is capable of giving results which compare very favourably indeed with the best type of L.F. transformer.

Your correspondent, Mr. Duff, mentions two instances where the megohm resistances are employed in resistance-coupled amplifiers.

The writer has an L.F. resistance-coupled amplifier with an anode resistance of 5 megohms which has been in daily use since 1923. This resistance is composed of a strip of leatheroid about 0.1 in. broad and 2 in. long, rubbed over with a lead pencil and its surface polished. This strip is inserted in a piece of leatheroid and fitted with brass clamps at either end. The resistance is connected to a 50-volt H.T. supply. The coupling condenser is 0.00002μF. Reaction is not employed owing to the extremely low anode current.

A grid-leak is not used but a suitable (slightly neg.) grid bias is automatically maintained by the grid condenser alone. The valves used at present are a DE3b and a B.T.H. B6, the latter working with 130 volts on plate and the former with 50 volts.

The following particulars give some indication of the strength of reception obtained with the stage at a distance of about 4 miles from local station.

A neon lamp was connected between anode of last valve and the H.T. neg.-terminal. This lamp glowed with a continuous flicker while receiving local broadcast.

This lamp was tested (keeping polarity the same) and found to strike up at 175 volts. Thus the voltage across the 100-volt battery and loud-speaker in series exceeded 175 volts. The battery volts were tested by means of an electrostatic voltmeter.

The fact that the original resistance is still in use speaks well for the permanency of a graphite resistance.

Glasgow. A. ROBERTSON.

Fading.

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

SIR,—I think that the statement of Dr. Oliver Hall, that "Fading is an Irregular Phenomenon," is quite correct, at any rate, such has been my experience, covering several years of marine operating in various parts of the world. I am of the opinion that no curves can be plotted, or formulæ deduced, to cover the "mystery" of fading. Certainly not for any great expanse of the globe, as fading in different parts of the earth is no doubt caused by various reasons. Hence, any set of rules or curves which may be applied quite successfully in, say, the British Isles, would be totally inapplicable in any other part of the earth, owing to the great difference in local conditions, governed by weather conditions, temperatures, rarefication of the atmosphere, also due to physical features of the earth such as the presence of conductors, iron ore deposits, etc. In support of the latter statement let me relate, on a voyage up Spencer Gulf in South Australia, in daylight, a strong wind sprang up, increasing to gale force, but with no sign of rain. On touching the earthing switch I received quite a shock, and found that a spark of half an inch in length could be obtained from aerial to earth owing to the former being charged with static electricity. These conditions prevailed for half an hour, then gradually ceased. During this time the signals from Adelaide Radio, VIA, faded out completely, though the distance was only about 20 miles. This "electrical storm" was due, in my opinion, to the presence of vast deposits of iron ore in the locality, both on land and under the sea. In this country the atmosphere is rarefied to a much greater extent than north of the tropics, and to this is due the greater distances over which reception may be had with equivalent apparatus. We are troubled greatly with fading towards the hinterland of Australia particularly on the lower broadcast band, 300 to 400 metres. But as yet I have heard of no fading effects being noticed over the Pacific Ocean, which, I think, goes to prove that the physical features of the land are the cause of many instances of fading, owing to the varying condition of the atmosphere, due to alternate heat and rain. Why is it that often a shower of rain will increase the range and clearness of reception of signals?

In conclusion, I would say that, were observations made simultaneously in different parts of the world, the data so obtained would go to prove that fading cannot be reckoned with as a regular phenomenon, but will be found to be due to the causes above stated.

A. C. Jackson (Senior Operator), Station 4QG.

Brisbane, Australia.

The Sodion Tube.

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

Sir,—I noticed in the August, 1926, issue of *E.W. & W.E.* a discussion by Mr. G. G. Blake in regard to the "Sodion" tube and Captain Eckersley's reply. I would like to say for Mr. Blake's information that the "Sodion" never made a startling success in this country. The tube was theoretically a wonderful thing, but it failed to measure up in practice. True, it did detect and amplify and did not oscillate but there were faults which I cannot explain here. To Captain Eckersley I would say in reply to his statement that he has "never met a valve which will amplify but not oscillate" that a few years ago the statement was made that a crystal could not be made oscillate.

I also noticed that there was considerable discussion about power supply devices. There has recently been brought out in this country a new filamentless rectifier tube called the "Raytheon." Several of the better manufacturers of transformers and like accessories in this country are making the supplementary parts necessary to assemble a complete "B" battery eliminator. The complete units are excellent—no hum, wide range of voltages obtainable simultaneously, and a high current output.

If any of your readers care to know more about this or any other American radio product, if they will write me I will be very glad to give them any information I can.

Wilbur C. Brown.

Holtville, Cal.

A Very Sensitive Valve Galvanometer.

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

Sir,—With reference to the article on "A Very Sensitive Valve Galvanometer" it can be remarked that the circuit described is not a new one. An exhaustive description of it was given by me nearly two years ago in the Dutch review *Radio Nieuws*.* This article also mentions the result of tests in which the slope of the characteristic was increased to 200mA/volt over a range of 0.0001 volt. With an output resistance of only 2,000 ohms an effective voltage amplification of 400 was obtained over that range. The circuit was also employed as an amplifier of alternating currents, for which it was pointed out that capacity and still more inductance must be carefully avoided in order to obtain satisfactory results.

The reader, who wishes to obtain more particulars as to the behaviour of the scheme, can refer to Mr. Turner's article on the Kallirotron, which is an equivalent circuit obtaining single grid valves.†

Rijswijk Z. H., Holland. H. O. Roosenstein.

* *Radio Nieuws*, February, 1925.
† *Radio Review*, 1, 317, 1920.

Books Received.

"Dictionary of Wireless Technical Terms."

Wireless experimenters, students and amateurs will welcome the very serviceable and compact little Dictionary of Wireless Technical Terms which has been compiled by Mr. S. O. Pearson, B.Sc., A.M.I.E.E., and is published by Messrs. Iliffe & Sons, Ltd., for the very modest sum of 2s. net or 2s. 3d. post free.

Nearly everyone, in his reading, comes across terms and expressions of which he does not know the meaning or of which he desires an exact definition, and this volume, which can be carried in the pocket, affords a convenient source of ready reference. Ample definitions are given of all technical terms commonly encountered and highly technical language has been avoided as far as possible. An extended system of cross-references makes it possible for the information to be understood by those possessing the minimum knowledge of wireless theory and practice.

The book, which contains 254 pages, is well illustrated, and, wherever necessary, an explanatory diagram has been added to a definition to enable it to be understood more easily.

Amateur Long-Distance Work.

[R545.009.2

EVER since long distance amateur work started, we have been accustomed to hearing about this time every year remarks to the effect that the "real DX season" was about to start. Most of us, however, thought that last autumn was the last occasion on which this annual remark could be made with any degree of truth; that, in fact, the use of wavelengths of about 40 metres was going practically to abolish the seasonal variations in DX conditions. This opinion has been justified to the extent that touch has been kept up with most of the world right through the year, but the amount of work done during the summer was very small indeed compared with that normally done in the winter, and this is probably not entirely due to the smaller number of stations working in the summer. It seems that conditions are getting decidedly better, and certainly more stations are working now, so we may say, once again, that the "real DX season" is about to start.

Everyone will agree that it is being well started by the "QRP week" organised by the Radio Society of Great Britain. During this (the first week in November) all stations are asked to limit their power to 5 watts input on the 45-metre band during the usual amateur working hours, and to keep an exact log of all working. They are further asked to make sure that the note of their transmissions is "pure D.C." This last rule is intended to prevent unnecessary jamming, but it has a further importance in that differences in reported signal strength will not be due to possible differences in note-readability.

Apart from the limitation of power to 5 watts, the anode voltage used must not exceed 220 volts, but it is difficult to see any justification for this rule. Five watts is a perfectly definite power, and to rule the voltage and current which must comprise it seems a definite bar to research, though from the purely competitive point of view it doubtless makes the tests fairer for those who only have 220 volts available.

Amateurs in all other countries are being asked to co-operate, and so the tests should produce some useful data.

A point which is worthy of mention at the present juncture is the extremely low standard of operating which prevails at present on the amateur waves. At the time of the early work with America, and even later, amateurs took some pride in a good "fist" and good operating procedure. Now, unfortunately, most of the older stations are not working, and those who have taken their places, though good stations technically, are operated in such a way as to make them an absolute nuisance to others, besides greatly prejudicing their chances of obtaining the reports they so often ask for. In view of the present state of affairs we may be forgiven if we repeat the "procedure" of good operating. To call a station, send his call-sign three times, then the "intermediate," then your own call-sign three times, and repeat the whole three times, then go over and listen. Many operators have great difficulty in believing that this is enough, but it is much more likely to get a reply than 40 calls, three intermediates and one signature (a case heard recently from a British station), and it does not occupy the ether so long. If a reply is not obtained the call can be repeated after about 20 seconds listening, and nothing is lost, but if you do get a reply (as is probable) or you find the other station already busy, the rest of a long call is saved as well as the patience of others listening.

When in touch with a station, send each of your words once unless asked to send each twice. It has become much too common to send each twice. Finally, never send faster than you can send accurately. It is not a crime to be a slow operator, but it is a crime to pretend to be a faster one than you are, and some of the operating now heard is quite unreadable. These references to operating are made at the request of a number of amateurs who have noticed the great decline in operating standard during the past year or so. H. N. R.

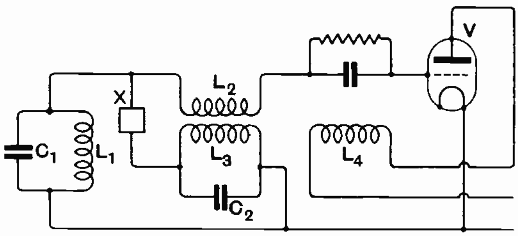
Some Recent Patents. [R008

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

A NEUTRALISATION SCHEME.

(*Application date, 9th July, 1925, and 20th January, 1926. No.* 257,708.)

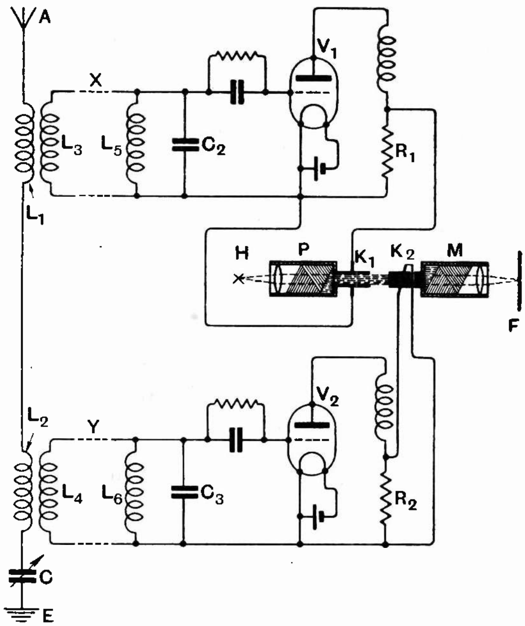
A form of neutralised or balanced circuit is described by the Igranic Electric Company, Limited, and P. W. Willans in the above British Patent. The arrangement is somewhat similar to the neutralised circuit which was described in last month's issue of *E.W. & W.E.* Essentially, the invention consists in connecting the primary winding of the neutralising transformer in series with an impedance across a tuned input circuit. Several arrangements are described in the specification one of which is illustrated by the accompanying diagram. A tuned input circuit comprises an inductance L_1 and capacity C_1, which, incidentally is referred to in the specification as an auto-transformer, having both its primary and secondary windings constituted by one and the same coil. The neutralising transformer consists of an inductance L_2 and an inductance L_3 tuned by a condenser C_2. The winding L_2 is connected between the grid of the valve V and the top end of the inductance L_1, the other winding of the transformer L_3, tuned by the condenser C_2, being connected between the filament and the top end of the inductance L_1 through an impedance X, the nature of which is not mentioned in the specification. A reaction coil L_4, included in the anode circuit, is shown coupled to the inductance L_3. It is stated that the system neutralises either the inductative or capacitative coupling.



ATMOSPHERIC ELIMINATION.

(*Convention date (Germany), 23rd May,* 1925. *No.* 252,409.)

A rather ingenious system of atmospheric elimination utilising the principle of the Kerr cell is described in the above British Patent by Telefunken Gesellschaft für Drahtlose Telegraphie. The system consists in connecting the receiving aerial to two slightly detuned circuits, the effects of which balance out when both tuned circuits are shock excited, but do not balance out when they are differentially affected by an incoming signal. The accompanying illustration should make the invention quite clear. Here it will be seen that the aerial circuit comprises an aerial, an earth connection and two inductances L_1 and L_2, the whole being tuned by a condenser C. Potentials set up across the inductance L_1 and L_2 are transferred by inductances L_3 and L_4 through lines X and Y, to two tuned circuits L_5 C_2 and L_6 C_3, the two circuits being tuned one slightly above and the other slightly below the desired frequency of reception. These two tuned circuits are connected to rectifying valves V_1 and V_2, the anode circuits of which are shown to contain inductances

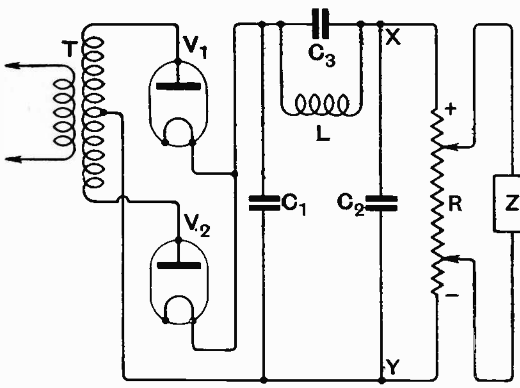


and resistances, the rectified low frequency potentials being taken across two resistances R_1 and R_2 respectively. The potentials across the resistance R_1 are connected to the two plates of the Kerr cell condenser K_1, while those across the resistance R_2 are taken to the two plates of the second cell K_2. The two cells K_1 and K_2 are arranged so that the planes of the condenser plates are at right angles. A source of light H is directed by a lens and polarising prisms P, the polarised light passing longitudinally through the nitrobenzine or similar dielectric in the first cell K_1. The light then passes through the dielectric of the second cell K_2, and is finally taken through an analyser M, where the light impinges upon a moving sensitised film F. The arrangement functions in the following manner: If the aerial system is affected by an atmospheric discharge the two tuned circuits L_5 C_2 and L_6 C_3 are shock excited at their natural frequency, substantially equal voltages being produced between the grids and filaments of the two valves V_1 and V_2. These voltages are amplified and passed on to the two cells K_1 and K_2. A given voltage across the electrodes of the cell K_1 will rotate the plane of polarisation through a given angle. A similar voltage, however, accompanied by an equal change of the plane of polarisation, will be obtained from the other valve system. However, since the plane of the two plates of the two cells are at right angles, the two shifts will cancel out and no light will pass through the analyser. In other words, the effect of an atmospheric discharge upon the receiving system will not influence the signal recorded at all. However, in the case of received desired signals, unequal voltages will be obtained from the two rectifying valves, and the shift produced by one Kerr cell will not be counteracted by the shift produced by the other cell, with the result that the light falling on the moving film will vary in intensity, thereby faithfully recording the signal.

VOLTAGE REGULATION OF MAINS UNITS.

(*Convention date* (*U.S.A.*), 6*th February*, 1925. *No.* 247,213.)

One of the chief troubles which is experienced in the utilisation of valve rectifiers for obtaining anode current supply from the mains lies in the fact that the voltage is apt to change very considerably with the variation of load taken by the receiver. A scheme which overcomes this difficulty is claimed by Marconi's Wireless Telegraph Company and F. H. Kroger in the above British Patent, which should be quite clear by reference to the accompanying illustration. A transformer T provides the high voltage for the two rectifying valves

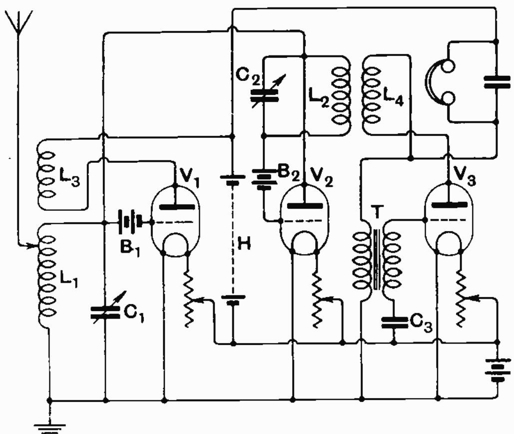


V_1 and V_2, the valves being used for full wave rectification in conjunction with a centre tap on the secondary of the transformer. The output of the rectifier is taken through a form of π filter comprising two condensers C_1 and C_2, on either side of an inductance L shunted by a capacity C_3. Normally, the load, such as the current used by a receiving circuit, is taken across the points X and Y, and is represented diagrammatically as Z. According to the invention, however, a resistance R is connected across the points X and Y, of such a value that the current flowing through it is very considerably greater than the current flowing in the load circuit. This results, of course, in any small variation in the load current making very little difference to the joint impedance of the circuits Z and R. In other words, the voltage across R, or the part which is tapped off in circuit, remains substantially constant.

A PECULIAR AMPLIFIER.

(*Application date*, 21*st March*, 1925. *No*. 256,998.)

A very peculiar amplifying circuit consisting of a three-valve arrangement which is claimed to have the amplification of a normal five or six

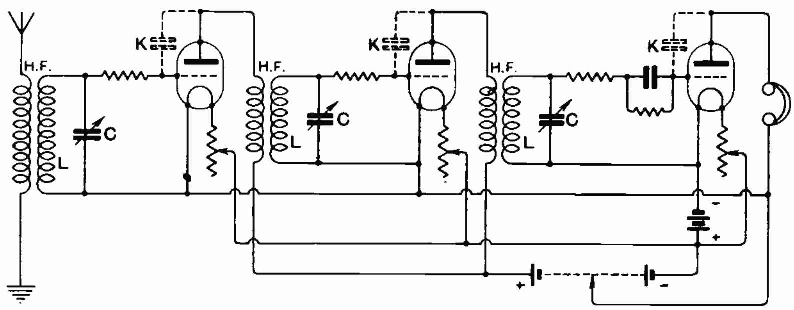


valve receiver is described in the above British Patent by J. Wilcockson and H. W. Roberts. It is stated that various valves acting in a reflex manner amplify both radio and audio frequencies. It will be seen that a tuned circuit L_1 C_1, provided with an aerial and earth, is connected between the grid and filament of the first valve V_1 through a negative bias battery B_1. The anode circuit of the valve contains a reaction coil L_3, coupled to the inductance L_1. Another circuit L_2 C_2 is connected between the upper end of the circuit L_1 C_1 and the grid of the valve V_2, again through a bias battery B_2, the other end of the tuned circuit being connected to the anode. The inductance L_2 is coupled to another inductance L_4, which is in series with the telephones and the anode of the valve V_3. The telephones are also in series with one winding of a transformer T, the other end of which is connected to earth, and the secondary of the transformer is connected between the grid of the last valve and to earth through a condenser C_3. One point which we notice is that the high tension battery H appears to be short-circuited to earth through the telephones and one winding of the transformer T. The specification also stated that low frequency potentials are induced from the inductance L_3 into the aerial tuning coil L_1. We believe, however, that the circuit is similar to that used in the "Retrosonic" receiver. Readers who are interested in the arrangement are referred to the specification, where they will find full details concerning the actual values of the coils and condensers.

STABILISING AMPLIFIERS.

(*Convention date* (*U.S.A.*), *26th July*, 1924. *No.* 237,553.)

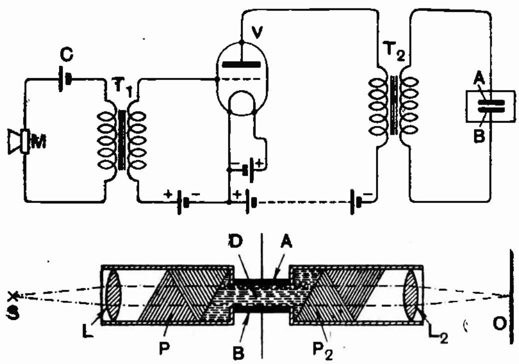
A resistance method of stabilising high frequency amplifiers is described in the above British Patent by Atwater Kent Manufacturing Company and A. D. Silva. Resistances have previously been employed for stabilising purposes in multivalve amplifiers by including them in the anode circuit, either in series with the tuned circuit or an impedance, or across the tuned circuit so as to increase the damping, and thereby reduce the voltage variation across the circuit. While stabilising the amplifier this system materially lowers the amplification, and also very considerably decreases the selectivity. According to this invention, however, stabilisation is obtained by the inclusion of resistances in series with the grids and tuned input circuits of the valves. The accompanying illustration should make the invention quite clear. A series of radio frequency transformers (H.F.) are used to couple together the three valves. The secondaries of the transformers comprise inductances L tuned by condensers C and connected between the filaments and the grids through the resistance. The inherent capacity coupling between the anodes and grids is shown dotted at K. Thus it will be obvious that if any capacity effect be transferred from the anode circuit of the valve to the critically tuned input circuit LC the current has to flow through the resistance. The resistances are made of such a value that the transference of voltage is insufficient to cause the valve to generate continuous oscillations. Since the resistances are in series with the grids they do not have any very material effect upon the sharpness of tuning, but, of course, tend to lower the overall amplification.



THE ELECTRICAL CONTROL OF LIGHT.

(*Convention date, 20th June*, 1924. *No.* 235,857.)

The above British Patent, No. 235,857, granted to Dr. A. Karolus, describes a method of electrically controlling a beam of light which can be applied to wireless television or for controlling purposes. The invention really consists in the utilisation of a Kerr cell. The accompanying diagram illustrates the arrangement of the Kerr cell and its associated electrical circuit. The Kerr cell consists essentially of an electrostatic condenser having some liquid or colloidal dielectric through which polarised light is passed. Thus a source of light S impinges upon the polarising arrangement such as a nicol prism device, consisting of a double convex lens L and two prisms P. The electrostatic condenser, comprising the Kerr cell, consists of two plates A and B having a dielectric D, such, for example, as nitrobenzine. A similar prism arrangement P_2 and lens L_2 acts as an analyser concentrating the light upon the screen O. Under the influence of a voltage between the two plates A and B the plane of polarisation of the light is altered thereby causing the beam of



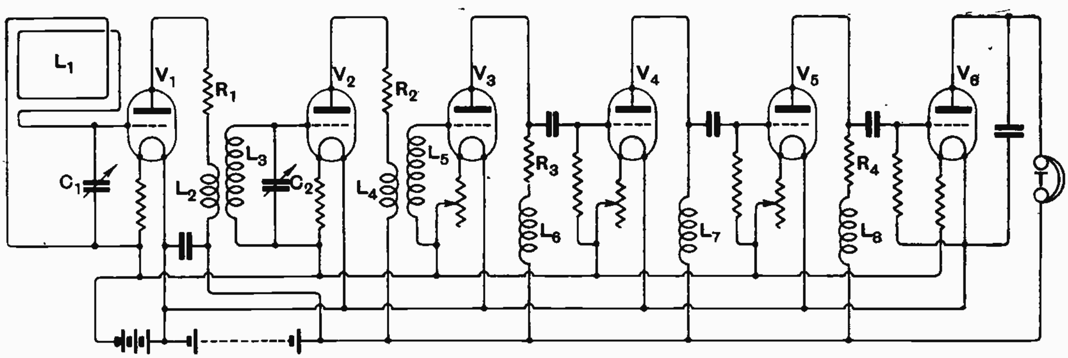
light to change in intensity. Since the rotation of the plane of polarisation occurs simultaneously with variation of voltage that is, there is no lag, the device is readily applicable to television purposes.

The illustration shows one method of controlling the light simply by a varying source of current produced by the microphone *M*, and a battery *C* connected through a transformer T_1 to the grid-filament circuit of a valve, the output of which contains another transformer T_2. Voltages produced across the secondary of this transformer are applied directly to the plates *A* and *B* of the Kerr cell, thereby controlling the light beam as previously mentioned. The specification gives details of several methods of utilising the system.

ANOTHER STABILISED AMPLIFIER.

(*Application date*, 20*th October*, 1925. *No.* 257,122.)

Another form of resistance stabilised amplifier is described by L. L. Jones in the above British Patent. Essentially the invention consists in providing a critically tuned input circuit and an untuned anode circuit, the natural frequency of which is higher than the highest frequency to which the tuned circuit is to be tuned, further stabilisation being obtained where required by the inclusion of series resistances. The accompanying diagram, which illustrates one arrangement of the invention, shows five cascaded valves with the sixth valve used as a detector. The aerial consists of a frame L_1, tuned by a capacity C_1, connected between the grid and filament of the first valve. The anode circuit contains an inductance L_2, which is coupled to an inductance L_3 tuned by a condenser C_2. The anode circuit also contains a resistance R_1 which is of the order of 1,000 ohms. The output of this circuit is connected through another inductance L_4 connected to an untuned inductance L_5, connected between the grid and filament of the next valve, another resistance R_2 being connected in series with the anode inductance L_4. The resistance, in this case, is of the order of 3,000 to 5,000 ohms. The successive stages are coupled by inductances L_6, L_7 and L_8, two of which are in series with resistances R_3 and R_4 respectively, again of the order of 3,000 to 5,000 ohms.



A REFLEX RECEIVER.

(*Application date*, 12*th May*, 1925. *No.* 256,688.)

The above British Patent, granted to A. G. Benstead and Rotax (Motor Accessories) Limited, described two reflex circuits, one of which is shown in the accompanying illustration. The anode circuit of the first valve contains a high frequency transformer *H*, the secondary of which is tuned by a condenser C_2, and is connected to the grid circuit of the second valve V_2. The anode circuit of this valve includes a low frequency transformer *T*, the secondary of which is connected to the grid circuit of the first valve V_1. The anode circuit of the first valve V_1 constitutes a frame aerial *F* tuned by a variable condenser C_1, the frame aerial *F* being inductively coupled to an open aerial *A*. The telephones, of course, are included in the anode circuit of the first valve as shown. A by-pass condenser C_3 is connected across the secondary of the transformer *T*.