EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial.

Esperanto and Technical Literature.

WE note that the *Electrician* is following our example in inviting their readers' opinions on the advisability of publishing summaries in Esperanto of articles appearing in the technical press. In the number of 9th July, the matter is discussed editorially under the above heading. It is objected that, being an artificial and not a natural language, Esperanto is not a vehicle of thought, by which is meant that it is not a language in which anybody thinks, but is merely a link between two other languages. It is admitted, however, that although from the literary standpoint this may cause a serious reduction in quality, this may not be of great importance in the case of a summary of a technical work. In the same issue of the *Electrician* there is a letter from a correspondent, which puts the case for a simple *auxiliary* language, such as Esperanto, very clearly. We shall watch with interest the response to the *Electrician's* invitation.

Valve Nomenclature.

IN our February issue we pointed out that the word "impedance" was being misused when applied to the ratio dV/dI of a valve, and we suggested that the correct term was "differential resistance." We have been pleased to note that several writers have adopted the suggestion. It was objected, however, that "anode differential resistance" was a cumbersome mathematical term which would not commend itself to valve manufacturers and users. The name finally adopted by the Committee of the British Engineering Standards Association which dealt with radio nomenclature—of which Committee the writer was a member—was "Anode A.C. resistance." Although not quite so mathematically definite as our original suggestion, in that it takes for granted that a small alternating current is superposed upon the steady direct current, and although in the matter of cumbersomeness "alternating current" is little, if any, improvement on "differential," it was felt that it would be more acceptable to valve makers and users and therefore more likely to displace the term "anode impedance," the use of which the Committee deprecated. It is to be hoped that all writers will now adopt this new term. We take this opportunity of drawing attention to the British Standard Glossary of Terms used in Electrical Engineering which has just been published by the British Engineering Standards Association, and about which we shall have more to say on another occasion.

In the *Electrician* of 11th June, a writer referred to the "curious but very common custom of referring to the ratio dV/dI as the anode *impedance*," and stated that, as it was of the nature of a pure resistance, there was no excuse for it. This remark led to some correspondence which brought out very clearly the disadvantages under which those labour who do not regularly read *E.W. & W.E.*

A New Theory of the Lead Accumulator?

By Prof. G. W. O. Howe, D.Sc. [621.355.01

THE theory of the chemical action occurring during the charging and discharging of the lead accumulator has always been unsatisfactory. The simple formulæ given in most text-books of electrical engineering were known to be incorrect—mere rough approximation to the actual changes which take place—but although chemists were ready to point this out they were not able to give a satisfactory alternative. Nothing can be a more effective hindrance to the development of any apparatus than ignorance of the principles underlying its operation, and there is little doubt that our ignorance of what really takes place in the lead accumulator has been one of the principal causes of the lack of development. As a proof of this we have only to draw attention to the fact that the new theory recently put forward by MM. Féry and Chéneveau led immediately to the design of a new type of lead accumulator which is alleged to be free from sulphation even if left standing discharged for many months or even years. As it is almost impossible to get beyond the crystal detector stage of radio telegraphy without being forced to cultivate an interest in the lead accumulator, we feel sure that our readers will be interested in this new theory and its developments.

The Old Theory.

According to the old theory the active material in the positive plate of the charged cell was lead dioxide (PbO_2) and that in the negative plate spongy lead. During the discharge the PbO_2 was first reduced to lead monoxide (PbO) and then converted to lead sulphate ($PbSO_4$); similarly the spongy lead in the negative plate was oxidised to PbO and then converted to lead sulphate. The complete process can be represented by the formula

$$\underset{-\quad\text{charged}\quad+}{Pb + 2\,H_2SO_4 + PbO_2} \rightleftarrows \underset{-\quad\text{discharged}\quad+}{PbSO_4 + 2\,H_2O + PbSO_4}$$

The left hand side represents the active materials when fully charged and the right hand side when discharged. According to this theory the normal discharge of the cell is associated from the very beginning with the production of lead sulphate, but this production must not be allowed to proceed too far or the cell becomes "sulphated"—one should perhaps say "super-sulphated"—and is very difficult to recharge. No very clear explanation has ever been given why the lead sulphate produced after the voltage has fallen to about 1.8 should be so much more harmful than that produced before, whether it differs in physical constitution or whether it is simply a question of quantity.

The New Theory.

According to the theory put forward by M. Féry and supported by considerable experimental data, the active material of the fully charged positive plate is a higher oxide (Pb_2O_5): during the normal discharge this is reduced by the liberated hydrogen to the dioxide PbO_2, whilst the spongy lead of the negative plate is converted to a black lead sulphate or plumbous sulphate Pb_2SO_4, not the plumbic sulphate $PbSO_4$ of the older theory. The changes during charge and discharge would then be represented by the formula

$$\underset{-\quad\text{charged}\quad+}{Pb_2 + H_2SO_4 + Pb_2O_5} \rightleftarrows \underset{-\quad\text{discharged}\quad+}{Pb_2SO_4 + H_2O + 2\,PbO_2}$$

To test the correctness of the theory two accumulators were made up in such a way that in one the positive plate was suspended from the arm of a balance, the negative plates being fixed, whereas in the other the negative plate was suspended between two fixed positive plates. Owing to there being one suspended plate and two fixed plates one was certain that the discharge was limited by the chemical action of the suspended plate. The plates were made by pasting a grid of antimony lead with a paste of red lead (Pb_3O_4) and ammonium sulphate; after drying in an oven for 36 hours, then soaking in sulphuric acid for an equal time and redrying, the plates were formed for about three days. After drying and weighing they were placed in the electrolyte, and submitted to successive discharging and charging whilst an accurate record was made of the weight of the suspended plate. Very elaborate precautions were necessary to avoid various sources of error; those interested in the details will find them fully described in the *Bulletin of the Société Française des Electriciens* for January, 1926. The amount of active material on each plate was about 100 grammes, the plates being 104×104×2 mm. divided into 144 square meshes about 8×8 mm.

According to the older theory the weights of the active materials should change during *discharge* as follows :—

Positive plate—*increase* of weight=26.8 per cent.,

Negative plate=*increase* of weight=46.4 per cent.,

whereas according to the new theory the changes should be as follows :—

Positive plate—*decrease* of weight= 3.2 per cent.

Negative plate—*increase* of weight= 23.2 per cent.

The changes of weight actually observed should therefore enable one to decide definitely between the two theories.

Now the results obtained did not agree with either theory although they were closer to those predicted on the new theory. It was then suggested that a secondary reaction occurred in the cell due to the fact that the electrolyte could not be regarded merely as acidulated water but must be looked upon as a saturated solution of lead sulphate in acidulated water. During discharge the electrolysis of this solution liberates the ion Pb at the positive plate and gives rise to the reaction

$$Pb + Pb_2O_5 + H_2SO_4 = 2PbO_2 + PbSO_4 + H_2O.$$

This reduction by the lead would cause an increase in the weight of the positive plate, whereas, as was pointed out above, the reduction by the hydrogen in the main reaction would cause a decrease of weight, the resultant change of weight being due to the difference between the two effects. It will be noticed that according to this theory lead is transferred during the discharge from the negative to the positive plate. As the result of experiment it is further assumed that a secondary reaction occurs at the negative plate during discharge, represented by the formula

$$Pb + H_2SO_4 + O = PbSO_4 + H_2O,$$

and that the weight of lead involved in this reaction is about a tenth of that involved in the transformation to Pb_2SO_4.

Experiment Supports the New Theory.

This theory gives results in strict accordance with the experiments, whereas the old theory gives results which cannot possibly be made to agree with the observations. As an example of the discrepancy in the experimental discharge already referred to, in which the old theory would lead one to expect an increase of 26.8 per cent. in the weight of the active material in the positive plate and of 46.4 per cent. in that of the negative, the increases actually observed were only 5.2 and 10.2 per cent. respectively. The new theory, without the secondary reaction, would as mentioned above give an increase of 23.2 per cent. in the negative plate, but a decrease of 3.2 per cent. in the positive plate. The actual increase of weight of the negative plate is thus much smaller than either theory would give without the secondary reaction which, by transferring lead from the negative to the positive plate, brings the new theory into agreement with the observed results.

Why the Discharge Curve drops at 1.8 volts.

M. Féry described experiments made with a cell in which the positive plate preponderated so that the discharge was limited by the exhaustion of the negative plate; in this case the discharge curve shows a very rapid drop at the end of the discharge and the resistance of the cell is found to increase rapidly. This is according to M. Féry due to the transformation of all the available lead in the negative plate to Pb_2SO_4—the conducting sulphate; at this moment P.D. is 1.8 volts and, as the positive plate is still active, its oxidising action continues and the Pb_2SO_4 tends to change into the insulating sulphate $PbSO_4$. One cannot explain this phenomenon on the old theory, according to which the latter sulphate was being formed all the time.

If the negative plate preponderates the discharge will be limited by the exhaustion of the positive; in this case the fall of potential is less sudden and is not due to an increase of internal resistance but to a decrease of E.M.F. This is due, according to M. Féry, to the disappearance of all the Pb_2O_5 leaving only PbO_2, which gives a much lower E.M.F. when acting as the positive plate material.

What is Sulphation ?

It was always difficult to understand why it was so easy to recharge a cell immediately after it had been discharged and yet so difficult to do so if it had been left standing for some time, seeing that the normal discharge was supposed to produce lead sulphate. One explanation was that the crystals of lead sulphate normally produced were very small, but gradually grew when the cell was left standing. On the new theory this is explained in a very simple way. The sulphate in the negative pastilles produced during normal discharge is the conducting black sulphate Pb_2SO_4. This has a strong tendency, however, in the presence of sulphuric acid to pass into the insulating white sulphate $PbSO_4$, and it is this change which causes "sulphation." It will go on rapidly at the surface, but slowly in the interior where the acid penetrates but slowly.

A Cell which cannot Sulphate.

These considerations have led to the design of a non-sulphating cell. The underlying idea is to protect the negative plate from the oxidising action of the air and of the Pb_2O_5 of the positive plate. The negative plate consists of a single slab of paste at the bottom of the cell whilst the positive plate is placed vertically above it. The negative plate is thus protected from the air and from the action of bubbles of oxygen rising from the positive plate. The electrodes are kept in position by packing the cell with a granular porous silica material which also protects the lower plate from particles falling from the upper one. M. Féry stated that cells made in this way may be left discharged for two years without sulphation; they may then be charged and put into service without any difficulty or loss of capacity. He also said that their loss of charge when left standing on open circuit is less than a tenth of that of the ordinary cell with vertical plates. At the meeting in Paris, M. Féry showed some small 20-volt batteries for use in anode circuits made on these principles by the firm of Gaiffe, Gallot et Pilon.

If these claims can be substantiated—and there is no question of the scientific ability and good faith of those who make them—an important step has been made in the design of the lead accumulator. The construction employed does not appear to lend itself to incorporation in cells of large capacity and it is noteworthy that the cells actually shown were only suitable for anode circuits, but this is an application which will appeal to many of our readers. If these do all that is claimed for them and the new theory is substantiated, ways will undoubtedly be discovered of applying the new principles to the improved construction of all classes of accumulators.

Use of Plate Current—Plate Voltage Characteristics in Studying the Action of Valve Circuits.

By E. Green. [R131

(*Continued from page 406 of July issue.*)

Amplification.

(A) *Resistance Amplifiers.*

The conditions to be fulfilled vary in different cases. In the reception of wireless signals, and the first stages of audio amplification, what is required is the maximum step up in voltage per valve, the actual amplitude of alternating grid voltage being small.

In the case of amplifiers using non-inductive resistances, as the output circuit (as shown in Fig. 3*a* and more particularly Fig. 7*b*) we have to find the condition giving maximum voltage variation at the terminals of R_e for a given variation of grid voltage on the first valve. In Fig. 7*b* are shown the normal connections from the grid of the first valve to that of the second. R_g is usually a resistance of 1 or 2 megohms, and the grids are made negative by means of the batteries B_1 and B_2 respectively. The blocking condenser C is so large that its reactance ($1/C\omega$) is small (over the range of frequencies to be amplified) compared with R_g. Hence for alternating currents R_g is substantially in parallel with R_e. The effective resistance of the output circuit for A.C. is therefore

$$\frac{R_e R_g}{R_e + R_g}$$

and it is this that fixes the slope of the working line and therefore the amplification. Normally, R_g is large compared with R_e and hardly affects the resistance of the output circuit. In what follows we shall use R_e to denote the effective A.C. resistance of the output circuit, which would more accurately be expressed as

$$\frac{R_e R_g}{R_e + R_g}*$$

Let the variation in grid voltage on the first valve be such as to carry the working line RS from curve 1 to curve 3 (Fig. 9). $R'S$, the projection of RS on OX, gives the corresponding variation of plate voltage. This will be a maximum $= S'S$ when RS is horizontal, *i.e.*, when $R_e = \infty$. The amplification in voltage is then represented by the change in plate voltage $S'S$ divided by the change in grid voltage between curve 1 and curve 3.

$$i.e. \text{ step up} = \frac{\text{change in plate voltage}}{\text{change in grid voltage}}$$

when the plate current is kept constant. This amplification is usually denoted by μ or m.

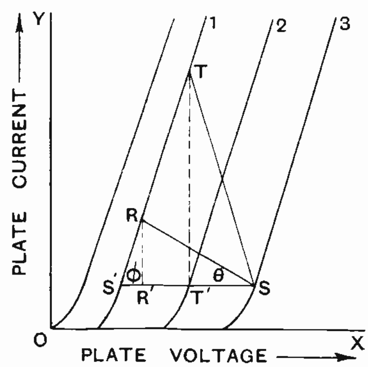


Fig. 9.

Hence for $R_e = \infty$ we can write

Voltage amplification =

$$\left(\frac{dE_p}{dE_g}\right)_{I_p \text{ constant}} = \mu.$$

*NOTE.—If R_g is of the same order as, or less than, R_e the accurate expression must be used. In this case also it is to be noted that the D.C. component of plate current flows through R_e only. If the grid bias is adjusted so that the mean plate current is I_p, the mean plate voltage is $(E_o - R_e I_p)$. This fixes the mean working position D of Fig. 3, whilst $\cot\theta = \frac{R_e R_g}{R_e + R_g}$ fixes the slope of the working line. This line will therefore not pass through A (where $OA = E_o$) but to the left of A.

For any other value of R_e we have,

$$\text{Voltage amplification} = \frac{R'S}{S'S}\mu.$$

Now $$\tan\theta = \frac{1}{R_e} = \frac{RR'}{R'S}$$

and $$\tan\phi = \frac{1}{R_o} = \frac{RR'}{S'R'}$$

where R_o = internal resistance of valve

$$= \left(\frac{d\,E_p}{d\,I_p}\right)_{E_g} \text{ constant}$$

Therefore, $$\frac{R'S}{S'S} = \frac{R'S}{S'R + R'S} + \frac{R_e}{R_o + R_e}$$

Hence for any value of R_e we have,

$$\text{voltage amplification} = \frac{R_e}{R_o + R_e}\mu$$

For the pure resistance amplifier it is not advisable to make R_e very large, as if E_o is fixed it reduces the voltage on the valve and will bring the working line on to the curved part of the characteristics, and beyond $R_e = R_o$ when its value is $\frac{1}{2}\mu$ the amplification only increases slowly.

For the amplifier using a choke in the plate circuit and resistance in the grid the plate voltage is not affected by change in R_e so that R_e can be made much greater than R_o and practically the full step up μ be obtained.

(B) *Transformer or Tuned Circuit Amplifiers.*

For the amplifiers using transformers or tuned circuits maximum amplification will be obtained when the output power is a maximum for a given amplitude of grid voltage.

Let 1, 2, 3, Fig. 10, be characteristics separated by differences of grid voltage equal to amplitude of variation of grid voltage, so that for any value of R_e the working line *JDK* will just extend from 1 to 3.

Draw *DM* and *KR* perpendicular to *LK*.

Then *AC* output power $= \frac{1}{2}$ *DM*. *MK* = area of triangle *DMK*.

It is required to find the value of R_e for which the area of *DMK* is a maximum.

We have $$\tan\phi = \frac{DM}{LM} = \frac{I}{R_o}$$

$$\tan\theta = \frac{DM}{MK} = \frac{I}{R_e}$$

i.e. $LM : MK : LK = R_o : R_e : (R_o + R_e)$

$$\frac{\text{area of triangle } DMK}{\text{area of triangle } DML} = \frac{MK}{LM} = \frac{R_e}{R_o}$$

$$\frac{\text{area of triangle } DML}{\text{area of triangle } RKL} = \left(\frac{LM}{LK}\right)^2 = \left(\frac{R_o}{R_o + R_e}\right)^2$$

$$\therefore \text{ area of triangle } DMK = \frac{R_e}{R_o} \times \left(\frac{R_o}{R_o + R_e}\right)^2 \text{ of triangle } RKL$$

Putting $$\frac{R_e}{R_o} = k.$$

And triangle $RKL = \frac{1}{2} RK.\ KL$

$$= \frac{1}{2} LK^2 \tan\theta$$

$$= \frac{1}{2}\frac{(\mu\, eg)^2}{R_o} = \text{constant for a given voltage of } e_g$$

where e_g = amplitude of grid voltage swing

$$\text{area of triangle } DMK = k\left(\frac{1}{1+k}\right)^2 \times \frac{1}{2}\frac{(\mu\, e_g)^2}{R_o}$$

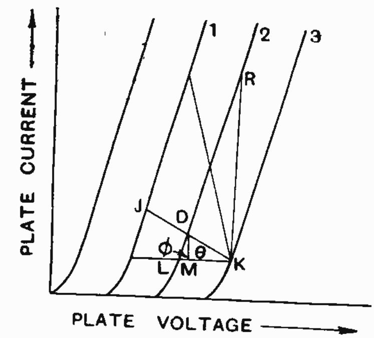


Fig. 10.

Now $$k\left(\frac{1}{1+k}\right)^2 = \left(\frac{1}{\frac{1}{\sqrt{k}} + \sqrt{k}}\right)^2$$

and $\frac{1}{\sqrt{k}} + \sqrt{k}$ is a minimum when $\frac{1}{\sqrt{k}}$

$$= \sqrt{k} \text{ i.e. when } k = 1.$$

Therefore $k\left(\frac{1}{1+k}\right)^2$ is a maximum when $k=1$ (when its value is $\frac{1}{4}$) that is when $R_e = R_o$.

Therefore power output and step up is a maximum when $R_e = R_o$

$$\text{when power output} = \frac{1}{8}\frac{(\mu\, e_g)^2}{R_o}$$

The step up in grid voltage will depend on the actual circuit. Take the case of the transformer amplifier Fig. 11*a* as used for audio-frequency amplification. If r = grid filament resistance, the best step up ratio for the transformer is $\sqrt{\frac{r}{R_o}}$ (since this makes

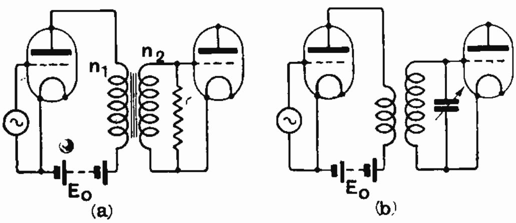


Fig. 11.

the load in the plate circuit $= R_o$), and if e_{g1} = amplitude of voltage at secondary terminals, then neglecting losses in the transformer, we have

$$\text{Power supplied to } r = \tfrac{1}{2}\,\frac{e_{g1}^2}{r} = \text{Input}$$

$$= \tfrac{1}{8}\,\frac{(\mu\, e_g)^2}{R_o}$$

$$\text{Voltage step up} = \frac{e_{g1}}{e_g} = \frac{\mu}{2}\sqrt{\frac{r}{R_o}}$$

In the case of an ordinary receiving valve, R_o may be about 10,000 ohms, while if there is no grid current r may be 1,000,000 ohms. This makes the transformation ratio $\sqrt{\frac{r}{R_o}} = 10$. A more usual figure is about 5, giving a voltage step up of 2.5μ.

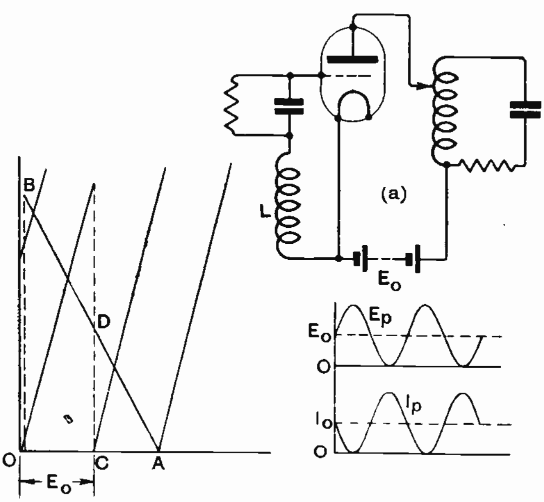


Fig. 12.

Compare this with the resistance type of amplifier in which the maximum step up is less than μ.

In the case of H.F. amplification the effect of a step up transformer is obtained by means of a tuned circuit as Fig. 11*b*.

Oscillating Circuits and Power Amplifiers.

The circuit will be somewhat as shown in Fig. 12*a*.

In either case we have a certain E.M.F. in the grid coil *L*. Hence in sinusoidal working if R_e is varied the A.C. output in the plate circuit will be a maximum when $R_e = R_o$, as we have just proved in the case of small

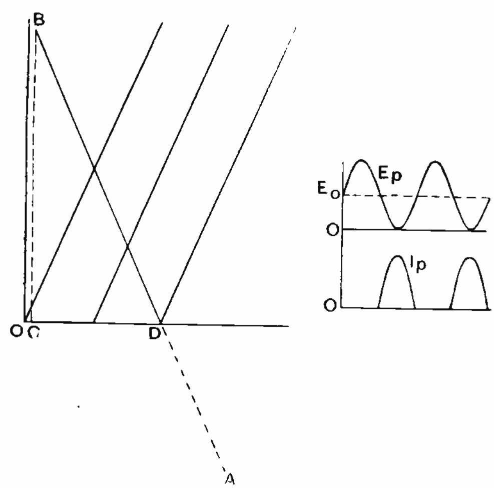


Fig. 13.

amplitudes of grid voltage. The effective R_e can be adjusted to the valve by the anode tap.

If we are restricted to sinusoidal working, but can run into grid current, the working line will be *BDA*, *D* being the midpoint. The plate current and plate voltage will be as shown in Fig. 12*b*, and the efficiency will be 50 per cent. In actual practice the plate volts will not drop absolutely to zero.

For conditions of working such as are shown in Fig. 13 where *D* is midpoint of a grid swing of fixed amplitude in which the plate current is zero over half the cycle and more or less sinusoidal over the other half, the condition $R_e = R_o$ will still be the one giving maximum output. For the A.C. output is proportional to *BC*. *CD* and as before this is a maximum when $R_e = R_o$.

The efficiency now however will be about 70 per cent. In the usual power oscillating circuit the gird has such a large negative bias that the plate current only flows for a small fraction of the cycle. In such a case $R_e = R_o$ is not necessarily the best condition.

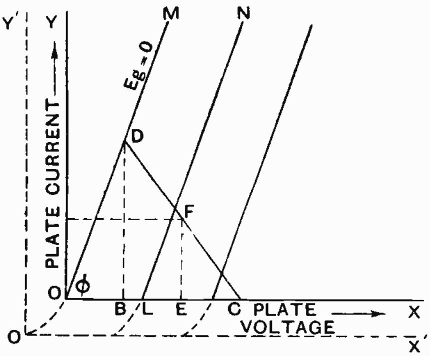


Fig. 14.

Distortionless Power Amplifiers.

In a power amplifier, such as would be used in the last stage of audio-magnification for loud speakers and so on, it is essential to have no distortion. We have to obtain the maximum output, keeping to the straight part of the plate characteristics, and keeping in the region of zero grid current. Maximum amplification is a secondary consideration.

Fig. 14 shows plate current—plate voltage characteristics in the ideal case where they are straight lines, such as *OM*, *LN*, etc.; *OX* and *OY* are the axes. For simplicity, we assume the type of circuits shown in Fig. 6 (*a*)—(*b*) as there is then no direct current loss in the load. Let the steady H.T. volts (E_o) on the plate be *OE*.

In working the alternating component must carry the instantaneous plate voltage, equal amounts above and below the mean value *OE*; for example to two points *B* and *C* where $BE = EC$. Let us find what range of variation (and therefore what value of R_e) will secure maximum output.

The vertical *BD* cuts the characteristic for zero grid volts in *D*. This characteristic represents one limit for distortionless working, the other being *OX*, the line of zero plate current. Hence *DFC* is the working line giving maximum A.C. output for this range of variation of plate voltage, since it gives the maximum variation in plate current.

For this line *DFC* we have

Max. value of A.C. component of plate
volts .. .. $= BE$ or EC
current .. .. $= EF$

$$\text{A.C. output} = \tfrac{1}{2}\, EC.\, EF = \tfrac{1}{8}\, BD.\, BC.$$
$$BD = OB \tan\phi = (OE - \tfrac{1}{2} BC) \tan\phi$$
$$BD.\, BC = (OE - \tfrac{1}{2} BC)\, \tfrac{1}{2} BC \times 2 \tan\phi$$

The sum of the first two factors is constant. Hence the expression is a maximum when the factors are equal, *i.e.*, when

$$OE - \tfrac{1}{2}BC = \tfrac{1}{2}BC$$
or
$$OB = BE = EC$$

that is when the amplitude of plate voltage swing $= \tfrac{1}{2} E_o$.

The resistance of the output circuit R_e is then

$$\frac{BC}{BD} = \frac{2.OB}{BD} = 2R_o$$

where R_o is internal resistance of valve.

With this condition

$$\text{A.C. output} = \tfrac{1}{2}\, EC.\, EF = \tfrac{1}{2}\,\tfrac{1}{2}\, E_o\, I_o = \tfrac{1}{4}\, E_o\, I_o$$
$$\text{D.C. input} = E_o\, I_o$$
$$\text{Efficiency} = 25\%$$

The condition $R_e = 2R_o$ does not give the maximum efficiency, and therefore not the maximum possible output when the anode voltage is also variable, but it gives the maximum output for a fixed anode voltage, and if the valve is then not overloaded, it will be the best condition for that voltage.

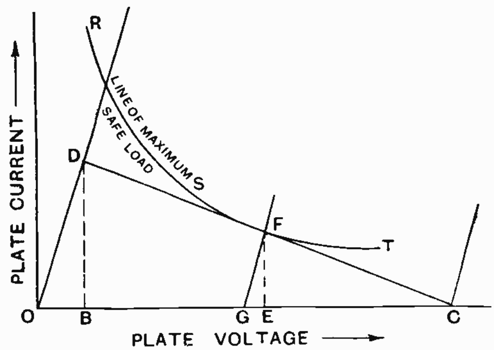


Fig. 15.

We can obtain greater efficiencies by increasing the resistance of the output circuit and raising the anode voltage as shown in Fig. 15 where *DFC* is working line.

For the last stage of audio amplification supplying a loud speaker, the output circuit will either be (1) a transformer as shown in Fig. 6 (*e*) (if the loud speaker is of the moving coil type). In this case the effective resistance of the output circuit can be adjusted to the required value by varying the ratio of transformation of the transformer; or it will be (2) the coils of the loud speaker itself (in the fixed coil type). The effective resistance of this is altered by altering the number of turns in the coils. Note that the effective resistance of the output circuit is *not* the ohmic resistance of the coils.

The fuller treatment of this would require a separate article, as neither transformer nor coils can be regarded as equivalent to a pure resistance over the range of frequencies with which they have to deal.

If either the resistance of the output circuit R_e or the maximum possible H.T. voltage is decided, we can determine the other, using the hyperbola of safe load, *RST*. This is a curve drawn so that the product $E_p \cdot I_p$ for all points on it is constant and equal to the watts that can safely be dissipated by the anode. Provided the mean working position is not above this curve the valve will not be overloaded.

(A) Given *OE* the anode voltage; draw *EF* to cut the hyperbola in *F* and *FG* parallel to *OD*. Make $OD = 2GF$ and draw *DFC* which will be the working line; for which $R_e = \frac{EC}{EF}$

(B) In the other case, if R_e is resistance of output circuit, the slope of *D FC* is fixed and by trial a position can be found where *F*, a point on the hyperbola, bisects *DC*.

With ideal characteristics, and R_e and high tension volts indefinitely great, the limit of efficiency would be 50 per cent. In actual valves it will not be possible to work down to zero plate current on account of the bend in the characteristics causing distortion. (The ends of the characteristics and the actual axes are shown dotted in Fig. 14.) The condition $R_e = 2R_o$ holds good as before, *i.e.*, it will give the maximum output for a fixed anode voltage and will be the best working condition if the valve is not then overloaded. It can be seen from the figure that the efficiency will be less than 25 per cent. Increasing R_e and the high tension volts, and altering the grid bias to suit, will increase the efficiency, but the upper limit will be less than 50 per cent. Usually it is not worth while making R_e greater than five or six times R_o. For the sake of economy

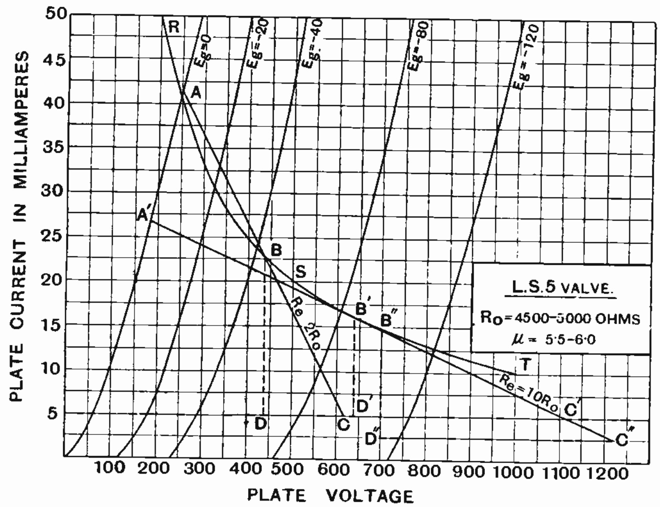


Fig. 16.

it is preferable to keep the anode voltage low. This entails for efficient working the use of a valve with a low value of plate resistance R_o. The lower this can be made, the better it is for the efficiency. To make R_o low, the grid and anode should be flat, enclosing a zigzag filament, and both should be as close to the filament as possible. Also the grid should have a very open mesh. Unfortunately, these conditions, more especially the last one, give a valve with a low value for μ the amplification factor. Also we saw that the maximum power amplification is obtained when $R_e = R_o$. With $R_e = 6R_o$ the amplification will be lower. For both these reasons a greater swing of grid voltage has to be provided.

Examples.

1. *LS5 Valves.*

Fig. 16 gives the characteristic curves of the LS5 valve. *RST* is the curve of maximum safe loss which is 10 watts. Also we conclude we cannot swing the plate current below 5mA on account of the bend in the characteristics.

The plate resistance of the valve $R_o = 4{,}500$ to 5,000 ohms.

The amplification factor $\mu = 5.5$ to 6.

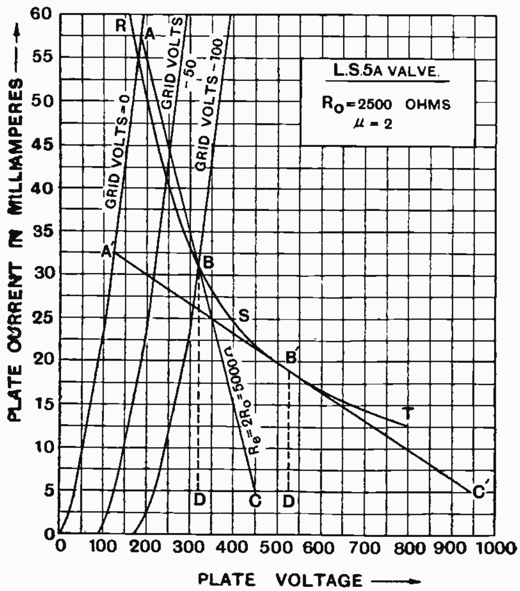


Fig. 17.

For $R_e = 2R_o$ the working line giving 10 watts loss is ABC. This gives an A.C.

$$\text{output} = \tfrac{1}{2}BD \ . \ DC = \tfrac{1}{2}\,\frac{18.0 \times 190}{1{,}000}$$

$$= 1.71 \text{ watts.}$$

Efficiency = 17 per cent.

This requires a plate voltage of 440 volts, grid negative —45 volts.

Hence for all plate voltages less than 440, $R_e = 2R_o$ will give the maximum possible A.C. output.

If we multiply the voltage scale by ½ and the current scale by 2, R_o is reduced to a quarter its old value, and the 10 watts loss line is unchanged; 220 volts will now be the minimum plate voltage to give efficient working at 10 watts loss.

Returning now to the *LS*5, if we increase R_e to 45,000 ohms we get a working line $A'B'C'$. This gives an A.C. output

$$= \tfrac{1}{2}\,B'D' \ . \ D'C'.$$

$$= \tfrac{1}{2} \ . \ \frac{10.7 \times 470}{1{,}000} = 2.52 \text{ watts.}$$

This is some improvement on the other arrangement but needs 640 volts on the plate and a grid bias of —87 volts. The gain would be greater if it were possible to work to lower values of plate current; and this should be possible with the higher resistance in the plate circuit. Thus if we worked to a minimum plate current of 2.5mA, the working line would be $A''B''C''$.

$$\text{Power output} = \tfrac{1}{2}\,B''D'' \ . \ D''C''$$

$$= \tfrac{1}{2}\,\frac{12.0 \times 520}{1{,}000} = 3.1 \text{ watts.}$$

Efficiency = 31 per cent.

It is clear that what is needed is a valve of much lower resistance (*i.e.*, R_o) to allow of efficient working at lower plate voltages.

Fig. 17 shows the characteristic curves of the LS5A valve, which has a special open mesh to give low resistance (R_o= 2,500 ohms). *RST* is the 10-watts loss line. *ABC* is the working line when $R_e = 2R_o$ whilst $A'B'C'$ is that for $R_e = 11.5R_o = 28{,}700$w. Taking 5mA as the minimum value for the plate current, we have,

$$\text{Output for } ABC = \tfrac{1}{2}\,BD \ . \ DC = \tfrac{1}{2}\,\frac{26 \times 130}{1{,}000}$$

$$= 1.69 \text{ watts.}$$

Plate voltage = 310.

Grid negative = —100 volts, whereas,

$$\text{Output for } A'B'C' = \tfrac{1}{2}\,B'D' \ . \ D'C'$$

$$= \tfrac{1}{2}\,\frac{13.7 \times 410}{1{,}000}$$

$$= 2.8 \text{ watts.}$$

Plate volts = 530.

Grid negative = —225 volts.

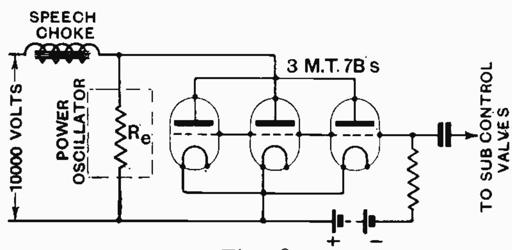


Fig. 18.

Note that in all cases the negative grid bias is a measure of the grid swing required to produce maximum output. Thus in the last case cited the amplitude of grid swing is 225 volts.

2. *Modulation on 6kW Broadcasting Transmitter using Choke Control.*

The modulation panel of the 6kW broadcasting set, as used in the British Broadcasting Company's stations, can also be analysed on the above lines. The circuit is as shown in Fig. 18, the power oscillator taking the place of the external load.

We have, $E_o = 10{,}000$ volts.

Power oscillator takes 150mA.

$$\therefore \; R_e = \frac{10{,}000}{.15} = 67{,}000 \text{ ohms.}$$

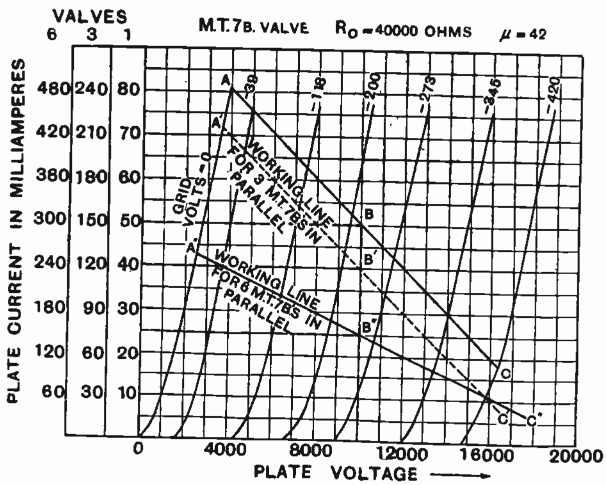


Fig. 19.

From the characteristics of MT7B valves (Fig. 19)

$R_o = 40{,}000$ ohms for one valve,

$= 13{,}300$ ohms for three valves in parallel.

So that $\dfrac{R_e}{R_o} = 5$.

Each valve has a safe loss of 500 watts. From the curves Fig. 19, we see that the working line for this case is ABC, or possibly $A'B'C'$, without much distortion.

For this line the possible range of modulation is 6,400 volts and 95mA.

A.C. output $= \frac{1}{2} + 6{,}400 \times .095$
$= 305$ watts.

For line $A'B'C'$ input to modulators is 1.2kW.

$$\therefore \; \text{Efficiency} \; \frac{305}{1{,}200} = 25 \text{ per cent.}$$

The possible depth of modulation is 64 per cent.

If we had 6 MT7B's in parallel with 1.5kW total loss the working line on the new scale would be $A''B''C''$ giving a range of 7,400 volts and 110mA.

A.C. output $= \frac{1}{2} \times 7{,}400 \times .110 = 408$ watts.
input $= 1.5$kW.

$$\text{Efficiency} = \frac{408}{500} = 27 \text{ per cent.}$$

The possible depth of modulation is 74 per cent.

If therefore we could reduce the plate impedance of the MT7B to half its present value we could obtain this result with three valves only.

From this calculation it is clear that there is not much gain in efficiency, in reducing R_o from $\frac{1}{5} R_e$ to $\frac{1}{10} R_e$.

No doubt other examples that can be elucidated by the methods outlined will occur to the reader. It will be seen that the advantages of the plate current—plate voltage characteristics arise from the fact that all the electrical quantities (such as voltage, current and power) of the plate circuit are directly represented.

Thus referring back to Fig. 3*b* we have :—

1. H.T. battery voltage $= E_o = OA$.
2. Working line for external resistance $R_e = AB$ where $\dfrac{OA}{OB} = R_e$.
3. Mean value of plate current $= I_p = CD$.
4. Resistance drop in external load $= R_e I_p = AC$.
5. Mean anode voltage $= E_p = E_o - R_e I_p = OC$.
6. Watts lost in valve with no alternating voltage on grid $= E_p I_p =$ area of rectangle $OC \,.\, CD$.
7. D.C. watts lost in external load $= R_e I_p =$ area of rectangle $CA \,.\, CD$.
8. Amplitude of alternating component of anode voltage $= e_p = HF$.
9. Amplitude of alternating component of anode current $= i_p = DH$.

10. $-e_p$ and i_p are also the amplitudes of the alternating components of voltage and current in the external load R_e.

11. A.C. power in external load $= \frac{1}{2} e_p i_p$ = area of triangle DHF.

My best thanks are due to Mr. H. J. Round for introducing me to the above methods of handling valve problems, and for his helpful interest in the work.

Although the $I_p - E_p$ characteristics can be easily derived from the $I_p - E_g$ characteristics usually provided by the valve manufacturers, it is to be hoped that the latter will see their way to provide the $I_p - E_p$ characteristics either as standard, or as an alternative.

Note.—DERIVATION OF I_p—E_p CHARACTERISTICS FROM I_p—E_g CHARACTERISTICS.

Fig. A shows the I_p—E_g characteristics for the LS5 valve, each individual curve being obtained at the constant plate voltage marked on it. Now take a definite grid voltage ($E_g=O$) for example represented by O on Fig. A. A vertical line OY through O cuts the family of curves in P, Q, R, S and T. These points give the relation between plate current and plate voltage at the particular constant grid voltage chosen (*i.e.*, $E_g=O$). We can tabulate these as shown in the first two columns of the table at the end.

In Fig. B we have taken plate voltage (E_p) and plate current (I_p) as axes and plotted the curve marked (E_g=o) from the figures given in the first

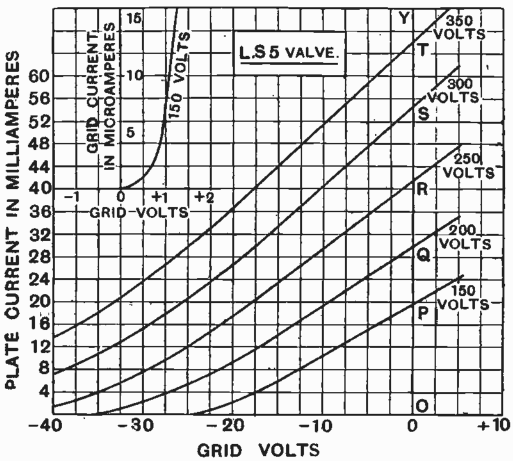


Fig. A.

two columns of the table. P', Q', R', S', T' correspond to P, Q, R, S, T of Fig. A. By taking a series of values of E_g (—10, —20, etc.) and going through a similar process we obtain the complete table and from these we can plot the family of E_p—I_p curves (shown in Fig. B) which we require. The full line curves are those representing definite points given in the table. The dotted lines represent extensions deduced from the others by similarity.

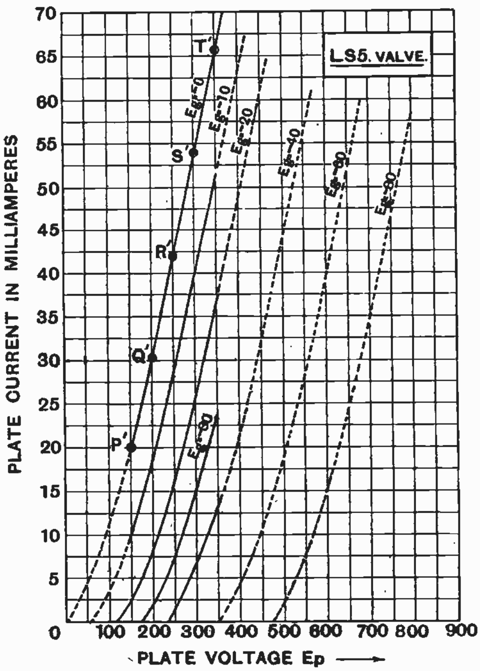


Fig. B.

Thus from the curves for E_g= o and E_g=—20 we see that a change of —20 volts on the grid requires an increase of 120 volts on the plate, to keep the plate current constant.

∴ Amplification factor = 120/20 = 6.

The curve for E_g=—60 volts is obtained by displacing the curve for E_g=—40 bodily 120 volts to the right, and so on.

Plate Voltage.	Plate current I_p in mA for the constant grid voltage shown.			
E_p	E_g= o.	E_g=—10.	E_g=—20.	E_g=—30.
150	20	10	0	—
200	30.2	18.5	8.4	2.0
250	42.0	29.0	16.6	7.2
300	54.0	40	23.5	15.5
350	66.0	51.5	36.8	24.4

DX Work with a Receiving Valve.

By A. D. Gay. **[R545.1**

MOST amateur transmitters will exercise a certain amount of caution in their selection of a transmitting valve, even if only from an economical point of view. For instance, if only a few watts are to be used the purchase of a large valve will not be justified. A valve designed for a large anode dissipation will much more easily lose a few watts than efficiently transfer a small power to the aerial, apart from the higher running cost for filament current. But, on the other hand, a large valve will become very useful when it is convenient to increase power input. When dry batteries are used it is not always desirable nor convenient to increase power unless power mains are going to be utilised at some future date.

When therefore the power is small it will be desirable to use a small valve independently of what will be used for ordinary work. There were a number of small ex-Government valves on the market suitable for low power working. The double plate "B" type, sold at ten shillings each, gave very good results. In size they were no larger than the usual "R" valve, but the plate, after making a complete turn to form the usual cylinder, was bent back the other way. The filaments required about 5.5 volts, but an increase of much above this caused them to give up the ghost!

After having a number of burn-outs in this way it was decided to look for something which might prove to be a cheaper and more durable form of oscillator. Experiments were tried with several types of receiving valves, not without a few mishaps, and at last a valve was found that gave excellent results combined with a long life, namely the Cossor P1. The filament rating of the Cossor valve is normally 3.5-4 volts, but it was found that a few have slightly longer filaments than others, and if one of these can be obtained so much the better. This feature can be detected when testing a few valves together, those with the longer filaments will not appear so bright.

It will be found necessary to run the filaments on about 5.5 volts in the transmitter. This might appear to be rather bright, but it will be found that they will stand up to this voltage quite well, and providing the anode does not become too hot an early burn-out need not be feared. Keying the negative H.T. is to be preferred as this helps to keep the anode cool. In keying any other part of the circuit the milliamps very often tend to rise in the plate circuit, but this method allows the plate current to drop to zero each time the key is lifted.

During the month of February, 1924, using one of these valves, the writer was able to work six French stations: 8DA Marseilles, 8CT Bordeaux, 8SSU and 8OH Rhineland, 8DU Metz, and 8CZ Paris; Flemish P2, Luxembourg 1JW, Dutch 0PB, and Danish 7EC were worked and among a number of British stations are 2AP Aberdeen, 5MO Newcastle, 5SI Shrewsbury, 5OL Liverpool, and 5KO Bristol. Several Scottish stations sent report cards.

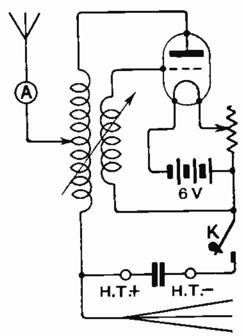


Fig. 1.

It was very interesting to note from reports received how reception varies in different parts of the country. In nine cases out of ten, signals reported heard in the Midlands are only about half as strong as they are in Scotland, but this may be due to a greater veracity on the part of the Midlanders! It would be very useful if some enterprising firm would bring out a map with these bad spots marked in different coloured inks. These spots are usually caused by local geological conditions, metallic deposits, etc.

With reference to the sending of cards, and reports of reception to transmitting stations, this proceeding is exceedingly useful to all DX workers and is to be encouraged by all. The collection of Official Station Cards seems to be the outgrowth of the schoolday habit of collecting anything, but, after all, they do look nice on the wall in all their varied hues. There are still a number of experimenters who do not trouble about cards, either sending or acknowledging, but these are neither DX workers nor morse senders, and usually cannot send their own call-signs properly.

The best piece of DX work done whilst using a receiving valve for transmitting was to Gibraltar, a distance of about 1,000 miles. The power input was 4.4 watts and strength of reception was R8. This must be nearly a record for this class of work at the time.

The transmitting circuit is shown in Fig. 1.

Makeshifts.

Making a Measurement in an unusual manner to use existing Instruments.

By G. H. Watson. **[R230**

THE following notes are penned in the hope of prompting others to seek alternative methods of measurement when ordinary instruments are not immediately obtainable.

It was desired to measure the inductance of an iron-cored coil wound with fine wire, but no A.C. milliammeter was available, the smallest one reading 0—2 amps, calibrated in $\frac{1}{4}$ amps, so the following circuit was fitted up.

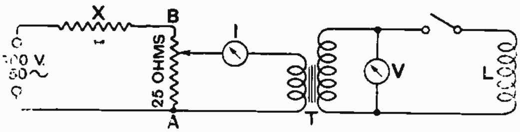


Fig. 1.

The inductance was designed to carry 10 milliamps so the voltage across it would be

$$V = I \times \text{Impedance}.$$

$$= \frac{10}{1,000} \times Z$$

The voltage was measured by an electrostatic voltmeter to prevent the instrument causing a load on the transformer. The current being measured in the primary circuit is 85 times larger than the secondary current. The operation was as follows :—

Commence with potentiometer slider at *A* and increase towards *B*, adjusting also resistance *X* until current in ammeter reads 85×10 milliamps$=0.85$ amp (it was actually made to read 0.75).

The secondary voltage is now read (it was 140V)

$$V = I \times Z$$

so $$V = \frac{\text{Primary } I}{T \text{ Ratio}} \times Z$$

and $$Z = \frac{V \times T \text{ Ratio}}{\text{Primary } I} = \frac{140 \times 85}{\cdot 75}$$

$$= 16,000\ \omega \text{ nearly,}$$

$$Z = \sqrt{R^2 + P^2}$$

so $$P = \sqrt{Z^2 - R^2}$$

The resistance was 5,000 ohms

so $$P = \sqrt{16,000^2 - 5,000^2}$$
$$= 15,000\ \omega \text{ approx.}$$

$\because$ $$P = \omega L$$

so $L = P/\omega$, where $\omega = 2\pi f$

f was 50

so $$L = \frac{15,000}{314} = 50 \text{ henries nearly.}$$

When the inductance was switched off, the primary current fell to a very low value—not measurable—and the secondary volts went up to 170. The drop of 30 volts on load, *i.e.*, 170—140, was accounted for by the transformer secondary resistance of 3,000 ohms.

$$V \text{ drop} = I \times \text{Internal resistance}$$

$$= \frac{10}{1,000} \times 3,000 = 30 \text{ volts approx.}$$

From receiving the request to returning the inductance only two hours elapsed, so it was much quicker than sending to the manufacturers for an A.C. milliammeter.

A Short Wave Wavemeter.

By A. E. Tubbs. [R384

FIRST of all it should be said that the heterodyne wavemeter herein described uses no so-called "new circuit," but is simply our old friend the Colpitt's oscillator.

The main advantages of this type of wavemeter are that it will oscillate on any wavelength from five metres upwards, by merely changing one coil, and that the rotor of the tuning condenser is at ground potential. The one constructed by the author covers a wavelength range from fifteen to eighty metres.

Because of the high frequencies covered it is, of course, necessary to have the inductance coils inside the shielded case if any degree of accuracy is desired. This is very simply accomplished by the use of low capacity switches which add additional loading coils to the circuit. Of course, it is necessary to have some inductance outside the shielding in order to couple the wavemeter to other circuits. This is best accomplished by the use of a one turn "pick-up" coil. This "pick-up" coil should not be too large, and should, above all, have a rigid construction. The one used by the author is about four inches in diameter and is constructed from $\frac{1}{16}$ by $\frac{1}{4}$ inch brass strip. For use on the very short waves it is not advisable to make this coil rotatable, because the frequency will be altered by different positions of the coil.

It is not thought advisable to go into actual constructional details in this article because most amateurs have some of the equipment which they will want to use in constructing such a wavemeter, and therefore, it seems advisable to give just a general description and let each amateur work out his own design to suit his particular requirements.

The main piece of apparatus necessary is the double variable condenser, in Fig. 1. This is a condenser having two sets of movable plates connected to the same shaft and two sets of fixed plates insulated from each other. Such condensers can easily be obtained on the open market, where they are sold mainly for the purpose of simultaneously tuning two stages of radio frequency amplification. If the wavemeter is designed to cover the short waves it will be *absolutely necessary* to have some sort of a high ratio vernier control. The author uses an "Accuratune" dial, having a ratio of eighty to one. And in the neighbourhood of fifteen and twenty metres a higher ratio would be desirable if obtainable. It should be unnecessary to say that the condenser should be one of the best obtainable, both from an electrical and from a mechanical point of view. If possible it should have brass plates, which should be soldered, and

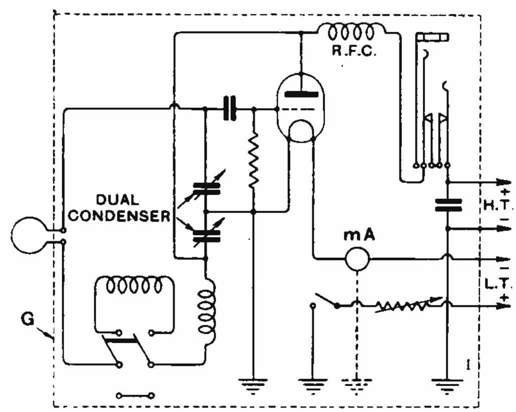


Fig. 1.

above all it should have *good* bearings so that it will hold its calibration. The dial must be fixed firmly to the condenser shaft. This is best done by drilling a hole in the condenser shaft to take the dial set-screw.

It is advisable to have a good strong box for the meter, which must be thoroughly shielded, and for the short waves this shielding *must* be rigid. The author's method was to cut pieces of heavy sheet brass to fit the four sides and bottom of the box and then, after these were tacked firmly in place, the seams were soldered. The panel will also have to be shielded. If it is possible to obtain ebonite which has the shielding already affixed to it, this will, of course, be the best. If not, a piece of sheet brass will have to be cut to fit the panel and after the instruments have been mounted, machine screws can be used to fasten the shielding at any place where it is not held firmly to the panel.

The author mounted everything on the panel so that it may easily be removed from the case. Fig. 2 shows the method of mounting the panel. A strip of angle brass is placed around the entire top of the box. This strip of angle brass serves the double purpose of holding the upper edges of the shielding in place and as a rest for the panel. The upper or horizontal flange of this angle brass has holes drilled in it and tapped to take machine screws which hold the panel in place.

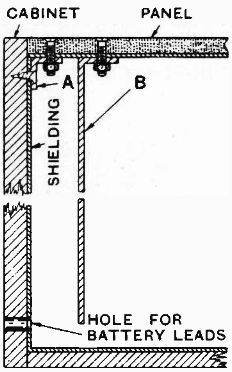


Fig. 2.

The battery leads were brought out through a hole at the bottom of the box, and in order to keep them rigid inside the box the heavy piece of brass strip *B* (Fig. 2) was fastened to the panel and the three battery leads were cabled and brought down this strip where they were rigidly fastened at its lower end. The negative H.T. lead, which is earthed to the shielding, was soldered to the lower end of this heavy brass strip.

A terminal was connected to the shielding (*G*. Fig. 1) and should be connected to a *good* earth when the instrument is being calibrated and, if possible, whenever it is used. This earth is for the purpose of reducing the effects of "hand capacity," etc. It should be borne in mind that a water pipe, or a radiator, on the third floor, is *not* a good earth and is worthless for this purpose.

The author used one of the Western Electric peanut valves because of their small size and because they remain very constant in frequency over their whole life. The meter *mA* (Fig. 1) was a 300 milliampere meter. A meter of some sort is absolutely necessary if any degree of accuracy is desired, because the frequency is naturally dependent, to some extent, on the filament temperature. If the windings of this meter are not earthed to the meter case the latter should be earthed to the wavemeter shielding. For the W.E. valve a 0.0001μF grid condenser and a 2 megohm grid-leak was used. The L.T. battery was one standard dry cell. The large dry cell was used instead of a small one because it was desired to use the wavemeter as a separate heterodyne at times. The H.T. battery was a 22.5 volt block and the condenser across this battery should be 0.25μF or larger. The telephone jack is very useful and it is advisable to include it in the wavemeter, although it should be unnecessary to say that no telephones should be plugged in when the meter is calibrated or when it is being used for accurate recalibration work, because, although theoretically the choke coil *R.F.C.* (Fig. 1) should prevent the telephones from having any effect on the frequency, practically this is not the case on high frequencies. But this jack will be found very useful for adding additional high tension when it is desired to find harmonics, although, of course, after the harmonic is once found, the additional battery should be removed because any wide variation in the H.T. will affect the frequency slightly. Also when it is desired to use the meter as a drive on long waves, a pair of telephones should be plugged in to act as an additional choke and a honeycomb coil of the proper size substituted for the pick-up coil.

The calibration of such a wavemeter on the short waves is what is most likely to bother the average experimenter, so the method used by the author will be described. First it was decided to calibrate it to one-tenth of a metre. Also the dial readings were laid off to a tenth of a degree. (These were just read by judgment because it was thought that they could be judged more accurately than it was possible to make a vernier reading against the main dial). Then on a short wave receiver having a range from fifteen metres to over a hundred metres NKF was picked up on his 71.5 metre wave. He can be found any morning (except Monday morning) about 01.30 G.M.T. transmitting to U.S. Shipboard, London.

His frequency is crystal controlled so he can be depended on for calibration. After he is located on the receiver the wavemeter is adjusted until the fundamental of the wavemeter produces a "zero-beat" with *his* wave (the receiver had better be in a non-oscillating condition for this). Next bring the wavemeter up near the receiver and disconnect the receiver from the aerial. The earth should be left on the receiver to stabilise it. Now go down in wavelength on the receiver until the second harmonic of the wavemeter is heard and obtain a "zero beat" between the receiver and the wavemeter's second harmonic. The receiver will now be tuned to 35.75 metres. The wavemeter should now be adjusted so that its fundamental beats with the fundamental of the receiver, in other words the wavemeter should be adjusted to 35.75 metres. In order to obtain this adjustment accurately it will most likely be found necessary to separate the wavemeter and the receiver farther from each other. In doing this, great care should be taken that the frequency being generated by the receiver is not altered in any way. After this point is marked on the curve the receiver should be reset to its original wave of 71.5 metres. This adjustment should be done by listening in the receiver until the double wave of the wavemeter is heard and *not* by attempting to reset the receiver to its original dial settings. Now with the receiver back to its original wave go down with the wavemeter until the third harmonic or 23.83 metres is found. The receiver is now brought down to 23.83 metres, always remembering to use the "zero beat" method. Next go up with the wavemeter until the second harmonic of the wavemeter is heard (the double wave of the receiver or 47.66 metres). Now run down with the receiver until the third harmonic of the wavemeter is found (15.88 metres). The wavemeter is now brought down to 15.88 metres and the receiver shifted up to the quadruple wave or 63.52 metres. This same procedure is continued until the desired number of points are located on the curve.

The points should be marked on the curve as each one is located, because it will then be possible to see if a mistake in locating the correct harmonic has been made. If a harmonic is missed, and a wrong one taken, it will, of course, make a bad hump in the curve. If a mistake in harmonics is made the wavemeter should *not* be placed back to the last correct setting by taking the reading from the curve, but the harmonics should be traced back by the zero beat method until the wavemeter is once more back to the last correct setting.

The curve can afterwards be checked from other stations of known wavelength. The American R.C.A. short wave stations are very handy for this purpose because they keep very close to their assigned frequency. The main R.C.A. short wave stations are WIR 74.03 metres, and WIZ 43.03 metres.

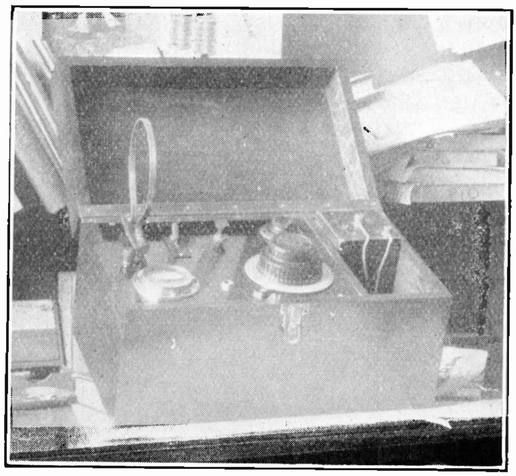


Fig. 3.

Of course, for short waves the oscillator coils should be of a low loss construction, but the constructor must remember that in an instrument of this type a rigid, solid coil is more important than one of low loss construction. For the band in the neighbourhood of fifteen or twenty metres do not use two or three turns of large diameter but rather more turns of small diameter. A good rule is to have the coil diameter approximately the same as the coil length.

An improvement that might be suggested would be the use of a large non-inductive resistance* of five or ten thousand ohms instead of the choke coil. This would

* [Troubles due to capacity in this resistance and fittings are likely to nullify the specified advantages of this method.—Ed.]

have the advantage of being constant over the whole wave band and also naturally has a more rigid construction. It should also make the circuit less sensitive to H.T. changes.

Fig. 3 is a photograph of the completed wavemeter. As can be seen from the photograph it is self-contained in a stout oak box, having two compartments; one for the wavemeter itself and the other for the batteries, pick-up loop, etc.

The pick-up loop, seen in the upper left hand corner, is detachable so that the cover may be closed. It has two small plugs which fit into two jacks, which are *well separated* on the panel.

To the right of the pick-up coil is seen the switch which is used for adding the extra inductance coil. Next comes the filament switch and to the extreme right of the panel, behind the tuning dial, is the filament rheostat. In the lower left hand corner is the filament milliammeter and just above it to the extreme left is the earth terminal. Next to the right of the milliammeter is the telephone jack. In the lower right hand corner is the "Accuratune" dial which controls the tuning condenser.

It will be noticed that the pick-up coil has been so placed that there will be a minimum of "hand-capacity" effect while tuning. Also notice that the marker, which the dial reads against, is placed on the lower left hand edge of the dial. This marker must have a rigid construction. The one shown in the photograph is a block of ebonite, tapered so as to go under the edge of the dial. This block is firmly held on the panel by *two* machine screws. A fine line was made on the bevelled surface which goes under the dial, and this line filled with a white substance.

The International Morse Code.

THE wide range and cosmopolitan nature of amateur transmission has brought into prominence the necessity for extending the International Morse Code to include the various accented letters peculiar to different languages. We understand that radio societies in several countries are endeavouring to draw up code signs to be used in national communications in their respective languages, and it is probable that these, when agreed, will eventually be used in international communication.

In the Czeck language there are the following accented letters :—

ž, č, š, ř, ě, á, ý, i, é, ú, ů, ť, ď,

for which, at present, the ordinary alphabetical signs are used, but the Czechoslovakian *Radio Revue* is strongly advocating the allotment of special signs to these letters.

We understand that in Russia the following signs are in use :—

ž - - - — (=v) č — — — - (=ö) š — — — — (=ch)
šč — — - — (=q) ja - — - — (=ä) Ju - - — — (=ü)
e - - — - - - (=é) v - — — (=w) ch - - - - (= h)

The Swedish language has the following accented letters with their corresponding morse signs :—

ö — — — - (as in German, pronounced as "i" in "bird").

ä - — - — (as in German, pronounced as "ai" in "fair").

å - — — - — (pronounced as "o" in "go").

These last are, of course, commonly used in Continental morse as are also—

ch = — — — — é = - - — - - ü - - — —

Effective Resistance of Inductance Coils at Radio Frequency.—Part IV.

By S. Butterworth

[R144

(*Admiralty Research Laboratory, Teddington.*)

22. Number of Turns in Coil.

A complete consideration of the factors governing design should also include the question of the relative number of turns in various shapes of coils, as it is clear that a coil of few turns is more quickly wound than one of a large number of turns. A glance at Table VIII. shows that L_0 diminishes both with increase of winding length and of winding depth.

Since $L = L_0 N^2 D$, the turns must therefore increase to hold the inductance constant as either b or t increases.

This is true if the diameter of the coil is held constant. For coils of equal surface areas the diameter diminishes as the winding length increases and this diminution must be further compensated for by added turns. These considerations give a further bias in favour of short shallow coils.

23. Determination of the Best Wire Diameter.

Whatever the basis of design we must make the wire diameter such that $R_s = MR_h$ where $M = 1, 2, 3.5$, or 3.67 under the various alternative conditions considered above.

If in all cases we make $R_s = R_h$, which is the correct relation for minimum resistance in a given space at high frequencies, then at low frequencies the resulting resistance is 1.06 times the least resistance possible in the available space, and 1.18 times the least resistance possible with the weight of copper employed. Thus if we use the condition of equal copper losses to determine the best diameter of the wire, we shall never be very far from the most efficient condition for the shape of coil employed. It is, however, to be understood that it may be profitable to use wire of a diameter slightly less than that estimated by the following method, particularly in the case of coils of large inductance working at long wavelengths.

Equating the values of R_s and R_h as given by equation (35) our equation to determine the wire diameter is

$$1+F = \tfrac{1}{4}(KNd/D)^2G = \tfrac{1}{4}(K^2/L_0)\,(L/D^3)d^2G$$
$$= \frac{S^2L}{D^3}d^2G = P^2d^2G \qquad (47)$$

in which we have written S^2 for the shape factor $\frac{1}{4}K^2/L_0$ and then put

$$P^2 = \frac{LS^2}{D^3} \quad \ldots \quad \ldots \quad (48)$$

Remembering that F and G are functions of $df^{\frac{1}{2}}$, that is, of $(Pd)\,(f/P^2)^{\frac{1}{2}}$, equation (47) may be regarded as an equation connecting the two variables Pd and f/P^2, so that, if a single curve be drawn with f/P^2 as abscissæ and Pd as ordinates, this curve may be used to determine d, the only calculation necessary being that for P from equation (48).

The curve connecting Pd with f/P^2 is given in Fig. 7, together with a table of values of the shape factor S for multilayer coils. For single-layer coils the following values hold for S :—

SINGLE-LAYER SOLENOIDS.

b/D	0.125	0.250	0.375	0.500
S	1.30	0.76	0.57	0.48

SINGLE-LAYER DISC COILS.

t/D ..	0.1	0.2	0.3	0.4	0.5
S ..	1.67	1.12	1.02	1.06	1.16

In order to obtain a long range for the abscissæ the horizontal scale has been made logarithmic and the curve divided into two sections (A) and (B). The section (A) holds from $f/P^2 = 10^4$ to 10^6 and the section (B) from $f/P^2 = 10^6$ to 10^8. When $f/P^2 = 10^8$ it is seen that Pd has nearly settled down to the constant value 0.165, so that this relation may be used to find d for values of f/P^2 greater than 10^8.

coil was to take a series of values of $df^{\frac{1}{3}}$ (thus fixing F and G) and then to find the corresponding values of d from (47). The value of f follows since $df^{\frac{1}{3}}$ is known.

24. Application to 2,000μH Coil.

In order to show the application of the theory in a practical case, we will consider the case of a coil intended to be used at a wavelength of 1,600 metres, as this is a

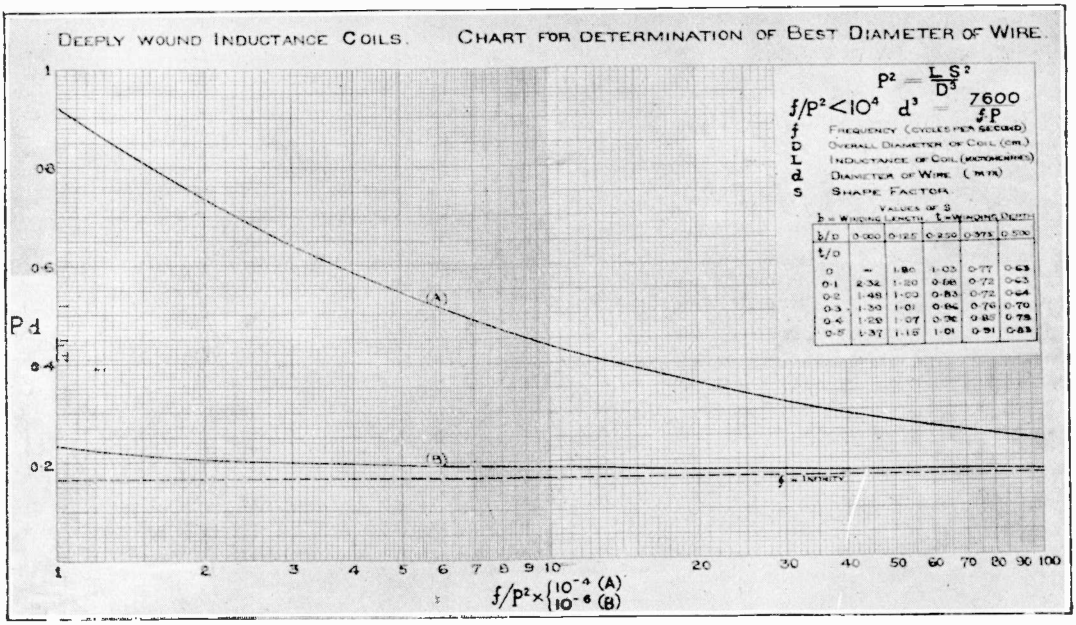


Fig. 7.

When f/P^2 is less than 10^4 the value of d is got from the formula

$$d^3 = \frac{7{,}600}{fP} \quad \cdots \quad \cdots \quad (49)$$

It will be noticed that the values of S in the Table are not equal to $K/2L_0^{\frac{1}{2}}$ but merely proportional thereto. This does not affect the accuracy of the curve provided that the constant of proportionality be included in (47) in calculating the curve. The reason for the change was to make S equal to unity for a shape which was considered to possess general efficiency, viz: $b/D = 0.125$, $t/D = 0.2$. In fact, the curve was calculated so as to give a direct relation between f and d for a coil of this shape for which $L = 1{,}000\mu$H and $D = 10$ cms. The mode of calculating the points for the curve for this

wavelength for which most coils on the market are at present wound with the wrong diameter of wire. We will choose for the inductance of the coil 2,000μH, as at the above wavelength the resonating capacity has the convenient value of 360$\mu\mu$F. A convenient size and efficient shape (see Tables IX. and X.) is

$$D = 4 \text{ in.} = 10 \text{ cm.}, \quad b = 1.25 \text{ cm.},$$
$$t = 2.0 \text{ cm.}$$

For this shape by Table VIII. $L_0 = 9.10$, so that the number of turns required is

$$\sqrt{\frac{2{,}000 \times 1{,}000}{9.10 \times 10}} = 149$$

by equation (36). We now determine the correct gauge of wire by means of Fig. 7.

From the Table accompanying the Fig.

$S = 1$, and therefore by equation (48)

$$P^2 = \frac{2{,}000 \times 1^2}{10^3} = 2 \text{ and } P = 1.414.$$

For a wavelength of 1,600 metres the frequency is 188,000 so that $f/P^2 = 9.4 \times 10^4$. Therefore, using curve (A), $Pd = 0.445$ and this gives $d = 0.314$ mm. The nearest gauge to this is No. 30 S.W.G. Remembering that this is the gauge which will make $R_h = R_s$ and that the best condition should be such that R_h is somewhat less than R_s as the frequency cannot be regarded as "high" in association with this diameter, it will probably be profitable to use No. 32 gauge.

To verify the design and to determine the expected copper resistance the following table of values of the copper resistances of the coil, using various wire gauges, has been calculated by means of the resistance equation (35).

Wire gauge.	D.C. resistance (ohms).	A.C. resistances.		Ohms. $R_c = R_s + R_h$.
		R_s.	R_h.	
36	21.7	21.7	1.2	22.9
34	14.8	14.9	2.5	17.4
32	10.8	10.9	4.7	15.6
30	8.2	8.3	8.1	16.4
28	5.7	6.0	13.7	19.7
26	3.9	4.3	24.0	28.3
24	2.6	3.1	37.6	40.7

The Table thus verifies the design in that No. 32 wire is showing the lowest resistance. The gauges have been carried to No. 24, as many commercial coils employ gauges up to this value. When it is pointed out that the winding section can accommodate the required turns with No. 18 wire it will be seen that even with the thickest tabulated wire there is ample spacing but not enough to reduce the copper losses to their minimum value. The advocates of very thin wire are justified by the results of the Table, as No. 36 wire gives better results than the gauges usually employed.

To return to the design, all we now require is the mode of distributing the turns throughout the winding section. This distribution will hardly affect the copper losses, but will have a considerable effect upon the self-capacity and therefore on the dielectric losses (such as they are).

The principle is simple. Double spacing requires considerable care and an elaborate framework, while the gains are doubtful. With single spacing (that is spacing between the layers but none between the turns in one layer) the smallest self-capacity will be obtained if the layers are short and many. Thus with a coil of the present shape the layers must be parallel to the winding length and spaced throughout the winding depth. Allowing for insulation we should be able to obtain 30 turns in a winding length of 1.25 cm. and thus we should need five layers spaced at distances of 4 mm.

The former should have an inner diameter of about 6.4 cm., giving for the diameter of the outer layer 9.6 cm. The effective diameter is then 10 cm. as we must add the layer spacing to the outer layer diameter to obtain the effective outer diameter.

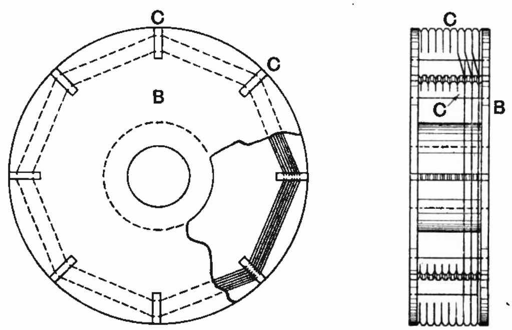


Fig. 8.

If we had chosen a shape in which the winding depth was less than the winding length, the type of winding to employ would be a "banked" winding with spacing between the banks. If suitable insulating combs are employed to support the banks a coil of this type may be wound very rapidly and thus has an advantage over a coil of the above type when very close coupling between other coils is not contemplated. The procedure of design for this type of coil is exactly as in the above case, the number of banks and of turns per bank being decided upon after the correct diameter of wire has been found.

An efficient coil of the "banked" type is shown in Fig. 8. The combs $c, c \ldots$ holding the windings are of ebonite $1\frac{1}{4}$ in. $\times \frac{1}{2}$ in. $\times$ $\frac{1}{8}$ in. and have nine slots $\frac{3}{8}$ in. deep and $\frac{1}{8}$ in.

apart, the slot width being such as to give an easy fit to No. 30 D.S.C. wire. A V-shaped opening is filed into each slot mouth so that the wire will slip readily into its proper slot when winding. The combs are supported as shown round the circumference of a mahogany bobbin of external diameter $4\frac{3}{4}$ in., the width of the cheeks being $\frac{1}{8}$ in. and their internal separation 1 in. If the coil is intended for use at 1,600 metres the wire to use is No. 30 D.S.C. and the coil is wound bank by bank, allocating 15 turns to each bank so that the total turns in the coil is 135. Three of these banks are shown wound in the end elevation.

A coil wound by the writer to the above specification gave the following effective dimensions :—

$$D=11.0 \text{ cm.}, \quad b=2.7 \text{ cm.}, \quad t=0.65 \text{ cm.}$$

As regards D it will be noticed that the coil is octagonal, and therefore the value given for the external diameter has been taken as the mean between the diameters of the inscribed and circumscribed circles of the external octagon. The theoretical calculations assume this diameter for the equivalent circular coil.

It was found that the measured and calculated inductance were both equal to 2,420μH, the measurement being made

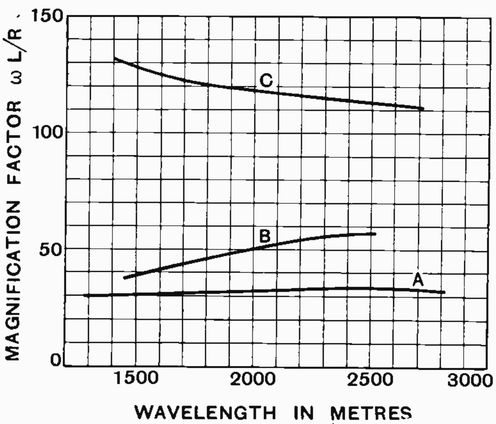


Fig. 9.

on an inductance-capacity bridge at a frequency of 1,000 cycles per second An inductance measurement made at radio frequency by the calibration department of *E.W. & W.E.* gave a value of 2,445μH and a self-capacity of 1.5$\mu\mu$F.

As regards the high frequency resistance the writer obtained the following results using the resistance variation method and a thermo galvanometer of resistance 5.1 ohms as detector. The tabulated measured values include all losses in the circuit apart from the copper losses in the leads and the D.C. losses in the detector.

The calculated resistances have been obtained from equation (35), using the measured value of the D.C. resistance, viz. : 10 ohms.

Wavelength (metres)	Obsd. A.C. Res. (ohms.)	Calcd. A.C. Res. (ohms.)
2,270	15	12
2,500	16	14
2,070	18	16
1,850	21	18
1,580	23	20
1,470	24	21

Two measurements of H.F. resistance were also made by the calibration department of *E.W. & W.E.*, in which the losses in the rest of the circuit were carefully estimated. They found at

1,605 metres A.C. resistance = 20 ohms.
2,090 ,, ,, ,, = 15 ,,

These are in practical agreement with the calculated copper resistance and thus indicate that the copper losses are the sole measurable losses in the coil.

In order to see what gains have been effected by scientific design two popular commercial coils having an approximate inductance of 2,000μH were also measured. The results are exhibited in the curves of Fig. 9. In this fig. the curves of $\omega L/R$ are plotted against wavelength for each coil. It is readily shown that if an E.M.F. e be impressed on a resonant circuit containing the coil and a condenser free from loss the P.D. developed across the condenser terminals is given by $\omega Le/R$, so that the factor $\omega L/R$ tells us what magnification of the applied E.M.F. may be obtained under ideal conditions when using the coil under test. This factor is probably thus the best factor to use for the comparison of coils of slightly different inductances.

The two commercial coils give the curves marked *A* and *B* and the above "banked winding" coil gives the curve *C*. The data for the coils *A* and *B* are as follow :—

	Coil *A*	Coil *B*
Wire gauge	24	26
External diam.	8.3	6.6 cm.
Coil length	1.5	2.6 cm.
Self-capacity	5	21$\mu\mu$F.
Inductance	2,300	2,180μH.

The curves show that at 1,600 metres the magnification factors for the coils *A*, *B* and *C* are 31, 42 and 125 respectively. It is true that in constructing what we consider to be the best solid wire coil for reception at this wavelength we have allowed ourselves rather more space than is usually assigned to these coils, but the difference is not so much due to this as to a correct choice of wire diameter. For coils of the size of *A* and *B* it is not unreasonable to expect a magnification factor of 100 without having recourse to stranded wire, provided that the correct diameter of wire is employed and the coils are wound in such a manner as to give the minimum self-capacity.

25. Stranded Wire Coils.

We are now to investigate what advantage may be gained by winding coils with stranded instead of solid wire. The type of stranded wire studied is that known as "litzendraht" in which each strand is separately insulated either by enamel or a single silk covering and the strands braided together in such a manner that throughout the length of the multiple conductor an individual strand occupies in turn all possible positions in the winding section. The object of this braiding is to ensure that each strand of the parallel system is subject to the same induced E.M.F. when alternating current flows along the conductor. Otherwise the outer strands would shield the inner strands and the current at high frequencies would only be carried by the outer strands. The necessary intermingling of the strands is usually brought about by constructing the cable on the "three" system, in which three strands are first twisted together to form a single cable and then three 3-stranded cables are twisted to form a 9-stranded cable and so forth so that we may use cables having 3, 9, 27, . . . 3^r strands. The wire gauges used in constructing stranded cable usually vary from No. 36 to No. 44.

It will be seen from the mode of construction that the D.C. resistance of a stranded cable having *n* strands is somewhat greater than the resistance of an equivalent length of solid conductor having the same copper section, as each strand makes a helical path and has thus a length greater than the length of the cable. This fact should be remembered when we are comparing theoretical and observed resistances.

There appears to be considerable diversity of opinion as to the relative merits of stranded and solid conductor for use in A.C. work. Some experimenters have even come to the conclusion that stranded wire coils have higher resistances than *corresponding* solid wire coils. The italics are introduced as the whole controversy on this point revolves round the fair method of comparison. The experimental comparison usually made is between coils having some simple common property in addition to equality between inductances. The favourite mode of comparison is to make the D.C. resistances equal and then to compare the A.C. resistances of the pair over a range of frequencies. When this mode of comparison is adopted it is found that the stranded wire coil has the initial advantage, the resistance of both coils increasing as the square of the frequency but the rate of increase of resistance of the solid wire coil being greater. At higher frequencies the solid wire coil falls away from the square law before the stranded wire coil, so that the two resistance curves tend to approach. At a certain frequency the curves cross and the solid wire coil then becomes better than the stranded wire coil. The experimenter then says that it is better to use solid wire above the frequency of cross over. The critical frequency he recommends depends upon the type of coil he happens to use for his experiments.

A more scientific mode of comparison was that made by Prof. Howe in a theoretical investigation on stranded conductors (*loc.cit.*[10]) Howe pointed out that for a given overall diameter of stranded cable there was an optimum number of strands of given diameter which would give a minimum A.C. resistance. He estimated the minimum resistance in a number of cases and compared it with the resistance which would be obtained with a solid conductor having the same overall diameter as the stranded wire. The cases he considered were those of straight cable and of long single layer solenoids. He described this as a "safe" mode of comparison, as we should be certain that both types of conductor would fit into the available space. It may be said that the comparisons did not augur well for stranded wire, particularly at the higher frequencies. In criticism of the method it may be pointed out that we have already shown that there is a great deal of air space still available in deeply wound inductance coils when the best diameter of solid wire is employed, so that it may (and will) turn out that the best stranded wire coil will have greater overall diameter than the best solid wire diameter and yet the wire may be accommodated. The above comparison in these cases therefore fails.

Prof. Fortescue (*loc. cit.*[11]) made a still better comparison, in that he found the best solid wire diameter and the best number of strands and compared coils under these conditions. The limitations of his theory have already been discussed and it is considered advisable to use the same method of comparison with these limitations removed.

The basis of comparison will therefore be between the best solid wire and best stranded wire coil at a particular frequency. An experimental comparison on this basis for all frequencies is obviously a task of some magnitude, as it would involve winding a great number of coils, particularly if we are ignorant as to the best diameters of wire to employ. It is better to compare the theoretical resistance formulæ with experiment in a few typical cases and, if these comparisons justify the formulæ, deduce the relative merits of the two types of coils from the theoretical formulæ.

The comparison will differ from that of Fortescue in that the best gauge for a given number of strands will be found instead of the best number of strands for a given gauge, as the latter mode of comparison often leads to a number of strands not practically available; whereas if we choose the nearest gauge to that indicated by theory for a known possible number of strands we are never very far from the minimum possible resistance.

25.1. *Resistance of Stranded Wire Coils.*

Let d be the diameter of one strand, n be the number of strands and d_o the overall diameter of the stranded wire. Then it has been shown (*loc. cit.*[12]) that the alternating current resistance of the stranded conductor when straight is given by the formula

$$R_s = R\{1 + F + k\,(nd/d_o)^2G\} \quad \ldots \quad (49)$$

in which R is the D.C. resistance of the stranded conductor and F and G have the same significance as before, z being calculated from the diameter of a single strand. As regards k, this depends upon n. For the usual types of stranded wire we have :—

n	=	3	9	27	large
k	=	1.55	1.84	1.92	2

For the case of a coil of stranded wire the resistance due to the remaining turns is calculated as in the case of solid wire coils. Thus, since the D.C. resistance of each strand is nR, and since there are n strands in each turn, we obtain

$$R_h = \tfrac{1}{4}\,R\,(KNnd/D)^2G \quad \ldots \quad (50)$$

Hence for the whole resistance

$$R_c = R_s + R_h = R\{1 + F + (k/d_e^2 + \tfrac{1}{4}K^2N^2/D^2)\,n^2d^2G\} \quad (51)$$

25.2. *Test of Formula by Comparison with Observation.*

A series of stranded wire coils, forming part of the Standard Multivibrator Wavemeter in use at the National Physical Laboratory, serve admirably to test the adequacy of the formula. The comparison will also clear up certain doubts which have been raised in regard to stranded wire.

The values of the decrements ($R/2fL$) of these coils have been given by Mr. D. W. Dye (*loc. cit.*[1]) and the coil details are to be found in the "Specification and Notes" supplied by the N.P.L. From these data the following Tables have been prepared.

The calculated A.C. resistances have been corrected for capacity in accordance with the formula already given. The agreement is very satisfactory, and shows that the losses other than copper losses are small even in these very efficient coils. The last column gives the magnification factor $\omega L/R$ and is inserted to show the increase in efficiency to be expected by resorting to stranded wire and having coils of this diameter. It is interesting to notice that the first coil has not symmetrical stranding, but this does not appear to affect seriously the copper losses.

The type of insulation covering the individual strands is given and the Tables clearly show that no disadvantage is to be expected by employing enamelled instead of silk-covered strands.

COIL I.

INDUCTANCE 100,000μH, TURNS 1,024, WIRE 10/36 S.S.C.
D=18.8 cm., b=5.1 cm., t=5.2 cm.

Frequency. Kilocycles Per sec.	Estimated D.C. resistance. Ohms.	Measured A.C. resistance. Ohms.	Calculated A.C. resistance. Ohms.	$\omega L/R$
10	25.3	30	28	210
15		32	31	295
20		36	35	350
25		47	38	330

COIL II.

INDUCTANCE 20,000μH, TURNS 427, WIRE 27/40 S.S.C.
D=19.5 cm., b=3.0 cm., t=5.8 cm.

Frequency. Kilocycles. Per sec.	Estimated D.C. resistance. Ohms.	Measured A.C. resistance. Ohms.	Calculated A.C. resistance. Ohms.	$\omega L/R$
25		10.5	10.4	300
30	9.84	10.8	10.7	350
40		12.2	11.4	410
50		15.0	12.2	420
60		19.7	13.2	380

COIL III.

INDUCTANCE 5,000μH, TURNS 200, WIRE 81/40 ENAMEL.
D=18.0 cm., b=1.6 cm., t=5.0 cm.

Frequency. Kilocycles. Per sec.	Estimated D.C. resistance. Ohms.	Measured A.C. resistance. Ohms.	Calculated A.C. resistance. Ohms.	$\omega L/R$
50	1.47	3.1	2.8	505
60		3.8	3.3	495
80		5.4	4.8	465
100		7.0	6.7	450

COIL IV.

INDUCTANCE 995μH, TURNS 96, WIRE 81/40 ENAMEL.
D=17.5 cm., b=1.5 cm., t=5.8 cm.

Frequency. Kilocycles. Per sec.	Estimated D.C. resistance. Ohms.	Measured A.C. resistance. Ohms.	Calculated A.C. resistance. Ohms.	$\omega L/R$
100	0.63	1.2	1.1	520
150		1.7	1.7	550
200		2.4	2.5	520
250		3.4	3.6	460

COIL V.

INDUCTANCE 202μH, TURNS 36, WIRE 81/40 S.S.C. DOUBLE-LAYER DISC COIL.
D=16.7 cm., t=3.9 cm.

Frequency. Kilocycles. Per sec.	Estimated D.C. resistance. Ohms.	Measured A.C. resistance. Ohms.	Calculated A.C. resistance. Ohms.	$\omega L/R$
250	0.258	0.9	0.7	350
300		1.1	0.9	345
400		1.7	1.4	300
500		2.4	2.0	265
600		3.4	2.9	225

As regards Coil V, Mr. Dye stated that its decrement curve (which is distinctly worse than that for the other coils) was not understood, but the Tables show that it is behaving exactly as expected by theory. As to how it may be improved will be considered when we have dealt with the theory of the design of stranded wire coils.

25.3. *Design of Stranded Wire Coils.*

The procedure of design is exactly analogous to that for solid wire coils, using formula (51) for our resistance equation. The only difficulty is that due to the term involving d_0, the overall diameter of the stranded wire. If we regard the number of strands (n) as fixed and seek the best diameter of an individual strand, then, as d varies, d_0 will also vary, but not so rapidly as d because of the space occupied by the insulation. As a rough approximation, therefore, we take d_0 to be independent of d and to have a value which is correct for the mid gauges of wire usually used in stranded conductors. This makes $d_0^2 \doteqdot 0.07n$ when d_0 is measured in millimetres. This approximation is probably good enough for the purpose, as the term involving d_0 will usually contribute only a small amount to the total resistance. When the approximate gauge has been found using this assumption, formula (51) may then be employed, using the correct values of d_0 to calculate the resistance for a gauge or two on either side in order to discover the true best diameter.

With the assumption $d_0^2=0.07n$, the method of determining the best d is as follows :—

Calculate P from the formula

$$P^2 = \sigma + n^2S^2L/D^3 \qquad \dots \quad (52)$$

in which σ is a function of n having the values

$\sigma =$	..	0	0.9	3.3	10.4	$0.4n$
for n	..	1	3	9	27	large

The best diameter d of an individual strand is then found from Fig. 7, exactly as in the case of solid wire coils.

It must be remembered that Fig. 7 gives the diameter which will make $R_s=R_h$, and since the wire usually turns out to be thin the correct relation for minimum losses is $R_s=2R_h$. The result is that the wire gauge should be somewhat less than that estimated by the above method. If, as is often the case, we are intending the coil for a range of frequencies it is well to estimate the diameter by the above method for the *highest* frequency, as then the minimum condition will fall well inside the range of working frequency.

25.4. *Example.*

In illustration of the method of design we will take Coil V. of the wavemeter series above. An examination of the Table shows that the measured A.C. resistance is much more than double the D.C. resistance, and as the D.C. resistance is practically also the skin resistance for this gauge, we see that the general field losses are too big, which indicates thinner wire if we keep to 81 strands. This is probably impracticable on account of the difficulties of manipulation. So we will try what may be obtained with 27 strands. From the coil shape we find $S=1.34$. Inserting this and the remaining factors in (52), $P^2=67$, and as we are designing for $f=600{,}000$ $f/P^2<10^4$ and therefore the formula $d^3=7{,}600/fP$ is applicable; this gives $d=0.116$ mm. and No. 40 wire is indicated. The data are now complete for calculating the A.C. resistance by formula (51), which, with $d_0=1.4$ mm., gives $R_c=1.8$ ohms at 600,000 cycles per second. This is an appreciable gain on the value found with 81/40 wire. The resistances at the lower frequencies may readily be found as the square law of frequency holds for this case. It is found that at 250,000 cycles per sec. the A.C. resistance is 1.0 ohm, somewhat higher than that for 81/40 wire, but, taken over the whole range the coil is a better coil in regard to efficiency, and this has been obtained after sacrificing the extremely fine stranding. The example clearly shows how difficult it would be to obtain the best results from stranded wire without having recourse to theory.

25.5. *Stranded and Solid Wire Coils compared.*

The comparison between the two types of coils is most readily effected by making use of formula (52). As a first approximation we will neglect σ. This approximation is suitable particularly for coils of large inductance and for coils in which a high degree of stranding is employed. For coils otherwise equal, P is then proportional to n. Now if the frequency is *low* the best diameter of wire is given by (49), from which we see that d is proportional $1/n$. Further, when the best diameter of wire is used, the A.C. resistance is proportional to the D.C. resistance of the stranded conductor, so that both are proportional to $1/nd^2$ that is to $1/n^{\frac{1}{3}}$. For *low* frequencies, therefore, the best A.C. resistance varies inversely as the cube root of the number of strands. Next suppose the frequency so high that the square root law holds for *all* possible diameters of strand. The law for determining the best diameter is then $Pd=0.165$ and since P is proportional to n, nd is constant. But at these high frequencies the A.C. resistance is inversely proportional to nd. Thus at very high frequencies there is no gain whatever by stranding.

If, now, σ be included, the low frequency gain estimated above will be somewhat reduced and at very high frequencies stranding will actually increase the resistance. In practice, however, this case will rarely arise, and it will be found possible to design small low inductance coils for use at a wavelength of 100 metres which have lower resistance than the best corresponding solid wire coil.

The gain, however, will be small. The real objection to stranded wire coils at very high frequencies is not that the resistance cannot be reduced but that the gain is so small that it is not worth the extra expense. In order to obtain some concrete idea as to the relative merits of solid and stranded wire coils we may take the first five coils of the series of coils quoted in Section 15.

The following Table shows the theoretical magnifications for these coils when they are wound with the best solid and 9-stranded wire respectively, the wave lengths being such that each coil is in resonance with a condenser of $500\mu\mu F$.

MAGNIFICATIONS OF SOLID AND STRANDED WIRE COILS.

$D=8.3$ cm., $b=1.5$ cm., $t=3.0$ cm.

Coil No.	1	2	3	4	5
Inductance (μH)	73	183	343	765	2,170
Wavelength (metres)	362	563	786	1170	1,970
Magnification ($\omega L/R$)					
Best solid wire	133	122	116	112	108
Best 9-stranded wire	192	198	203	208	224

It may be remarked here that the above shape of coil is not at the peak of efficiency in regard to shape. The coil of Section 24 is better in this respect and, as we have seen, gives a magnification of at least 125 at 1,600 metres. If wound with 9/38 wire (in 13 banks of 10 or 11 turns each) this magnification should be doubled.

It is not therefore unreasonable to expect a magnification of 100 for all solid wire coils and of 200 for all 9-stranded wire coils while still keeping to the usual sizes of receiving coils.

APPENDIX.

Determination of Mean Square Field over Winding Section of Inductance Coils.

(A) *Deeply Wound Coils.*

It is necessary first to find expressions for the axial and radial magnetic field components throughout the section of the coil. These components may be calculated if we know the axial and radial fields at any point on the end face of a "solid" coil, that is, a coil wound full from the centre. The writer was unable to find any published formulæ for these components, but as reliable formulæ exist for the mutual inductance between solid coils (*Phil. Mag.*, 29, p. 578, 1915) the necessary formulæ were derived from these fundamental formulæ, and tables of field values calculated. By using a system of curves drawn with the help of these Tables it is possible to determine the field at any point within the winding section of a coil which is not fully wound, as the process is merely one of addition and subtraction.

For the determination of the mean square field throughout the length of wire it is necessary to find the mean value of H^2r over the winding section, H being the field at radial distance r. Now as regards the mean value of this quantity over any cylinder co-axial with the coil, it is easily deduced by Taylor's Theorem that if b be the winding length of the coil a good approximation to the required mean value is obtained by taking the values at the three points within the winding section situated at $0.056b$, $0.250b$, and $0.444b$ respectively and finding their weighted mean, the respective weights being 5, 8 and 5. The same process may be applied in taking the mean of the means for the various elementary cylinders. The operation for determining the mean square field is thus reduced to the determination of the weighted value of H^2r at nine points in the winding section, whose positions and respective weights are as follow :—

u/b =	0.056	0.250	0.444
v/t	Weights.	Weights.	Weights.
0.112	25	40	25
0.500	40	64	40
0.888	25	40	25

Here u is the axial displacement of the point from the end plane of the coil and v the depth below its outer surface.

The values of K given in the text were found in this manner, but in order to remove any doubt in regard to the accuracy of the above approximation, the values of K were in a few cases also calculated by graphical integration using a much larger number of points. These determinations agreed with the tabulated values.

(B) *Solenoids and Disc Coils.*

From the formulæ given in the text for these cases it is easily shown that for single-layer solenoids $K^2=4uD^2/b^2$ and for single-layer disc coils $K^2=4uD^2/t^2$. As regards the m layered coils we merely replace u by $u+3.29(1-1/m^2)$.

(C) *Coils for which the Winding Section is very small compared with the Coil Diameter.*

In this case the function K becomes very large and it is preferable to write

$$H^2m = UN^2I^2/b^2$$

where b is the winding length and U is a function of t/b calculated by a method similar to that for the deeply-wound coils. When t is less than b, U has the following values :—

t/b =	0.00	0.02	0.04	0.06	0.08	0.10	0.20
U =	26.3	24.7	23.7	22.4	21.2	20.1	16.8
t/b =	0.40	0.50	0.60	0.70	0.80	0.90	1.00
U =	12.4	10.9	9.6	8.5	7.5	6.8	6.1

When t is greater than b it is only necessary to interchange b and t in the formula.

The above results are only strictly true for an infinite number of turns. The way in which the values for finite turns approach the tabular values may be illustrated by the case of a square section in which the wires are arranged in square order. For this case we have :—

Turns ..	4	9	16	25	36	64	100	Inf.
U ..	4.5	5.4	5.7	5.8	5.9	6.0	6.0	6.1

We may also use this type of coil to estimate the effect of groupings of the wires which are other than in square order. Thus we may take the case of a coil for which $t/b=0.5$ having 54 turns. Suppose this first wound in 6 short layers each of 9 turns, the distance apart of layers being three times the distance of turns in a layer. We find $U=10.9$ agreeing exactly with the tabular value for infinite turns. If the winding is in three long layers each containing 18 turns, the ratio of layer to turn distance being again 3 to 1, the value of U is 10.6.

These examples appear to indicate that the tabular values for infinite turns are good enough for purposes of design when the number of turns exceeds about 16 and will hold whether the wire is spaced in layers or arranged in square order. The mode of spacing affects the self-capacity rather than the copper losses.

(The author is indebted to the Admiralty for permission to publish the work relating to multilayer coils).

A Note on Transmission.

Taking Advantage of the Voltage Node. [R344.3

THE following method of feeding the high tension supply to the anode of the transmitting valve has been adopted at 5RF in order to eliminate the losses in

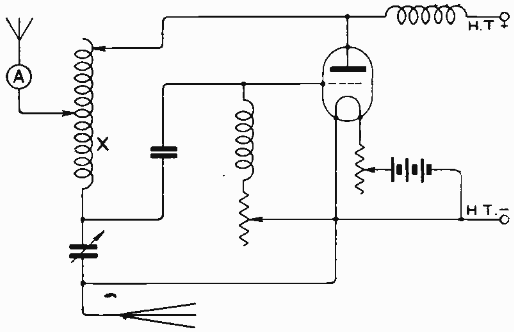


Fig. 1.

the radio-frequency choke employed in the shunt feed circuit. The removal of this choke probably has the effect also of sharpening the tuning—always a desirable feature.

In using the Colpitt's circuit, as shown in Fig. 1, it was found that a voltage node occurred at X and that the H.T. positive lead could be connected to this point on the inductance coil instead of to the anode via the radio-frequency choke.

Since the radio-frequency potential here is zero no current (except the feed current) flows along the wire W (Fig. 2) and therefore no loss of aerial current results; indeed, by this means a greater aerial current is obtained for the same power input.

The procedure for finding the nodal point is to reduce the power to one or two watts and to search along the inductance coil with the H.T. positive lead (no choke being inserted) until a point is found on either side of which the aerial current falls off. This, then, is the node where the H.T. lead is left until a change in wavelength is made. In this case, as the adjustment is critical, it will be found necessary to slide the connecting clip along the turn to which it is connected on the coil to obtain a fine adjustment. A movement of one inch makes a perceptible difference in the value of the aerial current.

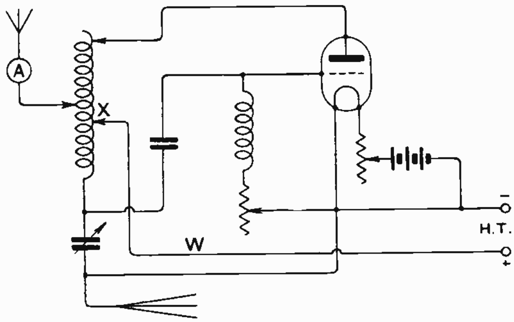


Fig. 2.

No doubt this is not a convenient method to employ where a frequent change of wavelength is necessary but it is a valuable point to consider in striving after efficiency.

L. F. HUNTER.

Mathematics for Wireless Amateurs.

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

(*Continued from page 450 of July issue.*)

(E) Division.

FOLLOWING the same method as for the other fundamental operations, we will approach the general or algebraic idea of division through the familiar ground of arithmetic. What do we really mean when we say that 15 divided by 5 is 3? Actually of course it is the mere repetition of a formula by memory, but the real basis of the formula is this: If the group called fifteen is separated out into five equal groups, each of these will be the group that we call three. In other words, the process of dividing 15 by 5 consists of finding that group, five of which combined together will make up the group called 15. Thus there are really three steps in the statement, as the reader will be able to prove to himself if he will think about it carefully enough. The steps are

$$(15 \div 5) \times 5 = 15$$

because that is what division means, followed by

$$3 \times 5 = 15$$

as an act of memory, followed by the deduction

$$(15 \div 5) = 3$$

The important step for our present purpose is the first, because it shows the reader that the formal algebraic definition of division

$$(a \div b) \times b = a$$

is identical in form with that which he already accepts, though perhaps unconsciously, as the definition of division in ordinary arithmetic.

The first thing to notice about the operation of division so defined is that $(a \div b)$ may or may not be a number in the original sense of that word, *i.e.*, a characteristic property of a group of things that can be counted. Thus $(15 \div 5)$ is the number 3, but $(4 \div 5)$ is not a number, because there is no simple group 5 of which combined together will make up the group 4. This fact has occasioned some hard thinking to pure mathematicians who, in a laudable desire to make the basis of their science as simple as possible, take the operation of counting rather than the measurement of magnitude or quantity as their fundamental conception. (They get over their difficulty by adding rational fractions to the class of numbers, an application of what Prof. Whitehead has described as the Humpty-Dumpty Principle.*)

However, as practical mathematicians, we shall be more interested in quantity than in magnitude or number, and in terms of quantity $(4 \div 5)$ is an idea that presents no difficulty whatever. We can take any quantity, such as a journey of four units (*e.g.*, inches) in a given direction and divide it into five equal journeys without turning a hair, let alone splitting one. Then if the number 4 represents the original journey, each of these smaller journeys (call it "a") is such that

$$a+a+a+a+a=4$$

i.e. $$a \times 5 = 4$$

so that $$a = (4 \div 5)$$

in terms of our original definition.

It will be convenient to introduce a few more special terms at this point. If $(a \div b) = c$ where c is a number, then a, b, and c are called respectively dividend, divisor, and quotient. The sign $\div$ is not a very convenient one to use in practice, and $(a \div b)$ is usually written $\frac{a}{b}$ or, to get it on one line a/b. A group a/b which cannot be expressed as a number, and in which a and b contain no common factor greater than 1 is called a fraction, b being the denominator and a the the numerator. In practice these names are often applied to any expression of the form a/b, a useful extension of the meaning of these words,—indeed a necessary one, since until

* Humpty-Dumpty in conversation with Alice, talking about words, "I pay them extra and make them mean what I like."

a and b are given specified numerical values one cannot say whether a/b is a number or a fraction.

It is important to realise that as far as the interpretation in terms of quantity is concerned there is no essential difference between a whole number and a fraction. In fact the same quantity can be represented by either. Thus a given weight may be represented by the number 7 or the fraction 7/16 according as to whether it is measured in ounces or pounds. Here the representation in the first place by a number and in the second by a fraction is seen to mean nothing more than a difference in the unit of measurement.

One very important conclusion follows at once from this. The Laws of Commutation and Association and the rules relating to sign in the addition and subtraction of numbers were stated and demonstrated in terms of magnitudes—lines or journeys of various lengths represented by symbols which in their turn represented numbers. It would make no difference to the reasoning employed if the units and lengths had been such as to require the use of the fractional form for the numerical description of the various magnitudes. We can therefore proceed at once to the conclusion that the Laws of Commutation and Association and the rules of sign apply without modification to the addition and subtraction of fractions, and the symbols used in Section 3 as far as paragraph C (2) can be given this additional freedom of interpretation. They may represent positive or negative whole numbers or fractions.

Giving to the word fraction the extended meaning which has been indicated above, the determining of the rules of algebraic division really amounts to finding out how such quantities enter into the operations of addition, subtraction and multiplication.

First, however, it will be well to consider how the negative sign will enter into the operation of division as defined above, for it will be a convenience if the letter symbols used in the remainder of this section can be given their unrestricted meaning as positive or negative numbers.

(E1) The Negative Sign in Division.

The statement

$$(-a \div b) \times b = -a$$

presents no difficulty. By interpreting it in terms, for instance, of the journey units used in connection with simple addition and subtraction, it can easily be shown that

$$(-a \div b) = -(a \div b)$$

i.e.

$$(-a/b) = -(a/b)$$

This is division *of* a negative number. But is division *by* a negative number a comprehensible operation ? If so, what does it mean ? In any case, its meaning must be consistent with our definition of division, so we can start with

$$(a \div -b) \times -b = a$$

which brings us back to multiplication by a negative number. Now an explanation has already been given for the apparently incomprehensible operation of multiplication by a negative number, and it has been shown that no mistake will arise from using the formal rule

$$(a \times -b) = -(a \times b).$$

Applying this rule in the above case we have

$$a = (a \div -b) \times -b = -\{(a \div -b) \times b\}.$$

Therefore

$$(a \div -b) \times b = -a.$$

Comparing this with the previous result, *i.e.*

$$(-a \div b) \times b = -a$$

we see that the apparent process of division by a negative number will be consistent with our interpretation of multiplication by a negative number if $(a \div -b)$ is taken to mean the same thing as $-(a \div b)$, so that

$$(a \div -b) = (-a \div b) = -(a \div b).$$

Applying these formal rules to the case $(-a) \div (-b)$ will obviously give

$$(-a) \div (-b) = (a \div b).$$

Thus we have the three general rules for the combination of signs in division :—

Minus divided by Plus is Minus.
Plus divided by Minus is Minus.
Minus divided by Minus is Plus.

These, however, will not impose any additional burden on the memory, for they are the same as those for multiplication.

Now that an intelligible interpretation has been found for division of or by a negative number, together with the rules that apply, the letter symbols may be taken to represent any positive or negative numbers as practical conditions may require. On this basis we can proceed to deduce formulæ appropriate to various operations with the fractional form.

(E2) Various Operations with Fractions.

In the following paragraphs the name fraction is taken to mean any combination of the form $(a \div b)$ where a and b are positive or negative numbers. The reader is asked to obliterate from his mind as completely as may be any preconceptions about fractions based on imperfectly or even misunderstood rules remembered from school days and to think instead of the operation of division as defined completely and exclusively by the statement

$$(a \div b) \times b = a.$$

(a) Reduction of a Fraction to its lowest Terms.

Suppose $a \times p = c$
$b \times p = d$

Then $(a \times p) \div (b \times p) = (c \div d)$

and by the definition of division

$$(a \times p) = (c \div d) \times (b \times p)$$

Therefore $a \times p = \{(c \div d) \times b\} \times p$

and $a = (c \div d) \times b$

whence, by definition $(a \div b) = (c \div d)$

i.e. $(a \times p) \div (b \times p) = (a \div b)$

or $ap/bp = a/b$

This shows that if the numerator and denominator of a fraction contain a common factor, this factor can be removed from each without altering the magnitude of the fraction. This process is called the reduction of a fraction to its lowest terms.

(b) Distribution of Denominator.

By the Law of Distribution in multiplication

$$\{(a \div c) + (b \div c)\} \times c = (a \div c) \times c + (b \div c) \times c$$
$$= a + b$$

Therefore, by definition,

$$(a \div c) + (b \div c) = (a + b) \div c$$

or

$$\frac{a}{c} + \frac{b}{c} = \frac{a+b}{c}$$

It will be a useful exercise for the reader to prove for himself the statement

$$c \div (a + b) = (c \div a) + (c \div b).$$

If he succeeds the truth is not yet in him, for the proposition is false. The attempt to prove it will assist in impressing its untruth.

(c) The Addition of Fractions.

The results stated in (*a*) and (*b*) taken together show how any two fractions can be added together and expressed as a single fraction, for

$$\frac{a}{b} + \frac{c}{d} = \frac{ad}{bd} + \frac{cb}{db} = \frac{ad}{bd} + \frac{bc}{bd} = \frac{ad + bc}{bd}$$

The extension of this process to give

$$\frac{a}{b} + \frac{c}{d} + \frac{e}{f} = \frac{adf + cbf + ebd}{bdf}$$

is obvious, but the reader is advised to check it for himself. A little further thought will show that these formulæ are illustrations of the fact that only groups of like things can be combined arithmetically.

In virtue of the Law of Association the addition of any number of fractions can be represented as a single fraction by repeating the above process as often as necessary. It should be noted that the numerator of the combined fraction is obtained by combining according to sign the products of each numerator with all the other denominators, the sign being considered to be attached to the numerator in each case. Thus

$$\frac{a}{b} - \frac{c}{d} + \frac{e}{f} = \frac{adf - cbf + ebd}{bdf}$$

(d) Multiplication of a Fraction.

Since a fraction, interpreted quantitatively, is not essentially different from a whole number, the multiplication of a fraction by a whole number does not involve any new ideas at all. It is worth while to notice, however, that the result of any such multiplication can be represented as a single fraction.

$(a \div b) \times b = a$ by definition.

Therefore $(a \div b) \times b \times c = a \times c$
$(a \div b) \times c \times b = a \times c$ (Law of Commutation)

i.e. $\{(a \div b) \times c\} \times b = (a \times c)$

Therefore $(a \div b) \times c = (a \times c) \div b$

by the definition of division.

In fraction form

$$(a/b) \times c = (ac/b).$$

(e) Multiplication by a Fraction.

Remembering that the fundamental definition of the operation of multiplication is that contained in the statement

$a \times b = a + a + a + a +$ *etc.*, b terms in all it appears that multiplication *by* a fraction is not a comprehensible operation, and in point of fact it certainly is not. There is nevertheless an operation that can conveniently be described as multiplication by a fraction provided its real character is clearly understood. The fraction $(a \div b)$ can be multiplied by c giving $(a \div b) \times c$. This number or fraction can then be divided by d, giving $\{(a \div b) \times c\} \div d$. Now this process of multiplication by c followed by division by d can be expressed for the sake of abbreviation as multiplication by $(c \div d)$. In fractional form the operations can then be written

$$\frac{a}{b} \times \frac{c}{d}$$

It will be assumed that whenever the apparent process of multiplication by a fraction arises in practice it will be legitimate to re-interpret the operation in the above manner, *i.e.*,

$$\frac{a}{b} \times \frac{c}{d} = \{(a \div b) \times c\} \div d.$$

In fact this assumption is necessary for only on these lines can a comprehensible meaning be attached to the process. On this understanding we can proceed to find the single fraction that shall have the same magnitude as the " product " of two fractions. Suppose $(e \div f)$ to be this fraction. Then

$$\{(a \div b) \times c\} \div d = (e \div f)$$

and by the definition of division

$$(a \div b) \times c = (e \div f) \times d.$$

Now it has been shown above that

$$(a \div b) \times c = (a \times c) \div b$$

therefore $\quad (a \times c) \div b = (e \div f) \times d$

and by definition $\quad (a \times c) = (e \div f) \times d \times b = (e \div f) \times (b \times d)$

therefore $\quad (a \times c) \div (b \times d) = (e \div f)$

i.e.

$$\frac{a}{b} \times \frac{c}{d} = \{(a \div b) \times c\} \div d = (a \times c) \div (b \times d) = \frac{ac}{bd}$$

The extension of the above reasoning to give

$$\frac{a}{b} \times \frac{c}{d} \times \frac{e}{f} \times \frac{g}{h} \times \text{etc.} = \frac{aceg \text{ etc.}}{bdfh \text{ etc.}}$$

is a straightforward application of the Law of Association.

(*f*) *Division of a Fraction by a Fraction.*

Strictly speaking division by a fraction is no more intelligible than multiplication by a fraction. It can easily be shown, however, that its meaning can be immediately derived from that of multiplication by a fraction, if it be assumed, as it obviously must be, that the apparent process of division by a fraction is consistent with the formal definition of division.

Putting $\quad (a \div b) \div (c \div d) = (e \div f)$

then by the definition of division

$$(a \div b) = (e \div f) \times (c \div d) = \{(e \div f) \times c\} \div d$$

as above.

Therefore $\quad (a \div b) \times d = (e \div f) \times c$

and by definition $\quad \{(a \div b) \times d\} \div c = (e \div f)$

Therefore $\quad (a \div b) \div (c \div d) = \{(a \div b) \times d\} \div c$

and on the understanding indicated in para. (*e*) above, the right hand side can be written in the form $(a/b) \times (d/c)$ giving

$$\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \times \frac{d}{c} = \frac{ad}{bc}$$

This shows that dividing by a fraction is the same as multiplying by the same fraction inverted. The result of inverting a fraction in this way is called the " reciprocal " of the fraction.

Since $c = c \div 1$, we have as a special case

$$(a/b) \div c = (a/b) \times (1/c) = a/bc.$$

Thus division by a number can be represented as multiplication by a fraction having 1 as numerator and the number as denominator.

(E3) **The Division of Zero by a Number.**

There is no difficulty about this operation. The fraction $(0 \div a)$, if it exists, must have a meaning consistent with the definition

$$(0 \div a) \times a = 0.$$

for any positive or negative value of a. Now, as shown in para. D2 of Section 3,

$$0 \times a = 0$$

Therefore, the statement that

$$(0 \div a) = 0$$

fits in quite satisfactory with the rest of our rules and definitions.

(E4) The Division of a Number by Zero, and the Collapse of Mathematics.

What is the meaning of $(a \div 0)$? The meaning, if any, must be consistent with the definition

$$(a \div 0) \times 0 = a.$$

But for all positive and negative numbers

$$b \times 0 = 0$$

and the reader can easily prove for himself that this is equally true for any positive or negative fraction. Therefore $(a \div 0)$ must be something essentially different from a whole number or a fraction, and the rules of algebra must *not* be applied to the group $(a \div 0)$. To prove this statement we will proceed to wreck the whole structure of mathematics by assuming that they can be applied to it.

$$\frac{a}{0} + \frac{b}{c} = \frac{a \times c + b \times 0}{c \times 0} \quad \text{by para. E2 } (c)$$

$$= \frac{ac}{0}$$

Now let d be some other number different from b. Then

$$\frac{a}{0} + \frac{d}{c} = \frac{a \times c + d \times 0}{c \times 0}$$

$$= \frac{ac}{0}$$

Therefore

$$\frac{a}{0} + \frac{d}{c} = \frac{a}{0} + \frac{b}{c}$$

$$\frac{d}{c} = \frac{b}{c}$$

and finally

$$b = d$$

Therefore, any number is equal to any other number, and the whole of mathematics is nonsense.

In fact, the group $(a \div 0)$ is a germ of insanity that is liable to infect the most sedate of propositions and set it babbling gibberish. If at any time a set of equations goes thus suddenly mad and announces that the moon is made of green cheese the baneful effect of division by zero can be suspected. The germ may have crept in disguised as something quite harmless and respectable, for instance, division by $(a—b)$ at one point, followed at a later stage by the condition "let $a = b$."

(F) The Fundamental Rules of Algebra—General Conclusions.

Intelligible interpretations have now been found for positive and negative fractions and for the addition, subtraction, multiplication and division of positive and negative fractions. We can now proceed to the full generalisation of the letter symbols. In any expression in which letter symbols are associated with all or any of the operations of addition, subtraction, multiplication, or division, the letter symbols may be taken to represent any positive or negative whole numbers (integers) or positive or negative fractions as the conditions of the problem may require.

The writer has deliberately refrained from presenting any tabular summary of the rules and formulæ so far developed. Any reader who is new to the subject is strongly advised to do this for himself, as this will help him in the understanding and memorising of the more important conclusions. He is also recommended to familiarise himself with the technique involved by working out far more examples than can be presented in the limited space available for this series. Plenty can be found in any elementary text-book of the subject. An even better, and certainly more interesting way, is to make up a number of examples for some imaginary pupil.

(G) Mathematics as a Thought-Saving Device.

Before going on to the interesting elaborations and developments of the fundamental rules of algebra it will be well to say a final word with regard to the character of mathematics in general and the right way of applying it.

The writer has been at some pains to invest the mystic symbols of mathematics with a precise and real, one might almost say homely, significance. This is strictly in accordance with the spirit of modern mathematicians, who are becoming increasingly distrustful of any purely formal symbolism of doubtful interpretation, and who seek to base their science on a few simple ideas about number or magnitude. Clearness in the initial ideas is essential, and this clearness has to be paid for in hard thought; but it is not for a moment suggested that all the ideas involved are to be turned over in the mind every time the fundamental formulæ are applied. In fact, nothing could be farther from the object of mathematics, which is, though it may sound paradoxical, the elimination of thought. This is very clearly stated by Prof. A. N. Whitehead, a mathematician who combines the intellect of a scientist with the imagination of a poet and whose book, *An Introduction to Mathematics* (Home University Library) can be very warmly recommended to all who are interested in this subject. The object of the symbolism of mathematics is to enable us to "make transitions in reasoning almost mechanically by the eye, which otherwise would call into play the higher faculties of the brain. It is a profoundly erroneous truism . . . that we should cultivate the habit of thinking of what we are doing. The precise opposite is the case. Civilisation advances by extending the number of important operations that we can perform without thinking about them." This may sound like a glorification of "rule of thumb," but it is "rule of thumb" with a difference. To apply a formula without thinking about it is a gesture not unworthy of a mathematician. To apply it without understanding it, or without ever having understood it, is at best a *pis aller* and at worst an unintelligent faith in Mumbo-Jumbo.

Examples—Division.

1. Show that

$$\frac{3}{10}+\frac{7}{100}+\frac{9}{1,000}+\frac{6}{10,000}+\frac{8}{100,000}=\frac{37,968}{100,000}$$

2. If $\frac{1}{b}-\frac{1}{a}=\frac{c}{ab}$

prove that $ac+bc=aa-bb$

3. Show that

$$\left\{\left(\frac{1}{a}+\frac{1}{b}+\frac{1}{c}\right)-\left(\frac{a}{bc}+\frac{b}{ac}+\frac{c}{ab}\right)\right\}\div\left(1-\frac{b}{a}\right)\left(1-\frac{c}{b}\right)\left(1-\frac{a}{c}\right)=\frac{1}{a-b}+\frac{1}{b-c}+\frac{1}{c-a}$$

4. Prove that if

$$R_0R_1R_2+R\,R_2R_3+R_0R_3R_1-R_1R_2R_3=0$$

$$\frac{1}{R_0}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

5. Show that $\frac{R_1R_2}{R_1+R_2}$

where R_1 and R_2 are positive numbers or fractions, is less than the smaller of R_1 and R_2.

(*To be continued*).

THE EMERALD WAVEMETER.

This wavemeter, designed by Lt.-Col. Edgeworth, is an instrument with which the amateur can obtain accurate measurements of wavelength —the accuracy of calibration being a lasting quality not depending on the actual valve in the wavemeter, provided a similar type to the one originally supplied is used.

Another very good point that the average user will appreciate, is that the wavemeter is direct reading—*i.e.*, the wavelength is read off directly on the wavemeter scale and not from a calibration curve. A very neat arrangement is adopted in order to give a large and uniform wavelength scale, and it speaks well for both the design and the construction of the instrument that the slow motion arrangement on the condenser may be relied on sufficiently well to make the instrument direct reading.

Various two-volt valves, made by different makers, but more or less similar in type, were tried in one of these wavemeters, and the wavelength checked against our standard heterodyne instrument.

The method of testing was to obtain a heterodyne note of about 1,000 volts with the valve supplied and then to insert other valves in succession and note the change in beat note—which change was exceedingly small, *even near the minimum of the wavemeter condenser*, thus showing that valve capacities were unimportant in determining the calibration.

The price of the wavemeter is remarkably low, but in spite of this the instrument can be strongly recommended as reliable and accurate as well as robust in construction.

It may be obtained from Messrs. Heath and Co., New Eltham, S.E.9. A. P. C.

VARLEY MAGNET CO.

The Varley Magnet Co., which is well-known as a subsidiary Company of Oliver Pell Control Ltd., is now marketing Varley Bi-Duplex Wire Wound Anode Resistances. This firm is not connected in any way with the Varley Radio Co., but we find that there has been a little confusion owing to the similarity in name.

Problems in Broadcast Receiver Design.

A Lecture delivered by Mr. P. P. ECKERSLEY, Chief Engineer of the British Broadcasting Company, before the Radio Society of Great Britain, on 26th May, 1926.

[R160.04

I AM going to try to take you through some of the problems that beset the designer of broadcast reception apparatus, and if I do not accept certain ideas that are common, I do so in the hope that discussion will be promoted.

Broadcasting, like any system of communication, depends on the two ends of the chain, Transmitter and Receiver, and for that reason one who is responsible for the transmission side has some excuse for talking about reception.

I would say that in general there are two types of receiver which people visualise when thinking of broadcast reception. The first is one which has a good many knobs on it, and about which people tell lies to their friends—to borrow an Americanism a "reaching-out receiver." The second is the "local station" type which gives, or tries to give, perfect quality.

I should like first to deal with the "reaching-out" set. It is designed to get the distant station and therefore has great sensitivity. I would say that in general there are two main types of "reaching-out" receiver: one is the Neutrodyne or tuned high frequency magnifier, and the other the "Supersonic." The principle of the neutrodyne is illustrated in Fig. 1, which shows a tuned anode system of magnification with two similar circuits in cascade; inter-electrode valve capacity, among other qualities of the circuit, introduce reaction and the whole system would oscillate were it not for the introduction of small inter-electrode balancing capacities.

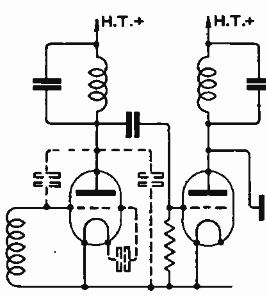


Fig. 1. *Two circuits in cascade employing the neutrodyne principle.*

A typical form of this circuit which has taken on here and in America, is shown in Fig. 2, where aperiodic windings give a "step up" effect and allow a gain of sensitivity.

A very common type of set used in America employs two high frequency amplifiers, a

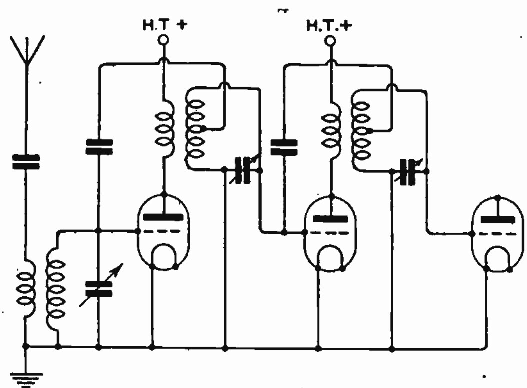


Fig. 2. *Aperiodic transformer couplings.*

detector and one or two note magnifiers, switched in or out at will. It is sensitive enough to pick up fairly distant stations, and sufficiently selective for most purposes, a ubiquitous receiver which is deservedly popular. The maximum number of high frequency stages used in one set is five (used in a British set). This is one developed by Captain Round in this country, namely the "Straight Eight," which has a larger number of neutrodyne stages than any receiver in the world.

The principle adopted has been to have a smaller magnification per stage than is usual with the multi-cascade arrangement, which has the advantage of very great selectivity. But the main disadvantage of this type of set is that the number of handles to be accurately set is considerable, otherwise the system has much to recommend it. It is only by getting them adjusted one by one that you get the signal, and as the tendency must be towards simplification, I think that that fact might be considered a disadvantage of the neutrodyne receiver. Otherwise it is extremely simple and a perfectly practicable proposition. The reproduction can be made good; the set can be used close to the local station without undue effects of saturation, by mistuning the aerial circuit—a crude method but one that works.

The superheterodyne is the other main type used for distant receiving. The theoretical diagram is given in Fig. 3.

If you receive a certain signal in a circuit with a frequency of N_1 and introduce a closed circuit beating with that circuit with a frequency of N_2, after rectification you produce a new frequency, which is equal to $N_1 \pm N_2$. Obviously in receiving a particular frequency and beating it with another, you obtain a third frequency, and can amplify that third frequency by any means that you like. Selectivity comes in by the fact that the small change in the added frequency makes a large change in the beat frequency, and any other station coming in at a different frequency produces signals which, in a highly selective high frequency receiver on the beat note, will be completely lost. You get over the disadvantage in the previous receiver inasmuch as theoretically there need only be two adjustments, namely the aerial tuning and the beat note tuning, but there is an ambiguity: you can adjust the added frequency by a certain percentage up or down

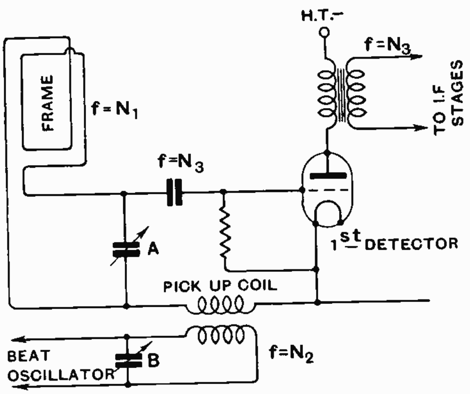


Fig. 3. *Theoretical diagram of superheterodyne.*

and produce the same beat frequency. This, however, has been got over ingeniously in one particular receiver.

What is done is to use a coupling (Fig. 4). *A* is the adjustment on the aerial and *B* is the adjustment on the beat note. These two are coupled together mechanically so that they both turn together. Any small discrepancy between the two readings can be adjusted, as the coupling is not rigid and it is possible to move one dial without the other to get final adjustment.

A disadvantage of the superheterodyne is the tendency to saturate when you are

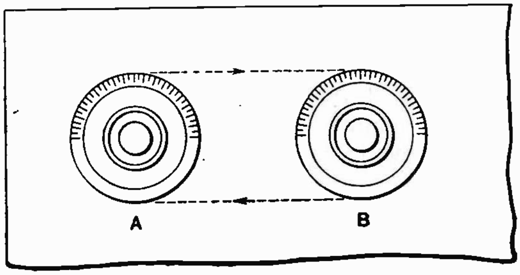


Fig. 4. *Mechanical coupling arrangement.*

listening to the local station. The preponderating effect of the local station is apt to produce saturation in the rectifying valve, and very poor quality indeed. Obviously, although some do not think so, this receiver, which incorporates an independent oscillator, will produce interference with other receivers; the aerial will pick up a certain amount of the beat oscillations and radiate them, other listeners will get a whistle, if the beat frequency nearly coincides with the frequency on which they happen to be listening. This can be overcome, and it is advisable to do so, by putting a high frequency stage between the aerial and the beat producing system. If the high frequency stage is properly neutrodyned, Fig. 5, and that is important, you will get a better measure of freedom from interfering with other people. The fact that a frame only is used minimises the possibilities of interruption. But I can assure users of frames that they radiate quite enough.

In summing up the general principles of these two types of receiver, "superheterodyne" and "neutrodyne," I am aware that there are other methods of achieving high frequency magnification, but those with which I have dealt represent two distinct types, on which practically all others are based, one way or another.

Coming to a consideration of the local station receiver, I feel very strongly that the development of broadcasting must be towards alternative stations with as little interference as the system of to-day gives. It is our proud boast that 80 or 90 per cent. of the population can receive broadcasting on very simple sets. In using the term " crystal area " I mean it to be known as an area in which any simple receiver can get absolutely uninterfered-with reception. What can be received on a crystal set satisfactorily will be sufficiently powerful to drown local interference such as trams, railways and so forth, and it is possible thus to concentrate on a programme. While there will always be those who are interested in the electrical side, I still think that the main development of broadcasting must be an interest in what is received rather than an interest in the method of receiving it, and that is the justification for the local station receiver—giving above all things perfect quality. We must concentrate upon receiving in our rooms sounds that do not differ

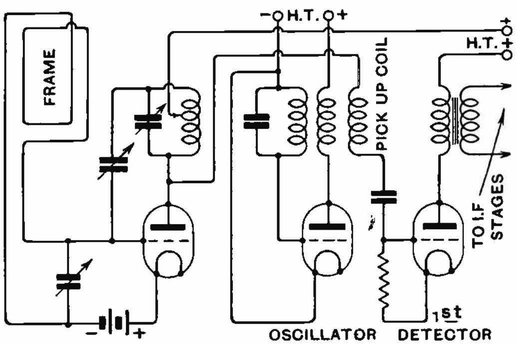


Fig. 5. *Circuit showing method of neutralising.*

in great respect from the sounds produced in the studio. The obvious criticism of the local station receiver is, where is the variety that it is possible to get from broadcasting? As I have said before, future engineering development must be towards giving alternative programmes, but they must be as strong as the local programme under the present system. If this is so, we shall have to get more selectivity into our receiving sets. The " crystal area " policy has produced many sets that are not efficient on the high frequency side; but 90 per cent. of valve sets I inspected the other day were unable to cut out the local station. The policy of alternative stations obviously demands selectivity. " Local receivers " rely too much on the straight " detector and low frequency " circuit. Selectivity is extremely poor, and, in order to use " bottom bend " rectification a considerable sweep on the detector grid is necessary, which rather points to it being more satisfactory to put in at least one high frequency stage. To take the high frequency first, it is very easy to add a high frequency stage on an existing receiver. Two high frequency stages, shall we say, neutrodyned with a one-handled adjustment, would be sufficient for most listeners even with an indoor aerial. However, even with satisfactory high frequency, the method of detection needs careful consideration, because, although " any old thing " works, very few " old things " work at all well. The commonest form of detection used throughout the world is the grid-leak and condenser method. While it is true that this method frequently facilitates the use of reaction, no instrument should rely entirely on the use of reaction for its efficiency.

In the second place, many people find that a high value of grid-leak will give a louder signal, but it will give worse distortion too. It is possible with a detector of the bottom bend type, that is to say, utilising the non-linear properties of a valve characteristic, very similar to that of many crystals, to introduce to a limited extent reaction in two high frequency stages which will not involve any oscillation in the aerial and which will never interfere. So that the argument that the grid-leak will give you facility in the use of reaction falls to the ground. In general, with the grid-leak method the disadvantage is that you rectify first and amplify afterwards; but with bottom bend you amplify first and then rectify.

A point about these two systems is that in essence they do not differ to any great degree as far as their function is concerned. You may draw " A " simply as a box and call it a rectifier which has in series with it a resistance and a condenser. You can draw " B " as a box and call it a rectifier in the same way. But the " A " system has the disadvantage that the impedance values of the grid circuit are much greater than in " B " and the values of the components will more greatly affect performance.

I do not wish it to be thought that the grid-leak method need be so absolutely condemned, but I think, after comparing it judicially with the bottom bend method, the latter scores considerably, as it is, as I have said before, in fact a crystal rectifier. You can work this bottom bend rectifier with grid current or without, and the question as to whether grid current produces distortion in the bottom bend rectifier is answered very inconclusively by experiments on the point. It needs a high anode voltage and a high impedance value. In that connection, it is interesting that grid current almost inevitably flows in high frequency magnification, and those systems, unlike low frequency amplification, with grid current present, do not introduce very much distortion, the reason perhaps being that the high frequency circuits in front of the grid, being tuned, are free to swing, and are therefore not unduly influenced by the load of the grid current, and are not immediately checked, like low frequency, by the effect of the load.

I would ask, "Why is it that in valve sets the crystal is not more used as a rectifier?" It is true they are said to be unreliable, but in speaking of crystals I mean the sort that was used before the valve was invented. Did we have a lot of trouble with them in those days? From beginning to end they never seemed to do anything else but rectify.

Fig. 6 shows a convenient way of using a crystal rectifier with one high frequency

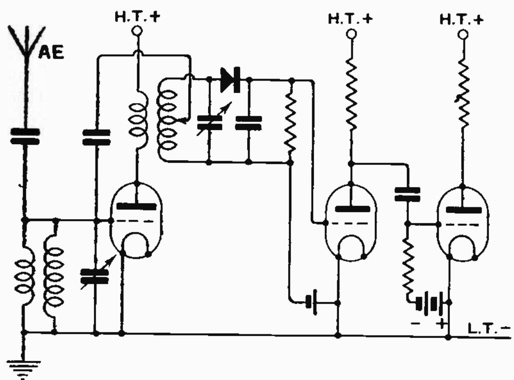


Fig. 6.
Convenient circuit for using a crystal with one H.F. valve stage neutralised followed by L.F. stages.

valve neutrodyned and one or two low frequency stages. This system has the advantage that there is less to maintain in the way of filaments and high tension. I doubt whether there is any difference between a crystal and a bottom bend rectifier provided you have sufficient grid sweep. It is possibly not quite so sensitive and might be unreliable but with correct design that is not necessarily so.

Turning to the low frequency amplifier, it is definitely dangerous to use transformers,

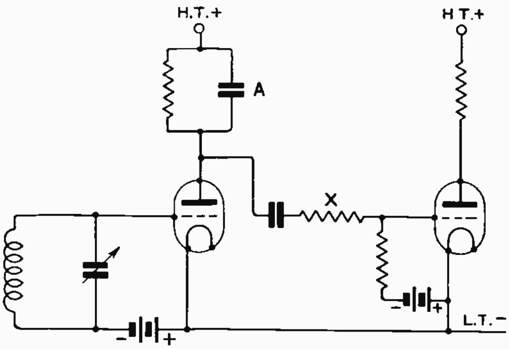


Fig. 7. *Interesting circuit for producing a drop in H.F. voltage.*

mainly because transformers are very difficult to design, and even the best that we have designed still suffer from some slight falling off in characteristics on either side of the frequency gamut, and few appreciate the important point that a load on the secondary or even on the primary makes an enormous difference to the characteristics. A damp transformer may completely change its characteristics by leakage across the terminal. Doubtless the justification for transformers in the past has been that they do give a tremendous lot of "noise," and in the absence of the perfect loud-speaker perhaps there was some excuse, but it is now time to say "good-bye" to the transformer wherever we can and introduce resistance or choke capacity. I am wondering, in the light of the disadvantage with resistance capacity—the necessity for increased high tension—whether one would not gain by using choke capacity, and it would be interesting to know if anyone has any figures or views on the question.

With resistance type of magnification, there is a disadvantage in that the low frequency amplifier may pick up high frequency and magnify that up as well. This is apt to produce nasty reactions. There is an interesting connection, due to Captain Round, which may be of interest. The method is shown in Fig. 7. Connect a resistance *X*, which has the effect of producing a drop of high frequency voltage so that the voltage on the grid, thanks to the valve inter-electrode capacity, is negligible. A very useful point.

The use of choke or resistance capacity brings up the question of power supply. I, myself, although I use rather an inefficient circuit and a considerable amount of voltage and current, am fortunate in living in a district which has A.C. supply which I take through a transformer with a centre tap secondary and rectify and smooth. The method I use is shown in Fig. 8. There is a large choke *K* and a condenser *Z* and double rectification. The circuit can easily be smoothed. I find a couple of .5μF condensers with a 20 or 30 henry choke are quite sufficient. I find it possible to light my two low frequency valves from the power mains also, but in order to avoid fluctuating A.C. on the grids it is necessary to take the grids down to the centre point of the secondary of the filament transformers.

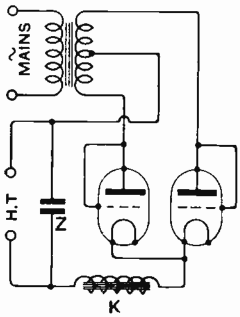


Fig. 8.
A.C. smoothing circuit.

With this method it is not necessary to put a potentiometer across the valves. The particular method that I use is rather expensive because I use three-electrode valves instead of two. Perhaps it would be better to load all the valves from a low tension accumulator charged through another system, but I feel sure that the system can be made to be extremely cheap, even though the initial outlay is perhaps a little more. Operating on a power circuit with a cheaper unit its maintenance would amount to practically nothing. Perhaps the future will see valves with finer filaments and with even less filament current than they have to-day, when dry battery lighting will be possible on an economical scale. Remembering that the average loud-speaker to-day has a very low efficiency, perhaps the high efficiency loud-speaker of the future will remove the necessity for a constant change of high tension batteries.

I am not sure whether controlling the volume of a set by dimming the filaments of high frequency valves is a good one. It is possible to dim the filaments but when you have a set in one room and a loud-speaker in another then it becomes rather unsatisfactory practically. It should be possible to design a potentiometer system on the loud-speaker itself, bearing in mind that it is necessary to keep a constant impedance across the transformer.

Finally, I give the circuit shown in Fig. 9, not because I think it represents finality, but merely to show what might be done on the lines that I have suggested. A small series condenser in the aerial circuit will make it possible to calibrate the closed circuit. There may be one or two high frequency valves. The crystal set can be connected across the secondary of a high frequency transformer; which is neutrodyned, thus introducing a limited amount of reaction without the possibility of re-radiating.

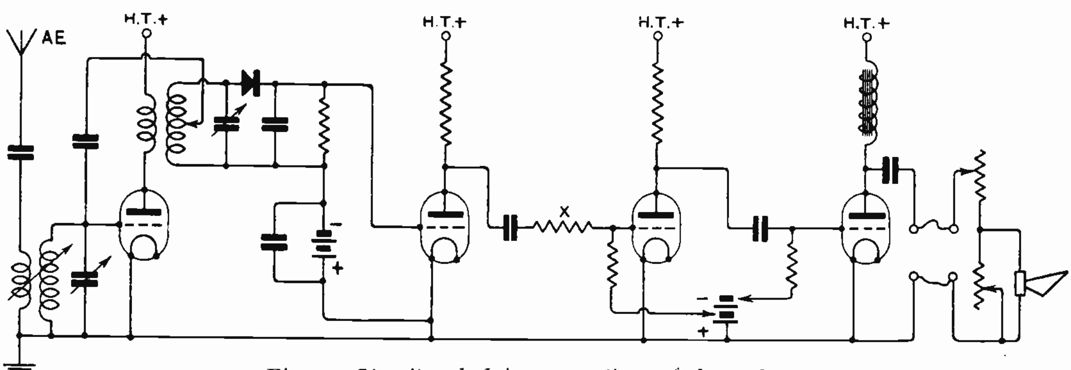


Fig. 9. *Circuit embodying suggestions of the author.*

DISCUSSION.

Admiral Sir H. B. Jackson: Captain Eckersley has enlightened, enlivened and advised us a good deal. He is helping all listeners by trying to stop this oscillation nuisance. I am very much in agreement with what he has said about it. I live within a mile of that West End store and have almost given up reaching out, except when 2LO is not working. When I do try there is always oscillation present; he is quite right in driving the point home.

Mr. R. W. Minter: I rise to answer Captain Eckersley's accusations against the neutrodyne. I think the reception problem starts at the transmitter, and it seems to me rather late in the day to start up so many transmitters, irrespective of what is happening, and then get the engineers to clean up the mess. As far as I can see, the neutrodyne is the thing that solves the problem we have at the present moment. In his description of the neutrodyne, Captain Eckersley said one or two things which were not quite right, but, in the first place, a little more information might be useful. The neutrodyne is in two sections usually. The one with two stages is the unshielded one, and that with more than two stages is shielded. With more than three stages it does not seem at all satisfactory. The trouble which arises in this country, is that the American neutrodyne has been developed for American valves. Up to the the present time, no British manufacturer has produced a valve which happens to have a capacity equal to that of the R.C.A. valves used in America with the neutrodyne, so that anybody using an American neutrodyne here who cannot get the valves which are used with it in America will have bad results. As to rectification, and Captain Eckersley's remarks about the grid-leak, there is a neutrodyne without the grid-leak, but it does not seem to be as popular because it does not give so much noise. Referring to crystal rectification, I remember that at one time we had good crystals, which would not go off, but I do not think one is made at the present time; I have had a great deal of trouble with them during the last few years. They will not stand any appreciable current through them, and I think they would be rather out of place in an amplifier with high frequency stages in front of them.

Mr. H. L. Kirke: I should like to thank Captain Eckersley for his excellent lecture, and to make one or two comments. With regard to reaction, I think that it is a thing which is so valuable to the manufacturer that he must use it in order to get his price down and compete, but I also think that manufacturers should have a little conscience and should endeavour to produce sets in which reaction is controllable. I have had the misfortune to advise friends of mine at various times on the buying of sets, and on several occasions have actually tested the set before sending it to them. I think on every occasion the reaction was so absurdly coarse, except for two positions, one with great oscillation and the other irregularity in signal strengths, that it was necessary to stand on your toes, grease your fingers, and, after ten minutes playing about, you might get a reasonable signal. Greater care should be taken in designing sets so that reaction should be capable of complete control. Another point I should like to bring out is the question of grid currents in bottom bend rectifiers. I have had a certain amount of experience in designing a particular piece of apparatus in which it is necessary to use a rectifier which is very perfect from the point of view of no distortion, and we found it essential to use bottom bend rectification, which was the best. It was also essential that there should be no grid current, but the grid circuit was an aperiodic one. I think the distortion from grid current is due to the fact that it produces harmonics in the carrier wave and the side band, and the harmonics in the carrier wave and the side band heterodyne, showing themselves as harmonics in the rectified low frequency current. If you have a fairly low damped oscillatory circuit which can by-pass all the harmonics produced by the distorting grid current you will not get distortion. With regard to crystal rectifiers, I think that carborundum has the advantage that it is a high resistance rectifier, and as the amount of damping introduced across the circuit varies with the resistance, it is an advantage to use a high resistance rectifier, in that variations in the resistance caused by adjusting the contact will not have such a great variation in the damping of the circuit. With regard to transformer coupling, resistance coupling and choke coupling, with resistance coupling you have to use low impedance valves, because you lose a lot of high tension voltage in the resistance, and you do not get the magnification out of the low impedance valve that you do out of the valve plus transformer. But if you use choke coupling you do not lose any high tension in the choke, or, at any rate, very little, and you can use high impedance, high magnification valves and get the same amount of output, although for less input, than with the low impedance resistance-coupled valve. That is, you can get the same amount of voltage sweep out of the valve without distortion with a high magnification valve with choke-coupling as out of a low magnification valve using resistance coupling, and that is the great advantage of choke coupling, I think. In connection with the question of high tension, usually it is not necessary to use resistance magnifiers before the telephone stage, where we use low anode voltage, but where one has a loudspeaker it is necessary to use a high tension voltage, 100 or 150 volts, if one wants to get good quality output without great distortion. One might just as well use this H.T. on the valve before, so that one gets plenty of sweep to use the high impedance valves without distortion at all. In connection with rectifiers, it was mentioned that there are no two-electrode valves on the market. I believe, however, that one is now being designed by one of the valve companies, working on the 6-volt. ¼-amp. filament, and it is the same as the standard valve of that type, without a grid.

Mr. G. G. Blake: I should like to add my thanks to Captain Eckersley for his most instructive and amusing lecture. He mentioned his trip to America and the investigations he made there, but he did not mention the "Sodion" valve. In 1922, Donle invented a valve called the "Sodion," which, it was claimed, was absolutely non-oscillating; it was also claimed that its sensitivity was even greater than a valve making use of reaction.* I should like to have Captain Eckersley's opinion of that type of valve. With regard to Captain Eckersley's last diagram, there is one point that stands out in my mind particularly. On the blackboard we have a very complicated arrangement of circuits, and it seems to me that it is fortunate that a crystal circuit is included, for then if everything else failed one could plug in a receiver and use it straight off the crystal.

Mr. R. E. H. Carpenter: I feel rather like a small puppy who has been tied by a strong string to the back of a fast car, and have not much breath left, but my interest in anything Captain Eckersley says was sufficient to have kept me running. The remarks made by Mr. Kirke tacitly stressed the only point I wished to make—that the best of circuit arrangements are quite useless unless quantities and values are properly chosen. Captain Eckersley has drawn on the board a circuit which, if I may venture to have an opinion when he is in the room, is an excellent circuit, but unless the various values—the values of the leaks, the coupling condensers and so on—and the types of valves, or, at any rate their impedances, are given, I think that circuit might cause a great deal of disappointment, particularly as it comes from the fount of "Please don't do it" (laughter), and it is therefore sure to receive a great deal of attention.

Mr. Maurice Child: I have done a good deal of experimental work in connection with crystals in telephonic reception. Some years ago I made some experiments in a very short time, when there were a series of experimental transmissions from Chelmsford on a fairly long wavelength. I had, for the purpose of test, a standard ship receiver designed by Messrs. Siemens Brothers, and in that receiver it was possible to insert various types of crystals. It might interest you to know—and probably Captain Eckersley knows—that the quality of reproduction with a receiver with absolutely fixed adjustments varies enormously according to the crystal you are using, and I have a very clear recollection that in those experiments the best quality of reproduction, using a standard adjustment in each case as regards tuning coils and so on, was given by a zincite-bornite detector. While I have a great deal of praise for the carborundum detector for ordinary commercial purposes, I venture to suggest that it has one serious disadvantage, in that there are very few specimens of carborundum which work really well unless you apply local potential to it. Captain Eckersley has touched on another matter to which I have given a good deal of attention, probably in common with many others, and that is the question of power supply, and I have been trying to get out comparatively small units. Usually, one firm makes the transformer, another makes the valve, or various kinds of valves, another firm tries to make a choke, and can't (laughter), and so on. We have to put the whole thing together, and after a lot of juggling about we manage to get a rectifier which is quiet on two valves and gives a horrid noise on three, but on four the whole receiver and rectifier packs up completely and we get nothing. That is solely because very few firms—in fact, I do not know of any—really make proper sized transformers for the job. I have in mind one which has to handle 10 watts or so, and it needs quite an effort to lift it to the table. Transformers to give adequate outputs can be designed in quite small sizes and at a reasonable price. I do not agree with Captain Eckersley's figures with regard to his condensers and their requirements. I have found that it is not satisfactory, on 50-cycle A.C. supply, to use anything less than three $4\mu F$ condensers, with a low resistance, highly inductive choke. That gives you a smoothing out which is absolutely good for a 4-valve set. The trouble with power supply for high tension is not set aside by simply saying that we can do all this quite smoothly with two or three valves. The apparatus, to be satisfactory, has got to be in such a form that, no matter what a man's receiving set may be, it will work it properly. If you have an experimental receiver, you have probably an arrangement of switches on it, so that you can have one, two or three valves, but when you put that on a good new dry battery it makes very little difference to your high tension voltage whether you put on one, two or three valves. You get a voltage drop, but it is not very serious. The accumulator battery solves that problem perfectly. Its voltage remains practically constant, irrespective of the number of valves used, so long as it is in good condition, but that cannot be said of the ordinary type of A.C. rectifier. In the past we have had to put up with the three-electrode valve with the grid joined up to the plate for these rectifiers, and even so the internal resistance—you note that I use the term "resistance," and I think it is right—of the valves is of such an order that the moment you put on the second valve, down go the high tension volts. We start with, say, 100, and inevitably reduce the high tension volts when increasing the output current from, say, a couple of milliamperes to 50 or 60. That is the usual thing. That problem has been solved at last by an enterprising manufacturer, who has turned out a special valve which is just about to be put on the market. I was testing it this morning, and it might be of interest if I give some of the figures which I obtained. It was possible to get an output of 80 milliamperes at 40 volts absolutely smooth D.C., putting on an A.C. voltage in the first stage, from the transformer, of 130. When I reduced the milliamperes to 18, which is far more than most sets require, the pressure was 130 volts. I think that is a very fair performance. The valve takes 4 volts on the filament, with 1.1 amps maximum load, and the manufacturers state that it is impossible to test the emission because if attempted up to the maximum it would completely destroy the valve. The internal resistance is stated to be only 375 ohms—I have not tested it—accurately, but when you get a valve of that order and put two of them on a rectifying circuit, it is possible to put one, two or three valves on your receiving set and only get a variation of 3 or 4 volts in 100 to 120 maximum with each valve coming on. That compares exceedingly favourably with an ordinary dry cell battery, and I think the A.C. supply with valves will be the thing of the future. The problem is just about solved at the present time.

* Harold P. Donle, *Proceedings of Institute of Radio Engineers*, Vol. XV., No. 2, p. 97, 1923.

Mr. D. S. Richards: I should like to put forward the view of the man in the street who has the problem of maintenance to consider. We have heard some very excellent suggestions this evening, and to me it seems to indicate that the time is rapidly approaching for further development and general improvement in the design of broadcast receivers. The subject of high tension supply will never, I think, be effectively solved until further advancements are accomplished in the science and construction of valves. I should like to mention that in the town in which I reside, direct current has been used quite successfully for obtaining high tension supply. But apparatus has been constructed which will give absolute satisfaction in one part of the town, and when the same apparatus is used in another part, the high tension so derived develops an unpleasant hum. The whole success of broadcasting in the future is bound up very largely with the factor of maintenance, and I doubt whether Captain Eckersley or anybody else in this great wireless community can persuade the general public to carry out any great alterations or improvements in their sets while the factor maintenance still provides so many objections. Low tension supply from house mains generally involves a bigger electric light bill. We must have cheap electricity before we can make the broadcast receiver quite the simple and inexpensive instrument that would be so desirable.

Mr. J. H. Reeves: On this question of maintenance, rectified A.C. has got to such a stage that you can use it on an exceedingly powerful superheterodyne set, as I have, and there is not a sign of a hum anywhere. I should like to confirm Mr. Child's remarks with regard to the new valves, with extremely low impedance, which are just on the market, but there is another point which Mr. Child did not mention, and that is that we have various periodicities and various voltages on our A.C. supply. Only last Saturday I heard of another enterprising firm which is going to turn out a transformer which can be used at practically any voltage and will work at any periodicity, so that possibly before the summer is out the whole question of rectified A.C.—where we are so fortunate as to have A.C. supply—will be fully solved. There is one point, raised by Captain Eckersley, with which I disagree, and that is his reference to the great advantage of simplicity for sweeping. Undoubtedly it seems very nice to be able to turn one or two handles and sweep, but what do we want to sweep for ? Do we want to sweep just to see how many things we can get in one evening ? My set is calibrated—it might take a fortnight or a month, perhaps, to calibrate for any wavelength from 230 to 600—and I do not want to sweep, but I want as a rule to get at its best some one particular station. I think it is a mistake to try to increase simplicity to such a stage that you can run all round if, by calibrating, you can get better reception, either by way of selectivity or any other means. Therefore, I am to a certain extent against all this simplicity.

Mr. J. Selwyn Jackson: With regard to rectified A.C. for receivers, I have a receiver which uses about 15 milliamps from the A.C. mains through a transformer, and it is remarkable what liberties you can take with the smoothing circuit, so long as you do not use headphones. I have used a smoothing circuit with a 0.005 condenser before the choke, and a very small spark coil as a choke coil, and another 0.005 condenser across the main supply after the spark coil. It is remarkable what small condensers you can use in order to get quite a large degree of silence in a loud-speaker when there is no signal coming through at all. It is a completely different tale, however, if you want to use headphones.

Mr. A. J. Hall: I should like to ask Captain Eckersley if he will explain whether the ease with which he rectifies his A.C. is not due to the fact that it is drawn from a district in which they have no industrial loads of bad power factors ? I find that it is practically impossible to work a receiver of any type from the supply with which I am connected with anything up to 5μF and 50 henries of inductance. There is a cinema some little distance away, and things are worse when their motor generators are running. That is just a theory of mine, but I should like Captain Eckersley's views.

Mr. J. A. Whitehouse: No mention has been made of the electrolytic rectifier, but in my experience and the experience of others, that can be made to work in a very satisfactory way. With regard to charging accumulators off D.C. mains, the floating accumulator is apt to give trouble, but if it is connected to the right side of the meter, in the house mains, and a change-over switch arranged from "set" to "charge," it is quite possible to have the accumulator on charge whenever the light is on in the house. So far as H.T. accumulators are concerned, they are quite easy both to make and to work. The trouble with charging those on the main is that they cause a considerable drop in the house lighting, but if arranged with a series parallel switch, in banks, of about 10 volts each, that can be dealt with satisfactorily.

Mr. A. E. Symonds: For two years I have had a broadcast receiver in operation, running totally off the electric light mains, both for lighting the filament and for high tension. I live in a D.C. district, and the hum is really very small. I choke with an ignition coil and 5μF on output side of the ignition coil. The valve filaments are in series, and I supply them with 1 amp, shunting each valve with a resistance to take off the amount I do not want. I use bright emitters for safety, so that I can see the valves. Each valve takes 0.7. It took me some time to find out how to get rid of the hum almost completely. One point is that it was very necessary to connect the earth side of the receiver to a certain point in the filament system. One can connect it to the positive end of the two filaments in series, or to the negative end, and again, it was useful to try putting the resistance, which controls the current from the main, in the positive or the negative end of the system. My arrangement, which gives the minimum hum, is to put the resistance in the positive end of the system, and to have the earth connection from the mid-point, not the terminals of the filament system. In the second valve I had to use grid bias, and even there it was necessary to connect the grid bias to a certain point of the system. Finally, I cut down the hum still more by using low frequency choke-coupled amplification, and a secondary circuit gave improved results on the tuning side of this system. The results are quite satisfactory to those who have listened in.

Captain Eckersley, replying, said : With reference to Mr. Minter's remarks. Nearly all our transmitters are separated by 20 or 30 kilocycles, but it is the foreigner who has erected the transmitters that have created the difficulty of selectivity for reaching out. But the point seems to be to listen to the local station, which is not so much interfered with, because the station is not distant and will be relatively stronger. I did not say that the " Straight Eight " was the only receiver that was any good, but I did say that it was the one which has the greatest number of high frequency stages.

With regard to noise, I do not think the public want a tremendous lot of noise. I think if they listen to a set which gives signals as loud as the gramophone of to-day—a very good standard—they will have nothing to grumble about. Generally speaking, the signals are usually not loud enough, or much too loud. But the point is quality —quality plus loudness.

With regard to carborundum crystals, it is true that a priming cell is required. I agree with Mr. Child that crystals do vary tremendously in quality in accordance with the sort of priming you give them, but I am only dealing with crystal *qua* crystal as a general principle.

With regard to Mr. Kirke, I am not absolutely convinced that he is right on the question of economy in voltage, but no doubt he can show me a page of figures proving that he was right and that I was wrong.

As to Mr. Blake's remarks about the Donle " Sodion " valve, I personally have never met a valve which will amplify but not oscillate. I have not seen the Donle valve.

I agree with Mr. Carpenter that it is a great thing to measure specific quantities. But when one is giving a lecture to a scientific society, it is most embarrassing because to give quantities is to give components. I merely put the circuit forward as a suggestion. I agree also that the speaker who doubted very much whether, if you have two high frequency stages in front of a crystal, there might not be a possibility of the rectification being wiped out. That is an interesting point, but I have put a lot through crystals that I have had, and they behave well.

On the question of power supply, I am interested to hear of the valve mentioned by Mr. Child. Personally, I use two low impedance valves in parallel on each side of the rectifier, so that I use four valves in all, which is certainly not economical. The transformer will stand 30 or 40 watts.

With regard to using D.C., I agree that, provided conditions are straightforward, it is perfectly simple to do. The difficulty I put up to Mr. Richards is that, when the centre is earthed, it is a difficult connection to get at, and I would suggest that it might be possible to design a small generator, cheaply, which could be put straight on the mains, and which would turn out low tension and high tension.

Mr. Reeves has talked of his supersonic set. It is true that high frequency stages will not " mag " the " hum," and it is possible therefore to use incompletely smoothed current on high frequency. The difficulty arises when you come to the detector and the low frequency stages. My point is that you have to make sets fool-proof if you are to sell them. People have to operate them who do not know the meaning of the word " calibrate." Simplicity is necessary if the set is to be a selling proposition.

We have heard some interesting values for smoothing mains. One speaker suggested two 0.005 condensers. Another suggested half a microfarad. Then it was suggested that very likely trouble was due to the power supply varying in its harmonics. Indeed, I do not think it possible to lay down definite rules. It is, however, remarkably good in my case, and smoothing has been easy.

Mr. Whitehouse asked about the electrolytic rectifier. I know nothing about it.

BOOKS RECEIVED.

Variations of Apparent Bearings of Radio Transmitting Stations.—Radio Research Board Special Report, No. 4, pp. 53.—H.M. Stationery Office, price 2s. 6d.

Under the auspices of the Board a comprehensive investigation into this subject has been carried out by Dr. R. L. Smith-Rose of the National Physical Laboratory and a staff of assistants. Parts I. and II. of the Report have already been published as Special Reports, No. 2 and 3: the report just published forms Part III. The previous reports dealt with long wavelengths, the present report deals with what were then regarded as short wavelengths, viz., 450 to 600 metres ; these are of great importance as they are the wavelengths mainly employed for direction finding in marine navigation. It is reassuring to read that the results "are considered to afford valuable evidence as to the reliability of wireless direction finding at all times, and its freedom from errors when employed under the usual conditions demanded for marine navigation." This Report should be carefully studied by everyone interested in direction finding.

British Standard Glossary of Terms used in Electrical Engineering.

Issued by the British Engineering Standards Association (Publication No. 205, 1926), pp. 263, comprising Introduction, Glossary divided into sections and sub-sections in accordance with the International Decimal Classification, Symbols for the Quantities and Units Defined, Summary of Sub-sections arranged in the order of the Decimal Classification and General Alphabetical Index.—Published by Crosby, Lockwood & Son, London, price 5s. net, post free 5s. 6d.

Abstracts and References.

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

R000.—WIRELESS IN GENERAL.

R008.—DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY.—Issued March 9th, 1926-May 4th, 1926.—John Brady. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 413—421.)

R010.—THE CORRELATION OF SOME RECENT ADVANCES IN WIRELESS.—Dr. Balth van der Pol. (*E.W. & W.E.*, June, 1926, pp. 338—343.)

R040.—RADIO COMMUNICATION. (*Electrical Review*, June 11th, 1926, p. 888.)

Abstract of paper by Mr. Elwell, read before the Royal Society of Arts, dealing with past and present aspects of radio-communication and its future possibilities.

R064.—THE NATIONAL PHYSICAL LABORATORY. (*Electrical Review*, July 2nd, 1926, pp. 39—41.)

An account of the exhibits, including those connected with radio research, on the occasion of the annual inspection by the General Board, June 22nd.

R080.—LA RÈGLE À CALCULS DU RADIO ELECTRICIEN. (*L'Onde Electrique*, May, 1926, pp. 226—228.)

This rule has been constructed so that, in addition to the ordinary operations (multiplication, division, raising to the power of, calculation of logarithms, sines and tangents), the following special operations current in radio practice can be performed :—

1. Resolution of Thomson's formula.
2. Conversion of wavelengths into frequencies and *vice versa*.
3. Resolution of Nagaoka's formula for the calculation of a round or square inductance coil, according to its geometrical data.
4. Calculation of the wavelength of beats.

R082.—ALIGNMENT CHARTS FOR SELECTIVE AMPLIFIERS.—W. A. Barclay. (*E.W. & W.E.*, June, 1926, pp. 344—348.)

R100.—GENERAL PRINCIPLES AND THEORY.

R110.—HARMONICS AND THEIR EFFECT ON WAVE FORM.—J. F. Herd. (*E.W. & W.E.*, July, 1926, pp. 407—410.)

R112.—THE TRANSMISSION OF SIGNALS FROM A HORIZONTAL ANTENNA.—M. Taylor. (*Nature*, June 5th, 1926, p. 791.)

A letter stating that, in the course of a mathematical investigation of the propagation round the earth of electro-magnetic waves from a horizontal antenna, the result has emerged that, when the earth is regarded as a perfect conductor, the components of electric and magnetic force are zero both when the earth is regarded as surrounded by a conducting Heaviside layer and when no layer is present. Finite conductivity of the earth must thus be assumed in order to account for the propagation, and it is then found that the resulting forces are a small vertical electric force and a much larger horizontal magnetic one. The electric force is due to the "space waves," the magnetic force to the "surface waves" described by Sommerfeld (*Annalen der Physik*, 1909, p. 665) : the result of the analysis is in remarkable agreement with the conclusions he there expresses. The magnetic force may be analysed into perpendicular components, each of which consists of two simple harmonic oscillations differing in amplitude and phase, results of the same general type being obtained both with and without the Heaviside layer.

R112.1.—SHORT-WAVE STATION MAKES NEW RECORD. (*Scientific American*, April, 1926, p. 274.)

2GY, an amateur short-wave station in New York, established a new record for low-power transmission by carrying on two-way communication with 9CCQ, Missouri, using only .04 watt power in the plate circuit of the transmitting valve. Both stations employed standard receiving valves and "B" batteries as their power source. This transmission feat represents 25,525 miles per watt.

R113.—DIAGRAMME DES CHAMPS ELECTRIQUES MESURÉS À MEUDON PENDANT LE QUATRIÈME TRIMESTRE, 1925. (*L'Onde Electrique*, May, 1926, pp. 223—226.)

Graphs are shown of the electric field in microvolts per metre of Bordeaux, Nantes, Rocky Point, Rome and Leafield, measured at Meudon during the last quarter of 1925, and also the monthly averages of these stations for the year.

R113.—PROPAGATION OF RADIO WAVES. (*Nature*, July 3rd, 1926, p. 28.)

Abstract of paper read by Dr. Alexanderson to the Academy of Swedish Engineers.

Each new discovery in long or short-wave propagation is eagerly studied for the light that it might throw on the structure of the electromagnetic field, which still remains a mystery.

According to our present knowledge of wave propagation, the waves sent out from a radio station are divided into the earth-bound wave, guided by the proximity of the conducting earth, and the space wave, guided by refraction in the upper atmosphere. Long-wave telegraphy depends mainly upon the earth wave. Short-wave long distance communication depends entirely upon the space wave. Broadcast reception depends upon the earth-bound wave for near stations, and on the space wave for distant stations. It is stated that at a distance of about 100 miles from the station the intensities of the two waves are nearly equal. It has been found that at a distance of ten miles from a 50-metre station the plane of polarisation of the space wave has been twisted by between 20° and 30°, and therefore it follows that at some distance between 60 and 90 miles the twist would be 180°. Thus, since the earth-bound wave maintains its vertical plane of polarisation, the two waves may cancel one another at a distance of about 100 miles. This explains " blind " spots.

As a model of radio transmission, the motion is discussed of a horizontal rubber sheet actuated by a vertical shaft making rotatory oscillations. Straight lines drawn on the rubber sheet will appear to have a wave motion.

Dr. Alexanderson thinks that a harmonious theory requires the proof that the electron is an entity with an aurora reaching from it into infinite space.

R113.1.—Co-operative Investigation of Radio Fading.—J. Dellinger, C. Jolliffe and T. Parkinson. (*Physical Review*, June, 1926, p. 816.)

Abstract of paper presented at April meeting of American Physical Society.

With a view to securing quantitative data on signal intensity fluctuation, the Bureau of Standards invited a number of University and other laboratories to engage in a co-operative programme of fading measurements. This report summarises the progress made in 1925 when five series of simultaneous observations were made on certain specially arranged transmissions from broadcasting stations. The measurements consisted of recording graphically variations of deflection of a galvanometer connected to radio receiving apparatus so as to indicate directly variations in the received field intensity. The measurements yielded data of value on the characteristic radio wave phenomena during a solar eclipse, during the sunset period and the variations throughout the whole diurnal cycle.

R113.4.—Electrical Constitution of the Upper Atmosphere.—T. L. Eckersley. (*Nature*, June 12th, 1926, p. 821.)

The writer has suggested (*Phil. Mag.*, June, 1925) that a certain type of atmospheric, which is semi-musical in nature, owes its character to the dispersive action of the medium, assumed to consist of an assembly of electrons in a rarefied atmosphere. The lowest pitch of the disturbance was shown to depend upon the number of ions per unit volume and called the characteristic frequency of the medium. In some recent tests it was noticed that the prevailing characteristic frequency has risen two or three times in the last eighteen months, suggesting a four to ten-fold increase in the ionic density. Associated with these changes there has been an increase in sunspot activity, magnetic storms and an auroral display so far south as London, and a noticeable falling off of the strength of short-wave signals from America. There seems little doubt that these are all connected with the approach of the period of sunspot maximum in 1928. It appears probable that observations of these musical atmospheric disturbances will provide additional data for determining the electrical constitution of the upper atmosphere.

R113.4.—Pouvoir Inducteur des Gaz et de l'Air Humide (Inductive power of gases and moist air).—Delcelier, Guinchant and Hirsch. (*L'Onde Electrique*, May, 1926, pp. 189—216.)

Present theories on the propagation of radio waves consider atmospheric air as a materially homogeneous medium with the properties of a vacuum, the ions alone producing physical heterogeneity. To establish a more precise theory, the velocity with which the waves are propagated in the gases of the atmosphere must be known. It has been shown (*C.R.*, 1924, p. 32) that variations in composition, pressure, or temperature can *à priori* produce changes in velocity, and consequently changes in direction, as for light waves: a slight variation will produce an even greater effect for radio waves, owing to their much longer path through the atmosphere.

According to Maxwell's theory

$$V = \frac{A}{\sqrt{\mu K}}$$

where V is the velocity of propagation in an insulating homogeneous medium,

A the ratio of the units of quantity of electricity in the electro-magnetic and electro-static systems,

μ the magnetic permeability of the medium, and

K its specific inductive power.

For a vacuum, we have from the definitions of μ and K

$$\mu_0 = K_0 = 1$$

whence $$V_0 = A$$

Very concordant measurements made from 1907 to 1920 give $A = 2.9979.10^{10}$ cms. per sec.

For gases, μ only differs from unity by some ten millionths (air $\mu = 1{\cdot}00000036$), but the inductive power by some ten thousandths (air $K = 1{\cdot}0006$), so that in more accurate measurements this factor has to be taken into account.

The speed of propagation V in air will thus be connected to the speed of propagation V_0 in vacuo by the relation

$$V = \frac{A}{\sqrt{K}} = \frac{V_0}{\sqrt{K}}$$

but V_0/V is the absolute index of the gas,

whence $$\mu = \sqrt{K}$$

The measurement of K will enable the index n to be calculated and consequently the velocity of propagation V.

In this article different ways of determining K are discussed, three methods giving concordant results. For moist air the Hertzian index is greater than that for light. At 15°, air saturated with moisture has a dielectric excess equal to about 1·3 times that of dry air, consequently the presence of water vapour in the atmosphere should considerably diminish the velocity with which electromagnetic waves are propagated in it.

R113.4.—Luminous Night Clouds.—V. Malzev. (*Nature*, July 3rd, 1926, p. 14.)

The interesting feature of these clouds for us is their unchangeable height above the earth's surface of about 82 km. It is stated as well that the tails of meteors are also generally observed at this same height. These facts indicate peculiar properties for the layer occurring at this altitude and provide outside support for the existence of the Heaviside layer to which radio experimenters have assigned just this same height.

R113.8.—A NEW THEORY. THE EFFECT OF THE MOON ON RADIO RECEPTION.—D. Shannon. (*E.W. & W.E.*, July, 1926, pp. 429—433.)

R114.—UPPER AIR TEMPERATURES AND THUNDERSTORMS.—J. S. Dines. (*Nature*, June 12th, 1926, p. 822.)

An account of how the daily aeroplane ascents from the R.A.F. station at Duxford have proved the close association between energy and thunderstorms, which is very valuable for the forecasting of thunderstorms.

R114.—HIGH FREQUENCY RAYS OF COSMIC ORIGIN II. MOUNTAIN PEAK AND AIRPLANE OBSERVATIONS.—R. A. Millikan and R. M. Otis. (*Physical Review*, June, 1926, pp. 645—658.)

When suitable precautions are taken for eliminating the activity of adjacent rocks, both airplane and mountain peak observations agree in showing a definite variation of the penetrating radiation with altitude alone. Within the limits of experimental error all observations are consistent in showing no dependence of the penetrating radiation upon the time of day or upon the position of heavenly bodies.

R114.—YUCATAN BLAMED FOR STATIC. (*Scientific American*, April, 1926, p. 272.)

The crashing and grinding static noise that disturbs radio listeners in the United States originates in the atmosphere of Yucatan and Mexico, according to Dr. Austin of the Bureau of Standards. It is believed that "upside-down" lightning, consisting of a steady discharge of electrical energy from clouds into a conducting layer high above the earth of Central America, is the chief source of static.

R115.—THE CAUSE AND ELIMINATION OF NIGHT ERRORS IN RADIO DIRECTION FINDING.—Dr. Smith-Rose and R. H. Barfield. (*E.W. & W.E.*, June, 1926, pp. 367—369.)

R120.—MAIN CONSIDERATIONS IN ANTENNA DESIGN.—N. Lindenblad and W. Brown. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 291—323.

A general treatment of the complicated problems of antenna design intended to explain how these problems are attacked and also have been to a large extent solved. The reduction of resistance of high-power long-wave antennæ to a value considerably less than one-half ohm has introduced two problems: the limitation of signalling speed and the increased sensitivity of tuning. The lower the resistance and power factor of an antenna, the greater is the effect of its electrical inertia, which opposes rapid signalling. The tuning of an antenna having a power factor of the order of 0·0015 is so sharp that small changes in capacity, due to wind, reduce the antenna current very appreciably. An automatic tuning device has been developed which maintains correct tuning when the changes are not too rapid.

R124 & R125.—RECEPTION CURRENTS FROM A LOOP ANTENNA.—R. Colwell. (*Physical Review*, June, 1926, p. 816.)

If the oscillations in the four sides of a loop antenna are regarded as made up of the oscillations of a succession of vibrating doublets, an integration around the loop will give the resultant electric vector for any point in space. For the two vertical sides of the loop, the electric intensity takes the form $E_\theta = (2I \tan \theta / c r_0)(1 - \cos 2\pi h \cos \theta / \lambda r_0)^{\frac{1}{2}} (1 - \cos 2\pi a X / \lambda r_0)^{\frac{1}{2}}$ This equation shows that a loop has a directional effect high up in the air as well as along the ground. If the integration is taken over one vertical and one horizontal side, we have the electric intensity due to a bent antenna. The resulting equation is in the form $E_\theta' = (I_c / r_0) [(A + B \cos a)^2 + (C + D \cos a)^2]^{\frac{1}{2}}$. The $\cos a$ changes sign when the azemuth is 90° in such a way as to give a directive effect to the wave sent out from this antenna; the intensity being greatest for azimuth 180° and least for azimuth 0°.

R132.—SOME NOTES ON INTERVALVE COUPLINGS. H. L. Kirke. (*E.W. & W.E.*, June, 1926, pp. 350—362.

R132.—A NEW HIGH FREQUENCY AMPLIFIER BALANCING OUT INTER-ELECTRODE CAPACITY IN FOUR-ELECTRODE VALVES.—Dr. Kröncke. (*Wireless World*, June 9th, 1926, p. 774.)

R132.1.—LOW-FREQUENCY INTER-VALVE TRANSFORMERS. (*Electrician*, 11th June, 1926, p. 59; *E.W. & W.E.*, July, 1926, pp. 435—439.)

Abstracts of a paper by Mr. Willans read before the Institution of Electrical Engineers.

The paper is mainly mathematical and deals with some special aspects of inter-valve transformer design.

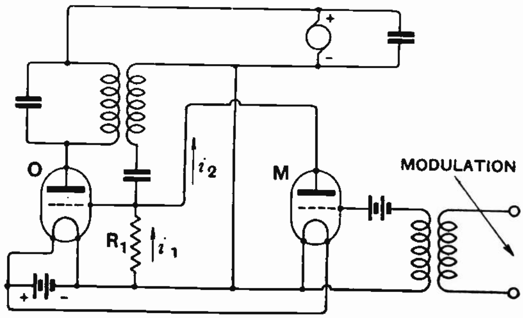
R135.—NOTE SUR UN PROCÉDÉ DE MODULATION DES EMETTEURS À LAMPES.—Capt. Caillat. (*L'Onde Electrique*, May, 1926, pp. 216—219.)

Description of a new method of modulating valve transmitters that combines the following advantages:—

1. No separate battery.
2. Economical use of valves.
3. Greater simplicity and ease of adjustment.
4. Immediately adapted to any transmitter.

The circuit diagram is shown on next page:

The resistance R_1 lowers the potential of the grid and renders it negative and in the absence of oscillation there is no current through R_1. When oscillation starts the grid has an alternating potential of high frequency and the positive alternations cause a current i_1, passing through the resistance in the direction of the arrow. M is a valve heated by the same battery as O, on the grid of which the source of modulation or microphone is made to act through the medium of a transformer or amplifier. The plate of M is joined to the grid of O. When O oscillates, a part of the grid current, i_2, will divide off through M. If the source of modulation is made to operate, the internal resistance of M will alter and the current i_2 will vary in the same manner. Lastly, the potential of the grid of O will vary and the waves emitted will be modulated



R137.—NOTES ON WIRELESS MATTERS.—L. B. Turner. (*Electrician*, June 11th, 1926, pp. 596—597.)

A discussion of reception in wireless telephony and low-frequency amplification.

In a footnote the writer states that there seems no excuse for the curious but very common custom of referring to the resistance of the anode-filament path as the anode impedance.

In the *Electrician* for June 25th, p. 675, W. H. Date maintains that the custom is reasonable owing to the necessity of distinguishing between V_a/I_a and $\delta V_a/\delta I_a$.

In the *Electrician* for July 2nd, p. 13, J. F. Stanley, while thoroughly agreeing that it is reasonable and in fact imperative to distinguish between these two quantities, thinks it is incorrect and therefore highly undesirable to perpetuate the use of the term impedance to express the quantity $\delta V_a/\delta I_a$. He points out that the value of an impedance is necessarily related to a specific frequency, and unless this frequency is stated or understood, the magnitude of the impedance has no real significance. Now the quantity commonly called anode impedance is quite independent of the frequency. The term proposed therefore is anode A.C. resistance, which has the advantage of conveying the correct meaning as well as distinguishing between the miscalled impedance and the actual anode resistance.

R138.—THE THEORY OF THERMIONICS.—N. Rashevsky. (*Physical Review*, June, 1926, p. 810.)

Abstract of paper presented at April meeting of American Physical Society.

An expression for the free energy of a metal is derived, special account being taken of the fact that thermionic phenomena are essentially surface phenomena. The expression for the free energy thus obtained is substituted in the general formulæ for thermionic emission previously derived. The final formula thus obtained gives indications for the understanding of the fact that while for pure metals the " A " constant of Richardson's equation has almost the universal value postulated by Dushman, it has a largely different value for oxides and absorbed films. The question as to the existence of an electric double-layer on the surface of a metal is discussed, as well as the influence of such a layer on thermionic emission. It is shown that while the existence of such a layer follows from Schottky's " Equilibrium Theorems," the same theorems lead to the conclusion that the temperature change of the moment of such a layer is relatively small. Its value may be approximately estimated.

R138.—THE ABSORPTION OF CALCIUM ON TUNGSTEN AND OXIDISED TUNGSTEN. — J. Becker. (*Physical Review*, June, 1926, p. 811.)

R139.—THE PENTATRON.—Dr. Kröncke. (*Wireless World*, June 23rd, 1926, p. 854.)

Description of a new five-electrode receiving valve.

R139.—MEASUREMENT OF ELECTRONIC CHARGE BY SHOT EFFECT IN APERIODIC CIRCUITS.—N. Williams and H. Vincent. (*Physical Review*, June, 1926, p. 810.)

R139.—EXPERIMENTS ON CATHODE SPUTTERING.—E. O. Hulburt. (*Physical Review*, June, 1926, p. 805.)

R144.—HIGH-FREQUENCY RESISTANCE.—S. Butterworth. (*Wireless World*, June 9th, 1926, pp. 767—768.)

The case for low-loss coils in tuned anode circuits.

R144.—EFFECTIVE RESISTANCE OF INDUCTANCE COILS AT RADIO FREQUENCY.—PART III.—S. Butterworth. (*E.W.& W.E.*, July, 1926, pp. 417—424.

R148.—THE USE OF A CATHODE-RAY TUBE FOR THE TRANSMISSION OF SPEECH.—C. W. van der Merwe. (*Physical Review*, June, 1926, p. 805.)

R149.—A NEW TYPE OF CONTACT RECTIFIER.—L. Gvondahl. (*Physical Review*, June, 1926, p. 813.)

A piece of copper with a layer of copper oxide formed on it at a high temperature is an unsymmetrical conductor of electricity. Ratios between high resistance and low resistance as high as 20,000 have been obtained.

R162.—SELECTIVITY PAR EXCELLENCE.—The Staff of the Radio News Laboratories. (*Radio News*, May, 1926, pp. 1552—1555.)

An account of broadcast reception employing the phenomena of closely-coupled circuits.

R200.—MEASUREMENTS AND STANDARDS.

R230.—THE INDUCTANCE OF A HELIX MADE WITH WIRE OF ANY SECTION.—C. Snow. (*Physical Review*, June, 1926, p. 815.)

Abstract of paper presented at April meeting of American Physical Society.

A formula is derived for the inductance of a single layer helix for use in absolute measurements of precision. Account is taken of the helical nature of the winding and hence of the axial component of current in it. For windings of ordinary dimensions a precision is claimed of at least one part in a million.

R240.—On the Calculation and Application of High Resistances of small Self-Inductance for all Frequencies.—R. Wilmotte. (*Philosophical Magazine*, July, 1926, pp. 65—86.

In many accurate measurements it is necessary to know the exact phase angle of high resistances of the order of several thousand ohms, when capacity effects are often very large. In this paper formulæ are given for the self-inductance of high resistances formed by long parallel wires of circular cross-section and screened from earth by a cylindrical metal shield. The formulæ for the use of such a standard as a ratio arm and potential divider are also given, together with its application in bridges.

R240.—The Resistance of Condensers at Radio Frequency.—R. Ramsey. (*Physical Review*, June, 1926, p. 815.)

For the measurement a "differential thermometer" was employed, made of two 800 cc. pyrex glass beakers inverted on and sealed to two glass plates. The radio condenser was placed in one of the beakers and connected through the glass plate into a radio-frequency circuit. Into the second beaker an exactly similar condenser was placed and a resistance wire was connected through the plate to a D.C. circuit. Assuming both beakers are exactly alike thermally when the pressures indicated are the same, we have I^2R in the high-frequency side equal to i^2r in the D.C. side.

R240.—Some Notes on High Ohmic Resistances.—Dr. H. Kröncke. (*Wireless World*, June 30th, 1926, pp. 892—893.

R240.—Inductance Coils Quantitatively Compared. Part II.—A. L. M. Sowerby. (*E.W. & W.E.*, June, 1926, pp. 363—366.)

R270.—Portable Receiving Sets for Measuring Field Strengths at Broadcasting Frequencies.—A. Jensen. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 333—344.)

Description of an improved form of measurement set for use in the field, recently developed in the Bell Telephone Laboratories, which is now being used by the American Telephone and Telegraph Co. for field strength surveys, etc. A schematic diagram is given.

R271.—Comparison of Signal Strength.—P. Tyers. (*Wireless World*, June 23rd, 1926, p. 842.)

A development of the shunted telephone method.

R281.—Dielectric Absorption and Theories of Dielectric Behaviour (Abridged).—J. W. Whitehead. (*Journ. Amer. Inst. Elect. Engineers*, June, 1926, pp. 515—524.)

R300.—APPARATUS AND EQUIPMENT.

R329.—Receiver for Short Waves. (*Radio-electricité*, June 10th, 1926, p. 213.)

Abstract of an article in *Der deutsche Rundfunk* (March 28th, 1926, p. 871) describing a receiver developed by Riechers with a pencil of ultra-violet rays for antenna. The rays are produced by a special projector and are said to give excellent results as antenna, particularly when guided in given directions.

R331.—Reactivation of Radio Tubes. (*Electrical World*, May 15th, 1926, p. 1,066.)

The General Electric Co. has found out that thoriated tungsten filaments can be rejuvenated. The process essentially consists in operating the filament for a very brief interval at a specified high voltage (called "flashing"), followed by a lower voltage for a longer time (called "ageing"), all with no grid or plate voltage. The flashing reduces some of the thorium oxide in the wire to thorium and the ageing forms the required surface layer.

R340.—Sources of "A," "B" and "C" Power for Radio Receivers.—W. Holland. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 345—372.)

A paper describing the characteristics of the various present-day sources of "A," "B" and "C" power for radio receivers, namely, storage batteries, dry primary batteries, trickle-charge power units and battery substitute devices.

The development of radio storage batteries is traced from the earliest types up to the highly-specialised radio "A" and "B" batteries of to-day, having built-in charge indicators, visible water level and spray-proof construction, and information is given on "A" socket power units containing such batteries in combination with newly-developed trickle chargers.

A perfected aluminium electrolytic rectifier is announced, and "B" battery substitutes embodying this rectifier are described and their electrical characteristics given. Rectifiers and smoothing filters generally are discussed and their application to radio uses.

R342.—Battery Eliminators: Rectified A.C. as a substitute for L.T. Batteries.—F. H. Haynes. (*Wireless World*, July 7th, 1926, pp. 2—3.)

R344.—An Oscillator without Battery or Transformer.—A. T. Hanscom. (*Q.S.T.*, June, 1926, pp. 43—44.)

Description of a convenient portable oscillator for laboratory work and receiver testing, which can be operated from 110 volts A.C. without using any battery.

R344.9.—Piezo-Electric Quartz Oscillators coated with Metallic Films.—E. O. Hulburt. (*Physical Review*, June, 1926, p. 814.

Recent experiments have demonstrated that a quartz piezo-electric crystal with the sides coated with films of platinum, copper, or other metals may be used in a suitable valve circuit as a generator of sustained oscillations. The natural frequency of the crystal is but slightly changed by the addition of the metallic film. W. G. Cady has shown that a piezo-electric crystal coated with chemically deposited silver will serve as a resonator in a radio-frequency circuit: its use as an oscillator however seems to have been unsuspected, previous experience in fact suggesting that a metallic film adhering to the crystal would destroy its oscillating properties, just as an oil film is known to do.

R344.9.—A Multi-Stage Crystal-Controlled Transmitter.—J. Wells and E. Tillyer. (*Q.S.T.*, June, 1926, pp. 29—32.

The authors explain the construction and adjustment of a crystal-controlled transmitter in which a thick crystal is used to control a low-power tube. Amplification is effected through two low power stages operating on harmonics of the crystal oscillator. Such a transmitter avoids several difficulties which may be experienced when using a relatively thin crystal and amplifier stages operating at the crystal frequency.

R376.3.—A REMARKABLE LOUD-SPEAKER.—Dr. Eugen Nesper. (*Radio News*, June, 1926, p. 643.

Description of a Reisz loud-speaker employing a new principle in the actuation of its diaphragm—which is made of indiarubber covered with electrified carbon grains.

R377.—ADDITIONAL APPLICATIONS OF THE MAGNETIC DRUM PRINCIPLE.—Dr. McLachlan. (*Journ. Inst. Elect. Engineers*, June, 1926, pp. 671—682.)

A description is given of a new form of siphon recorder, with a very small transit time, for high speed reception on commercial circuits (beam stations). Legible tape records are secured when atmospheric disturbances are neither too severe nor too frequent. Other applications of the magnetic drum principle to a delayed-action relay and the checking of clocks by wireless signals are described. The valve circuits associated with the various devices are discussed and shown diagrammatically.

R380.—TUBES WITHIN TUBES.—G. Rowe. (*Radio News*, July, 1926, pp. 30—31.)

Description of a new type of vacuum tube developed by Dr. Siegmund Loewe of Berlin. This new tube incorporates within itself almost a complete radio set, including detector and amplifier elements, resistances and condensers; the variable condenser and inductance alone remaining outside. In this way the length of the leads is reduced to a minimum, eliminating undesirable capacities, also moisture and air are kept away from sensitive parts. Great things are predicted for this tube. Illustrations are shown.

R384.6.—THE MULTI-RANGE AMMETER OF CONSTANT RESISTANCE.—L. Sims and M. Heywood Hunt. (*E.W.& W.E.*, July, 1926, pp. 425—428.)

R400.—SYSTEMS OF WORKING.

R430.—LE SECRET EN RADIOTÉLÉGRAPHIE (Secrecy in radio telegraphy.)—Général Cartier. (*Radioelectricité*, April 25th, 1926, pp. 142—144.)

Detailed explanation of the Vernam system, which was employed by the American army during the war.

R500.—APPLICATIONS AND USES.

R520.—WIRELESS WITH THE BYRD ARCTIC EXPEDITION.—R. Bloxam. (*Wireless World*, June 9th, 1926, pp. 771—772.)

R520.—WIRELESS BEARINGS FROM THE AIR. (*Wireless World*, June 30th, 1926, pp. 866—868.)

R530.—TURKEY—FRENCH RADIO COMPANY. (*Electrical Review*, July 2nd, 1926, p. 21.)

The Compagnie Générale de Telegraphie Sans Fil has concluded a contract with the Turkish Government for the erection of radio stations of 15kW in Angora and Constantinople, the latter being equipped with automatic receiving and transmitting apparatus.

R555.—A.R.R.L. STANDARD FREQUENCY STATION 1XM.—K. Lansingh. (*Q.S.T.*, June, 1926, pp. 45—48.)

Illustrated description of the experimental station of the Radio Society of the Massachusetts Institution of Technology. The Armstrong circuit is employed for the standard frequency transmitter, the valve being generally operated at from 200 to 300 watts input.

R557.—INDIA: NEW COMPANY. (*Electrical Review*, June 11th, 1926, p. 874.)

Prominent Bombay business men have floated the Indian Broadcasting Co., Ltd., with a capital of £112,500 in 10-rupee shares. Stations will be built at Calcutta and Bombay which, it is anticipated, will be ready to transmit programmes next December.

R557.—JAPAN: NEW OSAKA STATION. (*Electrical Review*, June 4th, 1926, p. 837.)

Work has begun on a site in Otemae, where the Osaka Radio Broadcasting Bureau is to build its main station. The site covers 754 tsubo and the plan is to build a three-storeyed ferro-concrete structure with three radio rooms, the first intended for foreign music, the second for Japanese music, and the third for lectures, with a battery room to make broadcasting possible should the supply of electricity fail. The height of the antennæ will be 250 feet, and the construction is expected to be complete before the end of the year.

R557.—SWEDEN: NEW STATION. (*Electrical Review*, June 4th, 1926, p. 837.)

The Swedish Telegraph Board has concluded a contract with Marconi's Wireless Telegraph Co., Ltd., regarding the delivery of transmitting apparatus for Sweden's first large broadcasting station. The equipment will be similar to that at the English station at Daventry.

R557.—PERSIA. (*Radio-electricité*, June 10th, 1926, p. 210.

The Government of Persia intends erecting very shortly a system of broadcasting stations comprising a powerful station at Teheran and six stations of smaller range distributed over the State. The stations will be under the control of the Minister of War.

R570.—THE AIR SERVICE RADIO LABORATORIES.—Lieut. Breckel. (*Radio News*, July, 1926, pp. 12, 13, 68 and 70.)

Experiments with radio-controlled air-planes are described together with the radio beacon for air-planes, carried out in Ohio.

R581.—FORESEES BROADCASTING OF HEAT. (*Scientific American*, April, 1926, p. 272.)

Broadcasting of heat by radio is predicted when instruments to control heat waves are discovered; principally a detector that will intercept, hold and amplify the waves. Professor Dibble, of the Carnegie Institute of Technology, says that the transmission of heat is essential because of the gradual exhaustion of the elements of fuel. "The day is not far off, in my opinion, when we shall see huge centralised heating plants broadcasting heat to homes, industries, and office buildings. Our hope is to incline the activity of research men towards this objective."

R582.—FUNKBILD-ÜBERTRAGUNG IM AUSCHLUSS AN RUNDFUNK-GERÄT (Radio picture transmission attached to broadcast apparatus).—M. Dieckmann. (*Elektrische Nachrichten-Technik*, June, 1926, pp. 201—208.)

Particulars are given of a simple system for reproducing pictures in rough outline. Illustrations are shown.

R582. — HIGH-SPEED PHOTOTELEGRAPHY. — P. Gordon Fischel. (*Wireless World*, June 9th, 1926, pp. 777—779.)

Account of the system developed by the Telefunken Company and Dr. Karolus of Leipzig.

R586.—THE LATEST ADVANCE TOWARD TELEVISION. —L. FOURNIER. (*Radio News*, July, 1926, pp. 36, 37 and 84.)

An account of Professor Belin's apparatus which will cover ten complete images in one second, and so receive and reproduce a moving scene with continuity of action.

R586.—THE BAIRD TELEVISOR SYSTEM. (*Electrician*, June 25th, 1926, p. 672.)

Some particulars are given of Mr. Baird's invention which has been taken over by the company, Television, Ltd. It is stated that while artificial light is used at present, there is nothing to prevent the use of ordinary daylight, and that when certain refinements have been made, outdoor scenes will be able to be transmitted.

R600.—STATIONS: DESIGN, OPERATION AND MANAGEMENT.

R611.—THE RUGBY RADIO STATION OF THE BRITISH POST OFFICE.—E. Shaughnessy. (*Journ. Inst. Elect. Engineers*, June, 1926, pp. 683—713.)

The full text of the paper read before the Wireless Section, 14th April, together with the illustrations shown and the discussion that followed. Abstracts have appeared in most wireless journals.

R611.—BRAZIL—NEW STATION. (*Electrical Review*, June 18th, 1926, p. 917.)

The new high-power wireless telegraph station at Rio de Janeiro, which was opened recently by the Brazilian Minister of Communications, has been equipped with a 20,000 metre-ampere valve transmitter by the Marconi Telegraph Co. The station is being used for communication with Europe, Africa, Australia, North America, and the other countries of South America.

R615.12.—TRANSATLANTIC TELEPHONY TESTS.—A. Dinsdale. (*Wireless World*, June 16th, 1926, pp. 792—797.)

Description of the apparatus and methods employed at the American end of the circuit.

R615-12. — TRANSATLANTIC TELEPHONY. — A. Oswald and El Deloraine. (*Electrician*, June, 4th and 25th, pp. 572 and 666.)

Description of the telephony system at the Rugby station, including the single side-band equipment and power amplifier, the speech current apparatus, protective and testing measures, shielding arrangements and the control system.

R616.5. — GERMANY'S HIGH-POWER BROADCAST STATION: KÖNIGSWUSTERHAUSEN, BERLIN. —Prof. Howe. (*E.W.& W.E.*, July, 1926, pp. 411—415.)

R621.4.—CHOICE OF POWER FOR A RADIO STATION. —N. Tsiklinsky and V. Volynkin. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 381—389.)

A paper presented before the Russian Society of Radio Engineers, Leningrad, attempting to define that power of a radio station for which the desired service can be secured with the minimum outlay for installation and maintenance.

The cost of a radio station may be looked upon as the combined value of the buildings, the generating machinery, and the antenna with its masts and ground connection. It is here shown that, for a given transmission, the necessary power P in the antenna and its effective height h are connected by the equation $P = a + bh^2$. By this formula the cost of the antenna and masts, as a function of their dimensions, may be expressed as a function of the power: hence all the curves of cost may be combined graphically. The resulting curve of total cost clearly shows that there is some power for which the cost of a radio transmitter is a minimum. It is also shown how the power should be chosen to give the smallest annual expense.

The methods described are illustrated by determining the power in the antenna and height of the masts for a station with a range of 3,000km., operating on an optimum wavelength of 5,070m. Here the power for the least outlay works out to 30kW and for the lowest annual expense to 20kW.

R800.—NON-WIRELESS SUBJECTS.

538.—AUFNAHME VON MAGNETISIERUNGSKURVEN MIT DER BRAUNSCHEN RÖHRE (Tracing magnetisation curves with the Braun tube.—K. Krüger and H. Plendl. (*Zeitschrift für Hochfrequenztechnik*, 27, 5, pp. 155—161.)

539.—VELOCITY DISTRIBUTION AMONG THERMIONIC ELECTRONS IN VACUUM AND IN HYDROGEN ATMOSPHERE.—C. Del Rosario. (*Physical Review*, June, 1926, p. 810.)

The distribution of velocities among the electrons was found to follow Maxwell's law—contrary to the experience of other observers.

539.—PROBABILITY OF IONIZATION OF GAS MOLECULES BY ELECTRON IMPACTS—II. : CRITIQUE.—K. Compton and C. van Voorhis. (*Physical Review*, June, 1926, pp. 724—731.)

539.—COLLISIONS BETWEEN ELECTRONS AND GAS MOLECULES.—I. Langmuir and H. Jones. (*Physical Review*, June, 1926, p. 806.)

539.—THE COMPTON SCATTERING AND THE STRUCTURE OF RADIATION.—T. L. Eckersley. (*Philosophical Magazine*, July, 1926, pp. 267—287.)

539.—VARIATION WITH PRESSURE OF THE RESIDUAL IONIZATION IN GASES.—W. Merryman. (*Physical Review*, June, 1926, pp. 659—671.)

621-313-3.—FUR ERMITTLUNG DES ZEITLICHEN VERLAUFES VON WECHSELSTRÖMEN MIT HILFE DER BRAUNSCHEN RÖHRE (Determining the wave-shape of alternating currents by means of the Braun tube).—H. Plendl. (*Zeitschrift für Hochfrequenztechnik*, 27, 5, pp. 153—155.)

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

R000.—RADIO 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.

R100.—ĜENERALAJ PRINCIPOJ KAJ TEORIO.

R110.—HARMONIKOJ KAJ ILIAJ EFIKOJ ĈE LA ONDA FORMO.

La artikolo ilustras grafike la efikojn de harmonikoj je l'onda formo, ekz., de oscilo. Komence traktita estas simpla sinusa kurvo ; poste ilustrita estas la aldono de dua harmoniko de varianta amplitudo kaj fazo, kaj montrita la rezultanta modifiĝo de onda formo. Aliaj harmonikoj estas simile traktitaj, kaj la ĝenerala efiko de paraj kaj neparaj harmonikoj diskutitaj.

La artikolo finiĝas per ilustrado de kelkaj bone konataj serioj "Fourier"aj, kompilitaj laŭ terminoj difinitaj, kaj montras ankaŭ la formon je kiu la onda formo fine alproksimiĝas.

R113.8.—NOVA TEORIO. La Efiko de la Luno je Radio-Ricevado.—Derek Shannon.

La aŭtoro rimarkis, ke sendoj el malproksimaj (ekz., Amerikaj) stacioj riceviĝas plibone dum lunlumaj noktoj, kaj sugestas, ke la rotacio de la luno ĉirkaŭ la teron influas tiajn sendojn. Ilustrita estas cirkvito per kio oni faris mezurojn koncerne la stacion KDKA, kaj oni publikigas du kurvojn de rezultoj, kiuj montras grandan plifortiĝon de signaloj dum la plena luno, kaj malfortiĝon dum la luno malpliiĝas. Oni urĝigas la neceson de pli kompleta esplorado pri la luna influo.

R131.—UZADO DE PLAT-KURENTAJ—PLAT-TENSIAJ KARAKTERIZOJ DUM STUDADO PRI LA FUNKCIADO DE VALVAJ CIRKVITOJ.—E. Green.

La artikolo montras ke, je multaj okazoj, estas preferinde, revuante la konduton de valvaj cirkvitoj, konsideri la karakterizojn de anoda kurento rilate al anoda tensio (je konstantaj kradvoltoj). Post konsiderado pri la karakteriza familio, diskutitaj estas la konduto de kelkaj malsamaj tipoj de anoda cirkvito, sub la apliko de sinusoida voltkvanto. La ekzemploj pritraktitaj estas pura rezisteco, reaktanco indukta aŭ kapacita, rezisteco kaj reaktanco laŭserie, rezisteco kaj reaktanco laŭparalele aranĝitaj, k.t.p. La klarigo estas bone ilustrita per diagramoj. La nuna parto finiĝas per diskutado pri maksimuma elmeto, kaj efikeco por diversaj tipoj de praktikaj cirkvitoj.

R132.1.—MALALTFREKVENCAJ INTERVALVAJ TRANSFORMATOROJ.—Resumo de Referato legita de S-ro. P. W. Willans, M.A., antaŭ la Senfadena Fako de la Institucio de Elektraj Inĝenieroj, je la 2a Junio 1926a.

La referato detale konsideras la malaltfrekvencan intervalvan transformatoron. Unue diskutitaj estas teoriaj konsideroj, kaj resumitaj iliaj efikoj je transformatora funkciado. Poste priskribita estas metodo de eksperimenta mezurado, kaj la rezultoj ilustritaj kaj diskutitaj.

La aplikado de teorio kaj eksperimento al transformatora desegnado estas poste pritraktita, kun aparta aludo al komerca modelo de transformatoro evoluigita de la aŭtoro.

En la lasta parto de la referato presitaj estas notoj pri diversaj metodoj konekti la transformatoron, speciale kun celo havigi pligrandigitan skalon de unuforma amplifado. Ankaŭ aperas raporto pri la diskutado kiu sekvis la legadon de la referato.

R144.—EFEKTIVA REZISTECO DE INDUKTANCAJ BOBENOJ JE ALTA FREKVENCO.—Parto IIIa. S. Butterworth.

Parto Ia aperis en la Aprila numero, Parto IIa en Majo, kaj ambaŭ el ili estis resumitaj en ĉi tiu sekcio, en la Junia numero.

La nuna parto aplikas la argumenton, antaŭe disvolvitan, al multtavolaj bobenoj de malgranda profundeco por vindado, kaj al tiaj bobenoj de limita profundeco por vindado. Por faciligi kalkuladon, oni presigis tabelojn kaj kurvojn. Provajn rezultojn oni montras de komparoj inter kalkulitaj kaj mezuritaj valoroj. Ĉi tiuj montras, ke la kupra perdo estas 0.77 ĝis 0.92 de la tuta perdo. La desegno de induktancaj bobenoj por minimumaj kupraj perdoj estas poste diskutitaj. Post traktado pri ĝeneralaj principoj, la diskutado dividiĝas laŭjene: (1) Desegno por citita volumeno de kupro, (2) Desegno por konstanta longo de fadeno, (3) Desegno por konstanta supertuta surfaco. Esprimoj por la kalkulado de induktanco kaj rezisteco estas donitaj, kun tabeloj. La artikolo finiĝas per mallonga komparo de grandaj kaj malgrandaj bobenoj, kaj per noto pri eksperimentaj mezuroj de S-ro. A. L. M. Sowerby, resumitaj en ĉi tiu fako en la Julia numero.

R300.—APARATO KAJ EKIPAĴO.

R355.077.5.—AKIRO DE ANODA KURENTO PER LA ELEKTRAJ ĈEFTUBOJ.

Mallonga artikolo traktanta aparte pri la konduko al tero de meza aŭ neŭtrala konduktoro, kaj emfaziganta, ke ĉi tiu konduktoro devus esti kondukita al tero ĉe la genera stacio, sub-stacio, aŭ transformatoro, kaj ne ĉe la instalaĵo de la konsumanto.

R384.6.—KONSTRUADO DE MEM-ENHAVA AŬ APERIODA PUNKTA GALVANOMETRO.—F. A. Boyce.

Priskribo pri konstruado de malmultekosta punkta galvanometro posendanta la jenajn trajtojn: (1) Mem-enhava, la punkta lumo estante konstante fokusita al smirgita vitra skreno, kiu estas parto de la ŝranko mem, (2) Balistika aŭ aperioda, la ŝanĝo estante farita per komutatoro sur la borna panelo. (3) Simpla konstruo.

La instrumento estas movbobena modelo, kaj konstruaj detaloj kaj diagramoj estas publikigitaj por fabriki aŭ akiri la diversajn partojn. La aperioda komutatoro enkondukas eksteran ŝarĝon de ne-indukta rezistanco, kiu tuj amortizas osciladon de la bobeno. La lampo estas 4½-volta, simila al tiu uzata kiel poŝlampo. Ĝeneralaj notoj pri l'uzado de l'instrumento ankaŭ aperas.

R384.6.—LA MULT-SKALA AMPERMETRO DE KONSTANTA REZISTECO.—L. G. A. Sims & M. Heywood Hunt.

La artikolo diskutas aranĝojn por certigi, ke la kombinita rezisteco de ampermetro kaj ŝunto estu ĉiam la sama kiel tiu de l'instrumento kiam uzita sole. Diskutinte la ĝeneralajn principojn pri ŝuntigo de tia instrumento kaj pri aldono de kompensa seria rezistanco, la aŭtoroj montras kiel, per aranĝo de taŭgaj konektigaj punktoj sur la rezistanco, porcio de ŝunta rezistanco, kiu estas elŝuntigita, povas esti aldonita al la efektiva seria cirkvito. La kompensado ne estas absolute preciza, sed la eraro estas malgrandega, dum multa simpliĝo efektiviĝas. Oni citas esprimojn por la seriaj kaj ŝuntaj valoroj, kaj tabelo montras ilian aplikon al altrezisteca kaj al malaltrezisteca instrumento, montranta ankaŭ la procentan eraron pere de ideala okazo de konstanta rezisteco.

R500.—APLIKOJ KAJ UZOJ.

R540.07.—SENFADENAJ ANTENOJ KAJ LA DOMLUIGANTO.

Mallonga artikolo de advokato, revuanta la kondiĉojn sub kiuj antenoj aŭ aliaj senfadenaj objektoj povas esti fiksitaj al konstruaĵoj okupitaj de luantoj.

R600.—STACIOJ: DESEGNO, FUNKCIADO KAJ ADMINISTRADO.

R616.5.—LA GERMANA ALTPOTENCA BRODKASTA STACIO.—Prof. G. W. O. Howe.

Priskribo pri la Germana altpotenca brodkasta stacio ĉe Königswusterhausen. Estas tri apartaj sendiloj, unu 14-kilovata kaj du 7-kilovataj, ĉi tiuj potencoj estante liveritaj al la valvoj sen modulado. La priskribo traktas pli precize pri la unue aludita sendilo. La provizo de anoda potenco estas per transformatoro el 500-cikla alternkurenta generatoro je 220 voltoj. La sendilo konsistas el kvar partoj: (1) Sendependa oscilatoro, (2) Rektifikatoroj kaj altpotencaj valvoj, (3) Meza cirkvito ĉe anodo de altpotencaj valvoj, (4) Antena agorda bobeno. Modulado estas efektivigita per patentita metodo Telefunken'a, ĉe kiu la kutima krada rezistanco estas anstataŭigita de la variebla rezistanco de la modulaj valvoj, kies rezisteco dependas de la krada tensio, kiu, siavice, estas regita de la amplifita mikrofona kurento. Fotografaĵoj de l'stacio kaj de diversaj eroj de ĝia aparataro kaj ekipaĵoj estas presitaj.

R800.—NE-RADIAJ TEMOJ.

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

Daŭrigo de la serio komencita en la Maja numero. Pritraktitaj estas algebraj multiplikoj, la multipliko de numero-grupoj, nulo en la multipliko, dissolvo je faktoroj, la fizika aplikado de multipliko, k.t.p.

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.

A New Theory.

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

SIR,—The method of measurement used in the article entitled " A New Theory " is very interesting. I have been making measurements with methods similar to this, and would suggest the insertion of a large condenser ($2\mu F$) from the H.T. side of coil L_3 to L.T.—. It is important to keep the load in the anode circuit as constant as possible, otherwise small alterations in H.T. resistance, etc., may give variable results. The first valve is really a form of Moullin voltmeter using grid rectification.

Great stress appears to be laid on the supersensitivity of the galvanometer. This galvanometer has to be shunted to pass the anode current and it is not clear to me why a less sensitive galvanometer should not be used giving full deflection for, say, 200 or 300 microamps. I believe the Cambridge Instrument Co. can supply pivoted instruments to read as low as this without the trouble of a mirror suspended type. It is only fair to add that I have used an ex-Government micro-volt-ammeter as mentioned with very satisfactory results, but this instrument is unnecessarily sensitive.

Methods of measurements such as this could be used more extensively by experimenters and are well worth while. I have also noticed a connection between signal strength and tides.

E. A. ANSON (Capt.) 2OA.

The Valley, Narberth,
Pembrokeshire.

Fading.

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

SIR,—As suggested by Mr. W. H. Maddison in a letter published in the June issue, any effect of cloud on reception phenomena should be taken into account. It is not so certain, however, that, as he says, the conductivity of a cloud is far greater than that of ionised air. Indeed, experiments carried out by the writer so far have shown the reverse to be the case.

For a homogenous medium to be conductive the ions (including isolated electrons, if any) must be capable of free movement along a line of potential gradient. Now a cloud or fog is not homogenous. It consists of discrete particles of water dispersed throughout a bulk of air. These particles are condensed around solid or ionic nuclei, thus imprisoning and hampering the movements of those ions which would otherwise render the medium a conductor. True, the aqueous particles possess a small electric charge, either by virtue of the occluded ions and by any other charged matter which may be adsorbed by them, or by other means, and so a general but slow drift may occur in a negative or positive direction. This results in a much smaller conduction than might be expected.

A parallel case may be instanced. Some years ago the writer had occasion to measure the conductivities of dry and moist solutions of hydrochloric acid gas in toluene. It was rather surprising to observe that the moist solutions showed lower conductivities than the dry. The explanation was that the particles of water dissolved out the HCl forming a fine cloud of minute globules dispersed throughout the non-conducting toluene.

If Mr. Maddison has any data it would be most interesting.

Harrogate. A. WOODMANSEY (6LU).

SIR,—I share entirely the ideas of Mr. W. H. Maddison, g2BOX; one seems ever fascinated by the Heaviside layer theory, and does not look enough into atmospheric disturbances.

As a matter of observation, I can assure you that clouds have a great effect on the production of fading. I conducted tests here with a Belgian friend. As a rule, my signals were quoted *r*7 on his receiver, but when the weather was cloudy, and clouds passing just over my house, my signals dropped *in each case* to *r*5 or *r*4. This " law " has never been found wrong here. I may add that frosty nights give no fading effect, and that foggy days seem to have no effect on radio signals.

Paris. HENRY PIRAUX (f8PY).

SIR,—I have been greatly interested in recent articles and correspondence *re* " Fading," and I beg to state that, judging from my own observations which have been purely aural, I feel that there is something worthy of consideration in the remarks attributed to the old lady who hesitated to buy a broadcast receiver because she thought that as so many aerials were popping up, there would not be sufficient energy to go round.

Many DX listeners are aware that the proximity of other receivers, each tuned to the same distant station, produces serious changes of signal strength more especially when they are in a direct line between the desired station and the point of observation. Perhaps it would not be unreasonable to suppose that although the effect would be inversely proportional to the square of the distance between the observer and the interfering receivers, it would, nevertheless, be a factor which cannot totally be ignored when one considers that there may be some hundreds of receivers in the direct line, each swinging through the band of frequencies round about the particular one under observation.

I am not suggesting that fading is likely to be non-existent were there no interfering receivers, but I am of the opinion that this effect does seem to complicate matters to observers in crowded districts, and would possibly give rise to the irregularity in fading.

Highbury. WILFRED GARTLAND (G2GP).

Inductance Coils Quantitatively Compared.

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

SIR,—With reference to Mr. P. K. Turner's letter, published in *E.W. & E.W.* for July, I feel it is necessary for me to take arms in my own defence.

Mr. Turner has evidently realised that Part I. of my article was simply a repetition of Mr. Reyner's work, made in order to check his rather astonishing conclusions, and Mr. Turner has therefore restricted his criticisms to Part II.

He deprecates, for example, the "simultaneous change of several variables"—and then proceeds to suggest another set of measurements, also involving simultaneous changes in several variables. The truth is, of course, that it is utterly impossible to change only one variable at a time—and I am not sure that I prefer Mr. Turner's selection of simultaneously changing variables to my own. The same difficulty occurs in Mr. Butterworth's mathematical work, and the sets of simultaneous variables that he has chosen are different again, as he points out in the courteous note at the end of his July instalment.

Actually, my own selection was made in such a manner that the variable under consideration should have the preponderating influence in varying the resistance, which would not be the case in getting experimental figures for the effect of D/l ratio in the manner suggested by Mr. Turner.

Mr. Turner's remarks on the probable inaccuracies of the method that I adopted are just enough in essence, though heavily exaggerated in numerical value.

In the first place, it is necessary to state that at the time when the measurements were made, I was living in extremely cramped temporary quarters, and had no chance whatever either of making up or using anything like decent measuring apparatus, and I had to do the best I could under the circumstances. Now I have a home, and the deficiencies, with the sterling aid of *E.W. & W.E.*, are being rapidly made good.

It is obviously impossible for me now to measure the resistance of the actual aerial used in the measurements published, but I have rigged up a pretty close duplicate, and its resistance, measured by the resistance variation method, comes out at about 11 ohms at 380 metres, which is far below Mr. Turner's suggested figure.

In making his remarks about the probable large variation in the self-capacity of the coils, Mr. Turner has quite evidently overlooked the fact that all the coils were solenoids, and would therefore have a pretty low self-capacity, with but small variations from coil to coil. To check the point, coils 1, 3 and 10 of Table IIA (p. 365) have been measured up on apparatus now available, and come out as 11.8, 11.3, and 11.5$\mu\mu$F respectively. Since the same tuning capacity of about 120$\mu\mu$F tuned all these coils to the same frequency, their true inductances differed, in the extreme case, by one part in about 240, which is certainly too small an error to be seriously considered in any but the most accurate measurements of H.F. resistance.

Direct pick-up was pretty effectually swamped, as stated in the article, by the much greater pick-up of the aerial—it was found at the time that the orientation of the coil did not affect the reading of the meter.

Whether small differences were, or were not, brought out by the measurements in question depends on Mr. Turner's definition of a "small difference"—a tenth of an ohm would certainly have passed unnoticed, whereas half an ohm as certainly would *not*. The resistance of a circuit comprising a coil, condenser, leads and Moullin voltmeter have been measured to settle this point, and the values obtained with various coils of Table IIA, were as follows:—

Using Coil 1	...	14¼ ohms	at 380 metres.
,, ,, 2	...	11½ ,,	,, ,,
,, ,, 3	...	9 ,,	,, ,,
,, ,, 10	...	10¼ ,,	,, ,,

and the "deflections" already recorded were 810, 875, 955 and 910 respectively. A change in "deflection" of 5 units (the smallest readable) thus represents roughly one-sixth of an ohm.

In conclusion, may I be allowed to express my hope that I have persuaded Mr. Turner to agree that my measurements, although not up to the best laboratory standards, were yet a good deal more accurate than he imagined in writing to you a month ago.

A. L. M. SOWERBY.

119, Westbourne Grove, W.2.

"Aperiodic" or "Untuned"?

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

SIR,—With reference to correspondence by "F. A." in the current issue of *E.W. & W.E.* in which he prefers the use of the expression "untuned" to that of "aperiodic" when dealing with certain types of radio receivers, I venture to suggest that both expressions are equally incorrect, inasmuch as, to quote his own words that "any circuit which contains capacity and inductance must have a natural frequency (even when not purposely tuned)"—surely, if a circuit is not "purposely tuned" it is nevertheless tuned to some definite frequency, so why refer to it as being "untuned"?

I think that "Fixed Tune" would perhaps be more nearly correct.

Highbury. WILFRED GARTLAND (G2GP).

ERRATUM.

Germany's High Power Broadcasting Station.

It is regretted that through an error an incorrect diagram was inserted for Fig. 10 on page 415 of our last issue.

For convenience in making the correction, we have inserted the correct diagram in the advertisement pages of this issue.

CALIBRATION DEPARTMENT.

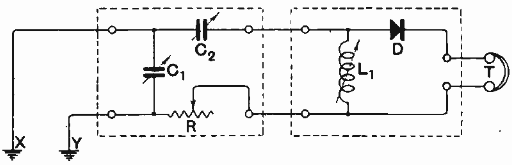
E.W. & W.E. Calibration Department is temporarily closed. An announcement will be made in these columns when readers' apparatus can again be received by this Department for calibration.

Some Recent Patents. [R008

A DOUBLE EARTH RECEIVING SYSTEM.

(*Application date, 6th February,* 1925. *No.* 251,693.)

G. A. Morris and B. C. Stevenson describe in the above British Patent Specification the arrangement of a device to substitute the normal receiving aerial. The scheme consists essentially in providing a receiver with two earth connections, the second earth connection substituting the usual aerial. Thus in the accompanying illustration two earth connections are shown at X and Y respectively. The ordinary receiver comprises a variable inductance L_1, a detector D and telephones T. The normal aerial and earth terminals of the receiver are not connected directly to the two

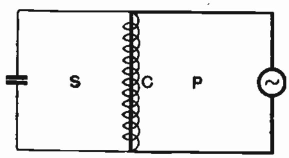


earth connections X and Y, but are taken through a network of capacities and a resistance. The capacity C_1 is placed across the earth connections. One end of the variable condenser C_1 is taken through another condenser C_2 to one end of the variable inductance L_1, while the other end of the inductance is connected to the other side of the capacity C_1 through a variable resistance R. It is stated that dissimilar earth connections may be used, such as a water pipe and a gas pipe. Alternatively, two earth tubes or plates may be used, placed some twenty feet apart, and preferably along the line joining the desired transmitting station with the receiver. The value of the condenser C_1 is of the order of .001μF while that of the condenser C_2 may be between .00001μF and .0003μF. Another modification of the invention consists in placing radio frequency chokes in shunt with the two variable condensers.

A FREQUENCY TRANSFORMER FOR SHORT WAVES.

(*Convention date (Germany),* 16*th August,* 1924. *No.* 238,559.)

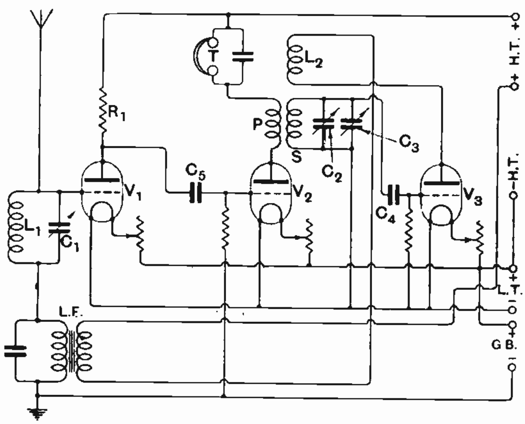
The Telefunken für Gesellschaft Drahtlose Telegraphie M.B.H. described the construction of a rather interesting frequency transformer in the above British Patent. It is stated that the use of iron for frequency transformers for the purpose of generating very short waves introduces difficulty, owing to the losses which occur when a very great number of ampere turns per centimetre winding is necessary for a small volume. This results in considerable heat being generated which it is not possible to dissipate in the normal manner. The conductor carrying the currents at the fundamental frequency is surrounded with a thin ferro-magnetic layer, preferably not thicker than about 0.1 mm. For example, as shown in one of the figures reproduced, the conducting wire or tape may be surrounded with thin ferro-magnetic hair wire. The secondary circuit S and primary circuit P are connected through a conductor C spun round with thin hair wire. In an alternative modification the iron may be applied in a thin sheet by plating, spraying or powdering. The specification also includes other detailed modifications and alternative methods.



A REFLEX CIRCUIT.

(*Application dates,* 11*th February and* 28*th March,* 1925. *No.* 251,374.)

C. A. Cleghorn describes in the above British Patent a three-valve reflex circuit, the novelty of which lies in the introduction of resistance-coupled stages for both high and low frequency amplification. A three-valve circuit is shown in the accompanying illustration in which the first two valves act as dual amplifiers, the first one being resistance coupled and the second one being coupled by a

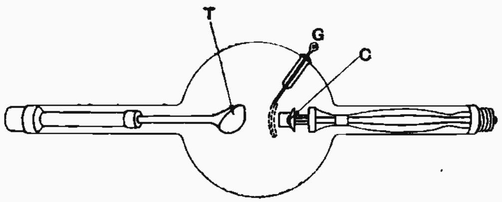


high frequency transformer to the rectifier, the output of which is fed back to the first amplifier. Thus, in the accompanying illustration it will be seen that the aerial circuit comprises an inductance L_1 and variable condenser C_1, connected in the grid circuit of the first dual amplifier. The dual amplifier contains a resistance R_1 in the anode circuit, which is coupled by a .005 fixed condenser to the grid of the second valve V_2. The anode circuit of the valve V_2 contains the primary P of a high frequency transformer, and also the telephones T. The secondary of the transformer S is tuned by condensers C_2 and C_3, and is connected through the usual grid condenser C_4 to the grid of a detector valve V_3. The output circuit of this valve contains a reaction coil L_2, which is coupled to the secondary of the transformer, and also contains the primary winding of a low frequency transformer LF. The secondary winding of this is connected between the earth and the lower side of the input. Low frequency potentials which have been amplified by the first valve are passed on by the resistance R_1 to the grid of the second valve which amplifies them still further, the final output being taken to the telephones T contained in the anode circuit of the second valve.

A TELEVISION DETAIL.

(*Application date, 6th March,* 1925. *No.* 252,799.)

A rather interesting television scheme is described by G. M. Wright and R. N. Vyvyan in the above British Patent. The object of the invention is to control or modulate the rays as reflected from the target to an X-ray tube so as to effect a photographic device, or florescent screen. Thus, in the accompany illustration it will be seen that an X-ray tube

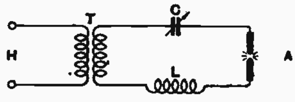


of the Coolidge type is shown, in which T is the target and C the cathode which is heated in the normal manner. A grid G is interposed between the cathode C and the target T, so that potential variations applied between the cathode and the grid will control the intensity of the rays which are emitted, thus causing a variation in the effect on the florescent screen, or other device which may be employed.

"A TALKING ARC."

(*Application date, 23rd September,* 1925. *No.* 241,874.)

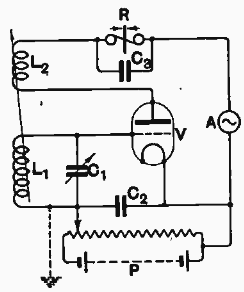
Dr. H. Konemann describes in the above British Patent, No. 241,874, a modification of the singing arc. The object of the invention is to convert electrical into acoustic energy; that is, to provide some form of loud-speaker or telephone with the aid of an arc. The invention consists essentially in striking an arc between two carbon or similar electrodes, the arc being fed from high frequency currents, which are modulated at an audible frequency. Thus, a source of high frequency energy is obtained from H through the medium of a transformer or coupling device T, which is tuned by a condenser C and inductance L connected across the two carbons A. When the source of high frequency current is substantially steady the heat in the air gap remain constant, and there is no alteration in air density except, of course, at a radio frequency which is inaudible to the human ear. If, however, the high frequency current is modified by speech currents from a microphone, or similar source, the high frequency energy will vary, causing a change in temperature between the electrodes of the arc, with a resultant change in air wave pressure, giving rise to ordinary sound waves. The advantage of the arrangement is that there is substantially no mechanical or electrical inertia.



A TRIGGER SYSTEM OF RECEPTION.

(*Application date, 31st March,* 1925. *No.* 250,748.)

A system of trigger reception is described by W. J. Brown, C. E. Burch and Metropolitan-Vickers Electrical Company, Limited, in the above British Patent, which includes several modifications of the invention, one of which will be described in detail. The accompanying illustration shows an ordinary three-electrode valve V, provided with a tuned grid circuit $L1$ $C1$, and a reaction coil $L2$, the two coils being coupled so as to produce a regenerative effect. The lower end of the grid circuit is connected to the lower end of the filament by a potentiometer P and a by-pass condenser $C2$. The potentiometer P is adjusted so that the steady voltage of the grid is sufficiently negative to prevent the maintenance of oscillations. The anode voltage is derived from a source of alternating current A, and is connected in series with an inductance such as a relay R, shunted by a condenser $C3$. When the negative half cycle is applied to the anode the valve, of course, is inoperative, but when the anode is positive with respect to the filament then the valve is operative, a certain steady anode current flowing and passing through the relay, which is adjusted so that at those values it does not quite pull over. If, now, the inductance L_1 be coupled to an aerial system, and tuned to resonance with a given signal, it follows that potential variations will occur between the grid and the filament with the result that the grid will become more positive on the positive half cycles. This increase of positive potentials is sufficient to cause the valve to oscillate when the valve is positive with respect to the filament. As soon as the valve commences to oscillate there

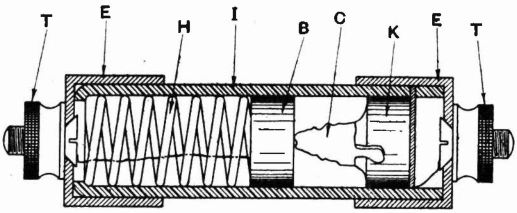


will be a considerable increase in steady anode current, sufficient, in fact, to cause the relay to become operative. If the device were supplied with direct current it is probable that the oscillations would be maintained immediately the device had been trigged. However, as soon as the anode becomes negative with respect to the filament the anode current will be materially cut down, sufficient, in fact, to quench the oscillations, and at the same time cause the relay to return to its normal position. The arrangement thereby being ready to deal with the next signal. The specification is very detailed, and includes other modifications, particularly the adoption of this principle to super-regenerative circuits. Where an indicator is used instead of ordinary telephone receivers the frequency of the alternate potentials applied to the anode may be quite low, a 50-cycle commercial supply, for example, being suitable. In the case of telephone reception, or with a super-regenerative arrangement, a local oscillator valve functioning at a frequency in the neighbourhood of audibility is preferred.

ANOTHER CARBORUNDUM DETECTOR.

(*Application date, 26th March,* 1925. *No.* 251,408.)

Another modification of the Carborundum Company's crystal detector is described in the above British Patent. The chief novelty of the detector is in the preparation of the carborundum crystal,

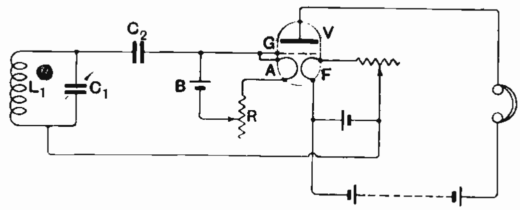


a portion of which is metallically coated and soldered into a containing cup, or similar device. In this particular modification, however, a carborundum crystal *C* treated in this manner is fixed to a cup *K*, the point of the crystal, which is made chemically pure, being in contact with a steel block *B* in the form of a cylinder which moves in an insulating tube *I*. The end of the steel piston or block *B* is controlled by a strong helical spring *H*. The ends of the tube are closed by means of end caps *E* to which are fixed terminals *T*. Other modifications of the patent include the substitution of other forms of springs such as leaf springs, and those of *U*-shaped formation.

A DOUBLE FILAMENT VALVE.

(*Application date, 19th June,* 1925. *No.* 252,554.)

The Dubilier Condenser Company (1925), Ltd., and J. V. Capicotto describe in the above British Patent the construction of a valve which can be used without the normal grid-leak. The idea of the invention can be gathered by reference to the accompanying illustration, in which it will be seen that a tuned circuit L_1 C_1 is connected between the grid *G* and filament *F* of the valve *V*, the usual grid condenser C_2 being included. Normally with this arrangement the grid would assume a negative charge, thus causing the valve to become inoperative. It will be noted, however, that a small additional filament *A* heated by a battery *B* and controlled by a rheostat *R* is included in the valve, and is connected to the grid *G*. Thus it will be



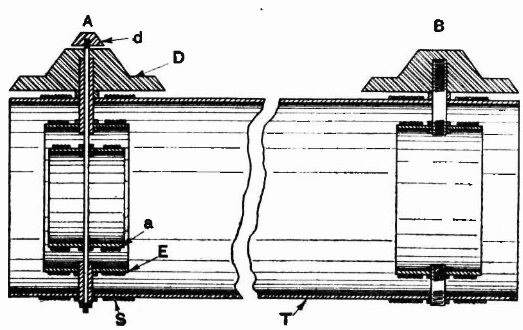
seen that if the filament *A* is heated it will emit electrons which will thus enable the charge which is collected on the grid to leak away to the main filament. In other words, the auxiliary filament *A* acts as the grid-leak of the arrangement, and the value of the grid-leak can be varied by controlling the rheostat associated with the auxillary filament.

In a modification of the invention, the second filament is used as the grid or control electrode.

A MULTIPLE VARIOMETER.

(*Application date, 13th July,* 1925. *No.* 250,278.)

R. B. Matthews and W. H. R. Pike described in the above British Patent the construction of a multiple variometer, which consists essentially of a stator, and two co-axially mounted rotors. One modification of the invention is illustrated by the accompanying diagram, in which two variometers *A* and *B* are mounted upon a common stator tube *T*. The variometer *A* consists of a rotor *a* controlled by a knob *d*, and a stator *S*. An additional rotor *E* controlled by a knob *D* forms part of the winding of the variometer *B*.



By this arrangement it is found easily possible to couple the two variometers together. The specification also provides for the use of one of the windings as a reaction coil.

LOUD-SPEAKER MOVEMENT.

(*Application date*, 6*th August*, 1925.
No. 251,151.)

J. Piquart claims in the above British Patent, No. 251,151, the construction of a loud-speaker movement which is represented diagrammatically by the accompanying illustrations. The loud-speaker movement consists of a horseshoe magnet *H* (Fig. 1) provided with L-shaped laminated pole pieces *L*, which carry the usual windings *W*. A peculiar

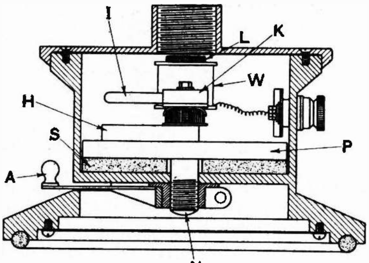


Fig. 1.

feature of the invention is the inclusion of some iron rods *I*, which are clamped over the edges of the laminated pole pieces by means of clamping devices *K*. The horseshoe magnet is carried by a plate *P*, which rests on a block of sponge rubber *S*, which, in turn, rests upon the base of the container. The plate is provided with a screwed stud *N*, other screwed studs *M* (Fig. 2) projecting in the lower face of the plate, and surrounded with helical springs. Adjustment of the magnetic portion with respect to diaphragm is obtained by means of a lever *A*, which rotates a threaded device co-operating with the screwed stud *N*, thereby causing the stud to rise and fall, and

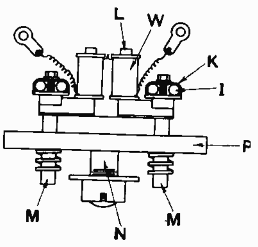


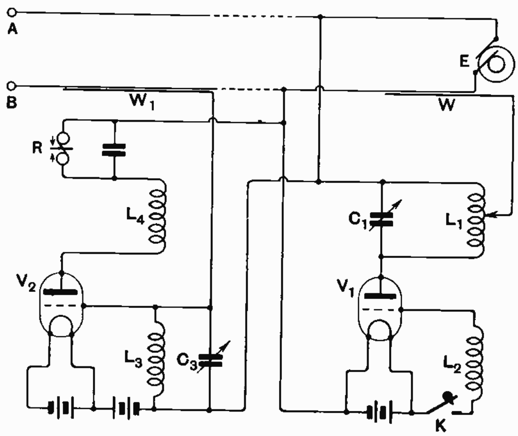
Fig. 2.

carry with it the movement. The specification is fairly detailed, and contains constructional information and additional minor features. For example, it may be mentioned that the end of the sound conduit is screwed rigidly into position.

DUPLEX SIGNALLING.

(*Application date*, 31*st March*, 1925.
No. 250,747.)

E. W. Braendle and Metropolitan-Vickers Electrical Company, Limited, describe a system of duplex signalling in the above British Specification. Essentially, the invention consists in utilising synchronised sources or a common source of high tension supply, one half cycle of which is used to make the transmitter valves operate, while during the other half cycle the receiving valves are operative. This enables duplex signalling to be carried out, accompanied, of course, by a superimposed hum, due to the frequency of the alternating current supply. A source of alternating current supply *E* feeds two conductors *A* and *B*. The valve V_1 is used as a generator of high frequency currents, a tuned circuit L_1 C_1 and a grid coil L_2, coupled in the usual manner, a key *K* being used. The anode of this valve is supplied from current derived from the source *A*, while the filament of the valve is connected to the conductor *B*. The valve V_2 is used for reception, and comprises a tuned grid circuit L_3 C_3, a reaction coil L_4 being included in the anode circuit. A relay *R* is shown as the indicating device. A bias battery will be noticed in the grid circuit of this valve, arranged so as to give the grid a negative potential with respect to the filament. The valve receiver is of the trigger variety, in which the received signals



cause oscillations to commence which are subsequently quenched when the anode becomes negative with respect to the filament. The anode of the valve V_2 is fed from the conductor *B*, that is, the opposite conductor from that feeding the anode of the valve V_1, while the filament of the valve V_2 is connected to the conductor *A*. The two valves are electrostatically coupled to the conductor *B* by means of wires *W* and W_1 respectively. An exactly similar arrangement of valves is shown connected to the same conductors *A* and *B* intended to be placed some distance away. Thus it will be obvious that on one half cycle one transmitter and distant receiver will become operative, while on the other half cycle the distant transmitter and near receiver will be operative. In this way duplex signalling can be carried out. The system is not applicable as indicated to telephony owing to the trigger type of receiver and the superimposed hum.