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Editorial.

Olympia Radio Show, 1928.

THE National Radio Show, 1928, which was held at Olympia from September 22nd to 29th, provided an opportunity for making a comparison between the state of development of wireless to-day and the point which had been reached at the time of the Olympia Show last year, in-so-far as the broadcasting aspect of radio is concerned.

Quite apart from a consideration of detailed improvements in the design of apparatus, there are several wider influences which have been at work during the past year to contribute towards directing the future tendencies of broadcasting. It is probably correct to regard the outstanding evidence of progress to be the present state of education of the public in the appreciation of better quality in reproduction, and this improvement in the general standard of public requirements is reflected in the efforts which have been made by the manufacturers. What the radio engineer regarded as a supreme achievement in quality of reproduction a year or so ago would not be tolerated in the home of the connoisseur layman of to-day. Instead of discussion being devoted mainly to the topic of quality, as in the past, quality to-day is taken almost for granted, and problems of the moment are of a more obscure character, such as that of the correct contrast in volume in loud-speaker outputs.

Next we should mention alternative programmes, for although a year ago the idea was not new, yet the Regional Scheme, with the choice of transmissions, could not then be looked forward to with the same degree of confidence as is possible to-day. The choice of programmes, and the probable reduction in price due to royalty cuts, are accelerating the rate at which valve receivers with loud speakers are replacing the crystal sets of old. Moreover, with the disappearance of the crystal set we look forward to a revision of the present B.B.C. control-room policy, which, so long as the Corporation feels it necessary to cater specially for the crystal-set user, must mar the reception of loud speaker reproduction on account of disproportionate strength of speech and music.

Another new departure in broadcasting is picture transmission. We have at present no experience of the possibilities of still life picture transmissions as applied to broadcasting, beyond the fact that satisfactory results can be attained, but that in itself is not sufficient unless the obtaining of results is to prove of interest and benefit to the community. It seems likely, however, that picture transmissions may open up an interesting new field in the future and then, perhaps, at some more distant date, it may be succeeded by the more ambitious possibilities of a television service.

In next month's issue we propose to review those exhibits at the Olympia Show which we feel would be of special interest to our readers, dealing in particular with apparatus suitable for laboratory use.

The Design of Non-contact Thermo-junction Ammeters.

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Abstract.

The contact and non-contact types of thermo-junction alternating current ammeter are compared. The general principles of the design of the non-contact type are stated. Two designs embodying these principles are described with particulars as to their performance. An account is given of a particular application as a known source of radio-frequency potential difference.

1. Introduction.

By a non-contact thermo-junction ammeter is meant one in which there is no conductive connection between the heater element and the thermo-junctions. From the point of view of the measurement of current at radio-frequencies, this is a very considerable advantage for the following reason. With either type the heater element is of necessity included in the circuit carrying the radio-frequency current to be measured. With the contact type of thermo-junction ammeter, the heater is in conductive contact with the thermo-junction and thus with the galvanometer or whatever direct current instrument is employed for the measurement of the thermal E.M.F., together with its associated leads. The appreciable capacity effect of this auxiliary apparatus may, and in fact generally does, introduce an element of uncertainty into the reading of the ammeter. The reading will be found to depend to a serious extent on the position of the ammeter relative to the remainder of the circuit, particularly on its position relative to any earthed point of the system. The element of uncertainty can of course be minimised, though not necessarily eliminated, by making the point of contact of the ammeter an earthed point, and this precaution should always be taken where possible, but it is obviously preferable that the measuring instrument should be free from this restriction.

A further characteristic of the contact type, and one which is particularly disadvantageous from the point of view of experimental work, is that the destruction of the heater through over-loading means the replacement of the whole thermal element of the instrument. This is a fact of considerable economic weight, since the commercial forms of contact thermo-junction are somewhat expensive, and their use in resonant circuits makes them very liable to this kind of accident. Finally, in the matter of calibration, it is usually found that the direct current calibration depends on the relative direction of the current, so that a double calibration is required—or alternatively, calibration with low frequency alternating current.

On the other hand it must be admitted that the contact type is generally much more sensitive than the non-contact pattern. However, sensitivity is not always the most important factor.*

In non-contact thermo-junction ammeters the disturbing effect of the galvanometer need only arise from the capacity between the heater and the thermo-junctions. In the instruments described below this is of the order of 5 $\mu\mu$F., a value which is quite negligible except perhaps at ultra high frequencies.

* Since this was written a new pattern of non-contact vacuum thermo-junction has been put on the market. The sensitivity of this is comparable with that of the contact type and it appears to be a very satisfactory unit. Moreover, the capacity between the heater and junction is very low, being of the order of 1.5 $\mu\mu$F. without a holder. It is, however, somewhat expensive and not repairable in case of injury.

2. General Principles of Design.

Apart from any question of sensitivity a satisfactory thermo-junction ammeter should possess two further characteristics—quickness of response and stability of reading. The thermal aspect of these requirements is that the thermo-junction and heater system must attain a thermal equilibrium in a short time. This involves two features of design, (*a*) that part of the system which changes in temperature (the heater and the heated junctions) must be of small thermal capacity —the smaller the better from the present point of view; (*b*) the cold junctions must be of such large heat capacity that their temperature is not appreciably raised by the conduction of heat from the heated junctions. Both these features will be found embodied in the thermo-junction systems designed by Dr. W. J. H. Moll (Journal of Scientific Instruments, 1926, Vol. III, pp. 209–210, and *Proc. Phys. Soc.*, 1923, Vol 35, pp. 257–260), whose work on this subject constitutes the most important advance since the development of the Duddell Thermo-Galvanometer. Dr. Moll's thermo-junctions were made by rolling out thin plates of Manganin and Constantan, welded together along one edge, into a foil as thin as 0.005 mm., this foil being cut into strips to make the separate junctions. The junctions are mounted on copper pegs plugged into a sheet of metal, each peg being electrically insulated from the metal base by a very thin coating of lacquer or varnish. It was found that the time of response of such a system is limited by the inertia of the associated galvanometer rather than the heat capacity of the junctions.

The design to be described below is not claimed to be of the quality attained by Dr. Moll, but it has one important advantage—it is easy to construct and is quite sufficiently quick and stable for ordinary laboratory use.

A further essential characteristic is constancy of calibration. This involves two features of design: (*a*) the metal elements should not have any gradual change of surface conditions of a kind likely to modify appreciably their thermal radiation and absorption; (*b*) the relative position of the parts, particularly the relative position of the thermo-junctions and the heater, must not vary irreversibly under conditions of operation. In Dr. Moll's design the alloys, Constantan and Manganin, were chosen on account of their satisfactory surface constancy, while the constancy of relative position between junctions and heater was obtained by weaving the heater (an enamel insulated wire) over and under the junctions.

In the designs to be described below no attempt is made to secure constancy of surface conditions. In fact, copper is employed as one of the junction metals and the surface of this changes comparatively rapidly from an original bright and clean condition. The change, however, is not continuous and after an ageing period of a month or so, the surfaces appear to reach an effectively stable condition.

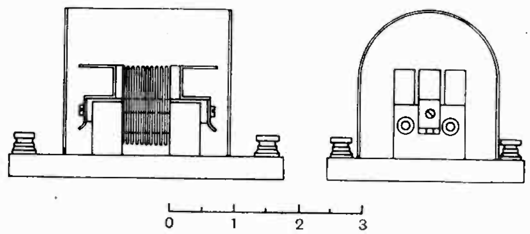


Fig. 1.

Variation of calibration attributable to relative shift of junctions and heater is avoided in two ways. In the first place the heater is maintained under a slight tension, to take up the small but by no means unimportant elongation with the use in temperature in operation. In the second place it is at such a distance from the junctions (0.5mm. or so) that the calibration is not critically dependent on this distance.

Another essential general principle of design is that the thermal system must be protected against extraneous air currents. In the designs described below the thermal systems are completely enclosed to shield them against draught. The covers are transparent or windowed for convenience of inspection.

3. Description of Two Actual Designs.

Preparation of Thermo-junctions.

Thermo-junctions of the desired characteristics can be prepared very simply by the plating process introduced by Mr. W. H.

Wilson and Miss T. D. Epps, and described by them in a paper read to the London Physical Society (*Proc. Phys. Soc.*, 1920, Vol. 32, pp. 326–339). A length of bare No. 47 S.W.G. Eureka wire is rolled out to a strip about 0.0005in. thick. This strip is wound on a frame of copper wire (about 2½in. by 3in.) which frame is then immersed vertically to about half its depth in slightly acidulated copper sulphate solution and the Eureka strip is plated with copper to a total overall thickness of about 0.001in. (There appears to be no advantage in making the coating any thicker than 0.00025in.) The frame is then washed thoroughly in tap water, followed by distilled water, and the junctions can then be removed and are ready for mounting. The copper coating may not be deposited very uniformly if the Eureka wire is not quite chemically clean. An effective, if somewhat drastic, method of cleaning the strip is to plunge that half of the frame which is to be plated, in concentrated nitric acid and then into water as rapidly as the necessary movements can be made. An alternative method of cleaning is to immerse the frame in a 5 per cent. solution of potassium hydroxide raised to boiling point and at the same time pass sufficient current through the liquid, using the frame as negative electrode and a platinum wire as positive electrode, to maintain a steady evolution of gas at the frame.

A number of different gauges of Eureka wire were tried, both in round and strip form, but in every case it was found that the slight additional sensitivity (due to lower junction resistance) was obtained at the expense of a considerable increase in the time required for thermal equilibrium, due to the increased heat capacity.

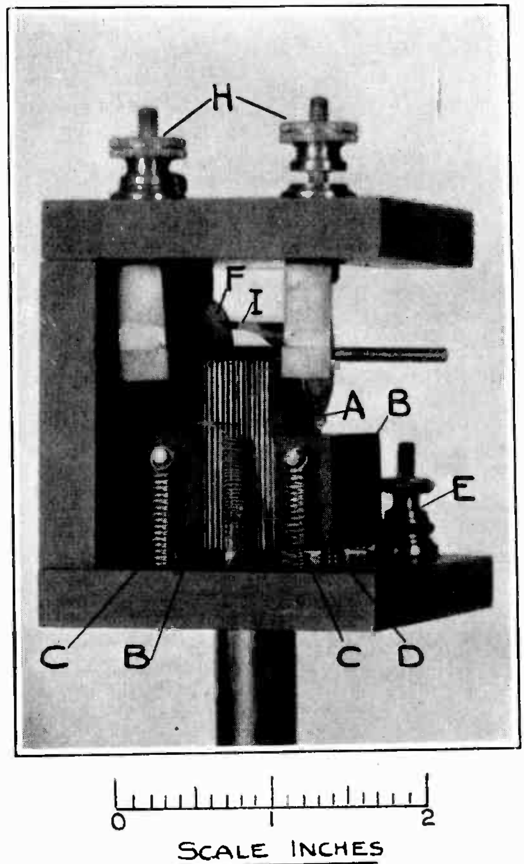


Fig. 3.

Design of Mounting.

Two different designs have been used at the National Physical Laboratory. The first is shown complete in Figure 1. The junctions are soldered, as shown in Figure 2a, to the tops of the copper stampings, shown in Figure 2b. These are stamped from hard copper sheet about 0.025in. thick. The bank of plates, separated by small fibre or ebonite insulating washers of about the same thickness, are clamped between ebonite end blocks, as in Figure 2c. These end blocks are screwed from underneath to the base

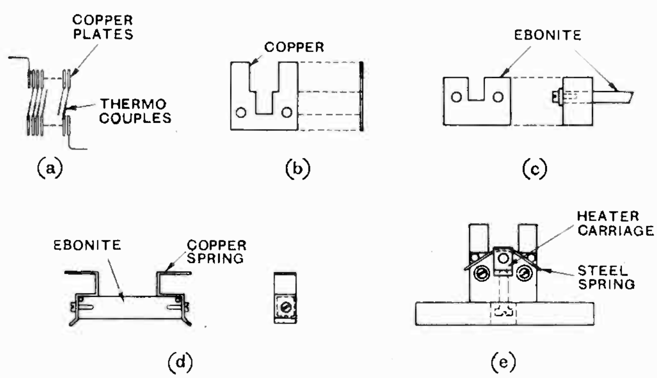


Fig. 2.

plate, which is also of ebonite. The carriage for the heater wire is shown in Figure 2d, the heater strip, about which more will be said later, being soldered to the upper surfaces of the hard copper springs, which keep it under a light tension. The heater can be passed under the junctions or over them. The latter is simpler for replacement. The carriage should fit smoothly in the grooves in the copper plates and the ebonite end blocks, and is located by means of the steel springs and the adjusting screws, as shown in Figure 2e, its height being capable of adjustment by means of the screws. In the actual models the carriage is made of

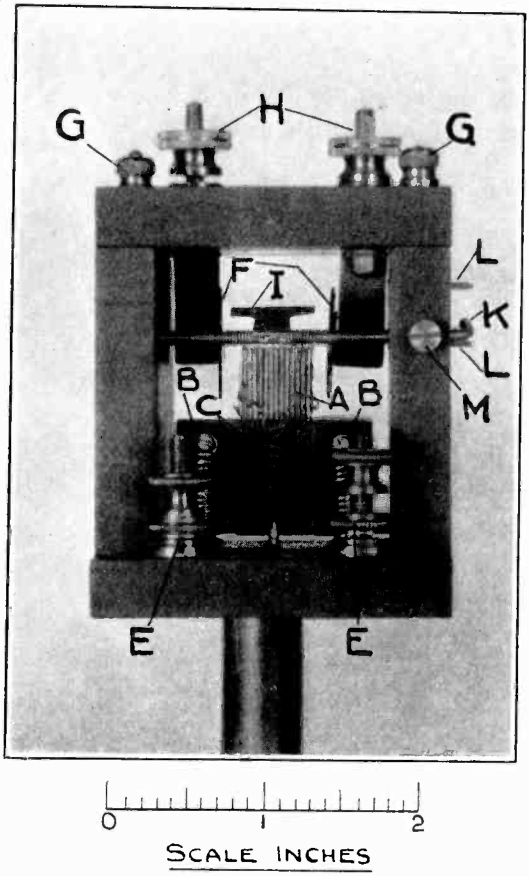


Fig. 4.

ebonite, but this is liable to slight deformation by the locating springs, and bakelite would be preferable from the point of view of mechanical strength. The cover shown is made of celluloid and is located in grooves in the base plate, being held down by two small screws through flanges cemented to the end walls.

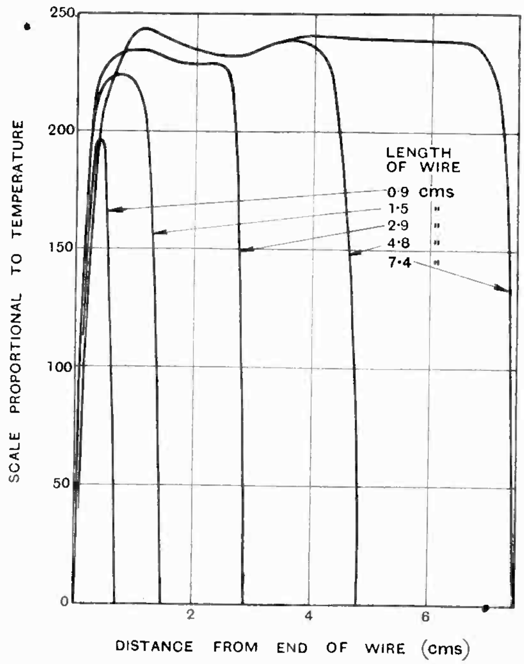


Fig. 5.—*Temperature variation along a wire carrying a current. No. 47 S.W.G. Eureka wire.*

Further design details relating to the heater strip will be found in a later section.

A second design is that shown in the photographs, Figures 3 and 4. Figure 4 shows the complete instrument and Figure 3 shows the instrument with one side of the cover removed. The junctions are soldered to copper stampings which are similar to those used in the former design but without the slot for the heater carriage. The stampings are clamped between ebonite blocks (B). These are held down to the base by means of springs (C) and supported on three screws being geometrically clamped on the cone, slot, and plane principle. One of the screws (D) can be seen in Figure 3. The thermo-junctions are connected to the terminals (E). The heater is held under a slight tension between two copper discs (F) to which it is soldered. These discs have sufficient cooling effect to permit of rapid terminal equilibrium under conditions of operation. The heater mounting and its terminals are carried by the ebonite lid, which is removable for replacement or adjustment. The distance of the heater from the junctions can be adjusted by means of the levelling screws (D). Glass windows on each side and a small mica window in the lid permit of easy inspection during adjustment.

It is often convenient to have some little degree of control over the calibration, so that a simple numerical relationship can be obtained. A very simple addition to the instrument permits of such control over a range of 10 per cent. or so. It consists of a small copper vane (I) the proximity of which to the heater can be controlled by means of the handle (K). Stops (L) prevent the possibility of damage to the heater or junctions. The vane can be clamped in position by the screw (M). This adjustment can be used if desired for correcting any small change in the calibration with time.

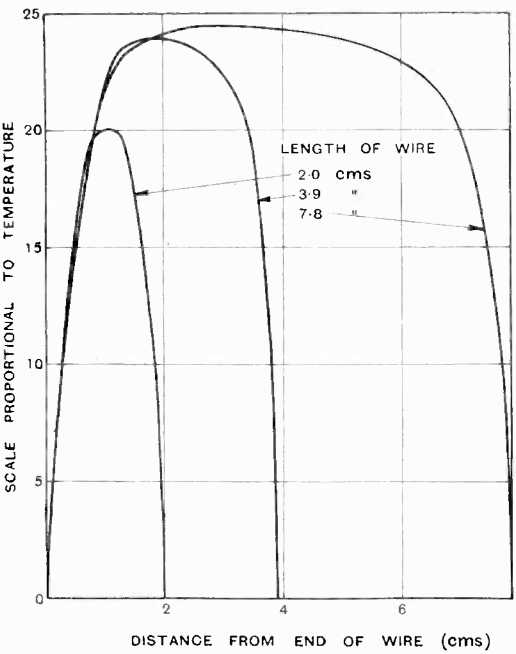


Fig. 6.—*Temperature variation along a wire carrying a current. No. 46 S.W.G. copper wire.*

This design is somewhat more compact and rigid than the other, though not quite so simple from a constructional point of view.

4. Design of Heater.

A first essential in the design of the heater element, if the instrument is intended for use at very high (radio) frequencies, is that it shall be of such a form that its resistance shall vary as little as possible with frequency.

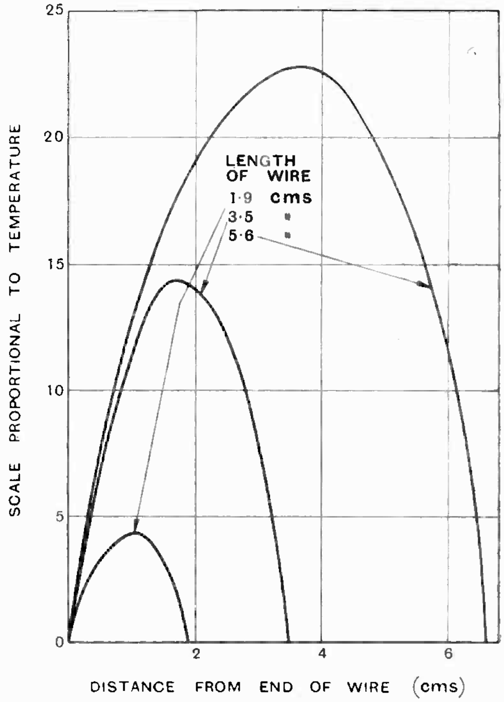


Fig. 7.—*Temperature variation along a wire carrying a current. No. 40 S.W.G. copper wire.*

This limits the heater to wires of small diameter, preferably not exceeding No. 40 gauge, or, better still, very thin strip (about 0.0005in. or so). The strip form is better in every respect.

High resistance material should be used, since this reduces the bulk of the heater for a given resistance. Another important reason why such material (*e.g.*, Eureka strip) should be used is that it will have a comparatively low heat conductivity. This restricts the flow of heat back to the heater-supports and thus enhances both sensitivity and stability of reading. This factor obviously imposes a lower limit on the length of the heater. The matter was investigated experimentally by traversing a single thermo-junction along the length of various heaters of different length and material at a constant height above the heaters and noting the thermal E.M.F. developed in the various positions. The ends of the heaters were clamped in sufficiently massive copper blocks to ensure constancy of temperature.

Results obtained for heaters of various lengths of No. 47 Eureka wire, No. 46 copper wire, and No. 40 copper wire are shown in Figures 5, 6, and 7. The superiority of the Eureka wire is obvious. Figure 7 further shows the loss of sensitivity which will be caused by end cooling if low resistance heaters of insufficient length are used. Even if No. 46 copper is used the length should not be less than 4 cms.

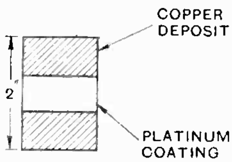


Fig. 8.

For heaters of very high resistance, platinised mica strip can be used. This is prepared by splitting the mica sheet to 0.0005 to 0.001in. in thickness and rubbing down with fine glass paper to give a matt surface. This is then platinised, using the colloidal preparation known commercially as "liquid silver." The thickness of coating can be varied within wide limits by means of successive thin coatings. The ends of the sheet can be electrically plated with copper to ensure good terminal contact (see Figure 8). The sheet can then be cut into strips of suitable width. Such heaters require a somewhat different mounting from those already described, some form of light copper clamp being substituted for the sheet copper soldering surfaces of the other mountings. Resistances varying from ten ohms to several thousands of ohms can be obtained in strips about $1\frac{1}{2}$in. by 1/16th in. in this manner.

No. 47 Eureka wire rolled of a strip 0.0005in. thick is the most generally useful heater, carrying currents up to 0.2 ampere. It burns out at about half an ampere. No. 47 copper similarly rolled to strip will carry about one ampere.

The designs described are not very suitable for the measurement of currents greater than an ampere, as the increasing bulk of the heater leads to loss of watt sensitivity and sluggishness in action.

5. Effect of Variation of Distance between Heater and Junctions.

The apparatus used for the determination of the end effect described in the preceding section was applied to an investigation of the variation of the thermal E.M.F. with the distance between the heater and the junctions. The curve shown in Figure 9 records the mean values of a large number of observations. The somewhat irregular variation for small distances was confirmed by repetitions. This irregular variation is probably attributable to the fact that heat transference to the junction is affected in at least two ways, *i.e.*, radiation and convection. (The thermo-junction was above the heater in these measurements.) The curve shows that for distances less than about 0.3 mm., the calibration will be rather sensitive to small variations of distance. From the point of view of stability of calibration it appears preferable to sacrifice some degree of sensitivity and adjust to a separation of half a millimetre or so, where the variation with distance is comparatively slow.

It can easily be shown that for such distances the heat transference by convection is negligible, for the thermal E.M.F. is only affected to a few per cent. by inverting the system.

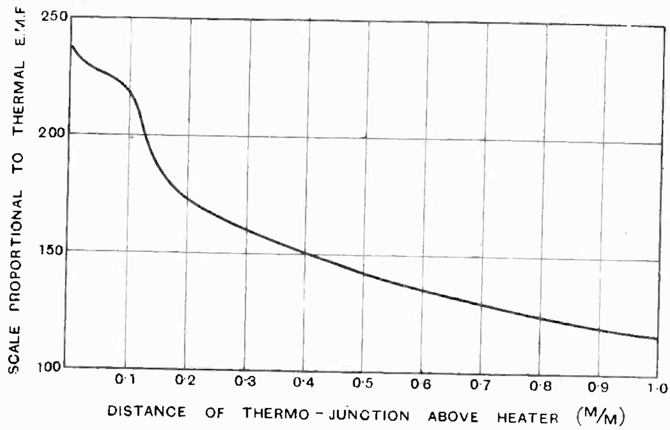


Fig. 9.—*Curve showing relation between the thermal E.M.F. produced in a copper-Eureka junction and its distance above a* 0.002 *in. diameter. Platinum wire carrying a constant current.*

6. Calibration.

The calibration with direct current shows that the instrument follows very approximately a square law. A typical calibration curve is given in Figure 10. Where absolute values are not required the square law assumption can be made with sufficient accuracy for most purposes. This is more particularly true for smaller values of heater

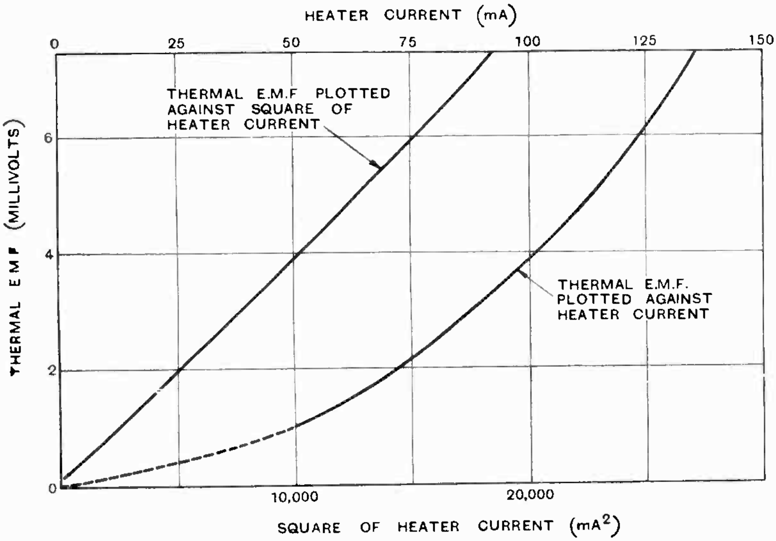


Fig. 10.—*Calibration curve for thermal ammeter.*

temperature. The instrument is, therefore, more accurately square law in association with a reflecting galvanometer than with a pointer galvanometer or milli-voltmeter. With junctions constructed as described the thermo-junction group will have a resistance of the order of ten to twenty ohms, and a measuring instrument having a resistance of this order should, therefore, be used with it.

The actual sensitivity varies from 10 to 20 milli-volts per watt consumed in the heater. As already pointed out, this is very low compared with that obtainable from a vacuum contact thermo-junction, which will generally be of the order of several hundred milli-volts per watt. However, sensitivity is not always a very important factor, and in many cases, particularly in experimental work, ease of repair and heater replacement will outweigh the drawback of low sensitivity.

7. Use as a source of known radio-frequency potential differences.

A particular application that has been made of the above described thermo-junction system is that illustrated diagrammatically in Figure 11. Leads of thin copper strip are soldered to the heater just outside the length that lies directly under the junctions. These are used as potential leads, giving a source of radio-frequency potential of from a tenth of a volt to about a volt. This arrangement has the advantage that the current is measured along the length of the actual resistance (the heater) which constitutes the source of potential difference, and thus eliminates any uncertainty due to a possible variation of the current in the other parts of the circuit.

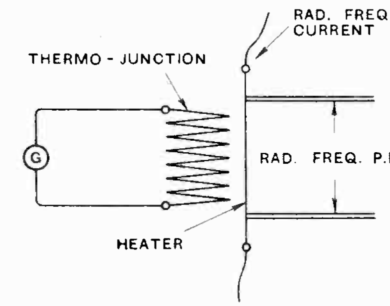


Fig. 11.—*Use of non-contact thermo-junction ammeter as a source of known potential difference at radio-frequencies.*

Effect of Anode-grid Capacity in Detectors and L.F. Amplifiers.

By W. B. Medlam, B.Sc., A.M.I.E.E.

In radio receivers the couplings between circuits which should be electrically separate make it almost impossible to predict exactly the performance of a complete receiver from a knowledge of the performance of its components. There are many sources of undesirable couplings, the most important of these are :

(1) The feed-back effect. This is the modification of the output circuit of a valve by the presence of the input circuit, due to anode-grid capacity.

(2) The input load effect. This is the modification of the input circuit of a valve by the presence of the output circuit, also due to anode-grid capacity.

(3) Direct inductive or capacity coupling between components.

(4) Couplings due to common leads in the wiring of the receiver.

(5) Resistance couplings due to the use of common batteries, or common mains units.

Considering the above effects in inverse order, (5) has become acute with the extended use of comparatively high resistance mains units, and moving coil speakers necessitating large outputs. The effect of this form of coupling can be eliminated by the use of anode feed resistances and condensers.* The effects of (4) have been dealt with recently in *The Wireless World*.† The elimination of effects due to (3) is a matter of the construction, disposition, and shielding of components. The effects of couplings (1) and (2) have been overcome in H.F. amplifiers by the use of the screened grid valve and neutrodyne circuits ; but their effects in the detector and L.F. amplifying stages have received very little quantitative attention, and circuits designed to cut them out do not appear to have been developed. In the present article the effects of the anode-grid capacity on the audio frequency characteristic of the detector and L.F. stages are shown to be serious, and suggestions are made for their elimination.

Effect of Anode-Grid Capacity in Detector Stage.

Equivalent Circuit of Detector.—From the point of view of the input voltage, the input circuit of a curvature detector is equivalent to the arrangement of Fig. 1. An input E.M.F., e, is injected into the original input circuit C, L, r. When this circuit is attached to the valve it is modified by the connection of the anode-grid capacity, C_{ga} ; the internal resistance of the valve, r_a ; a capacity, C_a between anode and filament ; a shunt capacity which becomes a part of C, and a resistance due to this capacity, the effect of which may be included in r. The radio frequency load in the anode circuit of a detector is always capacitative, the impedance of C_a being much less than that of the external load resistance or inductance at the radio frequency ; also, in general, the reactance of C_a is much smaller than r_a. Thus, except for a detuning effect, which can be corrected by adjustment of C, the capacity C_{ga} leads to but slight resistance loading of the input.

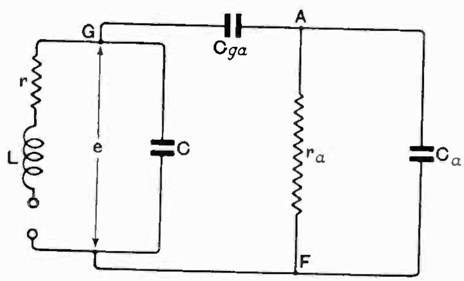


Fig. 1.—*Equivalent input circuit of detector as modified by anode-grid capacity.*

The position as regards the feed-back effect is, however, much more serious. As the three electrode valve is not a perfect

* "Low-frequency Oscillation," *The Wireless World*, January 4th, 1928.

† "Scientific Wiring," April 25th, 1928.

rectifier there will be a radio frequency E.M.F. (μe_g) in the anode circuit when a voltage (e_g) is applied to the grid. The value of μ is, of course, quite different from the normal value for the valve under amplifying conditions. Experimental results indicated a value of μ between 0.1 and 0.2 for an anode bend rectifier adjusted for optimum rectification with a high resistance as external anode load.* Although the radio frequency E.M.F. in the anode circuit may be considerably less than that applied to the grid it has, nevertheless, a relatively large effect on the audio frequency characteristic of the detector, particularly on the lower audio frequencies, as is shown later. If the grid bias or H.T. are considerably below their values for maximum efficiency of rectification,

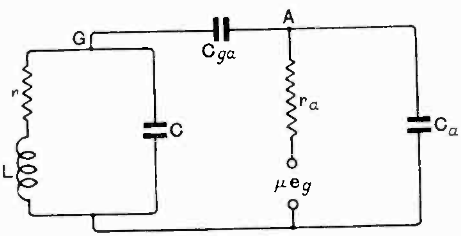


Fig. 2.—*Equivalent output circuit of detector as modified by anode-grid capacity.*

so that the valve begins to amplify, then owing to the consequent increase in μ, it may be impossible for the valve to give any reasonable output on the lowest audio frequencies, and the effective modulation in the resultant input may rise to 100 per cent. with quite low modulations (say below 20 per cent.) in the original input to the valve. The full reasons for this are rather complex, and before dealing with the action mathematically, they may be stated, roughly, as follows: The equivalent circuit of the detector for the E.M.F. μe_g is shown in Fig. 2. As before, the external anode circuit load is omitted as it has negligible effect on the radio frequency current distribution. The circuit in Fig. 2 for μe_g is quite different from that in Fig. 1 for the input voltage e owing to the different location of the E.M.F. In Fig. 2 the E.M.F. μe_g sets up a voltage across the input circuit in partial anti-phase to the signal voltage. The magnitude (and phase) of this feed-back voltage depends on the impedance of the input circuit in relation to the reactance of C_{ga}. On the frequency to which the input circuit is tuned, say to the carrier frequency, its impedance is much larger than the reactance of C_{ga}, and a large share of the feed-back voltage falls across it, leading to the maximum drop in the input. On the side band frequencies more remote from the carrier the impedance of an input circuit of reasonable efficiency falls to a value which is not large compared with the reactance of C_{ga}, and the feed-back voltage across the input circuit is less. Thus, the input is maintained at a higher value on the side bands than on the carrier, leading to an increase in the effective modulation.

* "The Performance of Valve Detectors," Medlam and Oschwald, Journal I.W.T., Vol. 1, No. 4.

Tuning Conditions.—With the input circuit connected to the valve and the filament off to cut out the action of μe_g, the tuning capacity for the input voltage e is C (which includes the grid-filament capacity of the valve) plus the capacities C_{ga} and C_a in series. That is, the input circuit tunes to the input voltage with a capacity $C + C_x$ in which

$$C_x = C_{ga} . C_a / (C_{ga} + C_a) \quad \ldots \quad (1)$$

If the valve filament is now switched on the input circuit is distuned to the anode circuit E.M.F., μe_g, although it remains tuned to the input voltage, e. The impedance of the input circuit to μe_g is that given with a tuning capacity C only—a capacity less than that required for resonance. That is, the input circuit behaves as an inductive reactance to μe_g when the frequency of μe_g (and e) is that giving resonance to the input voltage. Suppose this frequency to be that of the carrier. Then on a neighbouring side band it is possible for the input circuit C, L, r. to resonate for μe_g and offer its maximum impedance to this voltage, and at the same time to be distuned to the input voltage e. On this frequency the effective input will rise or fall depending on the phase of the feed-back voltage. Evidently this parallel resonance condition can only occur on an upper side band.

There is another critical condition operative only on a lower side band. On a certain side band frequency the condition for series resonance of the input circuit with C_{ga} will occur for μe_g, again throwing a large feed-back voltage across the input. The tuning condition for this is

$$\omega^2(C + C_{ga})\,L = 1 \qquad \ldots \quad (2)$$

As the capacity $C + C_{ga}$ is slightly greater than the input carrier tuning capacity $C + C_x$, series resonance can only occur when the frequency is below the carrier frequency, *i.e.*, on a *lower* side band.

To determine exactly where these two critical conditions occur, let the carrier frequency be $\omega_c/2\pi$, and the modulation frequency $m/2\pi$. Then, for parallel resonance with μe_g on an upper side band

$$\omega_c^2\,(C + C_x)\,L = (\omega_c + m)^2 CL \qquad \ldots \quad (3)$$

assuming the input circuit resonates on ω_c to e.

Thus $$C + C_x = (1 + m/\omega_c)^2 C \qquad \ldots \quad (4)$$

As m/ω_c is small compared with unity $(1 + m/\omega_c)^2$ is very nearly equal to $1 + 2m/\omega_c$,

and $$m/\omega_c = C_x/2C \qquad \ldots \quad \ldots \quad (5)$$

If N is the audio frequency, and n the radio frequency (carrier), equation (5) may be written

as $$N/n = C_x/2C \qquad \ldots \quad \ldots \quad (6)$$

Substitution of average numerical values in the last equation shows that parallel resonance can occur on Broadcast frequencies only when C is comparatively large. For example, if $n = 800$ kilocycles, $N = 8{,}000$ cycles, $C_{ga} = 5\mu\mu F$, $C_a = 100\mu\mu F$, then $C_x = 4.8\mu\mu F$, and the value of C is $240\mu\mu F$. For values of C less than that given by equation (6) the input circuit C, L, r, behaves (towards μe_g) as an inductance reactance to the whole side band range.

For series resonance with C_{ga} on a lower side band of frequency $(\omega_c - m)/2\pi$ the condition is

$$\omega_c^2(C + C_x)\,L = \omega_c^2(1 - m/\omega_c)^2(C + C_{ga})\,L, \qquad \ldots \quad (7)$$

i.e., $$m/\omega_c (= N/n) = C^2_{ga}/2(C + C_{ga})(C_a + C_{ga}) \qquad \ldots \quad (8)$$

Substitution of average numerical values shows that the critical value of the audio frequency given by (8) is comparatively low. For example, on a carrier of 800 kilocycles, with $C_{ga} = 5\mu\mu F$ and $C = C_a = 100\mu\mu F.$, the value of $N = 900$ cycles. On the lower side band corresponding to this audio frequency a resonant rise of the feed-back voltage occurs across the input circuit. The precise effect of this depends upon the phase of the voltage.

Resultant input under Feed-back Conditions.—Assuming the value of C to be less than that required for parallel resonance to occur within the normal side band region, the input circuit may be represented by an equivalent inductance of value L_e, so far as μe_g is concerned, and the equivalent circuit is as shown in Fig. 3, in which e_r is the instantaneous value of the feed-back voltage across the input. If the original input between grid and filament is

$$e = E \sin \omega t, \qquad \ldots \quad \ldots \quad (9)$$

where $$\omega = \omega_c \pm m, \qquad \ldots \quad \ldots \quad (10)$$

the upper (in this case the positive) sign being taken for the upper side band, and the lower sign for the lower one, the resultant voltage between grid and filament at any instant is given by

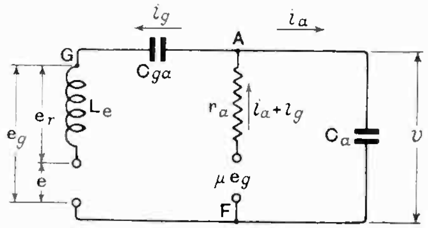


Fig. 3.—*Equivalent output circuit of detector when the input circuit is tuned to the original input voltage.*

$$e_g = e - e_r \qquad \ldots \quad \ldots \quad (11)$$

It is assumed that the anode circuit E.M.F. (μe_g) at any instant during the final steady state is always μ times the resultant grid voltage (e_g) existing at the same instant.

The circuit equations for μe_g are

$$\frac{dv}{dt} = \frac{i_a}{C_a} = \frac{i_g}{C_{ga}} + L_e\frac{d^2 i_g}{dt^2} = \mu\frac{de_g}{dt} - r_a\left(\frac{di_a}{dt} + \frac{di_g}{dt}\right) \quad (12)$$

After eliminating i_a from the above equations, the following results :—

$$C_a L_e r_a \frac{d^3 i_g}{dt^3} + L_e \frac{d^2 i_g}{dt^2} + r_a\left(1 + \frac{C_a}{C_{ga}}\right)\frac{di_g}{dt} + \frac{i_g}{C_{ga}} = \mu\frac{de_g}{dt} \quad \ldots \quad (13)$$

The feed-back voltage

$$e_r = \omega L_e i_g \,. \qquad \ldots \quad \ldots \quad \ldots \quad (14)$$

Eliminating i_g from (13) by means of (14) gives

$$\frac{r_a C_a}{\omega}\frac{d^3 e_r}{dt^3} + \frac{1}{\omega}\frac{d^2 e_r}{dt^2} + \frac{r_a}{\omega L_e}\left(1 + \frac{C_a}{C_{ga}}\right)\frac{de_r}{dt} + \frac{e_r}{\omega C_r L_e} = \mu\frac{de_g}{dt} \quad \ldots \quad (15)$$

But from (9) and (11) the resultant grid voltage is given by

$$e_g = -e_r + E \sin \omega t \quad \ldots \quad (16)$$

Eliminating e_r from (15) by means of (16) gives, after rearrangement of terms,

$$\frac{r_a C_a}{\omega}\frac{d^3 e_g}{dt^3} + \frac{1}{\omega}\frac{d^2 e_g}{dt^2} + \left[\frac{r_a}{\omega L_e}\left(1 + \frac{C_a}{C_{ga}}\right) + \mu\right]\frac{de_g}{dt}$$
$$+ \frac{e_g}{\omega C_{ga} L_e} = E\left(\frac{1}{\omega C_{ga} L_e} - \omega\right) \sin \omega t$$
$$+ E\left\{\frac{r_a \omega\left(1 + \frac{C_a}{C_{ga}}\right)}{\omega L_e} - \omega^2 C_a r_a\right\} \cos \omega t \quad (17)$$

The steady state solution for e_g is

$$e_g = E\sqrt{\frac{k_1^2 + k_2^2}{k_1^2 + (\mu + k_2)^2}} \sin\left[\omega t - \omega t \tan^{-1}\frac{k_2}{k_1} - \tan^{-1}\frac{\mu + k_2}{k_1}\right], \ldots \quad (18)$$

in which $k_1 = \frac{1}{\omega^2 C_{ga} L_e} - 1, \quad \ldots \quad (19)$

and $k_2 = \frac{r_a}{\omega L_e}\left(\frac{C_a}{C_{ga}} - 1\right) - \omega C_a r_a. \quad \ldots \quad (20)$

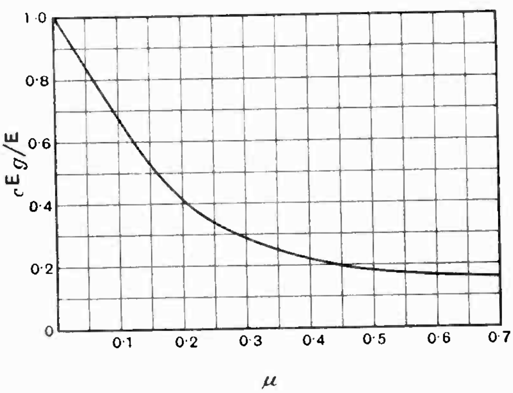


Fig. 4.—*Relation between μ of detector and the ratio of resultant to original input voltage on the carrier frequency, showing the effect of feed-back.*

The equivalent inductance, L_e, has now to be evaluated.

To μe_g the impedance of the input circuit C, L, r, when untuned is given by

$$Z = \omega L \Big/ \omega C\sqrt{r^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}, \quad \ldots \quad (21)$$

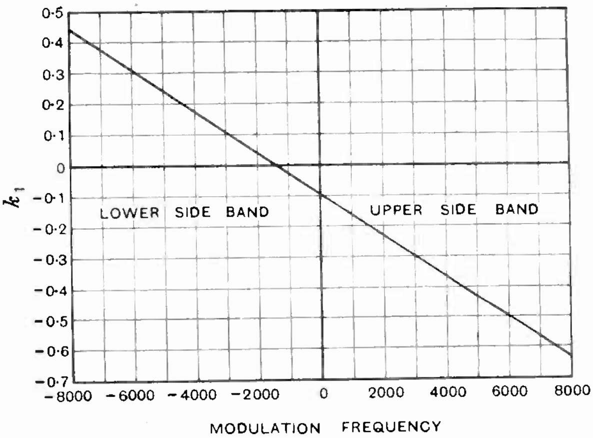


Fig. 5.—*Relation between k_1 and modulation frequency.*

when $r^2 << \omega^2 L^2$; or, replacing ω by $\omega_c(1 \pm m/\omega_c)$, and dividing through by $1 \pm m/\omega_c$, gives

$$Z = \omega_c L \Big/ \sqrt{\left(\omega_c C r\right)^2 + \left\{\left(1 \mp \frac{m}{\omega_c}\right) - \left(1 \pm \frac{m}{\omega_c}\right)\omega_c^2 CL\right\}^2} \quad \ldots \quad (22)$$

If the input is tuned to the carrier frequency $(\omega_c/2\pi)$ for the original input e, this condition, from (1), is

$$\omega_c^2(C + C_x)\,L = 1 \quad \ldots \quad \ldots \quad (23)$$

Eliminating C between (23) and (22) gives

$$Z = \omega_c L \Big/ \sqrt{\left[\mp 2\frac{m}{\omega_c} + \left(1 \pm \frac{m}{\omega_c}\right)\omega_c^2 C_x L\right]^2 + \frac{r^2}{\omega_c^2 L^2}\left(1 - \omega_c^2 C_x L\right)^2} \quad \ldots \quad (24)$$

In general the effect of the resistance term $r^2(1 - \omega_c^2 C_x L)^2/\omega_c^2 L^2$ may be neglected, as $\omega_c^2 C_x L$ is always appreciable owing to the initial assumption that parallel resonance does not occur. In this case the equivalent inductance of the circuit is given by

$$L_e = L \Big/ \left[\mp 2\frac{m}{\omega_c} + \left(1 \pm \frac{m}{\omega_c}\right)\omega_c^2 C_x L\right]. \quad (25)$$

Substituting the value of L_e from (25) in (19) and (20), the value of k_1 becomes approximately

$$k_1 = \mp \frac{2\,N/n}{\omega_c^2 C_{ga} L} - \frac{C_{ga}}{C_{ga} + C_a}, \quad \ldots (26)$$

and, very closely,

$$k_2 = \mp 2\frac{N}{n} \cdot \frac{r_a}{\omega_c L}\left(1 + \frac{C_a}{C_{ga}}\right). \quad \ldots (27)$$

The above values of k_1 and k_2 inserted in equation (18) give the amplitude and phase of the resultant grid voltage on any side band frequency. To avoid confusion over the double sign in (26) and (27) the values may be restated as follows:

For the carrier frequency:

$$k_1 = -C_{ga}/(C_{ga} + C_a), \quad \ldots (28)$$

and

$$k_2 = 0. \quad \ldots \quad \ldots \quad \ldots (29)$$

For all upper side bands corresponding to a modulation frequency N,

$$k_1 = -\frac{2N/n}{\omega_c^2 C_{ga} L} - \frac{C_{ga}}{C_{ga} + C'} \quad (30)$$

and

$$k_2 = -2\frac{N}{n} \cdot \frac{r_a}{\omega_c L}\left(1 + \frac{C_a}{C_{ga}}\right). \quad \ldots (31)$$

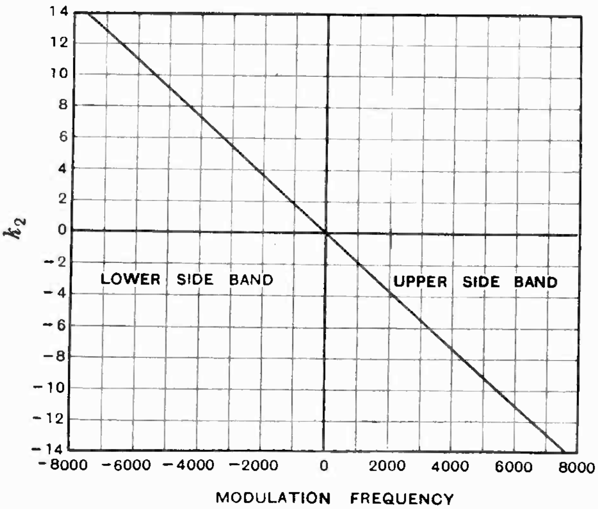


Fig. 6.—*Relation between k_2 and modulation frequency.*

For all lower side bands corresponding to a modulation frequency N,

$$k_1 = \frac{2N/n}{\omega_c^2 C_{ga} L} - \frac{C_{ga}}{C_{ga} + C'} \quad \ldots (32)$$

and

$$k_2 = 2\frac{N}{n} \cdot \frac{r_a}{\omega_c L}\left(1 + \frac{C_a}{C_{ag}}\right) \quad \ldots (33)$$

Numerical Example.

To show the order of magnitude of the

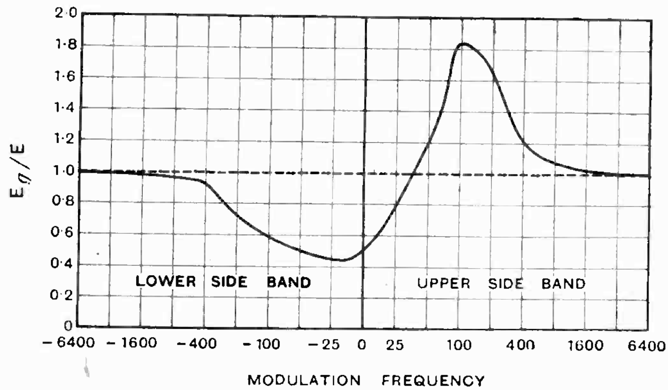


Fig. 7.—*Relation between modulation frequency and the ratio of resultant to original input voltage to a detector, showing the effect of feed-back.*

interference of the feed-back action on the audio frequency characteristic of the detector a numerical example will be worked out, taking average values applicable to Broadcast receivers. Let $C_{ga} = 5\mu\mu F.$, $C_a = 50\mu\mu F.$, $\omega_c L = 1{,}500$ ohms, $\omega_c = 5 \times 10^6$, corresponding to a wavelength of 375 metres, and radio frequency $n = 800$ kilocycles. For an audio frequency modulation $N = 8{,}000$ cycles, $n/N = .01$, and the value of k_1 is -0.624 for the upper side band, 0.442 for the lower side band, and -0.091 for the carrier.

To determine the value of k_2 an average value of r_a must be assumed. Under the conditions of operation here considered r_a will be much greater than the nominal value for the valve, and a value $r_a = 100{,}000$ ohms will be taken. The substitution of other values for r_a will show that the results are very little affected indeed by large changes in r_a. From (31), (33) and (29), the value of k_2 is -14.7 for the upper side band, 14.7 for the lower side band, and zero for the carrier.

Amplitude of Resultant Grid Voltage.—From (18) the amplitude of the resultant grid voltage is

$$E_g = E\sqrt{\frac{k_1^2 + k_1^2}{k_1^2 + (\mu + k_2)^2}} \quad .. \ (34)$$

Substituting the numerical values of k_1 and k_2 in (34) gives the resultant amplitude of the upper side band

$${}_uE_g = E\sqrt{\frac{0.39 + (14.7)^2}{0.39 + (\mu - 14.7)^2}}, \ (35)$$

of the lower side band

$${}_lE_g = E\sqrt{\frac{0.19 + (14.7)^2}{0.19 + (\mu + 14.7)^2}}, \ (36)$$

and of the carrier

$${}_cE_g = .091E/\sqrt{.00083 + \mu^2}. \ .. \ (37)$$

Effect of μ on Voltage Amplitude of Side Bands.—The form of the numerical results given above shows that when μ is less than unity the extreme side band voltages are each practically equal to the corresponding input voltage amplitude of the original input, *i.e.*, approximately,

$${}_uE_g = {}_lE_g = E,$$

and the input is unaffected by the feed-back action so far as amplitude is concerned, but there is a large phase shift of the resultant input, as is shown later.

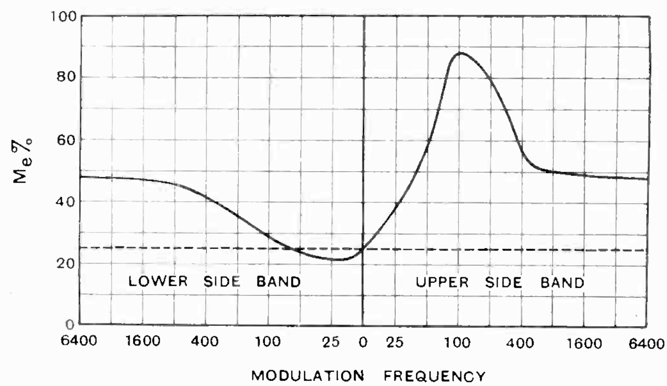


Fig. 8.—*Variation, due to feed-back, of effective modulation in resultant input to a detector (for a constant original input modulation of 25 per cent.) with the modulation frequency.*

If the detector is badly adjusted so that the value of μ is very considerably increased, the resultant grid voltage tends to increase on the extreme upper side band and to decrease on the extreme lower one.

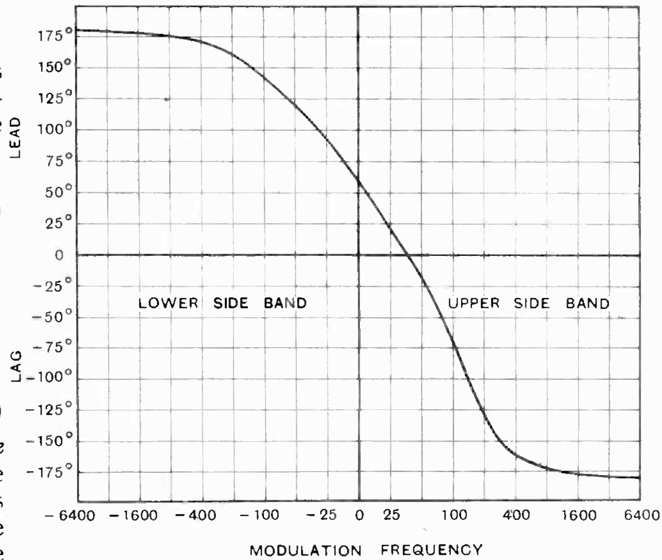


Fig. 9.—*Phase shift, due to feed-back, of side band frequencies in a detector.*

On the carrier frequency the relation between μ and the ratio ${}_cE_g/E$ is shown graphically in Fig. 4. Taking an average value of $\mu = 0.15$, the feed-back reduces the input to about 50 per cent.

Audio Frequency Characteristic. — The numerical relations between k_1 and k_2, and the modulation frequency (N), are given in Figs. 5 and 6 respectively. The values of k_1 and k_2 were calculated using the same numerical values of capacity, inductance, and carrier frequency, as stated above, and with $\mu = 0.15$.

The corresponding relation between E_g/E and N is shown in Fig. 7. For frequencies above $\pm$ 500 cycles the curve becomes asymptotic to the horizontal line for which E_g/E is unity. The same curve may be taken to represent the audio frequency characteristic of the detector assuming the characteristic to be level in the absence of C_{ga}. The characteristic does not settle down until the audio frequency exceeds about 1,000 cycles, and the two side bands corresponding to any given modulation frequency below 1,000 cycles are unequal; they may be in any ratio up to 3 to 1 in this particular case.

If the value of C_a is reduced the disturbance of the input extends to higher audio frequencies than in the above numerical case where $C_a = 100\mu\mu F$.

Effective Modulation in Grid Voltage.—As the feed-back affects the carrier and side band voltages in different degree, the effective modulation in the resultant input to the grid of the valve is altered from its value in the original input. If M is the original modulation, the effective modulation is given by

$$M_e = M\sqrt{\frac{\left\{1+\mu^2\left(1+\frac{C_a}{C_{ga}}\right)\right\}^2(k_1^2+k_2^2)}{k_1^2+(\mu+k_2)^2}} \quad (38)$$

Taking the same average numerical values as before, the variation of the effective

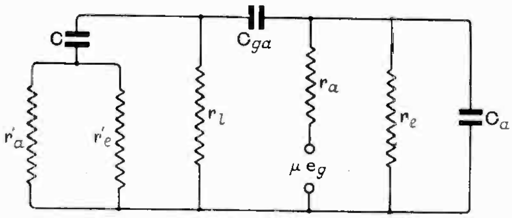


Fig. 10.—*Equivalent output circuit of R–C amplifier as modified by feed-back.*

modulation with the modulation frequency is shown in Fig. 8, assuming a constant original input modulation of 25 per cent.

On side bands more than about 800 cycles from the carrier M_e is practically constant at about 50 per cent., *i.e.*, *at double the input modulation*; on side bands closer to the carrier M_e varies from 24 per cent. to about 90 per cent.

These results indicate the very important effect the feed-back action may have in causing distortion on deep input modulations, especially in the region of particular modulation frequencies.

Really, the frequency characteristic of a detector is unstable below about 1,000 cycles, as the slightest change in the various capacity values produces disproportionate changes in the effective modulation.

Phases of Side Band Voltages.—The resultant grid voltage lags behind the original input voltage by an angle

$$\tan^{-1} k_2/k_1 + \tan^{-1} (\mu + k_2)k_1.$$

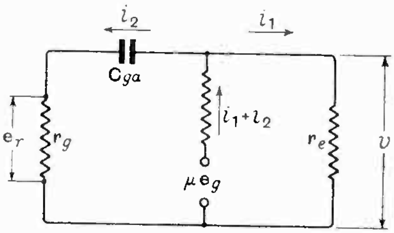


Fig. 11.—*The circuit of* Fig. 10 *simplified.*

Values of this phase displacement of the modulation frequencies, for the circuit values already stated, are shown in Fig. 9.

Feed-back in L.F. Amplifier.

As regards the anode circuit E.M.F., the equivalent circuit of a resistance-capacity coupled amplifier is as shown in Fig. 10, in which r_e is the external resistance in the anode circuit, shunted by a small stray capacity C_a; r_a is the internal resistance of the valve; C_{ga} the anode-grid capacity, and r_l the resistance of the grid leak. As the coupling capacity, C, to the preceding stage has a comparatively low reactance to the audio frequency, it is necessary to include the internal resistance, r'_a, and the external

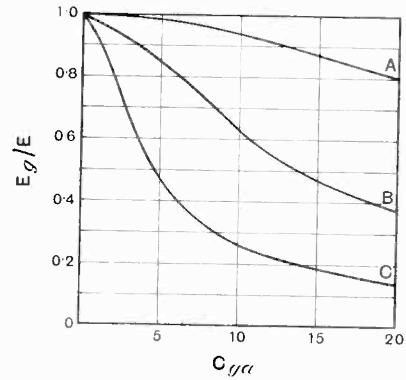


Fig. 12.—*Variation with anode-grid capacity of the ratio of resultant to original input voltage, for first and subsequent stages of R–C amplification.*

resistance r'_e, of the preceding stage as a part of the input circuit of the stage under consideration. In fact, as r'_a will be, in general, much less than r_e or r'_e, the effective input resistance, for the E.M.F. μe_g, will be about equal to the internal resistance of the valve in the preceding stage.

In the following analysis the small effect of the stray capacity, C_a, on the anode potential will be neglected, and C will be assumed to be sufficiently large for its reactance to be negligible on the higher audio frequencies. Then, taking the resultant of the three parallel resistances r'_a, r'_e, r_l as the effective input resistance r_g, the circuit reduces to that shown in Fig. 11.

The circuit equations for μe_g are

$$v = r_e i_1 = \mu e_g - r_a (i_1 + i_2) = r_g i_2 + \frac{1}{C_{ga}} \int i_2 dt.$$

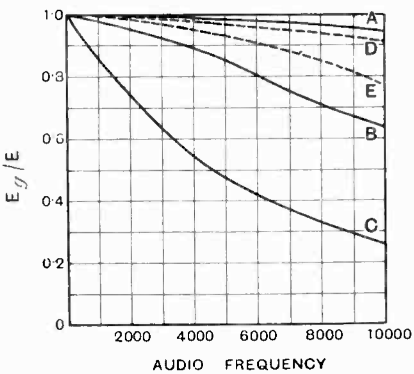


Fig. 13.—*Variation with audio-frequency of the ratio of resultant to original input voltage, for first and subsequent stages of R–C amplification.*

Eliminating i_1 from the above equations, and differentiating,

$$\left(r_g + \frac{r_a r_e}{r_a + r_e}\right)\frac{di_2}{dt} + \frac{i_2}{C_{ga}} = \frac{\mu r_e}{r_a + r_e}\frac{de_g}{dt} \quad \ldots (39)$$

The feed-back voltage between grid and filament

$$e_r = r_g i_2 \quad \ldots \quad \ldots \quad \ldots (40)$$

Eliminating i_2 between (40) and (39) gives

$$\left\{1 + \frac{r_a r_e}{r_g(r_a + r_e)}\right\}\frac{de_r}{dt} + \frac{e_r}{C_{ga} r_g} = \frac{\mu r_e}{r_a + r_e}\frac{de_g}{dt} \cdot (41)$$

If the original signal voltage between grid and filament is

$$e = E \sin \omega t, \quad \ldots \quad \ldots \quad \ldots (42)$$

then the resultant input voltage (e_g) is given by

$$e_g = - e_r + E \sin \omega t \quad \ldots \quad \ldots (43)$$

Eliminating e_r between (43) and (41), and writing A for $r_g + \dfrac{r_a r_e}{r_a + r_e}$, gives

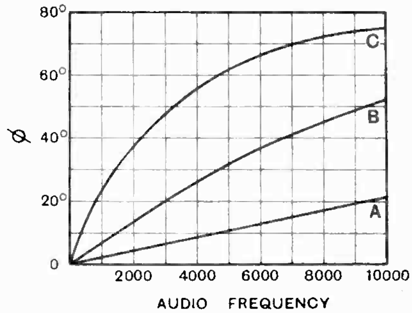


Fig. 14.—Relation between the audio frequency and the phase shift of the resultant input voltage for a R–C amplifier.

$$\left(A + \frac{\mu r_g r_e}{r_a + r_e}\right)\frac{de_g}{dt} + \frac{e_g}{C_{ga}} = \frac{E}{C_{ga}} \sin \omega t$$

$$+ A\omega E \cos \omega t = E\sqrt{\frac{1}{C^2_{ga}} + \omega^2 A^2} \sin\left(\omega t\right.$$

$$\left. + \tan^{-1} A\omega C_{ga}\right) \ldots \quad \ldots (44)$$

The solution of (44) for e_g is

$$e_g = E\sqrt{\frac{\dfrac{1}{\omega^2 C^2_{ga}} + A^2}{\dfrac{1}{\omega^2 C^2_{ga}} + \left(A + \dfrac{\mu r_g r_e}{r_a + r_e}\right)^2}}.$$

$$\sin\left\{\omega t + \tan^{-1} A\omega C_{ga} - \tan^{-1}\omega C_{ga}\left(A + \frac{\mu r_g r_e}{r_a + r_e}\right)\right\}. \quad \ldots \quad \ldots (45)$$

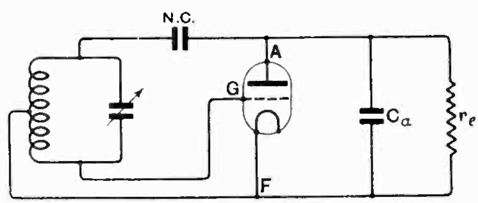


Fig. 15.—*Detector with neutrodyned input circuit to eliminate the feed-back and input load effects of anode-grid capacity.*

Inserting the value of A in (45), and writing

pr_a for r_e, and qr_a for r_g, the amplitude of the resultant grid voltage is

$$E_g = E\sqrt{\frac{\frac{1}{\omega^2 C^2_{ga}} + \left(q + \frac{p}{p+1}\right)^2 r_a^2}{\frac{1}{\omega^2 C^2_{ga}} + \left\{q + \frac{p}{p+1}\cdot(1+\mu q)\right\}^2 r_a^2}} \quad \ldots \quad (46)$$

When r_e is much greater than r_a, so that $p/(p+1)$ can be taken as unity, and μ is large compared with unity, then approximately

$$E_g = \frac{E}{\sqrt{1 + \mu^2 r_g^2 \omega^2 C^2_{ga}}} \quad \ldots \quad (47)$$

If the amplifying stage under consideration is the second of two similar stages, r_g, will be about equal to r_a. If the stage immediately follows the detector, r_g, will be considerably greater owing to the high average internal resistance of the detector, and will be different for the two halves of the voltage wave. This difference will cause the production of even harmonics in the resultant grid voltage of the amplifier, and in μe_g.

To give an idea as to the order of magnitude of the effect of the feed-back on the amplitude of the input an average numerical case will be considered. As the feed-back

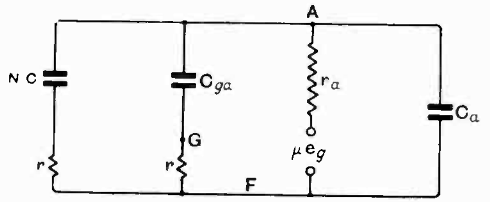


Fig. 16.—*Equivalent output circuit of neutrodyned detector.*

is only appreciable at the higher audio frequencies, the effect at 10,000 cycles will be considered. Let $r_a = 20{,}000$ ohms, and $\mu = 30$ for the amplifying valve. If the preceding stage is similar, r_g may be taken as 20,000. The relation between E_g/E and C_{ga} is given by curve A in Fig. 12.

If the preceding stage is the detector, it may be assumed that during the positive half cycle the average value of the internal resistance (r'_a) is 100,000 ohms. Taking the detector external resistance (r'_e) = 250,000, and the amplifier leak resistance as 1 megohm, gives an effective input resistance $r_g = 66{,}700$ ohms. The corresponding relation between E_g/E and C_{ga} is given by curve B, Fig. 12.

For the negative half cycle of the same stage it may be assumed that r'_a is high compared with the external resistance and leak in parallel. Thus r_g will be about 200,000 ohms.

The corresponding relation between E_g/E and C_{ga} is shown by Curve C, Fig. 12.

In all cases the effect of the feed-back is to reduce the input. The reduction is not serious with the second L.F. stage (curve A), even at 10,000 cycles, if the anode-grid capacity does not exceed $10\mu\mu F$. The effect

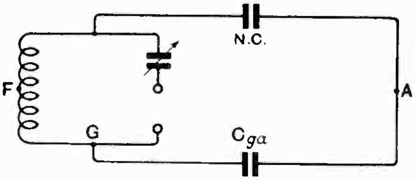


Fig. 17.—*Equivalent input circuit of neutrodyned detector.*

is more serious in the first L.F. stage, and the large difference between curves B and C indicates the probability of considerable wave form distortion—the resultant grid voltage amplitude in the positive direction is nearly twice the negative amplitude with $C_{ga} = 5\mu\mu F$.

The effect of feed-back on the audio frequency characteristic is shown in Fig. 13 for a constant value of C_{ga} $10\mu\mu F$. The curves A, B, and C, refer to the same conditions, respectively, as the curves in Fig. 12.

Frequency curves for other values of C_{ga} may be easily deduced from the curves in Fig. 13 by a change in the frequency scale. If C_{ga} has any value $10x\mu\mu F$., the same curves will apply if the frequency scale is divided by x. Thus, if $C_{ga} = 5\mu\mu F$., then $x = 0.5$, and the frequency scale must be multiplied by 2.

In order to improve the performance of the first L.F. amplifying stage (represented by curves B and C, Fig. 13) it is evident from equation (47) that $\mu r_g \omega C_{ga}$ must be reduced to make the characteristics more level, and also the values of r_g for the positive and negative half cycles must be made more nearly equal to reduce wave form distortion.

The latter condition can be partially met by inserting a high resistance—say 100,000 ohms—between the grid leak and grid of the amplifying valve; but unfortunately, this increases the effective input resistance (r_g) for both half cycles and makes the characteristic less level than before. In other words, the effect of the series grid resistance is only to lower B (Fig. 13) more than C at the upper frequencies. As both curves B and C require raising at these frequencies, the series grid resistance has, on the whole, a harmful rather than a beneficial effect.

Alternatively, as ω and C_{ga} are outside control, the value of μ for the first L.F. valve may be reduced, and the leak resistance and external resistance in the anode circuit of the detector may be lowered. All these changes have the desired effect of raising both characteristics, and of raising C more than B. Suppose μ is reduced to 16, r'_e to 100,000 ohms, and r to 0.5 megohm. Then, for the positive half cycle, taking r'_a as 100,000 ohms as before, $r_g = 45{,}600$ ohms. For the reverse half-cycle $r_g = 83{,}300$ ohms (*i.e.*, the joint resistance of r'_e and r in parallel). The audio frequency characteristics for these new values, and $C_{ga} = 10\mu\mu F.$, are shown by the dotted curves D and E in Fig. 13. The improvement in the characteristic is obtained only, as usual, at the expense of signal strength which, in the case considered above, would be reduced to about a quarter of its original value.

However, the entire effect of the feed-back may be overcome, without loss of signal strength, by the adoption of a neutrodyned push-pull system, as shown later.

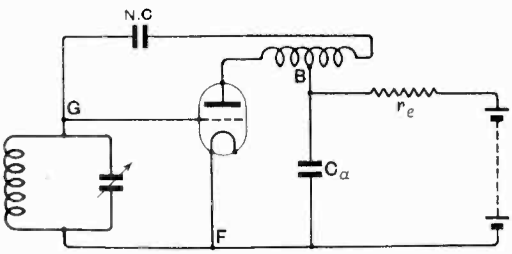


Fig. 18.—*Illustrating an ineffective anode circuit neutrodyne. Potential variations at B are fed back to the grid.*

Phase Shift of Audio Frequencies.—From equation (45) the angle of lag of the resultant grid voltage behind the original input voltage is given by

$$\phi = \tan^{-1} \omega C_{ga} r_a \left[\left(q + \frac{p}{p+1} \right) + \frac{\mu p q}{p+1} \right] - \tan^{-1} \omega C_{ga} r_a \left(q + \frac{p}{p+1} \right) \quad .. \quad (48)$$

Assuming, as before, that $p/(p + 1)$ can be taken as unity, and that μ is large compared with unity, the angle of lag reduces, approximately, to

$$\phi = \tan^{-1} \mu r_g \omega C_{ga} \quad .. \quad .. \quad (49)$$

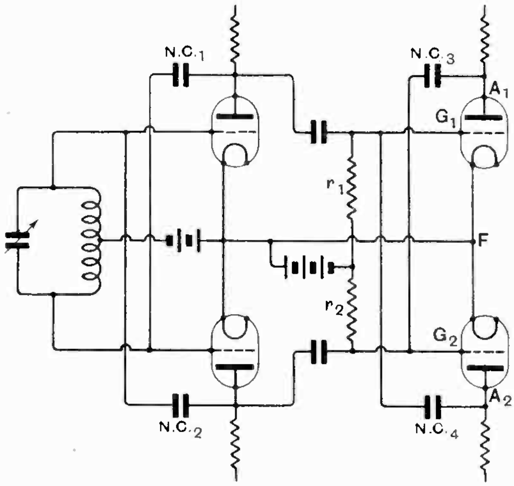


Fig. 19.—*Neutrodyned push-pull circuit for detector and R–C amplifier, to eliminate the effects of anode-grid capacity.*

The numerical relation between ϕ and the audio frequency is shown in Fig. 14. The curves A, B, and C, refer to exactly the same conditions as for the corresponding curves in Fig. 13. As the phase displacement of the resultant input varies considerably with the audio frequency, the shape of a complex wave form will be distorted by the feed-back action, the higher frequency components lagging behind their position in the original input wave.

Elimination of Feed-back Effect in Detector.—By employing a neutrodyne input circuit to the detector it is possible to cut out both the feed-back and the input load effect due to the anode-grid capacity. The connections are shown in Fig. 15. This circuit, from the point of view of the radio frequency voltage (μe_g) in the anode circuit is equivalent to that shown in Fig. 16. As μe_g sends current in opposite directions through the two halves of the input winding its inductance will be practically neutralised if the two sections are closely coupled and balanced. The impedance between grid and filament then reduces simply to the ohmic resistance (r) of the grid-filament section of the winding. As this resistance is negligible compared with the reactance of C_{ga}, the feed-back voltage between grid and filament will be negligible. This applies equally to all side band frequencies as there is no resonant circuit for μe_g to operate upon.

As regards the original input voltage the circuit is equivalent to that shown in Fig. 17. The capacity load on the input is that due to C_{ga} and NC in series. When the circuit is balanced there is no P.D. across r_a or r_e due to e (points F and A being at the same potential) so that their resistance loading effect is eliminated. This is true whatever may be the nature of the external load in the anode circuit.

By adjustment of NC the resultant voltage on the grid may be made to increase, keep constant, or to decrease, when the filament of the valve is switched on and μe_g comes into action.

It may be mentioned that it does not appear to be practicable to neutralise the effect of C_{ga} from the anode circuit, by any arrangement such as that shown in Fig. 18. In this scheme any variation of potential at the point B is fed back to G.

The divided input circuit of Fig. 15 is easily adaptable as a neutralised push-pull detector to be followed by resistance-capacity stages similarly arranged, as described later.

Elimination of Feed-back Effect in L.F. Amplifier.—The effects of the anode-grid capacity in a resistance-capacity coupled amplifier may be eliminated by the push-pull arrangement of Fig. 19, in which the connections for the detector and first L.F. amplifier are shown. An important feature of the arrangement is that the balance for the anode circuit E.M.F. of the amplifier is not disturbed at all by any inequality in the effective input resistances of the two L.F. valves, such as may be due to the use of leak resistances of unequal value or to the fact that the internal resistance of the detector valves is different for the positive and negative half-cycles. The reason for this will be clear from the equivalent circuit (for the anode circuit E.M.F.) of the amplifier given in Fig. 20, which is lettered to correspond with Fig. 19. If the capacities are balanced it is evident that the A.C. potentials of both G_1 and G_2 are equal to that of the mid-point of the total anode circuit E.M.F., *i.e.*, to that of the filament F. Hence μe_g can produce no current through the input resistance r_1 and r_2, whatever their values may be; and any point on them between G_1 and G_2 may be connected to F without affecting the balance.

As regards the input voltage applied across G_1, G_2 (Fig. 20), the anode potentials (A.C.) at A_1 and A_2 are the same, their value being that of the mid-point of $r_1 + r_2$. If F is joined to this mid-point no current from the input can flow through either r_a. Thus, in this case, the input load due to r_a (and also that due to the external load in the anode circuits of the amplifying valves) is

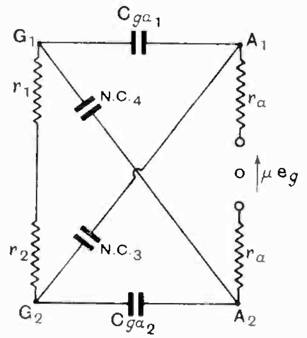


Fig. 20.—*Equivalent circuit of neutrodyned push-pull R–C amplifier.*

cut out. This means that the leak resistances r_1 and r_2 must be equal to reduce the input loading effect to a minimum.

Evidently the same method of neutralising C_{ga} is applicable to push-pull transformer coupled L.F. stages.

The Final or Power Stage of Amplifiers.*

By Manfred von Ardenne.

IN considering the final stages of an amplifier it is possible to start from very different hypotheses. If it is assumed that the voltage applied to the grid of the last valve is *small*, then it is known that the best conditions are complied with when the internal resistance of the output valve is made equal (by selection of a suitable amplification factor) to the resistance offered by the loud speaker to notes in the middle of audible range. If the preceding stage of voltage amplification can be assumed capable of delivering to the last valve alternating voltages which, within the range of frequencies considered, may be as large as desired without distortion, one arrives at a different result. Provided further that the output valve does not show saturation, or that saturation first makes its appearance in the region of positive grid voltages (as in Fig. 1), then the maximum output, as different authors† have deduced, is given *when the resistance in the anode circuit has double the value of the internal resistance of the valve.*

If full dynamic use is to be made of the valves, it becomes necessary to determine the operating voltages with which a given valve delivers the maximum output to a particular loud speaker. The last case is therefore of particular importance, for in practice the voltages are always easy to alter, while in most cases one has to make use of the valves and loud speaker available. The electrical output is dependent upon the magnitude of the alternating component of the anode current and the value of the resistance of the loud speaker through which this current flows. The maximum output is determined by the value of the greatest permissible current through the valve. The highest value of the alternating component of the anode current can be read off from the characteristic curve. In the case of the valve of which the characteristic curve is given as an example, in Figure 1, the anode current must not fall below the value $\overline{I_{p2}}$, nor rise above the value $\overline{I_{p1}}$, for only within the range between I_{p1} and I_{p2} is it permissible to regard the characteristic of this valve as a sufficient approximation to a straight line. The maximum alternating current is obtained when the working point

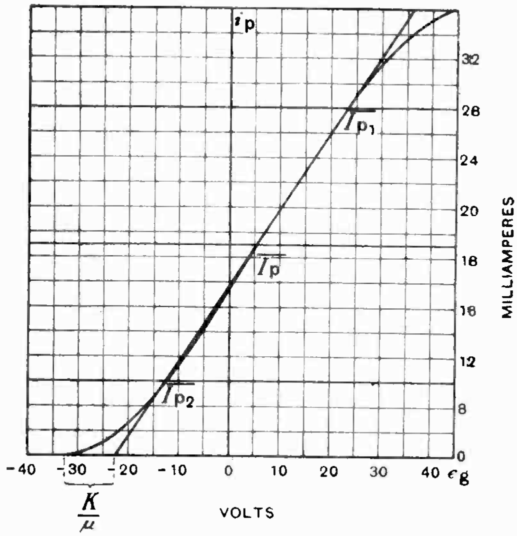


Fig. 1.

is at the middle of the straight region, that is, at $\overline{I_p}$. The greatest value of the alternating anode current which can be delivered without distortion has the value

$$\tfrac{1}{2}(I_{p1} - I_{p2}) = I_p.$$

Whether this current can be delivered without distortion to the loud speaker at all relevant frequencies depends only upon the anode and grid voltages in use.

In order to avoid distortion it is not only necessary to ensure that the working point cannot travel out to the regions in which

* The nomenclature employed in this paper corresponds to that given by E. L. Chaffee in his paper "Vacuum Tube Nomenclature," *Proc. I.R.E.*, March, 1927.

† W. F. Brown, *Proc. Phys. Soc.*, Vol. 36, III, 1924. W. P. Radt, "Ueber Maximalleistungen von Verstärkerröhren," *E.N.T.*, 1926, Part 3. J. C. Warner and A. V. Loughren, *Proc. I.R.E.*, Vol. 14, No. 6, 1926.

the characteristic is curved, but it is even more important to take care that the working-point always remains within the region of grid voltages to which there

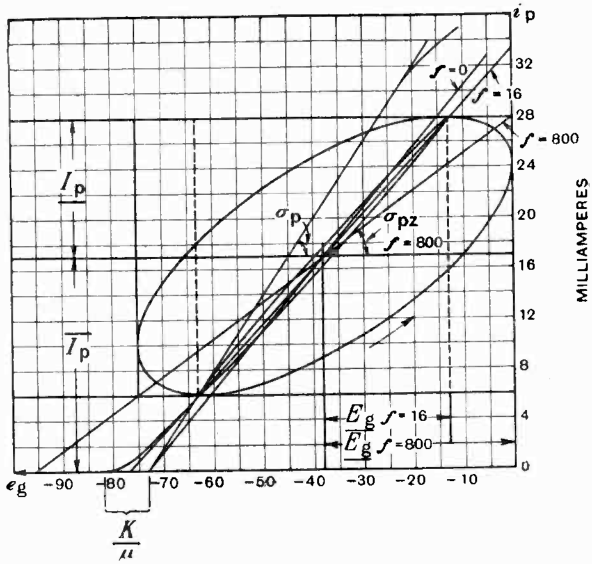


Fig. 2.

corresponds *zero grid current*. It is equally necessary to fulfil these two conditions for freedom from distortion when considering the working characteristic; that is, when examining the properties of valve and loud speaker as a single whole.

The load in the plate circuit of the output valve, if the usual inductive loud speaker is used, consists essentially of an inductance L and an effective resistance R_{bw}. The resistance can be resolved into the pure ohmic resistance of the bobbin windings and the resistance of operation R_w. The resistance of operation, which depends upon frequency, is in its turn made up of the loss-resistance R_{wv}, which is chiefly determined by the losses in the iron, and the *useful resistance* R_{wn} occasioned by the reaction of the moving parts of the loud speaker system. On account of the poor electro-acoustic efficiency of most loud speakers in use to-day the useful resistance R_{wn} is very small in comparison with all other resistances of the loud speaker. R_{wn} can therefore be neglected in many calculations. In cases where the useful resistance cannot be neglected, as for example in the investigation of the effect of frequency in the output stage, a mean value for R_{wn} will be assumed in later paragraphs. It is necessary to take a mean value, for with loud speakers of all types the useful resistance can vary over a wide range. In particular it increases for the frequencies for which the moving parts of the loud speaker come into resonance with the current energising it.

In order to obtain an insight into the dynamic relations holding in the output stage, the influence of the loading of the anode circuit occasioned by the loud speaker will now be examined. In the case of a purely ohmic anode resistance the dynamic characteristic, or the working characteristic which can be deduced from the familiar relations of resistance amplification, is practically a straight line, the slope of which is given by the following expression:

$$\sigma_{pr} = \frac{\sigma_p}{1 + \frac{R_b}{r_p}} \quad \ldots \quad \ldots \quad (1)$$

As soon as the load in the anode circuit ceases to be a pure resistance but has in addition an inductive or capacitative component, a phase-displacement between the grid voltage $\underline{E_g}$ and the anode current I_p of the valve makes its appearance. The characteristic then becomes an ellipse, which is elongated more or less according to the ratio of the imaginary to the real component. The ellipse can be constructed graphically, or accurately calculated.‡ In Figure 2 ellipses have been calculated for two different frequencies under the conditions given. From the ellipses the phase-displacement between the anode current and the grid voltage can be deduced. When the grid voltage is at its maximum or minimum, then the anode current, in the case of the inductive load here considered, attains its maximum or its minimum; that is, the ellipse is traversed in a counter-

‡ See Manfred von Ardenne, "Zur Theorie der Endverstärkung," *Jahrb. d. drahtl. Telegraphie u. Telefonie*, Vol. 30, Part 4. Manfred von Ardenne, "On the Theory of Power Amplification," *Proc. I.R.E.*, 1928. L. Müller and M. von Ardenne, "Die Transformatorenverstärker," published by R. C. Schmidt, Berlin.

clockwise direction. In the majority of cases it is not necessary to know the exact path of the ellipse which is the real working characteristic; it is almost always sufficient to know the diagonal of the rectangle which encloses the ellipse. The slope of this diagonal, which we can use as an ideal working characteristic, expressed in terms of the lengths of the sides of the rectangle, is in the general case:

$$\sigma_{pz} = \frac{I_p}{E_g} = \frac{\mu}{Z_B} \quad \ldots \quad \ldots \quad (2)$$

and in the case of inductive loud-speakers with small self-capacity this becomes:

$$\sigma_{pz} = \frac{\mu}{\sqrt{(\omega L)^2 + (r_p + R_{bw})^2}} \quad \ldots \quad (2a)$$

It follows from this that for an inductive loud speaker the slope decreases with rising frequency, and with decreasing frequency approaches the limiting value

$$\frac{\mu}{R_{bw} + r_p} \approx \frac{\mu}{r_p + R_b} = \sigma_{pr} \quad \ldots \quad (3)$$

determined by the resistances, R_b and r_p.

On the basis of the conditions for freedom from distortion that have already been mentioned, the following reasoning can be applied to the rectangle. The top and bottom sides of the rectangle are given by the two values I_{p1} and I_{p2} of the current, provided that the straight portion of the static curve extends over the region between these two values. If it is assumed that no appreciable grid current flows until zero grid voltage is reached, we know also that the grid voltage may not travel to the right of the vertical axis; that is, the vertical axis itself forms the third side of the rectangle. We can regard as a critical rectangle for distortionless working the rectangle having sides of lengths $(I_{p1} - I_{p2})$ and $2E_c$, so that one corner is given by the point $e_g = 0$, $i_p = I_{p1}$. Then $I_{p1} = i_{p\max}$ and $I_{p2} = i_{p\min}$, so that $(I_{p1} - I_{p2}) = 2I_p$, and further $2E_c = 2\ E_g$. These relationships can be clearly seen by referring to the diagram of Figure 3. So long as the working ellipses for all frequencies within the audible range lie within this rectangle, there will be no distortion. The conditions for operating the valve outside the regions of curvature of the characteristic on the one hand, and grid current on the other, can therefore be formulated in the following manner:

In order that a given valve may deliver to a given loud speaker a maximum undistorted output, the anode voltage must be so chosen that the ideal characteristic (diagonal of the rectangle) for a critical frequency goes through a point having the co-ordinates $e_g = 0$, $i_p = I_{p1} = \bar{I}_p + I_p$. From this statement and from certain elementary mathematical deductions it follows that the necessary voltage for the anode-current source is given by the general formula:

$$E_B = K + \bar{I}_p\,(r_p + R_b) + I_p Z_B \quad \ldots \quad (4)$$

In this equation K represents a voltage-correction which can easily be read off from the characteristic of the valve, and which is inserted in order to make possible the use of a linear relation for the anode current. Z_B, which also enters into equation (2) represents the absolute total of all

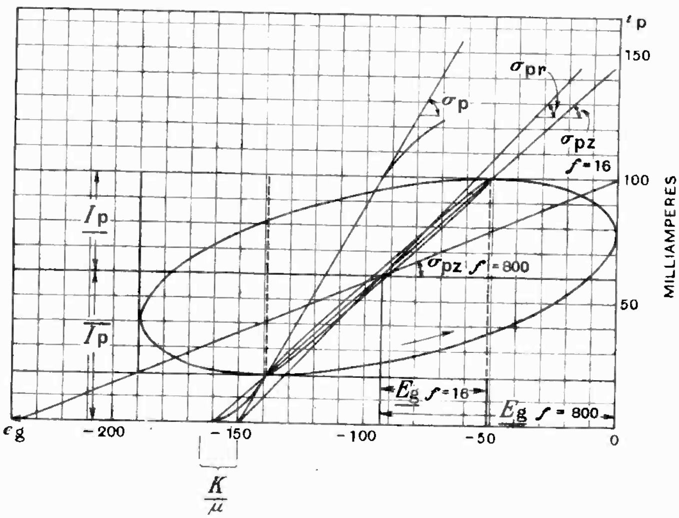


Fig. 3.

resistances in the valve circuit. Equation (4), in the case of an inductive loud speaker becomes :

$$E_B = K + I_p(r_p + R_b) + I_p \sqrt{(\omega L)^2 + (r_p + R_{bw})^2} \quad .. \quad (4a)$$

This expression gives us, to repeat it once more, the minimum value of voltage necessary for the anode current supply in order to make full use of the output valve, in conjunction with a given loud speaker. Expressed in words the formula, which is exceptionally easy to understand and can be grasped at a glance, states that *the voltage of the anode-current supply must be at least high enough to cover, in addition to the voltage-correction K, both the D.C. voltage-drop in the ohmic resistances r_p and R_b, and the A.C. voltage-drop in the impedance Z_B made up of r_p and Z_b.* As can be seen from the physical relationships mentioned, which find their expression in the formula given, the voltage of the anode-current supply must be greater, in the case of inductive loud speakers, the higher the frequency that is adopted for purposes of calculation. If, for the calculation of the anode voltage, we assume a frequency of 10,000 cycles, which lies at the upper limit of the audible range, and put ω equal to 63,000, we shall obtain from the usual data very high values for the anode voltage.

In practice, however, it is desirable to base the calculation, whether for music or speech, on a very considerably lower frequency, for in both the greatest sound intensities are to be found about the middle of the audible range. It follows therefore that the greatest signal voltages which are applied to the grid of the output valve, and are liable to cause overloading, are of medium frequency. On the basis of measurements which have been made during operation, it can be stated definitely that in both music and speech the amplitude of the signal voltages of a frequency higher than 800 cycles falls away more rapidly than does the slope of the ideal working characteristic. In considering inductive loud speakers we can therefore take 800 cycles as the *critical frequency* for the purpose of choosing the anode voltage. Quite different relationships apply in the case of an inductive loud speaker with a parallel capacity, or of a capacitative speaker with choke-feed, where the valve circuit contains both inductance and capacity. These form an oscillatory circuit, for the resonance frequency of which the impedance to alternating currents attains its highest value. The resonance frequency must, then, be taken as the critical frequency for the purpose of calculation, provided that it does not lie at a frequency above 800 cycles.

From equation (4), with the assistance of the relation

$$E_c = \frac{I_p}{\sigma_{pr}} - \frac{E_B - K}{\mu} \quad .. \quad (5)$$

we obtain the following expression for the grid-bias required :

$$E_c = -\frac{I_p}{\mu} . Z_B \quad .. \quad .. \quad (6)$$

The equation for the grid-bias shows that the amplitude of the signal voltage must never exceed the value

$$E_g = \frac{I_p}{\mu} . Z_b \quad .. \quad .. \quad (7)$$

Care must be taken here that the frequency taken as critical for the purpose of choosing the anode voltage is not inserted into this expression without some consideration. As can be seen, for example, in Figure 2, the narrow working ellipse corresponding to a low frequency will extend upwards and downwards into the region within which the characteristic is curved if a signal voltage of low frequency and of amplitude greater than that calculated from equation (7) for this frequency is applied to the grid of the output valve. It follows that for inductive loud speakers the limiting value for the signal voltage must be calculated for the lowest frequency that needs to be taken into consideration. With present-day transmitting and reproducing apparatus it is in most cases sufficient to take 50 cycles for this purpose. When the last valve has both capacity and inductance in its plate circuit, it is not possible to state generally whether the lowest value of permissible signal voltage corresponds to the upper or lower critical frequency, for this will depend on the position of the resonance frequency between the two critical frequencies. There have been calculated in Figures 2 and 3 for two output valves the anode voltages necessary in order that a maximum undistorted alternating current output may be delivered to a loud speaker having the properties there shown. In order to make full use of the valve shown in Figure 2, in conjunction with the loud speaker suggested, which is typical of the average commercial instrument, the calculation gives 374 volts as the necessary anode voltage. For the valve of Figure 3 the corresponding anode voltage is 927 volts. The grid-bias and the alternating

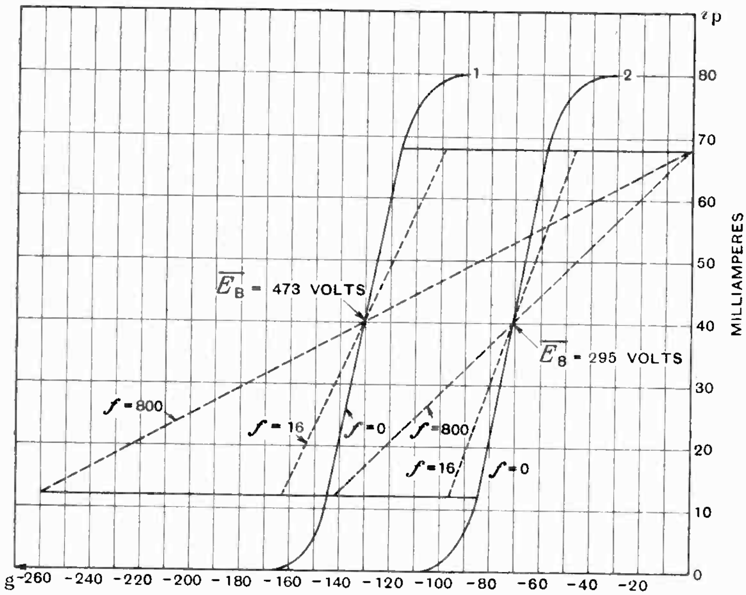


Fig. 4.

grid voltages corresponding to the two critical frequencies can be read off from the two Figures. Both diagrams show clearly the flattening of the working characteristic by the ohmic component of the resistance in the anode circuit. As can clearly be seen from Equation (4) which gives the anode voltage necessary, the voltage of the anode current supply must be increased by the amount of the voltage-drop $I_p . R_b$ across the ohmic component of the impedance in the anode-circuit. The ohmic resistance of the loud speaker is generally given, and in any case can only be brought with difficulty below a certain value if an adequately large useful resistance is required. In order to avoid this difficulty without being compelled to employ an unnecessarily high anode voltage, the well-known choke-feed can be employed; in this case the direct current passes through a choke with low ohmic resistance and high inductance, while the signal current passes through a suitable large condenser and the loud speaker. The employment of choke-feed in the output stage is not only helpful in reducing the value of the anode voltage necessary, but in the case of all modern loud speakers in which polarisation by a steady current is undesirable, it is absolutely necessary. In considering the output stages and the characteristics which follow, the adoption of choke-feed, using a choke of negligible resistance, is assumed.

With the aid of the formula for the necessary voltage of the anode-current supply quite a number of other interesting questions concerning the output stage can be answered. If, in place of a single loud speaker, the output valve is made to supply two identical loud speakers in parallel, and if we assume that this change leaves the steady plate current and the maximum alternating current in the anode circuit unaltered (which is true if choke-feed is in use), then each loud speaker will carry a current half as great as that which would flow through a single speaker. The output wattage, in the case of one loud speaker, is given by:

$$W_o = R_{wn} \frac{I_p^2}{2} \quad \ldots \quad \ldots \quad (8)$$

By connecting two loud speakers in parallel the *total* current will not be changed. The useful resistance, however, will be reduced to half its previous value on account of the parallel connection.

$$\frac{R_{wn}}{2} \cdot \frac{I_p^2}{2} = \frac{W_o}{2} \quad \ldots \quad \ldots \quad (8a)$$

It follows from this that the output wattage attainable with a valve is reduced by connecting two speakers in parallel to half the value that can be reached with one loud speaker only. At the same time, however, as can be seen from Equations (4a), (6) and (7), the anode voltage and grid-bias necessary, together with the signal voltage required to load the valve fully, are all reduced. In order to present these relationships more clearly, there have been calculated in Figure 4 the characteristics and the necessary (optimum) working voltages both for one loud speaker, and for two connected in parallel. With the valve used here (actually two identical valves connected in parallel), and with the given data for the loud speaker, the anode voltage necessary for a *single* loud speaker comes out as 473 volts, while for two connected in parallel the anode voltage is reduced to 295 volts.

The next point to consider after the parallel connection of loud speakers is the effect of connecting them in series. Several loud speakers connected in series cause an increase of the resistance in the plate circuit of the output valve, and therefore involve an increase in the anode voltage, as can immediately be calculated from Equation (4). If the anode voltage, the grid-bias, and the signal voltage applied to the grid are all increased to the extent demanded by Equations (4a), (6) and (7), the output, for n loud speakers connected in series, is increased n times, for

$$nR_{wn} \cdot \frac{I_p^2}{2} = nW_o \quad .. \quad .. \quad (8b)$$

From this it follows that the output wattage obtainable from very small valves can be increased if the resistance in the anode circuit is raised and the anode and grid voltages are increased to correspond. On account of the danger of high voltages and of the fact that the usual output valves will only stand with safety a certain voltage, dependent for its exact value on the type of valve employed, this method for increasing the output is not in general to be recommended.

Rather is it desirable to endeavour to obtain the required high output with *low anode voltages*. Small output valves require proportionately low anode voltages, when they are used in conjunction with a given loud speaker. But as soon as several small valves are connected in parallel in the endeavour to obtain high outputs, higher anode voltages are again necessary. This is shown clearly by Equations (4) and (4a). If n small valves are connected in parallel, the necessary voltage of the anode-current supply becomes :

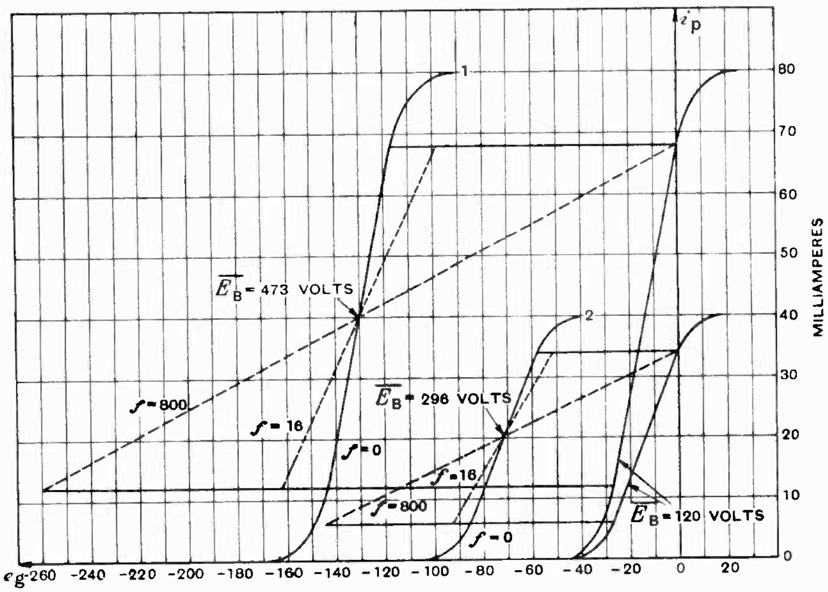


Fig. 5.

$$\bar{E}_B = K + {}_n\bar{I}_p\left(\frac{r_p}{n} + R_b\right) + nI_p\sqrt{(\omega L)^2 + \left(\frac{r_p}{n} + R_{bw}\right)^2} \quad .. \quad (4b)$$

The various characteristics for *a single valve* and *for two valves connected in parallel*, the valves being of a modern output type, are given in Figure 5. If it were possible to neglect the effect of the resistance in the plate circuit on the characteristics, or if this resistance were small compared with the internal resistance of the valve for all frequencies within the audible range, then an anode voltage of 120 volts would be sufficient, for valves of this type, to permit of making full use of the valve. If a single valve is used in conjunction with a loud speaker of which the ohmic resistance can be neglected (compare in this connection the remarks already made), and of which the remaining data are given in Figure 5, an anode voltage of 296 volts is necessary. The corresponding grid voltages can be found from Figure 5. So long as it is only required to listen in an ordinary living-room, and no very great sound intensity is needed, an output stage with a valve such as is given in Figure 5 is quite sufficient. If it is desired to deliver still greater undistorted alternating-current power to the loud speaker, two valves of the same type can be connected in parallel. The anode voltage required then rises considerably, amounting, in the example given in Figure 5, to 473 volts. The two valves connected in parallel then behave exactly like a single valve of correspondingly greater size. We know therefore that it is not possible, *with low anode voltages*, to obtain a higher maximum output by connecting valves in parallel. By connecting n valves in parallel the anode output itself increases n^2 times, provided that the working voltages are increased in accordance with the equations given.

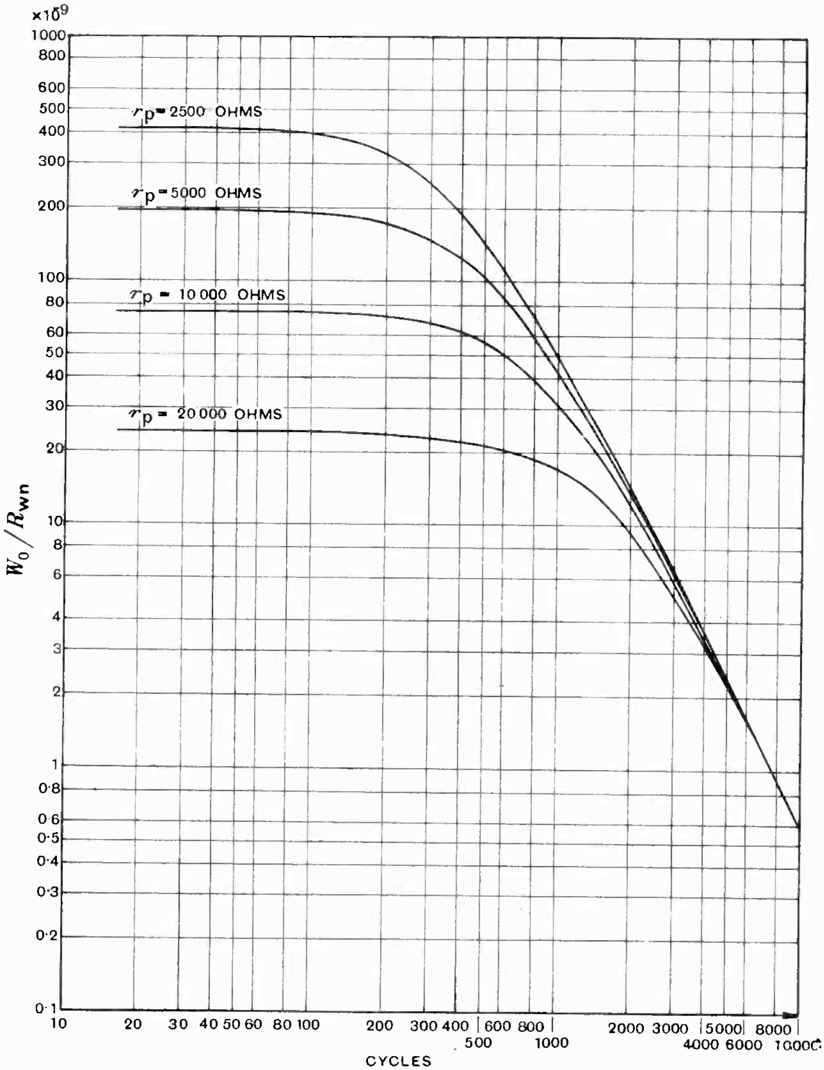


Fig. 6.

$$R_{wn} \cdot \frac{(nI_p)^2}{2} = n^2 W_o \qquad .. \text{(8c)}$$

In this connection the comparison of the anode output from an output stage consisting of a single valve and a single loud speaker, and that from an output stage consisting of two valves in parallel feeding two loud speakers also connected in parallel is of especial interest. As can be seen by a comparison of Curve 2 of Figure 4, which corresponds to two valves in parallel supplying two loud speakers in parallel, with Curve 2 of Figure 5, which is based on only *one* valve and *one* loud speaker, the working voltages correspond closely in the two cases, and the output wattage for n loud speakers in parallel, and n valves in parallel is

$$\frac{R_{wn}}{n} \cdot \frac{(nI_p)^2}{2} = nW_o \quad .. (8d)$$

The output wattage is thus n times that from a single loud speaker (Equation 8). The example shows that by connecting in parallel a number of identical valves, and by connecting in parallel a corresponding number of loud speakers (or by employing a loud speaker of lower resistance) it is possible to increase the output wattage, and with it the output of sound, without the necessity for raising the voltages on grid and anode.

In this connection attention may be drawn to a few points connected with the construction and choice of output valves. From the equations given in this article can be deduced the following general statement, which is also immediately obvious. *The necessary voltage for the anode-current supply can be decreased, and the alternating-current power delivered to the loud speaker can be increased, by choosing a smaller value for the internal resistance of the output valve.*

The internal resistance of a valve can, as is well known, be lowered by lowering the amplification factor. In the output stage, where we are in most cases not greatly concerned with the voltage-amplification, we can employ values of μ as small as $2\frac{1}{2}$. If so small a value of μ is used we must of course increase proportionately the signal voltage applied to the grid, and must therefore choose suitable values for the voltage-amplifying stage that precedes. If we insert into the equation for the output wattage (8) the relation for the alternating anode current, we arrive at the following expression :

$$W_o = \tfrac{1}{2} R_{wn} \cdot \mu^2 \cdot E_g{}^2 \cdot \frac{1}{Z_B{}^2} \quad .. (9)$$

which, for the case of an inductive loud speaker, becomes :

$$W_o = \tfrac{1}{2} R_{wn} \, \mu^2 \, E_g{}^2 \cdot \frac{1}{(\omega L)^2 + (r_p + R_{bw})^2} \quad (9a)$$

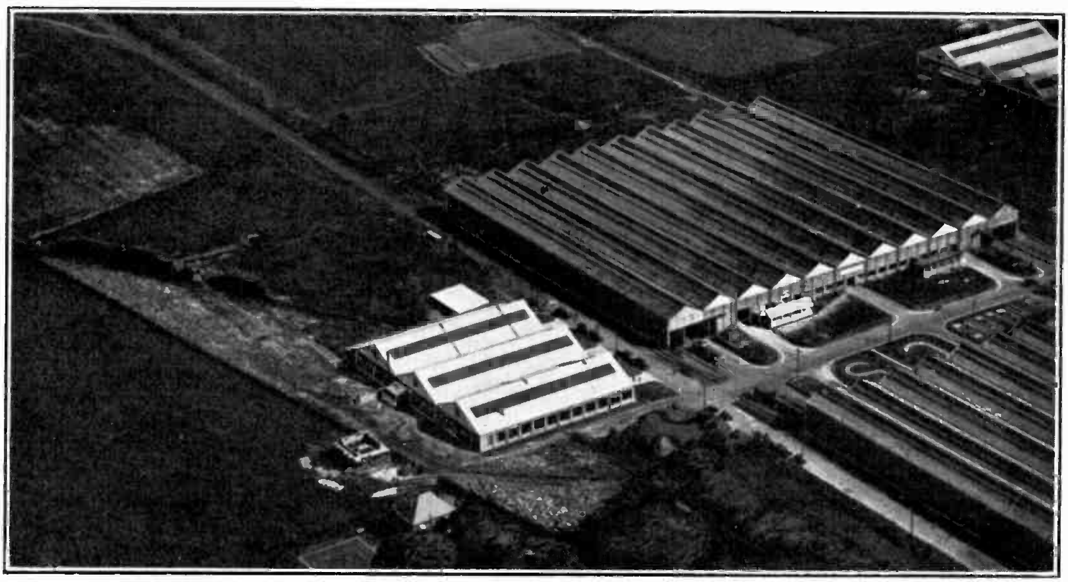
The equation shows that E_g must be increased or diminished in proportion to $\frac{1}{\mu}$ if it is required to keep the output wattage constant. From Equation (9a) for the output wattage with an inductive loud speaker there follows further the dependence of the output wattage upon the frequency, which will now be considered.

The dependence upon frequency of the output wattage, or rather of the ratio $\frac{W_o}{R_{wn}}$ for $E_g = 1$ volt, and the values for loud speaker and valve characteristics there shown is given in Figure 6 for several values of the internal resistance of the valve. The slope of the curve at the higher frequencies corresponds approximately to a decrease of the output according to the second power of the frequency. We know that the variations with frequency in the output stage are extraordinarily large, and of quite a different order of magnitude to those obtaining in the voltage-amplifying stages, even if we remember that a decrease of voltage in the voltage-amplifying stages to $\frac{1}{n}$th corresponds in the output stage to a decrease of output in the ratio of $\frac{1}{n^2}$.

It has already been pointed out above that R_{wn} is not constant, but increases, as a very rough approximation, as the second power of the frequency. We therefore obtain in the region of the higher frequencies an approximately constant sound-pressure for equal voltages on the grid of the output valve. At low frequencies, on the other hand, owing to the dependence of R_{wn} on frequency, the strength of sound becomes less. The curves of Figure 6 show that *the low notes are better reproduced as the internal resistance of the output valve is reduced.* For this reason also a low valve-resistance in the output stage is important. When it is said that the useful resistance increases as the second power of the frequency, this statement is only intended to be very approximate. In spite of the fact that with commercial loud speakers the values for the inductance and the ohmic resistance of the windings do not depart greatly from one another, the R_{wn}-curves diverge so widely that it is not possible to give any general best value for r_p from the point of view of dependence on frequency. Good reproduction of the lower notes, without unfavourably affecting the higher notes, is obtained from the usual loud speaker when it is used in conjunction with valves having an internal resistance of from one to two thousand ohms. In order to obtain in the output stage as little variation as possible with frequencies within the audible range, it would be possible to use in the output stage two valves, one with a very high and the other with a very low internal resistance, each of them independently working its own loud speaker.

A new output valve that was recently being developed in the Philips Laboratory seems to contradict the points of view put forward in the present article. This valve, which is of the screened-grid type, has an amplification factor of about 100 and an internal resistance of about 60,000 ohms. If this valve is used in conjunction with a loud speaker having the usual characteristics, then for the lower frequencies, and for the middle frequencies of the audible range (*i.e.*, for frequencies below 800 cycles) the internal resistance of the valve is very much greater than the resistance in the anode circuit. As a result, the working characteristics will deviate but little from the static characteristics of the valve with comparatively low anode and auxiliary grid voltages, for in spite of its high internal resistance it possesses a slope of over 1mA/V over a wide range of anode currents.

On account of the high internal resistance the electrical effect of frequency, if the usual type of inductive loud speaker is in use, will be small, as can be seen from the formulæ given and from Figure 6. With regard to the dependence upon frequency of the useful resistance, the high frequencies will on this account be very well reproduced, while middle and low frequencies will be poor in comparison. The valve is however so constructed, in order that there may be the possibility of reproducing the low notes with it, that by connecting the screening-grid and the anode there results an output valve having an amplification factor of about 5 and a low internal resistance.



An aerial view of the new works of Graham Amplion, Ltd., at Slough. The offices of the administrative staff are on the left, whilst the buildings on the right comprise the factory.

On the Application of Condensers to the Measurement of Large Radio-frequency Currents.

By Philip R. Coursey, B.Sc., M.I.E.E.

FROM the earliest production of radio-frequency currents of any considerable magnitude—whether by the earlier damped-wave methods, or by the more modern C.W. apparatus—the measurement of such currents has presented a problem for which several solutions have from time to time been offered. The most important of these solutions so far utilised are as follows :—

(1) Hot-wire expansion type instruments giving direct deflectional readings on a graduated scale.

(2) The thermocouple type of instrument with appropriately constructed or shunted heater element.

(3) Transformer-coupled instruments with or without iron-core for the transformer, and utilising as indicator an instrument constructed in accordance with (1) or (2) above.

To these must now be added a method which has recently been developed into a practical form :—

(4) Condenser-shunt instruments, utilising as indicator a low-range meter constructed in accordance with (2) above.

In addition to these main methods, a considerable number of special instruments have been suggested, or used, from time to time, utilising other forms of construction or indication, but these have found no practical applications on any extended scale. It is the main purpose of this article to deal with the fourth class referred to above, and to indicate its sphere of utility in comparison with the other and better known arrangements.

The first method is perhaps the oldest as far as practical utilisation is concerned, since indicating ammeters utilising the expansion of a wire heated by the current were in use for industrial electrical measurements before any extended utilisation and measurement of radio frequency currents was required. While such instruments are practicable, even for large currents, for low- and for audio-frequencies, they are not practicable with any degree of accuracy for radio-frequency currents above about 10 amperes. For larger currents it is customary for low-frequency circuits to shunt the instrument, but such a method usually gives very inaccurate readings in radio-frequency circuits owing to the important part that the inductance of the parts of the circuit inside the instrument plays in determining the subdivision of the current between the shunt and the heater wire of the instrument. With such instruments the only way to ensure more consistent subdivision of the current through the meter is to construct the expansion element of a number of exactly similar strands of thin wire, all connected in parallel, one of the wires being used to operate the index. Such an arrangement is however, bulky and inconvenient. Somewhat similar disadvantages are attendant upon the construction of heavy current instruments of the second class, in order to ensure absolutely uniform subdivision of the current between the multiple wires of the heater. The disadvantage is, however, less serious in this case, since the heater and thermocouple elements of the meter can be located at some little distance, if necessary, from the indicating instrument used with them. A not inconsiderable expenditure of energy is moreover often called for in the heater element when the currents are large.

The transformer-coupled radio-frequency ammeter is a very satisfactory apparatus for the medium radio frequencies, but presents an increasing difficulty of construction for the higher frequencies called for in modern short-wave transmission. Whether the transformer has air or an iron core, errors creep in due to capacity currents and eddy currents in the conductors of the transformer, both of which become more serious as the frequency is raised. With iron-cored transformers the iron losses also increase with frequency and serious over-heating may arise unless very great care is taken in the design.

With the fourth method, tabulated above, making use of electrostatic condensers, these difficulties are not encountered, since on account of the decreasing impedance of a condenser as the frequency is raised, no excessive energy losses are found, and the method readily lends itself to accurate measurements at the highest frequencies.

The general principle of the arrangement, which is the invention of one of the Dubilier engineers, is depicted diagrammatically in Fig. 1*. Between the main instrument terminals T_1, T_2, two condensers C_1, C_2 are connected in parallel. One of these C_1 is

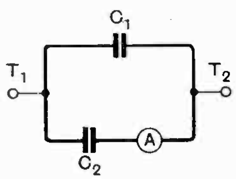


Fig. 1.

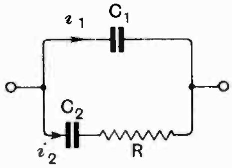


Fig. 2.

given a capacity value very much larger than the other. In accordance with the well-known formula $I = C\omega V$, the total current flowing through the instrument divides in proportion to the capacity values of the two condensers. In practice, the ratio between the two capacity values is arranged to be a definite predetermined integral quantity, so that the large condenser shunts off a predetermined fraction of the total current, leaving the balance only to produce an indication on the low reading radio-frequency ammeter A. Ratios of 99 : 1 or 199 : 1 are convenient values, giving shunt powers of 100 and 200 respectively. The ammeter A used with this arrangement may be any one of the three types mentioned at the beginning of this article, but for preference is of the second or thermocouple type. Low direct-reading pointer instruments of this type can be used with these condenser shunts, and ammeters of this type in the lower ranges up to about 1 ampere are very accurate over a wide range of frequencies.

The accuracy of the complete meter incorporating these condenser shunts and the thermocouple indicating meter is necessarily limited to the accuracy of calibration of that meter, but with proper design satisfactory measurements of large currents at frequencies up to at least 60,000 kc. can be obtained. For still higher frequencies special ammeters of this type can also be designed to retain high accuracy of reading. An additional advantage of the thermocouple type of indicating meter as compared with the hot-wire type is that in the former case the actual indicator portion of the ammeter can be located at a distance from the main circuit. This is referred to more in detail below. The complete arrangement of an ammeter of this type incorporating the condenser shunts is theoretically subject to an error due to the resistance of the indicating meter. In Fig. 2, if C_1 and C_2 are the capacities of the two condensers and R is the resistance of the thermocouple the currents flowing through the two branches of the meter will be as follows :—

$$i_1 = C_1\omega v \qquad i_2 = \frac{v}{\sqrt{R^2 + \frac{1}{\omega^2 C_2^2}}}$$

If the meter had no resistance, that is $R = 0$, the current in the second branch would be $i_2' = C_2\omega v$. The effect of the resistance is to reduce the current flowing in the second branch of the shunt by an amount equal to

$$i_2' - i_2 = C_2\omega v - \frac{v}{\sqrt{R^2 + \frac{1}{\omega^2 C_2^2}}}$$

The indicating meter A Fig 1, will therefore read low by this amount, and expressing this as a fraction of the correct reading the error becomes

$$100 \times \left(1 - \frac{1}{C_2\omega\sqrt{R^2 + \frac{1}{\omega^2 C_2^2}}}\right) \text{ per cent.}$$

$$= 100 \times \left(1 - \frac{1}{\sqrt{R^2\omega^2 C_2^2 + 1}}\right) \text{ per cent.}$$

Taking values of C_1 and C_2, which are commonly adopted for a condenser shunt

* *British Patent*, 259,533. See also A. Nyman, *Proc. Inst. Radio Engineers*, February, 1928.

of this type for reading radio-frequency currents up to about 50 amperes, the meter is normally given a ratio of about 200 : 1, in which case $C_1 = 0.2\mu F$ and $C_2 = 0.001\mu F$. With this arrangement a thermo-junction ammeter reading up to 0.25 ampere will be used and an indicating meter of this type would normally have a resistance of about 2.6 ohms. Taking this figure and substituting in the above for the error, it is found that for a frequency of 6,000 kc. (which is a wavelength of 50 metres) the error in the ammeter reading becomes

$$100\left(1 - \frac{1}{\sqrt{(2.6)^2 \times 36 \times 10^{12} \times 4\pi^2 \times (10^{-3})^2 \times 10^{-12} + 1}}\right)$$
$$= 0.5 \text{ per cent.}$$

If these particular values were used in a condenser shunt ammeter for frequencies up to 60,000 kc., the error would still be less than 5 per cent., which considering the high frequency is not very serious. For frequencies of this order and still higher capacities of lower value would be used so as to reduce the percentage of error in the readings.

The only source of error of any seriousness actually found in the use of meters of this type arises from the fact that the two condensers C_1 and C_2 and the thermocouple A form a closed circuit which necessarily has some resonant frequency when the meter is used in short wavelength circuits and it occasionally happens that this resonant frequency comes within the range of a definite harmonic of the frequency of the currents passing through the meter, and in such cases a considerable irregularity in the meter readings is observed. It has been found that an effective method of overcoming this source of error is to absorb the energy of any circulating currents of this type by means of a small auxiliary circuit included in the main meter casing and itself tuned to the resonant frequency of the main loop in the meter. This absorbing circuit is connected to the meter circuit immediately adjacent to the thermo-ammeter as shown in Fig. 3, and then serves to absorb the power of the harmonic. This local tuned circuit is connected to the meter at one point only and in consequence its effect at all other frequencies than the resonant frequency is entirely negligible.

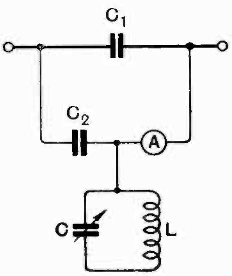


Fig. 3.

With this arrangement it should be noted that a meter of this type probably constitutes the most accurate standard known for the measurement of high-frequency currents. Apart from it, the only fundamental method of measuring such currents is a thermal method, involving the measurement of the heating due to the high-frequency current flowing through a known resistance, but this method is liable first to inaccuracy arising from the slight uncertainty of the value of the "known resistance" at high frequencies, and secondly to unknown shunting effects due to stray capacities between the heating elements and the calorimeter apparatus in which the measurements are carried out. With the condenser-shunt radio-frequency ammeter, errors due to stray capacities become entirely negligible, since the capacity values of the condensers in the ammeter are so much in excess of any stray capacities. A possible source of error may arise if the capacity values of the condensers used in the meter do not remain constant, but with properly constructed mica dielectric condensers the

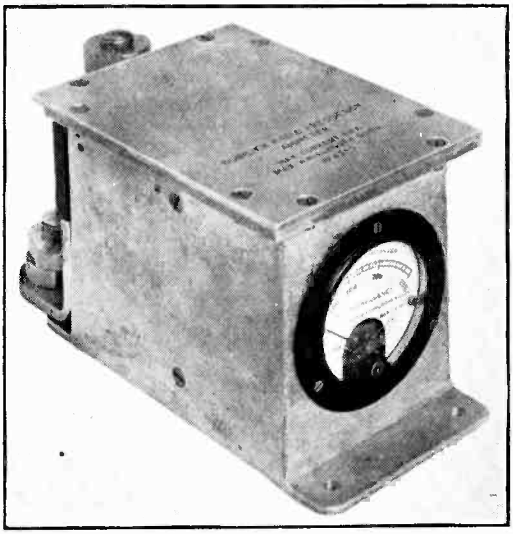


Fig. 4.

constancy is of a high order and practically independent of the frequency.

Fig. 4 illustrates an ammeter of this type, constructed with the condenser shunts included in a metal case to which is fitted a Weston thermo-junction milliammeter having a full scale reading of 250 milliamperes, thus giving, with a condenser shunt of 200 : 1, a range up to 50 amperes in the main circuit. As may be seen in the photograph the meter is provided with two substantial terminals for the main current connections, one of these terminals being mounted directly upon the case of the instrument and the second on an insulated conductor leading through to the condensers in the interior. The particular ammeter illustrated is constructed with capacity values of $0.199\mu F$ and $0.001\mu F$, so that the

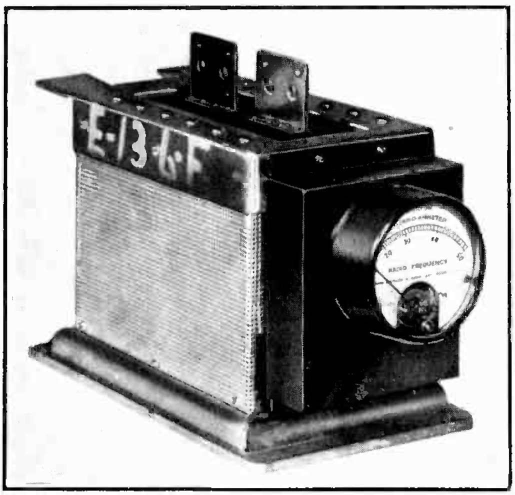


Fig. 5.

smaller condenser has a value of exactly 1/200th of the total capacity in the ammeter.

Since the passage of radio-frequency current through the meter gives rise to a volt drop across the terminals of the condenser which will increase with increase of wavelength of these currents, there is evidently a maximum wavelength (or minimum frequency) for which the meter is suitable without causing excessive stress in the dielectric of the condenser. By increasing the bulk of dielectric in the condenser for a given capacity value, the meter could be used for lower-frequency currents, but if this were done the volt drop would tend to become excessive, and a more practical solution would be to use condensers

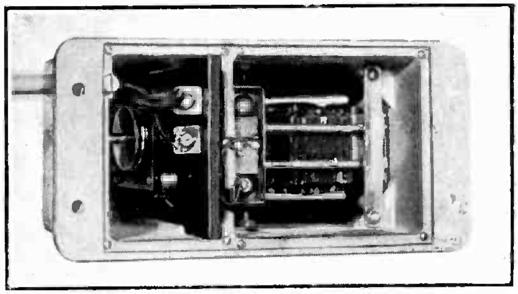


Fig. 6.

of larger capacity values in the meter. Such an arrangement would, however, increase the cost of the meter and render it excessive as compared with the other types of radio-frequency meter already mentioned. Essentially, therefore, this type of ammeter is most suited for higher frequency currents. The particular meter, illustrated in Fig. 4, is suitable for wavelengths less than 500 metres, the useful range of frequencies for this meter, therefore, being about 10–500 metres (600 to 30,000 kc.).

In the construction of the experimental model meter, illustrated in Fig. 4, a thermo-ammeter calibrated to 250 milliamperes was used. In practice, of course, in constructing meters of this type, the thermo-

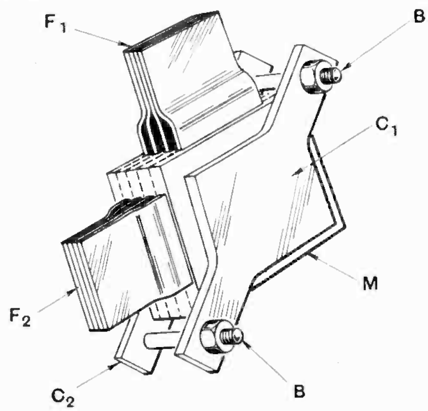


Fig. 7.

ammeter would be fitted with a false scale so as to read the true values of the main current correctly. Such an instrument is illustrated in Fig. 5, this one again having a maximum current-carrying capacity of 50 amperes, but provided in this case with two terminals both insulated from the container in which the whole apparatus is mounted as well as a common terminal connected to the metal case. These two insulated terminals enable the instrument to be used with two current ranges as is explained below.

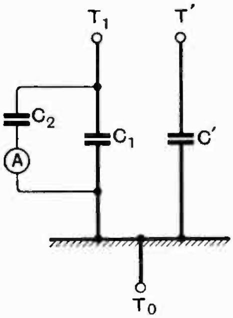


Fig. 8.

The tuned circuit to which reference has been made for absorbing the energy of stray harmonics is preferably constructed with a small fixed inductance used with a small adjustable capacity condenser so that the resonant frequency of this circuit can be adjusted to the required value after the meter has been constructed. A small parallel plate variable condenser provided with an adjusting screw which can be moved from outside the meter case is convenient for this adjustment. Such an arrangement is illustrated in Fig. 6, which is an inside view of the condenser shunt for one of these meters, the actual indicator in this instance being arranged at the end of two twisted leads enclosed in a metal tube leading away some distance from the condenser shunt.

In the construction of condensers for use in radio-frequency ammeters of this type, it has been found that special precautions are necessary over and above those commonly adopted in the design of mica condensers for use in radio-frequency circuits. In the first place, very rigid clamping of the parts of the condenser is essential, and this clamp must be so arranged that it does not form a closed metallic loop surounding the main current path through the instrument. One way in which this desired result may be obtained is indicated in Fig. 7*. In this diagram the sheets of mica dielectric are arranged in square form as shown at M, and the metal foil conductors forming the two armatures of the condenser are brought out at adjacent sides of the dielectric pieces as at F_1, F_2, these foils all being soldered together into two groups for the large capacity condenser in the ammeter. The whole condenser is held rigidly together by clamping members C_1, C_2 secured by the bolts B B. The current flowing through a condenser constructed in this manner through the conductors F_1 F_2 forms a small loop with which the metallic loop of the clamp itself is not linked, so that energy losses in the clamp are reduced to a minimum, while adequate spacing of the condenser from the clamping members helps also in this direction.

It is very easy to arrange instruments of this type to be suitable for more than one range of current measurements by enclosing more than one main condenser element for the shunt inside the single instrument casing. An instrument having two ranges is illustrated in Fig. 5, the arrangement of the circuit inside the instrument being as sketched in Fig. 8. In this diagram the main insulated terminal is marked T_1, this leading to the first main large capacity condenser element of the shunt C_1, and

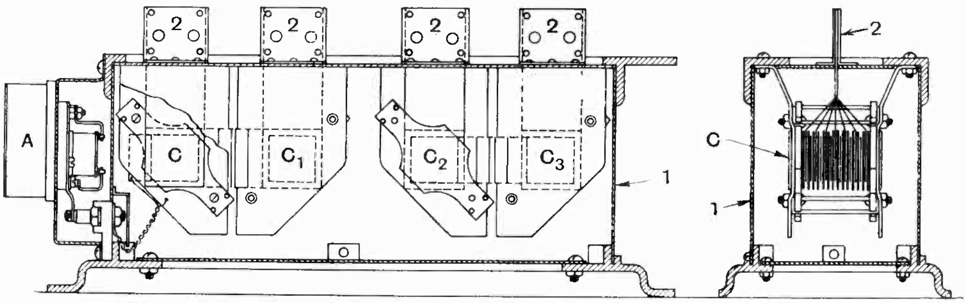


Fig 9.

* Dubilier Condenser Company, Ltd., *British Patent*, No. 267,568.

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across this being connected the small capacity condenser C_2 in series with the indicating thermo-ammeter A as before, the second main terminal T_0 being joined to the case of the instrument as indicated. A second main large capacity condenser element C' is also included in the casing, one terminal of the condenser being joined to the case at T_0, the other terminal being brought out as a second insulated terminal T'. These two main condenser elements C_1 and C' are constructed in exactly similar manner and arranged symmetrically inside the casing so that the self-inductances of the two parallel paths through the meter are sensibly the same. The range of the instrument is increased by connecting the two condensers C_1 and C' in parallel. An extension of this idea to the construction of an instrument with four ranges is described and illustrated in the British Patent 277,933.*, from which the diagram in Fig. 9 has been reproduced. In this diagram four similar condenser elements are shown marked C, C_1, C_2, C_3, respectively, the insulated terminals of these four condensers being brought out to the four insulated terminals marked 2 in the diagram, the whole being enclosed in the metal casing 1 upon one end of which the ammeter A is mounted.

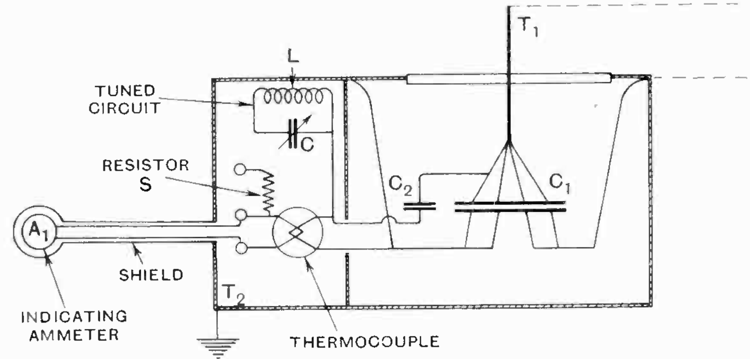


Fig. 10.

An advantage of the use of the thermo-junction ammeters as indicated for instruments of this type is that the indicator portion of the meter can be separated from the main radio-frequency circuit if desired. By arranging the thermo-junction of the indicating ammeter as at A, Fig. 8 with one pole connected to the case of the instrument, which is preferably earthed, the flow of any stray radio-frequency currents through the leads to the indicating meter can be largely avoided, and since the indicator for such thermo-junction meters is a D.C. instrument, the currents flowing through these connecting leads are very small. In Fig. 10 the diagrammatic arrangement is given of one of these meters with a separate indicating instrument spaced away from the main circuit and marked A_1 in the diagram, the other parts being lettered to agree with the parts marked in Fig. 3. With this arrangement the thermocouple is preferably mounted inside the main casing of the instrument so as to shield it from stray radio-frequency fields while the connecting wires are enclosed in a metal tube as also illustrated in the photograph Fig. 6. The thermo-junction used with these meters may be of the ordinary open type, but preferably of the vacuum type sealed into an exhausted glass bulb. Fig. 11 shows such a vacuum thermo-junction connected to a small indicating meter

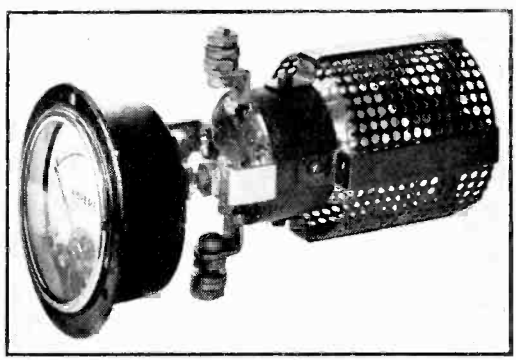


Fig. 11.

suitable for this class of work, this meter being provided with a special scale graduated to read the true current flowing through the main circuit of the meter. Another

* Issued to the Dubilier Condenser Company, Ltd.

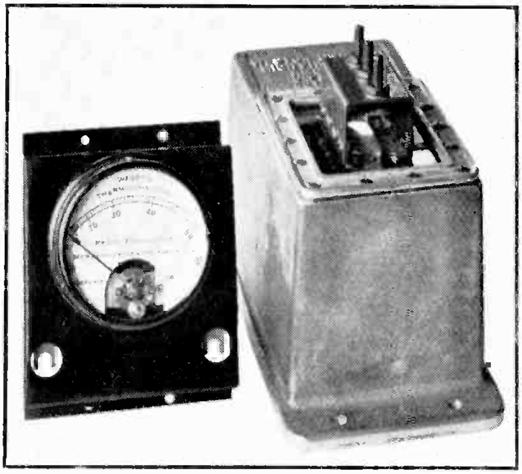


Fig. 12.

arrangement is illustrated in Fig. 12, in which arrangement the indicating meter can be mounted either directly upon the main casing of the meter (as in Fig. 5) or spaced away from it as in Fig. 10, a standard length of connecting leads being used in the latter case. For such an arrangement it is advantageous to include a small resistance marked S in Fig. 10, having an effective resistance equal to that of the leads used to connect up the distant indicating meter. When the indicator is used at a distance it is then connected directly to the thermo-couple through the special leads, but when it is used close up to the main meter the connection is shifted over so as to include the resistance S in the meter circuit and retain the same accuracy of calibration.

From tests carried out during the last three years in the Dubilier Laboratories, it has been found that the indications of meters of this type remain consistent and reliable at all times, such that they can be kept as standards for the measurement of radio-frequency currents, their small size and negligible energy dissipation rendering them specially advantageous in this direction, particularly for the measurement of currents at very high frequencies.

The Application of Alignment Charts to Valve Characteristics.*

By M. Reed, M.Sc., A.C.G.I., D.I.C.

In this article it is shown how an alignment chart can be used to obtain the ordinary valve characteristics from the design data of the valve.

For the sake of completeness, an outline of the geometry of the alignment chart used, is given.

Consider an equation of the form :

$$au + bv = c \qquad \ldots \qquad \ldots \quad (1)$$

in which a, b, and c are constants and u and v are variables.

Let values of u be marked off along Au and values of v along Bv (Fig. 1). AB is the datum line connecting $u = 0$ with $v = 0$.

Let AD and BF intersect at P. A third line joining two other values of u and v will be found to pass through P also.

Take AB as x axis and OY as y axis,

then
$$x = d\left[\frac{b-a}{a+b}\right] \qquad \ldots \qquad \ldots \quad (2)$$

and
$$y = \frac{c}{a+b} \qquad \ldots \qquad \ldots \quad (3)$$

Thus x depends only on a and b, whereas y is directly proportional to c. Therefore, if c is now considered as a third variable, its successive values will give a scale of points similar to P along the line CE. This third scale will be parallel to the other two

* An article on "The Alignment Principle in Calibration," by W. A. Barclay, appeared in Experimental Wireless of December, 1925.

as x is still a constant according to equation (2).

Suppose the equation to be charted is :

$$aU + bV = c \quad .. \quad .. \quad (4)$$

and that scale values have been chosen for U and V so that

$$u = I_1 U \quad \text{i.e., } U = u/I_1$$
$$v = I_2 V \quad \text{i.e., } V = v/I_2$$

Substitution in (4) gives :

$$auI_2 + bvI_1 = cI_1 I_2 \quad .. \quad .. \quad (5)$$

$$\therefore \quad x = d\left[\frac{bI_1 - aI_2}{aI_2 + bI_1}\right]$$

$$\therefore \quad \frac{bI_1}{aI_2} = \frac{d + x}{d - x} = \frac{AC}{CB} \text{ (see Fig. 1)} \quad .. \quad (6)$$

and $\quad y = \dfrac{I_1 I_2 C}{aI_2 + bI_1}$ [see (3)]

From which by similarity with U and V

$$I_3 = \frac{I_1 I_2}{aI_2 + bI_1}$$

where I_3 is the scale for the third variable c.

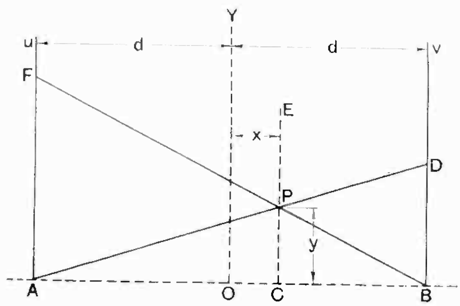


Fig. 1.—From (1) if $u = 0$, then $v = c/b$. $\therefore BD = c/b$. Also, if $v = 0$, then $u = c/a$. $\therefore AF = c/a$.

Since a scale can be made out for $a\,u$, but actually scaled off in values of u, we can put $a = b = 1$.

$$\therefore \quad I_3 = \frac{I_1 I_2}{I_1 + I_2} \text{ and } \frac{AC}{CB} = \frac{I_1}{I_2}$$

This alignment chart will now be used to obtain the ordinary valve characteristics.

The relation between the plate current, the plate volts, and the grid volts is given by the expression :

$$I_p = a\left[\frac{E_p}{\mu} + E_g + e\right]^\beta \quad .. \quad .. \quad (7)$$

Where I_p = plate current.
E_p = plate volts
E_g = grid volts
μ = amplification factor of the valve.
a = constant depending on the disposition of the electrodes.
β = constant decided by the shape of the valve characteristics.
e = intrinsic potential between the filament and the system constituted by the grid and plate.

[See Van de Bijl, "Thermionic Vacuum Tube," page 156.]

e is determined by putting $I_p = 0$.

$$\text{i.e., } e = -\left[\frac{E_p}{\mu} + E_g\right]. \quad .. \quad .. \quad (8)$$

where E_p and E_g are the voltages corresponding to $I_p = 0$.

Expression (7) can be used to draw the alignment chart between I_p, E_p, and E_g.

From (7) we have that :

$$\left[\frac{I_p}{a}\right]^{1/\beta} = \left(\frac{E_p}{\mu} + e\right) + E_g$$

comparing this with

$$c = U + V$$

we have that

$$c = \left[\frac{I_p}{a}\right]^{1/\beta} \quad .. \quad .. \quad (9)$$

$$U = \frac{E_p}{\mu} + e$$

$$V = \quad E_g \text{ for } + ve \text{ bias}$$
$$= - E_g \text{ for } - ve \text{ bias.}$$

It is now necessary to decide the scales.

Let A_p = length of plate volts scale in inches.
A_g = length of grid volts scale in inches.
D = distance between the scales.
$V_a - e$ = maximum value of plate volts.
V_g = maximum value of grid volts.
I_1 = scale for plate volts.
I_2 = scale for grid volts.
I_3 = scale for plate current.

$$\text{Then } I_1 = \frac{V_a}{\mu \cdot A_p} \text{ and } I_2 = \frac{V_g}{A_g}$$

$$\therefore I_3 = \frac{I_1 I_2}{I_1 + I_2} = \frac{V_a V_g}{V_a A_g + \mu V_g A_p} \text{ amps./inch.}$$

∴ from (9) a current of I_p amps will be represented by a length of

$$\left[\frac{I_p}{a}\right]^{\frac{1}{\beta}} \times I_3 \text{ inches} \qquad .. \quad (10)$$

Also
$$\frac{AC}{CB} = \frac{I_1}{I_2} = \frac{V_a}{\mu V_g} + \frac{A_g}{A_p}$$

$$\therefore \quad \frac{AC}{AC + CB} = A_gV_a/\mu A_pV_g + V_aA_g$$

$$\therefore \quad AC = D \times A_pV_a/\mu A_pV_g + V_aA_g$$

From (8) we have that $I_p = 0$, when $E_g = -\left[\frac{E_p}{\mu} + e\right]$, thus giving the zero on the plate current scale.

The plate current scale can then be calculated according to (10).

The alignment chart can be drawn as in Fig. 2.

It is, therefore, seen that by knowing the values of a, β, and μ, the alignment chart can be drawn. Of these, a and μ depend on the design of the valve, and β is decided by the nature of the electron emission from the filament. From the chart shown in Fig. 2 we can obtain :

(1) The "plate current—grid volts" characteristics.

i.e. For any fixed value of E_p, we can determine the values of I_p corresponding to given values of E_g.

e.g., If we fix E_p at E_p', then from the chart the values of E_g corresponding to $I_p = 0$ and $I_p = I_p'$ are readily determined, and so on.

(2) The "plate volts—grid volts" characteristic for constant values of the plate current.

e.g., If I_p is fixed at 0, then the values of E_g corresponding to $E_p = V_a$ and $E_p = E_p'$ are readily determined, and so on.

(3) The "plate current—plate volts" characteristic.

i.e., For constant values of the grid volts we can easily obtain the corresponding relationship between I_p and E_p.

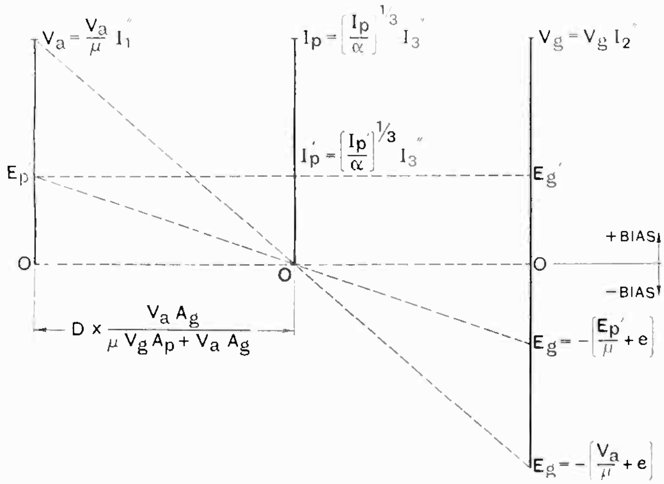


Fig. 2.

Example.

An example will now be worked out in full for a valve having the following constants.

Filament volts $= 4$
Filament current $= 0.265$ amp.
Impedance $= 6{,}000$ ohms
$\mu = 6.6$
$a = 0.068 \times 10^{-3}$

For a valve of this type e is generally small and can be neglected.

In practice β varies from about 1.6 to 2.0. In this example $\beta = 1.8$* will be used.

$$\therefore I_p = 0.068 \times 10^{-3}\left[\frac{E_p}{6.6} + E_g\right]^{1.8} \quad .. \quad (11)$$

The range of plate volts will be taken from 30 to 130 volts, and the range of grid volts will be taken from − 20 to + 10 volts.

For the plate volts let 1 volt = ¼ in. = I_1, and for the grid volts let 1 volt = ¼ in. = I_2.

$$\therefore \qquad I_3 = \frac{I_1 I_2}{I_1 + I_2} = \tfrac{1}{8}''.$$

TABLE I.

Plate Voltage Scale.

E_p	$\frac{E_p}{\mu}$	Scale Length in ¼ in.	Scale Length with $E_p = 30$ as Zero.
30 volts	4.55 volts	4.55	0
70 ,,	10.60 ,,	10.60	6.05
100 ,,	15.15 ,,	15.15	10.60
130 ,,	19.70 ,,	19.70	15.15

* This value has been found to hold for a number of valves whose characteristics were analysed.

$$\therefore \quad I_p \text{ amps} = \left[\frac{I_p}{a}\right]^{1/\beta} \times \tfrac{1}{8} \text{ inch.}$$

$$\therefore \quad I_p \text{ milliamps} = \left[\frac{I_p}{0.068}\right]^{1/1.8} \times \tfrac{1}{8} \text{ inch} \quad .. \ (12)$$

$$\text{also} \qquad \frac{AC}{CB} = \frac{I_1}{I_2} = 1. \qquad \therefore AC = \frac{D}{2}.$$

Tables 1 and 2 give the calculations necessary to graduate the plate volts and

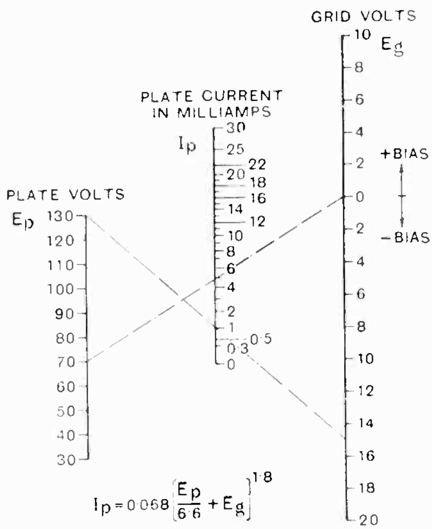


Fig. 3.

the plate current scales. Only a few of the values calculated are given. The grid volts scale is self-evident. The resulting alignment chart is shown in Fig. 3.

To obtain the alignment chart the procedure is as follows :

1. Draw the plate volts and the grid volts scales. These are parallel lines drawn in a convenient position and a suitable distance apart. In the case of Fig. 3, the distance apart is 2 inches.

2. Obtain the zero of the plate current scale. This is obtained by the method given on page 572. In the case of Fig. 3 the zero was obtained by determining the point of intersection of the lines joining $E_p = 130$, $E_g = 19.7$ and $E_p = 100$, $E_g = 15.15$, respectively.

3. Draw a line through the point of intersection parallel to the voltage scales. This line will satisfy the relation $\frac{AC}{CB} = 1$ if the voltage scales have been drawn correctly.

4. Graduate the plate current scale according to the expression given in (12).

In Fig. 3 the method of using the chart is indicated. It is seen that when $E_p = 130$ and $E_g = -15$, the resulting plate current is 1 milliamp. When $E_p = 70$ and $E_g = 0$, the resulting plate current is 5 milliamps. It was found that these values agreed with those given by the ordinary valve characteristic.

One precaution must be taken when using the alignment chart. The expression will not hold when the top bend of the "plate-current—grid-volts" characteristic is reached, therefore the plate current cannot be obtained from the alignment chart for all positive values of the grid volts. The following working rule can be used. If E_g is the value of the grid volts necessary to reduce the plate current to zero for a given plate voltage, then $E_g/3$ is the maximum positive value of the grid volts for which the plate current should be determined from the alignment chart for the given value of the plate voltage.

TABLE II.

PLATE CURRENT SCALE.

I_p in Milliamps.	$(I_p)^{1/1.8}$	$(I_p)^{1/1.8} \times \frac{0.5}{(0.068)^{1/1.8}}$	Scale Length in $\frac{1}{8}$ in.
0	0	0	0
5	2.44	5.15	5.15
10	3.60	7.90	7.90
15	4.50	9.90	9.90
20	5.30	11.65	11.65
30	6.60	14.50	14.50

Polar Diagrams Due to Plane Aerial Reflector Systems.

By T. Walmsley, B.Sc. (Lond.), Assoc.M.Inst.C.E., M.I.R.E.

IN descriptions of reflector or "beam" systems it is customary to plot the polar diagram in a horizontal plane only (*e.g.*, Marconi "Radio Communication," Proc. I.R.E., 1928, No. 1) with the result that radiation behind the reflector is shown as being either negligible or very small.

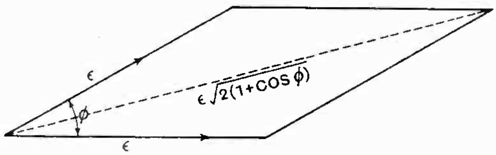


Fig. 1.

The purpose of these notes is to obtain formulæ to enable the polar diagram in any vertical plane to be plotted and thereby to explain the well-known fact that field strength behind the reflector is considerable. For this purpose the complex field due to the exciter array is calculated.

The field due to the reflector is similar to that due to the exciter, assuming similar current distribution in the wires. It differs in phase, however. The difference between the phase angles being known, then, by a simple combination of vectors an expression may be deduced which, used as a multiplier of the field strength due to the exciter, gives the total field strength of the combined aerials. The value of this multiplier, assuming equal amplitudes of currents in reflector and exciter, is $\sqrt{2(1 + \cos\phi)}$ where ϕ is the difference in phase. Fig. 1 illustrates this statement.

The problem is to ascertain the effect of a reflector upon an exciting aerial, at all angles in any vertical plane.

Take an exciter made up of a number of grounded wires and consider the electric field strength at a point P distant r_0 from the base of the exciter system.

Let P (Fig. 2) be in a plane making an angle α with the vertical plane normal to the array.

Levin and Young* have shown that the field strength E, due to a single grounded vertical antenna is

$$E = -\frac{2a}{c\,r_0}\cos\frac{2\pi}{\lambda}(ct - r_0)\cos\left(\frac{B\cos\psi}{\sin\psi}\right)$$

where $a = \frac{\pi}{2}n\left(1 + \frac{4d_0}{\lambda_0}\right)$

$n = \frac{\lambda}{\lambda} = 4 \times \frac{\text{length of ungrounded antenna}}{\text{operating wavelength.}}$

d_0 = distance of lower end of antenna from ground ($= o$ in this case).

$\beta = \frac{\pi}{2}n$

ψ = angle between horizontal and line jointing P to the base O of the antenna, and c = velocity of light.

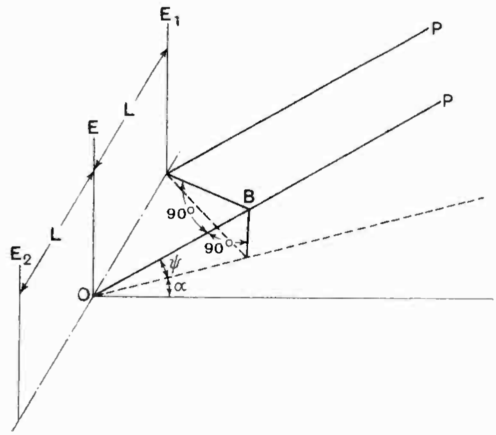


Fig. 2.

Now consider an array such as shown in Fig. 2 having equal currents in each wire. All lines drawn from P to each reflector wire may be regarded as parallel.

Hence the value of the electric field at P due to the current in E_1 will be equal in amplitude and similar in wave form to that

* *Proc. I.R.E.*, Vol. 14, No. 5, 1926.

due to the current in E. It will, however, lead in phase by an angle proportional to the length OB.

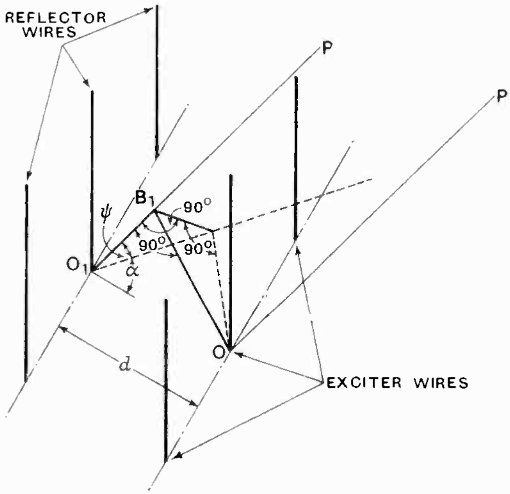


Fig. 3.

If $OB = X$, the angle of lead $= \frac{X}{\lambda} . 2\pi$,

but $X = L \cos\psi \sin\alpha$

where L = distance between wires.
ψ = angle between OP and horizontal.
α = angle between the plane and the plane normal to the array.

$$\therefore \quad \text{Angle of lead} = \frac{2\pi L}{\lambda} \cos\psi \sin\alpha$$

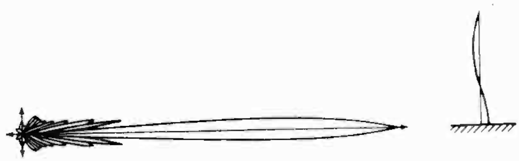
Also the angle of lag of wave due to E_2 is equal to the angle of lead of wave due to E_1. Thus if there are N wires on each side of the centre wire

$$E = -\frac{2a}{c\,r_0}\frac{\cos(\beta \sin\psi)}{\cos\psi}\Big[\cos\frac{2\pi}{\lambda}(ct - r_0)$$
$$+ \cos\frac{2\pi}{\lambda}(ct - r_0 + L\cos\psi\sin\alpha)$$
$$+ \ldots . \cos\frac{2\pi}{\lambda}(ct - r_0 + NL\cos\psi\sin\alpha)$$
$$+ \cos\frac{2\pi}{\lambda}(ct - r_0 - L\cos\psi\sin\alpha)$$
$$+ \ldots . \cos\frac{2\pi}{\lambda}(ct - r_0 - NL\cos\psi\sin\alpha)\Big]$$
$$= -\frac{2a}{cr_0}\frac{\cos(\beta\sin\psi)}{\cos\psi}$$
$$\times \frac{(\cos\frac{2\pi}{\lambda}(ct - r_0)\sin\left\{\frac{2N+1}{\lambda}.L\cos\psi\sin\alpha\right\}}{\sin\frac{(\pi L}{\lambda}.\cos\psi\sin\alpha)}$$

To find the phase lag due to an identical system of reflector wires, consider Fig. 3. Then the lag is due to three causes: (i) the time taken by an exciting pulse to travel across distances d; (ii) the lag between the arrival of the exciting pulse at the reflector and the resulting radiated wave; (iii) the time taken by the reflected wave to travel through the distance $O_1B_1 = b$ where OB_1 is perpendicular to O_1B_1.
Now $b = d \cos\psi \cos\alpha$

$$\text{Angle of lag} = \frac{2\pi d}{\lambda} + \pi + \frac{2\pi d}{\lambda}\cos\psi\cos\alpha$$
$$= \frac{2\pi d}{\lambda}[1 + \cos\psi\cos\alpha] + \pi$$

There is considerable controversy as to the justification for regarding the lag due to the distance d as $\frac{2\pi d}{\lambda}$. According to Fleming the magnetic field travelling with infinite speed is the exciting influence upon the reflector. Fleming, however, confines his remarks to reflectors spaced $\lambda/4$ from the exciter. He makes no reference to reflectors spaced more than $\lambda/4$, at which distance true radiation due to the exciting aerial is stated to begin. Sometimes a reflector is placed $3\lambda/4$ behind the exciting aerial and as



(a) (b)

Fig. 4.

at this distance the influencing magnetic field will be much less than that due to the exciter electric radiation, there would appear to be some justification for accepting the value $\frac{2\pi d}{\lambda}$ for the lag. Again, the value π for the phase angle between exciting influence and reflected radiation might be too great. However, even if π is too great and a correct value is, say, δ, the sum $\frac{2\pi d}{\lambda} + \delta$ can be made equal to the value assumed in the calculation by increasing the distance d.

The need for a reflector which is readily capable of horizontal adjustment is thus apparent. Although a knowledge of the accurate value of the phase angle difference is essential for exact calculation, inaccuracy does not vitiate the general conclusion of this article.

Results.

In Figs. 4 to 6 the polar diagrams for various values of α are given for a 15-wire

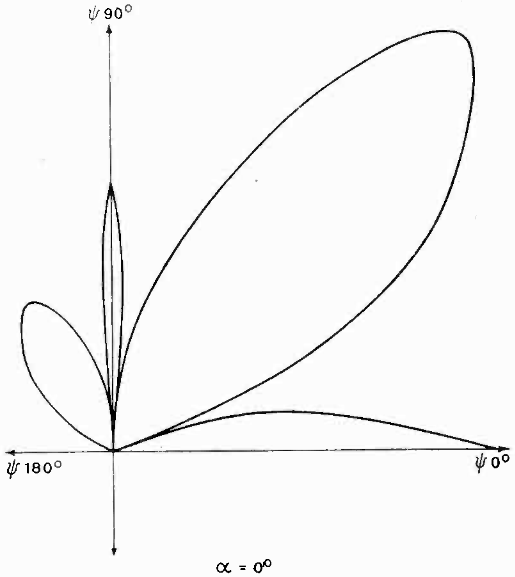


Fig. 5.

aerial with a 15-wire reflector, the spacing between wires being 0.62λ and the reflector λ/4 behind the exciter. These have been obtained by multiplying the value of E due to the exciter by the reflector expression $\sqrt{2(1 + \cos\phi)}$ where ϕ

$$= \frac{2\pi d}{\lambda}[1 + \cos\psi\cos\alpha] + \pi$$

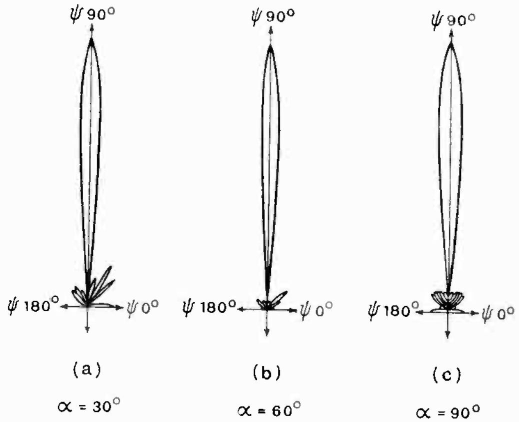


Fig. 6.

Fig. 4a shows the horizontal polar diagram. Fig. 4b shows the assumed current distribution. Horizontal radiation behind the reflector is here seen to be zero or approximately zero. The remaining curves give, for the particular type of aerial excitation considered, the radiation in vertical planes making angles of 0 deg., 30 deg., 60 deg. and 90 deg. to the normal to the array. When this angle is 0, *i.e.*, in the normal plane, the backward radiation about an angle of 120 deg. to the horizontal is quite considerable. The refraction or reflection of this radiation by the upper ionised layer will thus give rise to an appreciable field strength behind the reflector.

Abstracts and References.

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PROPAGATION OF WAVES.

LES PHÉNOMÈNES DE PROPAGATION DES ONDES RADIOTÉLÉGRAPHIQUES (The phenomena of propagation of radio-telegraphic waves).—R. Jouast. (*Comptes Rendus*, 23rd July, 1928, V. 187, pp. 208–209.)

The writer maintains that the usual "ionised layer" theory is inadequate, and that it does not cover the phenomenon of echoes, single or multiple, shown by the "jab" method of short signals; for not only are these echoes apparent a few kilometres from the transmitter (whereas rays reflected from such a layer would only return to earth at much greater distance), but they appear to come from a height of 200–400 km., this height often varying within a few seconds. Maurain and others have shown that the relations between solar activity and terrestrial magnetic conditions suggest that the variations of the magnetic constants are due to an ionisation at great altitude produced by those solar particles whose arrival in our atmosphere is often signalised by aurora. The facts that the "echoes" seem to come from a height corresponding with that of the aurora, and that the characteristic green auroral ray is visible in all latitudes, make the writer believe that the same agents produce electron-clouds, of dimensions comparable with the length of wave, at high levels. These clouds would be capable of diffusing the waves in all directions.

THE DIAMAGNETIC LAYER OF THE EARTH'S ATMOSPHERE AND ITS RELATION TO THE DIURNAL VARIATION OF TERRESTRIAL MAGNETISM.—Ross Gunn. (*Phys. Rev.*, July, 1928, V. 32, pp. 133–141.)

An investigation of the motion of ions and electrons in the region of long free paths shows that the electrical conductivity in the direction of the earth's magnetic field is that predicted by simple theory. A theory of the diurnal magnetic variation is worked out which explains quantitatively the major phenomena in terms of the diamagnetic effect produced by ions spiralling about the earth's magnetic field. The average maximum number of ions of all kinds per cm.^{3} in the upper atmosphere is computed from observed magnetic data, and found to be about 5×10^{10}, a number not inconsistent with the ionic density inferred from radio phenomena.

THE STUDY OF SIGNAL FADING.—E. V. Appleton. (*Journ. I.E.E.*, August, 1928, V. 66, pp. 872–881.)

An account of recent work of the Peterborough Radio Research Station of the Department of Scientific and Industrial Research. The method chiefly employed is the wavelength change method. The paper deals particularly with the investigation on waves within the broadcasting band. Among the conclusions arrived at may be mentioned: (1) Fading is chiefly due to the effects of intensity variations, and to a less extent phase-variations, of rays deviated from the upper atmosphere; (2) there are nights when, during the period before dawn, the ionisation in the Kennelly-Heaviside layer has been sufficiently reduced by recombination to permit of its penetration by waves of this frequency, which are, however, deviated by an upper layer richer in ionisation. At sunrise, solar radiation reforms the Kennelly-Heaviside layer at a height of about 100 km.; (3) the downcoming ray is approximately circularly polarised with a left-handed rotation: possibly by the influence of the earth's magnetic field—a critical test would be to repeat in the Southern Hemisphere. The application of the methods to the Solar Eclipse observations is described. The paper is followed by a discussion (pp. 881–885).

RADIO TRANSMISSION FORMULÆ.—G. W. Kenrick. (*Phil. Mag.*, August, 1928, V. 6, pp. 289–304.)

By an application of the optical point of view, and a direct summation of the reflected rays, the author derives an expression for the field between two concentric conducting spheres, and considers its application to the problem of long-distance radio communication. The first part of the work, dealing with propagation between two perfectly conducting planes, is not limited to long-distance, long-wave communication; but certain approximations introduced in correcting for earth curvature and for finite conductivity need further investigation before the method can be applied to short-wave communication over short or moderate distances. On long-wave, long-distance work the author compares his formulæ with the original Austin formulæ.

RECENT RESEARCH IN GREENLAND ON TERRESTRIAL MAGNETISM.—de la Cour. (*Nature*, 28th July, 1928, V. 122, p. 153.)

A paragraph regarding a paper read before the Royal Danish Academy of Science and Letters, on the work of the Godhavn Observatory, where research on magnetic variations near the Magnetic Pole is being carried on.

ZUR THEORIE DER LICHTZERSTREUUNG IN DER ERD-ATMOSPHÄRE (The Theory of Light Dispersion in the Earth's Atmosphere).—J. J. Tichanowsky. (*Physik. Zeitschr.*, 1st July, 1928, V. 29, pp. 442–447.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

ATMOSPHERIC MEASUREMENTS AT THE SHUAN-CHIAO RADIO STATION.—Kinase, Maeda and Saito. (*Journ. I.E.E., Japan*, April, 1928, pp. 427–445.)

ON THE SOURCES OF ATMOSPHERICS RECEIVED IN JAPAN.—J. Obata. (*Journ. I.E.E., Japan*, July, 1928, pp. 712–721.)

Among the conclusions may be mentioned that a permanent source of atmospherics (except in winter) seems to exist at a bearing 300° to 330° from Tokio.

Another seems to be in the S.W. direction, presumably in the tropics: disturbances from here continue in the winter.

OBSERVATIONS SUR LES PERTURBATIONS ATMOSPHERIQUES DANS LES ÎLES KOURILES SEPTENTRIONALES (Atmospherics in the N. Kurile Islands).—Nagashima and Matsudaira. (*Journ. I.E.E., Japan*, March, 1928, pp. 277–283.)

The directional measurement was carried out on a receiver with cardioid polar diagram and tuned to 7,700 m. Intensity and number per minute were judged by the shunted telephone method. Disturbances were more intense at night than by day, and increased from July to August and September. The majority came from the direction of the mountainous parts of the island and of the Kamschatka peninsula. No definite correlation between atmospherics and meteorological conditions could be defined, but showers and storms were always preceded by a continuous whistling lasting several minutes.

ON THUNDERSTORMS IN JAPAN AND RECENT THEORIES OF THUNDER ELECTRICITY.—S. Fujiwara. (*Journ. I.E.E., Japan*, June, 1928, pp. 634–646.)

RENDERING VISIBLE A MAGNETIC FIELD.—Elihu Thomson. (*Scientific American*, September, 1928, pp. 236–239.)

The author describes an optical phenomenon due to the effect of a magnetic field on the iron smoke produced by an electric welder, and suggests that it offers an explanation of the Zodiacal light.

LARGE MAGNETIC STORMS AND LARGE SUNSPOTS.—Greaves and Newton. (*Monthly Notices Roy. Astron. Soc.*, May, 1928; summarised in *Nature*, 4th August, 1928.)

Discusses the occurrence of sunspots at the time of magnetic storms for the years 1874 to 1927.

ELECTRIC POTENTIAL GRADIENT MEASUREMENTS AT ESKDALEMUIR, 1913–23.—R. A. Watson. (*Geophys. Mem. Met. Office*, No. 38, 1928; summarised *Nature*, 18th August, 1928.)

Contrary to Bauer's conclusion from the first eight years' data, the writer finds no significant indication of a connection between sunspot numbers and the departure of the mean gradient in any month from its eleven-year mean for that month. A theory of the connection between gradient and wind is outlined.

THE REDUCTION OF ATMOSPHERIC DISTURBANCES.—J. R. Carson. (*Proc. I. Rad. Eng.*, July, 1928. V. 16, pp. 966–975.)

Analyses an arrangement which provides for H.F. selection plus L.F. balancing after detection, and refers particularly to Armstrong's recent proposal (*cf.* March Abstracts). The conclusions are entirely negative; that is, no appreciable gain is to be expected from balancing arrangements.

SUR LA LOI DE CONSTITUTION DE L'ATMOSPHÈRE (The law of atmospheric constitution).—Esnault-Pelterie. (*Comptes Rendus*, 23rd July, 1928, V. 187, pp. 241–242.)

More about the author's formula for determining altitude (*cf.* September Abstracts). He derives from his calculations the result that at a height of 5,170 metres μ is almost exactly independent of T_o, the ground temperature.

MÉTHODE PRATIQUE DE CALCUL DE LA RIGIDITÉ DIÉLECTRIQUE DE L'AIR (A practical method of calculating the dielectric strength of air).—G. Devillez. (*Bull. d. L. Soc. Belge des Élec.*, January, 1928, V. 42, pp. 1–28.)

The methods developed are shown to agree quite well with experimental results obtained with various shapes of electrodes.

PROPERTIES OF CIRCUITS.

STABILISATION DES OSCILLATIONS DE RELAXATION (Stabilisation of "oscillations of relaxation").—Bedeau and de Mare. (*Comptes Rendus*, 23 July, 1928, V. 187, pp. 209–210.)

Van der Pol has recently shown that the oscillations named by him "oscillations of relaxation" are not very constant in period. The writers have stabilised them by an electrically driven tuning fork, and by using three neon tubes—the first (thus controlled) controlling the second, the second controlling the third—have obtained simultaneously three groups of flashes, at 10^{-1}, 10^{-2} and 1 per second. The last can be compared with a chronometer. The apparatus can be adapted for determining radio frequencies (cf. Decaux, July Abstracts).

LA QUESTION D'AMPLIFICATION. II. LA RÉTROACTION.—P. Olinet. (*Q.S.T. Fran.*, Aug., 1928, pp. 52–57.)

The first paper in this series defined amplification as the functioning of a relay, and gave various examples. The present part deals with thermionic valves from this point of view, and shows that the increase of amplification due to reaction arises from modification not of the relay itself but of the output and (particularly) the input circuits. The latter part of this paper deals with the mathematical derivation of the amplification constant under various conditions of coupling.

DISTORTION CORRECTION IN ELECTRICAL CIRCUITS WITH CONSTANT RESISTANCE RECURRENT NETWORKS.—O. J. Zobel. (*Bell Tech. Journ.*, July, 1928, V.7, pp. 438–534.)

Takes up first the general problem of distortion correction, then this method of correction and its application—*e.g.*, for phase correction in the transatlantic telephone system.

ÜBER DIE SPANNUNGSVERSTÄRKUNG MITTELS TRANSFORMATORENKOPPLUNG BEIM NIEDERFREQUENZVERSTÄRKER (Voltage Amplification by Transformer-coupling in L.F. Amplifiers).—H. Reppisch. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 22–24.)

The physical constants of L.F. intervalve transformers are investigated. It is shown that where, for speech and music amplification, a uniform amplification is desired over a large frequency range, this can be obtained by using a small turns-ratio and keeping the losses small. With turns-ratio $u = 4$, a satisfactorily uniform curve over about 8 octaves can be obtained. The author quotes recent workers who have maintained that with resonance, the voltage-ratio cannot reach the magnitude of the turns-ratio, whereas he shows that under certain conditions it can actually exceed it.

SUR UN DISPOSITIF ÉLECTROMAGNÉTIQUE DE LAMPES À TROIS ÉLECTRODES (An electromagnetic arrangement of three-electrode valves).—J. F. Thovert. (*Rev. Gén. d. l'Élec.*, 28 July, 1928, V. 24, p. 152.)

The plate of the first valve is connected through a small battery to the grid of the second valve. The voltage of this battery (which may be a small dry cell) is chosen according to the valve used (between 0 and 10 v.). With a power valve in the second stage, an overall amplification of the order of 10^7 to 10^8 is obtained. The time constant is of the order of one minute.

EQUILIBRES INSTABLES ET RÉGIMES STATIQUES PARASITES DANS LES CIRCUITS ÉLECTRIQUES ASSOCIÉS AUX TRIODES (Conditions of unstable equilibrium and of parasitic disturbances in electric circuits associated with 3-electrode valves.)—Podliasky. (*L'Onde Élec.*, July, 1928, pp. 287–306.)

The present instalment deals with the internal and external characteristics of the Dynatron, but by the word dynatron is included ordinary types of valve used as a dynatron—*i.e.*, used in such a circuit that the secondary emission is preponderant.

ZUR FRAGE ÜBER DIE ENERGIEVERTEILUNG ZWISCHEN DEM SENDER UND DEM REGENERATIVEN EMPFÄNGER (The distribution of energy between transmitter and regenerative receiver).—G. Ostroumoff. (*Ann. d. Phys.*, 24th May, 1928, V. 85, pp. 1103–1112.)

TRANSMISSION.

ON THE WIRELESS BEAM OF SHORT ELECTRIC WAVES: HIGH ANGLE RADIATION OF HORIZONTALLY POLARISED WAVES.—S. Uda. (*Journ. I.E.E., Japan*, April, 1928, pp. 395–405.)

Wavelength was 260 cms. Transmitting aerial (length nearly a half wavelength) was placed horizontally above the ground; receiving aerial, also horizontal, was moved up and down in a vertical line, measuring the field intensity at various angles to the ground. Polar diagrams show that the radiation is chiefly at high angles, being very small along the earth's surface.

If height of transmitting aerial $h = \frac{\lambda}{8}$ or $\frac{\lambda}{4}$, maximum radiation will be vertically upwards; if $h = \frac{3}{8}\lambda$ or $\frac{\lambda}{2}$, it will make 45° or 30° with the horizontal. If h is increased to $\frac{5}{8}\lambda$ or $\frac{3}{4}\lambda$, two maxima appear—one upwards, the other at 25° or 20° respectively; if $h = \frac{7}{8}\lambda$ or λ, the two maxima become 60° and 15°, or 50° and 13° respectively. A series of wave directors produces added sharpness of beam, maximum radiation lying not exactly along the line of directors, but at a rather higher angle. (cf. Yagi, September Abstracts: Uda, February Abstracts).

LA DIRECTION DES ONDES RADIOÉLECTRIQUES. RADIO-COMMUNICATIONS PAR ONDES COURTES PROJETÉES (The direction of radioelectric waves. Radio communication by directed short waves).—L. Bouthillon. (*Bull. d.l. Soc. Franc. d. Physique*, 18 May, 1928, pp. 84S–85S.)

A general survey, including an outline of the general theory and of the various methods of carrying it out.

DIE ERZEUGUNG SEHR KURZER ELEKTRISCHER WELLEN MIT WECHSELSPANNUNG NACH DER METHODE VON BARKHAUSEN UND KURZ (The production of ultra-short waves by the B-K method but with A.C. voltage).—W. Wechsung. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 15–18.)

The first part of a long paper in which the author sets out to investigate, by methods using both D.C. and A.C. voltages, the results of Barkhausen and Kurz, Gill and Morell, and Sahánek, which were all based on D.C. voltage.

ÜBER DIE GÜNSTIGSTE BELASTUNG DES HOCHFREQUENZ-GENERATORS (The Optimum Loading of the H.F. Generator).—Y. Watanabe. (*E.N.T.*, July 1928, V. 5, pp. 259–267.)

Since the internal inductive reactance is considerable, it is often necessary to compensate by a capacitive reactance. The correct value is worked out for the two cases: (*a*) where the load is given in volt-ampères, and (b) for a given power-loss in the generator.

TELEPHONIE AUF EXTREM KURZEN WELLEN (Telephony on ultra-short waves).—H. E. Hollmann. (*E.N.T.*, July, 1928, V. 5, pp. 268–275.)

The transmitters described used wavelengths from 38 to 100 cms., and in a closed oscillating circuit give from 0.16 to 0.51 ampere. For telegraphy, tonic train is employed; for telephony, modulation is obtained by parallel control-valve or by D.C. modulation (grid or anode) with or without an amplifier-valve. Parallel wires with movable bridge are used as oscillating circuits both for transmitter and receiver, together with a dipole antenna, each pole of which is extensible for tuning. Using a single-valve receiver, distances of 500 wavelengths have so far been covered without using a "beam."

RECENT DEVELOPMENT IN LOW POWER AND BROADCAST TRANSMITTERS.—(*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 981–982.)

Discussion on Byrnes' paper (cf. August Abstracts) which, however, is limited to the part dealing with quantitative data on harmonic radiation.

RECEPTION.

SUR LA QUALITÉ DE LA REPRODUCTION RADIOPHONIQUE (The quality of radiophonic reproduction).—P. David. (*L'Onde Élec.*, July, 1928, pp. 309–312.)

The author's conclusion is that the average receiver is far too selective and loses too much of the higher frequencies. He recommends increasing the damping and suppressing reaction, or the use of true band filters, etc., sacrificing for good quality the number of stations received.

SPANNUNGSBEGRENZER FÜR VERSTÄRKER (Voltage Limitation for Amplifiers).—O. Kappelmayer. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 25–26.)

Former methods of automatic volume-control have worked on H.F. amplification (cf. Wheeler, these Abstracts, March, 1928). The author describes a simple method for L.F. amplifiers, using one of the "relay glow-lamps" (Richter and Heffcken) to limit the amplitude of the A.C. voltage on the grid of the final valve.

MOVING COIL MODIFICATIONS.—L. E. T. Branch. (*Wireless World*, 1 Aug., 1928, V. 23, pp. 122–124.)

The author recommends virtually short-circuiting the inductance of the moving coil by wrapping round the inside or outside with a thin strip of copper. Various advantages are described.

THE OUTPUT STAGE AND THE MOVING COIL: HOW RELATIVE IMPEDANCES AFFECT QUALITY.—N. W. McLachlan. (*Wireless World*, 8 Aug., 1928, V. 23, pp. 154–157.)

MAINS SUPPLY FOR VALVE RECEIVERS.—(*See several articles, Wireless World*, 22 August, 1928, V. 23.)

COMPROMISE IN RECEIVER DESIGN (Part 5. The H.F. Amplifier. How the Tuned Circuits Affect Quality).—(*Wireless World*, 29 August, 1928, V. 23, pp. 242–245.)

This instalment of a series begun in the issue for 25th July, contains the following sections: the comparative advantages of the screened valve and the neutrodyne: the subject of screening (not merely for the sake of stability): sensitivity and selectivity versus quality: detuning and quality: good quality with high selectivity is possible.

THE REDUCTION OF ATMOSPHERIC DISTURBANCES.—J. R. Carson. (*See under "Atmospherics."*)

FERNEMPFANG MIT MEHRFACHRÖHREN (Distant reception with multiple-valves).—R. Neuroth (*Rad. f. Alle*, July, 1928, pp. 298–304.)

Multiple valves are generally used for local reception. The writer shows how to extend their use to distant reception; taking as an example, the Loewe triple (L.F.) valve, he shows how this can be extended by 1, 2 or 3 stages of H.F. amplification; or by one Loewe double (H.F.) valve.

VALVES AND THERMIONICS.

THERMAL AGITATION OF ELECTRICITY IN CONDUCTORS.—J. B. Johnson. (*Phys. Rev.*, July, 1928, V. 32, pp. 97–109.); and THERMAL AGITATION OF ELECTRIC CHARGE IN CONDUCTORS.—H. Nyquist (*ibid.*, pp. 110–113).

The author of the first paper reports the discovery and measurement of an E.M.F. in conductors which is related in a simple manner to the temperature of the conductor and which is attributed to the thermal agitation of the carriers of electricity in the conductors. The effect is one (in fact, often the greatest) of the causes of valve noise in amplifiers. The possibility of such an effect was recognised on theoretical grounds by Schottky, who, however, concluded that it would be so small as to be masked by the small-shot ("schrot") effect. Under certain conditions this is by no means the case, *e.g.*, when a good amplifier has a high resistance between grid and filament of the first valve on the input side. The effect has also made itself felt in experiments with highly sensitive string galvanometers by Dutch workers. It seems that galvanometric measurements of D.C. of less than 10^{-12} amp. become unreliable, just as the alternating potential of 10^{-6} volt marks the critical region for amplifiers.

The second paper is a calculation of the electromotive force due to thermal agitation in conductors, by means of principles in thermodynamics and statistical mechanics. The results agree with the experimental findings.

LES DIFFÉRENTES MÉTHODES DE DÉTERMINATION DE LA CONDITION D'ENTRETIEN DES OSCILLATIONS DANS LES ÉMETTEURS À LAMPES (The different methods of determining the conditions for the maintenance of oscillations in valve transmitters).—F. Bedeau. (*L'Onde Élec.*, July, 1928, pp. 265–286.)

A comparison of the four "classic" methods: Gutton's, where the negative end of the filament is taken as the origin of potentials; Hull's, where the valve is regarded as a relay; the method where the valve is regarded as a circuit of negative resistance (adopted by Blondel and Gutton); and the method based on "curves of work and coupling" (Groszkowski). Among other applications, the case of a tuned amplifier using screened grid valves is dealt with.

SCHROT-EFFECT IN HIGH FREQUENCY CIRCUITS.—S. Ballantine. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 159–167.)

The writer points out that all the theoretical work done hitherto on the schrot-effect in thermionic circuits has considered only the gross phenomena, and the assumption underlying all this work has been that the period of the LC-circuit connected to the schrot-tube is long compared with the time of passage of the electron. He therefore investigates the effect in H.F. circuits, when this condition no longer obtains and a microscopic view of the electron's flight must be taken.

UNE SUGGESTION NOUVELLE POUR AUGMENTER L'EFFICACITÉ DE LA DÉTECTION (A New Suggestion for increasing the Efficiency of Detection).—J. Marcot. (*Q.S.T. Fran.*, August, 1928, p. 42.)

For the detection of weak signals by grid-circuit rectification, the efficiency is greater the slower the electrons. Postumus separates out the slower electrons by means of a magnetic field, leading them to a special grid and thus improving detection.

EINE GROSS-VERSTARKERRÖHRE MIT QUECKSILBERDAMPF (A high-power Mercury Vapour Valve).—E. Lübcke. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 1–10.)

This valve works at 220 v., with an anode current up to 5 amps. (in special cases up to 14 amps.), which is controlled by a grid. Internal resistance is about 70 ohms. It is thus suitable for power work as well as for many other purposes. Applications described include: the regulation of generators and motors; as power valve for powerful loud speakers; as generator for note-frequencies (500–20,000 cycles) and as amplifier down to wavelengths of 100 metres. The work has been done at the Siemens Laboratory.

THE EFFECTS PRODUCED BY POSITIVE ION BOMBARDMENT OF SOLIDS: METALLIC IONS.—M. L. Oliphant. (*Proc. Camb. Phil. Soc.*, July, 1928, V. 24, pp. 451–479.)

The primary object of these experiments was to deduce something of the nature of the energy exchange in a collision between ion and atom in the surface of the bombarded substance, by measurements of the minimum potential required to produce sputtering. They were unsuccessful in this respect, but revealed several points of interest: *e.g.*, the magnitude of the effects which have to be attributed to layers of absorbed gas over the target, and the support given to the photo-electric theory of the production of electrons by neutralisation of positive ions at the cathode.

IONEN UND ELEKTRONEN IN DER VAKUUMGLÜHLAMPE (Ions and electrons in incandescent lamps).—P. Selényi. (*Physik. Zeitschr.*, 15th May, 1928, V. 29, pp. 311–318.)

Among other things, the writer shows how the lamp can be used as detector, magnetron, photocell and vacuum-meter; and describes methods by which the vacuum of a completed lamp may be determined.

ÜBER DIE VERGRÖSSERUNG DES SATTIGUNGSSTROMES VON GLÜHKATHODEN DURCH STARKE ELEKTRISCHE FELDER (The Increase of Saturation Current through Strong Electric Fields).—W. S. Pforte. (*Zeitschr. f. Phys.*, 8th June, 1928, V. 49, pp. 46–51.)

Tests are quoted from which it would appear that Schottky's theory holds good from 1,400 to 2,100° abs., and for fields up to 0.7.10⁶V/cm.

ÜBER DEN MECHANISMUS VON ELEKTRONEN SCHWINGUNGEN (The Mechanism of Electron-oscillations).—H. E. Hollmann. (*Ann. d. Phys.*, 5th June, 1928, V. 86, pp. 129–187.)

Four different frequency zones have been found, with the circuit arrangements used by Barkhausen and Kurz, Gill and Morrell. The shortest wave so far obtained was 21.4 cm., but one of 15 cm. is indicated as being obtainable.

DIRECTIONAL WIRELESS.

DEVELOPMENT OF RADIO AIDS TO AIR NAVIGATION.—Dellinger and Pratt. (*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 890–920.)

Deals chiefly with more or less unsuccessful attempts to adapt the "equi-signal zone" crossed-coil beacon (referred to in the August and September Abstracts) to give satisfactory visual indication, leading up to an apparently highly successful conclusion. The goniometer now has two sets of rotor coils in series, each set being in the field of one of the stator coils. This reduces the coupling between the latter; it is further reduced by screening and by earthing the rotor systems at their mid-points. Two independent modulation frequencies (65 and 85) are supplied, taking the place of the interlocked "A" and "N" signals; two vibrating polarised steel or composite reeds are used as indicators, their tips being white in a dark background so that when vibrating each appears as a white line: if the pilot is on the right course, the two white lines are equal. Successful flights have been made up to 135 miles, in fog and over hazardous mountain terrain. The beacons will be placed not over 200 miles apart. Small "marker" beacons at intervals along the route will send out characteristic signals showing on the visual indicator what point is being flown over.

RADIO DIRECTION-FINDER: PART I—THE THEORY OF THE FRAME AERIAL: AVOIDING ELECTROSTATIC PICK-UP.—R. L. Smith-Rose. (*Wireless World*, 15th August, 1928, V. 23, pp. 186–188.)

The second and final instalment, giving design data for a practical direction finder, appears in the issue dated 29th August.

MEASUREMENTS AND STANDARDS.

STUDY ON THE NATURAL ELECTRICAL OSCILLATIONS OF CONICAL COILS.—I. Yamamoto. (*Journ. I.E.E., Japan*, April, 1928, pp. 375–383.)

EINE EINFACHE METHODE ZUR MESSUNG DER EIGENWELLENLÄNGE VON ANTENNEN (A Simple Method of Measuring the Natural Wavelength of an Aerial).—H. Bruun. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, p. 25.)

Methods depending on plotting curves, with varying inductance and capacity in series with the aerial, demand at least six or eight observations. The present method is designed to obtain an equal accuracy with one single observation. A small valve transmitter calibrated in wavelengths is very loosely coupled to a loop connected in series with the aerial. Resonance results in a minimum grid current, as shown on an indicator included in the instrument. It is not clear how allowance is made for the effect of the added loop.

THE NATURAL PERIOD OF LINEAR CONDUCTORS.—C. R. Englund. (*Bell Tech. Journ.*, July, 1928, V. 7, pp. 404–419.)

Describes the experimental determination of the frequency of free electrical oscillation of straight rods and circular loops. The results agree more closely with Abraham's formula ($\lambda/l = 2$, with a correcting term) than with Macdonald's ($\lambda/l = 2.53$). The writer found that a quarter wavelength Lecher frame was a very satisfactory wavemeter for the short waves, giving easily an accuracy of 1 part in 2,500.

DIE PHYSIKALISCHEN GRUNDLAGEN UND DIE TECHNIK DER FELDSTARKEMESSUNG IN DER DRAHTLOSEN TELEGRAPHIE (The theory and practice of Field Strength Measurement in Wireless).—M. Bäumler. (*T.F.T.*, July, 1928, V. 17, 193–199.)

Based on the methods of the German G.P.O.

CHARACTERISTICS OF CERTAIN BROADCASTING ANTENNAS AT THE S. SCHENECTADY DEVELOPMENT STATION.—H. M. O'Neill. (*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 872–889.)

The radiation efficiencies of various types of broadcast aerials are compared by field intensity measurements on a constant radius several wavelengths long. The comparisons are subject to the limitation that in thus comparing different aerials it is not certain to what extent an increased average intensity is due to greater concentration of power close to the horizon rather than to increased radiation efficiency. The measure of radiated power is expressed in arbitrary units, the author considering the present radiation formula and field intensity standard to be insufficiently correct to justify expressing the result in Watts.

The effect on signal strength, as measured locally, of varying aerial height is considered; also the effect of high steel towers on aerials operated at 380 m. wavelengths. Aerial ground system losses, local radiation losses, directional effects and field distortion are discussed to a limited extent.

SOME PRACTICAL APPLICATIONS OF QUARTZ RESONATORS.—Cobbold and Underdown. (*Journ. I.E.E.*, August, 1928, V. 66, pp. 855–871.)

GERÄUSCHMESSUNGEN IN FLUGZEUGEN (Noise Measurements in Aircraft).—Fassbender & Krüger. (*Luftf. forsch.*, 7th May, 1928, V. 1, pp. 117–120).

The noises in various types of aeroplanes were measured by the use of the Siemens-Barkhausen noise-meter. Tables are shown giving the results for varying motor-revolutions and various observation-points.

A SIMPLE METHOD OF MEASUREMENT OF CAPACITY AND HIGH RESISTANCE BY MEANS OF A THERMIONIC VALVE.—G. R. Toshniwal. (*Journ. Sci. Inst.*, July, 1928, V. 5, pp. 219–221.)

Charging a capacity by means of a suitable battery and discharging it through the grid-filament circuit, provided with a suitable leak, allows very small capacity values (*e.g.*, down to 5 cm.) to be determined within 1 per cent. By a similar process, values of high resistance have been obtained.

THE MEASUREMENT OF CAPACITANCE IN TERMS OF RESISTANCE AND FREQUENCY.—Ferguson and Bartlett. (*Bell Tech. Journ.*, July, 1928, V. 7, pp. 420–437.)

The adaptation of a bridge circuit allows such measurement to be made with an accuracy comparable with that of the primary standards. No general limitation is placed on the type of condenser or on the frequency at which the measurement may be made. The method is also applicable to the determination of inductance.

THE MEASUREMENT OF HIGH D.C. POTENTIAL DIFFERENCES WITH APPLICATIONS TO THE CALIBRATION OF ELECTROSCOPES AND ELECTROSTATIC VOLTMETERS.—W. Bender. (*Journ. Opt. Soc. Am.*, July, 1928, V. 17, pp. 72–76.)

An arrangement of series condensers, switches, and a ballistic galvanometer is discussed, by means of which measurements can be made with considerably greater precision than that given by ordinary high voltage electrostatic voltmeters.

THERMOSTAT DESIGN FOR FREQUENCY STANDARDS. —W. A. Morrison. (*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 976–980.)

Discusses the advantages of the use of a "temperature attenuating" layer, interposed between the object to be controlled and the region about the responding element; and the best design of such a layer.

SUR LES FORCES ÉLECTROMAGNETIQUES S'EXERÇANT ENTRE CONDUCTEURS (The Electromagnetic Forces Between Conductors).—W. F. Dunton. (*Rev. Gén. de l'Élec.*, 12th May, 1928, V. 23, pp. 819–824.)

The author points out the errors arising when formulæ based on infinitely long conductors are applied in the calculation of apparatus. He derives the correct formulæ for calculating the force between two conductors, parallel or inclined to each other.

traversed by currents of known intensity; and also deals with the case of a moving conductor sliding perpendicularly to two parallel conductors. (*Cf.* "A New Ammeter," August Abstracts.)

THE MEASUREMENT OF THE DEPARTURE OF A WAVE FORM FROM THE SINE-WAVE FORM.—Benischke and Hammerer. (*E.T.Z.*, 26th July, 1928, V. 49, pp. 1136–1137.)

Conclusion of the argument referred to in September Abstracts.

THE APPLICATION OF A VALVE AMPLIFIER TO THE MEASUREMENT OF X-RAY AND PHOTO-ELECTRIC EFFECTS.—C. E. Wynne-Williams. (*Phil. Mag.*, August, 1928, V. 6, pp. 324–334.)

A THERMIONIC VOLTMETER FOR MEASURING THE PEAK VOLTAGE AND THE MEAN VALUE OF AN ALTERNATING VOLTAGE OF ANY WAVE-FORM.—G. B. Moullin. (*Journ. I.E.E.*, August, 1928, V. 66, pp. 886–895.)

The application of the arrangement here described is illustrated by curves showing the distortion produced by a 4-stage amplifier.

THE APPLICATION OF THE PHONODEIK IN DETERMINING THE PERFORMANCE OF ELECTRO-ACOUSTIC DEVICES.—Miller and Martin. (*Phys. Review*, No. 4, 1928, V. 31, p. 708.)

By this instrument, a sound wave can be photographed as it is received by the ear. Thus the tone as reproduced by some electro-acoustic device can be compared with the original.

ÜBER NEUERE AKUSTISCHE UND INSBESONDERE ELEKTROAKUSTISCHE ARBEITEN (Latest Work on Acoustics and in particular Electro-acoustics).—F. Trendelenburg. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 27–35.)

This first part of a long survey is limited to Acoustic Methods of Measurement, Sound Analysis, Determination of Frequency Curves of Acoustic Filters, acoustic impedance measurements, etc. Future instalments will deal with sound-field processes; the acoustics of rooms; sound-senders and sound-receivers.

SUR LA DISTORSION TÉLÉPHONIQUE ET SA MESURE (Telephonic distortion and its measurement).—P. David. (*Rev. Gén. d. l'Élec.*, 21st July, 1928, V. 24, p. 22D.)

A method depending on the transmission of lists of meaningless monosyllables and the use of the percentage of errors as a measure of the distortion.

A SHIELDED BRIDGE FOR THE MEASUREMENT OF INDUCTANCE IN TERMS OF RESISTANCE AND CAPACITY.—B. W. Bartlett. (*Journ. Opt. Soc. Am.*, June, 1928, V. 16, pp. 409–418.)

This modification of the Owen Bridge will measure inductance at frequencies up to 50,000 cycles with an accuracy limited only by the accuracy with which standards of resistance and capacity can be obtained. In the case described, this was ± 0.003 per cent. at speech and ± 0.05 per cent. at carrier frequencies.

ÜBER PONDEROMOTORISCHE WIRKUNGEN DES LICHTES AUF UNGELADENE SUBMIKROSKOPISCHE KÖRPER IM ELEKTRISCHEN FELDE (Ponderomotive effect of Light on uncharged submicroscopic bodies in electrical fields).—G. Placzek. (*Zeitschr. f. Phys.*, 4th July, 1928, V. 49, pp. 601–603); and ZUM PROBLEM DES RADIOMETERS (The Radiometer Problem).—I. Bleibaum. (*Ibid.*, pp. 590–600.)

MEASUREMENTS OF RADIANT ENERGY BY MEANS OF THE MAXWELL-BARTOLI FORCES.—del Nunzio. (*Ann. R. S. Ing.*, Padua, March, 1927.)

A paper describing the use of the pressure of radiation as a means of measuring the energy contained in a bundle of rays.

A GRAPHICAL METHOD FOR CALCULATIONS BY AUSTIN'S FORMULA.—N. P. Suvorov. (*Telegraphia i. Telefonia b.p., Nichny-Novgorod,* June, 1928, V. 9, pp. 251–258.)

CALCULATION OF RADIATION RESISTANCE FOR DIRECTIVE SHORT-WAVE ANTENNÆ.—A. Pistolkors. (*Teleg. i. Telef. b.p., Nichny-Novgorod,* June, 1928, V. 9, pp. 333–347.)

SUBSIDIARY APPARATUS AND MATERIALS.

AN AMPLIFIER TO ADAPT THE OSCILLOGRAPH TO LOW-CURRENT INVESTIGATIONS.—S. K. Waldorf. (*Journ. Am. I.E.E.*, Aug., 1928, V. 47, pp. 594–597.)

The use of the D'Arsonval oscillograph can be extended by the specially selected amplifier to currents down to about 5 effective microampères at 1 effective volt.

NOTE SUR QUELQUES PERFECTIONNEMENTS DES AMPLIFICATEURS À COURANT CONTINU (Some improvements in amplifiers for continuous current).—Jouaust and Décaux. (*L'Onde Élec.*, July, 1928, pp. 306–308.)

For the amplification of very small differences of D.C. potential, the writers have avoided the complication of many stages by a specially designed two-stage arrangement. The first valve is chosen to have great amplification and high internal resistance, the second so as to give the maximum current variation for a given grid voltage change. The circuit is very stable, and an input variation of 0.005 V produces a change in output current of 2.5 mA.

NOUVEAU DISPOSITIF STABILISATEUR DE TENSION, SYSTÈME SOULIER (New arrangement for stabilisation of voltage, system Soulier).—(*Rev. Gén. de l'Élec.*, 4th Aug., 1928, V. 24, p. 196.)

A more complete exposition of the arrangement referred to in the August Abstracts. The solenoid with its self-adjusting iron core is connected in series with the condenser and the combination placed across the mains, the working voltage being taken from the condenser terminals. The vectors U_s and U_c, representing the voltages across solenoid and condenser respectively, are each at right angles (in the ideal case) to the vector of the current circulating in the system, and are therefore opposed ; if U_r represents the vector of the mains voltage,

$$U_r = U_s - U_c,$$

so that any variation in U_r can be compensated for by a suitable variation in U_s, keeping U_c constant. The condenser used is 200 μF, and the iron core weighs about 2 kg.

Ein Wechselstromkompensator mit Grossen Frequenzumfang (An A.C. compensator with wide frequency-range).—K. Lion. (*E.N.T.*, July, 1928, V. 5, pp. 276–283.)

A simple apparatus consisting of two field coils at right angles, with two rotor coils mounted side by side on the common axis of the whole system. Each rotor can be adjusted separately. The application to amplifier measurements, the quantitative determination of harmonics in amplifiers, microphones, etc., the measurement of mutual inductance, permeability, etc., is described.

Un Nouvel Isolant—la Thiolite (A new insulating material, Thiolite).—(*Bull. d.l. Soc. Fran. des Élec.*, June, 1928, V. 8, pp. 647–648.)

A white powder, capable of being moulded, obtained by the introduction of sulphur into bakelite. Being soluble in alcohol, etc., it can be used as varnish. Resistivity is of the order of 300 million megohms/centimetre, dielectric strength is high and H.F. losses small. S.I.C. is 4.5.

Primary Wet Cells.—A. M. Codd. (*Elec. Rev.*, 10th August, 1928, V. 103, pp. 223–226.)

Includes a description of the "Codd" primary cell using a zinc mushroom-form element, one or more carbon plates or rods, and an electrolyte of ferric chloride. 1.2V is the working voltage.

Ein Elektrometer Für Messung Sehr Hoher Gleich- und Wechselspannungen (An Electrometer for very high direct and alternating potentials).—Starke and Schroeder. (*Arch. f. Elektrot.*, June, 1928, V. 20, pp. 115–122.)

This instrument will measure up to 300 kilovolts with accuracy, and can be designed for still greater voltages.

See also H. Dember, *Phys. Zeitschr.*, 1st June, 1928), "A Simple Arrangement for Measuring High Electric Potentials.")

Renseignements sur une Nouvelle Matière Isolante pour la Haute Tension (Information on a new high tension insulating material).—W. Meyer. (*Rév. Gén. de l'Élec.*, 30th June, 1928, V. 23, p. 244D.)

Extract from *Bull. A.S.E.*, 22nd March, 1928, concerning "Di-El" manufactured at Oerlikon : a distillation product which is non-hygroscopic and unaffected by the atmosphere : resistance to compression 800 kg./cm², to extension 500 kg., to bending 550–1,400 kg. It stands up to very high pressures in air or in oil : no actual values are here given.

Étude des Valves de Redressement (Rectifiers of valve form).—Y. Doucet. (*Q.S.T. Franç.*, July, 1928, pp. 5–11.)

I. Electronic valves : the original Fleming valve and its descendants, including the Kenotron. Limited to small currents, the largest output mentioned (so far as valves on the "amateur" market are concerned) being 125 mA. at 200 v. II. Electro-ionic valves, type Tungar, Raytheon and mercury vapour arc. The last is specially praised for its efficiency and reliability, for voltages 100–500 and currents 1 to 50 A.

Das Glimmlichtrohr als Gleichrichter von Wechselströmen (Blue-glow valves as A.C. Rectifiers).—G. Seibt. (*E.T.Z.*, 19th July, 1928, pp. 1077–1079.)

General physical principles are discussed, half-wave and full-wave rectification are compared, various types of valve illustrated and their performances compared ; and finally improved "Anotrons" (the largest giving 250 mA. at 1,000 v.) are described in which two anodes and a specially shaped cathode improve the efficiency, the second anode reducing the cathode fall by providing the necessary electrons and ions.

The Direct-current Transformer Utilising Thyratron Tubes.—D. C. Prince. (*G.E. Review*, July, 1928, V. 31, pp. 347–350.)

A few years ago, Pliotrons were made to function as "inverters" and thus to complete the process D.C.–A.C.–A.C.–D.C. For power applications, the thyratron (one form of which consists of a mercury-arc rectifier with a grid added to each anode) appears likely to supersede the pliotron inverter, owing to its smaller loss.

Redresseur à Simple Effet ou Redresseur à Double Effet ? (Half wave or full wave rectifier ?).—A. Vernay. (*Q.S.T. Franç.*, July, 1928, pp. 20–24.)

This investigation ends with the conclusion that the full-wave rectifier is much to be preferred on economic grounds.

Some Experiments on Geiger Ion Counters.—R. D. Bennett. (*Journ. Opt. Soc. Am.*, May, 1928, V. 16, pp. 339–354.)

It is concluded that the counter is a very sensitive instrument for detecting single ions, an only moderately sensitive detector of ultra-violet light because of low efficiency, and that it is primarily a qualitative instrument though of possible quantitative use subject to the difficulty of keeping the sensitivity constant over long periods.

STATIONS, DESIGN AND OPERATION.

MULTICOMMUNICATION GÉNÉRALISÉE PAR TRÈS COURTES ONDES ÉLECTRIQUES (Multiplex communication by very short waves).—A. Turpain. (*Bull. d.l. Soc. Fran. des Élec.*, June, 1928, V. 8, pp. 570–593.)

This paper was read in 1925, but its publication has been delayed on account of patent processes. It outlines a system of telegraphy and telephony on very short waves, generated by very symmetrical thermionic apparatus and propagated along one common non-inductive conductor which may simultaneously serve other purposes.

THE CUPAR RECEIVING STATION OF THE TRANS-ATLANTIC TELEPHONE SYSTEMS.—(*Engineering*, 24th August, 1928, V. 126, pp. 225–228.)

A technical outline of the whole equipment, with photographs.

POSTES PORTATIFS À ONDES COURTES (Portable short-wave stations).—(*Bull. d.l. Soc. Fran. Radioél.*, April–May, 1928, V. 2, pp. 3–8.)

The apparatus described is designed to be suitable for rough transport and for all climates, and includes military and aircraft sets. Wavelengths vary from 10 to 100 m.; thoriated filament valves are employed for transmission.

TRANSATLANTIC SUCCESS ON 10 METRES: A DESCRIPTION OF THE APPARATUS USED IN SUCCESSFUL TWO-WAY AMATEUR COMMUNICATION.—P. Auschitzky. (*Wireless World*, 15th August, 1928, V. 23, pp. 201–202.)

NOTE ON THE EFFECTIVE HEATING OF CODE TRANSMITTERS.—F. E. Terman. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 802–804.)

Owing to the fact that Morse Code transmission only occupies the transmitter 46.5 per cent. of the time, the average rate of heating is only 46.5 per cent. of that during a long dash; the percentage is still less for fast sending where the times taken for the current to rise and fall are appreciable fractions of the dot-time. Therefore, if suitable protective relays are provided to guard against over-heating by long tuning dashes, etc., a set can be used at twice its normal rating (3½ times for high speeds) if its power supply and other equipment are designed to allow this. The full power could at any rate be used during periods of heavy static or weak signals.

GENERAL PHYSICAL ARTICLES.

PHYSICO-CHEMICAL CONSIDERATIONS IN ASTROPHYSICS.—W. Nernst. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 135–142.)

Among the many points of interest in this paper is the light thrown on the objects of the experiments (high potentials from the atmosphere) referred to in the August Abstracts. Nernst's hypothesis, that the source of energy of the sun and other fixed stars lies in radio-active elements which decompose more rapidly and with greater emission of energy than uranium, etc., finds support in the highly penetrating cosmic radiation which he refers to as "Hess-Kolhoerster" radiation, and likens to a very hard Roentgen radiation. He estimates that from 5 to 20 million volts would be necessary for its artificial production, and it is chiefly for this purpose (and for the much sought-after "splitting of the atom") that his three young assistants are repeating, on a gigantic scale, the Franklin kite experiment.

THE PENETRATION OF ULTRAVIOLET LIGHT INTO PURE WATER AND SEA WATER.—E. O. Hulbert. (*Journ. Opt. Soc. Am.*, July, 1928, V. 17, pp. 15–22.)

The transparency of sea water declines rapidly with decreasing wavelength in the ultraviolet, becoming quite small below $\lambda = 3{,}000$ A.U.; thus resembling the transparency of the atmosphere in clear weather, which begins to decrease rapidly at 3,900 A.U. and falls to zero at about 2,900 A.U. Both transparencies thus fall off with decreasing wavelength, very much as the spectral energy of the sun falls off; and the writer suggests that this is no mere coincidence, but that (to put it graphically) sodium chloride remains in the sea and nitrogen in the atmosphere because, in part, they are transparent to the energetic waves of the solar spectrum, whereas other original constituents, opaque to these waves, have been destroyed and dispersed.

A PROPOSED EXPERIMENT ON THE NATURE OF LIGHT.—D. M. Dennison. (*Proc. Nat. Acad. Sci.*, July, 1928, V. 14, pp. 580–581.)

The writer proposes that a beam of high frequency X-rays should be diffracted at a single crystal lattice, and at the positions of two Laue Spots—say of equal intensity—two Geiger ion counters should be placed; the intensity of the beam being so adjusted by means of filters that only a few light quanta fall upon each counter per minute. If the classical wave theory alone governed the transmission of light, the absorptions at the two counters must take place simultaneously, since it is essential to this theory that any group of waves, however faint, arriving at a grating will be diffracted to all the orders of reflection simultaneously. If, however, the dualistic character of light as explained by quantum mechanics is correct, the absorptions at the two counters will be independent and governed only by the laws of probability in such a manner that the *mean* energy arriving at each spot will be equal to that predicted by the wave theory.

ABSOLUTE X-RAY WAVELENGTH MEASUREMENTS.—A. P. R. Wadlund. (*Proc. Nat. Acad. Sci.*, July, 1928, V. 14, pp. 588–591.)

A further development of the work of Compton and Doan on the diffraction of X-rays by a ruled grating.

THE COMPTON EFFECT AND POLARISATION.—P. Lukirsky. (*Nature*, 25th August, 1928, V. 122, pp. 275–276.)

ÜBER DAS AUFTRETEN VON EIGENSCHWINGUNGEN BEI ERZWUNGENEN BEWEGUNGEN EINES LINEAREN HARMONISCHEN OSZILLATORS (The production of natural oscillations by forced vibrations of a linear harmonic oscillator).—H. Schmidt. (*Zeitschr. f. Phys.*, 28th July, V. 50, pp. 153–160.)

ON THE THERMODYNAMIC EQUILIBRIUM IN THE UNIVERSE.—F. Zwicky. (*Proc. Nat. Acad. Sci.*, July, 1928, V. 14, pp. 592–597.)

ON RELAXATION OF ELECTRIC FIELDS IN KERR CELLS AND APPARENT LAGS OF THE KERR EFFECT.—Beams and Lawrence. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 169–179.)

The writers conclude from their experiments that there is no evidence for the existence of a lag of the Kerr effect behind rapidly changing electric fields, and explain on other lines the results of previous workers who considered they had found such lag.

KERR EFFECT IN WATER DUE TO HIGH FREQUENCY RADIO WAVES.—A. Bramley. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 151–157.)

Investigations on the index of refraction of water for wavelengths between 3 and 300 cms. have indicated the existence of absorption lines in this region. For examining this electric spectrum of water, the author used a method involving the measurement of the Kerr effect produced by the electromagnetic field of the oscillator. Results showed that the retardations due to the Kerr effect were proportional to the square of the electric induction, and that water has a number of absorption lines in this region which are equally spaced on a frequency scale, the constant difference between the lines being 4×10^{-6} cm. A further experiment proved that the radiation was selectively reflected when its frequency was nearly the same as the natural period present in the water, thus showing analogy to the case of infra-red absorption bands.

VERSUCHE ÜBER DIE RESONANZ DER RESTSTRAHLEN UND DER KÜRZESTEN HERTZSCHEN WELLEN (Tests on the Resonance of Residual Rays and the Shortest Hertzian Waves).—M. A. Lewitsky. (*Phys. Zeitschr.*, V. 28, No. 23, 1927, pp. 821–825.)

Two experiments to demonstrate the essential similarity of the short electric waves and the long heat waves. A reflection-spectrum from Iceland Spar was reflected from an electrical oscillator-system (formed of small pieces of wire, 0.1 mm. long, glued by Canada-balsam to a glass plate) the reflection being greatest where the heat-ray wavelengths agreed with those of the oscillator (32 and 92μ). Secondly, the oscillator was excited electrically and its radiation was reflected at an Iceland-Spar surface, analysed by a grid and measured by a thermo-element. Here again the strongest reflection was at 32 and 92μ.

DEMONSTRATION OF PARTIAL FREQUENCIES IN LIGHT WAVES OF PERIODICALLY VARYING INTENSITY.—E. Rupp. (*Zeitschr. f. Phys.*, V. 47, 1–2, 1928, pp. 72–88.)

The modulation of a "radio" wave by a wave of another frequency is imitated in the case of a light wave. A light wave of known frequency is modulated by short electric waves (of the order of 50 cms. wavelength) by the use of the Kerr effect, and the presence of partial frequencies is shown by suitable means.

ÜBER DEN URSPRUNG DES AUF DER ATOMSTRUKTUR BERUHENDEN MAGNETISMUS (The Origin of the Magnetism due to Atomic Structure.)—Kotarô Honda. (*Zeitschr. f. Phys.*, 16th March, 1928, V. 47, pp. 691–701.)

Dia-magnetism is attributed to the outer ("optical") electrons, but para- or ferro-magnetism cannot be explained in this way; they must be due to the very rapidly rotating electrons in the atomic nucleus.

A SUGGESTED THEORY OF ELECTRIC CONDUCTION.—W. H. McCrea. (*Proc. Camb. Phil. Soc.*, July, 1928, V. 24, pp. 438–444.)

It is a well-known characteristic result of Quantum Mechanics that, given two fixed nuclei at a definite distance apart, an electron initially rotating about one of them will, after a finite time, be found rotating about the other. The author investigates the modification of the effect produced by an external electric field, and shows that this effect so modified suggests an explanation of electric conduction in certain circumstances.

SUR LA CONTRACTION GAZEUSE DE L'HYDROGÈNE SOUMIS À LA DÉCHARGE ÉLECTRIQUE (The gaseous contraction of hydrogen under electric discharge).—R. Delaplace. (*Comptes Rendus*, 23rd July, 1928, V. 187, pp. 225–227.)

This contraction has been attributed to polymerisation of the hydrogen to the form H_3. The author, however, finds no grounds for this, but obtains definite percentages (up to 4.2 per cent.) of carbon monoxide and methane. In the present note he promises to analyse this result, but does not here indicate the origin of the gases which appear.

DIE ABHÄNGIGKEIT DES NORMALEN KATHODENFALLES DER GLIMMENTLADUNG VON DER GASDICHTE (The dependence of the normal cathode fall of the glow—Geissler—discharge on the gas pressure).—A. Güntherschulze. (*Zeitschr. f. Phys.*, 4th July, 1928, V. 49, pp. 473–479.)

Textbooks state that the least potential at which the discharge can be maintained on a cold cathode is independent of the gas pressure. The writer shows that while this is approximately true for helium, oxygen, air, etc., nitrogen or hydrogen give a decrease of the order of 100 volts for an increase of pressure from a fraction of a millimeter to about 20 m.

THE STARK EFFECT AT VERY HIGH FIELD.—Toshio Ishida. (*Nature*, 25th August, 1928, V. 122, p. 227.)

APPLICATION DES LOIS DE L'IONISATION A L'ÉTUDE DE LA DÉCHARGE DANS LES GAZ RARIFIÉS (Application of the laws of ionisation to the study of the discharge in rarified gases). —M. Morand. (*Rev. Gén. d. l'Élec.*, 28th July, 1928, V. 24, pp. 150–151.)

ZUR PROBLEM EINER EINHEITLICHEN FELDTHEORIE VON ELEKTRIZITÄT UND GRAVITATION (The problem of a uniform field theory of electricity and gravitation).—L. Infeld. (*Zeitschr. f. Phys.*, 28th July, 1928, V. 50, pp. 137–152.)

The author develops a world geometry leading to a common theory for the two.

ON THE POTENTIAL OF ELECTROMAGNETIC PHENOMENA IN A GRAVITATIONAL FIELD.—E. T. Whittaker. (*Proc. Roy. Soc.*, 1st August, 1928, V. 120, Series A, pp. 1–13.)

SOME EXPERIMENTAL EVIDENCE SUPPORTING THE KINETIC THEORY OF GRAVITATION.—C. F. Brush. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 143–149.)

The writer's ether-wave, or energy-shadow, theory of gravitation is supported by the experimental discovery that certain substances (complex silicates) are endowed with persistent heat-generating activity not due to radio-activity; and still more by the latest discovery that such substances exhibiting small, moderate or large generation of heat show comparatively small, moderate or large impairment (respectively) of their gravitational acceleration when compared with normal substances. These experiments are described.

THE INFLUENCE OF GRAVITATION ON ELECTROMAGNETIC PHENOMENA.—E. T. Whittaker. (*Nature*, 30th June, 1928, V. 121, pp. 1022–1024.)

Taken from a lecture to the London Mathematical Society, this article propounds the question " do the effects of the distortion of space " (of the fixed gravitational field) " resemble in any way the effects of a variable dielectric constant and permeability ? " The answer is in the affirmative, though the resemblance is not quite perfect. Among various interesting deductions, the writer points out that an electron at rest in a varying gravitational field will, in general, emit radiation ; while (as a natural consequence) an accelerated electron does not necessarily radiate in a gravitational field. This may prove useful in accounting for the behaviour of electrons in atoms.

THE SUGGESTED APPLICATION OF ULTRA-MICRONIC OSCILLATING CIRCUITS TO NEW ETHER DRIFT EXPERIMENTS.—*H. Hamer*. (*Journ. Opt. Soc. Am.*, May, 1928, V. 16, p. 335.)

The great development in the use of oscillating circuits should make it possible to secure now a sensitivity of about one-part in 10^8 at least, and to permit testing the effect of a possible Fitzgerald-Lorentz contraction on the capacity of a parallel plate condenser or on the inductance of the coil of a H.F. oscillating circuit. These can be rotated about different axes in space into the direction of the supposed ether drift. The tests should determine on the classical basis if the ether, whether considered streaming or stationary, is isotropic or not as regards either its permeability or dielectric values.

SUR LES EXPÉRIENCES DE M. ESCLANGON ET LEUR APPLICATION À L'ÉTUDE DES MOUVEMENTS DE L'ÉTHER À PROXIMITÉ DES MASSES MATÉRIELLES (M. Esclangon's Experiments and their application to the study of the movements of the ether near material masses). — – Corps. (*Comptes Rendus*, 14th May, 1928, V. 186, pp. 1351–1353.)

The writer places confidence in these experiments (*Comptes Rendus*, 27th December, 1927) which showed that when reflection takes place at a mass in movement in the medium through which the rays are propagated, the angles of incidence and reflection are not rigorously equal, their sines being proportional to the velocities of the incident and reflected waves ; these themselves being the resultants of the true velocity of light and of the velocities of the ether relative to the reflecting surface. He maintains that M. Esclangon has established a positive and clear result, the existence of which is the negation of the Principle of Relativity, since it establishes a discrimination between the directions of space, and opens the possibility of disclosing an absolute movement of the Earth. Interpreted according to the classic theory founded on the hypothesis of a fixed ether, this result gives a value not less than 75 km. per second (and probably much more) for the total velocity of the Earth. Previous observations tended to place the horizontal component of the apparent ether-wind at not more than 9 km. per second, and the writer suggests that the discrepancy is due to the fact that M. Esclangon's results give the mean between the vertical and horizontal components, the former of which is greatly increased at the expense of the latter in the neighbourhood of material atoms. This suggests a difficult extension to the experiments, to determine the vertical component which should be still higher in value.

SOME EXPERIMENTS ON THE AUTO-ELECTRONIC DISCHARGE.—de Bruyne. (*Phil. Mag.* March, 1928, V. 5, pp. 574–580.)

Del Rosario maintains that the " auto-electronic discharge " from cold cathodes is due to residual gases. The author describes experiments from which it is concluded that this is not the case, and that the currents depend on the nature of the cathode and behave in ways analogous to those of thermionic currents.

MOLECULAR SPECTRA IN THE EXTREME INFRA-RED.—Raman and Krishnan. (*Nature*, 25th August, 1928, V. 122, p. 278.)

THE FERMI-DIRAC HYPOTHESIS OF GAS DEGENERATION AND ITS APPLICATIONS.—E. S. Bieler. (*Journ. Frank. Inst.*, July, 1928, V. 206, pp. 65–82.)

This review follows partly the lines of the original treatment by Fermi, but the connection between the Fermi-Dirac principle and the de Broglie wave has been taken from a paper by Pauli.

ÉTUDE EXPÉRIMENTALE ET THÉORIQUE DE LA VARIATION DES CONSTANTES DIÉLECTRIQUES DE QUELQUES LIQUIDES AVEC LA PRESSION (Variation with pressure of dielectric constants of certain liquids).—L. Cagniard. (*Ann. de Phys.*, May-June, 1928, V. 9, pp. 460–553.)

THE COMPLETE PHOTO-ELECTRIC EMISSION FROM POTASSIUM.—Jessie Butterworth. (*Phil. Mag.*, July, 1928, V. 6, pp. 1–16.)

The author seeks verification, or the opposite, of Dember's assumption of positive photo-electric emission, working on potassium as one of the metals likely to show the phenomenon to the greatest degree. Her tests lead to the conclusion that if the positive effect does occur, it is at least a thousand times smaller than the current which Dember attributed to the emission of positive ions by photo-electric action, *i.e.*, it is less than 10^{-7} times the negative emission from the same surface under the conditions of the experiments. Further results suggest also that potassium has at least two work-functions corresponding to the wavelengths 9,700 A.U.'s and 57,000 A.U.'s, the lower work-function being possessed by "patches" of the surface which under prolonged illumination acquire the greater work-function (corresponding to the shorter wavelength) possessed by the main surface.

MISCELLANEOUS.

TRANSMISSION OF INFORMATION.—R. V. L. Hartley. (*Bell Tech. Journ.*, July, 1928, V. 7, pp. 535–563.)

Sets up a method of quantitative comparison of the capacities of various systems to transmit information. Among other uses, it provides a ready means of checking whether the transmission possibilities of a complicated system can be what they are claimed to be. It can, for example, be applied to various systems of television, as it has already been applied to cable work and picture transmission.

ÜBER DIE INDUKTIONSWIRKUNG VON STARKSTRÖMEN AUF BENACHBARTE LEITUNGEN (The induction effect of power currents on neighbouring conductors).—H. Schiller. (*Arch. f. Elektrot.*, 19th July, 1928, V. 20, pp. 252–263.)

CARRIER SYSTEMS ON LONG-DISTANCE TELEPHONE LINES.—Affel, Demarest and Green. (*Bell Tech. Journ.*, July, 1928, V. 7, pp. 564–629.)

Describes developments during the past few years which have resulted in improvement.

CARRIER-CURRENT CONTROL FOR STREET LIGHTING.—R. R. Cowles. (*Elec. World*, 28th April, 1928, V. 91, pp. 863–866.)

Control is by a 100-watt transmitter (Colpitt circuit) of three optional frequencies, 35,000, 40,000 or 45,000 cycles per second. The system is used in San Francisco.

DIE EINPHASENKOPPELUNG, EIN MITTEL ZUR ERHÖHUNG DER BETRIEBSICHERHEIT DER HOCHFREQUENZ TELEPHONIE AUF LEITUNGEN? (Single-phase coupling, a method of increasing the reliability of high-frequency telephony along power lines?).—Dressler and Tätz. (*E.T.Z.*, 26th July, 1928, V. 49, pp. 1101–1103.)

An argument as to the relative advantages of single-phase and two-phase coupling.

PROJECTION OF CURVES CORRESPONDING TO VARIABLE CURRENTS.—A. Bartorelli. (*Science Abstracts*, 25th July, 1928, V. 31, p. 579.)

A method depending on the ponderomotive action of a constant magnetic field upon a wire carrying a current, combined with an arrangement of stroboscopic projection.

VERSUCHE ZUR ERKLÄRUNG DER STAUBELECTRISIERUNG (Experiments for the Elucidation of Dust-electrification).—H. Israel. (*Zeitschr. f. Tech. Phys.*, No. 8, 1928, pp. 289–293.)

Böning's theory, dividing the process into two parts—the collision effect and the friction effect, the former causing positive charges on the smaller, negative on the larger particles, and the latter causing positive charges on the larger, negative on the smaller particles—is here tested by a long series of tests, using particles of unlike composition. Böning's original tests were made with particles of the same composition, but of differing size, and his theory is confirmed without exception under these conditions; the author shows that it also applies, with certain reservations, to particles of differing composition.

ÜBER DEN WIDERSTAND VON FLUGZENGANTENNEN UND DIE DADURCH VERURSACHTE VERRINGERUNG DER FLUGLEISTUNGEN (The resistance due to aircraft aerials and the consequent diminution of flying power).—F. Liebers. (*Luftf. forsch.*, 7th May, 1928, V. 1, pp. 147–152.)

DIE VORZÜGE DES KURZWELLEN-VERKEHRS MIT FLUGZEUGEN (The advantages of short-wave communication with aircraft).—H. Fassbender. (*Luftf. forsch.*, 7th May, 1928, V. 1, pp. 122–125.)

One great advantage mentioned is the possibility (long desired) of using fixed aerials. Success in short-wave aircraft wireless is due chiefly to the dipole fixed antenna. Another is the fact that a purely battery-driven transmitter can telegraph 550 km. or more either in the air or after landing.

The writer finds no evidence of the "dead zones" referred to by American short-wave workers—possibly because in transmission from the air the direct wave suffers less attenuation (*cf.* Plendl, March Abstracts, p. 163).

INTERFERENCE ELIMINATION. (*Elec. Review*, 13th July, 1928, V. 103, p. 66.)

A note on the methods used by the Canadian Government to prevent, or trace and remedy, interference with broadcast reception due to electric power lines (which are practically all overhead).

SOUND-PROOF ROOMS, Bell Telephone Laboratories. (*Nature*, 4th August, 1928, V. 122, p. 186.)

Formerly, the walls were deadened with hair, felt and other absorbing materials, but the result was not good. Recent theories of sound absorption have led to the construction described, involving brick walls covered on both sides with hard cement plaster, air spaces, wood and celotex (the new building material made of matted vegetable fibre).

AIRCRAFT RADIO INSTALLATIONS.—M. P. Hanson. (*Proc. I. Rad. Eng.*, July, 1928, V. 16. pp. 921–965.)

Deals in a general way with the technical aspects of aircraft (lighter and heavier than air) radio design and installation, and illustrates the trend of recent development. Advantages and disadvantages of various directional radio applications are shown. The good points are admitted of the British airways' system of having the D.F. equipment favourably located on the ground and manned by capable specialists. The American radio beacon system is the most easily applied of all methods from the pilot's point of view.

BIBLIOGRAPHY ON AIRCRAFT RADIO.—Jolliffe and Zandonini. (*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 985–999.)

CONTRACTIONS FOR TITLES OF PERIODICALS.—R. L. Sheppard. (*Nature*, 25th August, 1928, V. 122, pp. 277–278.)

Criticisms of the abbreviations used in the "World List of Scientific Periodicals (1901–1920)."

RADIO COMMUNICATION ON MOVING TRAINS. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 283–284.)

Describes recent tests, on the Pennsylvania Railroad, on maintaining communication between engine and guard van by wireless, loud speakers being used both for telephonic and code messages. Each train works on a wavelength of its own, so that passing trains do not interfere with each other. One example where the system is of use is afforded by the case of a standing train having to be parted at a grade crossing to allow highway traffic to pass; the driver can be advised by wireless to back so as to permit uncoupling at the right point, to proceed, and then to stop.

DIE ZUGBEEINFLUSSUNGSSYSTEME BEI DEN EISENBAHNGESELLSCHAFTEN DER V.S. AMERIKA (Train-control systems on the U.S.A. Railways).—A. Kammerer. (*E.T.Z.*, 5th July, 1928, V. 49, pp. 1005–1009.)

The methods fall into two classes, the "continuous" or line-induction and the "intermittent" or point-induction methods. Both are dealt with in this survey.

T.S.F. ET GÉOLOGIE : LA DÉRIVE DES CONTINENTS (Wireless and Geology: the Origin of Continents).—J. Vivié. (*Q.S.T. Fran.*, August, 1928, pp. 25–32.)

A description of the work recently completed on the determination of the difference of longitude between three points of the globe spaced about 120 deg. along the same parallel of latitude—Algiers, Zi Ka Wei and San Diego; secondary points being Greenwich, Paris, Washington, Tokio and Vancouver. Results appear to be accurate to 4 metres in 20,000 kms., and the writer points out that such accuracy will enable us in a few years to see whether the continents are moving relatively to one another, thus testing Wegener's theory that they were originally one large continent.

LES STATIONS DE SIGNAUX HORAIRES (Time-Signal Stations).—de la Forge. (*Q.S.T. Fran.*, August, 1928, pp. 43–51.)

The present article deals with America and Oceania. Certain errors and omissions in the previous papers (*cf.* July and August Abstracts) are corrected.

ÜBER ELEKTRISCHE FELDER IN DER UMGEBUNG LEBENDER WESEN (Electrical Fields in the Neighbourhood of Living Beings).—M. v. Ardenne. (*Zeitschr. f. Tech. Phys.*, No. 8, 1928, pp. 288–289.)

A very sensitive apparatus, including a thermionic voltmeter, and retaining its sensitivity up to frequencies of 200,000 p.s., was used to look for the presence of electrical fields near human beings. Results were positive in the presence of muscle-contractions (as had been found by other workers) but negative for brain-actions. The author, however, suggests that it is just possible that the fields in this latter case have too high a frequency even for this special apparatus; further work is being done to test this possibility.

FREQUENZVERVIELFACHUNG DURCH EISENWANDLER (Frequency multiplication by iron frequency transformers) — Part I. — E. Kramar. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 10–15.)

SUR L'EMPLOI DU DÉMULTIPLICATEUR DE FRÉQUENCE FERROMAGNÉTIQUE COMME MULTIPLICATEUR DE PHASES (The use of the ferromagnetic frequency transformer as a phase multiplier).—E. Rouelle. (*Rev. Gén. d. l'Élec.*, 28th July, 1928, V. 24, pp. 151–152.)

The "Ultramicrometer."—J. Obata. (*Journ. Opt. Soc. Am.*, June, 1928, V. 16, pp. 419–432.)

Detailed construction and various examples of application are here given of the instrument referred to in the June Abstracts.

Study of Imperfect Metallic Contacts.—Todesco and Rossi. (*Nature*, 11th August, 1928, V. 122, p. 227.)

Resumé of a paper read before the Italian Academy. Pélabon recently showed that an imperfect contact between two electrodes of the same metal but of different shape may serve for the rectification of oscillating currents, and hence may replace the crystal or thermionic valve detector. The present paper investigates this effect, and points out that steps must be taken to avoid cohesion, which abolishes the rectifying effect.

Conducteurs n'Obéissant pas à la Loi d'Ohm : Les Soupapes Électriques à Contact (Conductors which disobey Ohm's Law : electric contact rectifiers).—L. Dubar. (*Rev. Gén. d. l'Élec.*, 28th July, 1928, V. 24, pp. 153–159.)

The electronic theory of the conductivity of metals is here applied to the solution of various contact-rectifying processes.

The Theory of Contact-detectors : Investigations of Detector Contacts : More about the Crystal Detector Problem.—(*See Ann. d. Phys.*, 10th July, 1928, *Phys. Zeitschr.*, 1st July, 1928.)

Les Symboles Graphiques Internationaux Concernant L'Électrotechnique (The international graphic symbols relating to electrical engineering.)—(*Rev. Gén. de l'Élec.*, 7th July, 1928, V. 24, pp. 11–26.)

A list of symbols adopted by the International Commission for general "power plant" usage (*cf.* July Abstracts).

The National Physical Laboratory, Teddington : Inspection by the General Board.—(*Nature*, 21st July, 1928, V. 122, pp. 112–113.)

An account of the recent annual inspection, with a description of the extensive programme of exhibits illustrating the activities of the laboratory.

Sur la Constante Diélectrique du Benzite (The dielectric constant of benzil).—L. Saint Antoine. (*Comptes Rendus*, 21st May, 1928, V. 186, pp. 1429–1431.)

Benzil ($C_6H_5COCOC_6H_5$) when dissolved in benzine has exceptional electro-optical properties. The author finds that fused benzil has a very high dielectric constant (13.04 at 95 deg.) which varies rapidly with the temperature (it is 12.12 at 120 deg.). To this fact he attributes the marked electro-optical quality.

Experiments on the Space Charge Around a Conductor emitting Corona.—Carrol and Lusignan. (*Journ. Am.I.E.E.*, Dec., 1927, V. 46, pp. 1350–1357.)

In one experiment, using the straight wire and coaxial cylinder arrangement, the cylinder was earthed through a condenser shunted by a D.C. galvanometer. Directly corona is produced by an increasing A.C. voltage, the galvanometer shows a deflection. At first the current passes from cylinder to earth but as the tension increases the effect is reversed. Several other experiments are described, one of these using a straight wire, flat plate and interposed metallic grid.

Les Lignes Électriques en Cables à 132,000 Volts de New York et de Chicago (132,000 volt Cables).—Emanueli. (*Bull. d.l. Soc. Fran. des Élec.*, May, 1928, V. 7, pp. 480–515.)

A full description of the cables themselves, junctions, insulators, etc., fully illustrated. The work was carried out by the Société Pirelli of Milan. 90,000 kVA. is the maximum load.

Luminous Pressure Waves.—(*Journ. Frank. Inst.*, July, 1928, V. 206, p. 111.)

Photography of the phenomena taking place when a cartridge of dynamite is detonated has shown the existence of luminous waves propagated at high speed in the air surrounding the explosive : tests have shown almost certainly that these are not merely reacting gases projected from the explosive, but real pressure waves at such high temperatures that the gas radiates in the visible region of the spectrum.

Über Piezoquarzplatten als Sender und Empfänger Hochfrequenter Akustischer Schwingungen (Piezo-quartz plates as sender and receiver of H.F. acoustic oscillations).—F. W. Hehlgans. (*Ann. d. Phys.* 10th July, 1928, V. 86, pp. 587–627).

Ultrasonics.—R. W. Boyle. (*Science Progress*, July, 1928, V. 23, pp. 75–105.)

A comprehensive survey, which includes the latest work (*cf.* Langevin, July "Abstracts.")

Über die Vorgänge am System Halbleiter-Leiter (The processes in the "Semi-conductor - Conductor" - Johnsen - Rahbek - system).—H. Toby. (*Ann. d. Phys.*, 30th June, 1928, V. 86, pp. 353–392.)

In these investigations, special attention is given to conditions of dryness.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPAGADO DE ONDOJ.

VELKAJ MEZURADOJ EN HINDUJO KONCERNE LA MALLONGONDA STACIO PCJJ (HOLANDO).—T. S. Rangachari.

La aŭtoro priskribas mezuradojn en Bangalore, Hindujo, koncerne la Holanda Stacio, PCJJ, je 30–2 metroj.

La cirkvito uzita konsistas el agordita anteno, kun reakcio, konektita senpere al detektoro kaj sekvita de du Malaltfrekvencaj ŝtupoj. La telefona transformatora elmeto estas aplikita al kristalo kaj mikroampermetro. La anteno estas streĉita vertikala fadeno 30-futojn alta, streĉita inter la laborstablo kaj la tegmento interne de la laborejo. Oni faras observadojn je intervaloj de 5 sekundoj dum periodo de 20 minutoj, kaj du rezultaj kurvoj estas publikigitaj montrantaj rapid-periodan velkadon, krom plimalrapida ŝanĝo de l'meza valoro.

Oni diras, ke fazoj de la luno ŝajnas havi nenian efekton ĉe la naturo de velkado.

PROPRECOJ DE CIRKVITOJ.

LA MALUTILAJ EFEKTOJ DE INTER-ELEKTRODA KAPACITO.—M. von Ardenne kaj W. Stoff.

La kapacitoj ĉeestantaj ĉe unuopa ŝtupo estas montritaj, kaj ilia ekvivalenta cirkvito diskutita detale. La efektoj de reakcio de la kradanoda kapacito estas poste pritraktitaj. Ĉi tio kondukas al diskutado pri l'efekto de la reakcio ĉe malsamaj tipoj de amplifikatoroj, plispeciale kun malsamaj tipoj de anod-cirkvita ŝarĝo. La efekto de hazardaj kapacitoj en 4-elektrodaj kaj multoblaj valvoj estas laste konsiderita.

La teorio de l'diskutado estas bone montrita per ekvacioj kaj vektoraj diagramoj.

GRAFIKA KONSTRUMETODO POR REZISTANCAJ AMPLIFIKATOROJ.—W. A. Barclay.

Ĉi tio estas mallonga artikolo en kio grafikaj metodoj estas donitaj por la rapida solvo d l'kvantoj pritraktita en antaŭa artikolo de A. L. M. Sowerby (*E.W. & W.E.*, Aprilo, 1928a), pri "Kalkuladoj por Rezistancaj Amplifikatoroj."

La grafikaj konstruaĵoj estas ilustritaj kaj diskutitaj, ilia teorio estante pliampleksigita de du mallongaj aldonaĵoj.

KADRA TRAPENETREBLECO ĈE FERO, KAJ LA OPTIMUMA AERA INTERSPACO ĈE FERA ŜOKBOBENO KUN K. K. EKSCITADO.—A. A. Symonds.

Oni faras aludon al Redakcia artikolo (de Februaro, 1928a), kiam oni montris, ke antaŭ kontinukurenta ekscitado, cikla kurvo reprezentanta la alternantajn fluojn devas esti desegnita ĉirkaŭ iu punkto sur la B—H diagramo, donita de la magneta stato de l'fero. Oni poste montras, ke la sola grava kvanto estas la kliniĝo de la pligrava akso de la SB/SH kadro. Mezuradoj de ĉi tiu kvanto estas poste priskribitaj, kun cirkvita diagramo kaj rezultaj tabeloj kaj kurvoj, kiuj estas ankaŭ diskutitaj.

La dua parto de l'artikolo traktas pri l'optimuma aera interspaco ankaŭ pritraktita en la Redakcia artikolo aludita. La kondiĉoj por kombinita fera kaj aera interspaco estas diskutitaj, kaj oni montras, ke la aera interspaco povas esti elektita por doni kiel eble plej bonan mezan valoron, kiu devus esti uzita kiam ajn oni scias, ke la aplikitaj A.K. voltoj varias laŭ amplitudo kaj frekvenco iugrade.

La efekto de hazarda fluo estas ankaŭ diskutita kaj la artikolo finiĝas per ekzemplo pri l'uzado de la kurvoj kaj informoj cititaj por la desegno de difinita ŝoko.

VALVOJ KAJ TERMIONIKO.

NOVA IDEO POR DETEKTORA VALVO.

Ĉi tiu artikolo pritraktas sugeston ŝuldatan al K. Posthumus (de la Laborejoj de la firmo Phillips).

Oni montras, ke elektronoj forlasas la filamenton kun malsamaj rapidecoj, kaj ke la detektado, aparte de malfortaj signaloj estas efektivigita plejparte de malrapide movantaj elektronoj. Oni sugestas, ke apartigo de l'elektronoj povas esti efektivigita pere de magneta kampo. La malrapide movantaj elektronoj estus defleksitaj ĝis pligranda grado, ol tiuj movantaj plirapide, kaj se ili estus kondukitaj al aparta krado, estus eble multe pliigi la detektajn ecojn de valvo.

HELPA APARATO.

VALV-PROVILO KUN SENPERA MONTRILO.—M. G. Scroggie.

Simpla kaj rapida metodo estas priskribita por mezuri anodan impedancon, pligrandigan proporcion, kaj komunan konduktancon de ricevaj valvoj. La metodo konsistas, necese, el utiligo de la tensia falo trans rezistanco konektita inter la malaltatensia baterio kaj altatensia negativo, por obteni negativan tension ĉe la krado, kaj el mezurado de la ŝanĝo de anoda kurento naskita de ĉi tiu ŝanĝo de krada tensio.

La principo de la metodo estas diskutita, kaj plena cirkvita diagramo de l'aparato estas donita, kun rimarkigoj pri ĝia utiligo en la praktiko.

KELKAJ ELMETAJ POTENCO-MEZURADOJ ĈE LAŬTPAROLILO FUNKCIIGITA PER MOVA BOBENO.—H. A. Clark kaj N. R. Bligh.

La artikolo priskribas eksperimentojn pri la rezisteco kaj reaktanco de reprezenta laŭtparolilo de la tipo movbobena trans la skalo de aŭdeblaj frekvencoj, kaj kun la laŭtparolilo je ĝia normala funkcia stato kaj kun la diafragmo rigide krampita, tiel ke la akustika elmeto estas malpliigita ĝis nulo.

La mezura metodo uzita estis egalproporcia induktometra ponto, kun telefona detektado super, kaj vibro-galvanometra detektado sub, 200 cikloj. La aparato estas ilustrita diagrame, kaj antaŭzorgoj de funkciado estas diskutitaj.

Rezultkurvoj estas donitaj pri rezisteco kaj pri reaktanco, kun la diafragmo kaj libera kaj krampita, pri l'impedanco de la laŭtparolilo sole, kaj pri la parolilo, transformatoro kaj valvo, k.t.p. La eksperimentaj rezultoj estas diskutitaj, kune kun la efekto de tensio-malpliiga transformatoro, valva impedanco, kaj la efekto de l'valva karakterizo.

La rezultoj malkaŝas diafragman resonancon je ĉirkaŭ 40 cikloj, kun malpliiĝo de elmeto je la plialtaj frekvencoj (ekzemple, pli ol 1000 cikloj), kaŭze de pligrandigita reaktanco.

Aldonaĵo donas ampleksan diskutadon pri l'Ekvacioj de Movo por movbobena laŭtparolilo.

GENERALAJ FIZIKAJ ARTIKOLOJ.

Kelkaj Novaj Aplikadoj de Mallongonda Radio.—D-ro. J. Taylor kaj D-ro. Wilfrid Taylor.

La aŭtoroj priskribas la utiligon de tre altfrekvencaj (mallongondaj) osciladoj por eksciti lumeton en ege vakuigitaj tuboj je treege plimalaltaj tensioj, ol estas bezonitaj ordinare.

La efekto estis unue eksperimentita de Gutton en Francujo kaj de Kirchner en Germanujo, dum Wood kaj Loomis en Usono utiligis ĝin por eksciti spektrojn en diversaj gasoj.

La aŭtoroj priskribas kaj ilustras ekscitan cirkviton konsistantan el valva generatoro kuplita per fadenaranĝo Lecher'a al malŝarĝa tubo kun eksteraj elektrodoj. La ĝenerala formo de l'malŝarĝoj estas priskribita, kaj la problemo de alta frekvenco diskutita kaj klarigita. La artikolo poste traktas pri malŝarĝoj en mallarĝaj tuboj kaj en bulboj, priskribante la efektojn obtenitajn, ĉi tiuj estante bone ilustritaj per serio de fotografaj platoj.

Oni laste diskutas aplikadojn, kun sugestoj pri la funkciado de valvoj je tre altaj frekvencoj, la naturo de l'tavolo Heaviside, kemiaj efikoj de industria aplikado, kaj la efektoj de vitraĵo, kiel ĉirkaŭaĵo por vakuigitaj bulboj, k.e., valvoj.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

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

Ĉapitro en la Historio de Radio-Mezuradoj.

Redakcia artikolo (super la ĉefliteroj de Prof. Howe) pritraktanta la fondon antaŭmilitan de la Internacia Scienca Radiotelegrafia Komisiono, kaj mezuradojn pri signalforteco de l'aŭtoro sub la aranĝoj de l'Komisiono.

Libro—Recenzo.

Oni donas recenzon de Speciala Raporto No. 6 de la Radio-Esplorada Komitato :—

"Esplorado pri Rotacianta Radio-Signalilo," de R. L. Smith-Rose kaj S. R. Chapman, eldonita de *H.M. Stationery Office*, Londono.

Ĉiujara Vizito al la Nacia Fizika Laborejo.—Aferoj Interesaj laŭ Senfadena Vidpunkto.

Oni donas mallongan noton pri aferoj interesaj laŭ senfadena vidpunkto, montritaj ĉe l'Nacia Fizika Laborejo, Teddington, dum la ĉiujara vizito je 26a Junio, 1928a.

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.

Loop Permeability in Iron.

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

Sir,—In view of correspondence concerning the position of a small hysteresis loop relative to the *B—H* curve, some further explanation of the first figure of my article on "Loop Permeability"* may be advisable.

In drawing such a loop it should be borne in mind whether the loop is to represent a single small cycle or the effect of an applied alternating E.M.F. The top of a single small loop, which, strictly speaking, will not be a closed curve, will lie near the main curve from which it sprung, but a loop representing events in the iron after a large number of similar small cycles will occupy a different position.

Ewing has investigated such phenomena very thoroughly.† The effect of superposed magnetic cycles, at first large and then gradually reduced after the manner of demagnetising by reversals, is to render the iron almost entirely independent of the previous magnetic history of the piece, the final induction being somewhat higher than that given by the reversal curve for the same constant magnetic force. The change seems due to the violent molecular shaking up, and the effect of very small cycles, though less marked, is also to increase the mean induction.

It is apparent, then, that after a number of cycles have been superposed on an existing induction due to a constant magnetising force, the mean induction will be changed.

* See *E.W. & W.E.*, p. 485, September, 1928.

† "Magnetic Qualities of Iron," J. E. Ewing and H. G. Klaussen, *Phil. Trans.*, 1893, pp. 1024–1032.

In the article referred to, this induction, the D.C. component, is as stated, taken as being defined by the reversal curve, and the loops are drawn about it accordingly.

A. A. SYMONDS.

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

SIR,—There is not a wide difference between μ' at 90~ as found by Mr. Symonds and μ' at 500~ as found by the writer (*W.W.*, July 14th, 1926). Clearly μ' does not decrease rapidly with increase in f. At $f = 40{,}000$~ the initial μ' was found to be 270 for 0.0015″ iron. After saturation the value was reduced to 160 (*W.W.*, Nov. 24th, 1926).

The values of δB used by Mr. Symonds and myself are in excess of those found in a modern intervalve transformer. For example, at $f = 90$~, secondary peak voltage = 15, ratio $3.5/_1$, primary inductance 100 henrys. δB is about 10 lines per sq. cm. Above and below 90~ δB would decrease and increase respectively.

Since μ' varies with δB (see Fig. 2a) the primary reactance ωL_1 at any value of f will depend upon the signal strength. Thus at frequencies below 100~ where the valve resistance is comparable with ωL_1, the amplification will vary with the signal strength. In a complete receiver with inter and output transformers, the proportion of acoustic energy below 100~ will therefore be greater for strong than for moderate signals (apart from the sensitivity of the ear).

In many cases the valve feed current is carried by the primary of the output transformer to the L.S. This causes a serious fall in L_1 especially when L.S.5A valves are used at high voltage. It can be obviated by using the familiar choke-condenser-feed system, but in this case the transformer iron is worked on a main and not on a subsidiary loop—assuming the iron to be demagnetised initially. With a moderate magnetisation, the main hysteresis loop introduces harmonics. Whether these are as large as those with the subsidiary loop can only be decided by measurement. I have not noticed much difference when using a loud speaker, but the harmonics may be too small to be readily perceptible by ear.

I should like to indicate a drawing error in Figs. 1 of the three articles mentioned above. The subsidiary loop should be wholly to the left of the B-H curve. As shown it is symmetrical, but not scientific.

N. W. MCLACHLAN.

London.
3rd September, 1928.

Output Power Measurements on a M.C. Loud Speaker.

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

SIR,—It is not clear from Messrs. Clark and Bligh's article in your September issue that the resonance at 40 ~ is due to the diaphragm vibrating *as a whole on its oiled-silk support*. The resonant frequency can be reduced well below 40 ~ by using a suitable grade of thin rubber. In the *Wireless World*, 8th August, 1928, I described experiments showing a support resonance at 50 ~ due to rubberised silk. There was also a resonance due to the diaphragm alone (apart from its support) at 200 ~. I see that Messrs. C. and B. found no diaphragm resonance, but this may have been due to the frequency gaps in their curves. The Editor of the *W.W.* has several of my articles in his possession dealing with various aspects of this problem which will be published in due course. In particular there is the case of a small diaphragm on a leather surround. This has a pronounced and distressing resonance at 70 ~. Although the coil current at 4,000 ~ is only about *a fifth* of that at 400 ~, there is a tendency to accentuate the upper register. This can be attributed to the mechanical acoustical properties of the diaphragm, presumably some form of resonance apart from the surround.

Fig. 3c for low frequencies is incorrect since the condenser effect of the moving coil has been omitted. The equivalent circuits together with the theory—minus the mathematics which were beyond the scope of the journal—have been published in the *W.W.* from 30th March, 1927, onwards. Also vector diagrams are given in my handbook *Loud Speakers*, pp. 67–70.

The values of motional resistance from 100 ~ upwards seem to be unduly high. At 250 ~ the value is 4 ohms. Taking a gap density of 8,000 lines per sq. cm. and assuming the diaphragm to be a flat rigid disc, I find the acoustic radiation resistance to be of the order 0.4 ohm. The difference between their figure and mine seems to be too large for frictional and other losses.

With a coil of 1,000 turns I have found the motional resistance by experiment to be 73 ohms at 250 ~, corresponding to an efficiency of 6.5 per cent. By calculation, using the equivalent rigid disc, the radiation resistance is of the order 70 ohms. A similar agreement between theory and practice has been found at higher frequencies. As a consequence, I am inclined to doubt the high value of efficiency, namely, 16 per cent. at 100 ~ given by Messrs. C. and B. Incidentally I calculate the resistance of their coil at rest as 15 ohms, whereas from Fig. 5 curve B, the value exceeds 18 ohms, which seems peculiar.

At the higher frequencies, *e.g.*, 5,000 ~, since a coil movement of a few millionths of an inch corresponds to a loud sound, special precautions must be taken to ensure that the coil does not move.

A point of interest is the effect of the field coil on the moving coil. Since the coils are coupled electromagnetically, the inductance and resistance of the M.C. alters according as the field coil is open or closed. When closed through a battery, the iron is magnetised by the A.C. in the moving coil, and therefore works round a subsidiary loop. The M.C. inductance varies slightly with the battery current. Since the coil moves in a steady field with an A.C. field superposed, currents of double frequency, etc., are induced. An investigation by an oscillograph indicated that these alien frequencies were of no importance for a coil of 1,000 turns used to give moderate output.

N. W. MCLACHLAN.

London.
5th September, 1928.

Some Recent Patents.

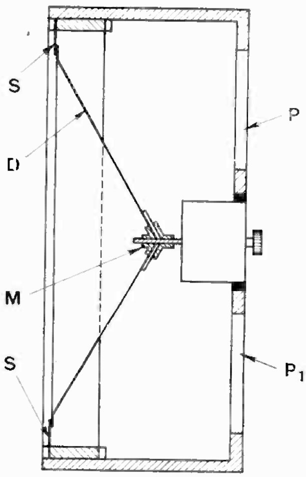
The following abstracts are prepared with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

LOUD SPEAKERS.

(*Application date, 11th January*, 1927. *No.* 288,713.)

A conical diaphragm D is made of hot-press paper about 0.02 millimetre thickness and weighing about 0.015 gramme per square centimetre. From a circle of $8\frac{5}{8}$ inches radius, a sector is cut of 60 degrees, giving a cone-base of $13\frac{3}{4}$ inches diameter and a projected area of slightly less than 1,000 sq. cms. This is then glued to a circular surround S of thin paper, such as is commonly used for charcoal sketches. The terminal condition at the periphery is arranged to reduce reflection and therefore diaphragm resonance to a minimum.

Such a diaphragm is stated to "break-up" at all frequencies above about 80 cycles, so that the effective area in vibration is less than the actual area of the diaphragm. Moreover, as the applied frequencies increase from 80 to 6,000 cycles, the effective area in vibration decreases progressively, so that in combination with the varying sensitivity of the reed the overall response remains uniform from 150 cycles upwards, instead of tending to favour the higher frequencies as usual.



The driving elements (not shown), including the reed and its connections M to the diaphragm, are designed to have a natural frequency of between 2,500 and 3,500 cycles per second, whilst the natural frequency of the whole vibrating system (including the diaphragm) lies between 700 and 1,100 cycles. The diaphragm is housed in a box which acts as a baffle, as shown, the front being covered with silk, and the back formed with apertures P, P_1 to reduce undesirable resonance effects.

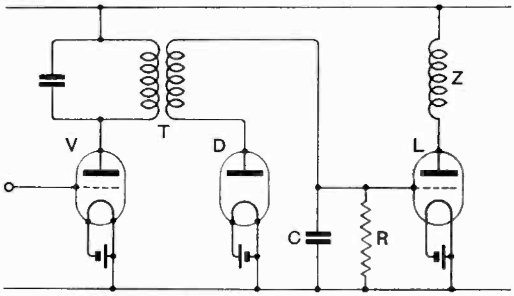
Patent issued to N. W. McLachlan.

VALVE TRANSMITTERS.

(*Convention date (Germany), 29th March*, 1927. *No.* 287,903.)

In high-powered transmission it is desirable to provide a load-compensating circuit during "spacing" periods, or at other times when the aerial oscillations are cut out or reduced, so as to prevent dangerous surges of voltage likely to injure the installation. With this object in view, a special compensating valve is arranged so that its conductivity varies with the conditions of the keying-circuit.

As shown in the figure, the compensating-valve L is shunted across the main transmitting-valve V in series with a choke Z or other suitable resistance. The grid circuit comprises a condenser C, leak resistance R, and a diode or rectifying valve D



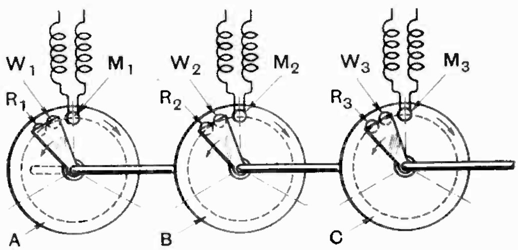
coupled to a resonant circuit T in the plate of the transmitter. Under these conditions, the greater the energy flowing in the circuit T, the greater will be the negative bias thrown by the rectifier D on the grid condenser C, and the less the resultant conductivity of the compensating valve L, so that it takes practically no load. As the aerial oscillations decrease, the negative bias on C is reduced, so that the conductivity of the valve L increases and it comes automatically into action to maintain the overall load constant.

Patent issued to the Telefunken Co., Ltd.

TELEVISION APPARATUS.

(*Application date, 26th January*, 1927. *No.* 292,632.)

In order to speed-up the process of exploring a scene or object to be televised, a number of



different sections are explored simultaneously, and magnetic records are taken on a rotating disc in a manner similar to that of the well-known Telegraphone. The records are subsequently read at a higher speed than that at which they were originally recorded.

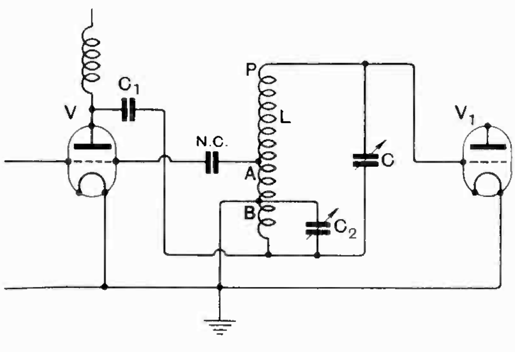
As shown in the figure, three magnetic discs A, B, C are mounted on a common shaft. Light-modulated signals from the object or scene to be televised are then fed through coils associated with magnetic recorders M_1, M_2, M_3, so that a transient "magnetic image" of the signals is impressed upon the discs. Pick-up or receiving devices R_1, R_2, R_3, adapted to convert the impressed images into corresponding current-variations, are so mounted in conjunction with the discs A, B, C that they can traverse the discs in the opposite direction to the recorders M and at a higher speed. Mounted close to each receiver R is a "wipe-out" device W_1, W_2 W_3 adapted to erase the transient image previously recorded, so as to leave the disc free to receive the next impression. In operation the pick-up or receiving devices R are rotated at three times the speed of the recorders M, giving a corresponding gain in the speed of the original exploration. As soon as the record on disc A has been finished, the disc B is switched into circuit, and is then followed by disc C. Meanwhile, a fresh record is being traced on the first disc.

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

NEUTRALISING CAPACITY EFFECTS.

(*Application date, 4th April*, 1927. *No.* 292,716.)

In order to stabilise a valve amplifier over a wide range of working frequencies an additional capacity is inserted between the main oscillatory circuit and a point at a steady or earth potential in such a way as to make all the associated capacities symmetrical about this point. As shown in the figure, the valve V is coupled to the valve V_1 through a condenser C_1 connected to the lower end of the tuned circuit $L\,C$. The upper end P of the inductance L is taken to the grid of the second valve, whilst a neutralising condenser $N\,C$ is tapped off from an intermediate point A on to the grid of the first valve. The point B is connected to the common filament circuit.



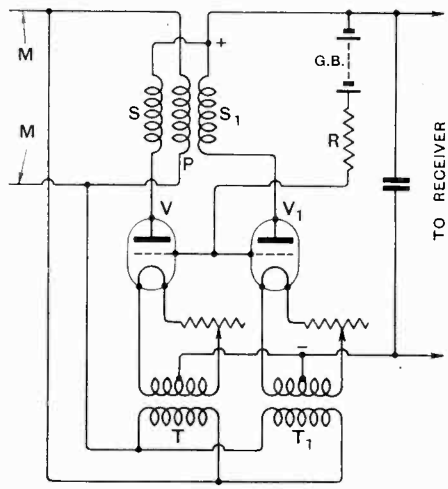
In these circumstances the capacities to earth are unsymmetrical about the point B. The grid-filament capacity of the valve V_1 is shunted across the large portion $P\,B$ of the inductance L, and in general the capacity to earth of the portion $P\,B$ of the inductance L is greater than that between B and the lower end of the inductance ; so that the potential difference between the points A and B is greater than if a true balance existed. Also the ratio of the currents in the part $A\,B$ and the part from B to the end of the inductance increases as the tuning condenser C is reduced, necessitating a continual readjustment of the neutralising condenser $N\,C$. The insertion of an additional condenser C_2 across the point B and the lower end of the inductance L is found to remove this lack of symmetry and the difficulties consequent thereon.

Patent issued to W. J. Brown and the Metropolitan Vickers Co., Ltd.

A.C. MAINS UNIT.

(*Convention date* (*U.S.A.*), 31*st March*, 1926. *No.* 268,797.)

A pair of thermionic valves is used to rectify the current supply from A.C. mains M, a biasing potential on the grids serving automatically to



smooth the pulsating output. The transformer P across the mains M has two secondary windings S, S_1, the common or neutral point P constituting the positive terminal of the rectified current. The free ends of the two secondaries are connected to the plates of two three-electrode valves, the common point of the filament forming the negative terminal of the rectified current. The filaments of the valves are energised by two transformers T, T_1, shunted across the main supply leads M, as shown.

The grid of each valve is biased with a positive voltage approximately equal to the D.C. voltage required, derived from a battery GB in series with a resistance R. Under these conditions, when the rectified voltage wave drops below the required D.C. voltage, each grid will become positive, relatively to the filament, and the effective impedance and voltage drop across the valve rectifiers will be reduced. Conversely when the output wave rises above the desired D.C. voltage, the valve impedance is increased, so that the action automatically tends to smooth-out any variations above or below the steady voltage to be fed to the wireless receiver.

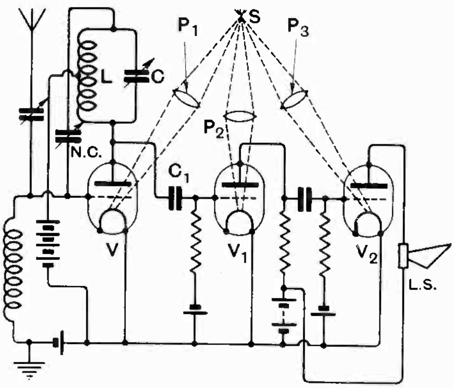
Patent issued to the Metropolitan Vickers Co., Ltd.

PHOTO-ELECTRIC AMPLIFIERS.

(*Application date, 29th March,* 1927. *No.* 293,107.)

Photo-electric cells provided with a control grid are used as a substitute for three-electrode thermionic valves, the electron stream being produced by the action of light upon a sensitive cathode. The source of light is preferably passed through a rotating drum or moving screen, so that the cathode stream is rendered intermittent at a definite frequency, a feature which facilitates subsequent amplification.

As shown in the figure, incoming signals are applied between the control grid and sensitised cathode of the first amplifier V, which is coupled through a tuned circuit L, C and condenser C_1 to a similar amplifier V_1. The latter in turn is resistance-coupled to a cell V_2 feeding a loud speaker LS. The high-tension supply is taken through a mid-point tapping on the coil L, a neutralising condenser NC balancing the inter-electrode capacity. All the amplifier cathodes are rendered active by a common light-source S through focusing lenses P_1, P_2, P_3, suitable means being provided for protecting them from fortuitous light-rays. The rotating drum or interrupter (not shown) is interposed between the source S and the focusing lenses. Such photo-electric amplifiers may be used in combination with thermionic valves of standard type, the overall response being stated to be strictly proportional to the applied signal energy.



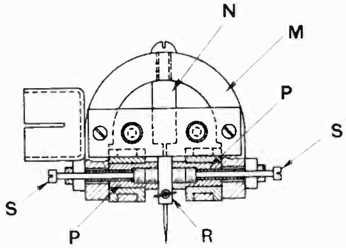
Patent issued to W. S. Smith and N. W. McLachlan.

GRAMOPHONE PICK-UPS.

(*Application date, 7th April,* 1927. *No.* 293,483.)

In order to reproduce faithfully from a gramophone record it is necessary that the reed and needle should both be suitably damped, so that they are effectively held from any uncontrolled movement. In the pick-up device shown in the figure, a permanent magnet M is fitted with pole-pieces P, between which depends a metal reed R, carrying the record needle and anchored to a suitable support N.

Each pole-piece P is of tubular formation and accommodates an adjusting screw S, by means of which a small piece of rubber can be pressed gently against the reed R, so as to centre the latter and impose a damping or restraining action. This does not prevent any movement imparted to the needle by the record, but will effectively damp out any promiscuous or uncontrolled lateral vibration. The rubber dampers, being located close to the fulcrum of the reed, allow the needle maximum leverage, and so ensure a highly sensitive operation.

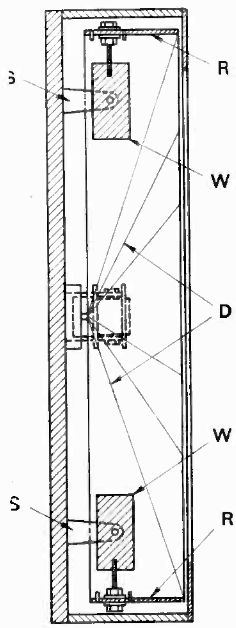


Patent issued to L. H. Pearson and C. Marshall.

LOUD SPEAKERS.

(*Application date, 7th July,* 1927. *No.* 293,200.)

When the edge of a conical or similar diaphragm is rigidly clamped, there is a tendency for the reed or other driving means to be forced out of proper adjustment, either by temperature changes or by any sudden blow or shock. In order to avoid this, the diaphragm D is attached to a cylindrical ring R of cardboard, which, in turn, is loaded with weights W secured at intervals around it. The weights are balanced upon pivotal supports S.



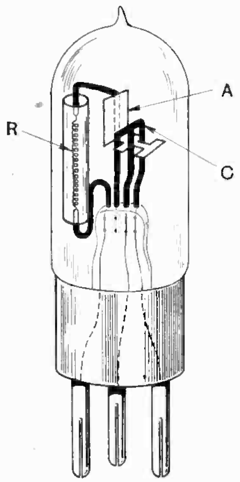
In such an arrangement the diaphragm is free to take up its own position under temperature changes without throwing any strain upon the reed. Also the diaphragm and balance weights can move relatively to the containing box or case if the loud speaker as a whole is subjected to accidental shock. Finally, since the weights are balanced, the parts are not affected if the position of the containing case is altered. The total mass of the supporting means is such that the natural free period of vibration of the diaphragm and its supports is below audibility.

Patent issued to E. V. Mackintosh and C. French, trading as Celestion Radio Co.

GAS-FILLED RECTIFIERS.

(*Application date*, *2nd March*, 1927. *No.* 293,365.)

In order to maintain a constant current through a gas-filled discharge tube used for rectifying, in spite of fluctuations in the supply voltage, a special resistance *R* is incorporated in series with the anode *A* and is mounted inside the bulb. A low-temperature incandescent cathode of the Wehnelt type is preferably used.



The ballasting resistance *R* consists of an iron or tungsten wire, which in an atmosphere of argon has the property of passing a constant current within certain limits of voltage variation. In order to prevent it from taking part in the actual discharge between cathode and anode, and so suffering gradual disintegration, the resistance is screened by a small tube of insulating material, such as glass, located behind the anode proper.

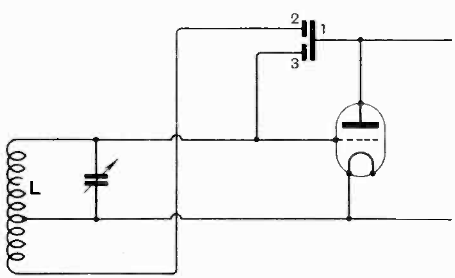
Patent issued to H. Wade (N. V. Philips Glowlamp Co.)

BALANCING CONDENSERS.

(*Application date*, *26th April*, 1927. *No.* 293,926.)

The circuit illustrates a receiving loop-aerial *L* having one end connected to the grid of an amplifier, an intermediate tapping to the filament, and the other end connected to the plate through the special balancing and reaction-control condenser shown. The latter consists of a movable plate 1 co-operating with two fixed plates, 2, 3, the arrangement being such that as the capacity between 1 and 2 increases, that between 1 and 3 decreases, and *vice versa*.

It will be seen that the capacity between the plates 1 and 3 is in parallel with, and is therefore



added to the inter-electrode grid-plate capacity to be balanced. The arrangement gives a smooth reaction control, since the capacity between plates 1 and 3 is added to the inherent grid-plate capacity of the valve just at the point where that capacity may be insufficient to secure a stabilised balance.

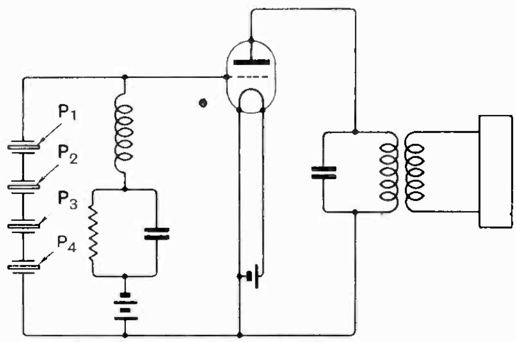
Patent issued to Burndept Wireless, Ltd., and C. F. Phillips.

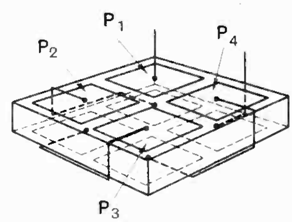
PIEZO-CONTROLLED OSCILLATORS.

(*Application date*, *31st December*, 1927. *No.* 294,061.)

Relates to means whereby the power output of a crystal-controlled valve oscillator can be greatly increased without danger of fracturing the crystal, whilst at the same time eliminating any fluctuations in the fundamental frequency due to temperature variations. When the oscillator *O* is in steady operation, the voltage between grid and filament converges towards a certain definite value, depending upon the applied plate tension and the amplification factor of the valve. In practice it is found that for grid voltages beyond a few hundred volts there is danger of the crystal being ruptured.

According to the invention, four separate crystals, P_1 to P_4, having substantially the same fundamental frequency, or related in harmonic ratio,





are connected in series across the grid and filament, so that the effective voltage across each individual crystal is only one-fourth the full drop. The output power can therefore be increased proportionally without exceeding the safety factor. The first two crystals should be cut perpendicular to, and the last two parallel with a natural face of the mother crystal, so that they have temperature coefficients of opposite sign. The effect of any overall temperature variation is therefore balanced out. Instead of using separate crystals, a single large crystal may be fitted with a series of separate electrodes, as shown in the lower figure, the lower plate of one pair being connected to the upper plate of the next pair, so that the four pairs are in series relation.

Patent issued to Standard Telephones and Cables, Ltd.