The Electrostatic Loud Speaker

1. How It Works

By M. G. SCROGGIE, B.Sc., A.M.I.E.E.

If a sufficiently high voltage were applied between the plates of a variable condenser, and the moving plates were sufficiently freely suspended, they would rotate into the maximum capacity position. In practice there is no great likelihood of our tuning dials moving round in this way when an extra powerful "atmospheric" arrives, because the friction at the bearings is so great that the voltage would spark across between the vanes long before being enough to shift them round. But the electrostatic voltmeter, which is simply a very tiny and lightly suspended variable condenser fitted with a pointer, demonstrates the truth of this principle every time it is used.

The principle, of course, is that a difference of potential or voltage between any two conductors causes them to attract one another, and, where they are free to move, to approach one another.

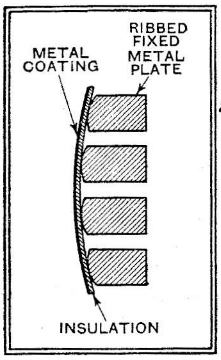


Fig. 1.—Section of the "Kyle" electrostatic loud speaker.

If the potential continually varies, the degree of attraction varies and the motion is continuous. A back-and-forward motion repeated at anything between about 16 and 16,000 times a second causes sound. Therefore, a condenser is, in principle at least, a loud speaker. Actually an ordinary paper fixed condenser may sometimes be heard to emit a faint note on being connected across the A.C. mains or other source of high alternating voltage. But generally the manufacturer has taken good care that the two strips of foil that make up the condenser are too tightly sandwiched between the waxed paper dielectric strips to vibrate at all.

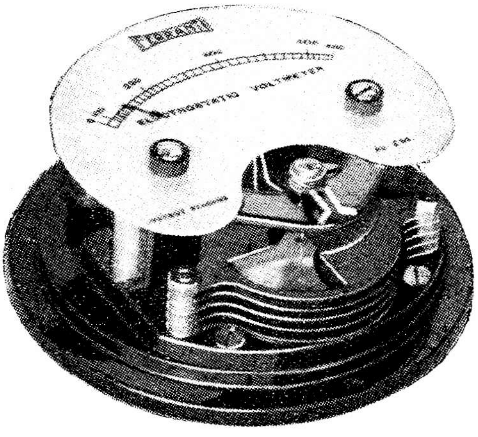
Practical Considerations

If a condenser is to be any good as a sound reproducer it should be exposed to the open air, and one at least of its two conducting elements should be reasonably free to move to and from the other. This could be done by suspending it a little distance away, with a layer of air in between. There are several disadvantages in this. The layer of air acts as a cushion, tending to damp out the motion, just as a pneumatic stop prevents a door from being slammed, however hard it is pushed. Then the force set up by a given voltage falls off very rapidly as the plates are separated even slightly. And to keep them separated at a fixed distance without solid material in between it is necessary to impede their free motion still further, either by making the plates very thick and stiff or by stretching them tightly.

The result is that the simple condenser loud speaker tends to be very inefficient and insensitive, and the object of design is to remove these objections. An example of the stretched diaphragm type is that by Hans Vogt, of Ferrocart fame. He used an extremely thin moving diaphragm, stretched so tightly, close to a perforated fixed plate, that the natural frequency was above the usual audio frequency range—about 15,000 cycles per second, in fact. The perforations were intended, of course, to remove the air damping.

The amount of information which has been published about the electrostatic or condenser loud speaker is almost negligible. Being such an unknown quantity it has not yet come into general use, although it has been on the way for over fifty years. This neglect is not altogether deserved, for in some respects, particularly reproduction of the higher frequencies, it is unrivalled. Being fundamentally different from other types of loud speaker it is unfair simply to substitute it and expect the best results. The purpose of the author of this contribution will be to explain how the electrostatic loud speaker works and to give advice on its use.

The Kyle loud speaker—of American origin—has the effect of splitting up the total surface into a vast number of tiny diaphragms, by stretching the moving element directly on the fixed one, separated only by a thin layer of flexible insulation. Fig. 1 shows in section a small portion of this arrangement. The fixed plate is slotted and ribbed, and so shaped where it makes contact with the composite moving plate that an increase in voltage between them causes the latter to cling closer to the fixed plate and squeeze some of the air out through the slots. The reverse action takes place when the voltage relaxes.



The Ferranti electrostatic voltmeter illustrates the principle of electrostatic attraction.

A still closer approach to unrestricted motion is obtained in the "Primustatic" speaker, which, as it is one readily obtainable in this country, will be principally considered. Fig. 2 shows an enlarged section of it, in which the fixed plate, of perforated aluminium, is slightly curved. Behind it is a tinfoil-coated sheet of waxed paper, folded so as to form tiny triangular-sectioned air spaces behind the perforations. At the "dead" lines, in between the rows of perforations, where there is no motion, the foil paper is held in position by a special sort of hairy thread which makes very light, but adequate, contact everywhere. It is possible to use graphite-coated paper instead of metal, as a fairly high resistance does not interfere with the operation.

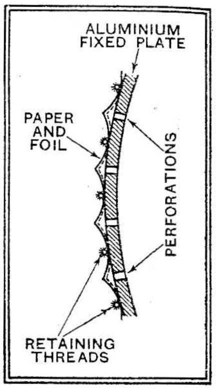


Fig. 2.—Section of the "Primustatic" loud speaker. The dotted line shows the position of the diaphragm under the force of attraction.

It will be clear that when a voltage is set up between the plates a sort of rolling action takes place, causing the line contact to spread out into a strip, as shown dotted, and air to be expelled through the perforations.

Possibilities of Distortion

As the attractive force takes place whenever a difference of voltage exists between the plates, it is obvious that they will move together during both positive and negative halves of an alternating wave. Thus, in Fig. 3, if (a) represents two complete periods of a 50-cycle supply, (b) represents the corresponding attractive force set up, and it will be seen that there are *four* complete waves. So instead of a 50-cycle note we get a 100-cycle note.

Reproduction in which every frequency is double what it ought to be is not likely to be considered satisfactory. It is interesting to note that precisely the same result is obtained in a moving-iron loud speaker or headphones in which no permanent magnetism is provided, the only

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attractive force being due to the signal current. The remedy in the latter case gives us the clue to that for the electrostatic speaker defect—the provision of a steady initial force considerably larger than any due to the signal.

Fig. 3 (c) shows the combination of the high steady voltage and the alternating signal voltage, and one important feature is that it never reverses—the initial voltage being relatively large keeps it on one side of the base line throughout. Consequently the frequency-doubling effect is absent, and the attractive force closely follows the outline of the voltage, Fig. 3 (d).

The Polarising Voltage

It can be shown mathematically that not only is the distortion reduced to an unimportant quantity, but also the sensitivity is considerably increased. In practice it is not advantageous to increase the initial polarising voltage indefinitely, even if it were convenient. There would be the danger of breaking down the insulation—air or solid according to the type of construction—between the plates. Also the freedom of motion would be impaired by an excessive displacement in one direction. So the actual voltage is something of a compromise, and one is not far wrong in imposing the voltage used at the anode of the output valve. The signal voltage at this point is, of course, always substantially less. If the latter is stepped up, however, it may be necessary to increase the polarising voltage also, to make sure that it is in the correct proportion.

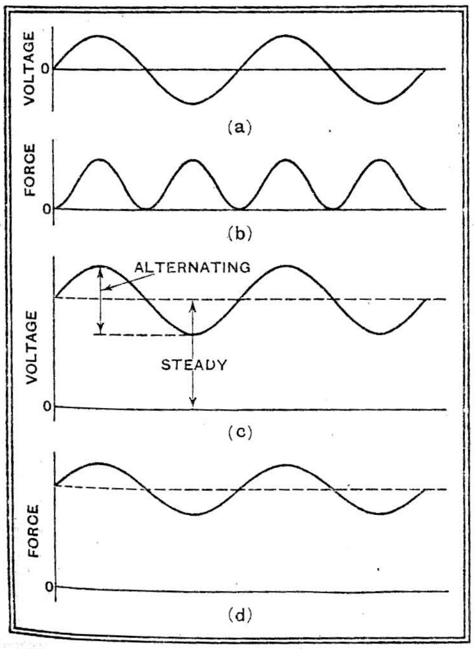
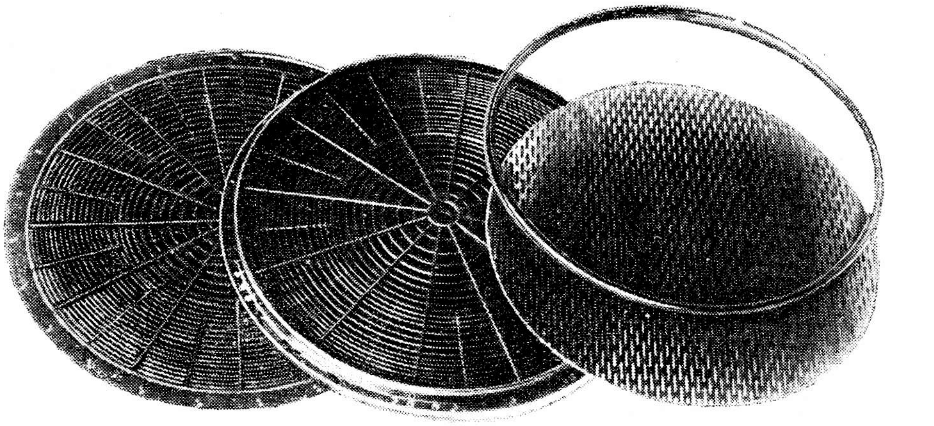


Fig. 3.—Without a polarising voltage, frequency doubling would occur in an electrostatic loud speaker.

A polarising voltage of 1,000 used to be necessary for the earlier types, which is sufficient to explain the disfavour with which they were regarded for general use, and an advantage of the Primustatic type is that about 250 volts is usually enough. So what used to be a serious drawback now seldom presents much difficulty. The loud speaker being in effect a condenser draws no current from the polarising source.

A rather more serious criticism is that the amplitude of motion is not very great, and that there is therefore difficulty in obtaining strong reproduction of the lowest frequencies. This can be got over to some extent by increasing the area of the diaphragm, which can be done as much as one pleases by adding more units in parallel.



Component parts of the Vogt stretched diaphragm loud speaker.

Lastly, on the debit side of the account there is a problem in efficiently coupling the speaker to the output valve. This matter will be gone into in detail later.

High-frequency Response

Now for the credit side. It has already been pointed out that the high note reproduction is a strong feature. There are several reasons for this. Instead of the relatively heavy and complex moving system of any of the magnetic types of speaker, which renders it difficult to get upper frequency reproduction except in the form of resonances, there is a light uniform moving diaphragm, with extremely low inertia. Moreover, this is actuated all over its surface instead of at one part, as in other types, thus avoiding the complicated modes of vibration with resulting resonances and irregularities that distinguish the latter. Further, the area of the diaphragm can be made as large as one pleases, and the focusing and "interference" effects of a small cone are avoided. It is a better sound radiator, in other words. There is practically no upper frequency limit, and therefore it is in advance of present day microphones and transmitting systems, and advantage can be taken of any improvements in the latter. But even with existing standards of transmission, so long as local interference does not impose a severe limit, it is possible to appreciate a very greatly increased clarity and faithfulness of reproduction. It is significant that for special experiments in America, where substantially uniform output of sound was required up to 14,000 cycles, a condenser reproducer was employed.

The advantage is particularly marked in speech, string tone, and sounds involving transients, such as clapping, tapping, paper rustling, and cymbals.

The construction is much simpler than that of any other type. There are no coils, magnets, or field excitation. For the same reason it is extraordinarily light, and as regards compactness it can be made into panels of very little depth—an inch or so, for example, or even less if necessary.

An electrostatic loud speaker, used alone, is far superior in naturalness and clarity of speech to a moving coil speaker, particularly of the cheap sort now almost universal. But unless very large there is not enough depth to music to please most listeners, although even this deficiency can be made considerably more tolerable by the delightful distinctiveness of the instruments in the upper registers, which is variously described as brilliance, "life," and crispness. It is a great relief to get away from the thumpy whoofy reproduction that is so common, or the still commoner apology for "brilliant" tone produced by a fierce high note resonance.

The best overall reproduction is therefore given by a combination of moving coil and electrostatic speakers. To obtain a satisfactory distribution of labour between the two, or even to run an electrostatic on its own, we must consider how it behaves as a load in the valve circuit. Unless attention is given to this the results can be very bad indeed. So it will form the subject of the next part of this article.

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II. Matching Loud Speaker and Output Valve

By M. G. SCROGGIE, B.Sc., A.M.I.E.E.

THE electrostatic loud speaker is unique in presenting a capacitative load to the output valve, and the conditions necessary to prevent distortion and overloading are essentially different from those of moving-iron or moving-coil types.

WE have seen the fundamental difference between the electrostatic loud speaker and all other types. Before it can be effectively used it is necessary to consider it as a load in a valve circuit.

A moving-iron speaker can be considered approximately as an inductance. A moving-coil speaker is conveniently (but not very accurately) assumed to be a resistance. An electrostatic speaker may be represented as a capacity, perhaps not quite so pure (i.e., free from resistance) as the very best condensers, but one does not go far wrong in neglecting the impurity.

It has already been explained that the effect of a voltage between the two plates is to draw them closer together. Therefore, one would expect the capacity to be increased thereby, and this is exactly what happens. Fig. 1 shows the measured capacity of a "Primustatic" loud speaker with an 18in. by 20in. diaphragm. The capacity averages about 0.008 mfd. per square foot, or a reactance of about 20 megohms divided by the frequency in cycles per second.

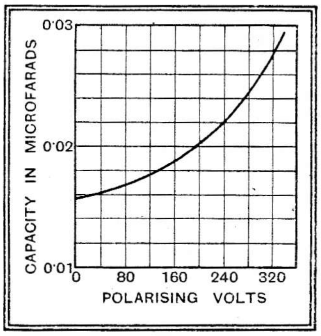

Fig. 1.—Variation of capacity with polarising voltage in the "Primustatic" 18in. × 20in. loud speaker.

The Load Diagram

In drawing load curves on a valve diagram the loud speaker is usually represented by a straight line, which means a resistance, constant at all frequencies. No loud speaker ever does act just like that, but a moving-coil type is near enough to it over the middle range of frequencies for one to get at least a hazy idea of how to match it to the valve. Our condenser speaker has this advantage at least, that it is very closely a capacity load, but, unfortunately, it is therefore not a straight line at all, but an ellipse, and one of a different size at every frequency. So it is rather an exasperating business trying to fit it comfortably into the valve diagram. To start with, it would be worse than manufacturing a "Mickey Mouse" film to draw a diagram for *every* frequency, so let us select three only—80, 800, and 8,000. The respective reactances of a 2½ square foot speaker are 100,000, 10,000, and 1,000 ohms,

There are two ways in which these figures can be altered to suit the valve: first, by selecting a diaphragm of different area, and, secondly, by using a step-up or step-down transformer, which has the effect, looked at from the *primary* side, of multiplying the reactance by the square of the transformer ratio. A step-up is equivalent to an *increase* in capacity. But it is inevitable that with any one arrangement the reactance must vary over the same range as the frequency.

The result of this characteristic is that the behaviour is strikingly different according to whether a triode or a pentode is used. Fig. 2 shows a diagram for a triode with an internal resistance (impedance) of about 2,500 ohms, and the three reactance eclipses have been drawn in to show what happens at the lowest, middle, and highest frequencies. The ellipses in each case are the largest that can go in without running into grid current on the left, or bottom-bend rectification at the foot.

At 80 cycles the full grid excitation is possible; that is to say, the grid voltage can be swung right from zero on one side to double the bias voltage on the other, without any possible risk of overloading due to rectification. The voltage developed across the loud speaker is the maximum possible.

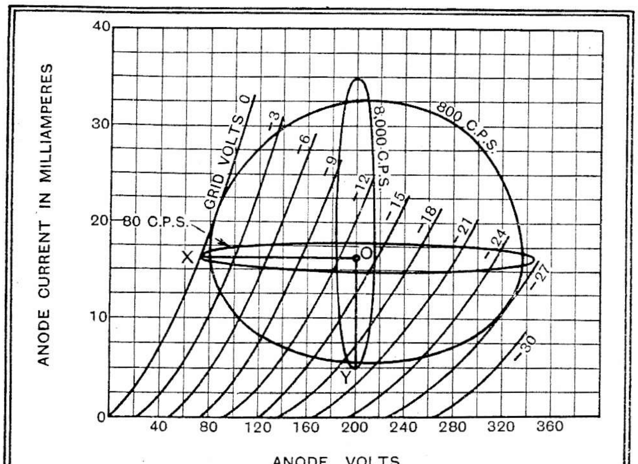

Fig. 2.—The load ellipse of an electrostatic loud speaker varies in shape and inclination as the frequency changes.

Permissible Grid Volts

At 800 cycles it is just possible to give it the full grid, but the ellipse has opened out so much that it is approaching the danger zone along the foot. Still, it is working quite happily and developing practically the full voltage. At any higher frequency, however, the lower half would be flattened out, unless the whole ellipse were reduced in size by reducing the grid input. This is well shown at the upper extreme of 8,000 cycles, where the grid excitation must be reduced to less than a half in order to avoid rectification distortion, and the anode voltage developed across the loud speaker dwindles to about a tenth.

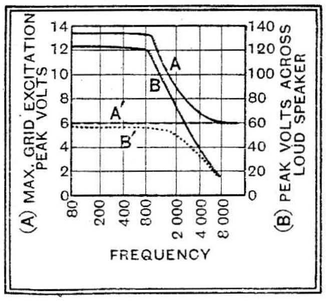

Fig. 3.—Curves showing maximum permissible grid volts with capacity load.

These features are illustrated rather more concisely in Fig. 3. Curve A shows the maximum peak volts that can be applied to the grid without overloading, and curve B shows the voltage developed across the loud speaker with maximum grid volts as given. In each case the voltage is level up to a certain critical frequency, in this case 800 cycles, after which it rapidly falls. It must not be hastily concluded that the response suddenly falls off above 800 cycles, for it must be emphasised that curve B is strictly dependent on A, and shows the maximum output short of overloading the valve.

P. P. Eckersley has shown experimentally that in normal broadcasting the amplitudes to be expected at the upper frequencies are considerably lower, and would come well below curve A. In addition, by-pass condensers, H.F. tuning characteristics, and other factors are almost certain to prevent the grid voltage from breaking the allotted bounds. So if the grid excitation is kept at a level six volts throughout, as it can be without fear of overloading (curve A′), the output is as shown by B′.

Another point is that it is the falling part of curve B′, rather than the level part, that is correct. The amplitude of diaphragm required to give a constant

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output of sound gets steadily less as the frequency rises. It is not possible to state exactly what is the ideal characteristic

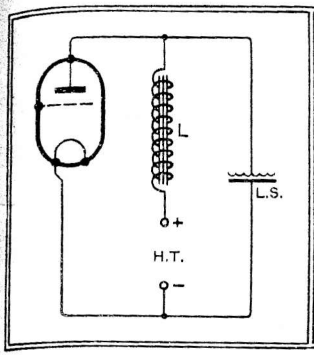


Fig 4.—Choke coupling provides the simplest connection between valve and loud speaker.

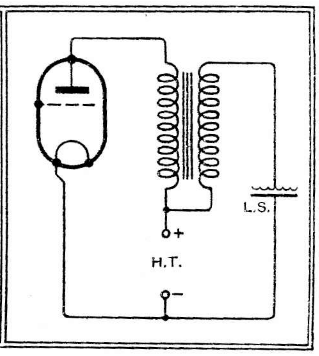


Fig. 5.—Connections for applying polarising voltage with transformer coupling.

without knowing exactly how the particular type of diaphragm behaves at various frequencies; but a listening test with a constant-amplitude pure tone shows a satisfactory response down to about 800 cycles, and a falling response below that.

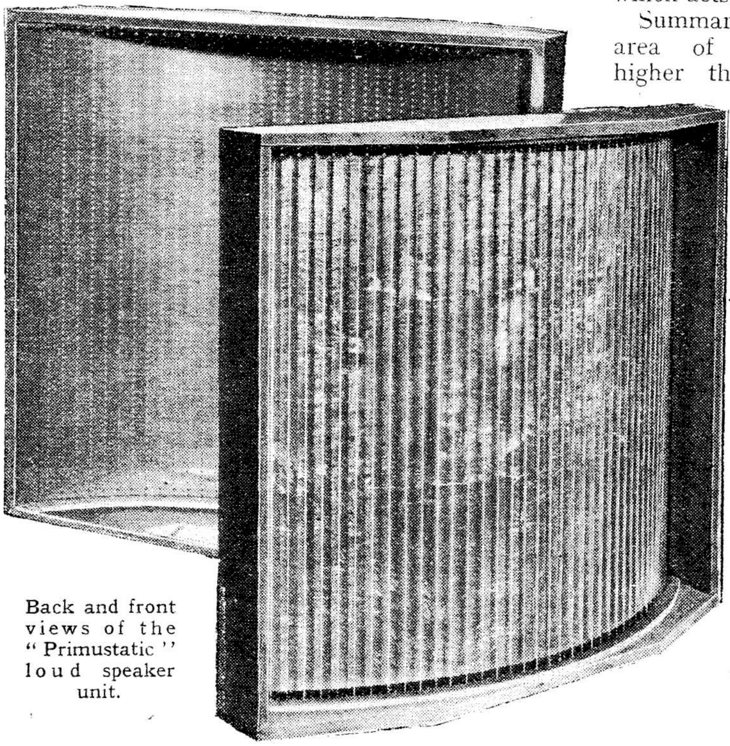
The Critical Frequency

We can calculate this critical frequency by measuring the distance in anode volts horizontally from the initial working point O on the valve diagram to the zero grid voltage point X, and dividing this by the vertical distance, in anode milliamps, from O to Y, the minimum current consistent with avoiding severe curvature. This gives the reactance in thousands of ohms, which is also equal to $\frac{1{,}000}{2\pi fC}$, where f is the frequency and C is the capacity in microfarads; so it is easy, knowing C, to calculate f. By altering C in either of the two ways already described it is possible to shift the critical frequency f, thus extending either the level or the falling part of the curve.

As it has just been stated that it is the falling part that is correct, it would seem that the sensible thing to do would be to make the critical frequency as low as possible. That means making either the actual capacity or the step-up ratio as large as possible. An additional allurement is that an increase in capacity means an increase in sound-radiating surface, and an increase in step-up means an increase in signal voltage, and in either case it looks as if the volume would be increased without any greater expenditure of power. But, while it is true that there is improved *uniformity* of response, the improved *efficiency* fails to materialise; for curve A is shifted to the left too, and necessitates severely cutting down the input. And, as the lower tones are less audible than the upper, there is an apparent falling-off in volume, and in endeavouring to restore it by the volume control the only result is rattling and distortion. If, on the other hand, the capacity is too small, the volume again drops, and what output there is consists almost entirely of extreme top.

Hence a compromise is necessary, giving a reasonable efficiency at the upper frequencies, the lower being augmented, if necessary, by a bass moving coil unit.

To descend for a moment from these theoretical reasonings to consider how the connection is made in practice, the simplest circuit is that of Fig. 4, where L is a choke of high inductance capable of carrying the valve anode current. In this way the loud speaker receives both the output voltage from the valve and the steady polarising voltage from the H.T. source. The choke behaves as a 1:1 transformer, and if its inductance is sufficiently high it by-passes a negligible proportion of the "signal," and so the whole arrangement conforms very closely to the preceding theory. It may be of interest to realise that at one particular frequency the impedance of the anode load is almost infinite, due to the resonance of choke and loud speaker, and is also a pure resistance, and hence a nearly horizontal straight line instead of an ellipse. With normal components this frequency is about two or three hundred cycles, but the phenomenon does not appreciably modify the performance as already described. The whole action is very beautifully confirmed by cathode ray oscillograph tests, using a variable-frequency oscillator. Beginning at the lowest frequencies, we see the "lengthwise" ellipse become a straight line, and then open out into an "upright" ellipse, which, unless the input is reduced, causes terrible overloading.



Back and front views of the "Primustatic" loud speaker unit.

the anode current rising much above normal.

If a transformer is used to alter the ratio it is essential to allow for the polarising voltage (Fig. 5), and if it is a step-up ratio it may be desirable to add some auxiliary voltage, but only if the H.T. voltage itself is rather low. An old dry battery can be used, as no current is drawn. If the secondary is linked to the anode end of the primary the sum or difference of the voltages across both windings is obtained, giving a choice of three ratios altogether.

Push-pull Connections

A push-pull stage is much to be recommended, and Fig. 6 shows one method of connection. If there is no secondary winding, or if it is being used for another loud speaker, the connection of Fig. 7 is another of the many schemes. Although this looks a one-sided arrangement, it actually loads the whole transformer, which acts as a 2:1 step-down.

Summarising: the larger the area of diaphragm, or the higher the step-up, the lower is the frequency below which response falls off. But the lower also is the efficiency and the greater the tendency to rattle. So only when there is plenty of power available in the last stage is it possible to arrange these matters so as to go low down the scale. The smaller the number of milliwatts available the higher must be the critical frequency. A dual speaker combination is in any case the best for effective reproduction over the whole audible scale. Methods of obtaining this, together with tone control, and the conditions for pentode operation, will next be considered.

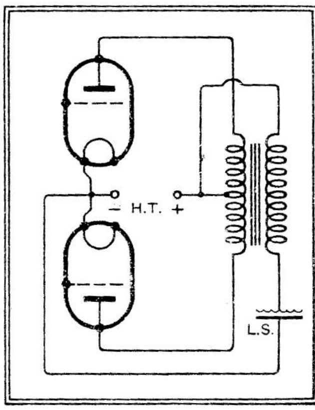


Fig. 6.—Push-pull output using transformer secondary winding to energise the loud speaker.

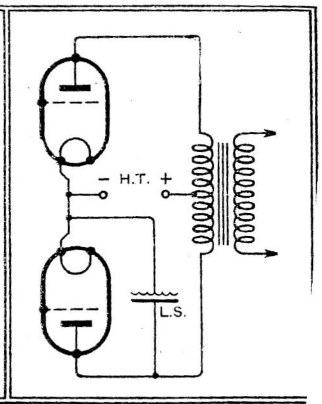


Fig. 7.—This circuit gives a 2:1 step-down and leaves secondary free for an additional loud speaker.

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III.—Circuits for Operation with a Moving-coil Unit

By M. G. SCROGGIE, B.Sc., A.M.I.E.E.

In this article the author concludes his review of the electrostatic loud speaker with an analysis of the operating conditions when using pentode output valves and gives practical hints on the best method of combining electrostatic and moving-coil units.

IT has been shown that when an electrostatic loud speaker is connected to a triode output valve there is a certain critical frequency below which the response falls off. The critical frequency is that which makes the reactance of the loud speaker (which being in effect a condenser is dependent on frequency) equal to OX (volts) divided by OY (amps) (Fig. 1) where Y is the lowest permissible anode current without serious bottom-bend rectification.

It is convenient to remember that this reactance is roughly equal to the optimum load for the valve. The critical frequency can be pushed lower to widen the effective response, but only at the expense of efficiency. So unless a very large output is available and used rather wastefully, it is better to obtain the bass response by means of a moving-coil loud speaker and to make the critical frequency quite high, say about 1,000 cycles per second. The table below may be useful.

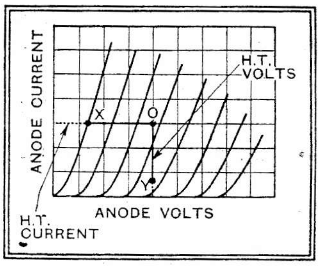

Fig. 1.—Critical reactance is given by OX in volts divided by OY in amps.

The capacity of the loud speaker is the actual capacity multiplied by the square of the output transformer ratio; a step-up giving a larger capacity and vice versa.

Fig. 2 shows a method of adding an electrostatic speaker to an existing triode and moving-coil (or inductor) speaker. The latter is likely to have a resonance somewhere about 2,000 or 3,000 cycles; and as this comes within the province of the electrostatic it is desirable to cut it out by inserting a choke L1, with an inductance of about one henry, preferably variable to allow of adjustment to suit the working conditions. If L1 is used, it is important to avoid any capacity across the transformer, or even excessive self-capacity, or there will be a series resonance and a worse state of affairs than ever. Another improvement is a variable resistance R of about 10,000 ohms, which can be used to prevent the high-note overloading described last week. A further refinement, with the object of preventing large low-frequency voltages reaching the electrostatic speaker and causing it to rattle, is the choke L2, also tapped, with values up to 2 or 3 henrys.

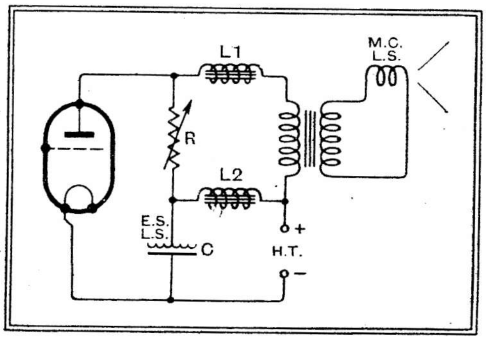

Fig. 2.—Practical circuit for combining the electrostatic with a moving-coil loud speaker following a triode output valve.

The Pentode Valve

If R is in, the parallel resonance due to C and L2 may undesirably emphasise one frequency; if it is out, there may be both high- and low-note overloading. But as L2 is of value mainly in high-power stages, the overloading point is not likely to be reached; and, in any case, the danger of overloading can be minimised by stepping down, as shown in Fig. 3. Remember that stepping down tends to reduce the electrostatic low-note response, and vice versa, while excessively wrong ratio causes loss of volume too.

The case of the pentode is considerably different from that of the triode, and the situation is best explained while looking again at a valve load diagram (Fig. 4). Again we take the extreme and middle frequencies of 80, 800, and 8,000, giving with a loud speaker capacity of 0.02 mfd. reactances of 100,000, 10,000, and 1,000 ohms. Neglecting for the moment any complications due to the necessary coupling arrangement, these three conditions are again represented by the three ellipses. Here the lowest frequency ellipse develops across itself the maximum possible anode voltage, but unlike the triode it does so with a very small grid swing. Any larger grid swing would result in excessive voltages being developed, besides severe distortion.

The medium-frequency condition is similar to that of the triode in so far as the full grid swing results in full output voltage with just tolerable distortion. The load ellipse only just succeeds in fitting in. The highest frequency condition is also similar in that the anode voltage developed is very low, but full grid swing is possible at all the upper frequencies. Transferring these results to Fig. 5, it is seen that curve B, which shows the maximum voltage that can be developed across the speaker without overloading the valve, is practically the same as that for a triode. But the actual state of affairs is very different, for the output shown is on the assumption of maximum allowable grid swing, which as indicated by curve A is just the opposite to that of the triode. Moreover as in average broadcasting the actual distribution of grid swing over the frequency scale is very different from curve A, being greatest at low frequencies, curve B must be interpreted accordingly. If the grid swing were distributed according to the intensity given at the various frequencies during normal broadcasting,

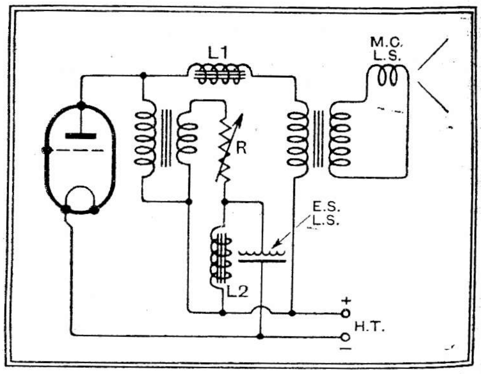

Fig. 3.—Modified arrangement of Fig. 2, with step-down transformer to minimise overloading.

Critical frequency.	Critical reactance of loud speaker in ohms.					
	0.064 8	0.040 5	0.024 3	0.016 2	0.008 1	0.004 cap. mfd. 0.5 sq. ft. approx.
250	10,000	16,000	26,500	40,000		
400	6,200	10,000	16,500	25,000		
600	4,100	6,600	11,000	16,500	33,000	
1,000	2,500	4,000	6,600	10,000	20,000	40,000
1,500	1,650	2,600	4,400	6,600	13,000	26,000
2,000	1,250	2,000	3,300	5,000	10,000	20,000
3,000	830	1,300	2,200	3,300	6,600	13,000

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the resulting curve B would slope off at the high frequency end very steeply indeed. A listening test confirms this by giving the rather surprising result that this type of loud speaker, noted for high-

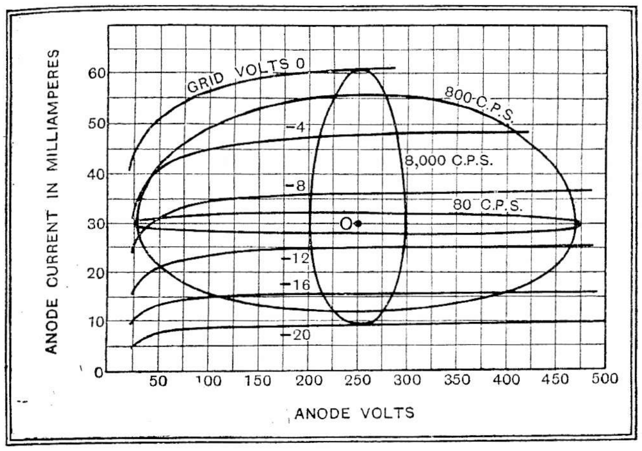


Fig. 4.—Load diagram for the electrostatic loud speaker in conjunction with a pentode output valve.

note response, is deficient in the same when run from a pentode.

At the lowest frequencies, however, there is a considerable divergence between theory and practice. It was explained in connection with the triode that some sort of coupling device is essential, and if this takes the form of a choke or a transformer, the loud speaker resonates with the inductance at some moderately low frequency. That causes little concern in the triode, for as long as the impedance in the anode circuit is *greater* than several times the valve impedance it makes little difference, and it is a *series* resonance, which causes the load impedance to become very small, which is to be guarded against. But in the pentode the output voltage increases almost without limit as the load impedance is raised, and the effect of a parallel resonance is to cause excessive emphasis of the resonant frequency, accompanied by severe overloading unless the volume is reduced so that all other frequencies are very feebly reproduced.

Practical Schemes

This serious objection can be counteracted by connecting a resistance in parallel with choke and loud speaker. If, for example, the resistance is 20,000 ohms, it

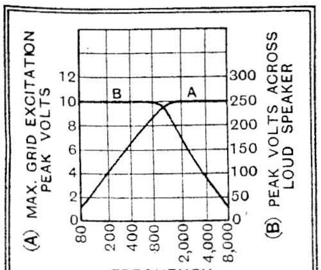


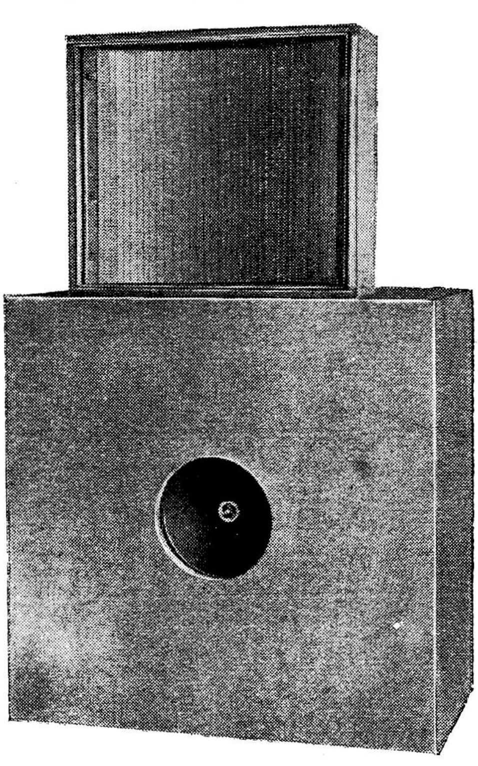
Fig. 5.—Operating conditions for a pentode derived from the curves of Fig. 4.

is obvious that the load can never *exceed* this figure, and so a limit is set to the voltage that can be developed, and a much more uniform response obtained, but somewhat at the expense of efficiency.

Fortunately, the efficiency of the pentode drive starts off at a considerably higher maximum than that of the triode.

But the desirability of a dual loud speaker system is even more marked with the pentode, and so is the desirability of preventing the low-frequency voltages from being set up across the electrostatic loud speaker. This object can be achieved by shunting it with a relatively low inductance and also a resistance to prevent a sharp resonance. A fairly large condenser shunt across the moving-coil loud speaker completes the division of labour, and a resistance is necessary here also. All this sounds very complicated, but Fig. 6 shows how a single variable resistance can be made to serve not only as both shunting resistances but also as an effective tone control.

The ordinary transformer is used for the moving-coil loud speaker, and the upper frequencies are by-passed by the 0.1 mfd. condenser. The electrostatic loud speaker coupling choke may be 1 or



The combination of moving-coil and electrostatic units gives full bass response with unusually good reproduction of high frequencies and transients.

1.5 henrys on the primary side, and a secondary inductance to suit the size of loud speaker. The Varley 3H choke provides a variety of taps for obtaining the best balance. A 1 : 1 ratio is about right for a 0.01 mfd. speaker.

The tone-control potentiometer gives every tone from extreme low to extreme high preponderance.

Although any standard moving-coil loud speaker can be successfully used in a circuit of this type, it is, of course, preferable to use one specially intended for low-note reproduction. If there is no neces-

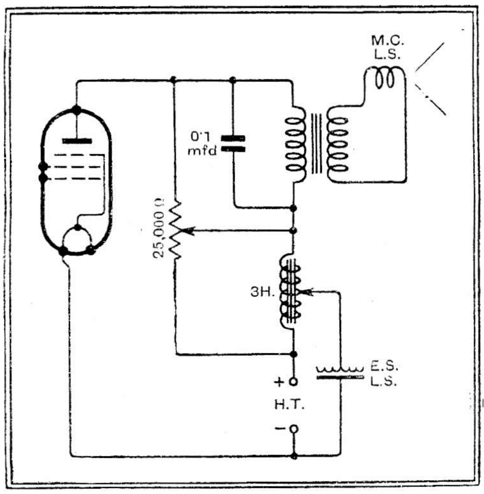


Fig. 6.—Dual loud speaker connections for a pentode output valve. The variable resistance provides tone control.

sity to look after the high volts, it is possible to do better justice to the bass by selection of suitable cone material and dimensions, and in other ways.

A simpler and less satisfactory circuit, but one which is more convenient to add to an existing receiver, and also gives some degree of tone control, is given in Fig. 7. It will be seen that in this the electrostatic loud speaker takes the place of the usual tone-compensating condenser, but, of course, it is essential that the H.T. voltage should come across it.

When applying to existing sets, it is important to see that any tone-compensating system that may be left in circuit is not preventing the electrostatic loud speaker from pulling its weight. In fact, the whole receiver, whether with triode or pentode output, must obviously be capable of passing the higher audible frequencies to the loud speaker if it is to reproduce them. This point needs to be stressed, because it is customary to cut high frequencies down fairly drastically in the interests of selectivity and freedom from mush, scratch,

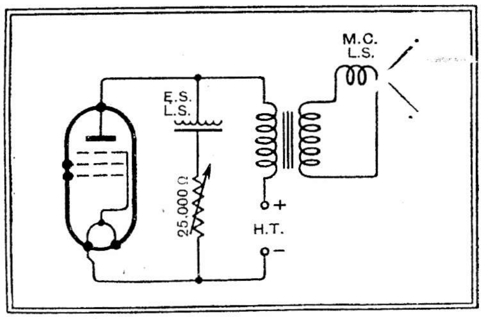


Fig. 7.—Simplified circuit for adding the electrostatic loud speaker to existing receivers. The loud speaker takes the place of the tone-correction condenser.

and hiss. The best plan is to restrict such limitation to one particular part of the circuit, where it can be controlled.

Where conditions permit—as when a station is being received at short range in relation to its power—the "top cut" can be removed and the advantages of the elec

The Electrostatic Loud Speaker—

trostatic principle realised to the full. Attention should therefore be paid to by-pass condenser, anode filter chokes, grid "stopper" resistors, and other devices which tend to side-track the high tones.

It is a disputed point whether *phase* distortion is an important imperfection in reproduced sound. It is generally agreed that the ear is not sensitive to displacement of phase, such as occurs whenever a transformer coupling is used, in the case of sustained sounds like those of the flute or organ. This matter, being so extremely difficult to handle either theoretically or experimentally, seldom goes beyond vague references to "attack," yet it is undoubtedly of importance.

There seems little doubt that the electrostatic type of loud speaker is superior to any other in the reproduction of transients, but it hardly has a chance if there is considerable phase distortion in the preceding stages. The substitution of well-designed resistance coupling for transformers helps, but even if transformers are eliminated from the receiver there are likely to be several in circuit before ever the wave strikes the receiving aerial. Careful test has established, however, that the removal of even one transformer of several can be detected by a sensitive ear. So the point is one worth considering, and the electrostatic loud speaker is the most useful with which to consider it.

Distant Reception Notes

DETAILS of France's revised Ferrié Plan announced by M. Eynac in his speech at the Paris Wireless Exhibition are interesting, for they show that the Government has no intention of taking over any of the large privately owned stations which are already in existence. These stations will have apparently to come down to a maximum power output of 5 kilowatts and to work on common-wave channels. It seems rather a curious business, for some Government high-powered stations are being built quite close to the private ones.

One correspondent enquires why there is now nothing to be heard on the short waves before the time when reasonable men go to bed. I am afraid that I cannot say why *he* hears nothing, for there is certainly a great deal going on on most evenings. Zeesen, for instance, has five different transmissions, DJA, DJB, DJC, DJD, DJE, three of which are generally well received before midnight. DJC is a small hours station on 49.83 metres, but DJA on 31.38 metres starts operations at 11 p.m. DJD on 25.51 metres transmits from 4 p.m. until midnight, and DJB on 19.73 metres from 2 to 10.30 p.m. DJE on 16.89 metres has no regular times at present.

Other European short-wave transmissions worth attention are Rome, 2RO, on 25.4 metres, usually to be heard at good strength at any time during the evening. Radio Nations, Switzerland, HBP, on 38.47 metres, to be heard on Saturdays after 11 p.m., Madrid, EAQ, on 30 metres at work from 11 p.m., and Skamlebaek, Denmark, OXP, on 49.4 metres from 7 p.m.

Of American short-wave stations, W2XAD of Schenectady, works on 19.6 metres on Mondays, Wednesdays and Fridays from 9 to 10 p.m., W8XK, of Pittsburgh, transmits on 25.27 metres from 10.30 p.m. onwards, and W3XAL, of Boundbrook, is to be heard on 49.18 metres on Saturdays after 9.30 p.m. W2XAF, of Schenectady, on 31.48 metres does not come into operation until 1 a.m.

There is still occasional interference with Huizen (Hilversum programmes) from a Russian transmitter. Radio-Paris, Luxembourg, Kalundborg and Oslo are excellent on the long waves, and Motala is showing considerable improvement. Zeesen has been particularly good lately.

Lyons Doua has returned to splendid strength on the medium waveband, and Beromünster is coming in so well that it is frequently receivable in daylight. First-rate reception has also been obtained during the past week from Budapest, Munich, Vienna, the two Brussels stations, Prague, Langenberg, Rome, Katowice, Leipzig, Toulouse, Hamburg, Strasbourg, Milan, the Poste Parisien, Breslau, Bordeaux, Hilversum, Bratislava, Heilsburg, Turin, Hörby, Trieste and Nürnberg.

D. EXER.

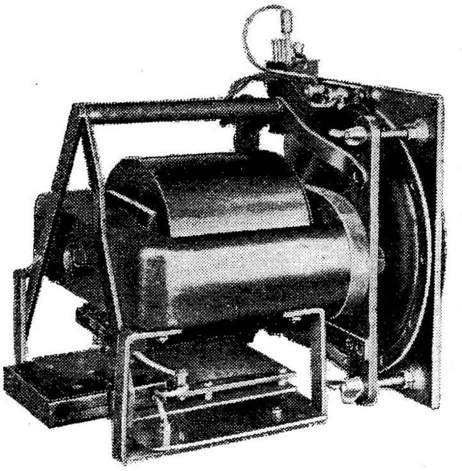
VOIGT LOUD SPEAKERS

Moving-coil Units of High Electro-Acoustic Efficiency

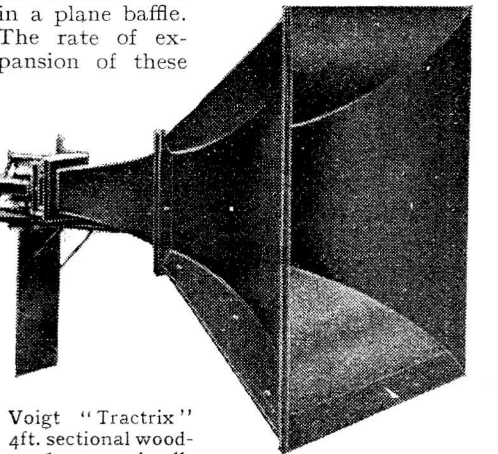
THE driving unit, is of the moving-coil type with a 6in. cone diaphragm, and is remarkable for its exceptionally high efficiency. To obtain some estimate of the relative efficiency, the unit was first tested on a plane baffle, and it was found that for a given input the sound output was fully 5 db. above that of any unit we have so far tested. With the 4ft. horn a further increase of 3 db. was obtained.

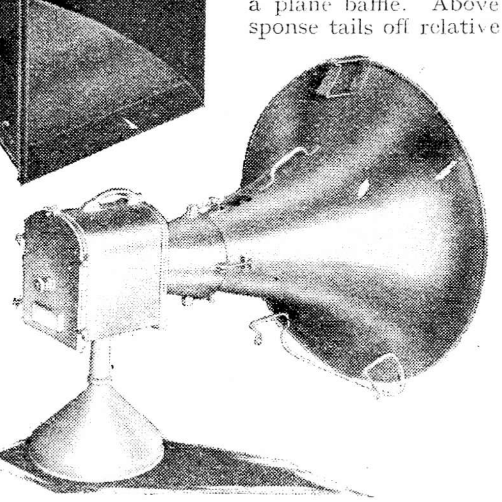
The efficiency is largely attributable to the high flux density—according to N.P.L. tests, about 17,000 lines under working conditions. This has important consequences in other directions, for not only is the diaphragm damping increased, with consequent improvement in transient response and freedom to overloading due to excessive diaphragm displacement, but the usual rise in the impedance of the coil at high frequencies is prevented. Actually, the average impedance is between 30 and 35 ohms, and the impedance at 8,000 cycles is of the order of 50 ohms. Much better matching with the power valve is thus obtained over the frequency range.

The unit has been designed to work in conjunction with the Voigt "Tractrix" horns rather than in a plane baffle. The rate of expansion of these horns is calculated for a spherical wave front, and it is claimed that the loading of the diaphragm is more uniform and efficient than in the case of the logarithmic or exponential types. The standard horn has a 4ft. square mouth and is built up of wood sections which are readily dismantled for transport. It is intended for indoor use, and a smaller horn of the same type with a 2ft. mouth is available for use where space is limited. Naturally, the bass



The Voigt moving-coil unit is provided with a field magnet giving 17,000 lines per sq. cm.





Voigt "Tractrix" 4ft. sectional wooden horn and all-weather metal horn.

cut-off in the latter is higher, and was estimated aurally to be in the region of 110 cycles; the larger horn goes comfortably down to 75 cycles. For outdoor work a spun metal horn has been developed in conjunction with a cast aluminium housing for the moving-coil unit.

The frequency response with the standard 4ft. horn is aurally uniform from 75 to 6,000 cycles with the exception of a just perceptible resonance between 3,500 and 4,000 cycles. It was interesting to note that the increase of output in this region was much less marked with the horn loading than on a plane baffle. Above 6,000 cycles the response tails off relative to the general level, but the response at 8,000 cycles is nevertheless higher than that of the majority of high-grade moving-coil loud speakers. The performance in general sets a very high standard of quality, both as regards balance and the reproduction of transients.

The makers are Voigt Patents, Ltd., The Courts, Silverdale, London, S.E.26, and the prices are as follow: Moving-coil unit, £14 10s.; 4ft. horn, £8; 2ft. horn, £4; all-metal horn and unit housing, £12 (provisional).

Letters to the Editor :—

Valves or Stages ?

Electrostatic Speakers : Ohms per Volt : Output

The Editor does not hold himself responsible for the opinions of his correspondents

Valves or Stages ?

THE recent correspondence between Mr. Baggs and Mr. Barry Kay cannot be other than inconclusive if conducted on its present terms. Mr. Baggs maintains that, since nomenclature by both valves and stages must be misleading in respect of many details of design, it would be better to leave even the main framework of receivers altogether unspecified. Mr. Kay, on the other hand, apparently intoxicated with the ingenuity of the new designation, does not seem to envisage the fuller description of sets, but rests content with a considerable degree of vagueness.

A parallel may be drawn from the case of motoring. Those who held that cars should only be advertised on the basis of the number of their cylinders could never be made to agree with those who held the same view in respect of their horse-power. In either case it is clear that what is wanted is not alternative erroneous systems, but a fuller system which can give rise to no misapprehensions. The number of valves is necessary to give an estimate of costs of replacement; the number of stages, an estimate of performance.

But it is also clear that radio sets have now become such complex pieces of machinery that even the conjunction of valves and stages cannot adequately describe their abilities. If nothing were known about a certain car save that it had eight cylinders, it could not be positively affirmed that it was better than another car with two, for the relative efficiencies with which these cylinders were used might differ widely. Similarly, a four-stage set might be very inferior to a three-stage set if the first contained a detector and three low-frequency stages, and the second was a normal I-v-I. The motoring public has set itself to master the intricacies of differing design, and is now well acquainted with fluid flywheels, automatic clutches, self-changing gear boxes, and so forth. There is no reason why the ignorance of the radio public, if such ignorance exists, should be pampered and encouraged. If it does not exist, there is still less reason.

There is no danger of misunderstanding in providing figures for the sensitivity, selectivity, and degree of automatic volume control, of all receivers. In America, the input-output ratio for the first figure has been related to a standard base; selectivity can be defined in terms of the detuning in kilocycles required to reduce a signal by a given proportion; while the effect of A.V.C. may be displayed by a simple graph. All these factors are within the understanding of the public, if they were carefully explained. Nothing but harm can arise from hazy and ill-defined statement. This type of error is well exemplified in the mention, criticised by "Free Grid," and made by Mr. Taylor, and no less an authority than Messrs. Ferranti, of "anode-to-cathode-streams." The reversal of these streams would, I feel sure, require the exercise of as great Authority as once reversed the waters of the Red Sea.

R. J. SPOTTISWOODE.

Oxford.

Electrostatic Speakers

MANY thanks to WIRELESS WORLD and Mr. Scroggie for the excellent articles on the electrostatic speaker; a device which until now, in my opinion, has not received the attention it deserves. Experience has shown me that there is one practical point which it is very easy to overlook when designing a dual speaker combining electrostatic and moving-coil speakers. It is that on no account should the distance between the two units be less than 24in. from edge to edge.

It will be readily appreciated that when the electrostatic unit is in close proximity to the moving coil, its diaphragm will be, in effect, part of the baffle board, and, in consequence, considerable differences of air pressure generated by the moving coil will be developed on either side of it, with the result that the distance between diaphragm and fixed plate will vary at low frequencies. At first sight it would appear that this movement will only result in loss of radiation by the moving-coil speaker and possible rattle; but further consideration shows that, since the capacity of the electrostatic unit will be varied at low frequency, any notes reproduced by it will have their *intensity* modulated by the bass—a distinctly unpleasant effect which is all too common in the reproduction given by cheap moving-coil speakers with speech coils of very short winding length concentrated in the magnet gap to extract the last decibel of noise with an inadequate field density.

L. H. MOORE.

Liverpool.

Ohms per Volt

THE question of terminology is frequently raised in your columns, and, as far as I can see, the definitions and terms used by *The Wireless World* are those generally accepted by the Trade and the Technical Press.

Nevertheless, there is one expression used by yourselves and manufacturers to which a practical engineer may take exception; that is, the *ohms per volt* specification applied to voltmeters.

Taken literally, the description of a meter as 500 ohms per volt implies that a resistance of 5,000 ohms is in circuit at a reading of 10 volts, and of 50,000 ohms at 100 volts. Unfortunately, not all those connected with either the amateur or professional sides of wireless know how far this is from the truth, and that, provided the same meter or scale be in use, the resistance in circuit is the same in each case.

The vast majority of "voltmeters" are basically "current reading instruments," the internal resistance in series within the meter is determined by the maximum current reading and the maximum voltage to be measured. From this aspect the resistance as a specification would only be useful when coupled with the full-scale voltage reading. With it, a 100,000 ohms/500 meter would be equivalent to a "200 ohms per volt" meter. Though it would specify the meter more definitely it would be clumsy and would not immediately convey th information the engineer requires.

As both these terms depend entirely on the current taken by the meter at full-scale deflection the "goodness" of a voltmeter could be expressed much better by that current, and, so that there could be no misinterpretation, the fact that it is the *maximum* current could be added. What I suggest is that the above meter be specified as a "5 mA. max." meter.

The current taken at any voltage can be expressed by the formula:—

$$\text{Current} = \frac{\text{voltage reading}}{\text{full-scale reading}} \times \text{max. current.}$$

Thus, a reading of 50 volts on a "5 mA. max." meter with a full scale of 250 volts means that a current of 1 mA. is flowing.

The service engineer and the set constructor are often faced with the problem of the change in circuit conditions brought about by the insertion of a voltmeter into the circuit. As the estimation of the change is more easily calculated in terms of current flowing through the circuit resistances, the use of the above terminology would simplify matters considerably. The formula would be equally simple:—

$$\text{Voltage change} = \frac{\text{voltage reading}}{\text{full-scale reading}} \times \text{max. current} \times \text{resistance.}$$

This, of course, is neglecting any change brought about by the alteration of the D.C. resistance of the valve or valves in parallel with the meter.

I venture to suggest that the majority of engineers and constructors would welcome this simplification of our terminology, particularly when it also makes it more explicit.

London, S.W.5. W. MACLANACHAN.

Output

THE following apparent fallacy may b of some interest to readers. Assume a power valve capable of a maximum undis torted output of 4 watts, with grid bias= 50 volts. If two such valves are connecte in parallel, the maximum undistorted out put will be 8 watts, so that if an A.C. volt age of 25 volts (peak) at frequency f_1 b applied to the grids, the output will b 2 watts, since output is proportional to th square of the volts applied to the gric Now apply another 25 volts (peak) at fr quency f_2 at the same time as the firs There will be then 2 watts of f_1 and 2 watt of f_2 in the output, making 4 watts in al and in addition the valve grids will be full loaded with 50 volts peak. On the oth hand, if the valves are operated separatel with 50 volts of f_1 on one grid, and 50 vol of f_2 on the other, each valve will give i full 4 watts output, and if these are cor bined there will be a total of 8 watts.

Under both conditions the valves are ful loaded, yet by separating the frequen components double the output is obtai able. The fallacy is obvious, but t example given is a strong argument for t use of a double output stage when separa high or low note speakers are used, unles of course, the transmission is heavily mod lated with one frequency only.

Persia. LEAD-IN.

Correspondence should be addressed to the Editor, "The Wireless World," Dorset House, Stamford Street, S.E.1, and must be accompanied by the writer's name and address