A loudspeaker is not necessarily of high excellence because it is a moving-coil type, but a good moving-coil speaker represents the highest attainment in this field at the present moment, and as explained above, it is peculiarly suited to work out of a penthode power-valve.

Match the Moving-Coil to the Valve.

MOST manufacturers state the average value of the impedance of the voice coils of their moving-coil speakers, while in many cases the necessary transformer is included with the loudspeaker.

Let us take some representative figures, and work out the transformer ratio required to give the ideal impedance match.

Case 1: E443N valve with speaker impedance of 50 ohms, then:—

$$\text{Impedance Ratio} = \frac{10{,}000}{50} = 200 \text{ to } 1$$

The impedance of a transformer winding at a given frequency is proportional to the square of the number of turns of winding, consequently the impedance relationship between two windings of a transformer is proportional to the square of the turns ratio, e.g., a 10 to 1 turns ratio gives a 10 x 10 or 100 to 1 impedance ratio, so that the required turns ratio for our matching transformer becomes $\sqrt{200}$, approximately 14 to 1.

Case 2:—C443 with 10 ohm coil.

$$\text{Impedance Ratio} = \frac{9000}{10}$$

$$\text{And turns ratio} = \sqrt{\frac{9000}{10}} = \sqrt{900} = 30$$

And a 30 to 1 ratio step-down transformer is indicated.

If you have tried a penthode-dynamic combination without full success, just check up your operating conditions as above, and make the necessary correction in your transformer ratio.

Magnetic Speakers.

MAGNETIC speakers without exception have a rapidly rising impedance at the higher musical frequencies, in fact the impedance of a so-called "high impedance" magnetic speaker is commonly of the order of 2000 ohms at 256 cycles (middle C), rising somewhat slowly at first, with increasing frequency, but later increasing more rapidly until a value of around 20,000—40,000 ohms is reached at 5000 hertz. (The hertz is now the adopted unit indicating cycles per second.)

Think in terms of triode theory for a moment, and remember the glibness with which speaker impedance "matching" is spoken.

The so-called "match" is made at a comparatively low frequency, say 256 hertz, but as the impedance at 5000 hertz is many times the value at 256, it follows that for high frequencies the speaker is very much mismatched.

With triodes, this results in a drastic reduction of energy expended in the speaker at high frequencies, and the consequent lack of proper proportion of these in the reproduction. Mechanical high frequency resonances cannot properly make up this loss, and the treble is unnatural.

With the penthode this increased impedance at high frequencies acts somewhat in the reverse manner, and the upper frequencies are accentuated. Further, if the listener is critical, he will notice that distortion first occurs on the higher notes.

Fortunately, this effect can be overcome without much trouble by paralleling the speaker circuit with another whose characteristics are exactly the reverse of the speaker winding.

The speaker winding increases in impedance with rising frequency because it is inductive (the impedance being proportional to $2 \times 3.1416\ fL$ where f is the frequency in hertz and L the inductance in henries).

The impedance of a condenser, on the other hand, decreases with frequency increase (being proportional to $1 \div 2 \times 3.1416\ fC$, where C is the capacity in farads).

A condenser shunted round the speaker windings then has a marked effect in stabilising the plate load impedance at different frequencies, and this is really the main action of a "tone-filter" used with a magnetic speaker on a penthode output. An auxiliary effect is, of course, the greater "by-passing" of the upper frequencies, but the major effect is obtained through impedance stabilisation.

Such a simple capacity filter helps considerably, and is sufficient in certain cases, but a slight elaboration of this idea is an improvement, and consists of adding a fixed resistance in series as indicated in Fig. 2.

In fact, if the speaker inductance, capacity, and resistance are known, it is comparatively simple to proportion the values of the shunt capacity and resistance so that the effective impedance of the speaker-filter network remains substantially constant over the useful part of the audio-frequency range.

The "plate-load" of the penthode thus remains constant, as in the case of the moving coil speaker.

The effective impedance of the speaker circuit at, say, middle C (256 hertz), is reduced by the effect of the shunt circuit, and it may then be desirable to use an impedance adjusting device to have the effect of raising the speaker impedance to the optimum value indicated previously.

This can readily be done with an output choke or output transformer, and is amenable to mathematical analysis precisely as shown for the moving coil case.

However, as hardly any readers have at their disposal means of measuring their effective speaker impedance or other characteristics, the output choke filter system will be adopted here as it is comparatively easy to build one with the necessary high inductance, and tappings can be readily brought off, and the correct one determined by trial.

The circuit will then be as in Fig. 1.

Alternatively the filter C2R may be shunted round the choke, in which case:

(a) The breakdown voltage across C2 will be greater.

(b) C2 requires to be smaller for the same effect.

(c) R requires to be larger for the same effect.

A suitable choke for any of the penthodes mentioned in this article could then be constructed by winding on a ¾in. square core some 9500 turns of 36 s.w.g. enamelled wire.

The core window would require to be approximately 1¼in. v 7-8in. in view of the desirability of layer insulation, and particularly of adequate end turn insulation from core (the voltages developed across it being several times the plate voltage). The airgap in the core would be in the vicinity of 1.32nd inch.

An alternative design, using ⅞in. material for the core limbs, would require 6300 turns of 36 s.w.g. enamelled wire, the window being approximately 1in. x ⅞in., and the airgap about 3-64th in.

Suitable tapping positions from the commencement of the coil (say the top or HT end) are given in the following table with the impedance ratios thus available—they will cover all ratios possibly required.

Impedance Ratio.	Turns Ratio.	Tap at
16 to 1	4 to 1	1/4
12 to 1	7 to 2	2/7
9 to 1	3 to 1	1/3
6 to 1	5 to 2	2/5
4 to 1	2 to 1	1/2
3 to 1	1.75 to 1	4/7
2 to 1	1.4 to 1	5/7
1.5 to 1	1.25 to 1	4/5

If the whole choke is common to both circuits, the ratio is of course 1 to 1. The taps must be well insulated where they are brought out.

It is interesting to note in passing that the average magnetic speaker cone material is made unduly hard to accentuate the high notes, to make up for the triode power valves deficiencies previously discussed. A softer paper can be used to advantage with the penthode valve.

Using the corrective methods outlined above, the penthode user will be delighted with the quality of reproduction obtainable on even a magnetic speaker.

Adjustment Hints.

THE negative grid bias should first be set at the value given by the valve maker for the plate voltage used. This can then be varied slightly under operating conditions until a milliammeter inserted in the B+ lead shows a minimum of "flicking."

Do not worry unduly about whether the needle flicks upwards or downwards, as this is often governed by another factor which does not seem to be at all well known.

This is the correctness of the plate load, and in general it may be stated that if with correct bias and "B" voltage a strong signal causes the needle to flick upwards, second harmonic distortion is indicated, and a higher load impedance is desirable. This is obtained by using a higher step-down ratio in the output choke or transformer.

If, on the other hand, the milliammeter needle kicks downward, the principal distortion is due to the presence of a third harmonic component, and the load impedance may with advantage be reduced (by lowering the step-down choke or transformer ratio). Careful attention to these points will prove well worth while.

Caution.

UNDER certain conditions, e.g., with very high impedance plate load, the penthode is capable of developing enormous voltages which may rise to a value many times that of the plate voltage, and this voltage can easily wreck the valve itself, or break down the choke, transformer, condenser, or speaker insulation.

As an open circuit is an infinite impedance, enormous voltages are developed if any part of the plate circuit is opened with the valve in operation.

It is therefore absolutely imperative that the speaker is not disconnected, while the penthode grid is being excited (i.e., while the amplifier is functioning.)

The above article is by no means intended to be an exhaustive treatment of the penthode, in fact many alluring possibilities, such as its use as a detector, or in other positions have not even been hinted at, but it is hoped that the notes on its handling as a last stage "power amplifier" will at least assist in drawing aside the veil, and making the penthode better understood and appreciated, as it is undoubtedly destined to be used much more freely than at present.

A Super-power Transmitter

American Experiments

BROADCASTING power of 1200 k.w. is the goal of station KDKA, whose engineers are now conducting experiments with the new 200 k.w. valves in the expectation of transmitting shortly a series of after-midnight tests with super power. Station KDKA's experimental license from the Federal Radio Commission authorises the use of up to 400 k.w. in the series of experiments.

This will require the use of two of the giant 200 k.w. valves, each of which stands six feet high and requires the passage of five tons of cool water through its jacket every hour. The engineers are arranging the plant of KDKA so that six of the giant valves may ultimately be used, which would give the station an output of 1200 k.w.