FERRANTI

PUSH-PULL TRANSFORMERS

FOR PROVIDING LARGE DISTORTIONLESS
L.F. AMPLIFICATION WITH MODERATE H.T. VOLTAGE.

AUDIO FREQUENCY TYPES

Ratio 1/3·5.

			Prices in Irish Free State.
Type AF3c.	- -	Price 29/–	*34/-*
Type AF5c.	- -	Price 34/–	*40/–*
Type AF5cc	- -	Price 35/–	*41/6*

STANDARD OUTPUT TYPES.

Maximum Total Primary Current = 100 Milliamps.

Type OPM1c	...	Ratio 1/1, 1·6/1, & 2·7/1
Type OPM2c	...	Ratio 3/1, 5/1, & 7·5/1
Type OPM3c	...	Ratio 9/1, 15/1, & 22·5/1
Type OPM4c	...	Ratio 25/1, 40/1, & 66/1

Price - 26/6 each.

Price in Irish Free State 31/- each.

HIGH POWER OUTPUT TYPES.

The following can be supplied specially to order :—

Single ratio Output Transformers having any of the above mentioned ratios and each capable of handling a total primary current of 200 milliamps.

Type OPcX (ratio to be specified when ordering). Price 31/–.
See section 4, page 4. *Irish Free State* 37/–.

Single ratio Output Transformers having any of the above given ratios and each capable of carrying a total current of 400 milliamps.

Type OPcXX (ratio to be specified when ordering). Price 60/–.
See section 4, page 4. *Irish Free State* 70/6.

Including Royalty under Patent No. 275 of 1915 for use in Broadcast Receivers.

The licence so granted is limited to the construction of a push-pull amplifier employing not less than two valves for use in connection with a wireless broadcast receiver ; and no licence is granted for any other purpose.

PUSH-PULL TRANSFORMERS.

FERRANTI Push-Pull Audio Frequency Transformers, AF3c and AF5c, are generally similar in appearance, construction, and dimensions to the standard types AF3 and AF5, except that they are each provided with an additional terminal which is connected to the electrical centre of the secondary winding.

The Intermediate Push-Pull Transformer type AF5cc is similar to the AF5 but has a centre tapping on both primary and secondary windings. The amplification curves of all these Push-Pull Audio Frequency Transformers are identical with those of the corresponding ordinary types when used under similar conditions. The Push-Pull Output Transformers have centre tappings on their primary windings but are otherwise similar in appearance to the standard Multi-ratio types OPM1 and OPM2, etc.

To facilitate the obtaining of good results by enabling the Valve and Speaker impedances to be suited in all cases, the whole of our Push-Pull Output Transformers are of the Multi-ratio type, a set of four covering the whole range of Speaker impedances likely to be met with in ordinary practice, including both high and low resistance—Horn, Reed driven Cone, or Moving Coil Speakers.

This circuit includes the Anode Resistance Feed System which has been developed by Ferranti Ltd., and which forms the most effective method known at the present day of reducing back coupling and low frequency reaction between the amplifier stages to a negligible quantity

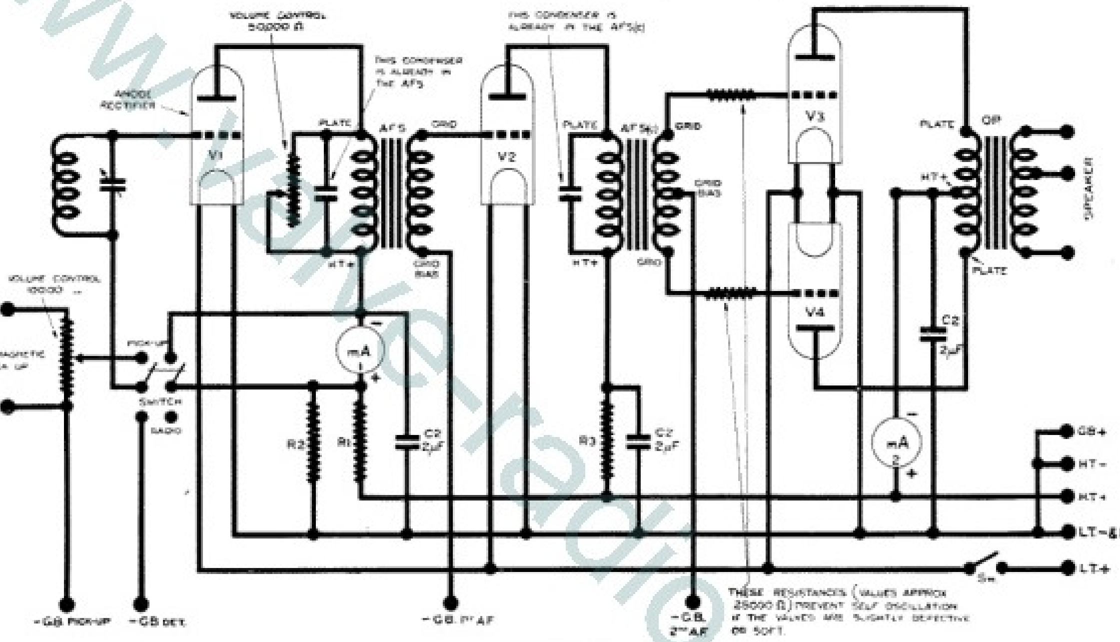

Fig. D 966.

This figure shows a circuit comprising an Anode Bend Rectifier arranged alternatively for use with a Gramophone Pickup, followed by two Audio Frequency stages, the second stage employing Push-Pull coupling. No attempt has been made to show the circuit prior to the detector, this being left to the discretion of the constructor. It should be observed, however, that for the best results with Anode Bend Rectification at least one H.F. stage should be used.

This System, in addition to preventing back coupling and "motorboating," at the same time forms a ready means of providing suitable values of H.T. for the respective valves and also allows the whole of the H.T. Battery to be discharged equally, a very important point where H.T. accumulators are used.

The values of the Anode Feed Resistances R1 and R2 may be calculated as follows :—Knowing the voltage and milliamps required by each valve, subtract the voltage from the total H.T. available, and divide the difference by the milliamps expressed as a fraction of an ampere.

e.g.—Total Voltage available is 200 Volts.
Voltage required by valve is 120 Volts.
Milliamps with 120 Volts and 3 Volts negative bias, = 2 (obtained from Makers' Valve Curve).

$$\text{Resistance required} = \frac{\text{Total Voltage available} - \text{Voltage required}}{\text{Milliamps expressed as a fraction of an Ampere.}}$$

$$\text{In this case} = \frac{200-120}{\cdot 002}$$

$$= \frac{80}{\cdot 002}$$

$$= 40{,}000 \text{ ohms.}$$

PUSH-PULL AMPLIFICATION.

In the Push-Pull System the Output of the Receiver is divided between two Valves, or a multiple of two Valves where larger powers are required. The Output from these Valves is then combined by means of a Push-Pull Output Transformer and fed to the Speaker.

In certain cases it is desirable to connect the preceding stage in Push-Pull by means of an Intermediate Push-Pull Audio Frequency Transformer which is centre tapped on both primary and secondary windings; the object of this arrangement is mentioned later.

Speaker performance from an ordinary Receiver is seldom entirely satisfactory. This is due to the fact that when the Receiver is adjusted for correct volume on passages of moderate strength the last or output valve is at the point of overloading, and consequently when louder passages are reproduced the valve is overloaded and harshness or "blast" introduced, frequently accompanied by a form of "rattle" apparently in the Speaker.

This difficulty can be overcome to a large extent by using better valves and much higher plate voltages and it has been suggested that no Speaker is worth listening to unless at least 300 volts H.T. is employed.

The use of voltages in excess of 250 is not practicable for the ordinary user because of the expense, and IT IS NOT DESIRABLE BECAUSE OF THE DANGER INVOLVED, IF NOT TO THE EXPERIMENTER HIMSELF, TO UNSKILLED MEMBERS OF HIS FAMILY, UNLESS SPECIAL PRECAUTIONS ARE TAKEN.

The Push-Pull method forms the solution of the difficulty, and the Transformers described in this list are necessary in a satisfactory amplifier or set involving this method.

ADVANTAGES OF PUSH-PULL.

1. The use of two valves in Push-Pull provides the equivalent of double the normal grid swing permissible without distortion when using only one valve, that is, a much louder signal may be handled without distortion due to valve overloading.
2. The Output Transformer is more effective because there is no appreciable Direct Current magnetisation of its iron circuit, thus keeping the inductance high and leaving the iron fully operative under the best conditions for the signal.
3. The size and cost of the Output Transformer may be kept small even with large anode currents. This is a very important point, as it is not possible to build an ordinary Output Transformer or Choke capable of carrying heavy currents to give a performance equal to a Ferranti Push-Pull Transformer without so increasing the size and cost as to make its use by the ordinary individual prohibitive.
4. The even harmonics which are introduced in any Receiver owing to the slight curvature of all valve characteristics, even at their straightest parts, are cancelled out by the Pull-Push system. Thus two valves operated in Push-Pull give only a third the second harmonic distortion as compared with the same two valves in parallel when giving the same output.
5. When using Push-Pull the tendency to back coupling between the output stage and the previous stages of the Receiver is reduced to a very small amount and is less than when other forms of output are employed.
6. The use of a Push-Pull Output Transformer is preferable to the employment of a Push-Pull Choke. When a Choke is used it is necessary for the average impedance of the Speaker Coil to be equal to twice the impedance of the Output Valves, and as the Valve impedance may easily be 5,000 ohms this presents considerable difficulties. Also with the Choke method, a blocking condenser of at least 4 mfds should be connected at each end of the Choke to isolate the Speaker and comply with the recommendations of the Institution of Electrical Engineers. The cost, therefore, becomes greater.
7. With the Push-Pull method it is unnecessary to employ greater H.T. than 250 volts for domestic purposes. This voltage is readily obtainable from the electric light mains by means of an H.T. Supply Unit.
8. The Push-Pull Output Transformer, apart from its other advantages, completely isolates the output terminals of the Receiver and the Speaker terminals and windings from the source of H.T., thus avoiding the possibility of shock, particularly where high voltages and H.T. Supply Units are used, and at the same time complies with the recommendations of the Institution of Electrical Engineers.

INSTRUCTIONS.

To obtain the finest results the following instructions should be adhered to :—

1. The circuit should be arranged as shown in Fig. D 966 (page 2), the Valves V1 and V2 being of any good make, having an impedance between 7,500 and 20,000 ohms and consuming under operating conditions not more than 4 milliamps each.

2. (*a*) The first Audio Frequency Transformer when using Anode Bend Rectification should be of the AF5 type, but when Grid Leak Rectification is used the AF5, AF3, or AF4 models may be employed, depending upon the proposed expenditure and the results required.

   (*b*) The Push-Pull Audio Frequency Transformers may be of the AF5c, or AF3c, patterns, the type employed in this as in the first stage depending on the balance between reproduction required and expenditure.

   (*c*) Where the Output Valves are of the LS5A class used with high voltages to provide the great power necessary for public demonstration work, it sometimes happens that the preceding valve is overloaded before the Output Valves are loaded to their full capacity. To avoid this difficulty, the first Audio Frequency Stage should be connected in Push-Pull by means of the AF5cc Transformer, the valves preceding this, being of a type having a normal impedance preferably not more than 10,000 ohms and capable of taking at least 3 volts negative grid bias. The resulting absence of D.C. magnetisation from the Audio Frequency Transformer causes its effective inductance to be increased to approximately 200 henries with a still further improvement in the reproduction.

3. The Output Valves may be ordinary Power Valves or Super Power Valves, but they should be of the same type and reasonably alike in their characteristics. **They need not be accurately matched.**

4. The type and ratio of the Push-Pull Output Transformer depends on the effective impedance of the output valves and the impedance and type of Speaker used.

   FERRANTI Multi-ratio Push-Pull Output Transformers are available in three current handling capacities. The standard types OPM1c, OPM2c, OPM3c, OPM4c, are designed to operate with primary currents up to 100 milliamps, namely 50 milliamps through each half of the primary winding.

   They are suitable for use with all ordinary Super Power Valves, their maximum capacity being 2 LS5A Valves with 400 volts on their anodes.

   The types OPcX and OPcXX are of the single ratio type and are supplied only to order. The ratio required must be specified at the time of ordering, as well as the number and types of Output Valves employed, the H.T. voltage and grid bias to be used, and the resistance and the impedance, if possible, of the Speaker to be operated. If more than one Speaker is to be operated the number used and whether in series or in parallel should be specified.

   The OPX types are suitable for use with LS6A Valves in push-pull, the impedance of each Valve being about 1,300 ohms, and the total current taken by the Valves not exceeding 200 milliamps, that is 100 milliamps through each half of the primary winding.

   The OPXX types are intended for use where unusually great power is required for Public Address and Auditorium work generally. They will handle a total primary current of 400 milliamps, that is 200 milliamps through each half of the primary winding.

   The maximum operating pressure of these Transformers is 450 volts, except in the case of the OPXX types where the maximum working pressure is 750 volts. Transformers can be quoted for higher anode voltages on receipt of full particulars.

5. PUSH-PULL OUTPUT TRANSFORMER RATIOS. Owing to variations in individual valves and Speakers, it is not possible to state absolutely that an Output Transformer of certain ratio is ideal in any particular instance, but the following information is for approximate guidance.
   To obtain good results the Valve impedance and Speaker impedance must bear a definite relation to one another. If the Speaker impedance were constant at all frequencies the best performance would be obtained when the equivalent speaker-impedance was equal to twice that of the valve. In practice this is not the case and the method of estimating the required ratio of Output Transformer is in the case of Horn and Reed Cone types different from that in the case of Moving Coil Speakers. Ordinary Horn and Reed Cone Speakers increase greatly in impedance with increase in frequency, so in

estimating the ratio of Output Transformer it is desirable to take the impedance of the Speaker at about 200 cycles. The Valve impedance is then divided by this figure and the square root taken :

$$\text{Thus: Ratio} = \sqrt{\frac{\text{Total Valve impedance.}}{\text{Speaker impedance.}}}$$

Push-Pull Valves are in series, that is, their impedances are added together, so that if fairly good results have been obtained from a Speaker operating from two power valves in ordinary parallel by means of a 1/1 straight Output Transformer or Choke Filter; when using the same two valves in Push-Pull with a Horn or Reed Cone Speaker a Push-Pull Output Transformer having a ratio of approximately 2/1 is required and a ratio of 1·6/1 or 2·7/1 will be found suitable. Frequently the impedance of Horn and Cone Speakers is so high that a 1/1 Push-Pull Output Transformer ratio 1/1 gives the best results.

Moving Coil Speakers usually do not vary greatly in impedance throughout the audio frequency range and when employing these the ratio of Output Transformer to give the maximum *undistorted* output is obtained by dividing double the total Valve impedance by the Speaker impedance and taking the square root of the result :

$$\text{Thus: Ratio} = \sqrt{\frac{2 \times \text{Total Valve impedance}}{\text{Speaker impedance.}}}$$

The following Charts enable the Transformer ratio required with any particular combination of Valve and Speaker impedance to be determined at a glance, the lines being drawn for standard ratios which are available.

FOR ORDINARY HORN OR CONE SPEAKERS.

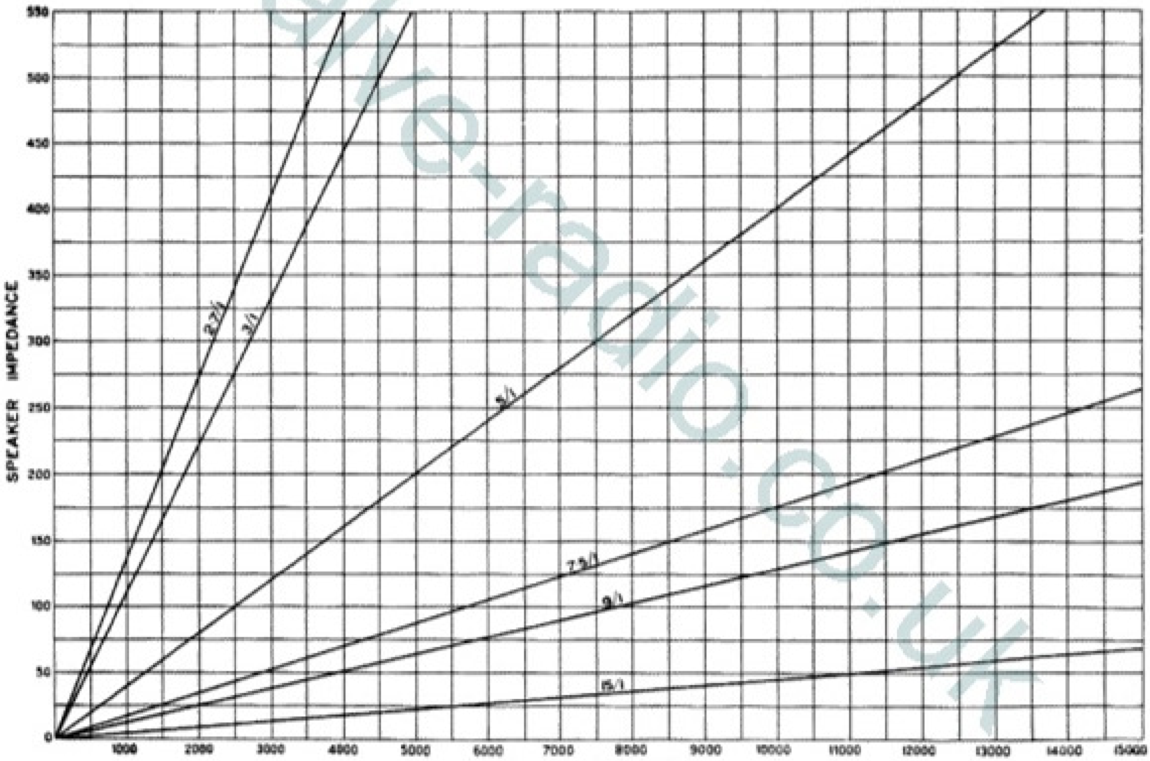

Fig. D 942.

Charts Figs. D 942 and D 943 apply to Output Transformers for use with ordinary Horn or Reed driven Cone types, and in these cases the Speaker impedances should be taken as its impedance at 200 cycles, at which frequency the impedance may be taken as being approximately 2½ times the D.C. resistance. Owing to the fact that the impedance of such Speakers frequently varies between 1,000 and 30,000 ohms over the audio frequency range, ideal results are not possible, but Transformers of the ratios indicated will give the best results that can be obtained, with the knowledge and apparatus at present available.

PUSH-PULL TRANSFORMERS.

FOR ORDINARY HORN OR CONE SPEAKERS.

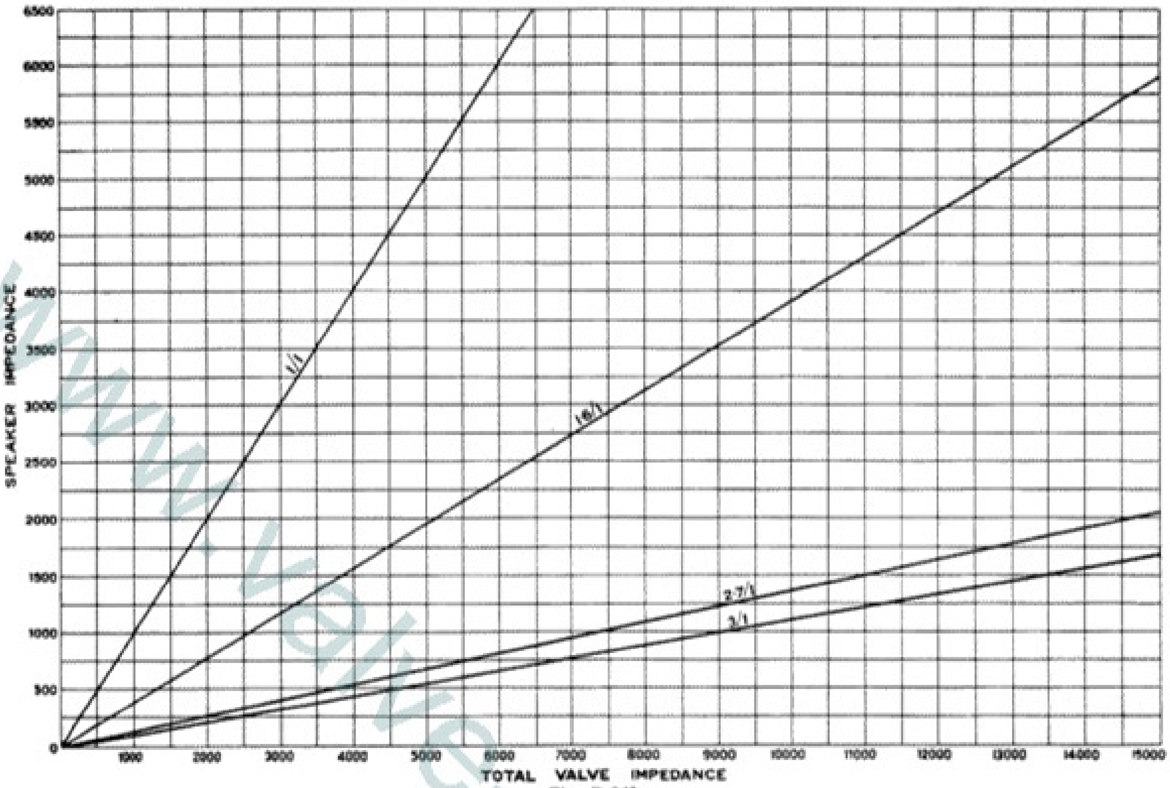

Fig. D 943.

FOR MOVING COIL DYNAMIC SPEAKERS.

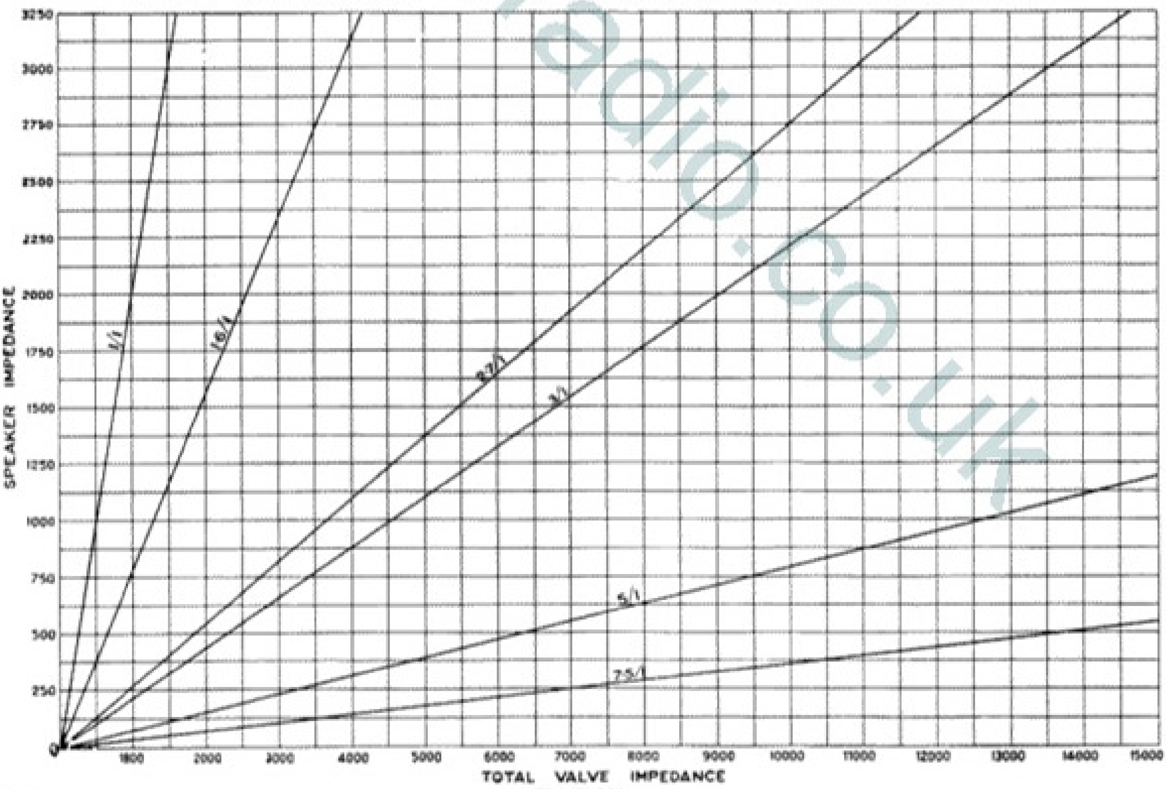

Fig. D 944.

FOR MOVING COIL DYNAMIC SPEAKERS.

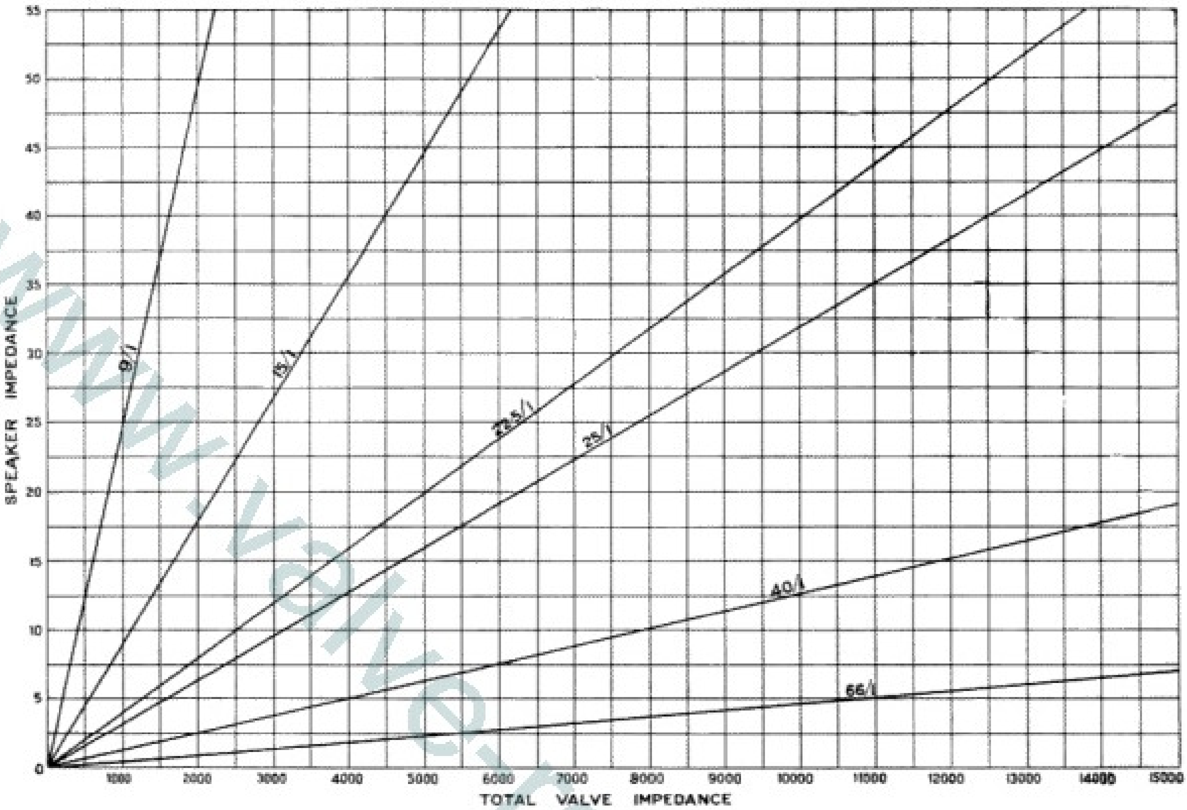

Fig. D 945.

Charts Figs. D 944 and D 945 refer to Output Transformers required for use with Moving Coil Speakers, and it is found that the impedance of such Speakers is sensibly constant throughout a wide range of audible frequencies and that this value should be taken as approximately double the D.C. resistance.

If in using any of the charts the intersection of the lines relating to Speaker impedance and Valve impedance does not in any particular case fall on one of the ratio lines, the line that is nearest to the point of intersection gives the requisite ratio.

6. The H.T. employed on the output valves should not be less than 120 volts and may usefully be increased up to 250 volts.

7. The Grid Bias used should be the same as would be employed if either of the output valves were used singly. The valves should not be biassed up to half-way round the curved portion of their characteristic, as is sometimes recommended, as in this case distortion will result if the valves are not identical, which is difficult to attain in practice.

8. In case of doubt as to a type of Output Transformer required in a particular case, we invite you to communicate with us, stating the number, types, and impedances of the output valves, and the resistance, impedance, and type of Speaker to be used.

To obtain the best possible results from any Receiver it is essential that the source of H.T. Supply shall be free from "ripple," and shall not cause interaction between the stages of the Receiver which is being supplied.

The Ferranti H.T. Supply Units comply with this requirement and provide adequate output free from mains hum and the possibility of "motorboating" even when feeding a Receiver employing the best amplifying arrangements. Details of this apparatus are given in List Nos. W.416 and W.417.

PUSH-PULL TRANSFORMERS.

The following figure shows a Circuit for handling unusually great power such as that required for demonstration purposes. Two stages of Push-Pull coupling are used employing the intermediate Push-Pull Transformer, type AF5cc.

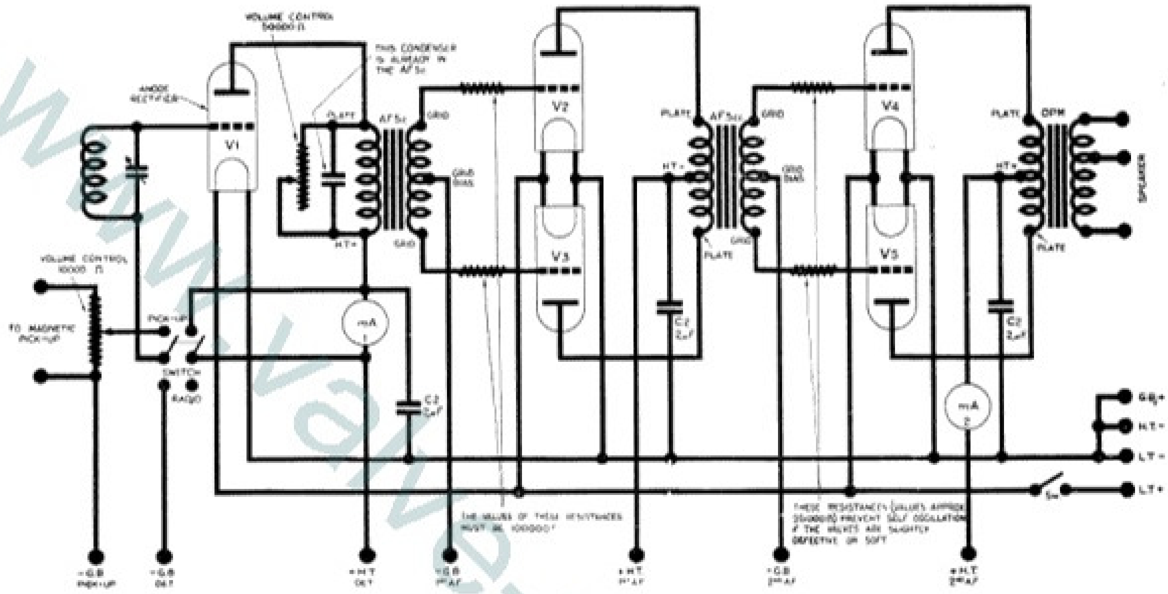

Fig. D 973.

Such an arrangement requires considerable H.T. Voltage and Current for its satisfactory operation, and for this reason the Circuit is shown only for operation from the Mains through an H.T. Supply Unit. The Anode Feed System has not been included because this should be incorporated in the H.T. Supply Unit, as it is in the case of all Ferranti Units.

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