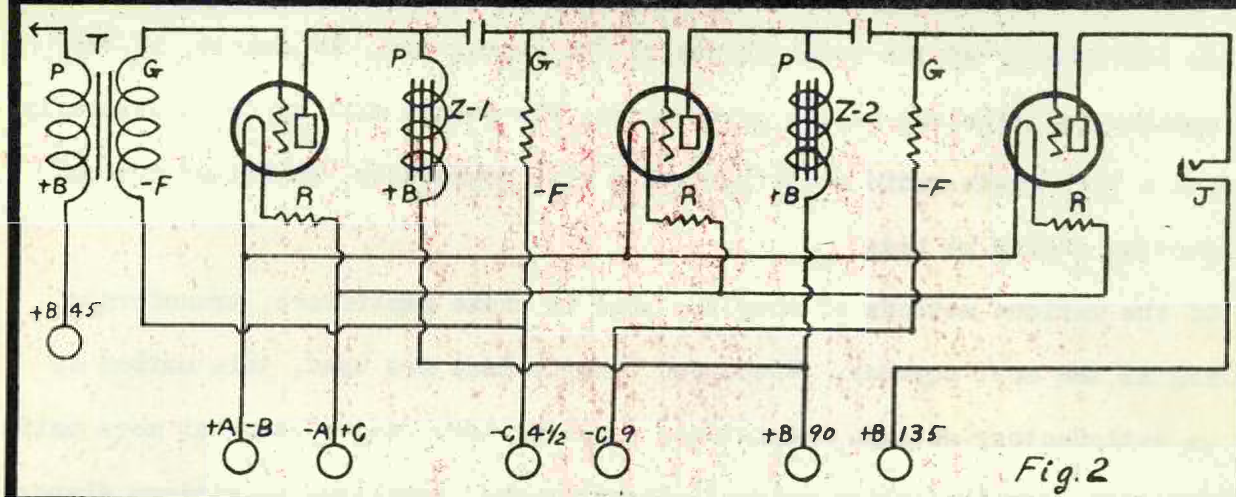

Fig. 2

LESSON 30 R

AUDIO AMPLIFICATION METHODS

RADIO-TELEVISION TRAINING SCHOOL, INC. LOS ANGELES ESTABLISHED 1922

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AUDIO AMPLIFICATION METHODS

Audio or voice frequency amplification, it was previously explained, is the process of strengthening or amplifying the output of a detector tube so that a greater volume of energy is rendered available for operating a loud speaker or reproducer effectively. Upon the operating characteristics of this amplifier depends the quality of the tonal output of the reproducer. Of course, if the loud speaker is deficient in its performance, the output will suffer accordingly. But with a high grade radio amplifier and a good reproducer, excellent musical reproduction should be had.

Of the various methods of coupling used in audio amplifiers, transformer coupling is the most popular. When good transformers are used, this method is just as satisfactory as any. Resistance coupling does render somewhat more uniform amplification over the entire voice frequency range, resulting in minimum distortion. But on account of the limited amount of amplification per unit, three stages are generally necessary to obtain sufficient amplification for a large output. Although lower in initial cost, the fact that three stages are needed and that higher plate pressure is necessary, greatly increases the maintenance and operating costs. Impedance coupling is a compromise between transformer and resistance coupling and also has excellent operating qualities.

It is nearly impossible to point out definitely any one system and say it is the best, for response from various persons differs, depending upon the acuteness of their sense of hearing. Every amplifying system produces a different tone quality, and whichever tone is most pleasing to any one individual, that is the best amplifying system as far as he is concerned.

Before taking up the remaining systems of coupling used in audio amplifiers, let us take up briefly this question of distortion, what it really is, etc.

THE NATURE OF DISTORTION

A radio receiving set at its best should be a real musical instrument, and reproduce all music and sounds in their true nature. But many receivers, both home made and factory built, fall far short from this standard on account of various forms of distortion that take place in some part of the circuit.

Distortion is merely a deformation of the electric current waves as they travel through the successive parts of a radio receiver. This statement will mean more if we remember that all sounds are a form of vibratory motion. The higher the pitch of a sound, the greater is the rate or frequency of vibration; and the lower the tone, the lower the vibrations. Also, all musical sounds are a rather complex form of vibration, in that they consist of a fundamental tone or vibration with a number of harmonics or overtones superimposed upon it. The nature and number of these overtones will determine the quality or timbre of the tone. It is this tonal quality that enables one to distinguish one person's voice from another, or to recognize notes as those from a violin, cornet, etc.

It is thus evident that the electric current waves corresponding to such sounds are themselves very complex, and these complex current waves must pass through a receiver from tuner through detector, amplifier and loud speaker, without being in any way altered or impaired. All frequencies must be conveyed with the same efficiency. If one piece of apparatus in a receiver is partial to the higher frequencies, while another passes on the lower frequencies more readily, then the output current waves will be quite different from the input waves. In other words, the current waves have been deformed, and the sounds emanating from the speaker are more or less distorted.

Distortion can occur in several parts in a radio receiver - in the detector tube, in the audio amplifying tubes, in the audio transformer, or in the loud speaker. Let it be said at this point that when a receiving set is being built, only the best parts and apparatus should be used. Cheap parts are generally poorly designed and made only to sell and not so much to operate or perform. It is well worth while spending a little more money for good parts and feeling sure that when everything is done the set will work and work right.

AN AUTO-TRANSFORMER COUPLED AMPLIFIER

As was previously stated, the key to a high quality output of an audio amplifier lies in the use of inter-tube coupling units which will pass all frequencies within the audible range with equal efficiency. The system described here and known as auto-transformer coupling, is a modification of impedance coupling. Its advantages are that it affords almost perfect reproduction, gives good amplification per stage and is fairly economical. It has been classed as an ideal audio frequency amplifier.

The general construction of an auto-transformer coupling unit is illustrated in Fig. 1, which illustrates the entire circuit arrangement of a three-stage amplifier. As can be seen, an auto-transformer consists of a single coil of wire wound on a large iron core, the coil having a tap brought out at one-third the distance from the grid end. One end of the coil is connected through a blocking condenser "C" to the grid of the next tube, the tap is connected to the plate of the preceding tube, and the other end of the coil is connected to the positive terminal of the B-battery. A ½-megohm grid leak is also used with each tube as a leakage path for the charges that pile up on the grid. The system operates in the following manner:

The rectified variable current in the output or plate circuit of the detector tube flows through the section "PB" of the auto-transformer winding, and in doing so sets up a potential difference (voltage) across this section of the coil. The grid-filament or input circuit of the next tube, however, is connected across the entire coil "GB", which has half again as many turns as the section "PB". The induced voltage in the coil "GB" will thus be one and one-half times the voltage input "PB". In other words, the resulting voltage variations available for the grid of the next tube are 50 percent greater than if any ordinary choke coil were used as in impedance coupling. It is in this voltage step-up feature that the auto-transformer excels as a coupling device.

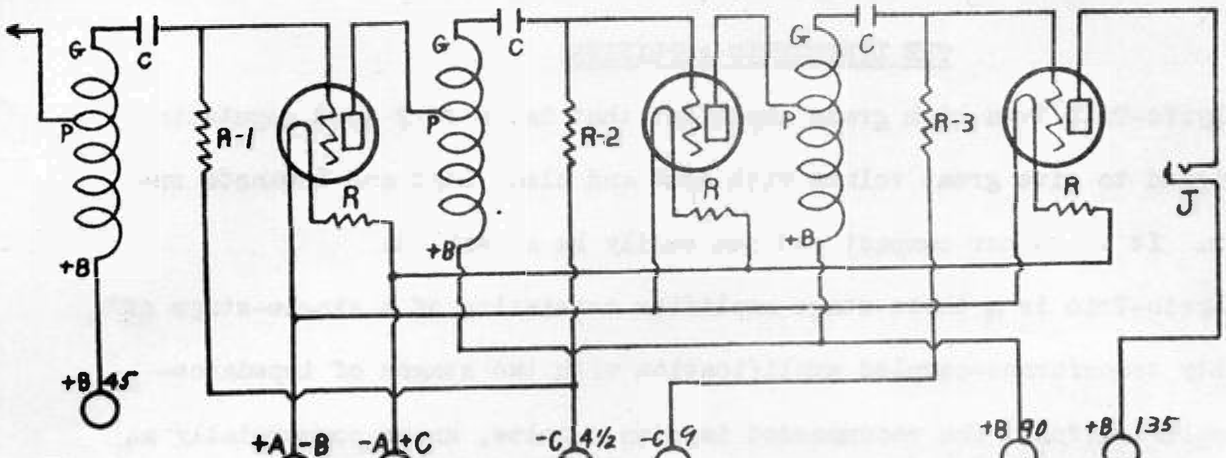

Fig. 1.

It is not a difficult task to construct a good auto-transformer. By the use of a large iron core, a highly inductive winding with a low ohmic resistance can be produced. This affords maximum coupling efficiency, and on account of the lower ohmic resistance excessive plate voltage is not needed as with resistance coupling. Ordinarily two stages of auto-transformer coupling are sufficient for reception from strong local stations, but where good loud speaker operation is desired from weaker signals coming from distant stations, three stages are recommended.

The blocking condensers should be of a good quality and have a capacity of about 0.25 Mfd. Grid leaks of one-half megohm resistance give best results. It is a good scheme to use a 500,000-ohm variable resistance for the second grid leak R-2, for this will serve as an excellent volume control. C-batteries are recommended in all three stages for bias voltage. A power tube is recommended in the last stage of the amplifier, and in such a case a larger C-battery will be needed depending upon the type of tube used. The auto-transformer amplifier can be added to any receiving set and will always give good results.

THE LYRIC-TRIO AMPLIFIER

The Lyric-Trio is a high grade amplifier that has a very good reputation. It is designed to give great volume with good and clear high and low-note reproduction. It is rather compact and can easily be assembled.

The Lyric-Trio is a three-stage amplifier consisting of a single-stage of high quality transformer-coupled amplification with two stages of impedance-coupled amplification. The recommended impedance units, known commercially as type R-300 and R-310, each consists of a choke coil, a blocking condenser and resistance element built into one compact unit.

The wiring diagram of the Lyric-Trio is illustrated in Fig. 2, in which "T" is the audio transformer and Z-1 and Z-2 are the two impedance units.

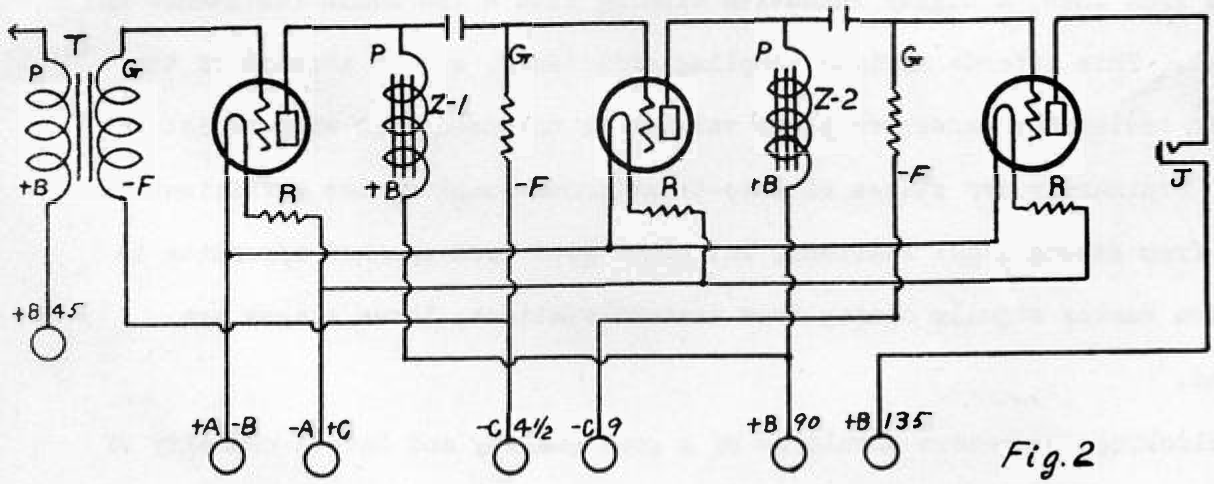

Fig. 2

In building any type of amplifier, the parts should always be arranged so that the grid and plate connecting wires will always be as short as possible, so as to prevent any coupling between the different stages. Such stray coupling always results in disturbing and unpleasant howling or whistling. The filament wires are not nearly so important. Practically all modern amplifying units are encased or shielded with a metal covering. This together with the closed core construction used prevents any stray magnetic fields from surrounding the units.

TUBE BLOCKING IN IMPEDANCE AND RESISTANCE AMPLIFIERS

Although resistance and impedance coupled amplifiers give excellent results as far as output quality is concerned, they are at times subject to various ills that are very annoying and disturbing.

The chief source of trouble in these amplifiers has been the high resistance grid leaks that must be used. Unless these are of the corréct value, best amplification will not be secured. Although a few of the better grade leaks that are available for this service are tested and rated fairly accurately, the greater number of them vary widely from their actual rating. As a result great disappointment is at times experienced with such an amplifier. In such cases the only solution is to experiment with a number of different leaks until a set is found that functions at maximum efficiency. This requires considerable painstaking and plenty of patience.

When a set of grid leaks have once been found that give real service, the next question is, will they retain their original values. Sad to say, very few do. Therefore, an impedance or resistance amplifier may work excellently at the outset, but in a short time its efficiency falls off, and the results are no longer what they were. Investigation readily will disclose that the leaks have changed their resistance and that a new set of leaks is needed. This again calls for some careful experimental work.

Another source of trouble is the following. When large coupling condensers are used (0.1 Mfd.), very loud signals or crashes of static will cause the condensers to accumulate larger charges than can readily be carried off by the grid leak. The result is the tubes become choked or blocked for short intervals causing cessation in the music or signals. The remedy that would at once suggest itself would be the use of a lower resistance leak. But the objection to such a change is that the amplifying action is greatly reduced, and especially at the lower frequencies. Trying to relieve one condition thus introduces another trouble. In order to remedy the entire situation, a coupling combination was devised in which the high resistance grid leak is replaced with a high impedance (choke coil). This system is known commercially as the dual-impedance system.

In the dual impedance system, as its name suggests, two impedances or choke coils are employed, one in the plate circuit and one in the grid circuit, the two being coupled by means of a large fixed condenser (0.1 Mfd. or larger). This coupling condenser, of course, serves to pass the audio frequency signals from the plate of one tube to the grid of the next, and also protects the grid against the high potential of the plate circuit. The action of the plate impedance is the same as when used in the straight impedance coupled amplifier. But the grid impedance is the element responsible for the big change and improvement. The impedance offers a lower direct current resistance to the grid circuit, and therefore removes any uncertainty as to the actual grid potential, and makes it possible to follow correctly the tube manufacturer's specifications as to the size of C-battery to use. At the same time the impedance offers a high resistance to the signal oscillations. This combination prevents tube blocking, and at the same time makes possible a much higher amplification factor per stage than is available with either straight resistance or impedance coupling.

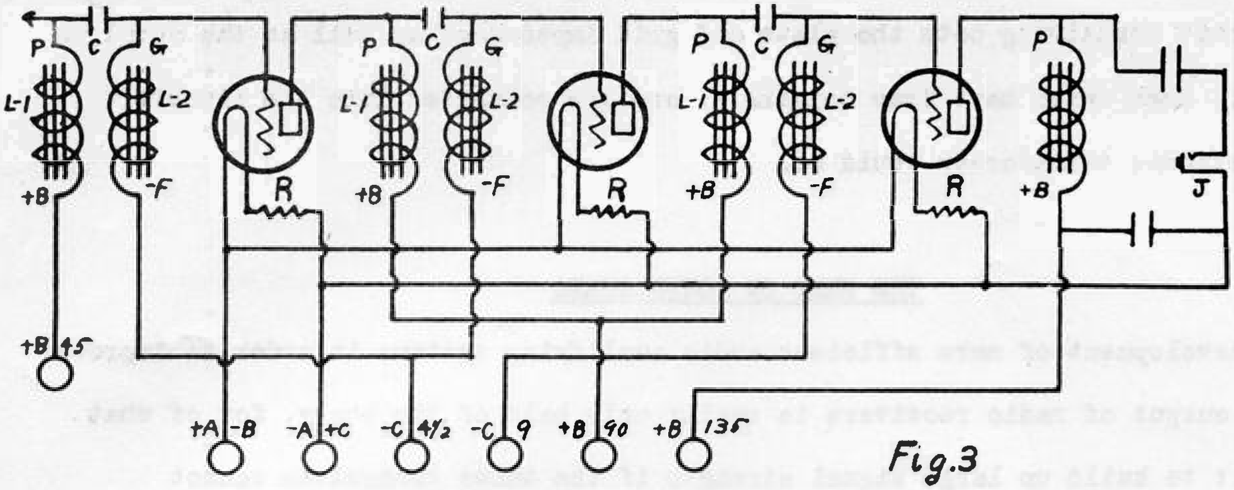

Fig. 3

The amplification effected with this dual impedance system of coupling is of the very best. A practically constant and uniform amplification is secured for all frequencies within the audible range. This factor together with the higher amplification factor that is obtained per stage makes this amplifying system a most desirable one to use.

The general circuit arrangement of a dual-impedance amplifier is illustrated in Fig. 3. The circuit in itself is really quite simple. Each coupling unit consists of a plate impedance L-1, a grid impedance L-2, and a coupling condenser "C." Two stages of dual impedance coupling can be used for powerful local stations, but for weaker signals from distant stations three stages are recommended. Three stages will produce about 20 percent more volume than two of transformer coupling, but the tone quality will be only the best.

Commercial units for constructing a dual impedance amplifier are available in two forms. One company manufactures special plate and grid impedance units. Although such an amplifier is rather costly and bulky, very fine results are obtained with it. Several other companies manufacture combination units, that are

a single unit containing both the plate and grid impedances as well as the coupling condenser. Such units have four terminals, and are connected into the circuit just as an audio transformer would be.

THE NEED OF POWER TUBES

The development of more efficient audio amplifying systems in order to improve the tonal output of radio receivers is really only half of the story, for of what value is it to build up large signal strength if the tubes themselves cannot efficiently transmit such volumes of energy. The greatly increased power output that is now being used by the larger broadcasting stations, as well as the use of several stages of radio frequency amplification in conjunction with super-sensitive detector tubes, has made it necessary for the audio amplifying tubes to carry much larger loads.

It was pointed out that the newer amplifying systems give faithful reproduction to all frequencies well below 100 cycles. It is also true that the lower frequency vibrations (base notes) require much more power than the high frequency notes. All this means that the higher the grade of audio amplifier - those which give the best reproduction of the base notes - the easier it is to overload the last tube and cause serious distortion in the quality of the tonal output. It is these conditions that have called for the development of tubes that have a larger energy capacity and that are now commonly known as power tubes.

One wrong idea that has been entertained extensively regarding the use of power tubes, is that by inserting such a tube in the last stage a greatly increased output volume will be obtained. Such, however, is not the case, for unless a great deal more plate energy is supplied to the tube, the volume output will be no greater at all. But the great advantage gained by the use of the power tube is that it can carry a far greater load without showing any signs of being overburdened.

No distortion occurs, and the tones are all conveyed through the tube in their true nature. A much fuller and rounder tone quality will thus result.

A number of different power tubes are now available on the market, each one having its own peculiar characteristics and being adapted for certain special purposes. The use of a power tube is highly recommended in the last stage of all of the better grades of audio amplifiers.

WHEN A POWER TUBE SHOULD BE USED

Although a power tube is generally recommended for the last audio stage of a radio receiver, there are times when such practice does not work out to the best advantage. In fact, it may even prove detrimental in some cases. What are the conditions, then, that determine when a power tube should be used and when an ordinary tube will actually prove more desirable?

The primary function of the vacuum tubes in a receiving circuit, it will be remembered, is to act as voltage amplifiers; that is, to take the feeble incoming signal impulses and step up their voltage so that they will ultimately be able to actuate the loud speaker with sufficient intensity. To accomplish this the tubes must have a fairly large amplification factor.

In the last audio stage, however, conditions are different, for here it is power output that is chiefly sought. The tone volume delivered by a loud spsaker depends entirely upon the amount of energy supplied to it. This is the purpose of the power tube, to develop and to deliver to the speaker larger volumes of electric energy and with less distortion than the ordinary tube can. The voltage amplification factor of a power tube, on the other hand, is relatively low. This can easily be verified by inserting the power tube in one of the stages and noting that the volume will not be great. But to operate such a power tube effectively, the signal impulses supplied to its grid by the preceding tubes must be of sufficient intensity, for they will undergo very little additional amplification in passing through the power tube. Unless their voltage variations are sufficiently great, no appreciable oscillations will be set up in the plate or output circuit of the power tube, and the expected large volume output will be lacking. This brings on the determining factor.

When a radio receiving set is operated in remote districts far away from the transmitting stations, the received signals will be very weak, and they will have to be subjected to considerable voltage amplification in order to operate a loud speaker effectively. When such signals have passed through the receiver and are ready for the last audio stage, they are still rather feeble; and if they are fed into a power tube, they cannot affect it sufficiently to produce really appreciable results.

However, when a receiver is operated in a large metropolitan district or near a powerful transmitter, the incoming signals will be relatively strong; and after they have passed through the receiver and are ready for the last audio stage, they are ready to operate the final tube with a considerable strength. The voltage variations impressed on the grid would be much stronger than would be healthy for the ordinary tube. Here a power tube should be used. The power tube is designed so that its grid can easily digest these greater signal impulses. The great volumes of energy will pass through the power tube and suffer no obstruction or distortion, and a most pleasing tone quality will be emitted by the loud speaker or reproducer.

The use of a power tube also calls for other considerations besides merely inserting it into the last socket. Generally higher plate voltages are needed, as well as greater negative biasing voltages on the grid. Another very important factor is the choice of a loud speaker and the method of coupling it into the plate or output circuit of the tube. The plate impedance of the power tube is relatively low, and the tube will not perform with maximum efficiency if it feeds directly into the loud speaker which has a high impedance magnet winding. Most of the cone-type speakers have a low impedance, and generally give better results when used with a power tube. Best performance, however, is obtained when the speaker is coupled into the plate circuit through an output transformer or filter consisting of a choke coil and condenser as illustrated in Fig. 3.

From the preceding discussion it is evident that a power tube serves a very useful and necessary purpose. But it must be used correctly and under the proper electrical conditions in order to be able to perform as it was designed to and to deliver the results that can rightfully be expected from it. Although the tubes on the market today are rather rugged, they can easily be stinted in their performance if mistreated or subjected to undue electrical strains.

A COMBINATION DUAL-IMPEDANCE AMPLIFIER

Another excellent audio frequency amplifier is illustrated in Fig. 4. This combination amplifier is marketed by the General Radio Company. As can be seen from the wiring diagram, it consists of two stages of dual impedance coupling and one of transformer coupling, together with an output filter for the loud speaker.

It is claimed that with this arrangement practically uniform amplification is secured from appreciably below 100 cycles to over 10,000 cycles, with only a slight decrease between 100 and 400 cycles. This means that its amplification curve representing the amplifying efficiency at the various frequencies would be a nearly smooth horizontal line with only a gradual downward slope from 400 to 100 cycles. An excellent tone quality would thus result if such an amplifier is used in connection with a good loud speaker.

The two impedance units DZ-1 and DZ-2, are known commercially as Type 373 Double Impedance Couplers. Each coupler consists of a double impedance and a fixed condenser contained within a neatly designed metal shell. It has four terminals, and is connected into the circuit in exactly the same manner as an audio transformer is.

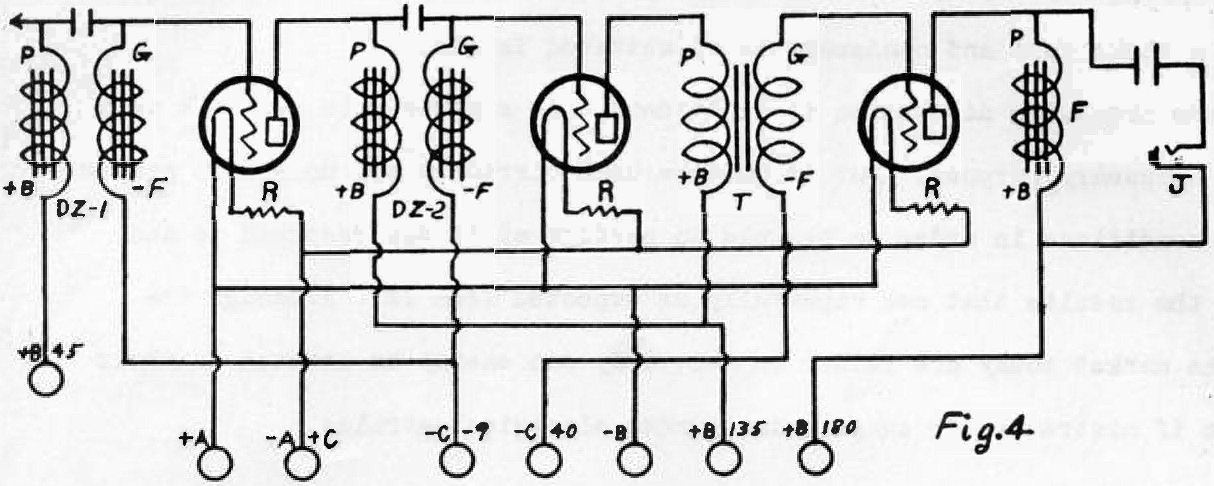

Fig.4

The entire amplifier is really quite simple to assemble and wire, and excellent results can be expected from it.

In the type of amplifier which has just been described, not only faithful reproduction but greater power is available. In fact, for a small sized living room the output would probably even be a little too large. In such a case a suitable volume control could be connected across the secondary of the audio transformer.

The use of a power tube in the second and third stages enables the amplifier to yield such a great output without distortion.

THE AMBASSADOR TONE-GATE AMPLIFIER

Good audio frequency amplification, we were told before, amplifies or multiplies all tones of both high and low frequencies as well as all overtones to the same degree and with full volume. If any of these overtones or harmonics are suppressed, or if strange overtones are introduced, the original nature of the tones will be changed and faithful reproduction impaired. Every manufacturer is not working along the same lines, but different schemes are being tried and perfected, so as to satisfy the ever increasing critical nature of the broadcast listener. Real music is what he wants, and better music is being rendered available as new apparatus is developed.

As a result of these untiring efforts there has been produced recently another new scheme of audio amplification which inherently is a combination of resistance and impedance coupling. Commercially this combination is known as the Ambassador Tone-Gate Amplifier, and great claims are made for it.

The circuit arrangement of the amplifier is illustrated in Fig. 5. Essentially this circuit is very similar to that of a straight impedance amplifier. But the difference liss in the construction of the units employed. The chokes Ch-1 and Ch-2 are wound with special enameled high resistance wire in multiple, wound with glassine paper between layers, all layers being impregnated with beeswax and rosin so as to render them absolutely impervious against moisture.

The chokes have been designed so as to give maximum amplification when used in connection with a power type tube. The resistance of the windings is sufficient to cause good amplification of the low notes, and the inductance high enough to enforce the overtones or high notes so necessary in clear articulation. A 0.5 Mfd. condenser is used to block the plate voltage from the grid of the next tube, and is of sufficient size to convey practically all the audio oscillations from the plate to the grid. The use of this type of choke, it is claimed, overcomes all the disadvantages encountered with resistance coupled amplifiers and impedance amplifiers. The resistance of the chokes is permanent, and is not affected by atmospheric conditions or by changes in the inherent structure of the materials. Special high amplification constant tubes are not needed, for a low amplification tube will perform excellently in this amplifier.

In the last stage a specially designed audio transformer is used to further step up the voltage of the signals. A power tube is recommended in this last stage when powerful incoming signals are dealt with. Great amplification as well as excellent tone quality are available as a whole with the amplifier.

The construction and wiring of the amplifier is quite simple. Fixed resistances are used in the filament circuits to control the current flow. Only the best grade of grid leaks should be used with a resistance as indicated of 5 megohms (5,000,000 ohms). The entire circuit as illustrated in Fig. 5 is self-explanatory.

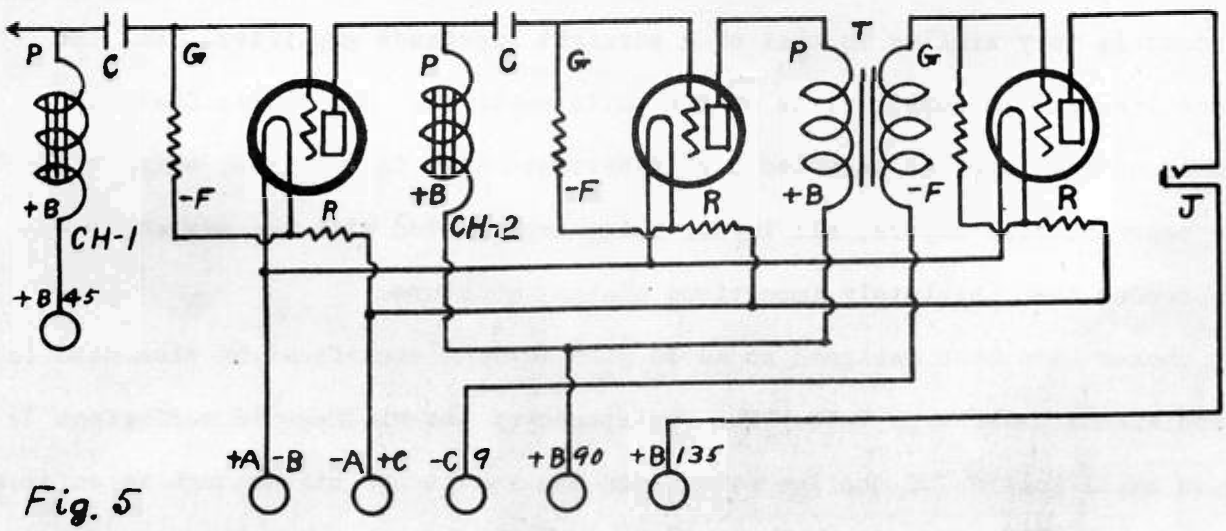

Fig. 5