SEE PAGE 44 GENE BRAKTIGAM

THE RESISTOR MANUAL

A practical handbook on Resistance-Coupled Amplification

25¢

DAVEN RADIO

"The Sine of Merit"

THE RESISTOR MANUAL

Being a treatise on high resistances in their various applications to radio reception and transmission, including a practical monograph on the characteristics, possibilities and advantages of resistance coupled amplification, with operating data.

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TECHNICAL INQUIRIES

All purchasers of Daven Products are requested to write us when in need of technical assistance. It may save considerable time if you furnish us with a circuit diagram of your set, and enclose a 2-cent stamp or self-addressed envelope for reply.

It is unnecessary to send us a fee for answering these questions, as our technical staff is at the service of all users, dealers and manufacturers concerning Resistance Coupled Amplification.

Do not hesitate to give us the opportunity to assist you in your Resistor problems.

The RESISTOR MANUAL should be read carefully before writing since the question may already have been covered in the publication.

Please do not ask us for comparisons between equipment of other manufacturers.

PART I

HIGH RESISTANCES AND THEIR USEFUL APPLICATION TO RADIO RECEPTION

By ZEH BOUCK

Far back in the pioneer days of modern electricity scientists discovered that electrical energy, like all other forms of force, suffered an impediment in its motion or flow. It was inevitable that this should have been one of their early discoveries for an observing person cannot send a current through any circuit without acknowledging this retardation. Because of the mechanical analogy, and the term being genuinely descriptive, this impeding quality—this mysterious something that cuts down the flow of current—was named "resistance"—often designated simply as "R."

It was found that all conductors, or everything in the world as far as that is concerned, has resistance. Silver has a very low resistance—copper slightly higher, but is much more practical from the standpoint of economy. Iron offers a comparatively high resistance to an electric current. Non-conductors, or insulators, are merely substances, the resistances of which are so high that they may be considered, in most cases, as passing no current at all.

The unit of resistance is the ohm, which is named after the famous German physicist Georg Simon Ohm, whose discoveries and electrical experiments greatly advanced our knowledge of the interrelation of potential current and resistance.

The ohm is that amount of resistance which, when one volt of potential is applied to the circuit, will pass one ampere of current. When resistance values become very high they are computed in "megohms"—one megohm equalling one million ohms (1,000,000 ohms).

The comparison between various conducting substances is made by passing a current through bars of different metals, etc., identical in shape and size. A high current indicates a low resistance. Thus, lowering the resistance of a circuit will increase the current. It was also found that the current (intensity of electric flow) could be increased by increasing the voltage (the pressure that forces the current through a wire). If the voltage is doubled or the resistance halved, the current is doubled!

These observations gave rise to Ohm's Law, which merely states this fact in the simple algebraic equation, $I = \frac{E}{R}$, where I is the current in amperes, E the potential in volts, and R the resistance in ohms. In other words, the current will always be equal to the voltage divided by the resistance.

By transposing, the following equations are very simply derived:

$$R = \frac{E}{I} \text{ and } E = R \times I$$

Now, as resistance cuts down the amount of current, it is quite obvious that it should be eliminated as far as possible from all efficient electrical circuits. That is why we solder joints, use large size wire, and take other precautions to prevent the dissipation of radio signals by resistance that can be done away with. However, there are certain places in radio circuits where resistances are purposely placed—where they perform a useful function. The rheostat is probably the most common example of this, and by means of varying its resistance we adjust the current flowing through the filament of the tube.

THE GRIDLEAK

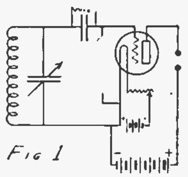


Fig 1

The gridleak in the conventional detecting circuit, Figure 1, is probably the most familiar demonstration of the purposeful inclusion of a high resistance in a radio circuit. The method in this madness can only be fully understood if the principles upon which the vacuum tube functions are appreciated.

The operation of a vacuum tube depends upon the electronic emission from the heated filament. Electrons are infinitesimal negative "particles," that, when they move, form an electric current. Whenever a metal, such as a wire filament, is heated, it throws off electrons, which, in the case of the vacuum tube, are pulled over to the plate by the positive charge which the "B" battery places upon it. (Unlike electrical charges attract each other—like charges are mutually repelled.) This flow of electrons, or cathode (negative) stream, forms the current which courses across the elements in a vacuum tube—the "space current" or "plate current."

However, due to the placing of the elements in an audion bulb, the current necessarily flows through the grid. A little thought will indicate the possibilities of this arrangement. The slightest charge, or variation of a charge on the grid, will cause a change in the plate current. If a positive charge is placed on the grid, more electrons will be drawn from the filament, and the plate current increased. If the charge is negative, the electrons (negative charges!) will be repelled—less will pass through the tube—and the plate current will drop.

Therefore, if a varying current, such as the current carrying a radio signal, is impressed upon the grid, the variations, caused by voice and music, will be heard in the telephone receivers, through which the plate current is made to pass!

Perhaps the reader may ask: "Would it not be more direct to place the receivers right in the antenna circuit?" More direct, yes; but it would not work. The antenna current is a very high frequency alternating current, which, due to a quality known as "reactance" in the magnet windings of the receivers, could not pass through them. Thus nothing would be heard. This alternating current, before it can pass through the telephone receivers, must be rectified or changed into direct current. As electricity (the plate current) can pass through a vacuum tube in only one direction, from the filament to the plate (the way the electrons go), the audion effects this rectification, giving a direct current output which varies more or less directly with the alternating current input—and we have "detection."

Experimentation has demonstrated that detection is most efficiently achieved through a combination of two effects—that which we have just considered, and the effect of periodic discharges from a grid condenser. In both of these effects the gridleak plays a most important part. In the first, the more simple to comprehend, it is this:

It has been shown that if the alternating current radio impulses are impressed on the grid of the tube a direct plate current, with corresponding variations, will result. Knowing what we do about the grid, and its relation to the strength of the plate current, it is not difficult to appreciate that, for the most efficient plate variations achieved in this manner, the normal, or starting point grid potential should have a certain, perhaps critical value. This the gridleak makes possible. In Figure 1 it permits the required amount of potential from the "A" battery to "leak" (through the tuning coil) to the grid. When the proper value of leak is secured the tube will be operated, in electrical parlance, over that portion of its characteristic curve most efficient for detection.

The second action, which contributes greatly to detection, is accomplished through rectification between the grid and filament. It has been explained how rectification is effected between the filament and plate. In the same manner, and by the same cause (the one-way electronic flow), rectification takes place between the filament and the grid. This rectified current charges the grid condenser. For every little voice impulse or vibration, electricity is stored up in the grid condenser. When each individual impulse has ceased—while the tube is waiting for the next vibration to come along, perhaps a thousandth of a second later—the grid condenser discharges, onto the grid, the comparatively powerful charge which it has accumulated. The plate current is of course greatly affected with an audible variation.

In the interval between vibrations, the grid condenser must fully discharge itself, and permit the plate current to return to normal, bringing the detecting system back to its original or starting point, ready for the next vibration, a series of which the ear interprets as sound. In very few cases can this complete discharge be effected—that is, it is almost impossible for the grid condenser to dissipate its stored-up energy through the grid of the tube in the short time before the next vibration arrives. Therefore, a gridleak is placed either across the grid condenser or from the grid to the filament. This leak regulates the condenser-detector action in two ways. It acts as a very high resistance short-circuit across the condenser, thus preventing the building up of an excessive charge which might take too long in discharging; and it offers an additional path to a slowly dissipating charge—it permits it to "leak" off.

If this correct timing, or return to normal, is not effected there will be a piling up, overlapping of sound vibrations, which is evident as distortion, mushy talk, weak signals, etc.

The tendency of a circuit to oscillate is also largely determined by the normal grid charge. An unstable, squealing tube can often be made to operate properly by clipping-in a gridleak of a higher or lower resistance than that originally employed.

ADJUST YOUR CIRCUIT!

It is thus evident that the gridleak is of paramount importance for the most efficient detection of signals. In appreciation of this there are several adjustments and tests which the experimenter should make in his endeavor to secure best results.

Very few tubes are identical, and many detectors of the same make and type have noticeably different characteristics. These inequalities are best compensated for by gridleak adjustment.

It has been shown that the efficiency of the first detecting effect (that of the direct relay to the plate current by a varying grid potential) depends upon the normal grid potential as determined by the leak. To determine this charge, the leak should be experimentally connected across the condenser, and then from the grid to the side of the filament to which the lower terminal of the variocoupler secondary, tuning coil, etc., does not run. Reverse the "A" battery leads and repeat the experiment.

It has also been demonstrated that the quality and amount of detection secured through the periodic discharge of the grid condenser depends upon the rapidity with which the stored-up grid condenser charge is dissipated—in other words, upon the resistance of the leak. It follows, therefore, that with different tubes, different leaks will very often be required for the best possible detection. The reader should experiment with various leak values, from one-half megohm up to five megohms. Two megohms is, perhaps, the average resistance.

A RESISTANCE COUPLED AUDIO AMPLIFIER

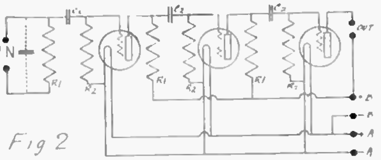


Fig 2

Resistance Coupled A.F Amplifier

R = 100 000 ohms R2 = Grid Leaks

C2 = .0025 to .006 Mfd

We have shown that the plate current varies with changes of the grid potential or charge. The space current fluctuations, however, are not equal in magnitude to the grid variations—instead, the plate current variation is several times greater than the grid change. In more correct electrical terms, the change in plate current, caused by the slight movement in the grid potential, is from four to eight times greater than would be effected by a similar change in the plate voltage. This numeric figure is known as the "amplification constant" of the tube. There are only a few who are unfamiliar with this phenomenon and who fail to take advantage of it in the conventional transformer coupled amplifiers.

However, there exist certain drawbacks associated with transformer coupled audio frequency amplification. The principal objection is that it is practically impossible to eliminate distortion. Due to certain inherent qualities in multi-turn iron core windings, some sound frequencies are amplified more than others. For instance, a high pitched tone may be favored and amplified more than a lower note. Therefore, wherever perfect amplification is essential, for example, in the speech amplifier of a broadcasting station, a resistance coupled amplifier free from this defect is often used.

A circuit for such an amplifier is shown in Figure 2, and the various values are indicated on the plate If the reader will glance back to our opening paragraphs, he will note the derivation of the formula, $E = I \times R$, which states that the voltage across any resistance is equal to value of that resistance in ohms times the current passing through it.

In diagram 2 the coupling resistances (R_1 is the first) are made so high that the voltage or potential drop across them is normally about three-quarters that of the "B" battery. In other words, the resistance of R_1 is made approximately three-quarters the resistance of the entire plate circuit, the other values of R being the internal resistance of the tube, the resistances of the "B" battery and wiring. Now, as the plate current (**passing through R_1**) varies with the changing grid potential, the voltage across the resistance, which is always equal to the current multiplied by the resistance, must likewise change—an amplified duplication of the varying grid charge! These amplified variations are impressed on the grid of the succeeding tube through condenser C_2. R_2 are **gridleaks** operating the tubes on that part of the characteristic curve best suited to audio amplification, and draining off an excess of accumulated charge.

Resistance coupled amplifications, having no distorting windings, is free from the defects of transformer coupled amplifiers. The clarity of speech is a revelation even to those who have enjoyed the output from the best of transformer amplifiers. However, as there is no step-up ratio, there is less amplification per stage. Three stages of resistance coupled audio frequency amplification is about equivalent in volume, and far superior in quality, to the best transformer coupled two-step intensifier. Two stages of resistance coupled A. F. will satisfactorily actuate a good loud-speaker.

It is unnecessary to emphasize that the system of amplification just described entails considerably less of an original financial outlay than the conventional amplifier. The cost of a three stage, with the extra tube and socket, approximates three-quarters that of a two-step transformer coupled amplifier.

The plate current consumption of the resistance coupled amplifier is also lower than that of the usual unbiased transformer coupled type. This is contrary to the prevalent and fallacious idea that the resistance coupled system imposes an excessive drain on the "B" battery. Applying a plate potential of 120 volts, through coupling resistances of 100,000 ohms, each tube will draw approximately one milli-ampere.

RESISTANCE COUPLED R. F. AMPLIFICATION

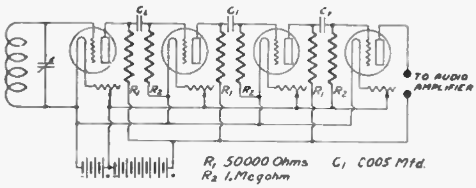


Fig 3.
LONG WAVE
RESISTANCE COUPLED R.F. AMPLIFIER

Resistance coupled amplification may be equally well applied to the intensification of radio frequency currents of **the higher wave lengths.** Due to certain characteristics of the higher frequencies (lower waves) they are less successfully amplified in this manner.

Figure 3 shows diagramatically a long wave resistance coupled radio frequency amplifier which will efficiently amplify all waves between three thousand and twenty-five thousand meters.

RESISTANCE COUPLING AND THE SUPER-HETERODYNE

The long wave resistance coupled amplifier will probably suggest itself to the more serious experimenter as a possible intermediate amplifier in the super-heterodyne receiver. The diagram, Figure 4, will be especially welcomed by the many enthusiasts who have been unable to secure efficient long wave transformers.

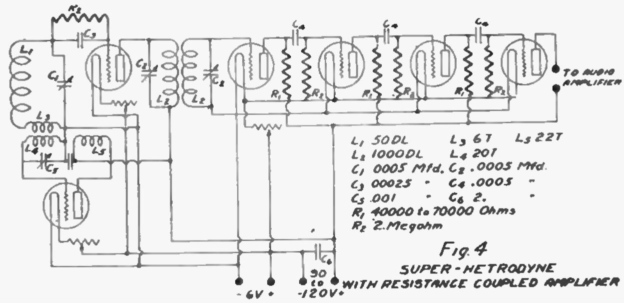


Fig. 4
SUPER-HETRODYNE WITH RESISTANCE COUPLED AMPLIFIER

This diagram follows very closely Armstrong's original circuit, and it is practically identical with Paul Godley's famous receiver with which he logged the American amateurs during the first transatlantic tests held in England.

The economy of resistance coupled amplification is to be particularly emphasized in so elaborate an undertaking as the super-heterodyne.

The reader is referred to the notes on Super-Heterodyne Receivers on pages 13, 19 and 34. On page 41 specifications are given for the plate resistors, gridleaks and isolating condensers suitable for an intermediate frequency amplifier. On page 32 will be found description of a one stage power amplifier for adding a final stage of Resistance Coupled Audio Frequency Amplification to the audio frequency amplifier or second detector of a super-heterodyne receiver. On page 34 is described an intermediate amplifier composed of alternate stages of Resistance and transformer Coupling.

HOW TO MEASURE THE RESISTANCE OF A GRID LEAK

There are two ways to measure the resistance of a Grid Leak or Resistor which will give a true resistance measurement without overloading the resistance:

(1.) Connect the Grid Leak or Resistor in series with a battery of known voltage and a milliammeter or microammeter, depending on the voltage or the resistance of the Grid Leak to be measured. The resistance equals the voltage divided by the current, for example: If the voltage of the battery is 100 volts and the current .001 ampere the resistance would be 100 divided by .001 equals 100,000 ohms.

(2.) The other method is to use a Megohmeter (not a Megger) which gives the resistance in ohms. Some well meaning but misinformed people use a Megger which generates from 500 to 1000 volts. This instrument should never be used for the reason that the voltage applied to the resistor or leak under test is many times greater than would be received under actual working conditions and the overload heats it up, and, in many cases, destroys it entirely. When a high voltage Megger is being operated, as stated above, a fluctuation of the pointer will often be noticed. This would lead many to believe that the resistor was unstable. The reason for this fluctuation is that any resistor made of carbon decreases in resistance when overheated.

PART II

THE HOW AND WHY OF RESISTANCE-COUPLED AMPLIFICATION

By ZEH BOUCK

This section has been prepared for the benefit of those few enthusiasts who may encounter occasional difficulties (as we all do, some time or another) and for the elucidation of the more serious readers who are genuinely interested in the theory and possibilities of this most efficient of amplifying systems.

1. What is Resistance Coupled Amplification?

Resistance coupled amplification as has been explained on page 6 is a system of intensifying current variations through the magnifying action of the three element vacuum tube. It is called resistance coupled amplification because the output of one tube is passed on and inputted to the succeeding tube through the functioning of a high resistance included in the plate circuit of the preceding bulb.

Figure 6 is the circuit of a three-step resistance coupled amplifier. Taking one of the coupled units as an example—bulb one and bulb two—the action of the amplifier is as follows: With an incoming signal, radio telephonic or telegraphic, the plate current of tube one necessarily varies

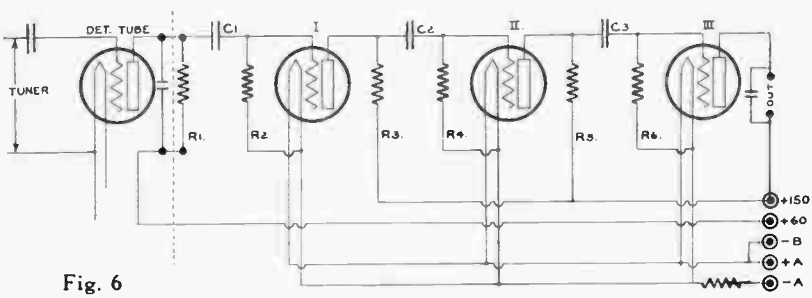


Fig. 6

in strength. This causes changes in the potential existing across the terminals of resistance R3, because the instantaneous voltage across any resistance is always equal to the momentary value of the current times the resistance. This is a derivation of Ohm's Law and may be expressed, E=IR, E being potential in volts, I current in amperes, and R resistance in ohms.

The varying potential is applied to the grid of the second tube through capacity C2—an isolating condenser (sometimes referred to as a coupling condenser because of its position) placed in the circuit to isolate the grid from the very high positive potential applied to the plate of the preceding tube through resistance R3.

R4 is a gridleak which, through leakage, prevents the accumulation of excessive charge on the grid which would cause the tube to choke, resulting in distortion or rendering it inoperative.

The average values for the circuit are: Coupling resistors, R1, R3 and R5, 100,000 ohms each; isolating condensers, C1, C2 and C3, .006 mfd. each; Gridleaks, R2, R4 and R6, respectively 1 megohm, ½ megohm and ¼ megohm. These values will seldom require variation when using the UV201A and similar tubes.

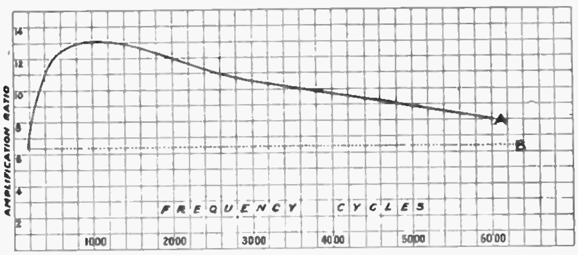
Any standard method of regulating filament current **may be employed.**

The gridleaks should generally be connected to negative filament terminals.

2. What is the advantage of Resistance Coupled Amplification over other systems?

The outstanding superiority of the resistance coupled amplifier is the quality of output. There are certain characteristics in inductive windings which give rise to frequency partiality. An amplifying transformer is composed of two highly inductive windings, the primary and secondary, and it is inherently impossible for a transformer to give the same degree of amplification at all frequencies. The result is distortion which, in defiance of improved design, is still noticeable to a greater or less degree varying with the excellence of the instrument. Corrective measures, such as elaborate filters, are possible, but these are only a pound of cure and beyond the facilities of the average experimenter.

The relation between the input and output of a resistance coupled amplifier is practically linear. Less technically, the elimination of all inductive windings results in amplifying all frequencies to practically the same degree, limiting distortion to stresses imposed by unfavorable characteristics of the tube. The output of a correctly designed and operated resistance coupled amplifier is auditively perfect.



The characteristics of resistance coupled and transformer coupled amplification are compared in the accompanying graph.

Curve A is characteristic of the average amplifying transformer, while the dotted "curve" B shows a resisto-coupler plotted in the same respect to amplification $\frac{EG2}{EG1}$ and frequency. As the curves indicate, the magnitude of amplification is greater with the transformer, but the practically straight dotted line (equal amplification throughout the audible range) recommends the resistance-coupled amplifier for decidedly superior quality.

3. How does Resistance Coupled Amplification compare with transformer coupled intensification in efficiency?

This really depends on the criterion of efficiency. The amplification per stage of resistance coupled amplifiers is not so great as that of transformer coupled arrangements. Also, for the correct operation of an R. C. amplifier, from one and a half to twice the usual amplifying plate voltage is necessary.

However, results per dollar is the ultimate standard of efficiency, and in this consideration the resistance coupled amplifier ranks first.

Three stages of resistance coupled amplification cost slightly less than two steps of transformer intensification, the former giving volume equal to the best and superior to the general run of the latter . Regardless of the extra "B" battery, the very low plate consumption, the "modulation down" (to be explained later) and the absence of "C" battery reduces the maintenance cost to an economy. Also, when the unequaled purity of tone—the quality—is considered, the efficiency of this amplifying system is doubly established.

4. How many stages of Resistance Coupled Amplification can be used? What are the values for additional steps?

Three steps are sufficient for all ordinary purposes, giving amplification generally equal to the output of a two-stage transformer coupled amplifier. Two steps inputted from an efficient regenerative or reflex tuner will operate a loudspeaker with fair volume.

More than three stages are not to be recommended in conjunction with reflex and super-heterodyne receivers. Two steps will generally give sufficient volume and obviate the complications to which additional stages may give rise.

For radio reception purposes, four stages is the practical limit. This means at least a five tube receiver. Switching or jack arrangement should always be provided for cutting out the last tube, for it will be necessary only on very weak signals and for concert or dance entertainment. A UV201A or a similar tube will seldom give satisfactory results as the fourth bulb on loud signals. The signal strength will generally exceed the capacity of the tube and distortion will result.

A 216A tube, or similar power bulb is recommended in the fourth stage. A coupling resistance of 100,000 ohms, and a gridleak of the same value should be used with this tube.

Employing a UV201A, a coupling resistance of 100,000 ohms is recommended with a gridleak of 100,000 ohms.

The preferred circuit for a four-stage resistance coupled amplifier is shown in Figure 7. The indicated switching arrangement makes possible the elimination of the last tube, transferring the output from the fourth to the third bulb and controlling the filament. A small double-pole double-throw switch, is used for this purpose. (The so-called "Anti-capacity" switch is

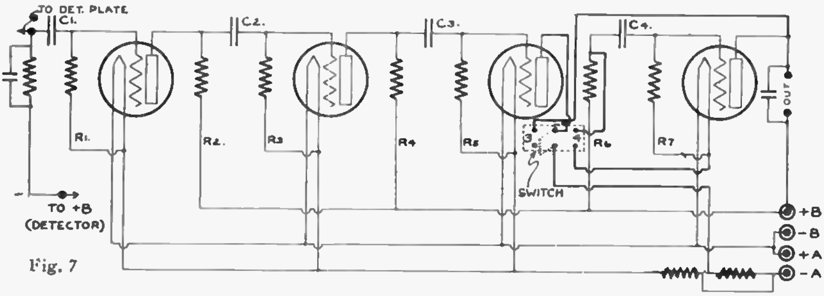


Fig. 7

quite convenient.) The values of the first three steps are identical with those outlined in our opening paragraphs.

5. Can a transformer amplifier be rebuilt without unjustified trouble into a Resistance Coupled Amplifier?

Yes—quite easily, especially if the Daven Resisto-Couplers are used. These have four connections similar to those on amplifying transformers—plate, plus "B," grid and filament. It is only necessary to effect the substitution.

6. Can Resistance Coupled Amplification be used successfully with a crystal detector?

Yes and no. It cannot be applied directly to the output of a crystal detector—that is, connecting it to a simple crystal receiver. The resistance coupled amplifier is essentially a current operated device. As before explained, the drop across the resistance is equal to IR—and I is very small in the case of energy picked up by the antenna and rectified through a crystal. One stage of transformer coupled amplification should be interposed between the crystal detector and the resistance coupled amplifier, as shown in Figure 8. The primary of the amplifying transformer is merely substituted for the telephone receivers, regardless of the tuning circuit. It may be necessary to reverse the primary connections.

The resistance coupled amplifier can, of course, be applied successfully to the output of a crystal rectified reflex receiver, such as the typical one tube reflex. This is a very desirable combination, the clarity and quality of the crystal detector being maintained throughout amplification.

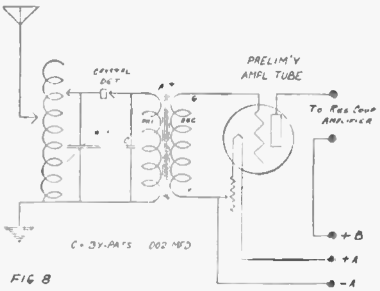


FIG 8

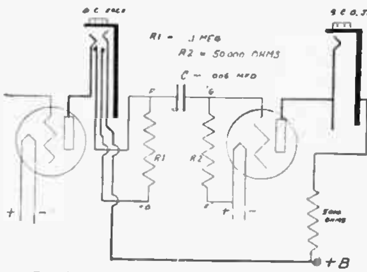


FIG. 9 THE USE OF JACKS

7. Can Resistance Coupled Amplification be added to a transformer coupled amplifier? Is this worth while?

Yes, this can be done quite readily and is often desirable. However, no more than one stage of transformer coupled amplification should be used before the resistance amplifier. If two transformer stages are used the distortion will be such that the great advantage of the resistance coupled amplifier, quality, will be lost.

Figure 8 shows the manner of connecting the resistance-coupled amplifier to the output of a transformer coupled intensifier. Two stages of R. C. will be sufficient.

8. Can Resistance Coupling be used for radio frequency amplification?

Yes. Some of the early radio frequency amplifiers employed this system. Unfortunately, resistance coupling for radio frequency amplification is comparatively ineffectual on the broadcast wave lengths in which the average reader is interested. The coupling resistor is virtually shunted by the plate to filament capacity of the preceding tube and by the grid to filament capacity of the succeeding tube, all of which forms more or less of a bypass about the resistor through which the high-frequency currents detour.

A radio frequency resistance coupled amplifier will work on the broadcast frequencies, but not so satisfactorily as to recommend it in preference to the more usual forms of amplification.

Resistance coupling is efficient on waves above two thousand meters, which makes it quite satisfactory as an intermediate frequency amplifier in super-heterodyne arrangements. This system was employed by Paul Godley, well known engineer, in his famous pioneer trans-Atlantic reception on amateur wave-lengths. Daven "Resisto-Couplers" are admirably suited for this purpose; with 50,000 ohm resistors in plate circuits, isolating condensers of .0005 mfd. and grid leaks of 2 to 5 megohms.

9. How can I use jacks in a Resistance-Coupled Amplifier?

This is quite simple—in fact almost self-explanatory. The manner of connection will be immediately apparent to the majority of enthusiasts employing the Resisto-Coupler who are already familiar with the method of connecting jacks to transformer coupled amplifiers.

Figure 9 shows the principle of wiring the double-circuit jack—the type most commonly employed—between two stages of resistance coupled amplification. Additional stages may be adapted in the same manner. The outside prongs of the jack run to the plate and plus "B" battery, while the inner prongs are led to the coupling resistor. The outer prong of the plate must connect to the inner prong leading to the upper side (isolating condenser) of the resistor when the jack is closed.

10. Should the gridleak values be changed?

The gridleak resistances for the UV201A and similar tubes may be fixed almost arbitrarily as given for diagram 6. The values for tubes of rather different characteristics will be given further on in this bulletin.

If the enthusiast desires to experiment, the gridleak resistances may be increased to just below that value at which distortion and blocking of the tube takes place on loud signals. The greatest amplification will be secured at this adjustment. In some cases it may be possible to eliminate the grid leak on the first tube.

11. Should variable resistors be used—and is it desirable to experiment with the values?

Variable resistors, while they will generally work well, are not necessary. The values are uncritical, and variable resistances are often accompanied with characteristics which make them less suitable as coupling resistors.

Any value of coupling resistor between fifty thousand and one hundred and fifty thousand ohms will give almost unchanging amplification, a preference being given to the one hundred thousand ohm resistor as being the most efficient.

When inputting from a reflex set, or a transformer coupled stage, slightly better amplification is sometimes secured by using a low value in the first stage—a 50,000 ohm resistor.

12. Can dry cell tubes be used in the Resistance Coupled Amplifier? It so, what are the resistance values?

Yes. Practically any modern amplifying vacuum tube can be employed successfully in a resistance coupled amplifier. For the UV199, the C299, the Western Electric "N" tube, the WD 12, the De Forest D2 and D3 and the Meyers tube (an exceptionally fine tube for this purpose!) the values for a three-stage amplifier are exactly the same as those specified for the UV201A —i. e., coupling resistors of 100,000 ohms and the 1st, 2nd and 3rd stage gridleaks respecitvely 1,000,000 ohms, 500,000 ohms and 250,000 ohms. Should a fourth stage be desired—the coupling resistor and gridleak should be 100,000 ohms each.

13. Is the Resistance Coupled Amplifier stable?

The resistance coupled system is probably the most stable of all amplifying arrangements due to the fact that plate inductances, with their accompanying feedback, are elminiated.

However, in the case of poor tubes, and when three or four stages are inputted from a multitube tuner such as the reflex, howling may occasionally be encountered. The various tubes should be tried in different stages in an endeavor to secure a satisfactory combination.

If howling exists only when the final stage is used, the ohmage of the last coupling resistor (or of the last two in extreme cases) should be increased—say to 250,000 ohms, and in a few instances even higher. These very high ohmages, however, will seldom be necessary, and probably only in a case of poorly matched tubes.

Adjustment of gridleaks will also often insure stability. In such cases, placing the fingers across the gridleak prongs will indicate the stage in which this resistance should be decreased.

Cases of instability will be few and far between, and only on such occasions when similar faults would arise to a still more annoying degree with a transformer or impedance coupled amplifier.

14. Is a bias necessary?

No. To insure quality, a bias by means of a "C" battery is not necessary in resistance coupled amplification. However, the use of a bias battery in the grid circuit of the last or "open" tube is effective in reducing the plate current consumption of the amplifier. These connections are suggested in the ideal amplifying circuit shown in Figure 9A. On this diagram, the first two tubes secure the correct degree of bias through the drop across rheostat and filaments, and three additional volts are applied to the grid of the final stage by means of the battery "C." In consideration of the

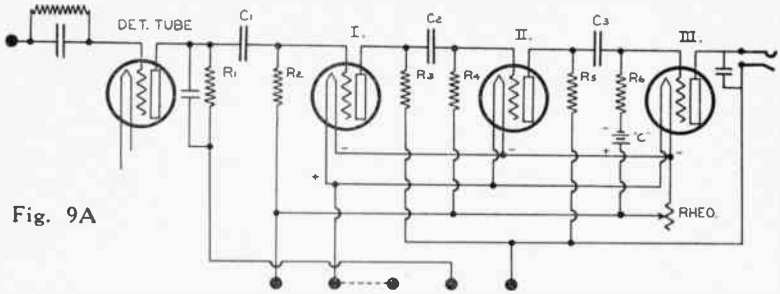


Fig. 9A

characteristics of resistance coupled amplifiers, greater bias than this is not recommended on tubes such as the Western Electric 216A or smaller.

15. What plate voltages shall I use?

The experimenter may go as high as twice the maximum potential recommended by the manufacturer of the tube. The actual applied voltage is greatly reduced by the coupling resistance which is in series with the plate supply. Voltages of at least one hundred should be used on all tubes.

Employing the suggested 100,000 ohm coupling resistors and the UV201A or the C301A tubes (an excellent and widely used combination), a 140 volt "B" battery will give very fine results. A lower potential of 90 volts will also output satisfactory volume.

When inputting to a resistance coupled amplifier from a detector tube, the plate voltage of the detector bulb should be doubled or tripled, again compensating for the coupling resistor. The detector plate potential should be increased until the tube detects most efficiently, or, in the case of a regenerative receiver, the set regenerates and oscillates in the normal manner.

Due to this increase in the detector plate voltage, jacks should never be introduced into the detector circuit. Plugging in the comparatively low resistance phones in this particular circuit would completely upset the adjustment, placing an inoperatively high potential on the plate of the detector. If jacks are used, it is advised that they be placed after the first, second and third stages.

Due to the fact that there is no plate resistor included in the plate circuit of the last tube, it is often good practice to place a "C" Battery of from 3 to 6 volts, (according to potential of "B" Battery) in series with the grid leak of last tube as shown in diagram 9-A. This will reduce the plate current by approximately one-half without decreasing volume. Tapping the plate voltage at a lower potential will secure the same result.

16. What are the most efficient values for the isolating condensers? Are they critical, and do they require change of adjustment?

The capacity of the isolating condensers is not at all critical, and may be anything from .0025 to 1 mfd. The lowest operative capacity is not advised in coupling the last tube of a four-stage amplifier. A good compromise, all the way through, is the .006 mfd. micadon which is quite as easily obtainable as the lower capacities. No adjustment is necessary.

17. Can Resistance Coupled Amplification be added to any set or output? How can it be attached to different commercial types of equipment?

Resistance coupled amplifiers may be used with any type or make of receiving set. Regardless of the diversification of circuits and receivers, resistance coupling is connected to all of them in exactly the same manner. The following procedure should be observed when inputting from any make or receiver design:

In the majority of instances the experimenter will desire to connect the resistance coupled amplifier to a detector output. The amplifier is wired to the "A" battery in the usual way. The input posts on the amplifier are connected to the telephone posts on the receiver or to a plug plugging into a telephone jack. An amplifying "B" battery should be provided and the plus side connected to the indicated post on the amplifier. It now only remains to complete the connections through the minus of the amplifying "B" battery.

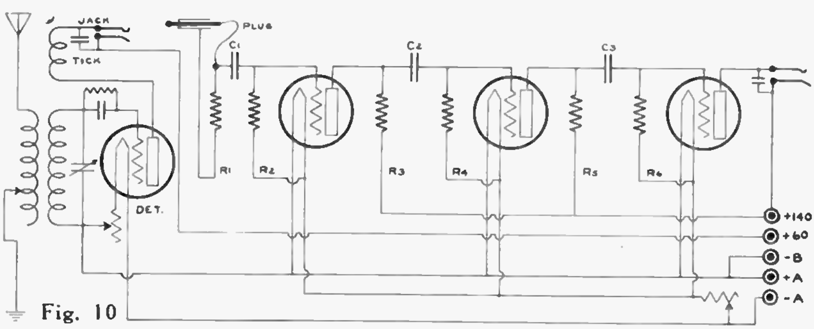


Fig. 10

The minus "B" battery terminal on the detector or tuner should be carefully inspected. In the majority of cases the experimenter will find that this post leads to either plus or minus of the "A" battery. In many instances the minus "B" and one of the "A" battery terminals are combined in a single post. If such is the arrangement in the case of the reader, the minus of the amplifying "B" battery should be connected to the plus terminal of the detector "B" battery.

Figure 10 shows three stages of resistance coupled amplification connected to a standard three circuit regenerative set in compliance with the principles outlined above

When amplifying the output of a transformer coupled stage, or a reflex receiver, no extra amplifying battery is really necessary, though as before explained the higher the voltage, within certain limits, the more efficient the amplification. The plus high voltage may be merely tapped from the positive terminal of the battery already in the circuit. The minus terminal of any additional battery is similarly connected—applying the accumulative potential to the plates of the resistance coupled amplifiers.

Part III, which follows, describes in detail how Resistance Coupled Amplification may be used with some of the popular types of receiving circuits.

PART III

AUDIO FREQUENCY AMPLIFIERS FOR STANDARD CIRCUITS

1. The "Three-Circuit Tuner"

The "three circuit tuner" is a designation applied in a rather free and easy manner to two more or less related receiving systems. Today the three circuit tuner usually refers to a set of three coils, primary, secondary and tickler. The circuit is tuned principally by a variable condenser across the secondary, and regeneration is effected by approaching the tickler to the secondary or grid coil. There are several commercial types of these tuners, (such as the Ambassador, Uncle Sam, Globe, Bremler Tully, Trans-Continental and the Lopez Low-Loss Tuner). Receivers employing these coils are very effective, but care should be observed in tuning them to subdue all unnecessary oscillations, for improperly operated such apparatus are radiators of interfering oscillations.

The same precaution holds true for the second class of "three circuit" arrangements, which differs from the foregoing apparatus in the method of regeneration. This is achieved through capacity feedback in the vacuum tube, with the assistance of a variometer included in the plate circuit. Many of these receivers also tune the secondary circuit by a grid variometer, dispensing with the secondary variable condenser.

Plus Resistance Coupled Audio

The addition of three stages of resistance coupled audio frequency amplification to the detector output of either of these two systems results in a thoroughly up-to-date broadcast receiver. The receiver is economical in initial expense and operation—the former, with justified extravagance, should not exceed thirty dollars. Selectivity, sensitivity and volume will be considerably above the average, and the output quality, the almost exclusive characteristic of resistance coupled intensification, will be auditively perfect!

Figure 11 illustrates the manner of adding resistance coupling to the circuit first described. The tuning arrangement (the apparatus to the left of the dotted vertical line) is self-explanatory, and will identify itself with thousands of receivers in use today. Ordinarily—when no amplification is employed—the telephone receivers are connected, directly or by jack, with the terminals marked W and X. C_1 is the usual bypass fixed condenser of about .002 mfd. capacity.

The apparatus to the right of the dotted line is the resistance coupled amplifier, which may justify a more detailed description. R, throughout the diagram, represents the coupling resistors of one hundred thousand ohms each. R_1, R_2, and R_3 are gridleaks having respective values of 1,000,000 ohms, 500,000 ohms and 250,000 ohms for most tubes.

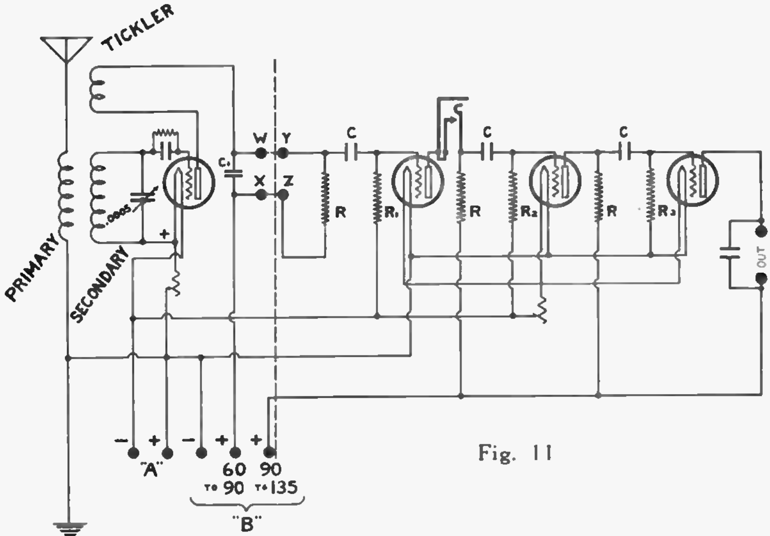


Fig. 11

C represents the coupling condensers, which are consistently of .006 mfd. capacity, with a permissible variation in either direction of .003 mfd.

Jacks have been included in the plate circuits of the first and third stages—the preferred positions.

The gridleak of the last tube has been brought down to the positive side of the filament. The experimentor should attempt connecting this to the negative lead (where it will reduce plate current consumption)—this latter connection being preferred if quality does not suffer on loud signals.

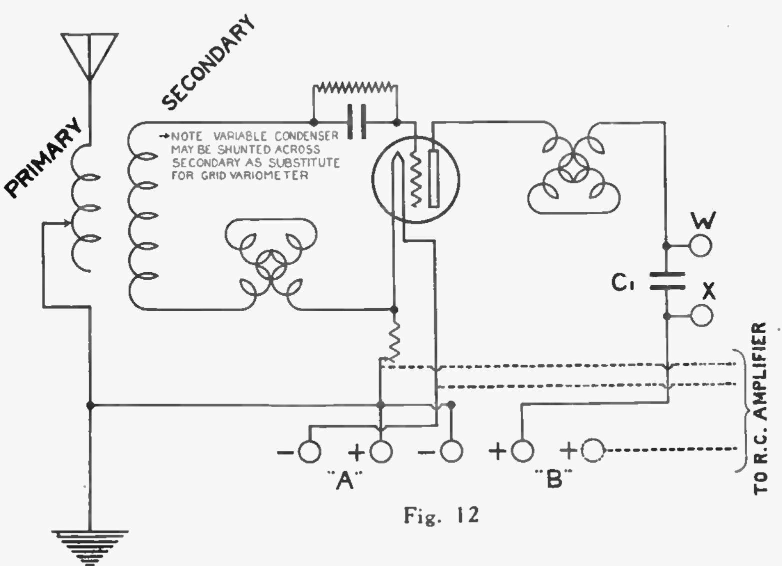


Fig. 12

It will be observed that a detector plate potential of from 60 to 90 volts has been recommended. This increase is necessary to compensate for the voltage drop across the added plate resistance. The highest detector plate voltage compatible with smooth and satisfactory regeneration should be employed. A quarter ampere amplifying tube is recommended in the detector circuit rather than a soft bulb. Almost all available tubes can be successfully employed in the resistance coupled amplifier. However, as amplification is altogether dependent upon the amplifying ability of the tube—the amplification constant—the writer personally recommends the DeForest DV-2, which is characterized by a slightly higher "mu" than the somewhat similar tubes of other manufacture.

The variometer-regenerative receiver (Figure 12) is outputted to a resistance coupled amplifier in the same way, with identical instructions and values. W and X are again connected respectively to Y and Z, with the advocated and obvious changes in "B" battery. In all cases it is important that Y connects to W—i. e., that the upper or condenser side of the resistor leads through to the plate of the preceding tube.

If the reader possesses either of the two tuning arrangements outlined, the addition of a three stage resistance coupled amplifier can be effected at an expense not exceeding $12.50. No complications or difficulties should be experienced, and the slight effort and expense are more than justified by the results.

2. The Super-Heterodyne Receiver

It has been pointed out on various occasions that the instability of a receiving system increases in a more or less direct ratio with the number of tubes employed. The super-heterodyne is fundamentally a multitude receiver. Five tubes is a practical minimum when the second harmonic principle is utilized, and this number is increased to six in the standard natural heterodyne arrangement. This number includes the frequency changing apparatus, the intermediate amplifier and the final detector. It is therefore rather obvious that the addition of audio frequency amplification must be effected with a certain amount of intelligent caution, in order to maintain a satisfactory degree of stability.

Instability can be traced almost invariably to the functioning of high inductance. It follows that the elimination or reduction of this quality lessens the possibility of undesired oscillations. A properly constructed resistance coupled amplifier (i. e., employing non-inductive resistors) is practically without inductance. It is this additional quality that particularly recommends the resistance coupled amplifier for use with the super-heterodyne receiver.

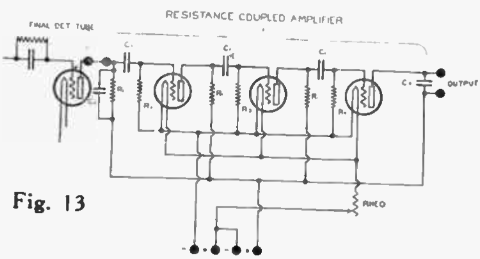


Fig. 13

We recommend three stages of resistance coupled amplification, inputted from the second detecting tube. Figure 13 shows the preferred diagrammatic connections, while Figure 14 is a photograph of such an amplifier functioning in our laboratory.

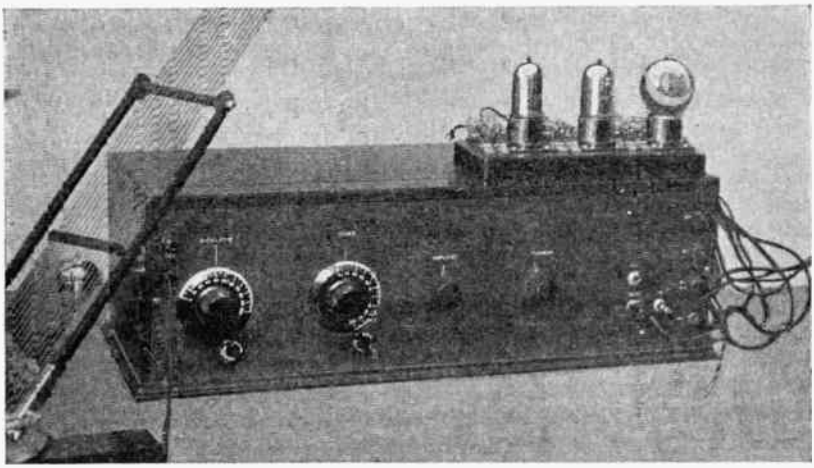


Fig. 14

The diagram follows out the consistant and simple method of applying resistance coupled audio intensification. The coupling resistors R_1 have an ohmage of one hundred thousand throughout. This holds regardless of tubes and satisfactory plate voltages. R_2, R_3 and R_4 are gridleaks with respective values of 1,000,000 ohms, 500,000 ohms and 250,000 ohms. C_1 throughout is the usual coupling or isolating condenser, having a consistent value between .003 mfd. and .006 mfd.—the latter capacity being easily secured and preferred. The experimentor is advised against employing larger condensers. A certain time element in the discharge characteristic of the condenser must be preserved, and the use of higher capacities will necessitate lower leak values in order to achieve this desired condition. A lower leak value will dissipate a large part of the signal energy across itself, with a resulting loss in signal strength.

C_2 and C_3 are bypass condensers, which, in individual installations may or may not be required. Their desirability should be determined by experimentation. In the majority of cases, the superheterodyne will tune more naturally and stably with these condensers in the circuit. Under certain conditions, a resistance coupled amplifier will oscillate (less easily than other amplifiers, however), and such electrically ideal circumstances are promoted by the inductance of the loudspeaker coils which are necessarily included in the plate circuit of the last tube. Bypassing these with a .006 mfd. condenser (C_3) will generally eliminate this difficulty when it exists. A similar effect is occasionally secured by bringing down the leak of the last tube to the positive side of the filament.

C_2 is the usual input bypass condenser of about .001 mfd capacity. Care must be observed to connect the upper or coupling side of the first resistor to the plate of the detector tube.

Plate potential and tubes have been treated in detail in the first section of Part III, to which the interested reader is referred. In the specific case treated in this paper, the highest plate potential employed is 135 volts supplied by three 45 volt batteries. The full voltage is applied to the intermediate amplifier, the last detector tube (a deliberately high potential to compensate for the drop across the first coupling resistor) and the a. f. amplifiers. The other voltages in the superheterodyne circuit are tapped from this battery.

The output of the amplifier described is of almost excessive volume, while the quality is auditively perfect. Outputted into an equally efficient loudspeaker (this is most important) it is an achievement most pleasing to the engineer and artist.

3. The Neutrodyne

There are two equally efficacious methods of adding resistance coupled audio frequency amplification to the neutrodyne type of receiver. One consists of knowing your tuning circuit (commercial neutrodynes are characterized by superficial variations), and applying resistance coupling deliberately in accordance to the principles discussed in the preceding articles. The second method approaches the achievement a little less directly, and is best adopted by the fan (differentiating from the "experimenter") who is unfamiliar with the detailed circuit of the set which he has doubtless purchased. These methods apply equally well to the addition of any form of audio intensification.

In following the first procedure, the experimenter should trace his circuit, drawing it out on paper, and add to it the desired stages of resistance coupled audio frequency amplification. Following the detector, three stages is the usual choice, though individual requirements may recommend one more or less. The completed diagram will be very similar to Figure 15,

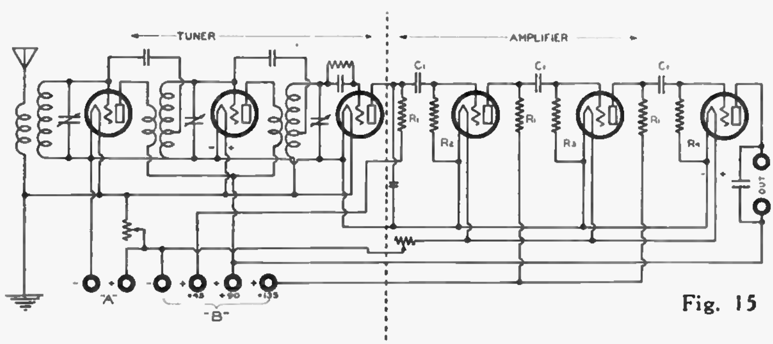


Fig. 15

which shows a standard neutrodyne tuning circuit outputted to a three stage resistance coupled amplifier. In all cases, any variations will be confined to the tuning apparatus to the left of the vertical dotted line. In designing or making up such a set, standard radio frequency transformers can be employed with the usual complementary parts.

The coupling resistors, R_1, of the A. F. amplifier are 100,000 ohm resistances. This value remains the same for all tubes (practically) as does the .006 mfd. coupling-isolating condensers, C_1. The gridleaks, R_2, R_3 and R_4 have respective values of one megohm, one half megohm and one quarter megohm.

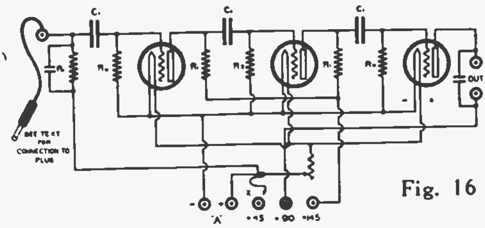


Fig. 16

Figure 16 shows the amplifier alone, wired to a plug by a single lead, which arrangement is suggested for adding resistance coupling according to the second plan. Practically no knowledge whatever of the receiving circuit is necessary. Wire X should be tapped on 45 volts of "B" battery. After tuning in a station on telephone receivers, the 'phones should be removed and the amplifier plugged into the jack. If no signals are heard, the single wire leading to the plug should be transferred to the other plug terminal. When signals are being amplified, X should be varied over the "B" battery taps until the response is the strongest without impairing quality.

The amplifier should always be plugged into the lowest stage jack on the receiver proper—the jack that ordinarily gives the weakest response. Many neutrodynes are so arranged that at least one stage of transformer coupled audio frequency amplification must be employed. This being the case, no more than two stages of resistance coupling should be added. One extra step will generally suffice. Quality will probably not suffer through the single stage of transformer coupled intensification. Properly designed and operated, one transformer coupled stage should be auditively perfect.

If the receiver to which the reader contemplates the addition of resistance coupling is a five tube set, and four tubes are used (lighted) on the lowest jack, it is an almost inflexible indication that one transformer coupled stage is being employed.

When inputting from the detector tube (Figure 15) from 45 to 60 volts should be applied to the plate of this bulb—compensating as usual for the voltage drop across the coupling resistor in the plate circuit. No more than 90 volts should be impressed on the r. f. circuit while 135 volts is about right on the a. f. amplifier. This last will function satisfactorily on 90 volts, though higher amplification is quite naturally secured on the increased potential.

When inputting from a transformer coupled stage, the normal detector voltage should be used. In this case it may be desirable to employ a coupling resistor in the plate circuit of the transformer coupled amplifying tube above or below the specified 100,000 ohm resistance—anywhere from 50,000 ohms to 250,000 ohms. One hundred thousand ohms, however, will always prove a satisfactory compromise. If only two resistance coupled tubes are used, the leak values should be those of the last two bulbs in Figure 15. If a single stage is employed, the gridleak should be a fifty thousand ohm resistance. The UV201A, the C301A and the DeForest DV-2 tubes will function satisfactorily in this amplifier. Tubes and plate voltages have been discussed at greater length in the first section of Part III.

Resistance coupled amplification can be added to any radio frequency amplified receiver, regardless of the method of stabilization, in the manner described for its application to the neutrodyne.

The addition of resistance coupling to the neutrodyne is, in the mind of the writer, decidedly worth while. The neutrodyne is an excellent receiver. Properly designed and constructed, it combines many desirable qualities that approach it to the ideal broadcast receiver. Resistance coupled audio intensification adds a finishing touch—quality that will do justice to the best loudspeaker made, and to ears and sensibilities appreciative of harmonic finesse.

4. Reflex Receivers

It is difficult if not impossible for the layman to add external stages of transformer coupled amplification to a reflex receiver without noticeably impairing the quality of reproduction. This is because such a combination almost invariably means at least three transformer coupled stages of amplification (including reflex), and auditively distortionless output from such demands engineering skill and laboratory facilities of no mean degree. And due to the characteristics of reflex apparatus, the stability of the resulting system is often precarious. Resistance coupling, as adapted with not uncommon ability, goes far towards killing these two birds with one stone.

However, the addition of resistance coupled audio frequency intensification to reflex receivers, represents the nearest approach to a problem that this really simple and efficient system of amplification assumes. The complication (which is easily obviated) arises from the fact that the output of most reflex receivers is from the plate circuit of a tube functioning as both radio and audio amplifier. This is invariably true of receivers that employ no external audio amplification—and to which it is probable that the experimenter will consider the addition of resistance coupling.

It is safe to say that the efficiency of all reflex receivers (probably most radio frequency sets for that matter) is indebted to the presence of regeneration in the r. f. stages. We do not declare that it is impossible to design and construct a radio frequency amplified system which will be both effective and free from regeneration; but there is no doubt that regeneration contributes largely to the efficiency of most receivers with which the layman is familiar. The inclusion of a high resistance, such as a 100,000 ohm coupling resistor, in the plate circuit of an r. f. tube, curtails regeneration—a dampening effect that cannot be counteracted by bypassing with a condenser, and which seriously hampers the function of the tube as an r. f. amplifier. A very efficient commercial receiver employs exactly this method to suppress over-regeneration and oscillations in a tuned r. f. circuit. It is obvious to the more experienced fan that adding resistance coupled amplification, with the usual values, would include such a resistance in the plate circuit of the r. f.—a. f. output tube, with the result that signal strength in the first stage r. c. audio may be less than the output of the tuner itself.

The solution lies in the correct combination of the first coupling resistor and the bypass condenser across it. Forty thousand ohms (rather than the more usual one hundred thousand) shunted by a .0025 mfd. condenser will generally approximate the most efficient combination. The remaining stages are characterized by the similar values.

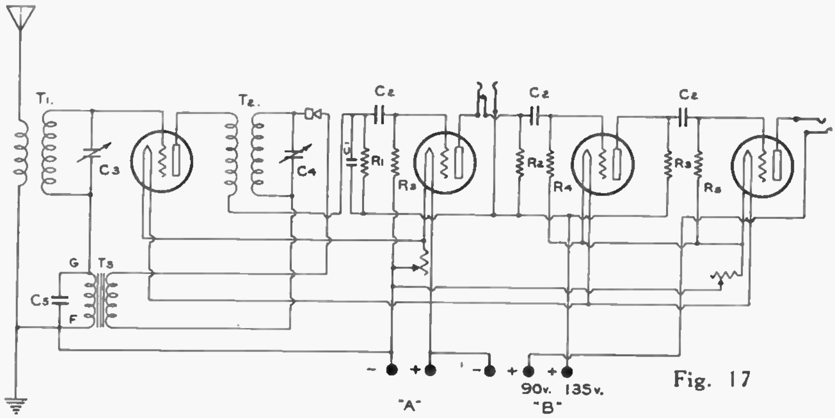


Fig. 17

Figure 17 shows how three stages of resistance coupled amplification have been very successfully added to the conventional single tube reflex circuit. The addition to the output of any reflex tuner can be effected in a similar manner and with the same values of R and C.

R_1 is the first coupling resistor of 40,000 ohms resistance. R_2 are the following resistors of 100,000 ohms each. C_1 is the bypass condenser already referred to of .0025 mfd. capacity. C_2 represents the isolating-coupling condensers—.006 mfd. throughout.

The plate voltages have been indicated on the diagram, and the tubes used in the four sockets were DeForest DV-2s. Bulbs and plate potentials have been discussed at greater length in the first article of this series.

The combination suggested in the diagram and illustrated in the back-of-panel photograph in Figure 18 is a remarkably fine combination for broadcast reception. The quality of the crystal rectifier is maintained throughout the audio amplifier. The values of the tuning circuit, with which most of us are familiar, can be outlined briefly as follows: T_1, primary, 15 turns, secondary, 60 turns on a two and a half inch solenoid form; T_2, primary 35 turns, secondary 60 turns as a two and a half inch solenoid; T_3, any good medium-ratio audio frequency amplifying transformer. An Amertran is

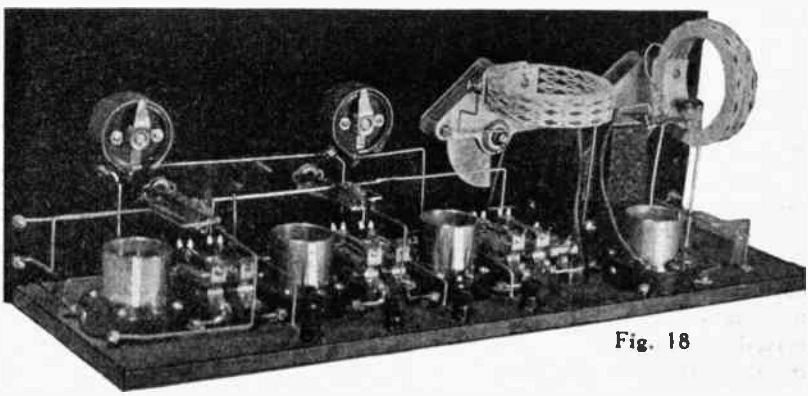


Fig. 18

used in the receiver photographed. Condensers C_2 and C_4 should be of the low-loss type having maximum capacities of .00035 microfarads. The crystal detector is preferably of the fixed type. Condenser C_5 is a small fixed capacity, about .00025 mfd., which had best be experimented with to suit individual regenerative conditions.

This receiver is very economical to operate. The plate current consumption, at indicated potentials averages about eight milliamperes when receiving stations of fair intensity. It is not a radiator of interfering oscillations.

5. Resistance Coupled Amplification following Transformer Stages.

In many cases the builder or experimenter will find it necessary or desirable to add one or more stages of resistance coupled amplification to the output of a transformer coupled amplifier. Probably the most common occasion suggesting this combination is the frequent desirability for an auxiliary stage of power amplification—a step of intensification raising the audibility of distant stations, or local stations for dance purposes, above the capacity of the receiver proper. The linear amplification characteristic (distortionless amplification) of the resistance coupled amplifier, particularly recommends it for such power purposes. It is in the final amplifying stage that the greater part of strain (distortion) is generated and emphasized. Such an amplifier is simple to construct as an external and individual unit, plugged in when desired and disconnected when the volume outputted from the set itself is satisfactory. This auxiliary amplifier proves a most useful addition to the standard seven tube super-heterodyne.

A second occasion for additional amplification that frequently presents itself, is the adaptation of resistance coupling to receivers where the lowest jack is in the plate circuit of a transformer coupled audio frequency bulb, thus making difficult, access to the detector circuit. This possibility has been referred to and considered in the preceding section of this series.

The third possibility, and a meritorious one, is illustrated in the deliberate design and construction of an amplifier consisting of one transformer coupled step—the first—followed by two stages of resistance coupled amplification. It has been pointed out previously that a single stage of transformer coupled audio intensification, employing a good transformer and tube, and properly operated, should be auditively perfect. That is, as far as the ear is concerned, there should be no distortion. This is assuming, incidently, that the average amount of power handled in the first stage following detector is being transferred by the circuit in question. Such an arrangement takes advantage of the superior intensifying characteristics of the transformer coupled amplifier in this primary stage.

The fourth and perhaps final classification of transformer-resistance coupled amplifiers, is found in the substitution of resistance coupling for the last transformer in a cascade amplifier, the operation of which has been unsatisfactory through the characteristic contributions of unstability and distortion. The resistance coupled amplifier is probably the most stable of all amplifying arrangements (due to the practical elimination of inductive effects) and an unstable transformer coupled amplifier can often be made to function beautifully by substituting resistance coupling in the completing stage. This consideration is particularly true of reflex apparatus, which is inherently unstable.

These four classifications, as far as result is concerned, are much the same thing. They are merely different causes arriving at the same effect—the combination of transformer and resistance coupled audio amplification. Typical connections for such an arrangement are sketched in the accompanying diagram (Fig. 19). It will be observed that if the individual parts comprising the resistance coupling system—the plate resistor, the coupling-isolating condenser and the gridleak—are grouped into a unit, they may be substituted. without additional alteration of the circuit, for any single amplifying transformer. The connections, plate, plus "B" battery, grid and filament are the same.

Due to the characteristics of a tube energized from a transformer, the best coupling resistor value R-1 may vary somewhat from the usual 100,000 ohms—generally going higher to perhaps 250,000 ohms. A few minutes of experimentation will quickly determine the most efficient individual resistance. Two hundred thousand ohms will be about correct for the gridleak, R-2. If an additional stage is added in the usual manner, a coupling resistor and a gridleak of a common 100,000 ohms resistance are recommended. The coupling condensers, C, should be .006 mfd. fixed capacities.

Any of the standard six volt tubes will function satisfactorily, using from ninety to one hundred and fifty volts on the plates. Tubes and plate potentials have been discussed at length in the first section of Part III.

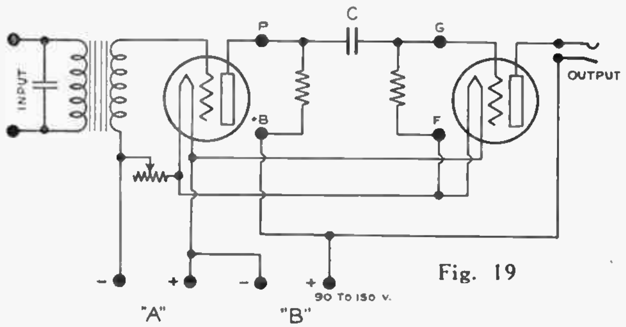


Fig. 19

6. Miscellaneous Applications and Notes.

Like all things worthy of the learning, a knowledge of resistance coupled amplification is best acquired through an appreciation of principle rather than by rote. This has been covered quite fully in the preceding paragraphs. The student—or even the casual reader—should now be able to add resistance coupled amplification (or any other amplifier for that matter) to receivers other than those specifically described, through application of the simple principles involved.

The various possibilities which have not been discussed in detail are the almost infinity of miscellaneous receivers functioning through the detecting or amplifying characteristics of the three element vacuum tube or audion—the crystal detector—and the Diode or two element Fleming Valve. Though the examples in the first group flourish under a multitude of names, they are easily resolved into a comparatively few variations of the standard circuits which the writer has discussed. In practically every case, resistance coupled amplification can be adapted to these receivers by the "plugging-in" procedure suggested for the Neutrodyne. If possible, it should be determined whether the external amplification is being inputted from a detector tube, a straight transformer coupled audio tube, or a reflex tube both as a R. F. and an A. F. amplifier. The addition should then be modified in accordance with the changes suggested for these three types of input in the separate articles devoted to their characteristics. The plugging-in method as applied to the Neutrodyne, is equally successful with practically every receiver in the world, and is simply applied by the non-technical fan.

The addition of resistance coupled audio amplification immediately after rectification (detection) through a crystal detector, or a Diode (two element) vacuum tube, is best accomplished by inputting to a transformer coupled stage, and following with two steps of straight resistance coupling. An amplifier of this type has been described in detail in the preceding section. In the case of the Diode, the transformer primary is similarly substituted for the telephone receivers.

A bypass condenser of about .002 mfd. capacity should always be employed across the first coupling resistor.

The resistance coupled amplifier, is probably the most stable of amplifying arrangements, but an occasional squealing, which would probably be considerably emphasized on other types of amplifiers, may evidence itself. This can generally be eliminated by lowering the value of the first coupling resistor, varying the capacity of the bypass, and by placing a .006 condenser across the winding of the loudspeaker. Sometimes raising the resistance of the first coupling resistor will also have a stabilizing effect.

Common "A" and "B" batteries can, of course, be used with resistance coupled amplifiers.

Resistance coupling for radio frequency amplification on the broadcast wavelengths is not recommended. The circuit characteristics of a resistance coupled amplifier, place a very low limit on the possible amplification of these high frequencies. This system, however, is quite successful on high waves—below 150 kilo-cycles—and it is satisfactory as an intermediate frequency amplifier in the Super-Heterodyne. A combination of transformer and resistance coupling in the intermediate frequency stages is a particularly efficient system characterized by the desirable elements of both amplifying arrangements.

The desirability of a bias in a resistance coupled amplifier, is open to some discussion. Due to the low space current consumption of tubes with coupling resistors in the plate circuit, there is little or no necessity for a "C" battery in these tubes from a point of view of economy. Certainly the comparatively high biases used in transformer coupled amplifiers should never be used with ordinary tubes in resistance coupling. Curves made in our laboratory would indicate that a small minus bias such as secured across the filament or rheostat drop (no "C" battery) may be used on the first two tubes in a three stage amplifier (leak connections as per the diagram 9-A), and a one and a half volt "C" battery may be applied to the last tube. The "C" battery is merely placed in series with the gridleak—at the lower end, with positive terminal connecting to the filament.

LOCATING TROUBLE IN A RESISTANCE COUPLED AMPLIFIER

Contrary to an impression of complexity that the novice may obtain through perusal of this section, resistance coupled amplification is a very simple and uncomplicated proposition. In nine out of ten cases, an amplifier built and wired in accordance with diagram 6, will work perfectly without further attention or the least bit of experimentation.

The builder should be able to locate and remedy difficulty by checking the following points:—

1. Check values of resistors and leaks and make sure that the Grid Leaks and Resistors have not been transposed.

2. Make sure that the vacuum tubes are making perfect contact with the socket springs.

3. Determine if the A and B Batteries are delivering proper voltage.

4. Always place a condenser of .00025 to .002 mfd. capacity across the input terminals, and if the amplifier squeals try .002 to .006 mfd. condenser across the output terminals.

5. If the received signals are intermittant or distorted, use a lower value of Grid Leak in the second or last stage. It is suggested that 50,000 or 100,000 ohms be substituted.

6. To reduce volume cut out one or two stages of amplification. Do not reduce the intensity of the signals by turning down the rheostat.

7. Make sure that the coupling condensers are not short circuited.

8. If no signals are heard on the first amplifier tube, reverse connections between detector and amplifier, so that detector plate current will run through the first coupling resistor in proper direction.

9. A potential of from 45 to 90 volts should be tried on the detector tube, until best detection efficiency is obtained. Even for tubes which normally require but 20 volts on the plate, the increase is necessary to compensate for the voltage drop across the added plate resistance. The highest detector plate voltage compatible with smooth and satisfactory regeneration (in the case of Regenerative Circuits) should be employed.

10. Distortion in signals amplified by a Resistance-Coupled Audio Frequency Amplifier will generally be found to originate in the loud-speaker. With the exception of poor or overloaded tubes, the possibility of auditive distortion is practically eliminated from the amplifier proper. Often when the loud-speaker is located facing the set there will occur a steady hum caused by the elements of the vacuum tubes being set into mechanical vibration by the sound-waves from the horn. It is often advisable to use a fixed condenser (.002 to .006 mfd.) as a by-pass across the output terminals of the amplifier in order to eliminate the chance of audio-frequency feedback from the cords of phone or loud-speaker. It may also be advisable to "ground" the negative side of the "A" Battery.

PART IV

APPARATUS EMPLOYING RESISTANCE-COUPLED AMPLIFICATION

*BROWNING-DRAKE RECEIVER WITH RESISTANCE-COUPLED AMPLIFICATION

BY M. B. SLEEPER

When Messrs. Browning and Drake delivered a lecture on their work before a gathering of radio engineers some time ago, it is doubtful if either of them had any conception of the remarkable popularity that their set was destined to receive within the course of a few months. The Browning-Drake receiver is all-popular in the New England States, and its popularity, based on sheer merit, is growing day by day all over the country.

The Browning-Drake does not employ a trick hookup. Its success is due to the scientific methods applied in determining mathematically the various constants of the coils and condensers when used with the vacuum tubes now available. This can be seen by studying the circuit diagram in Fig. 20.

A special feature of the Browning-Drake Five is that it has about half as many connections as an ordinary five-tube receiver. Therefore, it is a particularly fine outfit for the beginner or for the set builder who wants something that can be constructed very quickly. As a summer time proposition, this is an ideal outfit, because it can be operated with a small indoor antenna, with correspondingly lower static pick-up.

Tests on this outfit settled definitely the questions of B battery consumption. With five tubes in operation, under normal receiving conditions, the total plate current was 10 milliamperes. Five-tube neutrodynes, for example, draw 20 to 30 milliamperes. This is positive evidence that the resistance coupled amplifier draws less current than the transformer type. Moreover, when strong signals come in, the current is decreased and not increased.

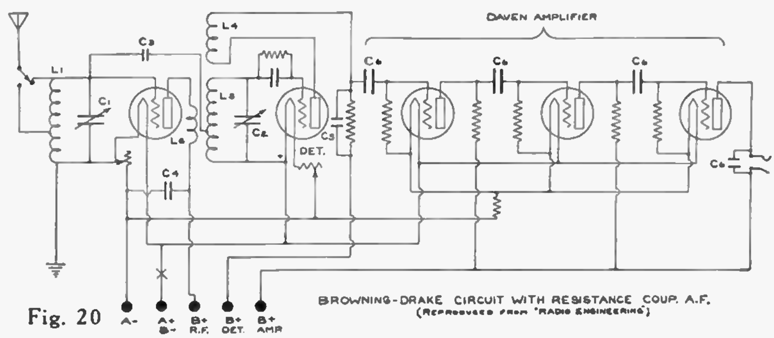
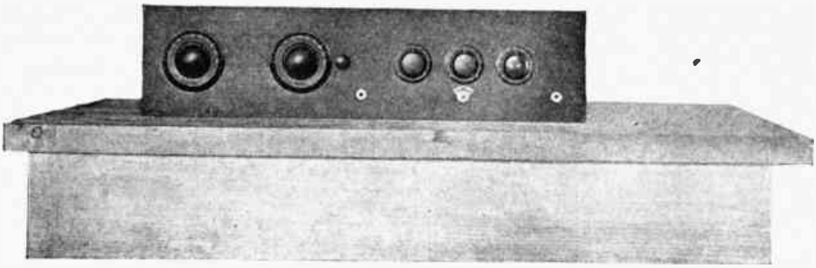


Fig. 20

*Reprinted from April, 1925, issue of Radio Engineering.



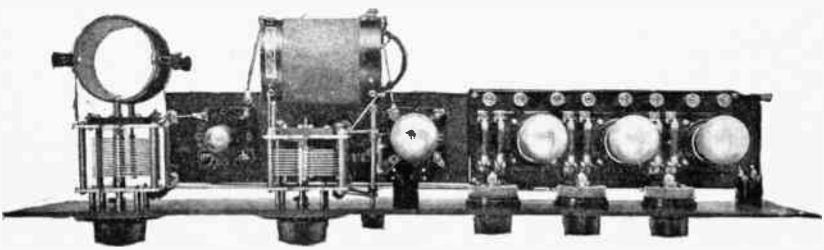
Improvement in Design

The publication of complete construction data for the Types 6600 and 7000 Browning-Drake receivers has resulted in a demand for a set of this kind employing resistance coupled audio amplification. The Browning-Drake Five, in our opinion, represents one of the highest types of radio receivers in use today, combining, as it does the extreme sensitivity and selectivity peculiar to this set, with a faithfulness of reproduction through the use of resistance amplification, which will satisfy even the most critical music lover.

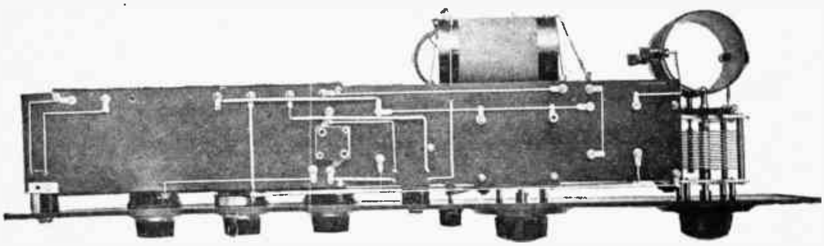
The design has been improved and simplified in various ways. No separate binding post strips are employed. The battery connections are all made to the binding posts already provided on the Daven Super Amplifier. A few simple changes in the wiring of the amplifier make this possible. The antenna and ground connections are made directly to binding posts fastened to the eyelet terminals of the antenna coil. A jack has been provided in the detection circuit, as well as a rheostat for controlling the filament current of the UV-199 tube. The loudspeaker can either be plugged into the third stage jack or be connected to the rear of the set at the two output binding posts on the amplifier unit, thus doing away with speaker cords and jack at the front panel. By using the Daven Super-Amplifier unit which comes already wired, the construction of the set has been made very simple and neat, without any appreciable increase in cost. Practically all of the wiring has been kept under the tube panel, adding greatly to the appearance of the outfit when it is installed in a cabinet.

Operating Data

The tuning is accomplished by means of the two large velvet vernier dials. The one on the left tunes the R. F. amplifier while the right-hand dial tunes the detector circuit. The small knob controls the coupling coil. We have found that it is not necessary to readjust it every time a new station is tuned in, as is the case with regenerative receivers. The position of the various parts and the wiring, have been so laid out that it is not necessary to neutralize this set, as it does not oscillate in the R. F. circuit.



The R. F. amplifier tube filament is regulated by a 30-ohm General Instrument Rheostat. One of 20 ohms controls the detector, and another of 6 ohms is connected to the three A. F. amplifier tubes. Tri-jacks are used for plugging in on detector or last A. F. stage. Below the center rheostat dial is a Keelok filament switch, by means of which the tubes can be turned on or off without disturbing the rheostat settings. This switch is provided with an ON-OFF sign which fits against the panel, and the fact that its depth behind the panel is very small makes it just right in this set.



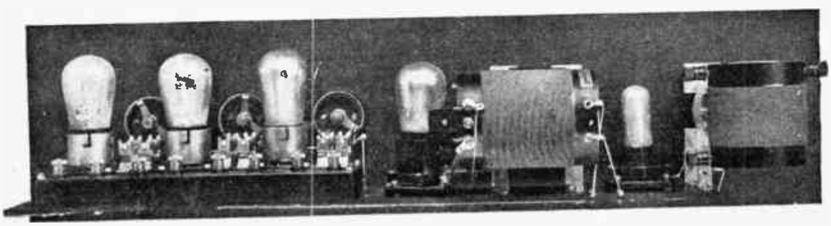
Set Does Not Radiate

The Browning-Drake receiver will not interfere with reception of other stations, because the detector tube is not used in an oscillating condition, and the R. F. tube does not oscillate at all.

The front panel is 7 by 28 by 3/16 in., and the base panel measures 3½ by 23 by 3/16 in. The panels must be strong mechanically because they support the weight of the instruments and any extreme bending or sagging will probably result in open or short circuited connections.

The two National tuning units come already assembled with the coils mounted on the condensers. These are of the design developed by Browning and Drake and are made under license by the National Company. The first unit consists of a .0005 mfd. condenser with the antenna coil, while the second is made up of a .00035 mfd. condenser with the radio frequency coil. Both of the condensers are provided with vernier dials. These dials have a reduction ratio of about 5 to 1, and are perfectly smooth and positive in operation.

On the front panel are mounted the three General Instrument rheostats, Keelock battery swith, and two Tri-jacks. The base panel carries the Daven Super-Amplifier unit, one standard Benjamin socket, one Benjamin 199 socket, a .001 mfd. New York Coil fixed condenser, and a .00025 mfd. fixed condenser, with a gridleak mounting clips for the 2-megohm Daven gridleak. Three Eby or Marshall-Gerken binding posts are used on the antenna coil.



The antenna and ground connections are made directly to the Eby binding posts on the antenna coil. The battery connections are made to the binding posts on the A. F. amplifier unit. The two binding posts marked Input P and B. should have these markings removed. The post formerly marked P now becomes the +90V terminal, and the one formerly marked B is now the DET+ terminal. These markings are shown correctly in the picture wiring diagram. The marking for the rest of the binding posts remain as they are.

Connect a six-volt storage A battery to the A+ and A— binding posts. Insert the tubes and turn the key in the lockswitch to the right. When the rheostats are turned up, the tubes should light. If everything seems all right, connect 90 volts of B battery across the B— and 90V+ binding post, and bring off a 45-volt tap to the DET+ binding post. Connect the 135 or 150-volt tap to the +150V binding post. Light the filaments and plug the phones or loudspeaker first into the detector jack, and then into the last stage jack. A strong click should be heard in both cases. One of the new Belden battery cables for the A and B batteries will be found very convenient for connecting up. Although 150 volts are commonly specified, 90 to 120 volts are sufficient.

Connect the antenna and ground and set the tickler coil at right angles to the main winding. Revolve the left hand condenser slowly while the other is turned back and forth. When a station is heard the volume can be increased by turning the tickler coil. When making up a log for the set it will be found best to tune in stations by advancing the left hand dial one small division at a time, and for each of these positions the right hand dial should be rotated back and forth. In this way the entire range will be covered. Try various B battery voltages across the detector R.F. and A.F. amplifiers until the best combination is found.

[If this set is not stable at the shorter waves it may be necessary to neutralize the first tube.—Ed.]

A ONE STAGE POWER AMPLIFIER

It has been mentioned in our theoretical discussion of resistance coupled amplification that this system is the most stable of all intensifying arrangements. Owing to this stability, an unstable multi-stage conventional amplifier can often be made to function satisfactorily and with improved quality by substituting a final stage of resistance coupled amplification for the transformer or impedance coupled amplifier already operating in the last step. Where the Resisto-Coupler is used, it is merely necessary to substitute for the transformer, following the original initialed connections.

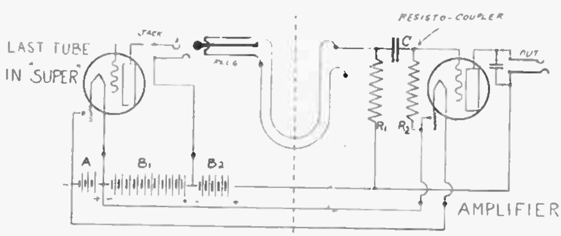


Fig. 21

In designing and constructing multi-tube receivers, it is always a commendable idea to anticipate possible instability (a tendency that increases with the number of tubes) and specify resistance coupled amplification in the last or two final stages of audio intensification. In many cases it is more convenient (and electrically more efficient) to build the final stage of resistance coupled amplification as an external power amplifying unit. Figure 21 shows the circuit of such an arrangement, while Figure 22 is a photograph of the unit in operation, being plugged in at the output of a Haynes seven tube Super-Heterodyne.

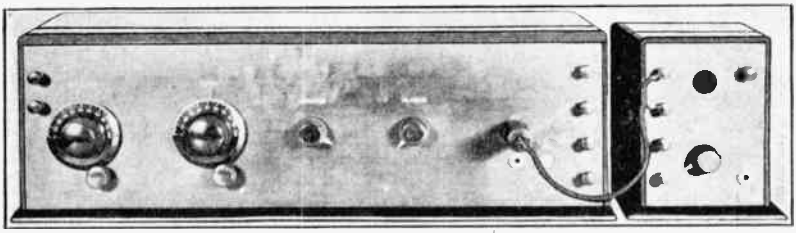


Fig. 22

The Haynes being a particularly efficient super, the resistance coupled power amplifier is used only on distant stations, and for dance reproduction in a large room or hall, in which cases the action is more stable, and the reproduction more perfect than when employing a second stage of transformer coupled audio amplification. This is a highly efficient combination—a de luxe broadcast receiver.

SPEECH AMPLIFIERS FOR RADIOFONE TRANSMITTERS

Due to the distortionless amplification of resistance coupled amplifiers, this system is employed for speech intensification in many broadcasting stations, especially in field work.

Apparatus of this type will vary with individual requirements, and the specific equipment is best designed by the station engineer. From three to five stages are generally used. Under proper conditions a five stage amplifier will give a voltage amplification of about 3,400 times, which, in telephone terminology, is equivalent to a gain of 75 miles. This is considerably more than is usually required, and amplification is generally controlled through a variable shunt. A workable arrangement is shown in Figure 22-A where the first coupling resistor is built up in ten thousand ohm units. Tapping to the isolating condenser, enables the operator to select one of seven different potential drops with corresponding control of amplification.

The coupling resistors for this purpose should be about 70,000 ohms throughout, with the gridleaks tapering from 2,000,000 ohms down to 100,000 ohms in the last stage. UV201A tubes with from 120 to 150 volts on the plate are recommended. The input transformer should be especially designed for its purpose, and will vary with the microfone. The output transformer may be a low ratio amplifying transformer, such as 2:1 if the output is to be applied directly to additional amplifying or modulating tubes. If the output is to the line, the transformer should again be especially designed bearing in mind the impedance characteristics of the load. The isolating condensers can be the easily obtainable .006 fixed capacities. Daven Resisto-Couplers are admirably suitable for the assembly.

For those using a low-power transmitter having a modulator tube of 5 watts, the Daven Super Amplifier Type 3-S will generally deliver sufficient amplificaton when connected wth a suitable microphone and input transformer, and with 120 to 150 volts B Battery on the plates of the amplifier.

For additional information on this subject the engineer is referred to page 784 "Proceedings of the Institute of Radio Engineers," Vol. 12, No. 6.

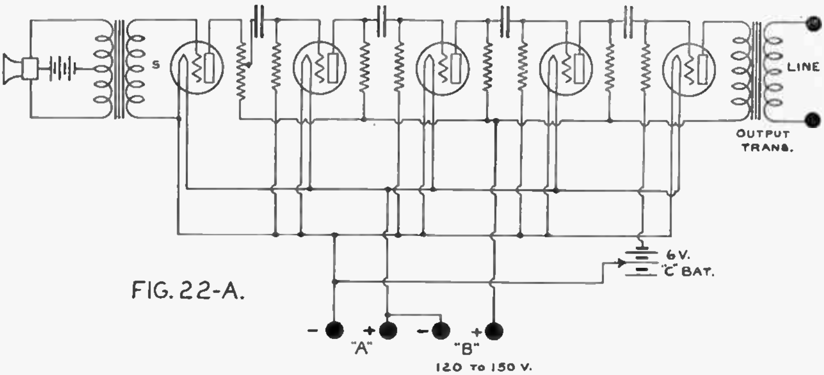


FIG. 22-A.

RESISTANCE-TRANSFORMER COUPLING IN THE SUPER

A rather novel intermediate frequency amplifier for the Super-Heterodyne, combining the advantages of resistance and transformer coupled radio frequency amplification, is diagrammed in Figure 23. This amplifier is characterized by the stability of the resistance coupled system, no potentiometer or oscillation control being required. On the other hand, the filter effect of the tuned transformers is maintained, along with their amplifying efficiency which eliminates an extra tube that would be desirable were straight resistance coupled amplification employed throughout the amplifier.

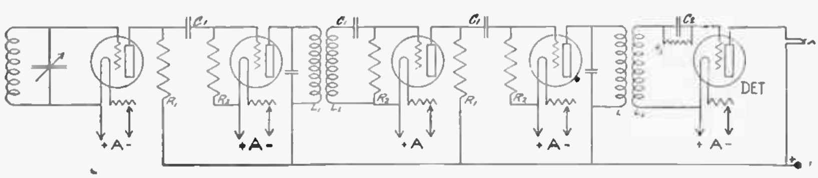


Fig. 23

The coupling resistors, R1, may have any non-critical value between fifty thousand and one hundred thousand ohms. The amplifying gridleaks, however, are rather critical, and experimentation is advised with values between ten and fifteen megohms. Reliable gridleak mountings must be used to preclude the possibility of a conducting base with an uncontrollable leak action. The coupling condensers, C1 are .001 mfd. Micadons, while C2 are similar condensers of .00025 mfd. capacity. L1 and L2 are respectively 250 and 350 turn duo-lateral coils.

Any conventional oscillating-detector system may be used preceding the diagrammed amplifier and second detector.

Following the commendable practice of using less plate voltage on radio frequency amplification, a plate potential from 45 to 90 volts is suggested. Readers desiring further information on this interesting and original arrangement are referred to the August, 1924, issue of "QST," with whose kind permission this diagram is reprinted.

THE KING GEORGE SET

The greatest engineers in Britain in designing receiving equipment for his Majesty King George V, chose Resistance Coupled Amplification, its quality of output being such that none other would satisfy.

For the information of our readers, Fig. 26 is a diagram of the circuit used, as presented by RADIO WORLD in the issues of May 24th and June 14th, 1924, with whose kind permission we give our readers this brief description. The circuit is recommended for experimenters, and further data may be obtained by reference to the issues of RADIO WORLD mentioned.

The set is reported to be thoroughly efficient with the use of the English vacuum tubes which are designed for low capacity between elements. If

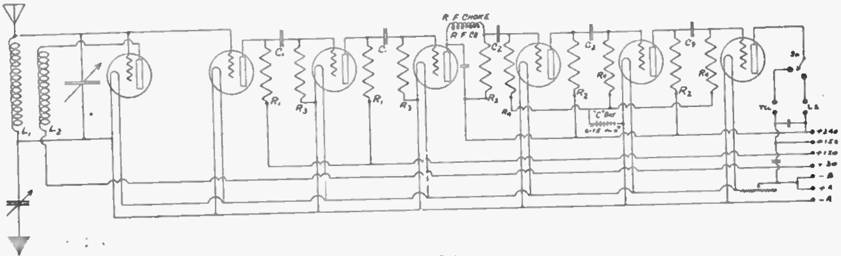


Fig. 26

English tubes cannot be obtained, it is suggested that "Hi-Mu" tubes be used with which good results may be expected. For the Antenna tuning device an ordinary vario-coupler may be used, employing the Rotor for regenerative effect. In the diagram as shown the resistances R-1 and R-2 should be 100,000 ohms while R-3 and R-4 are gridleaks of value suitable for the tubes in question. The capacities indicated by C-1 may be .006 mfd. while C-2 may be 1 mfd.; although experimenters will probably be able to determine modifications of these values which may be equally or more satisfactory. In the King's set, which is entirely self-contained, copper plates are used in place of aerial and ground, in the form of the so-called "condenser antenna." Variations may be made of the plate potentials applied to the several binding posts indicated. The first tube regenerates, but is counterbalanced to some extent by the second tube which operates in parallel with it. For the R. F. choke coil it is suggested that a DL-250 honeycomb coil be employed. Although the vacuum tubes manufactured here are not recommended for this set, ingenious experimenters very likely may obtain fair results. There will be no doubt, however, as to the quality and tonal purity of the output, due to Resistance-Coupled Amplification.

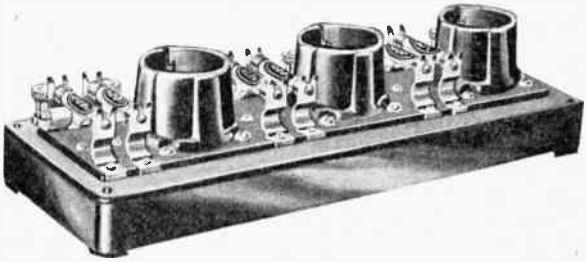
PART V

DAVEN ESSENTIALS
FOR RESISTANCE COUPLED AMPLIFICATION

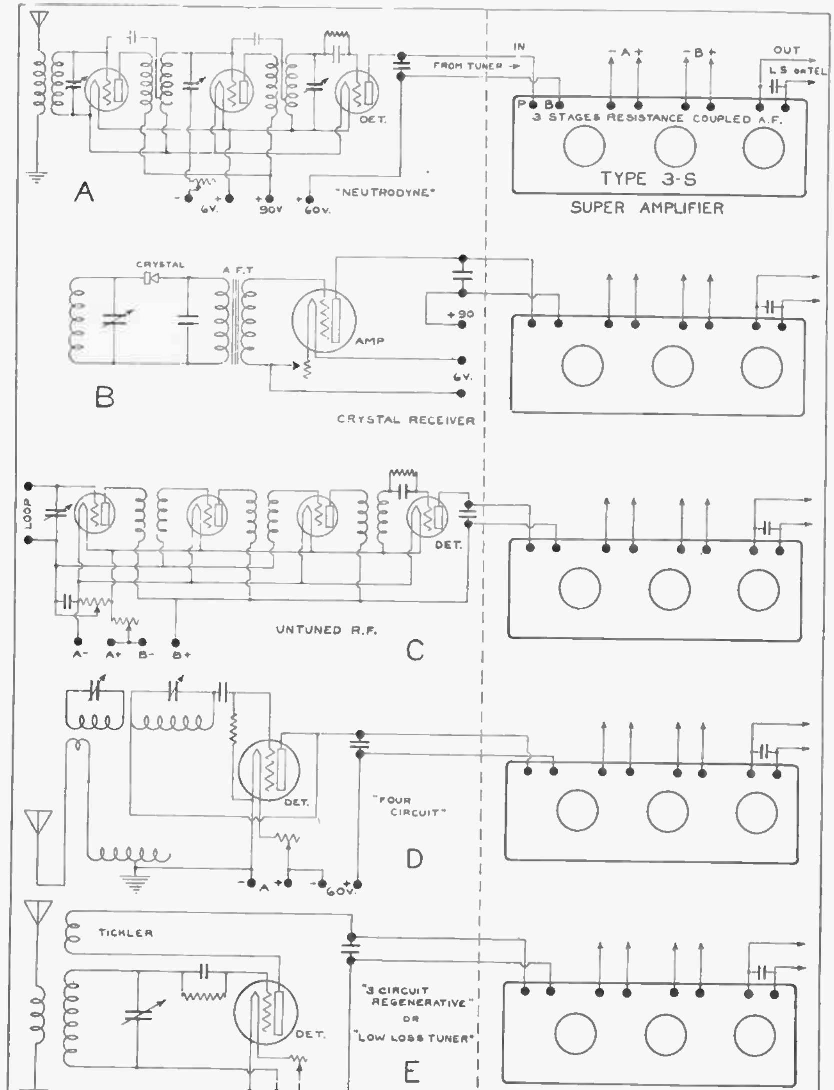
Resistance Coupled Amplifiers are unquestionably the best amplifiers available to the broadcast enthusiast, from both electrical and mechanical points of view. Electrically, they are the closest approach to amplifying perfection yet offered to the public, the output being absolutely distortionless in auditive tests. They are superior in quality to the very best of transformer coupled amplifiers, and the voice and music are amplified with the same beautiful clarity that heretofore has only been enjoyed on a crystal detector or the first tube. Such output will be a revelation to the music lover, and the immortal melancholy of Tschaikowsky will pour from the loud speaker as the Russian himself would have had it, and the listener will almost see again the rise and fall of the baton.

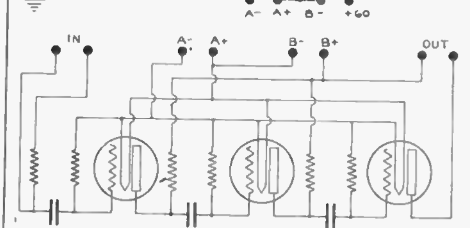
Furthermore the Resistance-Coupled system is the most economical. The individual tubes, in operation, consume one quarter the plate current of other amplifiers. "C" batteries, usually necessary for even fair amplification, are altogether eliminated, the amplifier itself functioning with the effect of a negative bias being applied at audio frequencies. There are no delicate windings or wires to fuse under the strain of excessive loads and therefore, the amplifier is fool proof.

DAVEN SUPER-AMPLIFIER TYPE 3S



Mechanically, the type 3-S amplifier exhibits refinements rarely if ever found in commercial equipment. The molded bakelite base is 3¾" wide by 10" long, and all clips and binding posts, heavily nickel plated, are inserted. It is the most compact three step amplifier unit on the market and greatly simplifies the adding of quality amplification to any receiving set. It may be used on base-board or back of panel of any cabinet, or it may be simply placed upon the table without permanent fastening to other equipment.





INTERNAL WIRING DIAGRAM OF 3-S.

The adjacent diagram on the left shows the internal wiring of the Super-Amplifier; and connections for standard tuners are indicated above. The same "A" and "B" batteries may be used for both the tuner and amplifier. In cases where the Super-Amplifier is preceded by one stage of transformer-coupled A. F. Amplification, power tubes are recommended in the Super-Amplifier.

Binding posts are provided for the Input, the Output, and both Batteries. All plate resistors, gridleaks and fixed condensers are included; so that it is only necessary to make the connections with tuner and batteries.

The volume delivered is about equal to the two step transformer coupled arrangement, but of course far superior to it in quality.

This unit is admirably suited to the needs of amateur set builders as well as manufacturers seeking quality amplification, but who have hesitated on account of the unknown factors of Resistance Coupling, or of obtaining the proper units. All connections of the amplifier are invisible, being underneath the base; and therefore, all of the labor of assembly is eliminated. Each amplifier is thoroughly tested in our laboratory, and is guaranteed to operate satisfactorily without experiment or any change in respect to the resistances or capacities supplied with it. It is the aristocrat of amplifiers, de luxe in every sense of the word, and is designed for those who appreciate the very best.

OPERATION

Fig. 28 indicates the proper connections for Input, Batteries and Output. The same "A" and "B" batteries may be used which are used for the detector equipment. A tube ballast resistance or ordinary variable rheostat should be used as indicated "R" inserted in series with the negative "A" battery and negative "A" binding post of the Super-Amplifier, to control the filament current of the three amplifier tubes. Type 201-A or similar amplifier tubes are recommended although others may be used with results which such tubes permit.

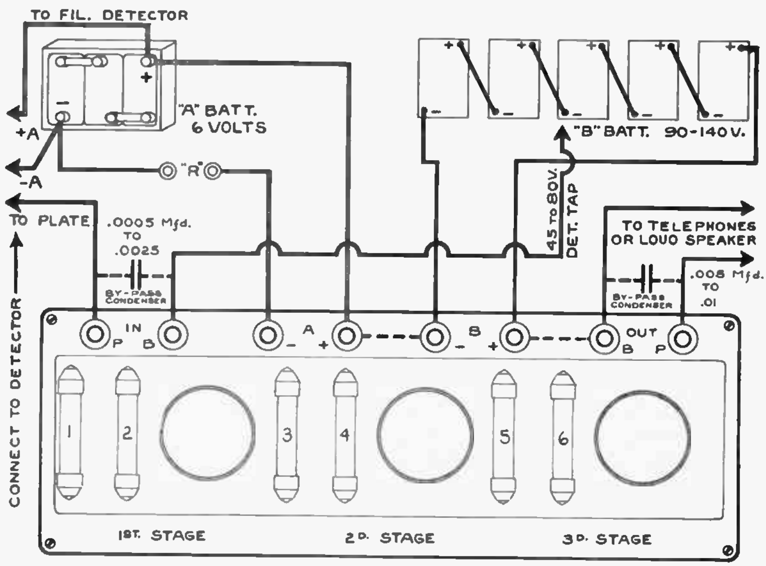


Fig. 28

If it is desired to make connections from detector to the amplifier by means of Plug and Jack, care should be taken that the Input terminal (P) of amplifier is connected to that portion of the Plug which contacts with the spring of the Jack leading to the plate of the detector tube; and that the Input terminal (B) of the amplifier is connected to the other portion of the Plug, contacting with the spring of the Jack leading to the tap of the "B" battery for the detector tube.

The plate voltage for the detector tube should be double or triple normal in order to compensate for the first coupling resistor in the plate circuit. (Increase it between 45 and 80 volts until the detector tube detects most efficiently; or if a regenerative tuner is used, until the detector oscillates in the normal manner). In most cases a fixed condenser of capacity .002 mfd. will be found desirable between the two Input binding posts of the amplifier.

The Daven Resistors furnished with this amplifier are correctly placed in the clips in the following order (See reference marks 1, 2, 3, 4, 5 and 6 on diagram):

No. 1 (first stage resistor) .1 megohm.
No. 2 (first stage gridleak) 1 megohm.
No. 3 (second stage resistor) .1 megohm.
No. 4 (second stage gridleak) .5 megohm.
No. 5 (third stage resistor) .1 megohm.
No. 6 (third stage gridleak) .25 megohm.

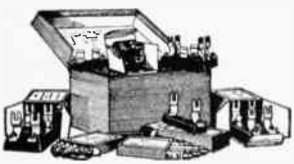
These values will be found highly satisfactory for all average conditions and tubes and will seldom require substitution. In rare cases, should the third stage show a blocking tendency, a lower resistance value of gridleak may be substituted in the position 6.

The plate voltage for the amplifier tubes should be not less than 90 volts, and as high as 150 may be used.

The Super Amplifier may be used to advantage for the three stages of audio amplification indicated in diagrams in this manual.

AMPLIFIER KITS

For those experimenters and set-builders who desire to assemble the complete Resistance Coupled Audio-Frequency Amplifier for addition to their tuner according to their own particular requirements, we recommend our Kits—Types 3-K and 4-K, which contain the DAVEN essentials necessary for three or four stage amplifiers.



Since it may be desirable to use various types of vacuum tubes—such as 201-A, 301-A, UV-199, C-299, WD-12, WD-11, C-12, C-11, or others, the sockets are not included in these Kits; and they may easily be procured from the dealer when purchasing the Kit. This also applies to the Mica Fixed Condensers, capacity .006 mfd., one of which should be obtained for each stage of coupling.

The following are the contents of these well-recommended amplifier kits:

Type 3-K Kit

3 Daven Resisto-Couplers No. 41.
3 Daven Resistors, 100,000 ohms.
1 Daven Grid Leak, 1 Megohm.
1 Daven Grid Leak, .5 Megohm.
1 Daven Grid Leak, .25 Megohm.
1 Daven Mounting No. 50.
1 Daven Ballast Unit, ¾ Ampere.
1 Daven Fixed Condenser Mtg. No. 52.

(In addition it will be necessary to secure from the dealer, the 3 tube sockets, and 3 Mica Fixed Condensers, capacity .006 mfd.)

Type 4-K Kit

4 Daven Resisto-Couplers No. 41.
4 Daven Resistors 100,000 ohms.
1 Daven Grid Leak, 1 Megohm.
1 Daven Grid Leak, .5 Megohm.
1 Daven Grid Leak, .25 Megohm.
1 Daven Grid Leak, .1 Megohm.
2 Daven Mountings No. 50.
1 Daven Ballast Unit, ¾ Ampere.
1 Daven Ballast Unit, ¼ Ampere.
1 Daven Fixed Condenser Mtg. No. 52.

(In addition it will be necessary to secure from the dealer, the 4 tube sockets, and 4 Mica Fixed Condensers, capacity .006 mfd.)

The Kits are supplied with complete instructions and circuit diagrams, and are neatly arranged in compartment boxes. To the experimental enthusiast these kits are doubly attractive, combining as they do, the skill of the builder and the perfect amplifying characteristics of the Resistance-Coupled Amplifier.

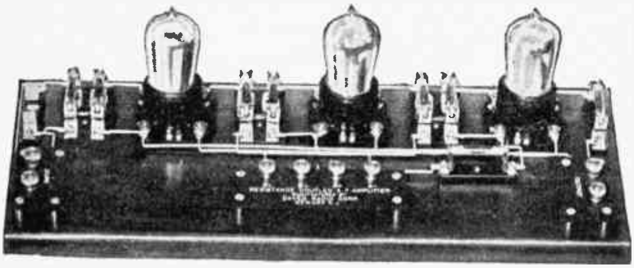


Fig. 29

Figure 29 will illustrate the assembly of the three stage kit upon a board; while figures 30 and 31 indicate an example of the construction of an amplifier in the form of a compact and convenient portable cabinet model amplifier.

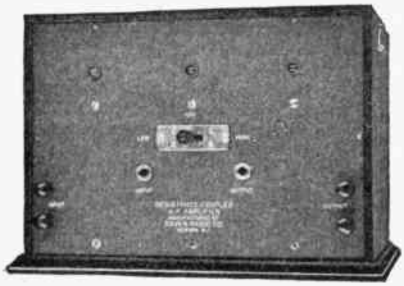


Fig. 30

The construction of this amplifier was described in detail in July, 1924, issue of "Radio and Model Engineering."

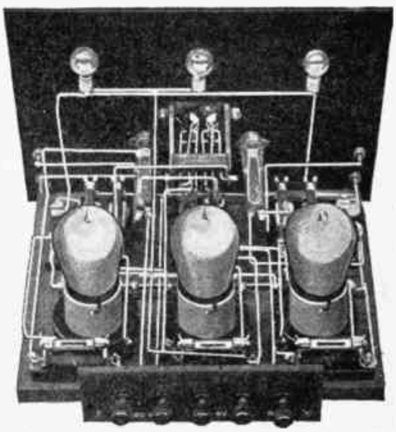


Fig. 31

RESISTO-COUPLER No. 41

(Patent Pending)

The resisto-coupler is a clip receptacle for mounting the coupling resistance, isolating condenser and gridleak of a resistance coupled amplifier as one convenient unit. It may be used in any of the amplification circuits described by Mr. Bouck in the first half of this booklet, and it is employed by us in our various amplifiers and kits.

There are four connections, plate, grid, plus "B" and filament, similar to those on the usual amplifying transformer. It may be connected in place of a transformer in any conventional amplifier, thus making it over into a resistance coupled system.

The resistance clips take the Daven Radio Resistors in both the leak and coupling circuits, while the condenser clips in the middle hold the isolating condenser, such as the Micadon .006 mfd. The base is of molded bakelite, eliminating the possibility of losses. It is furnished with full instructions for use, but without resistances or condenser.

The Resisto-Coupler may be used in:

(a) Resistance Coupled Audio Frequency Amplifiers.

(b) Resistance Coupled Radio Frequency Amplifiers.

(c) Intermediate Frequency Amplifiers in Superheterodyne Receivers.

For A. F. Amplifiers the proper Resistors, Grid Leaks and Isolating Condensers for each stage of the amplifier, are specified elsewhere in this pamphlet.

For applications (b) and (c), the fixed condensers used for isolating the grids should have a capacity of .00025 or .0005 mfd., the coupling resistors should have a resistance value of either 40,000 or 50,000 ohms, and the grid leaks should be from 1 to 5 Megohms. suitable for the type of vacuum tube employed.

The use of Daven Resisto-Couplers eliminates the difficulties connected with the design and construction of Resistance Coupled Amplifiers, saves space and makes for neat appearance.

To enable the experimenter or set-builder to select easily and intelligently the essentials needed, the following lists of parts are recommended:

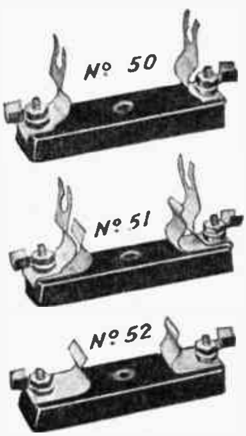
For	Resisto-Coupler (Daven)	Plate Coupling Resistor (Daven)	Grid Leak (Daven)	Isolating Condenser (Fixed)
1st Stage	One No. 41	100,000 ohms	1 Meg.	.006 mfd.
2nd Stage	One No. 41	100,000 ohms	½ Meg.	.006 mfd.
3rd Stage	One No. 41	100,000 ohms	¼ Meg.	.006 mfd.
4th Stage	One No. 41	100,000 ohms	100,000	.006 mfd.

The Daven Super-Amplifier (Type 3-S) is a complete three-stage Resistance Coupled Amplifier equivalent to the first three stages specified above, fully wired and ready for addition to any type of tuner. It will be found described in Part V of this pamphlet.

The Daven Type 3-K Amplifier Kit includes the individual parts specified for three stages, with the exception of the Mica Fixed Condensers of capacity .006 mfd., which should be secured with desired type of sockets from the dealer.

The Daven Type 4-K Amplifier Kit includes the individual parts specified for four stages, with the exception of the Mica Fixed Condensers of capacity .006 mfd., which should be secured with desired type of sockets from the dealer.

CLIP MOUNTINGS



The three mountings illustrated find a wide range of application in radio receiving and transmitting circuits. They provide the most convenient and efficient way of connecting resistances and capacities wherever such values are required.

Soldering to the actual condensers and resistors, with often injurious effects, is eliminated. Daven mountings also make possible an instant change in resistance or capacity, thus insuring the most efficient adjustment of a receiver with a minimum of labor.

All mountings have heavily nickel plated phosphor-bronze prongs mounted on a molded bakelite base.

No. 50 RESISTOR MOUNTING for the superior Daven Resistors or standard gridleaks.

No. 51 COMBINATION RESISTOR-CONDENSER MOUNTING. This mounting is especially designed for use in detecting circuits where it combines the gridleak and grid condenser in one adjustable unit. For highest detecting efficiency it is desirable to vary both condenser and leak.

No. 52 CONDENSER MOUNTING. This mounting will have a particular appeal to the enthusiast experimenting with reflex receivers, where a multiplicity of small fixed condensers is used across highly inductive windings.

Illustrating how fixed condensers and grid leaks are held in the Daven Mountings.

DAVEN RADIO RESISTORS

Zeh Bouck, in his treatise on resistances in radio circuits, has emphasized the desirability for accuracy, a quality that is particularly essential in resistance amplification circuits. The Daven Radio Corp. specializes in the manufacture of resistors, and we recommend the following units as fully complying with the requirements outlined by Mr. Bouck.

Ohms	Megohms	Ohms	Megohms	Ohms	Megohms
2,500	.0025	250,000	.25	2,000,000	2.
5,000	.005	300,000	.3	2,500,000	2.5
12,000	.012	400,000	.4	3,000,000	3.
25,000	.025	500,000	.5	4,000,000	4.
40,000	.04	600,000	.6	5,000,000	5.
50,000	.05	750,000	.75	6,000,000	6.
75,000	.075	1,000,000	1.	7,000,000	7.
100,000	.1	1,250,000	1.25	8,000,000	8.
150,000	.15	1,500,000	1.5	9,000,000	9.
200,000	.2	1,750,000	1.75	10,000,000	10.

The preceding range of values provides resistances suitable for many different circuits such as: Resistance Coupled Amplifiers (Radio or Audio Frequency): Oscillators and Heterodynes; Neutrodyne Receivers; Super-Heterodyne; Super-Pliodyne, Reflex, etc.

DAVEN BALLAST RESISTORS

These are designed to be used with amplifying tubes, where the critical filaments adjustment, essential in the operation of soft detector tubes, is unnecessary. The ballast resistor is merely connected in place of the usual rheostat, thus effecting an economy while eliminating a superfluous control.

The ballast resistances are wound with special wire possessing a high temperature coefficient. This achieves a balancing effect, and approximately the same correct operating current is passed through the filament of the tube during the voltage drop in the "A" battery occasioned by normal discharge. The Daven Ballast Resistors are designed for operating the UV201A and C301A tubes from a six volt battery.

They are uniform in appearance with Daven Resistors and are most conveniently held in Daven Mounting No. 50.

No. 1 for one tube.

No. 2 for two tubes in parallel.

No. 3 for three tubes in parallel.

No. 4 for four tubes in parallel.

Ballast resistors for other tubes and voltages made to order, for manufacturers.

PART VI

*THE ENGINEERING SIDE OF MANUFACTURING GRIDLEAKS

Some valuable notes in the methods employed at the Daven factory, where thousands of tubular resistors are manufactured daily

We have become so familiar with the various parts for sets, that most of us think of them merely in terms of actual performance and dollar and cents cost. We fail to appreciate the painstaking care and scientific investigation that is going on every day in the larger manufacturing plants in an effort to turn out products of the highest uniform quality possible, regardless of varying conditions which tend to alter their characteristics. It is gratifying to see that competition is forcing the manufacturers to keep on their toes constantly, experimenting with new and better ways of doing things, at the same time reducing overhead costs. All of this is ultimately passed on to the consumer in the form of better apparatus at lower costs.

This device keeps the elements from buckling as the corks are pressed into the glass tube.

A striking example of manufacturing under conditions in which every little step of the process must be carried out with the most exacting care and patience is furnished in the making of tubular resistance units for use as gridleaks and various other purposes. A trip through the plant of the Daven Radio Corporation, where thousands of resistance units are manufactured every day, reveals the inside story on the little gridleaks and resistors we usually snap into clip holders and proceed to forget all about, because experience has taught us that they can be depended upon without further attention.

The units have a resistance element of specially coated paper, which is held in place and centered in a glass tube by two corks. Connection is made to it by two tinned copper leads passing through the corks and soldered to the metal end caps. This gives a compact unit which is air tight, so that no atmospheric changes effect the paper elements after the tube is sealed with the end caps. The high quality of the finished product, which to all

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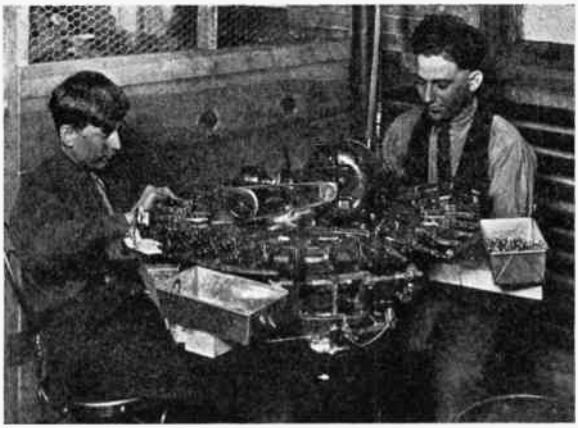
outward appearances is very simple, is only obtained by carefully planning each assembly operation so that the work follows right through the line, careful attention being paid to all the little kinks and tricks peculiar to the work.

The chemical composition and manufacturing process through which the raw paper has passed before reaching the factory, is a very important factor. To insure uniformity, paper of one stock is bought in large enough quantities to make millions of elements. When received at the factory it goes through a special aging process and is then coated with a resistance material held in a binder. The composition of this material and the conditions under which it is applied to the paper are a trade secret of the manufacturer. Experience with various forms of power and hand operated paper cutters has shown that the ordinary photographer's paper trimmer is the most satisfactory device for cutting up the paper into the little $\frac{5}{32}$ by $1\frac{1}{8}$ in. strips required.



A Grid Leak Capping Machine, the only device of the sort to be found in this country, for it was developed by the Daven Corporation.

The glass tubes, corks, and nickeled brass end caps are bought from outside manufacturers. It is interesting to note here that a tolerance of only 0.004 to 0.005 in. is allowed on the outside diameter of the glass, and a tolerance of 0.030 in. on the length. Also the glass is of special chemical composition since it is essential that it have practically infinite resistance. The stock of tubes, corks, caps, and elements is at all times kept in an electrically heated oven at a temperature of 115° Fahrenheit. This prevents any absorption of moisture. The subsequent assembling operations are so timed that not more than five minutes elapses between the time the stock is taken from the oven and the time the tubes are sealed airtight.

In the first operation, the connecting leads or clips are attached to the paper elements in hand presses. This takes place in two stages. In the first, the punch die bends the shoulders of the clips into a "U" shape to receive the paper. In the second stage the sides are bent down flat on the paper and nine little sharp points press into the clips and paper at the point of contact, insuring a good connection. (*A photograph of this press is shown on page 44.*) The two steps are necessary to prevent the paper from being bent and curled up. These elements with the clips are then placed in the heated stock oven.

In the next operation the resistance of the elements is measured and brought to the correct value. This is done in an ingenious way. Two supports are arranged on the table in the form of blocks which receive the clips of the elements. The two terminals of the measuring instrument are arranged on a bar so that by means of a foot operated lever they may be brought down tight on the clips and the meter read. If the resistance value is not correct, it is made so by special process.

As the work progresses along the table one operator threads one clip through a hole in the cork, the next person puts this unit in a glass tube and puts the other cork on loosely.

In the next step, the corks are passed tightly into the glass tube, and the ends of the clips are crimped slightly. A special machine was devised, for this work, to prevent the element from buckling up inside the tube when the corks are pushed in tight. When the lever is pushed down part way, two jaws come down and pinch the clips, holding them fast. A further movement of the lever pushes two plungers horizontally against the corks, driving them home into the tubes. (*This machine is shown below.*) The elements are then centered in the tube, and proceed to the soldering table.

The old method used to solder the caps to the clips was to have a jig which held nine units in an upright inverted position. The operator would hold a metal cap over a gas flame with a pincher and fill it with molten solder. Then he would put the cap under a unit and rest it in a hole in the bottom plate. By pushing the unit down into the cap and giving it a slight twist the clip and end cap were fastened and connected together by the solder.

The press which fastens the lead clips to the resistance elements.

Testing the grid leaks on a direct-reading meter.

While this method produced very good results, the problem of increasing production led the engineers of the Daven Corporation to devise a new capping process. The result of their work is the automatic capping machines shown on page 45. Each machine requires four operators, two for inserting caps and two for inserting glass, cork, and element units. These machines cap many thousand units per day.

The capper has thirty-two tube-holding arms arranged radially on a turn-table driven by an electric motor. One operator puts a cap in the lower holder of each arm as the table turns. The cap runs over a gas flame for a distance of about 12 inches as the arm travels around. This heat is so the solder will stick more readily. When it reaches a certain predetermined point a drop of molten solder is dropped into it from a spout leading from a solder pot. By means of a valve gear operated by the turn-table a slide valve in the bottom of the pot is opened and closed at the proper time to deliver the drops of solder. The cap continues on its way, still over the gas flame, until it gets to a place where it is carried over a flat supporting ring. At this point the next operator inserts the glass tube and presses it on firmly, the pressure being taken up by the ring underneath. This unit continues over to an automatic counting device and is then released from the arm by a tripper and falls into a box, the solder having hardened by this time. It then goes over to the other side of the machine where the process is repeated and the other cap put on. The glass tubes and caps are of such size that a clearance space exists between them to allow the excess solder to run out during the capping operation. This thin wall of solder between the glass tube and metal cap also serves as a cement so that it is impossible to pull the metal caps off from the tubes. The difference in the coefficient of expansion of the glass tube and brass cap also serves to aid this action.

The resistors are then inspected and any excess solder is trimmed off around the glass. An inspection is also made to insure that the paper element is properly centered in the glass tube and that the caps are on straight. A final resistance measurement is made and the resistors sorted according to their values. It has been found more practical to give an operator a tray full of resistors of various values and require that she test each one and sort them out, rather than keep the various sizes separate and have an operator test all resistors of one value. The latter method would be a temptation for her to slip through a batch of resistors without testing them since the readings would all be practically the same and the work monotonous.

When the final test has been completed, the paper labels having the resistance values marked on them, are pasted on the glass tubes and the finished products packed for shipment.

In measuring the resistances, a definite and constant voltage, provided by a bank of No. 6 Eveready dry cells, is applied to the resistor and the current flowing through it is measured by a sensitive microammeter calibrated to read directly in megohms. These meters are calibrated daily by comparison with a standard. The meter used for the first measurement when the primary operation is performed is checked every ten minutes by making up twenty complete resistors of different sizes and measuring their values with the final test meter. In this way a check is obtained on the meter, and the factory superintendent also knows exactly what is being turned out so that any troubles becomes apparent at once.

Every article described herein is guaranteed free from defects in material and workmanship, and is built in accordance with best electrical and mechanical design.

BUY FROM YOUR DEALER

The prices of Daven Radio Products described herein may be obtained from your dealer, or upon addressing any of our District Sales offices.

Our products are sold through dealers only, and we cannot promise quick service on mail orders it is necessary for us to accept.

If your regular dealer is unable to serve you, it is suggested that you send your order, for C. O. D. shipment, to our nearest branch sales office, from which it will be referred to the nearest dealer who will supply you.

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PIONEERS!

¶ Daven Engineers designed and built the first Resistance Coupled Amplifiers offered for broadcast receivers.

¶ They are the standard by which all others are judged, and are the last word in amplifier construction.

To listen is to be convinced!

DAVEN RADIO