# NATIONAL RADIO INSTITUTE

## Complete Course in PRACTICAL RADIO

**Radio-Trician**
(Trade Mark Reg. U. S. Patent Office)

*Lesson Text No. 25*
*(4th Edition)*

# THE SCREEN GRID VACUUM TUBE

Originators of Radio Home Study Courses
Established 1914
Washington, D. C.

## WRITING ONE'S IMPRESSIONS

### A PERSONAL MESSAGE FROM J. E. SMITH

When you have finished your first reading of a book, it is worthwhile to write in, say, two hundred words, the author's central thought as you obtained it. In another two hundred or two hundred and fifty words, write your own personal impression of the author's point of view, what questions and ideas the book has brought to you, what use you think it may sometime be to you. Save these statements for comparison with statements that you write after a second reading of the book.



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# Radio-Trician's
(Trade Mark Reg. U. S. Patent Office)

# Complete Course in Practical Radio

NATIONAL RADIO INSTITUTE WASHINGTON, D. C.


## THE SCREEN GRID VACUUM TUBE

The screen grid vacuum tube is one of the major contributions that science has made to the radio industry. This tube is new in the sense that its development to the stage of a practical device suitable for production in large quantities is comparatively recent. Prior to the advent of the screen grid tube, the three-electrode vacuum tube working into a carefully designed amplifier circuit, such as the neutrodyne, formed the only satisfactory means for obtaining amplification at radio-frequencies.

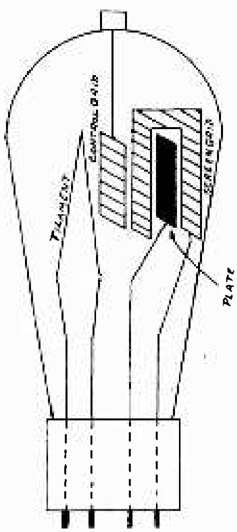


Fig. 1 — Illustrating the general make-up and method of connecting electrodes to terminals in the D.C. screen grid receiving vacuum tube.

The screen grid tube has, however, opened up an entirely new realm of possibilities and not only does it give greater amplification per stage but also it makes this amplification possible without neutralization or stabilizing grid resistors.

The fundamental principles of the screen grid tube were discovered and investigated several years ago by Schottky, a German scientist. Two American research workers are, however, responsible for the tube in its present form. Messrs. Hull and Williams of the General Electric Company research laboratories, continued the research begun by Schottky, improved the screening and produced a tube which enabled them to achieve almost to the theoretical limits of amplification. This particular tube though was a laboratory device, not suited to economical manufacture. Further work finally led to a production model which retained a surprisingly large proportion of the excellent characteristics of the earlier tube.

Before explaining the properties of this tube it should be pointed out that all tubes having two grids are not necessarily screen grid tubes. For many years there have been vacuum tubes with more than one grid. European manufacturers in

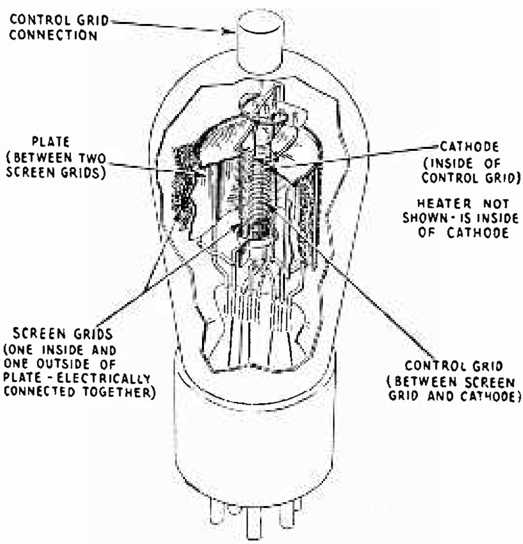


Fig. 1 (A)—Cross-sectional view showing the construction of an A.C. screen grid vacuum tube.

particular have been supplying two-grid and three-grid tubes and have developed several interesting circuits around such tubes. The two-grid and three-grid tubes of ordinary design are very different in action and construction from the screen grid type, for in the usual multi-grid tube such as has found wide application abroad, the several grids have been used as control grids. The screen grid receiving tube of the type described in this book is distributed by the Radio Corporation of America under their models UX-222 and UY-224 and by the E. T. Cunningham Co. as their CX-322 and C-324. Other manufacturers also furnish these tubes with the same or similar identifying numbers.

Figure 1 shows the general arrangement of the parts in a screen grid receiving tube. Instead of the usual three, there are four electrodes: the filament, the control grid, the screening grid, and the plate. It should be noted that the control grid is a name which has been adopted in place of grid. This has been required by the fact that there are now two grids: (1) the control grid, which has the same function as the grid of an ordinary three-electrode tube, and (2) the screening grid, a new electrode which gives certain remarkable properties to the tube.

While the general external appearance is similar to that of an ordinary tube it will be found, upon examination, that the internal arrangement is quite different. The four prongs which extend through the base are used for connection into a standard UX socket in the usual way except that the "grid" prong must be connected to the screen grid circuit wire. A fifth connection,

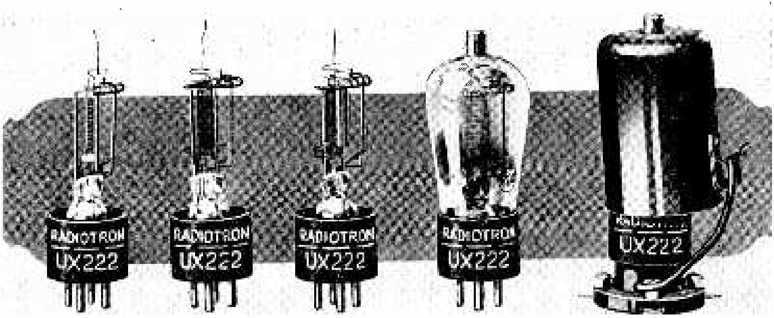


Fig. 2—Step by step construction of a D.C. screen grid vacuum tube.

that of the control grid, is brought out through the glass top to a small cap (see Fig. 2D). By referring to Fig. 2, a general idea may be obtained of the construction of the screen grid tube. The filament is a coarse spiral and forms the central element (Fig. 2A). Surrounding the filament and spaced from it by a few thousandths of an inch is the control grid which is made up of a fine spiral mesh (see Fig. 2B). The plate is an open-ended cylinder of thin sheet metal placed outside of the control grid (see Fig. 2C). The screening grid is in three sections; the first is a fine spiral mesh between the control grid and plate, the second a spiral mesh surrounding the plate, while the third is a flat metal disc which connects the upper of the two mesh sections. Fig. 2D shows the outer spiral mesh and the metal disc portions of the screen grid but the inner mesh is hidden by the plate. The object of the screen grid is to shield electrically the control grid from the plate. To accomplish this and to obtain the necessary degree of shielding requires the most accurate and careful mechanical construction of the electrodes located within the small space within the tube.

A more recent type of screen grid tube designated as the UY-224 has appeared on the market. This is essentially the same in electrical and constructional characteristics except that it is an A. C. tube having an indirect heater type filament. The base construction is of the standard UY five-prong type and the control grid is brought out through the top of the tube in the customary cap. (See Fig. 1A.)

### "A" AND "B" BATTERIES

The screen grid vacuum tube of the battery type requires for its operation a filament or "A" battery and a plate or "B" battery. As in the three-electrode tube the "A" battery is used

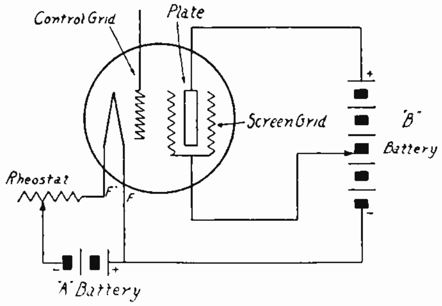


Fig. 3—Screen grid vacuum tube connections to "A" and "B" batteries.

to heat the filament to incandescence, while the "B" battery furnishes the energy which increases the effect of the radio waves. In addition, the screen grid must be kept at a voltage higher than the filament. This is most conveniently done by tapping the plate battery at a point which will give from ¼ to ⅓ the full plate voltage. A diagram of the screen grid vacuum tube with the necessary battery connections is shown in Fig. 3.

The A. C. screen grid tube employs alternating current on the heater. As with three-electrode tubes, twisted wires should be used leading from the transformer to the heater terminals. In addition to the usual voltages, it is of material help in reducing hum to make the heater slightly negative with respect to the cathode. The manner in which voltages are supplied to the alternating current tube is illustrated in Fig. 4.

## COMPARISON WITH THREE-ELECTRODE VACUUM TUBE

Before proceeding further, it should be thoroughly understood that the action of the filament, plate and control grid is exactly the same as for similar electrodes in the older tubes. The filament emits the electrons, and acts as the current carriers of the plate current between plate and filament. The control grid is the device which regulates the amount of plate current which flows between the plate and filament.

## INTER-ELECTRODE CAPACITY OF THE THREE-ELECTRODE VACUUM TUBE

Since the electrical characteristics of the battery and A. C. screen grid tubes are quite similar, the theoretical discussion will apply to both. In Fig. 5 is shown a diagram of a three-

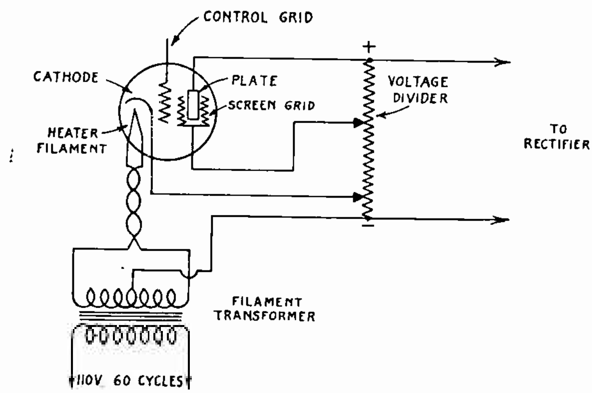


Fig. 4—A.C. screen grid tube current supply connections.

electrode tube illustrating the capacities which exist between the various elements. Of particular importance is the capacity C2 existing between the grid and the plate. This capacity in the average three-element tube has a value of from 6 to 15 micro-microfarads.

In the early days of vacuum tube amplification at radio-frequencies, this small capacity was of little importance because the frequencies in use were in the low range. With the advent of broadcasting on frequencies higher than 500 kcs. and, later with the discovery that frequencies higher than 3000 kcs. were worth while for long distance communication, the problem of grid plate capacity became one of utmost importance.

It will be recalled that the reactance of a condenser to the passage of alternating current depends upon the frequency of the current. At low frequencies the reactance is very high and a small capacity such as exists between the grid and plate of a vacuum tube of the three-element type will pass a negligible amount of current. As the frequency is increased, however, the reactance of the capacity becomes smaller and consequently larger currents are passed. When using ordinary tubes as radio-frequency amplifiers, it is found that the reactance of C2 at frequencies higher than 500 kcs. becomes so low that sufficient energy is passed from the plate circuit to the grid circuit to cause instability or oscillation. Reduced signal, poor quality and howling are some of the bad effects which result from this feed-back condition. Balancing or neutralizing schemes are necessary to counteract the feed-back which is so detrimental to radio-frequency amplifying circuits. A balancing circuit shown in Fig. 6 introduces a small condenser CB in the circuit. This

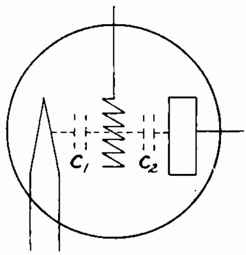


Fig. 5—Diagram of inter-electrode capacities in the three-element vacuum tube.

condenser is connected at one side to the grid and on the other side to a point on the plate coil which is below the effective ground tap. The condenser CB, when properly adjusted, carries a current equal to and opposite in phase from that passing through C2, hence the two currents neutralize or balance out, thus preventing oscillation and instability. It should be noted, however, that balancing counteracts but does not prevent feed-back.

## DEFECTS OF BALANCE CIRCUITS

At best, balancing is merely a way out. It does not eliminate the cause of the trouble and makes for circuit complication. It is virtually impossible to achieve a balance which will be correct for a wide range of frequencies such as is met with in broadcast reception. In such a case the balance for the middle frequency is obtained and certain instability exists at the terminal frequencies. At the very high frequencies (above 3000 kcs.) it is difficult to obtain a balance no matter how carefully the circuits are laid out and adjusted. Furthermore, whenever a tube is changed it is frequently necessary to re-balance, since the grid plate capacity of the replacement tube is usually different from that of the tube which has been removed.

## GRID PLATE CAPACITY OF THE SCREEN GRID TUBE

In the screen grid tube the grid plate capacity has been almost entirely eliminated and has a value between 0.01 and 0.1 micro-microfarads, or from 0.01 to 0.001 of the capacity present in the three-electrode tube. This low grid plate capacity has been obtained by inserting a screen or "shield" between the control grid and the plate. In Fig. 7 the screen grid tube is shown in diagrammatic form. The screen grid completely surrounds the

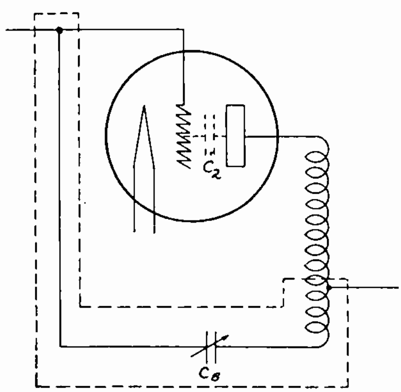


Fig. 6—Sketch of three-element tube and balancing circuit to neutralize the inter-electrode capacity. C2 represents the grid plate capacity and CB the equivalent balancing capacity.

plate and the lines of electric force which in the three-electrode tube run from plate to grid are now intercepted by the shield. The screen grid is kept at "ground" potential by means of a large capacity (C) which is connected on one side to the screen grid and on the other to the filament, thus providing a low reaectance by-pass for the radio-frequency potentials impressed on the screen grid. Hence, only a few of the lines of electric force pass through the screen to the control grid with the result that the capacity is very small. Since the control grid plate capacity is almost negligible, it follows that changes in the plate circuit will have no appreciable effect on the control grid circuit. Hence there is no path for the feed-back. Consequently, there is no instability or oscillation to hamper the radio-frequency amplifier performance. The practical elimina-

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tion of the control grid plate capacity virtually does away with the necessity for balances and the intricate circuits associated therewith. Also, radio-frequency amplification may be obtained with the screen grid tube at frequencies as high as 100,000 kcs.

## CHARACTERISTIC CURVE

Another interesting feature of screen grid tube performance may be discovered by examination of a characteristic curve. In Fig. 8, the plate current is plotted against plate volts with a fixed control grid and screen grid bias. Between the limits of 90 and 145 volts on the plate which is the limit of operating voltage, there is a change in plate current of only 0.1 milliampere. In the ordinary three-electrode tube, a similar change of plate voltage would cause a current variation of nearly 9 milliamperes. The practical value of small current variation due to voltage changes

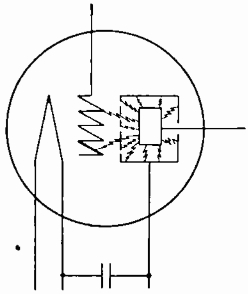

Fig. 7—A diagram showing the manner in which nearly all of the electrostatic lines of force between the control grid and plate are intercepted by the screen grid with the result that the control grid plate capacity is reduced to the vanishing point.

on the plate is readily seen when modern radio circuit power supply systems are considered. The majority of the new broadcast receivers, as well as many older types, make use of plate or "B" current supplied through rectifiers or filters from house lighting power. Such a power supply is subject to changes in voltage which, of course, affect the plate voltage. With ordinary tubes, the variation of plate potential by even a few volts causes signal fading. The screen grid tube remains unaffected by small voltage changes and is unlikely to reflect, except in limited degree, fairly large variations in the plate supply.

## RADIO-FREQUENCY AMPLIFICATION

One of the major improvements to be found in the performance of the screen grid tube is the exceptional sensitivity resulting from its high amplification factor. Fig. 9 shows the amplification to be expected from each of the three types of tubes at various frequencies: (a) three-electrode, (b) high mu,

(c) screen grid. Laboratory amplifiers have been built which used several special screen grid tubes. These amplifiers proved so sensitive that the effect of electrons striking the plate of the first tube has been heard as a roaring noise in the loudspeaker connected to the output stage.

The high amplification comes about as follows: Due to the absence of control grid plate capacity of appreciable value, the plate resistance of the commercial screen grid tube is extremely high. By reason of its very high value, which may be considered as infinitely large, the screen grid tube alternating current plate resistance may be neglected as a factor in determining the amplification. Hence, the amount of voltage amplifi-

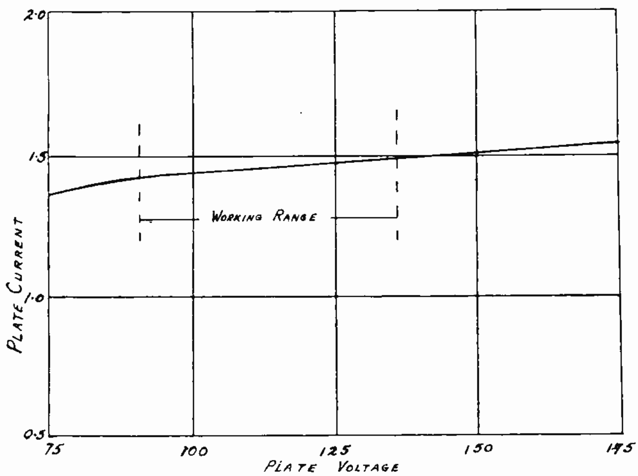

Fig. 8.

cation obtainable depends on the amount of resistance which can be placed in the external plate circuit of the tube times the mutual conductance of the tube itself. The mutual conductance has a constant value for any one grid potential, therefore, the amplification of the screen grid tube is in proportion to the amount of resistance in the external plate circuit. Fig 10 shows graphically how the amplification factor increases with the plate circuit resistance.

In theory the nearer the external plate resistance matches the internal plate resistance of the tube, the better the circuit and tube function together. This condition holds for three-electrode tube where the highest amplification from stage to stage is obtained when the tube and circuit resistances are equal. In screen grid tube circuits, this rule must be modified. It is, of course, necessary to couple each stage of amplification to the following tube. By doing so, the resistance of the plate circuit is decreased by an amount depending on the tightness of the coupling. If the coupling is made in a manner which permits of high plate resistance (above 200,000 ohms) it will be found that

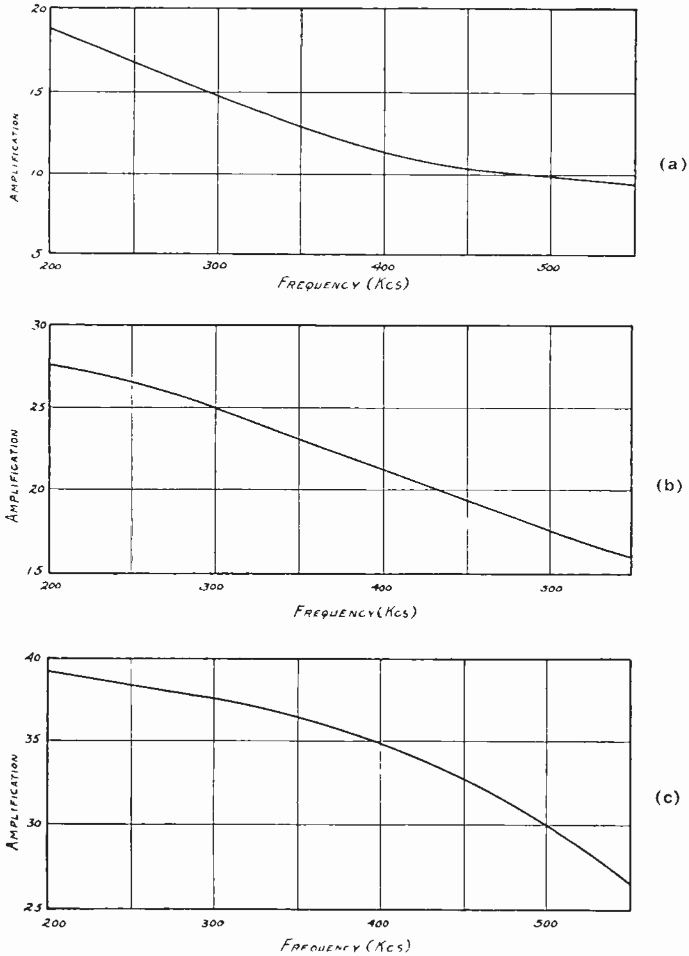

Fig. 9.

the grid of the following tube will get but little excitation and consequently the overall efficiency of the amplifier will decrease, though one stage may be operating at a very high rating.

Furthermore, it has been found that even the small grid plate capacity existing in the commercial type of tube is sufficient to cause a certain amount of feed-back which, in these highly sensitive tubes, results in instability. For this reason, the tuned plate circuit is not very satisfactory when applied to screen grid tube circuits in the broadcast frequencies. Without the most careful shielding and separate batteries for each stage, it is virtually impossible to realize the full amplification of these tubes and it has proved better to be content with somewhat less amplification in order to take advantage of circuit simplification. For this reason transformer coupling is widely employed. Four or five turns in the plate circuit are coupled closely to a tuned grid circuit. This arrangement gives excellent stability, good amplification, and is convenient to handle. The impedance of the plate circuit is considerably lower than that desirable for

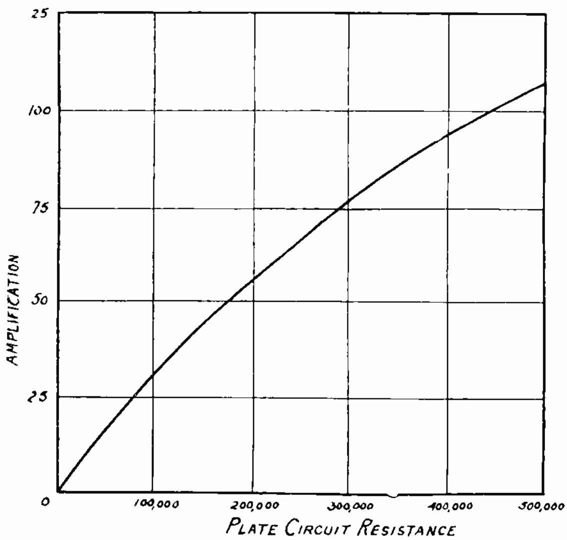

Fig. 10—Note the direct increase of amplification with increase in the plate circuit resistance.

the most efficient operation of these tubes but better all around performance is obtained.

## SUMMARY

The outstanding features of the screen grid tube as explained above are:

(a) The practical elimination of the troublesome grid plate capacity.

(b) The small changes in plate current due to changes in plate voltage.

(c) The high amplification attainable at both radio and audio-frequencies.

## THE SPACE CHARGE GRID

A further use of this adaptable tube requires a different connection from that specified in the preceding description. Fig. 11 shows the tube hooked up as a "Space Charge Grid" amplifier. In this case the inner grid is given a positive potential, while the outer grid performs the functions of the control grid.

It will be remembered that a heated filament emits electrons. If, as in the case of an electric light bulb, there is nothing to prevent, the electrons will be attracted back to the filament at the same rate as they are emitted. In the three-electrode vacuum tube the plate is given a positive charge and some of the electrons (negatively charged) which are emitted by the filament are attracted to the plate. For a given plate voltage, a certain number of electrons are attracted to the plate while the rest rejoin the filament. As the plate voltage is increased, more electrons

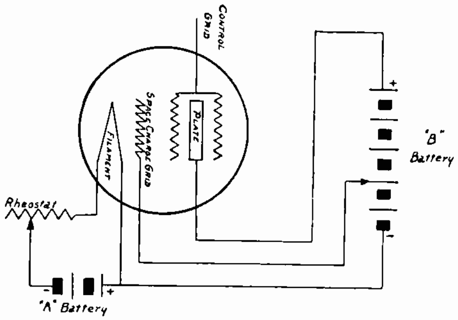


Fig. 11—The UX-222 vacuum tube with the necessary "A" and "B" battery connections for use as a "Space Charge" amplifier.

are attracted to the plate. The reason that all of the electrons emitted by the filament do not go to the plate is that the "Space Charge" between the two elements limits the electron flow. The space charge is the repelling effect of the electrons upon themselves and since the electron cloud is most dense near the filament the space charge is highest in that location.

Now, if an electrode be introduced very close to the filament and a positive potential placed upon it, this electrode will exert a great attraction upon the electrons in the cloud around the filament and cause a material reduction in the space charge. The inner grid of the new tube, when hooked up as in Fig. 11 serves just this purpose. Its positive potential neutralizes the space charge and imparts a tremendous velocity to the electrons leaving the filament. Because of the grid structure, only a few of the electrons are actually intercepted by the inner grid. The great majority pass through the space between the openings to come under the controlling influence of the outer grid which is now acting as the control grid. If the control grid happens to be positively charged, the electrons which have come through the inner grid are further accelerated and proceed to the positively charged plate. Should the outer (control) grid be negatively charged the electrons would, of course, be repelled and would not reach the plate. The practical results of the space charge grid connection may be summed up as:

(a) That the plate current for a given plate voltage is much increased.

(b) That the mutual conductance of the tube is increased.

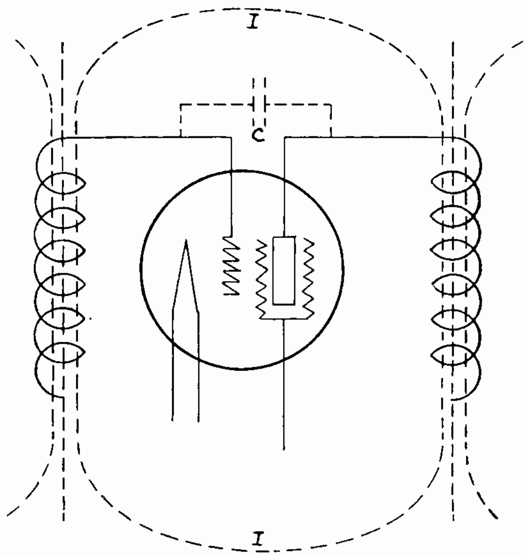


Fig. 12—Diagram of the capacity and inductive coupling which may exist in the external circuits of a screen grid amplifier. Under these circumstances, the advantages of the small internal capacity of the tube are lost. Proper shielding of the coils and condensers will eliminate these external circuit couplings.

The grid plate capacity has reappeared with this type of hook-up, however, making the tube of no use as a radio-frequency amplifier. It is in the audio-frequency circuits that the space charge grid finds its field of usefulness and very high amplification per stage can be obtained at the audio-frequencies. It will be improbable that more than one stage of space charge audio amplification followed by an output tube will ever be necessary for ordinary purposes.

## PRACTICAL APPLICATION OF THE SCREEN GRID TUBE

Having discussed the means by which the screen grid tubes accomplish their extraordinary performance, it remains to show the methods and circuits required for utilizing the tube in practice. First of all comes the necessity for the thorough shielding of all external circuits. The manufacturer in making the screen grid tube has done an excellent job in eliminating the capacity between the control grid and plate. His work will be nullified, however, if circuit capacities are permitted to act in the same manner as the old grid plate capacity. Without proper external shielding, the screen grid tube is valueless. In Fig. 12 the couplings which may exist in the external circuits are depicted.

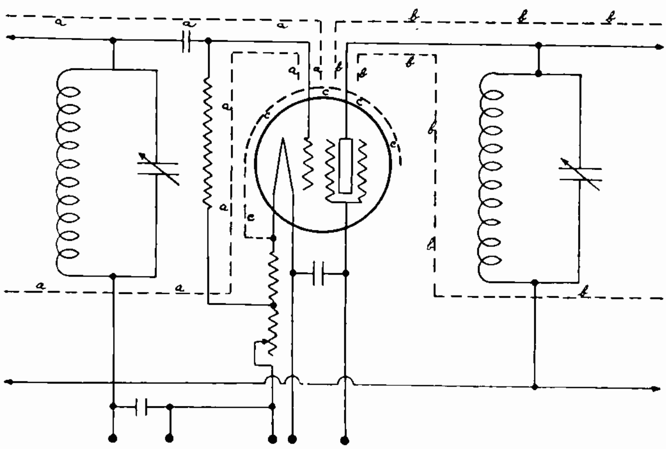

Fig. 13—Sketch of the shielding required for the most efficient use of the screen grid vacuum tube.

Since they couple plate and control grid circuits together, it can be understood that feed-back is again possible and that balancing or neutralizing methods will be required once more. Thus one of the prime factors in the excellence of the screen grid tube will have been lost through careless assembly or wiring.

The screen grid tube is a very fine and sensitive device. It is not pretended that this tube can be used in a "haywire" hookup with any degree of success. The circuits to which the tube is connected must be carefully laid out and shielded from one another and from the tube in order that the full possibilities of this new tube may be realized. In Fig. 13 a single tube is shown connected to the eternal circuits necessary for a single stage of radio-frequency amplification of the tuned plate circuit type.

The dotted lines represent the shielding which should be used for the effective action of the amplifying unit. In Fig. 13 a-a-a is the shielding around the control grid circuit. Notice that it completely surrounds the tuning coil and condenser of the input circuit and effectively confines all of the radio-frequency field within the limits of the shield. An extension of the shielding in the form of a small metal tube may lead to a point close to the control grid terminal so that only a fraction of an inch of unshielded connecting wire will be exposed. The plate circuit shield represented by b-b-b is as thorough as that of the grid shielding. Once more all of the elements of the radio-frequency circuit are confined within the shield which extends to within a short distance of the plate terminal at the tube socket. The shielding shown as c-c-c is a metal jacket fitting closely over the glass bulb of the tube, but having a hole with an insulated bushing at the top through which connection is made to the control grid. The

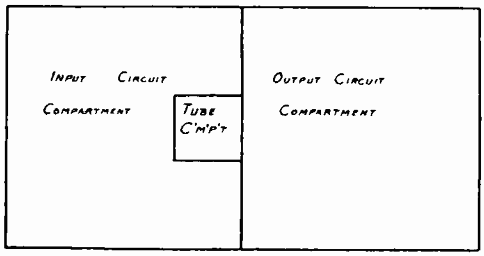


Fig. 14—The box layout which ensures proper shielding.

shielding for the plate and control grid circuits is in the form of a metal box or compartment for each circuit. In addition, it is desirable to have a separate small special compartment for the tube itself. The general layout of the compartments may be along similar lines to that shown in Fig. 14.

Shielding is also helped by keeping the control grid and plate wires as far apart as possible. This has been made relatively easy by the construction of the tube which brings the control grid out of the top and the plate out of the bottom of the tube assembly. A further aid is to make the control grid and plate connecting leads as short as possible in order that the capacity may be decreased and the coupling losses to the shield reduced. If these cautionary shielding measures are carried out, a long step towards satisfactory screen grid tube operation will have been taken.

## KEEPING THE SCREEN GRID AT GROUND POTENTIAL

It is important that the screen grid be kept at "filament" potential with respect to radio-frequency currents. From the foregoing explanation of the action of the screen grid, it will have been seen that the duty of the screen is to intercept the electrostatic lines of force between the plate and the control grid. If, however, the screen grid is at a higher radio-frequency potential than the filament, a charge will be induced on the control grid and feed-back will take place. The resistance of the "B" battery, especially when low, or the choking action of long or small wires may be the means for keeping the screen grid at a high radio-frequency potential with respect to the filament. To avoid this condition a large capacity condenser, about 0.5 microfarads, is connected between the screen grid and the filament. To assure that this condenser will act efficiently in by-passing the

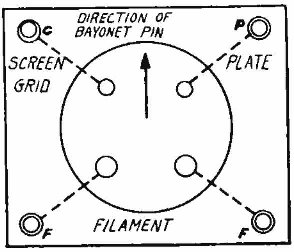


Fig. 15—The terminal arrangement of the D. C. screen grid tube when used in a standard socket.

stray radio-frequency energy, the location should be as close to the tube socket as possible with short leads to the socket terminals. By so doing the radio-frequency energy chooses the low impedance path represented by the condenser. Thus, long wires or battery circuits in which there may be considerable potential drop at high frequencies are avoided and the screen grid is thoroughly grounded.

## SELECTIVITY

The trend of radio receiver design is always along the lines of increasing sensitivity, better selectivity and improved quality. The advent of the screen grid tube solves beyond question the problem of sensitivity. With amplifications of from 20 to 40 per stage obtainable at the broadcast frequencies, one or two stages of efficient screen grid amplification will satisfy the desires of most broadcast listeners. The increased sensitivity has resulted in no loss of quality and as a matter of fact, the quality will usually be improved because of the elimination of feed-back and the absence of regenerative circuits. In the matter of selectivity, however, the application of the screen grid tube does have certain limitations. It has been quite the custom to rate the sensitivity of a radio receiver in terms of the number of tubes employed on the radio-frequency amplifying stage. It is quite as correct to regard the selectivity of a receiver as a function determined by the number of tuned radio-frequency stages. In other words, several stages of radio-frequency amplification are desirable not only for the sake of sensitivity but also for the necessary selectivity. Under the present conditions of broadcast reception, the general custom has been to demand a selectivity such as will be produced by two well-designed tuned radio-frequency stages (three tuned circuits) or one radio-frequency stage (two tuned circuits) with regenerative detector.

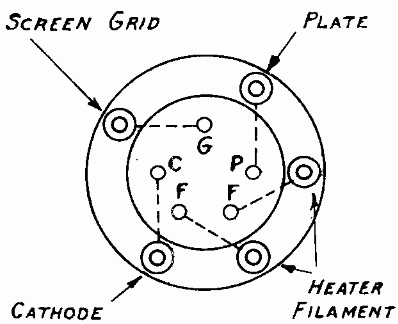


Fig. 16—The terminal arrangement of the A.C. screen grid tube when used in a UV socket.

The screen grid tube when employed in properly designed circuits will give a considerable increase in sensitivity over that possible with ordinary three-electrode tubes at no sacrifice in selectivity. To achieve this end, however, special attention must be paid to the tuning and coupling circuits. Coils of ample dimensions, good quality condensers and parts, the elimination of stray couplings with their increased resistance and the employment of loosely coupled circuits are some of the requirements to be met.

## NOISES

A new problem in the elimination of the many kinds of noises which interfere with radio reception is opened up by the use of multi-stage screen grid amplifiers. Further, while the grid plate coupling is reduced to a low value a certain amount is still present which, in multi-stage amplifiers, will cause trouble. Hence, it is recommended that no more than two or three screen grid stages be employed in any receiver intended for ordinary purposes.

## CHARACTERISTICS OF THE UX-222 OR CX-322 SCREEN GRID TUBE

The arrangement of the electrode terminals of the battery type screen grid tube is as follows: Standard UX base with two large and two small prongs. The electrode connection to each base prong may be easily ascertained by reference to Fig. 15 where, it will be noted, the arrangement is the same as for all UX tubes except that the screen grid prong is in the position usually occupied by the prong connected to the control grid of the three-electrode tube. The control grid of the UX-222 tube terminates in the metal cap on the top of the tube. Table No. I summarizes the battery requirements and amplification data for this tube.

### TABLE NO. I

**Characteristics of the Battery Type Screened Grid Receiving Tube**

| "B" Battery Volts | "C" Battery Volts | Plate Mils | Mutual Conduct-ance | Amplification Factor | "A" Battery Volts |
|---|---|---|---|---|---|
| 135 | 1.5 | 1.5 | 350 | 300 | 3.3 |

## CHARACTERISTICS OF THE UY-224 OR C-324 A. C. SCREEN GRID TUBE

The base layout of the A. C. screen grid tube is of the standard five-prong UY type with the exception that the screen grid is attached to the terminal marked "grid." The electrode connection to each base prong for this type of tube may be readily found by reference to Fig. 16. The control grid of the UY-224 or C-324 tube terminates in the metal cap on the top of the tube. Table No. II summarizes the voltage requirements and amplification data for this tube.

### TABLE NO. II

| Plate Volts | Negative Grid Bias | Plate Mils | Mutual Conduct-ance | Amplification Factor | Heater Volts |
|---|---|---|---|---|---|
| 180 | 1.5 | 4 | 1050 | 420 | 2.5 |

NOTE:—The UY-224 or C-324 tube may be used in battery circuits provided the necessary filament and plate potentials are supplied from the D.C. source.

# TYPICAL CIRCUITS FOR THE RECEIVING SCREEN GRID TUBE

The extreme sensitivity, high plate resistance and low internal capacity of the screen grid tube requires special circuits and arrangements in order that these excellent characteristics may be utilized to the fullest extent. In Fig. 17 is shown a screen grid receiver of an approved type. Two screen grid tubes are used as radio-frequency amplifiers while the detector is a three-electrode tube. The audio stages may employ any of the standard circuit arrangements and tubes. From a study of Table No. 1 it is noted that the voltage across the UX-222 filaments should be 3.3 volts while the negative bias on the control grid should be 1.5 volts. Inasmuch as the voltage for the UX-201A tube filaments must be 5 volts for best

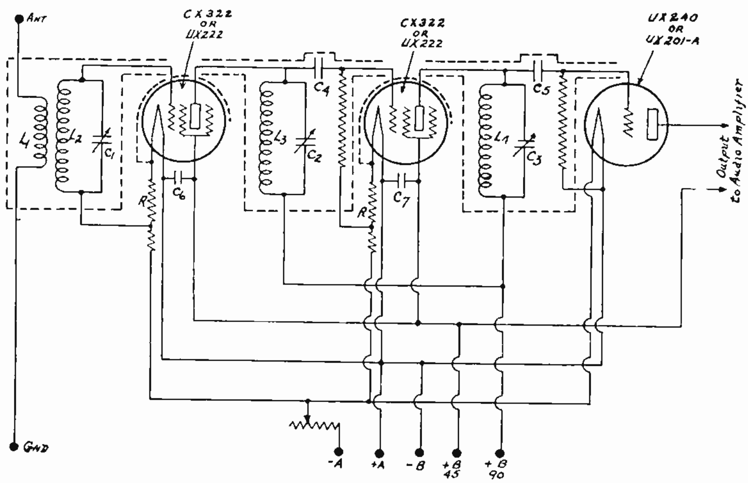


Fig. 17—Circuit showing D.C. screen grid used as R.F. amplifier.

operation it is necessary to insert a resistor "R" in series with each UX-222 filament in order to reduce the voltage to the 3.3 volts required. The resistance of "R" should be 15 ohms. By using a tapped resistor as shown or by using two resistors, one of 10 and one of 5 ohms, placed in series with the larger resistor nearest to the filament, it is possible to get the correct control grid bias from the drop in voltage across "R" thus avoiding the use of a "C" battery. Another type of circuit shown in Fig. 18 employs one screen grid radio-frequency amplifier feeding into a tuned three-electrode regenerative detector. This circuit while very sensitive and selective is likely to be rather unstable if not put together with extreme care. It should be noted that in this case the plate current of the screen grid tube is supplied through a radio-frequency choke "L."

## THE SCREEN GRID TUBE AS A DETECTOR

The present trend of receiver design is towards the attainment of the utmost fidelity in the reproduction of the broadcast signals. To attain this end it has been found most desirable to have the amplification concentrated at radio-frequencies since distortion is most likely to occur in audio circuits. By the use of screen grid tubes, a very considerable gain in radio-frequency amplification may be obtained but this gain is not of itself sufficient to eliminate any audio stages provided a three-

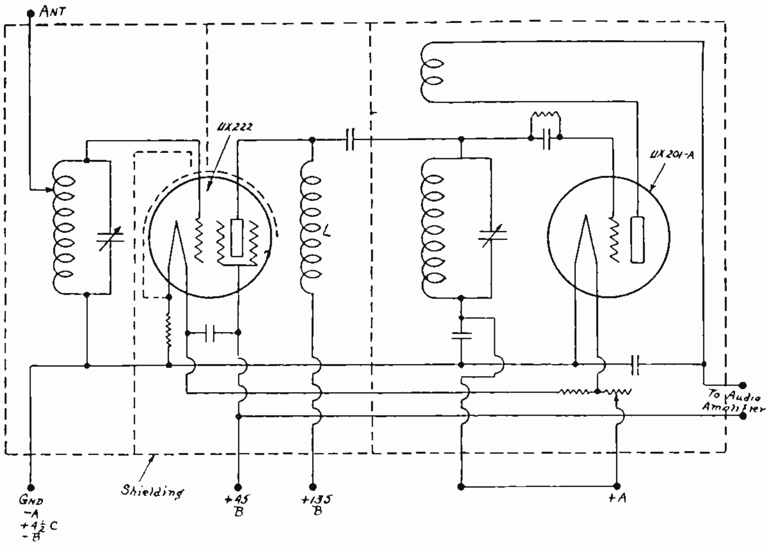


Fig. 18—Circuit diagram using D.C. screen grid as R.F. amplifier with a three element regenerative detector.

electrode detector is employed. If, however, a screen grid tube is used as a detector a very considerable amplification is obtained in the tube itself and the output of this tube may be used to directly excite a power tube feeding into a loud-speaker. The most efficient circuit for coupling the plate of the screen grid detector to the power tube is resistance coupling which is also very desirable from the standpoint of fidelity of reproduction. With this arrangement two audio transformers and one tube are eliminated and the major causes for audio distortion are thus no longer present. In order to handle the large voltages impressed on the grid by the powerful radio-frequency amplifier, it is necessary to use grid bias detection in the screen grid detector as shown in Fig. 19. The plate circuit employs a 250,000 ohm resistor and a .01 microfarad coupling condenser as shown. In order to compensate for the drop across this large resistor it is desirable to raise the plate supply voltage to 200 volts. In Fig. 20 is shown a modern screen grid broadcast receiver suitable for battery tubes (UX-222). A similar circuit is shown in Fig. 21 for an alternating current broadcast receiver employing two radio-frequency screen grid tubes, one screen grid detector and a power tube in the output stage.

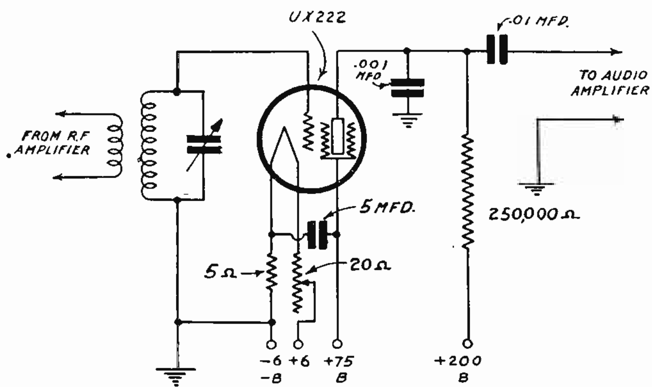


Fig. 19—The screen grid tube circuit for grid bias detection.

## HIGH FREQUENCY RECEIVERS

The foregoing diagrams have applied to receivers to be used in the broadcast frequencies. Standard parts and known circuits which need but slight modification to be applicable to the screen grid tube make the task of changing over existing sets or building a new receiver with screen grid tubes a comparatively easy one for the broadcast set builder. In the amplification of frequencies higher than 3,000 kilocycles, however, the situation is not and has not been so easy. It is only with the use of screen grid tubes that amplification has been obtained at all the very high frequencies. Even with the screen grid tube, it is necessary to take careful steps in the wiring and assembly and to provide filters in the battery and telephone leads.

The receiver illustrated in Fig. 22 is sufficiently sensitive for any purpose on short wave-lengths. The construction details will be considered at some length because of the excellent results which may be achieved on the higher frequencies from a well-made short wave receiver of this type.

The first question to be considered is the shielding. This must be absolutely complete except where wires enter the various compartments. A metal box should be secured and the compartment joints should be soldered or tightly screwed to angle pieces. Wire holes should not be larger than necessary to clear the insulation. The cover should fit tightly over the box and have angle pieces screwed or riveted on so that slots are formed into which the shielding walls can fit and make a good shield joint between compartments. The amplifier tube should be located in a separate small compartment as shown in order that the several circuits may not be coupled together through their wires which connect to the screen grid amplifier tube. A series

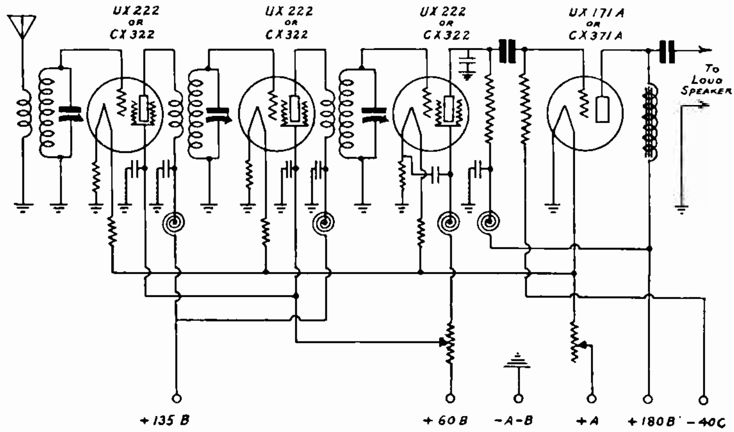


Fig. 20—Schematic circuit diagram of D.C. screen grid receiver.

of small compartments should be built under the receiver proper —these sections to take the different battery wires and introduce a filter between the battery and the receiver. Only a small coil and "postage stamp" condenser are in each of these filter sections so that these compartments need only have limited space.

All wires from the filter compartments to the points where they are connected to the tube, coils or condensers inside the receiver compartment should be covered with a copper braid for shielding purposes as a further precaution against stray couplings.

Taking the circuits in order: Condensers C1 and C2 are of the variable type and should have a capacity of about 150 micro-microfarads. A good vernier dial should be provided to secure easy tuning. Over the wave-length band of from 30 to 50 meters, the coil L1 should be made up of twelve turns of number 12 cotton-covered wire wound to make a two and one-half inch diameter coil of the self-supporting type. Turns should be spaced the width of the wire by means of string. The whole assembly should be boiled in paraffin after completion. L2 is the antenna coupling coil and should be made of two turns of ordinary annunciator wire two and one-half inches in diameter and placed so that the coupling to L1 is quite close. C8 is an insulating capacity intended to separate the negative filament from the grounded shield while permitting an easy path to ground for the radio-frequency currents in L1 and L2. The capacity of C8 should be about .001 microfarads and the condenser should be of the postage stamp mica variety. The high

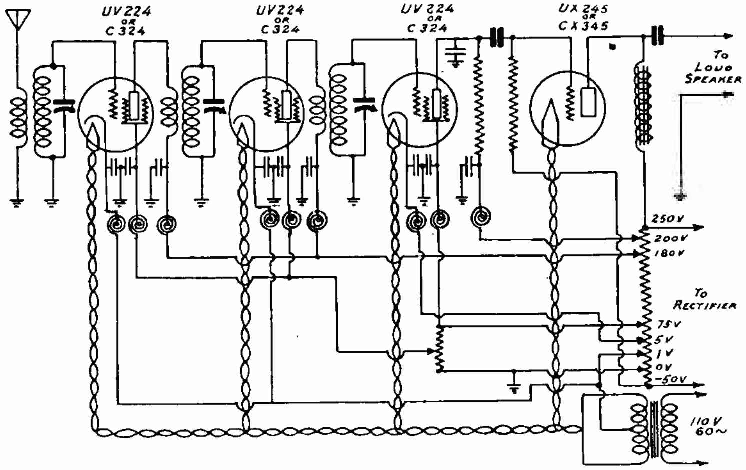


Fig. 21—Schematic circuit diagram of A.C. screen grid receiver.

potential wire from the tuning circuit L1 C1 passes through the upper part of the shield and goes directly to the control grid cap on the screen grid tube. R1 is a small fixed resistor in series with the negative filament of the screen grid tube. The resistance of R1 is 10 ohms and it supplies the necessary voltage drop for proper filament voltage and grid bias for the tube. C3 is the screen grid filament by-pass condenser, an item all too frequently left out in these circuits, yet a most important part if the best operation is desired. As noted before C3 has a capacity of .5 microfarads and may be a paper condenser. The plate of the radio-frequency amplifying (screen grid) tube connects through to the coil L3 and condenser C2 which make up the tuned plate circuit of the [illegible] ..e 30 to 50 meter band, L3 may be a [illegible] diameter coil similar in construction t[illegible] urns only. L3 is at high D.C. poten[illegible] of the plate battery circuit, hence an [illegible] ndenser of .001 microfarad capacity is connec[illegible] he low potential end of L3 and the low potential e[illegible] ondenser C2. The low potential end of C2 is also grounded to the shielding. C4 is a mica condenser having a capacity of .00025 microfarads and is the capacity which couples the circuit L3 C2 to the grid of the detector tube. The three megohm resistor R2 acts as the leak for the grid of the detector tube and also by reason of its being

NOTE - - The spiral symbols shown in Figs. 20 and 21 are radio-frequency choke coils

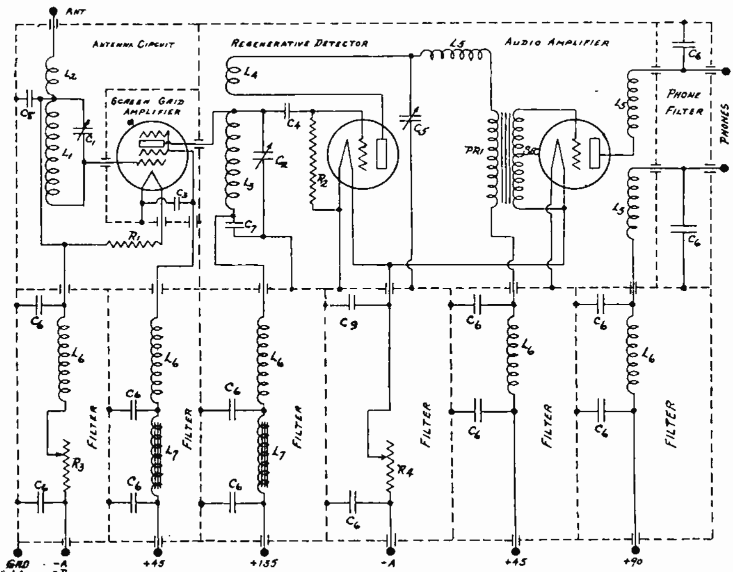


Fig. 22.

connected to the positive filament provides the positive bias, necessary for rectification, to the detector grid. L4 acts as the tickler and is an inch in diameter with eight closely wound turns of number twenty-six cotton covered paraffined wire. The condenser C5 is a small variable type and controls regeneration. Inductances L5 are radio frequency chokes which prevent high frequency currents from circulating in the audio-frequency circuits. These chokes may be made from 200 turns of number thirty wire either in a universal winding or in a home-made thin coil shaped like a disc. Condensers C6 are paper dielectric .1 microfarad capacities which act as by-passes in the various filter circuits. Inductances L6 are the radio-frequency chokes contained in the filter circuits and should be formed of a single layer winding of number forty enameled wire two inches long on a half-inch thick paraffined dowel stick. R3 and R4 are variable resistors used to control the filament current in the vacuum tubes. R3 should have a resistance of 20 ohms and R4 a resistance of 6 ohms.

The arrangement of the circuits should be similar to that shown in the diagram. In particular the filter circuits should have their apertures through which the receiver wires pass as close to the connecting element as possible.

L7 is an iron-core audio-frequency choke of good commercial design. The two chokes L7 prevent modulation and microphonic noises by "ironing out" the plate current.

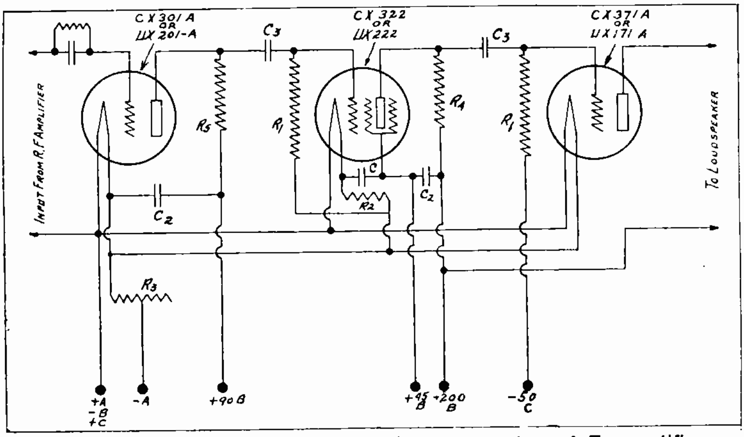


Fig. 23—Circuit showing screen grid tube used as A.F. amplifier (resistance coupling).

C9 is a .5 microfarad paper condenser which by-passes the radio-frequencies which may be impressed on the filaments of the audio tubes.

The importance of suitable filter circuits on high-frequency receivers can hardly be over-emphasized. Especially should a sensitive receiver of the type described have all the battery and phone leads pass through filters. By the use of filters the major part of the interfering noises found in a high-frequency receiver are eliminated. It is possible, however, under favorable conditions to secure good results with the receiver described even without the filter circuits. If, for reasons of economy or simplicity, the filters are not desired, the receiver may be built without them. In such a case the wiring diagram will be identical with that shown in Fig. 22, except that all lower compartments with their associated circuits are left out and the wires from the receiver are brought directly out to the batteries.

## THE SCREEN GRID TUBE AS AN AUDIO AMPLIFIER

So far the practical application of this tube has had to do with radio-frequency circuits only. The tube has excellent characteristics as an audio amplifier also provided only that the amplifier is to be used in a quiet location since these tubes are very microphonic in audio circuits. Where a high amplification is desired, an arrangement like that shown in Fig. 23 may be employed. It is advisable to use only one stage of screen grid audio amplification and to place that stage immediately after the detector tube in order that the power output of the tube

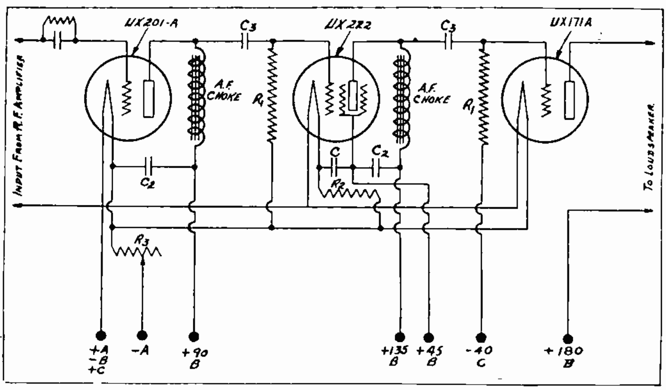


Fig. 24—Screen grid tube as A.F. amplifier (impedance coupling).

may not be exceeded. In Fig. 23 only the circuit from the detector tube through the audio stages is shown—the radio-frequency amplifier may be of any conventional type or may include a screen grid stage. As in the radio-frequency case a screen grid tube used as an audio-frequency amplifier must be carefully shielded and special pains must be taken to keep the control grid and the plate leads well separated and individually shielded. It is also desirable to have a large capacity by-pass condenser between screen grid and filament. Referring again to the diagram of Fig 23, the plate of the detector tube works into a resistive load and is supplied with plate current through resistor R5 which has a value of from 25,000 to 100,000 ohms. C2 is a by-pass condenser from the low potential end of the resistor R5 to ground and the value of the capacity is about .02 microfarads. The filament resistance combination R2, R3, is similar to that which has been described before and serves to reduce the voltage across the tubes to the proper amount as well as to furnish the correct grid biasing potential. In this case R2 has 10 ohms resistance, and R3 has 6 ohms resistance. R3 is, of course, variable as shown. C3-C3 are coupling condensers between tubes and should have a capacity of .01 microfarads. $R_1$-$R_1$ are grid leaks and should have a resistance of approximately three megohms. R4 should be a resistor of about 250,000 ohms (¼ megohm).

A modification of the above circuit and one which works very satisfactorily is shown in Fig. 24. In this audio amplifier and detector and screen grid tube, high resistance loads are composed of iron-core chokes. These chokes should have an

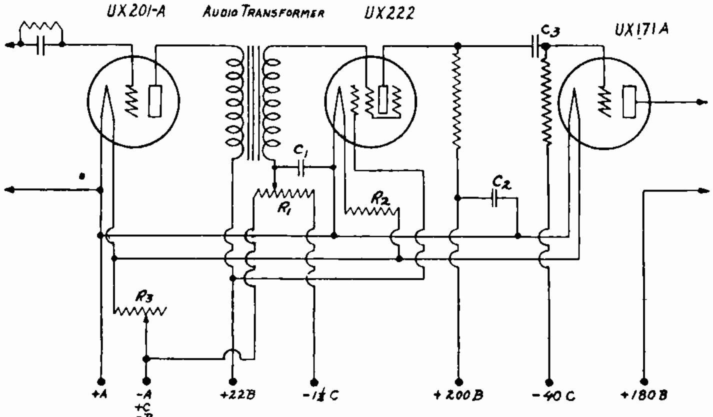


Fig. 25—Screen grid tube as A.F. amplifier (combination transformer and resistance coupling).

inductance of twenty or thirty henries for best operation. By placing large condensers across these audio chokes, it is possible to tune at specific audio-frequencies, a feature that is sometimes very desirable for code reception.

## THE SPACE CHARGE GRID AUDIO-AMPLIFIER

A third method audio amplification which is simpler in its application makes use of the tube as a space charge grid tube. It will be remembered that the space charge grid method does not prevent feed-back and, hence, is of no value in radio-frequency circuits. It is, however, applicable to audio-frequency use and is, possibly, somewhat easier to handle than an audio-frequency screen grid amplifier. The constants of the tube as a space charge amplifier are somewhat different from those of the tube as a screen grid amplifier. Table No. 11 summarizes in tabular form the characteristics of the tube for the space charge grid arrangement. In this hook-up it is also important to remember that the grid connected from the socket base becomes once more the control grid and metal cap from the top of the tube is the space charge grid.

In Fig. 25 is a diagram of a detector and two-stage audio-amplifier in which the first audio stage is of the space charge grid type. Referring to Fig. 25, the output from the detector is fed into an audio-frequency transformer in the usual manner. Any good audio transformer may be used in this place. The secondary of the transformer connects, on one side, to the control grid (a socket terminal) while the other or low potential

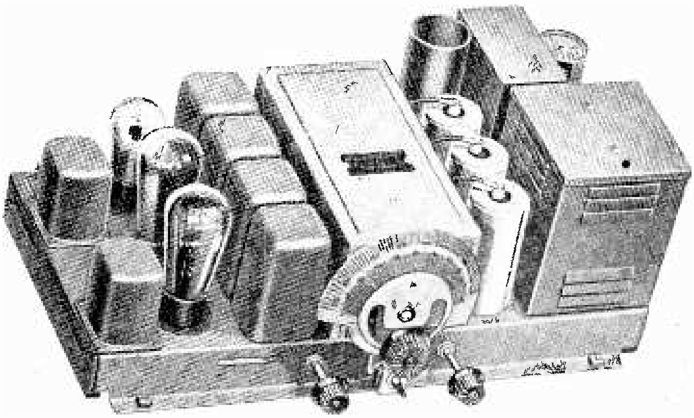

Fig. 26—Typical chassis of a screen grid receiver.

end of the secondary connects to a potentiometer R1 placed across a single dry cell. It is advisable to by-pass the potentiometer battery with a condenser C1 having a capacity of one microfarad. The space charge grid (top of tube) is brought directly out to a battery supply of plus 22 volts. Across the plate circuit of the tube is placed a resistive load of from .1 to .3 megohms and the resistor is by-passed to ground at its lower end through a 1.0 microfarad condenser C2. The coupling from the space charge tube to the following tube is taken care of by C3 which is a good quality mica condenser with a capacity of about .01 microfarads. Note that the plate voltage for the space charge tube is 180 volts. In other respects the amplifier resembles those that have been described before.

## TEST QUESTIONS

Number Your Answers 25—4 and Add Your **Student Number.**

Never hold up one set of lesson answers until you have another set ready to send in. Send each lesson in by itself before you start on the next lesson.

In that way we will be able to work together much more closely, you'll get more out of your course, and better lesson service.

1. Show by diagram how the "A" and "B" batteries are connected in the tube circuits of the screen grid tube.
2. Where is the control grid placed and what is its duty in the screen grid tube?
3. What is the screen grid and where is it placed and why?
4. What are the principal advantages of the screen grid tube over the three-electrode tube?
5. What should be done to keep the screen grid at ground or filament potential?
6. How does a space charge grid tube work?
7. What are the advantages to be gained from the use of the space charge grid tube?
8. Tell why shielding is so essential in circuits using the screen grid tube.
9. Why is the screen grid tube of such great value as a radio-frequency amplifier?
10. Draw a simple diagram of a receiver using a screen grid radio-frequency amplifier.

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