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MODERN VACUUM TUBES

AND How They Work

with complete technical data on all standard tubes and many special tubes

by Robert Hertzberg

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With Complete Technical Data on All Standard Tubes and Many Special Tubes

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Completely revised by J. T. Bernsley

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Preface

THE vacuum tube is unquestionably the most important single device used in radio, and is becoming increasingly important in many other phases of the electrical art. Its fundamental theory should be thoroughly understood by every radio Service Man, experimenter and constructor; the man who is ignorant of this theory works eternally in the dark.

The operation of vacuum tubes is not particularly simple, since it involves such intangible things as electrons, but this little book will help clarify it in the minds of willing students. The use of mathematics has been avoided, and explanations are given instead in more easily understood physical terms. A knowledge of ordinary electricity on the part of the reader is presumed, so the text is devoted entirely to tube phenomena. All types of present day tubes from diodes to pentodes are described and their characteristics given in detail. The various charts and curves will be found particularly valuable for reference purposes.

The reader is cautioned not to try to read and absorb all the information in this book at one sitting. He should study chapter by chapter, reading each one two or three times, until all the facts become fixed in his mind. Hasty reading is worse than none at all, as a thin skin of unrelated data makes for confusion rather than clarity.

—The Author.

Revised by J. T. Bernsley

CHAPTER I

The Edison Effect and the Electron Theory

Edison Effect:

DURING the course of his development work on the electric light, Thomas A. Edison performed thousands of experiments with different conducting materials sealed inside evacuated glass vessels. In 1884 he constructed a peculiar bulb having an ordinary carbon filament and also a small metal plate completely insulated from the filament. When this lamp was connected in the simple circuit shown in Fig. 1,

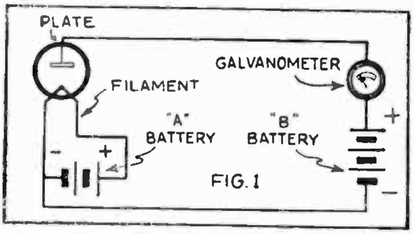


FIG. 1

This simple circuit illustrates the Edison Effect. When the filament is lighted and the plate made positive, the galvanometer will indicate a flow of current in the series circuit.

and the filament was lighted to incandescence, the sensitive galvanometer showed a reading. This indicated that a current of electricity was flowing through the circuit in spite of the fact that the filament and the plate of the tube were separated by a vacuum, which was known to be nonconductive. The galvanometer needle showed a deflection only when the positive pole of the "B" battery was connected to the plate. If the polarity was reversed no current flowed. The current flow could also be stopped by turning off the filament.

To Edison, who was seeking a perfect filament for his electric light, this effect was interesting but without particular significance. He recorded his observations and proceeded with other experiments. Later, the action became known as the "Edison Effect" and was further investigated by other scientists. Out of it grew the modern vacuum tube, which is the very heart of present day radio.

Electron Theory:

How did the current get through the apparently impassable barrier inside the tube? In 1884 Edison himself could not answer this question, but to-day we can explain the phenomenon quite satisfactorily with the aid of the electron theory. According to this theory, which is generally accepted, all substances consist of myriads of atoms, each atom being made up of a central nucleus surrounded by a number of "electrons". The nucleus is conceived as having a positive charge of electricity, and the electrons as having negative charges. Under normal conditions the positive charge is equal in strength to all the negative charges of the electrons put together, so the charges balance each other perfectly and there is no outward electrical effect. However, inside the atom itself one or more electrons is free to move around. In poor conductors of electricity the electrons are pretty well imprisoned. In good conductors a lot of them are likely to be running loose. Inert, "dead" materials like wood, cement, rubber and cotton are poor conductors, so poor, in fact, that they are known as "insulators"; electronically speaking, as they are very inactive. All metals, to a varying degree, are good conductors, because the electrons of their atoms are lively and active.

Now at ordinary temperatures the electrons do not have sufficient velocity to break through the surface of even the most conductive metals. However, when a metal is heated, the atomic agitation increases rapidly and finally a point is reached where some of the electrons are forcibly flung away from the surface of the material and form a cloud over or around it. The metal actually evaporates, just as water does. This action is known as "electronic emission," and can be defined as the setting free of electrons.

As the electrons have a negative charge, their departure from the nucleus disturbs the previous state of balance, and the positive charge of the nucleus more than equals the negative charges of the remaining electrons. The nucleus thus tends to attract or pull back the free electrons and does not let them go very far.

For the actual emission of electrons the metal must be heated to incandescence in a vacuum, as otherwise it combines with the oxygen of the air and simply burns up. The most convenient way to obtain emission of this kind is to heat a filament or wire inside an evacuated glass bulb by a current of electricity. Some substances throw off electrons more freely than others, and at lower temperatures.

The Edison Effect now almost explains itself. The filament of Edison's lamp, burning at red heat, emitted electrons. The metal plate, being charged positively, attracted some of these electrons and caused them to break away from the cloud surrounding the filament. As free electrons in motion constitute an electric current, the galvanometer indicated a current flow. (The direction of the current flow is conventionally considered as opposite to that of the electron stream.) The current registered by the meter is known as the "plate current."

Factors Determining Plate Current:

In a two-element tube of given construction, the actual amount of plate current depends on two factors: the filament temperature and the plate voltage. If the filament is maintained at a certain heat, it will emit a certain quantity of electrons per second. The proportion of these reaching the plate is determined by the plate voltage. As this voltage is gradually raised from zero, more and more electrons will reach the plate and the plate current will rise accordingly, until a point is reached where all of the available electrons are attracted to the plate. Raising the voltage beyond this point does not increase the maximum plate current, which is then known as the saturation current for the particular filament temperature or plate voltage. A further increase in plate current can be obtained only if the filament is made hotter, and then another saturation point will be reached. This effect is illustrated in Fig. 2.

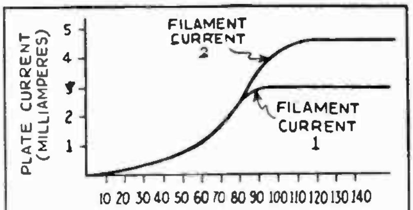


FIG. 2

This curve illustrates the increase in plate current obtained by raising the temperature of the filament. Saturation is reached at the point where the curve flattens out at the top. The values indicated are purely relative and do not apply to any particular tube.

Secondary Emission:

The plate or second element in the lamp must be relatively cold. If it warms up appreciably, because of radiation from the filament or because of the bombardment of the electrons striking it, it will emit electrons of its own and these of course will repel the filament electrons, thus neutralizing the effect of the positive plate potential. This effect is known as "secondary emission" (as distinguished from the primary emission of the filament) and should be remembered because it plays an important part in the operation of amplifier tubes.

Space Charge:

If the plate potential is kept at a fixed value, and the filament temperature raised gradually from a cold start, a similar limiting action takes place, but through a different cause, known as the "space charge" effect.

The space between the hot filament and the cold plate contains the electrons emitted by the filament. They are absorbed by the plate as long as the plate's rate of attraction is greater than the filament's rate of emission, and the plate current climbs accordingly. If the filament temperature is raised high enough, the electrons will become so dense that their overall negative charge, called the "space charge," is equal to the positive charge of the plate, and the plate current will not increase with further increase of filament heat. In other words, saturation has been reached for that particular plate voltage. Compare this effect with the one described in the preceding paragraph. When the filament temperature is raised beyond this saturation point, the space charge overcomes the plate charge, and any additional electrons from the filament are thrown back, in accordance with the fundamental law of electricity that like charges repel each other. In order to overcome the space charge and to obtain greater plate current, the plate voltage must be increased. See Fig. 3. Of course, both filament temperature and plate voltage cannot be increased indefinitely. The filament will burn out eventually, or the glass insulation of the bulb will break down under the strain of the high voltage.

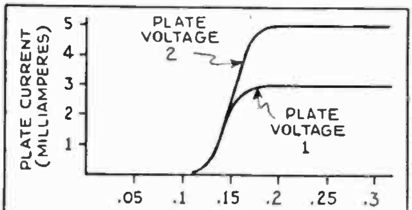


FIG. 3

The plate current stops increasing with increasing filament current at a point determined by the space-charge effect. The latter can be overcome only by raising the plate voltage. In this curve also the flat upper section represents the condition of saturation.

Fleming Valve:

The first practical use of the two-element tube or *diode* was made in 1890 by Dr. J. A. Fleming, a famous English scientist. The Edison lamp as he employed it for radio work is still known as the Fleming valve.

Since current will flow through the diode only when the plate is positive, the tube is a simple and perfect rectifier of alternating current, and found employment as a detector in the early days of wireless. Rectification is simply the changing of alternating current into direct current. When connected in an elementary receiving circuit such as shown in Fig. 4, the diode rectified radio frequency damped wave or "spark" signals, leaving an audio frequency component to which the earphones would respond. No plate or "B" battery is needed, as the incoming signal provides the plate energizing potential. During that part of the cycle when the plate is positive in relation to the filament, electrons are attracted to the plate and a pulse of current flows through the earphones; when the current reverses and the plate becomes negative in regard to the filament, the electrons are repulsed and that half of the cycle is eliminated. The net result is a series of audible current pulses, all flowing in one direction through the phones.

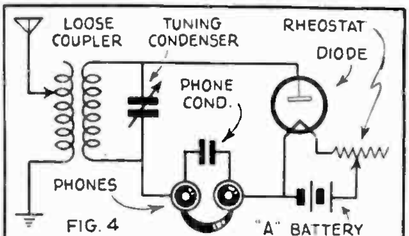


FIG. 4

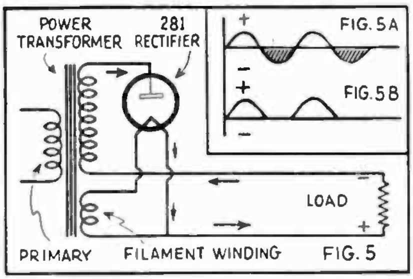
The two-element tube, when used in the circuit above, makes an effective detector or rectifier of radio-frequency currents. This elementary circuit was used at one time for the reception of "spark" signals from old-fashioned transmitters.

The diode detector was not particularly sensitive, and soon gave way to the three-element tube, or *triode*, developed by Dr. Lee de Forest in 1907. This is described in chapter 3.

Diode Rectifier:

The diode as a rectifier of alternating current has survived as an exceedingly useful and valuable device. The 281 and 280 rectifier tubes now in common use are ordinary two-element bulbs, differing very little in construction from Edison's original experimental lamp of 1884. The 281 is a true diode, containing a single filament and a single plate, and is used for "half-wave" rectification. The 280 is really two diodes in one glass envelope, having two filaments and two plates, and is used for "full-wave" rectification. Two 281's may be used for full-wave rectification just as easily as a single 280.

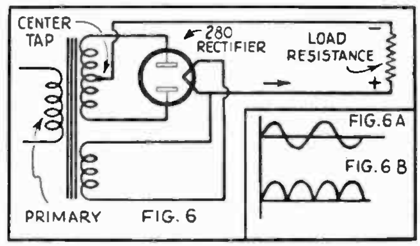
Because of the widespread misunderstanding of rectifier systems, an explanation of the half-wave and full-wave methods is in order. A simple half-wave circuit is shown in Fig. 5. The primary of the power transformer is energized by the usual 110 volt, 60 cycle line. One end of the secondary winding is connected to the plate of the 281 rectifier tube, and the other end forms the negative side of the output, running to the load resistance. The other secondary winding merely lights the filament of the tube.



Illustrating the circuit and action of a half-wave rectifier of alternating current. Note from Fig. 5B that the output current is not continuous, but has gaps in it.

The alternating current as it enters and leaves the transformer has the usual sine wave form shown in Fig. 5A. On the first half of the cycle, when the upper end of the secondary is positive and the lower end negative, the plate of the tube is charged positively, electrons are attracted and the current passes through unchanged in form, as indicated by the first pulse of current in Fig. 5B. When the current changes in direction, the upper end of the secondary becomes negative, the electrons are repelled, and no current flows. The entire circuit is thus really open for the length of time represented by the first shaded area of Fig. 5A. When the next cycle begins and the upper end of the secondary once more becomes positive, current again flows, as represented by the second pulse of current in Fig. 5B. This operation keeps repeating itself, so the output of the system is a series of direct current pulses, the time interval between them being equal to their own duration. This pulsating direct current, for receiving purposes, must be smoothed out by large filter systems.

It is obvious that the half-wave rectifier is only 50% effective, since only half of the alternating current wave is used. In the full-wave system, as shown in Fig. 6, both halves of the wave are utilized, and the current output is twice as steady. Here the power transformer secondary is tapped in the center. During one-half of the a.c. cycle, the top of the secondary is positive in relation to the center, and the bottom



In the full-wave rectifier, both halves of the alternating current wave are used, and the output current, as shown graphically in Fig. 6B, is much smoother than the output of a half-wave rectifier.

is negative. This means that the top plate of the 280 rectifier is positive, and the bottom plate is negative, and therefore all the electrons are attracted to the top plate and current flows through the circuit. When the a.c. reverses its direction, the top plate becomes negative and the bottom positive, and then current flows again. Note that in either case, the current flows from one plate, through the filament, out through the load resistance, and back through the center tap connection. Both halves of the a.c. wave flow in the *same* direction in the output circuit, as shown in Fig. 6B.

Two 281's are usually used in a full-wave circuit to obtain direct current at high voltage for the operation of power amplifiers and transmitters. Two separate tubes withstand the voltage strain better than a double tube like the 280, which is satisfactory for lighter duty in receiving sets. Both tubes develop considerable heat during normal operation.

CHAPTER 2

Electron Emitters and the Ionization Effect

Since the life as well as the fundamental action of a vacuum tube depends on the filament, this element is a very important one and has received the benefit of considerable research.

Tungsten Filaments:

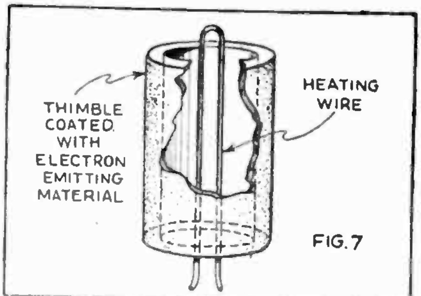
Early radio tubes used pure tungsten wire for their filaments. This was burned at a bright white heat to give adequate electron emission, and was not altogether satisfactory because it was erratic in behavior and short in life. Later, engineers found that a small amount of the metal thorium, added to the tungsten in the process of manufacture, acted as a coating for the latter and vaporized from the surface in the form of a strong electron flow. In fact, for the same normal filament temperature a thoriated tungsten filament gives twenty times the electron emission of a pure tungsten filament. Practically all of the millions of battery type tubes of the 201A variety used thoriated tungsten filaments, which operate at a temperature of 1800 degrees.

A. C. Tubes:

So far we have assumed that the filament is being heated by batteries, which give smooth direct current. As the demand grew for "electric" radio receivers that would operate off the a.c. line, tube designers found it necessary to seek new filament constructions, as thoriated tungsten is not suitable for a.c. use. The thin wire, carrying only a fraction of an ampere, responds readily to the 120 current pulses that take place every second in a.c. circuits, and the electron stream fluctuates at the same rate. This fluctuation makes itself heard in the loud speaker as a disagreeable hum. The first a.c. tubes, of the well known 226 type, used heavy oxide coated filaments operating at a comparatively low temperature with stepped down raw a.c. at a little more than an ampere of heating current. The heavy wire and the low temperature give the wire considerable thermal inertia, so it does not respond readily to the quick variations of the alternating current.

The coating on the filament is an oxide of either barium or strontium, and the filament itself is platinum, nickel or a special alloy. The electrons are emitted by this coating, and not by the filament itself, which serves only as a heater. Although the oxide coated filament burns normally at only 1300 degrees, as compared to 1800 degrees for thoriated tungsten, it gives six times the electron emission. Practically all present-day tubes taking raw a.c. on their filaments are of the oxide-coated type.

Heated Cathodes:



This exaggerated view shows the construction of the heated cathode used in the majority of present-day A.C. tubes. The filament in this case is merely a heater.

Although the oxide-coated filament reduced hum a great deal, it was still too noisy for satisfactory use in detector tubes. To overcome this shortcoming, engineers developed the cathode or indirect heater type of tube. Here the electron emitter is a tiny, hollow thimble of insulating material, coated on the outside with one of the efficient electron-emitting oxides. See Fig. 7. A wire, energized by raw a.c., runs through the center of this thimble, and heats the element sufficiently to cause it to emit electrons. A separate connection is made for the thimble, which is called the cathode. The filament in this type of tube is merely an accessory, and has no connection with the receiver circuit proper.

Cathode heater tubes are not limited to use on alternating current only. They can be heated just as well by battery current. In fact, the "automobile" series of battery tubes uses the cathode heater construction because it is rugged mechanically and flexible electrically. The fact that the electron emitting element requires only one connection, instead of two as in the case of regular filament types, makes the tube very convenient for many special purposes. Heated cathodes are now quite universally used, even in some diode rectifiers.

At the present time there is no simple and practical means of obtaining electronic emission for radio purposes without the use of heat. However, a number of experimenters are working on a "cold" tube, and developments along this line appear to be promising.

Ionization:

In the foregoing discussion of tube theory it has been assumed that the glass bulb containing the filament and plate electrodes is perfectly evacuated. If it is, the electron effect takes place precisely as described. However, if there is even a slight trace of air or other gas left in the tube, the action is complicated by a phenomenon known as "ionization." This is simply the process of losing electrons from an atom, and the part left behind after the electrons depart is called an "ion".

The atoms of any gas are normally in an agitated state, and can readily be broken up. This is just what happens to the gas atoms left in a vacuum tube, particularly when the plate voltage is high. The electrons emitted by the regular filament or cathode assume a rather high velocity under the urging of the positively charged plate, and in their hurry to get to the plate they collide with the gas atoms and knock some of their electrons loose. These electrons, being negative charges, are also attracted by the plate and serve to increase the plate current. This effect is known as "ionization by collision."

While it may appear to be helpful because it increases the plate current, it is undesirable because it makes the operation of the tube erratic. If the glass bulb is poorly evacuated the electron flow may be so heavy as to be uncontrollable. Also, it appreciably shortens the life of the tube, because the ions, being left charged positively by the escape of the negative electrons, are attracted violently to the highly negative filament and actually tear away its surface because of their great mass. Ionization in a tube is invariably accompanied by a characteristic bluish glow, although in some tubes a glow may be due to other causes which are not harmful.

Highly evacuated tubes are said to be "hard". Gassy ones are called "soft". With the perfection of pumping equipment, practically all modern vacuum tubes are of the "hard" type. When a tube absorbs gas through microscopic cracks or other causes it is said to have become "soft" or "gassy", and is usually discarded as undependable.

CHAPTER 3

The Three-Electrode Tube

"Grid" Electrode:

In 1907 Dr. Lee de Forest added a third element, called the "grid", to the two-element tube, and produced one of the most useful and versatile devices known to modern science. This grid is merely a helix of fine wire placed between the filament and the plate and completely insulated from both. A single connection wire runs from one end out through the glass. See Fig. 8.

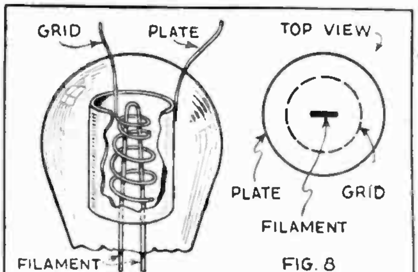


FIG. 8

The three-element tube or "triode" has a grid encircling the filament. This element thus can control the electron stream from the filament to the plate.

Since the grid is open in construction, it does not appreciably obstruct the normal electron flow from filament to plate. However, if it is given an electrical charge it will naturally have some effect on the sensitive electrons. If it is made positive in relation to the filament, it helps to break up the space charge, accelerates the electron stream, and produces an increase in plate current. It also acts as a plate and absorbs a few electrons itself, but since the surface of the thin wire is small, most of the electrons rush right through to the plate, and the grid current (from grid to filament) is infinitesimal compared with the plate current. If the grid is made negative it strengthens the space charge and repels the emitted electrons, causing a decrease in plate current.

Amplification Factor:

The important feature of this three-electrode arrangement is that the grid, being much closer to the filament than the plate, can control the electron stream (and hence the plate current), much more effectively than the plate itself can. A voltage applied to the grid will produce a much greater change in plate current than exactly the same voltage applied to the plate. For instance, let us take a theoretical tube and put two volts on the grid. The plate current increases say four milliamperes over its previous value, with a certain value of plate voltage. To obtain an equal increase in plate current by means of the plate alone, the plate potential must be raised considerably more than two volts. If the tube were a 201A, the increase would have to amount to 16 volts. The ratio of the change in plate potential required to vary the plate current a given amount, to the change in grid voltage to produce the same variation, is called the "voltage amplification factor" of the tube. It is usually represented by the Greek letter "mu." In the case just described the ratio is 16 to 2, or 8 to 1, and the *mu* of the tube is then said to be 8.

Characteristic Curves:

The properties of the three-element tube can best be understood from a study of a set of typical characteristic curves, as shown in Fig. 9. These are

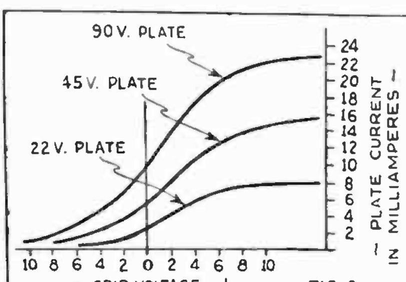
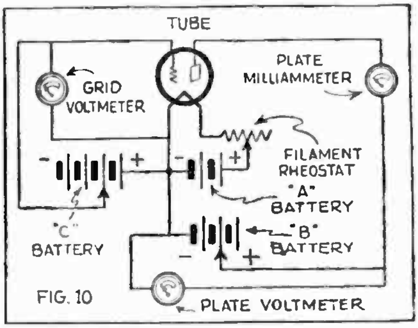


FIG. 9

These typical curves show how the plate current of a three-element tube varies with different grid and plate voltages. Notice how sharply the plate current rises when the grid is made positive.



The curves of Fig. 9 may be obtained quite easily with this circuit. Only three small meters are required, in addition to the usual filament, grid and plate batteries.

easily obtained by connecting the tube in a circuit such as shown in Fig. 10, and simply noting the meter readings as the various voltages are varied. Three curves are shown, for three values of plate voltage, 22, 45 and 90 volts. With the voltages fixed at these values, the grid bias is changed over different positive and negative values, and the curves then indicate the corresponding plate current variations. Notice that when the grid is positive the plate current rises sharply; when it is negative it drops off. There are two distinct bends or "knees" in each curve, one at the top and the other at the bottom. The curves flatten out at the top after a certain positive grid potential or bias is reached, and no further increase of plate current results from further increase of the bias. This condition merely represents saturation. Increasing the bias negatively enough eventually shuts off all the plate current.

Now in radio reception we are interested in doing two things: amplifying the weak signal impulses picked up by the antenna and then detecting them so that they can be heard through earphones or a loud speaker. The three-element tube lends itself admirably to both purposes.

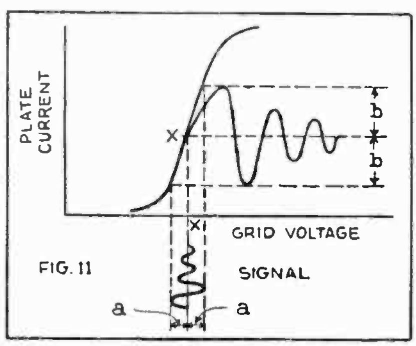
Action as Amplifier:

For use as an amplifier, the tube is simply operated along the straight section of the grid voltage-plate current curve. The action is made plain in Fig. 11. The value X represents the ideal grid bias, as this point on the curve is the center of the straight section. If we now impress the weak signal current having the amplitude a-a on the grid of the tube, the grid bias will be swung back and forth according to the fluctuations of the current. The plate current will fluctuate in exactly the same fashion, as the grid modulates the electron stream perfectly. However, the amplitude of the plate current variations, b-b, will be much greater than the original signal amplitude.

It can be seen that the grid has a "trigger" action, and allows small voltages to control the comparatively large power in the plate circuit.

It is quite possible to connect a whole series of amplifier tubes in a suitable circuit so that the plate current variations of the first one operates the grid circuit of the second, and so on down the line. In this way even a very weak signal can be brought up in strength by the overall repetition effect. Amplifiers are sometimes called "repeaters" because of this successive action. As many as fourteen "stages" of amplification have been used successfully to amplify extremely weak radio-frequency signals.

The frequency of the current fed to the grid of a three-element tube does not affect the amplifying action in the slightest, as the electron stream has no appreciable inertia and responds instantly to both the lowest and the highest frequencies encountered in radio and general communication work. The only limitation in this respect is imposed by



If a three-element tube is operated on the straight section of its characteristic curve, it will faithfully reproduce any alternating current impressed on its grid. The amplitude of the plate current variations represents amplification of the signal.

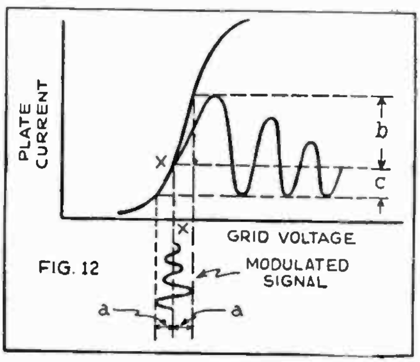
the incidental capacity effect of the tube elements themselves. This will be discussed in the section on screen-grid tubes.

Action as Detector:

After a radio signal has been amplified, it must be "detected" or lowered in frequency so that it will be audible to the human ear through earphones or a loud speaker. Bear in mind that radio waves as they are transmitted are at very high frequencies, much beyond the limit of audibility, which is only about 20 kilocycles. The three-element tube makes an excellent detector if it is operated in either of two connections.

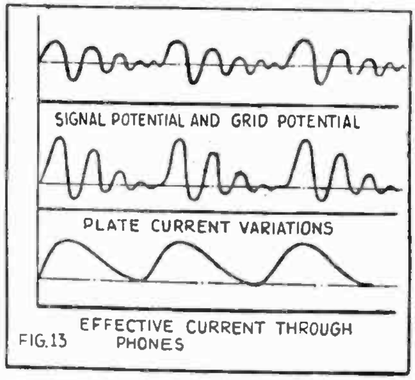
Grid Bias Detection:

The first method is the grid bias method, and is also known as the "power detection" or "plate rectification" system. It depends on the lower bend found in the characteristic curves of all three-element tubes. Refer to Fig. 12, which illustrates the action graphically.



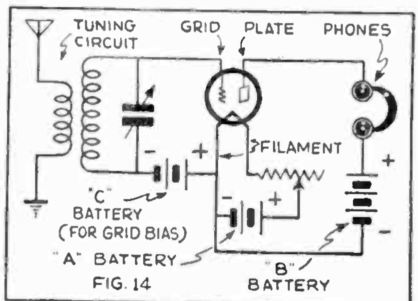
If a three-element tube is operated on the bend or "knee" of its curve, it will tend to amplify one half of the signal wave more than the other. Notice the difference in height between "b" and "c."

If the point X is selected on the curve, and the grid bias adjusted to this point, the plate current will not faithfully reflect the grid voltage variations, but instead will tend to distort them. Suppose we take a modulated signal and impress it on the grid. It has the amplitude a-a, and, of course, like all good alternating currents, the respective alternations on both sides of the zero line are of equal height. Now follow the wave form as it hits the



These three curves illustrate the detecting action of a three-element tube operated in the manner shown in Fig. 12. The little bumps below the time axis are practically eliminated.

curve, and you will observe that the alternations in one direction are amplified considerably in the plate circuit (b), while the other alternations produce only little bumps (c). The effect of every complete cycle of current is then a large increase and a small decrease of plate current. The decreases of current are so small, compared to the increases, that the alternating current is practically rectified, and the current in the plate circuit of the detector tube is then virtually a series of unidirectional pulses. They are still taking place at high frequency, but because of the inertia of the diaphragms of earphones and loud speak-



A typical grid-bias or power detection circuit. In slightly modified form, this is used in the majority of modern broadcast receivers. In A.C. sets the "C" battery is usually replaced by a biasing resistor connected in the plate return lead.

ers, only the peaks of the impulses register. Since these peaks represent the original audio frequency modulation of the high frequency carrier wave, the diaphragm reproduces the sound of the transmitted voice or music. Fig. 13 gives an idea of the current transformation, while Fig. 14 shows an elementary grid bias detection circuit.

Grid Condenser Detection:

The second method of detection is known as the grid condenser method,

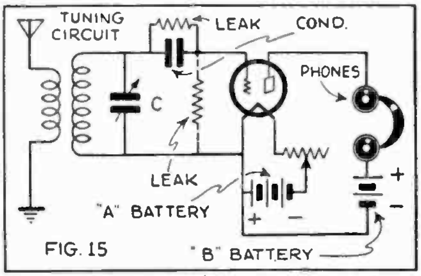


FIG. 15

In the familiar grid-condenser system of detection, a small fixed condenser is connected in the grid lead of the tube, with a resistance of high value added in either of the two positions shown.

and operates in an entirely different manner. In this system a small fixed condenser is connected directly in the grid lead, and the return side of the tuning circuit is brought to the positive side of the "A" battery. A fixed resistance of high value is connected either across the grid condenser or between the grid and the filament of the tube, as shown in Fig. 15. This gives the grid a slight positive bias, and, if the correct value of plate potential is chosen, the tube then operates along the straight section of its characteristic curve.

With no signals being received, the plate current assumes a fixed value, depending, of course, on the filament temperature and the plate voltage.

When actual radio signals from a broadcasting station are tuned in by the tuning circuit, an alternating voltage corresponding to these signals is generated across the tuning condenser C, and naturally flows into the grid circuit of the tube. During a half cycle when the grid is positive it acts like a little plate and attracts some electrons to it. When the current changes its direction and the grid goes negative, the electrons gathered by the grid just an instant before find themselves trapped in the insulated circuit consisting of the grid of the tube and the grid side of the grid condenser. On the next half cycle, when the grid goes positive again, it attracts another little bunch of electrons, and piles them up on the grid condenser along with the previous batch. As the current continues to flow, the grid condenser accumulates more and more electrons, and these tend to make the grid more and more negative in respect to the filament. If they are left piling up like this, they will eventually make the grid so negative that it will cut off all the plate current, and the tube then becomes "choked" and inoperative.

Purpose of the Grid Leak:

The grid "leak" serves the purpose of preventing this undesired accumulation, by giving the entrapped electrons a conducting path to the positive filament. Its value must be such that the electrons have a chance to gather during a single wave train and then discharge in a group, so that the circuit is normal again when the next wave train comes along. If its resistance is too low, the electrons will leak back to filament as quickly as the positive grid attracts them; if it is too high, they

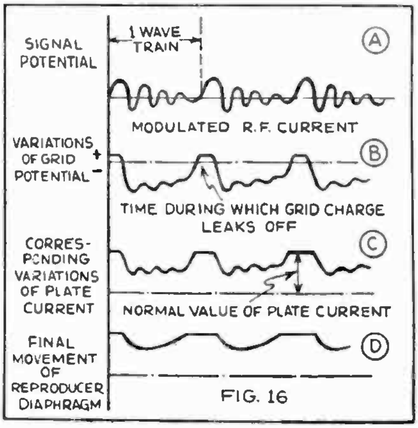


FIG. 16

These curves show how the grid-condenser detector changes modulated radio-frequency signals into audio currents that are capable of operating earphones or other reproducers.

will not leak back quickly enough, and the aforementioned blocking action occurs.

The manner in which this periodic accumulation and discharge of grid electrons effects a detecting action is illustrated graphically in Fig. 16. Here A represents the appearance of a carrier wave modulated by an audio frequency current such as produced by voice or music. B shows how the grid bias is depressed negatively from its normal slightly positive bias by the trapping of the electrons, as described. C shows the corresponding reductions in plate current, with the value returning to normal at the end of each wave train, when the accumulation of electrons is dissipated through the grid leak. As in the grid bias method of detection, the reproducer diaphragm does not respond to the individual little bumps of current, because they are taking place at the high carrier frequency. Instead, each wave train produces a single overall movement, and the net effect of a continuous series of such trains is a reproduction of the original program.

The wave patterns of actual speech or music are very much more complicated than the wave forms shown, but these serve to illustrate the general phenomenon.

Sometimes it is not necessary to provide a grid leak in grid-condenser detectors. If the insulation between the grid and the filament is slightly imperfect, or if there is a tiny trace of gas left in the tube, the grid charges will leak off automatically. However, in most modern tubes both the insulation and the vacuum are so good that grid leaks are usually quite essential to the successful operation of the circuit.

Comparison of Two Methods:

The grid-condenser method is more sensitive than the grid-bias method, because the accumulative effect of the wave train impulses produces a stronger change in plate current, and also because the tube operates on the straight section of its curve and therefore amplifies considerably as well as detects. However, the grid bias method, while not quite as sensitive, has the marked advantage of superior power handling capacity. It will comfortably detect, without distortion, loud signals that would absolutely choke a grid condenser detector. This is why practically all present-day broadcast receivers, which are built for high volume levels, employ grid bias detection in one form or another. In receivers that do not have much preliminary radio-frequency amplification, the grid-condenser detector contributes an appreciable amount of sensitivity.

Audio Frequency Amplification:

If, after detection, the signals are not loud enough, they can readily be amplified further, this time at audio frequency, since all detectors produce only the audio component of the sig-

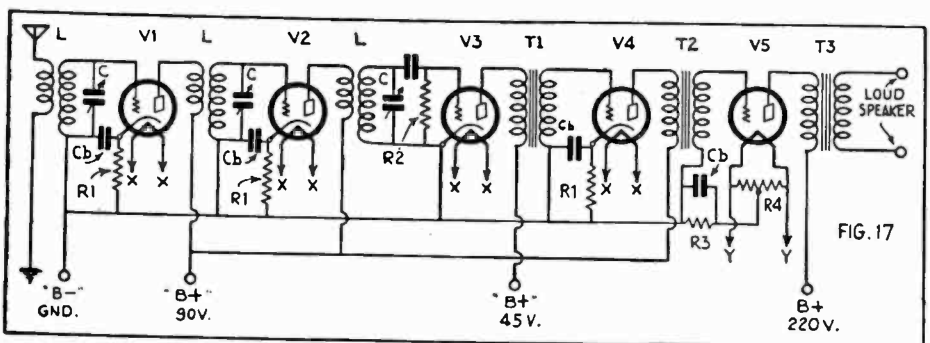


FIG. 17

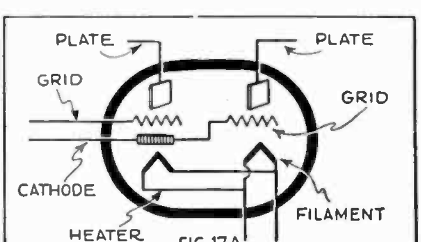
This typical tuned radio-frequency receiver shows the uses of three-element tubes as radio-frequency amplifiers, detector, and audio frequency amplifiers. The various "B" posts are intended for connection to a "B" power pack. Filament leads "X" and "Y" run to a filament light transformer. (Note: this circuit is shown only for purposes of illustration; we do not have constructional data on it.)

nal. One, two or three stages of audio amplification may follow the detector, the circuit being much like the radio frequency amplifier except that different coupling transformers are used.

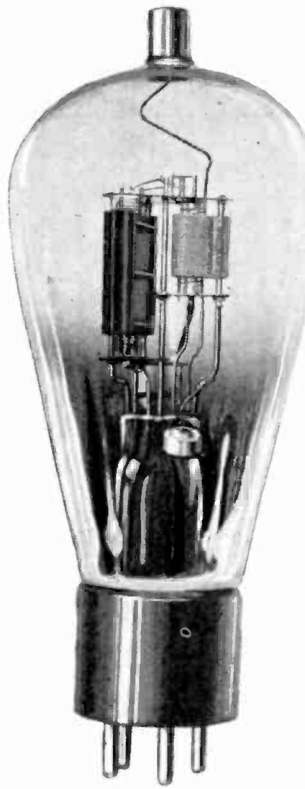
A complete radio receiver of typical construction is shown diagrammatically in Fig. 17. This comprises two stages of tuned radio-frequency amplification, (tubes V1 and V2 and tuning transformers and condensers L and C), a grid condenser detector (V3) and two stages of transformer coupled audio-frequency amplification (tubes V4 and V5 and transformers T1, T2, and T3) Tubes V1, V2 and V4 may be the 227 type, which have heated cathodes as the electron emitters. The filaments, marked X, are all connected in parallel to a 2½-volt winding on a power transformer. Tube V5 may be a 171A, which uses raw a.c. on its filament. The leads Y run to a 5-volt winding.

Obtaining Grid Bias:

Suitable grid bias for V1, V2 and V4 is supplied by the voltage drop across the fixed resistances R1. connected between cathode and ground. The plate current of each tube runs through its respective resistor, so if the grid return lead of each r.f. or a.f. transformer is brought to the bottom end of each resistor, each grid will assume a negative bias in relation to the cathode equal to the voltage drop across the resistor. Since a 227 as an amplifier requires six volts grid bias with 90 volts on the plate, and since the approximate plate current at this voltage is 3 milliamperes (.003 amperes), a simple calculation involving Ohm's Law will show that R1 should be about 2000 ohms. The 171A tube, requiring 40½ volts grid bias at 180 volts plate, uses a similar biasing resistor R3, of about 2025 ohms. Resistance R4 is simply a center-tapped resistance that provides a zero reference point for the grid return to the filament.



In the Triple-Twin tube, the cathode of the first section is connected internally to the grid of the second section.



The Triple-Twin tube resembles an overgrown '45-type. Notice how the two sections are mounted on a common stem.

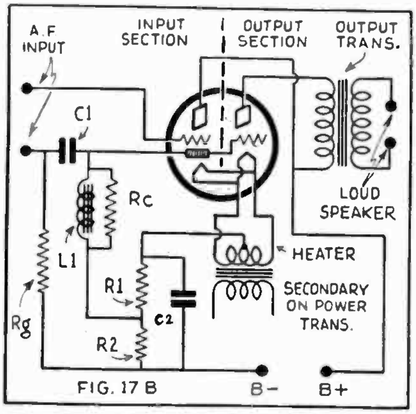
The various fixed condensers Cb are by-pass condensers to provide low impedance paths around the biasing resistors for the r.f. and a.f. currents present in the circuit.

Three-element tubes are made in many different models for different applications. The chart on page 30 lists the types in present day use.

"Triple-Twin" Tube:

A novel tube consisting really of two complete triode assemblies in one glass envelope was brought out a year ago. (Since then additional duo-triodes in a single glass envelope have been developed and are available, such as types 53 and 79.) However, this tube is very interesting and worth mentioning.

The tube looks like an overgrown 224, as it has a cap electrode at the top. Inside, mounted on a single glass stem, are the approximate elements of a 227 general purpose tube and a 245 power output tube, with the cathode of the former connected directly to the grid of the latter, as shown in Fig. 17A. There is no external connection for this grid.



How the Triple-Twin is used as a complete audio amplifier in itself. The circuit is rather unusual and requires careful study and consideration.

Known as the "Triple-Twin" tube this unit is virtually a complete direct coupled audio amplifier by itself, or a combination detector and amplifier. The input tube operates in the usual manner as a detector or amplifier, but the output tube utilizes the *positive* region of the grid voltage-plate current curve. The manufacturers claim this method produces a relatively high undistorted power output indenendent of grid current flow.

An amplifier circuit employing the Triple-Twin tube is shown in Fig. 17B. The input section is normal except that the cathode is above ground potential, and this means that the applied signal voltage is likewise above ground potential. The signal reaches the cathode through condenser C1, of low impedance. The grid of the input tube is properly biased negatively by resistor R2, the d.c. return path to the grid being through resistance Rg. The inductance L1 allows a low resistance d.c. path for the grid and plate returns. Resistance R1 establishes the grid of the output section a few volts negative and is only necessary in a.c. operation to suppress hum. Notice that the grid of the output section receives its bias, and also its energizing signal, from the cathode of the first section.

The action of the circuit combination is rather complicated and a full explanation of it is beyond the scope of an elementary manual. The output tube acts as a regular triode, but it is built in a special manner to provide self-compensation for the flow of grid current when the signal swings the grid positive.

CHAPTER 4
Vacuum Tube Characteristics

The study of vacuum tube characteristics is usually so confused by complicated mathematics that the average student is likely to become discouraged when he attempts to learn something about the subject. While a knowledge of advanced mathematics is exceedingly useful here, as it is in all phases of electricity, a practical understanding of tube operation can be achieved without recourse to trigonometry.

Amplification Factor:

The amplification factor of a tube has already been defined as the ratio of change in plate voltage required to change the plate current a certain amount to the change in grid voltage that produces the same variation.

The amplification factor of a tube depends to a large extent on its mechanical construction. It increases as the grid wires are brought closer together, thus increasing its effective area and giving this electrode greater controlling power over the electrons passing through it. It also increases as the ratio between the plate-filament and the grid-filament distances increases, as the closer the grid to the filament (in comparison to the plate), the more effectively will a small voltage on it retard or aid the electron bombardment of the plate.

The amplification factor of ordinary three-element tubes does not exceed 10, although *mu's* of two or three hundred have been obtained in special experimental tubes having the grid very close to the filament. Changing the mechanical inter-relation of the three elements changes other characteristics besides the amplification factor, and this must always be taken into consideration.

Close spacing of elements makes the assembly operations very difficult, and usually results in lack of uniformity in quantity production. Close spacing also makes a tube very sensitive to mechanical vibration, which manifests itself as a "microphonic" howling or ringing sound. In some sets the tubes are fitted with heavy metal or rubber caps to weight them down and prevent them from vibrating in sympathy with a nearby loud speaker.

The amplification factor of a tube is not a definitely fixed value, but varies slightly with the applied grid and plate voltages.

Plate Impedance:

Plate impedance is the second important characteristic of a tube. This may be understood from the fundamental action of three-electrode tubes, as already explained. When the plate is made positive in relation to the filament, a current of electricity flows through the battery circuit and also through the space between the plate and the filament inside the bulb. The actual amount of current for a given filament temperature depends on the grid bias or potential, as well as on the plate potential. The tube can thus be considered as a variable resistance. The lower the grid bias, the higher the plate circuit resistance; and the higher the bias (in a positive sense) the lower the plate resistance and therefore the greater the plate current. This resistance is known as the "internal resistance" of the tube.

The combination of the straight internal resistance of a tube and the reactance offered by the small condenser formed by the plate and the grid is the *impedance* of that tube. In most tubes this capacity effect of the electrodes is very slight and is noticeable only at very high frequencies. Therefore, for all practical purposes the internal resistance of the tube in ohms is taken as the plate impedance. More accurately, plate impedance may be defined as the change in plate potential in volts divided by the change in plate current in amperes that it produces. Of course the value will be different for different grid and plate voltages, but it is usually measured at the normal voltages used for radio set operation.

Mutual Conductance:

The third important tube constant to be considered is mutual conductance, or "transconductance," as it is now known in engineering circles. The primary purpose of an amplifier tube is to produce a large undistorted change in plate current for a small change in grid voltage. As this action depends on the ratio of the change in grid voltage to the corresponding change in plate current, by comparing these values we arrive at a value which is then known as the "mutual conductance." This is a mathematical ratio which takes into account both the amplification factor and the plate impedance, and is therefore a measure of the operating efficiency of the tube. It is equal to the amplification constant divided by the plate impedance, the resulting quantity being expressed in "mhos." The unit "mho" is the "ohm" spelled backwards, the "conductance" of a material being the reciprocal of its "resistance."

As a general rule, a tube with a high mutual conductance is the best one for amplifying purposes, but of course other considerations such as current consumption, inter-electrode capacity, etc., may also influence the selection of tubes for certain applications.

The relation between amplification factor and mutual conductance is bound to be confusing at first, but becomes clearer after the student has studied the factors carefully and is able to see the difference between the voltage and current variations and their connected effects.

Power Tubes:

The amplification factor indicates only a tube's voltage amplifying characteristic, and tells nothing about its *power* handling capacity. A tube that is used in the last audio amplifier stage of a receiver must deliver actual power to a loud speaker, so that the diaphragm of that instrument may vibrate, set air into motion and reproduce sound. Such a tube should have a low plate impedance, so that the power supplied to the plate circuit will not be wasted in merely overcoming the plate resistance. Most power tubes have this desirable low impedance, but they also have low amplification factors. They must be preceded by one or two amplifier stages using higher mu tubes in order that their full output may be realized.

Mechanically, output tubes differ from general purpose tubes like the 227 in that their filaments, grids and plates are larger and heavier. Since they are used only for audio amplification, the grid-to-plate capacity is of little importance. The plates are usually blackened to aid heat dissipation and reduce secondary emission, and the insulation between the elements is made extra heavy to avoid breakdown under the high voltages used. Power tubes get very hot in normal operation because of the terrific electron bombardment of the plate, and cannot be touched with the fingers after they have been working for more than ten minutes or so. In some of the larger power tubes used for transmitting work it is not uncommon for the plates to glow at a dull red or even a white heat. Such tubes require considerable ventilation. Tubes designed to handle powers of five kilowatts or more are provided with cooling jackets through which cold water must be kept flowing constantly to prevent the elements from melting.

In the "power" class are such tubes as the 112A, 171A, 245, 210, 250, and 231. Power pentodes are described in the next chapter. Among the transmitting tubes of the three-electrode type are the following: the 203A, rated at 75 watts output with 1000 volts on the plate; the 211, with a similar rating; the 852, 75 watts with 2000 volts on the plate; the 204A, 250 watts output with 2000 volts plate; and the 849, 350 watts with 200 volts plate. These are rarely encountered by the average radio man, being used only at amateur and commercial transmitting stations.

CHAPTER 5

Four- and Five-Element Tubes

Space Charge Effects:

The major limiting factor in the amplifying action of three-element tubes is the space charge. This has two undesirable effects: (1) it constantly opposes the attractive effect of the positively charged plate on the electrons; (2) it lowers the amplification factor, since the grid does not have complete control of the electrons flowing through it.

The space charge can be overcome or reduced considerably by the introduction of a positive charge in the tube near the region where it accumulates by simply adding a fourth electrode to the tube which is given a positive charge just like the plate. This new electrode may be placed between the filament and the grid, or between the grid and the plate, and of course must be of open construction, like the grid, so as to let the electrons fly through it.

"Space Charge" Tube:

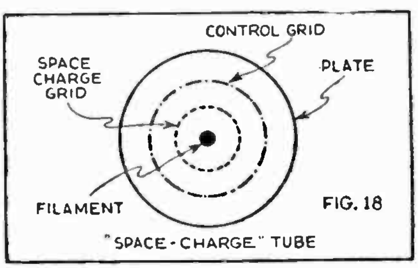
If the second grid is placed between the filament and the present control grid, the new tube thus formed is called a "space charge" grid tube, and has a greatly increased amplification factor, slightly increased plate impedance and about the same grid-to-plate capacity as before. See Fig. 18.

"Screen Grid" Tube:

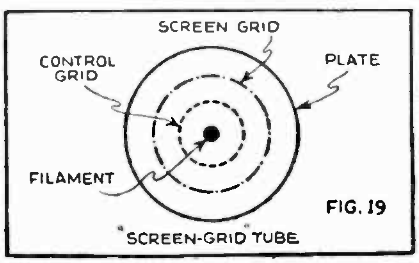
If the second grid is placed between the grid and the plate, the tube is called a "screen-grid" tube. See Fig. 19. In this position also it helps to break up the space charge, increases the effectiveness of the grid control, and therefore raises the amplification constant. It also has another very important effect, and that is a marked reduction in the capacity between the present control grid and the plate. The screen acts as the common plate of *two* small fixed condensers in series, the grid and the plate acting as the other plates. The two condensers being in series, the resultant capacity between the control grid and the plate is smaller than the capacity of either of the two condensers alone. In an ordinary 201A three-element tube the grid-to-plate capacity is something like 10 micromicrofarads; in the 222 screen-grid tube it is only about .025 micromicrofarad. That's quite a difference.

Importance of the Low Tube Capacity:

The great significance of this reduction of grid-to-plate capacity can be understood from a brief consideration of radio-frequency amplifier design. In Fig. 20 we have a typical tuned radio-frequency amplifier using three-element tubes. The capacity effect between the grid and plate elements is represented by the small fixed condensers C. Weak radio signals picked up by the antenna and tuned in by the tuning circuit LC1 have a choice of two paths: (1) the grid-filament circuit, in which they operate the grid properly and cause them-

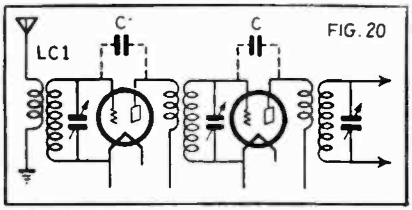


In the space-charge tetrode, the second grid is located between the filament and the regular control grid.



In the screen-grid tetrode, the second grid is situated between the control grid and the plate.

selves to be amplified by the tube; (2) the condenser C. Naturally any current that goes through C is not amplified by the tube, which loses just that much effectiveness.



The fixed condensers C represent the grid-to-plate capacity of ordinary three-element tubes. This capacity effect becomes very serious as the frequency of the radio signals goes up (as the wavelength goes down).

The extent of the by-passing of C depends on its own capacity in relation to the wavelength or frequency of the signal current. Since the reactance of a condenser varies *inversely* with the frequency of the current applied to it, the reactance of C will become lower and more current will pass through it as the signal frequency goes up (wavelength goes down).

The capacity C also provides a medium for the feed-back of energy from the plate circuit to the grid circuit, resulting in uncontrollable oscillation, heterodyne whistling, distortion and further loss of amplification. In early tuned r.f. amplifiers it was necessary to overcome these bad effects by "neutralizing" the tube capacity by various complicated methods, which at best allowed the circuits to realize only a fraction of the full amplification of which the tubes were capable.

This capacity effect, by the way, explains why some radio receivers seem to work just as well with the r.f. tubes turned *off*. The capacity exists all the time by virtue of the mere mechanical juxtaposition of the grid and the plate. Whether the filament is lighted or not makes no difference.

Since the grid-to-plate capacity of the screen-grid tube is comparatively small, no neutralizing of any kind is needed even on a wavelength as low as 5 meters, whereas with three-electrode tubes such neutralization is necessary even on 400 meters. The screen-grid tube has found widespread use as a radio-frequency amplifier for this reason. It is also an excellent detector, operating on the grid condenser methods.

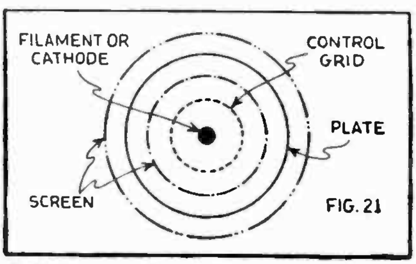
Comparatively little use is made of the space-charge tube, except as an audio amplifier in some special circuits. The main advantage of the second grid is in making the tube a better radio-frequency amplifier. Incidentally, any screen-grid tube can be used as a space-charge tube if the present control grid is given a positive charge and the screen grid then operated with a negative bias as the control grid.

In its commercial form the screen-grid tube uses either a filament, for battery operation, or a heated cathode, for a.c. operation, and the second grid or screen takes the shape of a double element completely surrounding the plate. See Fig. 21. The connection for control grid is brought out to a cap on the top of the glass bulb, so as to minimize the capacity effect between it and the connections of the other elements.

The usual grid pin in the base is the screen-grid terminal.

The voltage applied to the screen is usually a fraction of that applied to the plate. Since the screen acts like a plate and attracts electrons, there is a screen current, but this is very small because the screen is of open construction and presents only a limited surface. Besides, the electrons broken out of the space charge by the screen are attracted *through* the screen by the much higher positive charge on the plate.

Among the tubes in the screen-grid class are the following: the 222, which was the first four-electrode tube on the American market, and is now more or less obsolete; the 224, of the heated cathode type, for use on a.c.; the 232,



Relative location of the elements in an actual commercial screen-grid tube. The screen element completely surrounds the plate, thus shielding it thoroughly from the control grid.

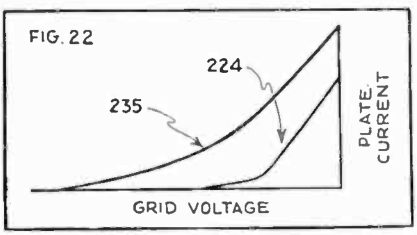
a two-volt battery tube with a regular filament; and the 236, a battery type tube using a heated cathode instead of a filament. The 224A has recently replaced the 224, from which it differs only in that its cathode heats to operating temperature more quickly.

Variable-Mu Tube:

One of the disadvantages of the 224 screen grid tube is its inability to handle strong signals. Its characteristic grid voltage-plate current curve is very steep, and if the signal is very strong it is likely to swing the plate current down to the bend of the "knee," resulting in grid-bias detection, and subsequent distortion on one half of the current cycle. Interference from neighboring stations sometimes also causes "cross-talk" on a desired station because of this same effect.

The trouble has been largely overcome by the introduction of a new type of screen-grid tube known as the "variable mu," in which either the control grid or the screen-grid is of somewhat uneven construction and gives the tube a varying amplification constant or *mu* as incoming signals necessitate making the control grid more and more negative. With weak or medium signals the tube has the same *mu* as a regular 224, but with stronger signals that would overload a 224 the amplification factor drops automatically and the tube *remains* operating on a straight section of its grid voltage-plate current curve. As long as the operating point is on a straight section no detecting action can take place and the signal is amplified just as it should be.

Two types of variable mu tubes have been introduced, the 551 and the 235. The 551 is much like the 224 and can be substituted for it with only a slight change in the grid bias; its range of control grid bias is more than twice that of the 224. The 235 has more than double the plate current of the 224 and only about half the plate resistance, which makes greater amplification per stage practical. It is not interchangeable with the 224, but in new sets it is replacing it almost entirely for amplification purposes. The "tailing" of the characteristic curve of the 235 and 551 makes these tubes poor grid bias detectors, the 224, with its more abrupt bend, being much better. An idea of the comparative curvatures of the 224 and 235 characteristics may be obtained from Fig. 22.



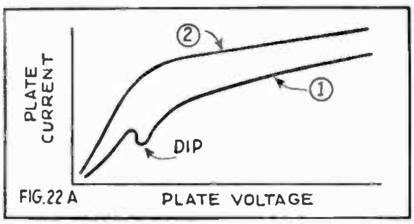
These curves show the difference in characteristics between the regular '24 screen-grid tube and the special '35 variable-mu type. Note the gradual slope and wider grid voltage range of latter.

Power Pentode:

The power output of the four-element tube or tetrode* is limited by a factor known as secondary emission, which was mentioned in Chapter 1. With the electron stream to the plate strengthened and accelerated by the breaking up of the space charge by the screen grid electrode, the bombardment becomes so heavy that the surface of the plate itself begins shooting off electrons. If the plate voltage is low the plate does not have sufficient attraction to pull them back, and they fly instead to the positively charged screen-grid, at the same time repelling other electrons away from the plate and causing a drop in plate current. This dip is illustrated by curve 1 of Fig. 22A, which shows the relation of plate voltage to plate current in a typical four-electrode tube.

To prevent the secondary electrons

*Diode, two electrodes; triode, three electrodes; tetrode, four electrodes; pentode, five electrodes.



The dip in the plate-voltage, plate current curve of screen-grid tubes is due to the secondary emission effect of the plate. This dip is eliminated in the "pentode" by the third grid element.

from aiding the space charge, a fifth element in the form of a third grid is added to the tube, between the present screen grid and the plate. This is connected back to the center of the filament, which, being at ground potential, prevents the loose electrons from passing further. The connection is made inside the tube, as shown in Fig. 23. The third or "suppressor" grid removes the plate current dip, as shown in curve 2 of Fig. 22A.

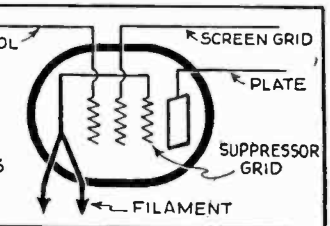


FIG.23

Arrangement of the electrodes in the pentode. The third grid, known as the "suppressor grid," is connected internally to the center of the filament, and has no external terminal.

This five-element tube, or "pentode", is a very useful device for audio amplification. In comparison with a triode of the same plate dissipation or power, it is capable of producing greater power output with less signal input. It has both high amplification factor and power capacity, which neither the triode nor the tetrode has by itself. A power pentode may be connected directly after a detector tube without the usual first stage of amplification, and will furnish plenty of volume for loud speaker operation. It is most valuable in receivers in which space is limited, since it eliminates one tube and its associated equipment.

Pentodes are now available for 2-volt and 6-volt battery service and for alternating current. The 233, the 2-volt tube, and the 247, the a.c. tube, use filaments as the electron emitters; the 238, one of the so-called "automobile" tubes, uses a heated cathode.

R.F. Pentode:

A suppressor grid may be added to a regular screen-grid amplifier tube to produce advantages similar to those obtained in the audio power tubes. This has been done in the new 239 tube, which belongs in the 6.3 volt "auto" family and has been designed especially for operation on low plate voltages. It combines the variable mu and the pentode features, and has particularly high mutual conductance. As in the 235 tube, the variable mu action is obtained by a control grid having uneven pitch or spacing between turns.

The advantages of the 239 over the 236, which it is intended to replace, are greater output for the same input, better control of volume on strong signals, and elimination of cross talk interference. As this tube is extensively used in power AF stages of battery and auto radio receivers, characteristic data is herewith given; more complete data will be found in the charts beginning on page 30.

Type 239

Variable-Mu R.F. Pentode

Purpose: radio-frequency amplifier

Base: UY

Dimensions: 4$\frac{11}{16}$" long, 1$\frac{9}{16}$" in diameter

Cathode Type: Heater

Cathode Rating: 6.3 volts, 0.3 ampere, D.C.

Plate Voltage: 90 to 135 (180 maximum)

Screen Voltage: 90

Control Grid Bias: 3 volts

Plate Current: 4.5 milliamperes

Screen Current: 1.7 milliamperes

Plate Impedance: 300,000 to 680,000 ohms

Amplification Factor: 285 to 700

Mutual Conductance: 950 to 1050 micromhos

Mutual Conductance at 40 volts control grid bias: 1 micromho.

Screen Grid Transmitting Tubes:

There are three screen-tubes in the transmitting class, finding use mostly in short-wave stations because of their low inter-electrode capacity. These are the 865, having an output of 7½ watts; the 860, rated at 75 watts; and the 861, rated at 500 watts.

CHAPTER 6

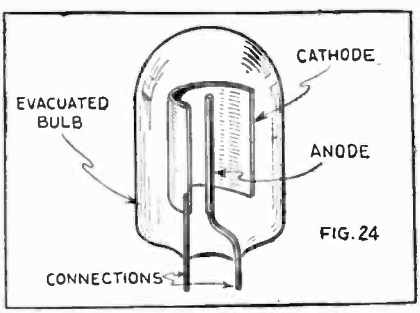
Light-Sensitive Cells and Other Special Tubes

Photoelectric Cell:

For many duties in industry the human eye is being replaced by an indefatigable electric eye—the photoelectric cell. Wide application has been made of this remarkable device, particularly in television and talking motion pictures, for counting objects passing a fixed point, detecting smoke, controlling illumination, and countless other purposes.

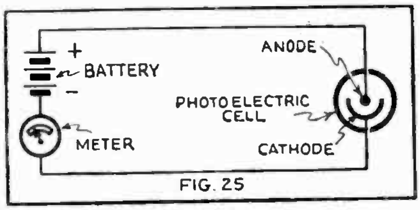
Light-sensitive cells have been known for a long time, but only recently have they achieved any widespread commercial use. Their application was formerly limited by their fragility and general unreliability, but they have been so greatly improved during the last three or four years that they are now entirely reliable. Because they are invariably used in conjunction with ordinary vacuum tube, and properly belong in the vacuum tube family, their theory and operation should be understood by every radio man.

A photoelectric cell is a light-sensitive device which, when connected to a circuit of proper voltage, permits a current to flow only when the cell is illuminated by a suitable source. The typical photoelectric cell, as shown in Fig. 24, is quite simple in construction, consisting merely of an anode and a cathode sealed in an evacuated bulb,



The photo-electric cell is a very simple device, consisting merely of a cathode coated with a light-sensitive material, and an anode to attract the liberated electrons. In some types, the cathode is a metallic deposit on the inside of the glass bulb.

or in one filled with gas at a low pressure. The cathode is a metal plate coated with a material that has the property of emitting electrons when light falls on it, while the anode is a bare conducting wire. An alkali metal like sodium, potassium, rubidium or caesium is used to form the sensitive cathode surface. In some cells the light sensitive coating is deposited on the inside of the glass containing bulb.



The circuit of the photo-electric cell is very similar to that of the two-element rectifier. The anode is made positive to accelerate and attract the electrons from the cathode.

Caesium is commonly used at present because it is more sensitive to the red end of the color spectrum than the other alkalis.

The operation of the cell may easily be understood from Fig. 25, which shows a simple photoelectric cell circuit. When light falls on the cell, the cathode liberates some electrons, just as the filament of an ordinary radio tube does. Since the plate is charged positively by a battery, it will accelerate and attract the electrons, and the meter will indicate a current flow, corresponding to the plate current of a radio tube. The stronger the light the greater the electron emission and the higher the current flow.

There are two general types of photoelectric cells: vacuum and gas filled. In the vacuum type, the glass bulb is evacuated as thoroughly as possible, and the current flow between cathode and anode is due purely to the electrons freed from the cathode surface. In the second type, the tube is filled with a gas at a low pressure. The maximum current which can flow is much greater than that represented by the electron emission alone, for ionization by collision takes place (See Chapter 2). The presence of the gas increases the current flow as much as ten times.

There are many variables in photoelectric cell structure which affect the characteristics. Briefly, they are: (1) the kind of light sensitive material; (2) the process of manufacture; and (3) the kind of gas and its pressure. The final characteristics of a cell d pend on the combination of these factors as arranged by the designer. Cells can be made sensitive only to certain sections of the light spectrum, for special purposes. Some cells respond only to ultra violet or infra-red. The majority of cells are designed to respond to light in the visible region of the spectrum and hence are the most suitable for most applications.

The response of a photoelectric cell to variations of light falling on it is instantaneous, the electron stream being without appreciable inertia.

Even in the most sensitive photoelectric cells the current flow is exceedingly small, possibly only a few microamperes. To make the current variations useful, they must be amplified considerably. Ordinarily multi-stage audio-frequency amplifiers are employed for this purpose when all the fine graduations of light must be translated into electrical energy, as in television systems. For many industrial purposes a special type of amplifier known as the "grid glow" tube is used. This differs from standard amplifiers in that it operates only when the illumination on the photoelectric cell, and hence the controlling current, reaches or drops below a certain point. Such a tube is virtually an electronic relay and is used to control power circuits and the like. An example of the application of a photoelectric cell and grid-glow tube combination is a factory or street lighting control system, wherein overhead lights are turned on as the natural lights grow dim, or are turned off as the daylight becomes brighter.

New applications for the photoelectric cell spring up daily. The following are only a few: sorting of cigars, beans, eggs, and various other kinds of foodstuffs according to color; counting of automobiles or pedestrians past a fixed point; recording of smoke density; control of baking or roasting processes; recording the thickness of various materials such as paper, wire, etc.

Other Light-Sensitive Cells:

There are other light-sensitive devices, such as the selenium tube and the electrolytic cell, but these are not as flexible as photoelectric cells and are rarely used except for laboratory experiments. Selenium is a material that changes in *resistance* when a light falls on it, just as a telephone transmitter changes in resistance when sound waves impinge on it. It is sluggish in action and not at all as dependable as vacuum tubes. The electrolytic cell, employing a light-sensitive liquid solution, has obvious mechanical disadvantages.

Neon Tube:

For the reproduction of television images, a device known as the neon glow tube is used. This consists of two flat metal plates mounted parallel to each other and about $\frac{1}{16}$ inch apart, inside a glass bulb filled with neon gas. See Fig. 26. When connected in a direct current circuit a reddish pink glow, characteristic of the gas neon, covers the entire surface of one of the plates. The usual neon tubes employed in television receivers glow properly at about 135 volts, passing about 15 milliamperes. Their plates are about 1¼" square.

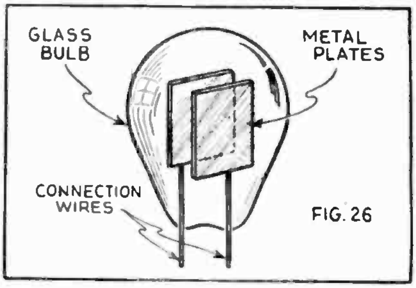
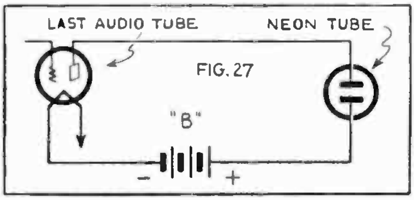


FIG. 26

The neon tube used for television reception consists merely of two flat metal plates, separated a short distance in a bulb filled with neon gas.

The neon tube is connected in the plate circuit of the last audio tube of the television receiver, just like a loud speaker. See Fig. 27. It is kept illuminated by the direct plate current, but flickers in accordance with the variations of the television signals. The scanning disc, rotating in front of the bulb (in a plane parallel to the plates), reconstructs the transmitted image. It should be clearly understood that while the flickering takes place over the entire surface of the plates, only a tiny section at a time is exposed to view by the holes in the scanning disc.



The neon tube is connected in the plate circuit of the last amplifier tube just like a loud speaker. It is illuminated by the normal plate current of the tube, to which it must be matched carefully for proper operation.

Neon tubes are used for television work because, like other radio tubes, they have no appreciable time lag and respond instantly to any changes of current through them. Ordinary electric lights have a much greater brilliancy, but there is no simple means of modulating them at audio frequencies. Considerable research work is being done on television glow lamps, as none of the available types are entirely satisfactory.

Other Special Tubes:

The "phanotron" is a gas vapor content vacuum tube. The name applies to gas or vapor tubes regardless of the number of electrodes or their nature. In practice it most often indicates a two-element rectifier. The "thyratron," which has recently been put to considerable industrial use, is a phanotron with three electrodes, a filament or other electron emitter, a grid and a plate. The word "thyratron" is derived from the Greek term meaning "door," and this tube is essentially a grid controlled arc rectifier.

A phanotron rectifier consists of two electrodes, an anode (or plate) and a cathode, mounted in an exhausted container in which there is a partial atmosphere of inert gas or vapor. The partial atmosphere is usually the vapor pressure of a quantity of mercury, although it is sometimes a gas like argon, neon or helium.

As explained in Chapters 1 and 2, in a high vacuum tube the current is limited by the supply of electrons emitted by the cathode, and by the electron space charge around the cathode. In the phanotron the cathode supplies the electron flow, but the space charge is neutralized by the ionization of the vapor or gas. (The ionization by collision effect, once more.) This results in a low voltage drop across the tube —only about 15 volts for mercury vapor—which is practically independent of current. Therefore a phanotron can rectify and carry much heavier currents than a high vacuum tube of corresponding dimensions.

An experimental type of mercury vapor rectifier intended to replace the standard high vacuum 280 has been released by at least one tube manufacturer. When substituted for a 280 in an existing power pack the output voltages are higher and the current carryin capacity considerably greater.

The Thyratron:

The thyratron is a phanotron with a grid control. This apparently makes the tube a regular triode, but the action of the thyratron grid is quite different from that of the triode grid. The grid controls only the starting of the internal discharge. After starting, it cannot modulate, limit or extinguish it, as can the grid of an ordinary triode. The ionization of the gas vapor not only overcomes the space charge, but also tends to neutralize the controlling charge on the grid. To allow the grid to regain control after the plate current has started to flow, a prohibitive grid charge is required. The plate voltage must be reduced to practically zero or made negative enough for the gas or vapor to become deionized. Once this deionization takes place the grid resumes control.

If alternating current is applied to the plate, the grid has an opportunity to regain control once during each cycle, and can delay the starting of the arc for as long a period during the subsequent positive half cycle as the grid voltage is sufficiently negative. This means that the grid can control the average current flowing through the tube and that this averaging can be made as "fine grained" as desired by increasing the frequency of interruption.

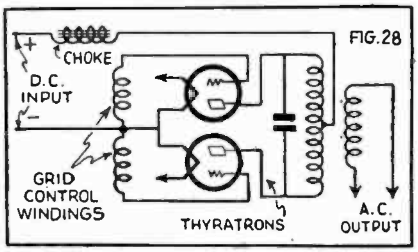
If the grid as well as the plate is supplied with alternating current, the phase relation between the grid and the plate naturally determines the amount of average current flowing through the tube.

The voltage conditions for starting the current depend largely on the structural design of the tube. A tube may be designed so that within the normal plate voltage limits the current always starts at a negative grid voltage, or always at a positive grid voltage, or at a negative voltage for high plate voltages and a positive voltage for low plate voltages. The ability of the tube to directly control large amounts of current without intermediate mechanical devices makes it extremely valuable for a variety of purposes.

Thyratron Inverter:

One of the most interesting uses of the thyratron is for the conversion of direct current into alternating current —just the reverse of its normal function. Direct current is applied to the plates and the grids are supplied with the desired frequency, either by an external exciter or by means of coupling to the output circuit. In this respect the thyratron inverter may be considered as an amplifier or an oscillator, respectively. The function of the tubes is to commutate, or perform a switching operation. In all inverters some form of power storage is necessary in order to supply power during the commutation period. This may be in the form of static condensers, a power system or in rotating apparatus.

The fundamental action of thyratron inverters may be illustrated by the simple single phase arrangement of Fig. 28. The plates of both tubes are positive. Assume that the grid of the upper tube is positive. Current will flow from the positive d.c. source through the transformer to the negative d.c. line by way of this tube. The grid of the lower tube is negative and allows no current to pass. The condenser is charged with the potential drop across the output transformer due to the cur-



This odd circuit shows how thyratron tubes are used to convert direct current into alternating current.

rent flow in the upper half of the winding, the upper terminal becoming negative and the lower positive. Toward the end of the cycle the grids exchange polarity. This has no direct effect on the current flow through the first tube, but allows current to flow through the second, which in effect connects the lower side of the condenser to the negative lead. This places a negative voltage of short duration on the upper plate, allowing the upper grid to regain control.

A number of types of thyratron tubes have been developed. They range in current capacity from 1 to 75 amperes and in voltage from 1000 to 20,000. A special tube capable of passing several hundred amperes has been made. This stands almost three feet high!

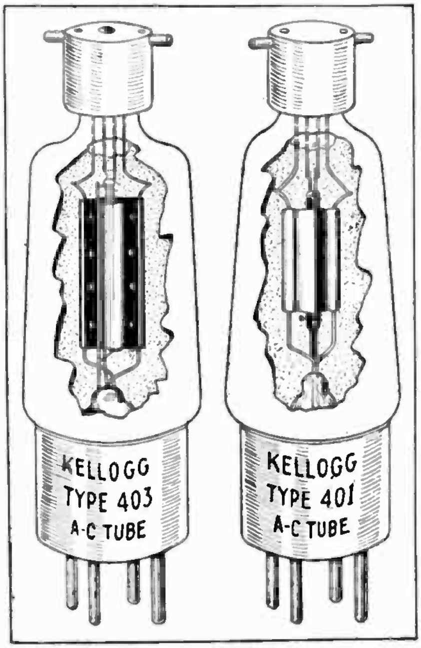
Special Overhead Heater Tubes

Overhead Heater Tube:

In all standard American receiving tubes the filament or heater connections are made through two of the pins in the base. Several years ago, however, an a.c. tube having the heater connections to a separate cap on the *top* of the glass achieved considerable popularity, and is still being used in many broadcast receivers. The appearance of this "overhead heater" tube is shown in the accompanying illustration. A special double-contact cap snaps over the top of the tube, the various caps in a set being joined by a flexible cable.

As the overhead heater tubes have characteristics different from those of standard tubes, the following charts should be consulted if the reader encounters the tubes in service work.

Service Men who encounter receivers using these tubes should take particular note of their filament voltage, which is *three* volts. Do not attempt to replace them by tubes of the 227 type unless you reduce the filament voltage with series resistors.



Average Characteristics Type 401

General Purpose Detector, Radio and Audio Amplifier Tube

Heater voltage—3.0 volts. Heater current—1.0 amp.

Plate voltage	45*	90		135		180	
Negative grid bias	0	4.5	6.0	7.5	9.0	10.5	12.0
Plate current (milliamperes)	3.8	3.7	2.5	5.3	3.9	7.2	5.8
Plate impedance (ohms)	9060	10750	13300	9520	11700	9330	10500
Amplification factor	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Mutual conductance (Micromhos)	1100	930	750	1050	850	1070	952
Power output† (milliwatts)		20	25	65	75	135	165

*For use as detector only using grid leak and condenser detection.

†The values given for output represent undistorted output or output of negligible distortion. These values are for optimum load resistance or a load resistance of approximately twice the tube impedance.

Average Characteristics Type 403

Power Amplifier for Last Audio Stage

Heater voltage—3.0 volts. Heater current—1.5 amps.

Plate voltage	135	180
Negative grid bias	27	40
Plate current (milliamperes)	15	20
Plate impedance (ohms)	2500	2500
Amplification factor	3.0	3.0
Mutual conductance (micromhos)	1200	1200
Power output* (milliwatts)	360	660

*The values given for output represent undistorted output or output of negligible distortion. These values are for optimum load resistance or a load resistance of approximately twice the tube impedance.

Filament Resistor Values for Two-Volt Tubes

Fixed Resistance Values for Two Volt Filament Tubes

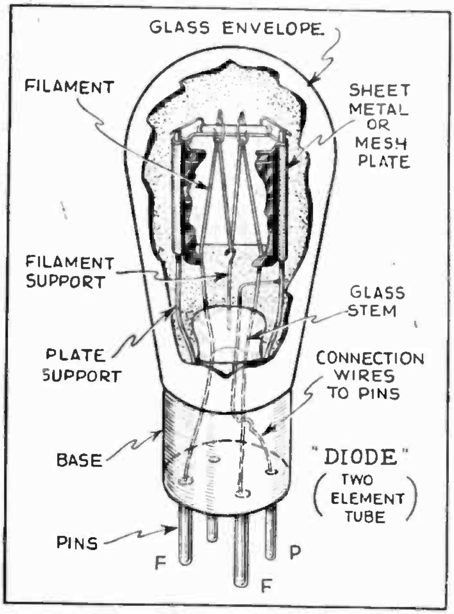
Number of CX-330's or CX-332's	Two Dry Cells (3.0V.)		Two Edison Cells (2.8V.)	
	1 CX-331	2 CX-331's	1 CX-331	2 CX-331's
1	4.2 ohms	2.5 ohms	3.2 ohms	1.9 ohms
2	3.2 "	2.1 "	2.4 "	1.6 "
3	2.6 "	1.8 "	1.9 "	1.4 "
4	2.2 "	1.6 "	1.6 "	1.2 "
5	1.9 "	1.4 "	1.4 "	1.1 "
6	1.6 "	1.3 "	1.2 "	1.0 "
7	1.5 "	1.2 "	1.0 "	0.9 "

Note: No resistances are needed when using a single cell storage battery

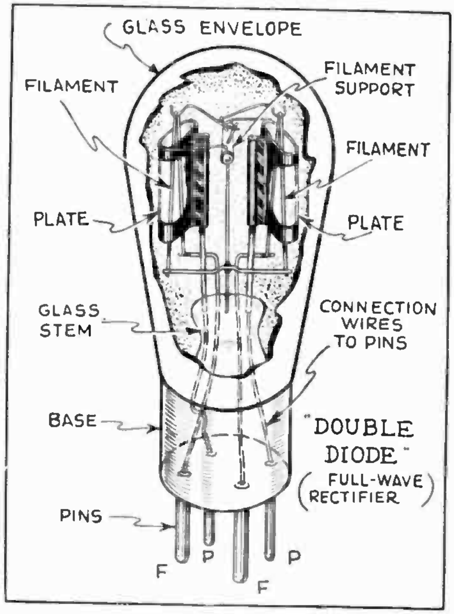
Rheostat Values for Two Volt Filament Tubes—(Minimum)

Number of CX-330's or CX-332's	Two Dry Cells (3.0V.)		Two Edison Cells (2.8V.)	
	1 CX-331	2 CX-331's	1 CX-331	2 CX-331's
1	6 ohms	5 ohms	5 ohms	3 ohms
2	5 "	3 "	4 "	2.5 "
3	4 "	3 "	3 "	2 "
4	3 "	2 "	2.5 "	1.8 "
5	3 "	2 "	2 "	1.5 "
6	2.5 "	2 "	1.8 "	1.5 "
7	2 "	1.5 "	1.5 "	1.3 "

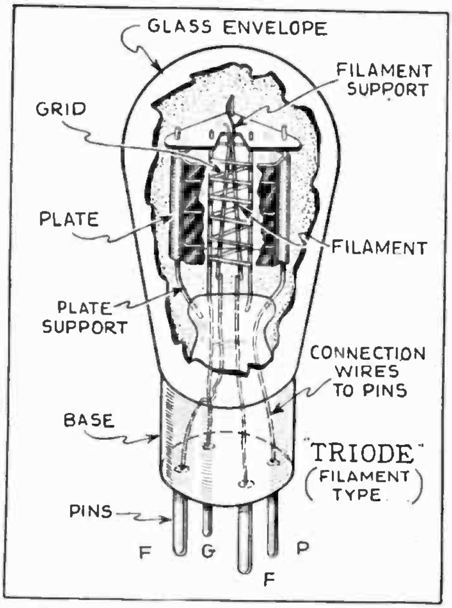
"Exploded" Views of 2- and 3-Element Tubes



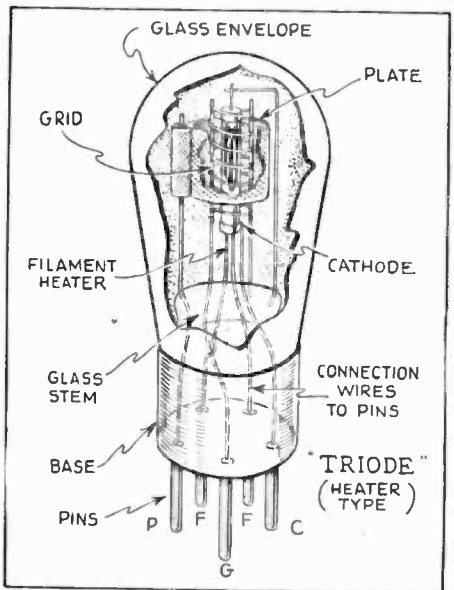
The commonest form of the diode or two-element tube is the 281 half-wave rectifier. Other diodes, built on a smaller scale, are used for detecting purposes.



The double diode consists simply of two sets of diode elements. The 280 is the most familiar tube of this type. Similar tubes are used for detection in some special super-heterodynes.

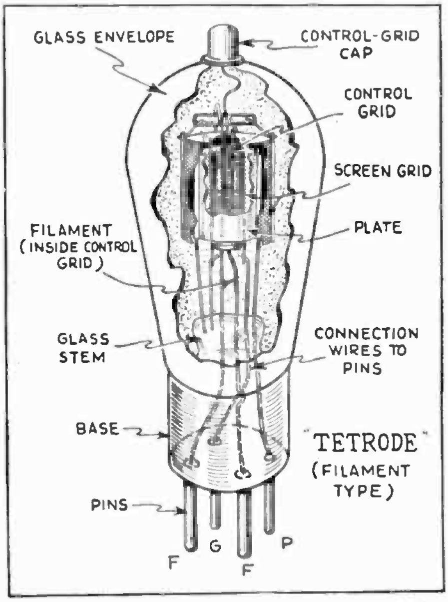


The triode or three-element tube is radio's "jack of all trades": amplifier, detector and oscillator. In this class are the 112A, 120, 171A, 201A, 226, 230, 245, etc.

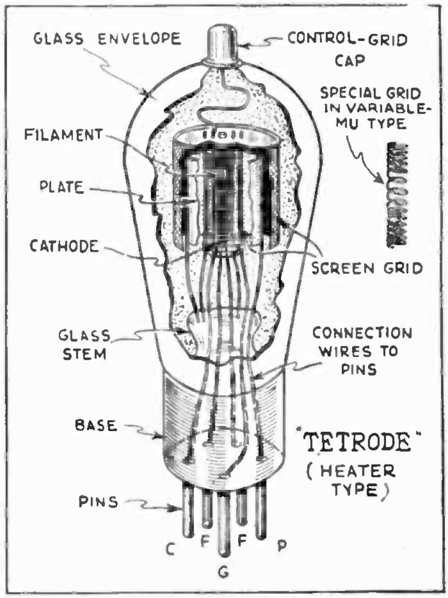


The triode with a heated cathode is the well-known 227. For purposes of heat radiation the plate in some makes is close mesh instead of sheet metal. Notice the filament inside the cathode.

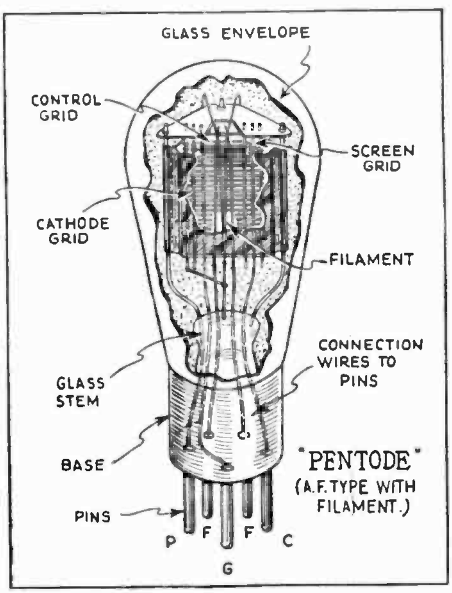
"Exploded" Views of 3- and5- Element Tubes



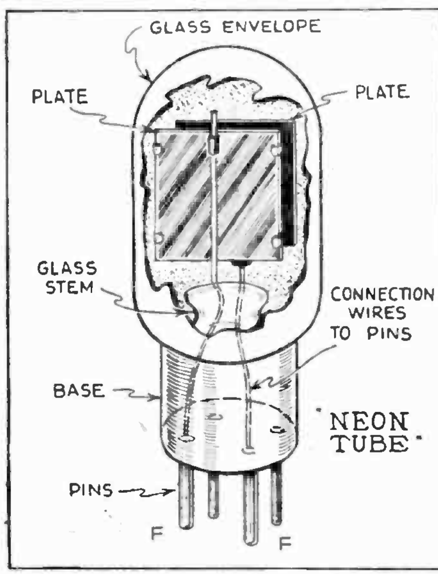
The tetrode or four-element (screen-grid tube has two grids in addition to the filament and plate. Note that the screen-grid completely encircles the plate. The 222 and 232 are in this class.



The tetrode with a heated cathode is the popular 224 screen-grid tube. An identical construction is used in the 236. In the 235 variable-mu type the control grid has uneven pitch, as shown.



The pentode or five-element tube has three grids. The cathode or suppressor grid, located between the screen grid and the plate, is connected internally to the center of the filament.



The neon tube used for television reception has two identical plates mounted parallel to each other and separated about 1/16 inch. The tube is filled with neon gas.

AVERAGE CHARACTER-

DETECTORS, AMPLIFIERS

6.3 Volt Group for

These Tubes Are Employed Chiefly in AC - DC or

Type	Use	Base	Bulb (See illustration)	Cathode Type	Rating: Filament Amps.	Rating: Plate (Max.) Volts	Rating: Screen (Max.) Volts	Plate Volts
6A4/LA	Power Amp.	5-3	ST-14	Filament	0.30	180	180	135
								165
								180
6A7	Det. Osc.	7-2	ST-12C	Heater	0.30	275	100	250
6B7	RF or IF Amp.	7-3	ST-12C	Heater	0.30	275	125	100
								180
								250
6B7	AF-Amp.	7-3	ST-12C	Heater	0.30	275	125	250‡‡
6C6	RF	6-1	ST-12C	Heater	0.30	275	100	250
6C6	Det.	6-1	ST-12C	Heater	0.30	275	100	250*
6C6	AF	6-1	ST-12C	Heater	0.30	275	90	250*
6D6	RF	6-1	ST-12C	Heater	0.30	275	100	250
6D6	AF	6-1	ST-12C	Heater	0.30	275	90	250*
36	RF	5-2	ST-12C	Heater	0.30	275	90	90
								135
								180
								250
36	Det.	5-2	ST-12C	Heater	0.30	275	90	250
37	Det. Amp.	5-1	ST-12	Heater	0.30	180	...	90
								135
								180
38	Power Amp.	5-2	ST-12C	Heater	0.30	180	180	135
39	RF	5-2	ST-12C	Heater	0.30	275	90	90
								135
								180
								250
39	AF	5-2	ST-12C	Heater	0.30	275	90	250*
41	Power Amp.	6-3	ST-12	Heater	0.40	200	200	125
								167.5
								180
*42	Power Amp.	6-3	ST-14	Heater	0.65	275	275	250
44	RF	5-2	ST-12C	Heater	0.30	275	90	90
								180
								250
44	AF	5-2	ST-12C	Heater	0.30	275	90	250*
75	Det.	6-4	ST-12C	Heater	0.30	275	...	250
77	RF	6-1	ST-12C	Heater	0.30	275	100	250
77	Det.	6-1	ST-12C	Heater	0.30	275	100	250*
78	RF	6-1	ST-12C	Heater	0.30	275	125	180
								250
								250
79	Power Amp.	6-5	ST-12C	Heater	0.60	180	...	180
								180
85	Det.	6-4	ST-12C	Heater	0.30	275		250
89	Power Amp.	6-1	ST-12C	Heater	0.40	180	180	160
								163
								180
								180

*Applied through 250.000 ohms. **Triode connection. ‡Pentode connection. ¶Plate to plate.
**Applied through 200,000 ohms. ‡‡For two tubes with 40 volts RMS applied to each grid.

ISTICS OF RADIO TUBES

AND RECTIFIERS

AC or DC Operation

DC Receivers, Auto Sets, Amplifiers, or in Special Model Receivers

Negative Grid Volts	Screen Volts	Plate Current ma.	Plate Resistance Ohms	Mutual Conductance Micromhos	Amplification Factor	Ohms for Stated Power Output	Undistorted Power Output Milliwatts
9.0	135	14.0	52,600	1,900	100	9,500	700
11.0	165	20.0	48,000	2,100	100	8,000	1,200
12.0	180	22.0	45,000	2,200	100	8,000	1,400
3.0	100	4.0	300,000	475△	....	....	....
3.0	100	5.8	300,000	950	285	....	....
3.0	75	3.4	1 Meg.	840	840	....	....
3.0	100	6.0	800,000	1,000	800	....	....
4.5	50	0.65	......	......	....	....	....
3.0	100	2.0	1,500,000+	1,225	1,500+	....	....
6.0	100	Plate curre	nt to be adj	usted to 0.	1 ma. wi	th no Inp	ut Signal
1.0	50	0.5	3 Meg.	600	1,800	....	....
3.0	100	8.2	800,000	1,600	1,280	....	....
3.0	75	0.5	1,500,000	600	900	....	....
1.5	55	1.8	250,000	850	215	....	....
1.5	67.5	3.0	300,000	1,050	315	....	....
3.0	90	3.1	350,000	1,050	370	....	....
3.0	90	3.4	400,000	1,100	440	....	....
6.0	20 to 45	Plate curre	nt to be adj	usted to 0.	1 ma. wi	th no Inp	ut Signal
6.0	....	2.5	11,500	800	9.2	17,500	30
9.0	....	4.1	10,000	925	9.2	14,000	80
13.5	....	4.3	10,000	900	9.2	20,000	175
13.5	135	9.0	102,000	975	100	13,500	525
3.0	90	5.6	375,000	960	360	....	....
3.0	90	5.6	540,000	980	530	....	....
3.0	90	5.8	750,000	1,000	750	....	....
3.0	90	5.8	1,000,000	1,050	1,050	....	....
1.0	67.5	0.5	2 Meg.	......	....	....	....
10.0	125	11.0	100,000	1,525	150	11,000	650
12.5	167.5	17.0	85,000	1,800	150	9,500	1,250
13.5	180	18.5	81,000	1,850	150	9,000	1,500
16.5	250	34.0	100,000	2,200	220	7,000	3,000
3.0	90	5.6	375,000	960	360	....	....
3.0	90	5.8	750,000	1,000	750	....	....
3.0	90	5.8	1 Meg.	1,050	1,050	....	....
1.0	67.5	0.5	2 Meg.	......	....	....	....
2.0	....	0.8	91,000	1,100	100	....	....
3.0	100	2.3	1,500,000+	1,250	1,500	....	....
7.0	100	Plate Curre	nt to be adj	usted to 0.	1 ma. wi	th no Inp	ut Signal
3.0	75	4.0	1,000,000	1,110	1,100	....	....
3.0	100	7.0	800,000	1,450	1,160	....	....
3.0	125	10.5	600,000	1,650	990	....	....
0.0	....	7.5	......	......	No Sign	al Applie	d
0.0	....	44.0†	Class B	Operation	....	7,000¶	5,500
20.0	....	8.0	7,500	1,100	8.3	20,000	350
20.0	160**	17.0	3,000	1,570	4.7	7,000	300
17.0	163‡	17.0	79,000	1,575	125	9,000	1,250
18.0	180‡	20.0	82,500	1,635	135	8,000	1,500
0	....	3.0	Class B	Operation	....	9,400¶	3,500††

†50 volts RMS applied to two grids.
△Conversion Conductance.

(Courtesy, Hygrade Sylvania Corp.)

2.5 VOLT GROUP FOR

In this group are listed tubes that are more commonly used. They will be found in most of the up-to-date a.c. receivers, with a few possible exceptions where the tube is designed for such special work, that it may be only employed in such equipment or apparatus.

The 59 or 2A3, are examples that may be placed in this category; although the latter type is employed in some very large and expensive receivers to deliver large power outputs to obtain tremendous volume levels. The 59, however, is almost always used exclusively in audio amplifiers for power amplification purposes, and either as a single class A

Type	Use	Base	Bulb (See illustration)	Cathode Type	Rating			Plate Volts
					Filament Amps.	Plate (Max.) Volts	Screen (Max.) Volts	
2A3	Power Amp.	4-1	ST-16	Filament	2.5	275	...	250 300
2A5	Power Amp.	6-3	ST-14	Heater	1.75	275	275	250
2A6	Det.	6-4	ST-12C	Heater	0.80	250	...	250
2A7	Det. Osc.	7-2	ST-12C	Heater	0.8	275	100	250
2B7	RF or IF Amp.	7-3	ST-12C	Heater	0.8	275	125	100 180 250
2B7	AF-Amp.	7-3	ST-12C	Heater	0.8	275	125	250‡‡
24-A	RF	5-2	ST-14C	Heater	1.75	275	90	180 250
24-A	Det.	5-2	ST-14C	Heater	1.75	275	90	250*
24-A	AF	5-2	ST-14C	Heater	1.75	275	90	250*
27	Amp.	5-1	ST-12	Heater	1.75	275	...	90 135 180 250
27	Det.	5-1	ST-12	Heater	1.75	275	...	250
35	RF	5-2	S-14C	Heater	1.75	275	90	180 250
35	AF	5-2	S-14C	Heater	1.75	275	90	250*
45	Power Amp.	4-1	ST-14	Filament	1.50	275	...	180 250 275
46	Power Amp.	5-4	S-17	Filament	1.75	400	250	250 300 400
47	Power Amp.	5-4	S-17	Filament	1.75	275	275	250
51	Amplifier	5-2	S-14C	Heater	1.75	275	90	180 250
55	Det.	6-4	ST-12C	Heater	1.00	275	...	250
56	Amp.	5-1	ST-12	Heater	1.00	275	...	250
56	Det.	5-1	ST-12	Heater	1.00	275	...	250
57	RF	6-1	ST-12C	Heater	1.00	275	100	250
57	Det.	6-1	ST-12C	Heater	1.00	275	100	250*
57	AF	6-1	ST-12C	Heater	1.00	275	90	250*
58	RF	6-1	ST-12C	Heater	1.00	275	100	250
58	AF	6-1	ST-12C	Heater	1.00	275	90	250*
59	Power Amp.	7-1	ST-16	Heater	2.00	275	275	250 250 400

*Applied through 250,000 ohms. **Triode connection. ‡Pentode
‡‡Applied through 200,000 ohms. ††For two tubes with 40

AC OR DC OPERATION

tube to drive two 59's in push-push or class B operation, or in either of the above as a final stage for large power outputs.

The 2B6 Tube

This tube is not described in the listing below. It is a duplex triode that has numerous features that enables it to be employed as a class B amplifier tube with the advantages of the high quality found in class A systems.

Full data pertaining to this tube will be found in the September, 1933 issue of Radio Craft magazine. Pertinent data regarding circuit applications, complete characteristic curves, resistor values to employ, etc., are all included.

Negative Grid Volts	Screen Volts	Plate Current ma.	Plate Resistance Ohms	Mutual Conductance Micromhos	Amplification Factor	Ohms for Stated Power Output	Undistorted Power Output Milliwatts
45.0	....	60.0	765	5,500	4.2	2,500	3,500
62	....	40 per tub	e Push Pull	......	....	3,000¶	15,000
16.5	250	34.0	100,000	2,200	220	7,000	3,000
2.0	....	0.8	91,000	1,100	100	....	....
3.0	100	4.0	300,000	475△	....	....	....
3.0	100	5.8	300,000	950	285	....	....
3.0	75	3.4	1 Meg.	840	840	....	....
3.0	100	6.0	800,000	1,000	800	....	....
4.5	50	0.65	......	......	....	....	....
3.0	90	4.0	400,000	1,000	400	....	....
3.0	90	4.0	600,000	1,050	630	....	....
5.0	20 to 45	Plate curre	nt to be ad	justed to 0.	1 ma. wit	h no Inp	ut Signal
1.0	25	0.5	2,000,000	500	1,000	....	....
6.0	....	2.7	11,000	820	9.0	14,000	30
9.0	....	4.5	9,000	1,000	9.0	13,000	80
13.5	....	5.0	9,000	1,000	9.0	18,700	165
21.0	....	5.2	9,250	975	9.0	34,000	300
30.0	....	Plate Curre	nt to be ad	justed to 0.	2 ma. wi	th no Inp	ut Signal
3.0	90	6.3	300,000	1,020	305	....	....
3.0	90	6.5	400,000	1,050	420	....	....
1.0	45.0 to 67.5	0.5	2 Meg.	......	....	....	....
31.5	....	31.0	1,650	2,125	3.5	2,700	825
50.0	....	34.0	1,610	2,175	3.5	3,900	1,600
56.0	....	36.0	1,700	2,050	3.5	4,600	2,000
33.0	250	22.0	2,380	2,350	5.6	6,400	1,250
0.0	0	4.0	Class B	Operation	....	5,200	16,000††
0.0	0	6.0	Class B	Operation	....	5,800	20,000††
16.5	250	31.0	60,000	2,500	150	7,000	2,700
3.0	90	4.5	300,000	1,020	305	....	....
3.0	90	6.3	400,000	1,050	420	....	....
20.0	....	8.0	7,500	1,100	8.3	20,000	350
13.5	....	5.0	9,500	1,450	13.8	....	....
20.0	....	Plate curre	nt to be ad	justed to 0.	2 ma. wi	th no Inp	ut Signal
3.0	100	2.0	1,500,000+	1,225	1,500+	....	....
6.0	100	Plate curre	nt to be ad	justed to 0.	1 ma. wi	th no Inp	ut Signal
1.0	50	0.5	3 Meg.	600	1,800	....	....
3.0	100	8.2	800,000	1,600	1,280	....	....
3.0	75	0.5	1,500,000+	600	900	....	....
28.0	250**	26.0	2,400	2,600	6.0	5,000	1,250
18.0	250‡	35.0	4,000	2,500	100	6,000	3,000
0.0	....	13.0	Class B	Operation	....	6,000'	20,000††

connection. ¶Plate to plate. †50 volts RMS applied to two grids.
volts RMS applied to each grid. △Conversion Conductance.

SPECIAL

Some of the tubes listed here are employed in the older models of battery or d.c. receivers only. These include the following types that are listed, the 01A, 12A, 22, X99, V99, and the 00A. The type 26 tube is a heavy-filament tube whose construction made it adaptable for a.c. operation in sets that were manufactured several years ago. Many of these early a.c. receivers performed excellently and are still in use, although this tube has been replaced by the 27 and screen-grid types that are much more efficient. The 485, 182B, and 183 are special tubes designed for replacement in Sparton receivers. Complete data on all of the tubes that are employed in Sparton receivers is given in a chart on pages 38-39.

Type	Use	Base	Bulb	Cathode Type	Filament Rating			Plate Volts
					Volts	Amps.	Supply	
00-A	Det.	4-1	S-14	Filament	5.0	0.25	DC	45
01-A	Det. Amp.	4-1	S-14	Filament	5.0	0.25	DC	90 135
10	Power Amp.	4-1	S-17	Filament	7.5	1.25	AC or DC	250 350 425
12-A	Det. Amp.	4-1	S-14	Filament	5.0	0.25	DC	90 135 180
18	Power Amp.	6-3	ST-14	Heater	14.0	0.30	AC or DC	250
20	Power Amp.	4-1	T-8	Filament	3.3	0.132	DC	90 135
22	RF	4-2	S-14	Filament	3.3	0.132	DC	135 135
26	Amp.	4-1	ST-14	Filament	1.5	1.05	AC or DC	90 135 180
40	Amp.	4-1	S-14	Filament	5.0	0.25	DC	135 180
43	Power Amp.	6-3	ST-14	Heater	25.0	0.30	AC or DC	95 135
48	Power Amp.	6-3	ST-14	Heater	30.0	0.40	AC or DC	95 125
50	Power Amp.	4-1	S-21	Filament	7.5	1.25	AC or DC	300 350 400 450
71-A	Power Amp.	4-1	ST-14	Filament	5.0	0.25	AC or DC	90 135 180
X-99	Det. Amp.	4-1	T-8	Filament	3.3	0.063	DC	90
V-99	Det.	4-4	T-8	Filament	3.3	0.063	DC	90
485	Det. Amp.	5-1	S-14	Heater	3.0	1.25	AC	90 120
182-B	Power Amp.	4-1	S-17	Filament	5.0	1.25	AC	250
183	Power Amp.	4-1	S-17	Filament	5.0	1.25	AC	250 250
864	Det. Amp.	4-1	T-9	Filament	1.1	0.25	DC	90 135

TUBES

Power Tubes

The 210, and 250, are tubes that are employed essentially for power amplification purposes, although the former is also used extensively as an oscillator or generator of high frequency currents (transmitters), where small power output is required.

The 43 is a power tube that is employed extensively in midget receivers. The data given for this tube will show numerous interesting features that make it particularly useful for adaptation in receivers of the a.c.-d.c. type.

Special Purpose Tube

The 864, because of its small glass envelope and other proportionately low dimensions, is generally employed as a pre-amplifier (AF) in "head" amplifiers where compactness is essential. It may be, and is, used as an RF amplifier, or for detection.

Negative Grid Volts	Screen Volts	Plate Current ma.	Plate Resistance Ohms	Mutual Conductance Micromhos	Amplification Factor	Ohms for Stated Power Output	Undistorted Power Output Milliwatts
Grid Return Fil.	....	1.5	30,000	666	20.0	....	....
4.5	....	2.5	11,000	725	8.0	11,000	15
9.0	....	3.0	10,000	800	8.0	20,000	55
22.0	....	10.0	6,000	1,330	8.0	13,000	400
31.0	....	16.0	5,150	1,550	8.0	11,000	900
39.0	....	18.0	5,000	1,600	8.0	10,200	1,600
4.5	....	5.0	5,400	1,575	8.5	5,000	30
9.0	....	6.2	5,100	1,650	8.5	9,000	115
13.5	....	7.7	4,700	1,800	8.5	10,650	260
16.5	250	34.0	100,000	2,200	220	7,000	3,000
16.5	....	3.0	8,000	415	3.3	9,600	45
22.5	....	6.5	6,300	525	3.3	6,500	110
1.5	45.0	1.7	725,000	375	270	....	....
1.5	67.5	3.7	325,000	500	160	....	....
7.0	....	2.9	8,900	935	8.3	....	....
10.0	....	5.5	7,600	1,100	8.3	....	....
14.5	....	6.2	7,300	1,150	8.3	....	....
1.5	....	0.2	150,000	200	30	....	....
3.0	....	0.2	150,000	200	30	....	....
15.0	95	20.0	45,000	2,000	90.0	4,500	900
20.0	135	34.0	35,000	2,300	80.0	4,000	2,000
20.0	95	47.0	10,000	2,800	28.0	2,000	1,600
22.5	100	50.0	10,000	2,800	28.0	2,000	2,500
54.0	....	35.0	2,000	1,900	3.8	4,600	1,600
63.0	....	45.0	1,900	2,000	3.8	4,100	2,400
70.0	....	55.0	1,800	2,100	3.8	3,670	3,400
84.0	....	55.0	1,800	2,100	3.8	4,350	4,600
16.5	....	10.0	2,170	1,400	3.0	3,000	125
27.0	....	17.3	1,820	1,650	3.0	3,000	400
40.5	....	20.0	1,750	1,700	3.0	4,800	790
4.5	....	2.5	15,500	425	6.6	15,500	7
4.5	....	2.5	15,500	425	6.6	15,500	7
3.0	....	5.0	10,800	1,150	12.5	....	....
4.0	....	6.0	9,300	1,350	12.5	....	....
35.0	....	18.0	3,330	1,500	5.0	4,500	1,750
58.0	....	20.0	2,000	2,000	3.0	4,500	2,000
65.0	....	26.0	1,500	2,000	3.0	....	....
4.5	....	2.9	13,500	610	8.2	....	....
9.0	....	3.5	12,700	645	8.2	....	....

2.0 VOLT GROUP—FOR BATTERY OPERATION

Type	Use	Base	Bulb (See illustration)	Cathode Type	Rating: Filament Amps.	Rating: Plate (Max.) Volts	Rating: Screen (Max.) Volts	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current ma.	Plate Resistance Ohms	Mutual Conductance Micromhos	Amplification Factor	Ohms for Stated Power Output	Undistorted Power Output Milliwatts
15	Det. Osc.	5-2	S-12C	Heater	0.22	135	67.5	135	1.5	67.5	1.85	800,000	625	500	....	....
19	Power Amp.	6-6	ST-12	Filament	0.26	135	....	135	0.0	....	27.0†	Class B	Operation	....	10,000¶	2,100
30	Det. Amp.	4-1	ST-12	Filament	0.06	180	....	90	4.5	....	2.5	11,000	850	9.3	....	....
								135	9.0	....	3.0	10,300	900	9.3	....	....
								180	13.5	....	3.1	10,300	900	9.3	....	....
31	Power Amp.	4-1	S-12	Filament	0.13	180	....	135	22.5	....	8.0	4,100	925	3.8	7,000	185
								180	30.0	....	12.3	3,600	1,050	3.8	5,700	375
32	RF	4-2	S-14C	Filament	0.06	180	67.5	135	3.0	67.5	1.7	950,000	640	610	....	....
								180	3.0	67.5	1.7	1,200,000	650	780	....	....
32	AF	4-2	S-14C	Filament	0.06	180	67.5	180*	3.0	67.5	....	1,200,000	650	780	....	....
32	Det.	4-2	S-14C	Filament	0.06	180	67.5	180	6.0	67.5	Plate current to be adjusted to 0.2 ma. with no Input Signal					
33	Power Amp.	5-3	S-14	Filament	0.26	135	135	135	Approx. 13.5	135.0	14.5	50,000	1,450	70.0	7,000	700
34	RF	4-2	S-14C	Filament	0.06	180	67.5	67.5	3.0	67.5	2.7	400,000	560	224	....	....
								135	3.0	67.5	2.8	600,000	600	360	....	....
								180	3.0	67.5	2.8	1,000,000	620	620	....	....
34	AF	4-2	S-14C	Filament	0.06	180	67.5	180*	1.0	22.5 to 45.0	....	....	....	....	....	....
49	Power Amp.	5-3	ST-14	Filament	0.12	180	...	180	0.0	....	4.0	Class B	Operation	2 Tubes	12,000¶	3,500

*Applied through 250,000 ohms. ¶Plate to Plate. †50 volts RMS applied to two grids.

RECTIFIERS

INDICATED PLATE VOLTAGE DESIGNATES RMS VOLTS PER PLATE

1-V	Half Wave	4-7	ST-12	Heater	6.3	0.3	AC or DC	250	....	....	50	......	......	....	....	....
5Z3	Full Wave	4-5	ST-16	Filament	5.0	3.0	AC	500	....	....	250	......	......	....	....	....
12Z3	Half Wave	4-7	ST-12	Heater	12.6	0.3	AC or DC	230	....	....	60	......	......	....	....	....
25Z5	Voltage Doubler	6-7	ST-12	Heater	25.0	0.3	AC or DC	125	....	....	100	......	......	....	....	....
80	Full Wave	4-5	ST-14	Filament	5.0	2.0	AC	350	....	....	125	......	......	....	....	....
								400	....	....	110	......	......	....	....	....
								550	....	....	135	With choke Input only			....	....
81	Half Wave	4-6	S-19	Filament	7.5	1.25	AC	700	....	....	85				....	....
82	Full Wave	4-5	S-14	Filament	2.5	3.0	AC	500	....	....	125	......	......	....	....	....
83	Full Wave	4-5	ST-16	Filament	5.0	3.0	AC	500	....	....	250	......	......	....	....	....
84	Full Wave	5-5	ST-12	Heater	6.3	0.5	AC or DC	225	....	....	50	......	......	....	....	....
866	Half Wave	4-3	S-19C	Filament	2.5	5.0	AC	7500	....	....	600	......	......	....	....	....

Interchangeable Tube Chart

The purpose of this Chart is to furnish information as to which types of SYLVANIA SET TESTED TUBES will satisfactorily replace tube types of other manufacturers having similar, or different, type designations.

As a rule, the last two digits of a type number are the designating numerals. In interchanging tubes, this rule may be followed except on special types and on tubes recently announced, bearing the new RMA system of type numbers. Except on Special Types all Sylvania tubes heretofore designated by a symbol and three numerals have been changed to conform to later designations. For example, SX-201A is now 01A, SY-227 is now 27, et cetera. Many of the Sylvania tubes recently introduced bear type numbers assigned under the new RMA system, which is characterized by a letter appearing between two digits (Example: 5Z3). The first digit indicating the filament voltage class, the letter being assigned arbitrarily, and the second digit indicating the number of useful elements in the tube.

Type No.	Description	Replace with Sylvania Type
'00-'00A	Special Detector	00A
'01-'01A-'01AA	Detector-Amplifier	01A
1-KR1	Mercury Rectifier	1-V
2	Ballast	*
G-2	Special Detector	*
3	Ballast	*
4	Ballast	*
G-4	Special Detector	*
5	Ballast	*
KR5	Power Amplifier	6A4
6	Ballast	*
7	Ballast	*
8	Ballast	*
9	Ballast	*
'10	Power Amplifier	10
WD-11	Detector-Amplifier	*
'12-'12A	Power Amplifier	12A
WD-12	Detector-Amplifier	*
'13	Full-wave Rectifier	80
14	Detector-Amplifier	*
15	Detector-Oscillator	15
'16-'16B	Half-wave Rectifier	81
17	Detector-Amplifier	*
18	Power Amplifier	18
19	Class B Amplifier	19
'20	Power Amplifier	20
KR20	Special Detector	*
'22	Amplifier	22
KR22	Special Detector	*
'24-'24A	Detector-Amplifier	24A
KR25	Power Amplifier	2A5
25S	Detector-AVC	*
'26	Amplifier	26
'27	Detector-Amplifier	27
'27HM	High Mu Amplifier	56
28	General Purpose	*
29	Special Detector	29
'30	Detector-Amplifier	30
'31	Power Amplifier	31
'32	Amplifier	32
'33	Power Amplifier	33
'34	Amplifier	34
'35	Amplifier	35 or 51
'36-'36A	Detector-Amplifier	36
'37-'37A	Detector-Amplifier	37
'38-'38A	Power Amplifier	38
'39-'39A	Amplifier	39 or 44
'40	Voltage Amplifier	40
41	Power Amplifier	41
42	Power Amplifier	42
43	Power Amplifier	43
44	Detector-Amplifier	44 or 39
'45	Power Amplifier	45
46	Power Amplifier	46
'47	Power Amplifier	47
48	Power Amplifier	48
49	Power Amplifier	49
'50	Power Amplifier	50
'51	Amplifier	51 or 35
52	Class B Amplifier	*
53	Class B Amplifier	53
55	Detector-AVC	55
56	Detector-Amplifier	56
57	Detector-Amplifier	57
57A-S	Detector-Amplifier	6C6
58	Amplifier	58
58A-S	Amplifier	6D6
59	Power Amplifier	59
59B	Power Amplifier	*
64-64A	Detector-Amplifier	36‡
65-65A	Amplifier	39‡
67-67A	Detector-Amplifier	37‡
68-68A	Power Amplifier	38‡
69	Special Detector	69
70	Detector-AVC	*
'71-'71A-'71B	Power Amplifier	71A
75	Detector-AVC	75
76	Detector-Amplifier	76
77	Detector-Amplifier	77
78	Amplifier	78
79	Class B Amplifier	79
'80	Full-wave Rectifier	80
80M	Full-wave Rectifier	83
'81-81M	Half-wave Rectifier	81
82	Full-wave Rectifier	82
83V	Full-wave Rectifier	83 or 5Z3
83	Full-wave Rectifier	83
84	Full-wave Rectifier	84
G84	Half-wave Rectifier	*
85	Detector-AVC	85
88	Full-wave Rectifier	83†
89	Power Amplifier	89
90	Special Detector	*
91	110 Volt Converter	*
92	Special Detector	*
95	Power Amplifier	2A5
96	Half-wave Rectifier	*
98	Full-wave Rectifier	84
'X99	Detector-Amplifier	X99
'V99	Detector-Amplifier	V99
1A6	Detector Oscillator	1A6
2A3	Power Amplifier	2A3
2A3H	Power Amplifier	2A3
2A5	Power Amplifier	2A5
2A6	Detector-AVC	2A6
2A7	Detector-Oscillator	2A7
2B6	Power Amplifier	*
2B7	Detector-Amplifier	2B7
5Z3	Full-wave Rectifier	5Z3
6A4	Power Amplifier	6A4
6A7	Detector-Oscillator	6A7
6B7	Detector-Amplifier	6B7
6C6	Detector-Amplifier	6C6
6C7	Detector	*
6D6	Amplifier	6D6
6D7	RF Amplifier	*
6E7	RF Pentode	*
6F7	Detector-Oscillator	6F7
6Y5	Full-wave Rectifier	*
6Z3	Half-wave Rectifier	1-V
6Z4	Full-wave Rectifier	84
6Z5	Full-wave Rectifier	*
12A5	Power Amplifier	12A5
12A7	Rectifier—Amplifier	*
12Z3	Half-wave Rectifier	12Z3
14Z3	Half-wave Rectifier	12Z3
25Z3	Half-wave Rectifier	*
25Z5	Voltage Doubler	25Z5
182B	Power Amplifier (Sparton)	182B
183	Power Amplifier (Sparton)	183
211	Power Amplifier	211
257	Amplifier	*
291	Triple Twin Tube	*
293	Triple Twin Tube	*
295	Triple Twin Tube	*
401	Amplifier (Sparton)	*
402	Amplifier (Sparton)	*
482A	Power Amplifier (Sparton)	71A
482B	Power Amplifier (Sparton)	182B
483	Power Amplifier (Sparton)	183
484	Detector-Amplifier (Sparton)	485
485	Detector-Amplifier (Sparton)	485
486	Detector-Amplifier (Sparton)	*
585	Power Amplifier (Sparton)	50
586	Power Amplifier (Sparton)	50
P-861	Full-wave Rectifier	84
864	Detector-Amplifier	264 or 864
866	Half-wave Rectifier	866
874	Voltage Regulator	*
876	Ballast Tube	*
886	Ballast Tube	*
985	Auto Rectifier	*
986	Full-wave Rectifier	83†
AD	Half-wave Rectifier	1-V
AF	Full-wave Rectifier	82
AG	Full-wave Rectifier	83
BA	Special Rectifier	*
BH	Special Rectifier	*
BR	Special Rectifier	*
GA	Power Amplifier	*
LA	Power Amplifier	6A4
PZ	Power Amplifier	47
PZH	Power Amplifier	2A5
Wunderlich	Special Detector	*

*Indicates types not directly interchangeable with Sylvania Set Tested Tubes.

‡Only when used in Auto Receivers or AC Receivers not having series filament.

†When receiver's transformer will stand one ampere additional filament current.

NOTE:—When interchanging several spray shield tubes in a receiver, it will be necessary to equip the receiver with metal tube shields.

SPARTON TUBE

These data are supplied with the intention of supplying a dearth of characteristics or specifications of tubes that are employed in Sparton receivers. It is conceded by Service Men that replacement tubes for these sets are generally difficult to obtain; or else, because of the special nature of these tubes, they are priced considerably higher than standard types. A careful study of those tubes will show that the differences are slight, and that with a few minor changes in the receiver's circuit—standard type tubes that are readily available—can be readily adapted. Not all of the tubes listed are different from stand-

GENERAL								DETECTION		
Type	Base	Use	Filament Heater Supply	Maximum Overall Dimensions Height	Maximum Overall Dimensions Diam.	Filament Terminal Voltage	Filament Current Amperes	Detector Plate Voltage	Grid Return Lead to	Detector Plate Current Milli-Amperes
181	Side Pin, 4-Prong	Power Amplifier	A.C. or D.C.	5⅝"	2 [illegible]"	5.0	1.25			
601	Side Pin, 4-Prong	Detector or Amplifier	A.C. or D.C.	5"	1¾"	3.0	1.35	45	Cath.	2
401-A	Standard, 4-Prong	Detector or Amplifier	D.C.	4 [illegible]"	1 [illegible]"	5.0	.25	45	+F	1.5
410	Standard, 4-Prong	Power Amplifier	A.C. or D.C.	5⅝"	2 [illegible]"	7.5	1.25			
412-A	Standard, 4-Prong	Detector or Amplifier	D.C.	4 [illegible]"	1 [illegible]"	5.0	.25	45	+F	1.5
412-A	Standard, 4-Prong	Power Amplifier	A.C. or D.C.	4 [illegible]"	1 [illegible]"	5.0	.25			
484	Standard, 5-Prong	R.F. Amp. or Detector	A.C. or D.C.	5¼"	1 [illegible]"	2.5	1.75	90—180	Cath.	1.0
484	Standard, 5-Prong	Audio Freq. Amplifier	A.C. or D.C.	5¼"	1 [illegible]"	2.5	1.75			
426	Standard, 4-Prong	Amplifier	A.C. or D.C.	4 [illegible]"	1 [illegible]"	1.5	1.05			
427	Standard, 5-Prong	Detector or Amplifier	A.C. or D.C.	4 [illegible]"	1 [illegible]"	2.5	1.75	180	Cath.	.5
430	Standard, 4-Prong	Detector or Amplifier	D.C.	4⅛"	1 [illegible]"	2.0	.06	45	+F	1.5
431	Standard, 4-Prong	Power Amplifier	D.C.	4⅛"	1 [illegible]"	2.0	.13			
432	Standard, 4-Prong	Radio Freq. Amplifier	D.C.	5¼"	1 [illegible]"	2.0	.06			
482	Standard, 5-Prong	Pentode Power Amplifier	D.C.	4 [illegible]"	1 [illegible]"	2.0	.26			
485	Standard, 5-Prong	Detector Amplifier	A.C. or D.C.	5⅛"	1 [illegible]"	2.5	1.75	250	Cath.	1.0—3.0
436	Standard, 5-Prong	Radio Freq. Amplifier	D.C.	4 [illegible]"	1 [illegible]"	6.3	.3			
437	Standard, 5-Prong	Detector or Amplifier	D.C.	4¼"	1 [illegible]"	6.3	.3	45	Cath.	.5—10
438	Standard, 5-Prong	Pentode Power Amplifier	D.C.	4 [illegible]"	1 [illegible]"	6.3	.3			
445	Standard, 4-Prong	Power Amplifier	A.C. or D.C.	5⅝"	2 [illegible]"	2.5	1.5			
447	Standard, 5-Prong	Pentode Power Amplifier	A.C. or D.C.	5⅝"	2 [illegible]"	2.5	1.5			
450	Standard, 4-Prong	Power Amplifier	A.C. or D.C.	6¼"	2 [illegible]"	7.5	1.25			
460	Standard, 4-Prong	Full Wave Rectifier	A.C.	5⅝"	2 [illegible]"	5.0	2.0			
461	Standard, 4-Prong	Half Wave Rectifier	A.C.	6¼"	2 [illegible]"	7.5	1.25			
482-A	Standard, 4-Prong	Power Amplifier	D.C.	5⅝"	2¼"	5.0	.5			
482-B	Standard, 4-Prong	Power Amplifier	A.C. or D.C.	5⅝"	2¼"	5.0	1.25			
483	Standard, 4-Prong	Power Amplifier	A.C. or D.C.	5⅝"	2¼"	5.0	1.25			
484-A	Standard, 5-Prong	Detector or Amplifier	D.C.	4 [illegible]"	1 [illegible]"	3.0	1.6	100	Cath.	6.5
485	Standard, 5-Prong	Detector or Amplifier	A.C. or D.C.	4 [illegible]"	1 [illegible]"	3.0	1.3	135	Cath.	0.8
486	Standard, 5-Prong	Radio Freq. Amplifier	D.C.	4 [illegible]"	1 [illegible]"	3.0	.25			

*Recommended values for use in Auotmobile Receivers.
†Recommended values for use in Receivers designed for 110 volts D.C. operation.

CHARACTERISTICS

ard types, although the first or prefix number for the entire listing begins with the figure "4," whereas standard makes of tubes employ no such prefix numbering system. Where both the types are identical in specifications and requirements, it may be generally recognized by the similarity in the assigned type numbers designating the respective tubes.

Sparton tubes that are immediately replaceable, without any circuit changes necessary, with those of other manufacturer's are listed separately in a special chart that precedes this, and which data was compiled by the Hygrade Sylvania Tube Corp.

AMPLIFICATION										
Amplifier Plate Voltage	Grid Bias Voltage— D.C. On Fil.	Grid Bias Voltage— A.C. On Fil.	Amplifier Plate Current Milli-Amperes	Screen Grid Volts +	Screen Current Milliamperes	Plate Impedance Ohms	Mutual Conductance Micromhos	Voltage Amplification Factor	Ohms Load for Maximum Undistorted Output	Maximum Undistorted Output Milli-watts
180	30.0	30.0	16			2,550	1050	3.0		
90 180	3.0 13.5	3.0 13.5	5 6			9,500 7,000	1000 1200	9.5 8.7		
90 135	4.5 9.0		2.5 3.0			11,000 10,000	725 800	8.0 8.0	11,000 20,000	15 55
250 350 425	18.0 27.0 35.0	22.0 31.0 39.0	10 16 18			6,000 5,150 5,000	1330 1550 1600	8.0 8.0 8.0	13,000 11,000 10,200	400 900 1600
90 135	4.5 9.0		5.2 6.2			5,600 5,200	1500 1600	8.5 8.5	6,000 7,800	30 130
135 157.5 180	9.0 10.5 13.5	11.5 13.0 16.0	6.2 9.5 7.6			5,300 4,700 5,000	1600 1700 1700	8.5 8.5 8.5	8,700 8,700 10,800	120 195 275
180 180	1.5 3.0	1.5 3.0	4.0 4.0	75 90	Not Over One-Third of Plate Current	400,000 600,000	1050 1000	420 600	—	—
250	1.0	1.0	0.5	25		200,000	500	1000	—	—
90 135 180	5.0 8.0 12.5	6.0 9.0 13.5	2.8 6.3 7.6			8,600 7,200 7,000	935 1135 1170	8.3 8.3 8.3	9,600 8,800 10,500	20 60 160
90 180	6.0 13.5	6.0 13.5	2.7 5.0			10,800 9,300	980 1150	12.5 12.5	—	—
90	4.5		2.0			12,500	700	8.5		
135	22.5		6.0			4,000	875	3.5		170
135	3.0		1.5	67.5	Not Over One-Third of Plate Current	800,000	550	400	—	—
135	13.5		14.0	135	3	45,000	1400	65	7,500	650
250	3.0	3.0	7.0	90	2.8 Maximum	350,000	1050	Controlled	—	—
90† 135* 135	1.5† 1.5* 1.5	—	1.8 3.0 2.5	55† 67.5* 75	Not Over One-Third of Plate Current	300,000 300,000 250,000	580 1050 1100	170 350 275		—
90† 135	6† 9	—	2.7 4.5			11,500 10,000	780 900	9.0 9.0	14,000 12,500	30 75
135	13.5		8.0	135	2.5	110,000	900	100	15,000	375
180 250	33.0 43.8	34.5 50.0	25 34			1,900 1,750	1850 2000	3.5 3.5	3,500 3,900	780 1600
250	15.0	16.5	32	250	2.5	38,000	2500	100	7000	2500
250 350 400 450	41.0 59.0 66.0 80.0	45.0 63.0 70.0 84.0	28 45 55 55			2,100 1,900 1,800 1,800	1800 2000 2100 2100	3.8 3.8 3.8 3.8	4,300 4,100 3,670 4,450	1600 3400 3400 4600
Maximum A.C. Voltage Per Plate 350 Volts R.M.S. Maximum Rectified Current 125 M.A.										
Maximum A.C. Voltage Per Plate 700 Volts R.M.S. Maximum Rectified Current 85 M.A.										
200	45		18			2,600	1500	3.0	4200	1000
250	32.5	35	18			3,250	1800	6.0	4000	1700
250 250	65.5 63.5	58.0 65.0	20 26			2,000 1,900	1600 2000	3.8 3.8	4000	3000
90 180	3 9	3 9	5 6			10,800 9,300	1150 1350	12.5 12.0	—	—
90 180	3 9	3 9	3 6			10,800 9,300	1150 1350	12.5 12.5	—	—
90	2.0		3.0			26,000	440	13.8	—	—

Courtesy, Sparks Withington Co.

WESTERN ELECTRIC

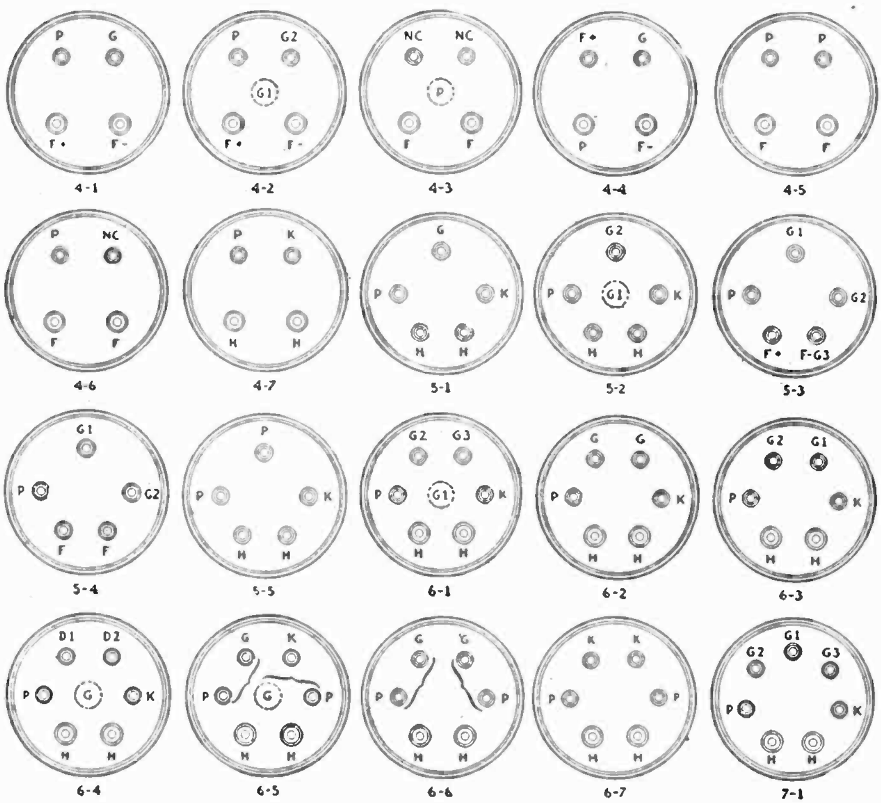
Type	Purpose	Base	RATING				Screen Volts
			FILAMENT OR HEATER			Plate Volts	
			Volts	Amps.	Supply		
101-D	Detector or Amplifier	4 prong	4.5	1.0	D. C.	190	—
101-F	Detector or Amplifier	4 prong	4.1	.5	D. C.	190	—
205-D	R. F., A. F., Det. or Osc	4 prong	4.5	1.6	D. C.	370 to 400	—
215-A	R. F., A. F., Amplifier	4 prong (peanut tube)	1.	.25	D. C.	100	—
231-D	A. F., Amplifier	4 prong	2.9 to 3.4	.06	D. C.	135	—
242-A	Osc., R. F. or A. F. Amp	4 prong	10.	3.25	A. C. D. C.	1250	—
244-A	A. F. Amplifier	5 prong	2.	1.6	A. C. D. C.	180	—
247-A	A F. Amplifier	5 prong	2.	1.6	A. C. D. C.	180	—
249-A	Half-Wave Rectifier	4 prong	2.5	7.	A. C.	6500 A. C.	—
252-A	Osc. or A. F. Amplifier	4 prong	5.	2.	A. C. D. C.	450	—
254-A	R. F. Amplifier or Osc.	4 prong	7.5	3.25	A. C. D. C.	750	175
254-B	R. F. Amplifier or Osc	4 prong	7.5	3.25	A. C. D. C.	750	150
256-A	Special	5 prong	2.3	1.7	A. C.	Special	Rectifie
259-A	R. F. or A. F. Amplifier	5 prong	2.	1.6	A. C. D. C.	180	90
262-A	A. F. Amplifier	4 prong	10.	.32	A. C. D. C.	180	—
264-A	A. F. Amplifier	4 prong	1.5	.3	D. C.	100	—
271 A	A. F. Amplifier	5 prong	5.	2.0	A. C. D. C.	400	—
272-A	A. F. Amplifier	5 prong	10.	.32	A. C. D. C.	180	—
274-A	Full-Wave Rectifier	4 prong	5.	2.0	A. C.	Approx. 525 RMS	—
275-A	A. F. Amplifier	4 prong	5.	1.2	A. C. D. C.	250	—
276-A	R. F.-A. F. Amplifier, Osc	4 prong	10.	3.	A. C.	1250	—
277-A	Special	4 prong	5.	2.	A. C.	—	Relay
280-A	Half-Wave Rectifier	4 prong	2.5	3.	A. C.	3500	—
282-A	R. F. Amplifier, Osc	4 prong	10.	3.	A. C. D. C.	1000	250
284-A	Amplifier, Osc., Mod.	4 prong	10.	3.25	A. C.	1250	—

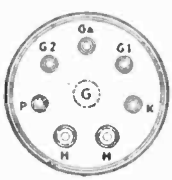
TUBES

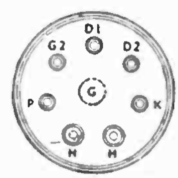
Plate Current M. A.	Amplification Factor	Plate Resist.	Load Resist.	Inter-Electrode capacities Without Socket, in mmf.			Power Output Milliwatts	Grid Voltage (Class A)	Power Output Class B Push-Pull
				P. to C	P. to F.	C. to F.			
8.35	5.95	5,600	11,200	5.	2.	3.7	230	—18	—
7.5	6.5	5,400	11,200	5.9	3.7	5.2	240	—16	—
21.	7.3	4,450	8,900	4.8	3.3	5.2	1,200	—30	12 watts
1.9	5.6	14,800	—	2.6	1.2	1.6	—	—10	—
2.5	7.8	14,600	29,200	3.2	2.5	2.4	—	—7.5	—
85.0	12.5	3,500	7,000	13.	4.	6.5	10,000	—50	125 watts
6.0	9.7	—	—	3.3	3.7	3.8	—	—10	—
3.8	14.6	16,000	—	3.2	2.7	3.4	—	—7	—
1100.	—	—	—	—	—	—	—	—	—
43.	5.0	1,700	—	—	—	—	—	—65	—
60.	80.	80,000	—	.1	9.4	4.6	—	—	—
75.	100.	75,000	—	.085	5.4	11.2	—	—	—
of Low Internal Impedance for Relay or Trigger Action Circuits									
7.5	480.	—	—	.004	5.8	14.0	—	—1.5	—
2.8	14.9	17,500	—	1.9	4.0	1.8	—	—7.5	—
2.6	7.	11,800	—	5.3	2.2	3.5	—	—7.	—
39.0	8.5	2,850	—	5.3	3.8	6.5	—	—30	—
5.9	5.5	7,200	—	2.8	2.6	3.4	—	—21	—
Approx. 125.	—	—	—	—	—	—	—	—	—
52.	2.85	1,000	—	12.	3.2	6.8	—	—60	—
850.	12.	3,500	7,000	9.	4.	6.	10,000	—50	—
Tube	—	—	—	—	—	—	—	—	—
500.	—	—	—	—	—	—	—	—	—
100.	100.	70,000	—	.2	6.8	12.2	—	—	—
100.	4.7	1,600	3,200	8.2	7.8	7.0	16,600	—106	—

BASES AND BULBS

BOTTOM VIEW OF BASES





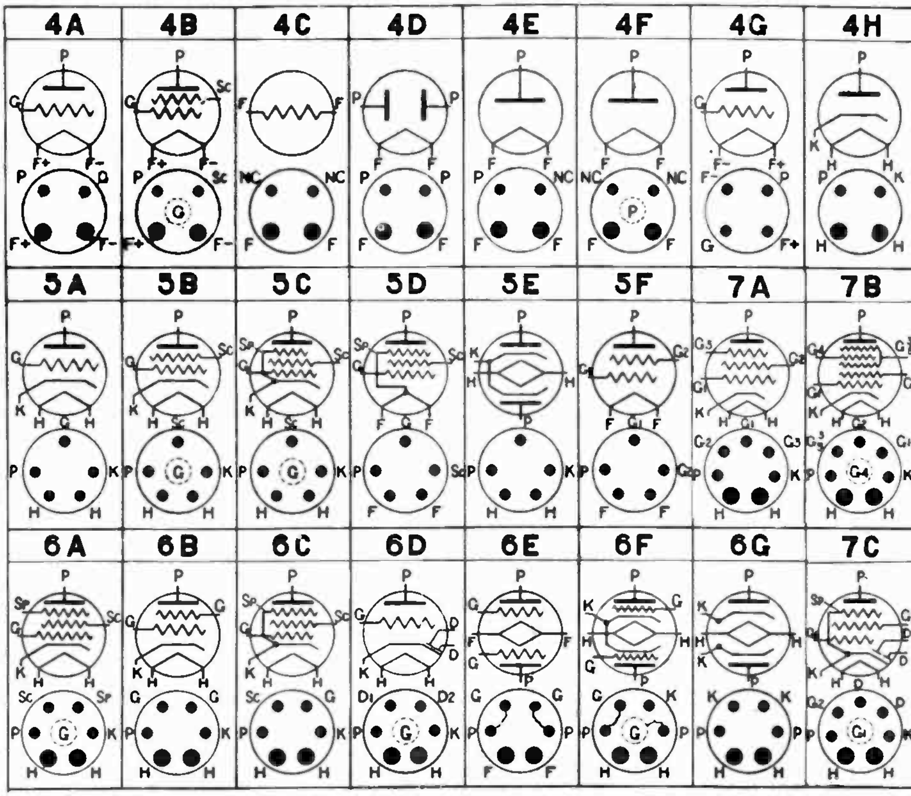


SYMBOLS

F—Filament; H—Heater; P—Plate;
K—Cathode; G—Grid; G1—Inner Grid;
G2—Screen Grid; G3—Suppressor Grid;
Ga—Anode Grid; D1 D2—Diode Plate;
NC—No Connection }—Adjoining Elements

TUBE SYMBOLS

Whereas it was simple for the early reader of radio periodicals to locate the various tube connections of the early three-element tubes, and to understand schematic diagrams indicating tubes of this type, the problem is not so simple with existing tubes that incorporate 6, 7, or more elements. To facilitate matters for the Service Man, who must trace wiring diagrams, and others who may desire to know elements employed, representative symbol, and the position of its respective base pin to which it is connected, this chart will prove most helpful.



BOTTOM VIEWS OF BASES AND SCHEMATICS OF TUBES

SYMBOLS — F = Filament. H = Heater. P = Plate. K = Cathode. G = Grid. G1 = Inner Grid. G2 = Second Grid. G3 = Third Grid. G4 = Fourth Grid. SC = Screen Grid. D1-D2 = Diode Plate. NC = No Connection. SP = Suppressor Grid. (= Adjoining Elements

BASE ARRANGEMENTS BY TUBE TYPES

Type	Base	Type	Base	Type	Base	Type	Base	Type	Base
00-A	4A	18	6C	39	5C	69	6B	182B	4A
01-A	4A	19	6E	41	6C	71-A	4A	183	4A
2	4C	20	4A	42	6C	75	6D	485	5A
3	4C	24	5B	43	6C	77	6A	866	4F
4	4C	26	4A	44	5C	78	6A	2A3	4A
5	4C	27	5A	45	4A	79	6F	2A5	6C
6	4C	30	4A	46	5F	80	4D	2A7	7B
7	4C	31	4A	47	5D	81	4E	2B7	7C
8	4C	32	4B	48	6C	82	4D	5Z3	4D
9	4C	33	5D	50	4A	83	4D	6A7	7B
10	4A	34	4B	55	6D	84	5E	6B7	7C
12-A	4A	35	5B	56	5A	85	6D	12Z3	4H
14	5B	36	5B	57	6A	89	6A	25Z5	6G
15	5B	37	5A	58	6A	X99	4A		
17	5A	38	6C	59	7A	V99	4G		

TUBE TYPES BY BASE ARRANGEMENTS

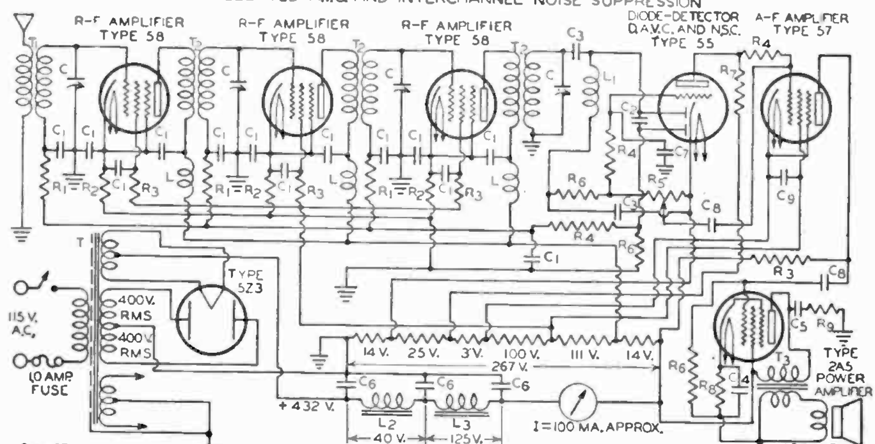
Base	Type	Base	Type	Base	Type	Base	Type
4A	00-A,	4D	80, 82,	5D	33, 47	7A	59
	01-A,		83,	5E	84	7B	2A7,
	10,		5Z3,	5F	46		6A7
	12A, 20,	4E	81	6A	57, 58,	7C	2B7,
	26, 30,	4F	866		77, 78,		6B7
	31, 45,	4G	V99		89		
	50, 71A,	4H	12Z3	6B	69		
	X99,	5A	17, 27,	6C	18, 41,		
	182B,		37, 56,		42, 43,		
	183,		485,		48, 2A5		
	2A3,	5B	14, 15,	6D	55, 75,		
4B	32, 34,		24, 35,		85		
4C	2, 3, 4,		36	6E	19		
	5, 6, 7,	5C	38, 39,	6F	79		
	8, 9,		44	6G	25Z5		

Courtesy Philco Radio & Telev. Corp.

TUBE APPLICATIONS AND CIRCUITS

Various circuits are shown here to illustrate the applications of tubes, (courtesy RCA-Radiotron, Inc.) particularly those that are latest and which may be employed for a multiple number of functions.

A TUNED RADIO-FREQUENCY RECEIVER CIRCUIT
WITH DELAYED A.V.C. AND INTERCHANNEL NOISE SUPPRESSION

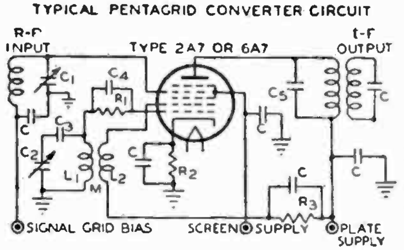


R₁ = 250000 OHMS
R₂ = 300 OHMS
R₃ = 20000 OHMS
R₄ = 1.0 MEGOHM
R₅ = 300000 OHMS (VOL. CONTROL)
R₆ = 500000 OHMS
R₇ = 50000 OHMS
R₈ = 410 OHMS (2 WATT)
R₉ = 10000 – 20000 OHMS
L = R-F CHOKE, 60 MILLIHENRIES
L₁ = HIGH-QUALITY R-F CHOKE, 85 MILLIHENRIES
L₂ = FILTER CHOKE, 400 OHMS, 30 HENRIES AT 100 MA.
L₃ = SPEAKER FIELD, 1250 OHMS

C = GANGED TUNING CONDENSERS
C₁ = 0.1 μf.
C₂ = 0.00005 μf.
C₃ = 0.0001 μf.
C₄ = 8–16 μf. (LOW VOLTAGE)
C₅ = 0.03 μf.
C₆ = 8.0 μf. (500 VOLT ELECTROLYTIC)
C₇ = 0.05 μf.
C₈ = 0.01 μf.
C₉ = 0.5 μf.
T = POWER TRANSFORMER
T₁ AND T₂ – SEE NOTE
T₃ = OUTPUT TRANSFORMER, PRIMARY IMPEDANCE 7000 OHMS

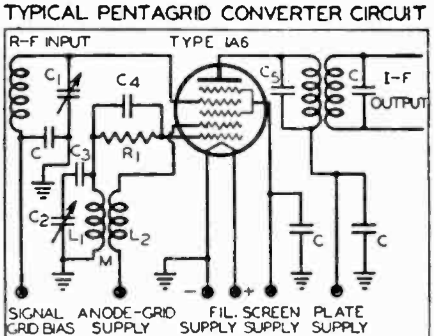
NOTE: THE CONSTANTS OF THE R-F TRANSFORMERS T₁ AND T₂ WILL DEPEND UPON THE FREQUENCY RANGE AND GENERAL LAYOUT OF THE SET. THE BLEEDER RESISTANCE VALUES WILL VARY WIDELY IN INDIVIDUAL SETS; THEY SHOULD BE CHOSEN TO GIVE THE VOLTAGES INDICATED ACROSS EACH SECTION.

TYPICAL PENTAGRID CONVERTER CIRCUIT



C = 0.1 μf.
C₁ = } C₂ = } GANGED VARIABLE CONDENSERS
C₃ = PADDING CONDENSER
C₄ = GRID CONDENSER OF 200 μμf.
L₁ = OSCILLATOR GRID INDUCTANCE } COUPLED
L₂ = OSCILLATOR PLATE INDUCTANCE }
M = MUTUAL INDUCTANCE OF L₁ & L₂
R₁ = OSCILLATOR GRID LEAK
R₂ = SELF BIASING RESISTOR
R₃ = VOLTAGE REDUCING RESISTOR OF 20,000 OHMS (USED ONLY WHEN PLATE VOLTAGE IS OVER 200 VOLTS)

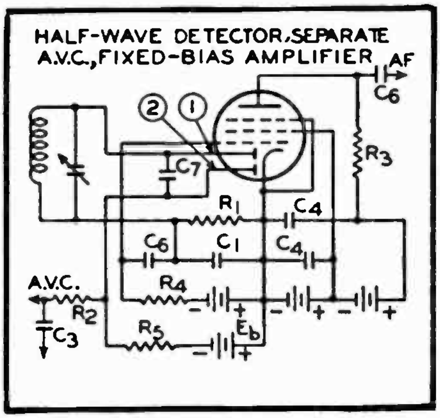
TYPICAL PENTAGRID CONVERTER CIRCUIT

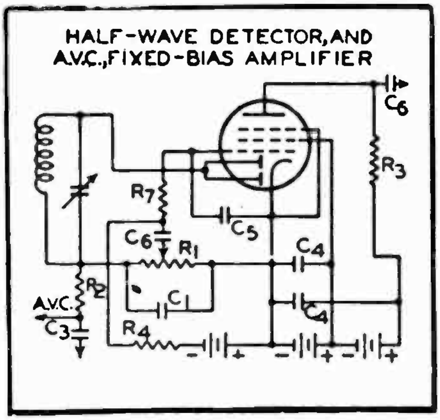


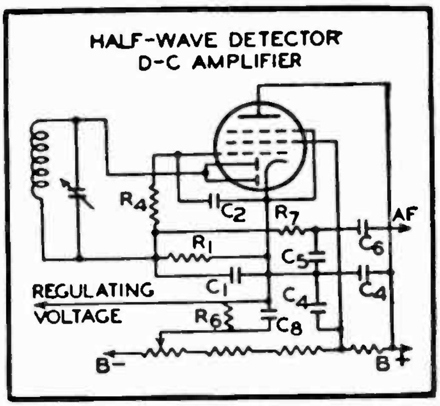
C = 0.1 μf.
C₁ = } C₂ = } GANGED VARIABLE CONDENSERS
C₃ = PADDING CONDENSER
C₄ = GRID CONDENSER OF 200 μμf.
L₁ = OSCILLATOR GRID INDUCTANCE } COUPLED
L₂ = OSCILLATOR PLATE INDUCTANCE }
M = MUTUAL INDUCTANCE OF L₁ AND L₂
R₁ = OSCILLATOR GRID LEAK

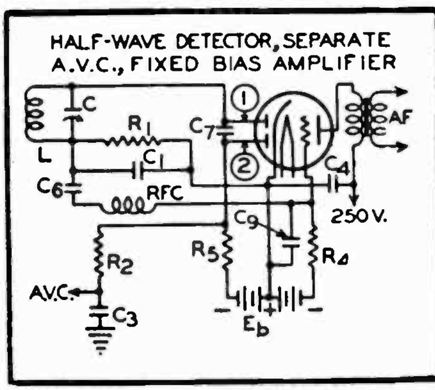
DUPLEX-DIODE PENTODE CIRCUITS

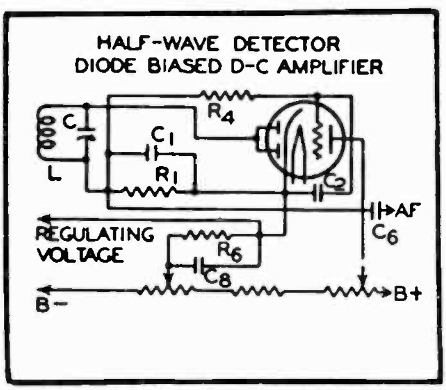
Using Types 2B7 or 6B7 Tubes

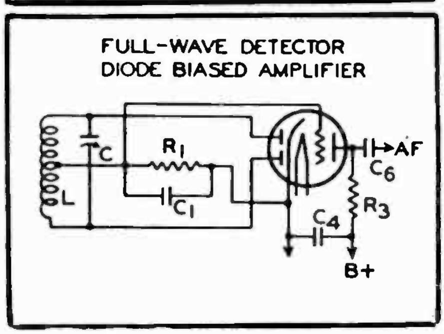












APPROXIMATE VALUES

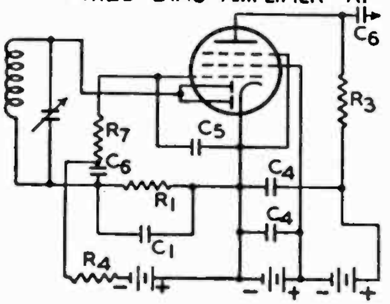
$C_1 = \begin{cases} 150 \text{ mmf. for } 500\text{-}1500 \text{ kc.} \\ 450 \text{ mmf. for } 175 \text{ kc.} \end{cases}$

C_2=0.1 mf.
C_3=0.1 mf.
C_4=0.5 mf. or larger
C_5=0.001 mf. or smaller.
C_6=0.01—0.1 mf.
C_7=0.0005—0.001 mf.
C_8=0.1 mf. or larger
R_1=0.5—1.0 megohm
R_2=1.0—1.5 megohms
R_3=0.1—0.2 megohm
R_4=0.5—1.0 megohm
R_5=1.0 megohm
R_6=30,000—100,000 ohms.
R_7=0.1—0.2 megohms
E_b=voltage for sensitivity control

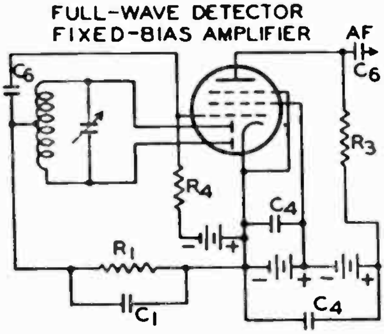
Note: Suppressor connected to cathode within bulb.

APPLICATIONS OF DUPLEX DIODE TRIODE TUBES, SUCH AS THE 55, 75, 85 AND 2A6 TYPES

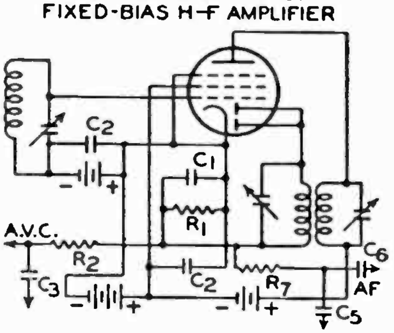
HALF-WAVE DETECTOR FIXED-BIAS AMPLIFIER



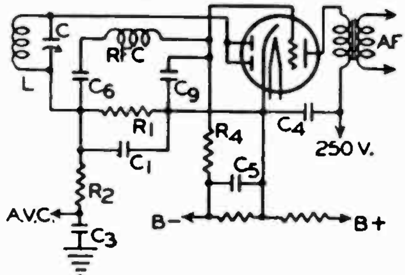
FULL-WAVE DETECTOR FIXED-BIAS AMPLIFIER



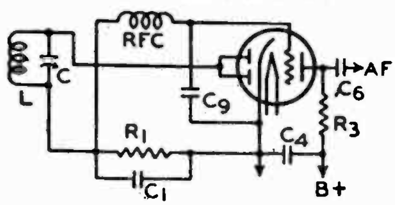
HALF-WAVE DETECTOR FIXED-BIAS H-F AMPLIFIER



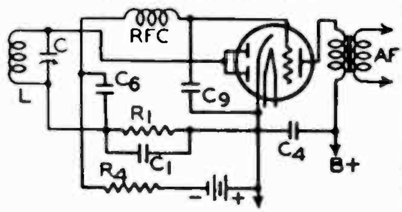
HALF-WAVE DETECTOR FIXED BIAS AMPLIFIER



HALF-WAVE DETECTOR DIODE BIASED AMPLIFIER



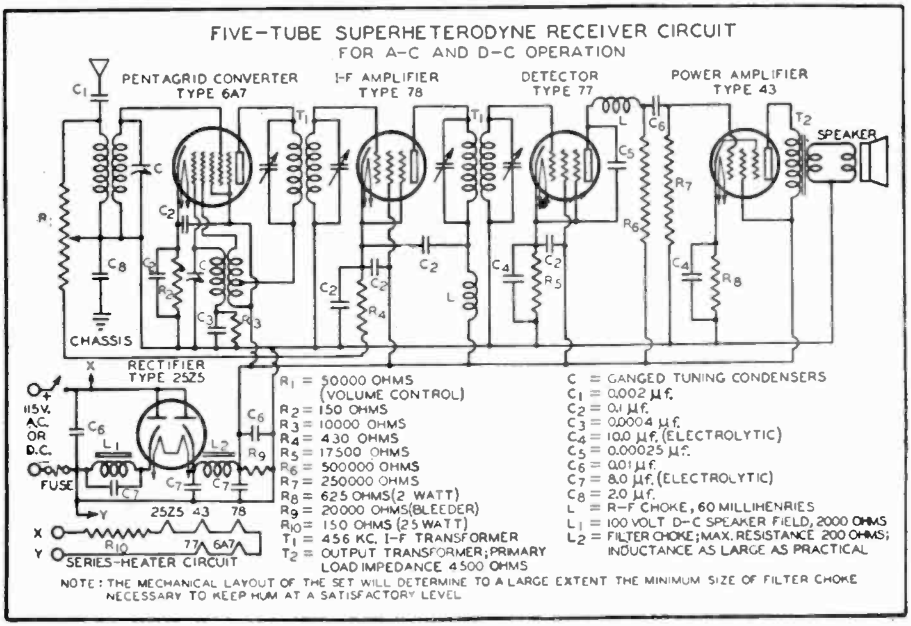
HALF-WAVE DETECTOR FIXED BIAS AMPLIFIER



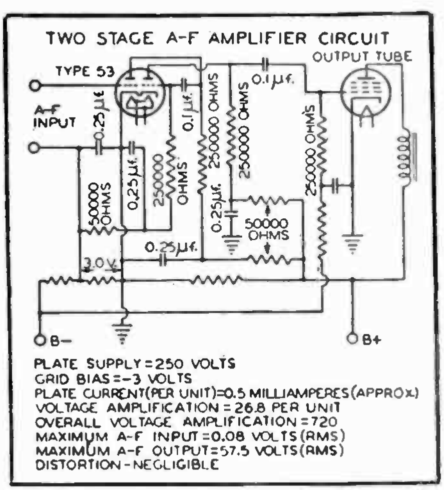
APPROXIMATE VALUES

$C_1=$ { 150 mmf. for 500-1500 kc.
{ 450 mmf. for 175 kc.

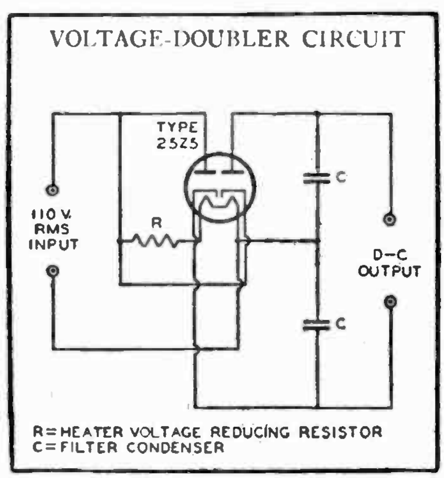
C_2=0.1 mf.
C_3=0.1 mf.
C_4=0.5 mf. or larger
C_5=0.5 mf. or larger
C_6=0.01—0.1 mf.
C_7=0.0005—0.001 mf.
C_8=0.1 mf. or larger
C_9=0.0001 mf. or smaller
R_1=0.5—1.0 megohm
R_2=1.0—1.5 megohms
R_3=0.1 megohm
R_4=0.5—1.0 megohm
R_5=1.0 megohm
R_6=25000—75000 ohms
E_b=voltage for sensitivity control.



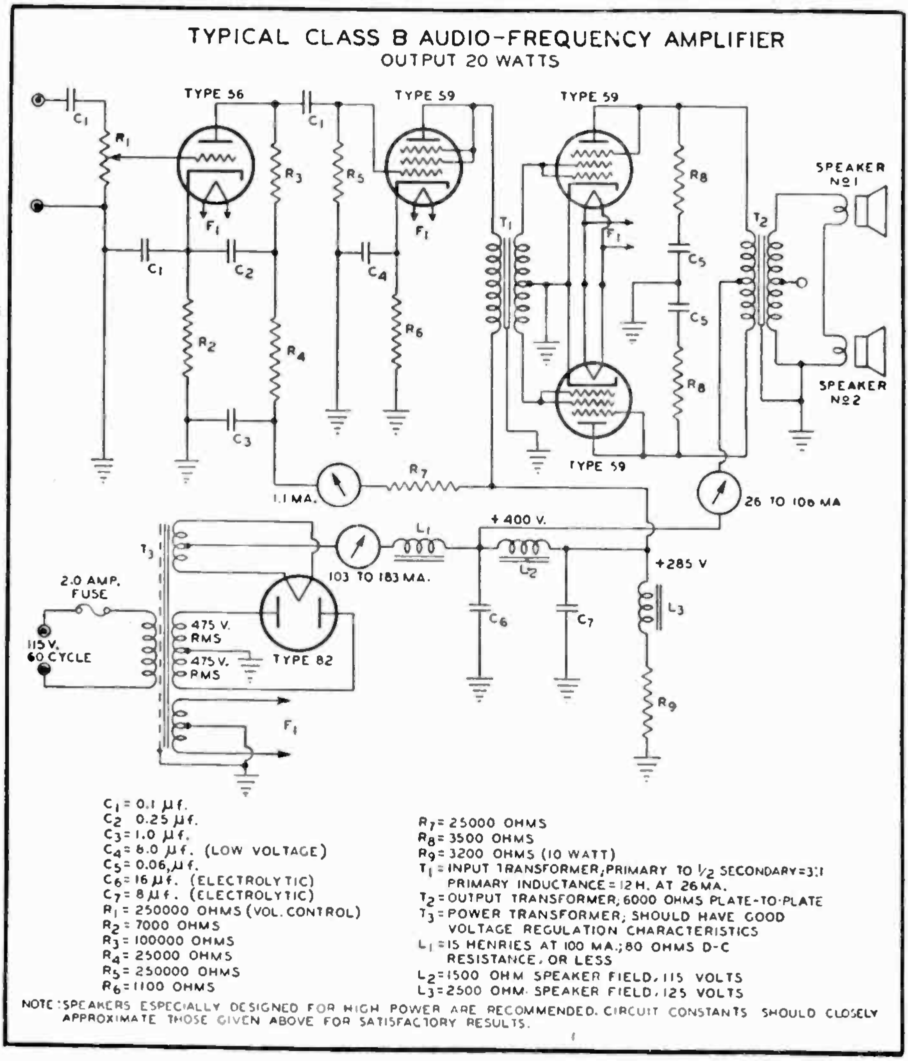
Illustrating the application of the 6.3-volt type tubes, in a typical midget receiver of the a.c.-d.c. variety. The 43 and 25Z5 are 25-volt tubes whose filament consumption is the same as that of the 6.3 volt types.



Application of the 53 tube as a class A driver. It may be also employed as a class B power stage. See chart for specifications.



The 25Z5 may be used as a half-wave rectifier, a full-wave rectifier, or to double the output voltage when a.c. is employed.



Illustrating the application of the 59 tube in a class A driver stage, and a class B power stage. A 56 tube feeds the 59 (in class A) whose output in turn drives the two 59's in class B. To obtain the specified output from a class B stage, it is essential that the grids of these tubes in this arrangement be properly excited. Push-push a.f. coupling must be used if quality amplification is desired; since the harmonic distortion that exists in the output of a class B stage is considerable, and this method of coupling balances out a great percentage of this type of distortion.

APPLICATION NOTE ON THE 37, 56, 57, AND 77 TUBES AS RESISTANCE-COUPLED HIGH-VOLTAGE AMPLIFIERS

The 37, 56, 57, and 77 type tubes may be operated as resistance-coupled amplifiers with high plate-supply voltages, of the order of 500 volts, to provide high audio input voltage for the operation of large power output tubes.

In the design of power amplifiers, the tubes, the coupling devices, and the operating voltages to obtain the highest output levels with the least amount of distortion must be carefully selected.

For representative tubes operated with a plate supply of 500 volts, a plate load of 250,000 ohms, and a grid leak of 500,000 ohms for the following tube, the voltages developed across the a.c. load of 167,000 ohms are:

TABLE I

Tube Type	Grid-Bias Volts	Screen Volts	Peak-Output Volts	Distortion Per Cent
37	—22.5	—	172	3.5
56	—16.0	—	180	5.9
57	— 3.5	92	180	5.0
57	— 3.5	90	200	7.0
77	— 4.5	100	200	9.5

From the standpoint of distortion, the 37 is the most satisfactory. The 37, however, requires 6.5 times as great an input voltage as the 57 to yield the same output. From the standpoint of gain, therefore, the 57 is to be preferred to the 37.

An excellent output tube for providing very large audio output of high quality is the 845. This tube operated as a self-biased audio amplifier with a peak-input voltage of 150 volts is capable of an a.f. output of 21 watts. Any of the tubes shown in the table (the 37, 56, 57, and 77) can be used to provide the necessary grid excitation for the 845.

From the plate characteristics of the 57 and 77, one might expect that low distortion at high output voltages would be obtained from these tubes when the plate supply is 500 volts, plate load is 250,000 ohms, and grid resistor is 500,000 ohms for following tube. However, distortion increases rapidly with output at high plate-supply voltages and, although large outputs can be obtained, they may not be sufficiently free from distortion. This relationship is indicated in Table I. Distortion, incidentally, is somewhat critically dependent upon screen voltage.

Operation of any of these tubes in push-pull will provide greater output at lower percentages of distortion. The accompanying tabulation shows self-biased push-pull operation for pairs of the same tubes as in Table I with the same conditions, i.e., plate supply voltage of 500 volts with plate and a.c. loads of 250,000 and 167,000 ohms respectively per tube. Screen voltage is given for minimum distortion.

TABLE II

Tube Type	Grid-Bias Volts	Screen Volts	Peak-Output Volts†	Distortion Per Cent
37	—22.5	—	275	0.7
56	—16.5	—	255	1.1
57	— 3.5	75	300	1.0
57	— 3.5	75	350*	2.5*
77	— 3.5	70	293	1.5

†The peak-output voltage is that measured between plates.

*For the 350-volt output condition in the above table, the input to the 57 tubes is sufficient to cause some grid current.

Considering both output voltage and distortion, the 57 provides the most satisfactory performance.

In cases where the grid leak of the power tube is limited to 100,000 ohms, the maximum output of two 57's in push-pull with plate load of 250,000 ohms is 315 volts peak with distortion of 1.8%. Screen voltage of 75 volts is used. The input signal is that which will just start grid current.

Thus, if it is desired to operate two 845's in push-pull with a plate voltage of 1000 volts and grid voltage of 155 volts to provide approximately 45 watts of power, very satisfactory results would be obtained by using a pre-amplifier stage of two 57's in push-pull with a plate-supply voltage of 500 volts and a control-grid voltage of 3.5 volts.

Where an amplifier is to be used in conjunction with low voltage inputs, the high gain of the 57 is a distinct advantage.

(Courtesy RCA-Radiotron, Inc.)

New 2.5 Volt Tubes

2A3—A power output triode designed for use in Class A service either in single or push-pull use where a large output is desired. The mutual conductance is particularly high, being 5500 micromhos. With a plate voltage of 250 volts and a negative grid bias of 45 volts, 3.5 watts output is obtainable from a single tube. A pair of these tubes operating in Class A push-pull with 300 volts on the plates and with a negative grid bias of 62 volts is capable of delivering undistorted output of 15 watts.

2A5—This tube is a 2.5 volt heater type output pentode with the same electrical characteristics as Type 42 of the 6.3 volt group. When operating the 2A5 with 250 volts on the plate, 16.5 volts negative grid bias and supplied with a peak signal equal to the grid bias, 3 watts may be obtained.

2A7—The electron-coupled pentagrid converter is a five grid electron-coupled detector-modulator tube with a high conversion gain intended for service in super-heterodyne circuits. Type 2A7 performs the functions of an oscillator-modulator, and at the same time is a satisfactory volume control tube, thus eliminating the necessity of having separate tubes perform the same functions. This is accomplished by having a sharp cut-off grid and a remote cut-off grid, respectively, perform the duties of an oscillator grid and a signal grid.

2B7—A double diode-pentode intended for service in circuits as a combined detector, RF, IF, or AF amplifier and AVC tube. This tube is somewhat similar to Type 55 but differs in that it contains a pentode section instead of a triode section, thus making possible additional circuits applications. This tube employs the new small seven-pin base providing separate connections for each of the two diode plates, making possible several circuit combinations.

55—A double diode-triode permitting diode detection followed by a stage of triode audio amplification to be obtained from a single tube. Various circuit combinations are possible with this tube, due to the fact that a separate connection is provided for each of the two diode plates. This facilitates the use of the tube in many special circuits of AVC, delayed AVC and QAVC types.

59—A three grid power output tube incorporating a seven-pin base which provides external connections for each grid. By using the flexible wiring possibilities of the socket the set manufacturer can provide suitable operating conditions so that the tube may be used for three purposes. As a Class A triode it will deliver 1.25 watts, as a Class A pentode 3 watts, and it may also be used as a Class B output tube. In the latter service a single 59 is used as a driver followed by a pair of these tubes, the combination being capable of supplying up to 20 watts.

NEW 2-VOLT SERIES FOR BATTERY OPERATION

15—The only cathode type R. F. pentode available for battery operation especially designed for use as detector-oscillator. Heater current is .220 ampere at 2 volts.

19—A complete Class B tube containing two triode elements. Filament rating is .26 ampere at 2 volts. Power output up to 2.1 watts may be obtained with a plate voltage of 135 volts. Designed for a small grid bias to accommodate a range of plate voltages and to secure maximum efficiency by reduction of input grid power. Suitable for use with Type 30 as a driver.

49—A double grid amplifier tube which may be used as a triode, for Class A service as a driver, or Class B service as an output tube, depending upon the circuit connections. A typical Class B output stage utilizes three of these tubes, or a single 49 as a driver may be used to supply the input power required by a Type 19 tube.

New 6.3 Volt Tubes

6A7—The electron-coupled pentagrid converter is a five grid electron-coupled detector-modulator tube with a high conversion gain intended for service in super-heterodyne circuits. Type 6A7 performs the functions of an oscillator-modulator, and at the same time is a satisfactory volume control tube, thus eliminating the necessity of having separate tubes perform the same functions. This is accomplished by having a sharp cut-off grid and a remote cut-off grid, respectively, perform the duties of an oscillator grid and a signal grid.

6B7—A double diode-pentode, intended for service in circuits as a combined detector, RF, IF or AF amplifier, and AVC tube. This tube is somewhat similar to Type 75 and 85 but differs in that it contains a pentode section instead of a triode section, thus making possible additional circuit applications. This tube employs the new small seven-pin base providing separate connections for each of the two diode plates, making possible several circuit combinations.

6C6—An efficient R. F. pentode of the sharp cut-off type. Recommended for use as detector, or detector-oscillator in superheterodyne receivers, as control tube and as audio amplifier with resistance coupling. Short-wave operation has been considered in the design of the tube, and inter-electrode capacities kept low for this service. The 6C6 is identical in characteristics with Type 57 except for heater rating which is 6.3 volts at 0.3 ampere.

6D6—A remote cut-off tube otherwise similar to the 6C6 described above. It is designed for R. F. and I. F. amplification, or for use as a first detector in a super. In this latter service translation gain is lower than that obtained from Type 6C6, but AVC voltage may be applied to this grid to secure increased range of control. Mutual conductance, high plate resistance, and low output capacity are features of the design of this tube. Except for heater rating this tube is identical with Type 58 of the 2.5 volt group.

41—An improved cathode type power pentode designed especially for automobile service. Useful in any installation where maximum power output is desired with plate voltages not exceeding 200 volts. The tube is very compact, using the ST-12 bulb and a six-prong base, no top cap being required. The tube will deliver 1500 milliwatts with 180 volts applied to plate and screen, and with 14.0 volts negative bias on the control grid.

42—A heater type output pentode of larger size than Type 41, and designed for operation on voltages up to 250. Compared with Type 247, the tube has the advantage of higher power output, separate cathode terminal and hum-free performance. The separate cathode is particularly advantageous in making complete self-bias operation possible and eliminating the need for a center tap on the heater winding. Rugged in mechanical construction and uniform in characteristics.

75—Is a double diode-high mu triode suitable for use as a diode detector and a triode audio amplifier. In addition, automatic volume control can be obtained from the diode. The triode unit has an amplification factor of 100. Type 75 is provided with a 6.3 volt .3 ampere heater, and like Types 36, 37 and 38, is manufactured with triple folded filament giving exceptionally fast heating time.

77—A triple grid amplifier and detector especially designed to operate satisfactorily in AC or DC use. Complete internal shielding is provided by use of the conventional outer cage, rigidly supported in the dome top of the ST-12 bulb. Type 77 is recommended for biased or grid leak detector service and a low signal input R. F. or A. F. amplifier.

78—A triple grid super control amplifier with remote cut-off similar in structural appearance to Type 77. This tube is particularly adaptable to radio frequency and intermediate frequency stages of receivers employing automatic volume controlling because of its ability to handle very high signal voltages without cross modulation or modulation distortion.

79—A complete Class B tube with two sets of triode elements designed for Class B output service. This tube delivers a power output far in excess of that obtainable from any previous tube comparable with it in size (ST bulb with top cap and six-prong base.) The heater rating is only .6 ampere at 6.3 volts. Power output up to 5.5 watts may be obtained when the plate voltage available is 180 volts. Moderate increases in plate voltage result in rapid increase in power output. Each triode element is of double grid construction, the two grids being connected permanently together. No grid bias is required and distortion is extremely low due to careful design.

84—Is a heater-cathode rectifier tube which can be used either in half-wave or full-wave operation. Because of its compact size and efficient operation it is especially adaptable to automobile B-supply devices. Type 84 heater rating is 0.5 ampere at 6.3 volts, and has a maximum load current drain of 50 ma.

89—A three grid power output tube incorporating a six-pin base and a top cap which provides external connections for each grid. By using the flexible wiring possibilities of the socket the set manufacturer can provide suitable operating conditions so that the tube may be used for three purposes. As a Class A triode it will deliver 300 milliwatts, as a Class A pentode 1500 milliwatts, and it may also be used as a Class B output tube. In the latter service a pair of these tubes is capable of supplying up to 3500 milliwatts.

Special Tubes

1-V—A high vacuum half-wave rectifier of the heater cathode type, with a heater rating of 0.3 ampere at 6.3 volts. This tube is unique in that the voltage drop is very low, being approximately 15 volts. Type 1-V is interchangeable with the mercury vapor tube, Type 1, and has all the proven advantages of the high vacuum rectifier.

5Z3—A 5-volt coated filament full-wave vacuum rectifier intended for heavy duty service. The tube is capable of supplying approximately twice the current available from a Type 80 with improvements in regulation. It should not be used in place of Type 80 in equipment designed for the latter tube.

12Z3—This tube is a half-wave high vacuum rectifier of the heater-cathode type, for use in DC power supplying devices where there is a load current not greater than 60 ma. The heater rating is 0.3 ampere at 12.6 volts, making it adaptable for series operation with 0.3 ampere tubes.

18—A cathode type power amplifier pentode with a heater rating of 0.3 ampere at 14 volts. The electrical characteristics are the same as Type 42 of the 6.3 volt group. Type 18 is ideal for 0.3 ampere series circuits and is especially recommended for transformerless receivers employing the 25Z5 voltage doubler rectifier tube.

25Z5—A high vacuum rectifier with a 25-volt 0.3 ampere heater. This tube is designed to supply DC power either in half-wave or voltage doubling circuits with a maximum load current of 100 ma. It is especially recommended for universal service and can be used in series operation.

43—This tube is a 25-volt heater type power pentode designed for use as a power tube for DC line operated receivers, supplying 900 milliwatts with 95 volts applied to the plate. Greater output may be obtained by operating at reduced grid bias of 10 volts and over-driving by applying signals up to 14 volts. Under these conditions an output as high as 1.6 watts is obtainable. Latest construction tubes made in dome shaped bulbs have been especially designed for resistance coupled input. In such installations the grid bias must be kept at normal value as over-driving is possible only with transformer coupled circuits and with suitable transformer design. The heater current is .3 ampere, a suitable value for use in series operation with 6.3-volt tubes.

48—Is a 30-volt 0.4 ampere heater type power pentode recommended for DC line operated receivers. The maximum plate operating voltage is 125 volts. The proper grid voltage is 22.5 with a plate current drain of 50 milliamperes. Under these operating conditions 2.5 watts power output is obtainable.

82—A mercury vapor full-wave rectifier with 2.5 volts, 3-ampere filament. The drop in the tube is constant over a wide range of load currents, a characteristic desirable when supplying receivers which include Class B output tubes. Voltage regulation depends only upon resistance of other circuit elements.

83—An improved heavy duty full-wave mercury vapor rectifier with a 5-volt, 3-ampere filament. This tube is capable of supplying heavy load currents up to 250 ma. and is rugged enough to stand all normal over-loads. Especially recommended for receivers employing Class B amplifiers.

Additional Tube Types

(Courtesy RCA-Radiotron Co., Inc.)

The '00-A is a three-electrode detector tube of the gas-filled type for use in storage-battery-operated receivers. As a grid-leak detector, this tube is especially effective on weak signals. See RADIO TUBE CHART for operating conditions.

The RCA Radiotron types WD-11 and WX-12 and the Cunningham types C-11 and CX-12, are detector-amplifier tubes of the three-electrode construction for use in older types of dry-cell-operated receivers. Their electrical characteristics are identical. The 11, however, fits only the WD socket, while the 12 fits the standard four-contact socket.

The '40 is a storage-battery tube of the three-electrode high-mu type designed for use in resistance- or impedance-coupled amplifier or detector circuits.

The RCA Radiotron UX-874, or the Cunningham CX-374, is a voltage-regulator tube designed to maintain constant d-c load current. In such devices, the 874, or 374, maintains an approximately constant d-c voltage of 90 volts across its terminals for any current from 10 to 50 milliamperes. This tube consists of two electrodes (a cathode and an anode) in a gas-filled bulb. It requires 125 volts for starting and shows a pronounced glow in operation. This type has an S-17 bulb and a medium 4-pin base.

The RCA Radiotron UV-876, or the Cunningham C-376, is a current regulator designed for use in series with the primary of a power transformer to absorb the voltage variations normal to a-c power lines. The operating current of this tube is 1-7 amperes for a voltage range of 40 to 60 volts drop in the tube.

The RCA Radiotron UV-886, or the Cunningham C-386, is similar to the UV-876 and C-376. The operating current of this tube is 2.05 amperes for a voltage range of 40-60 volts drop in the tube.

The RCA-868 is a sensitive phototube of the gaseous type. It is particularly well adapted for use with sound-moving pictures and for experiments with light because of its excellent response to incandescent lamp sources of light.

The New Tube-Numbering System

Type numbers for new tubes are now being assigned in accordance with the new system adopted in the early part of 1933 by the Radio Manufacturers Association. A new system was required because practically all of the available two and three digit numbers has been utilized.

The new system, which provides for future expansion of tube types, ordinarily requires only three symbols to identify a tube. These symbols are arranged with a numeral first, then a letter, and finally, a numeral. An example of the new type designation is the 2A5.

New type numbers are formed according to the following simple rules. The first numeral indicates the filament voltage in steps of one volt. For instance, 1 is used for voltages below 2.1; 2 is used for voltages between 2.1 and 2.9 inclusive; 3 for voltages between 3.0 and 3.9, inclusive; et cetera. The digit 1, rather than the digit 2, is used for the 2.0-volt types in order to separate the 2.0- and 2.5-volt tubes. Thus, the 2.0 volt 1A6, and the 2.5-volt 2A5.

The letter is used to distinguish the tube type and is assigned, starting with A, in alphabetical sequence. In the case of rectifiers, however, the assignment is made, starting with Z, in reverse sequence.

The final numeral indicates the number of useful elements *brought out to terminals*. Thus, the 2A5 has five such elements; a heater, a cathode, two grids, and a plate.

While these rules assist to some extent in classifying tubes by filament voltage and function, the significance of the individual symbols will in most cases be inadequate to identify features of a tube.

Recent Advances in Tube Design

(Courtesy RCA-Radiotron Co., Inc.)

Improvements in radio tube design and construction are not necessarily limited to the forward steps represented by the introduction of new tube types. Existing tube types can be made better by careful study of their inherent weaknesses and the adoption of new manufacturing technique designed to overcome these faults.

The RCA Radiotron Company and E. T. Cunningham, Inc., are constantly experimenting to determine how the quality and uniformity of their product can be improved. The past year has marked the introduction of many improvements in the design and construction of Cunningham Radio Tubes and RCA Radiotrons. Some of these improvements are readily apparent, while others of equal importance are not so obvious.

Dome Bulb Construction

The introduction of the dome-bulb type of construction has made possible the greater uniformity of RCA Radiotrons and Cunningham Radio Tubes. This dome-bulb construction has been incorporated in most of the newer types. Older types are being adapted to this form of construction as rapidly as development and manufacturing activities permit.

A mica support at the top of the electrode assemble fits into the dome of the bulb, bracing the tube's structure against mechanical displacement. Furthermore, the greater strength of the electrode assembly secured by the dome support has made it possible to simplify the construction of the tube, thus eliminating many welds and parts, and reducing the chances of error during assembly.

The resulting increase in uniformity of tube characteristics is a decided benefit to the set engineer, since it permits him to design receivers with closer tolerances and consequently better performance. The greater strength and rigidity of the dome bulb, preventing mechanical injury to the electrodes during shipment, is assurance that the tubes used by the consumer will meet the exacting requirements of the set engineer.

Reduced Size of Bulbs

Many new RCA Radiotrons and Cunningham Radio Tubes are considerably smaller than preceding types. In some cases this reduction in size has been made possible by the use of better glass and by structural improvements in the tubes themselves. Since more efficient dissipation of heat reduces the limiting effects of grid emission and stem electrolysis, higher outputs are obtainable with these small sized tubes.

The smaller size bulbs permit a saving in chassis space, a reduction in shipping weight, and the use of less packing materials.

Improved Cathode and Heater Designs

New types of cathodes (such as the multifilamentary cathode employed in the 2A3) have opened new possibilities in tube design. Because of the large surface area of these cathodes, improvements in mutual conductance, lower plate resistance, and greater power are possible. Consequently, improved receiver performance is possible while the cost of circuit apparatus is lower.

Developments in new and small-sized cathodes have been incorporated in heater type tubes introduced during the past year. The better emission characteristics of the new cathodes have permitted the design of more powerful output tubes, since more plate current is made available for a given size of cathode. Because of a decrease in the amount of heat required to produce a given amount of emission, the new cathodes are economical of heater-power consumption.

Smaller size cathodes are desirable because they allow the size of the whole electrode structure of the tube to be reduced. Economies in heater power consumption permit savings in circuit wiring and power transformer costs.

A careful study of heater-cathode-design problems has produced a new form of heater which has helped to decrease hum levels. Employing a reversed helical winding which is baked in a ceramic, the new heaters greatly reduce the electro-magnetic field responsible for a large part of the hum in heater-cathode tubes. A reduction in heater (cathode) hum means that the overall hum may be sufficiently reduced so that less plate supply filtering will prove satisfactory.

Reduced Grid Emission

Grid emission, which is always a troublesome problem in radio tube design and manufacture, has been greatly reduced by the application of new manufacturing methods.

The use of copper side rods, heat radiators, new grid materials, and grid wire which has been carbonized has aided in the control of grid emission. Certain older types of tubes, such as the 24A, have been redesigned to use copper side rods for the grid. Copper is a better conductor of heat than materials formerly used for side rods. The superior conduction characteristic of copper enables it to carry off and dissipate more heat, resulting in a cooler grid.

Newer types of tubes, such as the 43, 48, 2A5 and 42, which employ cathodes requiring a large amount of heat, are subject to grid-emission troubles due to the proximity of the control grid to the cathode. To overcome this difficulty, heat radiators are mounted on the top of the grid side rods to help dissipate the heat which causes grid emission.

In addition, the use of new materials for the grid wires themselves has produced a cooler grid. As one example, the 59 employs wire, which has been carbonized, for the grids adjacent to the cathode. The carbonized metal reduces secondary emission and radiates heat so as to maintain the grid at a temperature low enough to prevent excessive primary emission.

The practical effect of reduced grid emission is that the tube dissipation can be increased. Higher internal dissipation means higher output from the tube and better performance from the radio set.

Another practical benefit to the set engineer resulting from a reduction in grid emission is the feasibility of operating tubes such as the 2A5 with resistance coupling, since the use of moderate values of resistance in the grid circuit of these tubes will not cause a loss of bias due to grid emission. Unless grid emission in certain output tubes is held to a low value, their use is limited to transformer-coupled circuits.

Rigorous Tests for Every Tube

A more stringent and exacting series of tests has been initiated for each tube type. Every tube leaving the factory is subjected to these tests. Each tube must conform to the standards of quality and uniformity established for that type.

Noisy tubes are frequently the source of trouble in receivers after they have been put in use by the customer. While this trouble has often been blamed upon man-made static, in many cases the tubes themselves were the cause. To guard against noisy operation in preliminary amplifier and detector applications, every Radiotron and Cunningham tube of the types so employed receives a noise test in high-sensitivity receiving circuits in addition to numerous other electrical tests. In this way, those tubes which might cause trouble are eliminated.

Representative quantities of tubes, selected at random from production, are life tested. Characteristic checks made frequently during the life test reveal how well the tubes are standing up under actual operating conditions. In this way it is possible to determine the serviceability of each type. By controlling manufacturing processes in accordance with the results of these tests, each tube leaving the factory is particularly fitted for operation under the conditions for which it was designed.

The improvements in tube design and construction which have been made in the past enable the radio set engineer to achieve better set performance. The improvements which will be made in the future will make possible even greater advances in receiver design. Consequently, it is helpful to the radio set engineer to be conversant with the latest design features of all radio tube types, since these features provide better performance capabilities which can be readily capitalized by the set engineer.

CERTIFIED TRIAD TUBES

The LONG LIFE TUBE *of Universal Satisfaction*

TYPE T-244-AC

T-224-AC is an A. C. four element, screen grid tube, for radio frequency stages in special circuits. Separate heater type and operates directly on A. C.

Heater Fil. Volts..2.5
Heater Fil. Amps..1.75
Plate Volts (max.) 180
5 prong Y type base

TYPE T-227

T-227 A. C. detector or amplifier, separate quick heater type.

Heater Fil. Volts...2.5
Heater Fil. Amps..1.75
Detector Plate Volts 45
Used as amplifier
Plate Volts...90-135
5 prong Y type base

TYPE T-245

T-245 is a power amplifier for use in the output of receivers designed especially for its use. (Not interchangeable with T-171 or T-171A.)

Fil. Volts..........2.5
Fil. Amps..........1.5
Plate Volts....180-250
Negative Grid Bias 83-50

TYPE T-280

T-280 is a heavy duty full wave rectifier tube for use in A. C. receivers or A. B. and C eliminators.

Fil. Volts..........5.0
Fil. Amps..........2.0
A. C. Volts........300
D. C. M/A........125

TYPE T-171 AND T-171A

T-171 and T-171A power amplifiers for use in last audio stages only. Will handle great volume without distortion.

Fil. Volts..........5.0
T-71 Fil. Amps..... .5
T-71A Fil. Amps. .25
Plate Volts.....90-180

TYPE T-112A

T-112A output amplifier tubes are designed for use in the last audio stages of battery operated and A. C. sets.

Fil. Volts..........5.0
T-12 Fil. Amps..... .5
T-12A Fil. Amps. .25
Plate Volts......90-180

TYPE T-551

T-551 is a screen grid variable mu tube designed to eliminate cross talk and distortion and reduce static to a minimum, interchangeable with T-224 in most circuits.

Heater Vols........2.5
Heater Current....1.75
Plate Volts........250
Screen Volts........90
Grid Bias Volts... —3
Plate Current (ma.) 6.5

TYPE T-247 PENTODE

T-247 is a New Super Power Audio Amplifier with extremely high amplification factor and power output.

Fil. Volts..........2.5
Fil. Current........1.5
Screen Volts........250
Plate Volts.........250
Grid Bias Volts...16.5
Plate Current (ma.) 32.5
Power Output Watts 2.5

TYPE T-235

T-235 is a Variable Mu Screen Grid Tube similar to the type T-551. Type T-235 is especially adaptable to sets with automatic volume control.

Heater Volts.......2.5
Heater Current....1.75
Plate Volts........250
Screen Volts........90
Grid Bias Volts... —3
Plate Current (ma.) 7

TYPE T-201A

T-201A is a standard battery operated tube for use as detector and amplifier in any circuit.

Fil. Volts..........5.0
Fil. Amps.......... .25
Plate Volts..45 & 135

TYPE T-226

T-226 A. C. Amplifier for radio frequency and audio stages. Raw A. C. is used on the filament.

Fil. Volts..........1.5
Fil. Amps.........1.05
Plate Volts.....90-135

TYPE T-222 DC

T-222DC is a D. C. four element screen grid tube, for use in radio frequency stages of special circuits.

Fil. Volts..........3.3
Fil. Amps..........132
Plate Volts..........135
Control Grid Bias........1 to 1.5
Screen Grid Bias 45

CELL AND BATTERY TUBES FOR DRY OPERATION

TYPE T-230

A general purpose detector and amplifier tube for dry cells and battery operation.

Fil. Vols............2
Fil. Current........06
Plate Volts.........90
Grid Volts....... —4.5
Plate Current (ma.) 1.8

TYPE T-231

A power amplifier designed for dry cell and battery operation.

Fil. Volts............2
Fil. Current.. .13 amp.
Plate Volts.........135
Grid Volts...... —22.5
Plate current (ma.) 6.8
Undistorted Pow. Output (mw).....150

AFTER a thorough survey of all radio tube sales and an analysis of the reason for service calls, we have found that more than ever before is the serviceman being called upon for tube replacement and tube advice. We are thoroughly confident that there are thousands of intelligent servicemen, in all parts of the world who understand the desirability of knowing just what the tube characteristics are when the tube is put in your socket. Therefore, we are selecting and appointing CERTIFIED TRIAD SERVICEMEN in every corner of the globe, to enable you to get the performance you pay for. And we have decided to sell these special tubes through these reliable men, exclusively.

SERVICEMEN—WRITE FOR OUR SALES PROPOSITION

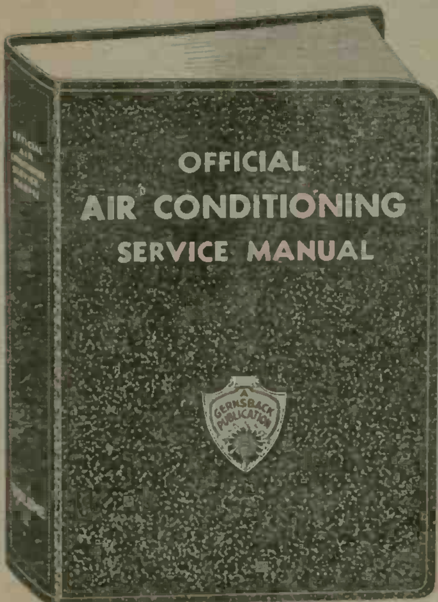
TRIAD Manufacturing Company
Television Mfg. Co.

This is a partial list of tubes manufactured by TRIAD

ANNOUNCING

A GOLDEN OPPORTUNITY FOR ALERT RADIO MEN IN

THE NEXT GREAT INDUSTRY



THE idea of electricians, radio service men and other mechanically inclined men, servicing Air Conditioning and Refrigeration Units is self-evident and the thought has occurred to some untold thousands ever since air conditioning equipment has been installed in public auditoriums, theatres, studios, department stores, office buildings and manufacturing plants. The tremendously broad possibilities in this new industry are bound to give employment and success to men far-sighted enough to see its advancement and development. We quote an excerpt from Mr. Hugo Gernsback's editorial which recently appeared in Everyday Science and Mechanics magazine.

> "I advise young and progressive men to go into the air-conditioning business during the next few years; because, this, without a doubt, is the coming industry in this country. Thousands of small firms will spring up, undertaking to air-condition private houses, small business offices, factories, etc. We are not going to tear down every building in the United States immediately. It will be a gradual growth; yet small installation firms will air-condition small houses, and even single offices in small buildings."

This is only partial proof of the certain success of this new field. Further assurance is that engineering schools have already added many important courses on air conditioning to their regular curriculum. Architects and building contractors are giving considerable thought to installation of this equipment in structures which are now being planned and built. The beginning of this business will probably be similar to the auto and radio industries, but in a few short years it will surpass these two great fields.

Official Air Conditioning Service Manual

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Over 600 Illustrations

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The OFFICIAL AIR CONDITIONING SERVICE MANUAL is being edited by L. K. Wright, who is an expert and a leading authority on air conditioning and refrigeration. He is a member of the American Society of Refrigerating Engineers, American Society of Mechanical Engineers, National Association of Practical Refrigerating Engineers; also author of the **OFFICIAL REFRIGERATION SERVICE MANUAL** and other volumes.

In this Air Conditioning Service Manual nearly every page is illustrated; every modern installation and individual part carefully explained; diagrams furnished of all known equipment; special care given to the servicing and installation end. The tools needed are illustrated and explained; there are plenty of charts and page after page of service data.

Remember there is a big opportunity in this new field and plenty of money to be made in the servicing end. There are thousands of firms selling installations and parts every day and this equipment must be cared for frequently. Eventually air conditioning systems will be as common as radios and refrigerators in homes, offices and industrial plants. Why not start now—increase your earnings with a full- or spare-time service business.

Here are some of the chapter heads of the **OFFICIAL AIR CONDITIONING SERVICE MANUAL**:

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History of Air Conditioning; Fundamental Laws; Methods of Refrigeration; Ejector System of Refrigeration; Compression System of Refrigeration; Refrigerants; Lubricating Oils; Liquid Throttle Devices; Servicing Expansion and Float Valves; Servicing Refrigerating Systems; Control Devices; Thermodynamics of Air Conditioning; Weather in the United States; The Field of Air Conditioning; Insulating Materials; Heat Transmission Through Walls; Complete Air Conditioning Systems; Estimating Requirements for the Home, Small Store, Restaurant; Layout of Duct Systems; Starting Up a System; Operating and Servicing Air Conditioning Systems; Air Filtration, Ventilating and Noise Eliminating Devices; Portable Electric Humidifiers and Room Coolers; Automatic Humidifiers; Air Conditioning Units for Radiator System and Warm Air Systems; Central Conditioning Units, etc.

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THE necessity of GERNSBACK Manuals in the radio field has been shown by the fact that the total sales of the first three OFFICIAL RADIO SERVICE MANUALS, including the new CONSOLIDATED EDITION, now exceed 80,000 copies. Radio Service Men and others engaged in various branches of radio know the importance of such books, and how they must depend upon them for reliable information. Whether for public-address work, tube information or a circuit diagram, the material needed is certain to be found in one of the OFFICIAL RADIO SERVICE MANUALS.

In preparing this new edition many of the outstanding problems of the Service Men have been considered—methods of servicing, the new equipment constantly needed to cope with new tubes and sets, and the other fields of radio, such as public-address systems, short waves, auto radio and others.

The illustrations in the 1934 Manual are more explicit than before; inasmuch as the diagrams are not limited to the schematic circuit, but other illustrations show the parts layout, positions of trimmers, neutralizers, etc. There are hundreds of new circuits included, and not one from any previous editions of the manuals has been repeated. This we unconditionally guarantee.

It is quite evident that the 1934 Edition of the OFFICIAL RADIO SERVICE MANUAL is a decided improvement over previous volumes. The new book will prove itself to be invaluable as those volumes for previous years.

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- Diagrams and service notes, more complete than ever before in any MANUAL. Not merely the schematic hook-ups will be found, but chassis drawings showing parts layouts, positions of trimmers, neutralizers, etc.
- Voltage readings for practically all sets, as an aid in checking tubes and wiring.
- All values of intermediate-frequency transformers used in superheterodynes, with the manufacturers' own suggestions as to correct balancing.
- Detailed trouble-shooting suggestions and procedure as outlined by the manufacturers' own engineers—in other words, authentic "dope" right from headquarters.
- Values of all parts indicated directly on all diagrams.
- A.C.-D.C. cigarbox midgets.
- Public-address amplifiers.
- Short-wave receivers.
- Remote-control systems.
- A complete compilation of radio tube data, covering both the old and the many new types.
- Section devoted to test equipment, analyzers, etc., with full diagrams and other valuable information.
- A complete list of American broadcast stations with their frequencies in kilocycles; extremely useful in calibrating and checking test oscillators and in calibrating receivers.
- Free Question and Answer Service, the same as in our last two Manuals.
- No theory; only service information in quickly accessible form.
- Absolutely no duplication of any diagrams; nothing that appeared in any of the previous Manuals will appear in the 1934 MANUAL. This we unconditionally guarantee.
- A handy, easily-consulted master index making it easy for you to find almost anything pertaining to your service problem instantly. This index includes all the diagrams published in all the previous GERNSBACK Manuals, as well as the 1934 diagrams. A big convenience and time saver!

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