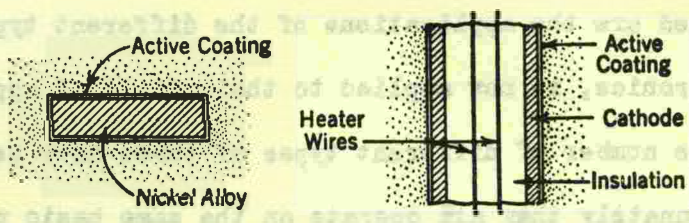

COATED FILAMENT

HEATER-CATHODE SECTION

LESSON 14 R

RADIO VACUUM TUBES

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

RADIO-TELEVISION TRAINING SCHOOL, INC.

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INTRODUCTION. No other single device has played a more important part in furthering the progress of the Radio Art than has the vacuum tube. The high power, high quality radio transmission and reception of today would be impossible if it were not for these highly developed tubes. Not only in radio, but also in many other lines are vacuum tubes put to a multiplicity of uses - in telephone and telegraph service, in signal and alarm systems, machinery and elevator control systems, etc. So numerous and varied are the applications of the different types of vacuum tubes, that the term, Electronics, is now applied to their field of applications.

Although a large number of different types of tubes have been brought out and are now in use, fortunately they all operate on the same basic principles. Some tubes with more internal elements have a more intricate mechanical structure, and hence possess certain operating refinements that require a more complex circuit arrangement. But the basis of operation of all radio vacuum tubes is the emission and flow of electrons, and the different tube structures serve merely to control this electron flow in such a manner that different operating characteristics are produced.

THE EDISON EFFECT IN A VACUUM TUBE

The principle of electron emission as employed in radio vacuum tubes is based on an early discovery by Thomas Edison. During his experimental work on incandescent electric lamps in 1883, he found that by placing a metal plate near the heated filament in the bulb and giving the plate a positive potential with respect to the filament, current would flow from the filament across the vacuum to the plate. This appeared strange, for a vacuum had always been considered a perfect electrical insulator; but later in 1899 J. J. Thompson explained the phenomenon by showing that the heated filament discharged or emitted a constant stream of small negative electrical charges that are now called electrons, and that these electrons in migrating from the filament to the plate rendered the intervening space capable of conducting electricity. As long as the filament is cold and no electrons are emitted, the vacuum is an insulator and no current can flow; but when heated, the filament releases the electrons, and these render the space conductive so that current can flow. The more electrons that are present, the better conductor is the space in which they are, and the more current can flow.

THE ELECTRON STRUCTURE OF MATTER

Although matter in general appears to possess a definite mass or body (for example, a piece of copper wire appears to be a solid bit of metal), still a final analysis will reveal that matter is not so very solid after all. All matter, it seems, is composed of myriads of tiny particles called molecules, a molecule being the smallest particle into which a substance can be divided and still retain the qualities of the original mass. In the case of some substances these molecules can be further subdivided, but the resulting particles are often entirely different from the original substance, for they are the materials of which the original substance is composed. These minute particles are called atoms. Those materials in which the molecules can be broken up into different kinds of atoms are called compounds, indicating that they are composed of several kinds of matter. Those in which the molecules are composed of only one kind of atom are called elements, indicating that they are basic forms of matter. In other words, chemically all substances can be classed as elements or compounds according to their molecular structure.

The atom, however, is not the ultimate particle of matter, for investigation reveals that the atom itself is of a complex structure, and that this structure is entirely of an electrical nature. Observations indicate that the atom appears to contain a central electrical nucleus consisting of one or several positive charges called protons around which there are moving in seemingly definite orbits and at great speeds a number of negative electrical charges called electrons. The atoms of various elements differ both as to the nature of the nucleus (the number of positive and perhaps negative charges) and also the number of revolving negative charges or electrons. In fact, it is the distribution of these electrical charges, protons and electrons, that determines the nature of different substances.

Under normal conditions an atom is electrically neutral, that is the positive and negative charges are of the same number and intensity and hence balance out. This means the object is not charged electrically as far as external conditions are concerned. However, as soon as a number of electrical charges or electrons disappear from an object, or a number of electrons are piled up in excess on another, the object becomes charged positively or negatively.

From this brief discussion it appears that matter is not really a solid mass, but is of a very porous or spongy nature, in view of the large spaces existing between the protons and the revolving electrons. The mass of a material object is apparently due to the mass of the protons and the kinetic energy (energy of motion) of the electrons. As the chemical composition of various substances becomes more complex, the electrical structure of the atom also becomes more so - the nucleus contains more positive and negative charges, and the number of electrons also increase and assume more intricate orbits of travel.

Although the subject of electronic structure is a most interesting one, the above brief facts are as much as can be covered in this text. Those desiring to read up further on the Electron Theory, will find many interesting books available on the subject in libraries and reading rooms.

ELECTRON EMISSION FROM HEATED OBJECTS

It was explained in previous paragraphs how the electrons in the atoms of a substance are in a constant state of motion and travel at great speeds in definite paths or orbits around the central nucleus. Also, it appears that there is surrounding each atom a restraining membrane or surface tension that keeps these electrons within their respective atoms. Under ordinary conditions the individual electrons do not possess sufficient energy to break through this restraining film; but if by some means their kinetic energy would be increased through an external influence, they could break through and dart out into space. However, as soon as one or more electrons have left an atom, the electrical balance within the atom is disturbed, and unless there is some external force to influence these liberated electrons, they are immediately attracted back to the object they left.

Electrons can be forcibly evicted from an object in several ways, the most common in radio practice being the application of heat or light. When an object is heated, the heat energy is imparted to the electrons and converted into kinetic energy or energy of motion, causing them to move faster and with greater vigor. Soon their kinetic energy is great enough to enable them to break through the restraining film and to dart out into space. If the heat application continues, more and more electrons acquire sufficient energy and break through, causing a steady emission of electrons.

Electron emission caused by the application of heat to an object is generally termed thermionic emission, therm referring to heat and ionic to electrical charges. The object from which the electrons are emitted (the electron emitter) is called the cathode and the nearby object to which they are attracted due to the presence of a positive charge on it is called the anode. In American tube language the word, plate, is usually used, but in British writings anode is used entirely.

Electron emission is very similar to the escape of vapors from the surface of a liquid. As a liquid is heated, the molecules become more and more active, causing increased agitation within the liquid. When the boiling point of the liquid is reached, sufficient energy is acquired by the molecules to enable those at the surface to break through and escape into the space above. As more heat is applied, more molecules escape from the surface and a constant vapor emission continues.

ELECTRON EMISSION FROM LIGHTED OBJECTS

Just as some substances become electrically active and emit a stream of electrons when heated, so others become similarly active when exposed to light rays of different colors or frequencies. Electron emission under such conditions is known as photo-electric emission, and devices employing this photoelectric effect are commercially referred to as photoelectric cells or merely photo cells.

Such photo cells are used in television and sound picture equipment. In sound picture projection a stream of light is projected through a film upon the active surface of a photo cell. On the film are various dark and light spots that interrupt the ray of light and thus indirectly control the electron emission within the photo cell. The pulsating stream of electrons is in turn converted into sound through a suitable reproducer system. Photo electric cells and their applications are discussed in detail in a later lesson.

ELECTRON EMISSION IN VACUUM TUBES

It was previously stated that it is the electron emission from a heated surface that forms the basic operating principle of the radio vacuum tube. The electron emitter is generally in the form of a treated filament rich in electrons and heated by means of an electric current passing through it. In some tubes the emitter or cathode is in the form of a tube or sleeve surrounding the filament, the filament in this case serving merely as a heater.

There is also a plate or anode at a positive potential with respect to the filament or cathode, and it is to this plate that the electrons are attracted. The electrons in their migration from the cathode to the plate render the space conductive and permit current to flow from the filament across the vacuum to the plate.

In most cases in radio circuits it is desired to control this flow of electrons to the plate, and for this purpose a third element is used known as the grid. The electrical condition of the grid whether positive or negative in potential, enables the grid to accelerate or retard the flow of electrons from the filament. In some of the later tubes as many as four and five grids are employed in order to bring about certain special operating features. It is evident that the grid can be made a real control lever in a tube, and it is in this way that the grid is commonly caused to function.

CONSTRUCTION OF RADIO VACUUM TUBES

Many types of tubes have been developed and are now in use in various radio receivers, but they are all only outgrowths or modifications of the original 3-electrode tube, the famous 201A. The rest merely have differently arranged or additional elements for the purpose of obtaining special operating characteristics. With a thorough knowledge of the operation of the 3-electrode tube, or triode, it will then be easy to understand its shortcomings and to see the advantages of the improved tubes that have been developed from it.

The modern triode vacuum tube has mounted within a glass bulb out of which practically all air has been exhausted, three elements or electrodes known respectively as the filament F, the plate P, and the grid G. These elements are supported rigidly in a glass stem that in turn is cemented into a bakelite base. Through the bottom of this base project four metal prongs or pins, two for the filament and one each for the plate and grid. The filament prongs can always be distinguished from the rest in that they are somewhat heavier. These pins fit into a standard 4-hole socket, and it is in this manner that the inner elements of the tube are connected to the other parts of the receiver circuit. In some of the tubes that have more than three elements an electrical connection is brought out in the form of a metal cap at the top of the tube.

FILAMENT AND CATHODE STRUCTURES

Two types of electron emitters or cathodes are used in modern radio tubes, the directly heated filament and the heater type or indirectly heated cathode.

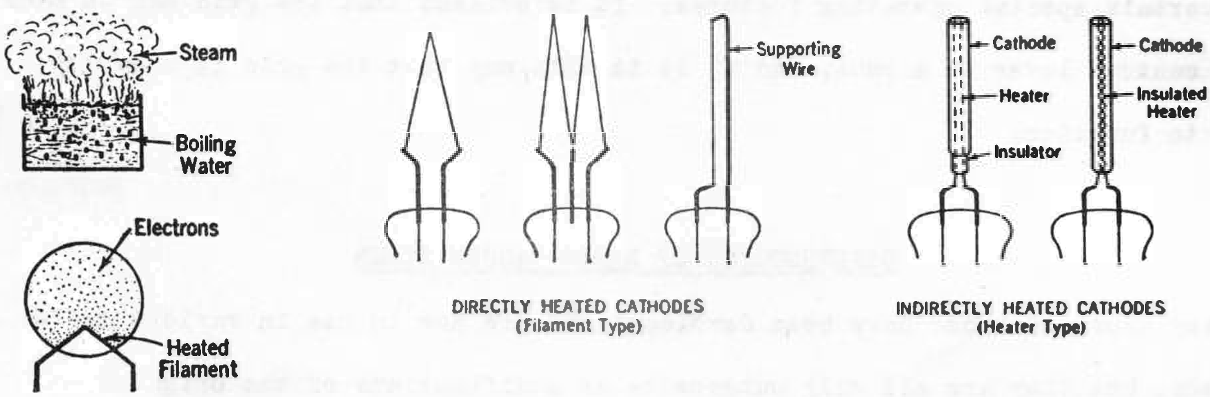

Fig. 1. Electron emission similar to escaping of steam from the surface of a liquid. Also, the directly and indirectly heated cathodes illustrated.

The directly heated filament consists of a small wire heated by means of an electric current sent through it to a temperature at which the electrons are emitted from the surface. In the early tubes a fine tungsten wire was used similar to that used in electric light bulbs, because tungsten was capable of liberating a fairly large supply of electrons. But quite a large current is required to heat pure tungsten to the temperature at which the electrons are emitted; and as the number of tubes used in a set increased, the filament current consumption became quite large. Two improved types of filaments were later developed that were capable of delivering the required volume of electrons with less current consumption. One of these was the thoriated tungsten filament and the other a nickel alloy wire coated with a layer of oxides rich in electron content. These filaments required only one-fourth as much current as the pure tungsten wire did.

The thoriated filament consists of a mixture of finely divided tungsten and thorium compressed at high pressure and drawn into wire of the required size. After the filament is built into the tube, it is given a special heat treatment that drives some of the thorium to the surface and forms an active outer layer that can freely emit the required electrons. Of course, as the electrons are emitted, the active layer gradually dissipates itself; but if the filament is operated at the proper temperature, enough thorium is constantly seeping to the surface to maintain an active surface layer. However, if the filament is run at too high a temperature, the active layer will be dissipated faster than it is replaced from the interior, and the tube will be below normal in performance. If the excess drain has not been too severe, it may be that by a rejuvenation or reactivation process some of the remaining active material can be driven to the surface and the tube restored practically to normalcy.

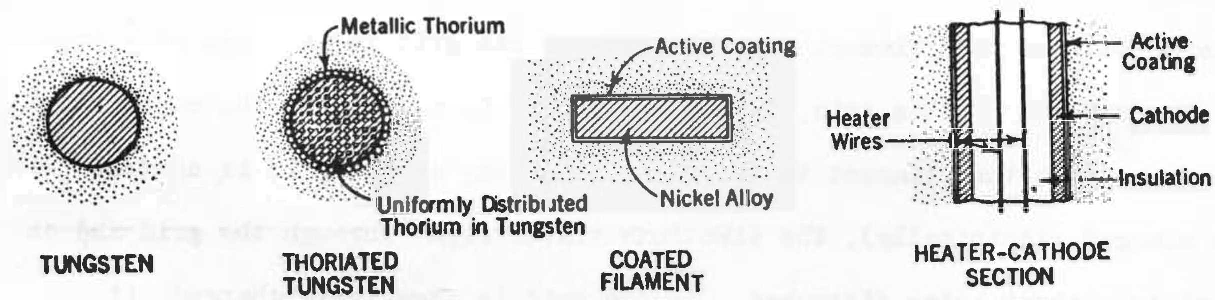

Fig. 2. The tungsten wire or directly heated filament, and thoriated and coated filaments illustrated. Also construction of indirectly heated cathode.

The coated filament, as its name suggests, has the active material in the form of an outer layer or coating. The nickel alloy wire is alternately dipped into a chemical solution and baked at a high temperature until sufficient layers have been deposited to form a thick enough coating. Such a coating is capable of emitting electrons freely at a rather low temperature and when the filament is operated at the proper voltage excellent tube performance is obtained. A coated filament of this type, however, cannot be reactivated, for once the active material is dissipated there is none left to replace it.

OPERATION OF THE TRIODE VACUUM TUBE

The triode vacuum tube, it was stated, is fundamentally the basic tube, most of the other tubes having been developed from it in order to obtain improved circuit performance. In this 3-electrode tube the filament is heated directly by an electric current sent through it so that a steady stream of electrons is emitted. Placed near it is the plate, which is at a positive potential with respect to the filament. Since unlike electrical charges attract each other, the negative electrons are quickly drawn to the positive plate. This stream of electrons renders the space conductive and permits current to flow from filament to the plate across the apparent vacuum. The more electrons that are present, the more current can flow.

Placed between the filament and the plate is the grid in the form of a wire mesh. The function of this grid, it was explained, is to control the movement of the electrons from the filament to the plate. As long as the grid is neutral (is not charged electrically), the electrons travel right through the grid and on to the plate without being disturbed. If the grid is negatively charged, it repels electrons back to the filament, and this decreases the conductivity of the space and reduces the plate current. If the grid is positively charged, it aids the plate in attracting more electrons. This makes the space a better conductor, and the plate current can increase. It is thus seen that as the potential of the grid is changed, the plate current changes accordingly. This explains how and why the grid can be made the control element of the tube. Also, since the grid is placed closer to the filament than the plate, a change in its potential will cause a greater change in electron flow than an equal change in plate potential would. In other words, a small change in grid potential will cause a relatively large change in plate current flow, which means that a small signal voltage impressed on the grid will reappear as a corresponding variation in plate current flow and at the same time be greatly amplified.

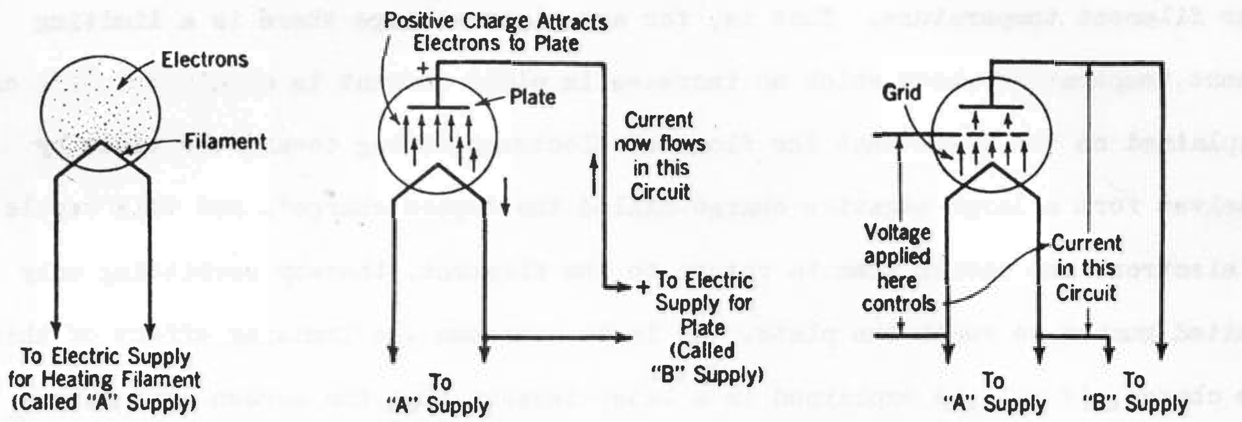

Fig. 3. Action going on within 3-electrode vacuum tube. Negative electrons emitted by filament are attracted to the positive plate, but electrical condition of grid controls the nature of the movement.

ELECTRON EMISSION AND SATURATION CURRENT

Although electrons are emitted freely when the filament is heated to the proper temperature, certain inherent conditions limit the plate current flow. For example, if the filament is at a given temperature and the plate voltage is gradually increased, the plate current at first also increases; but soon the rate of increase becomes less, and finally the current remains steady, in spite of further voltage increases. At this stage all electrons are drawn over to the plate, and the current has reached the saturation point. This saturation current is directly a measure of the rate of electron emission, and hence is also referred to as the emission current.

If the filament temperature is now raised, more electrons are emitted, and with a higher plate voltage more current can be drawn. But soon the saturation point is reached again and the current becomes steady even though the voltage is increased. These conditions are illustrated by the curve in Fig. 5, where current flow at a given filament temperature is shown as the plate voltage is varied.

If, on the other hand, the plate voltage is kept constant and the filament temperature is raised, the plate current will again at first increase rapidly and then become steady. If the plate voltage is increased, this steady value is at a higher filament temperature. That is, for any plate voltage there is a limiting filament temperature above which no increase in plate current is obtained. This can be explained on the basis that the flood of electrons moving toward the plate by themselves form a large negative charge called the "space charge", and this repels many electrons and causes them to return to the filament, thereby permitting only a limited number to reach the plate. It is to overcome the limiting effect of this space charge, it will be explained in a later lesson, that the screen grid tube was developed. The screen grid tube contains an additional grid, called the screen grid. This screen grid carries a positive charge that serves to neutralize the negative space charge, and thus permits more electrons to reach the plate.

It is evident from the above brief remarks that there is an optimum filament temperature and plate voltage at which a tube should be operated. These are the values prescribed by the tube manufacturer, and should always be adhered to for best results.

THE FILAMENT AND ITS CIRCUIT

The fundamental circuit showing the various connections to a 3-electrode tube is given in Fig. 4. The source of current for the filament is known as the "A" supply, and in the diagram a 6-volt storage battery is represented known as the A-battery. In the case of alternating current operated tubes the filament supply is in the form of a small step-down transformer that reduces the line voltage to the value specified for the tube.

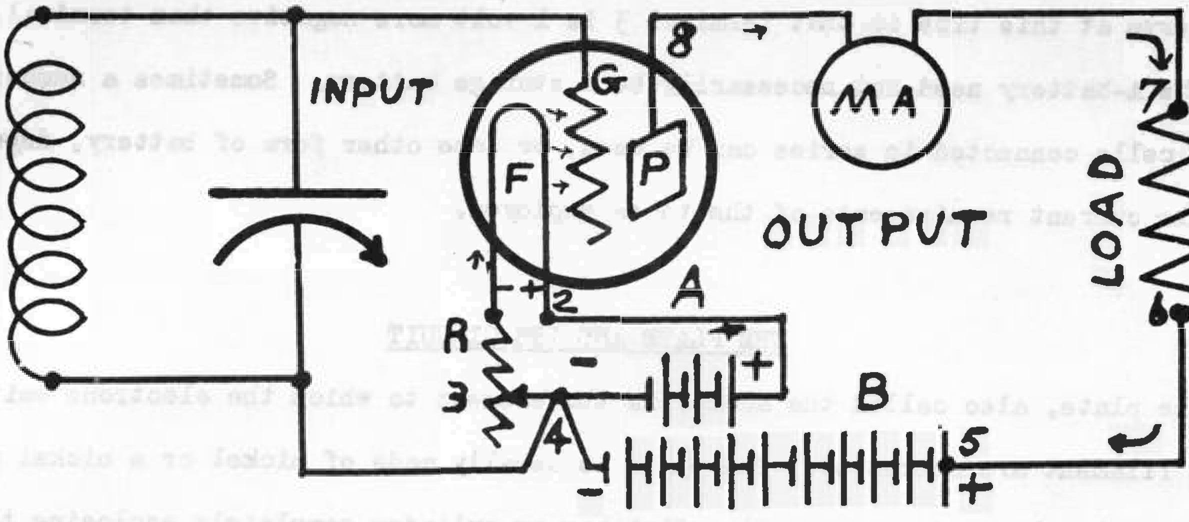

Fig. 4. Fundamental circuit of the 3-electrode vacuum tube showing connections of filament, plate, and grid, and A and B batteries.

If the battery voltage is higher than that required by the filament, means must be provided for reducing it. For this purpose a variable resistor or rheostat is used. As shown in the diagram, this rheostat is connected in series with the A-battery and tube filament, and is adjusted until the voltage "at the filament terminals" is that specified for the tube. For example, if a 201A tube is used, which has a filament rated at 5 volts, and current is supplied by a 6-volt storage battery as at "A" in the figure, there is an excess of 1 volt which must be dissipated somehow, or too much current will flow through the filament and burn it out.

For this purpose the rheostat "R" is used, connected between the negative filament terminal 1 and the negative A-battery terminal 4. The slider of the rheostat is adjusted until a voltmeter connected across the filament terminals 1 and 2 indicates 5-volts. The extra volt is then dissipated in the section of the rheostat between terminal 1 and the slider contact 3; that is, a voltmeter connected across points 1 and 3 would register 1 volt, for that much pressure is used up in sending the filament current through this section of the resistor. The 6 volts of the storage battery are thus used up in two ways - 5 volts are used to send the current through the filament and.1 volt is wasted in the active section of the rheostat. Another important point to observe at this time is that terminal 3 is 1 volt more negative than terminal 1.

The A-battery need not necessarily be a storage battery. Sometimes a number of dry cells connected in series can be used, or some other form of battery, depending upon the current requirements of the tubes employed.

THE PLATE AND ITS CIRCUIT

The plate, also called the anode, is the element to which the electrons emitted by the filament are attracted. The plate is usually made of nickel or a nickel alloy, and is in the shape of a rectangular flat box or cylinder completely enclosing the grid and filament.

The external plate circuit, often also referred to as the output circuit of a tube, includes a source of high voltage D.C. supply (commonly called the B-supply) and the load or device which is to be operated by the current flowing in the circuit. This load may be a set of head phones or loud speaker, a transformer or resistance coupler, etc. The high voltage plate supply may be either one or more B-batteries connected in series or an electric B-power unit. B-batteries and electric power units are taken up in detail in a later lesson.

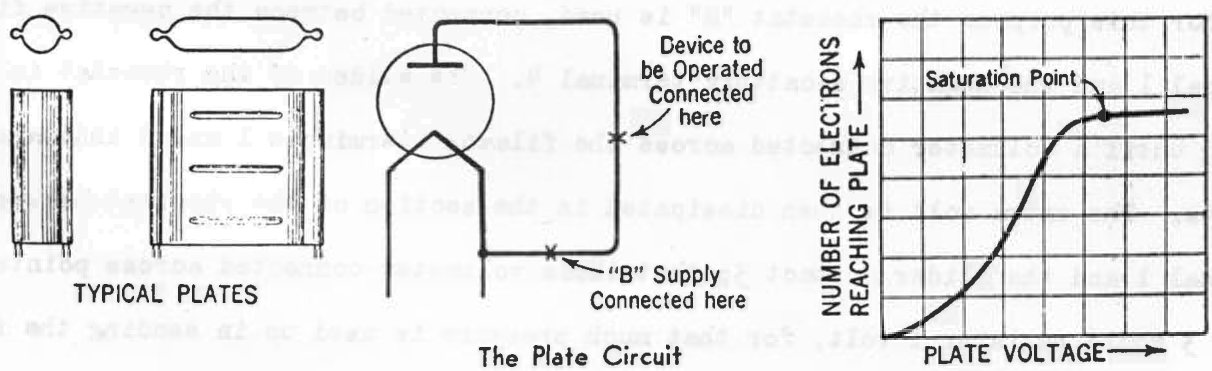

Fig. 5. Typical plate construction illustrated at left. Plate circuit connections shown in center diagram, and curve showing increase of plate current with change of plate voltage at right. Saturation point is marked.

The B-power supply, whether it consists of batteries or an electric unit, is connected between the plate and filament (or cathode) as is illustrated in Fig. 4, with the negative terminal to the filament and the positive terminal to the plate. The load is always connected between the positive B-supply terminal and the plate of the tube. The plate is thus always at a positive potential with respect to the filament, by an amount equal to the voltage of the B-supply minus the drop or loss in the load.

The path followed by the plate current is then as indicated by the long arrows in the diagram. When the filament is heated, current begins to flow from filament to the plate out through the load and re-enters the tube again at the filament terminal. If the filament is cold and no electrons are emitted, there will be no current flow to the plate. Therefore, no separate switch is needed in the plate circuit because turning the filament circuit on or off automatically closes and opens the plate circuit.

HOW TO MEASURE PLATE CURRENT AND PLATE VOLTAGE

If it is desired to measure the current (number of milliamperes) flowing in the plate circuit, this can be done by connecting a milliammeter into the circuit so that the entire plate current must flow through it. This milliammeter is illustrated as MA in the diagram. To measure the voltage of the B-supply unit, a high-resistance voltmeter is connected directly across its terminals, that is, across terminals 4 and 5 in the diagram. To measure the voltage actually supplied to the plate of the tube, a voltmeter is connected from the plate terminal of the tube to the point at which the plate circuit returns to the filament or cathode. If the filament is of the D.C. heated type, like that of the 201A type tube, this return point is at the negative filament terminal; while if the filament is A.C. heated like that of the 226 or 245 type, the return point is the center tap on the transformer winding or on a resistor connected across the winding. If the tube is of the indirectly heated or cathode type, the return point is to the cathode terminal on the tube. These circuits are illustrated in Fig. 6. The actual plate voltage is always less than the voltage of the B-supply by the amount of loss or drop in the load.

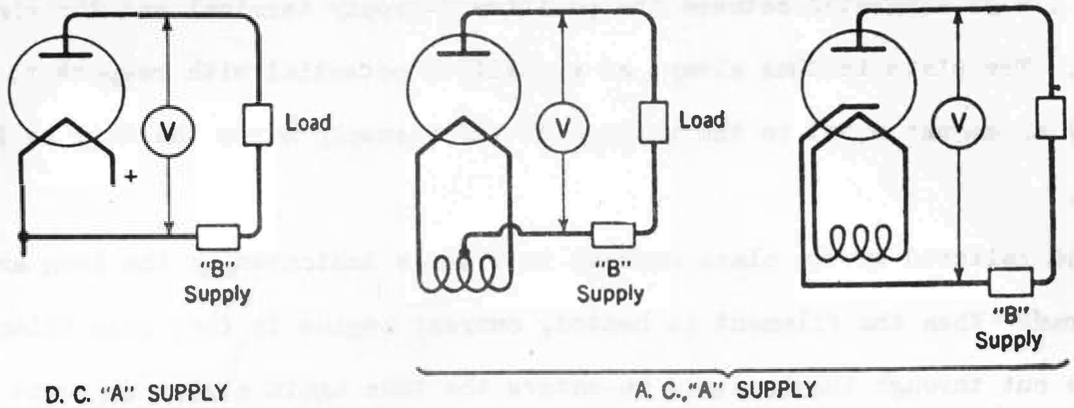

Fig. 6. Plate return circuits shown for D.C. operated filament, A.C. operated filament, and indirectly heated cathodes.

THE CONTROL GRID AND ITS CIRCUIT

When the grid or third element in the tube was first introduced by DeForest in 1907, its purpose was to control the number of electrons moving from the cathode to the plate. But it was soon learned that there are still several effects present in such a 3-element tube that impair its performance, and that these could be eliminated through the use of additional grids. To distinguish these various grids, they were termed the control grid, the screen grid, the suppressor grid, etc. These names indicate the functions they serve. The screen grid and suppressor grid are taken up in later lessons.

The control grid is in the form of a fine wire mesh or grating placed between the filament and plate. The electrons in their travel from the filament to the plate can readily travel through the open spaces in the grid; but if the grid is charged positively or negatively, it will either hasten more electrons to the plate or repel some of them and permit fewer to reach the plate. Since it thus regulates the movement of the electrons, it is called the control grid.

The external control grid circuit, also known as the input circuit of the tube, extends from the grid terminal to the filament or cathode. The closing connection of the grid circuit is called the grid return, and is brought either to the negative terminal, to the center tap on the transformer winding (or filament resistor) or to the cathode, according to the type of the tube used.

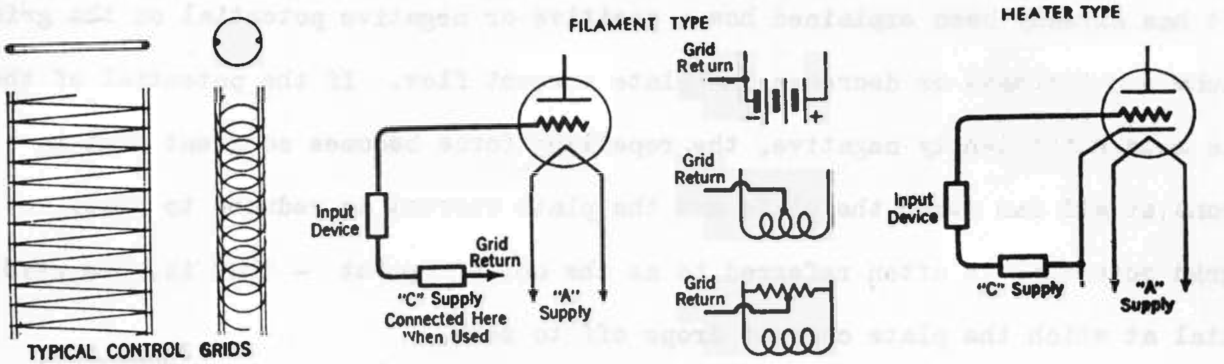

Fig. 7. Typical grid construction illustrated. Also grid return connections for directly and indirectly heated cathodes.

The grid circuit also includes some device for impressing the signal voltage on the grid of the tube. This may be in the form of an antenna coupling coil, a coupling resistor, or a transformer secondary, depending upon the nature of the circuit into which the tube is connected.

GRID POTENTIAL - ITS EFFECT ON PLATE CURRENT FLOW

The potential of an object refers to its electrical condition, and is always given with respect to some other point or object. Thus, if the potential of the grid of a tube is mentioned, it refers to the electrical condition of the grid with respect to the filament or cathode, or the center tap on the filament circuit in case of a directly heated A.C. filament (refer to Fig. 7). If the grid potential is said to be negative 3 volts, it means that the grid is 3 volts more negative than the filament. In other words, a high-resistance voltmeter connected with its positive terminal to the filament (or cathode) and its negative terminal to the grid, would register 3 volts.

In all tube circuits the negative filament or cathode terminal (or filament center tap) is always used as the point from which the potential of other elements is figured. That is, if the grid potential or plate voltage is referred to, it means that these elements are so many volts more positive or negative than the filament or cathode.

It has already been explained how a positive or negative potential on the grid of a tube can increase or decrease the plate current flow. If the potential of the grid is made sufficiently negative, the repelling force becomes so great that no electrons at all can reach the plate and the plate current is reduced to zero. This grid potential is often referred to as the cut-off point - that is, the grid potential at which the plate current drops off to zero.

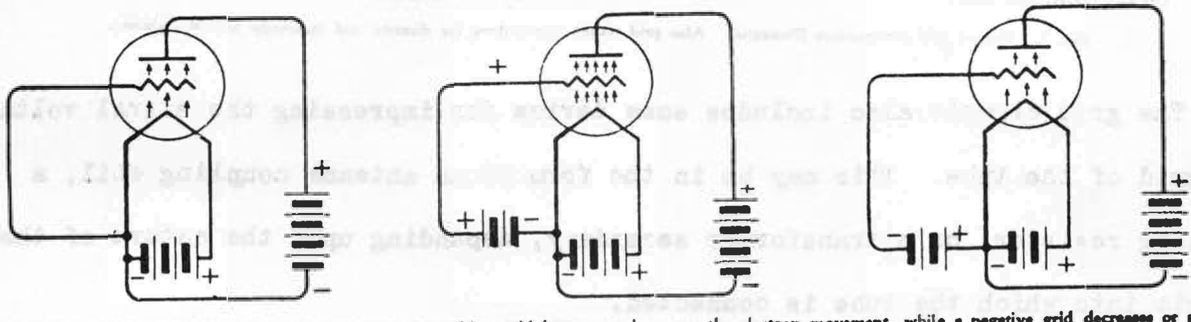

Fig. 8. Effect of grid potential on electron movement. A positive grid hastens or increases the electron movement, while a negative grid decreases or retards the movement.

If this cut-off grid potential is taken as the starting point, and the potential is gradually brought up to zero, the plate current increases, gradually at first and then quite rapidly until the point of zero potential is reached when the current begins to become steady. This variation of plate current with the grid potential is illustrated by the curve in Fig. 10. It can also be seen that when the grid potential passes zero and becomes positive, electrons are attracted to the grid and current flows in the grid circuit. This is purely a waste of energy, and is always avoided in ordinary vacuum tube practice, for current flow in the grid circuit contributes nothing toward the useful performance of the tube.

HOW A RADIO SIGNAL CAN AFFECT PLATE CURRENT FLOW

An incoming radio signal, it was previously explained, reaches the receiving set via the antenna in the form of an alternating current voltage. If this alternating voltage is impressed across a circuit, the terminals of the circuit alternately become positive and negative as the signal passes successively through each half cycle.

A vacuum tube receiving circuit is arranged so that the incoming signal voltage is impressed across the input circuit of the tube, that is, across the grid and filament (or cathode). Consequently the potential of the grid becomes alternately positive and negative according to the signal voltage variations. As the grid potential becomes positive, more electrons are attracted to the plate and the plate current increases; and as the potential becomes negative, some electrons are repelled and fewer reach the plate, causing the plate current to decrease. Since the plate current always changes in exact accordance with the variations in grid potential, the signal which was initially impressed on the input circuit in the form of an alternating voltage, reappears in the plate or output circuit in the form of a pulsating current.

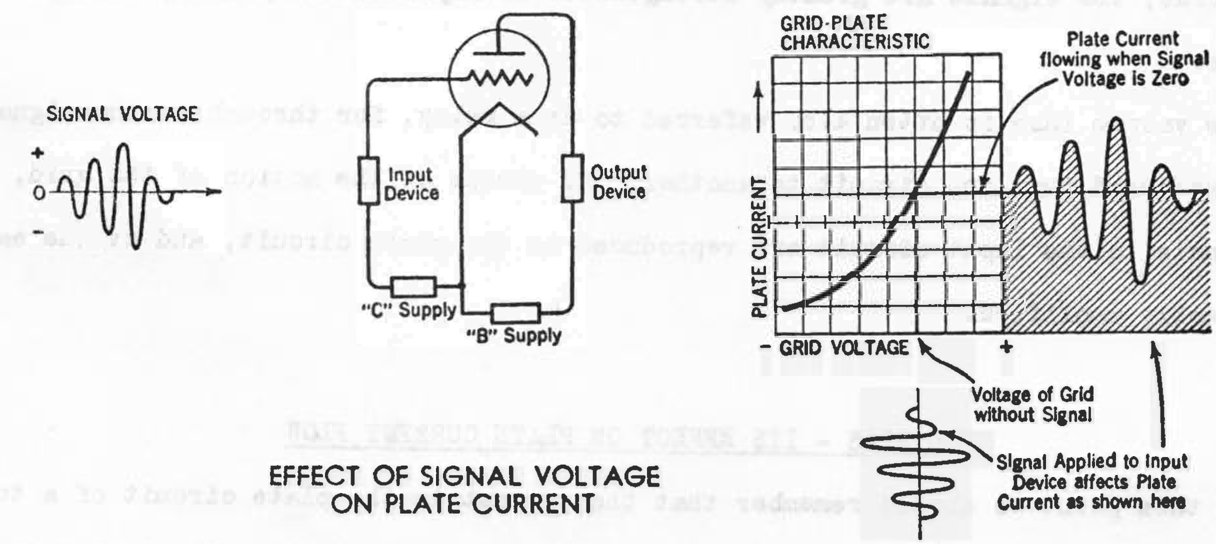

Fig. 9. Effect of signal voltage waves at left when impressed on input circuit of tube produce plate current fluctuations as shown at right.

This action is clearly illustrated in Fig. 9. At the left in Fig. 9 is illustrated the signal voltage in the form of a group of alternating voltage waves, and these are impressed through the input device on the grid and filament of the tube. With no signal voltage coming in, a steady plate current flows; but when the alternating signal voltage does reach the grid, it causes corresponding changes in plate current flow and hence reappears in the plate or output circuit as a pulsating current.

THE RELAY ACTION OF THE VACUUM TUBE

The grid, it can now readily be seen, is the control lever or governor of the tube, for its electrical condition determines the action that takes place. It is a very sensitive element, and very slight changes in its potential can be caused to produce appreciable changes in plate current flow. The amount of energy supplied to the grid is negligibly small, but the energy in the plate circuit depends only upon the voltage or power of the B-supply unit. Since the changes in plate current flow correspond to the voltages impressed on the grid, the weak incoming signals sent into the tube are reproduced in the plate circuit with far greater strength. In other words, the signals are greatly strengthened or amplified in passing through the tube.

The vacuum tube is often also referred to as a relay, for through it the signals are transferred from one circuit to another. By virtue of the action of the grid, the signals in the input circuit are reproduced in the plate circuit, and at the same time greatly amplified.

GRID BIAS - ITS EFFECT ON PLATE CURRENT FLOW

At this point we should remember that the current in the plate circuit of a tube fluctuates in accordance with the signal voltages impressed on the grid, increasing as the grid potential becomes positive and decreasing as the potential becomes more negative. For most economical tube performance, however, these plate current fluctuations must be confined to within certain limits. If the current is permitted to rise too high, the drain on the B-supply system is excessive, while if the current is permitted to drop too low, distortion will set in, that is, the reproduced sounds will not be natural.

In order that the plate current variations will therefore be limited to the values specified for best circuit performance, a constant negative potential is impressed on the grid to bring the operating point of the tube to the proper position on the grid voltage-plate current curve illustrated in Fig. 10. This negative potential is termed the grid bias, and the battery or unit used for providing it is called the C-battery or C-supply. This C-supply unit is always connected between the input device and the cathode, with its negative terminal to the grid and its positive terminal toward the grid return point as is illustrated in Fig. 7. Grid bias voltages ranging from 1-1/2 up to 50 volts and higher are used, depending upon the kind of tube and the conditions under which the tube is being used.

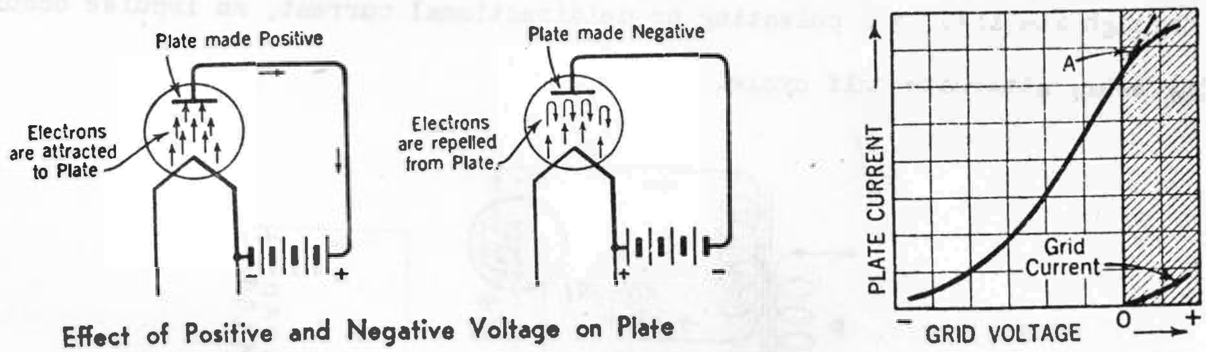

Fig. 10. Curve at right illustrates variation of plate current flow as grid bias is increased from cutoff point to positive value, causing grid current to flow.

DIODES

A diode, as its name suggests, contains only two elements, an electron emitting filament or cathode and a plate, as is illustrated in Fig. 11. If a positive potential is put on the plate, current can flow through the tube across the vacuum from filament to plate; but if the plate is made negative with respect to the filament, all electrons are repelled and no current can flow. In other words, a diode possesses only one-way conductivity.

As a result of this one-way conductivity, a diode can be used as a rectifier of alternating currents, either in a power supply system or as a detector rectifier. A power rectifier system is illustrated in Fig. 11. Here is illustrated a power transformer "T" with a 110-volt primary "P" for connection to the lighting circuit, and with two secondary windings, one S-1 a 7-1/2 volt filament winding and the other S-2 a high voltage winding the output of which is to be rectified by the diode, a type 81 rectifier tube.

As the filament is heated, electrons are emitted. With one side of winding S-2 connected to the plate and the other side to the load, during every half cycle that the plate is positive, current can flow from the filament to the plate and out through S-2 through the load and return to the opposite side of the filament. During the next half cycle the plate is negative and no current can flow. Therefore, the current flowing through the load is a pulsating or unidirectional current, an impulse occurring during every alternate half cycle.

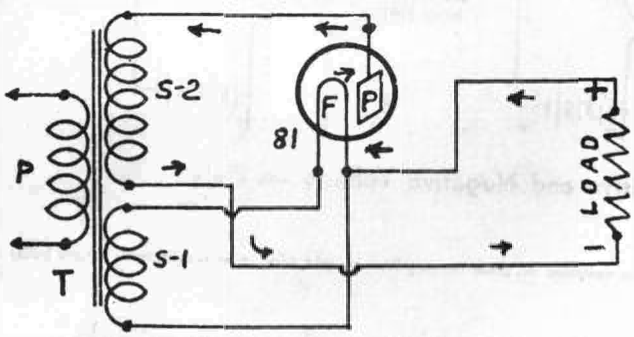

Fig. 11. A diode can act as a rectifier of alternating current if connected as illustrated here.