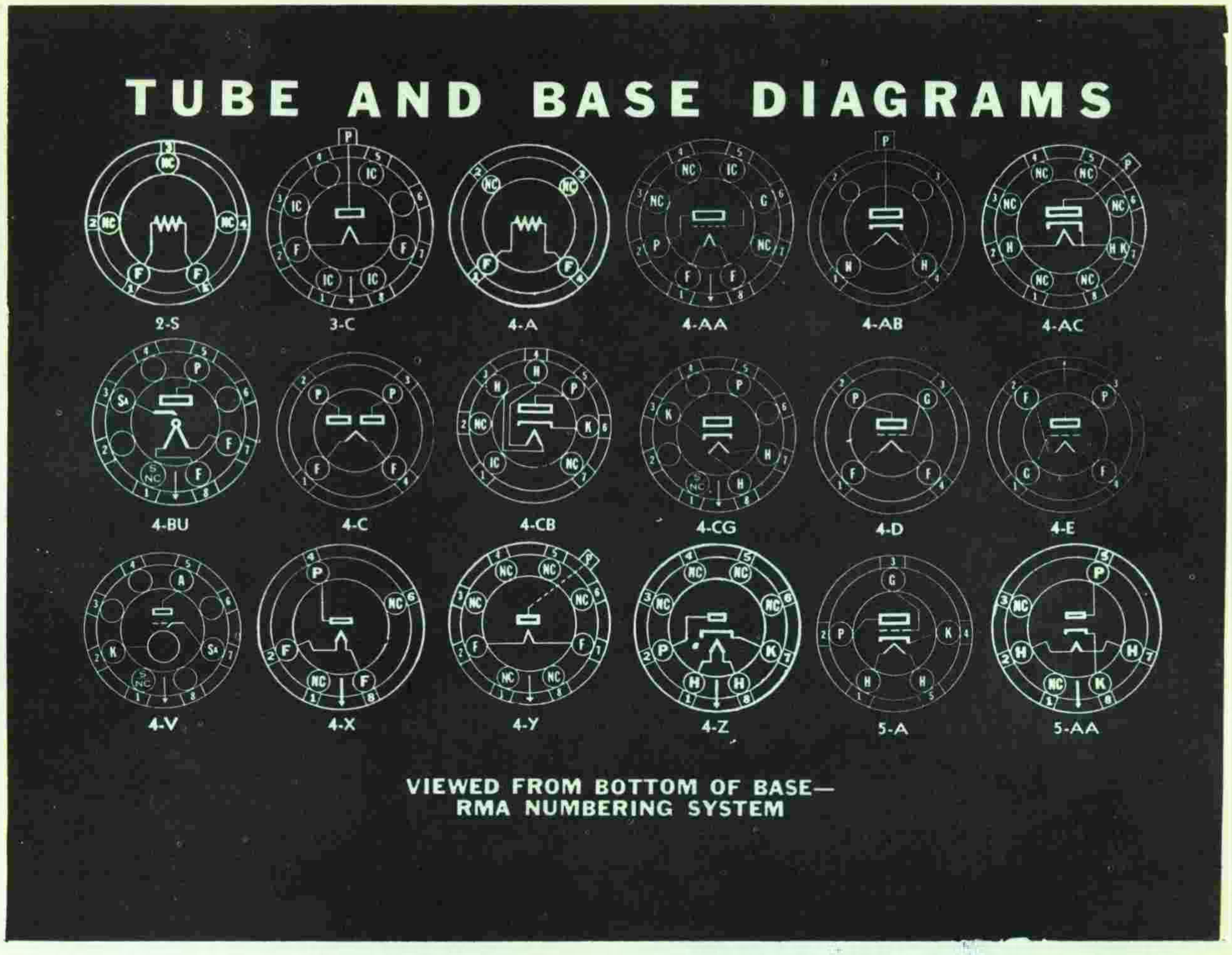

LESSON
16 RA

TUBE CLASSIFICATION
AND
OPERATING CHARACTERISTICS

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TUBES CLASSIFIED AS TO TYPE OF CONSTRUCTION

Radio tubes can be further classified into seven or eight groups according to their type of construction, especially as concerns the mounting base and enclosing shell. These are the standard glass tubes, the all metal tubes, the meta-glass tubes, and "S" series metal tubes, G-type glass tubes, the GT-type midget glass tubes and the Loctal tubes.

In the standard glass bulb tube the internal elements or electrodes are supported in a glass stem over which the glass bulb is sealed, and the entire structure is then cemented into a bakelite shell base. Through the bottom of this base project the metal pins into which the electrode terminal wires are soldered. In the dome at the top of the tube is a circular mica disk that further supports the internal electrodes and holds them in a rigid position. This type of construction has proven very satisfactory and is still used in most of the new glass tubes.

In the all-metal tubes the internal elements are arranged in a similar manner, but are supported in a metal seat over which a metal shell is sealed. Also, these tubes employ a special octal (8-pin) base with a center guiding pin or lug. The meta-glass tubes are essentially glass tubes with a smaller glass bulb, and this bulb is then surrounded with a metal shell to give the tube an all-metal appearance. They have an octal base.

The "S" series of metal tubes are of an improved design and employ no top-cap connections. In other words, the tubes are single-ended, therefore the use of the letter "S" in the tube symbol. The G tubes comprise a series of glass shell tubes that are equipped with an octal base. Some of these are similar in characteristics and applications to the all-metal tubes and others resemble some of the standard glass tubes. All of the new glass shell tubes are of this type, for they permit the use of one universal socket in all stages of a receiver.

The GT tubes are midget glass shell tubes similar in characteristics and applications to the regular G tubes. The GT tubes are not only smaller in construction, but some also have less heater current drain. Both of these factors, especially adapt these tubes for use in universal A.C.-D.C. sets. The Loctal tubes are another series of miniature glass-shell tubes with special structural features and operating characteristics that also make them very suitable for midget A.C.-D.C. sets. All these various types of tubes and their particular applications are taken up in detail in the following sections.

The spray-shield Majestic tubes which were made by the former Grigsby-Grunow Company and used in their Majestic sets, are merely glass tubes with a thin layer of copper sprayed over the glass shell. This film of copper was electrically connected to the cathode terminal, and served as a metallic shield for the tubes. Suitable replacement tubes with metallic shields also connected to the cathode terminal are now made by several tube manufacturers and are available at practically all radio jobbers.

METAL TUBES

The metal tubes employ the same basic operating principles as do the glass tubes, in fact, the internal electrode structure is practically the same in both types. In the metal tubes, however, an all metal enclosing shell is used, and since this shell is made to fit more closely around the inner elements, the metal tubes are much smaller in size than the corresponding glass tubes are. The lead wires are brought out through the base or "header", as it is called. This header also serves to seal the shell at the bottom. The metal shell is connected to a base pin which is always connected to ground potential so as to eliminate any danger of electric shock.

All metal tubes are provided with an octal (8-pin) base, the pins all being spaced uniformly at an angle of 45 degrees. At the center of the base is a bakelite lug with a projecting wedge or key, so that the tubes can be inserted in only one position in the socket. If the tube structure is such that all eight pins are not needed, the idle pins are omitted, but this does not affect the position of the remaining pins.

A standard numbering system is used for the base pins. If the tube base is viewed from below with the locating lug pointing toward the observer, the first pin to the left of the lug is No. 1. The pins are then numbered in a clockwise direction from 1 to 8, pin No. 8 then being immediately to the right of the locating lug. If some base pins are omitted, those remaining bear the same position number as though all were used. The advantage of this octal base system is that a universal 8-pin socket can be used throughout an entire receiver.

Since the metal tubes are so very much smaller than the glass tubes, there is less heat radiating surface, and consequently some of the metal tubes become extremely hot while in operation. Therefore, proper precaution should be taken when working on a set using metal tubes that the bare hands do not come in contact with them, or bad burnsmay result. Also, since the metal shell shields the inner elements from view, in case there is the least suspicion that faulty tubes are the source of trouble in a failing receiver, the tubes should be tested not only for operating fitness but also for shorts and leakage.

When octal base tubes are being inserted into their sockets, care should always be taken that the locating lug fits properly, for with some of the thin wafer sockets it is an easy matter to force a tube through and cut a new keyway, the result being that the set fails to work or that the tube is ruined completely. Likewise, inexperienced set owners should be warned not to remove these tubes, for since the tubes fit in any of the sockets it is an easy matter to insert them in the wrong place and thereby render a set completely inoperative.

In the following table are listed the commonly used metal tubes. The first column gives the metal tube number, the second column gives the number of the glass tube which each metal tube resembles, and the third column the type of tube it is or the class of service for which it is intended. In no case, however, are the metal tubes and the standard glass tubes interchangeable, for the characteristics of the metal tubes are just sufficiently different to require suitable circuit changes.

Metal Tube No.	Similar to Glass Tube No.	Type of Tube
5W4	80	Full-wave Rectifier
5Z4	—	Full-wave Rectifier
6A8	6A7	Pentagrid Converter
6B8	6B7	Duodiode Pentode
6C5	76	Triode Detector-Amplifier
6F5	75	High-Mu Triode
6F6	42	Pentode Power Amplifier
6H6	—	Duo-Diode
6J5	76	Triode Detector-Amplifier
6J7	77	Pentode Detector-Amplifier
6K7	78	Super-Control Amplifier
6L6	—	Tetrode Power Amplifier
6L7	6A7	Pentagrid Converter
6N7	6A6	Twin Triode Amplifier
6Q7	75	Duo-Diode Triode
6R7	85	Duo-Diode Triode
6V6	6L6	Tetrode Power Amplifier
25A6	43	Pentode Power Amplifier
25L6	6L6	Tetrode Power Amplifier
25Z6	25Z5	Rectifier and Voltage Doubler

THE S-SERIES OR SINGLE-ENDED METAL TUBES

The single-ended or S-series comprise a new group of metal shell tubes in which all electrodes, including the control grid, terminate in pins at the base, that is, the tubes employ no top-cap connection. These new single-ended tubes lend themselves well to efficient underchassis construction, for all connecting leads to the socket terminals can be made short or direct. Also, the elimination of the flexible top-cap connector results in an appreciable saving in cost and improves the circuit stability in that frequently these top-cap connectors are moved into a position where they cause stray coupling and disturbing oscillations.

The letter "S" following the first number in the tube symbol indicates the new single-end construction. Thus, 6SJ7 is a radio frequency pentode similar to the familiar 6J7, but with all electrodes terminating in base pins. This single-ended construction was made practical through the use of a new system of inter-lead shielding which protects the various base pins from each other. Another advantage of this new type of construction is that the input and output capacity of the tubes is further reduced, the grid-to-plate capacity being unchanged.

As was stated previously, these "S" tubes are metal shell tubes. The shell is 11/16 inch in diameter, and the tube measures only 2 1/16 inches above the chassis. The tubes employ a small octal base with the same base pin numbering system as is used with the regular metal tubes. The "S" tubes can be mounted either in a vertical or horizontal position, and therefore are very flexible in their applications.

Eleven single-ended metal shell tubes with their numbers and applications are given in the following table:

Tube No.	Type of Tube	Heater Volts	Heater Current	Similar to
6SJ7	Pentode Amplifier	6.3	0.3 Amp.	6J7
6SK7	Super-Control Amplifier	6.3	0.3 Amp.	6K7
6SJ5	High-Mu Triode	6.3	0.3 Amp.	6F5
6SQ7	Duo-Diode Triode	6.3	0.3 Amp.	75
6SA7	Pentagrid Converter	6.3	0.3 Amp.	New
6SC7	Twin Triode	6.3	0.3 Amp.	New
12SA7	Pentagrid Converter	12.6	0.15 Amp.	6SA7
12SC7	Twin Triode	12.6	0.15 Amp.	6SC7
12SJ7	Triple Grid Amplifier	12.6	0.15 Amp.	6SJ7
12SK7	Super-Control Amplifier	12.6	0.15 Amp.	6SK7
12SQ7	Duo-Diode Triode	12.6	0.15 Amp.	6SQ7

The last five tubes are exact duplicates of five in the first section, and differ only in their heater voltage and current ratings. The 6SA7 is a new form of pentagrid converter used in superheterodyne receivers and is taken up in greater detail in a future lesson.

THE "G" TYPE TUBES

The so-called "G" tubes comprise a special group of glass shell tubes that have octal type bases with bakelite locating lug and miniature size metal top caps. In these two respects they resemble the all-metal tubes. The glass bulbs are all of the "ST" type. There is a G-type glass tube corresponding to practically every metal tube (simi_ar types having identical base connections) and in addition many standard glass types have been duplicated with "G" tubes.

The main advantage of the "G" line of tubes is that they permit the use of octal sockets throughout an entire receiver. In most cases the "G" tubes can be substituted for the corresponding metal or standard glass tubes, but generally balancing and re-aligning will be necessary due to slight variations in characteristics and inter-electrode capacities. Where all of the eight base pins are not needed, the idle ones are omitted without affecting the spacing of the remaining pins.

The same base numbering system is used as with standard metal tubes, a number being assigned to each of the eight pin positions. If the tube base is viewed from below with the bakelite locating lug toward the observer, the pins are numbered in a clockwise direction, pin No. 1 being the first pin to the left of the locating lug, and No. 8 the pin to the right of the locating lug. If one or several base pins are not needed for a given "G" tube, these pins are left off, but the remaining pins are numbered normally as though all pins were present.

For most "G" tubes pin No. 1 is present but is not connected. On base diagrams the letter "S" (meaning shell) attached to pin No. 1 refers to the equivalent metal tube, for most of the diagrams also represent metal base connections where pin No. 1 is the termination of the metal shell. There are a few exceptions to this rule, such as in the 6C5G and the 6J7G in which pin No. 1 connects to an internal cage structure which serves as an additional shield.

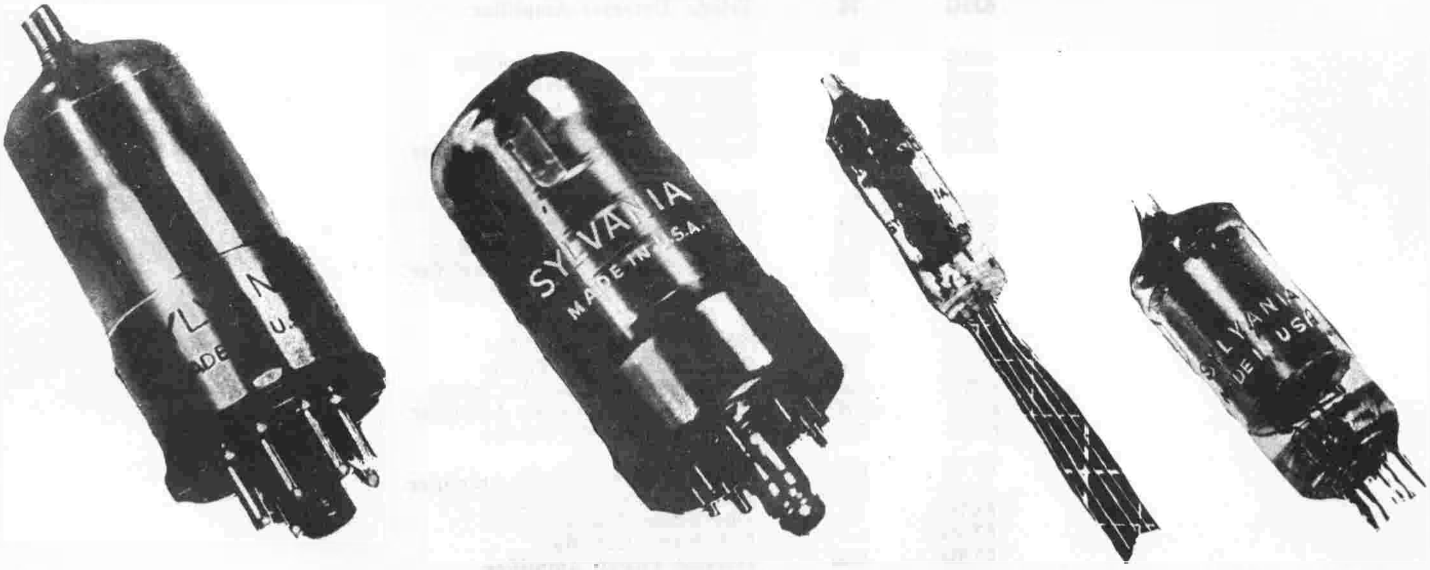
In the following table in the first column are listed the commonly used "G" type tubes. In the second column are given the metal or glass tubes which they resemble, and in the third column is given the type of service for which each is intended. Many of these tubes are directly interchangeable; but beforeany substitution is made the operating characteristics should always be compared, for if these differ greatly, the change cannot be made.

G Tube Number	Similar to	Type of Tube
5Y3G	80	Full-Wave Rectifier
6A5G	6A3	Triode Power Amplifier
6A8G	6A8	Pentagrid Converter
6AC5G	6B5	Triode Power Amplifier
6B4G	6A3	Triode Power Amplifier
6B6G	75	Duo-Diode Triode
6B8G	6B7	Duo-Diode Pentode
6C5G	76	Triode Detector Amplifier
6C8G	—	Twin Triode Amplifier
6D8G	6A7	Pentagrid Converter
6F5G	75	High-Mu Triode
6F6G	42	Pentode Power Amplifier
6F8G	—	Twin Triode Amplifier
6H6C	6H6	Duo-Diode Detector
6J5G	76	Triode Detector-Amplifier
6J7G	77	Pentode Detector-Amplifier
6J8G	—	Frequency Converter
6K5G	75	High-Mu Triode
6K6G	41	Pentode Power Amplifier
6K7G	6K7	Super-Control Pentode Amplifier
6L5G	76	Triode Detector Amplifier
6L6G	6L6	Tetrode Power Amplifier
6L7G	6L7	Pentagrid Mixer or Amplifier
6N6G	6B5	Direct Coupled Power Amplifier
6N7G	6A6	Twin Triode Power Amplifier
6P7G	6F7	Triode Pentode Amplifier
6Q7G	75	Duo-Diode Hi-Mu Triode
6R7G	85	Duo-Diode Medium-Mu Triode
6S7G	6D6	Super Control Pentode Amplifier
6T7G	75	Duo-Diode Hi-Mu Triode
6V7G	6D6	Super Control Pentode Amplifier
6V6G	6L6	Tetrode Power Amplifier
6V7G	85	Duo-Diode Triode
6X5G	—	Full-Wave Rectifier
6Y6G	6L6	Tetrode Power Amplifier
6Y7G	79	Complete Class B Amplifier
25A6G	43	Pentode Power Amplifier
25A7G	—	Diode-Pentode Power Amplifier
25L6G	6L6	Tetrode Power Amplifier
25Z6G	25Z5	Rectifier and Voltage Doubler

THE GT TUBES

The "GT" tubes, also referred to by some manufacturers as Bantam tubes, are a series of midget tubes designed especially for series filament operation in A.C.-D.C. receivers. The tube elements are mounted directly into a glass seat and over this is sealed the glass shell which is only 1 1/4 inches in diameter. The maximum overall length of these tubes is also only 3 5/16 inches. Around the bottom of the tube is a metal band shield with the socket guide pin or lug. This metal lug at the same time serves as a shield for the various base pins.

The "GT" tubes are equipped with the standard small octal (8-pin) base; and like the corresponding G-tubes many of them have the usual top-cap connection, that is, the "GT" tubes are not single-ended like some of the other midget tubes. In many cases the "GT" tubes and "G" tubes are interchangeable, except where the characteristics vary greatly or where the heater ratings are different.



Here are shown four different types of radio and television tubes. The octal at the left, the loctal second from the left, the miniature glass second from the right and the miniature 7 pin at the right. The octal, the loctal as well as the 7 pin miniature all require different sockets while the miniature glass tubes have long connecting leads and do not require sockets.

Some of the "GT" tubes are designed for higher heater voltages and lower heater current, only 0.15 ampere (150 milliamperes). These tubes are especially suitable for series filament operation, for on account of their lower current drain less heat is developed and the receivers in which they are used thus operate at a lower temperature. Also, the voltage dropping resistor can be removed from the line cord and built directly into the receiver.

In the following table are listed sixteen "GT" tubes. Those tube numbers marked with an asterisk (*) are directly interchangeable with the corresponding number "G" tube.

GT Tube Number	Type of Tube	Heater Volts.	Heater Amps.	Similar to G Tube No.
6A8GT*	Pentagrid Converter	6.3	0.3	6A8G
6J7GT*	Triple Grid Amplifier	6.3	0.3	6J7G
6K7GT*	SuperControlAmplifier	6.3	0.3	6K7G
6Q7GT*	Duo-Diode Triode	6.3	0.3	6Q7G
12A8GT	Pentagrid Converter	12.5	0.15	6A8G
12F5GT	High-Mu Triode	12.5	0.15	6F5G
12J7GT	Triple Grid Amplifier	12.5	0.15	6J7G
12K7GT	Super Control Amplifier	12.5	0.15	6K7G
12K7GT	Duo-Diode Triode	12.5	0.15	6Q7G
35L6GT	Beam Power Amplifier	35.0	0.15	6L6G
35Z4GT	Half-Wave Rectifier	35.0	0.15	New
50L6GT	Beam Power Amplifier	50.0	0.15	6L6G
35Z5GT	Half-Wave Rectifier	35.0	0.15	New
40Z5GT	Half-Wave Rectifier	45.0	0.15	New
12B8GT	Triode-Pentode	12.5	0.3	New
32L7GT	Output Tube & Rectifier	32.0	0.3	New

The four tubes in the first group marked with an asterisk (*) are exact duplicates of the corresponding number "G" tubes and are interchangeable with them.

The five tubes comprising the second group, it will be seen, have only a 0.15 ampere (150 milliampere) heater current drain. These were especially designed for series filament operation in A.C.-D.C. sets, for on account of their low current consumption less heat is developed and the receivers consequently operate at a much lower temperature. Furthermore, the voltage dropping resistor can be taken from the line cord and incorporated within the set.

The five tubes in the third group are special beam power amplifier tubes and half-wave rectifiers also with a low current drain and therefore intended for use in A.C.-D.C. sets. The 35Z5GT and 45Z5GT half-wave rectifier tubes also have a 6.3 volt tap brought out from the filament for a pilot lamp.

The 12B8GT is an entirely new tube and has a composite structure consisting of a high-mu triode and a radio frequency pentode. The 32L7GT is also a composite tube consisting of a beam power amplifier and a half-wave rectifier. With these two tubes it is thus possible to build a complete midget set having 4-tube performance.

LOCTAL TUBES

The Loctal tubes are another series of single-ended glass-shell tubes that were developed to make available a smaller tube of improved structural design and superior operating qualities. Being single-ended these tubes employ no top-cap connections and all electrodes are brought out to terminal pins in the base.

The Loctal tubes employ a number of unique structural features. The internal elements are mounted directly on a glass "seat" over which the enclosing glass shell is sealed. The lead wires to these elements are also sealed through this seat and at the same time serve as base contact pins, thus eliminating soldered connections. The entire lower portion of the tube is then covered with a close-fitting metal shield to which is also attached a guiding pin or locating lug. This metal guide pin further helps to reduce the capacity effect existing between the several base pins.

Although these Loctal tubes have a small octal (8-pin) base, a special type of socket is needed for them. The metal guide pin has a groove around the bottom which snaps into a catch or ring in the socket. This locking arrangement holds the tubes tight in the sockets and assures good contact at all times. It is from this locking-in feature and the use of an octal base that the term, Loctal, was formed. On account of this lock-in hold, Loctal tubes cannot be removed from their sockets by a direct upward pull. To remove a tube it is necessary first to exert a slight off side pressure on it. This releases the socket lock, and after that the tube can easily be removed.

Due to these individual structural features and socket requirements, Loctal tubes are not interchangeable with any other tubes nor can they be used as replacements for any other types of tubes. However, Loctal tubes on account of their lower heater current requirements are also especially well adapted for universal A.C.-D.C. sets. This smaller current drain greatly reduces the amount of heat developed by the tubes, and therefore receivers using these tubes operate at a far lower temperature. Also, the series filament resistor can be incorporated within the set itself and removed from the line cord.

Eight Loctal tubes are listed in the following table. Although some of these have operating characteristics similar to those of other types of tubes intended for a similar class of service, they cannot be substituted or used as replacements. The number and heater ratings of the Loctal tubes, also the class of service for which they are intended, and the numbers of the other tubes to which they are similar, are also listed.

Loctal Tube No.	Type of Tube	Heater Volts	Heater Current	Similar to Tube No.
7A6	Duo-Diode	7.	.160 Amp.	6H6
7A7	Pentode R. F. Amplifier	7.	.32 Amp.	6K7
7A8	Octode Converter	7.	.160 Amp.	6D8G
7B7	Pentode R. F. Amplifier	7.	.160 Amp.	6S7G
7C6	Duo-Diode Triode	7.	.160 Amp.	75
7Y4	Full-Wave Rectifier	7.	.53 Amp.	84
35A5	Power Output Amplifier	35.	.160 Amp.	25L6G
35Z3	Half-Wave Rectifier	35.	.160 Amp.	New

Although Loctal tubes can be used in either series or parallel circuit systems those tubes with a .160 ampere heater rating are specially designed for series filament operation in A.C.-D.C. sets on account of their lower operating temperatures.

THREE MAJOR OPERATING CHARACTERISTICS

The various types of tubes used in radio receivers all have their individual operating characteristics, and each tube is adapted for a certain class of service. Some tubes have a higher amplification factor, others a greater power output, etc., so that there is a tube available to meet practically every circuit requirement.

There are three major characteristics that determine the application and operating fitness of a tube. These are the mutual conductance, the amplification factor, and the plate impedance. Sometimes the mutual conductance is referred to as the trans-conductance of a tube, but both terms have the same meaning. The numerical value of these characteristics for any tube can be obtained from the tube data charts supplied by the various tube manufacturers.

MUTUAL CONDUCTANCE

It has previously been explained how the grid is the real control element within a tube, and how its electrical condition determines the flow of plate current. On further thought it is evident that the more effective the grid is in influencing the plate current, the more sensitive is the tube, that is, the more readily is a signal sent through the tube. The mutual conductance is merely a numerical measure of this sensitivity or excellence of a tube. Mutual conductance is defined as the ratio of a given change in plate current to the change in grid potential causing it, the plate voltage being held constant. The ratio of one quantity to another is the quotient obtained by dividing the first by the second.

Mutual conductance is measured commercially in a unit called the micromho, and is generally represented by the capital letter "G" with the subscript "m", namely, "Gm." In general it can be said that the tube having a high mutual conductance is the better tube.

In Fig. 4 is reproduced the grid voltage-plate current characteristic of a tube, which it will be remembered is a graphical representation of the relation existing between the plate current and grid potential at constant plate voltage. Often a whole family of curves are illustrated, each for a different plate potential. It can be seen that when a certain change in grid voltage causes a large change in plate current, the curve is very steep, and when the current change for the same voltage change is small, the curve is more horizontal. This indicates that the slope or slant of the curve is an indication of the merit of a tube.

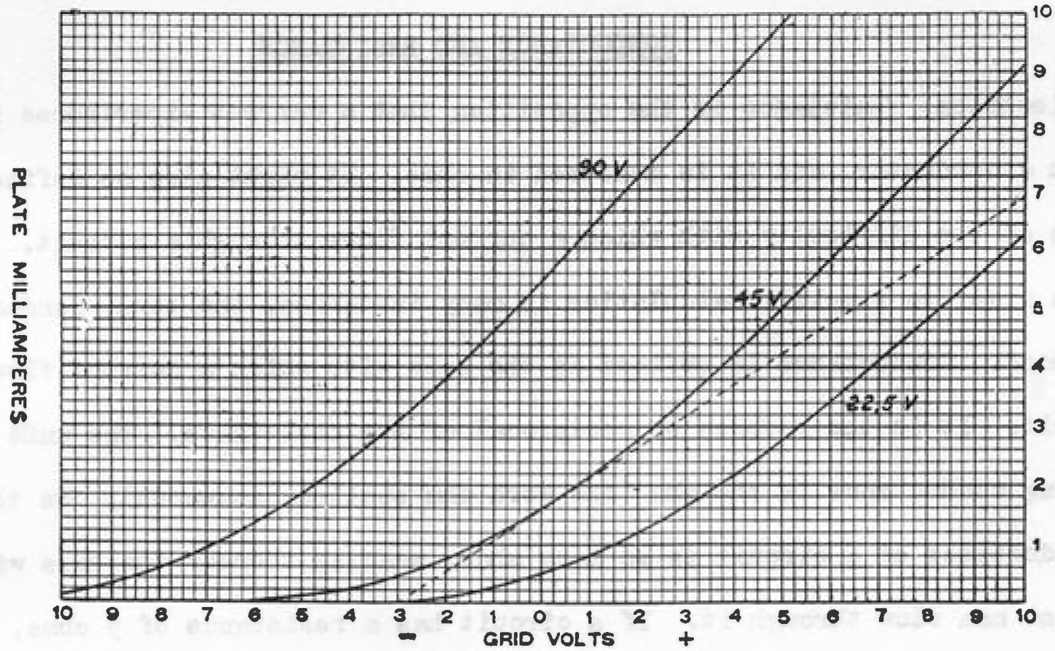


FIG. 4

MUTUAL CONDUCTANCE GRAPH

To get the numerical value of this slope or slant of the curve, a straight line is drawn tangent to (touching) the curve at the point at which the tube is working. This is illustrated by the dotted line in the figure. The slope is then calculated by taking the vertical distance of the intersection of the dotted line with the right hand edge, which in this case is 6.8, and dividing it by the distance along the base line from the right-hand edge, the positive and negative values amounting to 13. Dividing 6.8 by 13, we get 0.52 as the slope of the curve at the point selected. But since the plate current is measured in milliamperes (thousandths of an ampere) and the mutual conductance is measured in micromhos, it is necessary to divide by 1000 to change milliamperes to amperes and multiply by 1,000,000, to change mhos to micromhos. This is a net equivalent of multiplying by 1000. Therefore, the value of the mutual conductance in this case is 0.52 multiplied by 1000, or 520 micromhos.

CONDUCTANCE AND RESISTANCE

Electrical resistance is the opposition that a current experiences in flowing through a conductor, and it is measured in ohms. It might also be defined as a measure of the difficulty with which a current flows through a circuit.

In order to simplify calculation in many instances, the term, conductance, was introduced. Conductance is defined as the ease with which a current flows through a circuit. It is the reverse or reciprocal of the resistance. The unit used for measuring conductance is the mho (the word ohm spelled backwards). We thus say that the conductance of a circuit is so many mhos, meaning thereby the ease with which a current can flow through it. If a circuit has a resistance of 5 ohms, it has a conductance of 1/5 mho. In other words, the numerical value of the conductance is always equal to 1 divided by the resistance. Besides the mho, subdivisions of this unit are also used. One of these is the micromho. A micromho is one-millionth part of a mho, or one mho is equal to one million micromhos.

The term, mutual conductance, now has a little more meaning, in that it may be interpreted as the ease with which a signal can pass through the tube. The word, mutual, is used because the passage of the signal through the tube depends upon the relative or combined action of all three elements within the tube.

AMPLIFICATION FACTOR OF A TUBE

The amount of current flowing in the plate circuit of an electron tube depends upon the voltage applied to the plate and the resistance encountered within the tube. This internal resistance, in turn, depends upon (a) the design and arrangement of the elements within the tube and (b) the potential of the control grid. If the grid potential is negative with respect to the cathode, it retards the number of electrons that can reach the plate. The tube resistance is increased, and the plate current reduced. Similarly, a positive potential on the grid decreases the internal resistance and increases the plate current.

Due to the nearness of the grid to the cathode, a small change in grid potential causes a change in plate current that would require many times as large a change in plate voltage if the grid potential remained constant. Since it is the variations in plate current that determine the signal voltage developed in the plate circuit, it is evident that the ratio of these two voltages is an indication of the amplification the signal undergoes within the tube.

The amplification factor of a tube is merely a numerical measure of the amplification a signal experiences in passing through a tube. It is defined as the ratio of the change in plate volts to the change in grid volts required to produce the same change in plate current flow. The amplification factor is an abstract number and is commonly represented by the symbol "mu" or the small letter "u." It means that the signal impressed on the grid-to-cathode input circuit reappears in the plate circuit "mu" times as strong. In commercial tubes it ranges in value from 3 for a tube of the 71A type to 1500 for tubes of the 57 and 58 type.

It is the structure of the grid and its location with respect to the cathode and plate that to a great extent determine the amplification factor of a tube. In high "mu" tubes, that is, high amplification tubes, the grid is not only very close to the cathode, but it is wound in a close network or fine mesh so that it has a greater retarding effect on the electrons, or in other words, a greater screening effect on the plate influence.

MEASURING THE AMPLIFICATION FACTOR OF A TUBE

The amplification factor of a tube can be measured in two ways. In one method use is again made of the grid voltage-plate current characteristic. An amplified portion of the curve taken at a plate pressure of 45 volts is illustrated in Fig. 5. The curve crosses the 0 grid volts axis at 1.6 milliamperes. If the plate potential is reduced to 35 volts, the current drops to 0.95 milliampere, a decrease or change of 1.6-.95 or 0.65 milliampere represented by the distance "A".

From this point we then move horizontally to the left until we again hit the curve. The distance "B" represents the decrease in grid potential that would have to be made to bring about the same change in plate current as decreasing the plate voltage from 45 to 35 did. On the curve, "B" represents a decrease of 1.25 volts. The change in plate potential was from 45 to 35 or 10 volts. The amplification factor or "mu" is then equal to 10 divided by 1.25 or 8. This suggests that the amplification factor can also be defined as the ratio of the change of plate potential to the change in grid potential that will prevent a change in plate current flow.

Another method of measuring the amplification factor of a tube is with the apparatus arranged as in Fig. 6. Suitable "B" and "C" batteries are used to provide the normal operating plate and grid voltages. Across terminals marked "G" is connected a 1000-cycle audio oscillator "G" having at least a 1-volt output. A 1000-ohm potentiometer can be used for R-1 and R-2, or a suitable decade box for R-2 and a fixed resistor of 5 ohms for R-1. With the entire circuit in operation, resistor R-2 is adjusted until no sounds are heard in the phones. The oscillator signal is impressed on the grid and plate of the tube. As the grid potential goes up the plate potential goes down, and by means of the slider on R-2 the signal is so proportioned between the grid and the plate that no change in plate current takes place. This condition is indicated by no sound being heard in the phones. The amplification factor "mu" of the tube is then equal to R-1 divided by R-2.

The first method of determining the value of "mu" is known as the static method because it was obtained under sustained conditions. The second method described is known as the dynamic method because electrical oscillations are actually sent through the various circuits of the tube. This method requires the use of more complex and costly testing apparatus, and is therefore more confined to experimental laboratories where such instruments are available.

PLATE RESISTANCE

The current flowing in the plate circuit of a radio tube is of a dual nature - it consists of a steady direct current component, and superimposed on this is a pulsating component that fluctuates in accordance with the signal voltage impressed on the grid. The opposition experienced by this pulsating signal current in flowing through the tube is commonly referred to as the plate resistance or plate impedance, and like any other resistance quantity is measured in ohms. It is represented by the symbol "Rp".

It is this plate impedance that limits the effectiveness of the applied plate voltage. The plate impedance is not constant in value; it is relatively high at low plate voltages and decreases rapidly as the plate voltage rises. At very high plate voltages it again increases. This variation in plate impedance is a direct result of the number of electrons available from the cathode and the degree of saturation within the tube.

The plate impedance of a tube is defined numerically as the ratio of a change in plate voltage to the resulting change in plate current at a constant grid potential. To calculate the plate impedance of a tube, use is made of the same data that was employed in a previous paragraph. It was found there that when the plate pressure was reduced from 45 to 35 volts, the plate current was reduced from 1.6 to 0.95 milliamperes. The plate voltage change thus is 10 volts and the plate current change 0.65 milliampere or 0.00065 ampere, (ampere being equal to 1000 milliamperes). Since the plate impedance is the ratio of the change in voltage to the change in current, it is only necessary to divide 10 by .00065, and the result is 15,385 ohms.

The plate impedance of a tube, it was stated, is not a constant quantity but depends both on the applied plate pressure and the grid potential. Consequently, when the plate impedance is specified or is being determined, it should always be under the same circuit conditions as when it is operating in a radio receiver.

HOW TO MEASURE THE PLATE RESISTANCE OF A TUBE

To measure the A.C. plate resistance of a tube under dynamic conditions, the circuit arrangement in Fig. 7 is used. "Ro" is a 5000-ohm resistor that can be cut in or out of the circuit by means of a switch, and "G" is a 1000-cycle signal generator. Resistors X-2 and X-3 are a decade box or a calibrated variable resistance of the potentiometer type.

First the amplification factor is obtained by disconnecting "Ro" from the circuit and balancing the resistor until no sound is heard in the phones. The amplification factor "Mu" is then equal to "Xp" divided by "Xg". This is the same method as was explained in the previous section.

Next the resistor "Ro" is connected into the circuit, and the system is again balanced by adjusting the values of X-2 and X-3 until no sound is heard in the phone. The values of X-2 and X-3 are observed, and the plate impedance "Rp." is then calculated by means of the following formula:

$$Rp = Ro\left(Mu\,\frac{X-2}{X-3} - 1\right)$$

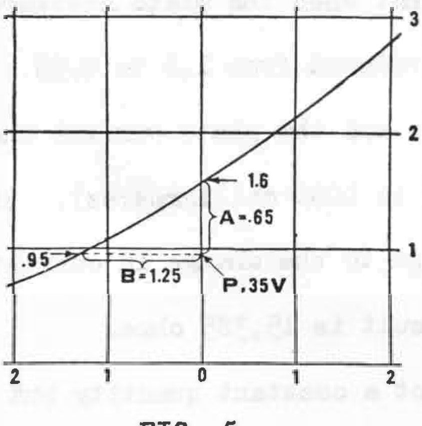


FIG. 5

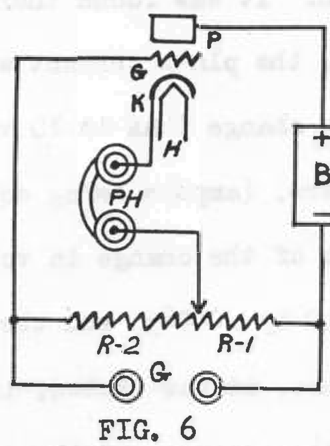


FIG. 6

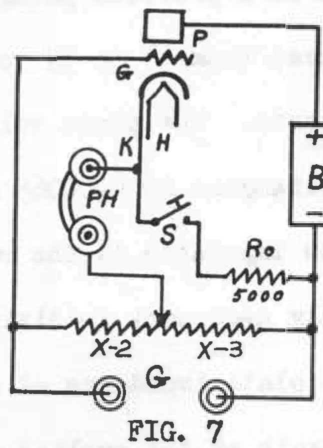


FIG. 7

ILLUSTRATING THE MEASURING OF THE AMPLIFICATION FACTOR OF A TUBE.

SUMMARY

The performance and operating qualities of a tube depend not only on its mechanical construction, such as the number of internal elements and their arrangement, but also on the electrical potentials operative in the circuit in which the tube is used. The condition of the cathode determines the number of electrons available, while the potential on the plate determines the rate at which these electrons reach the plate, that is, the rate of plate current flow. However, with the grid placed between the cathode and plate, its electrical condition also influences the electron movement, and these two combined actions fix the behavior of the tube.

It is not only the manner in which the grid influences or controls the flow of plate current, but also the amount of control exerted that is important. The mutual conductance measures the extent of this grid control, it is a mathematical expression for the variation in plate current that a certain change in grid volts will cause. The higher the mutual conductance the greater is the grid control, and the more sensitive is the tube. However, the mutual conductance is not a constant value, but depends also on the other circuit constants.

The amplification factor indicates the gain that a signal voltage impressed on the grid experiences as it passes through the tube and reappears across the load in the plate circuit. It deals with the combined influence of both the plate voltage and grid volts on the plate current flow. For example, an increase in grid potential causes a reduction in plate current flow which can be brought back to normal by increasing the plate voltage. If the change in grid potential is one volt and it requires an increase of ten volts in plate potential to restore the current, the ratio of the change in plate volts to the change in grid volts is 10 to 1, and the amplification factor is 10.

When the tube is used as an amplifier, the plate current should be a linear function of the grid potential, that is, the plate current should vary in direct proportion to the change in grid potential. For detection and modulation, however, the tube should operate on the lower bend of the curve where grid potential variations in one direction cause greater fluctuations in plate current flow than variations in the opposite direction.

For voltage amplification, as in radio frequency and intermediate frequency amplifiers, a very high plate resistance is essential, while for power amplification as in power output tubes, a low impedance is essential.

The plate impedance of a tube depends both on the applied plate pressure and the grid potential, that is, it is not a constant quantity.

This means that when the plate impedance is specified or is being determined, it should always be operating under the same circuit conditions.

The plate impedance of a tube is defined numerically as the ratio of a change in plate voltage to the resulting change in plate current at a constant grid potential. To calculate the plate impedance of a tube, use is made of the same data that was employed in a previous paragraph. It was found there that when the plate pressure was reduced from 45 to 35 volts, the plate current was reduced from 1.6 to 0.95 milliamperes. The plate voltage change, thus, is 10 volts and the plate current change 0.65 milliampere or 0.00065 ampere, (ampere being equal to 1000 milliamperes). Since the plate impedance is the ratio of the change in voltage to the change in current, it is only necessary to divide 10 by .00065, and the result is 15,385 ohms.

EXAMINATION QUESTIONS ON FOLLOWING PAGE