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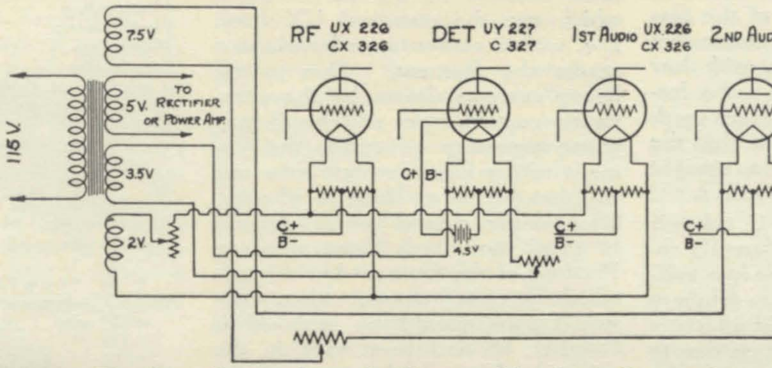
Complete A. C. Operation a Practical Reality

By *C. T. BURKE, Engineering Department*



The above diagram shows the filament wiring for A. C. operation of popular four tube type of receiver

The principal radio trend of the season just past has been toward the elimination of batteries. Many satisfactory plate supplies have been developed, but the problem of filament supply has offered more difficulty. Larger currents are required for filament than for plate supply, and this means greatly increased expense in the rectifier and filter circuit. Then too, many of the plans proposed for batteryless filament lighting required rewiring of the tubes in series. EXPERIMENTER readers may recall that an analysis of the filament supply problem appearing in this publication last October concluded with the suggestion that the problem of batteryless filament operation seemed to rest upon the manufacturers of tubes rather than upon the manufacturers of accessories.

The development forecast in that article has come to pass with the recent announcement of tubes for alternating current filament supply by several manufacturers. Many of these tubes will be available in the next few months, and the batteryless receiver will probably be the outstanding development of the coming radio season. This does not imply immediate obsolescence of present receivers. The new tubes will have plate characteristics similar to those now in use, and the present types of tubes will continue to be supplied. The trend will, however, undoubtedly be toward the A. C. filament tubes.

Two types of A. C. filament tubes are to be supplied, representing different methods of attack on the problem of A. C. filament operation.

In the conventional type of tube supplied for direct current operation, the filament forms a part of two circuits. The battery circuit through the filament is for the purpose of heating the filament to produce electron emission. This circuit is auxiliary to the main function of the tube, but the filament also forms one side of both input and output circuits of the tube.

If alternating current is supplied to the filaments of ordinary tubes, a hum will result. Several sources contribute to the hum. As the current through the filament changes during the alternating current cycle, varying from zero to maximum, the temperature of the filament, which depends on the current through it is also changing. The change in filament temperature results in a cyclic change in the tube characteristics which in turn produces a hum at twice the frequency of the supply. A certain amount of hum is due to capacity effect between the tube elements and to voltage drop along the filament. Another appreciable source of hum is the grid effect of one side of the filament on the other. The filament of most tubes (except the 199 tube) is triangular in shape (less the base). When direct current is applied to the filament, conditions are stable, and the grid effect of one end of the filament on the other introduces no disturbance. When alternating current is applied to the filament, the grid effect is variable. As the current increases through the filament one end of the filament is increasingly negative with respect to the other, and the emission from that end of the filament is reduced, since the other end is more positive and attracts a portion of its emission current. A half cycle later the two ends of the filament are reversed, and the effect repeats. A hum at twice the supply frequency results.

In one type of alternating current filament tube, the design is similar to the direct current type except for the construction of the filament which is short and heavy, taking materially more current than the modern direct current tubes and operating at low voltage. An advantage of the heavy filament is that it retains heat longer than the present type, i.e., there is less heating and cooling as the current goes through its cycle, the heat carrying over from one cycle to another. In fact, sufficient heat remains to produce audible signals for a few seconds after shutting off the current. It might be expected that such a filament would take longer to reach its operating temperature. This proves to be the case, and there is an appreciable wait between the turning on of the current and the appearance of the signals. It may be noted in passing that some of the direct current tubes have the characteristics of slow heating and cooling of the filament. The WX 12 type can in fact be used with fair results, with low A. C. on the filament in radio frequency stages, provided care is used. It is also interesting to note that the 199 type of tube, with a straight filament, shows little grid effect.

The filament of the A. C. tubes is short and straight, which greatly reduces the grid effect. The low voltage across the filament also tends to reduce the hum due to grid effect.

In order to eliminate hum due to the voltage drop through the filament the grid and plate returns must be connected at the average potential of the filament, i.e., the potential of the center point. Unless this is done a pronounced hum having the same frequency as the source of current will be produced by a periodic fluctuation of both the grid bias and plate voltage. The most satisfactory means of obtaining this connection is by means of a center-tapped resistance across the filament terminals of the tube. The center of the resistance is necessarily at the same potential as the center of the filament.

Tubes of the heavy filament type are generally made to fit the standard UX type of socket. This type of tube is suitable for either radio or audio frequency amplifier work. Some manufacturers do not, however, recommend tubes of this type for use as a detector.

In another type of tube for alternating current operation the two circuits which use the filament of the direct current tubes are separated. The cathode is heated from a separate heating element inside the cylindrical electrode, while an additional terminal is provided for the C+ and B— connection and the tube has therefore a five-prong base, requiring a special socket. This type of tube also requires a center-tapped resistance across the heating element. The center point of the resistance may be grounded in this case. When the mid point of the potentiometer is grounded, the setting is rather critical for best results. Another less critical method is to connect a 4.5 volt battery between the center tap and the cathode terminal. The negative of the battery is joined to the center tap. This type of tube is particularly recommended for use as a detector.

No power-tubes are listed among the new alternating current filament tubes, due to the fact that raw A. C. can be used with perfect satisfaction on the filaments of present last stage tubes. The output tube should always be the 112, 171, or 210 type. These tubes are connected in the same manner as the A. C. tubes which use the standard UX base, i. e. with a center-tapped resistance across the filament. Due to the heavy currents drawn by the alternating current types of tube, it may prove necessary to replace the filament wiring in some multi-tube sets with heavier wire. Number 18 wire, for example, should not be required to carry more than three amperes. Portions of the filament bus through which greater current than this would flow should be replaced if Number 18 had been used in the original wiring. As some of the new tubes draw two amperes each, quite large currents may flow in parts of the filament wiring carrying current for several tubes.

Another change which is necessary in all cases where a set is altered to accommodate the new tubes is the shifting of the plate and grid return connections. In the direct current types of tube the C+ and B— connections are made to one side of the filament. When using the five-prong type of A. C. tube, the C+ and B— connections are made to the fifth prong. In the other type of tube, using the UX base, the center of the resistance across the filament is used for the C+ and B— connections.

All the new tubes operate on low voltage and a transformer is required between the line and the tube. The transformer should be designed to provide a higher voltage than the tube requires, to allow for voltage drops in the wiring. Rheostats will be required, but once set no further adjustment will be necessary, so that rheostats may be placed behind the panel.

While variations may be necessary to meet the requirements of individual receivers, the diagram of filament wiring for a typical four-tube receiver as shown on the front page will be found a useful guide in changing over a receiver for the new tubes. No changes will be required except in the circuits shown.

Current Carrying Capacity of Wire (Rubber Covered)

This data will be found helpful in determining the size of wire to use in rewiring filament circuits for A. C. operation:

Size	Diameter (Mils)*	Current
12	80	20 amperes
14	64	11 "
16	51	6 "
18	40	3 "
20	32	1.5 "

*Mil=0.001 inch.

Data on New A. C. Tubes

The following are characteristics and specifications of the new A. C. tubes.

UY-227 or C-327 Detector Tube
(Separate Heater Type)

Heater voltage	2.5 volts A.C.
Heater Current	1.75 amperes
Plate voltage	
as detector	45 volts
as r. f. & a. f. amplifier	90-135 volts
Maximum voltage permissible	180 volts
Grid Bias	
at 180 volts	13.5 volts negative
" 135 "	9 " "
" 90 "	4 to 6.5 " "
Amplification Factor	8.2
Plate Impedance	
at 180 volts	9,400 ohms
" 135 "	10,000 "
" 90 " (-6 v. C)	11,300 "
Mutual Conductance	
at 180 volts	870 micromhos
" 135 "	820 "
" 90 " (-6 v. C)	725 "
Plate current	
at 180 volts	6 mils
" 135 "	5 "
" 90 " (-6 v. C)	3 "
Maximum Undistorted Output	
at 180 volts	0.140 watt
" 135 "	0.055 "
" 90 "	0.020 "
Base—Special five-prong type	
Mechanical dimension	
Maximum overall length	4-1/8 inches
" diameter	1-13/16 "

UX-226 or CX-326 Amplifier Tube
(A. C. Filament Type)

Filament voltage	1.5 volts A.C.
Filament current	1.05 amperes
Plate voltage—recommended	90-135 volts
maximum	180 volts
Grid Bias	
at 180 volts	13.5 volts negative
" 135 "	9-12 " "
" 90 "	6 " "
Amplication Factor	8.2
Plate Impedance	
at 180 volts	7,000 ohms
" 135 " (-9 v. C)	7,400 "
" 90 "	9,400 "
Mutual Conductance	
at 180 volts	1,170 micromhos
" 135 " (-9 v. C)	1,100 "
" 90 "	875 "
Plate current	
at 180 volts	7.5 mils
" 135 "	6 to 3 mils
" 90 "	3.7 mils

Continued on page 4, column 1

What Governs the Power Handling Capacity of an Amplifier

By A. R. WILSON, Engineering Department

As the novelty of radio has gradually disappeared, and more interest is taken in it purely as an instrument to reproduce with fidelity both music and speech, the listener and engineer have given more and more thought to the tonal qualities of the broadcast receiver. The vast radio audience today is first of all concerned in how **well** it can hear. How **far** is a secondary consideration.

It would seem to the average listener inexperienced in radio experimentation that all that is necessary to increase volume is the addition of a stage or two of audio frequency amplification to his existing equipment. This is true to a certain extent, but as we are interested only in *QUALITY VOLUME*, the design of the apparatus used in the "stage or two" of audio frequency amplification is of great importance.

A speaker, which does the actual reproducing of sound, is an energy operated device and as the energy is derived from the last audio tube alone, the undistorted volume obtainable from a speaker is wholly dependent upon the energy output of this tube and no other. The energy is measured in milliwatts and the following table gives the power output of the tubes now in common use, with the plate voltage necessary to obtain full output:

Tubes	Undistorted Output	Plate Voltage
UX 120	110	135
UX 226	160	180
UX 112	195	157
UX 171	700	180
UX 210	1500	425

In order to secure the maximum power output that a tube is capable of delivering, it is necessary that a sufficiently large voltage be placed on the grid of the tube to operate at its maximum output. At the same time certain conditions, however, must be satisfied to prevent distortion in the tube itself. First, the grid must not be allowed to become sufficiently positive to draw any appreciable amount of grid current, and second, the plate current must at no portion of the cycle be allowed to fall so low that distortion be caused by curvature of the plate current curve. The input voltage which may be applied safely to a tube without causing grid distortion is fairly well indicated by the grid bias voltage. Actually the effective grid swing permissible in volts R. M. S. is $\frac{\sqrt{2}}{2}$ or .707 times the grid bias.

The solution of the problem of *QUALITY VOLUME* is threefold, embracing tubes, transformers and speakers wherein distortion of various sorts and causes tends to develop. It may be well to state here that there are two apparent forms of distortion to guard against in any audio amplifier: frequency distortion and waveform distortion. Frequency distortion, which really is not distortion at all, but the relative differences in the amplification of different frequencies is caused by one of two things, either a coupling device that is not capable of even performance over the audio range, or the improper matching of impedances of the different circuits. It is extremely important from a frequency viewpoint that the impedances of the various circuits bear a definite relation to each other. To secure a maximum transfer of voltage from one circuit to another (and we are interested in this respect only in voltage and not in energy), the impedance of the transformer primary should be at least two or three times that of the tube circuit at the lowest frequency which we wish to amplify. Waveform distortion in the amplifier itself is caused by either an overloaded tube or saturation of the core of the audio transformers. With the present-day standards of transformers, however, the latter from a practical standpoint may be entirely disregarded. Obviously the remedy for an overloaded tube is the reduction of the input signal or the increase of grid bias and plate voltage, thus permitting the tube to be worked on the straight portion of its grid voltage plate current curve.

Assuming one to have an audio amplifier and tubes of the standards of two or three years ago, the most radical improvement in quality would be brought about by the replacement of the last audio tube by one of the new power tubes, such as the UX 171 or UX 210. This would increase the power handling capacity of the amplifier 50 to 100 times and this power handling capacity of an amplifier is something that is not very well understood by the average man, yet it is extremely important if faithful reproduction is to be obtained. In order to produce the same intensity to the ear, say at 60 cycles, many times as much power is required as at 1000 cycles. A somewhat disconnected yet fitting illustration would be the comparison between a Tuba player and a Cornet player in a brass band. The Tuba player expends much more energy, but to the ear the Cornet is louder. In the case of the loudspeaker far greater power is needed to supply the energy than was heretofore thought necessary to reproduce bass notes properly, and it is even very doubtful if the tubes on the market today are capable of supplying to the speaker enough energy to reproduce these low frequencies with the same intensity as the higher frequencies, unless a 50 or 100 watt power tube is used. This would require a type of plate supply device, which from an economic point of view, would be entirely out of the question.

While it would seem that increasing the energy output of an amplifier would result in extremely loud reproduction, this is not necessarily true. A loud sound may be doubled in intensity—that is, the energy doubled—and the ear may hardly detect the change. This fact will explain in some measure why many people are not able to note the difference in the volume produced by a UX 171 and UX 210 tube, although the maximum output of the UX 210 is double that of the 171. Everything else being equal, the reproduction, when using the UX 210, should appear much better on the lower frequencies—actually it is about the same, because the lower plate impedance of the 171 permits a greater transfer of energy from tube to speaker at these frequencies.

The power handling capacity of an amplifier using present day transformers is more or less limited by that of the tubes used, since the largest possible portion of the negative side of the grid voltage plate current curve is available for the actual plate voltage used. While resistance or straight impedance coupled amplifiers are better from a purely frequency standpoint, the power handling capacity is decidedly limited, as there is a certain rectifying action of a strong signal caused by the time action of the grid condenser and leak, and their purpose, even from a frequency standpoint, is often defeated by the improper use of tubes. A man will quite frequently pay from $10.00 to $20.00 for an impedance coupled amplifier only to use a 201-A tube in the last stage, and it is very doubtful if the improvement in quality in this case is even noticeable to the ear. This is only another example of insufficient power required to reproduce bass notes, although the frequency characteristic of an impedance or resistance coupled amplifier is essentially a straight line from 30 cycles upward. A very interesting laboratory experiment along these lines proved that where a pure 60 cycle note from a vacuum tube oscillator was fed directly into the grid of a UX 210 tube, the full output of this tube did not produce even an audible sound at this frequency. All low frequencies are not entirely lost, however, as their harmonics are reproduced, but with much less intensity, and the fundamental pitch is usually obtained by the beat note of a second and third harmonic.

In reviewing the subject of power handling capacity of an amplifier, there are many other more important phases to consider than the particular method of coupling (transformer, resistance, or impedance). It is a well-known fact that no better quality can be expected than is radiated from a broadcasting station or that can be faithfully reproduced by the loudspeaker — regardless of what coupling method or combination of methods may be used.

Bearing in mind that the frequency range of the better broadcasting stations is something like 80 cycles to 5000 cycles, and the better loudspeakers cut off at 80 cycles at the lower end and 7000 cycles at the upper end, also remembering that the better transformers in use today are capable of even amplification between 60 cycles and 6000 cycles, the selection of the amplifier tubes and proper operation for maximum efficiency of those tubes should receive more consideration than is generally given to amplifier tubes, particularly the last stage tube from which the loudspeaker is operated.

Data on New A. C. Tubes

Continued from page 2

Maximum Undistorted Output		
at 180 volts		0.160 watts
" 135	" (-9 v. C)	0.070 "
" 90	"	0.020 "
Base—Standard Large "UX" or "CX"		
Mechanical Dimensions		
Maximum overall length		4-11/16 inches
diameter		1-13/16 "

NOTICE

With each copy of the June issue of the Experimenter a postcard was mailed to be properly filled out and returned if future issues of the Experimenter were desired. So many cards have been impossible to revise our list before releasing the July issue. We are consequently sending the July issue to our complete list.

The August issue, however, will be mailed only to those who have returned postcards.

New General Radio Parts for A. C. Operation

TYPE 440A LOW VOLTAGE TRANSFORMER

The alternating current tubes require a source of low voltage capable of delivering large current. The various types of tubes require several different voltages. The Type 440A transformer supplies voltages for all popular tubes and sufficient current for all ordinary receiver requirements. Filament supply is provided for filament, separate heater, power and rectifier tubes.

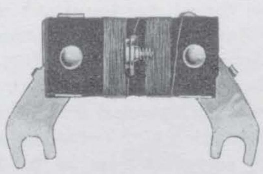
The transformer will carry a total load of 70 watts. The actual current which may be drawn from any winding depends on the current being drawn from the other windings. The watts being drawn from any winding when supplying filaments may be found by multiplying together the current and voltage for the winding. The sum of these products for all the windings is the total load on the transformer. In a particular case the loads might be:

Volts	Amperes	Watts
2	10	20
3.5	5	17.5
5	2.5	12.5
7.5	2	15
TOTAL WATTS		65

Pri. 115 V (for lines 105-125 volts) 60 cycles.

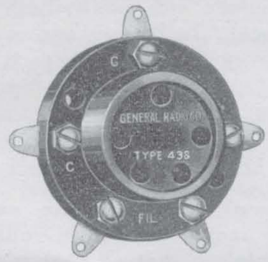
The Type 440A low voltage transformer sells for $10.

TYPE 439 CENTER TAP RESISTANCE



The new tubes for alternating current filament operation require a resistance with center tap across the filament. In the filament type of tube, the center tap provides the point of connection for the positive grid and negative plate potential sources. The Type 439 Resistance is designed to fit directly across the tube socket. No other mounting is necessary. Price, $.60.

TYPE 438 SOCKET



All of the new A. C. tubes, with the exception of the Type UY-227 or C-327 detector tubes, have the standard UX or CX four prong base and mount in the General Radio Type 349 Socket.

The new Type UY-227 or C-327 detector tube, however, has a separate heating element, and has consequently a five prong base which requires a socket especially designed with five spring contacts.

The Type 438 Socket is designed for the UY-227 or C-327 tube.

Firm contacts are made to the sides of the tube prongs with double gripping springs. The base of the socket is of moulded bakelite.

The Type 438 Socket sells for 50 cents.

TYPE 410 RHEOSTATS

The new A. C. tubes require low resistance rheostats capable of carrying appreciably more current than those used with D. C. tubes.

The resistance wire of the Type 410 Rheostat is of brass, tightly wound on a specially treated fibre strip. The form is of genuine moulded bakelite. The tapered knob, which is also of moulded bakelite, has an engraved pointer which indicates the position of the switch arm along the arc of the resistance unit.

The Type 410 Rheostat has the single hole mounting feature.

Resistance	Current	Price
.5 ohm	3.5 amperes	$1.25
1.5 ohm	2.0 amperes	1.25