A RIDER PUBLICATION

RECEIVING TUBE SUBSTITUTION GUIDE BOOK

BY H. A. MIDDLETON

FIRST EDITION

SECTION 1

THE BACKGROUND OF TUBE SUBSTITUTIONS

Were it not for the fact that tube development is a never-ending activity, there would be no purpose in describing the background of tube substitution. The substitution lists contained herein would suffice, for they include practically every tube which is used for receiving purposes serving many different electronic applications. These applications consist of radio receivers of all varieties (a-m, f-m, and TV), radar, facsimile (commercial and military), public address amplifiers, record changer amplifiers, test equipment, electronic computers — in fact every kind of equipment with the exception of transmitters, although even there, receiving tubes make their appearance in the speech amplifiers.

The basis of tube substitution is *similarity* or equivalence between the original and the substitute. The choice of these two words with different connotation is deliberate; similarity may mean equivalence in some respects but not in all. Thus if two tubes are similar (or identical) in electrical characteristics, one is the equivalent of the other. The use of two tubes, however, to replace one single tube which affords certain facilities, creates a state of equivalence rather than a state of similarity.

This is not intended as a play on words but deals with a very important situation that is developing fast in television receivers. Unwelcome as it may be, it means constructional modifications and even more important, a careful analysis of what suits the purpose. Any attempt to list all the substitutes within the meaning of equivalent as we have described it, would be a monumental task and would more than likely, never see the light of day. We hope, therefore, that the general details of the background of tube substitution given in this section combined with the tube substitution lists and the knowledge possessed by the technician who makes the change (and selects the substitutes) will result in satisfactory substitutions.

An examination of the tube substitution lists will disclose that the substitution of one type for another is not too frequently accomplished by a simple replacement of tubes. Differences in tube characteristics may demand some modifications in the circuit within the apparatus. Sometimes, only a change of socket is needed because of differences in the basing of the substitute tube. In other instances, definite restrictions are imposed relative to the heater circuits; some substitute tubes may be used only in parallel-wired heaters without any circuit changes, whereas in other instances, a tube substitution is applicable only to series-wired heaters. In some cases, a tube substitution may demand modifications in the cathode, control grid, plate, or screen circuits, or possibly in the power supply, so as to satisfy the needs of the substitute and accomplish the best possible performance. These circuit changes are not listed because they are peculiar to each system.

All of this means that although the lists in this Guide Book give the substitute or substitutes as the case may be, the final selection cannot be made without considering the conditions existing in the equipment which will receive the substitute. Where changes in heater or filament wiring are required, they are described. Changes necessary in the signal electrode circuits such as those of the control grid, screen grid, cathode, and plate so as to attain best possible performance become the function of the technician and are determined by the constants of the specific circuit in which the substitution is made.

As shown in the three series of Rider's Manuals (AM-FM, TV, and PA), many tens of thousands of models of receivers and amplifiers comprise the hundred odd million units which may require substitute tubes.

Fortunately, a certain amount of standardization does exist in receivers and other equipment designed to work with the tubes listed herein. This situation, together with the circuit and operating voltage details given in the above-mentioned manuals and manufacturers' literature affords the technician the opportunity of determining the operating conditions thereby enabling him to establish the correct voltages at the different signal electrodes. A familiarity with these techniques is not difficult to acquire, although we hasten to add that too many differences exist to permit circuit modifications based on guesswork or memory. Schematic wiring diagrams, operating voltage tables, and the tube characteristic charts demand attention if longest tube and component life are desired, and also, if best circuit performance is to be attained with the substitute tube.

Design engineers have their own ways of accomplishing performance with the standard run of tubes. Many substitutes are possible but all will not afford like performance. In listing the substitutions, only those substitutions considered practical, that is, which do not demand redesigning of circuits, were included. Many substitutes possess sufficient similarity to the original as to require no changes in either heater wiring or sockets. These are listed with the note "No changes." This does not mean, however, that the signal electrode operating conditions are identical for the original and the substitute. This should be checked in the tube characteristics chart contained in this Guide Book. It only requires a few minutes of time to do this and its results can be very gratifying.

If upon examination, the differences in electrical characteristics between the recommended substitute and the original are more than moderate, changes in the signal electrode operating circuits may be required. Since the plate voltage requirements for tubes in similar categories do not differ greatly, changes are not too frequent in the plate circuits. It is only when battery type and a-c operated tubes are being compared that one finds radical differences in plate and screen voltages. More critical points are the control grid and cathode bias — especially the latter. Small numerical differences in bias voltages (which are related to the plate current) produce great performance differences. For example, a change in bias from —2 volts to —4 volts is only 2 volts, but it represents a change of 100 per cent, and can very materially influence performance. A situation of this kind would demand a change in the value of the bias resistance.

A bias tube may be listed as the substitute for a zero bias tube. Reference to the electrical characteristics will disclose that the grid resistor must be changed; sometimes from 10 megohms to as low as 0.25 megohm. In addition, a cathode resistor of such ohmic value as will develop the bias shown in the tube characteristic chart must be added. Thus, the statement "No changes," does not refer to signal electrode operating conditions, rather to the fact that neither heater wiring nor socket changes are required.

Each substitution is an individual case requiring individual consideration, unless it is definitely known that the original and the substitute are identical in all respects other than heater voltage. Even then, if the substitution is made in a system which involves a state of resonance, realignment will be required. Similar tubes, even identical ones, do not possess identical values of interelectrode capacitance. This difference affects the final value of tuning capacitance. It is very important to bear this in mind when substitutions are made in wideband amplifiers particularly, since here, the interelectrode capacitance (direct and reflected) plays a paramount role in the peaking action. Examples are the video amplifiers in television receivers and the amplifiers in oscilloscopes and the like. In making substitutions it is often necessary to consider the function of the tube and its circuit so as to insure best performance in the circuit. The various types of circuits and functions will now be discussed.

Oscillator Systems

These may be heterodyning arrangements which involve tracking with other tuned circuits, such as in converter systems and separate oscillator and mixer circuits, or nontracking arrangements, such as beat-frequency oscillators. Also, there are the various kinds of multivibrator systems in television receivers. Each of these demands individual consideration.

Combination oscillators and mixers (converters) require substitutes which contain not only the identical number of electrodes as the original, but in addition, the functions of these electrodes must be the same. This immediately limits the number of possible substitutes. The list of tubes, classified by function found at the end of this section, is an aid in this respect. If the required substitutes can not be procured, it does not make sense to redesign the circuit so as to replace a single tube with two individual tubes. That is a design engineer's job. If the oscillator and mixer functions are performed by individual tubes in separate envelopes, then the latitude of substitution is greater, provided that the selection of the substitute tube is made carefully.

The higher the frequency of operation, the more critical is the choice. That is why new tubes are born as operating frequencies increase. Tubes designed for the broadcast band are frequently unsuited for use in the vhf band and most certainly not in the uhf band. Thus, in addition to recognizing the oscillator function, it is also imperative to pay heed to the frequency of operation. If a choice is available, the tube intended for a higher frequency is suitable for a lower frequency, but not vice versa with complete freedom.

Sometimes tubes specifically intended for use as oscillators will not perform properly in that position, it is difficult to account for this, but it is a fact nevertheless. This does not condemn the tube as a tube — it can still perform other functions — nor does it mean that another tube of like brand and type will behave in similar fashion. There is no remedy for such failure to function properly — it is simply a statement of fact.

What should be examined when comparing tubes intended for oscillators? Neglecting heater or filament ratings for the moment, these being assumed to be suitable and assuming that the number of circuit electrodes of the substitute original are the same, such details as the grid bias, the plate (and screen) voltages, the plate (and screen) currents, and the transconductance are paramount factors. If the exact duplicate is not available, the substitute tube which requires lower plate and screen voltages (differing only moderately from the original) is preferable to the substitute tube which requires higher plate (and screen) voltages than the original. The tube with the higher transconductance is preferable to the tube with the lower transconductance, everything else being equal. These preferences are more apt to furnish heterodyning voltage over the entire band embraced by the receiver, especially if the bias resistor is modified to suit the specifications of the substitute.

R-F and I-F Amplifiers

The general run of r-f and i-f amplifiers utilize tetrodes and pentodes. Since pentodes used as triodes (in a-f amplifiers) are substitutes for triodes, it is important when selecting a substitute to know the manner in which the tube is used in the r-f or i-f amplifier. A triode is a poor substitute for a pentode; if a pentode is used, the substitute should be a pentode. However, if a tetrode is used, the substitute may be either a tetrode or a pentode. Care should be exercised to note if a shield is a part of the tube. An unshielded tube may be substituted for a shielded tube provided that an external shield is used and is grounded properly. Single-ended tubes may be substituted for double-ended tubes, but the reverse may be troublesome. Care must be exercised relative to the control-grid lead dress so as to minimize regeneration.

Sharp cutoff tubes should be replaced by similar tubes; similarly with remote cutoff tubes. However, sharp cutoff tubes may be replaced by remote cutoff types without too much trouble. The avc may be affected somewhat, but this does not interfere with the effectiveness of the receiver. When sharp cutoff tubes replace remote cutoff types, however, some minor problems may arise. Their best location would be in places where the signal level is lowest, for example, in the first stage in either an r-f or i-f amplifier. If distortion is severe on loud signals (due to rectification in the sharp cutoff stage), a divider network may be required so as to reduce the avc bias being applied to the sharp cutoff tube. This is best accomplished at the source of the avc, and might call for a separate avc line to the sharp cutoff tube. It might even be satisfactory to operate the sharp cutoff tube (if it is located at the point of lowest signal level in the amplifier) without any avc, using a low fixed bias.

Where there is a high input signal, sharp cutoff tubes must be used in place of remote cutoff tubes, an auxiliary volume control (or divider) at the front end of the receiver (perhaps in the antenna circuit) may be required. This would be operated only on those channels which cause trouble. A panel switch would control the operation of this signal control element.

Transconductance is the important electrical characteristic to consider in r-f and i-f amplifier substitutions. The higher the mutual conductance is relative to an r-f or i-f transformer the better, assuming that the plate and screen voltage conditions are satisfied or approached. Inability to equal the original tube in transconductance means reduced gain in the stage, but this seldom is a problem in a-m or f-m receivers because the average receiver has excess gain for the reception of chain or local broadcasts. The same can be said about television receivers, provided that the receiver is located in a primary service area. When such a receiver is relatively close to a station, the problem is too much rather than insufficient signal, so that a reduction in r-f or i-f amplification (unless it is too severe) usually can be tolerated. In fringe areas, the situation is different, especially when the received signal levels already border on the inadequate. There it becomes necessary to approach the original, and if this cannot be attained, then it is preferable to select tubes with higher than the original transconductance and to adjust the operating voltages accordingly. General instructions of this kind are given elsewhere in this section.

Where r-f and i-f systems are subject to tube substitutions, realignment of the coupling transformers associated with the input and output circuits of the substitute stage are imperative. Sometimes it may appear that proper performance is being secured without realignment. This should not be accepted as fact without a test to establish if the circuits are peaked properly.

Whether the shift in frequency peaking is upward or downward depends upon the direction of the capacitance change. A reduction in distributed capacitance, which includes the plate-to-cathode (or control grid-to-cathode) capacitance tends to cause peaking at a higher frequency, whereas an increase in distributed capacitance tends to cause peaking at a lower frequency.

Many i-f transformers and some r-f transformers are permeability tuned, utilizing the related distributed capacitance including the tube capacitance to provide the *C* for the tuned circuit. Because of this, changes in distributed capacitance, due to different tube electrode capacitances, can cause major variations in operating conditions. Whenever possible, substitute tubes should approximate the input-output capacitance of the original tube. This data is found in the tube specification charts of Section 5.

Exception to the need for realignment of r-f and i-f coupling systems is found in those equipments which employ *R-C* coupling between tubes. While not a common practice, it is to be found in receivers. Sometimes the coupling element consists of a resistive plate load and a tuned grid load for the succeeding tube. The resistive plate load on a substitute tube requires no readjustment, but if the substitution is made in that stage which has a tuned grid load, realignment will be required. Examples of such arrangements are listed elsewhere in this section in connection with r-f and i-f transformer replacement.

Audio Amplifiers

All types of tubes are found in audio amplifiers: triodes, tetrodes, pentodes, pentodes used as triodes, and various kinds of output-stage power amplifiers. Voltage amplifiers are, in the main, resistance-coupled systems, whereas power amplifiers are transformer-coupled. The difference between these two general categories is the plate circuit load, that is, load impedance, and the grid bias.

There are some differences between the signal electrode operating conditions in resistance-coupled amplifiers, their operating voltage or load resistance may differ, but many substitutions are possible without changes. A fair degree of similarity exists between the fundamental designs of these circuits so that it is possible to generalize concerning substitutions. Pentodes can be used in place of triodes and, in turn, triodes may replace pentodes or tetrodes. The load resistances are pretty much the same for all of these tubes since the limitation is set by the plate voltage supply, and this does not differ too greatly in like categories of equipment. Naturally, the ideal condition is when the substitute is used exactly as the original, or the substitute type is the same as the original type.

In the case of triode-type tubes used in audio amplifiers, with the exception of the output stage, the amplification constant of the tube is the pertinent factor. The higher the amplification constant, the higher the stage gain, provided that the internal plate resistance is not too high relative to the load resistance. The higher the internal plate resistance of the tube, relative to the load resistance, the less the amount of signal taken out of the tube will be. The portion of the available signal taken out of the tube is expressed as

$$\frac{R_l}{R_p + R_l}$$

where R_l is the load resistance in ohms and R_p is the internal plate resistance expressed in ohms.

Another matter of concern to keep in mind is that relating to grid bias. Quite a few tubes used in *R-C* coupled amplifiers as well as in *L-C* coupled systems are of the zero-bias type. When adequate substitutes are not available and a self-bias tube is used in place of a zero-bias one, provision for the bias must be made in the circuit. This can be in the form of a bypassed cathode resistor. In addition, the grid resistor (grid leak) of the substituted stage will require reduction to perhaps one-thirtieth or one-fortieth of its original value. Zero-bias tubes utilize grid resistors of from 5 to 10 megohms. Self-bias amplifier tubes utilize grid resistors of from 0.1 to perhaps 0.3 megohms. These bias- and grid-resistor references will be found to apply to pentodes and tetrodes as well as triodes. When a zero-bias tube is used in place of a self-bias tube, the above-required changes in circuits are reversed.

In the output stages, for that matter, also in driver stages in audio amplifiers, attention must be paid to the recommended load impedance represented by the output transformer. Not only does it determine output power, which may or may not be important, but it also determines the quality of reproduction. The latter is important.

To begin with, the recommended load impedance for substitute tubes should be the *same* or *less* than that for the original. By being less than the original a fair semblance of the original quality will be retained because the tubes are working into a higher impedance, that represented by the output transformer already in the device. Power output will be reduced somewhat but quality of reproduction will be retained. If it is impossible to find substitutes which require the same, or a lower load impedance than the original, then a higher rating will have to be accepted, but it should be the closest approximation to the original.

A receiver installation can afford to sacrifice some power for quality. In public address systems, it is a question of how the system is used. If its full-rated power output is seldom used, then it can sacrifice some output for quality. If it is used for the reproduction of speech only, it can afford a greater mismatch than systems which reproduce music and speech. In the last analysis it is a compromise and each individual requirement determines the choice.

In view of the power-handling requirements of the output stage, only those substitutes, both triodes and pentodes, are usable which can handle power. These are interchangeable but only on that basis.

When two individual tubes are used in a push-pull output stage and a substitution is being contemplated for one tube, it should be carried out for both. If the characteristics of the original and the substitute differ markedly, parasitic suppressors may be required in grid and plate leads (if they are not already in the circuit). Fifty-ohm resistors capable of handling the currents involved are adequate. If two individual tubes replace two tubes in a single envelope, such resistors may prove very important because the changes in wiring and lengthening of the leads may cause oscillation.

Negative feedback is used in many audio systems between the output power stage and a preceding stage. Tube substitutions can upset the feedback conditions, especially if the electrical characteristics of the substitute are unlike the original. If audio quality or power over-all gain seems to have suffered too much, the feedback circuit should be checked.

When tube substitutions in a-f driver stages are contemplated, the range of substitutes is more limited than in the case of voltage amplifiers. While tubes designed for the driver stages of a-f amplifiers may be used in other capacities, tubes designed for other functions very often are not usable in a driver stage. Because the tube grid in the driver stage is driven into the positive region during certain portions of the signal cycle, the tube which feeds the driver-stage input transformer must be of the correct type for operation with the driver-stage input transformer. In like manner, the driver stage is impedance-matched to the transformer which feeds the succeeding stage. This is another requirement that must be satisfied when the substitute tube is selected from a number of types which possess the required over-all similarity in electrical characteristics.

Phase-Inverter Stages

Phase-inverter stages present no serious problems in substitution except for the fact that differences between the original and the substitute may demand readjustment of the load resistor so as to arrange that the signals from the phase-inverter stage to the control grids of the succeeding push-pull stage are of like magnitude. If the phase-inverter stage serves just one function, inverting the signal to one of the succeeding push-pull stage tubes, and it is of the same type as its related amplifier tube which feeds the other succeeding push-pull tube, then it may be convenient to *substitute like tubes for the phase inverter and its related amplifier.*

Diode Rectifiers (Signal)

Too much need not be said about signal-rectifying diodes. One significant detail is that power rectifiers are not substitutes for signal rectifiers. (They are not shown as substitutes on the list, but the comment is still required.) There is very little to choose from between signal-rectifying diodes for virtually anyone will perform the functions of the others, except perhaps in connection with frequency of operation. The transit time (time taken for the electrons to advance from cathode to plate relative to the period of a cycle of the signal) limits the application of the tube in terms of frequency. Uhf diodes are suitable for operation at lower frequencies. On the other hand, the low or conventional frequency diodes are not suitable for the rectification of uhf and sometimes even vhf signals, unless so specified.

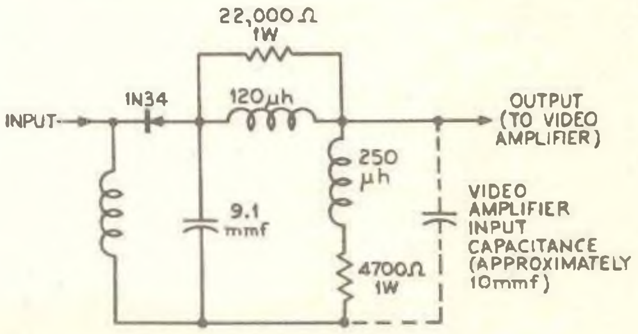
It is interesting to note that the equivalent of conventional signal-rectifying diodes may be formed out of conventional triodes by tying the grid and plate together thus forming one element, or by tying the plate to the cathode and using the control grid as the second element. Such equivalence is not indicated in the list of substitutions, but it should be kept in mind.

Sometimes multipurpose tubes used in receivers do not employ all of the electrodes. Quite frequently a duo-diode may have its two plates tied together forming a single diode to be used for a single purpose. It is well to try to disconnect one of the plates and to see if the operation is impaired; if not, then the other diode plate may, in conjunction with the common cathode, be used as the substitution diode. Whether or not such is possible depends upon the manner in which the common cathode is being used.

New advances in the design of germanium crystal diodes facilitate the use of these components as replacements for conventional diode tubes in signal-rectifying and detecting circuits. An important consideration in this connection is the fact that they require no heater supply and have an average life of over 10,000 hours.

Germanium crystal diodes are usable in vhf and even uhf circuits since their maximum operating frequency is about 500 Mc. They are rated for voltages of from 25 to 200 volts, with peak anode currents up to 200 ma. These components are particularly suitable for detector circuits where their low shunt capacities (of the order of 1 mmf) are advantageous.

The substitution of a crystal diode for a conventional-type tube is particularly simple because there is no need for a heater supply circuit. A typical use of a 1N34-type crystal diode is illustrated in Fig. 1-1.



Courtesy Sylvania Electric Products Inc.

Fig. 1-1. The use of a 1N34 type germanium crystal diode in the video detector circuit of a television receiver. Notice that the value of the circuit parameters are similar to those found in most video detector stages.

Here the component is shown being used in a video-detector circuit of the type common in most television receivers. The performance of the circuit with the 1N34-type crystal diode depends upon the proper choice of circuit parameters. In most circuits, however, it will be found that there need be no component modifications for good performance. Conventional-type tubes for which germanium crystal diodes are successful replacements are the 6AL5, 6H6, 6T8, and 12AL5. In the replacement of duo-diodes not only must the detector function be taken care of, but the sync limiter or other use must also be replaced. This is possible by using a 1N35-type matched duo-diode crystal component. See the table of geranium crystal diodes in Section 5.

For further information as to the use of germanium crystal diodes in video and f-m detector circuits as well as in other signal rectifiers, see *40 Uses for Germanium Diodes,* a booklet obtainable from Sylvania Electric Products, Inc.

Diode Rectifiers (Power)

Power rectifiers are of two types, high-vacuum and gaseous. Normally, high-vacuum rectifiers are interchangeable as are gaseous ones, within the limitations set by the current and voltage ratings of the device.

Gaseous-type rectifiers frequently may replace vacuum-type rectifiers provided that the electrical characteristics are the same and the related circuit requirements are satisfied. Replacement of high-vacuum rectifiers by the gaseous kind is not recommended except when high currents are involved and when a constant voltage drop in the rectifier is required; the need for high voltage alone is not sufficient.

To take a typical case, the mercury-vapor rectifier requires choke input instead of capacitor input in the filter system. The high current surges which occur with capacitor input would destroy the gaseous tube. Also, gaseous tubes are suitable for the rectification of medium voltages and higher (500 volts output and up) and they are intended for systems wherein high current loads exist and where the variations in current load are large. In the case of a-c—d-c receivers, there are no gaseous equivalents for the high-vacuum types used. Gaseous rectifiers, moreover, are a source of r-f "hash" and, therefore, are not suitable for use in close proximity to circuits susceptible to such radiations.

High-vacuum tubes, on the other hand, are suitable replacements for mercury-vapor rectifiers if the rectifier system can stand the increased voltage drop which occurs in the high-vacuum tube and if the electrical requirements are satisfied. As a rule, the heater current for high-vacuum rectifiers is less than that required for gaseous rectifiers of comparable d-c voltage and current output. Other important electrical requirements to consider are the a-c input voltage, output current, and inverse peak voltage. The last-named term expresses the ability of the tube to withstand the peak voltage between the anode and the cathode during the nonconducting portion of the cycle.

Assuming the lack of recommended substitutes, high-vacuum tubes are suitable for substitution in systems which operate at lower d-c output voltages and currents than the high-vacuum tubes are rated for, provided that the heater requirements are satisfied. Such substitution should be made only in extreme cases when no other means are possible and a system must be restored to operation. For that matter, in such an event, the mercury-vapor kind also can be used provided that there is a choke input in the filter system. This is a MUST condition.

The substitution of a filament-type rectifier for a cathode-type one introduces certain complications, especially when the remainder of the tubes in the system are of the cathode-heater variety. The difference in heating time would result in the very rapid build-up of the voltage output from the rectifier before the tubes receiving the plate and other voltages were in a conducting state. Thus, the rectifier would be operating for a period of time with practically no load. This results in a high output voltage — much higher than when the load is applied — and could very easily break down the filter capacitors and also some of the bypass capacitors in the equipment receiving its voltage from the rectifier. Replacing a filament-type rectifier with a heater type causes no complications of this sort.

From a practical viewpoint it seems worthwhile to go to no end of trouble to find a suitable filament-type substitute for a filament-type original. This seems easier than changing the voltage rating of all of the filter capacitors and the bypass capacitors for high working voltage units. Of course, if examination of the capacitor voltage ratings and measurement of the rectifier output voltage shows that the momentary peak is within the operating voltage rating of the capacitors, the change can be made without endangering the filter and bypass units. If this is not the case and replacement of the filter and bypass capacitors is not feasible, then the only alternative is to use an increased bleeder load and thus reduce the over-all output voltage from the power supply.

For medium- and low-voltage requirements, selenium rectifiers are far more suitable substitutes for high-vacuum rectifier tubes than are gaseous tubes. Miniature selenium rectifiers are available in various sizes rated from 50 to 500 ma. The 50-, 65-, 75-, and 100-ma sizes will, in most cases, best serve as replacements for half-wave rectifiers in a-c—d-c equipment.

Generally speaking, to replace the vacuum-tube rectifier in a phonograph oscillator, use the selenium rectifier rated for 50 ma, for three-tube amplifiers use the 65-ma size, for five- or six-tube receivers without a push-pull output, use the 75-ma rectifier, and for six-tube sets and up use the 100-ma rated one. To replace the 25Z5, 25Z6, 35W4, 35Y4, 35Z3, 35Z4, 35Z5, 45Z5, 50Y6, and 50Z7, use a 403D2625A type selenium rectifier with a rating of 100 ma.

When a rectifier tube is replaced by a selenium rectifier, a compensating resistor must be inserted into the filament circuit to make up for the resistance drop due to the elimination of the rectifier tube if its filament was in series with other filaments. The value of this compensating resistor depends upon the rectifying tube that has been replaced. The following table lists the resistance to be used for the tubes mentioned above.

TUBE	RESISTOR (ohms)	WATTS
25Z5	85	15
25Z6	85	15
35W4	230	10
35Y4	230	10
35Z3	230	10
35Z4	230	10
35Z5	230	10
45Z5	300	10
50Y6	330	15
50Z7	330	15
117Z3	none required	
117Z6	none required	

In some sets, the pilot light may be connected across a low-voltage tap on the rectifier tube filament. If this is so in the set in which the rectifier tube is being replaced, connect the pilot light across a tapped-down portion of the compensating resistor (about 10 to 25 ohms will do depending upon the current in the filament circuit). A No. 47 pilot light can be used in this case.

When replacing vacuum-tube rectifiers by selenium rectifiers in a-c—d-c portables using battery-type tubes that obtain filament voltages from B plus through a dropping resistor, reduce the value of the shunt resistor connected from the low end of the filament dropping resistor to the negative point. This will compensate for the increase in filament voltage.

In most cases, a protective resistor should be inserted in series with the selenium rectifier to protect the rectifier and filter capacitors from excessive current peaks during operation. The value of this resistor will vary from 5 to 50 ohms depending upon the current load of the rectifier: the higher the load, the smaller the protective resistor needed.

Manufactured adapters will probably be available for use with miniature selenium rectifiers in the future, in the meantime, they can be made fairly easily by using discarded tube bases. Following are instructions for making adapters for a few of the most popular rectifier tubes used in a-c—d-c equipment.

To make an adapter for the 35Z5 used in series circuits:

a) connect a 230-ohm, 10-w resistor from No. 2 to No. 7 on an octal base
b) connect a 20-ohm, ½-w resistor from No. 2 to No. 3
c) connect 25-ohm, ½-w resistor from No. 8 to positive side of rectifier
d) connect No. 5 to negative side of rectifier.

To make an adapter for a 35Z5 used by itself, follow the above steps but delete steps a) and b).

For the 25Z6, 25X6, 35Z6, 50AX6, 50Y6, and the 117Z6 when these tubes are used by themselves as half-wave rectifiers, make an adapter as follows:

a) connect a 25-ohm, ½-w resistor from Nos. 4 and 8 on octal base to the positive side of the rectifier
b) connect Nos. 3 and 5 to negative side of the rectifier.

If the filaments of these tubes are in a series circuit, then naturally a compensating resistor must be added with the selenium rectifier. This resistor, whose value may be obtained from the table given previously, will be connected between pins No. 2 and No. 7. No resistor is needed when the 117Z6 is replaced.

Wideband Amplifiers (Video and Others)

Although referred to earlier in this section, these systems are singled out for elaboration because of their seemingly peculiar conditions of operation. Examination will show that very low values of plate-load resistance are used and also that the applied plate voltage is very low, much lower than that shown in tube characteristic charts.

This is so because it is necessary to have wide frequency response. Gain in each stage is sacrificed for the attainment of low reflected capacitance and also the creation of suitable resonance.[1] By means of shunt or series peaking, or both, a wide band of frequencies can be amplified. (This is explained in detail in the book referred to in the footnote.)

Tube substitutions in wideband amplifiers, therefore, require very serious consideration. The substitute tube characteristics should approximate most closely the complete conditions existing in the original. Interelectrode capacitance is very important. Plate-current, grid-bias, and grid-circuit resistance ratings should be the same. Lead dress must be maintained as much as possible because changes in the position of leads will affect the frequency of resonance and thereby the over-all bandwidth of the system. This is very important if socket changes are required.

If possible, all stages should be replaced by like substitutes even if only one stage requires replacement. This is expensive but advantageous. If the facility to check frequency bandwidth exists, then it is possible to confine the replacement to only one stage, the one in which the original tube is bad. Make the frequency run, and if the response is satisfactory after the replacement in that stage, the other stages need not be changed. Such tests can be made by means of a square-wave generator or a sine-wave generator. Usually the limits of response are expressed by the lowest and highest frequency signals which are down not more than 3 db from the top. In some instances, the amplifier design is more critical and the over-all response is expressed in terms of only 1 db down from the top.

Utilization of Sections of Multifunction Tubes

A number of tubes found in television and other equipments combine three and four sets of electrodes in a single envelope, thus performing three or four different functions. Direct substitutions for these tubes may not be available. In that event it is necessary to utilize two individual tubes containing such electrodes as will furnish the facilities originally contained in the single tube which is being replaced. For example, a triple diode-triode such as the 6T8 may require replacement. If the original is not available, pairs of substitutes must be used, for example, a 6AL5 and a 12AV6 or a 6AL5 and 6AQ6. These are the recommended combinations, other combinations of a double-diode with a double-diode triode, or single diode-triode

---

[1] J. F. Rider and S. D. Uslan, *Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses,* John F. Rider Publisher, Inc., New York, N. Y., 1950, pp. 389-401.

that is, in each heater. This immediately establishes the requirement that all heaters connected in series must have similar current ratings. A variation of 10 per cent in heater rating is permissible so long as the heater has a higher rating than the current required by the other heaters in the circuit.

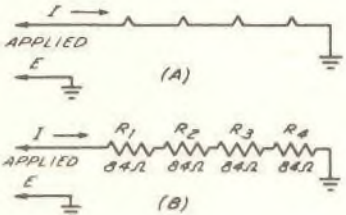


Fig. 1-5. Filaments connected in series (A) may be represented as individual resistances (B), each of which passes the same current determined by the applied voltage divided by the total resistance.

The numerical value of the current is dependent upon the applied voltage E and the total resistance R of all of the heaters, as stated in statement 2. above Since resistances connected in series are additive, the total heater resistance R, is equal to $R_1 + R_2 + R_3 + R_4$, as indicated in Fig. 1-5(B). If, for the moment, we assume that each heater is rated at 12.6 volts and 0.15 ampere (150 ma), then the resistance of each is 12.6 divided by 0.15 or 84 ohms. The four heaters in series, therefore, represent a total resistance of 336 ohms. Knowing the total R and the required current, the supply voltage necessary to limit the current to the required value is

$$E = IR$$

or

$$E = 0.15 \times 336 = 50.4 \text{ volts.}$$

If the voltage drops across each heater (or the voltage required across each heater) are aggregated, it is seen that the sum of the voltage drops equals the applied voltage. Thus are illustrated statements 1., 2., and 3.

In view of what follows it might be well to devote a little more time to the matter of voltage drops and applied voltage, or the possibilities of statement 3. Current flowing through a resistance will cause a voltage drop across that resistance. If the current flow is the rated value, then the voltage drop numerically is the same as the voltage rating of the resistance. If the resistance is the heater (or filament) of a tube, and the current through it is the rated value, then the voltage drop is equal to the voltage rating of the heater.

We have simplified the problem by deliberately making the applied voltage (which we also can identify as the line voltage) equal to the total of the voltage drops in the load. As a rule, this is not found in practice; the line voltage always exceeds the total of the voltage drops across the tube heaters. This excess voltage is dropped by means of a line voltage-dropping resistor across which there is a voltage drop equal to the difference between the sum of the tube heater voltage drops and the line voltage. For example, if the line voltage is 117 volts and the total of the tube heater voltage drops is 50.4 volts as in the above case, the line voltage-dropping resistor will drop 117 — 50.4 or 66.6 volts at the value of current which is flowing through the series chain.

Statement 3 still holds, except that now the series line voltage-dropping resistor has been added to the elements (heaters) which comprise the load. This action of the line voltage-dropping resistor may be considered from a different viewpoint. It is the means whereby the line voltage is dropped to that value which equals the sum of the voltage drops across the heater elements. This is not a play on words; it simply presents the relationship between the line voltage and the total heater drops from two angles relative to the purpose of the line voltage-dropping resistor. In one case, the line voltage-dropping resistor is considered a part of the load and, in the other, only the tube heaters are considered to comprise the load. Personally, we prefer the former and shall hold to it in these explanations.

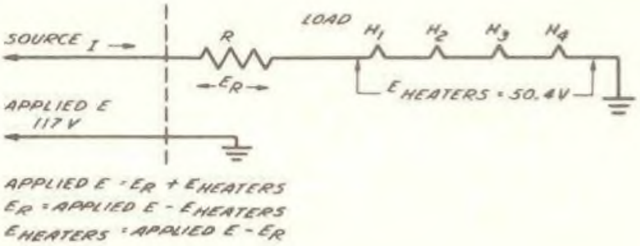


Fig. 1-6. A series chain of four filaments or heaters with a line voltage-dropping resistor. The voltage drop across the line voltage-dropping resistor makes up for the differences between the line voltage and the voltage required by the four heaters.

An example of the above is shown in Fig. 1-6. Here the elements of the load are shown to the right of the vertical dotted line and the applied voltage source is shown to the left. The series system indicates a total heater voltage drop of 50.4 volts at 0.15 ampere and a line voltage of 117 volts. The difference in voltage is dropped across the resistor R. Since the line voltage-dropping resistor is in series with the heater chain, the same current will flow through R as through the heaters. The voltage drop across this resistor is, therefore, a function of the current through it and its resistance. Since this voltage drop represents a dissipation of energy, the line voltage-dropping resistor bears a wattage rating in addition to its resistance rating. The power dissipation is a very important factor and must be taken into account in the event of any changes; in fact, it determines the type of resistor element which suits this purpose. The power dissipation in watts is expressed by either IE, I^2R, or by E^2/R, where I is the current in amperes, R is the resistance in ohms, and E is the voltage in volts, exactly the same units as are used for the other Ohm's law calculations.

The ohmic value of R is

$$\begin{aligned} R &= \frac{117 - 50.4}{0.15} \\ &= \frac{66.6}{0.15} \\ &= 444 \text{ ohms.} \end{aligned}$$

Its power dissipation is

$$\begin{aligned} P &= E \times I \\ &= 66.6 \times 0.15 \\ &= 9.99 \text{ watts (approx. 10 watts)} \end{aligned}$$

or

$$\begin{aligned} P &= I^2R \\ &= 0.0225 \times 444 \\ &= 9.99 \text{ watts (approx. 10 watts).} \end{aligned}$$

To prove these figures, the total resistance of the four heaters is 4 × 84 or 336 ohms; adding this to the 444 ohms resistance of the line voltage-dropping resistor results in a total circuit resistance of 780 ohms. With a current of 0.15 ampere flowing in the system, the applied voltage is $E = 0.15 \times (336 + 444) = 117$ volts.

Let us now examine the possible variables in a simple series chain of the kind shown in Fig. 1-6. Statement 3. of Ohm's law relates to an equality between the line voltage (applied voltage) and the total of the voltage drops in the load. No restriction is evident concerning the *number* of elements (tube heaters) which may comprise the load and across which the total of the heater drops will occur. In the system shown in Fig. 1-6, four elements comprise the heater load. These could be any number provided that the total voltage drop did not exceed the line voltage; if it equaled the line voltage, then the line voltage-dropping resistor (R in Fig. 1-6) would not be required in the circuit and the system would become the equivalent of Fig. 1-5(A), with more heaters than are shown there.

As a matter of fact, no matter what the total of the *rated* voltage drops across the heaters in the load is, this value can never exceed the applied (line) voltage, for statement 2. establishes that the current will adjust itself automatically in accordance with the total resistance and the total applied voltage. For example, if fourteen 12.6-volt, 0.15-ampere tubes were used in series across a 117-volt line, the total resistance would be 1,176 ohms. The current, therefore, would be

$$\frac{117}{1{,}176}$$

or 0.099 ampere, and the voltage drop across each heater would be 0.099 × 84 or 8.3 volts. It is obvious that the voltage across these heaters would be insufficient for proper operation of the tubes. Correction of this state would demand a revision of the circuit or an increase in the line voltage; the latter is impractical, so the former is the only solution. It will be treated later.

On the other hand, the need may arise to substitute a lower voltage rated heater for a higher rated one, such as a 6.3-volt tube for a 12.6-volt one. If the rated voltage drop across the series heaters is at least ten times the rated voltage drop across the substitute heater, the latter may be inserted into the string without requiring any correction. Thus, if the total rated voltage drop across the series heaters is 75 volts, and a 6.3-volt tube is a replacement for a 12.6-volt heater in the string, the replacement will be subject to a slightly higher voltage (and current) but it will do no harm.

For example, if the original series string consists of a 25-volt, 0.15-ampere tube and four 12.6-volt, 0.15-ampere tubes, the total resistance of these heaters is 502 ohms. Operation from a 117-volt line demands a dropping resistor of 227 ohms, making a total load resistance of 779 ohms. Substituting a 6.3-volt tube for the 12.6-volt one reduces the heater resistance to 460 ohms, and the total load to 737 ohms. This results in a circuit current of 0.158 ampere, and as a result, the 12.6-volt tubes are subjected to a voltage of 13.27 volts, the 6.3-volt tube to 6.6 volts, and the 25-volt tube to 26.4 volts. None of these voltages are so extreme as to endanger the tubes.

Battery tubes, however, should be treated with more care and every effort should be made to keep the voltage as close to the rated voltages as possible, especially when operation is intended on a-c lines.

Circuit conditions encountered in practice seldom are such that the total voltage drop across the heaters or filaments equals the applied or line voltage. The use of a line voltage-dropping resistor is very common, consequently, any change in the total voltage drop across the load caused by a substitution demands that the drop across the line voltage-dropping resistor be changed, and this means a change in its ohmic value. Whether the latter is done by shunting another resistor across it, by physically changing its length (as happens with line cords), or by substituting a new one of proper ohmic value for the original is determined by whichever is most convenient. If the total voltage drop across the heaters is *increased*, the drop across the line resistor must be *decreased*, and vice versa. A typical example follows.

Seven 6.3-volt heaters are in series with a 35-volt heater. All are rated at 0.3 ampere. The total voltage drop across the heaters is 79.1 volts and the total resistance of the heater load is 264 ohms as shown in Fig. 1-7(A). With a supply of 117 volts, 37.9 volts must be dropped across the line dropping resistor R. At 0.3-ampere current flow, the ohmic value of R must be 126 ohms and its power dissipation, therefore, is 11.3 watts.

Two 12.6-volt, 0.3-ampere tubes must be substituted for two of the 6.3-volt tubes. The modified circuit is shown in Fig. 1-7(B). Simple calculation of the total voltage drop across the heaters shows an increase of 12.6 volts, therefore, it is obvious that the value of R will have to be *decreased*. Its value may be determined in a number of ways, but a simple procedure is the following

$$R_{\text{new}} = \frac{\text{Original value of } E_R - \text{Increased voltage drop across heaters}}{\text{Current through the system}}$$

$$= \frac{37.9 - 12.6}{0.3}$$

$$= 84 \text{ ohms.}$$

The power dissipation in the new R is

$$P = I^2R$$

$$= 0.09 \times 84 = 7.5 \text{ watts.}$$

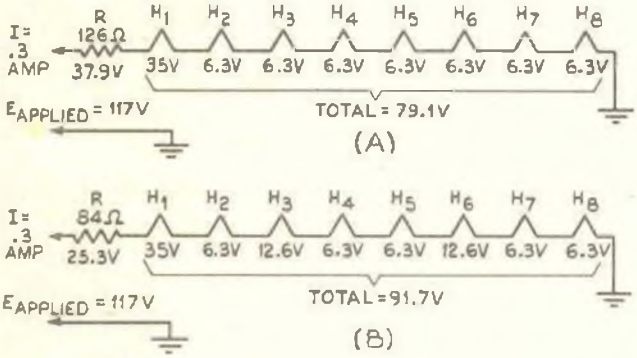


Fig. 1-7. In (A), a series chain of seven 6.3-volt heaters and one 35-volt heater requires a line voltage-dropping resistor R of 126 ohms to bring the applied voltage of 117 volts down to the value required by the heaters. When the total voltage drop across the heater is increased by 12.6 volts as in (B), the value of R must be decreased to 84 ohms.

Substituting Low-Current Rated Heaters for Higher-Current Heaters

Suppose that in the circuit of Fig. 1-7(A) two 12.6-volt heaters rated at 0.15 ampere must replace two of the 6.3-volt 0.3-ampere heaters. Let us select H_3 and H_6 as the specific heaters. How would this be accomplished? Two methods are practical, one being simpler than the other. Suppose we treat the more difficult one first.

Since the circuit current is 0.3 ampere and each substitute heater draws only 0.15 ampere, it stands to reason that they just cannot be connected into the circuit as is, otherwise each would be subject to a 100 per cent current overload. However, two such heaters connected in parallel would require 0.3 ampere, and because of the division of currents in a parallel circuit in accordance with the resistance of each branch, connecting these two tubes in parallel would result in 0.15 ampere flowing through each heater. Moreover, the voltage drop across two elements in parallel is the same as that across a single element and, since the total drop across the two 6.3-volt heaters which are being replaced equals 12.6 volts, the two 12.6-volt heaters in parallel can replace the two individual 6.3-volt heaters without changing the total voltage drop across the string of heaters. This is shown in Fig. 1-8(A). Note that the total drop across the string of 6.3-volt heaters originally [Fig. 1-7(A)] was 79.1 volts, and that the total drop across the heaters with the two parallel 12.6-volt substitutes is 79.1 volts. This means that the line dropping resistor R need not be changed since it is called upon to drop 37.9 volts at 0.3 ampere, the same as in the original circuit.

The other means of accomplishing the substitution is shown in Fig. 1-8(B). Instead of connecting the two substitute heaters in parallel, they are treated individually and separate current shunts are connected across each one. Since it is desired to split the current equally between the heater and its shunt, the ohmic values of the shunts must equal the resistances which they shunt. This means that R_2 = 84 ohms and R_1 = 84 ohms, and each dissipates 1.89 watts. [See Fig. 1-8(B)].

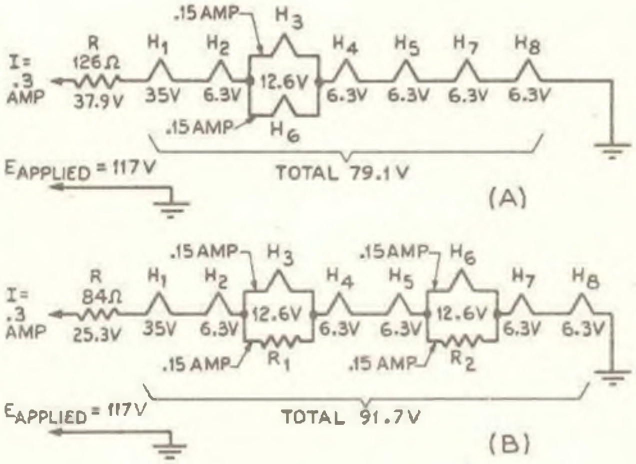


Fig. 1-8. Two methods of substituting 12.6 volt, 0.15-ampere heaters for 6.3-volt, 0.3-ampere ones are shown. In (A), both substitutes are paralleled together, splitting the current and keeping the voltage drop of the system intact; in (B), each heater has its own shunt, thereby drawing its rated current but increasing the total voltage drop of the heaters.

However, handling these substitutions in this manner means that the total voltage drop across the string of heaters has been increased by 12.6 volts, since two 12.6-volt heaters in series total 25.2 volts, and two 6.3-volt heaters in series total only 12.6 volts. The increased drop of 12.6 volts must be compensated for by reducing the drop across the line resistor R. Figs. 1-7(A) and 1-8(A) are comparable, as are Figs. 1-7(B) and 1-8(B). In Figs. 1-8(A) and (B), the total line current of 0.3 ampere flows into the junctions of the parallel systems (the parallel heaters in (A), and the heaters paralleled by the shunt resistors in (B), divides equally between the two paths, and then recombines again to equal the 0.3-ampere line current. Thus, the 0.3-ampere, 6.3-volt heaters receive the proper current and so do the two 12.6-volt, 0.15-ampere heaters.

If four tubes required substitution and they were of like voltage ratings, two pairs of heaters could be paralleled as shown in Fig. 1-8(A). If there were an odd number of substitutions, two heaters could be located in parallel and the odd one would be operated with a shunt as shown in Fig. 1-8(B). As a matter of fact, it is the principle underlying these techniques rather than the actual number of tubes involved which is important. Once the principles are understood, it will be simple to apply them, and in general, the most convenient method should be used depending on the circuit and the components available. For example, the availability of resistors is a determining factor in deciding whether the line dropping resistor will be replaced or if two small resistors will be used for the current shunts. If the substitution demands new sockets, then paralleling of the heaters is no problem, but if the sockets do not require changing to accommodate the substitutes it is more convenient to use the current shunts.

Substituting Higher-Current Heaters for Low-Current Heaters

Suppose the requirement is for the use of higher current heaters in place of lower current heaters in a series circuit. A single 0.3-ampere heater is to replace one rated at 0.15 ampere in a series string of five 12.6-volt, 0.15-ampere heaters and one 25-volt, 0.15-ampere heater. This substitution is to occur at H_6 in Fig. 1-9(A). Several solutions are shown in Figs. 1-9(B) through (G). The choice is determined by which is most convenient and best fits the need. The one fundamental requirement created by such a substitution is that the total line current must be increased to 0.3 ampere so as to serve the increased current demand of the substitute tube. Whether this means that the line current will be limited to 0.3 ampere or increased above that value is determined by the organization of the heaters which form the load. One circuit system [Fig. 1-9(B) and (C)] needs 0.45-ampere line current, whereas other arrangements can be served by 0.3 ampere; there is no way, however, of satisfying the requirements of the 0.3-ampere tube with a line current of 0.15 ampere. For comparison, let us keep the constants of the original circuit [Fig. 1-9(A)] in mind. Here we have a total drop of 88 volts across the heaters, and 29 volts across the line dropping resistor at a current flow of 0.15 ampere.

One solution for the substitution is the use of two series paths, one for the 0.15-ampere heaters and the other serving the 0.3-ampere heater, as shown in Fig. 1-9(B). In order not to change the total voltage drop in the 0.15-ampere chain, a resistance (84 ohms) corresponding to that of the heater (H_6) which has been removed is inserted in its stead. This establishes the total voltage drop at the original value of 88 volts and the original line dropping resistor remains intact. Compare Figs. 1-9(A) and (B). Since the drop across the 0.3-ampere heater is 12.6 volts and the line voltage is 117 volts, a line dropping resistor must be added to this circuit. R_2 serves this purpose; its ohmic value (348 ohms) is such that it will drop 104.4 volts at 0.3 ampere.

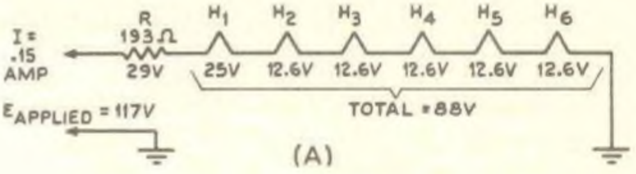


Fig. 1-9(A). A series chain of heaters each drawing 0.15 ampere in a circuit with a single voltage-dropping resistor.

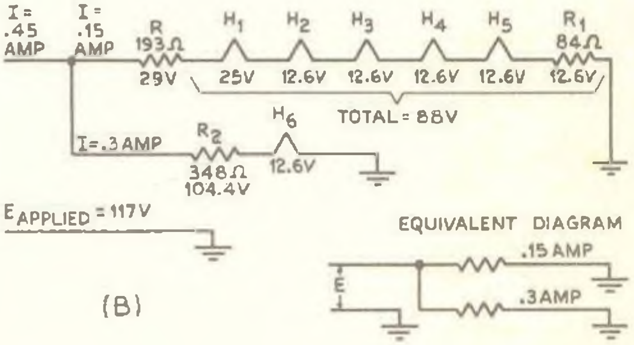


Fig. 1-9(B). H_6 of Fig. 1-9(A) has been replaced by a 12.6-volt, 0.3-ampere one requiring a separate series circuit and an increase in the current drawn from the line source. Now there are two dropping resistors, one in each branch of the circuit.

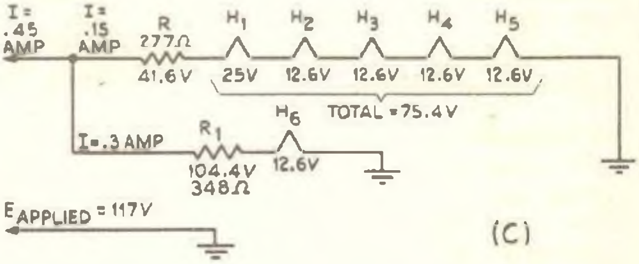


Fig. 1-9(C). Same as Fig. 1-9(B) except that the dropping resistor in the longer branch now is a combination of the dropping resistor R and the compensating resistor R_1 of the previous diagram.

Examination of the two series circuits of Fig. 1-9(B) shows that they are actually in parallel since each goes from the 117-volt line to ground. This is illustrated in the equivalent diagram in Fig. 1-9(B). The total resistance of each of the parallel branches is such that 0.15 ampere flows in one, whereas 0.3 ampere flows in the other.

The equivalent circuit in Fig. 1-9(B) is an important one to understand because it shows the application of two series circuits connected in parallel. Television receivers intended for use on a-c—d-c lines employ such circuit arrangements quite frequently, see Fig. 1-8 and the schematics at the end of Section 3.

A modification of Fig. 1-9(B) appears in (C). The substitution requirement remains the same, but this time the resistance equivalent of the heater which has been removed is not inserted. Instead, the line dropping resistor is changed in value so as to compensate for the reduced total voltage drop across the heaters. With one 12.6-volt heater removed, it has fallen to 75.4 volts from the original 88 volts. This necessitates an increase in the line resistor R from the original value of 193 ohms to 277 ohms. (This follows from the fact that the heater removed from the string had a resistance of 84 ohms, and in order to maintain the original amount of current in the circuit, this amount of resistance must be added to the line dropping resistor. The change is essentially the transposition of the resistor R_1 in Fig. 1-9(B) from its position at the grounded end of the string to the line dropping resistor.) Now the drop across the line dropping resistor is 41.6 volts, or the original 29.6 volts plus the 12.6 volts representing the displaced heater. The second series leg of the circuit is the same as shown in Fig. 1-9(B), because its demands have not been changed in any way by the modifications applied to the other series circuit.

Several other interesting details may be mentioned about the arrangements in Figs. 1-9(B) and (C). In the latter, the increase in the value of the line dropping resistor means an increase in power dissipation. The power dissipation in the resistor in (B) is 4.34 watts; the power dissipation in the resistor in (C) is 6.23 watts. However, it is necessary to add to the former the amount dissipated in the resistor R_1 which has replaced the heater. This power is 1.89 watts, which when added to the 4.34 watts, totals the same amount as is dissipated in the higher value of resistance used in Fig. 1-9(C). At first glance there may appear to be no difference between the two systems, yet there is a substantial difference. It is simply that two resistors, one of 4.34 watts and another of 1.89 watts rating (or whatever may be the wattage ratings selected to afford ample safety factor), are definitely more expensive than a single resistor of such wattage rating as will satisfy a power dissipation of 6.23 watts.

For purposes of comparison let us identify the power dissipation in the system shown in Fig. 1-9(C). The power dissipation in the 150-ma leg is 11.34 watts in the heaters and 6.18 watts in the line dropping resistor R, a total of 17.49 watts. The power dissipated in the 300-ma circuit is 3.78 watts in the heater and 31.32 watts in the line dropping resistor R_1, making a branch total of 35.10 watts. The dissipation in both circuits is the sum of the branch wattages or 52.59 watts.

A third possible arrangement for the substitution is shown in Fig. 1-9(D). In a way, this is a more practical way to connect a 12.6-volt, 0.3-ampere heater in place of a 0.15-ampere heater of like voltage rating. Only one series string is arranged, although it contains two parallel circuits. This system operates in a similar manner to that shown in Fig. 1-8. Of course, the ability to assemble such a circuit depends upon the number of heater elements present. The four heaters H_2, H_3, H_4, and H_5 are of like constants, therefore, two series pairs connected in parallel result in a system requiring 25.2 volts and 0.3 ampere. In order that heater H_1 draw only 150 ma, it is shunted with a resistance equal to its own resistance. Thus, the original six tubes now are arranged so that they can be assembled into a single series string and supplied with 0.3 ampere of current.

The rearrangement of the 150-ma tubes reduces the total voltage drop across the heaters because the paralleled pair of series heaters draws only 25.2 volts compared to its former 50.4 volts. The result is that the total drop across the heaters is reduced to 62.8 volts. This requires a change in the line dropping resistor to that ohmic value (181 ohms) which will draw 54.2 volts and so drop 117 volts to the 62.8 volts at 0.3 ampere required by the heaters. Relative to the power consumption in such a system, the four series-parallel

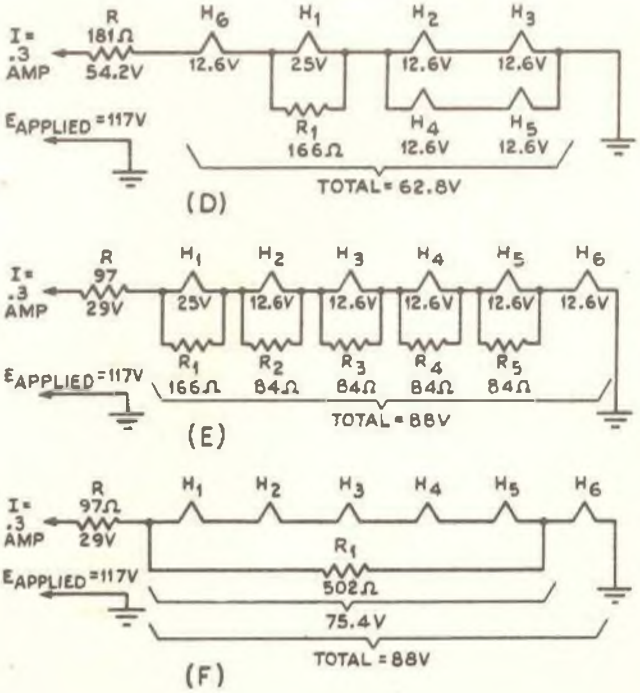
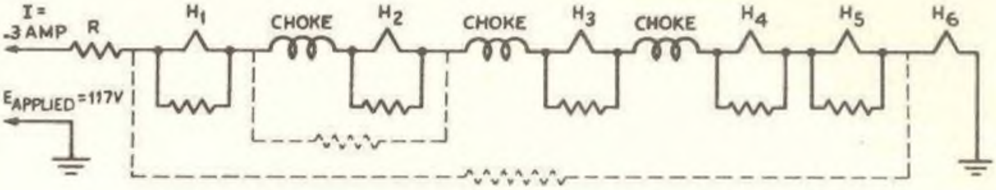


Fig. 1-9(D), (E), and (F). Various methods are shown here for shunting the heaters of the circuit shown in Fig. 1-9(A), after the substitution of a 12.6-volt 0.3-ampere heater for H_6, so that the voltage and current requirements of each heater are satisfied.



(G)

Fig. 1-9 (G). Part of a television receiver filament circuit showing the isolating chokes used between the heaters in the series chain. The shunts shown in dotted lines are unacceptable because they nullify the action of the chokes.

heaters dissipate 1.89 watts each for a total of 7.56 watts; the 25-volt heater H_1 with its shunt consumes 7.5 watts; the 12.6-volt 300-ma heater H_6 consumes 3.78 watts; and the line dropping resistor consumes 16.26 watts. The total power dissipation of the whole circuit is, therefore, 35.1 watts. A comparison between the total power consumption of the circuit in Fig. 1-9(D) and that in Fig. 1-9(C) illustrates the economy in power consumption possible by a choice of circuits.

A modification of the circuit in Fig. 1-9(D), designed to allow the replacement of a 150-ma heater tube with a 300-ma one, is shown in Fig. 1-9(E). Here, all the heaters are in a single chain with a current shunt across each 150-ma tube; the 300-ma heater H_6 does not require a shunt. The ohmic value of these shunts is equal to the resistance of each of the shunted heaters. The power consumption of the entire system totals 36 watts made up as follows: each of the shunted 12.6-volt heaters with its shunt consumes 3.8 watts, the unshunted 0.3-ampere tube requires approximately the same amount of power, the 25-volt shunted heater with its shunt consumes 7.5 watts, and the line dropping resistor consumes 8.7 watts, a total of 35.2 watts. This is slightly more than the consumption of the circuit of Fig. 1-9(D), but it is much less than that required by circuit 1-9(C). As to the relative ease of installation of circuits 1-9(D) or (E), it is a matter of specific circumstances, there being little to choose in terms of power saving.

The reduction of the line voltage-dropping resistor R, in Fig. 1-9(E) is significant. It means a smaller unit and one with lower power dissipation rating, making it more convenient to install than larger units.

A simplification of the shunted heaters is shown in Fig. 1-9(F). Instead of individual current shunts, a single shunt R_1 of suitable value (equal to the combined resistance of the shunted heaters) is connected across the 150-ma heaters, H_1 to H_5. As indicated in the diagram, this resistance amounts to 502 ohms, which is the aggregate of four heaters of 84 ohms each, and one heater of 166 ohms. The 300-ma heater H_6 requires no shunt, therefore, it is not included by the common shunt R_1.

The use of a common shunt across several tube heaters is not generally applicable to television receivers without taking special precautions. The reason for this is that it is common practice in series-wired television receivers to isolate one heater from the other by means of isolating chokes [see Fig. 1-9(G)]. These are part of the filament circuit, but their d-c resistance is extremely low. Any attempt to shunt current around these heaters must exclude the choke from the shunted circuit otherwise the effectiveness of the choke will be materially reduced, if not completely nullified. This means that the current shunts shown in dotted lines in Fig. 1-9(G) are undesirable, instead, each tube should be shunted separately and care must be exercised to see that the shunt is connected directly across the terminals of the related heater and does not include the associated choke.

Series-Parallel Circuits

Having described the parallel and the series systems separately, the organization of the series-parallel system should pose no problem. It is doubtful that the occasion will arise which requires the design of a complete new heater system, usually, the substitution involves one or two tubes at the most and these can be treated as illustrated in Figs. 1-9(B) through (G). An example of a series-parallel combination somewhat more complex than the usual is illustrated in Fig. 1-10. To simplify the treatment of this circuit, we will divide the heaters into two strings, and examine each separately.

In string 1, heaters H_1 and H_8 require heater current equal to the total line current entering the string. Heaters H_2 through H_7 are alike in their requirements for they draw the same current and voltage, however, the total current drawn by these heaters is less than I_1 because of the presence of the current shunt R_1. Furthermore, we note a number of voltage drops in string 1 indicated by the letter E with subscripts. Voltage drop E_1 appears across the extreme limits of the string and is equal to E, the line voltage. The presence of the line dropping resistor R in series with the heaters in string 1 indicates that the total voltage drop in the system E_{11} is less than the applied voltage. The latter is equal to the sum of E_{11} and E_{12}. In turn E_{11} is composed of the sum of the voltage drops E_a, E_b and E_c.

Suppose, for the moment, that heater H_1 is rated at 25 volts and 0.8 ampere, heater H_8 is rated at 12.6 volts and 0.8 ampere, and heaters H_2 through H_7 are rated at 12.6 volts and 0.15 ampere. This identifies E_b

as being 37.8 volts, and E_{11}, therefore, amounts to 25 + 12.6 + 37.8 or 75.4 volts. The line dropping resistor R, therefore, disposes of 41.6 volts at 0.8 ampere. The series-parallel arrangement of heaters H_2 through H_7, without the shunt R_1 requires only 0.3 ampere, however, the line current is 0.8 ampere. Therefore, shunt R_1 must bypass 0.5 ampere. Its value can be determined by $R = E/I$, where E is the voltage across the shunt, in this case E_b (37.8 volts), and I is the current to be shunted through the resistor (0.5 ampere). R_1, therefore, is equal to 75.6 ohms.

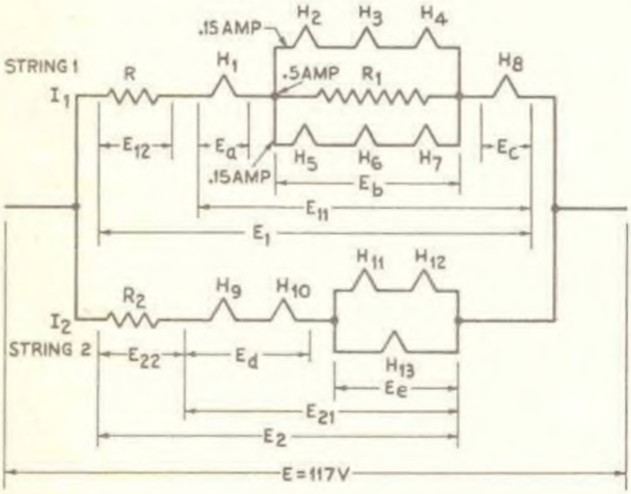


Fig. 1-10. In a series-parallel arrangement of tube heaters such as shown here, each string should be considered separately to find the requirements of each heater.

The distribution of voltages and currents in string 2 requires no special comment. What has been said so far will make the organization of this string easy to follow with the possible exception of the shunting of heater H_{13} across the series pair H_{11} and H_{12}. This is made possible by virtue of the relative voltage ratings of these three heaters; heaters H_{11} and H_{12} are rated at one-half of that of H_{13}, or the total drop across the series pair H_{11} and H_{12} equals the drop across H_{13}. The total current drawn by H_{11}, H_{12}, and H_{13} must equal the current flowing in the line through H_9 and H_{10}. Further examples of such circuits will be found in Section 3.

Dual-Heater Voltage and Current Tubes

Some tubes contain dual heaters which are connected in series and tapped at the midpoint, offering three points for connection. They bear one voltage rating when the two heaters are used in series and another voltage rating (half the previous value) when they are connected in parallel. Naturally, the parallel connection bears a current rating which is twice that of the series rating. Circuitwise, the heaters appear as shown in Fig. 1-11, and are listed in a tube characteristic chart as follows:

TUBE TYPE	FILAMENT VOLTAGE	OR	HEATER CURRENT
3E6	1.4		0.10 ampere
	2.8		0.05
12AT7	6.3		0.3
	12.6		0.15

Fig. 1-11. Dual heaters such as appear in dual-heater tubes have their midpoint tapped. This makes it possible to connect the heaters either in series or in parallel with each other.

The use of such tubes in a system affords a more convenient means of substitution than the use of single rated heaters for, by simply arranging the heaters in parallel, they can be made to serve in circuits which require the lower of the two voltages and the higher of the two current ratings. By using the tube with series-connected heaters, it will suit the needs of circuits which require the higher voltage rating and the lower current rating.

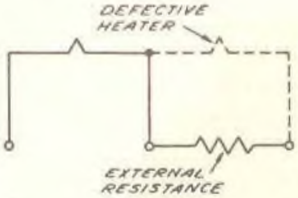


Fig. 1-12. A defective heater in a dual-heater tube may be replaced by an external resistor equal in resistance to the defective element.

Each of these dual heaters is a resistance and, when the heaters are used in parallel, the resultant resistance is half that of either. When they are used in series, the total resistance is equal to twice that of either. In the event of failure of either heater, the remaining heater is capable of causing sufficient electron emission from the cathode and the tube may be treated as if it had but one heater. If it is a matter of maintaining a certain voltage drop in a heater system, the defective heater may be replaced by an external resistance equal in value to that of the original heater. This is illustrated in Fig. 1-12. It must, of course, be understood that when this external resistance replaces the bad heater it will contribute nothing to the emission.

Resistor Substitution

A number of factors control the substitution of resistors, these are:

a. Type (wire or processed)
b. Ohmic value
c. Tolerance
d. Wattage rating.

Relative to the type, wire-wound resistors should not be used in frequency-sensitive circuits unless so stated. The reason for this is the winding has inductance and distributed capacitance. If a resonant peaking circuit contains a carbon resistor in series with the peaking coil, replacing that resistor with a wire-wound unit will change the frequency of resonance, and so alter the operation of the device. Such conditions will be found in wideband amplifiers. In general, therefore, replacement resistors should be of the *same type* as those which were removed. Carbon resistors are preferable in all high-frequency circuits, unless otherwise indicated. In circuits which are not frequency sensitive, the replacement of a processed resistor by a wire-wound one is satisfactory, except when wire resistors appear in both grid and plate circuits of the same tube. This may result in feedback and oscillation in amplifier circuits which handle reasonable amounts of power. Resonance may be created by means of the related distributed capacitance and the inductance of the resistor.

Concerning the ohmic value, it is assumed that the correct substitution will be made with whatever tolerance is indicated in the reference information that describes the constants of the circuit where the replacement is being made. Data concerning tolerance identifications on processed resistors will be found in Section 5.

Sometimes, a single resistor must be replaced by two resistors or a shunt must be added so as to change the ohmic value of a portion of the circuit in order to satisfy the requirements of a tube substitution. The equivalence between a single resistor and other combinations which can produce the same value is shown in Fig. 1-13.

When resistances are in series, the total resistance is equal to the sum of the individual resistances, no matter how many there are [Fig. 1-13(A)]. The resultant resistance of two resistances in parallel is equal to the product divided by the sum, see Fig. 1-13. The number of resistances which may be placed in parallel is limited by practical considerations. If more than two must be shunted in order to arrive at a certain resultant, the following equation should be used

$$\frac{1}{R} = \frac{1}{R_5} + \frac{1}{R_6} + \frac{1}{R_7} + \ldots \text{ [see Fig. 1-13(C)].}$$

For the case of three parallel resistors, the resultant reduces to the fraction shown in Fig. 1-13(C).

Sometimes the situation demands that a certain resistance be shunted by another to produce a certain final value. The ohmic value of the shunt is determined as follows

$$R_{\text{shunt}} = \frac{\text{desired resistance} \times \text{original resistance}}{\text{original resistance} - \text{desired resistance.}}$$

For example, a 100,000-ohm load resistance must be reduced to 30,000 ohms in order to suit the new tube used. What shall be the ohmic value of the shunt required for this job? Using the equation given above

$$R_{\text{shunt}} = \frac{30{,}000 \times 100{,}000}{100{,}000 - 30{,}000} = \frac{3{,}000{,}000{,}000}{70{,}000}$$

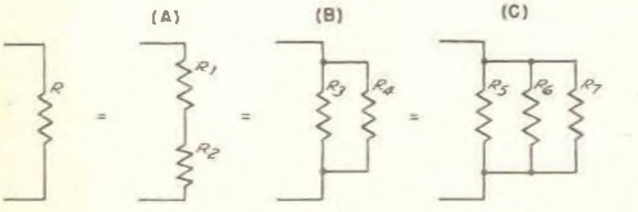
$$= 43{,}000 \text{ ohms (approx.).}$$

Tolerance ratings, expressed in percentage, are the amounts by which a rated resistance may differ from the actual resistance of the element. A plus tolerance means that the actual value may be higher than the rated value by some amount not exceeding the tolerance figure; a minus tolerance means that the actual value may be lower than the rated value by some amount not exceeding the tolerance. Thus, a 1-megohm resistor rated at + 5 per cent means that it may be as high as 1,050,000 ohms; if the tolerance was — 5 per cent, its value might be as low as 950,000 ohms. Combining a plus tolerance resistor with a minus one is a good way of arriving at a desired resultant when two of like value are not available. There are many resistors that have a plus and minus tolerance rating. Thus, a 1,000-ohm resistor of ± 10 per cent may be as high as 1,100 ohms, or as low as 900 ohms.

The power dissipation in a resistor carrying current may be expressed by any one of the following methods

$$P = I^2R = \frac{E^2}{R} = EI$$

where I is the current flowing through the resistor; R is its ohmic value, and E is the voltage drop *across* the resistor. In most cases, the wattage rating of a resistor is an important factor. In certain grid circuits, however, where the current is so small as to be negligible, the resistor's power dissipation value is not important. A half-watt rating will be found suitable for all such circuits. However, in those instances when



$$R = R_1 + R_2 = \frac{R_3 \times R_4}{R_3 + R_4} = \frac{R_5 R_6 R_7}{R_6 R_7 + R_5 R_7 + R_5 R_6}$$

Fig. 1-13. The use of a combination of resistors to produce the same total resistance as a single one is shown in (A), (B), and (C). The total resistance of each of the combinations may be found from the formula beneath it and is equal to the single resistance R shown at the left.

grid current exists and is used to develop all or part of the grid bias, the wattage rating must be based upon the calculated power dissipation. In general, a maximum safety factor of 100 per cent should be allowed above the calculated value. This means that the wattage rating of the resistor chosen should be equal to twice the calculated power dissipation. Such a factor of safety is more than ample. For example, if the dissipation is 1.2 watts, use a 2-watt resistor; if it is 3 watts, use a 5-watt resistor; if it is 6 watts, use a 10-watt resistor; and if it is 13 watts, use a 20-watt resistor. Note that the required wattage is slightly less than double the calculated value in each case. Thus we see why a 100-per cent factor of safety is considered a maximum.

A consideration of moment is the possible tube damage resulting when a resistor burns out. If damage can result due to an excessive rise in plate current or voltage, in the event that a resistor burns out, it is advisable to use a resistor which has a higher wattage rating than the one being replaced.

If the occasion arises to replace a resistor in one leg of a balanced circuit, for example, in the plate or grid circuit of a push-pull stage, it may be necessary to replace the resistor in the other leg also so as not to disturb the balanced condition of the circuit elements. When a replacement is made in such a case, both resistors should have not only similar ohmic values, but should be of similar construction and have similar tolerances and wattage ratings as well.

Fixed Capacitor Substitution

The cardinal factors associated with fixed capacitors are the capacitance, d-c working voltage, and leakage resistance. The requirements relative to capacitor values are so obvious as to require no discussion other than to mention the equivalence between several arrangements, as shown in Fig. 1-14. Two like-value capacitors in series produce a resultant which is equal to one-half the capacitance of either one. Two or more unlike capacitors in series are treated the same as resistors in parallel. Capacitors in parallel are additive.

The d-c working voltage corresponds to the peak a-c voltage which may be applied to the capacitor. Practically speaking, d-c working voltage ratings are somewhat lower than can actually be applied to the capacitor because of the safety factor, but common sense dictates that operations should be carried on within the limits set by the rated working voltage. In view of this situation, care must be exercised against interpreting the d-c working voltage as being the equivalent of the rms or effective value of a-c voltage; if this is done, the probability exists that the peak a-c voltage in the circuit will puncture the capacitor. The correspondence between these different values of voltage is as follows

D-C Working Voltage = Peak A-C Voltage = 1.414 × RMS Voltage.

If by error the rms voltage in a circuit equals the d-c working voltage rating of the capacitors, the peak a-c voltage in those circuits (exclusive of surges) will be 1.414 times higher. If any question arises concerning the rms voltage and the d-c working voltage of a capacitor in a circuit, the rms voltage which is usable may be found from the following equation

RMS Voltage = D-C Working Voltage × 0.707.

This is an important consideration in rectifier systems and wherever both a-c and d-c voltages are involved. The input capacitors in capacitance input filter systems should have a d-c working voltage rating which is somewhat higher than the peak voltage available from the plate winding of the power transformer. This will take into account possible surges which may occur. It is well to bear in mind that repeated failure of capacitors at one point in a system is proof of an insufficient voltage safety factor in the selection of the voltage rating. This is especially true when a substituted rectifier is of the filament type, whereas tubes which receive their voltage from the rectifier are of the heater type. In such cases, high voltages will prevail in the rectifier during the time required for the load tubes to reach the conducting state.

If parallel or series capacitor combinations are used as replacement for a single capacitor, care must be taken that the d-c working voltage across each part of the combination is its rated one. For example, if two capacitors are in series the voltage across each should be inversely proportional to their capacitances and together should equal the total voltage across them. When the combination is a parallel one, the same d-c working voltage will appear across each capacitor.

The d-c leakage in fixed capacitors is an important item in connection with substitution. For example, capacitors which are intended to isolate one point from another relative to d.c. should have low leakage, which means high insulation resistance. High leakage in coupling capacitors can very materially influence the bias on the grid of the tube connected to the resistor and adversely affect the performance of that tube. In this connection, electrolytic capacitors have the highest leakage, paper dielectric capacitors are lower, and mica or ceramic capacitors have the lowest leakage. Vacuum capacitors are, of course, ideal but their use is limited mostly to high-voltage points in transmitters and similar equipment.

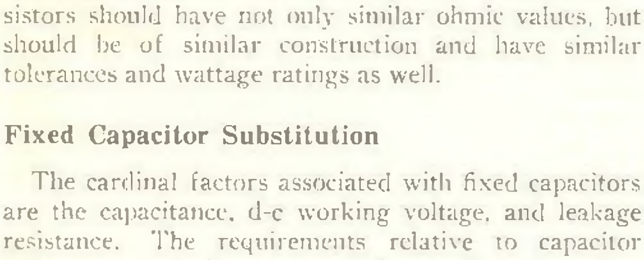


Fig. 14. Combinations of capacitors which give resultant capacitances equal to that of a single capacitor are shown here with the resultant capacitance of each combination listed below it.

When working in high-frequency circuits, the substitution should, if at all possible, be a duplicate of the capacitor being replaced, which in many cases will be a ceramic capacitor. If it is not available, then a mica is the next best choice.

As a means of conserving space, some ceramic capacitors are dual units, that is, the same housing includes a resistor (possibly more than one) which is associated with the operation of the device. Sometimes two such capacitors and a resistor, forming a complete load assembly, may be in one unit. These should be replaced as a unit, but in an emergency, a substitute may be used for only that part of the assembly which has failed. Note: an examination of a circuit may disclose more components than are present physically: some of these "missing" elements may be included in dual units.

I-F Transformer Substitution

The replacement of i-f transformers is determined by circuit location and circuit constants. The location determines whether it falls within the category of an "input," "interstage," or an "output" transformer. These identifications are found in service notes and parts catalogs. With the exception of receivers which contain only a single stage of i-f amplification, all superheterodynes make use of the aforementioned three general types of transformers. The input and interstage kinds may be interchangable but the output transformer, which feeds a diode demodulator, is of a special design. Therefore, when it is necessary to replace the i-f transformer which feeds the signal to the diode demodulator, every effort should be made to secure a replacement which has been designed to perform that function.

Substantial differences may be found in the numerous varieties of i-f transformers which are employed by receiver manufacturers. Replacement of identical units is possible only by procuring the part from facilities related to the original receiver manufacturer. However, general replacement i-f transformers are suitable substitutes if the proper precautions are exercised when the substitution is made. For example, some i-f transformers used in combination a-m—f-m receivers are of the dual-frequency variety, that is, two different transformers contained in the same can. In other cases, trimmers, or filter elements related to the stage are contained in the same can with the transformers. Examples of these two are shown in Figs. 1-15(A) and (B).

The replacement of such devices by substitutes involves consideration of all of the factors involved. Two individual i-f transformers, an a-m and a separate f-m unit, may be connected externally to form the equivalent of the original shown in Fig. 1-15(A). However, if the original contains additional elements such as resistors and filter capacitors, these must be added in the substitution. The same is true of the replacements for either a-m or f-m transformers which contain special elements. We are referring particularly to units in which the trimmer capacitor is a combination element, part of it being used in the grid filter system of that stage. This may not become evident in a casual inspection of the device or the schematic, for the symbols representing the filter resistors and capacitors are not necessarily shown as a part of the trimmer. This calls for a careful examination of the transformer and the filter circuits. If the transformer is removed and with it all of the filter elements, then a substitution must consist of a corresponding number of units.

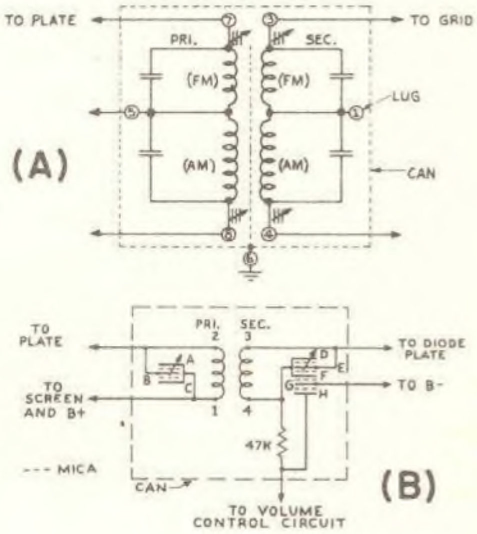


Fig. 1-15. (A) An i-f transformer of the dual-frequency variety found in a-m — f-m receivers. The a-m and f-m windings of the i-f transformer are in series and are contained in the same can; in (B) is shown a unit which contains, besides the i-f transformer, the filter capacitors and trimmers used in the associated circuit.

Relative to the general requirements of i-f transformers, those designed for use with pentodes will serve with any pentode or tetrode. The specific electrical characteristics of all pentode or tetrode i-f amplifiers are not alike, but the differences in i-f transformer performance due to this variable will not be significant if all other requirements are satisfied.

The intermediate frequency is another controlling factor in the selection of a substitute i-f transformer. Several broad categories exist, those used in a-m receivers, those in f-m receivers, and those in television receivers. In each group, the bandwidth requirement is pertinent to the selection of the replacement as is the specific intermediate frequency. Reference to the service data on the receiver is essential: the intermediate frequency used in a receiver does not disclose the specific bandwidth conditions in the i-f transformers. In some cases, all transformers are relatively broadband, being closely coupled. In other instances, the over-all broadbanding is accomplished by staggering the i-f peaks in the individual stages.

Concerning the center frequency, i-f transformers intended for a-m receivers have been standardized to four center frequencies, 130 kc, 175 kc, 262 kc, and 455 kc. From this point on, different types produced by different manufacturers afford different over-all frequency coverage. These vary from a low of about 5 per cent to a high of 40 per cent of the center frequency. For example, one manufacturer may produce an i-f transformer with a center frequency of 455 kc and an over-all tuning range of 50 kc, which is the equivalent of 25 kc each side of the rated center frequency. Some other manufacturer may design his transformers so that the over-all tuning range may be 200 kc, equal to about 40 per cent of the center frequency.

As a rule, the higher the center frequency, the wider is the over-all tuning range, but all makes of i-f transformers of like center frequency do not afford like frequency coverage. In other words, the selection of a transformer demands recognition of the bandwith requirements of the stage wherein it is to be used. Attention must also be paid to the tuning range of a unit if the intermediate frequency in the receiver is not the same as the center frequency of the transformer.

Concerning dual i-f transformers (a-m and f-m), the generally standardized frequencies found in the i-f systems of such receivers preclude any problems other than the one we referred to earlier, that is, to be certain that all of the filter components which exist inside of the original receiver manufacturer's unit appear in the receiver after the replacement has been made.

Up to this point we have neglected the factor of space relative to i-f transformer substitution. It can well be a problem. If the substitution is a transformer for a transformer, that is, single band for single band, it is not too difficult even if the substitute is larger than the original (which seldom is the case). If a dual band (single can) transformer must be replaced by two individual transformers, however, we have a problem. It is possible to find i-f transformers which are smaller than the usual variety. It takes effort to select the ones needed because several factors must be taken into account, but it can be done.

Power-Transformer Substitutions

The physical size and the electrical ratings are two dominant factors in such substitutions. The limitations caused by size are so obvious as to require no elaboration. Concerning electrical ratings, the first essential is that the transformer afford the same over-all capabilities as the original, that is, its windings should be equal in number to that of the original so as to duplicate the functions of the original. This statement is subject to some slight qualifications which will appear when we discuss the filament windings, but in general, it can be said that the maximum convenience in substitution is attained if the substitute has at least as many different windings of like electrical rating as the original.

So far as physical characteristics are concerned, if the original transformer is shielded completely, the substitution unit should be likewise. If the original employs vertical shield mounting, so should the substitute; if the original has horizontal shield mounting, the replacement should duplicate it. Such attention to shielding will result in freedom from field troubles. Open-core transformers can cause trouble if located close to grid and plate wiring. If they must be used because the exact replacement is not available, the possibility of hum troubles must be recognized.

Each winding bears a voltage and a current rating with supplementary identification concerning the center tap. Although a center tap can be arranged by means of a center-tapped resistor connected across an untapped winding, it is preferable if the tap is a part of the winding. A suitable value for a resistor to be used for a center tap is 100 ohms.

Increasing Heater Voltage Rating. Although it is best if the filament windings on the transformer are the same in number and rating as the original, it is very possible that such replacements will not be available. In that event, the following information will be useful. Filament windings when connected in series furnishes a resultant voltage which is the sum of the voltage ratings of the individual windings. A 2.5-volt winding in series with another of 5.0 volts will be the equivalent of a voltage source rated at 7.5 volts. Care must be exercised to see that the two windings are connected with the windings aiding each other. An a-c voltmeter connected across the combined windings will indicate if they are aiding or bucking. The current rating of a series winding of this kind is limited to the lower of the two ratings of the individual windings.

For example, if two 6.3-volt windings, each rated at 1.2 amperes are connected in series aiding, the voltage rating of the two windings is 12.6 volts at 1.2 amperes. If one of these is rated at 0.9 ampere and the other at 1.5 amperes, the current output of the series winding would be limited to 0.9 ampere.

Increasing Heater Current Rating. Windings may be connected in parallel so as to increase the current output rating, provided that each of the windings connected in parallel is rated at the *same* value of voltage. The current ratings need not be the same; the total current output will be the sum of the two individual current ratings. Care must be exercised to see that the two windings are connected in proper phase, otherwise they will buck each other. An a-c voltmeter connected across one winding while the other is being connected in parallel will show whether the phase is correct. If the voltage is reduced, they are bucking.

Relative to the center-tap connection, if two like voltage windings are connected in series, the junction between them can serve as the center tap; individual center taps on the two windings being disregarded. If two unlike voltage windings are connected in series, the midpoint of a 100-ohm resistor, shunted across the combined windings, can be used as the center tap.

If two windings are connected in parallel and each of them has a center tap, the two center taps may be connected together to serve as the combined center-tap connection. If only one of two windings in parallel has a center tap, it cannot be used as the center tap to serve both windings, a 100-ohm center-tapped resistor should be connected across the untapped winding and its midpoint joined to the other center tap, at which point the common connection can be made.

Substitute Heater Windings. If the replacement transformer does not contain all the required heater windings, a supplementary filament transformer, capable of furnishing the required voltage and current, can be used apart from the regular power transformer. Its primary should be connected in parallel with the other transformer.

Half-wave rectifier heater windings do not require center taps. Either end of the winding will serve as the positive output lead with a filament-type tube. Full-wave rectifiers should employ center-tapped heater windings even if the rectifiers are of the cathode type.

Heater-Winding Insulation

As a rule, the voltage breakdown requirements of most heater windings which are a part of the power transformer can be satisfied by a rating of about 2,000 volts since the highest voltage in the system is far less than this amount. In cathode-ray equipment and other systems, it is possible that the cathode may be as much as 4,000 volts above ground and, since it is connected to the center tap of the heater winding, the latter is also above ground by the corresponding amount. This demands that the heater voltage winding be so insulated as to withstand this difference of potential. Sometimes (although very seldom), this requirement may be stated in the specifications. If it is not, it becomes the province of the technician to decide the voltage breakdown requirements of the heater winding.

Rectifier Plate Windings

The conditions surrounding the selection of a substitute power transformer relative to the plate winding are varied, so much so, that it becomes necessary to examine several approaches to the subject. To begin with, the constants of a power transformer utilized in a receiver (or some other kind of equipment) may not be fully identified in service literature; a part number always is given, and sometimes, the current and voltage ratings of the heater windings are stated on the manufacturer's schematic. If this data is not given, the number required and the current rating of each become evident when reference is made to the schematic wiring diagram of the equipment in which the substitution is to be made. It discloses the number of heater or filament chains, and the voltage and current requirements of each. Summation of these indicates the minimum current ratings of the heater windings. The constants of the plate winding, however, are generally omitted. This means that some way must be found to ascertain the requirements of the plate winding so a proper substitute can be found in the event that an exact replacement from the original equipment manufacturer is not available.

The type of rectifiers and their ratings indicates the maximum voltage and current requirements of the plate winding. Seldom, if ever, are these tubes operated very close to their maximum ratings. Therefore, by noting the limits indicated in the tube characteristic chart, and the practical voltages being applied to the tubes in the system under consideration, it is possible to arrive at the voltage and current ratings of the plate winding. Whether it should be a full-wave winding, that is, center tapped, or a half-wave winding is indicated in the schematic of the equipment and by the organization of the rectifier system as a whole. But it is conceivable that there still may arise problems in establishing the voltage rating of the plate winding in view of the conditions experienced in choke- and capacitor-input filter systems, and because of the manner in which the parts catalogs describe the capabilities of the plate windings of power transformers. Generalizing, we can state that when the input of the power-supply filter system is capacitive, the voltage rating of each half of the power-supply plate winding in a full-wave system can be as much as 10 to 15 per cent lower than the d-c voltage output of the rectifier at the prescribed value of d-c load. This stems from the fact that the input filter capacitance can be charged to approximately the peak value of the a-c voltage applied to the rectifier tubes. Some parts catalogs state the voltage and current ratings based on full-wave operation of the rectifier with capacitance input, whereas many others show the a-c voltage across each half of the plate winding at certain d-c values in terms of choke input. This is a cause of confusion; in one case, the a-c voltage between the center tap and the extremes of the plate winding is less than the d-c voltage output from the rectifier by as much as 8 to 10 per cent, whereas in the other case, the a-c voltage rating of the plate winding may be as much as 10 to 15 per cent higher than the d-c voltage output from the rectifier.

What can be used as a guide in determining the basic requirements of the plate winding? The original schematic of the equipment should be the first source of information, especially when it is supplemented by a voltage chart which indicates the voltages being supplied by the power supply. If the plate-current requirements of the tubes are not shown in the voltage chart, a reasonable approximation of these current values can be developed from the tube characteristic charts contained herein. Then, allowing for a 10 per cent voltage drop in the filter system of the power supply and perhaps a loss of about 5 per cent of the total output current through the bleeder connected across the power supply, one can arrive at the total current load requirements of the system and the maximum a-c voltage required between the center tap and the extremes of the full-wave plate winding.

These data are naturally subject to variations, but the approach we have described is not too far off the path which must be followed. At least it suggests a way to gather the necessary information.

It may appear, because of the large number of commercial models, that receivers and amplifiers are distinctive in their general requirements. Such is not the case, for all fall into certain groupings and reflect certain general design considerations. It would be foolish to deny that such circuits as shown in Rider Manuals can serve as the guide for substitution requirements. So far as tube heater and signal electrode voltages and currents are concerned, there isn't much difference between the five- or six-tube table models produced by different manufacturers. Individuality appears in the number of tubes, the specific designs of the transformers, the combination of functions and the like, but these play very little part in establishing the requirements of a power supply.

Cathode-Ray-Tube Substitutions

Cathode-ray-tube substitutions are more involved than ordinary receiving tube substitutions, if for no other reason than that the physical dimensions of the various cathode-ray tubes differ, and the replacement of one by another may require substantial physical changes in the cabinet. Nevertheless, substitutions are possible and the following are offered as suggestions. They are to be used in conjunction with the cathode-ray-tube specifications contained in this Guide Book.

1. All picture tube phosphors must be number 4. This is the last digit in the tube type number.
2. Wholly electrostatically operated picture tubes must be replaced with similar tubes. Since these are restricted in screen size, replacement for 7- and 10-inch electrostatically deflected and focused picture tubes are very limited.
3. Tubes which employ magnetic deflection and electrostatic focusing have no substitutes among either completely electrostatic or magnetic types. The reverse is, of course, also true, a combination magnetic-deflection and electrostatic-focusing type tube cannot be a replacement for either an electrostatically or magnetically deflected and focused picture tube. Since the 7DP4, 9AP4, 10DP4, and 12AP4 are tubes of this type, they have no replacements except each other.

FOCUS COIL CURRENT RATINGS FOR MAGNETIC TYPE CATHODE-RAY TUBES

C-R Tube	Focus Coil Current (Ma)	C-R Tube	Focus Coil Current (Ma)	C-R Tube	Focus Coil Current (Ma)
10BP4	132	14CP4	115*	16MP4	110
10BP4A		14DP4	104	16MP4A	
10CP4	---	14FP4	115*	16QP4	125*
10DP4	---	15AP4	159	16RP4	100*
10EP4	132	15CP4	133	16SP4	110
10FP4	115	15DP4	140	16SP4A	
10MP4	---	16AP4	89	16TP4	115*
10MP4A		16AP4A		16UP4	100*
12JP4	158	16CP4	110	16VP4	110*
12KP4	140	16DP4	115*	16WP4	110*
12KP4A		16DP4A		16XP4	100*
12LP4	114	16EP4	105	16YP4	100*
12LP4A		16EP4A		17AP4	115*
12QP4	148	16FP4	140	19AP4	140
12QP4A		16GP4	100*	19AP4A	
12RP4	148	16HP4	110	19DP4	140
12TP4	114	16HP4A		19DP4A	
12UP4	114	16JP4	120	19EP4	140*
12UP4A		16JP4A		19FP4	97-126*
12VP4	---	16KP4	97*	19GP4	107-126*
12VP4A		16LP4	110	20BP4	122
14BP4	115	16LP4A		22AP4	108*
				22AP4A	

* Types employ RTMA Focus Coil #109, all others RTMA focus focus coil #106.

Courtesy DuMont Labs

4. Picture tubes differ in the focusing coil currents, consequently, in some instances the focusing coil for the substitute tube may require more current than for the original. This necessitates modification of the focusing current supply system. Conversely, some substitute tubes may require less current through the focusing coil than the original, in which case a resistor shunted across the coil will serve the purpose. This current shunt can be calculated using the d-c resistance of the focusing coil and the value of the current, just as in the case of heater current shunts. A variable resistance, 2,500-15,000 ohms, shunted across the coil can be used to determine the value for the fixed resistance shunt. The accompanying table lists the focusing-coil currents for the different magnetic-type cathode-ray tubes.
5. Replacing outside coated tubes with metal-cone types (or the reverse) requires care concerning the connection to the coating or the metal cone. The coating usually is connected to ground, whereas the metal cone usually is connected to a high voltage. The original receiver manufacturer's service notes must be consulted.
6. When a large tube is replaced by a smaller one, the characteristics of the substitute should be determined by reference to the characteristic chart; if the

conditions in the receiver exceed the maximum voltage ratings of the tube, these must be reduced in order to employ the substitute. Usually, those operations are too complicated for the average technician; such substitutions are not recommended.

7. All picture tubes do not utilize like tube basing. See the cathode-ray-tube basing chart in Section 5.

8. Bear in mind that the ion-trap magnets in magnetically focussed picture tubes are not all alike, some call for a single magnet, others for dual magnets; check the cathode-ray-tube characteristics in Section 5.

9. If tube characteristics indicate that the original tube has an external coating furnishing a certain amount of capacitance and the substitute tube does not, a corresponding value of capacitance should be added to the high-voltage power supply at the high-voltage output terminal. This capacitor must have the appropriate d-c working voltage rating.

10. If the ion-trap magnet for the original tube is of the electromagnetic type (coil) and the substitute utilizes a permanent magnet, the coil unit may be left intact (placed in a recess of the cabinet), or it may be replaced by an equivalent resistance of suitable wattage rating located as closely as possible to the power supply. It should not be disconnected without substituting the equivalent resistance into the current supply circuit.

FUNCTIONAL CLASSIFICATION OF TUBES

APPLICATION			HEATER VOLTAGES					150 MILLIAMPERE HEATER CURRENT	300 MILLIAMPERE HEATER CURRENT
			1.4	2.0	2.5	6.3	12.6		
RF - IF AMPLIFIERS	GENERAL PURPOSE	TRIODES	26 957* 958*	1H4G 30	27 56 485††	6AD4 6C4 6J4 6K4 6N4 7A4 37 76 955 9002 XXL	14A4	6AD4 6C4 955 9002	7A4 37 76
		DOUBLE TRIODES	3B7/1291		3B7/1291#	6AH7GT 6J6 7AF7 7F7 7F8	12AH7GT 12AT7 14AF7/XXD 14F7 19J6##	12AH7GT 12AT7 14AF7/XXD 14F7 19J6	6AH7GT 7AF7 7F7 7F8 12AT7
		TETRODES		1A4T 1D5GT 1E5GT 32	24 35	36			36
		PENTODES	1AB5** 1AD4 1AD5 1L4 1LC5 1LN5 1N5GT 1P5G 1P5GT 1SA6GT 1T4 1U4 1W5* 3E6 959*	1A4P 1B4P 1D5GP 1E5GP 15 34	3E6# 57 58	6AG5 6AH6 6AK5 6AU6 6BA5 6BA6 6BC5 6BD6 6BH6 6BJ6 6C6 6CB6 6D6 6E7 6J7 6J7G 6J7GT 6K7 6K7G 6K7GT 6S7 6S7G 6SD7GT 6SG7 6SG7GT 6SH7 6SH7GT 6SJ7 6SJ7GT 6SK7 6SK7GT 6SS7 6SS7GT 6U7G 6W7G 7A7 7AB7 7AD7 7AG7 7AJ7 7B7 7C7 7G7 7H7 7L7 7V7 39/44 77 78 954 956 9001 9003	12AU6 12AW6 12BA6 12BD6 12B7 12J7GT 12K7GT 12SG7 12SH7 12SH7GT 12SJ7 12SJ7GT 12SK7 12SK7GT 14A7/12B7 14C7 14H7	6BA5 6BH6 6BJ6 6S7 6S7G 6SS7 6SS7GT 6W7G 7AB7 7B7 7C7 12AU6 12AW6 12B7 12BA6 12BD6 12J7GT 12K7GT 12SG7 12SH7 12SH7GT 12SJ7 12SJ7GT 12SK7 12SK7GT 14A7/12B7 14C7 14H7 954 956 9001 9003	6AU6 6BA6 6BD6 6C6 6D6 6E7 6J7 6J7G 6J7GT 6K7 6K7G 6K7GT 6SD7GT 6SG7 6SG7GT 6SH7 6SH7GT 6SJ7 6SJ7GT 6SK7 6SK7GT 6U7G 7A7 7AG7 7AJ7 7H7 7L7 39/44 77 78
	TELEVISION	TRIODES				6AB4		6AB4	
		DOUBLE TRIODES				6J6 12AT7	12AT7 19J6##	12AT7 19J6	12AT7
		PENTODES				6AB7 6AC7 6AG5 6AK5 6AU6 6BC5 6BH6 6CB6	12AU6	6BH6 12AU6	6AG5 6AU6 6BC5 6CB6

* 1.25 V. ** 1.2 V. †† 3.0 V. # 2.8 V. ## 18.9 V.

Courtesy TUNG-SOL Lamp Works, Inc.

FUNCTIONAL CLASSIFICATION OF TUBES

	APPLICATION	HEATER VOLTAGES						150 MILLIAMPERE HEATER CURRENT	300 MILLIAMPERE HEATER CURRENT
		1.4	2.0	2.5	5.0	6.3	12.6		
AF AMPLIFIERS	TRIODES	1C3 1E4G 1G4GT 1LE3 26	1H4G 30	27 56 485††	01A	6AE5GT 6AD5G 6AF5G 6C5 6C5GT 6F5 6F5G 6F5GT 6J5 6J5GT 6K5G 6K5GT 6L5G 6P5GT 6SF5 6SF5GT 7A4 7B4 37 56 75S 76	12E5GT 12F5GT 12J5GT 12SF5 12SF5GT 14A4	6L5G 12E5GT 12F5GT 12J5GT 12SF5 12SF5GT 14A4	6AE5GT 6AF5G 6AD5G 6C5 6C5GT 6F5 6F5G 6F5GT 6J5 6J5GT 6K5G 6K5GT 6P5GT 6SF5 6SF5GT 7A4 7B4 37 56 75S 76
	DOUBLE TRIODES			53		6A6 6AE7GT 6C8G 6F8G 6N7 6N7G 6SC7 6SC7GT 6SL7GT 6SN7GT 6Y7G 6Z7G 7AF7 7F7 12AU7 12AX7 12AY7 79	12AU7 12AX7 12AY7 12SC7 12SL7GT 12SN7GT 14AF7 14F7	12AU7 12AX7 12AY7 12SC7 12SL7GT 14AF7 14F7	6C8G 6SC7 6SL7GT 6Z7G 7F7 12AU7 12AX7 12AY7 12SN7GT
	TETRODES		32	24		36			36
	PENTODES	1L4 1LG5 1U4 959*	1B4P 1E5GP 15	57		6AU6 6BA5 6BH6 6C6 6J7 6J7G 6J7GT 6R6G 6SG7 6SG7GT 6SH7 6SH7GT 6SJ7 6SJ7GT 6W6GT 6W7G 7AB7 7AG7 7AH7 7C7 7E5 7G7 7L7 7T7 7V7 7W7 77 717A 954 956 9001 9003	12AU6 12J7GT 12SH7 12SH7GT 12SJ7 12SJ7GT 14C7 14V7	6BH6 6W7G 7AG7 7AH7 7C7 7E5 12AU6 12J7GT 12SH7 12SH7GT 12SJ7 12SJ7GT 14C7 954 956 9001 9003	6AU6 6C6 6J7 6J7G 6J7GT 6R6G 6SG7 6SG7GT 6SH7 6SH7GT 6SJ7 6SJ7GT 7L7 7T7 7W7 77
INDICATORS	TUNING INDICATORS			2E5 2G5		6AB5/6N5 6AD6G 6AF6G 6AL7GT 6E5 6G5 6T5 6U5/6G5		6AL7GT	6E5 6G5 6T5 6U5/6G5
	INDICATOR CONTROL					6AE6G		6AE6G	

†† 3.0 V.   * 1.25 V.

Courtesy TUNG-SOL Lamp Works, Inc.

FUNCTIONAL CLASSIFICATION OF TUBES

APPLICATION			HEATER VOLTAGES										150 MILLI-AMPERE HEATER CURRENT	300 MILLI-AMPERE HEATER CURRENT
			1.4	2.0	2.5	5.0	6.3	12.6	18.9	25	35	50		
POWER AMPLIFIERS	GENERAL PURPOSE	TRIODES		1H4G 30 31	2A3 45	01A 12A 71A 183	6A3 50† 6A5G 6AC5GT 6B4G 6C4			25AC5GT				25AC5GT
		DOUBLE TRIODES	1G6GT 3C6/XXB	1J6G 19	53 3C6/XXB#		6A6 6Y7G 6AS7G 6Z7G 6E6 79 6N7 6N7GT							6Z7G
		TETRODES		49	46		6AL6G							
		PENTODES	1A5GT 3LE4 1AC5 3LF4 1C5GT 3V4 1LA4 3C5GT 1LB4 3Q4 1S4 3S4 1V5* 1W4 3A4 3D6	1F4 1F5G 1G5G 1J5G 33 950	2A5 3A4# 3C5GT# 3LE4# 3Q4 3S4# 3V4# 47 59	257	6A4/LA 6R6G 6AG7 7B5 6AK6 38 6AN5 41 6AR5 42 6F6 89 6F6G 6F6GT 6G6G 6K6GT	12A5		25A6 25A6GT 25B6G 43			6AK6 6G6G	6A4/LA 12A5 25A6 25A6GT 25B6G 38 43
		BEAM PENTODES	1Q5G 1Q5GT 1T5GT 3B5GT 3LF4 3Q5GT		3B5GT# 3LF4# 3Q5GT#		6AH5G 6V5GT 6AQ5 6V6 6AR6 6V6GT 6AS5 6W6GT 6L6 6Y6G 6L6G 7A5 6L6GA 7C5 6U6GT	12A6 12A6GT 14A5 14C5 1625		25C6G 25L6 25L6GT	35L6GT 35A5 35B5 35C5	50A5 50B5 50C5 50C6G 50L6GT	12A6 50L6GT 12A6GT 14A5 35A5 35C5 35C6GT 50B5 50C5 50C6G	25C6G 25L6 25L6GT
		DOUBLE PENTODES		1E7G				12L8GT					12L8GT	
		DIRECT COUPLED					6AB6G 6B5 6AC6GT 6N6G			25B5 25N6GT				25B5 25N6G
	TELEVISION	HORIZONTAL DEFLECTION BEAM PENTODES					6AU5GT 6BQ6GT 6AV5GT 6CD6G 6BG6G		19BG6G	25BQ6GT				19BG6G 25BQ6GT
		VERTICAL DEFLECTION TRIODES OR TRIODE CONNECTED PENTODES					6AR5 6K6GT 6S4 6SN7GT 6W6GT 12AU7	12AU7 12SN7GT					12AU7	12AU7 12SN7GT

* 1.25 V. # 2.8 V. † 7.5 V.

Courtesy TUNG-SOL Lamp Works, Inc.

FUNCTIONAL CLASSIFICATION OF TUBES

APPLICATION		HEATER VOLTAGES									150 MILLIAMPERE HEATER CURRENT	300 MILLIAMPERE HEATER CURRENT
		1.4	2.0	2.5	6.3	12.6	25	35	70	117		
MULTI-FUNCTION TUBES	GATED BEAM DEFLECTION				6BN6	12BN6					12BN6	6BN6
	DIODE TRIODES	1H5G 1H5GT 1LH4			6Q6G						6Q6G	
	DOUBLE-DIODE TRIODES		1B5/25S 1H6G	2A6 55	6AQ6 6AQ7GT 6AT6 6AV6 6AW7GT 6B6G 6BF6 6BK6 6BT6 6BU6 6C7 6Q7 6Q7G 6Q7GT 6R7 6R7G 6R7GT 6SQ7 6SQ7GT 6SR7 6SR7GT 6ST7 6SZ7 6T7G 6V7G 7B6 7C6 7E6 7K7 7X7 75 85	12AT6 12AV6 12BF6 12BK6 12BT6 12BU6 12Q7GT 12SQ7 12SQ7GT 12SR7 12SR7GT 12SW7 14B6 14E6 14X7					6AQ6 6ST7 6SZ7 6T7G 7C6 12AT6 12AV6 12BF6 12BK6 12BT6 12BU6 12Q7GT 12SQ7 12SQ7GT 12SR7 12SR7GT 12SW7 14B6 14E6 14X7	6AQ7GT 6AT6 6AV6 6AW7GT 6BF6 6BK6 6BT6 6BU6 6C7 6Q7 6Q7G 6Q7GT 6R7 6R7G 6R7GT 6SQ7 6SQ7GT 6SR7 6SR7G 6V7G 7B6 7E6 7K7 7X7 75 85
	TRIPLE-DIODE TRIODES				6R8 6S8GT 6T8	12S8GT	19T8##				12S8GT 19T8	6S8GT
	DIODE PENTODES	1LD5 1Q6• 1S5 1SB6GT 1T6• 1U5			6SF7 6SF7GT 6SV7	12SF7GT					12SF7GT	6SF7 6SV7
	DIODE POWER PENTODES	1N6G 1N6GT										
	DOUBLE-DIODE PENTODES	1F6 1F7G 1F7GH		2B7	6B7 6B8 6B8G 6B8GT 7E7 7R7	12C8 14E7 14R7					12C8 14E7 14R7	6B7 6B8 6B8G 6B8GT 7E7 7R7
	TRIODE PENTODES				6AD7G 6F7 6F7G 6P7G	12B8GT	25B8GT				25B8GT	6F7 6F7G 6P7G 12B8GT
	DIODE TRIODE PENTODES	1B8GT 1D8GT 3A8GT		3A8GT#			25D8GT				25D8GT	
	HALF-WAVE RECTIFIERS POWER PENTODES					12A7	25A7GT					12A7 25A7GT
	HALF-WAVE RECTIFIERS BEAM PENTODES							32L7GT●	70A7GT 70L7GT	117L7/ M7GT 117N7GT 117P7GT	70A7GT 70L7GT	32L7GT

• 1.25 V. # 2.8 V. ## 18.9 V. ● 32.5 V.

Courtesy TUNG-SOL Lamp Works, Inc.

FUNCTIONAL CLASSIFICATION OF TUBES

APPLICATION				HEATER VOLTAGES										150 MILLIAMPERE HEATER CURRENT	300 MILLIAMPERE HEATER CURRENT
				1.4	2.0	2.5	5.0	6.3	12.6	25	35	50	117		
CONVERTERS	GENERAL PURPOSE		PENTAGRID HEPTODE OCTODE	1A7G 1A7GT 1B7G 1B7GT 1E8 1L6 1LA6 1LC6 1R5	1A6 1C6 1C7G 1D7G	2A7		6A7 6A8 6A8G 6A8GT 6BA7 6BE6 6D8G 6SA7 6SA7GT 6SB7Y 7A8 7B8 7Q7	12A8GT 12BA7 12BE6 12SA7 12SA7GT 12SY7 12SY7GT 14B8 14Q7					6D8G 7A8 12A8GT 12BA7 12SA7GT 12SY7 12SY7GT 14B8 14Q7	6A7 6A8 6A8G 6A8GT 6BA7 6BE6 6SA7 6SA7GT 6SB7Y 7B8 7Q7
			TRIODE HEXODES TRIODE HEPTODES					6J8G 6K8 6K8G 6K8GT 7D7 7J7 7S7	12K8 12K8GT 14J7 14S7					7D7 12K8 12K8GT 14J7 14S7	6J8G 6K8 6K8G 6K8GT 7J7 7S7
			MIXERS					6AS6 6L7 6L7G							6L7 6L7G
	TELEVISION		DOUBLE TRIODE MIXERS					6J6 12AT7	12AT7					12AT7	12AT7
			PENTODE MIXERS					6AG5 6AK5 6BC5 6CB6							6AG5 6BC5 6CB6
RECTIFIERS	GENERAL PURPOSE — HIGH VACUUM	HALF-WAVE	DIODES			2W3 2W3GT 2Y2 2Z2		1-V 81†	12Z3	25W4GT	35W4 35Y4 35Z4GT 35Z5GT	45Z3** 45Z5GT**	117Z3 117Z4GT	35Y4 35Z3 35Z4GT 35Z5GT 45Z5GT	1-V 1Z2 12Z3 25W4GT
		FULL-WAVE	DOUBLE DIODES				5AZ4 5R4GY 5T4 5U4G 5V4G 5W4G 5W4GT 5X3 5X4G 5Y3G 5Y3GT 5Y4G 5Y4GT 5Z3 5Z4 80 83V	6AX5GT 6W5G 6X4 6X5 6X5GT 6Y5 6Z5/12Z5 6ZY5G 7X6 7Y4 7Z4 84/6Z4	6Z5/12Z5	25Z5 25Z6 25Z6GT	35Z6G	50X6GT 50Y6GT 50Y7GT 50Z7G	117Z6GT	50Y6GT 50Y7GT 50Z7G	6ZY5G 25Z5 25Z6 25Z6GT 35Z6G
		DETECTORS	DIODES	1A3 1R4/1294 2B25		9005*		6H4GT 7C4/1203A 9004 9006						1A3 1R4 6H4GT 7C4/1203A 9004 9006	
			DOUBLE DIODES					6AL5 6H6 6H6GT 7A6	12AL5 12H6					7A6 12AL5 12H6	6AL5 6H6 6H6GT
			QUADRUPLE DIODES					6AN6							
		VOLTAGE DOUBLER	DOUBLE DIODE							25Z5 25Z6 25Z6GT	35Z6G	50X6 50Y6GT 50Y7GT 50Z7G	117Z6GT	50X6 50Y6GT 50Y7GT 50Z7G	25Z5 25Z6 25Z6GT 35Z6G

* 3.6 V. † 7.5 V. ** 45 V.

Courtesy TUNG-SOL Lamp Works, Inc.

FUNCTIONAL CLASSIFICATION OF TUBES

APPLICATION				HEATER VOLTAGES							150 MILLIAMPERE HEATER CURRENT	300 MILLIAMPERE HEATER CURRENT
				COLD CATHODE	1.4	2.5	5.0	6.3	12.6	25		
RECTIFIERS	TELEVISION — HIGH VACUUM	HIGH VOLTAGE	DIODES		1B3GT 1X2 1V2 1Y2 1Z2	2V3G 2X2 2X2/879 879						
		VIDEO DETECTOR	DOUBLE DIODES					6AL5	12AL5		12AL5	6AL5
		DAMPER SERVICE	DIODES				5V4G	6U4GT 6W4GT		25W4GT		25W4GT
			DIODE CONNECTED					6AS7G			6AS7G	
		DC RESTORER	DOUBLE DIODE					6AL5	12AL5		12AL5	6AL5
	GENERAL PURPOSE—GAS	HALF WAVE	DIODES	0Y4 0Y4G								
		FULL WAVE	DOUBLE DIODE	0Z4 0Z4G		82 83						
VOLTAGE REGULATOR			GLOW DISCHARGE DIODE	0A2 0A3/VR-75 0B2 0B3/VR-90 0C3/VR-105 0D3/VR-150								
CONTROL SERVICE			GAS TRIODE	1C21		2A4G 2B4 2C4 885		6D4 6Q5G 884				
			GAS TETRODES					2D21 2050 2051				
			RELAY TUBE	0A5								

Courtesy TUNG-SOL Lamp Works, Inc.

SECTION 4

SERVICING SUGGESTIONS

Suggestions For Making Adapters

When they are available, the manufacturer's bases and sockets are the thing to use in making adapters but,when this material is not to be had,we have found the following methods very practical.

There is a molded octal socket sold everywhere, which, with the tinned metal mounting removed, fits into the top of a bakelite octal tube base as if made for the purpose. No. 24 or 26 wires are soldered to the socket and pulled down through the tube base pins, soldered and cut off. Bits of spaghetti should be used to avoid shorts. In the case of 12K7 and other tubes with top caps,a hole is drilled in the side of the base opposite the grid pin. A flexible wire with grid clip is brought out through this hole to connect the top cap. In case of substituting a loctal for an octal such as the 1LA6 for 1A7 the grid lead from tube socket is brought out through this hole to connect the top cap.

In case of substituting a loctal for an octal such as the 1LA6 for 1A7,the grid lead from the tube socket is brought out through the side of the base and an old tube cap soldered on. Always select bakelite bases with eight pins. Most octal tubes have only 7 pins or less, but pin 6 is needed in most adapters.

Another, and we believe, better way to make adapters is to remove the 8 pin wafers from the bases of metal tubes. Use No. 18 tinned wire soldering them in the pins first, preferably by dipping, then bend each one so that it will meet the terminal lug on whatever kind of socket is necessary. All of the socket terminal lugs sit down on the bakelite ridge around the wafer and the wires hold them firmly in place.

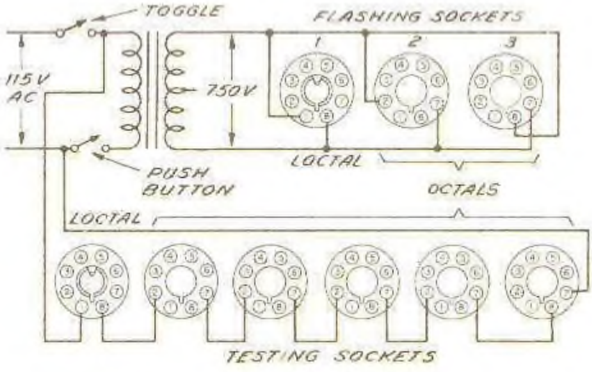
If 1R5 tubes are comparatively plentiful and 1A7's are impossible to secure, an adapter can be made easily and quickly as follows.

Select an 8 pin octal base with metal band. With the pliers remove the metal, leaving the bottom wafer and pins. Cut 5 pieces of No. 18 tinned wire 1 1/4 inches long, dropping them down into pins 2, 3, 5, 6, and 7, bending them over enough to avoid their falling through and then solder the ends. Put a piece of spaghetti 3/8 inch long on the wire from pin 6 and bend it flat down on the wafer and across to the pin 3, then straight up. Push the wires through holes in miniature socket lugs as shown in substitution data, bend wires outward and down, then cut off close, clinch with pliers and solder. This makes a rugged adapter with very little danger of shorts. The same procedure is followed in making an adapter to use a 1T4 in place of a 1N5. An 8 pin wafer from the base of a metal tube also makes a good adapter.

Adapters are best soldered by dipping. Melt enough solder in a very small pan or tin can lid over an electric or gas hot plate to just touch the ends of the pins on an octal base when the guide pin is on the bottom. Use a quarter-inch dowel pin or piece of shaft,pushing it down inside the guide pin so that it can be used as a handle. Dip the pins for 3 or 4 seconds then lift it out and dip the ends of the pins in water to cool them quickly. This is very much faster and better than doing it one pin at a time with a soldering iron.

To Repair the Filaments in 150 Ma Tubes
(For Emergency Use Only)

Many 150-ma heater tubes can be made to give additional service after they have been burned out, that is,after the filament is open. The necessary parts are: a power transformer with a 50-ma secondary that will deliver 750 volts across the high-voltage winding, seven octal sockets, two loctal sockets, and a chassis pan with room enough to mount them. The connections are very simple, as illustrated in the diagram of Fig. 4-1, and require less than two hours to assemble.



NOTE
BOTTOM VIEW OF SOCKETS ARE SHOWN

FIG. 4-1. Illustrating the setup for filament repair.

We have found by experience that putting the push button in the primary side of the transformer, in addition to protecting the operator from shocks, causes a hotter starting arc to weld the broken filament. The six sockets connected in series are for testing the repaired tubes. Put enough tubes in series to make as close as possible to 115 volts and short the filament connections on the remaining sockets that are left empty. Number 3 octal socket is for a 12SQ7, 6SQ7, and a few other types which have their heater connections on pins 7 and 8.

The operation is as follows. Insert the line plug, turn on the switch, and place the tube to be repaired in the proper socket. A low-wattage lamp drawing current from the same electric circuit should be in front of the operator. Press the button quickly, making as short a contact as possible. If the lamp dims, you have welded the ends of the heater together. If they are not welded, press the button several more times, while snapping at the tube with the fingers of the other hand. If this does not weld the filaments, allow three seconds to elapse when working with metal tubes and then push the button again. Repeat this, then wait ten seconds and press for the last time. The switch contact should be as short as possible each time.

For 6- and 12-volt glass tubes, the same procedure is employed except that you must observe the tube and continue to press the button at intervals until the filament shows light. For higher voltage tubes such as 50L6, 35L6, 35A5, etc. the button must be held down slightly longer. Success has been obtained in repairing about forty percent of burned out 150-ma heater tubes which include 12SA7, 12SK7, 12SQ7, 50L6, 35Z5, and almost all other 12-, 14-, 35-, and 50-volt heater tubes. The filaments of tubes having current ratings of less than 150 ma will be completely destroyed when burned in this apparatus, and tubes with high current ratings will overload the transformer severely, although in some cases a repair can be made. If the results are not satisfactory, try using a different transformer. Our experience shows, however, that a 750-volt secondary is the most satisfactory.

We have had many inquiries about the low-wattage lamp mentioned above. This lamp should be not larger than 40 watts and does not have to be connected to the apparatus. It may be the light in the shop where you are working and serves only to show you when the current has welded the ends of the broken filament in a metal tube. When the high voltage passes through the filament, there is a surge of current lasting only a very small fraction of a second. The transformer draws a rather large amount of current from the electric light line, pulling the voltage down and causing the light to blink or flicker. It is not needed in the case of glass tubes since you are able to see when the filament lights.

The average life of repaired tubes is short. We describe this process for use only in case of emergency and in no case recommend the use of a repaired tube when a new one is available. Even when the tube is not available, a repaired tube should be burned for at least one hour before putting it in a customers radio.

35Z5 Tubes

Possibly most service men know this, but it will bear repeating for the benefit of those who do not. The 35Z5 filament is between pins 2 and 7 with a tap brought out to pin 3. This tap is about 5 volts, from pins 2 to 3 and provides current for the pilot light. Operating the radio with burned out pilot light causes this section to burn out and breaks the filament circuit. Pins 2 and 3 may be shorted together so as to use the remaining 30-volt filament and the tube may still give long service. Check every burned out 35Z5, and if there is continuity between pins 3 and 7, the tube is still usable.

If it is necessary to use the pilot light, connect a 25- to 30-ohm resistor from pins 3 to 2, either on the tube base (be careful that it does not short to metal chassis) or on the socket terminals, and the pilot light will light as usual.

Substitution of Complete Sets of Tubes

Most of the popular 12-, 35-, and 50-volt tubes now in use are nearing the end of their lives. Often a customer comes in and pays for a substitute tube and the necessary rewiring job, only to be back again within a week or ten days with another "impossible to get" tube burned out. He may again go to considerable expense to replace that one and have the same thing happen again.

Since most of the 6- and 25-volt, 0.3-ampere tubes are comparatively plentiful, a complete changeover job is more practical and satisfactory. Replace 12SA7 with 6SA7, 12SK7 with 6SK7, 12SQ7 with 6SQ7, 50L6 or 35L6 or any of the other 25-volt, 0.3-ampere output tubes, and 25Z5 with 25Z6. The only necessary changes are in connection with the rectifier tube and replacement of the a-c line cord with a line resistor cord of 130 ohms. Red goes to the switch and black to pins 3 and 5 of the 35Z5 socket after removing the pilot light wire from pin 3. Any wire on pin 4 is removed and taped up, 4 is connected to 8, the line cord resistor and a 25-ohm resistor are connected to the wire from pin 3 and the other end of resistor to pin 2.

Changing Battery-Operated Radios For Electric Operation

This is not a job for the novice, but any experienced radio serviceman can make the change with very satisfactory results if there is room on the chassis for an additional tube.

First find a location for the rectifier tube, drill a hole and mount the socket. Remove all battery wires. Connect one side of the line cord to pins 2, 3, and 5 of a 117Z6 socket; connect the other side of the cord to the A battery switch, ground the other side of the switch and also pin 7 of the 117Z6.

From pins 4 and 8, the cathodes of the rectifier, connect a 1-w, 1,500-ohm resistor, R1, to the screen grid of the 3Q5 tube or whatever output tube is used. This is the filter resistor and must have a 20-mf, 150-volt capacitor, C1, from each end of the resistor to ground for 60-cycle operation, or 40 mf for 25-cycle operation.

It is quite likely that you will find one end of each tube filament connected to ground. All of these grounds must be removed and the filaments connected in series as shown in Fig. 4-2. The tubes indicated are for a typical battery-operated receiver. The capacitors and resistors connected to pins 2 and 7 may be left where they are, at least for the present. (We are using pin numbers of octal tubes. If the loctal series is used, the filament pins are usually 1 and 8 instead of 2 and 7. The loctal 1LA6 or 1LC6 is the equivalent of the octal 1A7, the loctal 1LN5 or 1LH4 for the octal 1H5, and the loctal 1LA4 or 1LB4 for the octal 1A5 or 1T5.) If there are more tubes than are shown in the diagram, connect their filaments between the 1N5 and the 1H5.

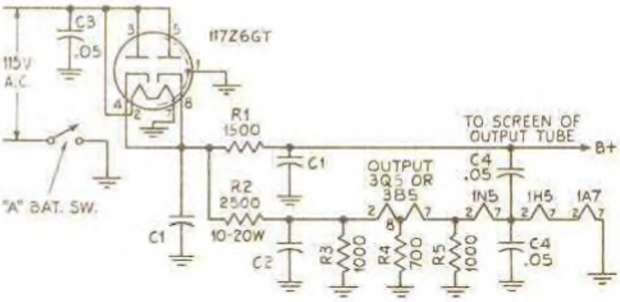


FIG. 4-2. Typical circuit arrangement for changing battery-operated radio to electric operation using a 117Z6GT rectifier tube.

Connect a 2,500-ohm resistor between the rectifier cathodes and one side of the filament of the output tube. This is the filament dropping resistor and has a filter capacitor of from 40 to 200 mf connected between its low end and ground. This capacitor should be rated at 25 volts because if a tube burns out the voltage rises and might break down a 6- or 12-volt rated capacitor. The filament dropping resistor should be 10 watts if mounted above the chassis and at least 20 watts if mounted underneath where it cannot radiate the heat so readily. There is a 2,200-ohm, 16-w flexible resistor, that seems to be quite plentiful, rather low priced, and is very easy to mount since it is insulated.

Wire in the resistors R4 and R5 permanently, and R3 temporarily as it may have to be changed. If a 1A5 or 1T5 is used instead of the 3Q5 or 3B5, resistor R4 is omitted. The purpose of R4 and R5 is to bypass the current passed from plate to filament in the output tube and to avoid overloading the other filaments.

Now check the grid resistors. The resistor from the grid of the output tube should go directly to ground and each of the others to its own negative filament, pin 7. The lower end of the volume control is connected either directly or through a resistor to ground, or to a filament (which has been disconnected from ground). Leave it where it is for trial; however, if there is distortion, try returning it to the filament circuit between the 1A7 and 1H5 for 1.4-volt bias, or between the 1H5 and 1N5 for 2.8-volt bias, leaving it wherever the tone is best.

Now make up a resistor to take the place of a set of tubes. The resistance of each 1.4-volt filament is approximately 28 ohms, and for the set shown in Fig. 4-2 should be a total of 140 ohms. If it had a 1A5 or 1T5 in the output, the resistance would be 28 ohms less, or 112 ohms. If there should be an additional 1.4-volt tube, it would be 28 ohms more, or 168 ohms. Connect this resistor from pin 2 of the output tube to ground. Put in the rectifier tube, connect the line cord of the set and then turn it on. The voltage across the resistor should be slightly less than 7 volts. If over 7 volts, replace resistor R3 with a lower value. If under 6.2 volts, replace R3 with a higher value. If you have difficulty in getting the correct filament voltage, remember that increasing the capacitance of C1 at the rectifier increases the voltage, and if this capacitor does not have sufficient capacitance you cannot get the correct voltage.

When the voltage has been adjusted, remove resistor R3 and then insert the tubes. The bypass capacitor C4 may already be in the set. If the capacitors are not in and there is a tendency to distort or oscillate, put them in, and make sure that all No. 1 pins of the tubes are grounded to chassis. If the radio does not have a series capacitor in the antenna, it is necessary to put in a 0.01 mf between the antenna and coil to avoid burning out the coil if the antenna should be grounded.

Many other types of rectifiers may be used instead of the 117Z6 which was chosen as the example because it does not require a resistor line cord. For 25Z6, use a line-cord resistor of 300 ohms, connecting red to switch, black to pins 3 and 5, and resistor to pin 2; for 35Z5 and 35Z4 tubes, use a 540-ohm resistor cord, connecting black to pin 5, red to switch, and resistor to pin 2; for a 25Z5 tube, use a 300-ohm cord, connecting red to switch, black to pins 2 and 5, resistor to pin 1, pin 6 to ground, and the filter resistor to pins 3 and 4. These are the most popular rectifiers, but several others may be used with the proper line-cord resistor.

The grounding system and physical factors of the receiver to be worked on should be examined before attempting the changeover. Some bugs may be expected on the first job so do not be discouraged if it does not work perfectly right at first; a little patience in trying to get rid of the bugs will be well rewarded. Remember that the filaments of tubes in most battery-operated radios are only d-c operated. Always check the filament conditions of the tubes with which you are working.

BALLAST TUBE AND RESISTOR NUMBERING CODES

FOR AC-DC RECEIVERS USING 0.3 AMP. SERIES CONNECTED HEATERS

There are two numbering codes now in use for ballast and resistor tubes. Both codes use parts of the type designation to indicate the various divisions of the tube's service. For example, type numbers in the first system (A) might be BKX51DJ or L55B and, in the second system (B), might be 200R44 or 200R. These letter and number combinations are explained by the following examples.

SYSTEM A

BKY49CJG

The letter G, if present, indicates that the tube has a glass bulb and octal base.

The letter J, if present, indicates that a jumper is located between pins 3 and 4.

Letters A to K here indicate the internal circuit connections. *(See adjacent figures.)*

This number gives the voltage drop with 0.3 ampere. *(See Note 4.)*

The letters X, Y, or Z, if present, indicate the style of base and the pin connections. *(See Note 3.)*

The letters K, L, or M indicate the type of pilot lamp that must be used with this tube. *(See Note 2.)*

The letter B, when present, indicates that the pilot-lamp shunt-resistor is a ballast type. *(See Note 1.)*

NOTE 1.

"Ballast" action indicates that the pilot lamp shunt resistor has low starting resistance when cold, protecting the lamp filament from the initial current surge, and has much higher resistance when hot, applying full operating voltage to the lamp.

NOTE 2.

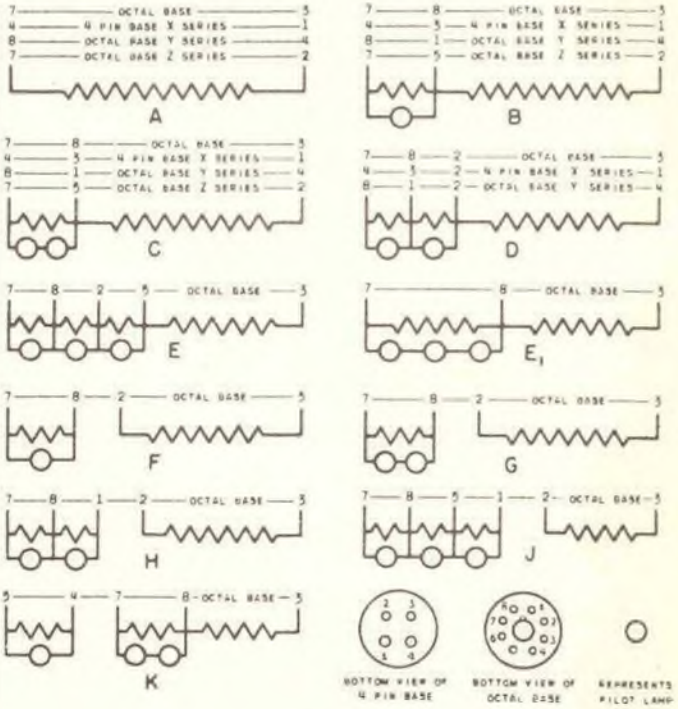
Tube Letter	Lamp No.	Volts	Amperes	Bead Color
K	40 and 47	6.3	0.15	Brown
L	44 and 46	6.3	0.25	Blue
M	50 and 51	7.5	0.2	White

NOTE 3.

X denotes a 4 pin base and metal shell. Y or Z denote octal bases but with different pin connections. *(See Figures A to K.)*

NOTE 4.

This number includes the drop in the series resistor plus the drop in the pilot lamp and its shunt. The number represents the difference between the sum of the heater voltages and the line voltage of 117.5 volts. Tubes are made with the following numbers: 98, 92, 86, 80, 73, 67, 61, 55, 49, 42, 36, 30, 23, 17, 11. The number to be used is the one closest to the voltage difference mentioned above.



SYSTEM B

All tubes under System B have glass bulbs and 4 pin bases and their type designations start with a number.

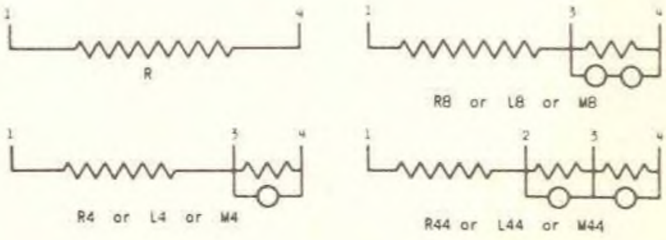
EXAMPLE

200R44

The numbers 4, 8, or 44, in combination with the preceding letter, indicate the internal tube connections. *(See below.)*

The letters R, L, or M, when followed by a number, indicate the type of pilot lamp which must be used with this tube. See Note 2, using the letter R in place of K. (The letter R, alone, indicates only a form of internal tube connection without pilot lamp.)

This number indicates the equivalent resistance in ohms at 0.3 ampere. Thus, 200 × 0.3 = 60 volts drop.

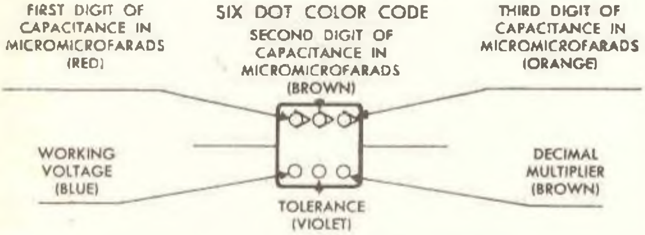


Courtesy TUNG-SOL Lamp Works, Inc.

RTMA CAPACITOR, RESISTOR, AND TRANSFORMER COLOR CODES

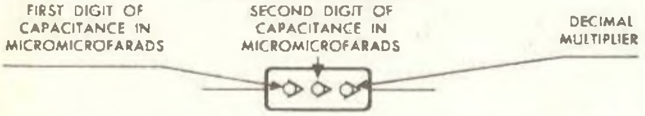
CAPACITOR COLOR CODE

SIX DOT COLOR CODE



EXAMPLE: 2130 μμf. ±7%, 600 W.V. (Values for color shown in the above parenthesis)

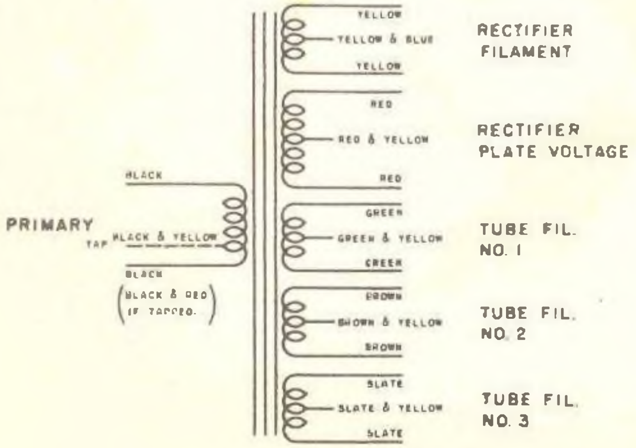
THREE DOT COLOR CODE



COLOR	DIGIT NUMERAL	DECIMAL MULTIPLIER	TOLERANCE	WORKING VOLTAGE
BLACK	0	1	20%	—
BROWN	1	10	1%	100
RED	2	100	2%	200
ORANGE	3	1000	3%	300
YELLOW	4	10000	4%	400
GREEN	5	—	5%	500
BLUE	6	—	6%	600
VIOLET	7	—	7%	700
GRAY	8	—	8%	800
WHITE	9	—	9%	900
GOLD	–	0.1	–	1000
SILVER	–	0.01	10%	—

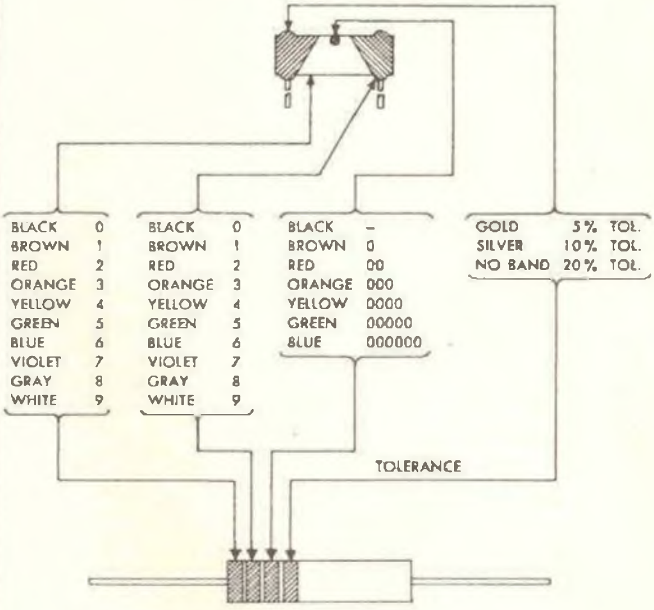
POWER TRANSFORMER LEAD COLOR CODE

Power transformer leads in radio receivers may be identified by the following colors (or color patterns) on the lead coverings.



Courtesy TUNG-SOL Lamp Works, Inc.

RESISTOR COLOR CODE



BLACK	0	BLACK	0	BLACK	–	GOLD	5% TOL.
BROWN	1	BROWN	1	BROWN	0	SILVER	10% TOL.
RED	2	RED	2	RED	00	NO BAND	20% TOL.
ORANGE	3	ORANGE	3	ORANGE	000		
YELLOW	4	YELLOW	4	YELLOW	0000		
GREEN	5	GREEN	5	GREEN	00000		
BLUE	6	BLUE	6	BLUE	000000		
VIOLET	7	VIOLET	7				
GRAY	8	GRAY	8				
WHITE	9	WHITE	9				

RESISTANCE VALUE: The nominal resistance value in ohms is identified by a three digit symbol. The first two digits are the first two figures of the resistance value in ohms. The third digit specifies the number of zeros which follow the first two figures.

I-F TRANSFORMER LEAD COLOR CODE

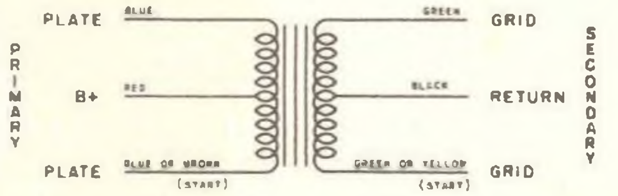
I-F transformer leads in radio receivers may be identified by the following colors on the lead coverings.

PLATE LEAD	BLUE	GRID (or diode lead)	GREEN
B+ LEAD	RED	GRID RETURN	BLACK

FOR "FULL-WAVE" TRANSFORMER SECOND DIODE LEAD WILL BE GREEN-BLACK.

AUDIO TRANSFORMER LEAD COLOR CODE

Interstage and Output Audio Transformer leads in radio receivers may be identified by the colors on the lead coverings as shown.



In cases where use is made of a single primary and/or a single secondary, the upper half of the diagram indicates the color coding. The brown and yellow leads indicate the start of the primary and secondary windings respectively and will be used in place of the blue and green (as shown) where polarity indications are required.

PILOT LAMP TABLE

Lamp No.	Volts	Amperes	Bead Color	Miniature Base	Bulb Type
40	6-8	0.15	Brown	Screw	T-3 1/4
41	2.5	0.50	White	Screw	T-3 1/4
42	3.2	0.35	Green	Screw	T-3 1/4
43	2.5	0.50	White	Bayonet	T-3 1/4
44	6-8	0.25	Blue	Bayonet	T-3 1/4
45	3.2	0.35	White	Bayonet	T-3 1/4
46	6-8	0.25	Blue	Screw	T-3 1/4
47	6-8	0.15	Brown	Bayonet	T-3 1/4
48	2.0	0.06	Pink	Screw	T-3 1/4
49	2.0	0.06	Pink	Bayonet	T-3 1/4
50	6-8	0.20	White	Screw	G-3 1/2
51	6-8	0.20	White	Bayonet	G-3 1/2
55	6-8	0.40	White	Bayonet	G-4 1/2
292	2.9	0.17	White	Screw	T-3 1/4
292A	2.9	0.17	White	Bayonet	T-3 1/4
1455	18.0	0.25	Brown	Screw	G-5
1455A	18.0	0.25	Brown	Bayonet	G-5
1490	3.2	0.16	- - -	Bayonet	T-3 1/4

GERMANIUM CRYSTAL DIODE CHARACTERISTICS

Germanium Crystal	Min. Forward Current at +1v (Ma)	Max. Reverse Current (Microamp.)	Peak Inverse Voltage (Volts)	Average Anode Rect. Current (Ma)	Peak Anode Rect. Current (Ma)
1N34 1N34A	5.0	50 at -10v 800 at -50v	75	40	150
1N35*	7.5	10 at -3v	75	22.5	60
1N38 1N38A	3.0	6 at -3v 625 at -100v	120	40	150
1N39	3.0	200 at -100v 800 at -200v	225	40	150
1N40**	12.75 (at 1.5 volts)	50 at -10v	75	22.5	60
1N41**	12.75 (at 1.5 volts)	50 at -10v	75	22.5	60
1N42**	12.75 (at 1.5 volts)	6 at -3v 625 at -100v	120	22.5	60
1N48	4.0	833 at -50v	85	50	150
1N51	2.5	1670 at -50v	50	25	100
1N52	4.0	150 at -50v	85	50	150
1N54 1N54A	5.0	10 at -10v	75	40	150
1N55 1N55A	3.0	300 at -100v 800 at -150v	170	40	150
1N56 1N56A	15.0	300 at -30v	50	50	200
1N57	4.0	500 at -75v	90	40	150
1N58 1N58A	4.0	800 at -100v	115	40	150
1N60†	†	†	70	40	150
1N63	4.0	50 at -50v	125	50	150
1N64	Tested for efficiency in 44 Mc video detector circuit.				
1N65	2.5	250 at -50v	85	50	150
1N69‡	5.0	850 at -50v	75	40	125
1N70*	3.0	410 at -50v	125	30	90
1N71††	15.0	300 at -30v	50	50	200

NOTE: Crystals 1N48, 1N51, 1N52, 1N63, 1N64, and 1N65 are General Electric types, all others are Sylvania types unless otherwise indicated.

* Units are matched in the forward direction at +1 volt so that the current flowing through the higher resistance unit is within 10% of that in the lower resistance unit. Ratings shown are for each diode.

**Consists of 4 specially selected and matched germanium diodes whose resistances are balanced within ± 2.5% in the forward direction at 1.5 volts. For additional balance, the forward resistance of each pair of varistor crystals are matched within 3 ohms. Ratings shown above are for each diode.

† Units are tested in a circuit employing an input of 1.8 volts rms at 40 mc. 70% modulated at 400 cycles. Demodulated output across a 4700 ohm resistor shunted by a 5 mmf capacitor is a minimum of 1.1 volts peak to peak.

‡ JAN types

††Consists of four matched low impedance germanium diodes each of which, with a voltage of one volt impressed in the forward direction, will pass a current within one ma of the average current of the four. Ratings shown above are for each diode.