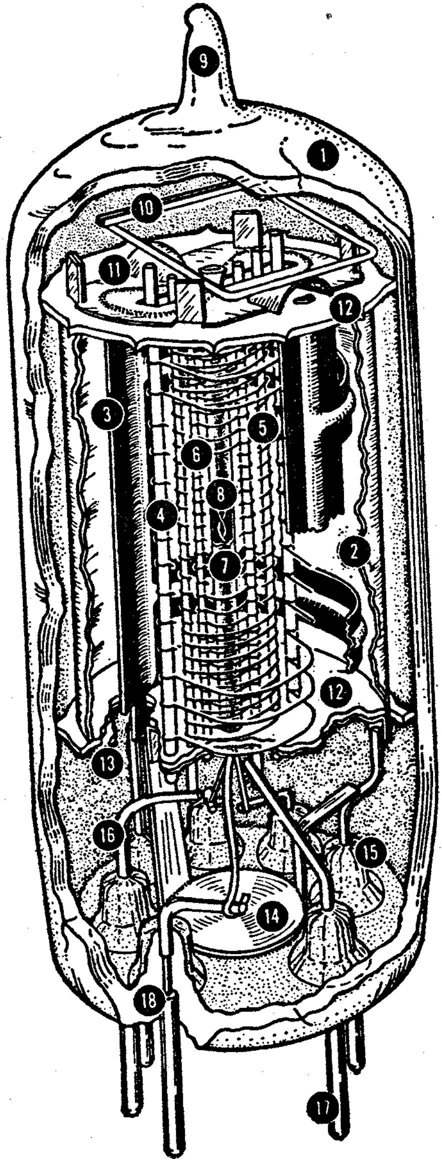


1—Glass Envelope
2—Internal Shield
3—Plate
4—Grid No. 3 (Suppressor)
5—Grid No. 2 (Screen)
6—Grid No. 1 (Control Grid)
7—Cathode
8—Heater
9—Exhaust Tip
10—Getter
11—Spacer Shield Header
12—Insulating Spacer
13—Spacer Shield
14—Inter-Pin Shield
15—Glass Button-Stem Seal
16—Lead Wire
17—Base Pin
18—Glass-to-Metal Seal

Structure of a Miniature Tube

Electron Tube Testing

THE electron-tube user-service man, experimenter, or non-technical radio listener—is interested in knowing the condition of his tubes, since they govern the performance of the device in which they are used. In order to determine the condition of a tube, some method of test is necessary. Because the operating capabilities and design features of a tube are indicated and described by its electrical characteristics, a tube is tested by measuring its characteristics and comparing them with values established as standard for that type. Tubes which read abnormally high with respect to the standard for the type are subject to criticism just the same as tubes which are too low.

Certain practical limitations are placed on the accuracy with which a tube test can be correlated with actual tube performance. These limitations make it impractical for the service man and dealer to employ complex and costly testing equipment having laboratory accuracy. Because the accuracy of the tube-testing device need be no greater than the accuracy of the correlation between test results and receiver performance, and since certain fundamental characteristics are virtually fixed by the manufacturing technique of leading tube manufacturers, it is possible to employ a relatively simple test in order to determine the serviceability of a tube.

In view of these factors, dealers and service men will find it economically expedient to obtain adequate accuracy and simplicity of operation by employing a device which indicates the status of a single characteristic. Whether the tube is satisfactory or unsatisfactory is judged from the test result of this single characteristic. Consequently, it is very desirable that the characteristic selected for the test be one which is truly representative of the tube's over-all condition.

The following information and circuits are given to describe and illustrate general theoretical and practical tube-tester considerations and not to provide information on the construction of a home-made tube tester. In addition to the problem of determining what tube characteristic is most representative of performance capabilities in all types of receivers, the designer of a home-made tester faces the difficult problem of determining satisfactory limits for his particular tester. Getting information of this nature, if it is to be accurate and useful, is a big job. It requires the testing of many tubes of each type, testing of many types, and correlation of the data with performance in many kinds of equipment.

Short-Circuit Test

The fundamental circuit of a short-circuit tester is shown in Fig. 106. Although this circuit is suitable for tet-

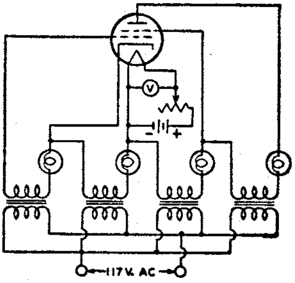


Fig. 106—Fundamental circuit of a short-circuit tester.

rodes and types having less than four electrodes, tubes of more electrodes may be tested by adding more indicator lamps to the circuit. Voltages are applied between the various electrodes with lamps in series with the electrode leads. The value of the voltages applied will depend on the type of tube being tested and its maximum ratings. Any two shorted electrodes complete a circuit and light one or more lamps. Since two electrodes may be just touching to give a high-resistance short, it is desirable that the indicating lamps operate on very low current. It is also desirable to maintain the filament or heater of the tube at its operating temperature during the short-circuit test, because short-circuits in a tube may sometimes occur only when the electrodes are heated. However, a short-circuit tester having too high a sensitivity may indicate very-high-resistance shorts that do not adversely affect tube operation.

Selection of a Suitable Characteristic for Test

Some characteristics of a tube are far more important in determining its operating worth than are others. The cost of building a device to measure any one of the more important characteristics may be considerably higher than that of a device which measures a less representative characteristic. Consequently, three methods of test will be discussed, ranging from relatively simple and inexpensive equipment to more elaborate, more accurate, and more costly devices.

An **emission test** is perhaps the simplest method of indicating a tube's condition. (Refer to *Diodes,* in **Electrons, Electrodes, and Electron Tubes** section, for a discussion of electron emission.) Since emission falls off as the tube wears out, low emission is indicative of the end of tube serviceability. However, the emission test is subject to limitations because it tests the tube under static conditions and does not take into account the actual operation of the tube. On the one hand, coated filaments, or cathodes, often develop active spots from which the emission is so great that the relatively small grid area adjacent to these spots cannot control the electron stream. Under these conditions, the total emission may indicate the tube to be normal although the tube is unsatisfactory. On the other hand, coated types of filaments are capable of such large emission that the tube will often operate satisfactorily after the emission has fallen far below the original value.

Fig. 107 shows the fundamental circuit diagram for an emission test. All of the electrodes of the tube, except the cathode, are connected to the plate. The filament, or heater, is operated at rated voltage; after the tube has reached constant temperature, a low positive voltage is applied to the plate and the electron emission is read on the meter. Readings which are well below the average for a particular tube type indicate that the total number of available electrons has been so reduced that the tube is no longer able to function properly.

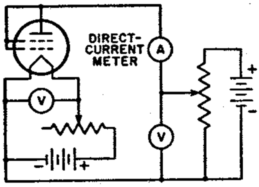


Fig. 107—Fundamental circuit of an emission tester

A **transconductance test** takes into account a fundamental operating principle of the tube. (This fact will be seen from the definition of transconductance in the Section on **Electron Tube Characteristics.**) It follows that transconductance tests, when properly made, permit better correlation between test results and actual performance than does a straight emission test.

There are two forms of transconductance test which can be utilized in a tube tester. In the first form (illustrated by **Fig. 108** giving a fundamental circuit with a tetrode under test), appropriate operating voltages are applied to the electrodes of the tube. A plate current depending upon the electrode voltages will then be indicated by the meter. If the bias on the grid is then shifted by the application of a different grid voltage, a new plate-current reading is obtained. The difference between the two plate-current readings is indicative of the transconductance of the tube. This method of transconductance testing is commonly called the "grid-shift" method, and depends on readings under static conditions. The fact that this form of test is made under static conditions imposes limitations not encountered in the second form of test made under dynamic conditions.

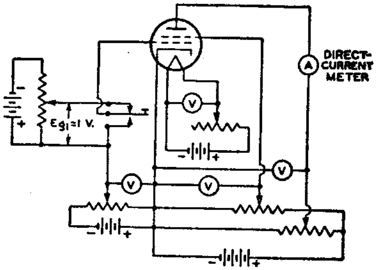


Fig. 108—Fundamental circuit of a transconductance tester using the "grid-shift" method.

The dynamic transconductance test illustrated in Fig. 109 gives a fundamental circuit with a tetrode under test. This method is superior to the static transconductance test in that ac voltage is applied to the grid. Thus, the tube is tested under conditions which approximate actual operating conditions. The alternating component of the plate current is read by means of an ac ammeter of the dynamometer type. The transconductance of the tube is equal to the ac plate current divided by the input-signal voltage. If a one-volt rms signal is applied to the grid, the plate-current-meter reading in milliamperes multiplied by one thousand is the value of transconductance in micromhos.

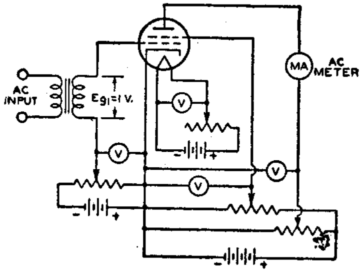


Fig. 109—Fundamental circuit of a dynamic transconductance tester.

The **power-output test** probably gives the best correlation between test results and actual operating performance of a tube. In the case of voltage amplifiers, the power output is indicative of the amplification and output voltages obtainable from the tube. In the case of power-output tubes, the performance of the tube is closely checked. Consequently, although more complicated to set up, the power-output test will give closer correlation with actual performance than any other single test.

Fig. 110 shows the fundamental circuit of a power-output test for class A operation of tubes. The diagram illustrates the method for a pentode. The ac output voltage developed across the plate-load impedance (L) is indicated by the current meter. The current meter is isolated as far as the dc plate current is concerned by the capacitor (C). The power output can be calculated from the current reading and known load resistance. In this way, it is possible to determine the operating condition of the tube quite accurately.

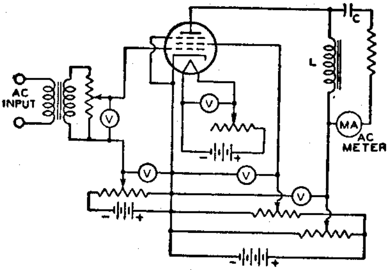


Fig. 110—Fundamental circuit of a power-output tester for class A operation of tubes.

Fig. 111 shows the fundamental circuit of a power-output test for class B operation of tubes. With ac voltage applied to the grid of the tube, the current in the plate circuit is read on a dc milliammeter. The power output of the tube is approximately equal to:

$$(I_b^2 \times R_L)/0.405,$$

where P_o is the power output in watts, I_b is the dc current in amperes, and R_L is the load resistance in ohms.

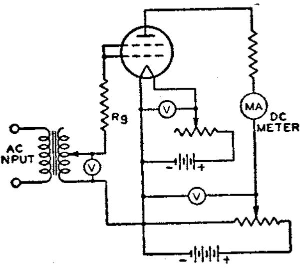


Fig. 111—Fundamental circuit of a power-output tester for class B operation of tubes.

Essential Tube-Tester Requirements

1. The tester should provide for making a short-circuit test before measurement of the tube's characteristics.
2. It is important that some means of controlling the voltages applied to the electrodes of the tube be provided. If the tester is ac operated, a line-voltage control permits the supply of proper electrode voltages.
3. It is essential that the rated voltage applied to the filament or heater be maintained accurately.
4. It is suggested that the characteristics test follow one of the methods described. The method selected and the quality of the parts used in the test will depend upon the user's requirements.

Tube-Tester Limitations

A tube-testing device can only indicate the difference between a given tube's characteristics and those which are standard for that particular type. Since the operating conditions imposed upon a tube of a given type may vary within wide limits, it is impossible for a tube-testing device to evaluate tubes in terms of performance capabilities for all applications. The tube tester, therefore, cannot be looked upon as a final authority in determining whether or not a tube is always satisfactory. Actual operating test in the equipment in which the tube is to be used will give the best possible indication of a tube's worth.

Resistance-Coupled Amplifiers

RESISTANCE-COUPLED, audio-frequency voltage amplifiers utilize simple components and are capable of providing essentially uniform amplification over a relatively wide frequency range.

Suitable Tubes

In this section, data are given for over 45 types of tubes suitable for use in resistance-coupled circuits. These types include low- and high-mu triodes, twin triodes, triode-connected pentodes, and pentodes. The accompanying key to tube types will assist in locating the appropriate data chart.

Circuit Advantages

For most of the types shown, the data pertain to operation with cathode bias; for all of the pentodes, the data pertain to operation with series screen-grid resistor. The use of a cathode-bias resistor where feasible and a series screen-grid resistor where applicable offers several advantages over fixed-voltage operation.

The advantages are: (1) effects of possible tube differences are minimized; (2) operation over a wide range of plate-supply voltages without appreciable change in gain is feasible; (3) the low frequency at which the amplifier cuts off is easily changed; and (4) tendency toward motorboating is minimized.

Number of Stages

These advantages can be enhanced by the addition of suitable decoupling filters in the plate supply of each stage of a multi-stage amplifier. With proper filters, three or more amplifier stages can be operated from a single power-supply unit of conventional design with-

Type	Chart No.	Type	Chart No.
3AU6	2	6CG7	8
3AV6	9	6CN7	5
3BC5	11	6EU7	9
3CB6	10	6FQ7	8
3CF6	11	6SL7GT	5
4AU6	2	6SN7GTB	8
4BQ7A	10	6T8A	5
4BZ7	10	7AU7	3
4CB6	11	8CG7	8
5BK7A	10	12AT6	5
5BQ7A	10	12AT7	4
5T8	5	12AU6	2
6AB4	4	12AU7A	3
6AG5	11	12AV6	9
6AT6	5	12AX7A	9
6AU6A	2	12AY7	1
6AV6	9	12SL7GT	5
6BC5	11	12SN7GTA	8
6BK7B	10	20EZ7	9
6BQ7A	10	5879P	6
6BZ7	10	5879T	7
6C4	3	7025	9
6CB6	11	7199P	12
6CB6A	11	7199T	13
6CF6	11		

T = Triode Unit or Triode Connection
P = Pentode Unit or Pentode Connection

KEY TO CHARTS

out encountering any difficulties due to coupling through the power unit. When decoupling filters are not used, not more than two stages should be operated from a single power-supply unit.

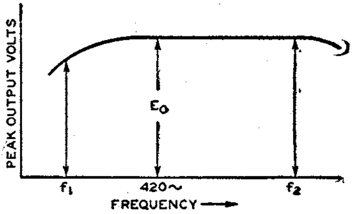
Symbols Used in Resistance-Coupled Amplifier Charts

C = Blocking Capacitor (μf).
C_k = Cathode Bypass Capacitor (μf).
C_{g2} = Screen-Grid Bypass Capacitor (μf).
E_{bb} = Plate-Supply Voltage (volts). Voltage at plate equals plate-supply voltage minus drop in R_p and R_k.
R_k = Cathode Resistor (ohms).
R_{g2} = Screen-Grid Resistor (megohms).
R_g = Grid Resistor (megohms) for following stage.
R_p = Plate Resistor (megohms).
V.G. = Voltage Gain.
E_o = Output Voltage (peak volts). This voltage is obtained across R_g (for following stage) at any frequency within the flat region of the output vs. frequency curve, and is for the condition where the signal level is adequate to swing the grid of the resistance-coupled amplifier tube to the point where its grid starts to draw current.

Note: The listed values for E_o are the peak output voltages available when the grid is driven from a low-impedance source. The listed values for the cathode resistors are optimum for any signal source. With a high-impedance source, protection against severe distortion and loss of gain due to input loading may be obtained by the use of a coupling capacitor connected directly to the input grid and a high-value resistor connected between the grid and ground.

General Circuit Considerations

In the discussions which follow, the frequency (f_2) is that value at which the high-frequency response begins to fall off. The frequency (f_1) is that value at which the low-frequency response drops below a satisfactory value, as discussed below. A variation of 10 per cent in values of resistors and capacitors has only slight effect on performance. One-half-watt resistors are usually suitable for R_{g2}, R_g, R_p, and R_k resistors. Capacitors C and C_{g2} should have a working voltage equal to or greater than E_{bb}. Capacitor C_k may have a low working voltage in the order of 10 to 25 volts.



Triode Amplifier

Heater-Cathode Type

Capacitors C and C_k have been chosen to give an output voltage equal to 0.8 E_o for a frequency (f_1) of 100 cycles. For any other value of f_1, multiply values of C and C_k by 100/f_1. In the case of capacitor C_k, the values shown in the charts are for an amplifier with dc heater excitation; when ac is used, depending on the character of the associated circuit, the gain, and the value of f_1, it may be necessary to increase the value of C_k to minimize hum disturbances. It may be desirable to operate the heater at a positive voltage of from 15 to 40 volts with respect to the cathode. The voltage output at f_1 of "n" like stages equals $(0.8)^n \times E_o$, where E_o is the peak output voltage of final stage. For an amplifier of typical construction, the value of f_2 is well above the audio-frequency range for any value of R_p.

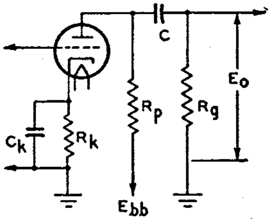


Diagram No. 1

Pentode Amplifier

Heater-Cathode Type

Capacitors C, C_k, and C_{g2} have been chosen to give an output voltage equal to 0.7 × E_o for a frequency (f_1) of 100 cycles. For any other value of f_1, multiply values of C, C_k, and C_{g2} by $100/f_1$. In the case of capacitor C_k, the values shown in the charts are for an amplifier with dc heater excitation; when ac is used, depending on the character of the associated circuits, the voltage gain, and the value of f_1, it may be necessary to increase the value of C_k to minimize hum disturbances. It may be desirable to operate the heater at a positive voltage of from 15 to 40 volts with respect to the cathode. The voltage output at f_1 for "n" like stages equals $(0.7)^n \times E_o$ where E_o is peak output voltage of final stage. For an amplifier of typical construction, and for R_p values of 0.1, 0.25, and 0.5 megohm, approximate values of f_2 are 20000, 10000, and 5000 cycles per second, respectively.

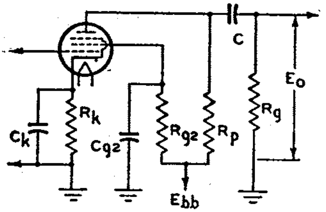


Diagram No. 2

①

12AY7•

See Circuit Diagram 1

Volts	Megohms	Megohms	Megohms	Ohms	μF	μF	μF	Peak volts	Voltage Gain
E_{bb}	R_p	R_g	R_{g2}	R_k	C_{g2}	C_k	C	E_o*	V.G.
90	0.1	0.24	—	1800	—	—	—	13	24
	0.24	0.51	—	3700	—	—	—	14	26
	0.51	1.0	—	7800	—	—	—	16	27
180	0.1	0.24	—	1300	—	—	—	31	27
	0.24	0.51	—	2800	—	—	—	33	29
	0.51	1.0	—	5700	—	—	—	33	30
300	0.1	0.24	—	1200	—	—	—	58	28
	0.24	0.51	—	2300	—	—	—	30	30
	0.51	1.0	—	4800	—	—	—	56	31

• One triode unit. * Peak volts.

▲ Coupling capacitors should be selected to give desired frequency response. Cathode resistors should be adequately bypassed.