62 IRE 7.S1

IRE STANDARDS ON ELECTRON TUBES
METHODS OF TESTING
1962

The Institute of Radio Engineers, Inc.
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* Approved by the IRE Standards Committee, May 11, 1961

Preface

The word *standard*, as used in this document, means that the definition, method of measurement or test has been investigated carefully and endorsed by the IRE Standards Committee and the IRE Electron Tubes Committee. The methods of measurement are recommended practices, which, with reasonable care, will permit objective measurements of performance.

This "IRE Standards on Electron Tubes: Methods of Testing, 1962" supersedes "Standards on Electron Tubes: Methods of Testing, 1950, Parts I and II (50 IRE 7.S2)."

This Standard combines the material published in the above Standard together with many revisions and new headings, in addition to a number of definitions which do not appear in "IRE Standards on Electron Tubes: Definitions of Terms, 1957 (57 IRE 7.S2)."

The IRE Electron Tubes Committee would appreciate hearing from users of this document relative to criticisms and suggestions for future proposed methods of test.

George A. Espersen, *Chairman*
IRE Electron Tubes Committee

Contents

Part 1

Conventional Receiving Tubes

Subcommittee 7.1

Tubes in Which Transit-Time is Not Essential

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1. INTRODUCTION

This Standard deals with the methods of measurement of the important characteristics of electron tubes. Terms used in this Standard are defined in the "IRE Standards on Electron Tubes: Definitions of Terms, 1957, 57 IRE 7.S2."[1]

1.1 General Precautions

Attention is called to the necessity, especially in tests of low-power apparatus, such as receiving tubes, of eliminating or correcting for errors due to the presence of the measuring instruments in the test circuit. This applies particularly to the currents taken by voltmeters and other shunt-connected apparatus, and to the voltage drops in ammeters and other series-connected apparatus.

Attention is also called to the desirability of keeping the test conditions, such as filament heating, plate potential, and plate current, within the safe limits specified by the manufacturers. If the specified safe limits are exceeded, the characteristics of the electron tube may be permanently altered and subsequent tests vitiated. When particular tests are required to extend somewhat beyond a specified safe limit (see Sections 2.1 and 3), such portions of the test should be made as rapidly as possible and preferably after the conclusion of the tests within the specified safe limit.

1.2 General Test Conditions

Except when the nature of a test calls for varying or abnormal conditions, all tests should be made at the normal rated conditions specified by the manufacturers of the electron tubes. If the manufacturer's rating is not specific, test conditions not specified should be selected in accordance with the best judgment of the tester and should be clearly and fully stated as a part of the test data. In general, measurements should be made after the tube has attained normal operating temperature.

When a filament is rated in both voltage and current, the rated voltage should be employed in tests. When filaments are to be used in series, the rated current may be employed, but this condition of measurement is to be stated as a part of the test data. Direct current should be used for filament heating, except where the normal operating condition is with alternating-current heating, in which case the use of the latter should be stated. When dc heating is employed, the negative filament terminal should be taken as the datum of potential. If the proper filament terminal to be used as the negative one is not indicated by the manufacturer or specified in any recognized standard manner for a given vacuum-tube structure, the terminal used as the negative one should be stated with the test data. When ac heating is employed for a filamentary cathode, the midpoint (*i.e.*, the center tap on the filament-transformer secondary, or the midpoint on a resistor shunting the filament) should be taken as the datum. It should be noted that these ac and dc heating potential datum conditions are not equivalent and should not be expected to give equivalent readings. If substantially equivalent readings are desired for the two cases, the datum of potential for ac heating must be taken at a point where the direct potential is more negative than that of the filament midpoint by an amount numerically equal to one half the root-mean-square value of the filament voltage. In the case of indirectly heated equipotential cathodes, the cathode is taken as the datum of potential. The connection of the cathode in any part of the heater circuit will usually have no effect upon the measured characteristics.

2. FILAMENT OR HEATER CHARACTERISTICS

2.1 Filament or Heater Electrical Characteristics

Readings of filament or heater current and voltage are taken with voltage applied only to the filament or heater terminals. Measurements should be made over a range of filament voltage or current from values too low to give appreciable electron emission in service to

[1] PROC. IRE, vol. 45, pp. 983–1010; July, 1957.

at least the safe maximum voltage or current.[2] The current should be measured when it has reached equilibrium and should be corrected for the current drawn by the voltmeter. Curves should be plotted with values of filament voltage as abscissas and values of filament current and filament power as ordinates.

The resistance of a cold filament or heater is much smaller than its resistance under normal operating conditions. If the filament of a large tube is connected directly to the heating source, excessive filament current may flow and cause damage to the tube or test equipment. Therefore, it may be necessary to limit the filament current to some specified starting value.

2.2 Filament or Heater Heating Characteristic

When tubes are operated with the filaments or heaters in series, it is desirable that the voltage be divided during the heating period as nearly as possible in accordance with the rated operating voltages of the individual filaments or heaters, in order to minimize the likelihood of burning out and to insure minimum heating time of the entire complement. In order to judge the heating characteristic of individual tubes in a series string, the time variation of the filament or heater resistance of each tube should be compared with the average of the entire complement.

Measurements are made in a circuit such as that shown in Fig. 1, and the resulting data are plotted as per cent of rated or final heater resistance against time as in Fig. 2. In Fig. 1 T_1 and T_2 are a variable and a tapped transformer, respectively, having ratings adequate to insure good regulation. Switch S_1 is for energizing the complete circuit, and the combination of switch S_2 and resistor R_m is used to protect the meter A against excessive initial surges, the resistance R_m being made equal to the impedance of the meter A. Protection against short circuits is afforded by the fuse.

The output voltage of T_2 is to be equal to the rated heater voltage of the tube plus the drop through the low-resistance meter A or its equivalent R_m. Readings of current I are taken at known intervals. The percentage of the final resistance attained at the time of any reading will be $100\ V/IR_f$, where R_f is obtained from the final heater voltage at rated heater current.

The curves of Fig. 2 show the percentage of final heater resistance plotted against heating time. Curve A may be considered as average for indirectly heated tubes used in series operation, while curves B and C are for heaters having relatively fast and slow heating characteristics, respectively (when operated in series with tubes having heating characteristics such as A, Fig. 2). It will be noted that a tube such as that having the characteristic B (Fig. 2) will operate with heater temperature above the final value during part of the heating cycle, and the maximum voltage across the heater will exceed the rated value in proportion to the amount by which the curve of per cent of final heater resistance against time differs from the average of that characteristic for all tubes in the circuit. On the other hand, a tube having a characteristic like that of C (Fig. 2) will reach its final temperature more slowly when operated in a series circuit than the average tube, and the heater voltage will never exceed the rated proportional value.

2.2.1 Heater Warmup Time for Series-String Operation: A special test method is used for obtaining heater warmup time for tubes with indirectly heated cathodes for series operation. The method has been established empirically and provides a useful index of comparison for heater performance during warmup in series-string circuits. The circuit for measuring heater warmup time is shown in Fig. 3. The tube to be tested is placed in the circuit cold with switch S open and with E_s and R adjusted to the values shown. Switch S is then closed, and the time t_w is measured from the closing of the switch until the voltmeter V reaches the value V_1. This time t_w is defined as the heater warmup time of the tube.

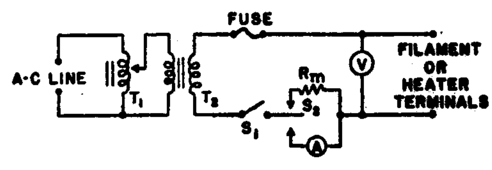

Fig. 1—Circuit arrangement for measuring filament or heater heating characteristic.

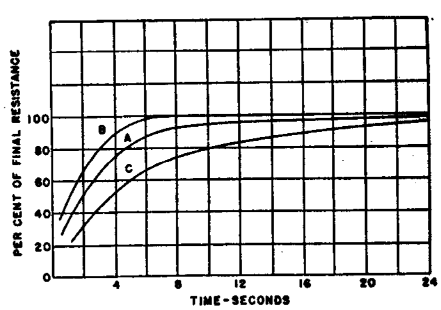

Fig. 2—Curves showing percentage of final heater resistance against heating time.

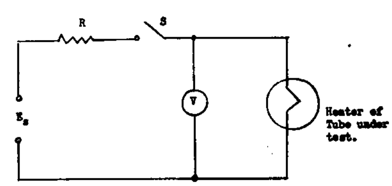

Fig. 3—Circuit for measuring heater warmup time. E_s=applied voltage rms or dc value; R=total series resistance including supply; E_f=rated heater voltage; I_f=rated heater current; V_1=heater test voltage$=5.0\ E_f/6.3$; $E_s=25\ E_f/6.3$; $R=30\ E_f/I_f$.

2.3 Cathode Heating Time

The cathode heating time is arbitrarily taken as the time required for the time rate of change of the cathode current to reach maximum value. All applied voltages are to remain constant during the measurement. The

[2] See Section 1.1, General Precautions.

electrodes must be at room temperature before the test is made.

A sample plot of cathode current aginst time is given in Fig. 4. From this it is seen that the current increases slowly at first, rises increasingly rapidly, and then gradually reaches its final value. The maximum time rate of change of cathode current referred to above corresponds to the point of maximum slope or point of inflection of the curve of Fig. 4. Measurement under this definition may be made by either of two circuits which give comparable results. Method A is sometimes used but the more recent Method B is recommended for new equipment, as it is free of the possibility of difference in saturation effects between different transformers.

2.3.1 Method A: The instantaneous current flowing in the secondary of the step-down transformer of Fig. 5 depends only on the rate of change of the current in the primary and is independent of its final value. Hence, the time of the maximum rate of change will be indicated by the maximum deflection of the meter needle. The speed at which the meter needle moves is indicative of the acceleration and has no bearing on the problem; only the time required for the needle to reach the peak of the swing is of importance.

The characteristics of the output transformer and/or meter should be specified. The meter should have a short period, and the step-down transformer should be selected to give convenient deflections.

2.3.2 Method B: In the circuit arrangement shown in Fig. 6, the meter preferably has a resistance of less than 1000 ohms and the low-leakage capacitor has a capacitance of about 8 μf. The shunting resistor is made variable to keep the indicator of the meter on scale. It is important that the meter used have good damping characteristics. The time is taken from the instant the filament or heater circuit is closed to the instant the capacitor charging current reaches a maximum. The circuit constants and the characteristics of the meter should be specified.

2.4 Cathode Cooling Time

The cooling time can be taken as the time required for the time rate of change in cathode current to reach a maximum after the filament or heater circuit is opened. The circuit given in Fig. 5 is applicable. Alternatively, it may be taken as the time required for the current to reach half its steady value after the heater circuit is opened.

2.5 Operation Time

Operation time in a vacuum tube is defined as the time after simultaneous application of all electrode voltages for an electrode current to reach a stated fraction of its final value. In practice, the final value is taken as the value reached after a specified time interval long enough for a normal tube of the type under test to have reached a substantially stable value. All electrode voltages are to remain constant during the test. The tube elements should be at room temperature at the start of the test.

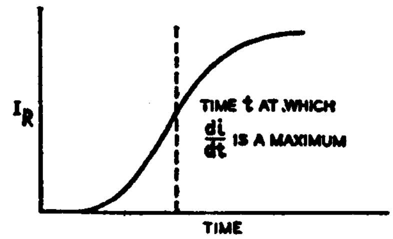

Fig. 4—Relation between cathode current and time

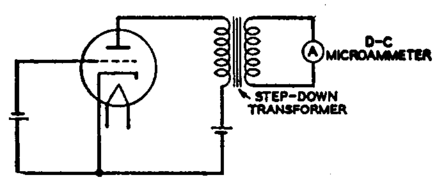

Fig. 5—Circuit arrangement for measuring cathode heating time (Method A).

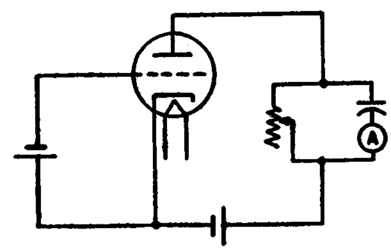

Fig. 6—Circuit arrangement for measuring cathode heating time (Method B).

3. Emission Tests

The emission of a thermionic cathode may be evaluated by measuring the diode characteristic of the tube.

Two regions of the diode characteristic are generally of importance. One is the temperature-limited-emission region in which the emission is limited principally by the temperature of the cathode (region *A* in Fig. 7). The other region of interest is that in which the departure from the law of space-charge-limited current becomes noticeable (region *B* in Fig. 7).

These two regions may be represented quantitatively by two specific emission currents. Region *A* may be represented by the flection-point emission current shown as point *a* in Fig. 7. Region *B* may be represented by the inflection-point emission current shown as point *b* in Fig. 7.

3.1 Measurement of Flection-Point Emission Current

The flection-point emission current, sometimes used as an approximate measure of total emission or temperature-limited emission, is defined as the current at the point on the diode characteristic where the second derivative has its maximum negative value. The value of this current may be obtained with reasonable accuracy from a diode characteristic taken by a suitable

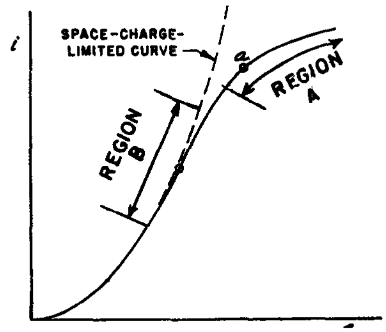

Fig. 7—Typical diode characteristic.

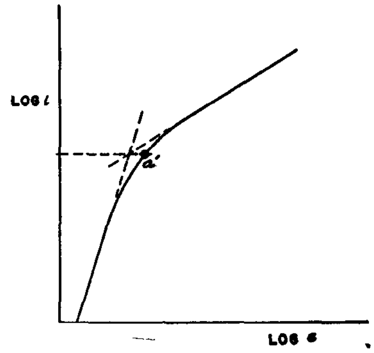

Fig. 8—Determination of flection-point emission current, slope-intersection method.

method, such as one of those described in Section 4.4.

3.1.1 Graphical Methods: An approximation of the flection-point emission current may be obtained from the diode characteristic by two graphical methods.

3.1.2 Slope-Intersection Method: The flection-point emission current is approximately equal to the current corresponding to the intersection of two straight lines representing the slopes of the diode characteristic in the space-charge-limited region and in the temperature-limited region, respectively (Fig. 8). This method is particularly effective if the diode characteristic is plotted on log-log paper. It tends to give a current value higher than the actual flection-point current.

3.1.3 Tangent Method: The point of tangency of a line drawn through the origin, tangent to the diode characteristic, as shown in Fig. 9, will indicate the approximate flection-point emission current. If a curve tracer is used to obain the diode characteristic, a rotatable line drawn on transparent material may be affixed to the screen of the indicator at the origin of the trace so that it can be manually adjusted to tangency with the trace. This method tends to give a current value somewhat lower than that corresponding to the flection point.

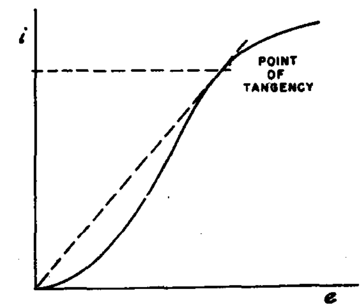

Fig. 9—Determination of flection-point emission current, tangent method.

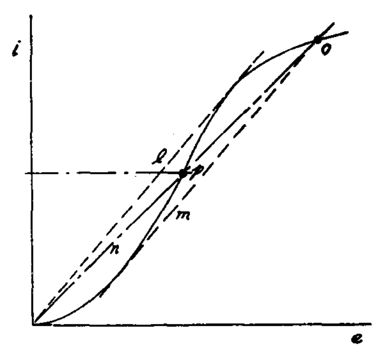

Fig. 10—Determination of inflection-point emission current, graphical method.

3.2 Measurement of Inflection-Point Emission Current

The inflection-point emission current is defined as the current at the point on the diode characteristic at which the second derivative is zero. The value of this current may be obtained with reasonable accuracy from a diode characteristic taken by a suitable method, such as one of those described in Section 4.4.

3.2.1 Graphical Method: An approximation of the inflection-point emission current may be obtained from the diode characteristic by a graphical method. The complete diode characteristic of the tube must be obtained and plotted. Then, as in Section 3.1.3, a line l is drawn through the origin, tangent to the characteristic, as shown in Fig. 10. Another line m is then drawn parallel to l and tangent to the lower part of the characteristic. From the point O, where m intersects the characteristic, a line n is drawn through the origin. The intersection p of line n with the characteristic will approximate the inflection point.

3.2.2 Break-Away Point: The inflection-point emission current is of particular interest for small-signal tubes used as linear amplifiers. Such tubes usually employ oxide-coated cathodes, in which the measure of inflection-point emission current is close to the so-called break-away point.

3.2.3 Determination of Break-Away Point: It can be shown experimentally that the break-away from the 3/2-power-law space-charge line in a diode characteristic of a tube with an oxide-coated cathode, plotted on two-thirds-power paper or on log-log paper, occurs very near the actual inflection point. Therefore, the break-away current i in Fig. 11 can be used as a measure of inflection-point emission current.

3.3 Comparison of Emission Currents of Tubes

When it is desired to compare the emission currents of several tubes of the same type at the flection point,

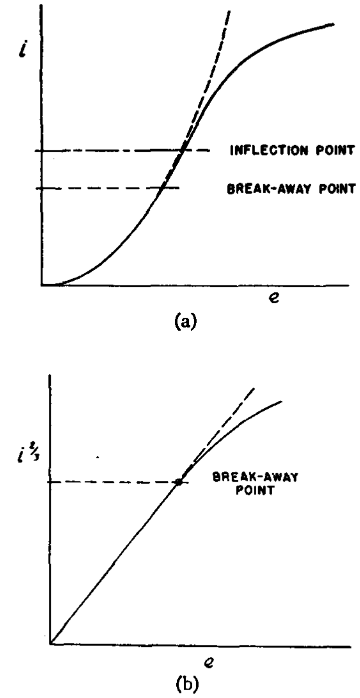

Fig. 11—Determination of emission break-away point.

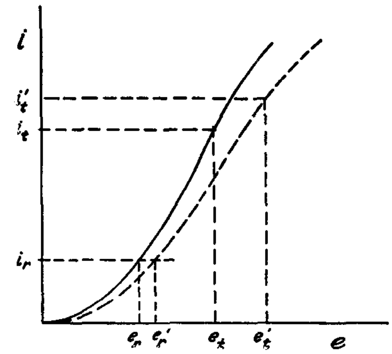

Fig. 12—Comparison of the emission currents of electron tubes.

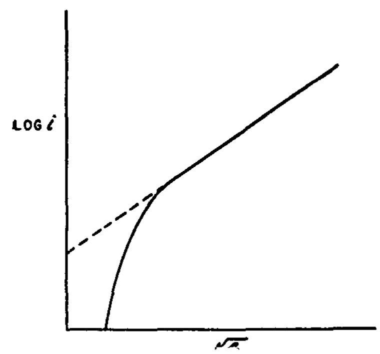

Fig. 13—Determination of field-free emission current.

inflection point, or any other specified point on the diode characteristic, such as point (e_t, i_t) in Fig. 12, it is possible to use the following procedure, in which the effect of small variations in cathode area and electrode spacings is eliminated.

A point (e_r, i_r) is selected on the space-charge-limited portion of the reference diode characteristic. To compare any other tube with the reference tube, it is first necessary to determine the voltage e_r' required to obtain the same current i_r. The proper voltage e_t' for the tube under test will then be given by the relation $e_t' = e_t(e_r'/e_r)$. The current i_t' will be a measure of the emission of this tube compared with the current i_t of the reference tube.

3.3.1 Precautions: The voltage e_r should be chosen sufficiently high so that contact potential is negligible in comparison. If this it not possible, the contact potential of each tube should be measured and the voltage e_r corrected for this effect.

The relatively large current obtainable in the inflection point region may cause a permanent change in the emission characteristic if the current is allowed to flow continuously. Since such a change must be avoided, pulse methods, described in Section 4.4, are desirable, and often essential.

3.4 Measurement of Field-Free Current

The value of field-free emission current of a cathode may be obtained from the diode characteristic. For this purpose the data are plotted as the logarithm of the current against the square root of the applied voltage; sufficient data beyond the flection point must be obtained to determine a straight line in this portion of the plot (Fig. 13). If this straight line is then extended to the point where it intersects the current axis, the value of current corresponding to this point will be the field-free emission current of the cathode. It may be found that sparking of the cathode, particularly with oxide-coated cathodes, occurs in the high-voltage region. Pulse methods, such as those described in Section 4.4, are ordinarily used for obtaining the data.

3.5 Emission Checks

For the purpose of making quick checks on the electron emission of a tube where apparatus for taking a complete diode characteristic is not available, or where a rough check is sufficient, one of the following methods may be used. It is necessary that the values obtained in such checks be correlated with results of more accurate tests in order for such information to be of value.

3.5.1 Direct Emission Check: For routine test purposes, electron emission may be checked with the filament or heater voltage adjusted to the rated operating value. Then all electrodes except the cathode are connected together to form a composite anode. A voltage, specified for the tube type under test, is applied to the composite anode, and a measurement is made of the electron current. The voltage may be direct or alternating.

In practice, anode potentials are chosen considerably lower than would be required for total emission. The choice of anode potential is determined to some extent by the sum of the maximum peak electrode currents that will be required in service, or by the maximum voltage that can be applied for a reasonable length of time to tubes of a particular type without injury.

3.5.2 Indirect Emission Check: In tubes having filamentary cathodes that might be injured by passing a relatively large average emission current through the filament, it is frequently desirable to obtain an indirect check of the emission by noting the value of filament voltage for which a specified value of emission current is obtained. Provided a low value of anode voltage is employed, this method also avoids false readings caused by such effects as local overheating of the filament, gas currents, or field-emission currents.

3.5.3 Oscillation Emission Checks: The following method of checking emission, in which the tube is operated under specified conditions as a self-excited oscillator, is particularly adapted to use with power tubes. The filament voltage is reduced until the total radio-frequency power output has been reduced by a specified percentage, and the filament voltage is then measured. This value of filament voltage is an indirect measure of the filament activity. Alternatively, the filament voltage may be lowered to a stated fraction of its rated value and the decrease in output noted. These methods are arbitrary and give relative check results that are valuable only as long as individual tubes of the same type are compared. The results depend in a great degree upon the circuit conditions.

4. Characteristics of an Electron Tube

The static characteristics of an electron tube are valuable as a means of predicting the performance of the tube, since load characteristics may usually be computed for assumed circuit conditions. The various tube constants and the perveance may be calculated from families of static characteristics. Load characteristics may be obtained in some cases by actually operating the tube in the desired circuit and making the appropriate measurements.

4.1 Static Characteristics

The more useful static characteristics of an electron tube are: electrode characteristics, constant-current characteristics, and transfer characteristics.

In general, these characteristics may be obtained by dc methods up to the point where electrode dissipations exceed safe values. Pulse methods such as those described in Section 4.4 are necessary to obtain the information beyond this point. It is desirable to obtain static characteristics up to and slightly beyond the extreme conditions of voltage and current that the tube will experience in operation.

4.1.1 Direct-Current Method: A representative arrangement for the determination of the characteristics of vacuum tubes is shown in Fig. 14.

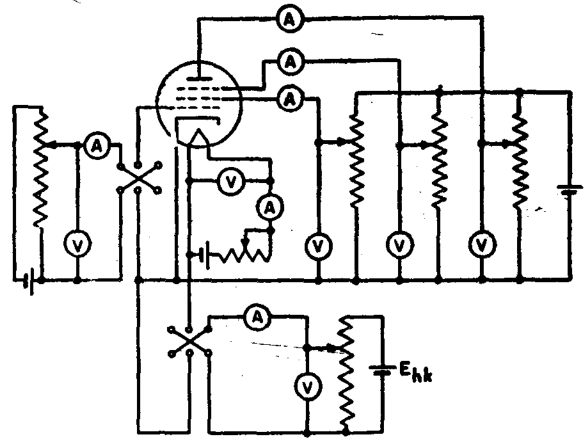

Fig. 14—Circuit arrangement for measuring static characteristics.

4.2 Load (Dynamic) Characteristics

4.2.1 Calculation of Load Characteristics from Static Characteristic Charts: Various forms of static characteristic charts can be conveniently used for precalculation or verification of tube performance by plotting load characteristics on them. In many cases the shape of the load characteristic can be predicted from the operating conditions and frequently is either a straight line or a portion of an ellipse. For example, class-A audio-frequency operation with resistive load may be represented as a straight line on a plate-characteristic chart. All classes of radio-frequency operation with resonant circuits in both input and output circuits are conveniently represented on a constant-current chart. Transfer characteristic charts are useful for class-B radio-frequency and audio-frequency plots when it is desired to examine the load characteristic directly for harmonics.

At frequencies where electron-transit-time effects become appreciable, it becomes inaccurate to calculate load characteristics from the static characteristics.

Load characteristics permit calculation of the entire performance data of the tube, such as input power, output power, efficiency, dissipation, excitation power, etc.

4.2.2 Direct Measurement of Load Characteristics: The load characteristics of a tube can be measured directly, without resort to calculation from the static characteristics. The tube should be set up for the required operating condition and the desired load characteristic observed by means of a cathode-ray oscillograph, the electrode voltage being applied to one pair of deflection plates and the voltage across a current-measuring resistor simultaneously applied to the other pair.

At frequencies at which electron transit time, tube capacitance, and tube lead inductance become important, they may have considerable effect upon the load characteristic. It is therefore advisable to take load characteristics at the frequency at which the tube is to be used.

4.2.2.1 Precaution: Care must be taken to insure that the measuring instrument and its connecting leads do not affect the shape of the load characteristic.

4.3 Perveance

4.3.1 Perveance of a Diode: The perveance of a diode with a unipotential cathode is given approximately by

$$G \simeq \frac{i_b}{e_b^{3/2}},$$

or more accurately by

$$G = 1/(3/2r_p)^{3/2} i_b^{1/2},$$

where i_b is the space-charge-limited current, e_b the anode voltage, and r_p the anode resistance.

The perveance, although ideally a constant which depends on the physical dimensions of the tube, actually varies somewhat with anode voltage and cathode temperature. Consequently, its value is of use primarily under specific conditions of cathode temperature and anode voltage. The numerical value of perveance of a diode can be calculated from measurements of voltage and current within the space-charge-limited region. If perveances at anode voltages on the order of one volt are desired, corrections for the effects of contact potential and initial electron velocities should be considered.

4.3.1.1 Graphical method: When current is plotted against the three-halves power of voltage, the slope of the curve is G. The slope is not constant over a wide range in voltage; consequently the perveance is determined at a desired value of voltage.

4.3.2 Perveance of a Triode or Multigrid Tube: The perveance of a negative-grid triode is given approximately by

$$G \simeq \frac{i_b}{e'^{3/2}},$$

where e' is the composite controlling voltage:

$$e' = \frac{\mu e_c + e_b}{\mu + 1}.$$

For multigrid tubes it is usually of sufficient accuracy to measure values of μ and the electrode voltages with the electrodes connected as a triode.

4.3.2.1 Low-voltage correction: When the diode voltage or composite controlling voltage has a low value (of the order of one volt), more accurate results are obtained by applying a correction for the effects of initial electron velocity and of contact potential difference. These effects are not readily separable, but their combined effect may be represented by a single voltage term ϵ. The composite controlling electrode voltage in this case is

$$e' = \frac{\mu e_c + e_b}{\mu + 1} + \epsilon,$$

and the perveance is

$$G = \frac{i_b}{\left[\dfrac{\mu e_c + e_b}{\mu + 1} + \epsilon\right]^{3/2}}.$$

Taking the transconductance g_m as i_b/e_c, and neglecting the partial derivatives of G, μ, and ϵ with respect to e_c, the correction voltage ϵ becomes

$$\epsilon \simeq \frac{(3/2) i_b \mu}{g_m(\mu + 1)} - \frac{\mu e_c + e_b}{\mu + 1}$$

$$G \simeq (1/i_b)^{1/2}\left[(2/3) g_m \frac{(\mu + 1)}{\mu}\right]^{3/2}.$$

When measured values of the terms on the right-hand side of the preceding expressions are used, the values of ϵ and G that may be computed are useful in problems of design and in the standardization of tube characteristics.

For multigrid tubes electrodes beyond the first grid are connected together, and the tube is measured as a triode.

4.4 Pulse Methods

It is of considerable importance to know the static characteristics of electron tubes in the region where electrode dissipation may exceed safe values. It is impossible to obtain these characteristics by the conventional direct-current methods without damaging the tube. In such cases it is necessary to employ pulse methods in which the tube is allowed to pass current only for short intervals of such duration and frequency that it is not damaged.

Pulse methods may be employed for obtaining electrode characteristics, transfer characteristics, or constant-current characteristics. The basic elements needed for a pulse method are the pulse generator and the current and voltage indicators. Where a single pulse generator is employed, it is usually connected to the control-grid circuit, as in Fig. 15, with the grid biased past cutoff in the absence of the pulse. If more than one pulse generator is used, as in Fig. 16, it is necessary to synchronize the pulses. In general, a single pulse generator is adequate and the single-generator method is simpler than the two-generator method.

Ordinarily, two methods are employed in obtaining characteristics, namely: the point-by-point method and the curve-tracer method. The point-by-point method consists of applying known pulse voltages to electrodes and simultaneously measuring the corresponding maximum pulse currents to the electrodes. The applied pulse voltages are adjusted point by point over the desired ranges to obtain a family of characteristic curves. The curve-tracer method consists of applying a pulse voltage of such magnitude that the entire range of the desired characteristic is covered and of such shape that the oscillograph indicator shows graphically the true relation between electrode current and voltage.

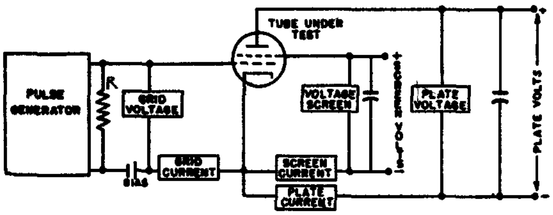

Fig. 15—Circuit arrangement for pulse measurement of tube characteristics, single-generator method

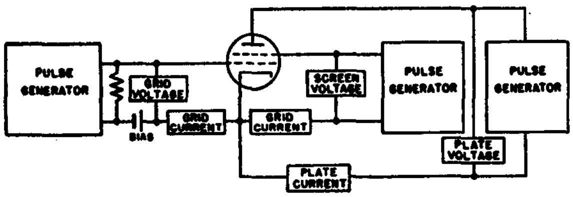

Fig. 16—Circuit arrangement for pulse measurement of tube characteristics, multiple-generator method.

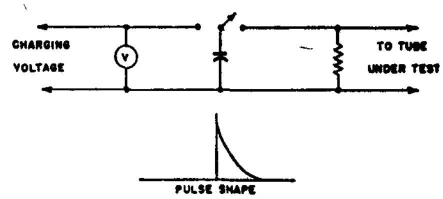

Fig 17—Basic circuit arrangement for capacitor-discharge pulse generator.

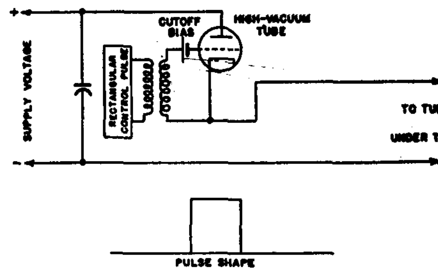

Fig. 18—Basic circuit arrangement for high-vacuum-tube pulse generator.

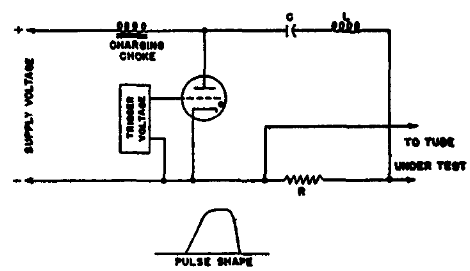

Fig 19—Basic circuit arrangement for gas-tube *LC* pulse **generator**

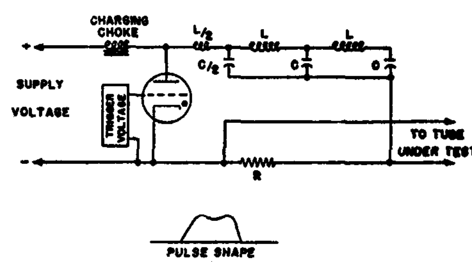

Fig. 20—Basic circuit arrangement for gas-tube pulse generator with pulse-forming line.

4.4.1 Point-by-Point Pulse Methods:

4.4.1.1 Types of pulse generators:

4.4.1.1.1 Capacitor-discharge type: The discharge of a capacitor provides one of the simplest means for obtaining a voltage pulse. The capacitor may be discharged either directly through the tube under test, or through a coupling device. In the absence of series impedance, the peak voltage applied to the tube is the voltage of the charged capacitor. Some means must be provided for switching the capacitor between charge and discharge circuits. The basic circuit is shown in Fig. 17. The switching device may be a mechanical switch, or an electron tube.

Because of the very short duration of the pulse voltage in a simple capacitor discharge, it is difficult to provide an accurate current indicator of good accuracy. It may therefore be desirable to shape the applied pulse so as to extend the duration of its peak. This may be done by the use of suitable networks and switching means. Figs. 18–20 show circuits for obtaining various pulse shapes. In the circuits of Figs. 19 and 20 the resistance of the parallel combinations of the coupling resistor R and the load of the tube under test should approximate the characteristic impedance $Z_0=\sqrt{L/C}$ of the network. In all of the foregoing circuits, except that of Fig. 17, the pulse voltage must be measured directly across the tube under test by means of a suitable indicator.

In the circuit of Fig. 18 the vacuum tube may be considered as a pulse amplifier in which any pulse shape applied to the control-grid circuit is amplified and applied to the tube under test. This circuit has the advantage of not requiring a specific terminating impedance. Several amplifier tubes may operate in parallel to provide additional current if precautions usual for parallel operations are observed. There are several arrangements of this basic circuit that may be used, depending on the location of the ground connection and the polarity of the output pulse.

If secondary-emission effects in the tube under test introduce a negative impedance, the pulse generator must be shunted with a noninductive load resistor of such value as to maintain a net positive impedance at its terminals. This resistor R should be located between the generator and the current indicator, as shown in Fig. 15.

4.4.1.1.2 Sine-wave type: Synchronous mechanical contactors or properly controlled thyratrons in conjunction with alternating voltages can be used to apply a half-cycle pulse, or a smaller portion of a cycle, to the tube under test, as shown in Fig. 21. It is usually desirable to use only one out of every two or more cycles in order to keep the electrode dissipation low. The system should have low internal impedance.

4.4.1.2 Types of indicators: Indicators are required for both current and voltage. In general, indicators for pulse methods may be divided into three types: dc meters, peak-reading meters, and oscillographs.

4.4.1.2.1 Direct-current meter indicators: Meters are the simplest indicators but have limited application for obtaining electron-tube characteristics by pulse methods. A dc voltmeter, may, for example, be used to read the capacitor voltage in the circuit of Fig. 17, a circuit that is sometimes useful in obtaining volt-ampere characteristics by point-by-point methods. The capacitor must have sufficient capacitance to supply the required charge, and the meter reading must be corrected for the voltage drop across any series impedance. Another circuit in which a dc meter gives satisfactory results is that of Fig. 23.

The dc meter may also be a useful type of indicator in the circuit of Fig. 15, where it may be used to indicate the voltage of the plate or screen. If high accuracy is desired, correction must be made for the voltage drop in the plate- or screen-current indicator.

4.4.1.2.2 Peak-reading voltage indicator: Peak-reading voltage indicators are useful in measuring the peak value of the pulse voltage applied to an electrode in obtaining vacuum-tube characteristics by point-by-point pulse methods.

In order to function successfully, the circuit consisting of the capacitor, resistance, and meter in Fig. 22 must have a time constant that is large with respect to the time interval between successive pulses. The indicator accuracy is greatest with rectangular pulses shown in Fig. 18, although good accuracy can be obtained with the pulse shapes shown in Figs. 19–21 if the pulse duration is sufficient.

Where the pulse is substantially square and the OFF/ON ratio is known, a moving coil or other averaging instrument may be used to measure the electrode current. The peak current is equal to the mean current (as measured by the meter) multiplied by the ratio of the total time to the pulse time.

The peak reading voltage indicator of Fig. 22 may be calibrated from a known dc source if correction is made for voltage drop in the high-vacuum diode. The usual practices of correcting for meter current or for voltage drop in current-measuring instruments should be followed. This type of indicator may be used also to determine peak current by measuring the peak voltage drop across a noninductive shunt resistor of known value.

The use of this indicator for current-measuring purposes may result in serious errors if the electrode characteristic of the tube under test exhibits a change of slope from positive to negative. Electrodes giving high-secondary-emission currents may have such characteristics, and a knowledge of the tube being tested or use of a cathode-ray oscillograph for checking purposes is desirable.

4.4.1.2.3 Cathode-ray-oscillograph current indicator: The indicator shown in Fig. 23 is useful in measuring the peak value of electrode currents in taking vacuum-tube characteristics by pulse methods based upon the circuits of Figs. 15 and 16. With large tubes, connection may in most instances be made directly to the vertical deflection plates of the oscillograph. Safety and good performance require that this method be applied only to those oscillographs in which connection may be made directly to deflection plates operated at or near ground potential.

It is usually desirable to utilize a linear horizontal sweep voltage, synchronized to the pulse-generator frequency, to spread out the current trace. In this manner the detection of possible errors caused by the negative slope of electrode characteristics is simplified. In

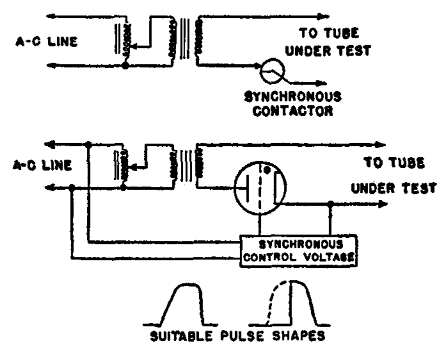

Fig. 21—Basic circuit arrangement for sine-wave-type pulse generator.

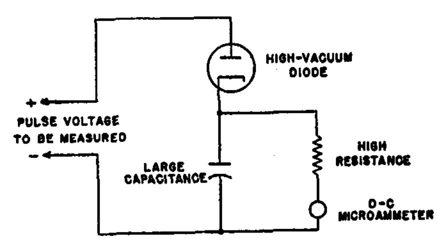

Fig. 22—Peak-reading voltage indicator.

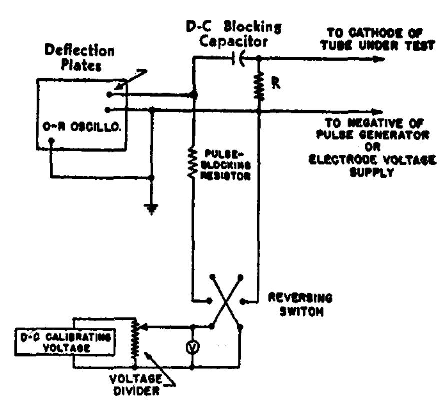

Fig. 23—Cathode-ray-oscillograph current indicator.