# A Pulse Emission Test For Field Testing Hot-Cathode Gas Tubes

Because of the particular voltage-current characteristics of gas-filled electron tubes, a single pulse test can be used in the field to detect both complete failures and "marginal" tubes. This Note describes a basic circuit for making such a test.

## Voltage-Current Characteristic of Gas Tubes

Hot-cathode gas tubes, like vacuum tubes, utilize oxide-coated cathodes which emit electrons copiously. In a vacuum tube, however, some of the emitted electrons are driven back into the cathode by a field of previously emitted electrons; the emission, therefore, is said to be space-charge limited. In a gas tube, on the other hand, electrons emitted from the cathode strike gas atoms and ionize them. The ions then neutralize the space charge around the cathode and thus remove the deterrent effect of the space charge on the current. As a result, most of the emitted electrons can reach the anode under the influence of a modest voltage.

Fig.1 shows a typical voltage-current characteristic curve for a gas-filled electron tube. The maximum voltage which can be applied to a gas tube before appreciable current flows is known as the starting or breakdown voltage, indicated in Fig.1 as $E_b$. After breakdown occurs, a gas tube needs only sufficient anode voltage to produce ionization of the gas, so long as the current drawn is within the emissive capabilities of the cathode. This voltage is about 9 volts for xenon-filled tubes, and about 12 volts for mercury-filled tubes. Because the current after breakdown increases rapidly without further increase in voltage, a series resistance is necessary to limit the current. In the typical rectifier circuit, this resistance is represented by the useful load. The operating point, A, is determined by drawing through the supply voltage, $E_{bb}$, a line with a slope equal to the reciprocal of the load resistance. The anode voltage across the tube, $E_a$, at a given current, $I_a$, is known as the tube drop.



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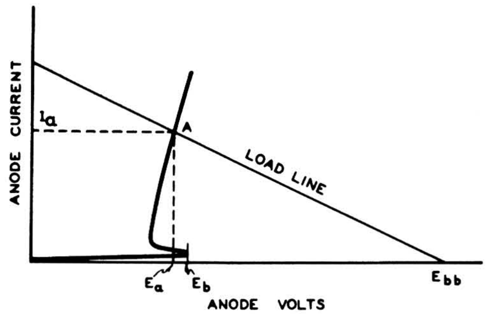



*Fig.1 - Typical Voltage-Current Characteristic for a Gas-filled Electron Tube.*

### Causes of Failure in Gas Tubes

Failure, or incipient failure, of gas tubes is usually evidenced by a decrease in the emissive capabilities of the cathode. The reduced emission, however, may be attributed to any one of several causes. The presence of a foreign gas such as oxygen or air in the tube may poison the cathode coating and reduce its emissive capabilities. This foreign gas, which may be introduced as a result of a leak in the glass envelope or through evolution of gas from parts within the tube, may also cause breakdown of the tubes on the inverse cycle of voltage if the ionization point of the foreign gas is lower than that of the original gas filling used in the tube.

Poor emission may also be caused by gas clean-up, which results when the cathode coating material in the tube sputters under the bombardment of the ions. The material thrown off from the cathode collects some of the gas atoms and is deposited on the tube walls. The decrease in emission results from both the damage to the cathode coating and the scarcity of ions.

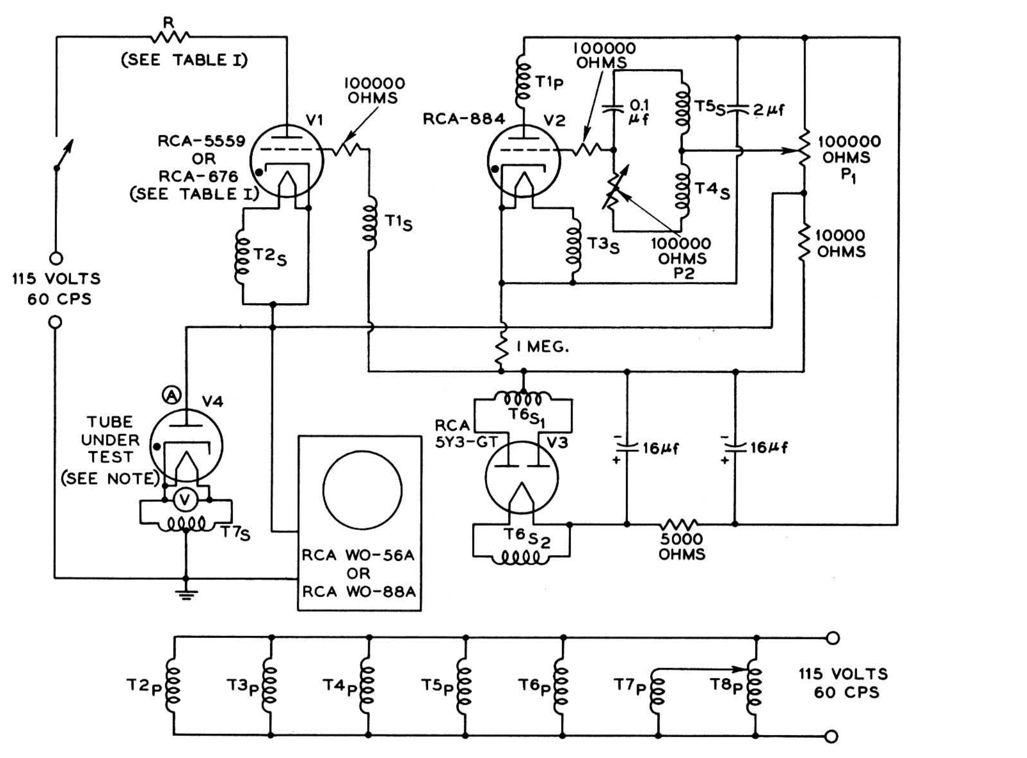
Poor emission or a complete lack of emission may also be caused by such defects as open filaments, improperly coated cathodes, and shorts. A suitable test of emissive capability, therefore, detects these defects as well as those mentioned above.

### Methods of Test

A conventional method of testing gas tubes in the field is the measurement of breakdown voltage. This test is a fairly accurate indication of the emissive capabilities of the cathode in tubes in which the anode directly faces the cathode. In most gaseous rectifiers, however, a cathode shield employed to improve thermal efficiency breaks up the direct path between cathode and anode. This shield also acts as a grid which is made positive or negative with respect to the cathode by the action of the ac heater voltage and, therefore, affects the breakdown voltage of the tube. If the shield is negative with respect to the cathode when the anode swings positive, the breakdown voltage of the tube is considerably higher than if the shield and anode voltages are in phase. In such tubes, therefore, the starting voltage should not be taken as a measure of the emission.

Measurement of dc tube drop at rated average current is also used quite often in the field to determine the performance level of gas tubes. A gas discharge is somewhat self-compensating, however, and, therefore, an increase of a volt or two in tube drop can compensate for a considerable decrease in emission. If the cathode emits insufficient electrons to provide the current which would normally flow through the given load resistance, the tube drop increases. Because of this increased voltage drop, the positive ions strike the cathode with higher velocity, raising the cathode temperature and also increasing the secondary-emission yield, and, as a result, bringing the emission back to normal. Because of this compensation, little is learned about the condition of the cathode by measurement of the voltage drop with a dc anode supply and with average current flowing.

If, however, a gas tube under test delivers a peak current several times its rated current, the rise in peak voltage drop is appreciable and is indicative of the quantity of electrons emitted by the cathode.




$T_1$ = Audio transformer-turns ratio 1:1

$T_2$ = Filament transformer suitable for $V_1$

$T_3$, $T_4$, $T_5$ = Filament transformer - 6.3 volts, 1 ampere

$T_6$ = Power transformer - 500 volts, 60 milliamperes; 5 volts, 2 amperes

$T_7$ = Filament transformer suitable for $V_4$

$T_8$ = Variac

NOTE: When a thyratron is being tested, the connection at A is made to grid No.1 of the thyratron; no connection is made to the thyratron anode or grid No.2.

*Fig.2 - Basic Circuit for Making Pulse Emission Tests on Gas Tubes.*

Such a high current cannot be drawn continuously because the anode-dissipation rating of the tube would be exceeded. The desired information can be obtained, however, when the current is drawn in short pulses and with a relatively long inter-pulse period (low duty cycle).

### Pulse Test Circuit

A basic circuit suitable for making pulse emission tests on gas tubes in the field is shown in Fig.2. This circuit causes the tube under test, $V_4$, to conduct about once a second, each conduction period lasting for only one half-cycle of the voltage from the 60-cycle supply. Such a low duty cycle permits high peak currents to be drawn without the dissipation limits of the tube being exceeded. The repetition rate is fast enough to permit observation of the tube drop on an oscilloscope.

In the circuit of Fig.2, thyratron $V_1$ serves as an electronic switch to pass the test current pulse through $V_4$. The value of the resistor R determines the amplitude of the current pulse. Suitable values of resistance for various types of gas tubes are given in Table I. Thyratron $V_2$ and its associated circuit comprise a relaxation oscillator which determines the repetition rate. The output of this circuit is coupled through transformer $T_1$ to the grid of thyratron $V_1$. The repetition rate is not critical; if desired, it can be adjusted with potentiometer $P_1$. The low-voltage windings of transformers $T_4$ and $T_5$ are connected in series aiding so that there is 12.6 volts across the outside leads. The trigger pulse applied to the grid of $V_1$ should occur at the beginning of a positive half-cycle of anode voltage on $V_1$. Potentiometer $P_2$ permits adjustment of the pulse phase over 180 degrees; it may also be necessary to reverse the transformer leads of both $T_4$ and $T_5$ to obtain the desired phasing. Rectifier $V_3$ supplies dc voltage for the relaxation oscillator and for the bias of thyratron $V_1$. The choice of thyratron $V_1$ depends upon the test current to be drawn; suggested thyratrons for use with various tube types under test are given in Table I. When the tube under test, $V_4$, is a thyratron, the connection at A is made to the grid No.1 of the thyratron; no connection is made to the thyratron anode or grid No.2.

### Use of Pulse Test

The conditions of tube operation during test should be controlled in order to assure reproducible results. The correct cathode temperature is obtained if rated heater voltage is applied for rated heating time; five minutes is adequate for all standard types. (This time should be doubled if heater transformers having poor regulation are used). The heater voltage should be measured at the socket with a good meter; the socket and top-cap contacts should be clean and snug-fitting.

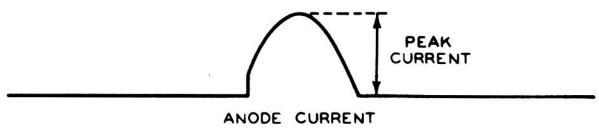
The tube drop of mercury-vapor tubes, in addition to being sensitive to heater temperature, is sensitive to changes of envelope temperature. The mercury-vapor pressure is determined by the temperature of a portion of the glass envelope half an inch long just above the base. The temperature of this portion of the envelope, sometimes called the condensed-mercury temperature, rises above the ambient temperature as the tube is operated. The rate of rise of the envelope temperature, as well as the operating temperature of the envelope, depends upon tube construc-

TABLE I

| *Tube Under Test* | *Auxiliary Thyratron* | *Peak Test Current* (amperes) | *Resistor R* (ohms) |
|---|---|---|---|
| Rectifiers | | | |
| 816 | RCA 5559 | 2 | 70 |
| 866A | " | 5 | 28 |
| 3B25 | " | 5 | 28 |
| 3B28 | " | 5 | 28 |
| 5558 | " | 5 | 28 |
| 872A | RCA 676 | 20 | 7 |
| 8008 | " | 20 | 7 |
| 4B26 | " | 20 | 7 |
| 575A | " | 30 | 4.7 |
| 673 | " | 30 | 4.7 |
| 5561 | " | 30 | 4.7 |
| 869B | " | 40 | 3.5 |
| 857B | " | 80 | 1.7 |
| Thyratrons | | | |
| 5696 | RCA 5559 | 0.2 | 700 |
| 884 | " | 1.0 | 140 |
| 885 | " | 1.0 | 140 |
| 2D21 | " | 2 | 70 |
| 502A | " | 2 | 70 |
| 2050 | " | 2 | 70 |
| 629 | " | 1 | 140 |
| 5557 | " | 5 | 28 |
| 627 | " | 5 | 28 |
| 3D22 | " | 10 | 14 |
| 3C23 | " | 10 | 14 |
| 5559 | " | 15 | 9.4 |
| 5720/33 | " | 15 | 9.4 |
| 5728/67/1904 | " | 15 | 9.4 |
| 5560 | RCA 676 | 30 | 4.7 |
| 672A | " | 40 | 3.5 |
| 5563 | " | 30 | 4.7 |
| 105 | " | 80 | 1.7 |
| 172 | " | 80 | 1.7 |
| 677 | " | 30 | 4.7 |
| 676 | " | 80 | 1.7 |

tion and upon the power dissipated in the heater and anode. When the condensed-mercury temperature is below 20 degrees Centigrade, the mercury pressure is less than one micron and the tube drop is so high that the cathode coating may be damaged. When the condensed-mercury temperature is 25 degrees Centigrade or higher, each additional increase of five degrees results in a decrease in tube drop of approximately two volts. Although the time required for a mercury-vapor tube to reach "equilibrium" temperature may be from 10 to 30 minutes, a warm-up time of five minutes should be sufficient to heat the cathode and to stabilize the mercury pressure before measurement of pulse emission and peak tube drop.

The oscilloscope used to measure the tube drop must be equipped to amplify dc signals so that the instrument may be calibrated with dc voltage and a convenient and stable zero voltage axis may be established. The RCA WO-56A and RCA WO-88A oscilloscopes are suitable and directly usable for this purpose. If conventional ac oscilloscopes are to be used in this application, they must be converted for dc amplification. In ac oscilloscopes having one stage of amplification, the input coupling capacitor should be shorted and the output coupling capacitor replaced with a 180-volt bias battery (isolated from ground) and a 0.5-megohm potentiometer for vertical-centering control. If there is no common connection between any two of the four deflecting electrodes, the centering may be accomplished without the internal battery by applying a suitable dc voltage from a tap on the internal supply to the vertical deflecting electrode opposite the signal electrode.



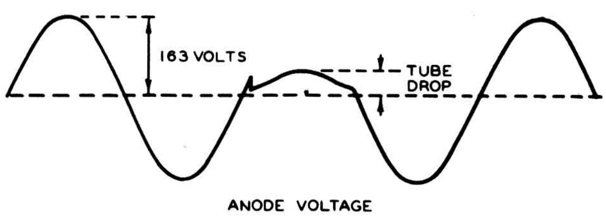




*Fig.3 - Waveform Produced on Oscilloscope such as RCA WO-56A by a Gas Tube Under Test in the Circuit of Fig.2.*

The waveforms produced on a suitable oscilloscope by the circuit of Fig.2 are shown in Fig.3. A single half-cycle of voltage appears across resistor R when $V_1$ fires. The peak current can be calculated after the peak voltage across R is measured. Because the tube drop is not sensitive to small variations in current, a fixed value of R may be used for any given tube type (see Table I). The tube drop is indicated on the oscilloscope by the perpendicular distance from the zero voltage axis to the point of the voltage wave form corresponding to maximum current flow. The value of the tube drop may be determined by substituting a dc voltage which produces the same amount of deflection on the oscilloscope.

When tubes having directly heated cathodes are tested, errors due to inclusion of the filament voltage in the reading can be eliminated by making all circuit returns to the center tap of the filament transformer. When tubes having indirectly-heated cathodes are tested, the return should be made to the cathode.

## Evaluation of Test Results

A major advantage of a pulse test for gas tubes in the field is the ease of locating "marginal" tubes before failure. The operational "danger zone" of tube operation, when failure may occur at any moment, can be avoided if the emission test described in this note is utilized. The tube drop of an average gas tube at the beginning of its life ranges from 8 to 16 volts depending upon the tube type and the test current. Tube drop may decrease slightly early in the service life, but it soon settles down to a nearly constant value for the major portion of the tube life. Toward the end of life, the tube drop rises, slowly at first but then at an increasing rate. A tube operating at 25 volts at normal current may fail at any moment. In equipment in which continuity of service is important, tubes having a drop of 25 volts under the test conditions shown in Table I should be taken out of service.

The peak test currents given in Table I are not critical; they may vary as much as ten per cent or more for the purposes of this test. These current values, however, are in excess of the rated peak currents for the tubes and are recommended only for pulse testing.

A suggested schedule of pulse tests in the field is at 100, 500, and 1000 hours, and at 1000-hour intervals thereafter. In general, this schedule will be sufficient to prevent excessive failure in operation; a modified schedule sometimes may be necessary to suit particular requirements.