The Application of Direct-Current Resonant-Line-Type Pulsers to the Measurement of Vacuum-Tube Static Characteristics*

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Summary—In order to utilize a power tube efficiently, the static characteristics of this tube must be known. From these characteristics, optimum load lines may be determined and circuit components of the equipment may be defined. The problem of obtaining these characteristics is usually not a simple one, due to the power-input limitations put upon a tube. For this reason, characteristic curves were previously plotted by capacitor-discharge methods or were calculated mathematically, using low power points as references. This paper describes a method of obtaining this information, employing pulse circuits commonly used in radar transmitters.

MEASUREMENT OF STATIC CHARACTERISTICS FOR POWER TUBES

THE PROBLEM of measuring static characteristics of power tubes is aggravated by the fact that these tubes always require positive grid driving voltage which results in appreciable power to be dissipated by the electrodes. These curves, therefore, cannot be obtained by ordinary direct-current means as is common in receiver-type tubes where the grids are mostly operated at a negative potential.

In a practical case, the ML-354, 50-kw FM tube, grid and plate dissipation at the end of a selected load line may be 65 kw, 14 kw on the grid, and 51 kw on the anode. This is not the maximum dissipation that would be encountered by using direct-current means of measurement, as the regions beyond and above the load-line figures quoted above must be explored. Power dissipation loads up to 5 times these quantities may be encountered.

Previously, capacitor-discharge methods were used or curves were obtained by calculation from low level direct-current points.[1,2]

DESCRIPTION OF CIRCUIT

Fig. 1 shows a simplified circuit of the test setup. The circuit to the left of line *A-A* is a conventional-line-type pulser using resonant charging. The principal components (Fig. 2) consist of a direct-current power supply, charging choke, pulse-forming network, load resistor and a 5C22 hydrogen thyratron.[3]

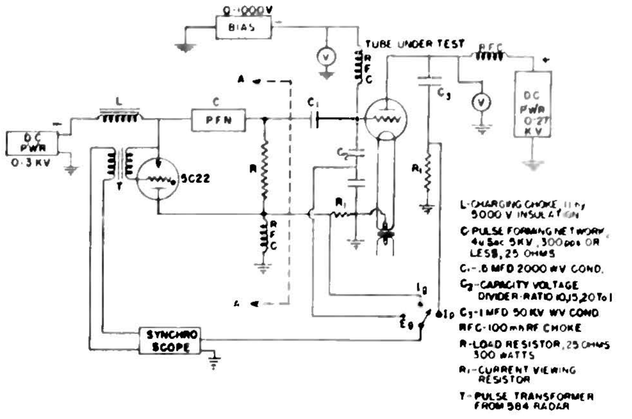

Fig. 1—Simplified schematic diagram of pulser.

Most power tubes have fairly low grid input impedances. The ML-354 with 100 ohms has about the highest. This input impedance should match the network impedance to avoid undesirable effects.

Since the pulser is to be used on many types of tubes, and therefore varying impedances, stability can best be obtained by using a resistor in parallel with the tube load. The tube load is, therefore, a small part of the load impedance for the line pulser resulting in more stable operation. The addition of the parallel resistor results in inefficient operation, but in this case a slightly higher expenditure of power from the direct-current power supply is tolerated to obtain added flexibility.

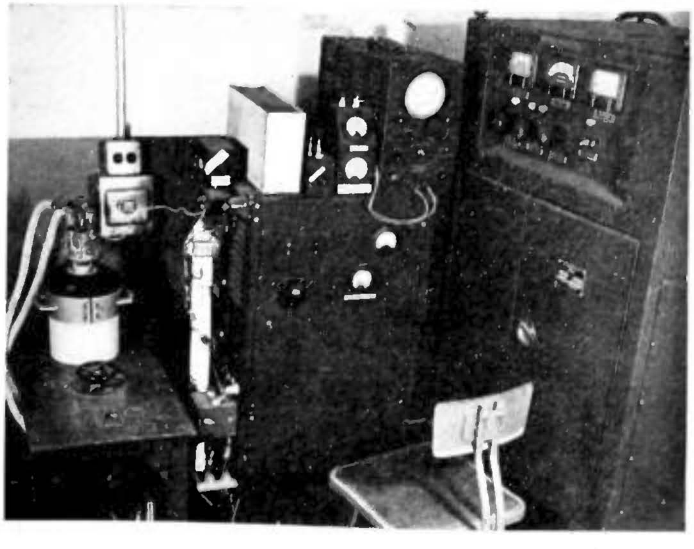

Fig. 2—Setup of equipment. The resistors on the side of the rack comprise the load resistor *R*. The rectangular can on the top left is the pulse-forming network, and the two cased meters read plate voltage applied to the tube under test and deflection voltage on the synchroscope.

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[1] E. L. Chaffee, "The characteristic curves of the triode," Proc. I.R.E., vol. 30, pp. 383–395; August, 1942.

[2] J. Bell, J. W. Davies, and B. S. Gossling, "High power valves: construction, testing and operation," *Jour. I.E.E.* (London), vol. 83, pp. 188–193; August, 1938.

[3] "Pulse Generators," edited by G. N. Glascoe and J. V. Lebacqz, Radiation Laboratory Series, McGraw-Hill Book Co., New York, N. Y., pp. 341–354, p. 173; 1948.

The front of a pulse from line-type pulsers is subject to oscillation and other distortions due to the large rate of rise of pulse current, so a fairly long pulse length is desirable. A range of from two to five microseconds has been found satisfactory. The pulse-repetition frequency is kept as low as feasible since average current from the direct-current power supply rises with the repetition frequency and a high repetition rate is not necessary. The tube under test is coupled directly to the output of the pulser to avoid using a pulse transformer. Pulse transformers require fairly close matching to ensure a satisfactory pulse and this is not possible if many tube types are to be measured. There have been occasions when a higher voltage was desirable, and a pulse transformer with a ratio of three to one has been inserted across the load resistor with satisfactory results. For the majority of the measurements, the pulse transformer is not used. Direct coupling necessitates reversing both the power supply and hydrogen thyratron, thereby running the cathode of the 5C22 at high voltage; but a pulse transformer similar to that used in the 584 radar for coupling to the output stage proves quite satisfactory.

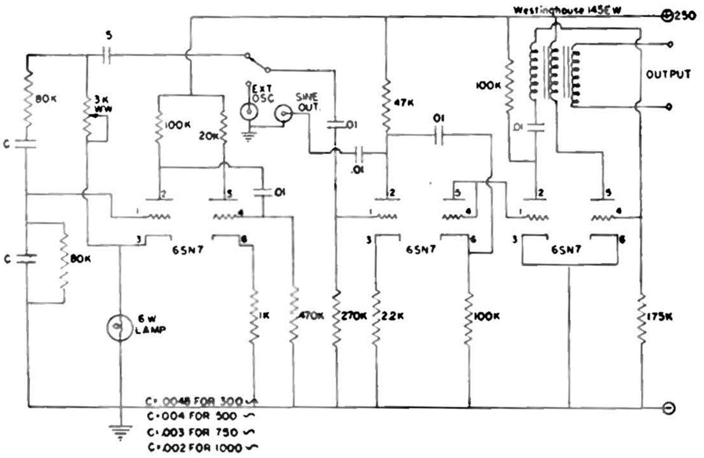

Fig. 3

The 5C22 may be driven by a synchroscope or any other frequency source giving approximately 150 volts. A synchroscope is an oscilloscope constructed so that the horizontal sweep is triggered by either the trigger source actuating the pulser (synchronous operation) or by the signal to be observed (self-synchronous operation). These are manufactured by several manufacturers, among them Sylvania Electric Products Inc., James Millen Manufacturing Company, Inc., and Browning Laboratories, Inc. Fig. 3 is the schematic of the trigger source being used at present to trigger a Browning P4 synchroscope which in turn is driving the 5C22 thyratron.

A description of the operation of the pulser follows. The tube under test is biased to a point where no plate current will flow at the maximum plate voltage to be used. This bias voltage is applied with a direct-current power supply and remains constant on the grid. The pulser impresses positive voltage pulses between the grid and cathode at the rate of 300 per second with a duration of 4×10^{-6} seconds. The amplitude of the pulse is chosen so as to drive the grid voltage to the point to be measured. The plate conducts for the same length of time, 4 microseconds. Plate voltage is applied to the tube by means of a direct-current power supply charging a storage capacitor C_3. This capacitator must be of such size that the voltage remains fairly constant during the time the tube conducts. Proper radio-frequency chokes are incorporated to isolate the pulse voltage from the various supplies.

The grid and plate current are read by means of voltages developed across current-viewing resistors. These resistors must be noninductive in nature since inductance will cause high voltage spikes in accordance with $E = L(di/dt)$. Sprague Koolohm noninductive resistors are quite satisfactory in this respect, and Fig. 4 shows a method of mounting these resistors to afford plug-in convenience.

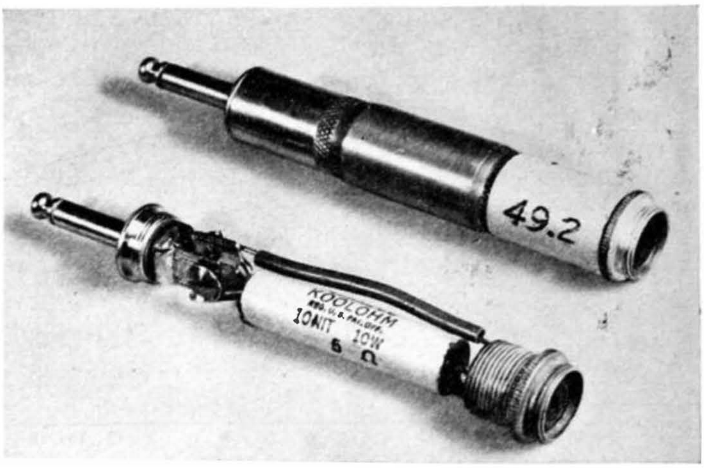

Fig. 4—Construction of current-viewing resistors. Sprague Koolohm noninductive resistors are satisfactory. The completed unit is calibrated on a bridge after assembly.

Bias voltage and plate voltage are read by standard direct-current voltmeters. Grid voltage is read by means of a capacity divider arranged so as to sample the pulse voltage going into the grid. Care must be taken in designing this divider so that reasonable deflection is obtained for any voltage range. This can be done by providing three ratios so that the appropriate one may be selected when needed.[4]

Using a suitable current-viewing resistor, capacity divider, and direct-current meters, an accuracy of ±5 per cent may easily be obtained. By using a little care in reading the synchroscope, an accuracy of ±2 per cent is possible. As a check, low current points are measured on a direct-current test set.

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[4] See pp. 673–677 of footnote reference 3.

Discussion of Results

The above pulser is used for many tests. By tying together the plate and grid of a tube and applying the pulse to these electrodes, peak cathode-emission data may be obtained. This is a very important characteristic since emission varies with cathode temperature and tungsten filaments must run ±15° C for uniform life. Routine measurements on production tubes are a check on standard quality.

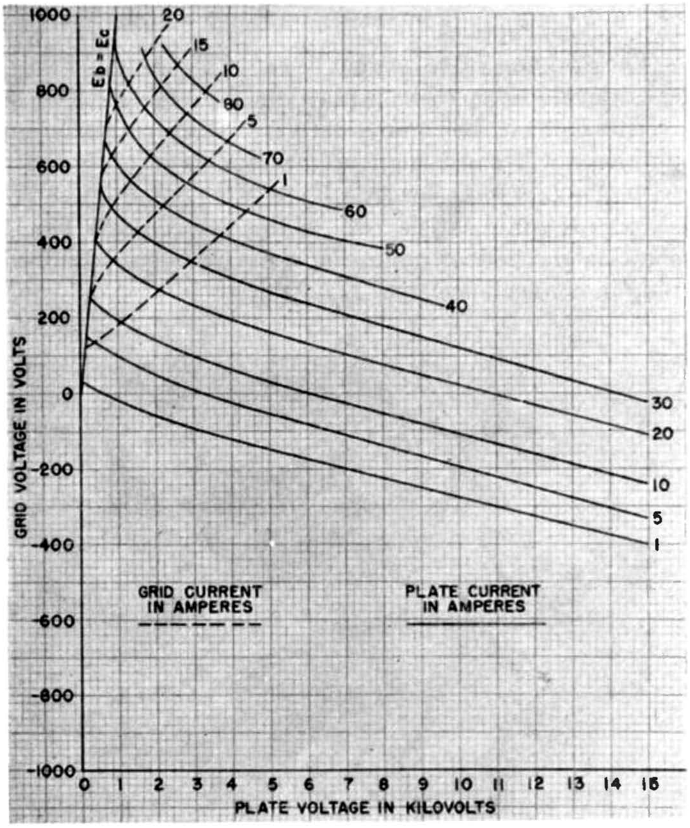

Fig. 5—ML-354 constant current characteristics.

In the experimental tube, cathode emission is very important, as is exploring the emission to ascertain the knee of the plate voltage-cathode current curve. These curves are easily obtained by the pulser method.

Static characteristics are obtained for every condition of operation with no injury to the tube. Fig. 5 is the static characteristic of the 50-kw, 100-Mc FM tube obtained with the above pulser. Since the duty cycle, 300 cycles per second $\times 4 \times 10^{-6}$ seconds equals 0.12 per cent, instead of 65-kw input to the tube, only 78 watts need be dissipated for the above-mentioned load-line point.

Primary grid emission, which varies with grid temperature and material, is of concern in connection with tube characteristics. Since the pulser described does not heat the grid of the tube under test, the effects of increased temperature will, therefore, not be apparent in the curves.

In the standard test for power tubes employed by Machlett Laboratories, alternating current is applied to the grid, the positive cycles used to heat the grid, and the negative cycles to measure the primary emission. A careful check on data obtained this way reveals that primary grid emission in properly designed and processed power tubes is low enough, up to maximum rated input, to be ignored when measuring static characteristics.

Effects of secondary grid emission, however, can be measured. Secondary grid emission is more a function of grid material and shielding at the ends of the grid itself. Tests have been made on the effects of enclosing the "cold" ends of the grid of an ML-846 tube with solid bands in place of the usual wire. Fig. 6 shows the curves of a regular production ML-846 compared with the test tube and the drastic change in grid current can be noted.

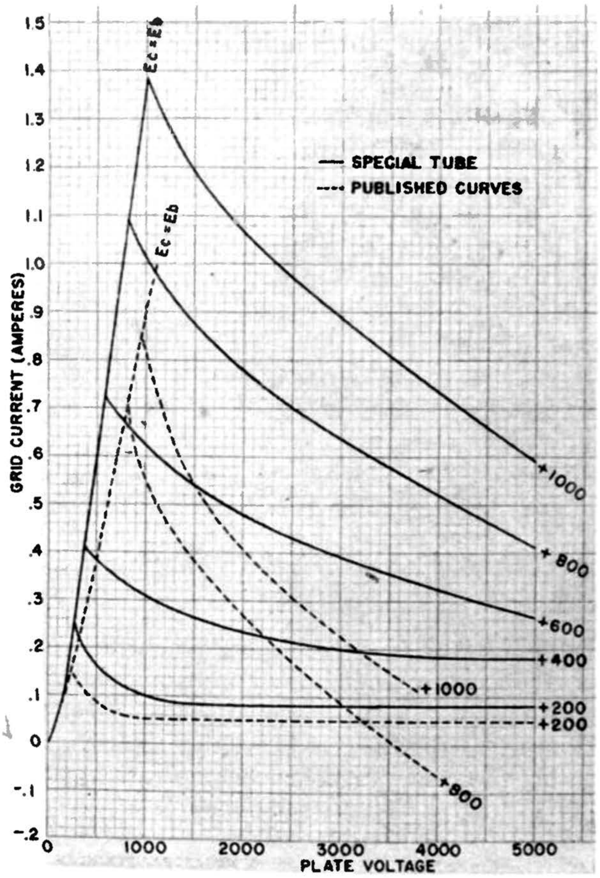

Fig. 6—ML-846 with special grid.

Acknowledgment

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