RECORDING THE CHARACTERISTICS OF TRANSMITTING VALVES

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A record can be made of the relation between different voltages with a cathode ray tube by applying them to the horizontal and vertical deflection plates respectively. An arrangement is described in this article with which it is possible to record the anode or screen grid current of a transmitting valve as a function of the anode voltage. By this method a number of curves are obtained at one time for different grid voltages.

Introduction

An arrangement was recently discussed in this periodical for recording the characteristics of receiving valves by means of cathode ray tubes. To each set of deflection plates of the cathode ray tube a voltage is applied which is proportional to one of the two quantities whose relation is represented by the characteristic obtained. If, for example, it is desired to record the $I_a$-$V_a$ characteristic of a valve, the cathode ray is given a horizontal deflection proportional to the anode voltage $V_a$ and a vertical deflection proportional to the anode current $I_a$. If the anode voltage is then allowed to oscillate with a sufficiently high frequency between zero and its maximum value, a line is observed on the fluorescent screen which has the form of the $I_a$-$V_a$ curve.

Instead of a single characteristic, it is also possible to make a whole series of characteristics appear on the screen at the same time. In this way it is possible to show the relation between anode current and anode voltage with the control grid voltage as a parameter. To do this it is only necessary that the control grid voltage should take on a number of different values while the characteristic is being recorded.

The advantage of recording characteristics with the oscillograph over the point-by-point measurement with dial instruments lies not only in the great speed, but chiefly in the fact that it is possible to reach parts of the characteristic where slow measurement would lead to overloading of the valve. These parts of the characteristics may be of great practical importance. This is especially true in the case of valves with which the load in ordinary use is not much smaller than the maximum permissible load, which is often the case with transmitting valves for example. When a transmitting pentode is normally loaded, the maximum permissible continuous value of the grid currents and the anode current is far exceeded at the positive peaks of the oscillating control grid voltage. It is important to know the shape of the characteristic for this high control-grid voltage, in order for instance to be able to calculate the output power of a transmitting valve.

The measurement of transmitting valve characteristics

Fig. 1 gives the principle of the previously described arrangement which was used for the recording of receiving valve characteristics. The anode of the valve to be examined is fed with a direct voltage and an alternating voltage of the same maximum value, so that the total voltage oscillates between zero and its maximum value. The grid of this valve is connected to the horizontal deflection plates. The grid voltage is made to oscillate between the grid voltage at which the valve is normally loaded and a high positive value, so that a whole series of characteristics is produced on the screen at the same time.

lates between zero and a maximum value. By means of a rotating commutator C a number of different control grid voltages are successively applied during each revolution, the horizontal deflection is obtained by means of a voltage which is taken from the potentiometer $R_2$, and which is proportional to the momentary value of the voltage anode. The vertical deflection is determined by the fall in voltage at the measuring resistance $R_1$, and is proportional to the anode current. On the screen of the tube there appears a series of $I_a-V_a$ characteristics with $V_g$ as a parameter.

This method is useful only when, as in the case given, curves are being recorded with negative control-grid voltages. When the value of the control-grid voltage is positive various difficulties are experienced with the commutator. In the first place sparks occur at the interrupter contacts due to the grid current, so that the voltage cannot be switched off at the desired moments. In the second place the voltage at the interrupter contacts does not remain constant on the occurrence of grid current because the grid circuit has resistance.

It was particularly the second difficulty which led to a modification of the principle. Instead of varying the grid voltage in steps, an ordinary practically sinusoidal alternating voltage is supplied to the grid. By means of an electronic switch, which will be described below, it was arranged so that the cathode ray tube only gives light when the grid voltage has just those values which have been chosen as parameters of the $I_a-V_a$ characteristics. In order to carry this out, irrespective of the form of the grid alternating voltage, which may change in some cases due to the appearance of grid currents, a switch arrangement without inertia is required. This can be obtained with the help of a second cathode ray tube which will be called the impulsetube.\footnote{This idea was proposed by K. Posthumus.}

\textbf{Fig. 2} indicates the principle of the impulsetube. The tube contains a pair of deflection plates $P$, to which is applied a voltage proportional to the control-grid voltage of the tube being investigated. Instead of a screen the impulsetube has two parallel plates $a$ and $b$, the first of which is provided with thirty narrow parallel slits at equal distances. When the cathode ray swings back and forth across plate $a$ under the influence of an oscillating deflection voltage, a small current strikes the plate $b$ every time the ray passes across a slit, and a voltage impulse on the resistance $R$ results. After amplification this impulse with the correct sign is applied to the regulatory electrode of the cathode ray tube.
which records the characteristics, and which we shall call the "characteristic tube" to avoid misunderstanding. This regulatory electrode has a negative bias such that the signal current of the characteristic tube is usually completely suppressed, and only flows during the impulses.

The grid direct voltage is best chosen strongly negative, so that current only flows during a small part of the period. This greatly reduces the average load \(^3\). The amplitude of the grid alternating voltage must of course be chosen so great that the maximum grid voltage still has the desired value. The anode direct voltage, as mentioned before, is best adjusted at a value equal to the amplitude of the anode alternating voltage.

The measuring voltages taken off are fed to the amplifiers \(V_1, V_2, V_3\). \(V_1\) receives the control-grid voltage, \(V_2\) the anode voltage and \(V_3\) the anode current. The amplified control-grid voltage is fed to the impulse tube and finally regulates the beam current of the characteristic tube. The anode voltage

Details of the circuit

After this description of the impulse tube we shall consider briefly the other components of the measuring arrangement. The diagram of the circuit of the measuring arrangement is reproduced in fig. 3, while fig. 4 is a photograph of it. An alternating voltage of 500 cycles/sec is supplied to the control grid of the valve to be investigated by the transformer \(Tr\, 1\), while the anode of the valve is supplied through \(Tr\, 2\) with an alternating voltage of 50 cycles/sec. Both voltages can be regulated and read. In addition the grid as well as the anode has a direct current which can also be regulated and read.

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\(^3\) This adjustment of grid direct voltage and alternating voltage, the so-called class C amplification, is often applied in practice to transmitting valves. See in this connection the article on transmitting pentodes: Philips techn. Rev. 2, 257, 1937.
provides the horizontal deflection and the anode current the vertical deflection of the electron beam. In order to obtain a good picture of the characteristics it is necessary that the amplified voltages on the deflection plates and the regulatory electrode of the characteristic tube should be exactly in phase with the corresponding quantities on grid or anode of the transmitting valve. A certain difference of time between the voltage on the characteristic tube and the corresponding quantity on the transmitting tube is of course permissible if it is the same for all three quantities. The amplifiers are so changed that the phase relation of output voltage and input voltage can be regulated to a certain extent. In the ordinary adjustment output and input voltage are in phase. If, however, for instance due to coupling condensers, a phase shift occurs, it must be corrected by a slight change of adjustment.

The circuit diagram of the amplifiers is given in fig. 5. Part of the input voltage \( V_i \) is tapped off from the potentiometer \( q \) and is amplified in two stages of resistance amplification. Each of the two anodes is connected over a condenser with one of the deflection plates of the cathode ray tube.

As may be seen the sum of the two anode currents flows through the circuit formed by the resistance \( R \) and the condenser \( C \). This causes a feedback. The feedback voltage will not be in phase with the input voltage because the \( RC \) circuit does not have a purely ohmic impedance. The result is that the output voltage is generally also out of phase with the input voltage. If, however, the anode alternating currents of the two amplifier valves have precisely opposite amplitudes, so that the sum of the anode currents is constant, the back coupling disappears and with it the phase difference between output voltage and input voltage. This latter is the normal adjustment.

As may be seen from the diagram the normal adjustment can be obtained by setting potentiometer \( p \) so that the amplitudes of the two anode currents become equal in size. Since the two amplifier valves work in opposite phases, the sum of the two anode currents then really does remain constant and the phase shift becomes zero. When, however, a slight phase shift occurs in the external circuits of the amplifier, it can be corrected by changing the potentiometer \( p \).

### How the installation works

The way in which the images are formed can be seen from fig. 6. In that figure of the curved surface \( I_a = f(V_a, V_g) \) is drawn with the \( I_a-V_a \) characteristics corresponding to nine equidistant values of the grid voltage. Each of these voltages may be made to correspond to a slit in the plate of the impulse tube; when the electron beam passes one of these slits the grid voltage has a definite value and a point of the respective \( I_a-V_a \) characteristic is drawn, point \( P \) for example. On the screen of the characteristic tube appear the projections on the \( I_a-V_a \) plane of the nine characteristics drawn on the surface.

For the sake of clearness in fig. 6 the frequency of the grid voltage is taken equal to four times that of the anode voltage (instead of ten times), and both are considered to be sinusoidal. It may be seen that the same points are traced over and over, so that a stationary picture of discrete points is obtained. In the \( V_a-V_g \) plane the same curve is traced over and over, namely a Lissajous figure for the frequency ratio 4 : 1.

The direct voltage for the anode, as already indicated, is chosen so that the total anode voltage varies between zero and twice the value of the direct voltage. It is hereby assumed that the anode current causes practically no voltage loss in the external circuit of the anode, a circumstance which is not always attainable in practice. If this is not the case the parts of the \( I_a-V_a \) characteristic corresponding to the highest positive grid anode voltages are of course not reached (see fig. 7).

![Fig. 7. \( I_a-V_a \) characteristics of the transmitter triode TC\(^{(\circ)} \). Abcissa: 1 cm = 150 volts; ordinate: 1 cm = 30 mA. The anode current was limited by an external resistance. The uppermost curve is for \( V_g = 40 \) volts, in the succeeding curves the grid voltage is 10 volts lower in every case.](image)

If the frequencies of the alternating voltages for grid and anode of the valve being investigated were 500 and 50 cycles/sec respectively, a stationary image, as is fig. 6, consisting of a number of points would appear. Actually the two voltages are taken from two independent sources which are practically never exactly synchronous. The result is that the points are not stationary but run along the char-
acteristic, so that the curves are drawn as continuous lines.

In order to obtain sufficiently sharp points on the characteristic tube, the width of the slits and the diameter of the electron beam must be carefully chosen in the construction of the impulse tube. If the width of slit or diameter of beam is too great, vertical lines instead of points appear in the characteristic tube, which decreases the precision. If they are both too small the impulses are too short, and the brightness of the image in the characteristic tube is too low.

Furthermore, in order to obtain sharp characteristics it is necessary that the impulse amplifier also be able to amplify relatively high frequencies sufficiently, so that the correct form of the voltage peaks will be retained. If for example twenty slits have been passed over, and the frequency of the grid voltage is 500 cycles/sec, then, since each slit is passed over twice in every oscillation, there will be $500 \times 20 \times 2 = 20000$ impulses per sec. The duration of each voltage peak is thus in any case small compared with $1/20000$ sec, and the amplifier must be able to amplify high harmonics of 20000 cycles/sec in order to transmit these voltage peaks undistorted.

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS OF THE N.V. PHILIPS GLOEILAMPENFABRIEKEN


For several typical cases (air, Ne, Ne + 0.1% Ar) the relation is given between the breakdown potential between parallel plates and the elementary processes. From the manner in which the breakdown potential depends upon the potential difference traversed per free path, the relation is deduced between the breakdown potential and the product of gas density and breakdown distance (Paschen curve), which is a measure of the breakdown distance with unit density of gas. The shapes of these different kinds of curves are discussed.


The breakdown in a gas differs in many cases from the simple case of breakdown between two parallel plates. The breakdown potential and the characteristic of the corona discharge are explained qualitatively. The ignition of the positive column and of an arc with externally heated cathode are discussed.


The experiments of Strigel, Braunbek, Hertz and Schade on the temporal aspect of the breakdown in gases at different pressures are discussed. Especially attention is given to Schonland's physical explanation of lighting discharges, and the possibility is pointed out of generating artificial lighting.


As a supplement to previous investigations (cf. 1264 and also 1318) the distribution of field strength is calculated for a transmitter which emits radio waves over a homogeneous spherical earth with an arbitrary electrical conductivity and dielectric constant. The transmitter and receiver are assumed to be on the surface of the earth. As far as is known to the authors the calculations give the most accurate results. Finally curves are given for the field strength as a function of the distance of propagation over the sea and over an average type of land.