ELECTRON TUBES

RCA Application Note

AN - 150

Measurement of Dissipation in Plate of Horizontal-Deflection Output Tube

In the design of television horizontal-deflection circuits, a knowledge of the power dissipated in the plate of the horizontal-output tube enables the designer to make sure that the tube rating is not exceeded and that circuit efficiency is high. This Note* describes a method of determining this dissipation. In its simplest form, the method involves the measurement of only four factors: (1) the rms current in the horizontal-deflecting windings; (2) the total dc resistance of these windings; (3) the rms diode current; and (4) the average plate current of the horizontal output tube. Although this method was developed for the popular circuit of Fig.1, in its most general form (equation 1) it is applicable to all deflection circuits. When separate-winding output transformers are used, however, the transformer copper losses and the plate dissipation due to leakage inductance should be determined.

Components of Plate Dissipation

The effective load in the plate circuit of the horizontal-output tube in Fig.1 consists of a reactive and a resistive load. The reactive load represents the power terms P_s, P_x, and P_r, where P_s is the power lost due to leakage inductance in the transformer, P_x is the power output from the boost voltage, and P_r is the power absorbed by the deflection system during retrace (this power is partly dissipated in the windings and partly converted to high-voltage power output). The resistive load consists of R_p which represents both the diode plate loss and the copper losses of the circuit during scanning.

The plate dissipation of the power tube supplying these loads has three components. One is a fraction of P_s, another is a fraction of the power input to R_p, and the third is the so-called "minimum" plate power

* This note is based on material contained in an article entitled "Characteristics of High-Efficiency Deflection and High-Voltage Supply Systems for Kinescopes" by O.H. Schade. This article appeared in the March 1950 issue of the RCA REVIEW.

loss determined from the plate characteristic. Methods for determining these components are developed below.

Leakage-Inductance Component

The amount of plate dissipation due to leakage inductance is difficult to measure. When the transformer is of the autotransformer type, this dissipation can be assumed to be approximately 0.5 watt in most cases. If desired, however, it may be determined more accurately from an expression discussed later in the Note. The more accurate determination may be advisable when the approximate calculation indicates that the plate dissipation is close to the tube rating.

Resistive Component

For all practical circuits and plate-current waveforms (Fig. 2), the conversion efficiency is approximately 0.65, or 1/1.55. In other words, P_R, the dc power input to R_p, equals 1.55 P_{R_p}, where P_{R_p} is the power output dissipated in R_p. The plate dissipation due to R_p is P_R minus P_{R_p}, or 0.55 P_{R_p}. Power P_{R_p} is the sum of the diode plate dissipation and all copper losses in the system. The copper losses, P_{cu}, in the transformer and horizontal-deflecting windings are readily determined from the I^2R formula after the rms currents in the various windings and the corresponding dc resistance of the windings have been measured. To reduce the number of measurements, it may be assumed that $P_{cu} = 1.5\ P_{cu_h}$, where P_{cu_h} is the copper loss in the horizontal-deflecting windings of the yoke. This approximation is valid when an autotransformer is used.

The diode plate loss, P_{p_2}, can be computed from the equation:

$$P_{p_2} = 0.18\ i_{p_2} e_{p_2}$$

After I_{b_2}, the rms current of the diode, is measured with a thermal-type meter, the peak diode current, i_{p_2}, can be determined from the equation:

$$I_{b_2} = 0.41\ i_{p_2}$$

Alternatively, i_{p_2} can be measured directly by means of a calibrated oscilloscope and resistor. The peak plate voltage, e_{p_2}, is then found on the static characteristic of the diode at the point corresponding to a plate current of i_{p_2}.

The values of P_{lin}, the copper loss in the linearity transformer, is approximately 25 per cent of the power it handles, i.e.,

$$P_{lin} = 0.25(P_{p_2} + P_{cu}/2)$$

This relationship holds for linearity controls with either single or multiple windings.

"Minimum" Component

The "minimum" portion of the plate power loss is the product of I_{b_1}, the average plate current, and E_{min}, the minimum value that the plate voltage attains cyclically. The value of E_{min} should be adjusted to come slightly above the knee of the plate characteristic, as discussed later. Next, Ib_1 is measured with a dc meter. Because the peak current handled by the tube is closely equal to three times Ib_1, the peak current ip_1 is determinable. The value of E_{min} can then be found from the plate characteristic; it is the voltage that causes a plate current of ip_1 when the control-grid voltage reaches its most positive swing (usually zero volts).

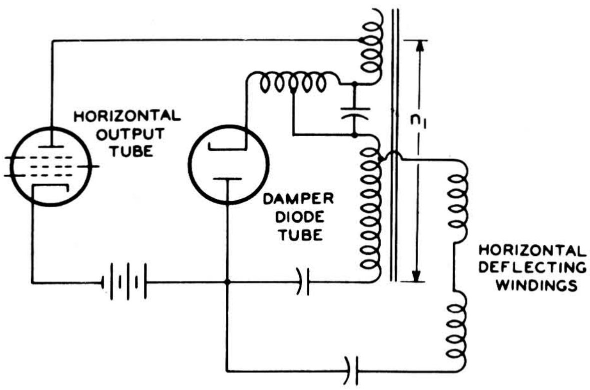


Fig.1 - Partial Schematic of Typical Horizontal-Output Circuit

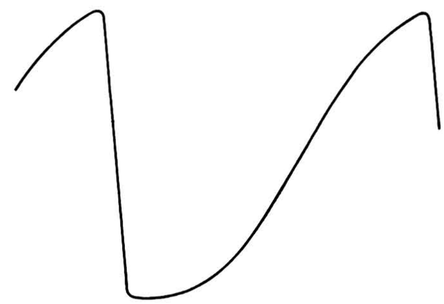


Fig.2 - Typical Waveform of Current in Horizontal-Output Tube

Total Plate Dissipation

The total plate dissipation of the horizontal-output tube is now seen to be the following:

$$\text{Plate dissipation} = E_{min}Ib_1 + 0.55\left[P_{cu} + P_{p2} + 0.25\ (P_{cu}/2 + P_{p2})\right] + 0.5$$

$$= E_{min}Ib_1 + 0.62_{cu} + 0.69P_{p2} + 0.5 \qquad (1)$$

or, more approximately, on the previously discussed assumption that $P_{cu} = 1.5P_{cuh}$,

$$\text{Plate dissipation} = E_{min}Ib_1 + 0.93P_{cuh} + 0.69P_{p2} + 0.5 \qquad (2)$$

Precise Evaluation of Leakage Component

The value of P_{sp}, the plate dissipation due to leakage inductance, which is assumed above to be 0.5 watt, may be computed, if desired, from the following expression.

$$P_{sp} = (E_{bb} - E_{min} - E_{R_p})(1 - \frac{L}{L + L_s})(Ib_1) - 0.5fL_s(ip_1)^2$$

where E_{bb} is the boosted voltage; L_s is the leakage inductance of the section of the transformer across which the horizontal-output tube is connected; L is the inductance of this section when the deflecting windings are connected in conventional fashion; f is the horizontal-scanning frequency, 15,750 cycles per second; and E_{R_p} is the voltage which causes the dc power input P_R to the load R_p, as determined from the equation:

$$E_{R_p} = 1.55P_{R_p}/Ib_1$$

The magnitude of L is determined by measuring the inductance of transformer winding n_1 (Fig.1) with the deflection winding connected as shown. The value L_s is the inductance measured across n_1 when the deflection windings are shorted out. In both cases the linearity transformer should be shorted out.

Correct Operating Conditions

An excess value of B voltage, E_b, causes increased circuit losses (Fig. 3a); insufficient B voltage reduces the output. The correct E_b is that which causes E_{min} to fall slightly above the knee of the characteristic curve (Fig. 3b). A way to determine this correct operating condition follows. Apply a moderately excessive value of B voltage. Slowly reduce this voltage while holding all grid voltages constant. While the output power of the horizontal-output tube decreases slowly, the minimum tube drop is still above the knee of the curve. When, at length, any further decrease in B voltage causes a sudden sharp decrease in output and an increase in screen current, E_{min} has just passed below the knee of the curve. The value E_b at which this phenomenon occurs should be noted. The B voltage used in the design should be a few volts greater than this value, so that E_{min} will fall at or just above the knee.

Sample Calculation

An example follows of the determination of plate dissipation. The circuit measured uses a 6BQ6-GT horizontal-output tube, a 6W4-GT damper diode, and an experimental autotransformer and yoke. The calculated dissipation is close to that obtained by a more time-consuming thermocouple method in which the dynamic plate loss is equated to the static plate loss that causes the bulb temperature to be the same as under dynamic conditions.

After E_{min} has been adjusted to come above the knee of the characteristic curve, the dc plate current I_{b_1} is measured to be 83.5 milliamperes. From the relationship that i_{p_1} equals $3I_{b_1}$ the calculated peak plate current is 250 milliamperes. From the characteristic curve, E_{min} corresponding to 250 milliamperes is 60 volts. The copper loss (P_{cu_h}) in the horizontal-deflecting windings is determined from measurement of the rms current in the windings, 305 milliamperes, and of the resistance of the windings, 22 ohms. Therefore,

$$P_{cu_h} = I^2R = (0.305)^2 \times 22 = 2.04 \text{ watts}$$

Dividing 0.41 into the rms diode current I_{b_2}, measured at 164 milliamperes, gives the peak diode current i_{p_2}, 400 milliamperes. From the 6W4-GT characteristic curve, the plate voltage for a current of 400 milliamperes is 29 volts. Therefore,

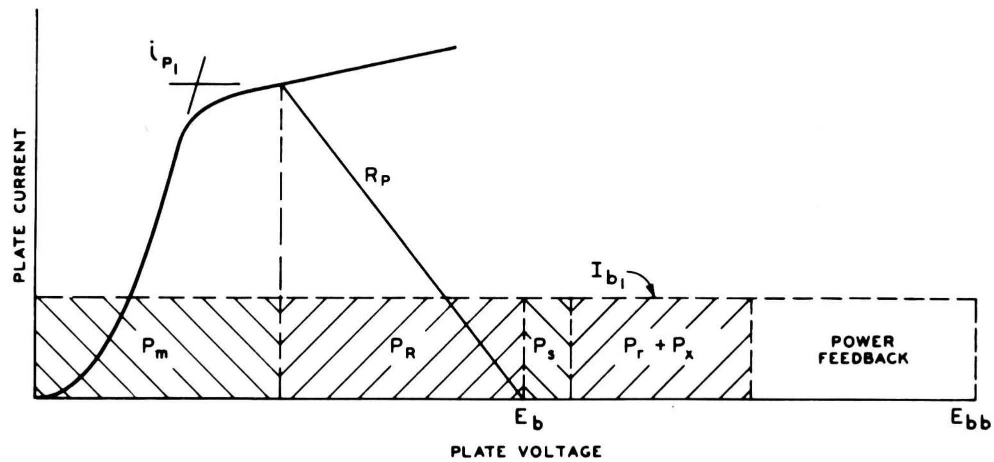
$$P_{p_2} = 0.18\, i_{p_2} e_{p_2} = 0.18 \times 0.4 \times 29 = 2.09 \text{ watts}$$

From equation 2,

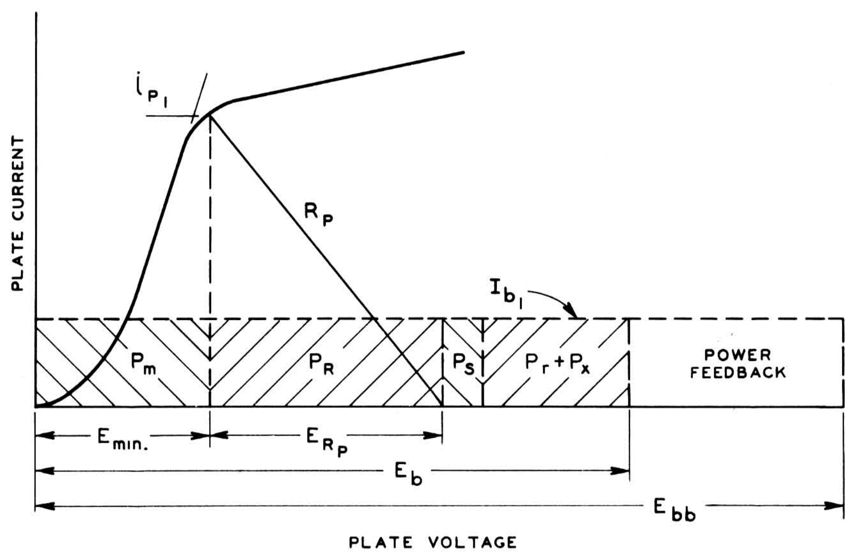
$$\text{Plate dissipation} = E_{min} I_{b_1} + 0.93 P_{cu_h} + 0.69\, P_{p_2} + 0.5$$

$$= (60 \times 0.0835) + (0.93 \times 2.04) + (0.69 \times 2.09) + 0.5$$
$$= 8.85 \text{ watts}$$

The comparable value arrived at with the thermocouple method is 9.1 watts.



- a -



- b -

Fig. 3 - Plate Load Diagrams for Horizontal-Output Tube Under (a) Excessive B-supply Voltage, and (b) Correct B-supply Voltage. In these Diagrams, E_b is the B-supply Voltage and E_{bb} is the Boosted Voltage; the other Symbols are Defined in the Text