the valve will run into grid current as soon as the load resistance either increases or decreases. It is therefore not suitable for use on a loudspeaker load unless the input voltage is reduced. A 10% reduction in input voltage (19% in power output) would be some improvement, but greater reduction is desirable, say 20% to 30% of the input voltage, depending on the operating conditions. Even with an input reduction giving a power output of only 50% maximum, the pentode is still less flexible with regard to load resistance than an ordinary triode. This position improves as the amount of feedback is increased.

See References D4, D12.

FIG. 7.95

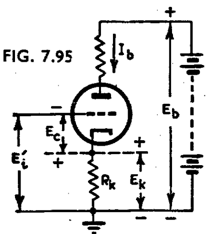

Fig. 7.95. *Basic circuit of cathode degenerative triode.*

(v) Cathode degenerative triode

The circuit diagram of a cathode degenerative triode is shown in Fig. 7.95 from which it is evident that

$$E_c = E_i' - E_k \tag{10}$$

The curves of a cathode degenerative triode may be drawn by the procedure outlined below, although a special set of characteristics is required for each value of R_k. Fig. 7.96 shows the curves for a typical general purpose triode with $R_k = 1000$ ohms. The input voltage curves are straighter than those without feedback, and the two curves coincide only at $I_b = 0$. The E_i' curves have a lower slope, indicating a higher plate resistance, than the E_c curves.

Take the $E_i' = -4$ V curve as an example of the calculations. We know that $R_k = 1000$ ohms and $E_i' = -4$ V. If $I_b = 2$ mA, then $E_k = 2$ V and $E_c = E_i' - E_k = -4 - 2 = -6$ V.

Refer to the plate characteristics to find the plate voltage which will give a plate current of 2 mA at a bias of -6 V —the value is $E_{pk} = 144$ volts.

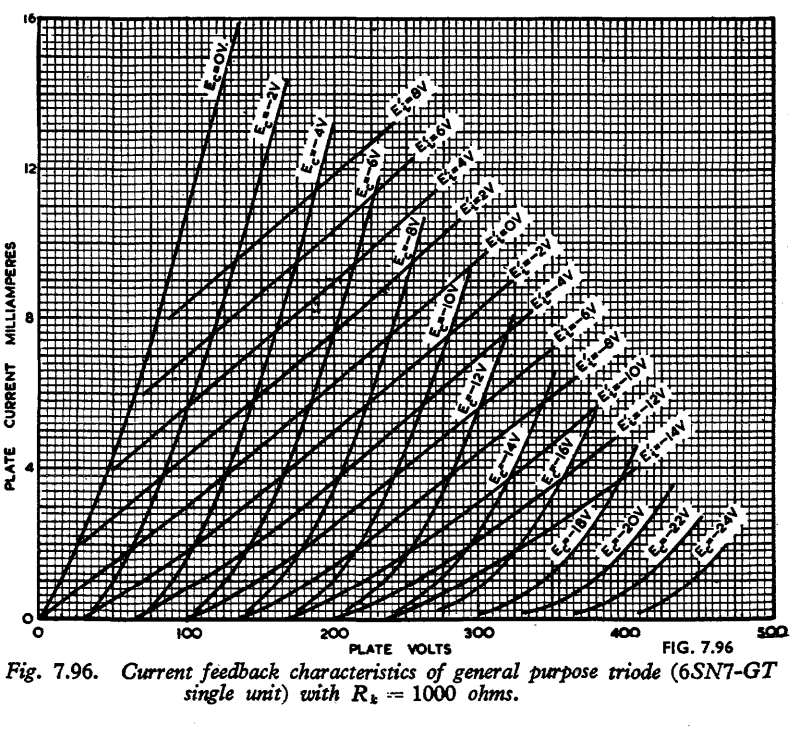

FIG. 7.96

Fig. 7.96. *Current feedback characteristics of general purpose triode* (6*SN*7-*GT single unit*) *with* $R_k = 1000$ *ohms.*

The total voltage (E_b) from plate to earth is

$$E_b = E_{pk} + E_k = 144 + 2 = 146 \text{ V}.$$

Therefore the point ($E_b = 146$ V; $I_b = 2$ mA) is on the $E_i' = -4$ V curve. Repeat this procedure for $I_b = 0$, 4, and 6 mA to give the whole curve; then perform a similar operation for $E_i' = -6$ V, -8 V and so on.

The loadline may then be drawn in the normal manner, except that its slope will be $-1/(R_k + R_L)$. The E_i' curves are to be used for calculating gain and distortion.

The method generally employed with cathode degenerative triodes makes use of the published characteristics. There are several methods including those of Middleton, McIlroy, Huber, Lonsdale and Main; the following treatment is based on Krauss, and may also be applied to cathode followers.

As an example take the characteristics of Fig. 7.97 with $R_k = 8\,000$ ohms, $R_L = 32\,000$ ohms and $E_{bb} = 400$ volts. Draw the loadline corresponding to $R_k + R_L = 40\,000$ ohms, as shown. Add an E_k scale below the E_b scale, based on the equation $E_k = R_k I_b$, commencing from E_{bb}. The value of E_k at any point on the loadline may then be found by projecting downwards to the E_k scale.

The input voltage E_i' is not proportional to any scale on the diagram, because the amplification is not constant. The value of E_i' at any point of intersection along the loadline may be found by drawing up the following table where each value of E_c is taken in turn. The input voltage is actually ($E_k + E_c$), but for convenience the point ($E_c = -8$) has been selected as the operating point, and so shown in the E_i' column.

E_c	E_k	$(E_k + E_c)$	E_i'	
0	64	64	34.7	Point A
−2	57	55	25.7	
−4	50.2	46.2	16.9	
−6	43.6	37.6	8.3	
−8	37.3	29.3	0	Operating point (O)
−10	31.2	21.2	−8.1	
−12	25.1	13.1	−16.2	
−14	19.6	5.6	−23.7	
−16	14.7	−1.3	−30.6	} Point B at $E_k = 11.9$
−18	10.1	−7.9	−37.2	} and $E_i' = -34.7$
−20	6.2	−13.8	−43.1	

The values of E_i' may be plotted against E_k and therefore also against E_b to give the dynamic characteristic, but this is usually unnecessary. Once the maximum input voltage has been selected it is only necessary to mark the extremities on the loadline. For example, if it is desired to swing to $E_c = 0$, then the peak E_i' will be 34.7 volts in each direction. The peak in one direction will be A where $E_c = 0$, and the other will be B, determined by interpolation:

$$E_c = -16 \quad E_k = 14.7 \quad E_i' = -30.6$$
$$E_c = -18 \quad E_k = 10.1 \quad E_i' = -37.2$$
$$\text{Diff.} = \quad 6.6$$

Also the difference between the desired value (-34.7) and -30.6 is 4.1. The ratio is therefore 4.1/6.6.

Similarly with E_k: $14.7 - 10.1 = 4.6$.

The value of E_k for point B is therefore $14.7 - 4.6\,(4.1/6.6) = 14.7 - 2.8 = 11.9$.

The voltage gain and power output may be calculated from $E_b = 5E_k$, using the values of E_k at $E_i' = 34.7$ (point A), $E_i' = 0$ (point 0) and $E_i' = -34.7$ (point B). The second harmonic distortion may be found from the ratio AO/OB measured in volts (E_k); i.e. $(64 - 37.3)/(37.3 - 11.9) = 26.7/25.4 = 1.05$. Therefore $H_2 \approx 1\%$—see Chapter 13 Sect. 2(i).

References D1, D3, D5, D8, D9, D10, D11.

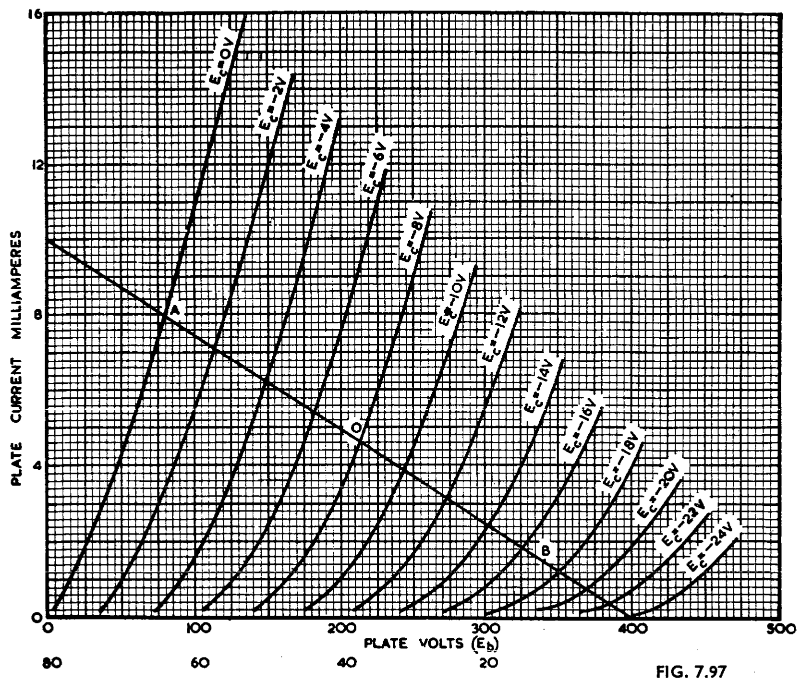

FIG. 7.97

Fig. 7.97. *Method of calculating performance of cathode degenerative triode without drawing special characteristics.*

(vi) Cathode degenerative pentode

The general procedure is the same as for triodes, except that allowance must be made for the d.c. screen current flowing through R_k. This is done by taking $(E_{bb} - R_k I_{c2})$ as the effective plate supply voltage, and then by carrying on as for the triode case.

For valves with a high plate resistance this method is not very satisfactory, and a more practical method has been described by Pratt.

References D1, D11.

(vii) Cathode-coupled triodes

It is possible to make a graphical analysis of the cathode-coupled amplifier, using ordinary published valve characteristics (Ref. D6).

(viii) Feedback over two stages

It is possible to draw the equivalent characteristics of two stages in cascade with feedback over both stages, following the method of Pratt (Ref. D1).

Alternatively, it is possible to use the published valve characteristics to obtain a graphical analysis (Ref. D7).

SECTION 6 : REFERENCES TO FEEDBACK

A) GENERAL REFERENCES TO THEORY OF FEEDBACK

A1. Black, H. S. " Stabilised feedback amplifiers " E.E. 53 (Jan. 1934) 114 ; Also B.S.T.J. 13.1 (Jan. 1934) 1.

A2. Black, H. S. " Feedback amplifiers " Bell. Lab. Rec. 12 (June 1934) 290.

A3. Editorial Review " Feedback amplifiers " Elect. 9.7 (July 1936) 30.

A4. Edit. " Negative feedback amplifiers—a new development " W.W. 39.19 (6th Nov. 1936) 475.

A5. Tellegen, B. D. H., and V. C. Henriquez, " Inverse feedback " W.E. 14.167 (Aug. 1937) 409.