RADIOTRONICS
AMALGAMATED WIRELESS VALVE COMPANY LIMITED

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RADIOTRON 6B7S AND AUDIO A.V.C.

Radiotron 6B7S was introduced so as to have a wide variety of applications, one of which is audio automatic volume control. In receivers employing a large number of controlled stages the A.V.C. characteristic is normally so good as to require no compensation in the audio circuit, but in receivers with two controlled stages or less audio A.V.C. may be employed to advantage in order to eliminate troublesome effects of fading.

In automobile receivers particularly a good A.V.C. action covering an extremely wide range of signal strengths is necessary, and in such an application audio A.V.C. is very valuable.

Although Radiotron 6B7S does not cut off until a bias of nearly 40 volts negative is reached, when used as an audio amplifier the distortion created due to the curved characteristic may be excessive over such a wide range of voltage on the control grid. Tests conducted in the laboratory of Amalgamated Wireless Valve Company Limited have indicated that a special arrangement of screen dropping resistor and potential divider gives very satisfactory operation with extremely low distortion over a fairly wide range of control (Fig. 1).

Fig. 2 gives the dynamic curves of Radiotron 6B7S when used with a plate voltage of 250 volts and a load resistance of 250,000 ohms. Each curve refers to a constant screen voltage, values from zero to 60 volts in 10 volts increments being shown. It will be seen that since the ordinates indicate plate current through a fixed resistance they may also be used to indicate either the steady voltage actually on the plate of the valve or the voltage drop in the load resistance.

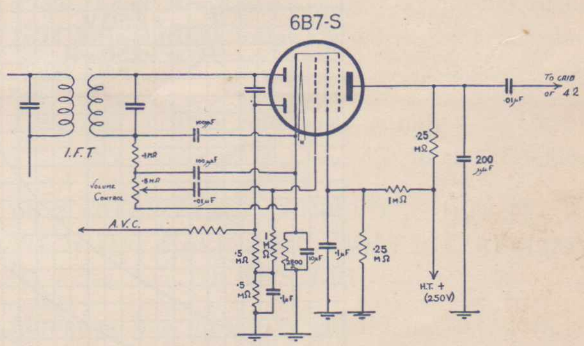


FIG. 1

Referring to the curve marked 30 volts Eg2, it will be seen that linear operation is obtained from about –2 to –3.5 volts beyond which limits the curvature becomes excessive. If a wider range of control is required it is, therefore, necessary to use some system whereby the screen voltage rises as the control grid is made more negative. In the ideal case the screen voltage would be arranged so that the plate current would remain constant, e.g., at 0.6m.A. plate current. In any practical application this would be impossible since it involves the

+250 B supply to the screen should be 1 megohm and from the screen to earth ¼ megohm. The initial bias is provided by a 2500 ohms cathode resistor. Returning the A.V.C. diode plate to earth provides approximately 2 volts delay.

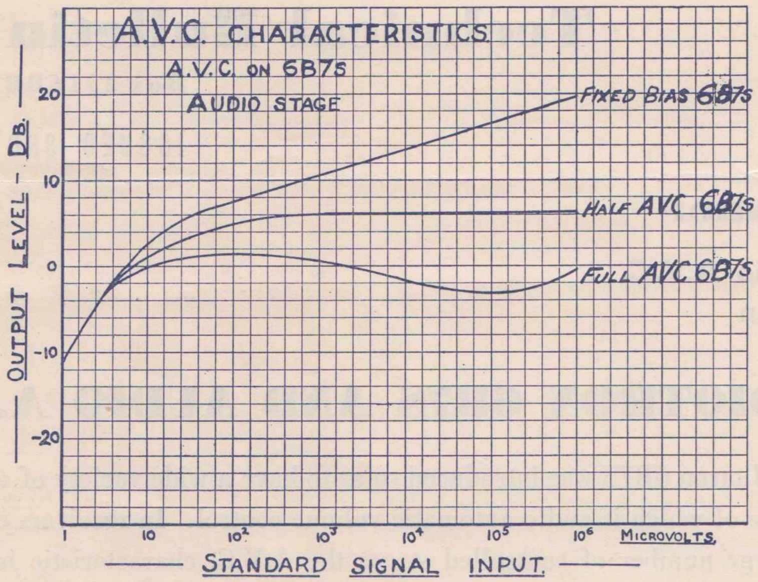


FIG. 2

use of infinitely high screen dropping resistance. A compromise has therefore been adopted (Fig. 1) which incorporates a potential divider for screen voltage supply. The value of the resistor from

In Fig. 2 the working path with the specified potential divider is shown as a dash line and it will be seen that the characteristic is substantially linear from –2 volts to –8 volts on the control grid.

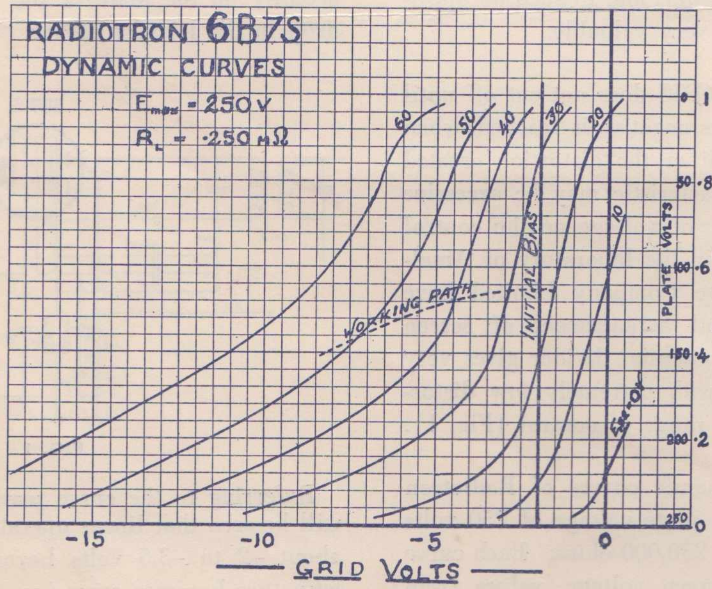


FIG. 3

With larger inputs which occur with signals developing 8 volts bias or more, serious distortion can occur. In order to avoid distortion it is advisable to tap the A.V.C. diode load at the centre and return the grid resistor of the 6B7S to the centre tap. (See Fig. 1.) Under such conditions only half the total A.V.C. bias is supplied to the 6B7S and the distortion is reduced. In addition to the effect of reduced distortion, tapping down the 6B7S A.V.C. to the mid-point also provides a more level A.V.C. characteristic with an average receiver.

Fig. 3 shows the overall A.V.C. curves taken with a receiver having two controlled stages before the second detector, together with three different arrangements on the audio side. The valves used valves used in this receiver were 6A7 Converter, 6D6 Intermediate Frequency Amplifier, and 6B7S Detector Audio A.V.C. and Amplifier.

With no A.V.C. on the 6B7S there is a rise of over 12 d.b. between signal inputs of 100 microvolts and 1 volt, while with half A.V.C. voltage applied to the 6B7S grid the rise over the same range is approximately 1 d.b. Full A.V.C. applied to the 6B7S grid causes a falling response at high input signals which is a serious disadvantage, particularly when tuning by ear. If fewer controlled stages are used, more than half the A.V.C. voltage may need to be applied to the grid of the 6B7S, cr in the other extreme if more than two controlled stages are used it will be preferable to have less than half A.V.C. voltage applied to the 6B7S grid.

This application of the 6B7S provides a A.V.C. characteristic which is superior to that obtainable with any other method of A.V.C. and is recommended for all applications where an ideal A.V.C. characteristic is desired. It must be pointed out, however, that with a perfect A.V.C. characteristic it is difficult to tune a receiver correctly unless a "Magic Eye" tuning indicator is used.

AVERAGE PLATE CHARACTERISTICS
TRIODE UNIT

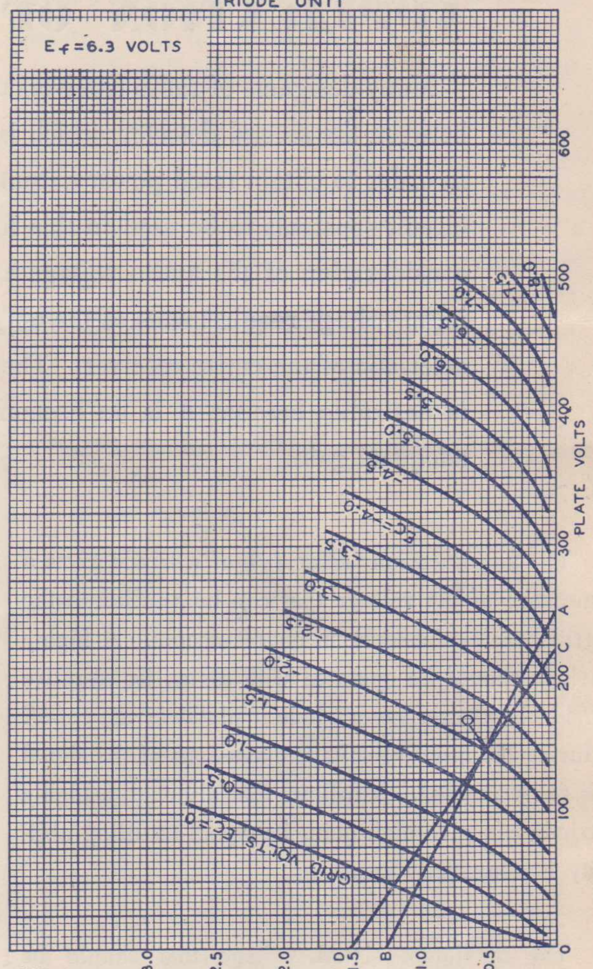


FIG. 1

Plate, Load Resistance . . . . . . 250,000 ohms
Grid Resistance of following valve . . 1 megohm
Stage Gain 60

Distortion at 16.5 volts peak output—
3% total harmonics

SUMMARY

6B7S—RESISTANCE-COUPLED AUDIO STAGE.

Plate Voltage . . . . 250 volts D.C.
Screen Voltage . . . . 24 volts D.C.
Cathode Resistor . . . . 2500 ohms

6B7S—RESISTANCE-COUPLED AUDIO STAGE WITH ONE-HALF A.V.C. VOLTAGE APPLIED TO 6B7S GRID:—

Minimum bias operating conditions, as above. Screen voltage to be obtained from voltage divider consisting of 1 megohm and ¼ megohm to give initial screen voltage of 24 volts.

APPLICATION OF RADIOTRON 6Q7

Many designers of radio receivers use a single stage of audio amplification between the second detector, which is usually a diode, and the output stage in order to obtain rated power output. The type of valve and its associated circuit constants to be used in this first-audio stage are determined from a consideration of the audio voltage available from the second detector, the input-voltage requirements of the output stage, and the desired fidelity characteristic of the entire receiver. The use of a triode in the first-audio stage is desirable because it is an economical way to obtain good fidelity and adequate gain.

The amplification factor (μ) of a triode gives a measure of the voltage that can be applied to the grid before plate-current cut-off occurs. A high-μ triode should be operated with a smaller negative grid bias than a low-μ triode if plate-current cut-off during the negative-voltage excursions of the signal is to be avoided. It follows that although a high-μ triode can give high gain, its signal-handling ability is necessarily small.

The maximum signal voltage that should be applied to the grid of a valve is limited also by the minimum grid voltage necessary to cause flow of grid current. When grid current flows through a high grid impedance, the wave form of the output voltage is distorted. Further, when the high-impedance grid circuit of a valve is isolated from the circuit of the preceding valve by a large blocking condenser, grid current may charge the condenser to a sufficiently high negative potential to cause plate-current cut-off.

Because of the effects of contact potential and the initial velocity of electrons, a heater-cathode type of valve usually draws some grid current when its grid has a small negative voltage. In practice, therefore, it is necessary to limit the most positive instantaneous grid voltage of the valve to a certain minimum negative value with maximum signal applied in order to prevent the flow of grid current during the positive voltage excursions of the signal. Hence, the peak signal voltage that should be applied equals the difference between the value of

CIRCUIT USED FOR DETERMINATION OF OPTIMUM BIAS AND PLATE LOAD

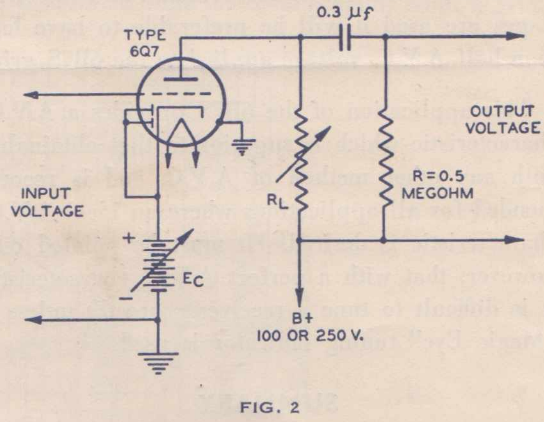


FIG. 2

this minimum voltage and the external negative bias that is required for Class A operation.

The negative grid voltage at which grid current flows is somewhat different for different valves of the same type and changes with age and with electrode voltages. For 100-volt operation of the 6Q7, the minimum grid voltage may be considered as

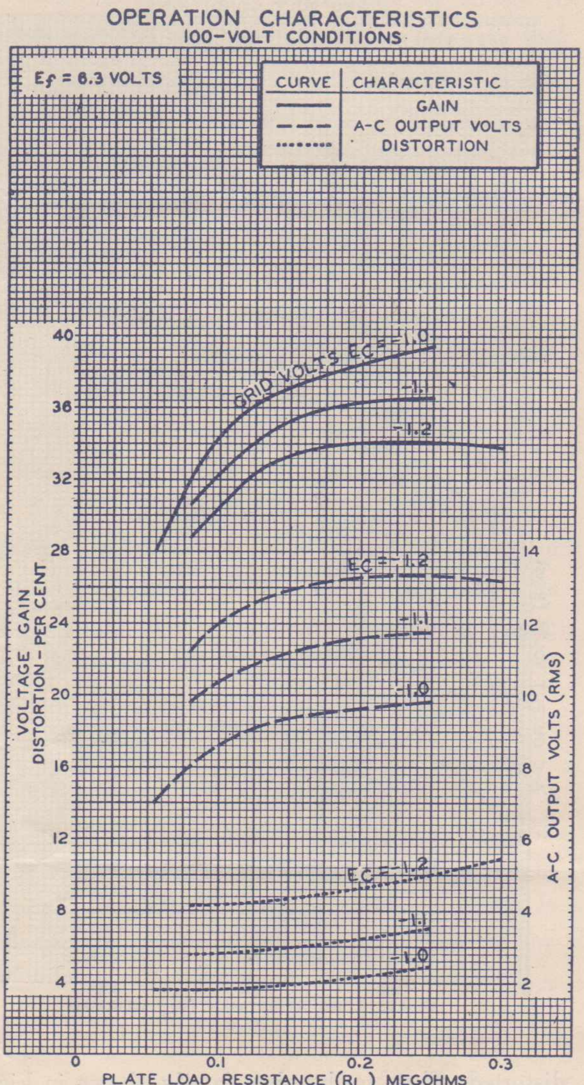


FIG. 3

0.65 volt, at which point the grid current is small enough to be negligible; for 250-volt operation, this voltage may be considered as 0.8 volt in order to provide a greater difference between peak signal and the minimum voltage.

These effects should be considered when choosing a high-μ triode that is to be operated in an a-f amplifier in a radio receiver. A triode that has too high a μ may require such a small bias for 100-volt operation that the permissible peak input signal may not be sufficient to deliver the required output.

The triode section of the 6Q7, an all-metal duplex-diode triode, has a μ of 70, which is high enough to insure adequate gain for most radio receiver applications and low enough to allow a sufficiently negative bias to be used. Therefore,

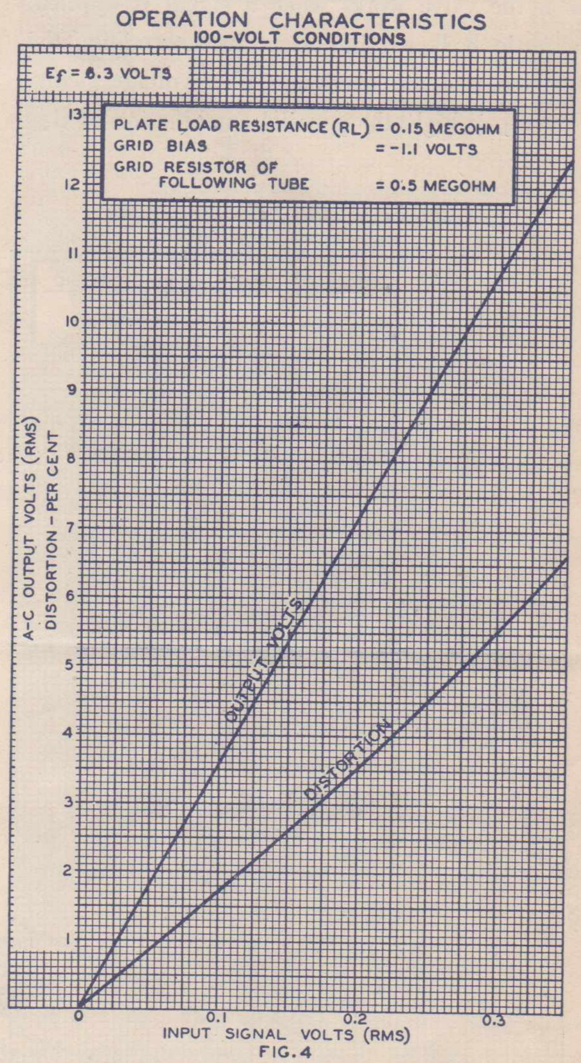


FIG. 4

reasonably high signal voltages may be applied at low plate voltages, where the bias required for Class A operation is small.

The circuit of Fig. 2 was used in order to determine the optimum bias and plate load for 100- and 250-volt operation of the 6Q7. The bias (E_c) and the plate load (R_L) were adjusted for optimum output. The 0.5-megohm resistor (R) represents the grid resistor of the following valve and was connected in the circuit throughout the tests. The value of R_L determines the operating point for given bias and B-supply voltage; the parallel combination of R_L and R determines the load into which the valve works when a signal is applied. The ratio R/R_L is important in determining the distortion and the maximum plate-voltage swing. When R_L is high, the parallel combination of R_L and R may be low enough to cause plate-current cut-off during negative voltage excursions of the signal. When this happens, the output voltage is distorted. Thus, in the plate family, shown in Fig. 1, (AB) is the load line which represents R_L; (CD), which passes through the operating point (O), represents the parallel combination of R_L and R. Load line (CD) is used to compute voltage output and distortion.

OPERATION CHARACTERISTICS
250-VOLT CONDITIONS

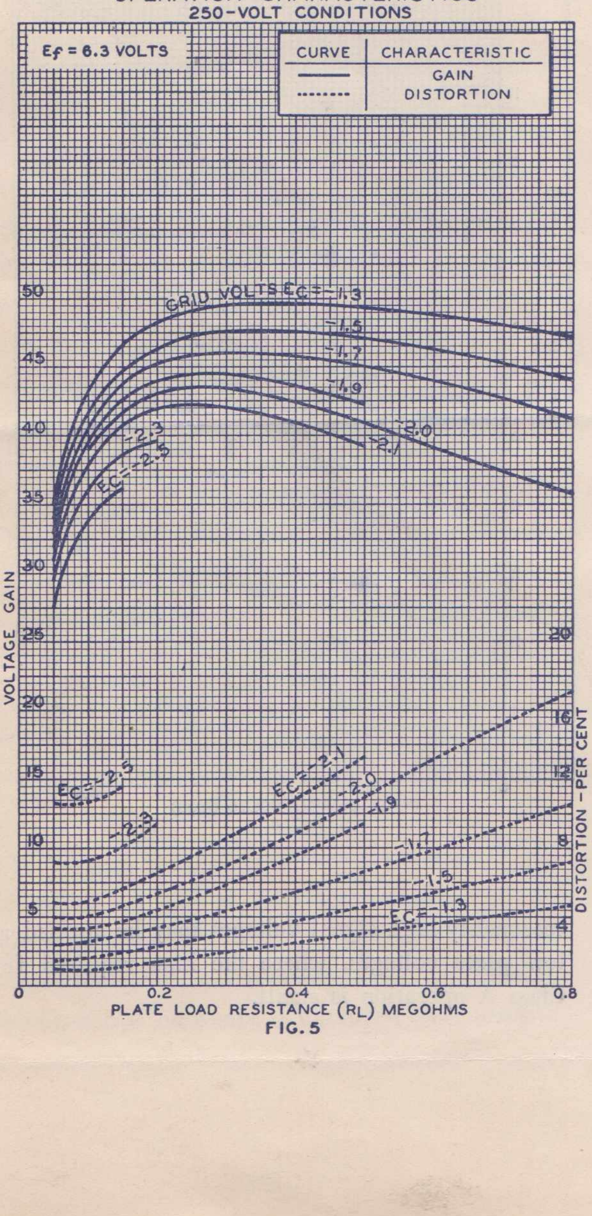


FIG. 5

OPERATION CHARACTERISTICS
250-VOLT CONDITIONS

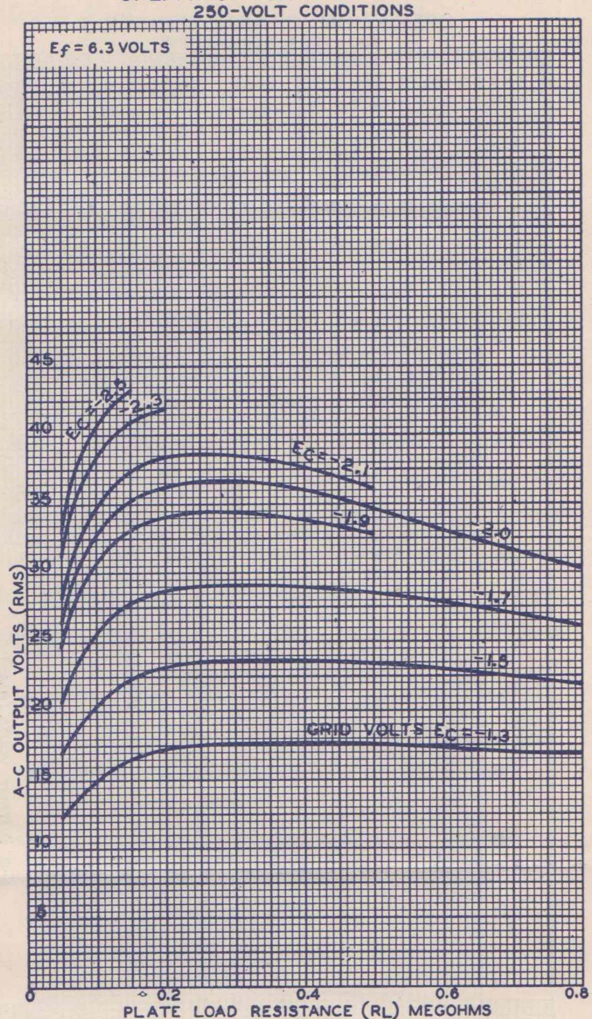


FIG. 6

100-VOLT OPERATION OF THE 6Q7

Fig. 3 shows curves of gain, voltage output, and distortion vs. plate load resistance (R_L) for grid biases of –1.0, –1.1, and –1.2 volts. In each case, the input signal was that which reduced the instantaneous grid voltage to a minimum of –0.65 volt; the B-supply voltage was 100 volts.

From these curves, it is seen that the effects of decreasing the bias are to increase the gain and decrease the distortion. The voltage output is also reduced, but this reduction is due to the small signal which can be applied before grid current flows. If the bias is fixed by the signal voltage available from the diode, the optimum plate load resistance (R_L) for a given application may be selected after considering gain and distortion requirements. For a given bias, both gain and distortion increase with R_L. For 100-volt operation of the 6Q7, a bias of –1.0 volt should be used when the applied signal is small; a bias of –1.2 volts should be used when the applied signal is large. For most applications in radio receivers, however, a bias of –1.1 volts and a plate load resistance (R_L) of 0.15 megohm are suitable. The voltage output under this operating condition is sufficient to drive a 25A6 to rated output.

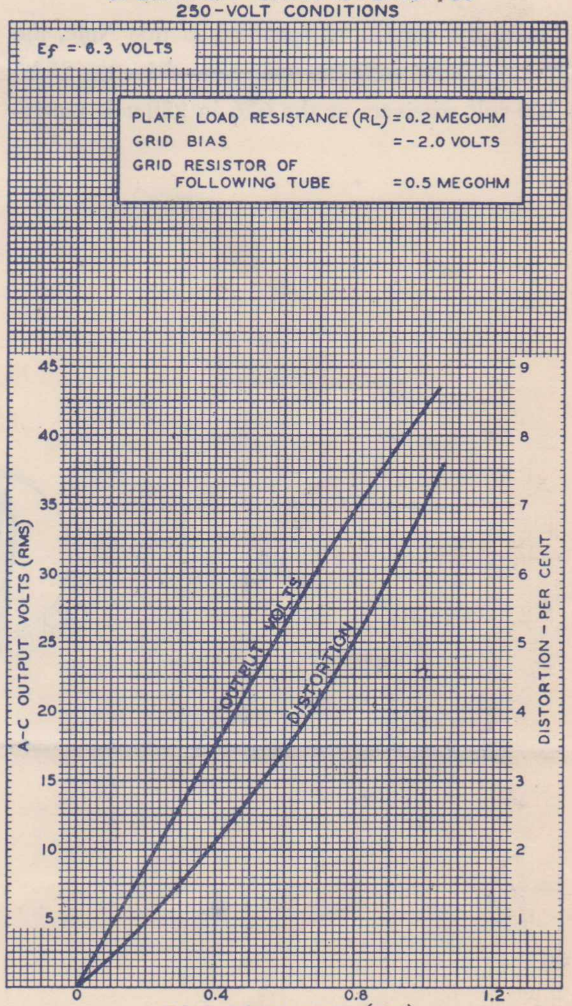
Curves of a-c output and distortion vs. input signal for the condition of –1.1 volts bias and 0.15-megohm plate load resistance (R_L) are shown in Fig. 4. At 10.6 volts (r.m.s.) output, which is necessary to drive a 25A6 to rated output for the 100-volt operating condition, the distortion is 5.5 per cent. and the required input signal is 0.3 volt (r.m.s.).

250-VOLT OPERATION OF THE 6Q7

Fig. 5 shows curves of gain and distortion vs. plate load resistance (R_L) for a number of grid biases. In each case, the input signal was that which reduced the instantaneous grid voltage to a minimum of –0.8 volt; the B-supply voltage was 250 volts.

As with 100-volt operation, highest gain and least distortion are obtained with the smallest bias; also, the a-c output increases with bias, as shown in Fig. 6. Since the bias is determined by the magnitude of the applied signal, the plate load resistance (R_L) can be selected after considering

OPERATION CHARACTERISTICS
250-VOLT CONDITIONS



INPUT SIGNAL VOLTS (RMS)
FIG. 7

gain and distortion requirements. For most radio receiver applications, a bias of –2.0 volts and a plate load resistance (R_L) of 0.2 megohm are suitable.

Curves of a-c output and distortion vs. signal input for the condition of –2.0 volts bias and 0.2

megohm plate load resistance (R_L) are shown in Fig. 7. At 11.7 volts (r.m.s) output, which is necessary to drive a 6F6 (Class A pentode connection) to rated output for the 250-volt operating condition, the distortion is 1.3 per cent. and the required input signal is 0.27 volt (r.m.s.).

CONCLUSION

Under the conditions specified in this Note, the 6Q7 can furnish sufficient voltage to drive the 25A6 in 100-volt receivers or the 6F6 in 250-volt receivers to full output. For convenience, recommended operating conditions are tabulated below:—

Heater Voltage (A.C. or D.C.)	6.3	6.3	Volts
Heater Current	0.3	0.3	Ampere
Plate-Supply Voltage	100	250max.	Volts
Grid Voltage	−1.1	−2.0	Volts
Plate Current	0.25	0.5	Milliampere
Plate Load Resistance (R_L) ..	150000	200000	Ohms
Grid Resistor	1.0max.	1.0max.	Megohm
Self-Bias Resistor	4400	4000	Ohms
Grid Resistor*	0.5	0.5	Megohm

* Of the following valve.