RCA MANUFACTURING COMPANY, INC.
A RADIO CORPORATION OF AMERICA SUBSIDIARY
Harrison, New Jersey

RCA RADIOTRON
DIVISION

APPLICATION NOTES

APPLICATION NOTE No. 59
May 7, 1936.

APPLICATION NOTE ON OPERATION OF THE 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 tube 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 tube 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 tube is isolated from the circuit of the preceding tube 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 tube 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 tube 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 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 tubes 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 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, 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 tube 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 tube 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.

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 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	250 max.	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	1.0 max.	1.0 max.	Megohm
Self-Bias Resistor	4400	4000	Ohms
Grid Resistor*	0.5	0.5	Megohm

*Of the following tube.

Cunningham Radiotron

RCA-6Q7

AVERAGE PLATE CHARACTERISTICS
TRIODE UNIT

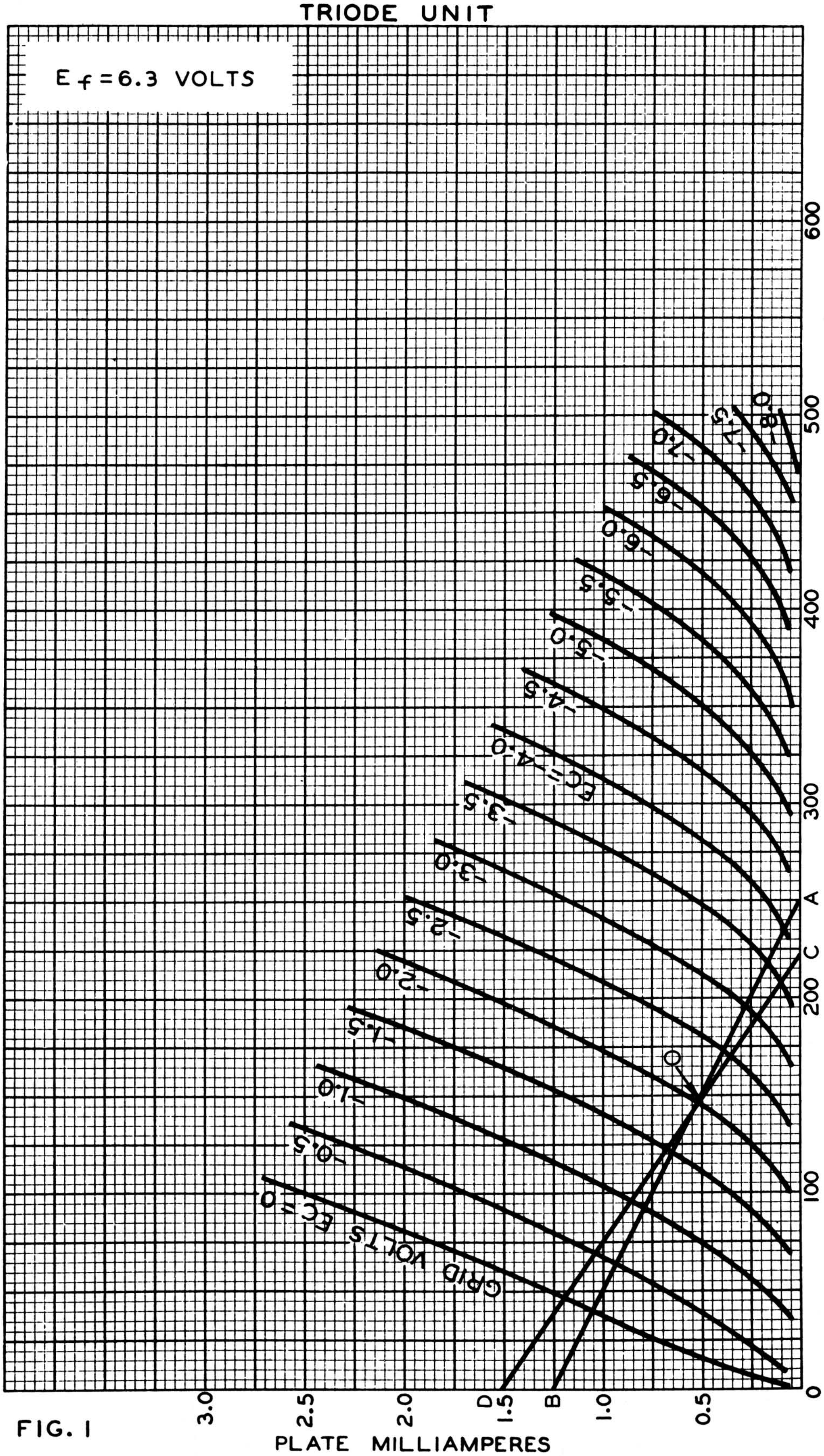

FIG. I

APRIL 9, 1936

RCA RADIOTRON DIVISION
RCA MANUFACTURING COMPANY, INC.

92C-4599

RCA Cunningham Radiotron RADIO TUBES

CIRCUIT USED FOR DETERMINATION OF OPTIMUM BIAS AND PLATE LOAD

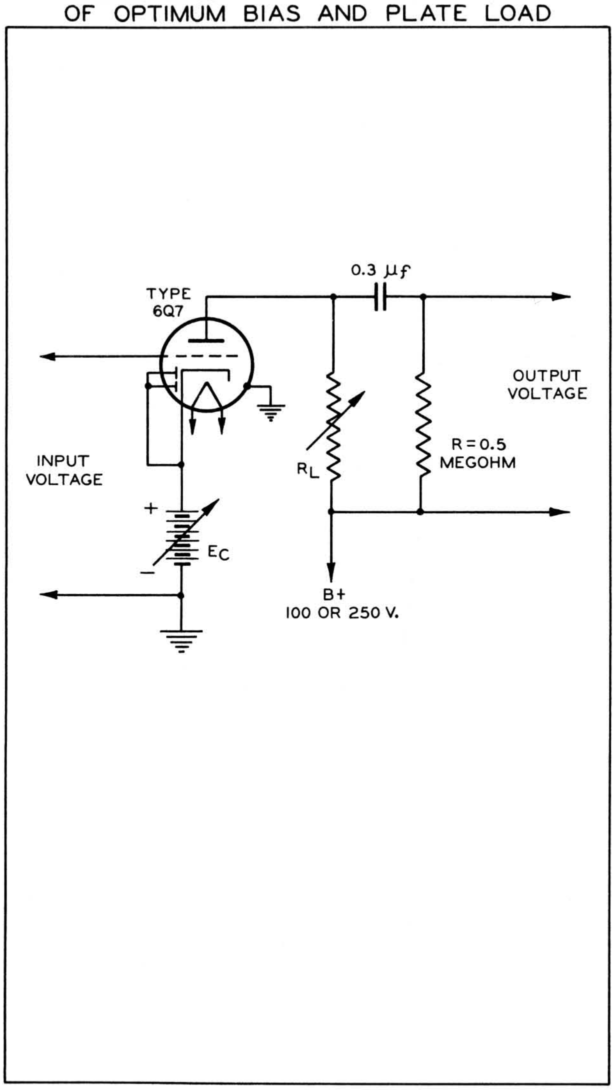

FIG. 2

RCA Cunningham Radiotron RADIO TUBES

RCA-6Q7

OPERATION CHARACTERISTICS
100-VOLT CONDITIONS

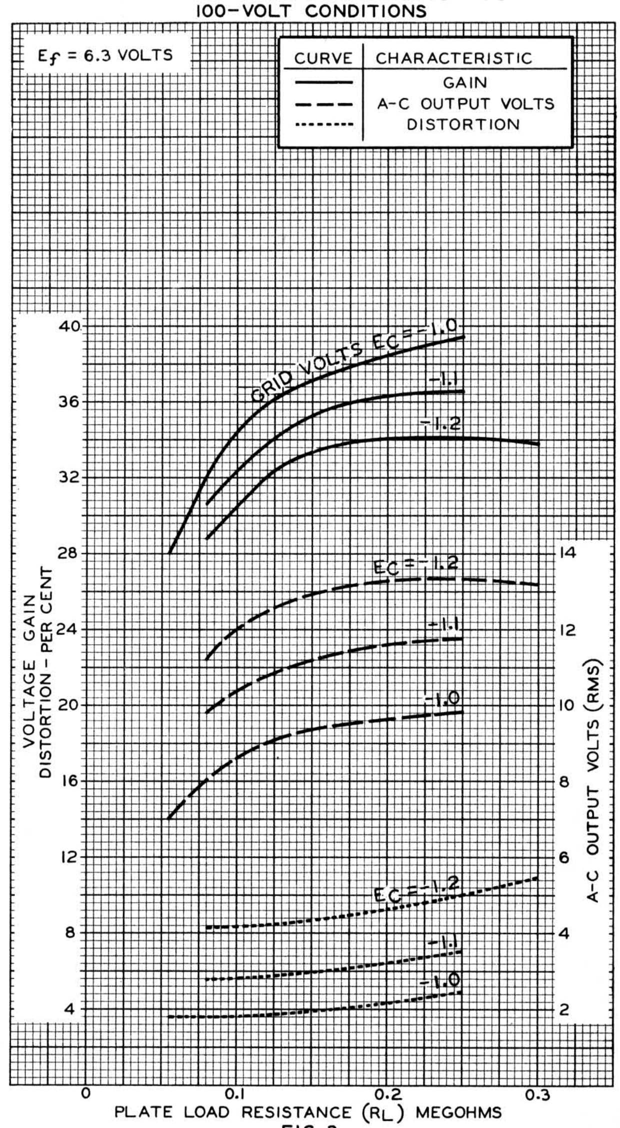

FIG. 3

RCA Cunningham Radiotron Radio Tubes

RCA-6Q7

OPERATION CHARACTERISTICS

100-VOLT CONDITIONS

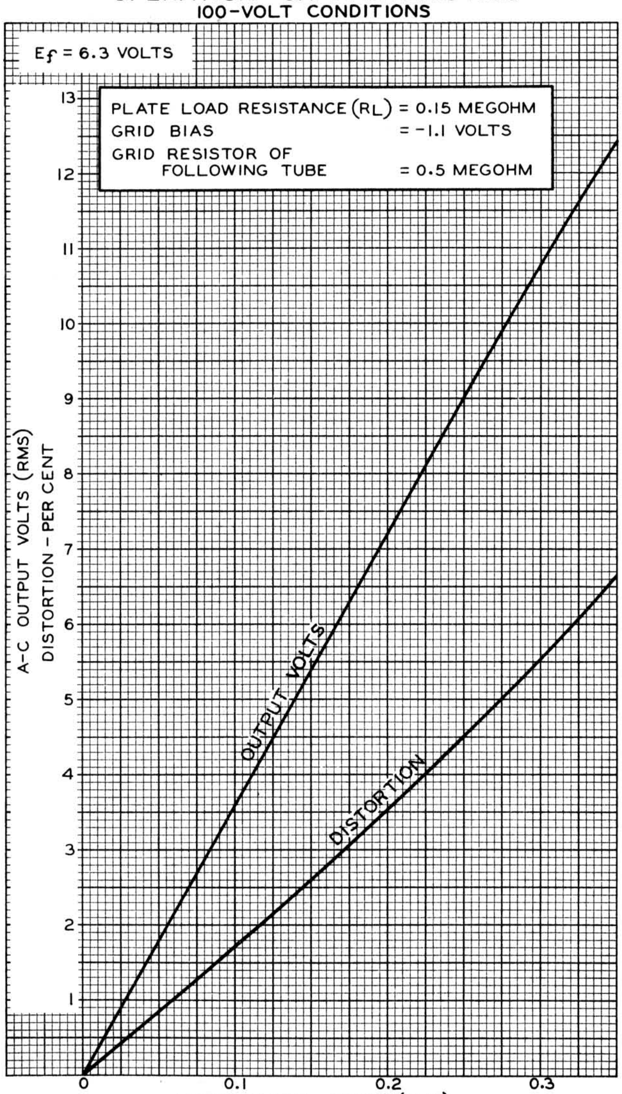

FIG. 4

APRIL 9, 1936 — RCA RADIOTRON DIVISION, RCA MANUFACTURING COMPANY, INC. — 92C-4598

RCA Cunningham Radiotron Radio Tubes

RCA-6Q7

OPERATION CHARACTERISTICS

250-VOLT CONDITIONS

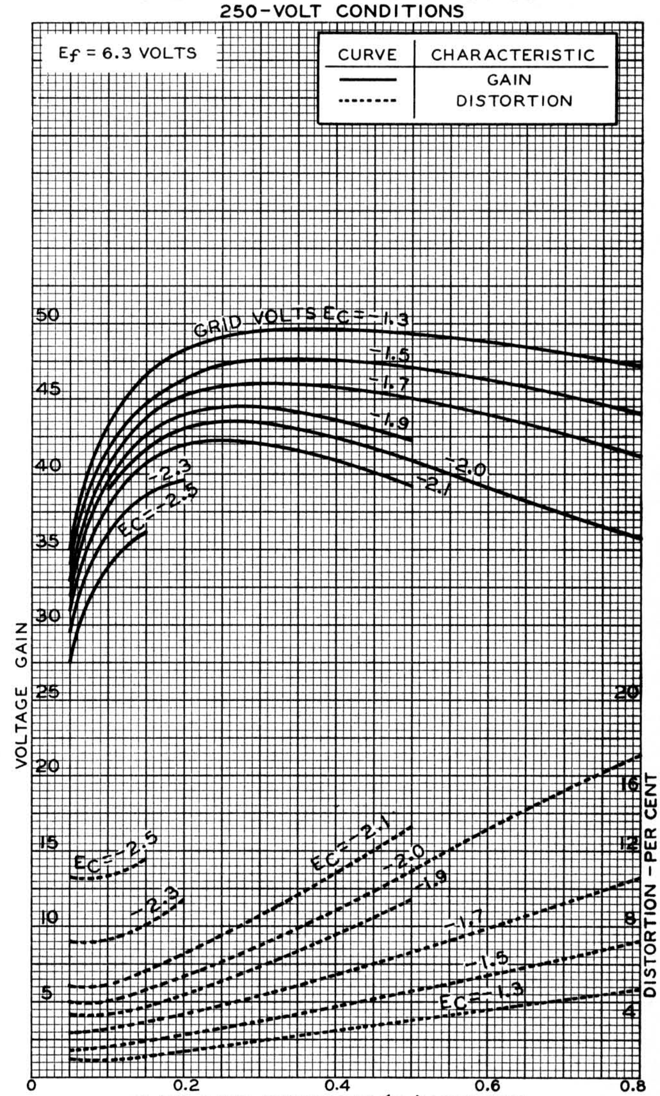

FIG. 5

APRIL 10, 1936 — RCA RADIOTRON DIVISION, RCA MANUFACTURING COMPANY, INC. — 92C-4600

Cunningham Radiotron

RCA-6Q7

OPERATION CHARACTERISTICS
250-VOLT CONDITIONS

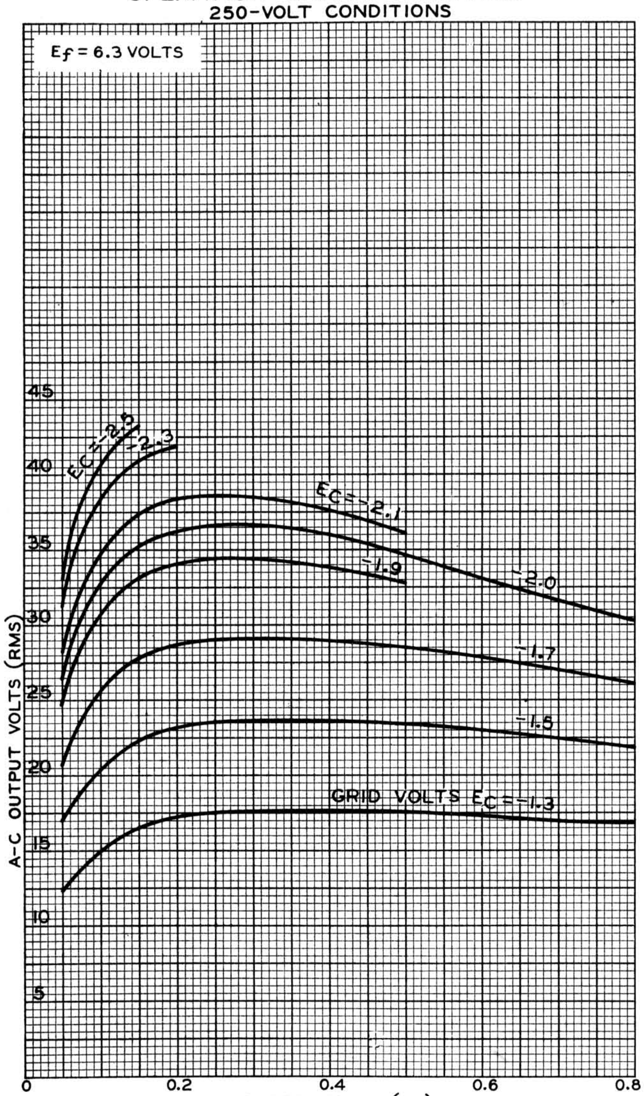

FIG. 6

APRIL 10, 1936 — RCA RADIOTRON DIVISION, RCA MANUFACTURING COMPANY, INC. — 92C-4601

Cunningham Radiotron

RCA-6Q7

OPERATION CHARACTERISTICS
250-VOLT CONDITIONS

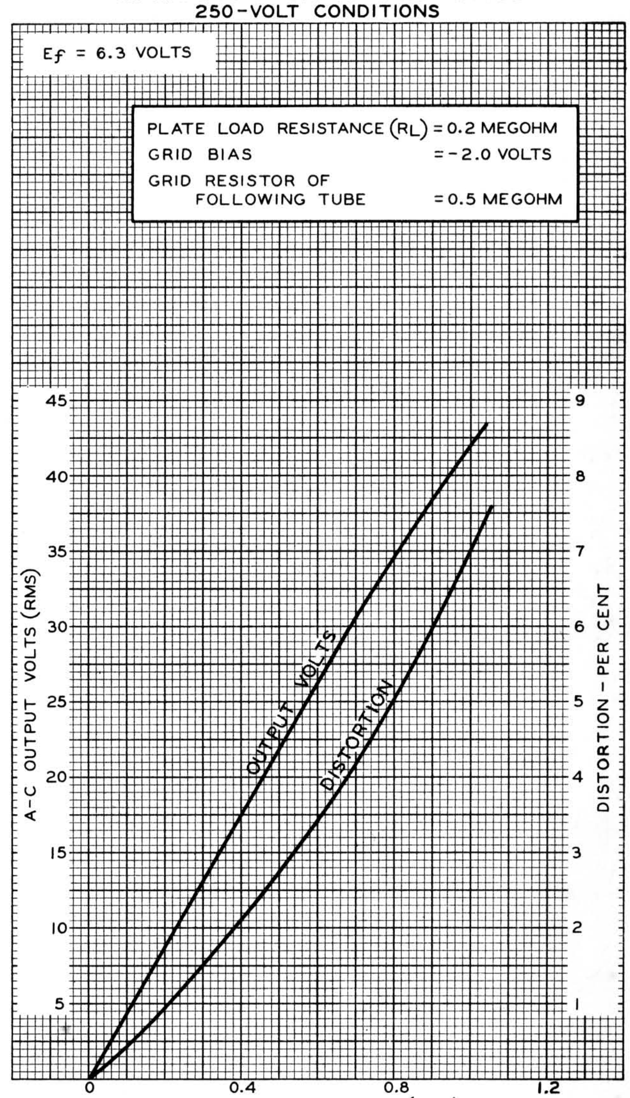

FIG. 7

APRIL 13, 1936 — RCA RADIOTRON DIVISION, RCA MANUFACTURING COMPANY, INC. — 92C-4602