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A RADIO CORPORATION OF AMERICA SUBSIDIARY

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RCA RADIOTRON
D I V I S I O N

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APPLICATION NOTE
ON
THE OPERATION OF SINGLE-ENDED TUBES

A single-ended tube is one in which all electrodes, including the control grid, terminate at base pins. Single-ended tube types are easily adapted to chassis construction, because leads connecting to socket terminals may be short and rigid. Furthermore, the elimination of a flexible lead and top-cap connector may effect an appreciable saving in cost. These and other advantages of single-ended tubes have been appreciated for some time, but the commercial availability of such tubes depended on a practical manufacturing technique.

This Note describes the features of four single-ended types -- 6SJ7, 6SK7, 6SF5, and 6SQ7 -- and suggests applications where the features of these new tubes can be used to advantage.

The 6SJ7 and 6SK7

The 6SJ7 and 6SK7 are, respectively, sharp and remote cut-off pentodes intended for use primarily in r-f or i-f circuits. In addition to their "single-ended" construction, these two types feature high transconductance.

When the control grid and plate of an r-f pentode terminate at base pins, these pins should be arranged for minimum plate-grid capacitance. Obviously, when all the base pins are placed around the circumference of a circle, minimum plate-grid capacitance is obtained when plate and control-grid pins are diametrically opposite. With such an arrangement of plate and control-grid pins, as shown in Fig.1, plate-grid capacitance may be reduced further by proper shielding. The sketch of Fig.2 shows the manner in which this shielding is accomplished in the types 6SJ7 and 6SK7. A cone of metal is inserted through the hole in the stem to which the exhaust tube connects; the cone extends some distance into the exhaust tube and connects to the shell of the tube. Another shield, cylindrical in shape, is inserted inside the locating base plug between the exhaust tube and the base plug; this shield also connects to the shell of the tube. The purpose of the conical shield is to reduce capacitance between leads in the glass of the stem; the purpose of the cylindrical shield is to reduce capacitance between those pins that are diametrically opposite. In the 6SJ7 and 6SK7, the plate-grid capacitance is 0.005 μmf (max.), the input is 6 μmf , and the output capacitance is 7 μmf .

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The socket in which the tube is inserted contributes to interelectrode capacitances. Capacitance measurements on a number of different types of sockets indicate that the capacitance between diametrically opposite socket terminals may have values between 0.005 $\mu\mu\text{f}$ and 0.01 $\mu\mu\text{f}$; however, when the shielded locating base plug of the 6SJ7 or 6SK7 is inserted, these capacitance values decrease to approximately 0.0001 $\mu\mu\text{f}$ and 0.003 $\mu\mu\text{f}$, respectively. The wafer type of socket ordinarily employed in radio receivers introduces very little capacitance and is entirely satisfactory for most applications. A further reduction in these capacitance values can be obtained by placing the screen by-pass condenser close to the base pins. Because one terminal of this condenser is grounded, it acts as a shield when it is in close proximity to the base pins. Placing high-potential leads close to the chassis also assists in reducing the effects of capacitance coupling between leads.

It is noted from Fig.1 that the basing of the 6SJ7 and 6SK7 is such that the control-grid pin is shielded from the heater pin by the suppressor pin, which normally is at ground potential. This arrangement minimizes the magnitude of hum voltage on the grid due to capacitance coupling between grid and heater.

The advantages of having short, rigid grid leads are easily demonstrable in high-gain receivers. For example, in one receiver employing top-cap tubes, capacitance coupling between the grid lead of an r-f amplifier and the grid lead of the converter tube was sufficient to introduce an appreciable amount of regeneration. This condition served a useful purpose in that the regeneration increased the sensitivity of the receiver. However, the amount of regeneration could be changed from a negligible value to a value high enough to cause oscillation by merely moving the grid leads farther apart or closer together. In this case, the usual amount of slack in the flexible grid leads permitted this motion of the wires. The substitution of a single-ended tube in the r-f amplifier of this receiver improved performance in two respects: (1) stability was increased considerably and (2) the gain of the r-f amplifier was higher than that obtained with the top-cap tube when regeneration was reduced, because of the high g_m (2000 micromhos) of the single-ended tube.

An increase in the transconductance of a tube is accompanied by an increase in regeneration for a given value of feedback impedance. Thus, when the 6SK7 is inserted in an i-f amplifier designed for use with tubes having comparatively low transconductance, the amplifier may oscillate. In order to prevent oscillation in such a case, it may be necessary to reduce the impedance of the i-f transformers by lowering the L/C ratio, keeping the Q of the coils constant. When L/C is reduced to the point where the stability of the amplifier with the high-transconductance tubes equals that with the low-transconductance tubes, there is no change in selectivity or in gain. However, the use of low-impedance i-f transformers with a high-transconductance tube may result in a lower-cost amplifier to give the same performance.

This point may be explained more fully by considering a single-stage i-f amplifier fed by a high-impedance converter tube. When the transconductance of the i-f amplifier is multiplied by a factor P, the stability of the

system may be held constant by (1) dividing the L/C ratio of the i-f transformer in the plate circuit of the i-f amplifier by the factor P or (2) dividing the L/C ratio of grid and plate transformers by an equal factor $P^{1/2}$. Under either of these conditions, the gain ($g_c g_m Z_1 Z_2$), the stability, and the selectivity of the entire system are not changed through the use of a high-transconductance amplifier tube. (In the expression $g_c g_m Z_1 Z_2$, g_c is the conversion transconductance of the converter tube, g_m is the transconductance of the amplifier tube, Z_1 is the impedance of the i-f transformer between the plate circuit of the converter and the grid circuit of the amplifier, and Z_2 is the impedance of the i-f transformer in the plate circuit of the amplifier tube.)

There are many receiver designs which have such good stability that an increase in transconductance of an i-f amplifier tube can be employed profitably. In such an amplifier, an increase in gain that is approximately proportional to the increase in transconductance is obtained without any changes in the characteristics of the i-f transformers.

The 6SJ7 as a Detector

An important application of the 6SJ7 is its use as a detector in small receivers. These receivers may be of the tuned r-f or superheterodyne type, and usually do not have automatic volume control. The output tube of these receivers is usually a 25L6 having an unby-passed cathode resistor; the detector tube is usually a pentode operated with a series screen resistor.

In order to determine the performance of the 6SJ7 in a typical receiver of this type, the circuit shown in Fig.3 was set up and the constants of the detector circuit were adjusted for good performance. Optimum values depend on whether adjustments are made for maximum gain, minimum distortion, or highest output voltage. The values of components suggested in this Note represent a suitable compromise when the output tube is a 25L6.

Curves of power output vs distortion, when the plate load of the 6SJ7 is 0.47 megohm, are shown in Fig.4; the solid-line curve corresponds to the circuit of Fig.3 and the dashed-line curve corresponds to the same circuit, except that the 25L6 cathode resistor is by-passed with a 10 μ f condenser. The reduction in distortion due to degeneration in the cathode circuit is apparent at low and medium output levels.

Power output is measured at the secondary of the output transformer; the power furnished by the tube, of course, is a value shown on the curves divided by the efficiency of the output transformer. The efficiency of the output transformer used in this test was approximately 83 per cent.

The curves of Fig.5 show the performance of the circuit when the plate load of the 6SJ7 is 0.27 megohm. Except for the value of cathode resistor, other values of components are as indicated in Fig.3. The 6SJ7 may also be used as a biased detector, as shown in the circuit of Fig.6. The data in Figs.4, 5, and 6 show that nearly the same performance can be obtained under a variety of operating conditions, provided circuit constants are properly chosen for each condition.

The 6SF5 and 6SQ7

The high-mu triode 6SF5 and the duplex-diode high-mu triode 6SQ7 correspond electrically to the 6F5 and the 75, respectively. Resistance-coupled data available for these latter types also obtain for the similar single-ended types.

With reference to the diagram of Fig.1, socket connections for the 6SQ7 are: (1) shell, (2) grid, (3) cathode, (4) diode plate No.2, (5) diode plate No.1, (6) triode plate, (7) heater, and (8) heater. With this base-pin arrangement, the grid pin is shielded from the nearest heater pin and from diode-plate pin No.4 by shell and cathode pins, respectively, which are usually at ground potential. The shielding afforded by these grounded pins reduces the capacitance between grid and diode-plate as well as the grid-to-heater capacitance.

Socket connections for the 6SF5 are: (1) shell, (2) cathode, (3) grid, (5) plate, (7) heater, and (8) heater. Note that heater pins are pins 7 and 8, and that the grid pin is shielded from the nearest heater pin by the shielded locating lug and by pins 1 and 2, which are usually at ground potential. Two grounded pins between grid pin and the nearest heater pin reduce capacitance and leakage currents between grid and heater to lower values than those obtained with a single grounded pin.

When the cathode is connected to one side of the heater and to ground, the equivalent hum voltage on the grid of the 6SF5 is approximately 100 microvolts across 0.5 megohm. In a radio receiver having an audio-frequency power sensitivity of 200 mhos at 60 cycles, 500 microvolts on the grid of the first a-f tube is required for 50 microwatts of hum output; experience indicates that 50 microwatts is a good value of maximum acceptable hum output of radio receivers. Moreover, hum due to leakage or capacitance coupling is proportional to the impedance in the grid circuit. The value of 0.5 megohm used in this test is higher than that usually used; a typical value for radio receivers is approximately 0.2 megohm, which represents the parallel combination of the resistance of the volume control and 0.25-megohm diode load. An audio-frequency power sensitivity of 200 mhos at 60 cycles is high for a radio receiver. For example, an amplifier consisting of a 6SF5 resistance-coupled to a 6F6 has a power sensitivity of approximately 75 mhos. (Power sensitivity in mhos is defined as the ratio of power output in watts to the square of the rms input signal in volts.) On the basis of a 0.5-megohm grid resistor and a 50-microwatt hum level, the equivalent hum voltage on the grid of the 6SF5 due to heater-grid capacitance and heater-grid leakage is very low for radio receivers, although it may not be an acceptable value for some high-gain a-f amplifiers which use high grid impedance and are critical as to hum. It is also interesting to note that, in many receivers, hum due to pickup by the leads to the volume control is several times that introduced by a 6SF5 or by its power supply unit.

The 6SF5 as a Detector

The 6SF5 is suitable for use as a biased detector in the circuits of Figs.3 and 6. Values of components are as shown in the figures, except in Fig.3 where R_c equals 27000 ohms, R_L equals 0.47 megohm, and the value of the 25L6 cathode resistor is 120 ohms; of course, resistor R_d and the screen by-pass condenser are not required. It was necessary to reduce the value of the 25L6 cathode resistor from 150 ohms, as shown in Fig.3, to 120 ohms in order that the maximum output voltage from the 6SF5 detector would be sufficient to drive the 25L6 to full output. This value of cathode resistance is suitable for use in most "compact" receivers, because electrode voltages in such receivers are usually less than the recommended maximum values for the 25L6.

Tests of the 6SF5 as a biased detector under the conditions stated in the preceding paragraph were conducted in a commercial "compact" four-tube t-r-f receiver of typical design. The circuit of the power-supply unit and a-f section of this receiver was essentially the same as that shown in Fig.3, except that the resistance of the speaker field was 450 ohms. The following table shows the performance of the 6SF5 in the detector circuits of Figs.3 and 6.

OPERATION OF 6SF5 AS BIASED DETECTOR

Power Output ¹ (Watts)	Total Harmonic Distortion (Per cent)		Input Signal (Volts RMS) ²	
	Fig.3 ³	Fig.6 ⁴	Fig.3 ³	Fig.6 ⁴
0.05	8.7	8.2	0.19	0.14
0.1	8.2	7.5	0.26	0.2
0.2	8.1	7.2	0.35	0.26
0.3	8.2	6.8	0.42	0.32
0.4	8.2	6.4	0.48	0.36
0.5	8.1	6.3	0.54	0.43
0.7	8.1	6.3	0.64	0.51
0.9	9.4	8.8	0.72	0.61
1.1	16.3	16.8	0.83	0.75
1.38	21.6 ⁵	22.4 ⁶	0.98	0.95

¹ Measured in primary of output transformer.

² Modulated 30 per cent at 400 c.p.s.

³ See text for values of circuit components.

⁴ See Fig.6 for values of circuit components.

⁵ Grid-current point of 6SF5 and 25L6.

⁶ Grid-current point of 25L6.

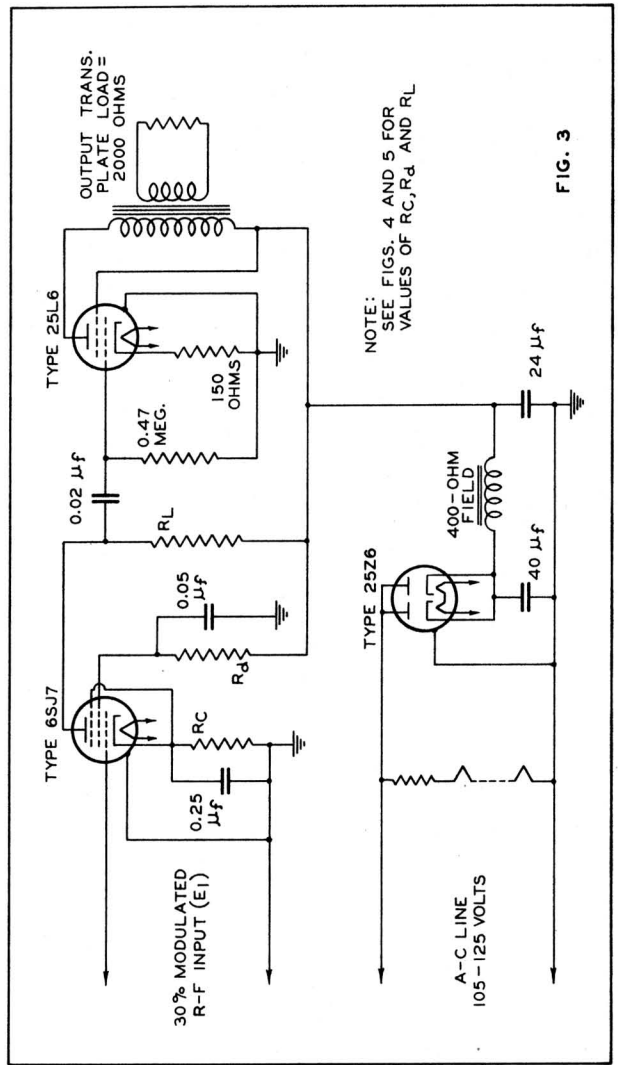
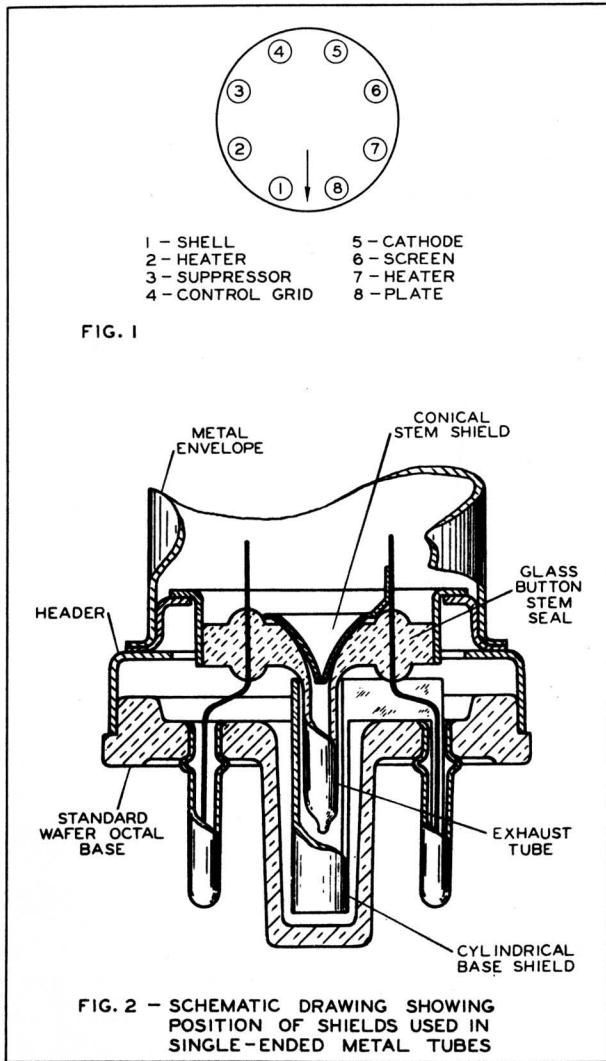
Although the 6SF5 does not furnish high output voltage at reasonable distortion when used as a biased detector, the output voltage it does furnish is sufficient to drive a 25L6 in a typical "compact" receiver. The important advantage of the 6SF5 over the 6SJ7 as a biased detector is that the cost of a series screen resistor and by-pass condenser is saved.

The type of biased detector shown in Fig.6 is not in general use. Because the no-signal bias on the tube is zero and the time constant of the grid circuit is high for audio frequencies, the 0.025- μ f condenser in the grid circuit is charged to approximately the peak value of the modulated signal input by grid current. Detection then takes place in the plate circuit in the usual manner; no audio voltage appears in the grid circuit. Because the bias on the tube, which is the voltage across the condenser in the grid circuit, is proportional to the per cent modulation and the amplitude of the carrier, it is not desirable to use this bias for AVC purposes. For these same reasons, high distortion might be expected when the per cent modulation changes suddenly from a low value to a much higher value. However, listening tests show that distortion due to rapid changes in per cent modulation is not serious in the "compact" type of receiver. For receivers designed for low distortion, of course, diode detection is preferable.

Applications of these four tubes are not restricted to the few described in this Note. In many other applications, these new types give improved performance over top-cap tubes; in addition, an appreciable saving in cost and an improvement in the appearance of the equipment may be realized through their use.



TYPES 6SJ7 & 6SK7



The license extended to the purchaser of tubes appears in the License Notice accompanying them. Information contained herein is furnished without assuming any obligations.



PERFORMANCE OF CIRCUIT SHOWN IN FIG. 3

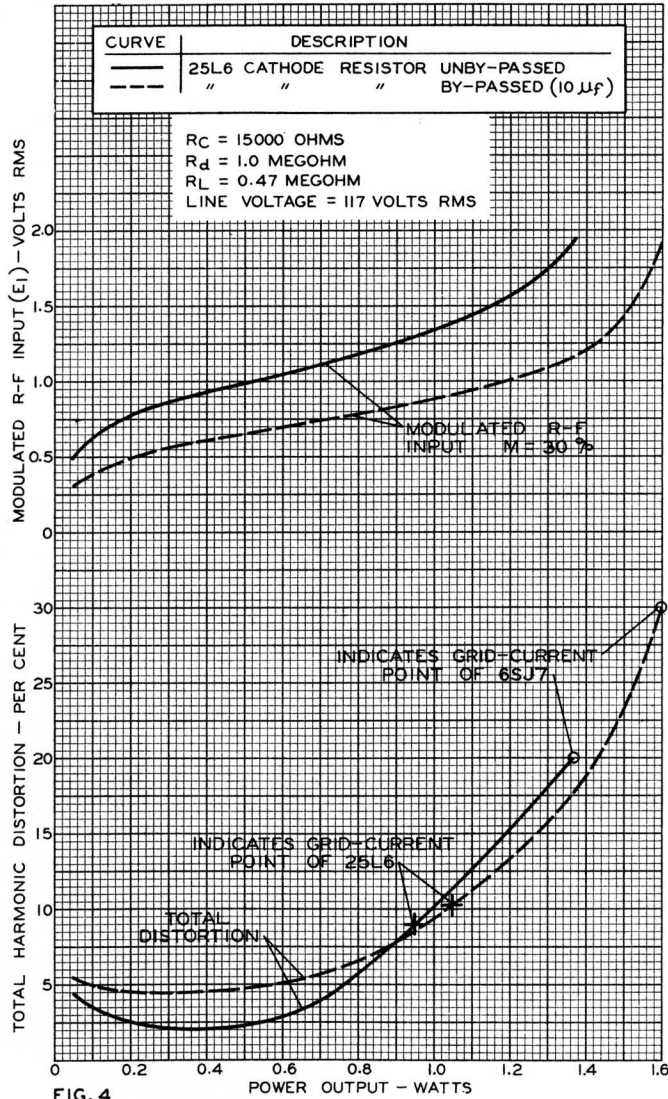


FIG. 4

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PERFORMANCE OF CIRCUIT SHOWN IN FIG. 3

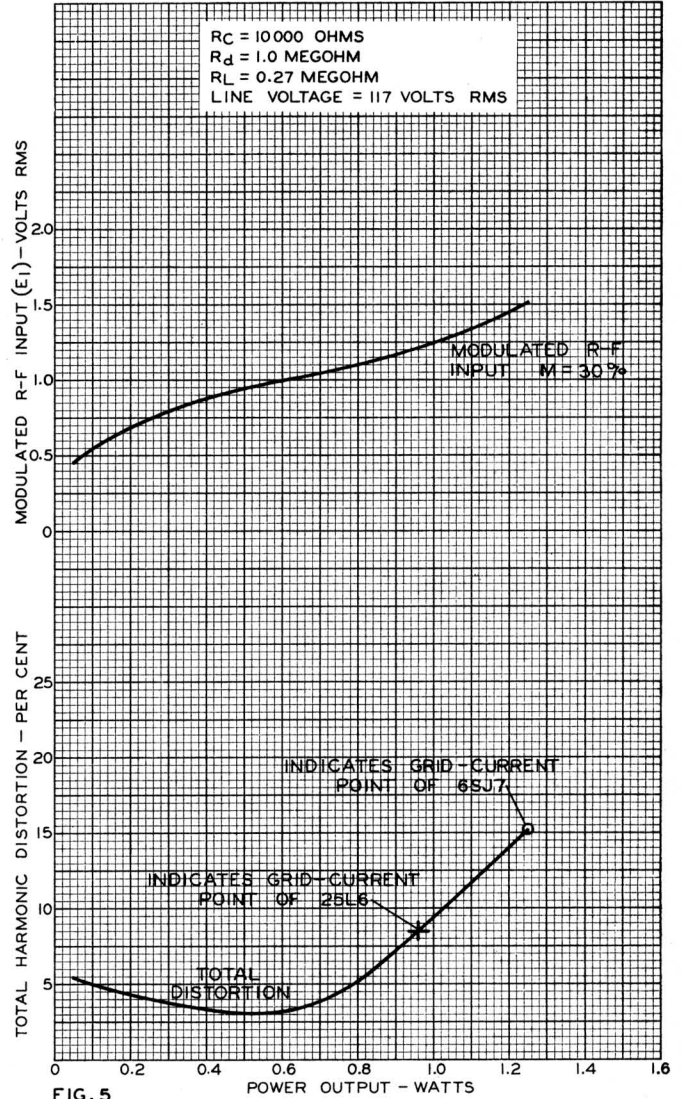


FIG. 5

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PERFORMANCE OF 6SJ7 AS BIASED DETECTOR

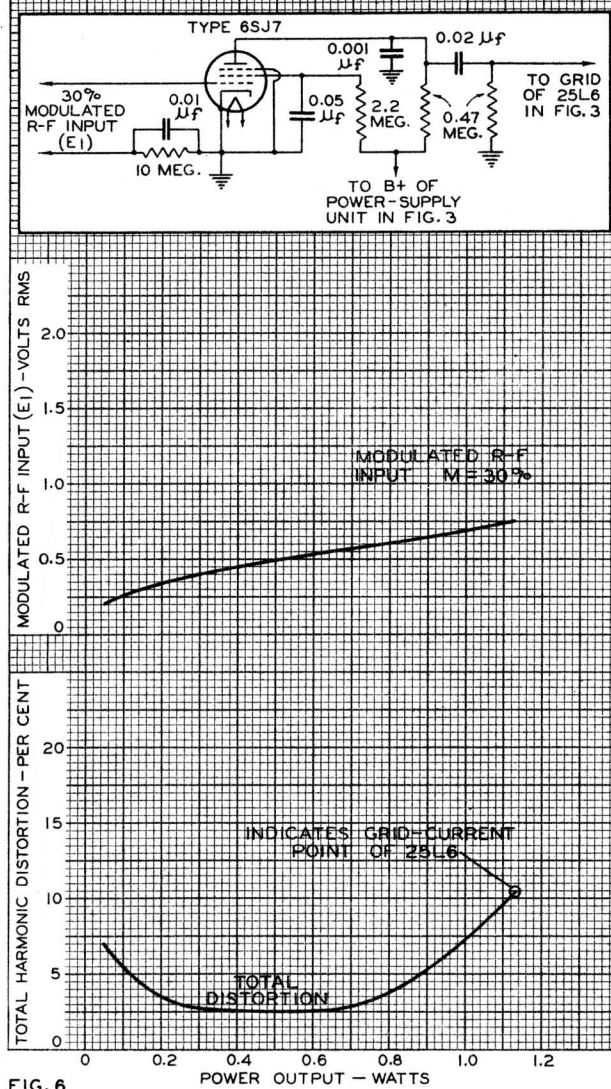


FIG. 6

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