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A RADIO CORPORATION OF AMERICA SUBSIDIARY
Harrison, New Jersey

RCA RADIOTRON
DIVISION

APPLICATION NOTES

APPLICATION NOTE No. 72
March 17, 1937

APPLICATION NOTE ON A 40-WATT OPERATING CONDITION FOR TWO TYPE 6L6 TUBES

Two type 6L6 tubes connected as a Class AB_2 amplifier can furnish approximately 40 watts at 7 per cent distortion when 400 volts are applied to the plates and 250 volts to the screens. This is an economical operating condition, because a single point on the power-supply unit can furnish screen voltage for the 6L6's and plate voltage for the other tubes. However, the power output and distortion that can be obtained with these voltages depend on the characteristics of the driver tube, the input transformer, and the power-supply unit. Hence, it is desirable to know what can be obtained in practice with representative equipment and typical circuits.

The Effects of Plate, Screen, and Bias Regulation

When the source of plate and screen-voltage supply of a Class AB amplifier has internal resistance, the d-c voltages applied to the plates and screens decrease as power output increases. The effect of reducing plate and screen voltage is to reduce power output; a change in load resistance may be necessary in order to reduce distortion. When the cathode current of the output tubes flows through a self-bias resistor, the bias voltage increases with power output. Therefore, it may be necessary to use a low value of zero-signal bias in order that the optimum value of bias exist at full output. The load resistance and zero-signal bias voltage recommended in this Note obtain for the plate, screen, and bias regulations that are considered.

In all tests described in this Note, the zero-signal plate voltage was 400 volts, the zero-signal screen voltage was 250 volts, and the zero-signal bias was -19 volts. The same input transformer was used in all tests The resistance and leakage reactance of this transformer was small; therefore, the high-order distortion generated in the grid circuit of the 6L6's was small. Detailed specifications for this transformer are appended. The driver tube was a 6F6 connected as a triode. A 6F6 connected as a triode has low internal resistance and can easily supply the power required by the grids of the output tubes.

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The internal resistance of the plate-supply sources of a number of receivers designed for high power output was measured. Values of resistance from 600 to 800 ohms, including the rectifier tube, were obtained; the average value was found to be nearly 700 ohms. The data to follow, therefore, obtain when the internal resistance of the plate-supply source is 700 ohms and when screen voltage is obtained from the plate-supply source through a tapped bleeder circuit; the field coil of a loud speaker may constitute part of this bleeder circuit. Bias for the output tubes was obtained from the voltage drop across a section of the bleeder resistor. The resistor elements of two typical circuits are shown in Figs. 1 and 2.

In Fig. 1, the total current through the bias resistor (R_c) is the sum of the bleeder current (I_x), the cathode current of the driver (I_c), and the cathode current of the output tubes (I_k). Because I_k varies with power output and ($I_x + I_c$) remains relatively constant, the ratio $(I_x + I_c) / (I_x + I_c + I_k) = K$ is a convenient measure of the constancy of the bias. In the tests, different values of K were obtained by adjusting I_x; the d-c input voltage and the value of screen-dropping resistor were adjusted for the zero-signal voltages shown in the figure. When $I_x = 0$, $K = 0.2$, the lowest value obtainable with this circuit. A practical upper limit of $K = 0.6$ was reached; the d-c input voltages and bleeder currents that are required for higher value of K are not justified by corresponding improvements in performance.

The circuit of Fig. 2 is similar to Fig. 1, except that I_c does not contribute to the voltage drop across R_c, the grid-bias resistor. In this circuit, therefore, $K = I_x / (I_x + I_k)$. When $I_x = 0$, $K = 0$, and the output tubes are completely self-biased. Increasing the value of I_x increases the value of K. A practical upper limit of $K = 0.5$ was reached. Values of K greater than 0.5 are not justified by corresponding improvements in performance. It should be noted that the B-supply voltage of the driver tube is 250 volts in the circuit of Fig. 1 and 269 volts in the circuit of Fig. 2.

Characteristics of Circuit of Fig. 1

The variation of distortion with power output at the grid-current point for several values of plate-to-plate load was determined for five values of K using the circuit of Fig. 1. The results are shown by the composite curves of Fig. 3. Each point on a solid-line curve specifies the power output and distortion at a definite value of plate-to-plate load (R_L); the dashed-line curves connect points which correspond to the same load resistance. For example, when $K = 0.2$, approximately 35.5 watts at 11.5 per cent distortion is obtained at the grid-current point of the driver when $R_L = 8000$ ohms. By a change of R_L to 5000 ohms, the power output at the grid-current point of the driver is reduced to 32.5 watts and the distortion to 4.7 per cent. The negative slopes of the solid-line curves at high values of R_L signify that power output decreases as R_L increases. The value of R_L which produces maximum power output for a given value of K is determined by a vertical tangent to the solid-line curve of interest. However, operation at this point is usually not desirable because the distortion is high. It is desirable to decrease the load impedance, at the expense of some power output, in order to reduce distortion.

Fig. 3 shows that power output is nearly maximum and distortion is low for the indicated values of K when R_L = 5000 ohms. This value of load impedance is recommended for use with the circuit of Fig. 1. The curves of Fig. 4 show the variations in power output, distortion, rectifier currents, and output-stage currents plotted against per cent fixed bias (K) for the grid-current point of the driver shown in Fig. 1. The data are useful in the design of the power-supply system.

Curves of distortion vs power output for K = 0.2 and K = 0.6 are shown in Fig. 5. The shapes of the two sets of curves are nearly alike; therefore, the end points obtained from Fig. 4 may be used to predict, with fair accuracy, the shapes of the characteristics for intermediate values of K.

Characteristics of Circuit of Fig. 2

The circuit of Fig. 2 is similar to Fig. 1, except that the cathode current of the driver (I_c) does not flow through R_c, the grid-bias resistor of the output tubes. Although this arrangement permits several simplifications in wiring, it requires more rectifier current and greater d-c input voltage for the same value of K than the circuit of Fig. 1.

The composite curves of this circuit are shown in Fig. 6. These curves should not be compared with those shown in Fig. 3, because the B-supply voltage of the driver tube is not the same in each case. The grid-current point of the driver occurs at higher power output in the circuit of Fig. 2 than in the circuit of Fig. 1. The characteristic of Fig. 6 shows that a suitable value of load resistance for the indicated values of K is 5000 ohms. However, a 6000-ohm load furnishes somewhat more power at slightly more distortion at low values of K than a 5000-ohm load. Distortion characteristics for three typical cases are shown in Fig. 7.

Curves of power output, distortion, rectifier currents, and output-tube currents vs per cent fixed bias (K) for a 5000-ohm load are shown in Fig. 8. These data should not be compared directly with those shown in Fig. 4, because the B-supply voltage of the driver is not the same in each case.

Receiver Tests

To confirm the results of these tests, a commercial audio-frequency amplifier designed for Class AB_2 operation of two 6L6's was tested. The essential elements of this amplifier are shown in Fig. 9. The internal resistance of the plate-supply source was measured and found to be 635 ohms; its circuit is similar to that shown in Fig. 1. The power output vs distortion curve of this amplifier, shown in Fig. 10, may be compared with that shown in Fig. 5, even though the internal resistances of the plate-supply sources are different. It is seen that the distortion curve of this amplifier is comparable to the total-distortion curves of Fig. 5.

Conclusions

These tests indicate that two type 6L6 tubes can furnish approximately 40 watts at reasonable distortion when 400 volts are applied to the plates and 250 volts to the screens Two types of circuits may be used: (1) a circuit in which the plate current of the driver contributes to the bias on the output tubes (Fig. 1), or (2) a circuit in which the plate current of the driver does not contribute to the bias on the output tubes (Fig. 2). When a 6F6 connected as a triode is used as a driver, slightly more power can be obtained from the circuit of Fig. 2 than from that of Fig. 1 for the same constancy of bias (value of K). However, this increased power is obtained at the expense of an increase in rectified voltage and current. Economic and technical requirements influence the choice of circuit.

INPUT TRANSFORMER SPECIFICATIONS (S-154)*

Core

Manufacturer, Allegheny Steel Company
Grade, Silicon
Watts Loss/lb. at 10000 gauss = 0.7
Punching, EI-11
Net Section, 6.5 cm^2
Window, 0.432" x 1-5/16"
Weight, 1.5 lbs.
Tongue, 7/8"
Stack, 1-5/16
Stacking Factor, 0.88
Joint, Butt

Windings	Primary 1	Primary 2	Secondary
Clearance Under	0.015"		
Clearance Over		0.045"	
Insulation Under	0.045"	0.020"	0.020" + 0.010' between sec.
Insulation Over		0.012"	
Sum	0.060"	0.077"	0.030" Total = 0.167"
Traverse & Margin	3/32" + 1-1/16" + 3/32"	Net = 1.0"	
Maximum Depth of Total Windings	0.438" - 0.167" = 0.271"		
Turns Total	1320 #37 En.	1320 #37 En.	2400 #34 En.
Taps			At 1200T 0.010" insulation after 1200T.
Size Insulated Conductor	0.0052"	0.0052"	0.0072"
Turns per Layer	190	190	138
Insulation between Layers	0.0015"	0.0015"	0.0015"
Numbers of Layers	7	7	18
Depth of Winding	0.046"	0.046"	0.165" Total = 0.257"
Form (Inside Dimensions)	29/32" x 1-3/8" x 1-1/8" lg.		
Winding Order	1st	3rd	2nd
Mean Length of Turn	6"	6"	6"
Total Length (ft.)	675	675	1200
Weight of Copper (lb.)	0.0425	0.0425	0.136
Resistance at 25° C (ohms)	350	350	310
Power Source	1 - 6F6 as triode		
Load	2 - 6L6's Class AB_2		

*Our design identification number.

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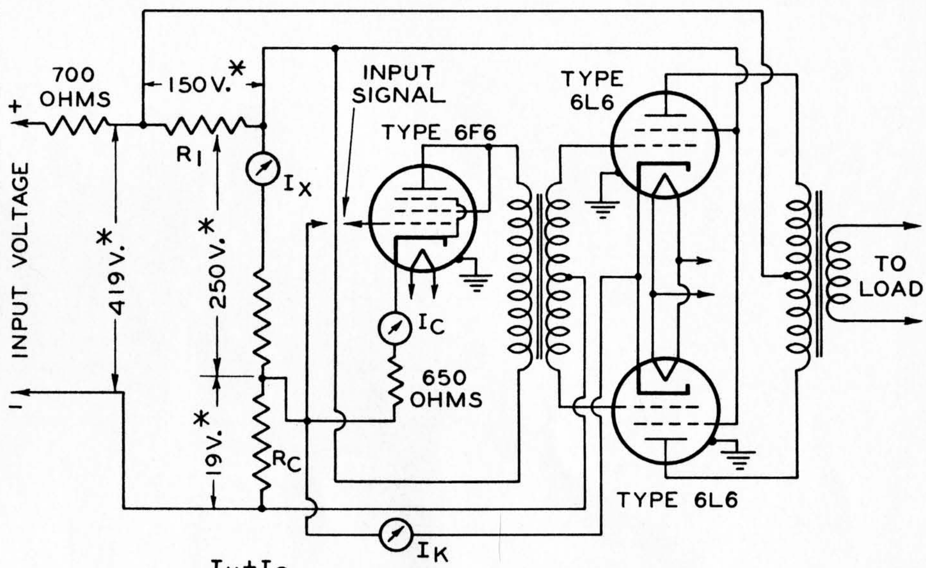
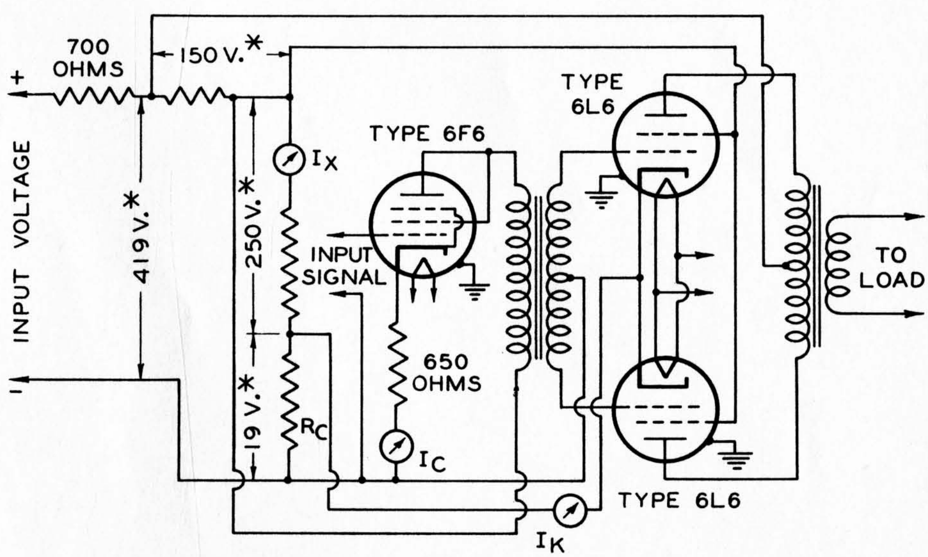
RESISTANCE ELEMENTS OF POWER-SUPPLY CIRCUITS FOR 40-WATT OPERATION OF 6L6'S



$$K = \frac{I_X + I_C}{I_X + I_C + I_K}$$

FIG 1



$$K = \frac{I_X}{I_X + I_K}$$

FIG 2

* ZERO SIGNAL

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TYPICAL CHARACTERISTICS OF CIRCUIT OF FIG.1 AT GRID-CURRENT POINT OF DRIVER

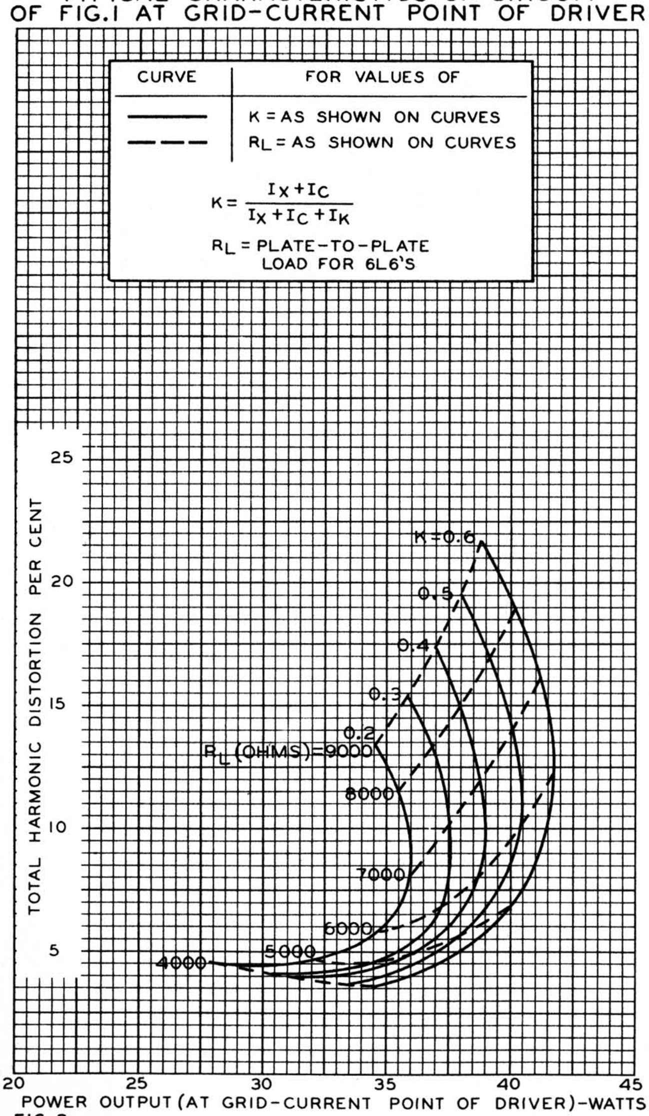

FIG.3

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TYPICAL CONDITIONS FOR CIRCUIT OF FIG.1 AT GRID-CURRENT POINT OF DRIVER

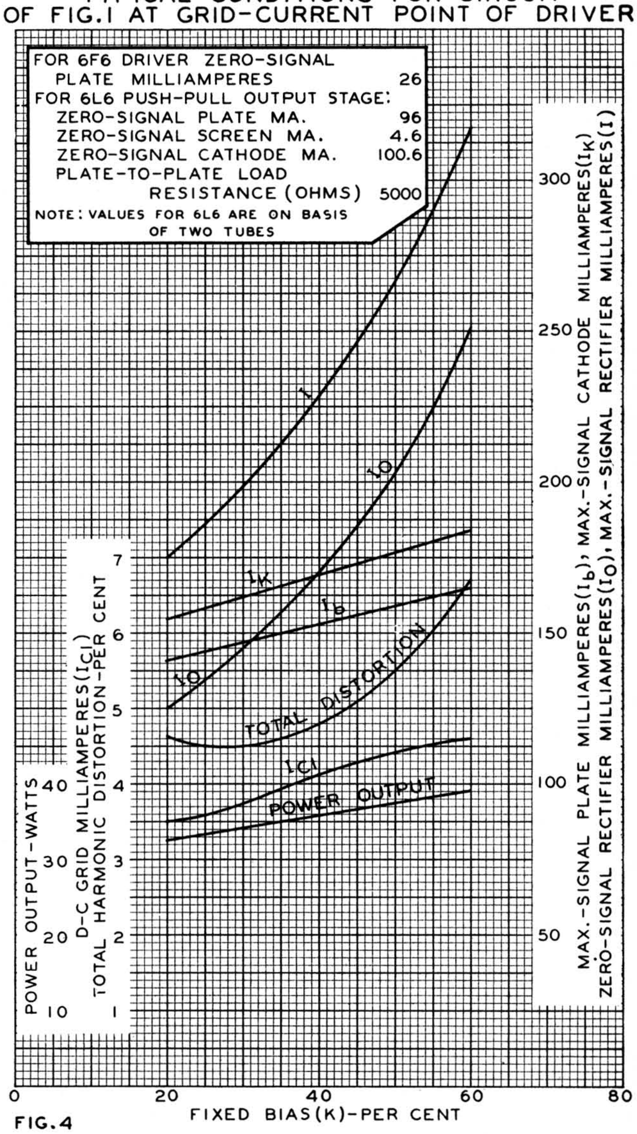

FIG.4

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TYPICAL DISTORTION CHARACTERISTICS OF CIRCUIT OF FIG.1

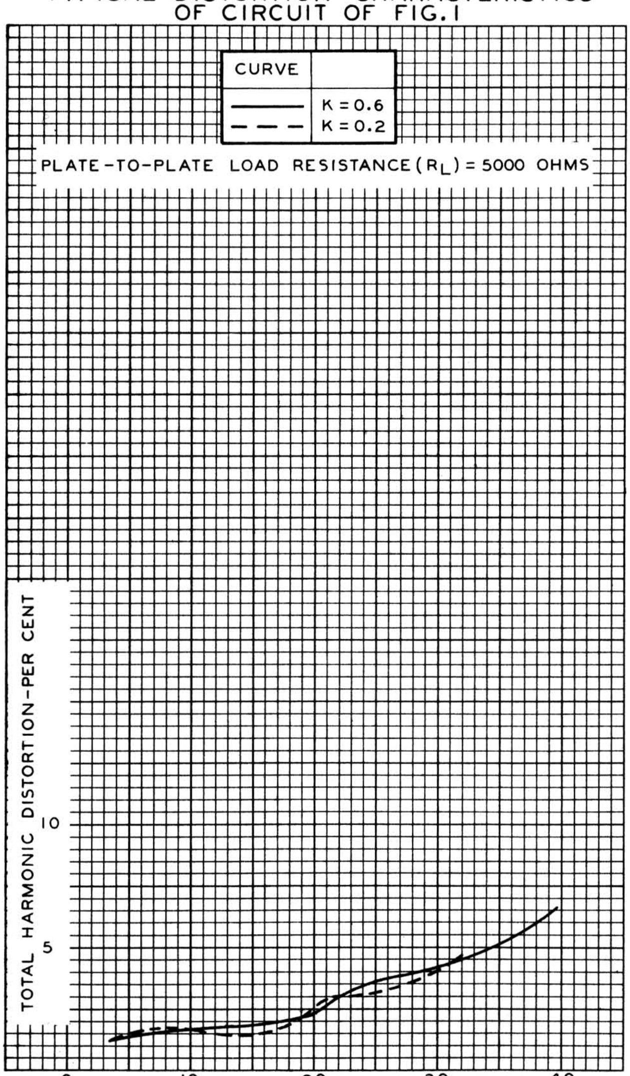

FIG 5

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TYPICAL CHARACTERISTICS OF CIRCUIT OF FIG 2 AT GRID-CURRENT POINT OF DRIVER

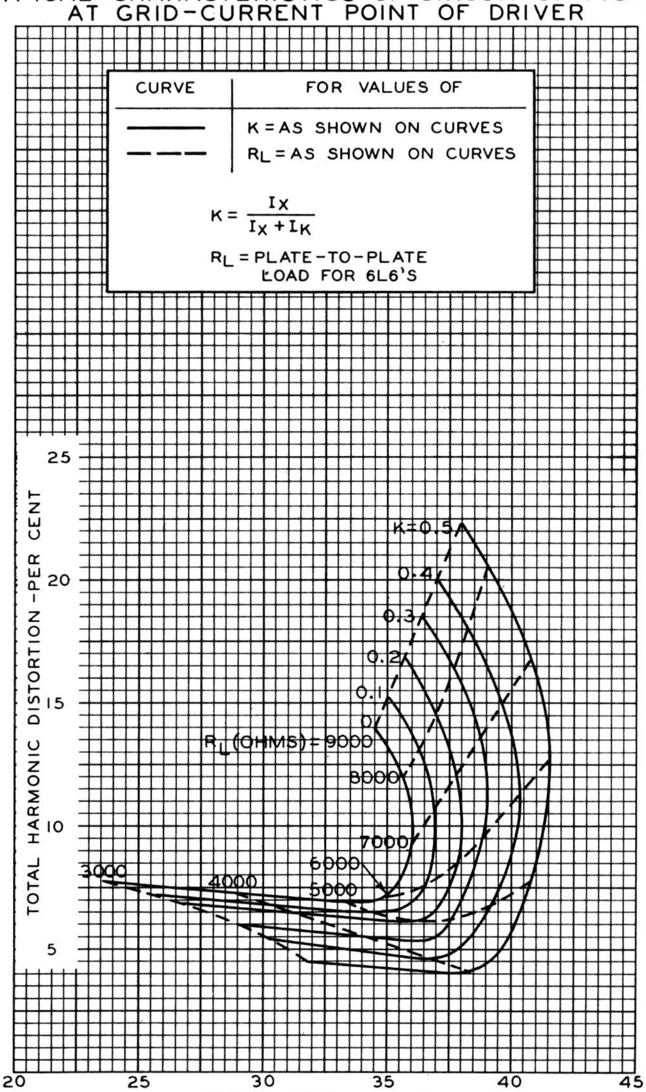

FIG.6

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TYPICAL DISTORTION CHARACTERISTICS OF CIRCUIT OF FIG. 2

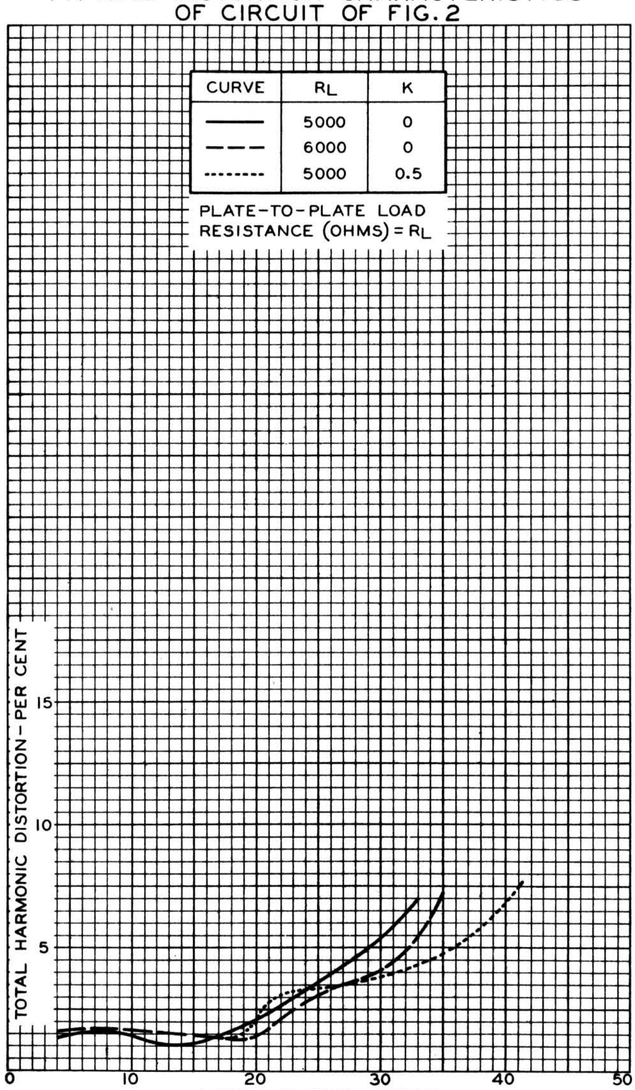

FIG. 7

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TYPICAL CONDITIONS FOR CIRCUIT OF FIG. 2 AT GRID-CURRENT POINT OF DRIVER

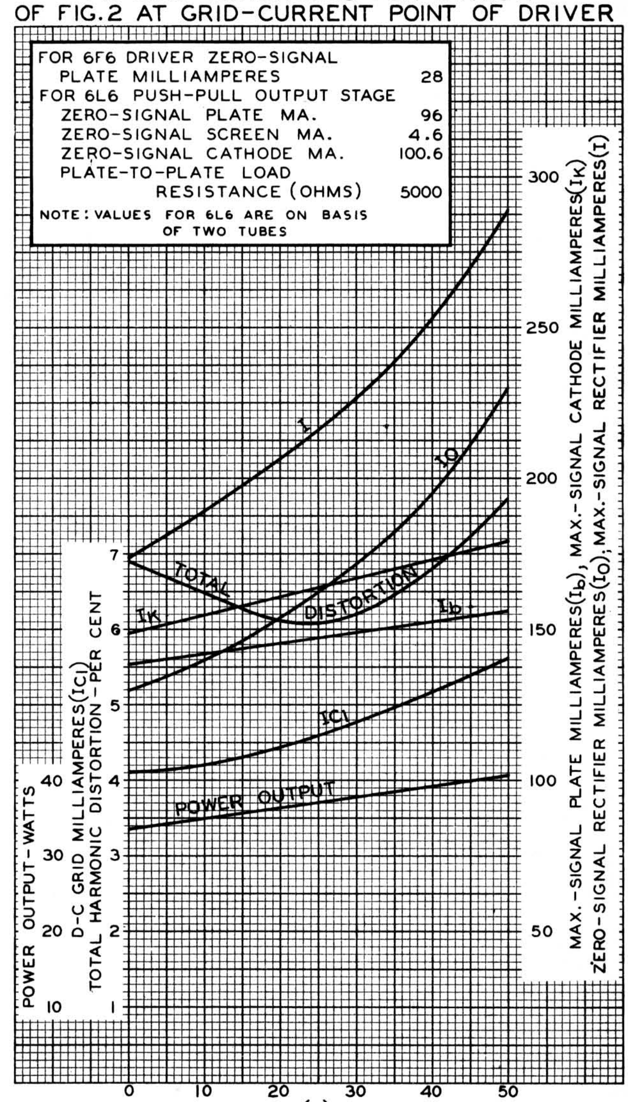

FIG 8

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AMPLIFIER CIRCUIT USED FOR OBTAINING CURVES OF FIG. 10

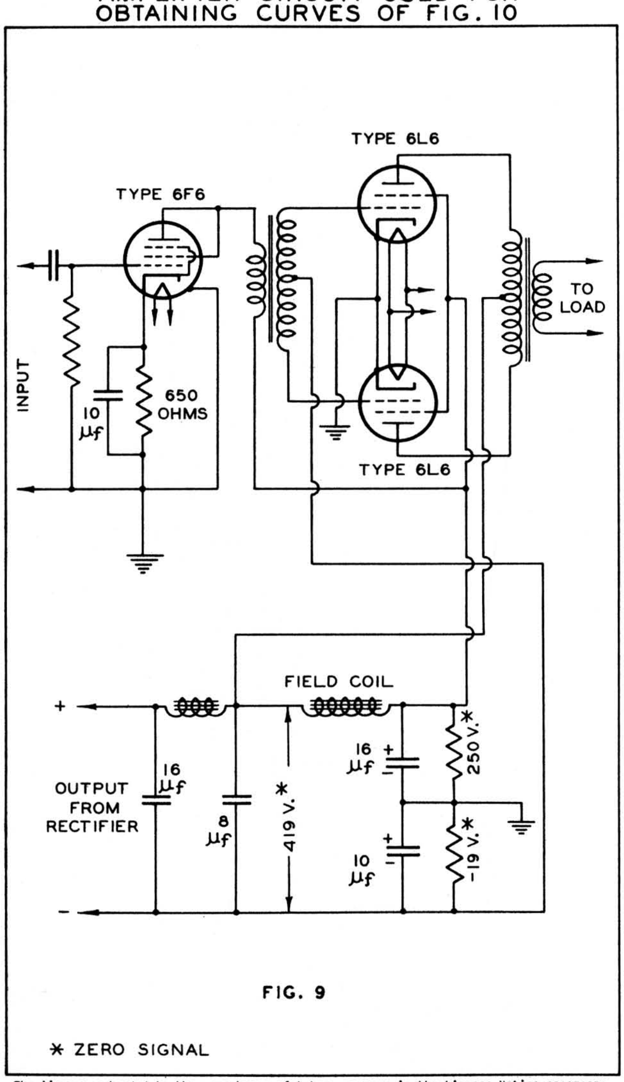

FIG. 9

* ZERO SIGNAL

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DISTORTION CHARACTERISTICS OF AMPLIFIER SHOWN IN FIG 9

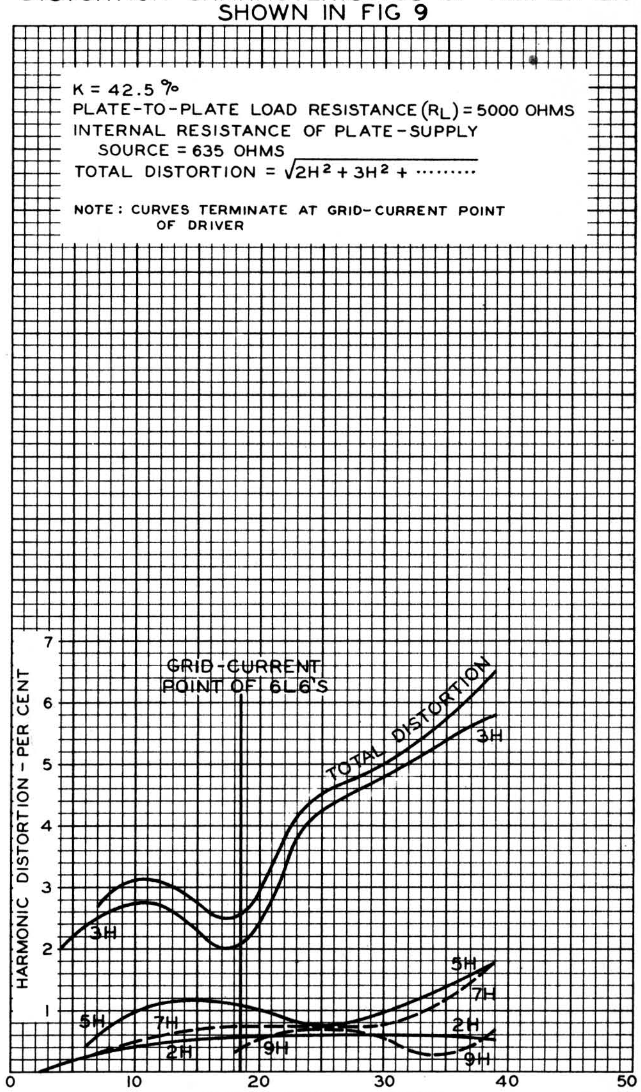

FIG. 10