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

RCA RADIOTRON
DIVISION

APPLICATION NOTE NO.68
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APPLICATIONS NOTES

APPLICATION NOTE

ON

A 55-WATT AMPLIFIER USING TWO TYPE 6L6 TUBES

Two type 6L6 tubes can furnish 60 watts at 2 per cent distortion when they are operated in an ideal Class AB_2 amplifier. However, when they are used in a practical amplifier designed for the 60-watt operating condition, the low distortion obtainable from the ideal amplifier cannot be realized. In the amplifier described in this Note, 55 watts at approximately 7.5 per cent distortion can be obtained. This amplifier can furnish more than 60 watts, but the recommended maximum screen dissipation is exceeded at these outputs. The data shown in the attached curves were obtained from measurements made with the equipment described in this Note.

Distortion

Two types of distortion should be distinguished: (1) plate-circuit distortion, which is due to the characteristics of the plate circuit, and (2) grid-circuit distortion, which is due to the effects of grid current flowing through an external impedance in the grid circuit. Plate-circuit distortion can be minimized by selecting the proper plate load; grid-circuit distortion can be minimized by reducing the external grid-circuit impedance to a minimum or by confining the grid-voltage swing to the negative portion of the operating range. However, it is sometimes necessary to operate in the grid-current region in order to obtain high power output.

When tubes are operated as a Class AB_2 amplifier, it is necessary to furnish the grids of these tubes with sufficient power to supply the losses in the grid circuit. This power is usually furnished by a driver tube through a suitably designed input transformer. The equivalent impedance in the external grid circuit of the output tubes consists of the reflected resistance of the driver tube, the reflected resistance and leakage reactance of the input transformer's primary, the resistance and leakage reactance of the input transformer's secondary, and the grid-bias resistance. The wave form of the input signal is distorted when grid current flows through the series connection of these impedances; this distortion consists of third and higher-order odd harmonics and sounds disagreeable to a listener, although the presence of these harmonics may not be apparent from an inspection of a total harmonic distortion characteristic.

In order to reduce the external grid-circuit impedance of the output stage, a low-resistance driver tube and a well-designed input transformer should be used. The driver tube should also be capable of supplying the power required by the grids of the output tubes and the input transformer with small distortion. The input transformer should furnish a signal of proper amplitude to the output tubes, reflect the least impedance into the grid circuit, and reflect the proper plate load to the driver tube.

Power-Supply Regulation

The effect of power-supply regulation in a Class AB amplifier is to cause plate and screen voltage to decrease and control-grid bias to increase as power output increases. In a practical amplifier, therefore, optimum conditions at full output may be different from the optimum conditions that obtain when electrode voltages do not vary with power output. The no-signal bias should be such that it increases to an optimum value at full output.

There is an optimum value of bias regulation for given values of plate and screen regulation. When the internal resistance of a bias-supply source is zero, reductions in plate and screen voltage with power output are comparatively large. The effect of reducing plate and screen voltage is to decrease power output; some change in load resistance may be necessary in order to minimize distortion. When the internal resistance of the bias-supply source is high, electrode-voltage variations with power output are reduced; however, distortion may rise appreciably. With some intermediate value of bias regulation, which depends on the values of plate and screen regulation, optimum conditions obtain. Bias regulation should be improved as plate and screen regulation are improved. It is best to determine the proper value of bias regulation by test.

Suggested Amplifier and Power Unit

Fig. 1 is the circuit of a power-supply unit and amplifier designed to furnish 55 watts to the primary of the output transformer. The driver stage consists of a 6F6, connected as a triode, and a suitable input transformer. The output stage consists of two 6L6's connected in push-pull. The no-signal plate voltage is 400 volts, the no-signal screen voltage is 300 volts, and the no-signal bias is -25 volts.

Plate voltage is obtained from a power-supply unit which uses an 83 as rectifier; screen and bias voltage are obtained from a second power-supply unit, which uses a 5Z3 as rectifier. Thus, the effects of large variations in plate current are reduced. An advantage of this arrangement is that over-heating of the 6L6's cannot occur when the bias resistor open-circuits or when the 5Z3 is removed from its socket. A disadvantage is that the screen current can rise to abnormally high values when the 83 is removed from its socket. Some means should be employed to prevent the flow of high screen currents when the 6L6 plate voltage is removed.

The input element to the plate-supply filter is a choke coil. The regulation which can be obtained from a choke-input filter is considerably better than the regulation which can be obtained from a condenser-input filter. A choke-input filter requires more input voltage and less current than a condenser-input filter; therefore, the size of the power transformer is nearly the same for both types of filters. A condenser-input filter is used in the screen-voltage supply unit, because screen current fluctuations are small.

Complete specifications for the plate-supply power transformer, input filter choke, input transformer, and output transformer are appended. The design of the screen-voltage supply unit is conventional; hence, no detailed specifications for the components used in this unit are given.

The wires in the vicinity of the output-tube sockets were carefully placed and shielded, as indicated in Fig. 1. A cathode-ray oscillograph was connected across the primary of the output transformer while listening tests were conducted and measurements were made. No trace of oscillation could be detected by this means. In the event that oscillation does occur, the placement of the output-stage wiring should be changed and the shielding should be made more thorough.

It is desirable to connect a resistance-capacitance filter across the primary of the output transformer. This filter serves to flatten the frequency characteristic of the amplifier and to prevent the generation of high transient voltages in the plate circuit. Under certain conditions, these transient voltages may be high enough to cause an arc between the plate lead and its eyelet inside the tube.

High transient voltages may be generated in the plate circuit of a tube when its load contains reactance. In a typical amplifier, the leakage reactance of the output transformer and the inductive component of the speaker impedance constitute part of the load impedance. The output capacitance of the tube, the distributed capacitance of the output transformer, and stray circuit capacitances tune the inductive component of the load impedance to a certain frequency. Unless this tuned circuit is highly damped, transient voltages of sufficient magnitude to damage the tube may be generated. The addition of capacitance across the primary of the output transformer serves to lower the resonant frequency of this tuned circuit. When the resonant frequency falls within the frequency range of the speaker, these transient voltages are audible and are superimposed on the normal output. The presence of these transients cannot be detected by an inspection of a frequency characteristic made under steady-state conditions.

At frequencies lower then the resonant frequency of the equivalent output circuit and higher than the resonant frequency of the speaker, the load presented to the output tubes acts like an inductance and resistance in series. This inductance is composed of the speaker inductance and the leakage inductance of the output transformer, referred to the primary of the output transformer. Thus, transient voltages are generated across the equivalent inductance in the plate circuit at medium audio frequencies. Correct compensation for the effects of an inductive load is obtained when the impedance of the load is made resistive by connecting a suitable resistance-capacitance network across the primary of the output transformer, as shown in Fig. 1. R should be made equal to 1.3 R_L, where R_L is the recommended plate-to-plate load (3800 ohms); C should be adjusted until the frequency characteristic is flat. When the load is compensated for the effects of inductance in this manner, the impedance of the load is nearly independent of frequency above 400 cycles. Transients are eliminated and the high-impedance tubes and load act like low-impedance triodes at these frequencies. Frequency characteristics of the amplifier described in this Note with correct compensation and with no compensation are shown in Fig. 2. A loudspeaker was connected to the amplifier during these tests.

Fig. 3 is a harmonic analysis of the output. Low-order harmonics are present at comparatively low outputs. The rapid rise of the seventh harmonic at the grid-current point is due to the effects of grid current and grid-circuit impedance. An output of 55 watts at approximately 7.5 per cent distortion is obtained at full output. Approximately 26 watts at 2.7 per cent distortion is obtained at the grid-current point.

Conclusion

Two 6L6's when operated in the amplifier described in this Note, can furnish 55 watts to the primary of the output transformer. The distortion, which is mainly third harmonic, is approximately 7.5 per cent. Other amplifier and power-unit designs may be used to obtain comparable results. The amplifier described in this Note is suggested in order to show what can be obtained with practical equipment.

POWER TRANSFORMER (T1)
SPECIFICATIONS (JTC-2)#

Core

Manufacturer, Allegheny Steel Company
Grade, Silicon
Watts loss/lb. at 10,000 gauss, 1.0
Punching, LE-4
Net Section, 14.2 cm^2
Window, 3-1/2" x 1-3/16"
Weight, 7.36 lbs.
Tongue, 1-1/8"
Stack, 2.22"
Stacking Factor, 0.88
Joint, Lap

Windings	Primary	High-Voltage Secondary	83 Rect.* Fil.	6.3 Volt* Secondary
Clearance Under	0.03"			
Clearance Over				0.2"
Insulation Under	0.063"	0.040" **	0.030"	0.030" **
Traverse & Margin	1/8" + 3-3/16" + 1/8" (3.03" net)			
Turns Total	295T #18 En.	2268T #28 En.	13T #17 En.	17T #16 En.
Taps		at 1134		
Size Insulated Conductor	0.0429"	0.0156"	0.0479"	0.0535"
Turns per Layer	59	189	13.0	17.0
Insulation Between Layers	0.005"	0.003"		
Number of Layers	5	12	1	1
Depth of Winding	0.240"	0.223"	0.050"	0.0535"
Form (Inside Dimensions)	2-9/32" x 1-3/16" x 3-7/16" long.			
Winding Order	1	2	3	4
Weight of Copper (lbs.)	1.053	1.022	0.083	0.143
Resistance at 25° C, Ohms	1.36	134.5 Total	0.067	0.073

Input Power Source, 125 V., 60 cycles

*Normal for 117-volt line.

**Contains Static Shield.

#Our design identification number.

FILTER CHOKE (T_2) SPECIFICATIONS (S-137)#

Core

Manufacturer,	Allegheny Steel Company
Grade,	Dynamo Special
Punching,	EI-12
Net Section,	12 cm^2
Window,	1-1/2" x 1/2"
Weight,	3.14 lbs.
Tongue,	1"
Stack,	2"

Stacking Factor, 0.94"
Gap, Approximately 0.005" each leg. Adjust for minimum hum.

Windings

Clearance Under	0.015"
Clearance Over	0.050"
Insulation Under	0.045"
Insulation Over	0.020"
Sum	0.130"
Traverse & Margin	1/8" + 1-3/16" + 1/8" (1.03" net)
Turns Total *	1250T #27 En.
Size Insula. Conductor	0.0156"
Turns Per Layer	66
Insula. between Layers	0.003"
Number of Layers	19
Depth of Winding	0.350"
Form (Inside Dimensions)	1-1/32" x 2-1/32" x 1-7/16" lg.
Weight of Copper (lbs.)	0.52
Resistance at 25° C, Ohms	44.5

* Start of winding connects to rectifier filament.

Our design identification number.

INPUT TRANSFORMER (T_8)
SPECIFICATIONS (S-154)

Core

Manufacturer, Allegheny Steel Company
Grade, Silicon
Watts loss/lb. at 10,000 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 1200 T.
Size Insulated Conductor	0.0052"	0.0052"	0.0072"
Turns per Layer	190	190	138
Insulation Between Layers	0.0015"	0.0015"	0.0015"
Number 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.

OUTPUT TRANSFORMER (T_4) SPECIFICATIONS (JTC-3)#

Core

Manufacturer, Allegheny Steel Company	
Grade, Silicon	
Watts loss/lb. at 10,000 gauss, = 0.8	
Punching,	EI-125
Net Section,	14.2 cm^2
Window,	5/8" x 1-7/8"
Weight,	4.45 lbs.
Tongue,	1-1/4"
Stack,	2"
Stacking Factor, 0.88	
Joint,	Lap
Core Loss Shunt Resistance, 63500 ohms	

Windings	Primary	Secondary
Clearance Under	0.015"	
Clearance Over		0.060"
Insulation Under	0.063"	0.030"
Insulation Over		0.010"
Traverse & Margin	1/8" + 1-9/16" + 1/8" (1.48" net)	
Turns Total	1300T #27 En.	330T #24 En.
Taps	at 650 turns	
Size Insulated Conductor	0.0156"	0.0219"
Turns per Layer	95	66
Insulation Between Layers	0.003"	0.005"
Number of Layers	14	5
Form (Inside Dimensions)	2-1/8" x 1-9/32" x 1-13/16" long	
Winding Order	1	2
Weight of Copper (lbs.)	0.54	0.34
Resistance at 25° C, Ohms	46 Total	7.0
Efficiency Full Load	90% at 60 cycles	
Power Source	2 - 6L6's, $E/_b$ = 400 v., E_{c2} = 300 v., E_{c1} = -25 v.	
Load Impedance, Ohms	250	
Reflected Load, Ohms	3800	

Our design identification number.

SCHEMATIC CIRCUIT OF 55-WATT AMPLIFIER USING TWO 6L6 TUBES

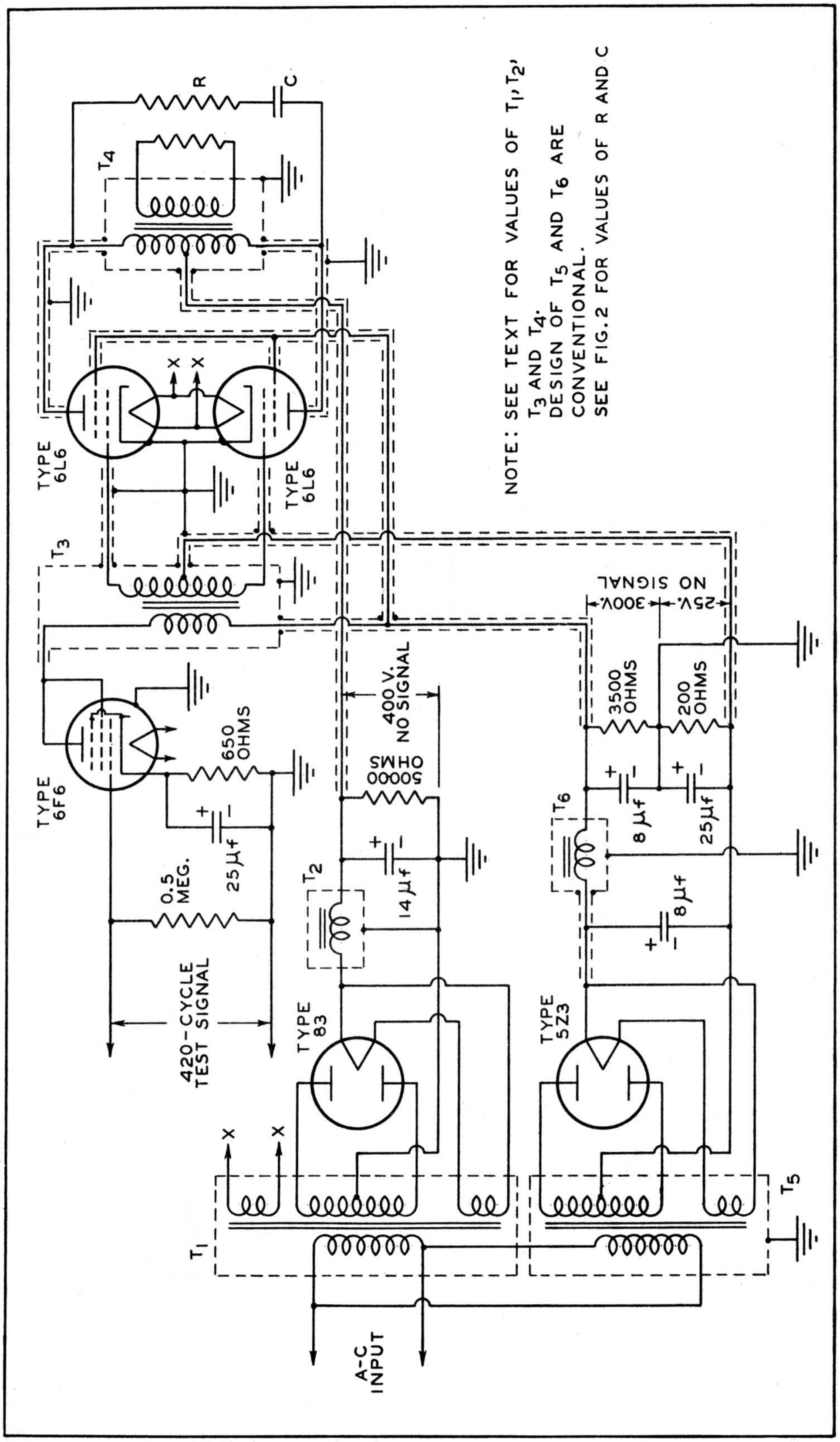

FIG. I

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DEC. 3, 1936

92C-4698

FREQUENCY CHARACTERISTIC OF AMPLIFIER SHOWN IN FIG. I

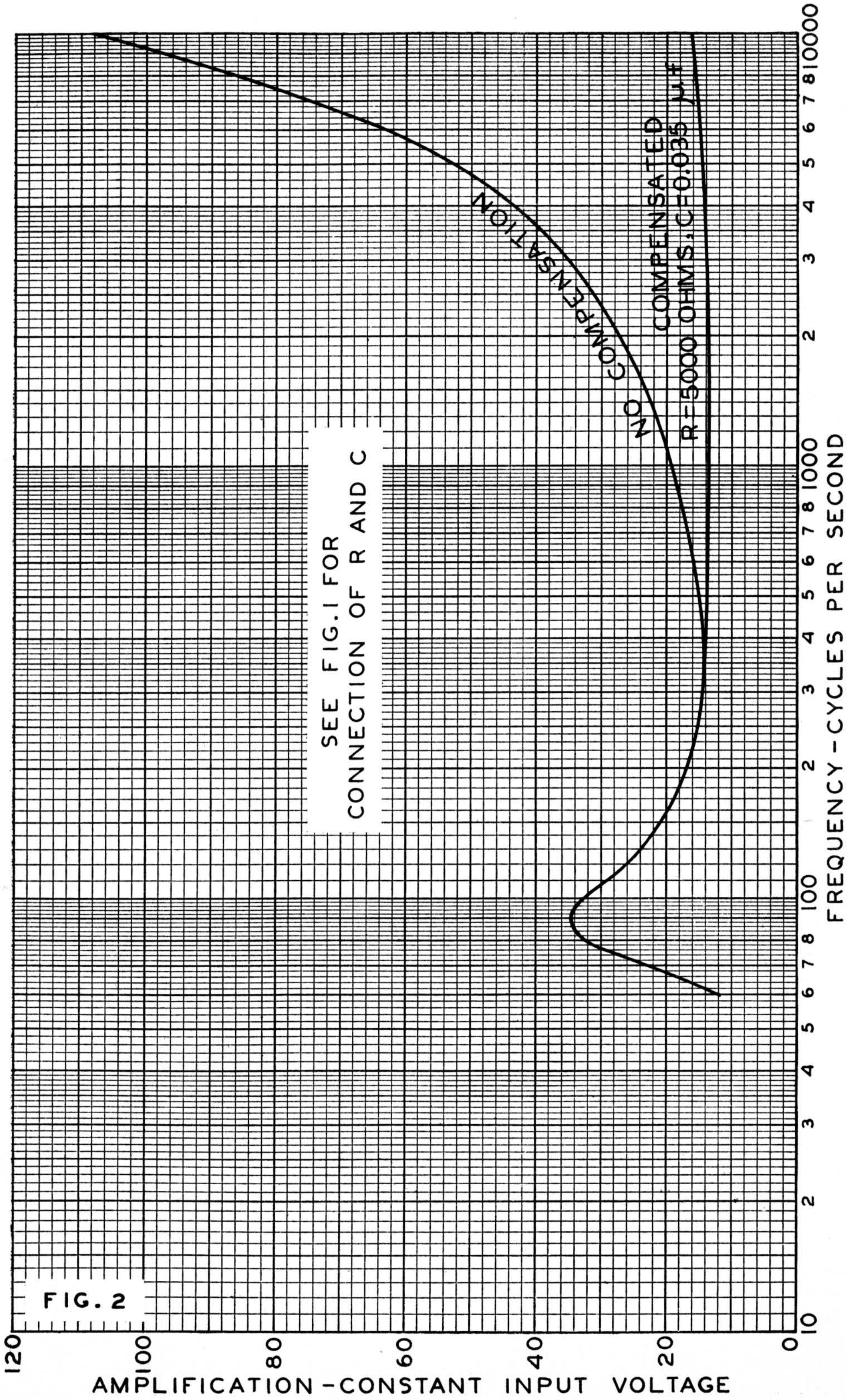

FIG. 2

RCA Cunningham Radiotron RADIO TUBES

RCA-6L6

DISTORTION CHARACTERISTICS

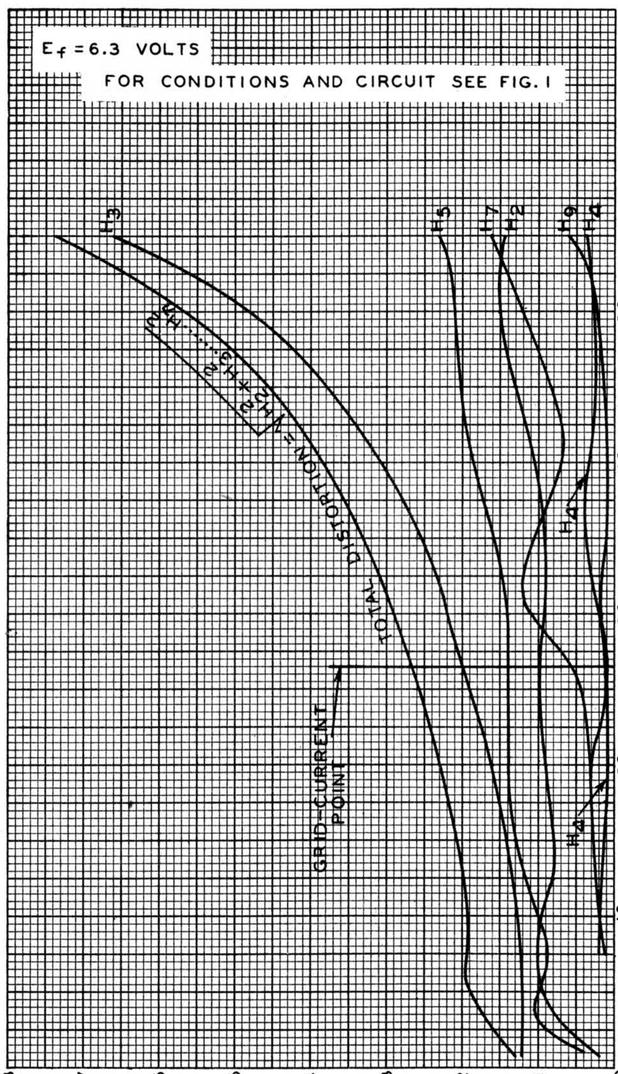

FIG. 3

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RCA Cunningham Radiotron RADIO TUBES

RCA-6L6

OPERATION CHARACTERISTICS

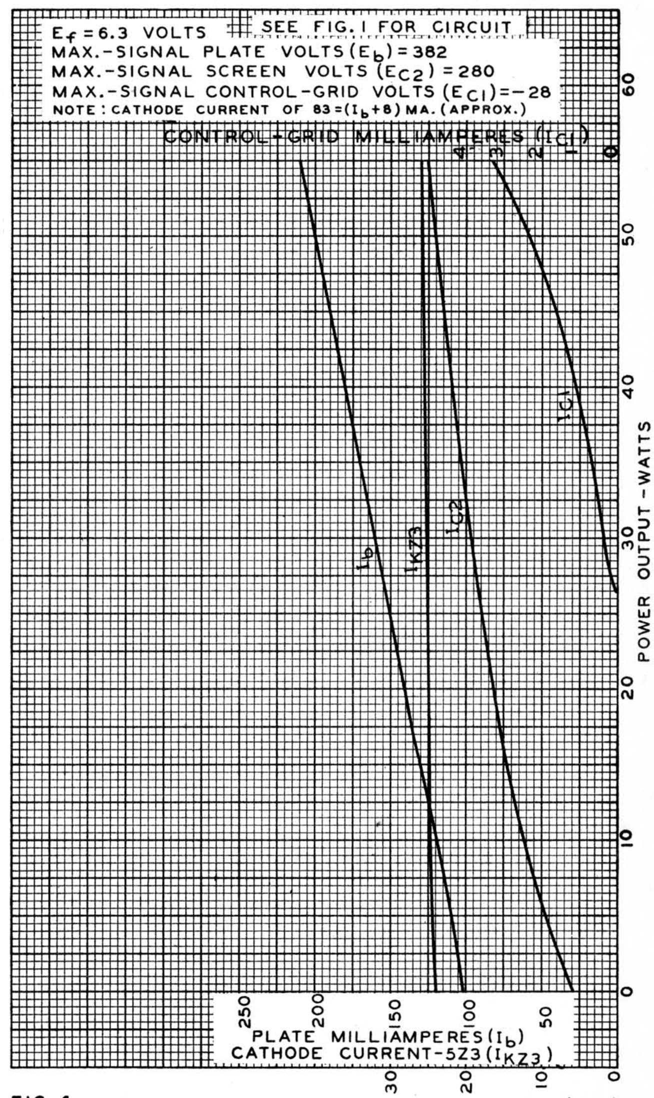

FIG. 4

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