



**RCA MANUFACTURING COMPANY, INC.**

A RADIO CORPORATION OF AMERICA SUBSIDIARY

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**RCA RADIOTRON  
D I V I S I O N**

APPLICATION NOTE No.52  
October 31, 1935.

APPLICATION NOTE  
ON  
CLASS AB OPERATION OF TYPE 6F6 TUBES CONNECTED AS TRIODES

The requirements for obtaining optimum power output from a Class AB amplifier are usually based on the assumption that the power-supply source has nearly zero resistance and, consequently, furnishes nearly constant voltage as the power output varies from zero to a maximum. Because this assumption is seldom true in practice, it is desirable to know the requirements for obtaining optimum power output when the power-supply unit has some resistance. It is the purpose of this Note to furnish detailed operating characteristics for two type 6F6 tubes when they are connected as triodes and operated as a Class AB amplifier. A subsequent Note will discuss the operation of these tubes when they are connected as pentodes and operated as a Class AB amplifier.

Description of Tests

The screen of each type 6F6 tube was connected to its plate and each control grid, in turn, was driven positive during a portion of the input-voltage cycle in order to obtain high power output; the power required by these grids was furnished by a suitable self-biased driver tube through an input transformer. In every case, the driver tube was biased to operate as a Class A amplifier.

Preliminary tests were conducted in order to determine the optimum input-transformer ratio and optimum plate-to-plate load for both fixed- and self-bias conditions and for several practical power-supply regulations. These tests show that the optimum plate-to-plate load is substantially independent of power-supply regulation. The value of this optimum load depends upon the power output desired, the permissible distortion, and whether or not the bias on the output tubes is obtained from a self-biasing resistor. The optimum input-transformer ratio was found to be a function of power-supply regulation only when the bias on the output tubes

A P P L I C A T I O N N O T E S



was fixed; when the output tubes were self-biased, the optimum transformer ratio was found to be substantially independent of power-supply regulation. The optimum plate-to-plate load and optimum input-transformer ratio for each test are given on the curve sheets and in the summary table.

### The Driver Tube

In order that a tube be suitable for use as a driver, it should have a reasonably high power sensitivity and should be capable of supplying the losses of both the input transformer and the grids of the output tubes. The results of a number of tests indicated that either a single 6F6 connected as a triode or a single 6C5 is a suitable driver. The 6F6 has reasonable power sensitivity and can satisfy the power requirements; the 6C5 has a high power sensitivity, although it cannot furnish all of the requisite power. The plate impedance of each type is low enough so that the inductance of the primary of the input transformer can easily be made sufficiently high to obtain good low-frequency response. In all tests, the 6F6 driver was self-biased to -20 volts and the 6C5 to -8 volts with no signal input; the zero-signal plate-to-cathode voltage was 250 volts for either type of driver. A comparison of the merits of the 6F6 and the 6C5 as drivers can be made from the attached curves or the summary table.

### Effect of Plate-Supply Regulation

The total series resistance in the plate circuit of the 6F6 output tubes consists of: (1)  $r_p$ , the plate resistance of the tubes; (2)  $R_p$ , the load resistance; (3)  $R_c$ , the series resistance common to grid and plate circuits; and (4)  $R_b$ , the equivalent series resistance of the power supply. It will be noted that  $R_c$  in self-biased circuits is equivalent to the grid-bias resistor.

When  $R_c$  and  $R_b$  are zero, best plate-voltage regulation and maximum power output are obtained. Therefore, it is advantageous to use fixed bias instead of self bias and to have  $R_b$  as small as possible. If a plate-voltage source of approximately zero resistance is used in place of the regular power supply, and if resistance is then introduced in series with this source until it has the same voltage regulation as the regular power supply, the resistance added to the circuit is the equivalent internal resistance ( $R_b$ ) of the power supply. In practice,  $R_b$  is determined by plotting the voltage-regulation curve of the power-supply system. This curve may be obtained conveniently by measuring the slope of the line joining the voltage outputs at the zero-signal and maximum-signal operating conditions. These correspond to minimum and maximum current drain. The slope of this line represents  $R_b$ , the equivalent d-c resistance of the power supply.

#### (A) Operation Using 6F6 Driver and Fixed Bias

Fig. 1 shows curves of d-c plate current, distortion, and d-c grid current vs. power output for power-supply regulations corresponding to 0, 500, and 1000 ohms. As mentioned previously, a different optimum input-transformer ratio is required for each power-supply regulation when the bias is fixed; these optimum ratios are shown in the insert of Fig. 1 and in the summary table. The input-transformer ratio (primary:1/2 secondary) decreases as  $R_b$  increases.

As the power output increases, distortion and plate current increase. Outputs of 18.8, 16.4, and 14.4 watts are obtained, corresponding, respectively, to power-supply regulations of 0, 500, and 1000 ohms. (All curves shown in this and in subsequent figures terminate at the start of driver grid current.) The distortion at maximum output for each power-supply regulation is approximately 7 per cent. If the input-transformer ratio is adjusted to optimum for zero power-supply regulation, the power outputs shown will not be obtained for any other power-supply regulation unless accompanied by increased distortion.

#### (B) Operation Using 6F6 Driver and Self Bias

The change from fixed- to self-bias operation requires the use of a different plate-to-plate load and input-transformer ratio for optimum results. The transformer ratio and load were kept the same throughout this test. The results, shown in Fig. 2, indicate that less power output is obtained when self, rather than fixed, bias is used and that both plate current and distortion are independent of power-supply regulation. Driver grid current started to flow at the same value of input signal for all three regulations. The power outputs corresponding to regulations of 0, 500, and 1000 ohms are 14.6, 14, and 13.5 watts; the distortions are 7.4, 6.2, and 5.4 per cent, respectively. It is seen that the effect of 1000 ohms in the power supply is to reduce the maximum power output from 14.6 to 13.5 watts, a decrease of 7.5 per cent; the corresponding decrease in test A with fixed bias was 23.4 per cent.

#### (C) Operation Using 6C5 Driver and Fixed Bias

Fig. 3 shows curves of d-c plate current, distortion, and d-c grid current vs. power output when a 6C5 is used as the driver and fixed bias is applied to the output tubes. In this test, as well as in test A, it was found that the optimum plate-to-plate load was 6000 ohms and that the optimum input transformer ratio was dependent upon power-supply regulation. Power outputs of 13.1, 12.1, and 11.5 watts were obtained, corresponding to power-supply regulations of 0, 500, and 1000 ohms. The distortion at maximum output for each power-supply regulation was approximately 7 per cent.

Comparing these curves with those in Fig. 1 which shows corresponding results for the 6F6 driver, it is seen that the maximum power outputs are much less, although the power sensitivity of the driver and output stages combined is higher with the 6C5 than with the 6F6 driver. The two distortion curves corresponding to regulations of 500 and 1000 ohms were found to be close enough to be represented by a single curve, as shown.

#### (D) Operation Using 6C5 Driver and Self Bias

Curves of d-c plate current, distortion, and d-c grid current vs. power output for this test are shown in Fig. 4. Power outputs of 11.4, 10.5, and 9.8 watts, corresponding to regulations of 0, 500, and 1000 ohms, were obtained. The distortion is approximately 6 per cent for all three cases. The plate-current and distortion curves are independent of power-supply regulation.

## Harmonic Distortion

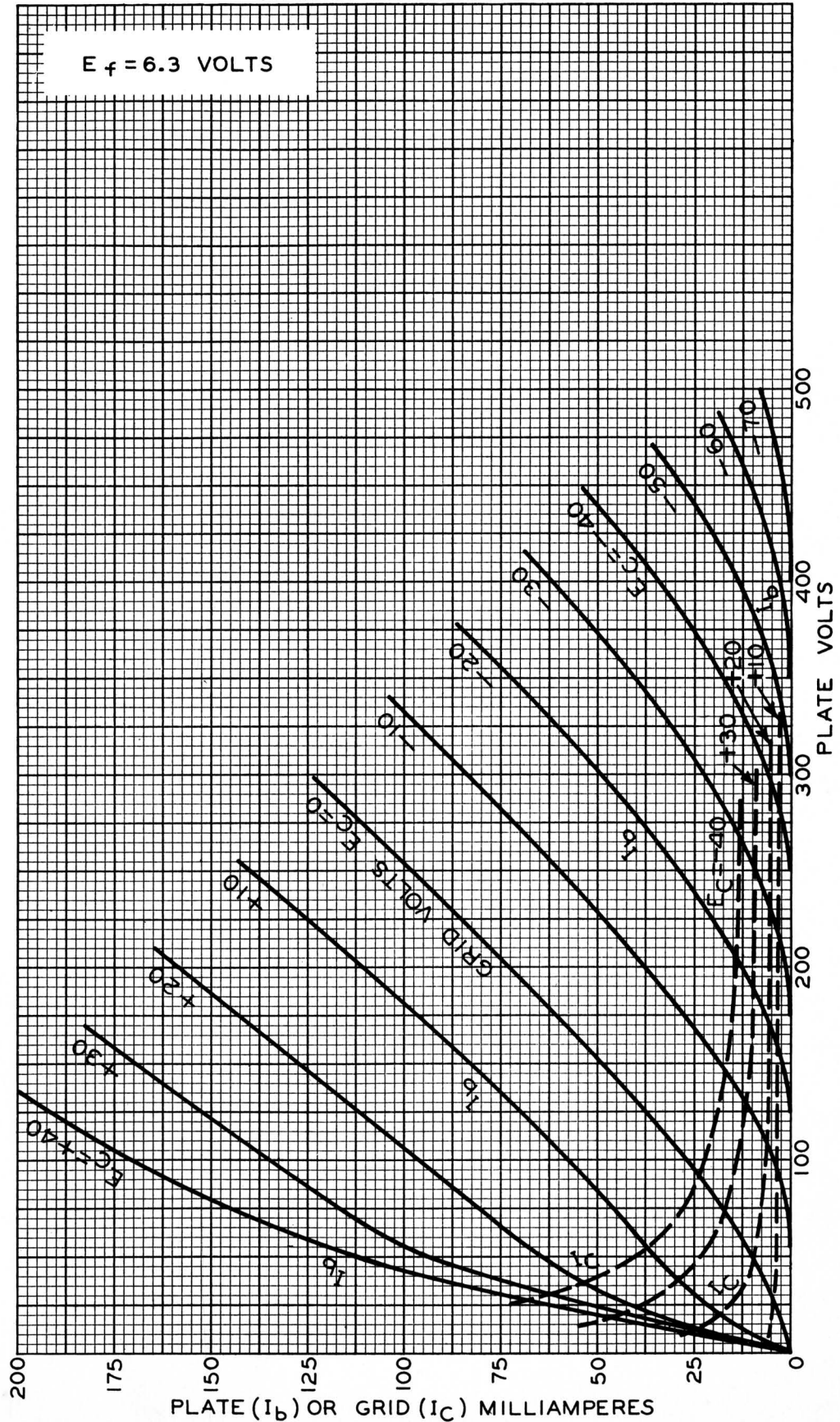
A harmonic analysis of the output using the set-up of test B was made in order to ascertain the nature of the distortion present under average operation conditions. The optimum plate-to-plate load was 10000 ohms, the input transformer ratio was 1.29, the tubes were self-biased, and the power-supply regulation was 500 ohms. The results are shown in Fig. 5. Only second and third harmonics are present at low signal levels; at higher levels, the fifth, seventh, ninth, and eleventh harmonics appear. At high signal levels, the high-order odd harmonics form an appreciable part of the total distortion. The lack of high-order even harmonics is due, of course, to the cancellation of these harmonics in the plate circuit of the push-pull stage; the second harmonic shown is introduced by the driver stage.

## Conclusion

Two 6F6's when connected as triodes in a push-pull circuit and operated to draw grid current, can provide power outputs up to approximately 18 watts at 7 per cent distortion; the actual output depends on the regulation of the power supply, the method of obtaining bias, and the type of driver tube. The variation in maximum power output and distortion with power-supply regulation is small when self bias is used. This characteristic is desirable when power-supply costs must be kept low, although it is obtained at a sacrifice of power output. In all tests, the driver tube was driven to its grid-current point and was operated as a Class A amplifier.

The efficiency of the input transformer used in these tests was average; the actual efficiency for each test is listed in the summary table. It must be remembered, however, that the leakage inductance of this transformer should be small at all times, regardless of the efficiency of the transformer as a power-transferring device. The ratio of the input transformer was optimum in each test; any deviation from the optimum values will result in either less power output or increased distortion. It is suggested, therefore, that those contemplating the use of this audio system first determine the regulation of the power supply to be used and then estimate the transformer ratio from the values given in this Note; power-supply regulations in excess of 1000 ohms are not recommended.

AVERAGE PLATE CHARACTERISTICS  
TRIODE CONNECTION



**SUMMARY TABLE**  
**CLASS AB OPERATION OF TYPE 6F6 TUBES (TRIODE CONNECTED)**

INDEX	DRIVER STAGE <sup>1</sup>						INTERSTAGE TRANSFORMER <sup>2</sup>		OUTPUT STAGE <sup>3</sup>									
	Tube Type	Input-Signal Volts (RMS)	Grid-Supply Resistance (R <sub>c</sub> ) Ohms	Zero-Signal Plate Current Milliamperes	Plate Load Ohms	Max Power Output Milliwatts	Primary/Secondary	Peak Power Efficiency Per cent	Plate-Supply Resistance (R <sub>p</sub> ) Ohms	Grid-Supply Resistance (R <sub>c</sub> ) Ohms	Grid-Input Peak Power Milliwatts	Grid-Input Peak Volts (per tube)	D-C Grid Current Milliamperes (per tube)	Zero-Signal D-C Plate Current Milliamperes (per tube)	Max.-Signal D-C Plate Current Milliamperes (per tube)	Plate-to-Plate Load Ohms	Power Output Watts (two tubes)	Total Harmonic Distortion Per Cent
Fig. 1	6F6 <sup>4</sup>	14.3	650	31	20000	690	1.67:1.0	73.2	0	0*	505	63.8	2	22.5	54.5	6000	18.8	6.8
Fig. 1	6F6	12.3	650	31	16150	685	1.48:1.0	75.8	500	0*	520	63.4	2	22.5	50	6000	16.4	7.0
Fig. 1	6F6	12.7	650	31	15000	690	1.43:1.0	75.6	1000	0*	525	63	2	22.5	45.5	6000	14.4	6.8
Fig. 2	6F6	14	650	31	15600	765	1.29:1.0	76.7	0	730	585	76.2	2	25	34	10000	14.6	7.4
Fig. 2	6F6	14	650	31	17400	592	1.29:1.0	76	500	730	450	71.6	2	25	33.5	10000	14	6.2
Fig. 2	6F6	14	650	31	17000	605	1.29:1.0	76.7	1000	730	465	71.4	1.8	25	33	10000	13.5	5.4
Fig. 3	6C5*	5.5	1000	8	40000	330	2.00:1.0	57.9	0	0*	190	54.5	0.93	22.5	47.5	6000	13.1	6.6
Fig. 3	6C5	5.3	1000	8	34800	330	1.82:1.0	61.5	500	0*	200	55.1	0.95	22.5	44	6000	12.1	6.8
Fig. 3	6C5	5.1	1000	8	32500	310	1.74:1.0	64.5	1000	0*	200	54.5	0.95	22.5	41	6000	11.5	6.8
Fig. 4	6C5	5.5	1000	8	35700	347	1.67:1.0	61.6	0	730	215	63.2	0.92	25	31.5	10000	11.4	6.2
Fig. 4	6C5	5.5	1000	8	38500	304	1.67:1.0	59.6	500	730	180	62	0.9	25	30.5	10000	10.5	6.2
Fig. 4	6C5	5.5	1000	8	37700	315	1.67:1.0	60.2	1000	730	190	62.4	0.9	25	30	10000	9.8	6.2

<sup>1</sup> Zero-signal plate volts equals 250.  
<sup>2</sup> Primary resistance, 1000 ohms; secondary resistance, 400 ohms; equivalent core loss, 100000 ohms.  
<sup>3</sup> Zero-signal plate voltage equals 350 volts.  
<sup>4</sup> Plate resistance of 6F6 under indicated conditions equals 2600 ohms.  
<sup>5</sup> Plate resistance of 6C5 under indicated conditions equals 10000 ohms.  
\* Fixed bias.



OPERATION CHARACTERISTICS  
TRIODE CONNECTION-CLASS AB OPERATION

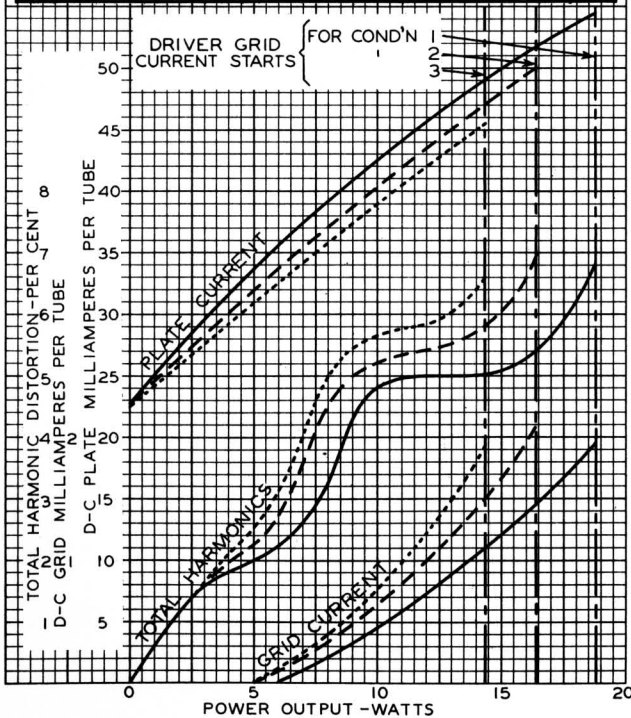
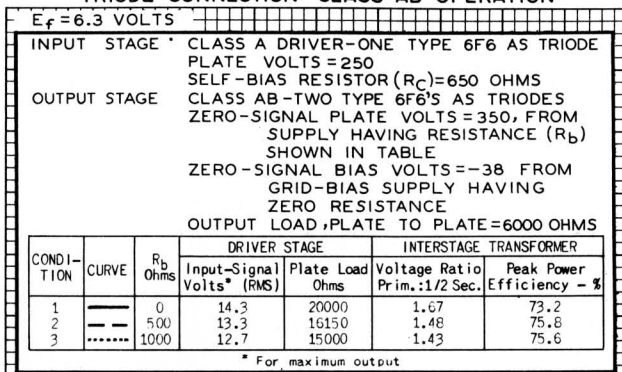


FIG. 1

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OPERATION CHARACTERISTICS  
TRIODE CONNECTION-CLASS AB OPERATION

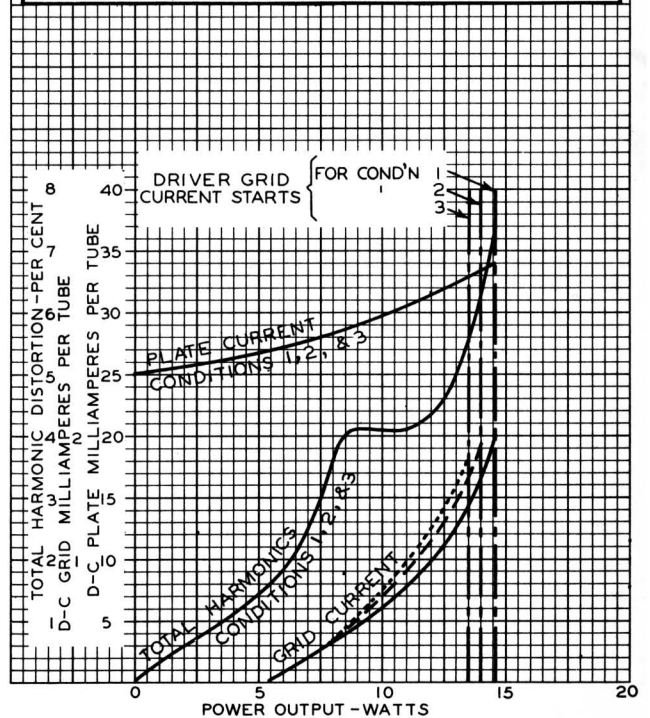
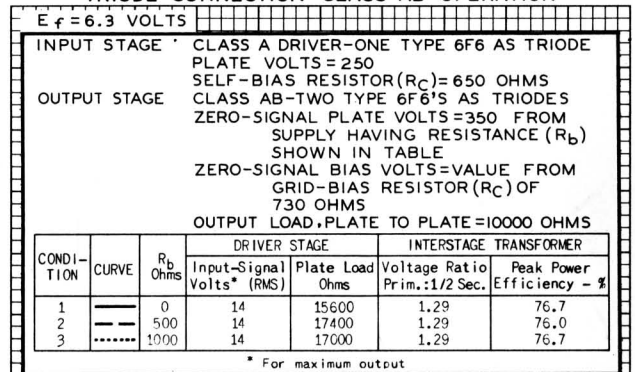


FIG. 2

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RCA-6F6

OPERATION CHARACTERISTICS  
TRIODE CONNECTION-CLASS AB OPERATION

$E_f = 6.3$  VOLTS

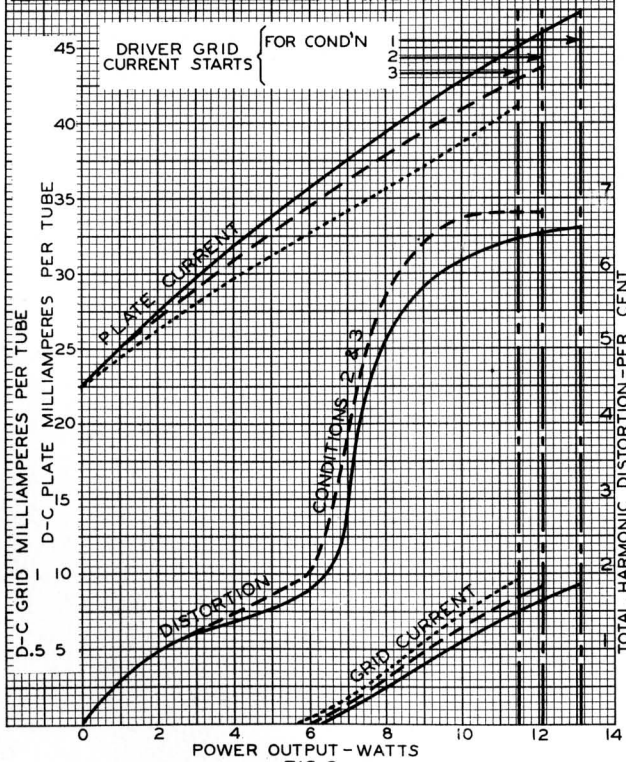
INPUT STAGE CLASS A DRIVER-ONE TYPE 6C5; PLATE VOLTS=250; SELF-BIAS RES. ( $R_c$ )=1000 OHMS

OUTPUT STAGE CLASS AB-TWO TYPE 6F6'S AS TRIODES ZERO-SIGNAL PLATE VOLTS=350, FROM SUPPLY HAVING RESISTANCE ( $R_b$ ) SHOWN IN TABLE

ZERO-SIGNAL BIAS VOLTS=-38, FROM GRID-BIAS SUPPLY HAVING ZERO RESISTANCE OUTPUT LOAD, PLATE TO PLATE=6000 OHMS

CONDI-TION	CURVE	$R_b$ Ohms	DRIVER STAGE		INTERSTAGE TRANSFORMER	
			Input-Signal Volts* (RMS)	Plate Load Ohms	Voltage Ratio Prim.:1/2 Sec.	Peak Power Efficiency - %
1	—	0	5.5	40000	2.00	57.9
2	- - -	500	5.3	34800	1.82	61.5
3	· · · · ·	1000	5.1	32500	1.74	64.5

\* For maximum output



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RCA-6F6

OPERATION CHARACTERISTICS  
TRIODE CONNECTION-CLASS AB OPERATION

$E_f = 6.3$  VOLTS

INPUT STAGE CLASS A DRIVER-ONE TYPE 6C5 PLATE VOLTS=250 SELF-BIAS RESISTOR ( $R_c$ )=1000 OHMS

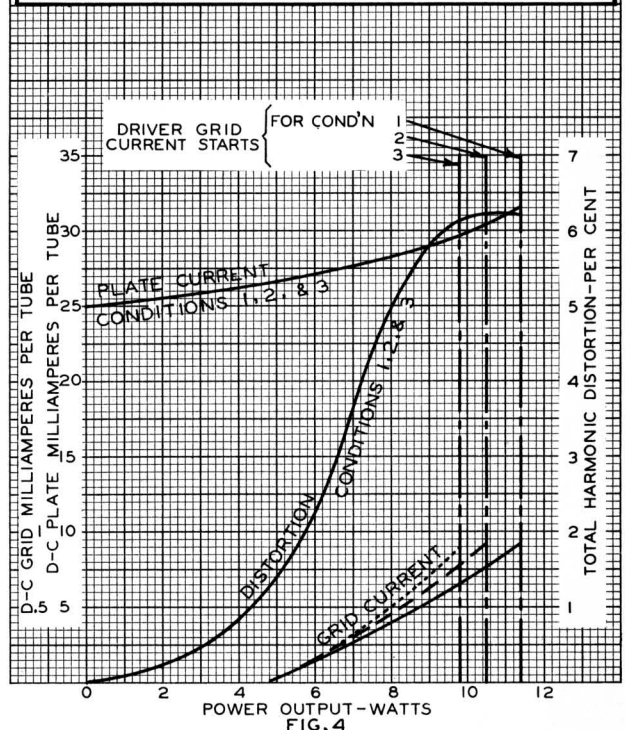
OUTPUT STAGE CLASS AB-TWO TYPE 6F6'S AS TRIODES ZERO-SIGNAL PLATE VOLTS=350, FROM SUPPLY HAVING RESISTANCE ( $R_b$ ) SHOWN IN TABLE

ZERO-SIGNAL BIAS VOLTS=VALUE FROM GRID-BIAS RESISTOR ( $R_c$ ) OF 730 OHMS

OUTPUT LOAD PLATE TO PLATE=10000 OHMS

CONDI-TION	CURVE	$R_b$ Ohms	DRIVER STAGE		INTERSTAGE TRANSFORMER	
			Input-Signal Volts* (RMS)	Plate Load Ohms	Voltage Ratio Prim.:1/2 Sec.	Peak Power Efficiency - %
1	—	0	5.5	35700	1.67	61.6
2	- - -	500	5.5	38500	1.67	59.6
3	· · · · ·	1000	5.5	37700	1.67	60.2

\* For maximum output



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OPERATION CHARACTERISTICS  
TRIODE CONNECTION-CLASS AB OPERATION

$E_f = 6.3$  VOLTS

INPUT STAGE CLASS A DRIVER-ONE TYPE 6F6 AS TRIODE  
PLATE VOLTS = 250  
SELF-BIAS RESISTOR ( $R_C$ ) = 650 OHMS

OUTPUT STAGE CLASS AB-TWO TYPE 6F6'S AS TRIODES  
ZERO-SIGNAL PLATE VOLTS = 350, FROM  
SUPPLY HAVING RESISTANCE ( $R_b$ )  
SHOWN IN TABLE  
ZERO-SIGNAL BIAS VOLTS = VALUE FROM  
GRID-BIAS RESISTOR ( $R_C$ ) OF  
730 OHMS  
OUTPUT LOAD, PLATE TO PLATE = 10000 OHMS

$R_b$ Ohms	DRIVER STAGE		INTERSTAGE TRANSFORMER	
	Input-Signal Volts* (RMS)	Plate Load Ohms	Voltage Ratio Prim.:1/2 Sec.	Peak Power Efficiency - %
500	14	17400	1.29	76.0

\* For maximum output

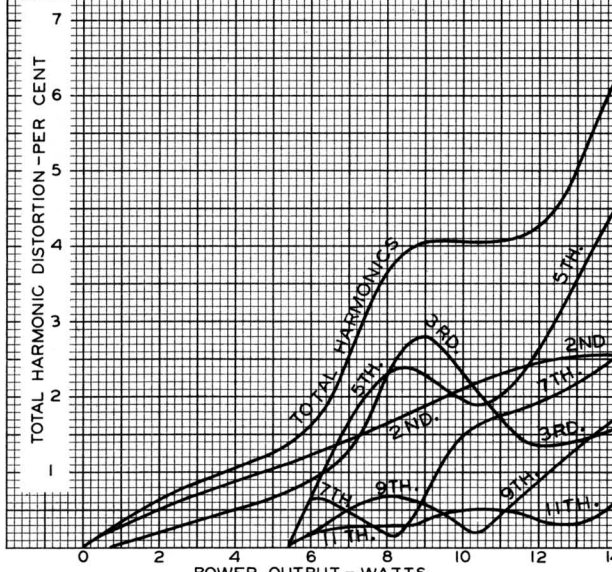


FIG. 5  
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