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

RCA RADIOTRON
DIVISION

APPLICATION NOTE No. 62
July 13, 1936

APPLICATION NOTE ON A NEW OPERATING CONDITION FOR TWO TYPE 6F6 TUBES CONNECTED AS PENTODES

The selection of the type of output tube to be used in a radio receiver is influenced by technical and economic requirements. For a given power output, the cost of the tube and the cost of the circuits associated with the tube often determine the tube selection; contributing technical considerations are the operating characteristics of the complete a-f amplifier system. Two important operating characteristics are: (1) the change in distortion with power output and (2) the rise in B-supply current with power output. The first describes the distortion characteristic of the system and the second imposes a limitation on the maximum permissible regulation of the B-supply source. This Note describes an economical push-pull amplifier which uses two type 6F6 tubes connected as pentodes. This amplifier has important technical features: it can furnish high power output, it has a good distortion characteristic, and the rise in B-supply current with power output is small. Complete data for ideal and practical operating conditions are shown in the accompanying illustrations.

Characteristics of Power Output Tubes

The shape of the distortion characteristic of a single 6F6 can be varied by choosing suitable values of bias and load. Thus, for a given bias, a value of load can be found for which the distortion characteristic rises slowly at low power outputs and very rapidly at high outputs. For the same bias, a more slowly rising distortion characteristic can be obtained with another value of load. As the bias is increased, it is necessary to increase the load resistance in order to reduce distortion. The efficiency of the tube as an amplifier is increased because of the increase in bias, but the power output may decrease. The screen voltage, however, can then be raised until the maximum dissipation rating of the tube is reached in order to compensate for the loss in power output. Thus, the bias and load of a 6F6 can be varied in order to satisfy a variety of design requirements. Such flexibility is not possible with some types of tubes, because the bias voltage is not completely independent of plate voltage.

The results of a number of preliminary tests have shown that high output at nominal distortion can be obtained from two type 6F6 tubes with 315 volts on plate and screen and -22 volts on the control grid. A single 6F6 operated with these electrode voltages can deliver 5 watts at 7 per cent total distortion; two tubes connected in push-pull can deliver 13 watts at 5.5 per cent distortion. In either case, negligible control-grid current is drawn at these outputs. In this Note, the characteristics of the push-pull connection will be discussed for three conditions: (1) fixed bias, zero power-supply regulation, and small grid-circuit impedance; (2) self bias, regulation due to a 1000-ohm power-supply circuit, and small grid-circuit impedance; and (3) operation in a commercial radio receiver of average design.

Operation Without Pre-Amplifier

Two type 6F6 tubes were connected in push-pull, as shown in Fig. 1. Plate and screen voltages were 315 volts and the bias was -22 volts. The control-grids were connected to the secondary of a low-impedance transformer, from which the signal voltage was obtained. The curves of Fig. 3 show the variation of power output and distortion vs. load resistance (R_L) for two operating conditions: (1) fixed bias and zero power-supply regulation and (2) self-bias and 1000-ohm regulation. The change from the first to the second condition was accomplished by means of switches S_1 and S_2.

The curves of Fig. 3 show that, with full signal applied, approximately 13.5 watts at 8.5 per cent distortion can be obtained from two type 6F6 tubes at the grid-current point with a plate-to-plate load of 12000 ohms. This output may be obtained from either condition of operation, as indicated in Fig. 3. However, with a load of 10000 ohms, the power output is 13 watts and the distortion is only 5.5 per cent. This value of load resistance is recommended because of the lower value of distortion.

The curves of Fig. 4 show the variation of cathode current, grid-to-grid signal voltage, and total distortion vs. power output for a load of 10000 ohms. The rise in cathode current (plate plus screen current) from zero to full output for the two tubes is only 22 milliamperes for the fixed-bias condition and 10 milliamperes for the self-bias condition; nearly all of the increase in cathode current is due to rectification in the screen circuit.

The curves of distortion vs. power output show that the distortion rises smoothly from low values at low power outputs to the nominal value at the grid-current point. These curves are not extended into the grid-current region, because the effect of grid current on distortion depends on the nature of the grid circuit. As indicated in Figs. 1 and 2, a 420-cycle signal was used for all tests. The distortion characteristics shown, therefore, obtain only for a signal of this frequency. Additional distortion is introduced by the output transformer at lower frequencies, because of the characteristics of the iron core.

Operation in a Typical Receiver

In order to determine the characteristics of the amplifier under practical operating conditions, two type 6F6 tubes were connected in the output stage of a commercial radio receiver of average design. The output stage was fed by a two-tube resistance-coupled phase inverter, which was preceded by a diode type of second detector. The output tubes were self-biased and the regulation was that due to an 850-ohm power supply. These characteristics are representative of average receiver design.

The results of the preliminary tests indicate that a plate-to-plate load of 10000 ohms is desirable. In order that the tubes actually work into this load, the parallel combination of the reflected load and the transformer primary impedance should equal 10000 ohms. This condition was satisfied by placing a 12700-ohm resistor across the primary of the receiver's output transformer; the power delivered to this resistor is the power supplied to the equivalent load, and not the total power furnished by the tube. A second test was conducted in this receiver with an almost ideal output transformer; the required reflected load resistance was 10700 ohms. The performance curves of the receiver with the practical output transformer and with the nearly ideal output transformer are shown in Fig. 5. The schematic circuit of a portion of the receiver is shown in Fig. 2.

It is not necessary to use the phase-inverter circuit of Fig. 2 in order to duplicate the results shown in this Note. The output tubes may be fed by a single-tube transformer-coupled amplifier, or by a push-pull resistance-coupled amplifier. In either case, results which are comparable to those shown in this Note can be obtained.

The phase inverter was adjusted by applying to the 6F5 a signal of such magnitude that grid current started to flow in Tube A. The signal input to the 6C5 was then adjusted by means of the potentiometer (P) until grid current started to flow in Tube B. After this adjustment was made, power output, distortion, and total cathode current were measured for both the practical transformer and the nearly ideal transformer. The tests were carried beyond the grid-current point in order to determine the practical distortion characteristic of the system.

Fig. 5 shows that, in a typical receiver, the distortion increases smoothly from low values at low outputs to reasonable values at high outputs. Under the conditions shown in Fig. 2, over 15 watts can be obtained from the system without any discontinuities in the distortion characteristic. These curves also show that the use of a practical output transformer does not reduce the maximum power output and that the total distortion at high outputs is reasonable. The total cathode current is not shown, because the rise was only 4 milliamperes at the 15.5-watt level.

A receiver designed for a maximum output of 15 watts will usually be operated at some lower output level. The distortion characteristics shown in Fig. 5 indicate that low distortion can be expected at these lower outputs and that reproduction will not break up at high outputs. These conclusions were verified by listening tests.

If the output at 5 per cent distortion is arbitrarily defined as a good operating level for this receiver, then the overload characteristic may be defined as the distortion characteristic between the output at 5 per cent distortion and maximum output, regardless of the output at which grid current flows. For this receiver, the output at 5 per cent distortion is approximately 9 watts; the overload characteristic, therefore, extends to 15 watts.

The features of the 6F6 output system described in this Note are: high output (15 watts) at reasonable distortion, low distortion at low outputs, a smooth distortion characteristic, and negligible rise in d-c plate current with signal. The operating conditions for a push-pull amplifier are tabulated below for convenience.

Heater Voltage	6.3 Volts
Plate Voltage	315 Volts
Screen Voltage	315 Volts
Control-Grid Voltage	-22 Volts
Zero-Signal Plate Current (two tubes)	84 Milliamperes
Zero-Signal Screen Current (two tubes)	16 Milliamperes
Plate-to-Plate Load	10000 Ohms
Self-Bias Resistor	220 Ohms

RCA Cunningham Radiotron

CIRCUIT USED FOR DETERMINATION OF OPTIMUM PLATE LOAD

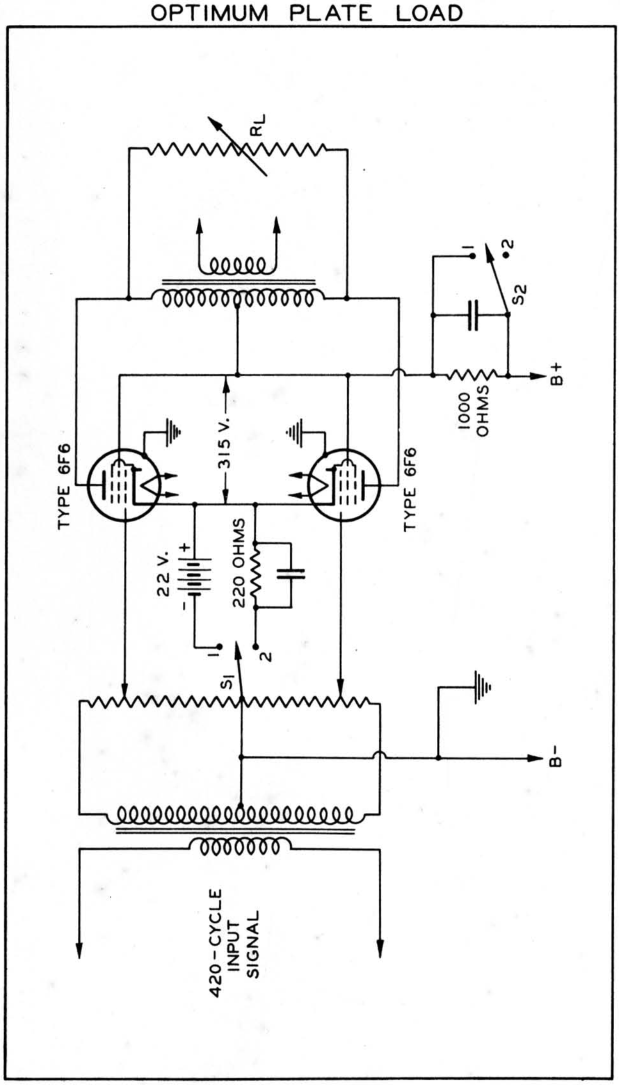

FIG. 1

JUNE 19, 1936 — RCA RADIOTRON DIVISION, RCA MANUFACTURING COMPANY, INC. — 92C-4632

RCA Cunningham Radiotron

CIRCUIT USED FOR DETERMINATION OF PRACTICAL OPERATING CONDITIONS

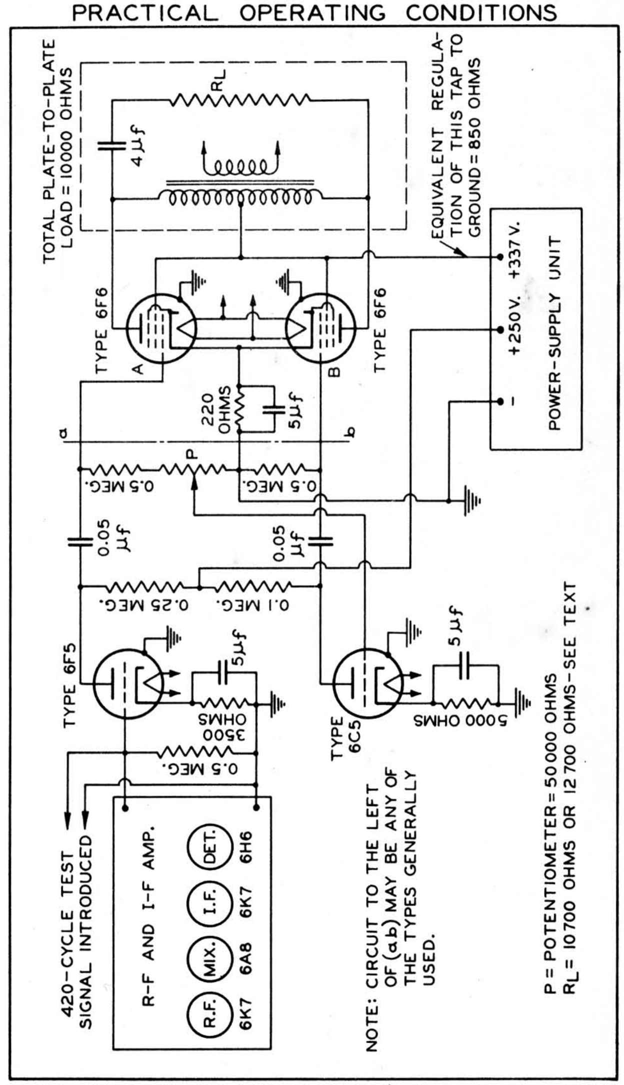

FIG. 2

JUNE 19, 1936 — RCA RADIOTRON DIVISION, RCA MANUFACTURING COMPANY, INC. — 92C-4633

RCA Cunningham Radiotron

RCA-6F6

OPERATION CHARACTERISTICS

CLASS A PUSH-PULL OPERATION

E_f = 6.3 VOLTS   PLATE VOLTS = SCREEN VOLTS = 315
CIRCUIT: SEE FIG.1

CONDITION	CURVE	BIAS	REGULATION (OHMS)
①	– – –	SELF: 220 OHMS	1000
②	———	FIXED: -22 VOLTS	0

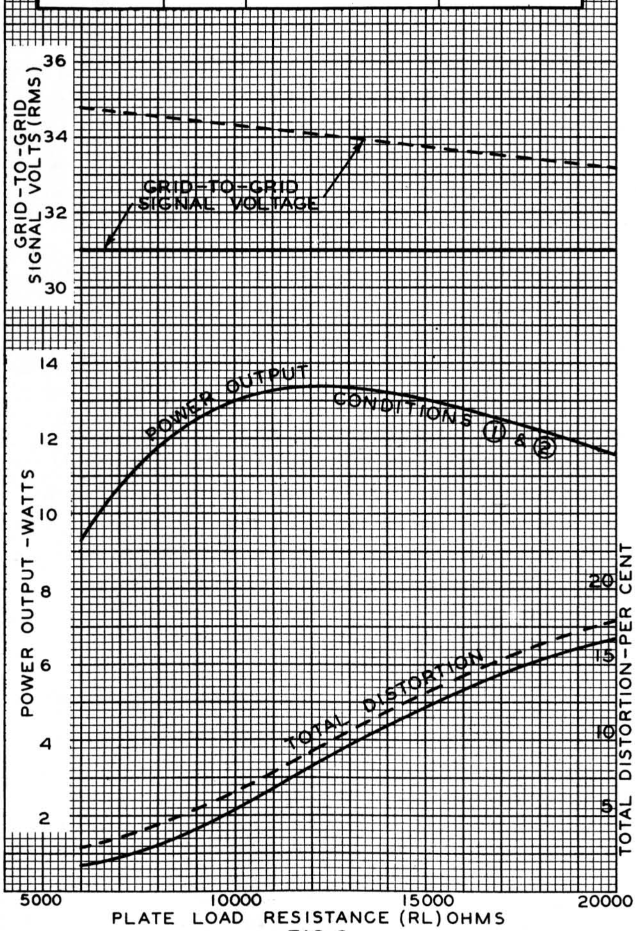

FIG.3

JUNE 19, 1936   RCA RADIOTRON DIVISION
RCA MANUFACTURING COMPANY, INC.   92C-4630

RCA Cunningham Radiotron

RCA-6F6

OPERATION CHARACTERISTICS

CLASS A PUSH-PULL OPERATION

E_f = 6.3 VOLTS   PLATE VOLTS = SCREEN VOLTS = 315
LOAD RESISTANCE (PLATE TO PLATE) = 10000 OHMS
CIRCUIT: SEE FIG.1

CURVE	BIAS	REGULATION (OHMS)
– – –	SELF: 220 OHMS	1000
———	FIXED: -22 VOLTS	0

NOTE: ALL CURVES TERMINATE AT GRID-CURRENT POINT

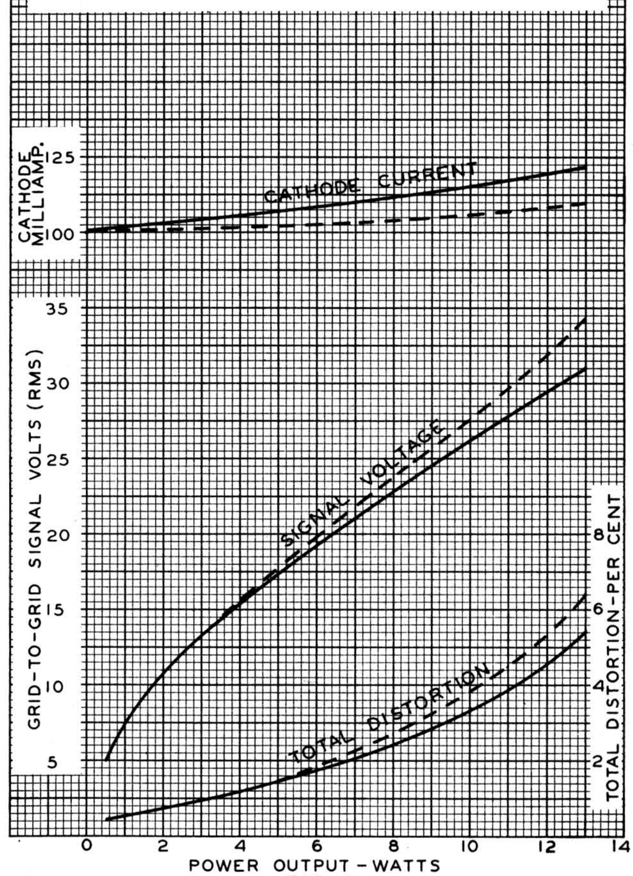

FIG.4

JUNE 19, 1936   RCA RADIOTRON DIVISION
RCA MANUFACTURING COMPANY, INC.   92C-4631

Cunningham Radiotron

RCA-6F6

OPERATION CHARACTERISTICS
CLASS A PUSH-PULL OPERATION

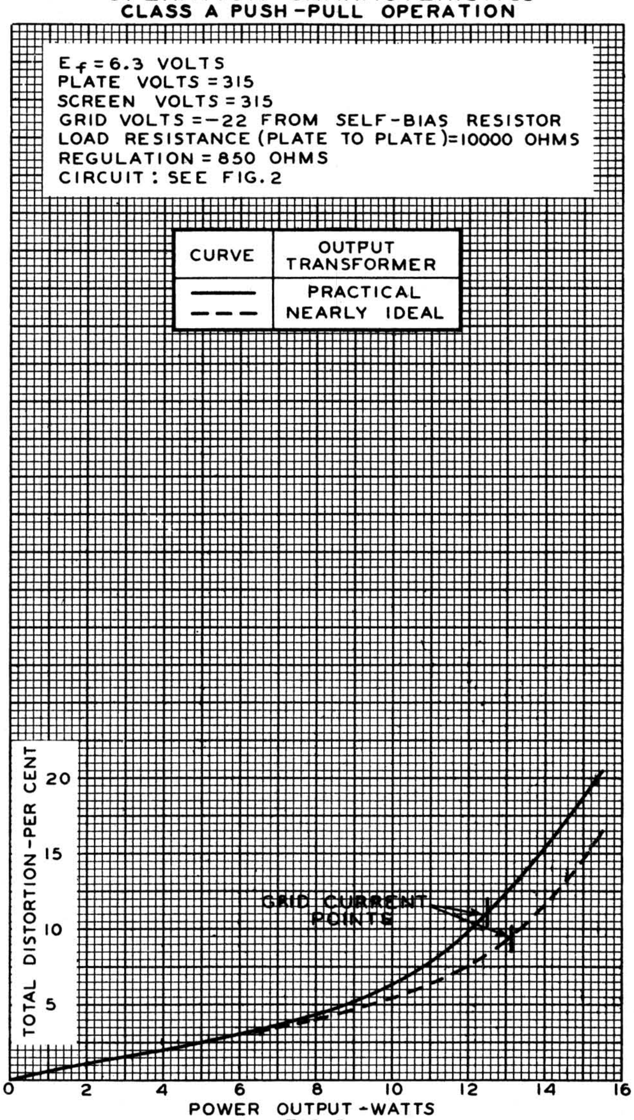

FIG. 5

JUNE 22, 1936

RCA RADIOTRON DIVISION
RCA MANUFACTURING COMPANY, INC.

92C-4634