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HARRISON NEW JERSEY

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UNIFIED SALES--ENGINEERING SERVICE
TO
EQUIPMENT MANUFACTURERS

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APPLICATION NOTE No. 30

January 3, 1934

APPLICATION NOTE ON THE CHARACTERISTICS OF THE 6F7 TUBE

The 6F7 is a vacuum tube consisting of two separate units, a triode unit and a pentode unit. Both units are contained within a single bulb and are constructed around a common cathode with the triode unit mounted below the pentode unit. This tube has a standard seven-pin base, a cap connection to the pentode grid on the bulb top, and employs an ST-12 bulb.

The 6F7 is designed to be used as a combined oscillator and mixer (first detector) in superheterodyne receivers. For this application, the triode is used as oscillator and the pentode, as mixer.

Other applications of the 6F7 in receiver design are: The use of the pentode unit as an intermediate-frequency amplifier with the triode unit connected either as a fixed-bias triode, grid-leak triode or as a diode second detector; the use of the triode unit as second detector with the pentode unit as an audio-frequency amplifier; the use of other combinations in which the triode functions as an a.v.c. device or as an inter-channel noise suppressor with the pentode unit used as detector or amplifier.

Typical operation conditions and characteristics for the 6F7 units in amplifier and converter service follow:

TYPICAL OPERATING CONDITIONS AND CHARACTERISTICS

Heater Voltage	6.3	Volts
Heater Current	0.3	Ampere

Amplifier Service (Class A)

	Triode Unit		Pentode Unit		
Plate Voltage	100 max.	250* max.	100	250	Volts
Screen Voltage	---	---	100 max.	100 max.	Volts
Grid Voltage	-3	37.5**	-3 min.	-3 min.	Volts
Amplification Factor	8	---	300	900	
Plate Resistance	17800	---	300000	850000	Ohms
Mutual Conductance	450	---	1050	1100	Micromhos
Mutual Conductance at -35 volts bias	---	---	10	10	Micromhos
Plate Current	3.5	**	6.4	6.5	Milliamperes
Screen Current	---		1.6	1.5	Milliamperes

* This rating applies for biased detector use only.

** Grid voltage to be adjusted to give approximately 0.2 milliampere plate current with no input signal.

Converter Service

	Triode Unit	Pentode Unit	
Plate Voltage	100 max.	250 max.	Volts
Screen Voltage	---	100 max.	Volts
Grid Voltage	##	-3 min.#	Volts
Oscillator Plate Current (Average)	4 max.	---	Milliamperes
Conversion Conductance	---	300#	Micromhos

Negative grid-bias voltage should be at least 3 volts greater than peak oscillator voltage. With peak oscillator voltage of 7 volts and a negative grid bias of 10 volts, the conversion conductance is 300 micromhos.

Oscillator grid bias usually obtained by means of a grid-leak resistor.

Figures 1 and 2 are average plate characteristics curves for the triode and pentode units of the 6F7. Maximum allowable plate voltages are: For the triode unit as an amplifier, 100 volts; for the triode unit as a biased detector, 250 volts; for the pentode unit as an amplifier or detector, 250 volts. Plate family and detection curves, curves of the pentode transfer characteristics, average characteristics of the pentode unit, operational characteristics of the pentode as a frequency converter, and pentode conversion curves are included in order that complete design information will be available.

The transfer and conversion curves are shown in Figures 3A and 3B, respectively. Their use is discussed in our Technical Discussion UL-7. Figure 3C shows the operation characteristics of the 6F7 as a frequency converter, Figure 3D shows dynamic characteristics of the pentode unit for variation of screen-grid voltage, and Figures 3E and 3F, respectively, show dynamic characteristics of the pentode unit for variation of control-grid voltage with plate voltages of 250 and 100 volts.

APPLICATIONS

Application as Frequency-Converter

Figure 4A is a circuit diagram showing the 6F7 used as a frequency-converter. In this diagram, the oscillator coil has been tapped and mixing is effected by introducing oscillator voltage into the common cathode return to ground. Figure 4B shows another circuit of frequency-converter application. This arrangement is generally preferable to that given in Figure 4A.

Application as I-F Amplifier and Second Detector

Figure 4C illustrates an arrangement whereby the pentode unit can be used as an i-f amplifier and the triode unit as a second detector. A biasing device consisting of a tapped cathode resistor is used to apply bias voltage to the grids of the two units. If desired, the biasing circuit can be arranged so as to include the cathode current of other tubes in the receiver such as the 6A7 or the 78. This makes possible, for purposes of volume control, the simultaneous adjustment of grid-bias voltages on all of the controlled tubes. The method is practical because cut-off voltages for the 6F7 pentode unit, the 6A7 pentode unit, and the 78 are approximately the same for the same plate voltages.

As a detector for small signal inputs, the pentode unit is more suitable than the triode because of its greater sensitivity. For this reason, the pentode rather than the triode, is generally used as mixer or first detector. Either unit may be used as a second detector, the unit chosen depending upon the level of the input signal. As a second detector, the triode unit can deliver sufficient output voltage to excite a power tube, if the signal input voltage to the detector is sufficiently high. This arrangement (in Fig. 4C) provides not only an i-f stage and second detector but also adequate input to the power output stage without intermediate audio amplification.

If automatic volume control is desired, it is most easily obtained by using the 6B7 (a duplex-diode pentode).

Application as Detector

Although either unit of the 6F7 can be used as a second detector, the characteristics of the tube are such that the triode is the preferable unit for this purpose. When the 6F7 is used as a combination intermediate- or radio-frequency amplifier, the pentode as previously indicated, is used as the amplifier unit and the triode as the detector. To interchange these functions would result in great loss in the overall gain obtained. Of the two units, the pentode is the better amplifier at either radio or audio frequencies. Hence, the most efficient application of the tube as combined detector and audio amplifier is that wherein the triode functions as detector (second) and the pentode, as audio amplifier. When so employed, the triode can be connected for grid-leak or fixed-bias detection. A limitation imposed by the common cathode makes it impossible to obtain true self-bias detection for the triode because the pentode plate and screen current greatly exceeds the triode detector plate current in the common cathode. As a result of this limitation when a tapped biasing resistor is used in the cathode return (as in Fig. 4D), the bias obtained for both the pentode and triode units is virtually a fixed bias. Calculations to determine the size of biasing resistor should take into consideration this fact. As a grid-leak detector, the triode unit will handle small signals to give small audio output voltages. As a fixed-bias detector, the amount of signal that the triode unit will handle, and also its sensitivity, are determined by the applied grid-bias voltage.

Application as Second Detector and Audio Amplifier

Diagrams 4D, E and F show how the 6F7 is used as a detector and audio amplifier. Figure 4D shows the pentode connected as an audio amplifier following the triode unit as a fixed-bias detector and Figure 4E shows the same arrangement except that the triode is connected as a grid-leak detector. Figure 4F shows the triode connected as a diode followed by the pentode unit connected as an audio amplifier. This arrangement provides diode detection with delayed automatic volume control and is accomplished by connecting the triode grid and plate separately for direct current but together for r-f input. The grid acts as the diode anode for detection and the plate with its associated circuit provides the delay bias. Where the series-cathode resistor R_{17} is made adjustable, the amount of delay can be varied.

OPERATING CHARACTERISTICS

Operating Characteristics as I-F Amplifier and Second Detector

For operation of the 6F7 as a combination i-f amplifier and fixed-bias second detector in the circuit shown in Figure 4C, plate and screen voltage supplies are 250 and 100 volts, respectively. The grid-bias voltage for the pentode unit is obtained from the drop across R_{16} and that for the triode unit from the drop across R_{15} and R_{16}. Grid-bias voltage for maximum volume-control setting, should be approximately 20 volts for the detector and 3 volts minimum for the pentode. The variable resistor R_{15} provides manual volume control by variation of the grid bias on the i-f amplifier.

Operating Characteristics as Fixed-Bias Detector

Figure 5 shows curves of fixed-bias detector operation for the 250- and 100-volt conditions. The radio-frequency input voltage as well as the corresponding grid-bias voltage required for a given audio-frequency output voltage are shown. These curves were taken with the radio-frequency input modulated 20%. Within the upper limits of these curves, the detector output will be relatively free from distortion.

In choosing the value of grid-bias voltage, one should be guided by the detector operating conditions. From the shape of the curves, it is noted that detection sensitivity decreases for the higher values of output. It is best, therefore, to operate the detector at the lowest bias voltage commensurate with the audio-output voltage required. For example, if the triode detector is to be followed by a power output tube requiring 14 volts peak or 10 volts RMS to excite it, the triode should be biased to approximately 21 volts for the 250-volt supply condition. If, however, the tube following the detector requires only a very small input voltage, such as that required by the 6F7 pentode unit, i.e. 3 volts peak or 2.1 volts RMS, detector sensitivity would be at its best if a bias voltage of 14.8 volts were supplied to its grid. The self-bias voltage can be obtained from a series-cathode resistance and is essentially fixed because of the smallness of the detector plate current as compared to the pentode plate current.

Operating Characteristics as Grid-Leak Detector

Figures 6 to 9, inclusive, show the characteristics of the triode and pentode units of the 6F7 as grid-leak detectors under various operating conditions. Figures 6 and 7 are for the triode; Figures 8 and 9 are for the pentode. The curves for operation as a grid-leak detector are taken with a one-megohm grid leak and a 0.00025 μf condenser and with other values as indicated on the curve sheets. The grid-leak detector is more sensitive than the bias detector. It is best used as a detector where sensitivity and small output voltage are required. Where larger output voltages are necessary, fixed-bias detection should be employed.

The following tabulation of the output voltages obtainable with 30% modulation of the input radio-frequency signal is representative of the maximum detector output voltages obtainable under the given conditions:

	Triode	Triode	Pentode	Pentode
Plate-Supply Volts	100	250	100	250
Input Volts (RMS)	2.1	3.0	0.7	0.7
Output Volts (RMS)	2.0	3.85	5.5	8.6

For the triode, these values are at saturation beyond which the output voltage will not increase with increased input voltage. For the pentode, the above values represent the points where appreciable distortion commences.

Comparison of the above tabulated values for the triode portion of the 6F7 with the corresponding values shown in Figure 5, shows quite clearly the differences in operating levels of the two types of detectors, their relative sensitivities, and the gain obtainable with each type.

Figure 10 shows the screen grid voltage necessary to obtain maximum audio output at different signal levels for the pentode unit operated with 250 volts total d-c supply, 20 per cent modulation of the input voltage, and optimum circuit values. The setting of screen voltage is quite critical. The accompanying screen current, plate current, and average d-c bias voltage are also shown in this figure.

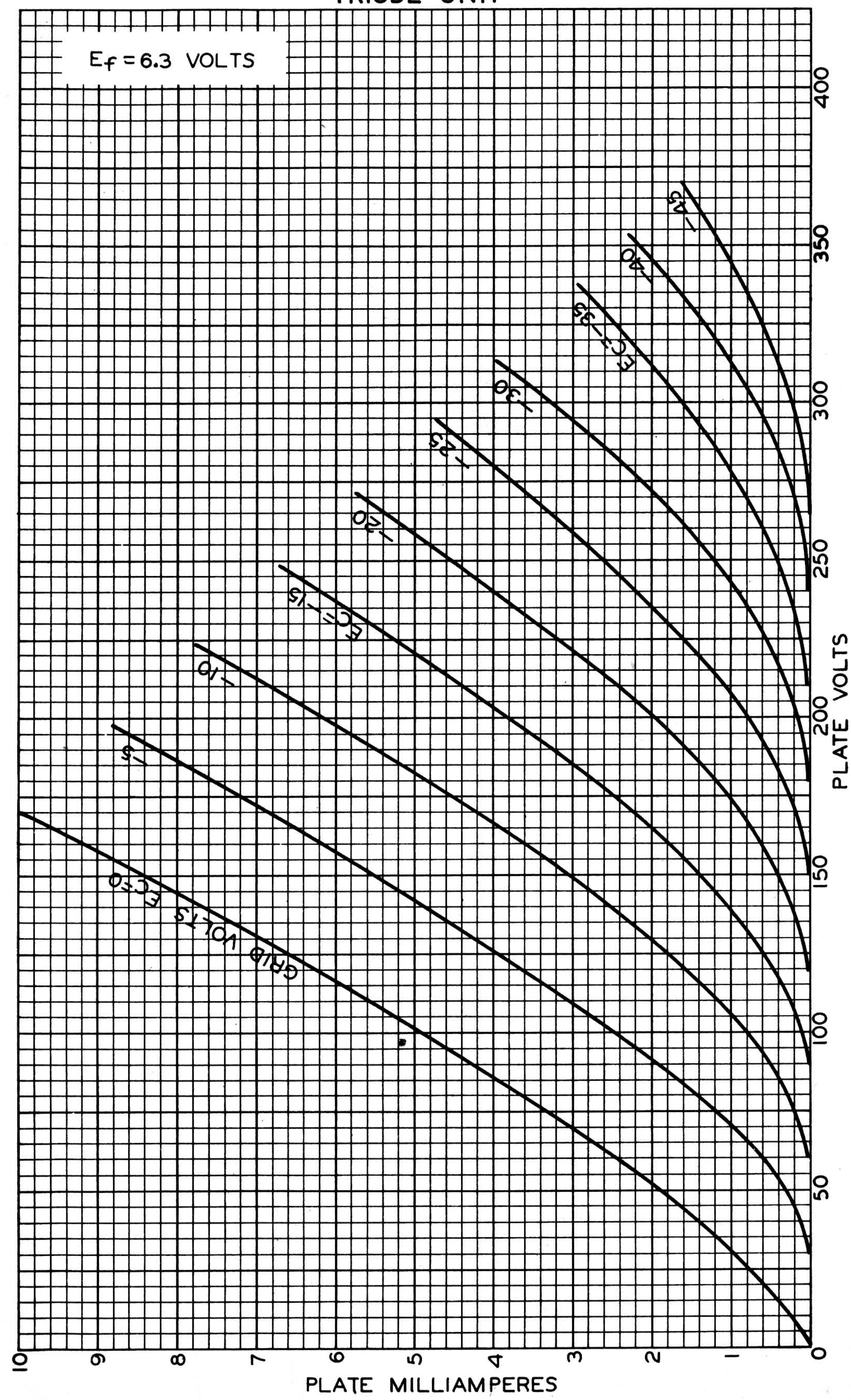
Operating Characteristics of the Pentode as Audio Amplifier

When used as an audio amplifier, the pentode may be resistance-capacity coupled to the preceding detector stage as illustrated by Figures 4D, E and F. A plate-coupling resistance of approximately 300000 ohms, with a plate-voltage supply of 250 volts and a screen-grid supply of 50 volts should be used. The resistor in the grid circuit of the following tube should be one megohm, if possible. For some tubes, where one megohm may be too large a value, the maximum recommended value should be used.

RCA Radiotron — RCA-6F7

Cunningham Radio Tubes — C-6F7

AVERAGE PLATE CHARACTERISTICS
TRIODE UNIT



DEC. 5, 1933

FIG. 1

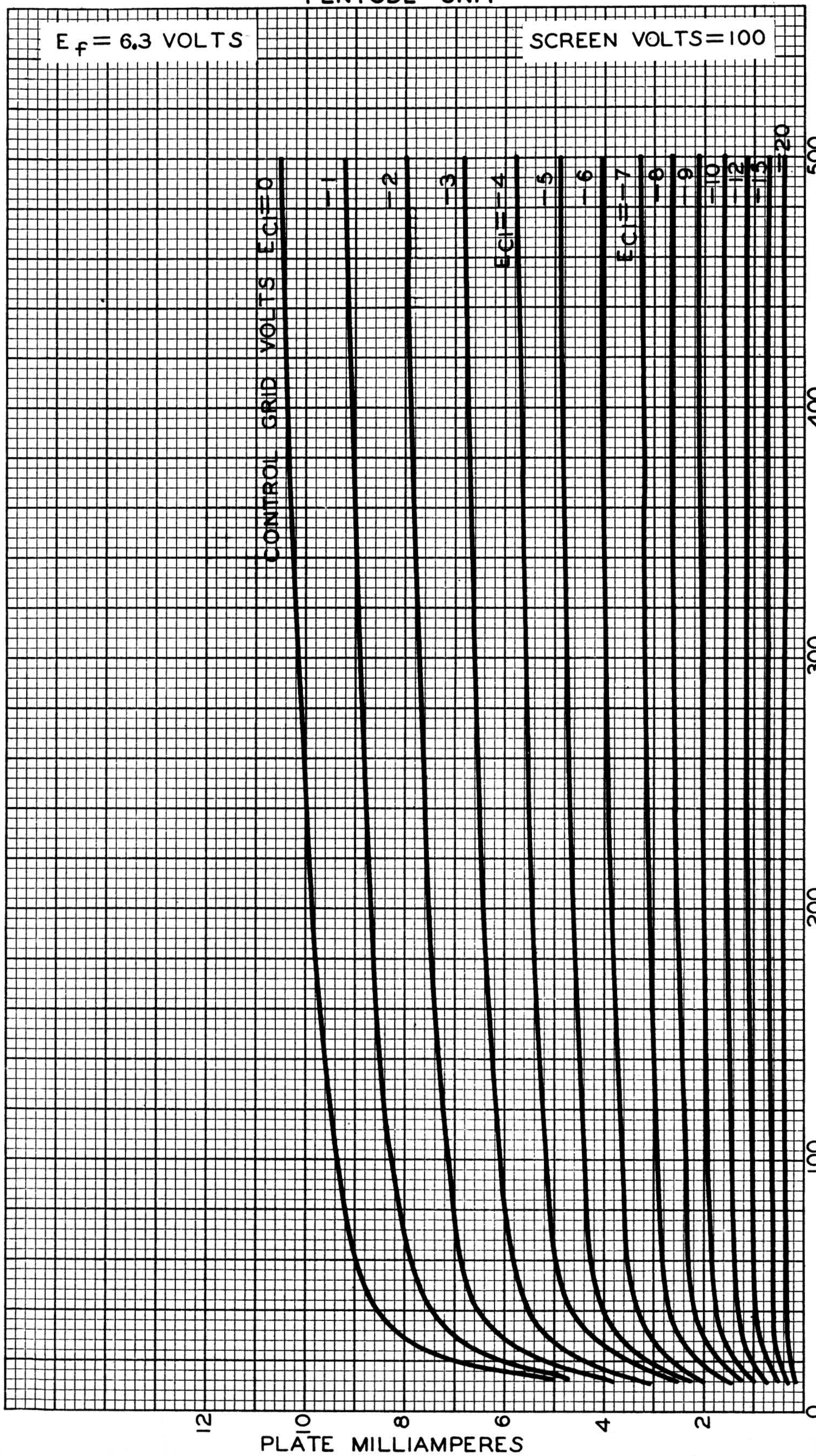
92S-5426

RCA Radiotron | Cunningham RADIO TUBES

RCA–6F7 | C–6F7

AVERAGE PLATE CHARACTERISTICS

PENTODE UNIT



AUG. 18, 1933

FIG. 2

92S–5360

RCA Radiotron Cunningham Radio Tubes

RCA—6F7 C—6F7

AVERAGE TRANSFER CHARACTERISTICS
PENTODE UNIT

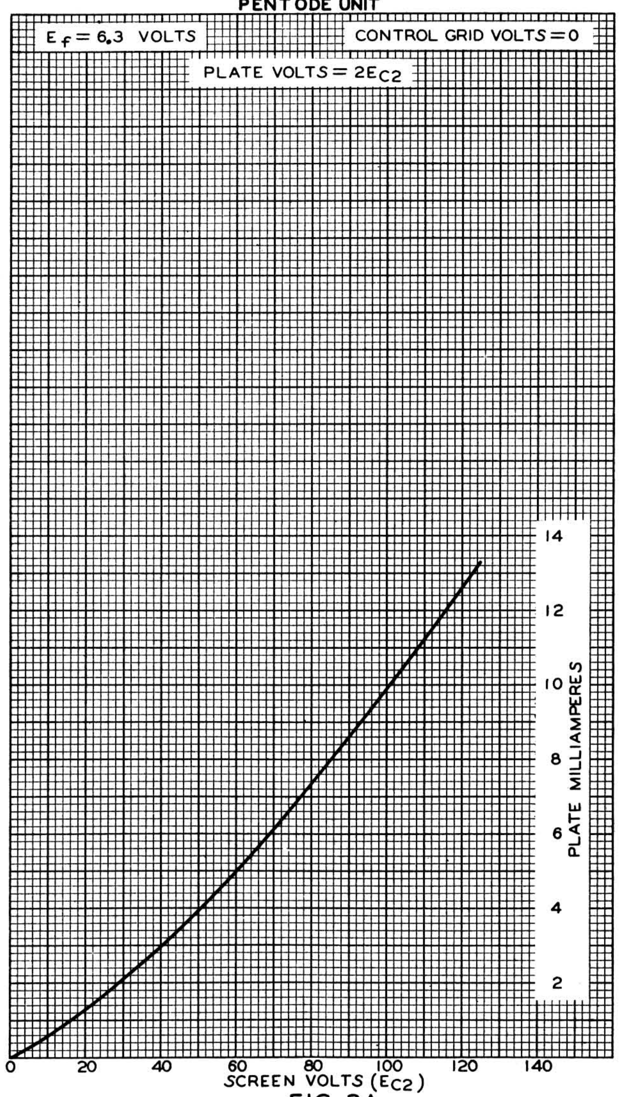


FIG. 3A

OCT. 3, 1933 92S—5390

RCA Radiotron Cunningham Radio Tubes

RCA-6F7 C-6F7

PLATE-CHARACTERISTIC CONVERSION FACTORS
PENTODE UNIT

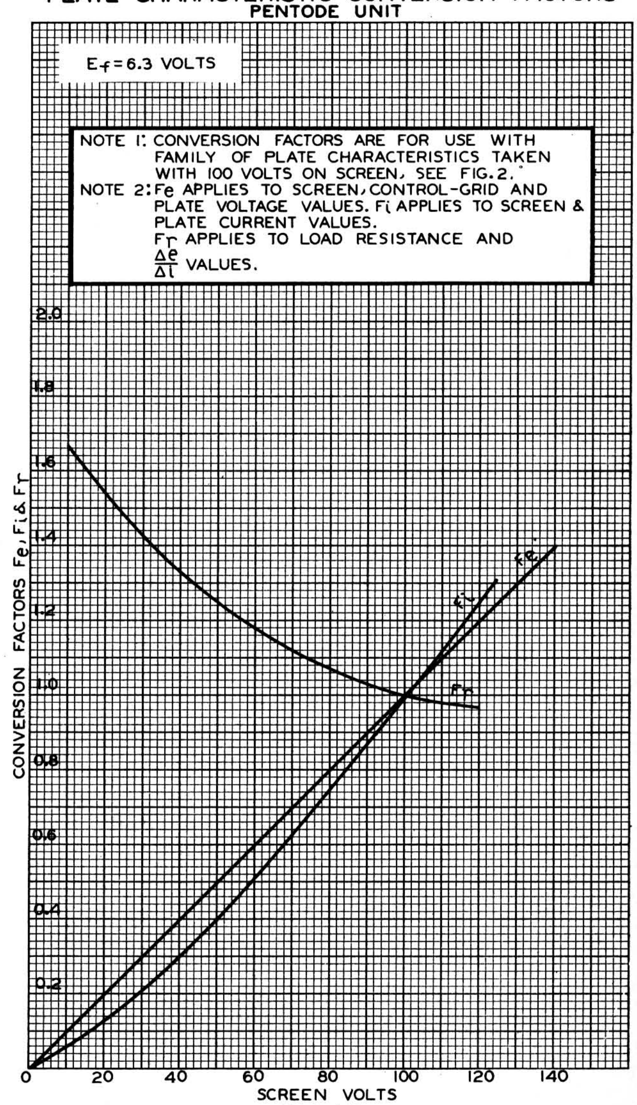


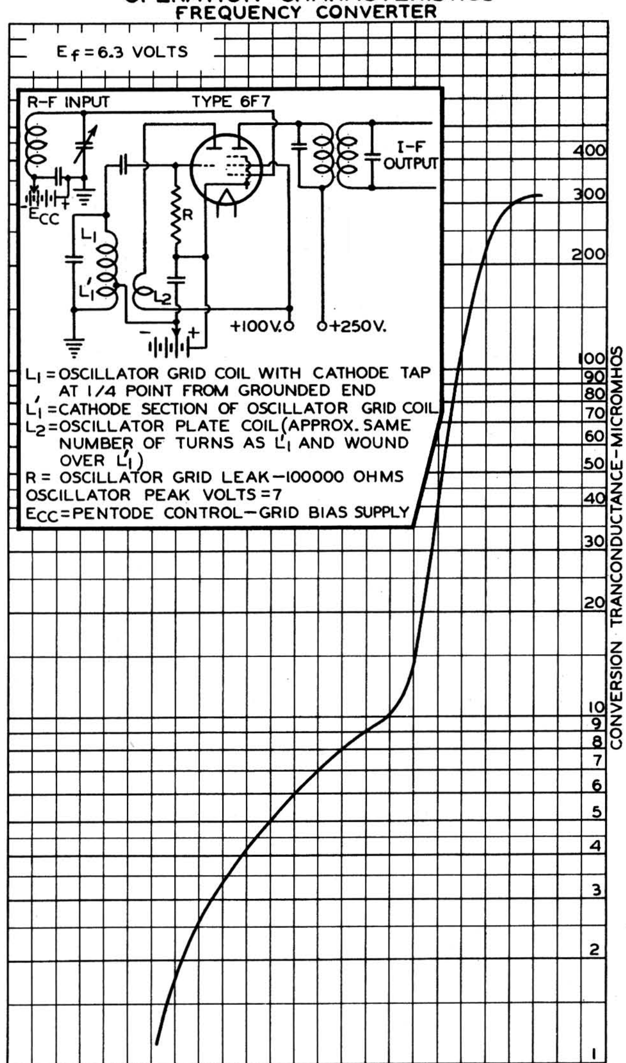
FIG. 3B

DEC. 5, 1933 92S-5425

RCA Radiotron — Cunningham Radio Tubes

RCA-6F7 C-6F7

OPERATION CHARACTERISTICS
FREQUENCY CONVERTER

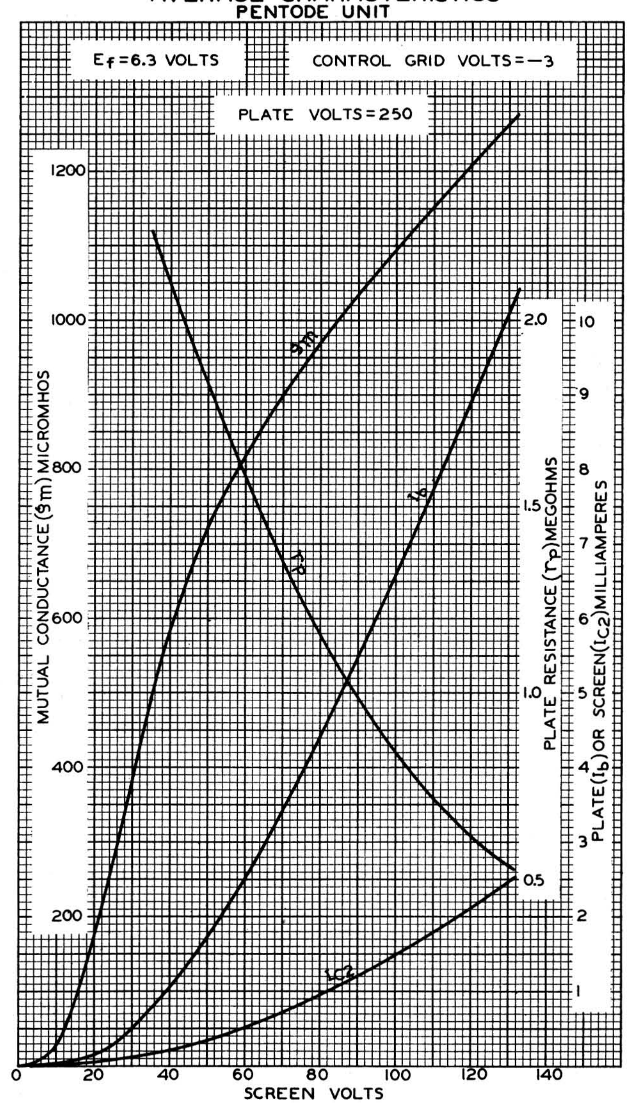


OCT. 10, 1933 FIG. 3C 92S—5400

RCA Radiotron — Cunningham Radio Tubes

RCA-6F7 C-6F7

AVERAGE CHARACTERISTICS
PENTODE UNIT

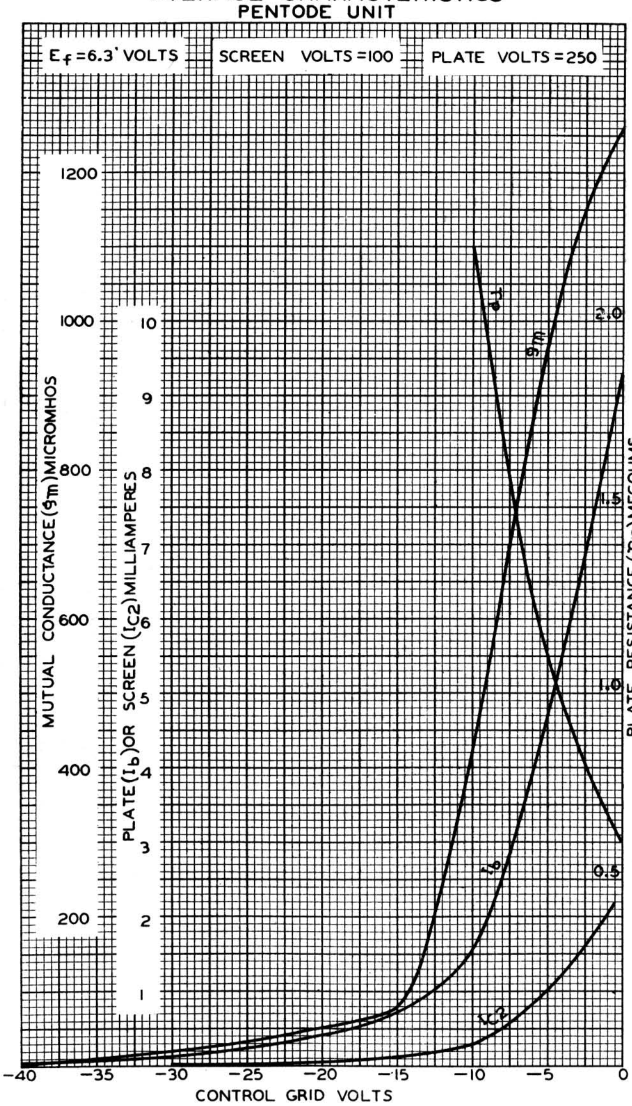


OCT. 3, 1933 FIG. 3D 92S–5389

RCA Radiotron Cunningham Radio Tubes

RCA-6F7 C-6F7

AVERAGE CHARACTERISTICS
PENTODE UNIT

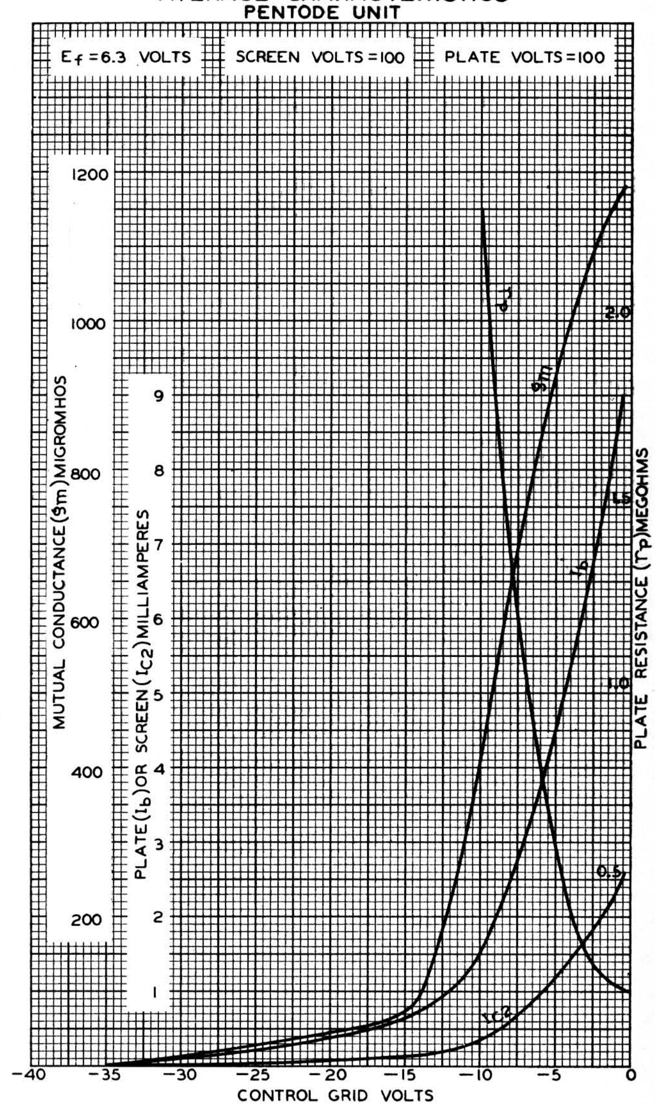


OCT. 4, 1933 FIG.3E 92S-5394

RCA Radiotron Cunningham Radio Tubes

RCA-6F7 C-6F7

AVERAGE CHARACTERISTICS
PENTODE UNIT



OCT. 4, 1933 FIG.3F 92S-5395

TYPICAL CIRCUITS

FREQUENCY CONVERTER

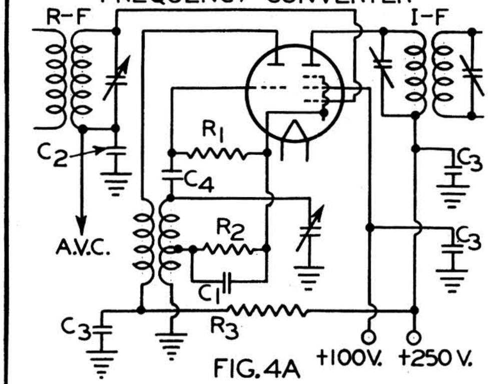


FIG.4A

FREQUENCY CONVERTER

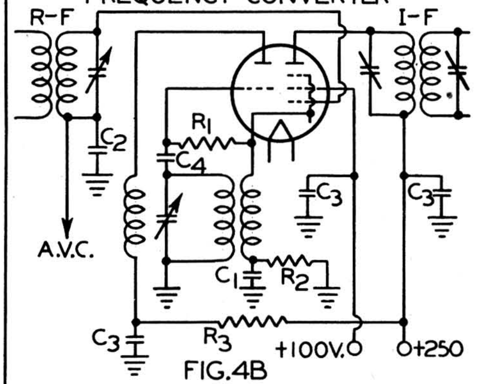


FIG.4B

PENTODE I-F AMPLIFIER & BIASED TRIODE 2ND DETECTOR

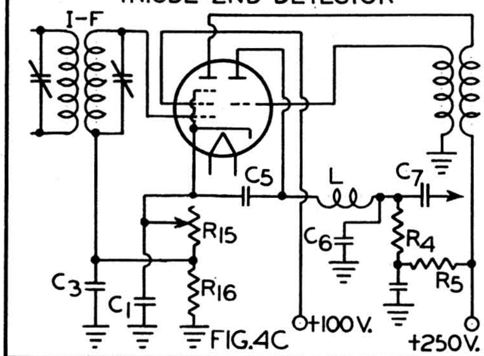


FIG.4C

BIASED TRIODE DETECTOR & PENTODE AUDIO AMPLIFIER

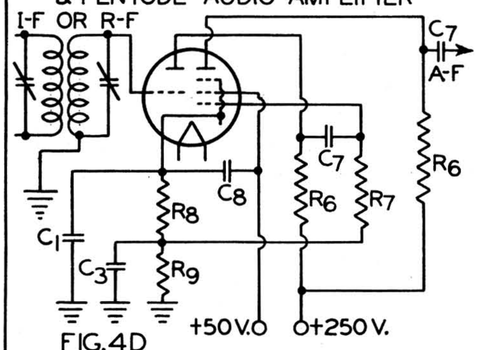


FIG.4D

GRID-LEAK TRIODE DETECTOR & PENTODE AUDIO AMPLIFIER

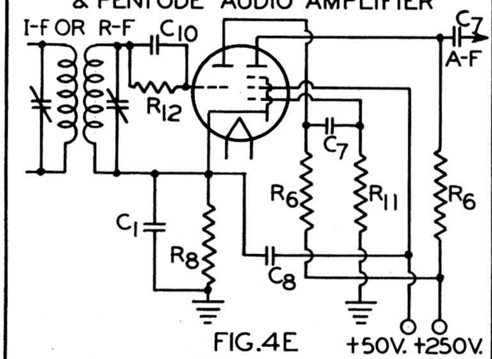


FIG.4E

DIODE DETECTOR & PENTODE AUDIO AMPLIFIER WITH DELAYED A.V.C.

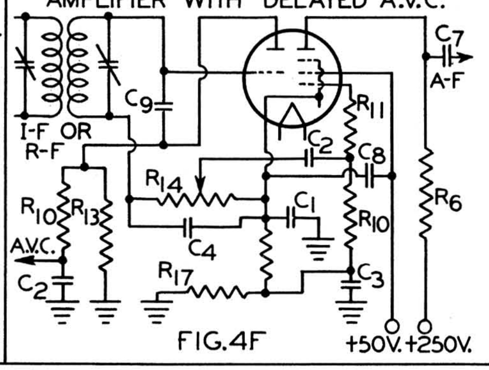


FIG.4F

APPROXIMATE VALUES

C_1 = 5 μf
C_2 = 0.05 μf
C_3 = 0.1 μf
C_4 = 0.0002 μf
C_5 = 0.0024 μf
C_6 = 0.00016 μf
C_7 = 0.01 μf
C_8 = 0.5 μf
C_9 = 0.0005 TO 0.001 μf
C_{10} = 0.00025 μf
L = I-F CHOKE COIL
R_1 = OSCILLATOR GRID LEAK-0.1 MEGOHM

R_2 = PENTODE SELF-BIASING RESISTOR-1500 OHMS
R_3 = VOLTAGE DROPPING RESISTOR-50000 OHMS
R_4 = PLATE COUPLING RESISTOR-170000 OHMS
R_5 = FILTER RESISTOR-30000 OHMS
R_6 = PLATE COUPLING RESISTOR-300000 OHMS
R_7 = PENTODE GRID LEAK-0.5 MEGOHM
R_8 = PENTODE SELF-BIASING RESISTOR-5000 OHMS
R_9 = 10000 OHMS. $R_9 + R_8$ = TRIODE BIASING RESISTOR
R_{10} = FILTER RESISTOR-1.0 MEGOHM
R_{11} = GRID RESISTOR-500000 OHMS
R_{12} = TRIODE GRID LEAK-1.0 MEGOHM
R_{13} = A.V.C. DIODE LOAD-1.0 MEGOHM
R_{14} = A-F DIODE-LOAD POTENTIOMETER-0.5 MEGOHM
R_{15} = PENTODE SELF-BIASING RES. 4000 OHMS VAR.
R_{16} = 1500 OHMS. $R_{16} + R_{15}$ = TRIODE BIASING RESISTOR

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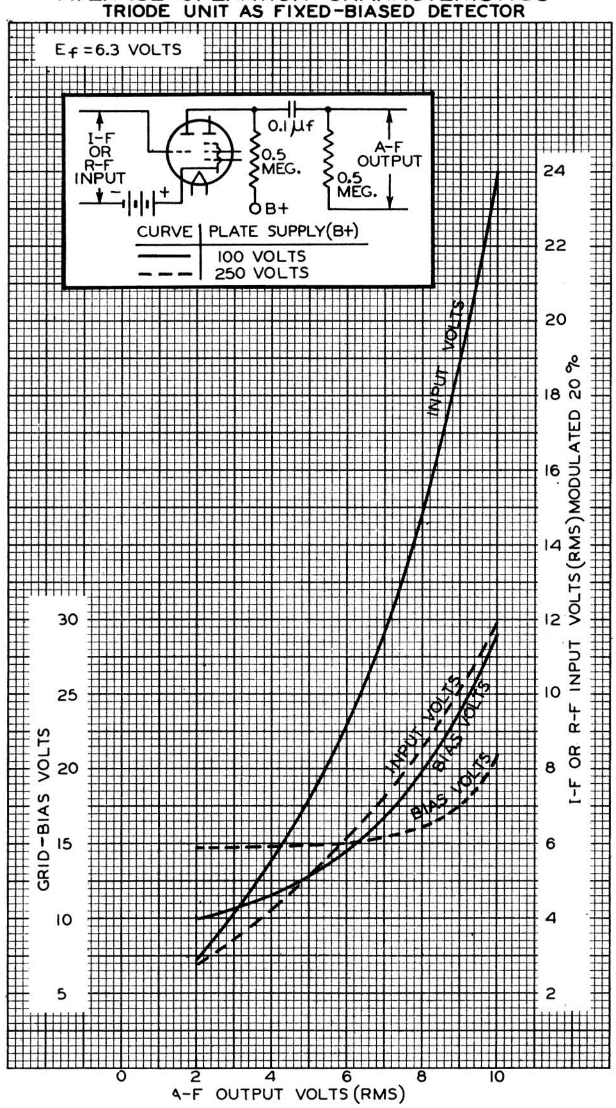
RCA-6F7 C-6F7

AVERAGE OPERATION CHARACTERISTICS
TRIODE UNIT AS FIXED-BIASED DETECTOR

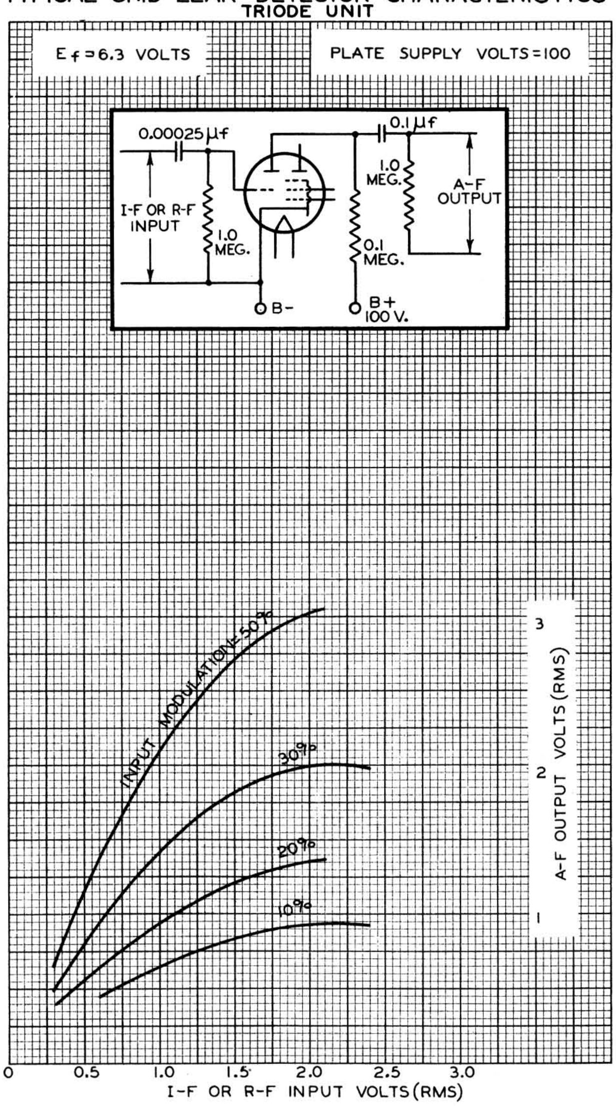


DEC. 22, 1933 FIG. 5 92S-5437

RCA Radiotron Cunningham RADIO TUBES

RCA-6F7 C-6F7

TYPICAL GRID-LEAK DETECTOR CHARACTERISTICS
TRIODE UNIT

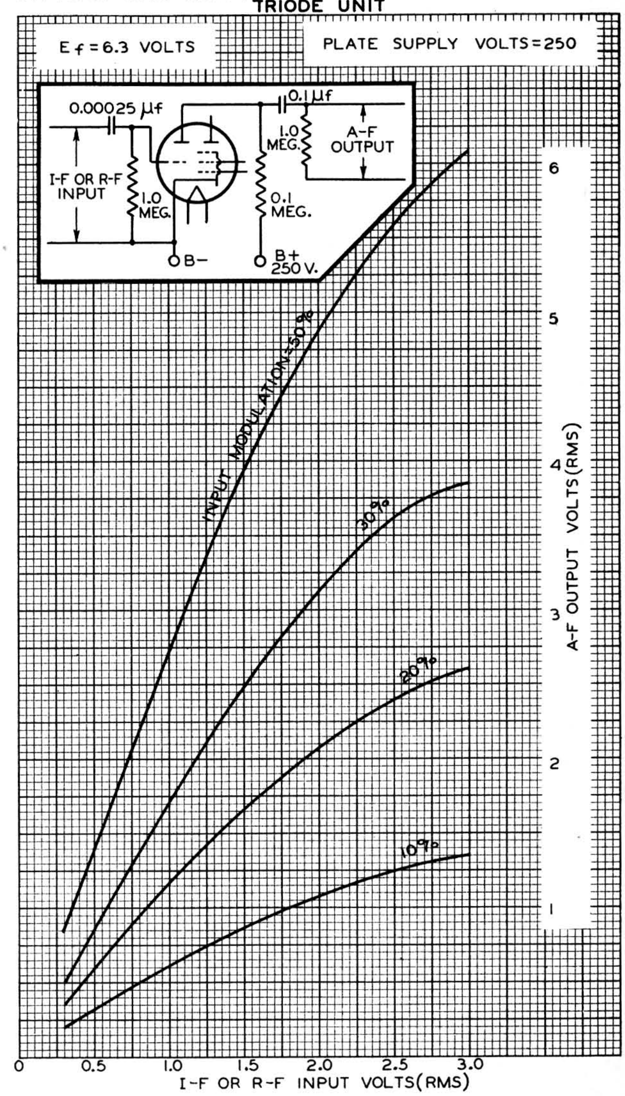


DEC. 6, 1933 FIG. 6 92S-5428

RCA Radiotron Cunningham RADIO TUBES

RCA-6F7 C-6F7

TYPICAL GRID-LEAK DETECTOR CHARACTERISTICS
TRIODE UNIT

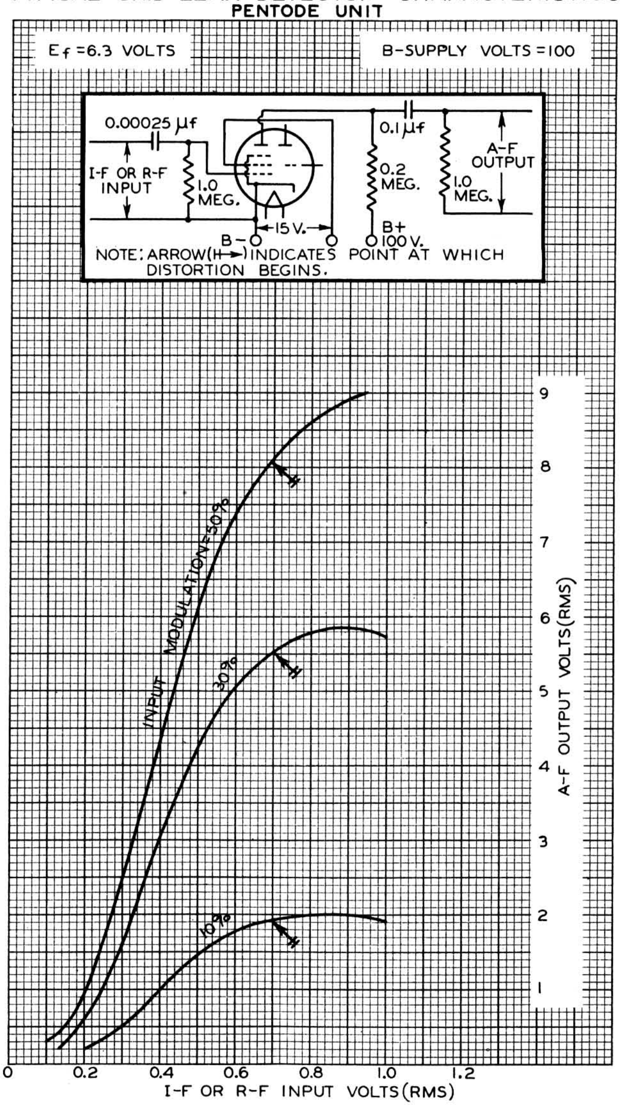


DEC. 6, 1933 FIG. 7 92S-5429

RCA Radiotron Cunningham Radio Tubes

RCA-6F7 C-6F7

TYPICAL GRID-LEAK DETECTOR CHARACTERISTICS
PENTODE UNIT

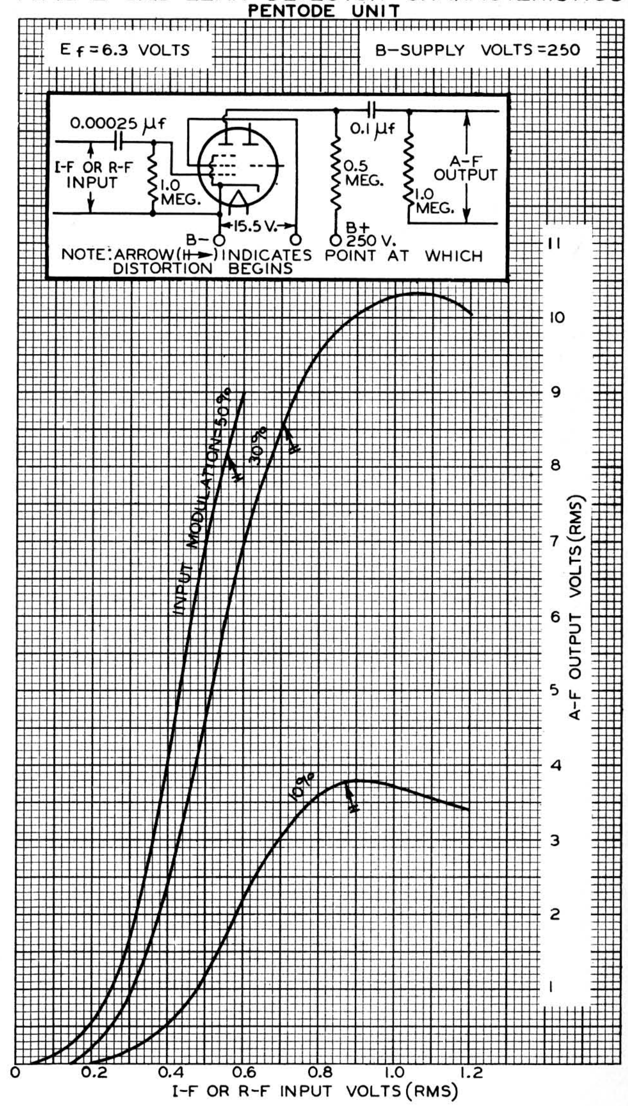


DEC. 7, 1933 FIG. 8 925-5430

RCA Radiotron Cunningham Radio Tubes

RCA-6F7 C-6F7

TYPICAL GRID-LEAK DETECTOR CHARACTERISTICS
PENTODE UNIT



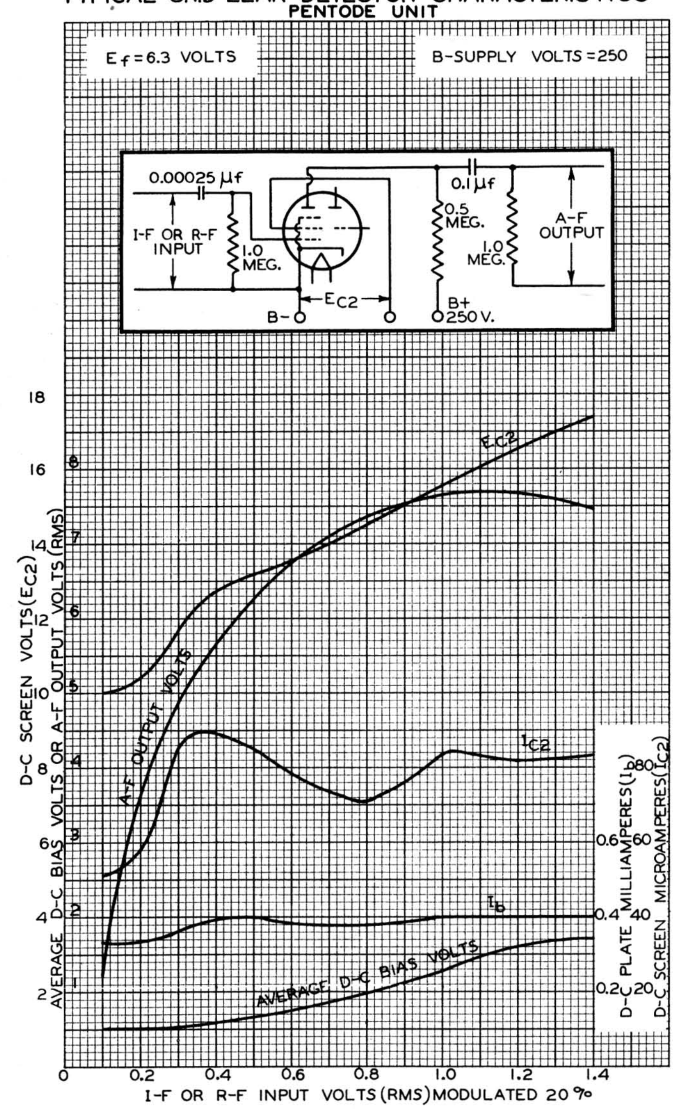
DEC. 7, 1933 FIG. 9 925-5431

RCA Radiotron — Cunningham Radio Tubes

RCA-6F7 C-6F7

TYPICAL GRID-LEAK DETECTOR CHARACTERISTICS

PENTODE UNIT



DEC. 11, 1933 FIG. 10 92S—5432