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

RCA RADIOTRON
DIVISION

APPLICATION NOTE NO.87
February 16, 1938

APPLICATION NOTE ON THE 6K8 -- A NEW CONVERTER TUBE

The pentagrid-converter type of tube now in general use is a good frequency-converting device at medium radio frequencies. However, the performance of this tube type is not as good in the high-frequency band as in the broadcast band because undesirable effects of interaction between oscillator and signal sections of the tube increase with frequency. The type 6K8, a new all-metal converter tube, is designed for improved performance in the high-frequency band of all-wave receivers. Because the 6K8 combines the functions of oscillator and mixer, it retains the important advantage of low circuit cost; moreover, because of improved design, it gives optimum performance with a low value of oscillator amplitude.

A disadvantage of the present pentagrid converter is the large variation in the transconductance (g_m) of the oscillator section with signal-grid bias. In practice, this characteristic is evidenced by a shift in oscillator frequency with change in avc voltage. This shift in oscillator frequency is appreciable in the high-frequency band because of the large ratio of signal frequency to intermediate frequency.

Several undesirable effects have been traced to oscillator-frequency shift with avc voltage: (1) alignment of r-f circuits may be difficult, (2) a receiver may motorboat when a strong signal is impressed, and (3) appreciable distortion may be introduced by the i-f amplifier, because the intermediate frequency differs from that to which the i-f transformers are tuned. Alignment difficulties which are encountered when avc voltage is applied to the signal grid of the converter is due to the dependence of oscillator frequency on avc voltage; the magnitude of the avc voltage, in turn, depends on oscillator frequency. Alignment difficulties which are experienced when no avc voltage is present may be traced to coupling between the oscillator grid and the signal grid. With the pentagrid-converter type of tube, a receiver may motorboat when a strong signal is impressed because of poor power-supply regulation or large oscillator-frequency shift with avc voltage. This effect is considerably reduced with the type 6K8, because oscillator frequency is not critical to changes in oscillator-plate voltage or signal-grid bias.

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Construction of the 6K8

The electrode arrangement and socket connections of the 6K8 are shown in Fig.1. Cathode (K), triode grid (G_T), and triode plate (P_T) form the oscillator unit of the tube; cathode (K), hexode mixer grid (G_{1HX}), hexode double screen (G_{2HX} and G_{4HX}), hexode signal grid (G_{3HX}), and hexode plate (P_{HX}) constitute the mixer unit. Note that a single cathode sleeve serves both oscillator unit and mixer unit. The oscillator voltage on G_{1HX} modulates the transconductance of the mixer unit to produce the intermediate frequency.

Electrical Characteristics of the 6K8

Direct Interelectrode Capacitances (Approx.):*			
Hexode Grid No.3 to Hexode Plate		0.03	μμf
Hexode Grid No.3 to Triode Plate		0.01	μμf
Hexode Grid No.3 to Triode Grid and Hexode Grid No.1		0.1	μμf
Triode Grid and Hexode Grid No.1 to Triode Plate		1.1	μμf
Triode Grid and Hexode Grid No.1 to Hexode Plate		0.05	μμf
Hexode Grid No.3 to All Other Electrodes = R-F Input		6.6	μμf
Triode Plate to All Other Electrodes (except Triode Grid and Hexode Grid No.1) = Osc. Output		3.2	μμf
Triode Grid and Hexode Grid No.1 to All Other Electrodes (except Triode Plate) = Osc. Input		6.0	μμf
Hexode Plate to All Other Electrodes = Mixer Output		3.5	μμf
Hexode Plate Voltage		250 max.	Volts
Hexode Screen (Grids No.2 and 4) Voltage		100 max.	Volts
Hexode Control-Grid (Grid No.3) Voltage		-3 min.	Volts
Triode Plate Voltage		200 max.	Volts
Total Cathode Current		16 max.	Milliamperes
Typical Operation:			
Heater Voltage	6.3	6.3	Volts
Heater Current	0.3	0.3	Ampere
Hexode Plate Voltage	100	250	Volts
Hexode Screen Voltage	100	100	Volts
Hexode Control-Grid Voltage	-3	-3	Volts
Triode Plate Voltage	100	100	Volts
Triode Grid Resistor	50000	50000	Ohms
Hexode Plate Resistance (Approx.)	0.3	0.3	Megohm
Conversion Transconductance	360	400	Micromhos
Hexode Control-Grid Bias (Approx.) for Conversion Transconductance = 2 μmhos	-30	-30	Volts
Hexode Plate Current	2.3	2.7	Milliamperes
Hexode Screen Current	6.9	6.5	Milliamperes
Triode Plate Current	3.5	3.5	Milliamperes
Triode Grid and Hexode Grid No.1 Current	0.15	0.15	Milliamperes

The transconductance of the oscillator unit (not oscillating) of the 6K8 is approximately 2400 micromhos when the Triode Plate Volts = 100, and the Triode Grid Volts = 0.

*With shell connected to cathode.

These data show that the recommended value of hexode screen voltage for 100- or 250-volt operation is 100 volts. The use of 100 volts on the hexode screen accounts for the comparatively high conversion transconductance of the 6K8 in a-c/d-c receivers. With the pentagrid-converter type of tube, screen voltage should be lower than the plate voltage to obtain high plate resistance, because of secondary-emission effects. This restriction is not imposed on the 6K8, because the internal shield plates act as a suppressor to raise the plate resistance of the hexode unit at low values of hexode plate voltage.

Another point of interest is the recommended value of 100 volts for the oscillator (triode) plate. With the pentagrid-converter type of tube, oscillator-anode voltage should be greater than the screen voltage to obtain sufficient oscillator-anode current. This condition does not obtain in the 6K8, because its oscillator-plate current is substantially independent of the voltage on its hexode screen, due to the geometry of the tube structure.

The recommended value of 100 volts for the screen of the hexode unit and for the plate of the oscillator unit is practical, because this value is also applied to the screens of r-f and i-f tubes, and may be taken from the same point in the power-supply system in series-feed oscillator circuits. In shunt-feed oscillator circuits, a separate resistor or choke is, of course, required in the oscillator-plate circuit. When oscillator-plate and screen voltages are taken from one point in the power-supply system, this point should be adequately by-passed to ground.

A third point of interest is the low value of oscillator grid current (I_5) required for high conversion transconductance (g_c) and high hexode plate resistance (r_p). Curves of g_c, r_p, and total cathode current (I_a) vs I_5 through 50000 ohms for 100- and 250-volt operation are shown in Fig.2. These curves indicate that nearly maximum conversion transconductance is obtained over a wide range of oscillator grid current and that r_p increases with oscillator grid current.

The recommended minimum value of oscillator grid current is 100 microamperes, and the recommended design value is 150 microamperes. The recommended minimum value is selected on the basis of low r_p and high I_a. The cathode current varies inversely with the oscillator grid current. The recommended maximum value of cathode current (16 milliamperes) is reached at a value of oscillator grid current a little less than 100 microamperes. The recommended design value of 150 microamperes is comparatively easy to obtain in practice. Inductive (tickler) feed-back circuits are usually designed for the proper value of oscillator grid current at the low-frequency end of a band; the oscillator grid current then increases with frequency over that band. It is possible to obtain substantially uniform oscillation amplitude over an entire band by using a shunt-feed oscillator circuit. In such a circuit, the series padding condenser provides electrostatic coupling at the low-frequency end of the band and the tickler provides inductive coupling at the high-frequency end of the band.

It should be noted that oscillator coils intended for use with the pentagrid converter type of tube may not be suitable for use with the 6K8, because of the possibility of over-exciting the oscillator unit of the tube. In order to use such coils, it may be necessary to reduce the oscillator plate voltage, the number of tickler turns, or the mutual inductance between tickler and secondary so as to reduce the oscillator grid current to a good value. The r-f input capacitance of the 6K8 is 6.6 μμf. Because this value is approximately half that of a pentagrid converter, a higher tuning ratio can be obtained with a converter stage employing a 6K8 than with a converter stage employing a pentagrid converter.

Operating Characteristics of the 6K8

The curves of Fig.3 show the variation in oscillator transconductance with signal-grid bias for the 6K8 and for a pentagrid converter. These curves indicate the effect of avc voltage on oscillator performance. As previously mentioned, one practical effect of the improved performance of the 6K8 indicated by the curves of Fig.3 is a reduction in oscillator-frequency shift with avc voltage. This is shown by the curves of Fig.4. The data of Fig.4 were taken in a radio receiver of typical design after a suitable micrometer condenser was installed to permit accurate determination of frequency shift. It is seen that a frequency shift of approximately 50 kc can be obtained in practice with a pentagrid-converter type of tube and that the frequency shift was reduced to approximately 2 kc when the 6K8 was installed; these data were taken at 18 megacycles.

Tests in a typical receiver of oscillator-frequency shift for line-voltage changes were conducted. A 6K8 was installed and electrode voltages adjusted for 250-volt operation at 18 megacycles. When the line voltage was varied from 100 to 125 volts, the oscillator frequency shifted approximately 6 kc. A pentagrid converter was installed in the same receiver under proper operating conditions and the line voltage was varied from 100 to 125 volts; the oscillator frequency shifted approximately 27 kc. The ratio of 6/27 represents a very worthwhile improvement.

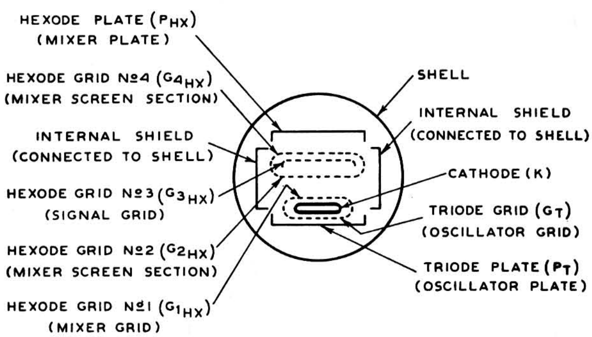
At frequencies of the order of 18 megacycles, effects of the time of transit of electrons through the tube cannot be neglected. One important transit-time effect is observed in the nature of the input conductance of the mixer unit (r-f input conductance). At 18 megacycles, the r-f input conductance of the 6K8 is negative. The effect of a negative input conductance is to improve the Q-ratio of the tuned circuit connected to the 6K8. This improvement in circuit Q was evidenced in one test by a higher image ratio. A tube type in which the input grid is adjacent to the cathode exhibits positive input conductance, and this decreases the effective Q of a circuit connected to the input grid.

The conversion transconductance of the 6K8 is 400 micromhos under the 250-volt operating conditions. The conversion gain, which is the ratio of the i-f voltage across the load to the r-f voltage input, is given by the relation:

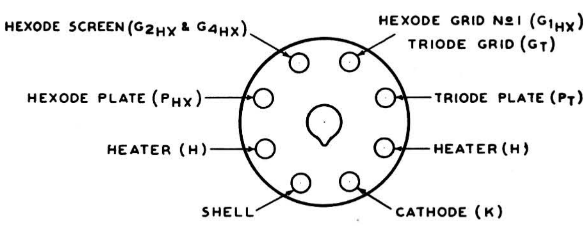
$$\text{Conversion Gain} = \frac{g_c\, r_p\, R_L}{r_p + R_L}$$

where R_L is the resonant impedance of the i-f transformer measured across the primary terminals. The conversion gain for different values of R_L is shown by the curve of Fig.5. It is seen that for values of R_L less than 0.35 megohm the gain obtained from a 6K8 is only slightly less than that obtained from a pentagrid converter. More gain is obtained from the 6K8 than from a pentagrid converter at values of R_L greater than 0.35 megohm.

SCHEMATIC DIAGRAM OF ELECTRODE STRUCTURE



SOCKET CONNECTIONS FOR TYPE 6K8 BOTTOM VIEW



CAP IS CONNECTED TO HEXODE GRID No 3 (G_{3HX})

FIG. 1

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OPERATION CHARACTERISTICS

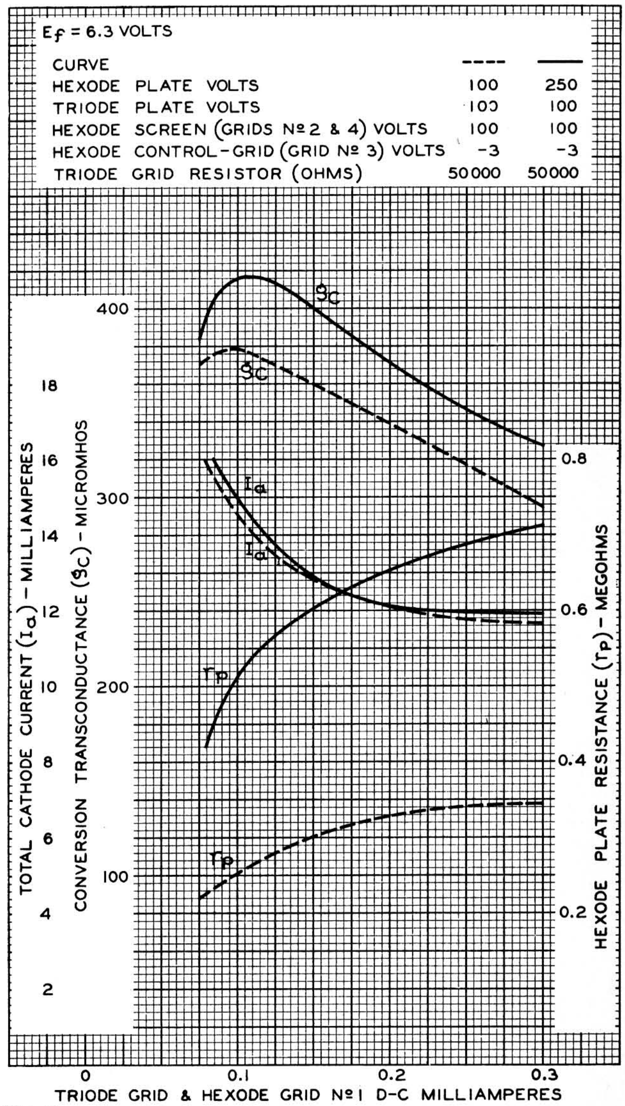

FIG. 2

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EFFECT OF AVC VOLTAGE ON OSCILLATOR TRANSCONDUCTANCE

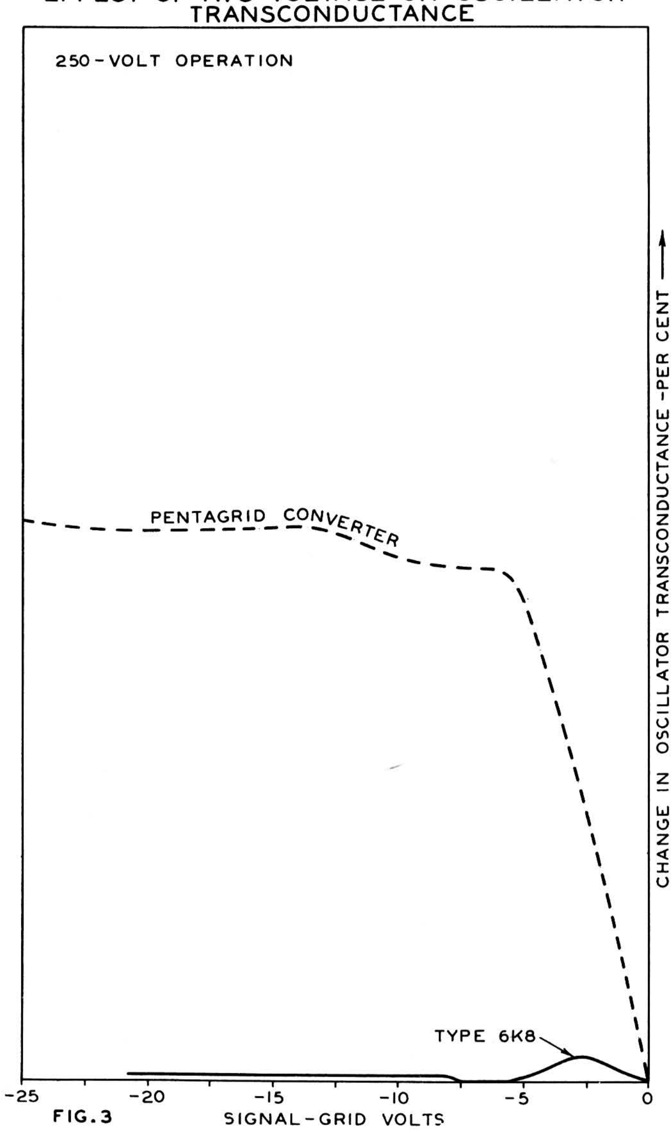

FIG.3

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OSCILLATOR-FREQUENCY SHIFT IN A TYPICAL RECEIVER

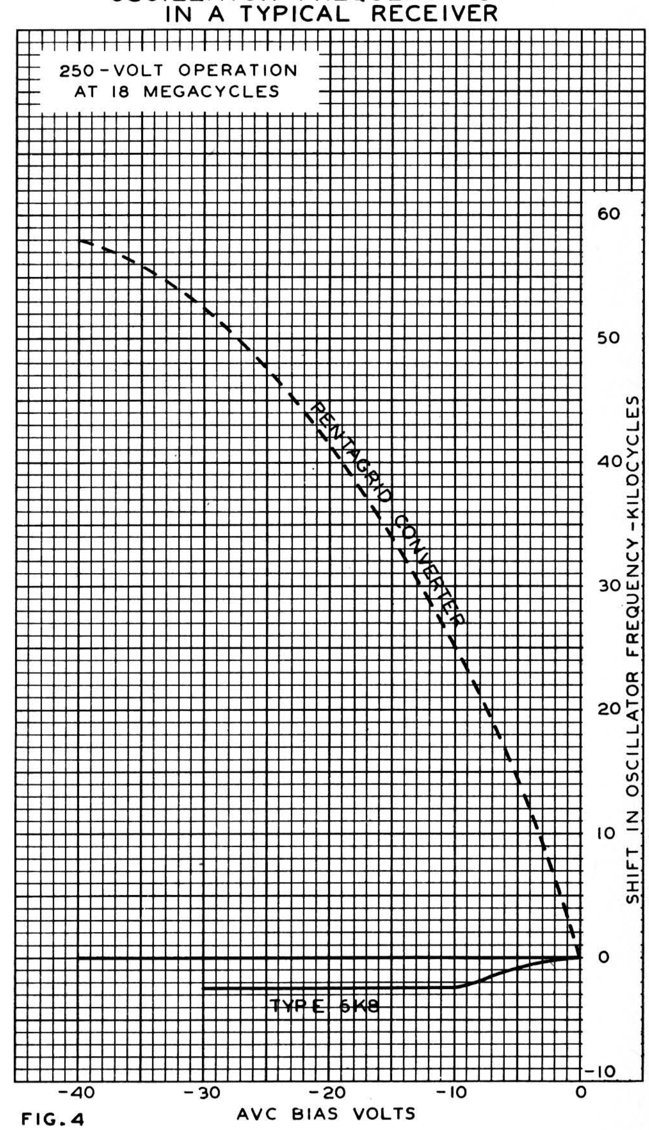

FIG.4

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OPERATION CHARACTERISTIC

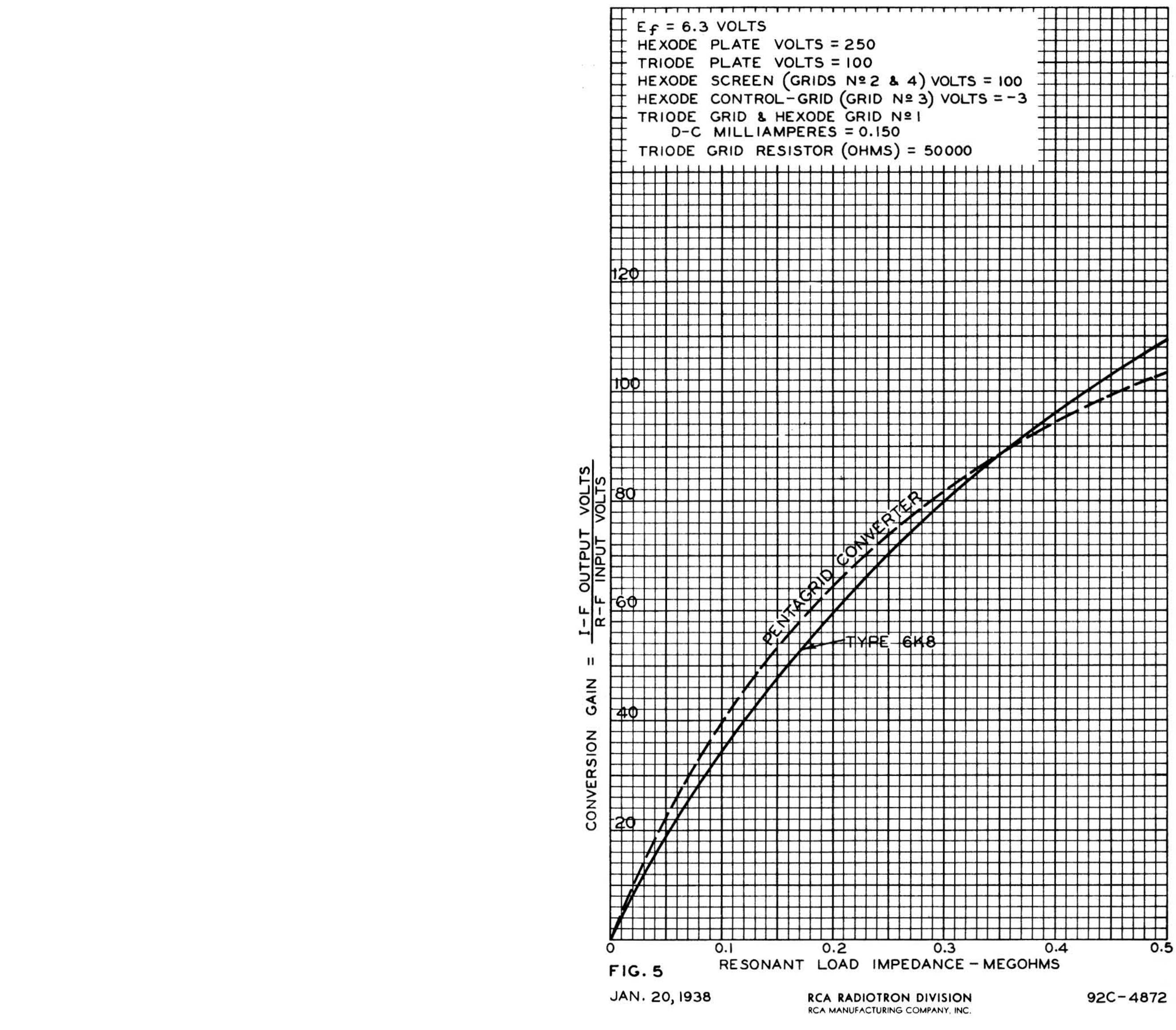

FIG. 5

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