Ken-Rad
Radio Tubes

ENGINEERING BULLETIN

"OPERATION CHARACTERISTICS OF THE TYPE 6L7"

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OWENSBORO - KENTUCKY

"OPERATION CHARACTERISTICS OF THE TYPE 6L7"

The 6L7 pentagrid mixer, because of its numerous electrodes and their control action, is a versatile tube and may be used in many types of radio and audio frequency circuits. Although designed for mixer operation, it may be used as a radio frequency amplifier having advantage over conventional pentodes, or as an audio amplifier with fixed or variable bias. The control action of the No. 3 grid enables the tube to be used as a controlled audio amplifier tube. This feature can be used to advantage to improve the overall A.V.C. curve of a receiver or to effect some special function as volume expansion. This bulletin shows typical operation of the tube as a mixer, and characteristic curves that will be helpful in the design of other circuits.

Though concerned mainly with the characteristics of the 6L7 when used in conventional mixer circuits, it is not out of place to mention the advantages of this type of mixer over converter operation with the pentagrid types or operation of suppressor-modulated pentode mixers.

The 6L7 construction incorporates a cathode, five grids, and a plate. The functions of the grids in mixer operation are as follows. The No. 1 grid is the signal-input grid. The

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No. 2 grid and the No. 4 grid are screen grids to shield the oscillator (No. 3) grid from the input circuit and to raise the effective plate resistance of the tube. The No. 3 grid is the oscillator-input grid and the No. 5 grid is a suppressor. The 6L7 construction minimizes the space charge coupling between oscillator input and signal input grids and results in a mixer tube having satisfactory conversion gain even at high frequencies. This space charge coupling is one of the inherent shortcomings of the pentagrid mixer tubes. The suppressor modulated pentode minimizes this space-charge coupling but it has the disadvantage of a low internal impedance and requires a large oscillator swing for a satisfactory conversion conductance. The high oscillator voltage required causes difficulty in oscillator design, especially at high frequencies. The high internal impedance of the 6L7 is also of advantage in receivers having high-gain intermediate frequency systems.

The 6L7 has a high input capacity to its oscillator grid, and in receivers requiring a wide tuning range, the oscillator constants must be designed to minimize the effect of this capacity. An oscillator coil with the 6L7 No. 3 grid connected across only a portion of the total inductance reduces the effective capacity and results in a wider frequency coverage. Two families of curves, showing conversion conductance versus oscillator grid current, taken with a tapped coil, are included in this bulletin.

Ratings for amplifier and mixer operation are shown on page 8 . As a radio frequency amplifier the tube operates with -3 volts on the No. 1 and No. 3 grids, 100 volts on the screen, and 250 volts on the plate. Performance as an amplifier is similar to conventional R.F. pentodes but this tube may be controlled in a manner to improve the A.V.C. characteristic of a receiver. This is accomplished by applying A.V.C. voltage to both No. 1 and No. 3 grids. A curve showing transconductance from grid No. 1 to plate versus grid No. 1 volts for several values of grid No. 3 volts is shown on page 9 . The curve taken with grid No. 3 equal to -3 volts is similar to most remote cut-off R.F. pentodes and indicates that with a fixed bias of -3 volts on the No. 3 grid more than 30 volts negative is required on the No. 1 grid to reduce the transconductance below 10 micromhos. If both grid No. 3 and grid No. 1 are A.V.C. controlled the effect is a sharp cut-off with actual operation over a remote cut-off curve. For example, with the potential of grid No. 1 and grid No. 3 both equal to -15 volts the transconductance is 4.6 micromhos. The operating line is the solid curve marked $Ec_3 = -15$. It can be seen that large signal amplitude may be applied with little resulting distortion.

There are two ratings for mixer operation. One condition

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is with a No. 1 grid voltage of -3, and a screen voltage of 100. The other condition is with a No. 1 grid voltage of -6 and a screen grid voltage of 150. These two ratings are necessary because of an unusual phenomenon that takes place at high frequencies with the low voltage rating. With the low bias at high frequencies the No. 1 grid draws current in spite of its negative potential. This is the result of a relation between the time of the electron travel between cathode and No. 3 grid and the frequency at which the potential of the No. 3 grid is fluctuating. At these high frequencies electrons approaching the No. 3 grid are repelled on negative swings of the grid and fall back to the No. 1 grid and cause a current to flow in the external circuit. A negative bias of -6 volts is required to overcome this effect. With the additional bias the screen potential must be increased to 150 volts to raise the conversion conductance to a value comparable to the low voltage condition. The 150 volt rating is recommended for all-wave receivers and the 100 volt rating for use only at broadcast frequencies.

On page 10 are curves of conversion conductance versus oscillator-grid bias for several values of oscillator grid swing. A family of curves is shown for both mixer ratings. With these curves performance of the 6L7 can be predicted. Although for the same oscillator swing the 100 volt rating

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gives the highest conversion conductance, the curves for the 150 volt rating show less variation and would give more uniform performance. In all-wave sets, where a wide tuning range is employed and oscillator design is difficult, this is an advantage.

On page 11 are two families of curves showing variation of conversion conductance versus oscillator-grid (No. 3) current with the oscillator voltage capacity coupled to the No. 3 grid. Curves are shown for several values of resistance in the grid return and indicate that a grid resistor of the order of 50,000 ohms gives the maximum conversion conductance. These curves are shown versus grid current because it is believed that in most cases it is more convenient to measure a D.C. grid current than an R.F. voltage. The circuit shown indicates the tube conditions. With the aid of these curves 6L7 performance in a similar set-up can be predicted simply by measuring grid current.

Another form of oscillator coupling is the direct-coupled circuit shown on page 12 . The oscillator is the conventional feed-back oscillator utilizing a 6C5. A variable-coupled oscillator coil was used so that several values of oscillator grid current could be produced. The curves on this page show variation of conversion conductance and are also plotted with a D.C. current as the independent variable.

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In this case the oscillator-grid (No. 1) current of the 6C5 was measured. Curves are shown for three values of oscillator grid leak (Rg_L) for both 6L7 mixer conditions. Oscillator and mixer performance can be checked with these data.

The operation characteristics of a system having a wide tuning range are shown by the direct-coupled curves of page 13. They were taken with a modified electron-coupled oscillator. The tuning range is increased by minimizing the effect of the oscillator input capacity by tapping down on the oscillator coil. Conversion conductance versus oscillator-grid (No. 1) current of the 6J7 is plotted for several different taps on the oscillator coil. The curves are labelled indicating percent of total turns included between tap and ground.

The oscillator shown is not a true electron-coupled oscillator, but it could be converted into one by using individual screen and plate resistors. The ratio of screen to plate voltage then could be adjusted so that the frequency would be practically independent of terminal voltage. The modified circuit shown is usually satisfactory and was used for these curves. This type of oscillator is inherently more stable than conventional feed-back oscillators. With the coil used for these measurements a change of tuning capacity from 50 to 1500 micromicrofarads produced only a slight change in oscillator grid current. Oscillators of this type can be recommended for all-wave receivers because of their wide tuning range, their inherent stability, and the simplicity of coil switching design resulting from only two leads not being connected directly to ground.

The curve sheets of pages 14, 15, and 16 show several characteristic curves of the 6L7. These curves are self-explanatory and should be of much help in the design of other circuits utilizing the 6L7.

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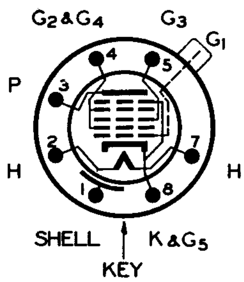
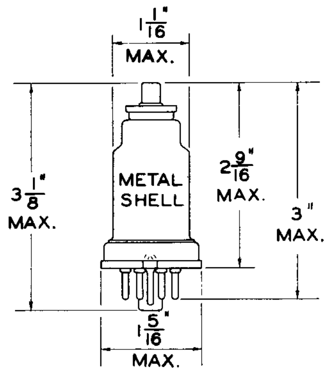
RATING AND CHARACTERISTICS

Physical Characteristics:





Heater:		
Voltage	6.3	Volts AC or DC
Current	0.3	Ampere

Note: Voltage between heater and cathode should be kept at a minimum if direct connection is not possible.

MIXER OPERATION

Plate Voltage	250	250 Max. **	Volts
Screen Voltage (Grids No. 2 and 4)	100	150 Max. **	Volts
Signal-Grid Voltage (Grid No. 1)	-3	-6 Min. **	Volts
*Oscillator-Grid Voltage (Grid No. 3)	-10	-15	Volts
Peak Oscillator Voltage (Applied to Grid No. 3)	12	18	Volts Min.
Plate Current	2.4	3.3	Milliamperes
Screen Current	6.2	8.3	Milliamperes
Plate Resistance	1.0	1.0	Megohm or greater
Conversion Conductance	350	350	Micromhos
Signal-Grid Voltage (Grid No.1) For Conversion Conductance of 5 Micromhos	-30	-45	Volts

*D.C. circuit resistance of Grid No. 3 must not exceed 50,000 ohms.
**Values recommended for all-wave receivers.

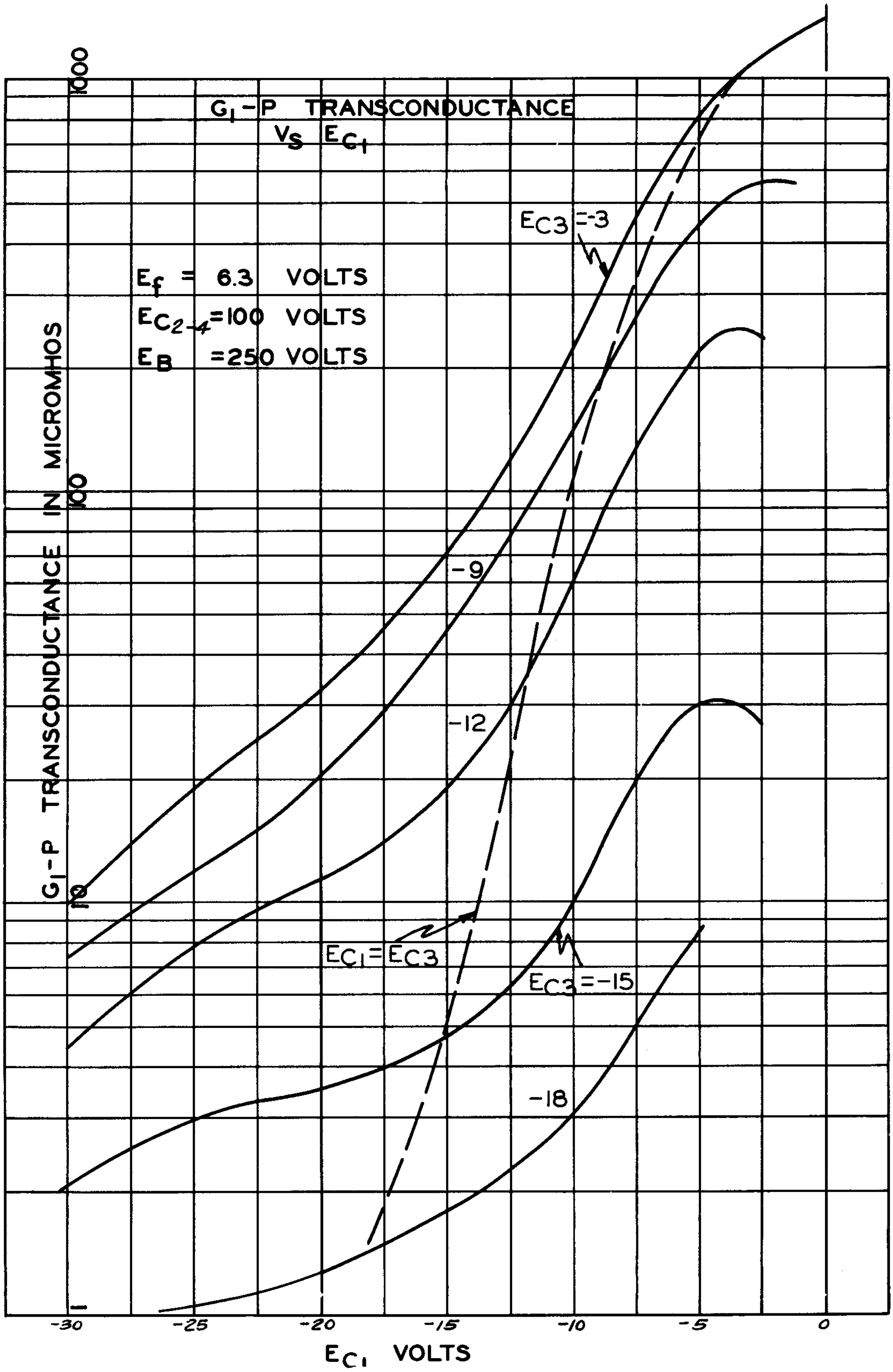
AMPLIFIER OPERATION

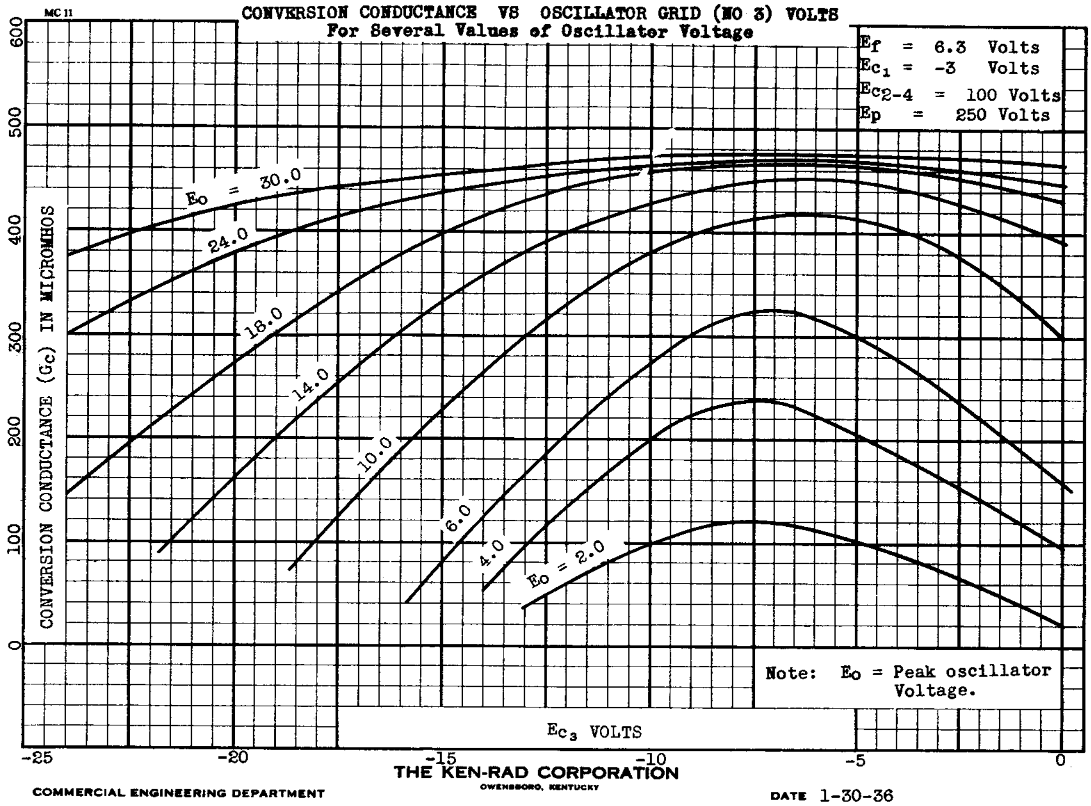
Plate Voltage	250	Volts Max.
Screen Voltage (Grids No. 2 and 4)	100	Volts Max.
Control Grid Voltage (Grid No. 1)	-3	Volts Min.
Control Grid Voltage (Grid No. 3)	-3	Volts Min.
Plate Current	5.3	Milliamperes
Screen Current	5.5	Milliamperes
Plate Resistance	800,000	Ohms
Mutual Conductance	1100	Micromhos
Mutual Conductance (-15 Volts on Grid No. 1) (-15 Volts on Grid No. 3)	5	Micromhos
Amplification Factor	880	

Direct Interelectrode Capacitances: (With shell tied to cathode.)

Grid No. 1 to Plate	.0005	μμf. Max.
Grid No. 3 to Plate	.25	μμf.
Grid No. 1 to Grid No. 3	.12	μμf.
Grid No. 1 to all other electrodes	8.5	μμf.
Grid No. 3 to all other electrodes	11.5	μμf.
Plate to all other electrodes	12.5	μμf.

MC1


G1-P TRANSCONDUCTANCE
VS EC1
Ef = 6.3 VOLTS
EC2-4=100 VOLTS
EB =250 VOLTS
G1-P TRANSCONDUCTANCE IN MICROMHOS
1000
100
10
1
EC3=-3
-9
-12
EC1=EC3
EC3=-15
-18
-30
-25
-20
-15
-10
-5
0
EC1 VOLTS


MC 11
CONVERSION CONDUCTANCE VS OSCILLATOR GRID (NO 3) VOLTS
For Several Values of Oscillator Voltage
Ef = 6.3 Volts
Ec1 = -3 Volts
Ec2-4 = 100 Volts
Ep = 250 Volts
CONVERSION CONDUCTANCE (Gc) IN MICROMHOS
600
500
400
300
200
100
0
Eo = 30.0
24.0
18.0
14.0
10.0
6.0
4.0
Eo = 2.0
Note: Eo = Peak oscillator Voltage.
Ec3 VOLTS
-25
-20
-15
-10
-5
0
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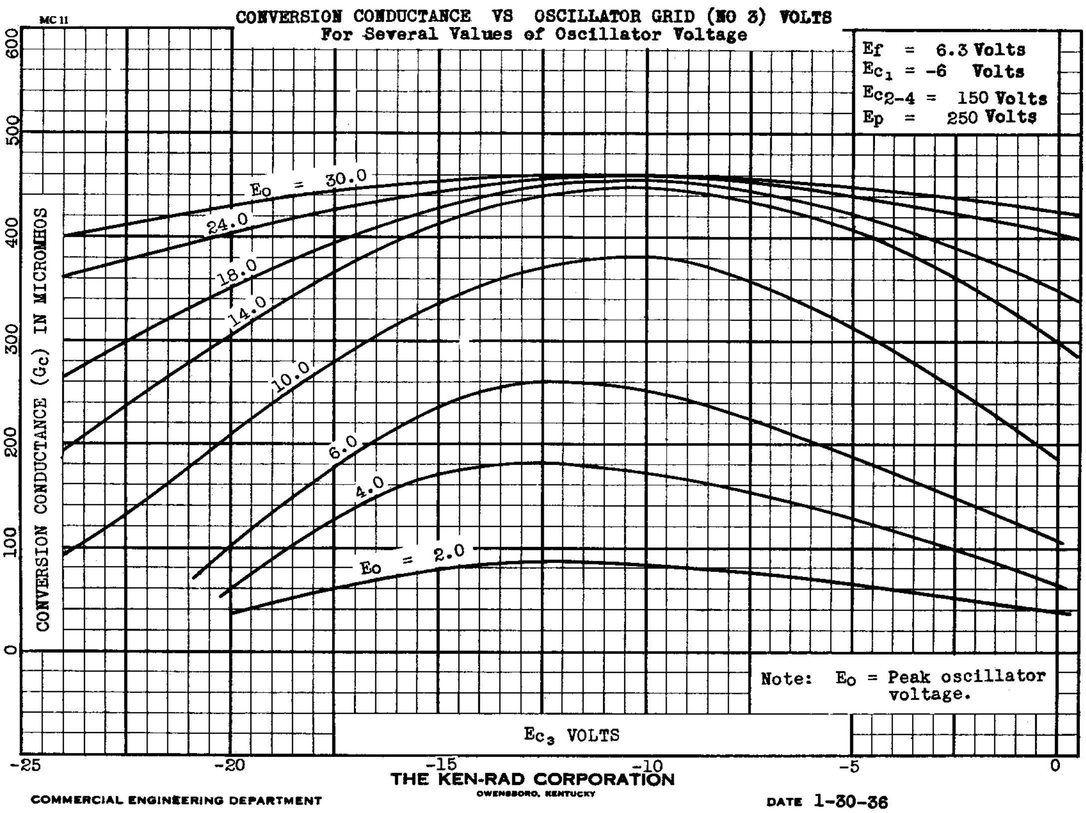
MC 11
CONVERSION CONDUCTANCE VS OSCILLATOR GRID (NO 3) VOLTS
For Several Values of Oscillator Voltage
Ef = 6.3 Volts
Ec1 = -6 Volts
Ec2-4 = 150 Volts
Ep = 250 Volts
CONVERSION CONDUCTANCE (Gc) IN MICROMHOS
600
500
400
300
200
100
0
Eo = 30.0
24.0
18.0
14.0
10.0
6.0
4.0
Eo = 2.0
Note: Eo = Peak oscillator voltage.
Ec3 VOLTS
-25
-20
-15
-10
-5
0
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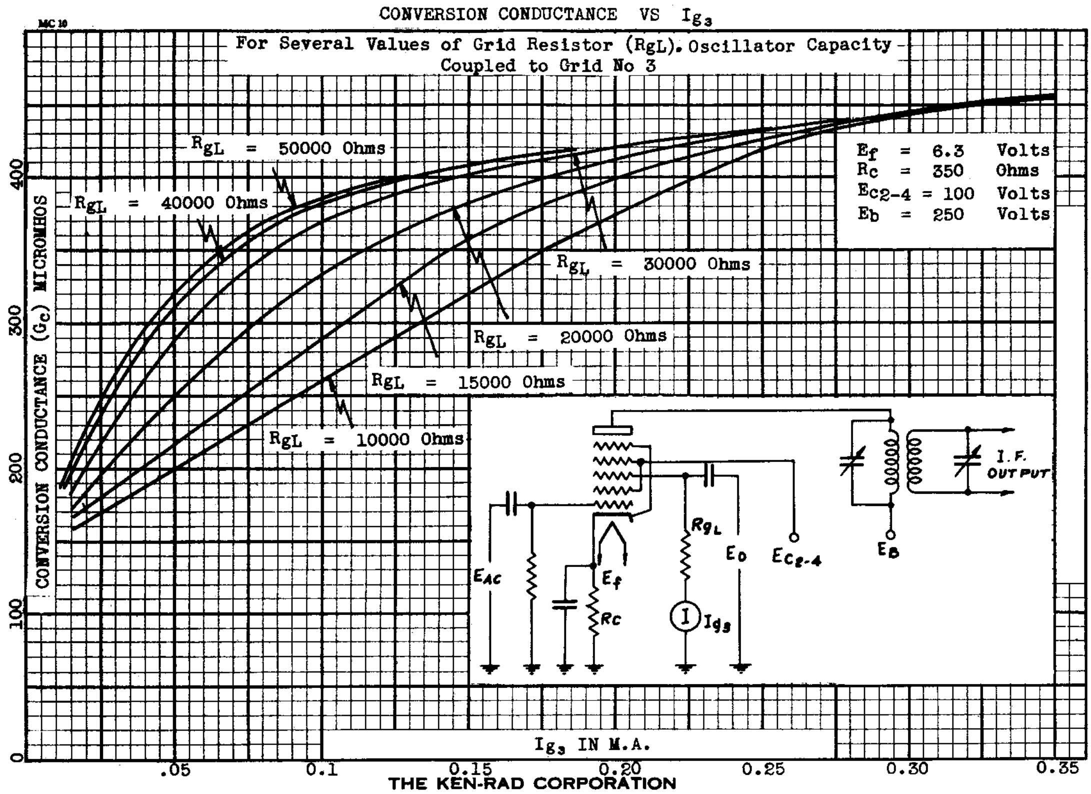

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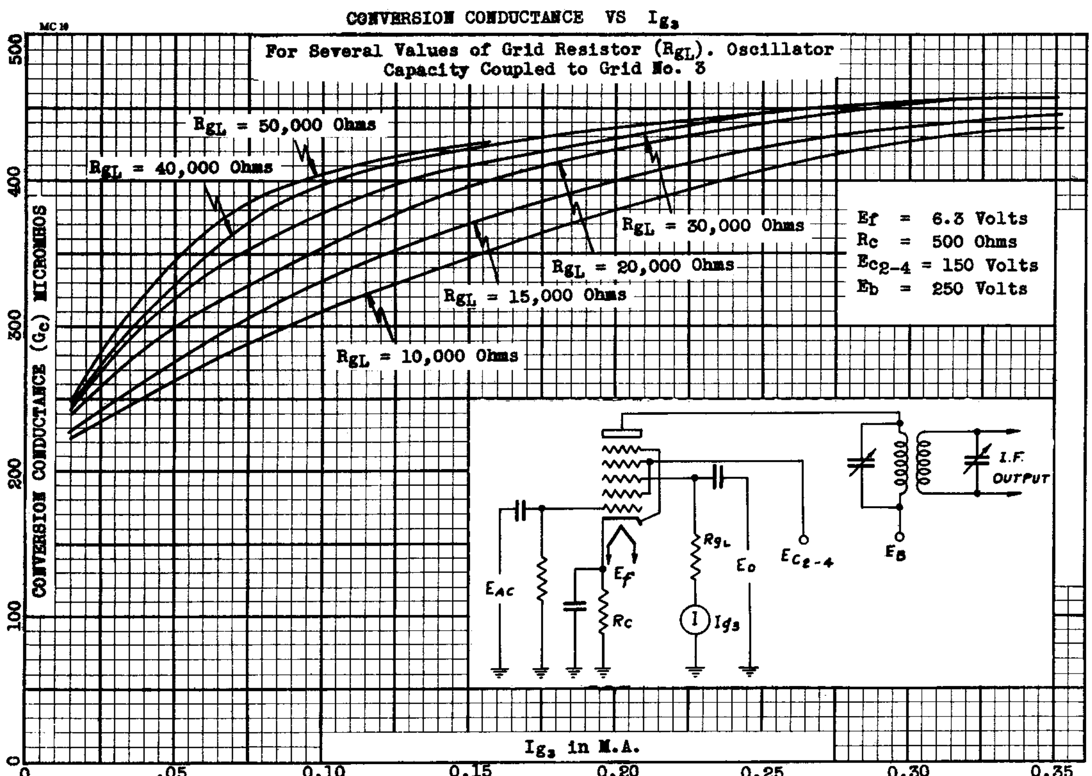

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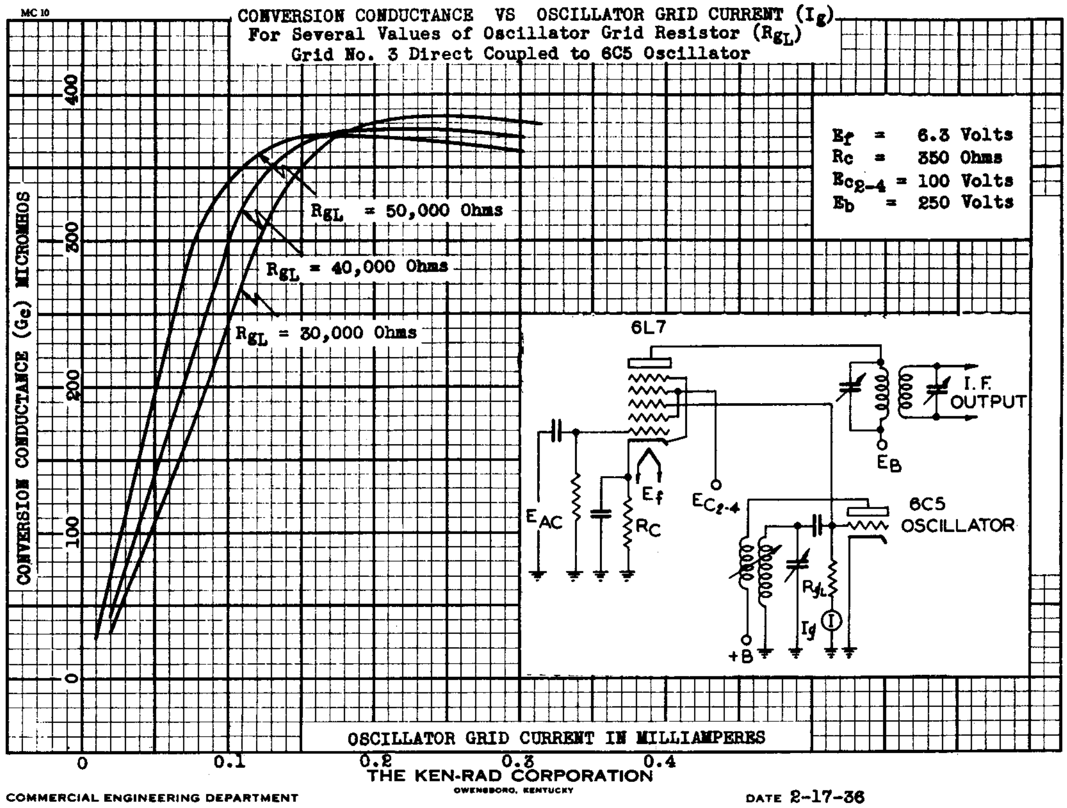
MC 10
CONVERSION CONDUCTANCE VS OSCILLATOR GRID CURRENT (I_g)
For Several Values of Oscillator Grid Resistor (R_{gL})
Grid No. 3 Direct Coupled to 6C5 Oscillator
E_f = 6.3 Volts
R_c = 350 Ohms
E_{c2-4} = 100 Volts
E_b = 250 Volts
R_{gL} = 50,000 Ohms
R_{gL} = 40,000 Ohms
R_{gL} = 30,000 Ohms
CONVERSION CONDUCTANCE (G_c) MICROMHOS
0
100
200
300
400
OSCILLATOR GRID CURRENT IN MILLIAMPERES
0
0.1
0.2
0.3
0.4
6L7
I.F. OUTPUT
E_B
E_{AC}
E_f
R_C
E_{C2-4}
6C5 OSCILLATOR
R_{gL}
I_g
+B
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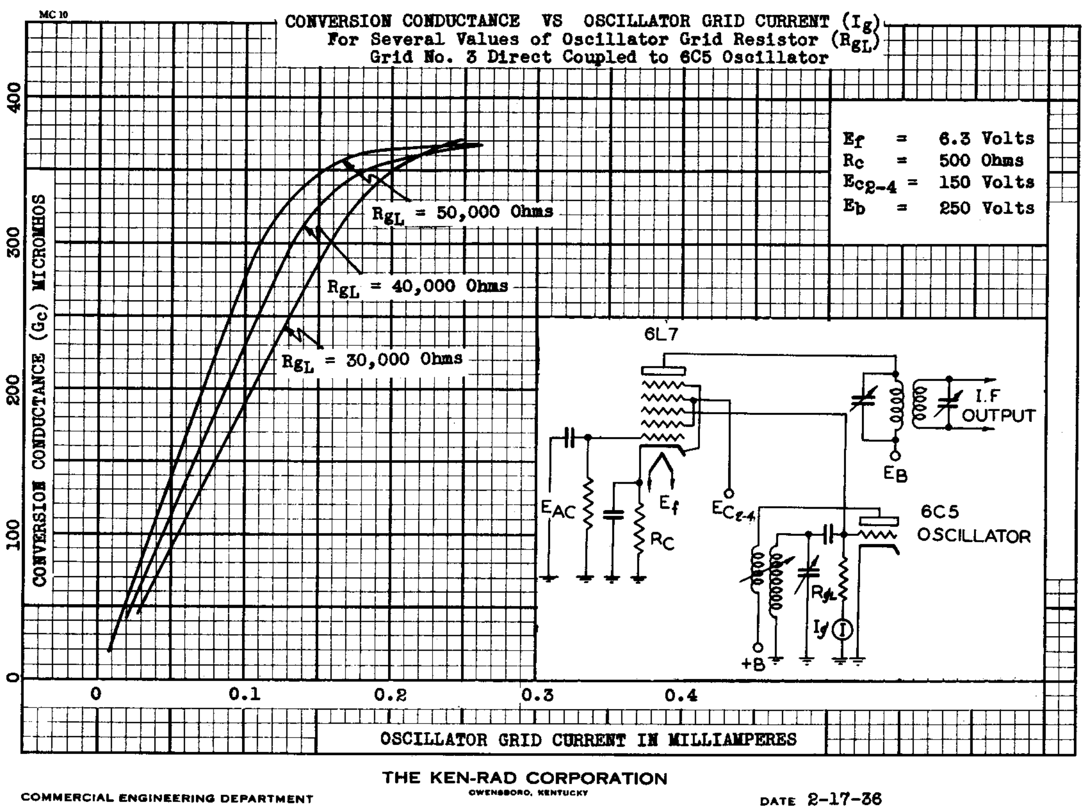
MC 10
CONVERSION CONDUCTANCE VS OSCILLATOR GRID CURRENT (I_g)
For Several Values of Oscillator Grid Resistor (R_{gL})
Grid No. 3 Direct Coupled to 6C5 Oscillator
E_f = 6.3 Volts
R_c = 500 Ohms
E_{c2-4} = 150 Volts
E_b = 250 Volts
R_{gL} = 50,000 Ohms
R_{gL} = 40,000 Ohms
R_{gL} = 30,000 Ohms
CONVERSION CONDUCTANCE (G_c) MICROMHOS
0
100
200
300
400
0
0.1
0.2
0.3
0.4
OSCILLATOR GRID CURRENT IN MILLIAMPERES
6L7
I.F OUTPUT
E_B
E_{AC}
E_f
R_C
E_{C2-4}
6C5 OSCILLATOR
R_{gL}
I_g
+B
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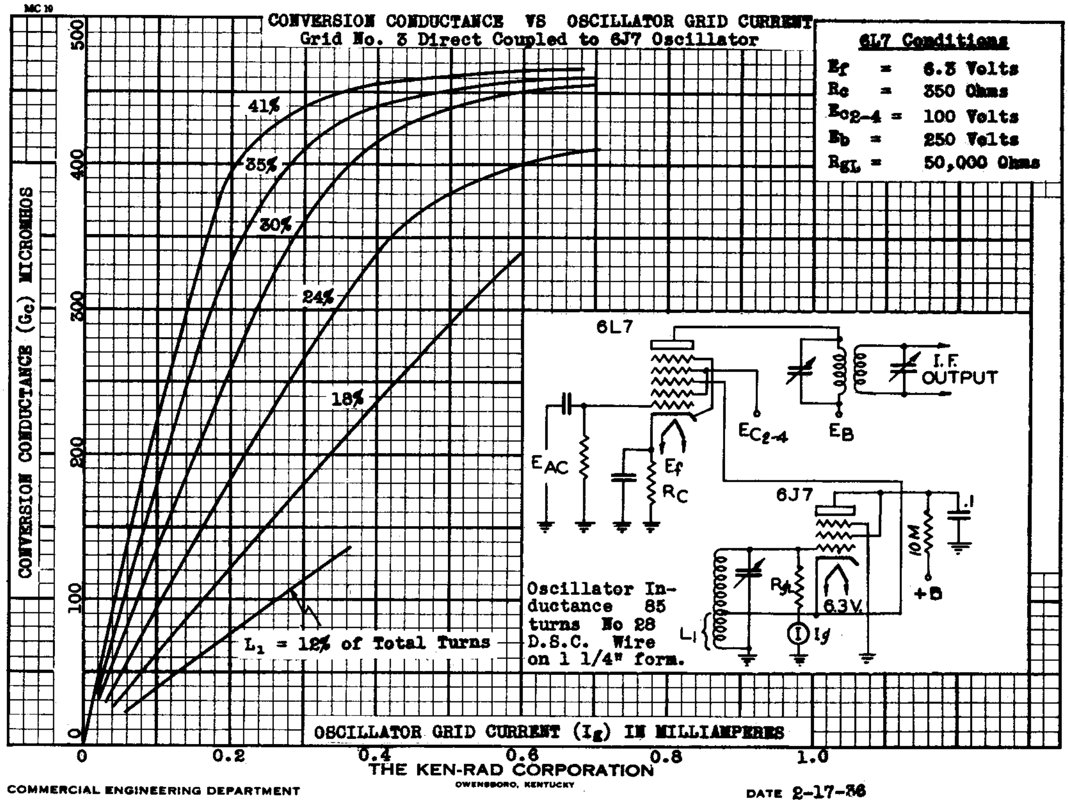
MC 10
CONVERSION CONDUCTANCE VS OSCILLATOR GRID CURRENT
Grid No. 3 Direct Coupled to 6J7 Oscillator
6L7 Conditions
Ef = 6.3 Volts
Rc = 350 Ohms
Ec2-4 = 100 Volts
Eb = 250 Volts
RgL = 50,000 Ohms
CONVERSION CONDUCTANCE (Gc) MICROMHOS
0
100
200
300
400
500
41%
35%
30%
24%
18%
L1 = 12% of Total Turns
6L7
I.F. OUTPUT
EAC
Ef
RC
EC2-4
EB
6J7
10M
.1
+B
RgL
6.3V.
Ig
L1
Oscillator Inductance 85 turns No 28 D.S.C. Wire on 1 1/4" form.
OSCILLATOR GRID CURRENT (Ig) IN MILLIAMPERES
0
0.2
0.4
0.6
0.8
1.0
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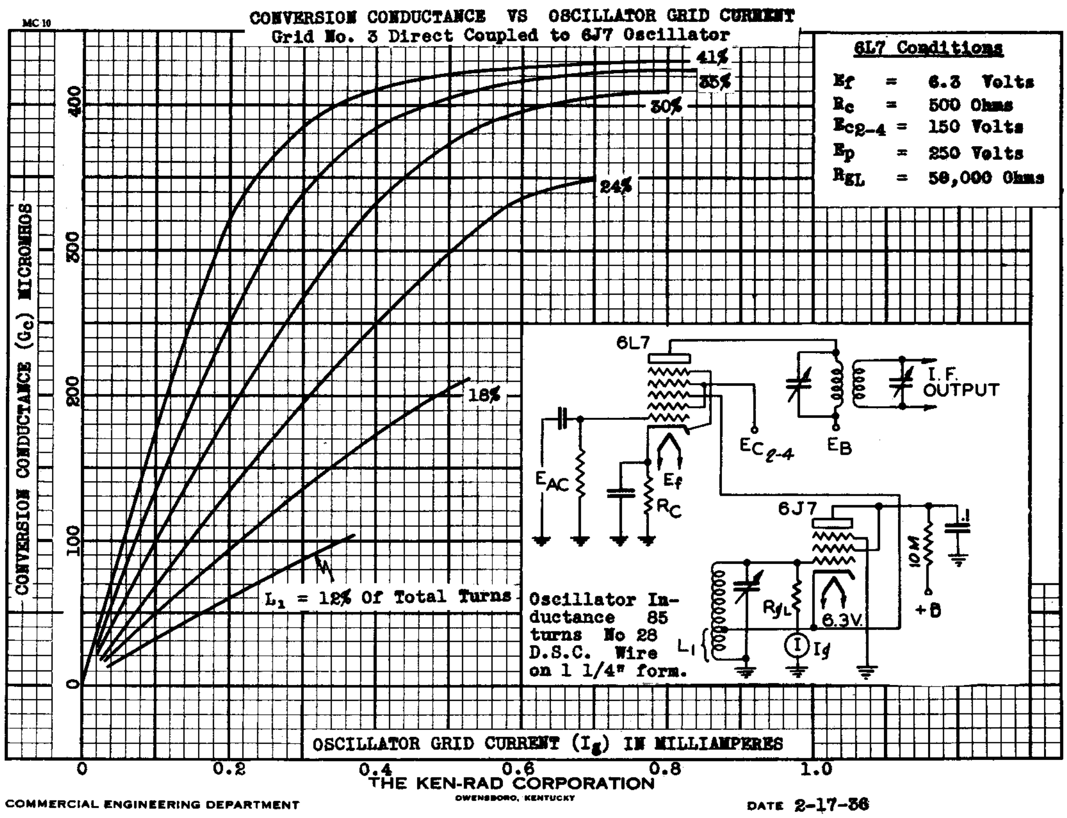
MC 10
CONVERSION CONDUCTANCE VS OSCILLATOR GRID CURRENT
Grid No. 3 Direct Coupled to 6J7 Oscillator
6L7 Conditions
Ef = 6.3 Volts
Rc = 500 Ohms
Ec2-4 = 150 Volts
Ep = 250 Volts
RgL = 50,000 Ohms
CONVERSION CONDUCTANCE (Gc) MICROMHOS
0
100
200
300
400
41%
35%
30%
24%
18%
L1 = 12% Of Total Turns
6L7
I.F. OUTPUT
EAC
Ef
RC
EC2-4
EB
6J7
10M
.1
+B
RgL
6.3V.
Ig
L1
Oscillator Inductance 85 turns No 28 D.S.C. Wire on 1 1/4" form.
OSCILLATOR GRID CURRENT (Ig) IN MILLIAMPERES
0
0.2
0.4
0.6
0.8
1.0
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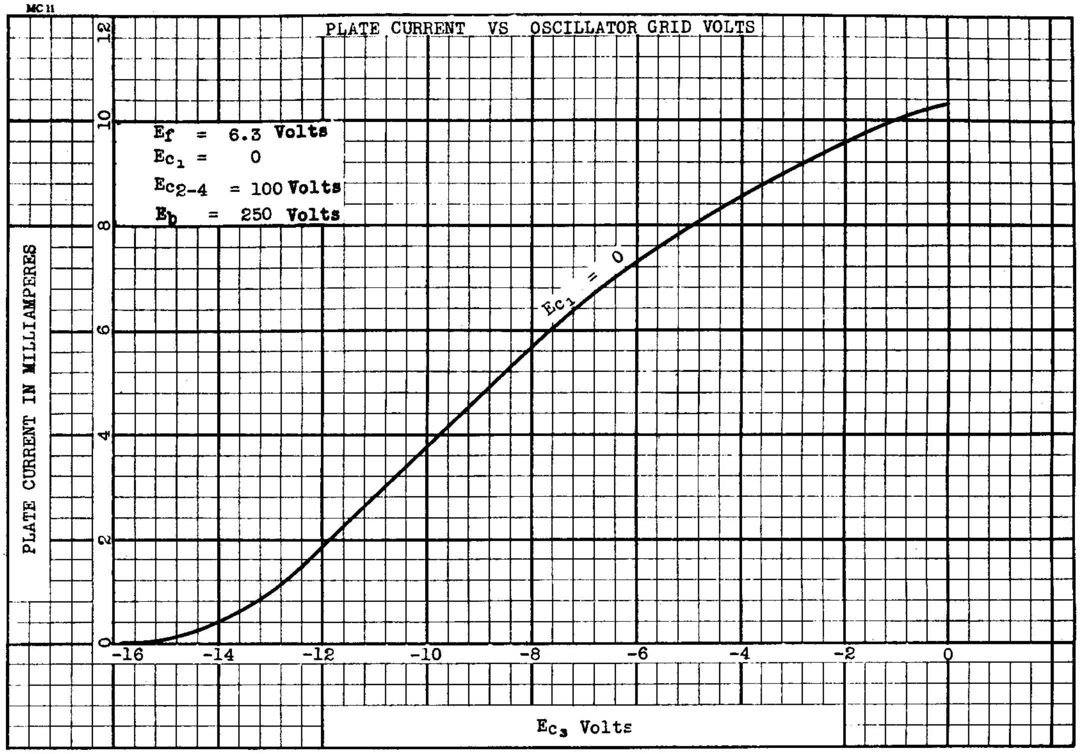

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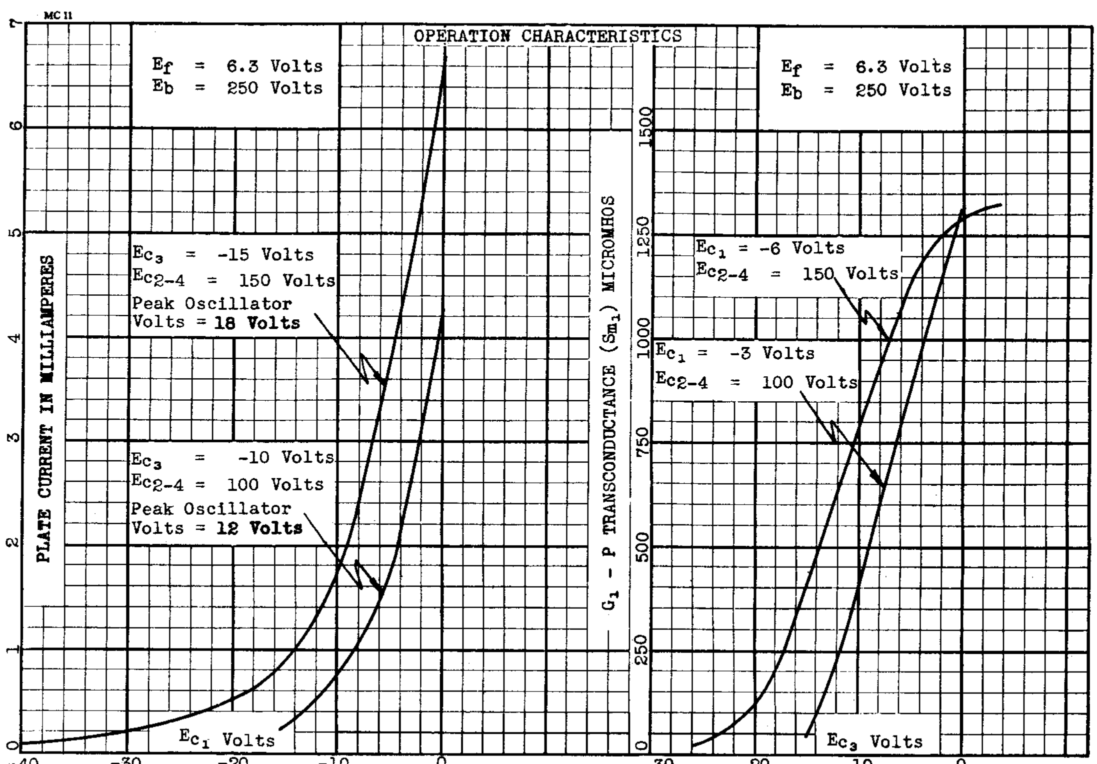

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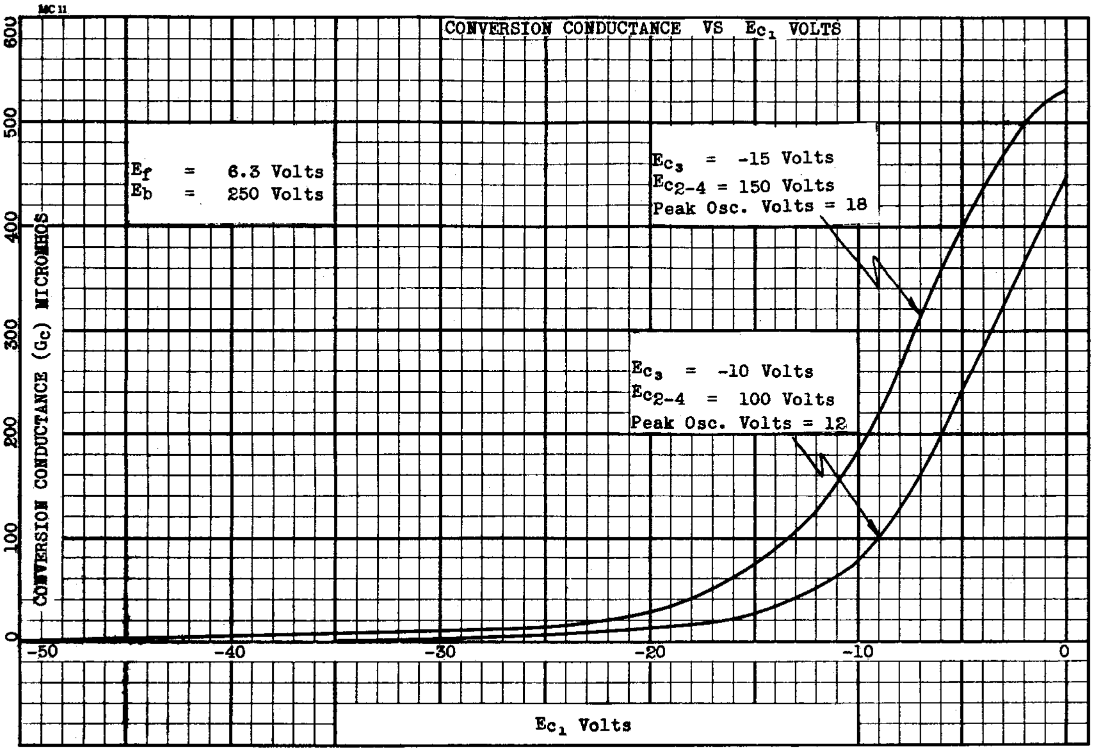

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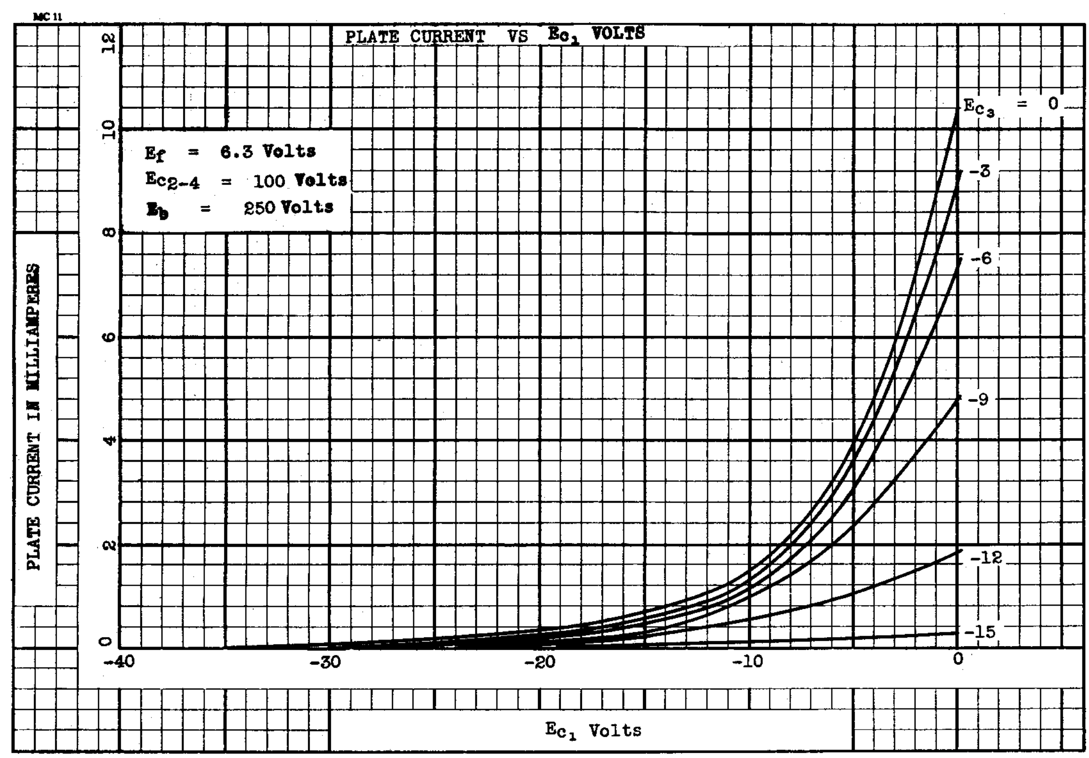

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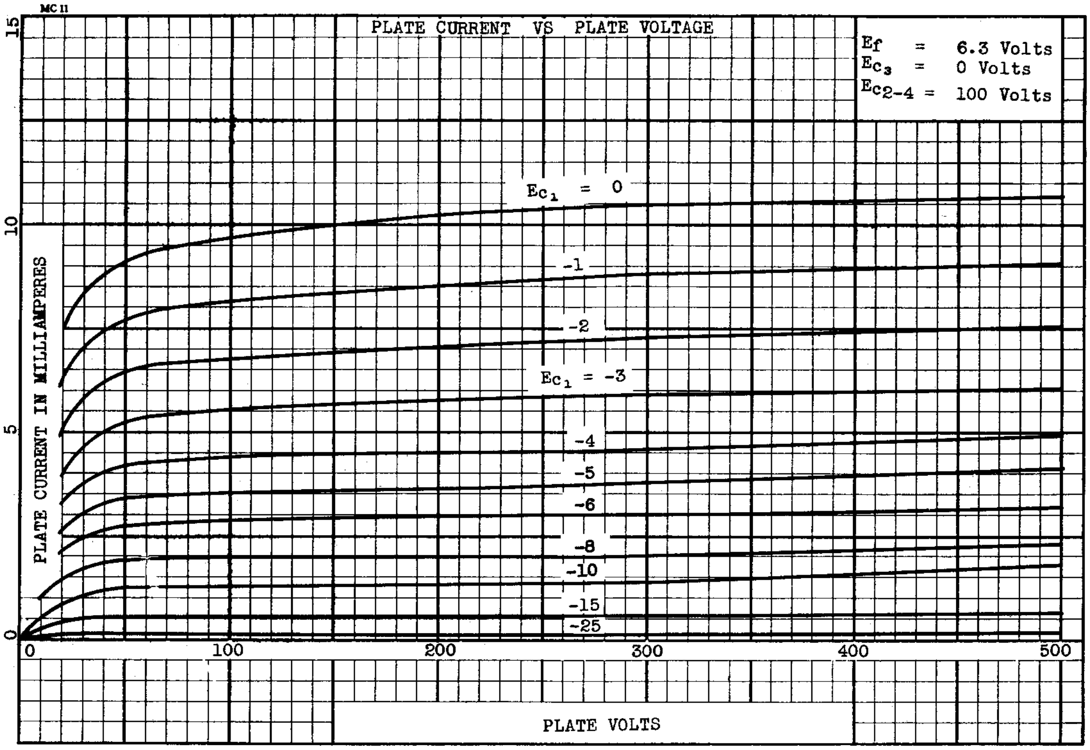

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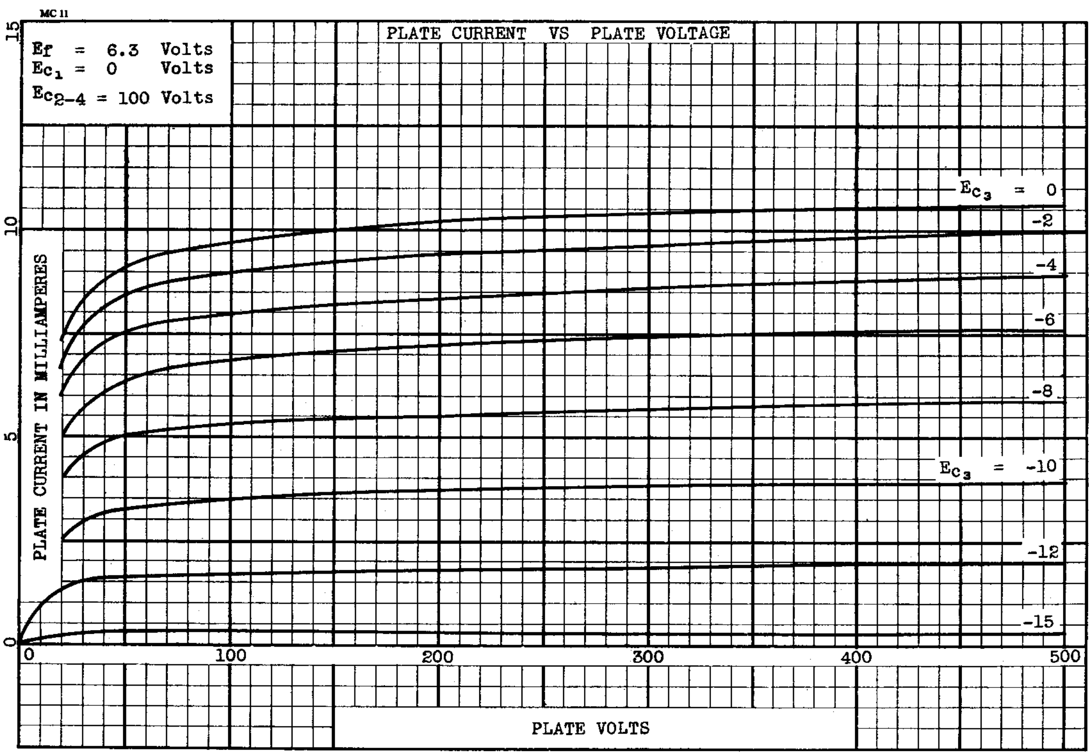

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