



RCA MANUFACTURING COMPANY, INC.

A RADIO CORPORATION OF AMERICA SUBSIDIARY

Harrison, New Jersey

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

APPLICATION NOTE NO.106

APPLICATION NOTE
ON
THE RCA MINIATURE TUBES

This Note presents information on the miniature tube types 1R5, 1S4, 1S5, and 1T4. These tubes can be operated from a 45-volt B-battery and a $1\frac{1}{2}$ -volt A-battery. The size of these tubes, in cubic inches of volume, is only about one-fifth that of the 1.4-volt GT tubes. The new tubes are, therefore, well suited for use in wearable hearing aids, meteorological balloons, pocket-size receivers, other portable receivers, or any radio equipment where small size and light weight are important. This Note is concerned principally with the use of miniature tubes in receivers and especially with the operation of the 1R5 pentagrid converter. A following Note will describe a miniature-tube hearing-aid circuit having an air-conduction output unit.

The small size of the miniature tubes is principally due to a new tube structure which eliminates the conventional base. The base of the miniature tubes is a glass button sealed to the bulb. Running through this button are seven stiff wire stubs which serve as electrode supports inside the tube and base pins outside the tube. The electrode assembly is only about $\frac{1}{4}$ inch above the base. This compact structure makes it possible to mount a full-size 1.4-volt filament in a tube only $2\frac{1}{8}$ inches long.

In addition to their small size and low B-voltage requirement, the miniature tubes have other important advantages. The 1R5 pentagrid converter employs an oscillator circuit which inherently gives high oscillator transconductance. Both the 1R5 converter and 1T4 i-f amplifier have a remote cut-off characteristic which enables them to handle a wide range of signal strengths without modulation distortion. The 1S5 diode-detector and a-f amplifier tube has a pentode amplifier section which can provide an audio gain of 30 when B-supply is 45 volts, and adequate signal output when the B-battery is at the end of its life. The 1S4 output tube has a maximum-signal power output of 65 milliwatts when plate and screen voltage are 45 volts, and 190 milliwatts when plate and screen voltage are 67.5 volts. All the miniature types have a single-ended construction which eliminates flexible grid leads and top-cap connectors.

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Circuits for the 1R5 Pentagrid Converter

The 1R5 is a pentagrid converter similar to the 6SA7 in that the 1R5 has no separate oscillator anode. Typical circuits for the 1R5 are shown in Fig.1. In Circuit I, oscillator feedback is provided by making plate and screen current flow through a tickler coil. In Circuit II, oscillator feedback is provided by connecting the filament to a tap on the oscillator tank coil. This second circuit is similar to the cathode feedback circuit used with the 6SA7.

In both circuits, the 1R5 has two important advantages in addition to the fact that the B-supply can be as low as 45 volts. One advantage is that, in both circuits, almost all the electron current emitted by the filament is effective in providing feedback. As a result, the oscillator transconductance of the 1R5 in the circuits of Fig.1 is higher than that of other battery-operated converter types in the conventional circuit where the feedback current (the oscillator-anode current) is only about 50% of the total emission current. The high oscillator transconductance of the 1R5 makes it possible to obtain wider tuning ranges with this tube.

A second advantage of the 1R5 is due to the fact that the arrangement of grid side-rods in the 1R5 is similar to that in the 6SA7. Because of this arrangement, most of the electrons turned back toward the filament by the negative signal grid are prevented from reaching the space charge near the filament. This action of the side-rods, together with the electrostatic shielding of the screen, practically isolates the filament space charge from the signal grid. As a result, changes in signal-grid bias produce very little change in oscillator transconductance. Changes in avc bias, therefore, produce very little change in oscillator frequency. This feature of the 1R5 is important in short-wave operation.

Comparison of Circuits I and II

In a receiver which is to use the 1R5, the choice between Circuits I and II depends on the frequency range of the receiver. In a set tuning not higher than about 6 megacycles, Circuit I is generally preferable. In a set which is to tune higher than this frequency, Circuit II may be preferable. At the high frequencies, the choice between the two circuits depends on the following considerations.

Circuit I has the advantage that it is somewhat easier to provide adequate grid excitation in a tickler-feedback oscillator than in a cathode feedback oscillator. When Circuit I is operated at frequencies higher than about 6 megacycles, a neutralizing condenser C_N should be connected in the circuit, as discussed in the next paragraph. Circuit II has the advantage that it does not require this neutralization. Also, band-switching in Circuit II may be simpler than in Circuit I. The relative importance of these advantages will determine the choice between the two circuits for use in a particular receiver operating at high frequencies.

Neutralization of Circuit I

In operation of Circuit I at frequencies above 6 megacycles, the oscillator voltage on the screen may cause considerable oscillator voltage to appear on the signal-grid. The reason is that, at these frequencies, there is

only a small percentage difference between the signal and oscillator frequencies. The impedance of the signal-grid circuit at oscillator frequency is therefore appreciable compared with that of the screen-to-signal-grid capacitance. To minimize the oscillator voltage on the signal-grid, a small condenser should be connected between the signal-grid and the No.1 grid, as indicated in dotted lines in Fig.1, when Circuit I is to be tuned higher than 6 megacycles. Because the oscillator voltage on the No.1 grid is in phase opposition to that on the screen, the oscillator voltage on the signal-grid can be practically cancelled by use of the proper capacitance for C_N .

The effect on receiver sensitivity of variation in the capacitance of C_N is indicated by Fig.2. This curve was plotted for a typical receiver operating at 16 megacycles. The values on this curve are not necessarily correct for other receivers, but the curve shape is approximately correct for other receivers. The explanation of this curve shape is briefly as follows: There are two components of oscillator voltage on the signal-grid, one applied from the No.1 grid, the other applied from the screen. The two components are in phase opposition. In the receiver for which the curve of Fig.2 was plotted, when C_N is approximately equal to 4.5 μmf , the two components are equal, and cancel each other. When C_N is smaller than 4.5 μmf , the net resultant oscillator voltage on the signal-grid is in phase with the screen voltage and out of phase with the No.1-grid voltage. As a result, the oscillator voltage on the signal-grid reduces the modulation of the electron stream by the No.1 grid and, therefore, reduces conversion transconductance. When C_N is larger than 4.5 μmf , the net resultant oscillator voltage on the signal-grid is in phase with the No.1-grid voltage. This in-phase voltage on the signal-grid increases plate current above the value giving maximum conversion transconductance, and causes the d-c current to the signal-grid to become comparatively large. This grid current loads the signal-grid tuned circuit and increases the avc bias voltage on the i-f tube. From this explanation it can be understood why there is a value of C_N giving maximum sensitivity. However, the value of C_N is not critical; it can be seen from Fig.2 that variations of $\pm 10\%$ in C_N do not cause excessive variation in the sensitivity of the receiver measured. In other receivers, it has been found that variations of $\pm 20\%$, or even more, can be tolerated.

Consideration of Circuit I shows that the value of C_N providing best neutralization depends on the ratio of the amplitude of oscillator voltage on the screen to that on the No.1 grid. This ratio is determined by the turns ratio between the tickler coil and the No.1-grid coil. The optimum value of C_N , therefore, depends on the number of tickler turns. A good method for adjusting C_N and the number of tickler turns for the frequency band between approximately 6 and 18 megacycles is as follows. First, tune to the low-frequency end of the band and adjust the tickler turns to give 20 microamperes No.1-grid current. Then, tune to the high-frequency end of the band and adjust the capacitance of C_N to give maximum receiver sensitivity. In receiver production, it may be desirable to use a value of C_N somewhat smaller than the value giving maximum sensitivity so that manufacturing variations will not make C_N much larger than the optimum-sensitivity value. If C_N becomes much larger than this value, circuit instability is likely to result because of interaction between the oscillator and signal-grid circuits. In the receiver for which the curve of Fig.2 was plotted, a value of 4 μmf for C_N gave practically no interaction, 5 μmf caused some interaction, and 7 μmf made the circuit inoperative. The value of C_N selected for use in the

6-18 megacycle band can also be used in the middle- and low-frequency bands. In the middle-frequency band, the optimum value of C_N is not at all critical, while in the low-frequency bands, the presence of C_N in the circuit has very little effect on circuit performance.

In the high-frequency band, the effect of variation in C_N on receiver sensitivity and stability depends on the amplitude of oscillation. When this amplitude increases, the value of C_N becomes more critical. Hence, this capacitance is generally most critical at the high-frequency end of the band. When it is desired to reduce the effect of variation in C_N on receiver sensitivity, this reduction can be made by limiting the amplitude of oscillation at the high-frequency end of the band. A simple method for limiting this amplitude is to connect a resistor in series with the oscillator trimmer condenser.

The method used to vary C_N in our laboratory tests consisted of connecting in the circuit different fixed condensers. Each fixed condenser was made by winding a length of bare copper wire tightly on a length of rubber-covered wire. The capacitances of these condensers were measured on a Q-meter.

R-F Choke for Circuit II

An r-f choke for Circuit II should meet the following requirements which are not difficult to satisfy. The resistance of the choke should not be so large as to cause excessive drop in the filament voltage supplied to the 1R5. A resistance of 1 ohm, or less, is satisfactory. The inductance of the choke should be large enough to provide effective choking at the lowest frequency to which the oscillator tunes. For operation in the domestic broadcast band, an inductance of 30-40 μ h is generally satisfactory. The distributed capacitance of the choke should be small enough so that the resonant frequency of the choke is higher than the highest frequency to which the oscillator tunes.

Adjustment of Feedback Turns for Circuits I and II

In Circuit I, the number of tickler turns should be large enough so that strong oscillation is maintained throughout the tuning range and throughout battery life. However, the number of tickler turns should not be much larger than necessary because an excessive number of tickler turns causes a reduction in conversion transconductance. The reason is that an increase in tickler turns causes an increase in the amplitude of oscillator voltage on the screen. When Circuit I is in normal operation, cathode current flows only during the positive half-cycles of No.1-grid voltage. During these half-cycles, the oscillator voltage on the screen is negative. Hence, an increase in the amplitude of oscillator voltage on the screen decreases the effective d-c screen voltage. As a result, an increase in tickler turns above a certain number reduces conversion transconductance. Similar statements are true of Circuit II. The filament tap on the oscillator tank coil should be far enough up the coil for strong oscillation. However, the tap should not be too far up the coil because the oscillator voltage on the filament makes the filament positive with respect to the signal-grid during positive half-cycles of No.1-grid voltage. Hence, the oscillator voltage on the filament has the effect of increasing the negative bias on the signal-grid and thus reduces transconductance. These statements are illustrated by the curves of Figs.3 and 4 which show the effect

on conversion transconductance of the oscillator voltage on the screen in Circuit I, and of the oscillator voltage on the filament in Circuit II. These curves can be used as a guide when a 1R5 oscillator coil is to be adjusted to give best sensitivity over a tuning band. The curves are convenient to use. A simple vacuum-tube voltmeter adequate for measuring oscillator voltage on the 1R5 screen or filament consists of a diode in series with a 100000-ohm resistor and a microammeter. In the domestic broadcast band, best sensitivity is usually obtained when oscillator-grid current ranges between 50 and 150 microamperes.

Modifications of Circuit I for 90-Volt Supply

Modification of Circuit I may be desirable when the B-supply is 90 volts. This supply voltage may be used in a receiver where it is desired to obtain more power output than can be provided by a 1S4. For such a receiver, a good tube line-up is a 3Q5-GT operated at 90 volts plate and screen voltage, a 1S5 operated at the 90-volt conditions given below under Resistance-Coupled Operating Conditions for 1S5 Pentode, a 1T4, and a 1R5. Because the maximum rated screen voltage of the 1R5 and 1T4 is 67.5 volts, a series screen resistor is necessary for these tubes unless a 67.5-volt battery tap is employed. Fig. 5 shows three methods of supplying screen voltage to a 1R5 and 1T4 from a 90-volt battery in a receiver where the 1R5 stage employs tickler feedback. In Circuit A, 1R5 plate current does not flow through the tickler coil; the tickler feedback current is the screen current alone. With this arrangement, the feedback current, and hence the oscillator transconductance, changes with avc bias. This change may be objectionable in the short-wave bands but is unimportant in the domestic-broadcast and long-wave bands. In Circuit B, the voltage on the 1R5 plate is lower than in Circuit A. As a result, the conversion gain obtainable from Circuit B is somewhat less than that from Circuit A. However, in Circuit B, both the plate current and screen current of the 1R5 contribute to the tickler-feedback current. Because the sum of plate current and screen current changes very little with avc bias, oscillator transconductance in Circuit B is less affected by avc bias than in Circuit A. As a result, Circuit B gives better oscillator performance in the short-wave bands than Circuit A. Circuit C gives somewhat more conversion gain than Circuit B because the 1R5 plate voltage is higher in Circuit C. Also, the oscillator performance of Circuit C is good in all bands because the tickler coil carries both the plate current and the screen current of the 1R5. However, Circuit C employs an additional screen resistor for the 1T4.

Remote Cut-Off in the 1R5 and 1T4

Both the 1R5 converter and 1T4 i-f amplifier have remote cut-off. As a result, a receiver using these tubes can have a better avc characteristic than a receiver using sharp cut-off types. This statement is illustrated by Fig. 6 which shows avc curves for a typical battery-operated receiver before and after conversion to the miniature tubes. The curve for the sharp cut-off tubes bends upward at an antenna input of about 30,000 microvolts. At this value of input, the avc bias on the converter and i-f tubes is a large percentage of their cut-off bias. As a result, there is some clipping of negative signal peaks on the i-f amplifier grid. This clipping produces an increase in the percentage modulation of the i-f amplifier output, and thus causes the upward bend in the curve for measured audio output. In other

words, the upward bend in the curve indicates the signal strength at which modulation distortion starts. The curves show that the range of signal strengths amplified without appreciable modulation distortion is about 5 times larger for the miniature tubes than for the sharp cut-off types.

Curves for Miniature Types Operated at 67.5 Volts on the Screen

The maximum rated screen voltage of the 1R5, 1T4, and 1S4 has recently been raised from 45 to 67.5 volts. The maximum rated plate and screen voltages of the 1S5 had been previously set at 90 volts. Curves for all four types at a screen voltage of 67.5 volts are given in Figs.7-14. Fig.9 also shows power output and distortion curves for the 1S4 operated at 45 volts plate and screen voltage. It should be noted that, in a receiver where part of the B-supply voltage is used to bias the output tube, the values of transconductance and power output will be somewhat less than those shown in the curves.

Resistance-Coupled Operating Conditions for 1S5 Pentode

Plate Supply Voltage	45	67.5	90	volts
Screen Supply Voltage	45	67.5	90	volts
Grid Voltage	0	0	0	volts
Load Resistor	1	1	1	megohm
Series Screen Resistor	3	3	3	megohms
Grid Resistor	10	10	10	megohms
Grid Resistor for Following Stage	2	2	2	megohms
Voltage Gain # (approx.)	30	40	50	

Obtained when the grid of the pentode unit is fed from a source having an impedance of 1.0 megohm.

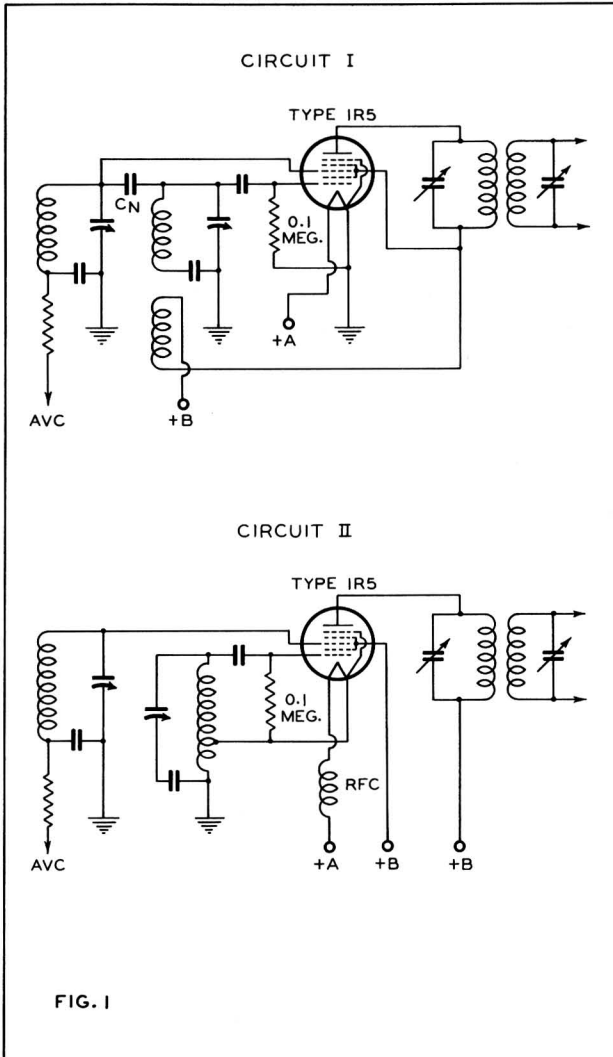
Shielding and Sockets for the Miniature Tubes

Shielding cans are not usually required for the miniature tubes. The 1T4 i-f amplifier tube has a shielding electrode which surrounds the plate and is internally connected to the filament. The socket for a 1T4 should have a central metal insert shielding the grid base-pin from the plate base-pin, which is opposite the grid pin. The socket for a 1R5 should be cushioned as a precaution against microphonics. Suitable cushioning can be provided by soft rubber grommets between the socket and chassis. Similar cushioning for the 1T4 may be desirable. It may be necessary to mount a baffle plate or other shielding between the 1S5 and output tube to prevent audio feedback. Also, in a receiver tuning to the long-wave band where signal frequencies are close to the intermediate frequency, it may be necessary to shield the 1S5 and 1T4 from the loop and the r-f input leads.

When a miniature tube is removed from its socket, the tube should be pulled straight away from the socket without rocking motion. Rocking the tube in its socket produces a transverse pressure on the base pins which may crack the glass base. Likewise, wiring to the sockets should not pull socket terminals out of position because this pull applies transverse pressure to the base pins. Socket contacts should grip the base pins not less than 1/8 inch below the base so that the base pins can bend slightly to make up for misalignment of socket holes or contacts.



TYPICAL OPERATING CIRCUITS
USING TYPE IR5



The license extended to the purchaser of tubes appears in the License notice accompanying them. Information contained herein is furnished without assuming any obligations.

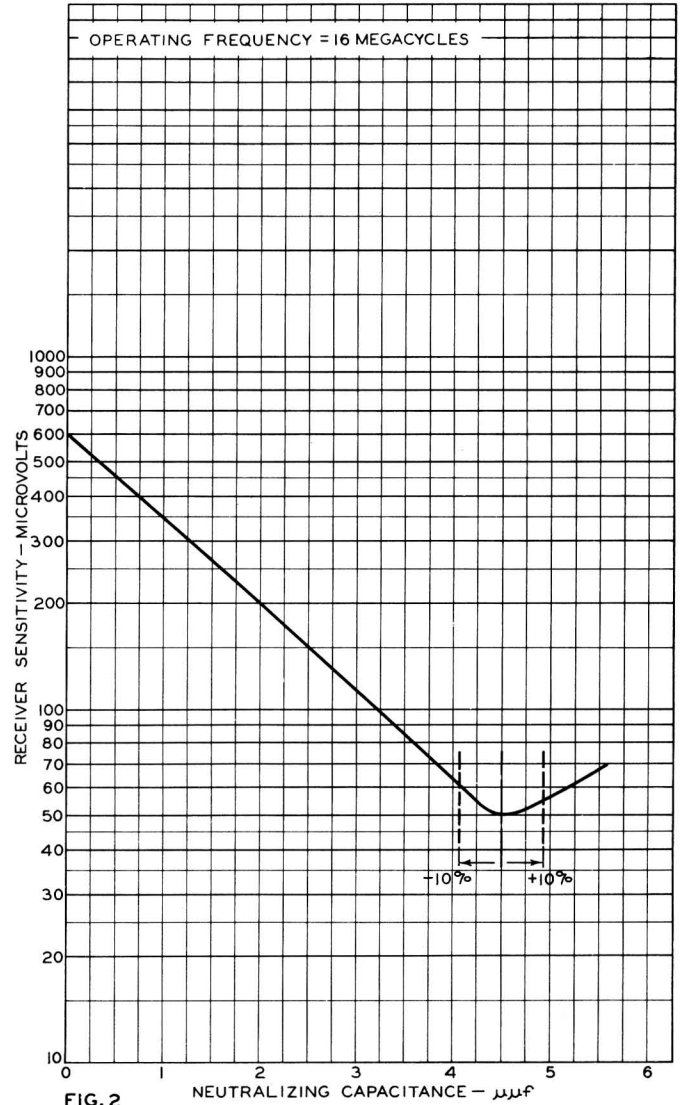
APRIL 3, 1940

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92C-6149



SENSITIVITY CURVE FOR TYPICAL RECEIVER
USING TYPE IR5



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92C-6150

NOTE: IN CIRCUIT I ABOVE, THE CONDENSER C_N AND ITS CONNECTIONS SHOULD BE SHOWN IN DOTTED LINES.



IR5

OPERATION CHARACTERISTICS

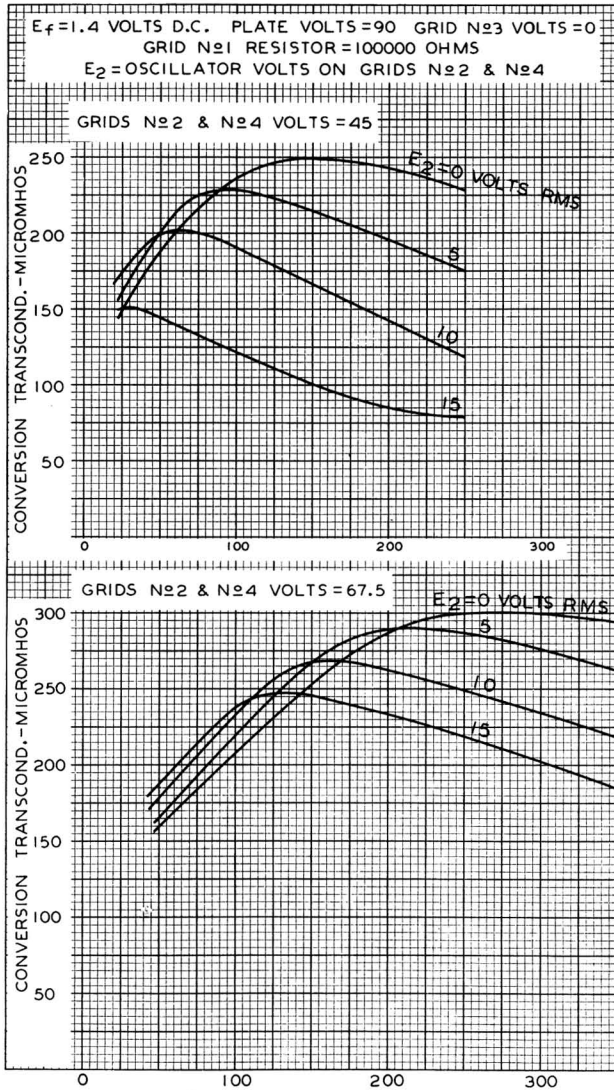


FIG.3 GRID No1 (OSCILLATOR-GRID) MICROAMPERES

MAY 24, 1940

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92C-6159



IR5

OPERATION CHARACTERISTICS

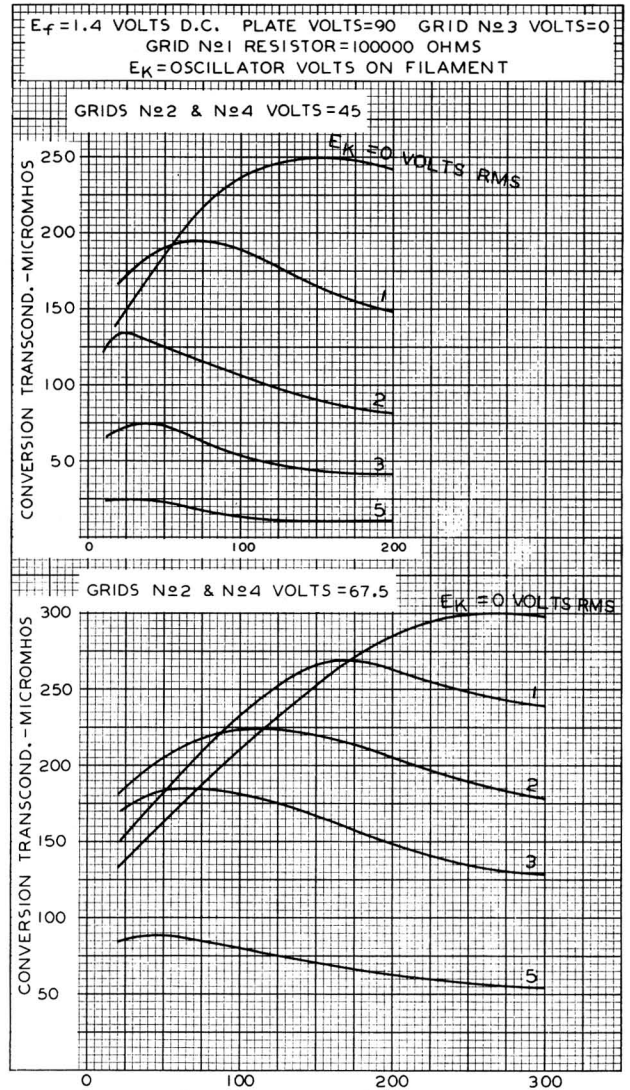


FIG.4 GRID No1 (OSCILLATOR-GRID) MICROAMPERES

MAY 24, 1940

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92C-6160



MODIFICATIONS OF CIRCUIT I
FOR RECEIVERS WITH 90-VOLT B-SUPPLY

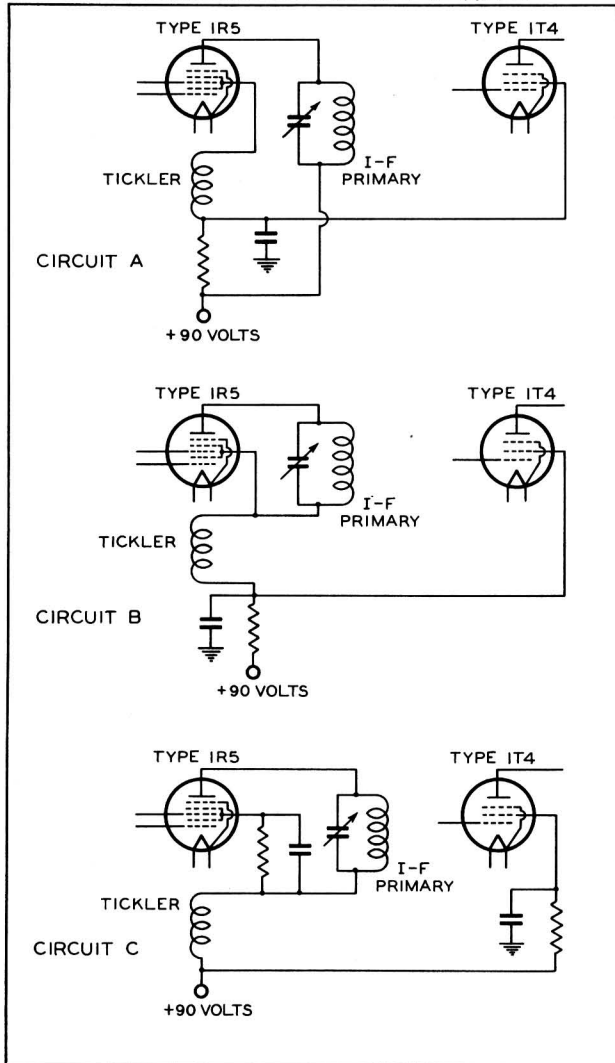


FIG. 5

JUNE 7, 1940

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92C-6171



AVC CURVES FOR TYPICAL BATTERY RECEIVER
BEFORE AND AFTER CONVERSION TO USE MINIATURE TUBES

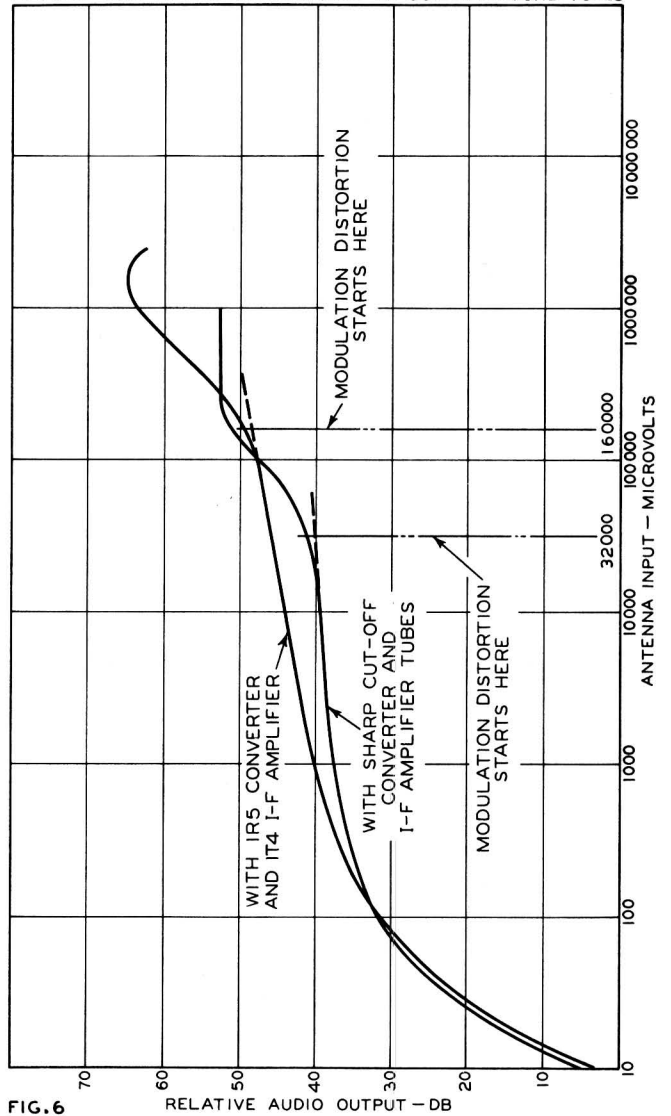


FIG. 6

JUNE 3, 1940

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92C-6163



IR5

OPERATION CHARACTERISTICS

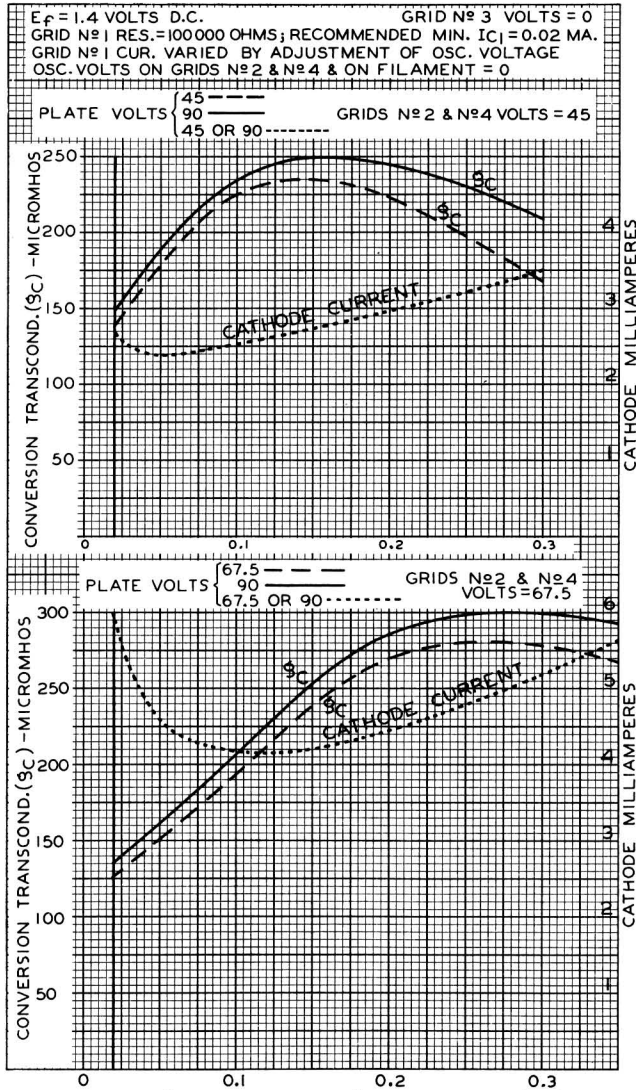


FIG. 7 GRID No 1 (OSCILLATOR-GRID) MILLIAMPERES (I_{c1})
 MAY 30, 1940 RCA RADIOTRON DIVISION 92C-6098R1
 RCA MANUFACTURING COMPANY, INC.



IR5

OPERATION CHARACTERISTICS

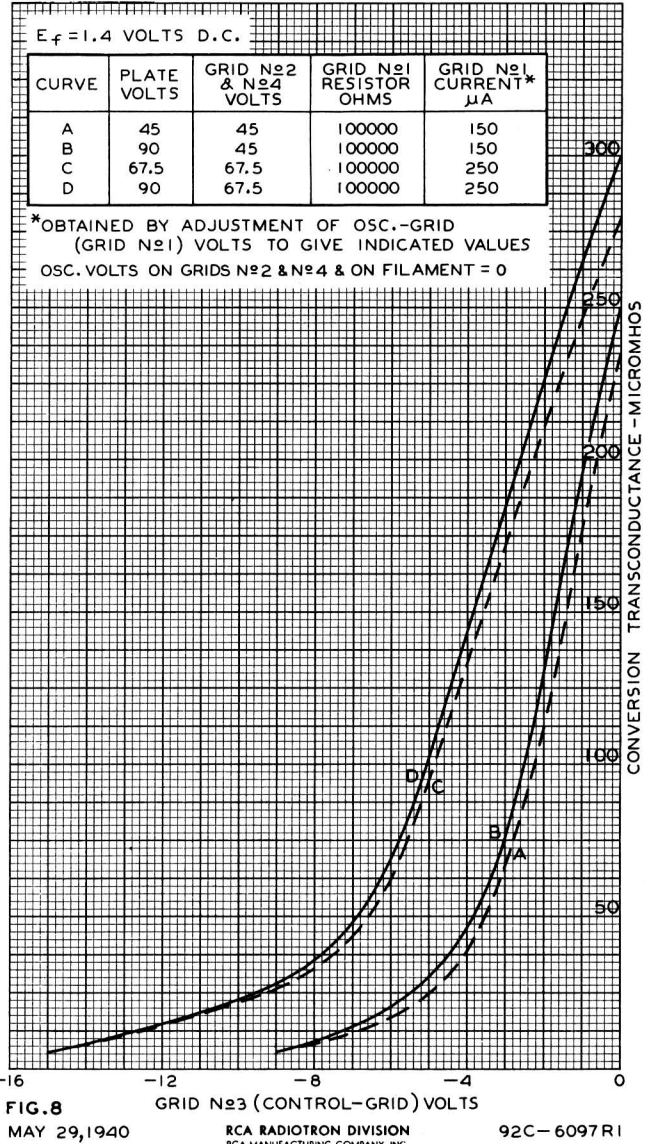


FIG. 8 MAY 29, 1940 RCA RADIOTRON DIVISION 92C-6097R1
 RCA MANUFACTURING COMPANY, INC.



IS4

OPERATION CHARACTERISTICS

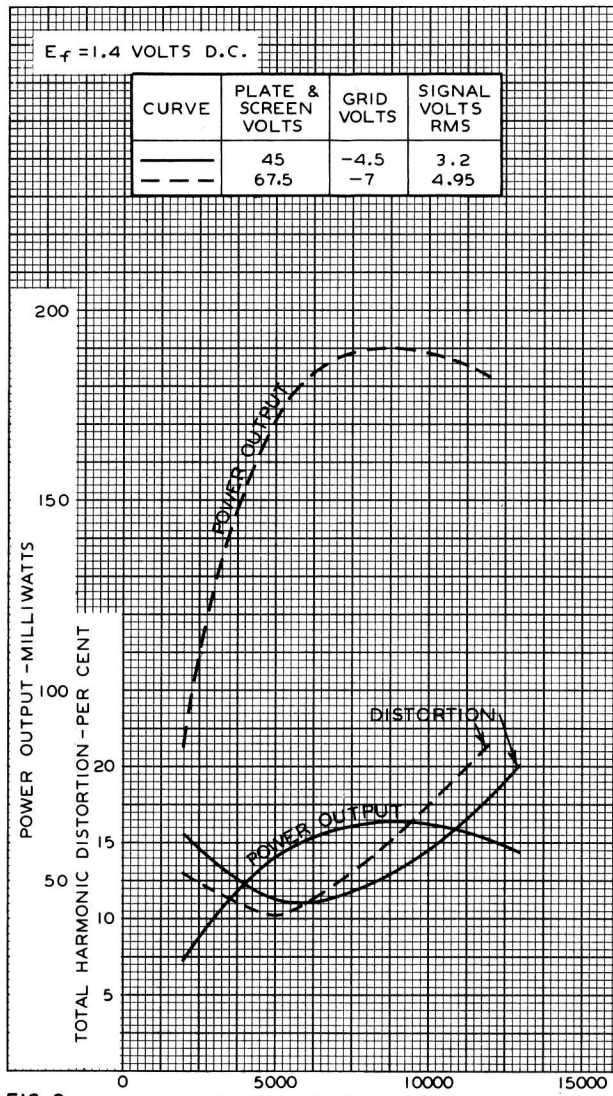


FIG. 9

LOAD RESISTANCE - OHMS

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92C-6175



1S4

AVERAGE PLATE CHARACTERISTICS

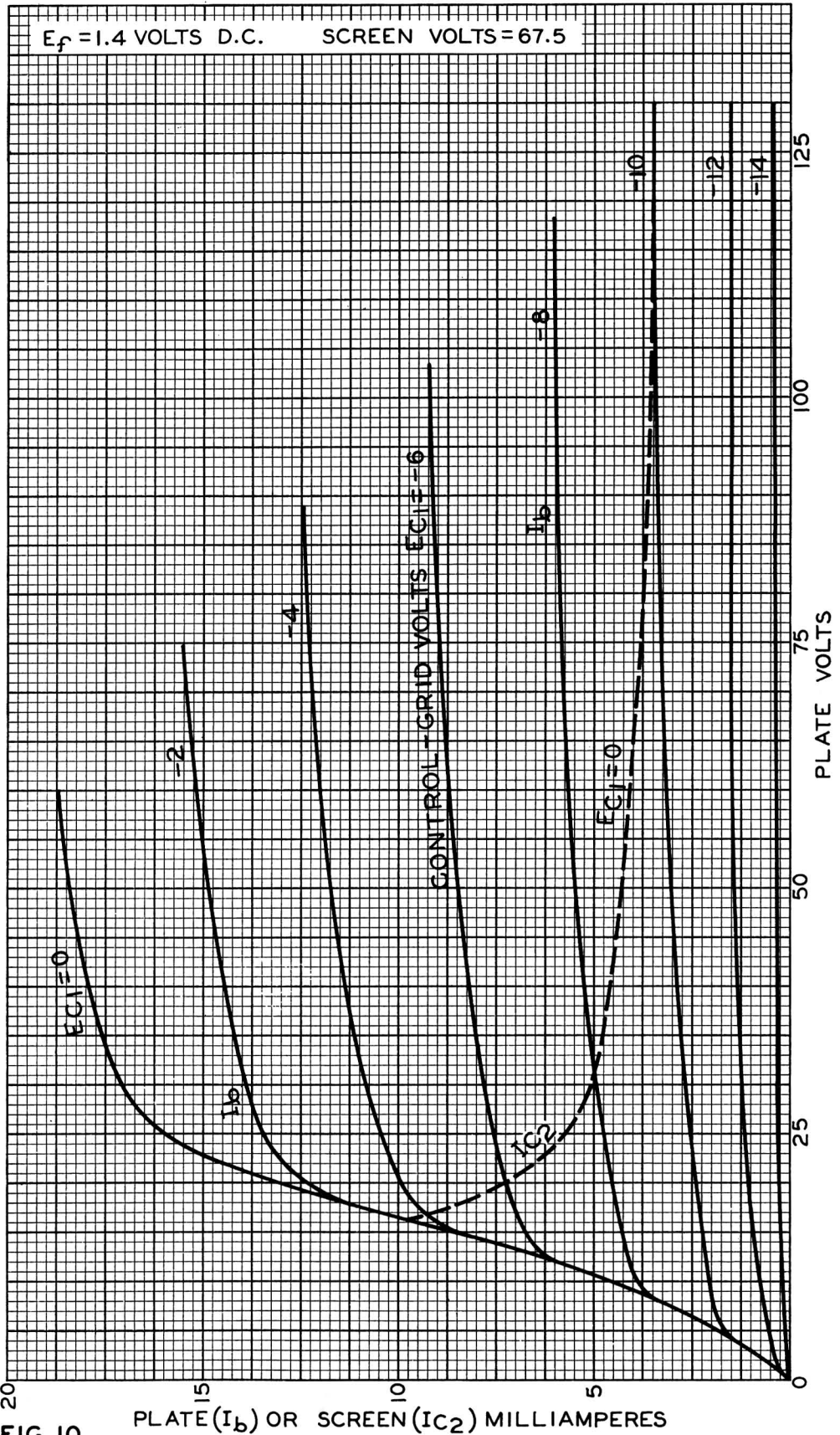


FIG. 10

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92C-6157



1S5

AVERAGE PLATE CHARACTERISTICS PENTODE UNIT



FIG. 11
MAY 21, 1940



1S5

AVERAGE CHARACTERISTICS

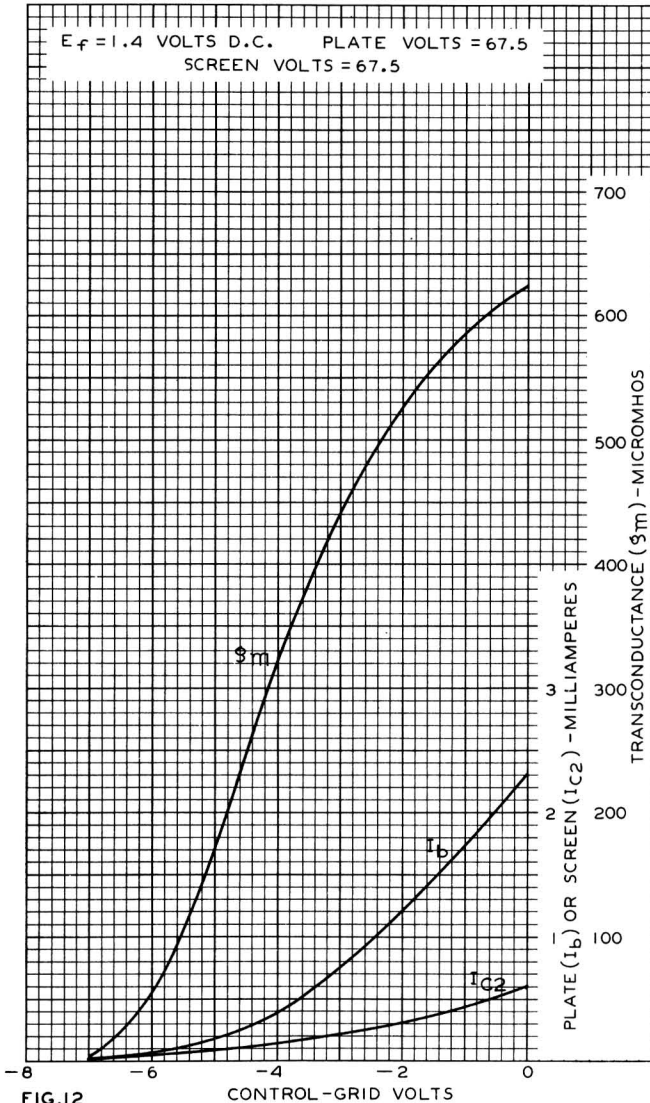


FIG.12

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92C-6172



1T4

AVERAGE CHARACTERISTICS

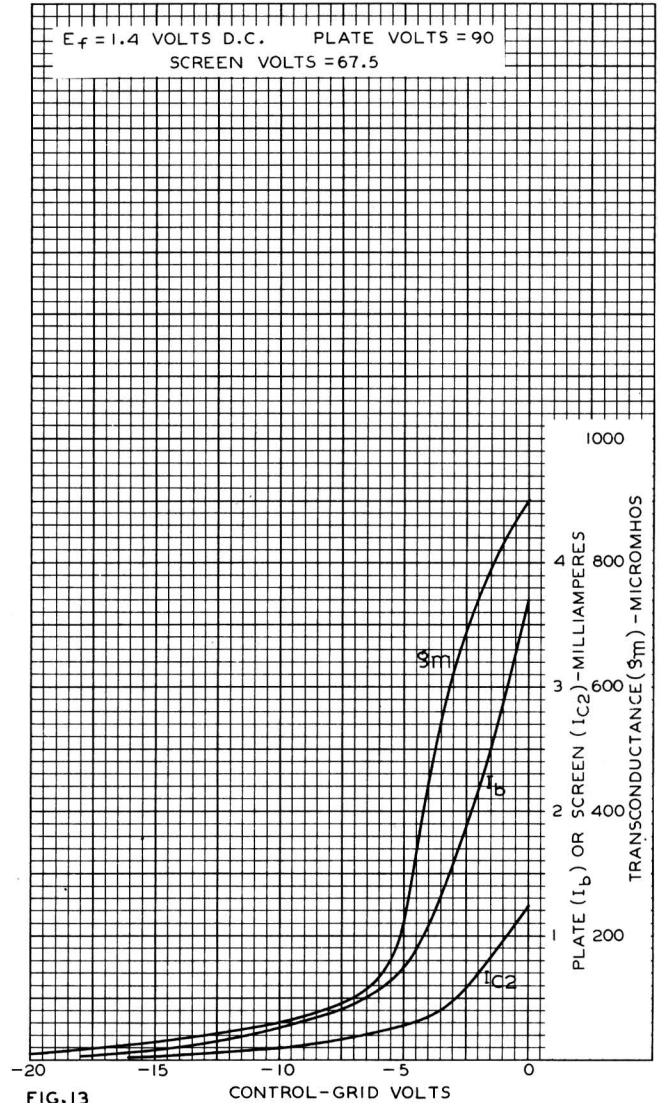


FIG.13

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1T4

AVERAGE PLATE CHARACTERISTICS

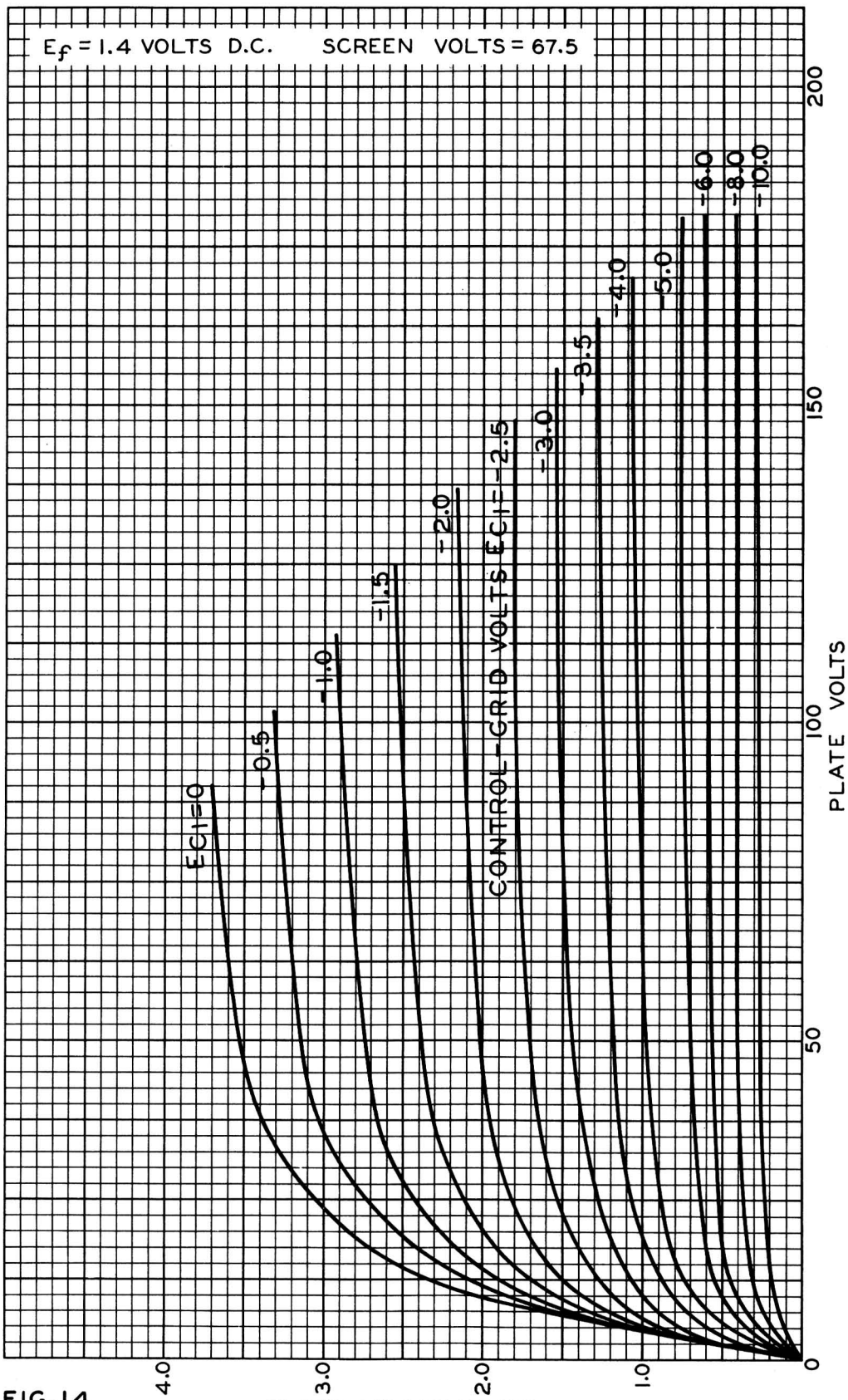


FIG. 14

MAY 27, 1940

PLATE MILLIAMPERES

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