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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Tests of Neon Lamps as Substitute for Vacuum Tubes in Radio Receiver Output Limiting Devices.

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AUTHORIZATION FOR TEST

1. The tests herein reported were authorized by Bureau of Engineering letter, reference (a). Other pertinent data are listed in reference (b).

Reference: (a) BuEng.ltr.S67/46(11-24-W8) of 1 Dec.1936.
(b) BuEng.ltr.S67/46(11-24-W8) of 19 Mar. 1937.

OBJECT OF TEST

2. The object of this test was to determine the feasibility of using neon lamps of standard manufacture as automatic volume control tubes in place of the 38027 type tubes now used in the Model RAA and RAB receivers, using the present level control to provide the necessary bias potential.

ABSTRACT OF TEST

3. The tests described in this report were made on a Model RAA-1 receiver. As this investigation concerned only the audio-frequency system, the test signal of 1000 cycles from the General Radio beat frequency oscillator was inserted into the primary of the first audio frequency transformer. Normal automatic volume control curves were made using the 38027 tubes furnished in the receiver for comparison purposes. These curves would be typical also of the early Model RAB receivers. Four types of neon lamps were tested in the 38027 sockets through the medium of adapters.

CONCLUSIONS

(a) That, as it is well known, the present output limiting characteristic of the Model RAA and RAB receivers, permits an undesirably large variation in the controlled level and operates very inefficiently at the lower levels useful to an operator wearing head phones.

(b) That neon lamps may be used with present circuits to produce flatter limiting characteristics than now prevail in the subject receivers. but with an unsatisfactory range of level control, and with objectionable breaks in the curve.

(c) That a change to neon lamps in place of the type 38027 tubes in the present limiter circuits is inadvisable.

(d) That the development of improved limiter circuits should be attempted.

(e) That the Western Electric type 313A tube stands out from most neon tubes in its ability through pre-ionization, to break down and sustain conductivity at a nearly constant voltage level, and offers promise for use in relay, rectification or voltage regulating circuits.

RECOMMENDATIONS

(a) That commercial neon lamps be not substituted for type 38027 tubes in Model RAA and RAB receiving equipments, as present circuits do not permit proper level control.

(b) That a broad study be made of output limiting devices for protection from interferences at higher level than the signals desired, to attain sharper cut-off and flatter limiting characteristics at lower output levels than are provided in present equipments.

DESCRIPTION OF MATERIAL UNDER TEST

4. The material under test consisted of four types of neon lamps in conjunction with the audio amplifier system (CRV-50024) of the Model RAA-1 receiver. The automatic volume control employed in the Model RAA-1 (and Model RAB) equipment may be readily understood by reference to the schematic diagram of Plate 8. Two type 38027 tubes are connected to operate as a full wave rectifier in connection with the high ratio step-up transformer #76 and the direct current bias, controlled by potentiometer #77. Whenever signal voltages in the audio-frequency output circuit, stepped up in transformer #76, are sufficient to overcome the positive cathode bias applied by #77, the diodes become conducting for a portion of the cycle, and their resistance is reflected back to lower the effective load impedance of the audio-frequency output tube, thereby preventing, to a considerable extent, excessive signal outputs. The output level may be controlled by the setting of the bias.

5. This device has the effect of cutting off the top of the wave form and produces harmonics. It is suited only to telegraph reception. It is obvious that for a given bias, a steadily increasing signal input will be cut to a decreasing percentage of its voltage by flattening the top of the wave, and that the effective voltage becomes an increasing proportion of the nearly constant peak voltage. This type of automatic volume control will therefore show a slowly increasing power output even though the control were effective in maintaining a constant voltage limit, and an absolutely flat limiting characteristic cannot be attained by this means alone.

6. The second or output audio frequency amplifying tube is a self-biased triode. Under operation conditions, when signals reach a predetermined level, the increase in plate current due to transrectification assists in the limiting action by steadily increasing the cathode bias.

7. The commercial neon lamps tested as substitutes for the Type 38027 tubes were of General Electric manufacture and of 3, 1, and 1/2 watt ratings, for 115 volt alternating current circuits.

8. The 3-watt lamp has the 1" Edison screw base and a bulb 1-3/4" maximum diameter, 3-1/8" in overall length. It includes within the base a series resistor rated at 3200 ohms. The electrodes resemble pie plates in shape with the concave sides toward each other, and are about 1" in diameter. The tube is rated to handle 20 milliamperes.

9. The 1-watt lamp has also the 1" screw base, a 1-1/4" spherical bulb, and is 2" in overall length. One electrode consists of a cylinder about 1/4" in diameter, 5/16" long, and is surrounded by a helically coiled wire electrode. This tube has an internal 3500 ohm series resistor and is rated at 20 milliamperes.

10. The 1/2-watt lamp is equipped with a candelabra screw base, a 9/16" bulb, with an overall length of 1-1/2". The electrodes form modified hemispheres with the concave sides together, the edges nearly meeting. This lamp has an internal resistor rated at 30,000 ohms and has a current capacity of 2 milliamperes.

11. The Western Electric Type 313-A neon tube suggested in reference (b) has been designed for use as a relay, voltage regulator, or rectifier. It differs from the commercial types described above in that an auxiliary low current ionizing circuit may be energized to reduce the breakdown voltage of the main gap to a value much closer than ordinary to the sustaining value, and permitting wide variations of current with but small variations of voltages. The tube employs a standard 4-pin base and a glass tube 1-1/8" in diameter, and has an overall length of 3-1/4". The glass is covered with black enamel. The glass used appears to be unusually brittle, and the tubes require more careful handling than ordinary types. The two control electrodes are similar to the diammetrically divided halves of a 3/4" metal disk, with the outer edge turned down. The anode consists of a waire, shielded by a glass tube through the center of the control electrode assembly, a short length of the wire projecting from the glass tube which extends about 1/2" above the control electrodes. When ionization exists between the latter electrodes, the positive anode has a breakdown and sustaining voltage to the negative control electrode of 75 to 80 volts. Without the above ionization, breakdown occurs at about 175 volts, after which the sustaining voltage is but 75 volts.

12. The costs to the Laboratory for the tubes reported on are listed here for comparative purposes:

Type 38027 tubes	$0.36
1/2-watt neon lamp	.30
1-watt neon lamp	.30
3-watt neon lamp	.30
W.E. Type 313-A tubes ...	2.00

All prices except for the 38027 tubes are for small lots.

METHOD OF TEST

13. The General Radio beat frequency oscillator type 513B, Serial No.44 set at 1000 cycles was used as a constant frequency source. The output of this oscillator was fed into the General Radio microvolter Type 546A, Ser/#119, reducing the voltage to milli- or microvolts as required. The output of the microvolter was fed into the primary of transformer #48, the first audio unit of CRV-50024 (see Plate 8). This method of obtaining and controlling the signal was used in all tests.

14. In testing the 115 volt Edison base lamps, the '27 type tubes were removed and adapters made which connected the two electrodes of each lamp to the plate and cathode socket connections in the receiver. The schematic diagram of the resultant circuit is shown on Plate 4. It will be noted that the only control is the AVC potentiometer, part #77. The polarity of the bias is relatively unimportant, the lamps being designed for alternating current.

15. The input signal was varied from 1 millivolt to one volt, one millivolt being required in practically all cases to give a readable meter indication on the output meter, while the frequency was held constant and output watts noted.

16. In the case of the Western Electric 313-A tubes, it was necessary to insert resistance R_1 as shown on Plate 6 in order to protect the potentiometer #77 and to insert resistance R_2 in series with the ionizing or control electrodes "CE" to insure positive ionization without excessive current. The bias potential was reversed for these tubes to assist breakdown and permit AVC at low signal levels, as the tube design is distinctly polarized. The method of test of these tubes was the same as for the 115 volt lamps. In both instances, data were taken at zero bias and at several other levels as the test required. For purposes of comparison, data for a set of normal AVC curves were also taken.

17. A General Radio vacuum tube voltmeter, Type 726A, Serial No. 107, and an improvised multiplier having a range up to 825 volts, R.M.S., was used to measure the alternating voltage across the Neon lamps under operating conditions as well as the open circuit voltage of one side of #76 transformer, i.e., one side to ground or that potential which would normally be applied to one AVC tube. Both alternating and direct current measurements were made by inserting the meter to be used in series with one of the Neon lamp electrodes under test.

18. In order to check the characteristics of the audio system under AVC conditions with a linear load, various values of non-inductive resistance were placed directly across transformer #48 secondary with the AVC tubes removed.

19. A 600 ohm rectifier meter, NRL type, calibrated for both voltage and power from a sine wave source, was used to measure outputs above 5 microwatts.

DATA RECORDED DURING TEST

20. Practically all data recorded have neen incorporated in the plotted curves, Plates 1 to 7 inclusive.

PROBABLE ERROR IN RESULTS

21. The Model RAA-1 receiver, Ser.#8, with which these tests were conducted was itself undergoing an endurance test at 125 volt line input as requested by the Bureau of Engineering. In analyzing the report this fact should be kept in mind.

22. The absolute accuracy of such relative tests as these is not particularly important, since no reasonable degree of inaccuracy could alter the conclusions reached. Curve shape is much more important than absolute values.

23. The rectifier type of output meter shows material errors on abnormal wave forms such as are produced in this circuit. However, this will have but little effect on the comparative shapes of the curves presented.

RESULTS OF TEST

24. Plate 1 shows the normal AVC curves for five bias levels, also a curve showing the output obtainable with no AVC. For all levels or all values of bias the output increases almost linearly with inputs up to 10 millivolts. Between 10 m.v. and 100 m.v. the increase is more gradual, the leveling taking place above 100. millivolts input.

25. Plate 2 shows the results obtained when 1/2 watt Neon lamps were substituted for the 38027 tubes normally used. All Neon lamps of the 115 volt type were tested in the circuit shown on plate 4. The "NO AVC" curve is again included for comparative purposes. The vertical breaks in the curves show where the Neon lamps break down and become conductive. As two lamps were used in each circuit, two separate breakdown points were observed. In the case of the 54 volt bias, the two breaks occur at widely different input voltages. It appears that although the lamps are reasonably well matched to each other, the loading of one half of the transformer secondary, when the first tube breaks down, materially delays the breakdown of the second tube.

26. The zero bias curve shows a series loss of signal at low levels, i.e., it does not come up on the entering slope of the other curves. This is presumed to be due to the start of the diode current at about one volt negative bias, so that the zero bias setting finds the high impedance transformer already loaded. The secondary will have a small continuous current and, the diodes being already conducting, the smallest trace of noise or signal starts the limiting action by decreasing the effective plate load impedance of the audio frequency output tube.

27. This standard limiter circuit provides a reasonable range of adjustment of output, but the range is considered high. It does not limit well to the range of signal comfortable to the operator, when the phones are properly adjusted on the ears.

28. The maximum output signal for a given bias is at about ten times the power level at which limiting control becomes noticeable. It is, of course, desirable that a sharp bend in the output characteristic take place at once when limiting starts. Where these breakdown points occur, the signal in the telephones changes accordingly. Consequently, if there are two breakdown points the operator will hear two sharp changes of output signal. It will be noted that the change in output level is not great over the range of zero to +54 volts bias. It is possible that a limiting resistor in series with the bias tap would have reduced the dip in the 54 volt bias curves.

29. Plate 3 consists of a group of curves for the 1/2 watt, 1 watt, and 3 watt Neon lamps. These curves show the alternating potential across one of the two Neon lamps used in its respective tests; also the output of the audio system for each of the three types of lamps tested.

30. The last group of curves on this plate gives the current through each of the three types of lamps under test. With respect to alternating potential across the lamps, it will be noted that there is so little difference between the 1/2 watt and the 3 watt size that it

caused the curves to fall very close together. Therefore, the 1 watt lamp curve was omitted as it would fall between the other two. The second group of curves on this plate gives the power output of the audio system for the three sizes of lamps. It will be noted that the output levels for the 3-watt and the 1-watt lamps is the same after the tubes have become ionized. The last group of curves show the alternating current through the Neon lamps under normal operation conditions. All of these curves were taken under zero bias conditions.

31. Plate 4 contains two curves showing the characteristics of the 3-watt lamps used as AVC tubes. It is interesting to note, on the zero bias curve especially, that the breakdown potential for the two lamps is decidedly different under the conditions in which the tubes were tested, the one tube breaking down at approximately 5 millivolts input and the other two not breaking down until over 100 millivolts input. When the 25-volt bias was applied, however, the addition of the d.c. bias seemed to assist in stabilizing this breakdown potential and brought the points much more closely together. It will be noted that the maximum output obtainable in all cases, of course, is under zero bias conditions and that the addition of the bias only drops the level a little compared to the normal AVC operating conditions with the '27 tubes in place. The curves shown on plate 4 are flatter than curves for standard AVC (Plate 1) at similar levels. At zero bias, both lamps presumably work both halves of the cycle. Higher levels would not be attainable readily, although this is considered no disadvantage. Since the average direct voltage for breakdown is about 75 volts, biases nearly this great could be used. As the bias increases, the breakdown voltages for the two directions through the tube separate in like amount. This affects the flatness of the curve.

32. Because of the small range of level between the 1/2 watt and the 3 watt lamps, curves for the 1 watt lamp were omitted.

33. Plate 5 shows three curves on the Western Electric 313-A tubes substituted for the 38027 tubes for three different bias potentials. The conditions under which these curves were made and the circuit which was used is shown on the same plate below the curve. With this type of circuit the only limit on the main anode current of the tubes was the impedance of the transformer secondary and the biasing potentiometer. During the tests, a potentiometer was burned out by excessive current drawn by the tubes. The zero and sine volt bias curves were taken without pre-ionization of the tube. The 82 volt bias provided pre-ionization. There was no bias added to the alternating voltage in this test. The rest of the data on these lamps were taken in the circuit shown on Plate 6. It will be noted in this diagram that two additional resistors are used for the purpose of limiting the current which can flow in their respective circuits. R_2 limits the ionizing current applied to the control electrodes, "CE", and R_1 limits the amount of current through the main gap to protect the biasing potentiometer #77. The main gap of these Western Electric tubes is from the anode "A" to the negative control electrode. With these control resistors in the circuit it will be noted that the output levels of the curves are separated a little more than those shown on Plate 5, although the range is still very limited.

34. The lower biases produced curves of reasonable form, a 54 volt bias showing a material decrease in level. The 82 and 250 volt biases, however, keep the tube continuously broken down, causing a material loading of the transformer, with attendant losses.

35. With this type of tube, reverse bias may be used to obtain higher levels than zero bias prevides. However, this is not convenient without material modification, and it also might introduce complications by virtue of the reaching of the high reverse breakdown voltage of the main gap. (It is evident that the high voltage of the AVC transformer will, at suitable signal levels, suffice to overcome the opposing bias and breakdown the main gap in the reverse direction, providing full wave but badly unbalanced operation.)

36. The output of the AVC transformer #76 with no tubes in the circuit and no load of any kind is shown by the curve at the top of Plate 6.

37. In order to obtain an idea of the characteristic of the audio system as a whole, '27 type tubes were removed and non-inductive resistors of various values were connected across the secondary of transformer #76. The results obtained are shown on Plate 7. The resistances used covered a range of from 50,000 ohms to 5 megohms. It is interesting to note that the bend of the curve comes at approximately 100 millivolts input under the conditions just stated, under normal AVC conditions using 38027 tubes, and also without any AVC. The '27 tubes furnish only a part of the existing control.

CONCLUSIONS

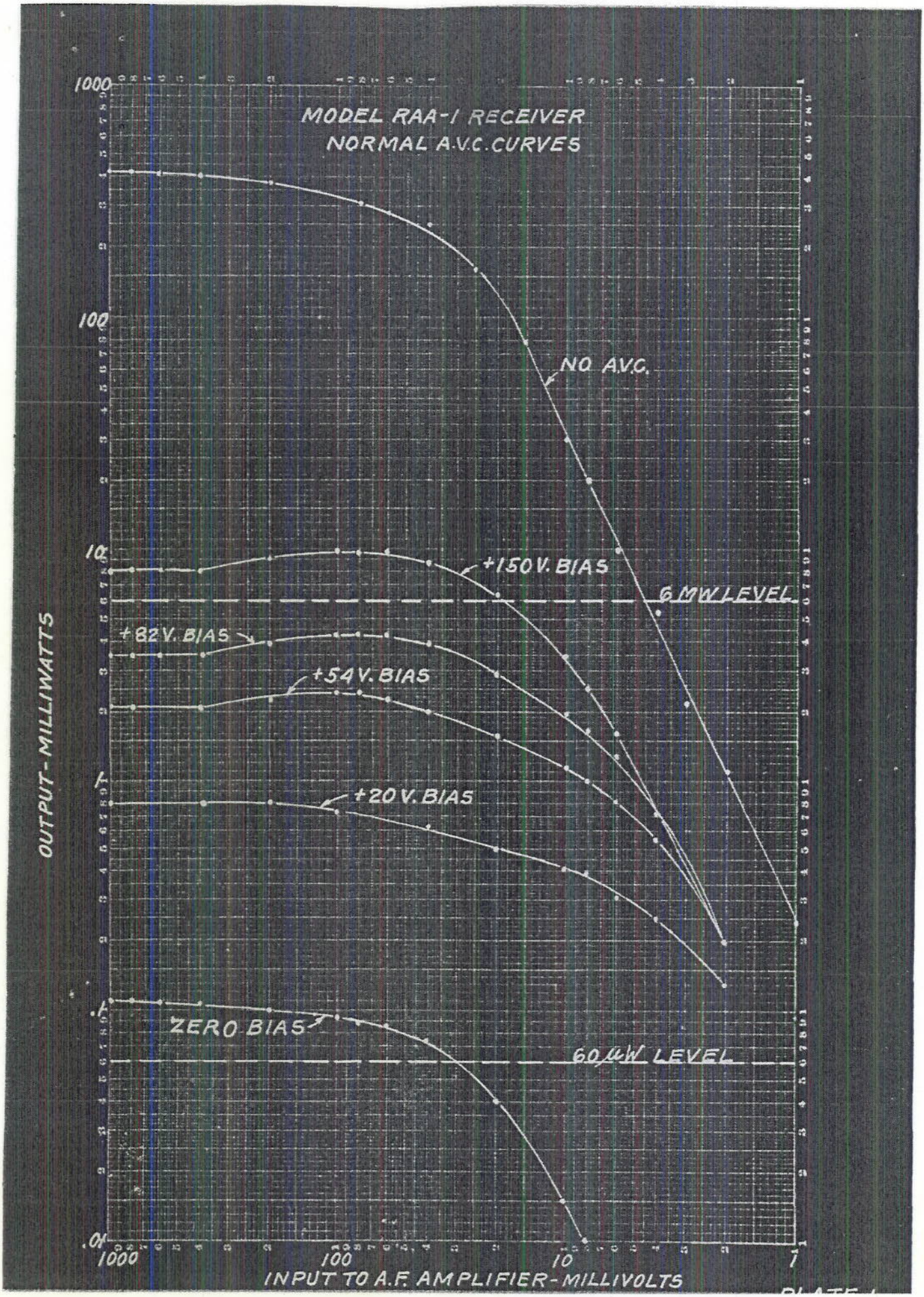
38. That, as is well known, the present output limiting characteristic of the Model RAA and RAB receivers, permits an undesirably large variation in the controlled level and operates very inefficiently at the lower levels useful to an operator wearing head phones.

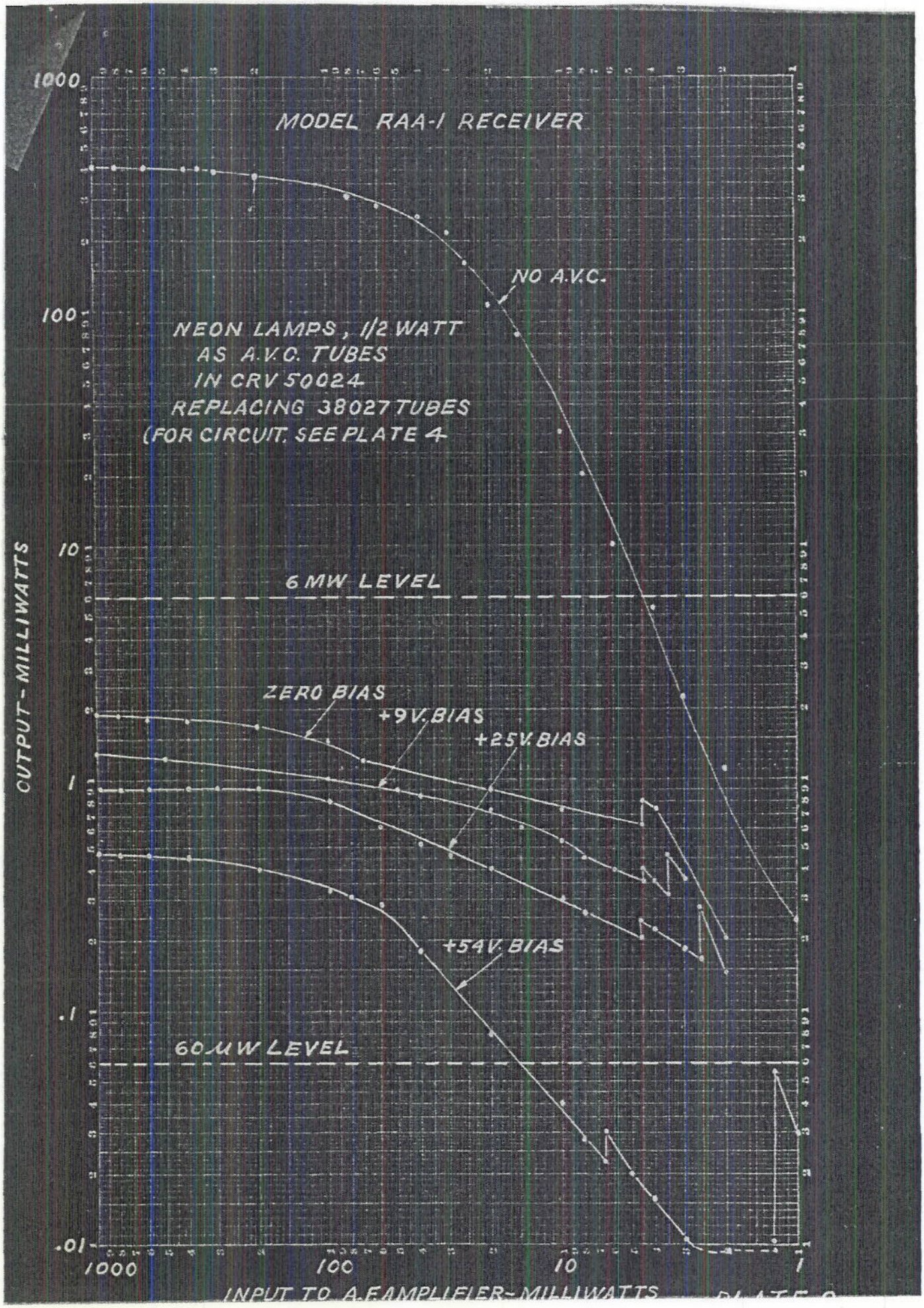
39. That neon lamps may be used with present circuits to produce flatter limiting characteristics than now prevail in the subject receivers, but with an unsatisfactory range of level control, and with objectionable breaks in the curve.

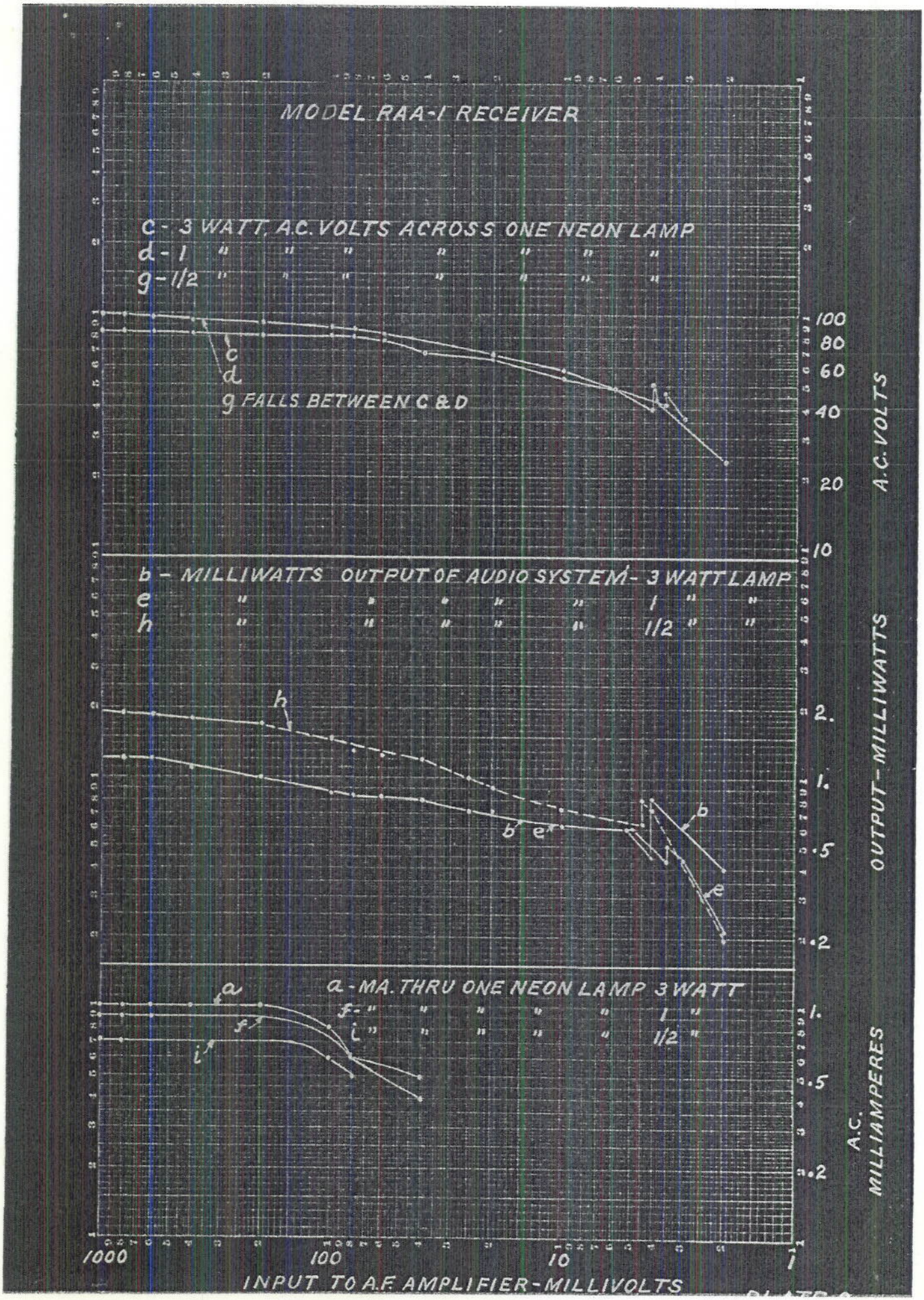
40. That a change to neon lamps in place of type 38027 tubes in the present limiter circuits is inadvisable.

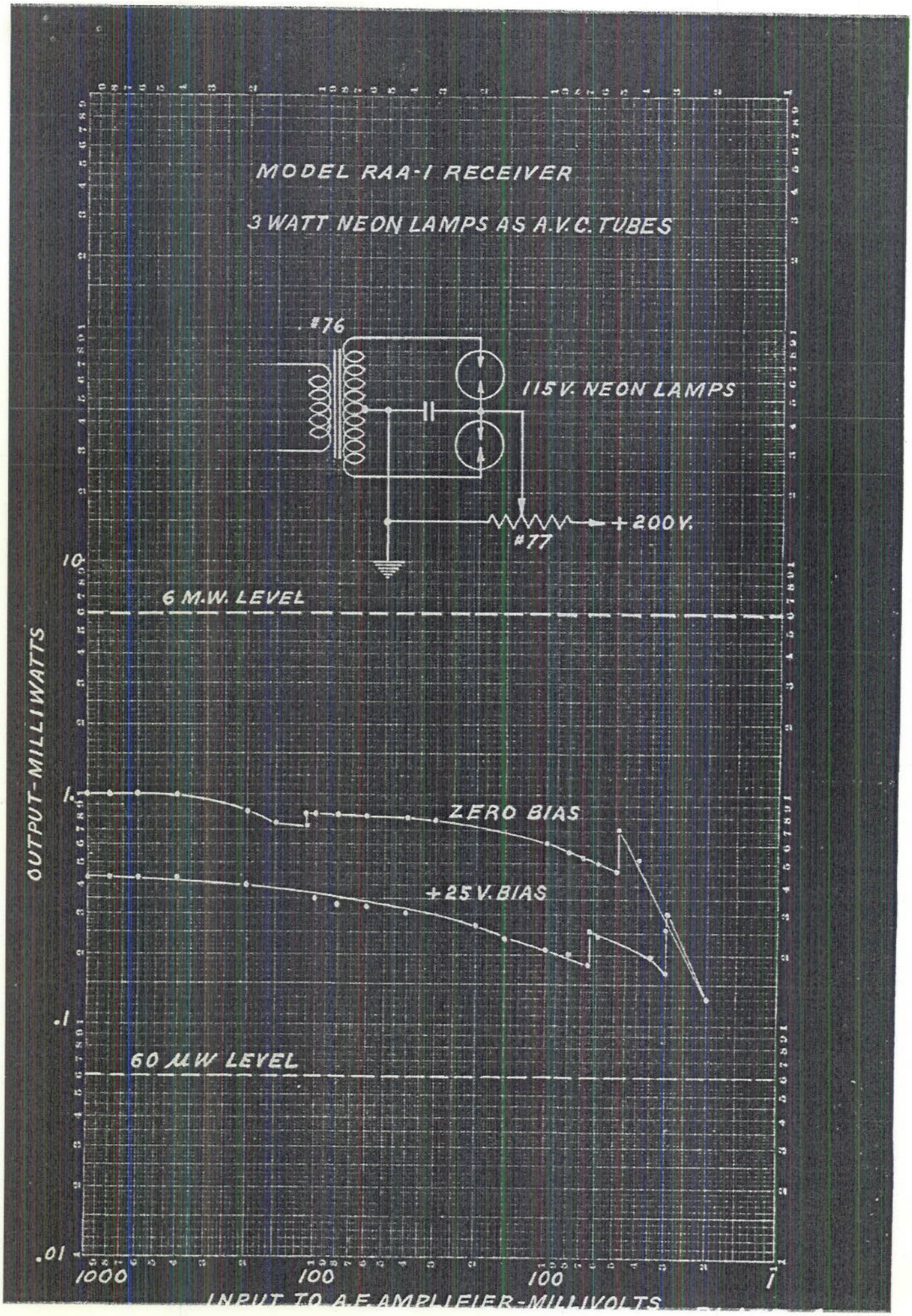
41. That the development of improved limiter circuits should be attempted.

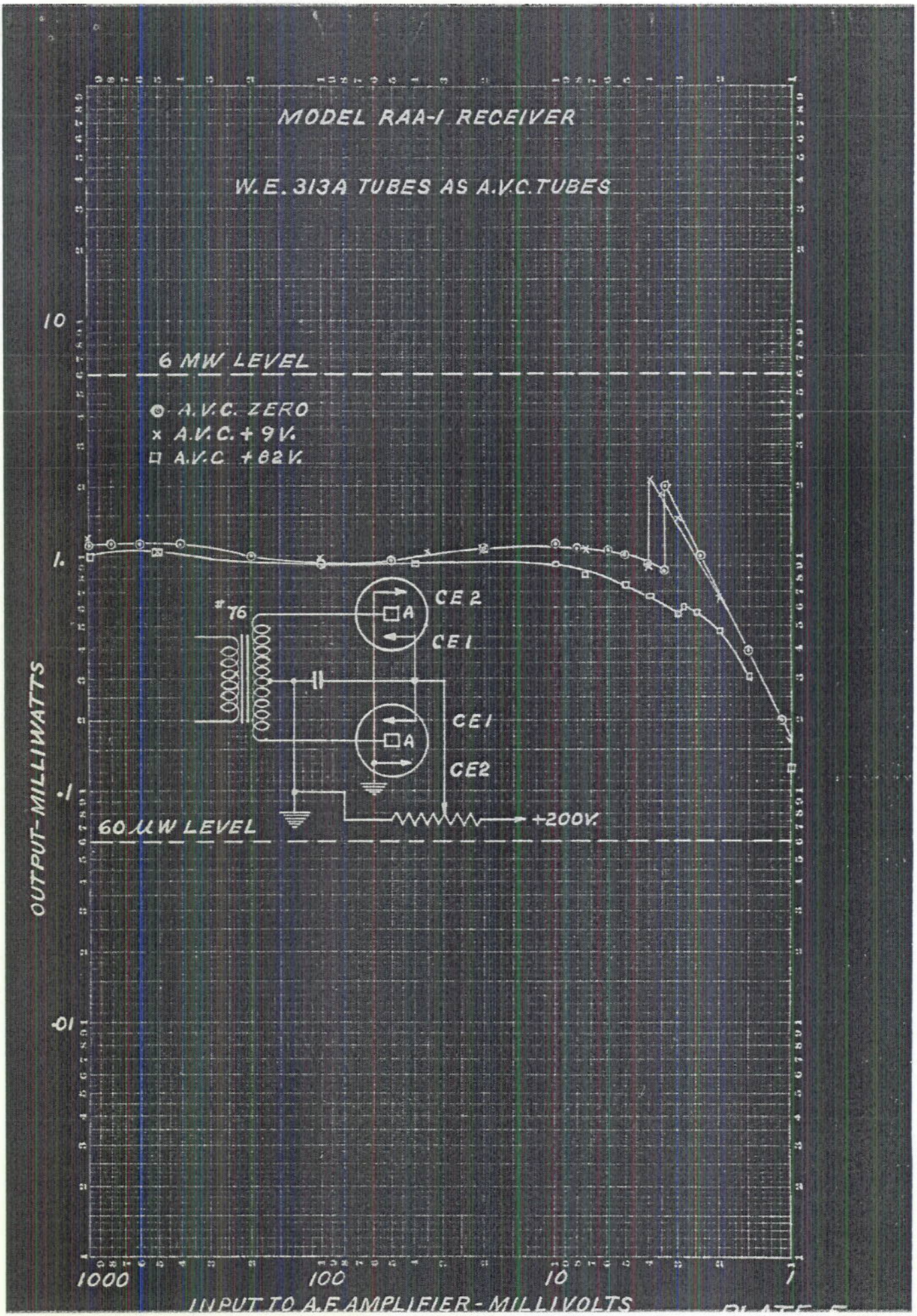
42. That the Western Electric type 313A tube stands out from most neon tubes in its ability through pre-ionization to break down and sustain conductivity at a nearly constant voltage level, and offers promise for use in relay, rectification or voltage regulating circuits.

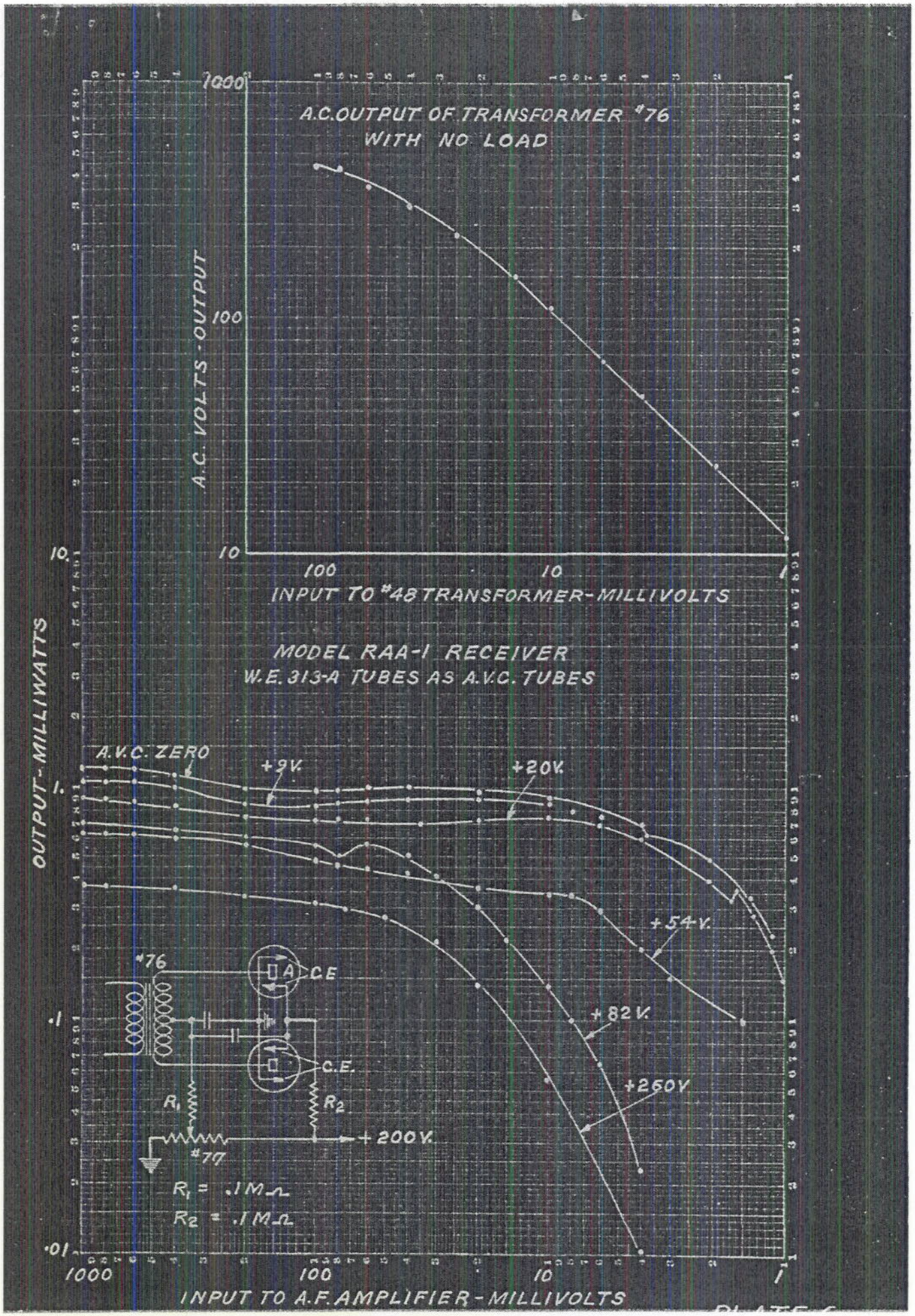

MODEL RAA-1 RECEIVER
NORMAL A.V.C. CURVES
NO A.V.C.
+150 V. BIAS
6 MW LEVEL
+82 V. BIAS
+54 V. BIAS
+20 V. BIAS
ZERO BIAS
60 μW LEVEL
OUTPUT - MILLIWATTS
1000
100
10
1
.1
.01
1000
100
10
1
INPUT TO A.F. AMPLIFIER - MILLIVOLTS

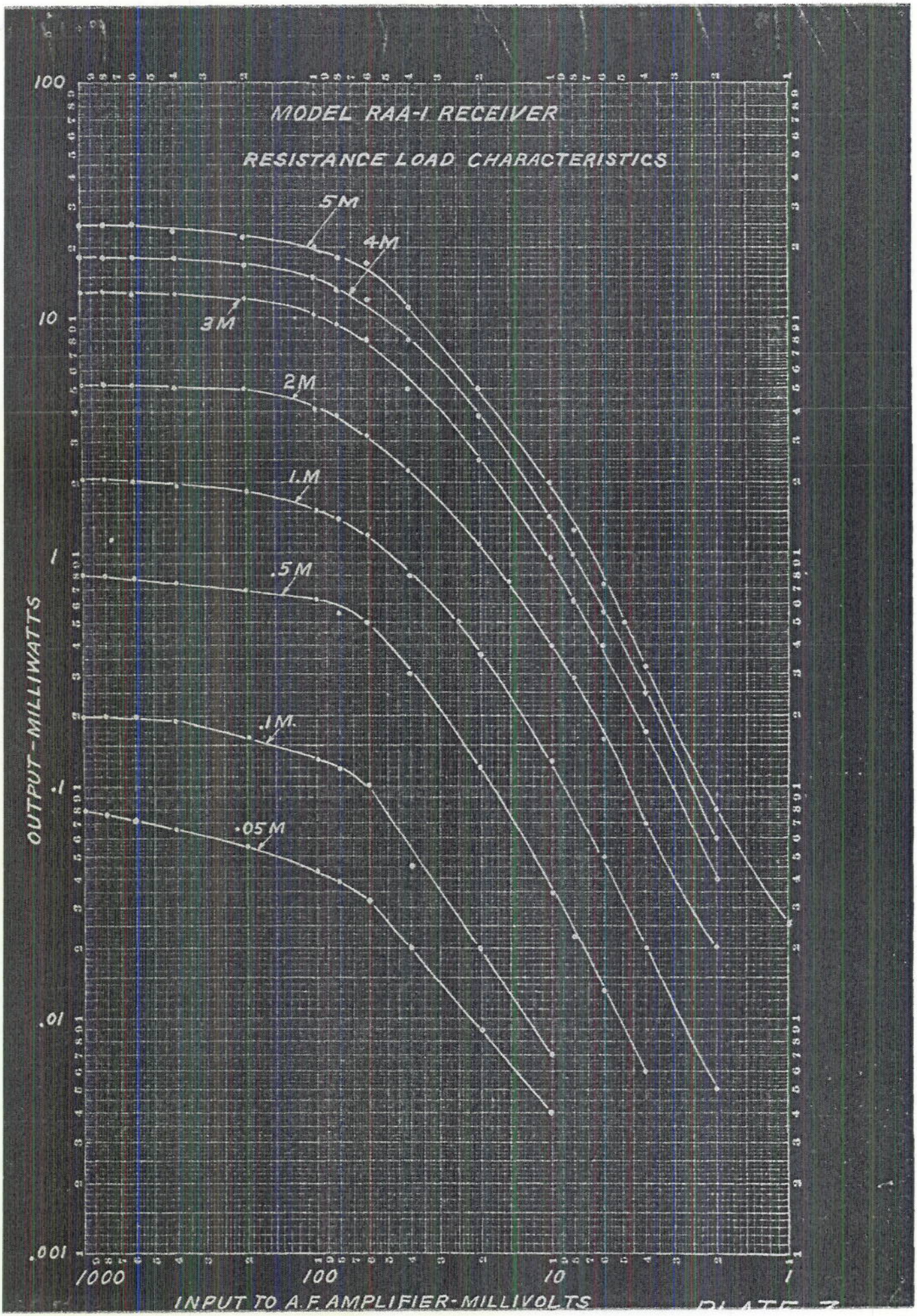

MODEL RAA-1 RECEIVER
NO A.V.C.
NEON LAMPS, 1/2 WATT
AS A.V.C. TUBES
IN CRV 50024
REPLACING 38027 TUBES
(FOR CIRCUIT, SEE PLATE 4
6 MW LEVEL
ZERO BIAS
+9V. BIAS
+25V. BIAS
+54V. BIAS
60 μW LEVEL
OUTPUT - MILLIWATTS
1000
100
10
1
.1
.01
1000
100
10
1
INPUT TO A.F. AMPLIFIER - MILLIWATTS


MODEL RAA-1 RECEIVER
c - 3 WATT, A.C. VOLTS ACROSS ONE NEON LAMP
d - 1 " " " " " " " "
g - 1/2 " " " " " " " "
c
d
g FALLS BETWEEN C & D
100
80
60
40
20
10
A.C. VOLTS
b - MILLIWATTS OUTPUT OF AUDIO SYSTEM - 3 WATT LAMP
e " " " " " " 1 " "
h " " " " " " 1/2 " "
h
b
e
2.
1.
.5
.2
OUTPUT - MILLIWATTS
a - MA. THRU ONE NEON LAMP 3 WATT
f - " " " " " " 1 "
i " " " " " " 1/2 "
a
f
i
1.
.5
.2
A.C. MILLIAMPERES
1000
100
10
1
INPUT TO A.F. AMPLIFIER - MILLIVOLTS


MODEL RAA-1 RECEIVER
3 WATT NEON LAMPS AS A.V.C. TUBES
#76
115 V. NEON LAMPS
+200 V.
#77
10
6 M.W. LEVEL
OUTPUT-MILLIWATTS
1.
ZERO BIAS
+25 V. BIAS
.1
60 μW LEVEL
.01
1000
100
100
1
INPUT TO A.F. AMPLIFIER-MILLIVOLTS


MODEL RAA-1 RECEIVER
W.E. 313A TUBES AS A.V.C. TUBES
10
6 MW LEVEL
A.V.C. ZERO
A.V.C. + 9V.
A.V.C. + 82V.
1.
#76
CE 2
A
CE 1
CE 1
A
CE2
+200V.
.1
60 μW LEVEL
OUTPUT - MILLIWATTS
.01
1000
100
10
1
INPUT TO A.F. AMPLIFIER - MILLIVOLTS


A.C. OUTPUT OF TRANSFORMER #76
WITH NO LOAD
A.C. VOLTS - OUTPUT
1000
100
10
100
10
INPUT TO #48 TRANSFORMER - MILLIVOLTS
MODEL RAA-1 RECEIVER
W.E. 313-A TUBES AS A.V.C. TUBES
OUTPUT - MILLIWATTS
10.
1.
.1
.01
A.V.C. ZERO
+9V.
+20V.
+54V.
+82V.
+260V
#76
A
C.E.
C.E.
R1
R2
+200V.
#77
R1 = .1 MΩ
R2 = .1 MΩ
1000
100
10
1
INPUT TO A.F. AMPLIFIER - MILLIVOLTS


MODEL RAA-1 RECEIVER
RESISTANCE LOAD CHARACTERISTICS
5M
4M
3M
2M
1.M
.5M
.1M.
.05M
OUTPUT-MILLIWATTS
100
10
1
.1
.01
.001
1000
100
10
1
INPUT TO A.F. AMPLIFIER-MILLIVOLTS

MODEL RAA-1 RECEIVER
A. F. UNIT CRV-50024

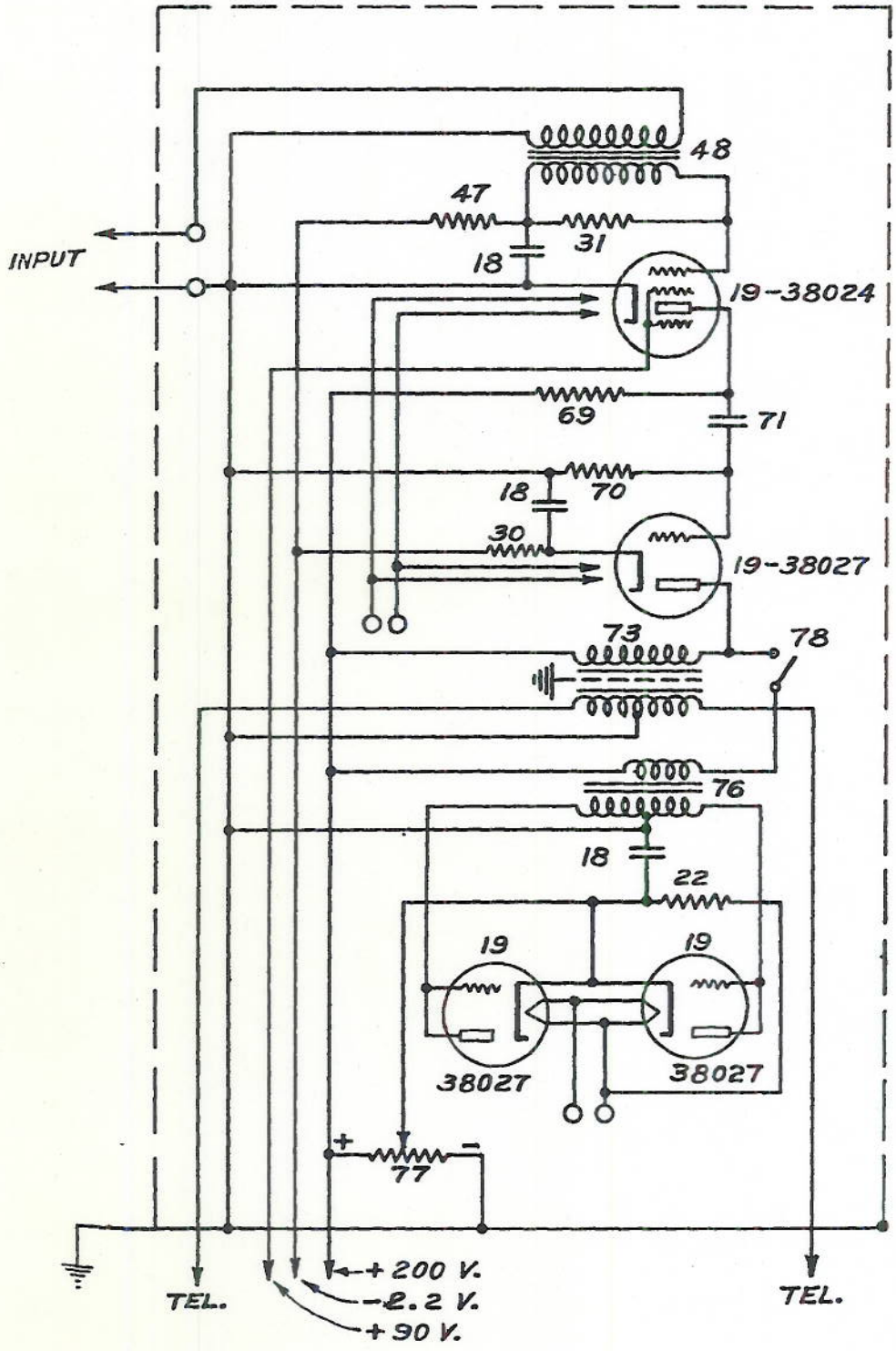


PLATE 8