FR-1001

NAVAL RESEARCH LABORATORY REPORT

October 19, 1933

REPORT ON EXAMINATION AND TEST OF RCA VICTOR COMPANY MODEL CXC HIGH FREQUENCY DIRECTION FINDER (Serial No. 2)

By
S. A. Greenleaf

Report No. 1001

NAVY DEPARTMENT
OFFICE OF NAVAL RESEARCH
NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

19 October 1933

BuEng.Prob. D2-3
N.R.L.Prob. RE270

#1001

REPORT ON EXAMINATION AND TEST OF RCA VICTOR COMPANY MODEL CXC HIGH FREQUENCY DIRECTION FINDER.
(Serial No.2)

Tests conducted 27 July to 18 August, 1933, and 11 September to 6 October 1933.

Submitted by:

S. A. Greenleaf.

Approved by:

H. R. Greenlee.

Copy to:
Bu.Eng.(4)

TABLE OF CONTENTS

Appendices

1. AUTHORIZATION

Problem D2-3 was authorized in Bureau of Engineering letter S67/69 (3-3-W8) of 3 April 1933.

2. PURPOSE OF TESTS

Examination and Test of RCA Victor Company Model CXC High Frequency Direction Finder, Serial No. 2, (Receiver Type CRV-46-AAB) to determine the general suitability and limitations of this model direction finder for Naval use.

3. DESCRIPTION OF APPARATUS

This equipment consists of a receiver, 14-1/2" wide, 12-11/16" high and 3-1/2" deep, with a loop collector, hand wheel, and indicator mounted directly on top of the receiver, the loop being enclosed in a circular aluminum casting 16" in diameter, the entire receiver-loop assembly standing 39-1/4" high. A separate metal box, 10" x 12" x 18-3/4", contains a six volt lead cell A battery and 135 volts of dry cell B batteries, with a 36" cable and multiple plug for connection to the receiver.

The weight of the loop, drive and receiver assembly is 53 pounds, and the battery box 89 pounds.

An extension is provided for the loop drive shaft, together with a deck mounting flange and bearing unit. There is a plug on the front panel for the single wire balancing antenna, but separate support for the antenna must be provided for the antenna when installed.

The receiver is a six tube unit employing an autodyne circuit with an oscillating first detector, two stages of 23 Kc i-f amplification, i-f oscillator, second detector, and a single audio stage, with an electrostatically shielded output transformer, designed for use with head phones having an impedance of 22000 ohms at 1000 cycles.

The frequency range is 2000 to 15,000 Kcs, covered in five bands by means of a tap switch, the bands being as follows, with ample overlap:

Band 1	1900-2875 Kcs
" 2	2875-4350 "
" 3	4350-6490 "
" 4	6490-9680 "
" 5	9680-15650 "

Tuning is accomplished with a single dial, with a vernier adjustment. Other controls on the panel consist of the frequency range tap switch for positions 1 to 5, volume control, regeneration control, balancing condenser, filament switch and switch for the CW oscillator. There is also a meter for indicating filament and plate voltages, jack for the antenna plug, two phone jacks, and socket for the battery plug.

The input circuit consists of a two turn untuned loop, in series with the primary of a coupling unit, the center of this inductance being grounded. The balancing condenser has two sets of stationary plates connected to either side of the loop terminals, with the antenna on the single set of rotary plates, by means of which quadrature currents are introduced to balance the residuals in the loop. The secondary of the coupling unit is tapped into five sections, permitting the sections to be shorted out by the frequency band switch. This circuit is tuned and coupled directly to the grid of the combination detector-oscillator, this being the only circuit with variable tuning controlled from the panel. The screen grid circuit of this tube has a feed-back coil coupled to the grid coil to cause the tube to oscillate, oscillations being controlled by a variable resistor to regulate the screen grid voltage.

The inner anode, or screen grid circuit is electron coupled to the plate or output circuit. By the combination of the incoming signal with the oscillation frequency, a heterodyne beat note of 23 Kcs is produced, which is fed to the i-f coupler, consisting of a single coil shunted by a trimmer condenser, which in turn is coupled to the grid of the first i-f tube through another trimmer condenser.

Volume is controlled by regulation of the voltage on the screen grids of the two i-f tubes with a variable resistor.

Two stages of i-f amplification are followed by the i-f detector, to which is coupled a separate i-f oscillator for use in CW reception. This tube is controlled by a toggle switch, mounted on the panel, which opens and closes the plate circuit. The i-f detector is followed by one stage of audio frequency amplification, a double section filter being contained in the plate circuit of the detector tube ahead of the interstage transformer. The output of the audio amplifier is fed into the output transformer which is provided with an electrostatic shield between primary and secondary, the secondary being also electrostatically balanced with respect to ground.

Tetrode tubes, commercial type '36, are used for the combination detector-oscillator, the two stages of i-f amplification and the i-f detector; a triode commercial type '37 for the CW oscillator, and a pentode, commercial type '38 for the audio amplifier.

In the first detector condenser and grid leak are used for detection, while in the second detector biased grid detection is used. Grid bias voltages are obtained by the use of resistors in the cathode legs of the i-f, second detector and audio stages. Plate voltages are supplied as required, by taps on the bank of B batteries.

This equipment has two pilot lights controlled by the filament switch, one each to illuminate the receiver tuning dial, and the loop indicator dial.

4. METHOD OF CONDUCTING TESTS

A model LC standard signal generator was used to supply test voltages for sensitivity and selectivity measurements, and a General Radio output meter type 483C, resistance 20,000 ohms to measure outputs. A General Radio signal generator type 604B was used to furnish signals for calibration and test of directional characteristics at close range. Signals from fixed land stations were used for taking bearings, principally NAA and WAR.

Signals from an airplane type XRE1 were used also for taking bearings. This ship was equipped with a transmitter Model GHX.

For the purpose of this test, the following definitions are applicable, and methods of procedure are shown:

Standard output is 5 milliwatts, or 10 volts across 20000 ohms.

Sensitivity is shown as the voltage induced in the loop antenna in microvolts to produce standard output, with a gain adjustment for .5 volts noise. For this measurement voltage from a standard signal generator was applied to the terminals of a coupling coil, placed at a suitable distance from the loop antenna, and the field intensity in microvolts per meter at the loop antena was calculated. The effective height of the loop antenna was also calculated, and from these two factors the induced voltage was determined.

Selectivity is shown as the ratio of input for standard output, at percentages of frequency above or below resonant frequency to the input for standard output at resonant frequency. This measurement was also obtained by inducing voltages in the loop antenna by means of a coupling coil to which the signal generator voltage was applied.

The following tests were made:

(a) Sensitivity, CW input.

(b) Selectivity, MCW input.
(c) Maximum noise level, CW oscillator on and off.
(d) Bearings taken at eight points through 360 degrees using signals from signal generator at a distance of 100 feet from direction finder.
(e) Test for minimum shift due to detuning and balancer, and change of position of balancing antenna with respect to receiver-loop assembly.
(f) Bearings taken on fixed land stations at various distances.
(g) Bearings taken on plane transmission.
(h) Test of detuning due to balancer.
(i) Test for minimum displacement from 180°.
(j) Test for body effects.

5. RESULT OF TESTS

(a) Sensitivity with CW input, and gain adjustment for 0.5 volts noise level, is shown on plates 1 to 3 inclusive. In order to obtain the required noise level, it was necessary to greatly reduce the gain, thus decreasing the sensitivity.

(b) Selectivity with CW input modulated 30% at 1000 cycles, taken with the second oscillator off, and full gain adjustment, is shown on plates 4 to 9 inclusive. Due to the combination detector-oscillator which heterodynes the incoming signal to produce a 23KC beat note, this may be accomplished by tuning either 23 Kcs above or below the signal frequency and there are therefore two resonance peaks in the selectivity curve 46 Kcs apart, the image response being about equal to the signal response. On plate 6, which is the curve taken at 3650 Kcs, both peaks are shown, this being typical with respect to the double peak feature, for all sensitivity curves.

(c) Maximum noise level both with CW oscillator on and off, is shown on plates 10 to 12 inclusive.

(d) With the signal generator placed at a distance of 100 feet from the loop, bearings were taken at eight points with the following results:

Freq. Kc.	True Bearing sighted	DF Bearing	DF Reciprocal bearing	Deviation
6150	21.5	26	206	-4.5
10800	21.5	26	206	-4.5
6150	61.5	63	243	-1.5
10800	61.5	64	243	-2.5
6150	100	95	275	+5
10800	100	95	275	+5
6150	135	132	310.5	+3
10800	135	132	310.5	+3
6150	175.5	177	357	-1.5
10800	175.5	177	357	-1.5
6150	223	224.5	44.5	-1.5
10800	223	224.5	44.5	-1.5
6150	285	285	105	0
10800	285	285	105	0
6150	339.5	343	162	-3.5
10800	339.5	343	163	-3.5

During this test the bearing of the balancing antenna was placed on an approximate bearing of 260° from the receiver-loop assembly, suspended at a vertical angle of 30° from horizontal, length of antenna 19.5 feet. The deviation shown is believed to be caused primarily by induction fields present to which any loop collector is subject, due to arrangement of the equipment, and other conditions existing at the particular location used. On distant signals further deviation may be introduced by the balancer due to the horizontal polarization of waves.

(e) With the signal generator placed at a distance of 200 feet from the loop, the position of the balancing antenna was changed with respect to the receiver-loop assembly, to note any shift in bearing due to such change, with the following tabulated results:

Frequency	DF	Balance dial	DF Reciprocal	Balance dial	Bearing of Ant. from Receiver loop
9800 Kc	95	-15	275	0	45°
	95	-10	275	-5	90°
	95	-5	275	-10	135°
	94	-5	274	-10	180°
	95	-5	275	-10	225°
	95	-5	275	-12.5	270°
	95	-7.5	276	-5	305°
	95	-15	276	0	360°

The same antenna was used as in (d), placed at the same angle throughout test. This shows a maximum shift of one degree in bearing due to change in position of antenna.

Test for shift in bearing due to change in balancer shows the following tabulated results:

Frequency	Balancer	Approx. Minimum	Minimum
8040 WAR	-25	328°	
	-30		328°
	-35	328°	
9050 NAA	-20	310°	
	-25		310°
	-30	310°	
9800 Sig.gen.	-5	94°	
	-10		94°
	-15	94°	

Bearings cannot be taken when signal is detuned, due to sharp tuning necessary to produce the heterodyne beat note frequency of 23 Kc.

(f) Using the same balancing antenna as in (d) and in all cases at an approximate bearing of 260°, the following results were obtained in taking bearings on fixed land stations.

Frequency	Total Bearings	Average Error	Maximum Error	Minimum Error	Distance
4015	1	1.5	-1.5	-1.5	5 miles
8040	12	14.9	+28.5	+2.5	5 "
8040	2	18.5	+18.5	+18.5	8 "
8040	4	11.4	+11.5	+11	14 "
8410	4	10	+10	+10	5 "
8410	1	8	+8	+8	8 "
8670	2	19.5	+23.5	-15.5	5 "
12060	26	17.3	-40	-3	5 "
12060	4	6.2	-14	0	8 "
12060	7	20.5	-25	-11.5	14 "
12060	2	5.2	+6.5	-4	21 "
12615	16	9.1	-19.5	+1	5 "
12615	3	21.6	+22	+21	8 "
13305	1	20.5	-20.5	+20.5	21 "

Poor minima resulted in taking bearings at a distance of 21 miles and at greater distances satisfactory minima could not be obtained due to attenuation of the ground wave. Most of the bearings were taken on transmitters at the Naval Radio Station, Arlington (NAA) and the Army Station (WAR) located a short distance from the Naval Station.

There is a complicated array of antenna at both of these stations used with numerous transmitters on low, intermediate and high frequencies, and discrepancies were noted between the bearings taken on a given station on closely related frequencies. A shift in the center of radiation is believed to be caused by this arrangement and must be taken into account in considering the accuracy of the observed bearings. The same deviation table was also used at locations 8, 14 and 21 miles distant as at Bellevue, 5 miles distant.

(g) Bearings taken on signals from a Naval plane type XRE1, equipped with a model GHX transmitter show the following results.

On a straightway course from location of direction finder, 164° true, the following bearings were noted, Frequency 8270 Kcs. Altitude 1500 feet.

Time	Bearing	Reciprocal	Error	Distance	Remarks
1048.5	172		-7	4.3	
1049	170	350	-7	5.8	
1054	170		-7	20.3	
1056	170	350	-7	26.1	
1058				32	Left turn 180°
1100	150		-4	31.8	
1102	150	330	-4	29.4	
1103.5	154		-3	25.8	
1104.5	165		-5	23.4	
1106.	170		-7	20.6	
1108	170		-7	14.7	
1109.5	173		-5	11	
1110.5	172		-8	8.7	
1112	172	352	-8	4.8	
1113	173		-9	2.4	
1113.5	175		-11	1.2	

On a straight away course from location of direction finder, 164° true, the following bearings were noted, Frequency 12405 Kcs. Altitude 1500 feet.

Time	Bearing	Reciprocal	Error	Distance	Remarks
1333	180		-16	2	
1337	200		-36	10	
1341	198		-34	18	
1343	198	18	-34	22	
1347	175		-11	30	
1349	175		-11	34	
1350.5	175		-11	37	Poor minima
1352				40	Over Potomac - signals weak.
1353				42	Signals faded out.
1355				46	Signals in but no minima
1357				50	Signals out
1403.5				63	Signals in but no minima
1406				70	Signals out
1407				70	Turned back
1421				44.1	Signals in but no minima
1424				39	Signals stronger but no minima
1425	180		-16	37.3	Broad minimum
1430	180	360	-16	28.8	
1434	170		-6	22	
1435.5	160		+4	20.3	
1436.5	160		+4	18.6	
1440	163		+1	12.7	
1442	165	345	-1	9.3	
1443.5	167		-3	6.8	
1446	170		-6	2.5	

On a straight away course from location of direction finder, 164° true, the following bearings were noted. Frequency 4135 Kcs. Altitude 1500 feet.

Time	Bearing	Reciprocal	Error	Distance	Remarks
1032	170		-8	12.6	
1034	170	350	-8	16.2	
1036.5	170		-8	20.7	
1042	170		-8	30.6	
1044	170		-8	34.2	
1049				47	Making circle over Potomac
1050.5					
[illegible]	[illegible]		-2	47	Very poor min.

Time	Bearing	Reciprocal	Error	Distance	Remarks
1054					Wide circle over Potomac signals fading badly - no minima
1056					Signals good but no minima
1058.5					Signals fading
1102	170		-8	45	
1104	170		-8	40.9	
1109.5	160		+4	29.4	
1112.5	170		-8	25.1	
1114	170		-8	19.9	
1118	146		-18	11.5	

On a straight away course from location of direction finder, 164° true, the following bearings were noted. Frequency 4135 Kcs. Altitude 1500 feet.

1102.5	170		-6	4.4	
1104.5	163		+1	7.9	
1105.5	165		-1	9.6	
1107	167		-3	12.2	
1108.5	170	350	-6	14.8	
1111	170		-6	19.1	
1113	170		-6	22.6	
1120					Transmitter trouble
1128				48.8	Signals but no minima
1131				54	" " "
1140				70	Turned 180°
1141					Signals but no minima
1151				48	South bank Potomac
1151.5	170		-6	47	Very poor minimum

Transmitter trouble balance of run.

On a circular run, with a radius of 10 miles around location of direction finder following bearings were note. Frequency 8270 Kcs. Altitude 2000 feet.

Time	Bearing	True	Error	Distance	Remarks
1026	210	174	36	10	
1031	135	98	38	10	
1039	80	45	35	10	
1041	75	25	50	10	Washington in line of Bearing
1044	45	347	58	10	" " " " "
1047	340	313	27	10	Over Potomac

On a straight away course from location of direction finder, the following bearings were noted: Frequency 8270. Altitude 3000 feet.

1516.5	302	300	-1.5	39.5	
1518	302	300	-1.5	41.9	
1520	302	300	-1.5	45.2	
1521					Signals faded out
1600	310	318	+9	5	

(h) Test for detuning of signal due to shift of balancer condenser showed the following results:

The balancer scale runs from 0 to 90 on either side of neutral position and on 1810 Kcs no effect was observed in shifting from 0 to 90.
On 6440 Kcs no effect was observed in shifting from 0 to 30. At 60 signal was reduced 29.2% and at 90 to zero.
On 15500 Kcs at 30 signal was reduced by 73.8% and at 60 to zero.
With a suitable antenna, tests showed this balancer to be normally used between 0 and 20.

(i) Throughout tests in taking bearings on different methods of transmission, no displacement from 180° greater than one degree was observed in taking reciprocal bearings.

(j) Throughout tests no body effect was noticed, the output transformer being electrostatically shielded and balanced to ground.

6. CONCLUSIONS

The usable sensitivity of the receiver used in this equipment is fairly good, after reducing the gain considerably to reach a noise level of 0.5 volt. Good results cannot be obtained in operating at a higher noise level when adjusting for minimum signal or a null point. The selectivity is very high except for the image response of intensity equal to the signal frequency response, these points being separated by 46 Kcs. The operation of the receiver is very stable except with respect to the band change switch. Contacts would often fail to make and the inability to detect this failure except by the absence of signals gives the operator no warning that the receiver is not functioning. A more sturdy type of switch construction is desirable. As a direction finder, the equipment functions very satisfactorily when taking bearings on signals at close range, 100 feet being the distance for first test, and excellent minima are obtainable, the deviation found being comparatively small.

As intended by the manufacturer this equipment, with a given satisfactory operation at short range should give useful results in taking bearings on signals where the ground wave predominates, with normally polarized waves.

Inasmuch as attenuation of the ground wave to a point where signals are no longer of sufficient strength to enable taking of bearings is not coincident with the introduction of horizontally polarized waves accuracy can only be obtained to the degree that the latter factor is absent.

Results in taking bearings on fixed land stations at various frequencies up to 21 miles distant show an average error of 13.1° for 85 bearings.

On plane transmission on various frequencies up to 47 miles distant, where course of plane was parallel to line of bearing, average error of 8.3° for 55 bearings. When course of plane was at right angles to line of bearing, on a frequency of 8270 Kcs at a distance of 10 miles, average error of 40.6° for 6 bearings. These results are in agreement with previous findings of this laboratory that the use of a direction finder with loop collector on high frequencies will not give accuracy comparable with that obtained when used on intermediate frequencies, except where only the ground wave is present.

It is, however, believed that a test made at this location will in all probability not give a full representation of the limitations of the equipment when used under Naval Service conditions, such as at sea, or on shore in taking bearings over water.

Topographical and other conditions in this vicinity are such as to produce erratic distortions in the wave front and investigations have shown that receiving conditions in this locality are seriously affected by dead spots and other influences due to the irregular combinations of land and water in the paths of transmission.

PROB. D2-3

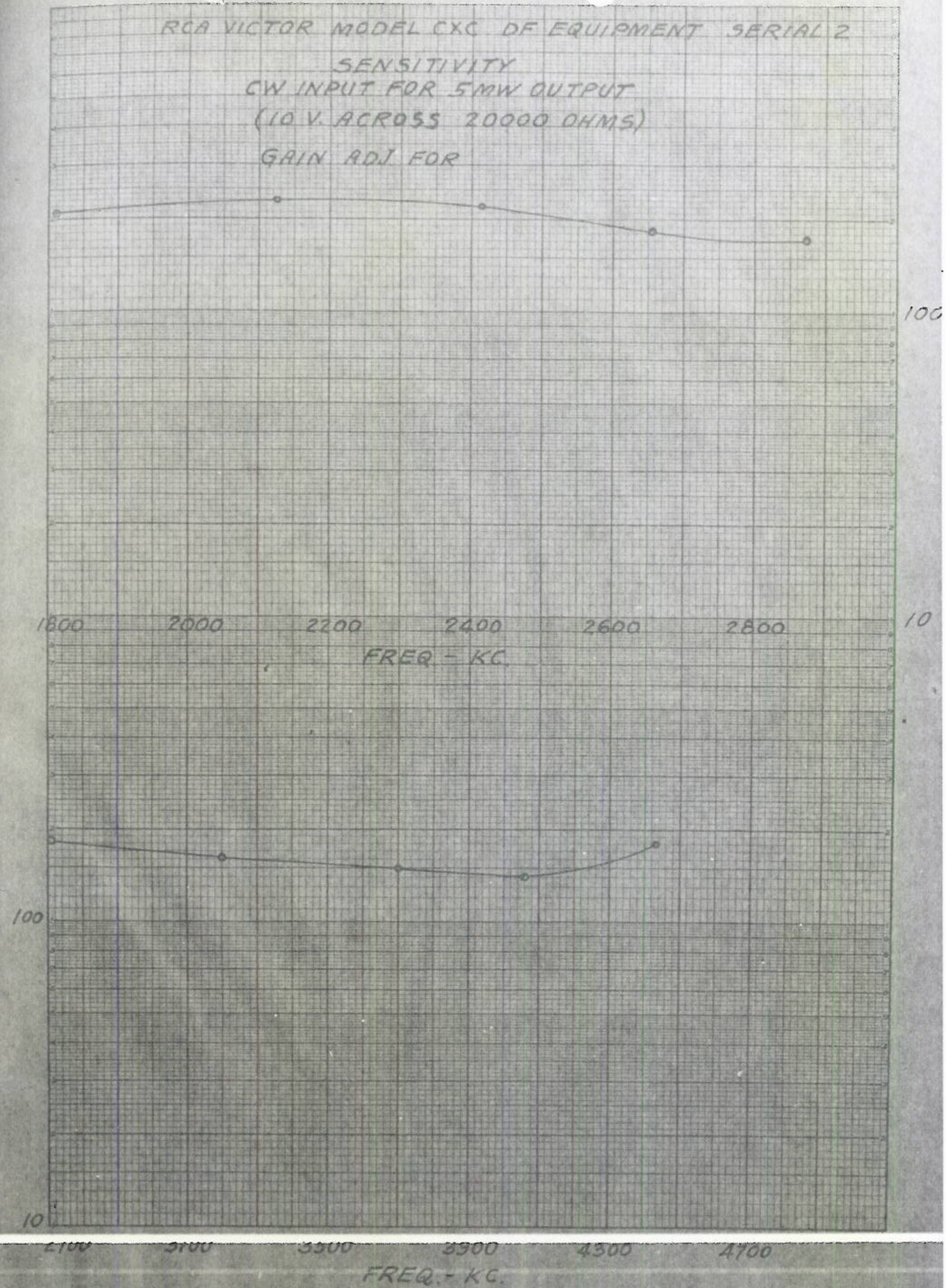
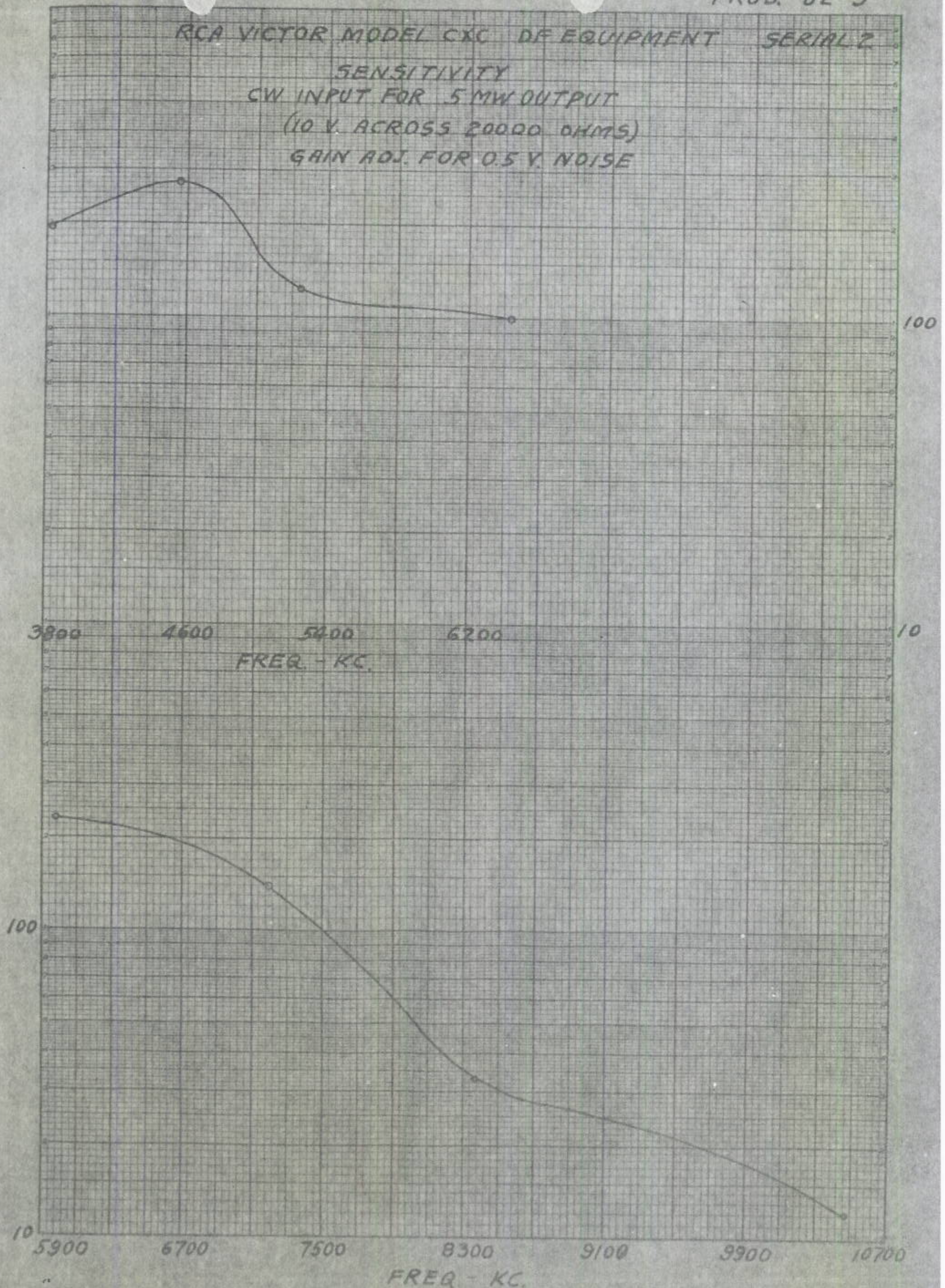


PLATE 1


RCA VICTOR MODEL CXC DF EQUIPMENT SERIAL 2
SENSITIVITY
CW INPUT FOR 5 MW OUTPUT
(10 V. ACROSS 20000 OHMS)
GAIN ADJ. FOR 0.5 V. NOISE
100
10
3800
4600
5400
6200
FREQ - KC.
100
10
5900
6700
7500
8300
9100
9900
10700
FREQ - KC.

PROB. DZ-3

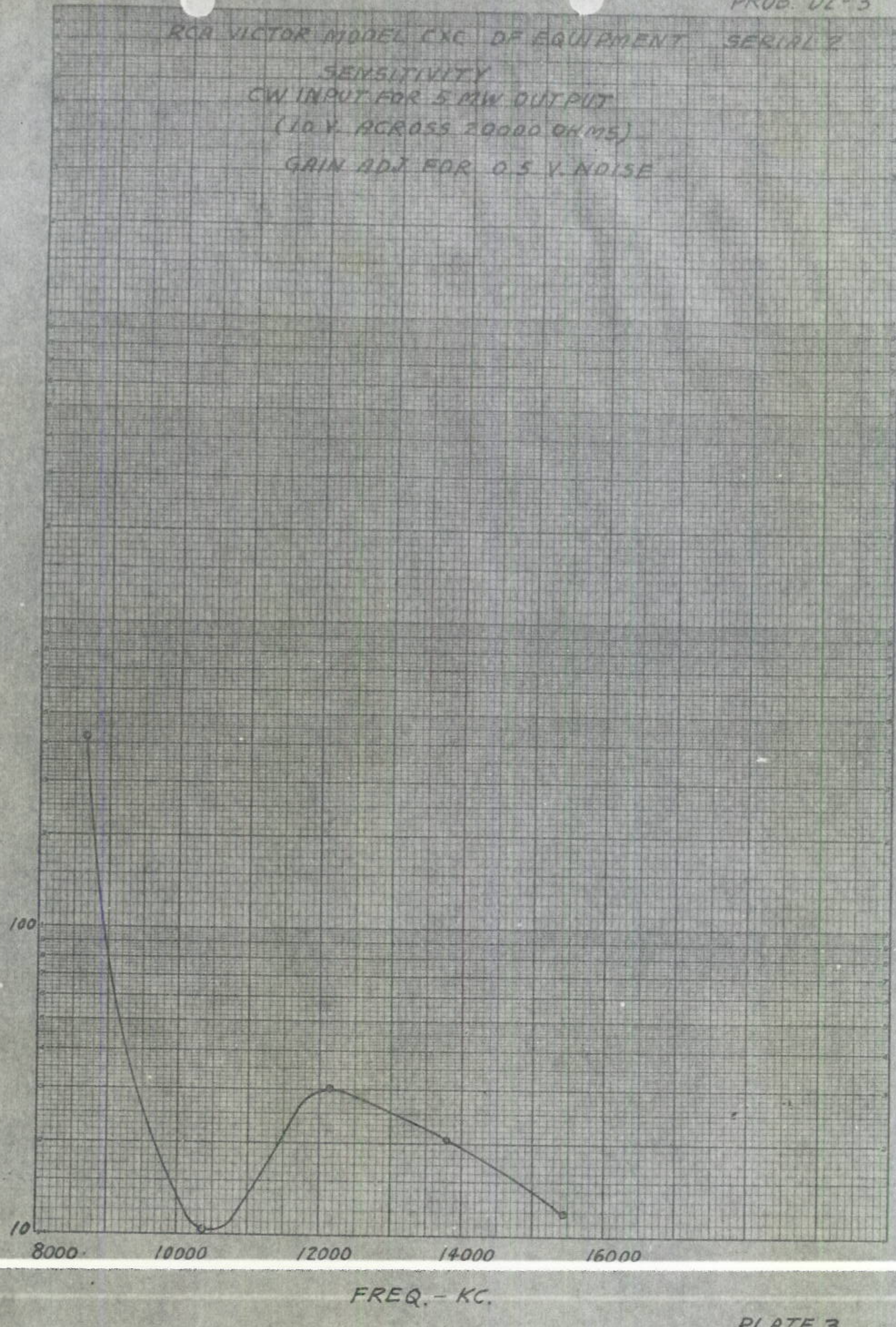
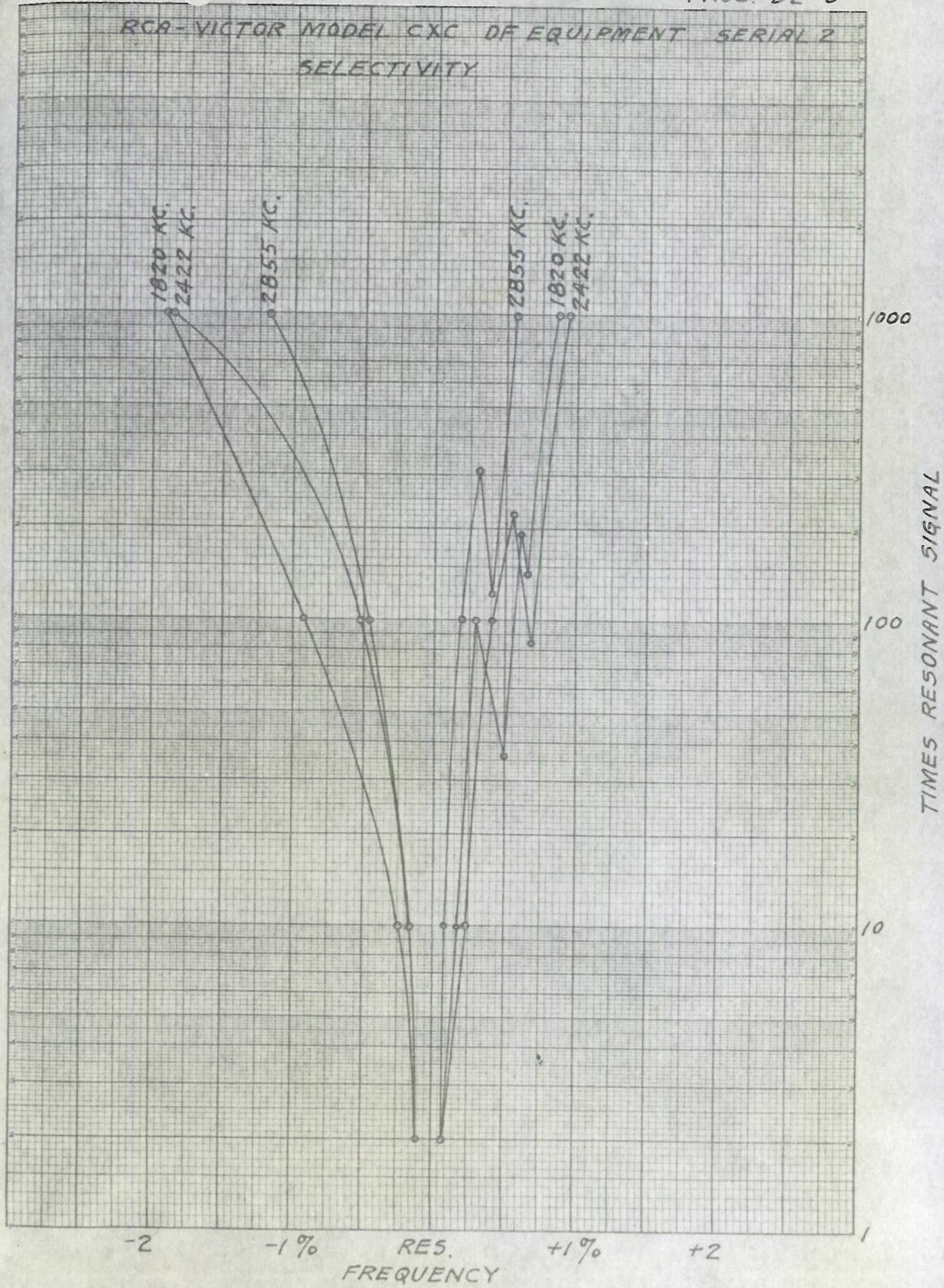


PLATE 3

PROB. D2-3


RCA-VICTOR MODEL CXC DF EQUIPMENT SERIAL 2
SELECTIVITY
1820 KC.
2422 KC.
2855 KC.
2855 KC.
1820 KC.
2422 KC.
1000
100
10
1
TIMES RESONANT SIGNAL
-2
-1%
RES.
+1%
+2
FREQUENCY

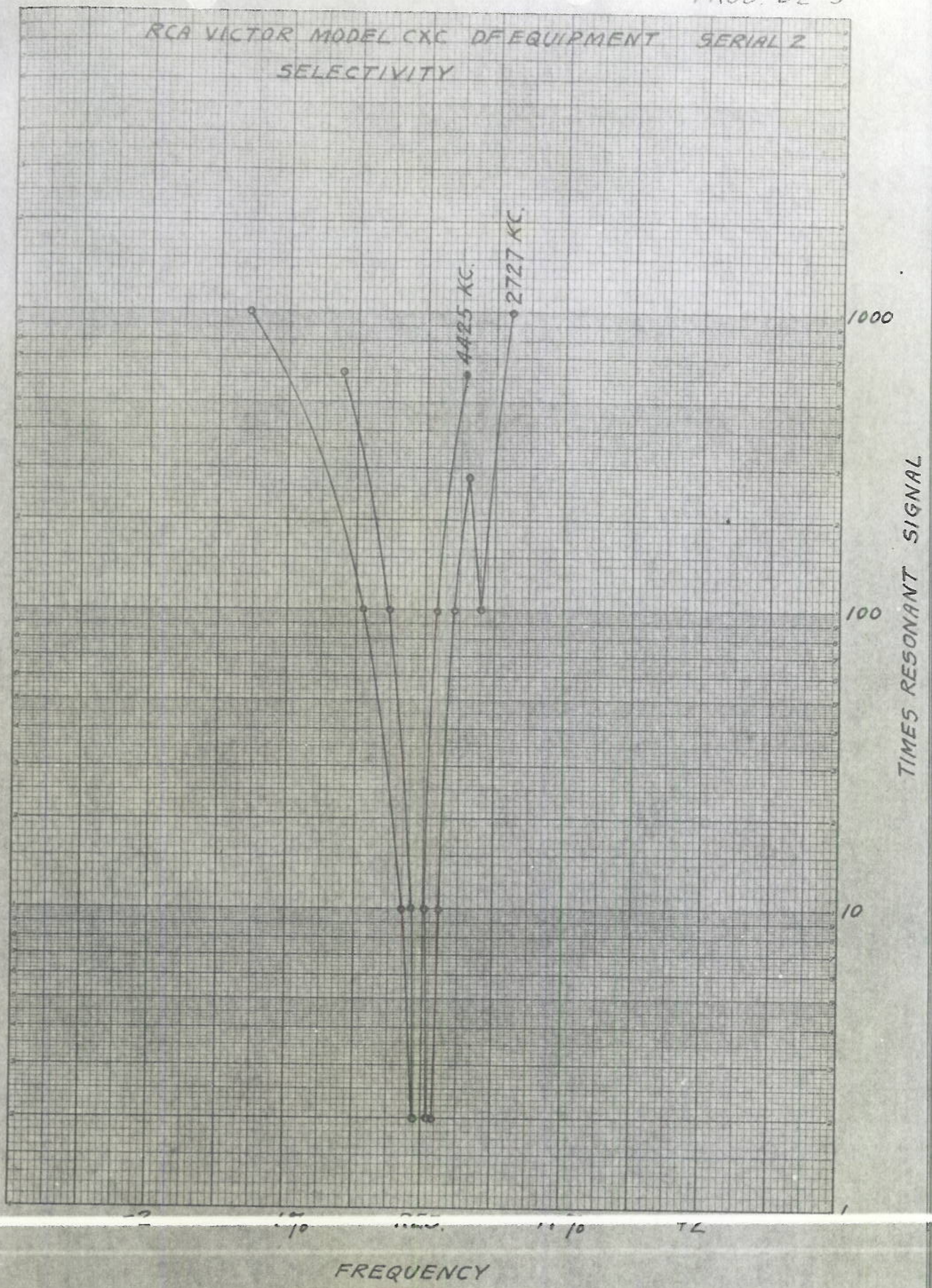
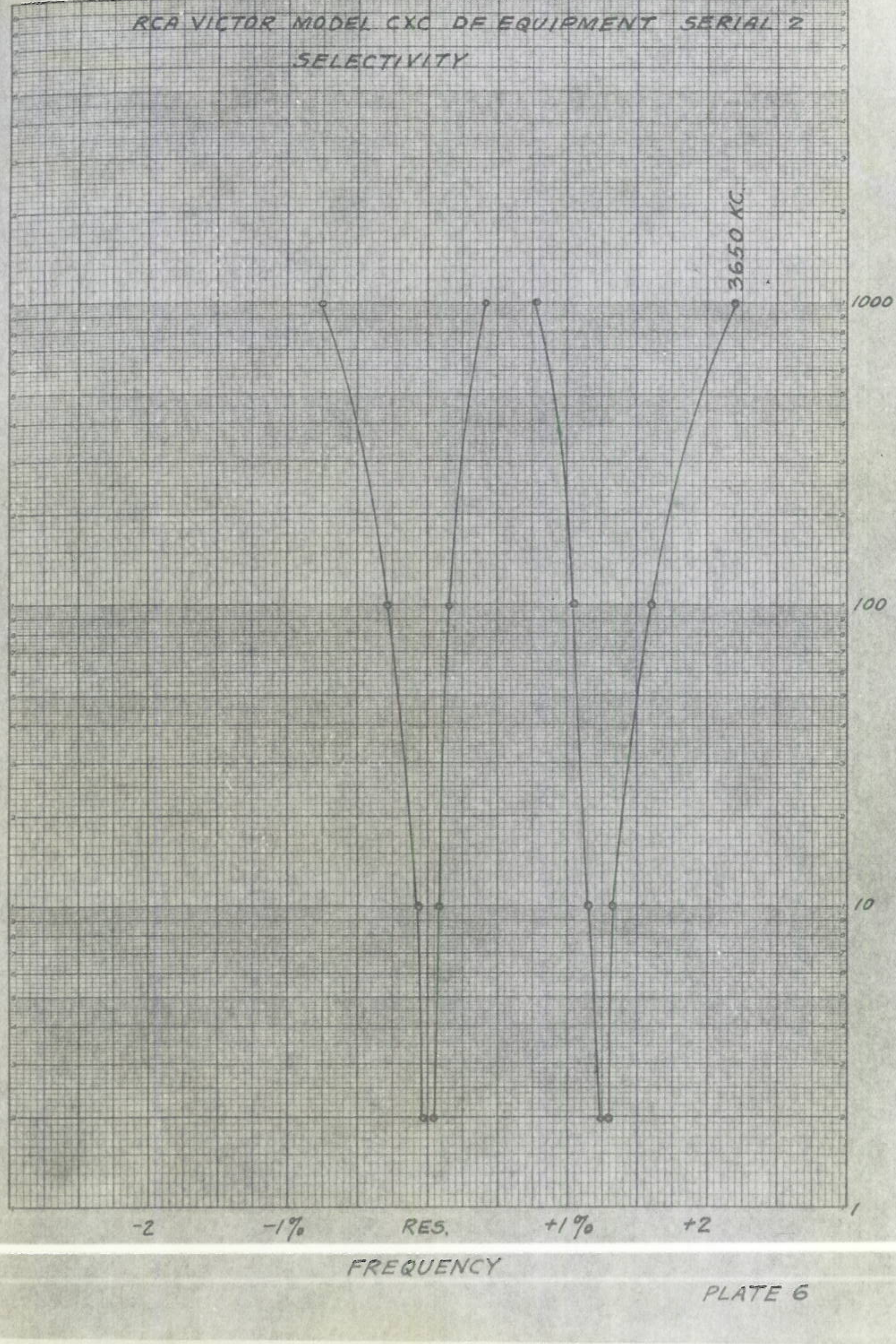
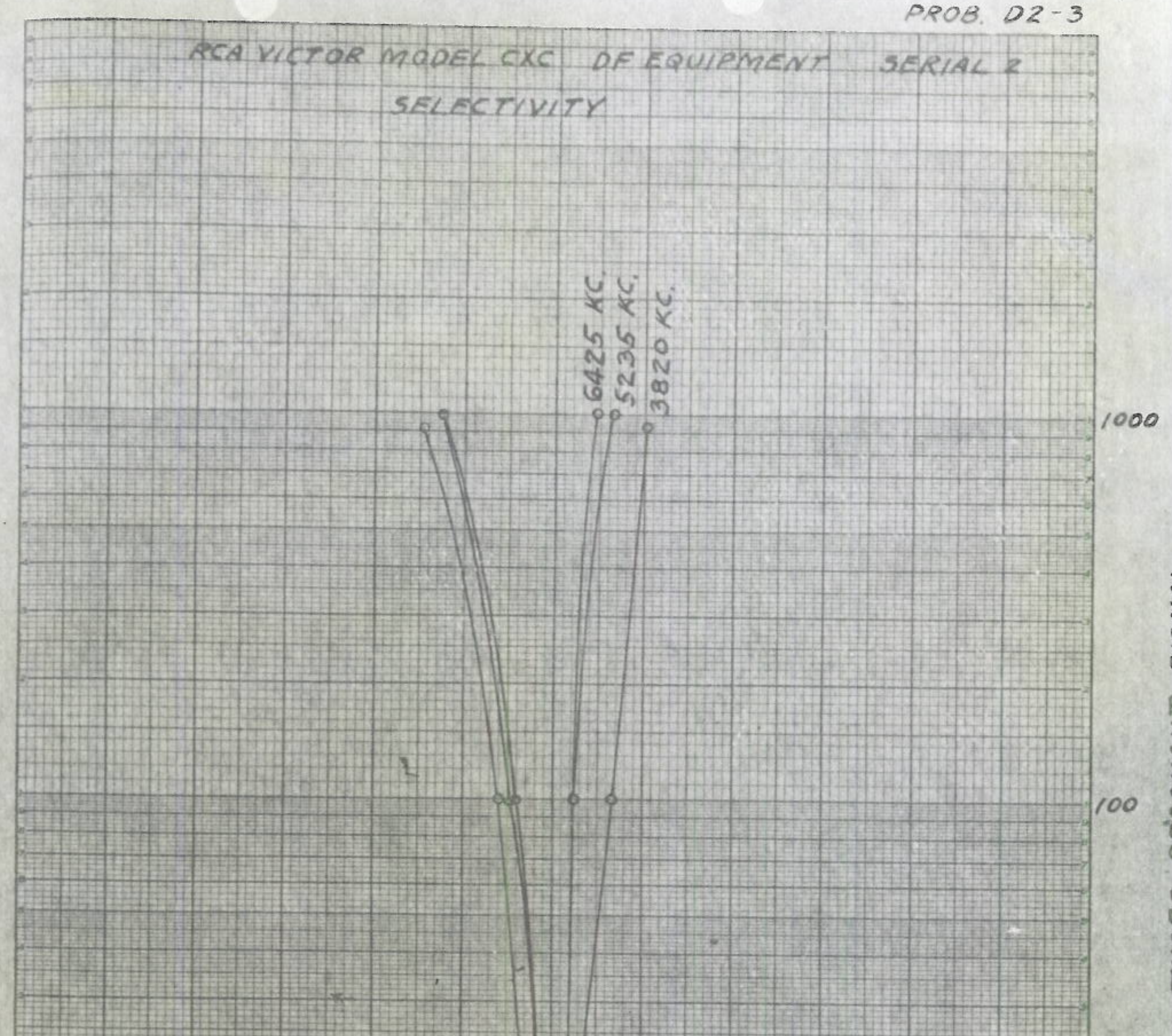
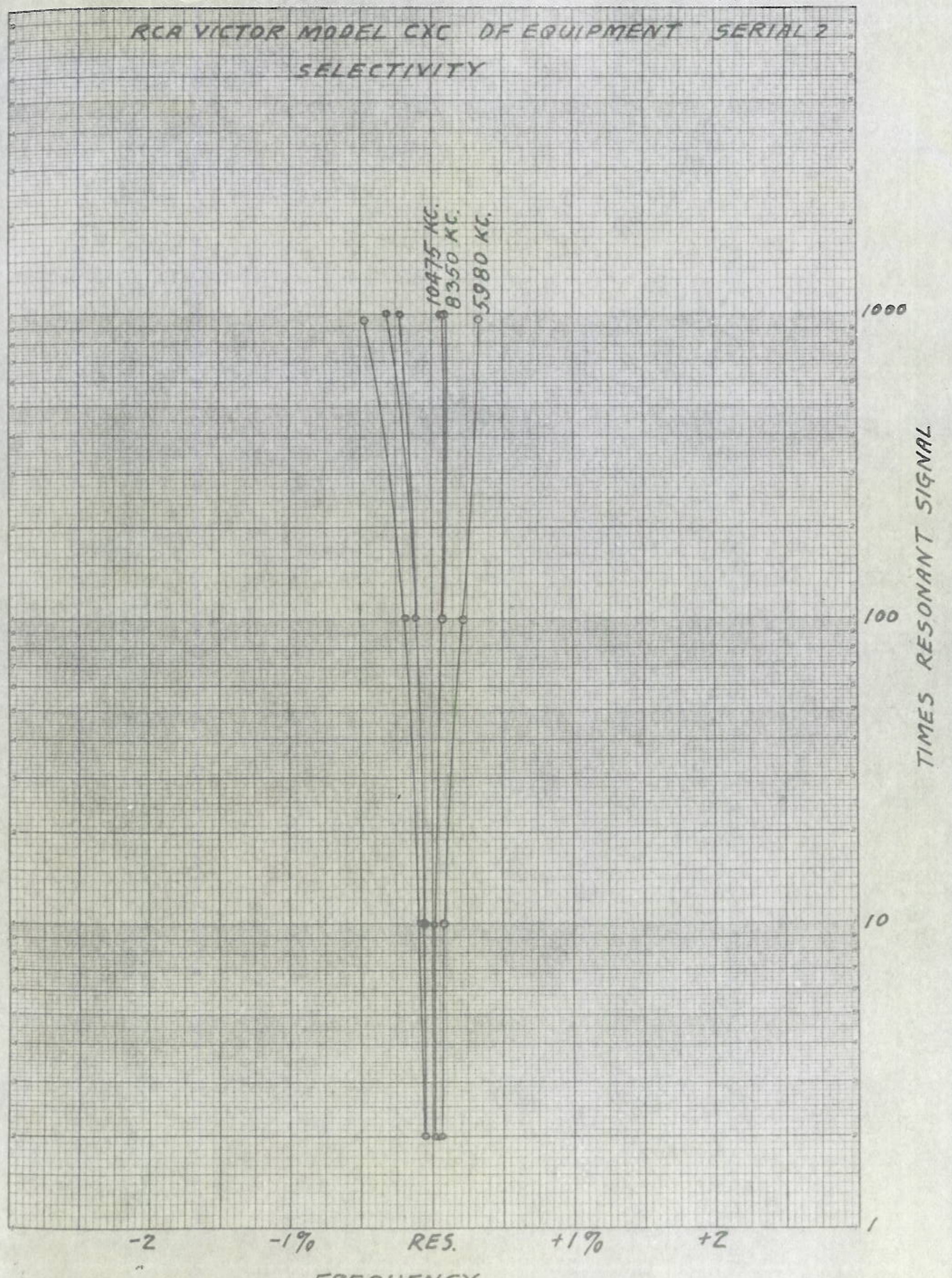

RCA VICTOR MODEL CXC DF EQUIPMENT SERIAL 2
SELECTIVITY
4425 KC.
2727 KC.
1000
100
10
1
TIMES RESONANT SIGNAL
FREQUENCY

PLATE 5


RCA VICTOR MODEL CXC DF EQUIPMENT SERIAL 2
SELECTIVITY
3650 KC.
1000
100
10
1
TIMES RESONANT SIGNAL
-2
-1%
RES.
+1%
+2
FREQUENCY


RCA VICTOR MODEL CXC DF EQUIPMENT SERIAL 2
SELECTIVITY
6425 KC.
5235 KC.
3820 KC.
1000
100
10
1
TIMES RESONANT SIGNAL
-2
-1%
RES.
+1%
+2
FREQUENCY


RCA VICTOR MODEL CXC DF EQUIPMENT SERIAL 2
SELECTIVITY
10475 KC.
8350 KC.
5980 KC.
1000
100
10
1
TIMES RESONANT SIGNAL
-2
-1%
RES.
+1%
+2
FREQUENCY

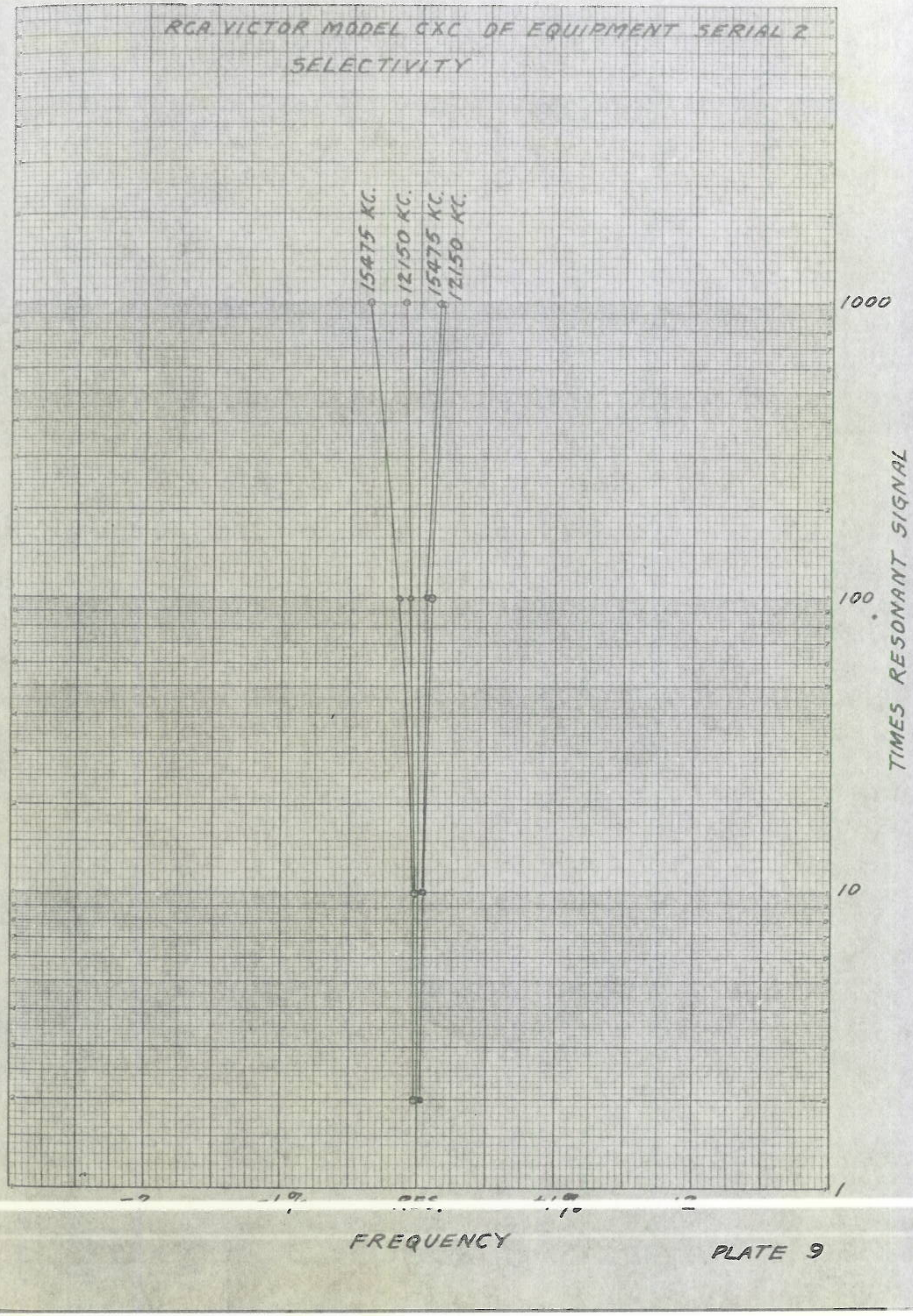
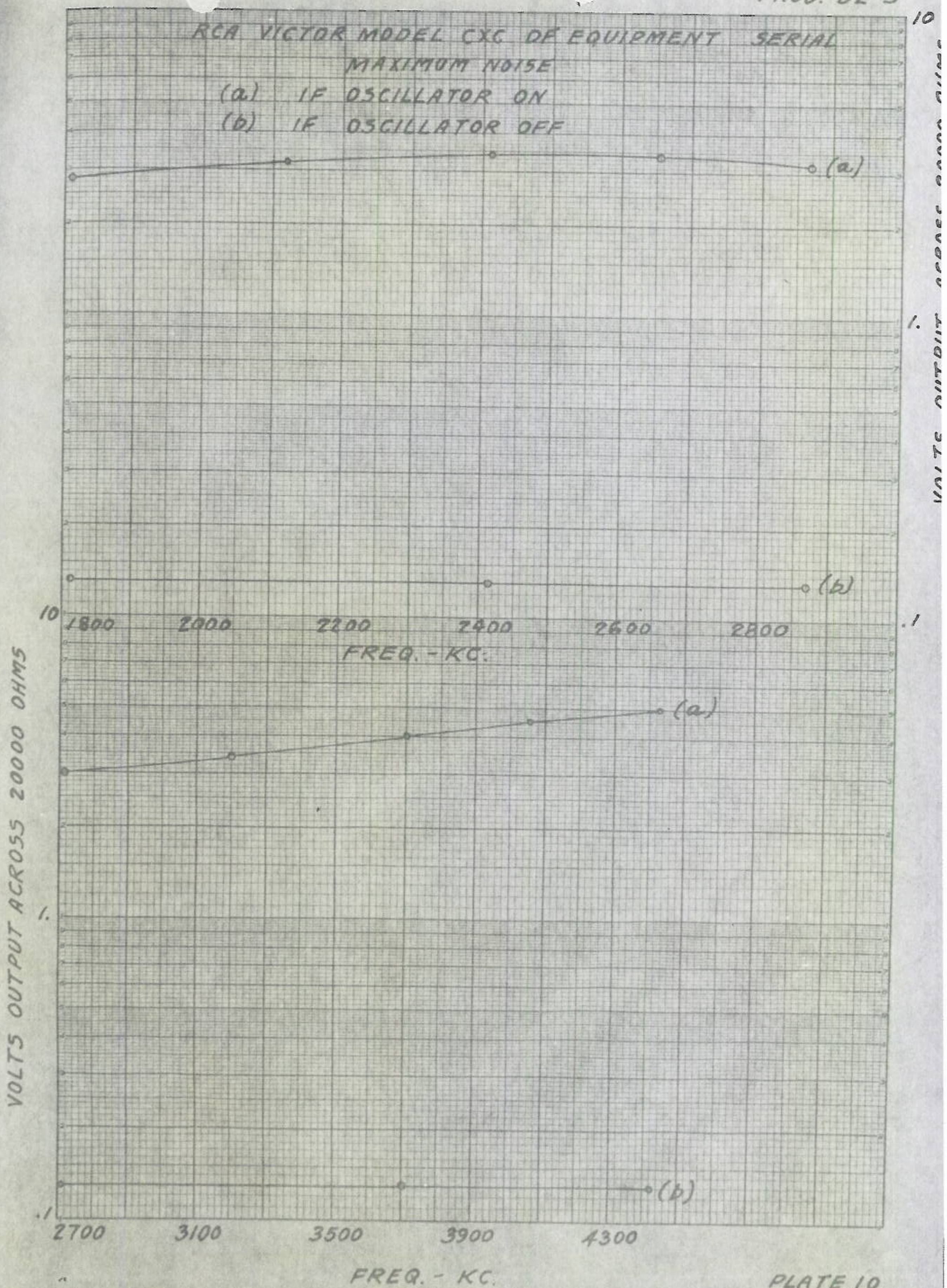
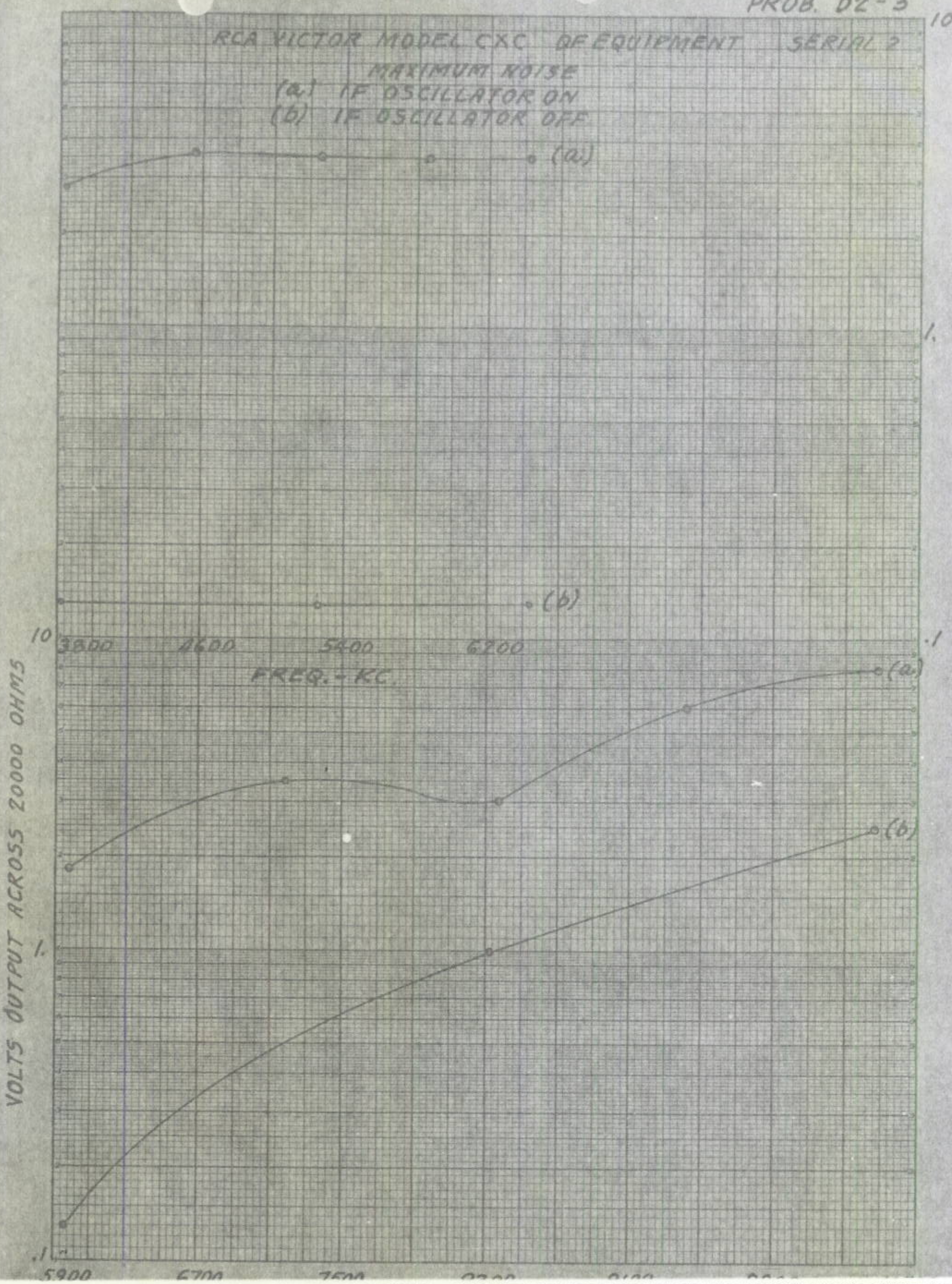
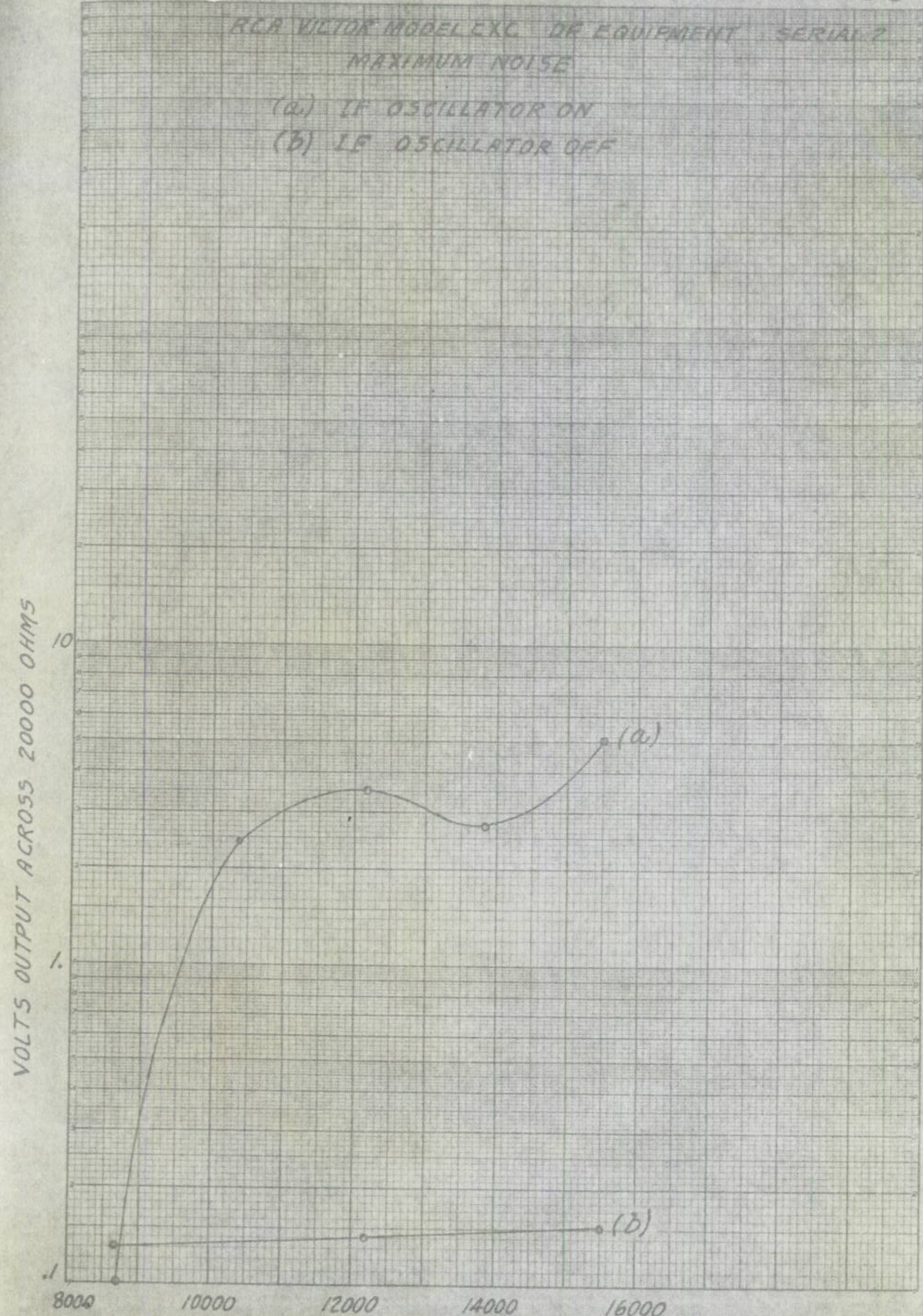

RCA VICTOR MODEL CXC OF EQUIPMENT SERIAL 2
SELECTIVITY
15475 KC.
12150 KC.
15475 KC.
12150 KC.
1000
100
10
1
TIMES RESONANT SIGNAL
FREQUENCY

PLATE 9


RCA VICTOR MODEL CXC OF EQUIPMENT SERIAL
MAXIMUM NOISE
(a) IF OSCILLATOR ON
(b) IF OSCILLATOR OFF
(a)
(b)
10
1.
.1
1800
2000
2200
2400
2600
2800
FREQ. - KC.
(a)
(b)
VOLTS OUTPUT ACROSS 20000 OHMS
10
1.
.1
2700
3100
3500
3900
4300
FREQ. - KC.


RCA VICTOR MODEL CXC QF EQUIPMENT SERIAL 2
MAXIMUM NOISE
(a) IF OSCILLATOR ON
(b) IF OSCILLATOR OFF
(a)
(b)
3800
4600
5400
6200
FREQ. - KC.
VOLTS OUTPUT ACROSS 20000 OHMS
10
1.
.1
5900
6700
7500
FREQ. - KC.


RCA VICTOR MODEL EXC DF EQUIPMENT SERIAL 2
MAXIMUM NOISE
(a) IF OSCILLATOR ON
(b) IF OSCILLATOR OFF
VOLTS OUTPUT ACROSS 20000 OHMS
10
1.
.1
(a)
(b)
8000
10000
12000
14000
16000
FREQ. - KC.