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17 March 1944

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NRL Report No. R-2221
Buships Problem D1-13C

NAVY DEPARTMENT

BUREAU OF SHIPS

[redacted]

Report of Test

of a

Special Model DP Direction Finder

Equipment Incorporating A Balance Amplifier

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

DECLASSIFIED by NRL Contract Declassification Team
Date: 29 Jan 2016
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Authorization: Buships ltr. C-NOs67/69 (480D) of 1 December 1941.

Date of Tests: 27 November to 20 December 1941

Prepared by: Harold E. Dinger
Harold E. Dinger

Submitted by: Warren B. Burgess
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Head, Measurement and Direction Finder Section

Reviewed by: A. Hoyt Taylor
A. H. Taylor, C
Superintendent, Radio Division

Approved by: for J. L. Reinartz
A. H. Van Keuren, Rear Admiral, USN
Director, Naval Research Laboratory

Distribution:

Buships (10)

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SERIAL No. 9

17 March 1944

[redacted]
NRL Report No. R-2221
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TABLE OF CONTENTS

APPENDICES

AUTHORIZATION

1. The tests herein reported were authorized by reference (a). Other pertinent data are listed as reference (b) to (e) inclusive.

Reference (a) Buships ltr C-S67/69 (480D) of 1 Dec. 1941 to NRL.
(b) RCA Manufacturing Co. ltr of 6 August 1941 to Buships.
(c) RCA Manufacturing Co. ltr of 14 November 1941 to NRL.
(d) Specifications RE 13A, 474B of 19 September 1935 with addenda of 6 February 1939 and 4 February 1941.
(e) NRL Report No. R-1347A of 19 March 1937.

OBJECT OF TEST

2. The object of the test was to determine, first, whether the maximum phase shift introduced by the balance amplifier circuit is of sufficient magnitude to introduce inherent deviating influences or otherwise mitigate against satisfactory operation of such a device; second, whether the additional noise level introduced by the balance amplifier seriously compromises the satisfactory operation of the equipment; third, to determine by comparison methods, any advantages or disadvantages inherent in the subject equipment over those of a standard model DP-9 direction finder; fourth, to recommend any changes or modifications that may be ascertained as being desirable.

ABSTRACT OF TEST

3. The equipment furnished the Laboratory was given a series of electrical tests in comparison with a standard model DP-9 equipment (loaned by the RMS of NRL). The tests are listed below:

A. General direction finder performance.
B. Sensitivity with loop excitation.
C. Sensitivity with balance antenna excitation for both balance and sense conditions.
D. Equality of balance effects at the maximum settings of the balancer.
E. Variation of quadrature voltage with respect to the balancer setting.
F. Ratio of the balance sensitivity to loop sensitivity.
G. Variation of noise output with respect to the balancer setting.
H. Balance sensitivity with respect to changes in line voltage.
I. Signal to noise ratio variation with respect to changes in line voltage.
J. Determination of the effect of the balance circuit upon the "Q" of the loop circuit.

CONCLUSIONS

It is concluded:

(a) That the subject equipment produces good bearings with a shorter balance antenna that a standard model DP-9 direction finder.
(b) That the noise introduced by the balance amplifier increases with displacement from zero balance and has the effect of decreasing the useful sensitivity of the equipment at the increased balancer settings.
(c) That it is advantageous to use the best possible balance antenna.
(d) That variation of line voltage produces excessive instability in the balancer adjustment.
(e) That both electronic control and amplification of balance voltages are worthy of further study.

RECOMMENDATIONS

It is recommended:

(a) That suitable power supply regulation be incorporated to reduce balance variations caused by line voltage fluctuations.
(b) That the time constant of the "electronic eye" be reduced to permit more rapid operation.
(c) That the sense resistors be connected for minimum resistance at counter-clockwise rotation as in the standard model DP's.
(d) That proper steps be taken to reduce the shock applied to the output meter when the sense button is pressed.
(e) That the antenna and sense relays be designed to operate at a somewhat lower voltage.
(f) That the specifications be so altered as to cover the changes adopted.

DESCRIPTION OF MATERIAL UNDER TEST

4. The equipment furnished by the manufacturer (RCA Manufacturing Company of Camden, New Jersey) for test, consisted of the following units:

Radio Direction Finder Receiver	No type No.
A-C Power Unit	Type CRV20049
Loop Pedestal	Type CRV69007
Loop	No type No.
Loop - Receiver coupling cable	No type No.
Power Supply Cable	No type No.

5. This equipment is essentially a model DP-4 direction finder with the loop connected directly to the receiver through the loop cable with the exception that the receiver unit incorporates a balance-sense amplifying system. The standard mutual inductance balancer is replaced with an electronic balancer consisting of two type 1851 tubes so connected that with zero setting of the balancer both tubes are biased to cut-off. As the balancer is turned in a "plus" direction one tube begins to amplify and in a "minus" direction the other tube becomes active. The antenna voltage is applied directly to the grids of both tubes. The plates of the two tubes are connected to opposite sides of the loop circuit through coupling condensers. The vernier adjustment operates an auxiliary bias control for "fine" degree of balance. An electronic eye is also incorporated for observation of minima. The electrical features of the balance amplifier are shown in Plates 16 and 17 and are more fully described in reference (c).

6. The equipment available at the Laboratory for comparison purposes, was a standard model DP-9, with the loop connected directly to the receiver unit, consisting of the following units:

Radio Direction Finder Receiver	
Model DP-9 No. 171	Type No. CRV46040
A-C Power Unit	Type No. CRV20049
Loop	Type No. CRV69046
Loop Pedestal	Type No. CRV69047
Loop Receiver Coupling Cable	No type No.
Power Supply Cable	No type No.

The units supplied by the RCA Manufacturing Company were delivered to the Laboratory on 18 November 1941. The tests were started on 27 November 1941.

METHOD OF TEST

7. Test (A) was made with the equipment set up near a metallic bulkhead surface in a corridor of building 29 at NRL in such a way as to simulate actual shipboard conditions as much as possible. The balance antenna was erected so as to require balancer settings of approximately 40 divisions on the standard model DP -9.

8. Tests (B) to (J) inclusive were made in a shielded room of such dimensions that the effect of the shielding upon the inductance of the loop was negligible. The power supply line to the room is equipped with an isolation transformer and suitable r-f filters.

9. Measuring equipment employed for the test consisted of the following units:

General Radio Model LP-1 Signal Generator No. 86
Raytheon 120 watt Voltage Regulator
2 General Radio variacs
Ballantine Electronic Voltmeter Model 300, No. 310
Ballantine Electronic Amplifier Model 200 No. 42
Boonton Radio Corporation, "Q" Meter Model 160 A No. 434.

10. General Direction Finder Performance Test. The standard model DP-9 equipment was first set up in a corridor of building 29, NRL. The antenna was erected to the top of the building about two feet away from the wall and its length adjusted so as to require about 40 divisions on the balancer scale for several broadcast stations. This required a physical vertical height of approximately 25 feet. The horizontal length was about 15 feet. Observations were taken on available signals to determine displacement and quality of minima, reaction of balance and other pertinent data as shown in Table I.

11. The special model DP receiver unit was then substituted for the standard model DP-9 receiver unit and similar observations made. These are listed in Table II. Both receivers were adjusted to the loop and sense antennas according to the model DP-9 instruction book. Several minor service jobs were performed on both receiver units before proper operation was obtained.

12. The vertical portion of the balance antenna was then reduced to a height of about 10 feet; of this about four feet were outside of the building. This was inadequate for the balancing of most stations on the standard model DP-9. Balance was still obtainable on the special model DP-9 as shown in Table III. A test was also made at this time to determine the effect of line voltage variation on the balancer setting. The results are shown in Plate 14.

13. Sensitivity with Loop Excitation. In the measurement of overall sensitivity with Loop Excitation, the loop and loop pedestal of the subject equipment was installed near the center of a screened room approximately 21 by 15 by 12 feet in dimensions. The effect of screening upon the loop inductance was considered negligible. The r-f voltage from the signal generator was applied to the center of the loop through the 10:1 attenuator pad and shielded leads. Leakage from the signal generator to the loop was not detectable with the

loop in any position. Both equipments were then measured according to the procedure given in reference (e). All measurements were made c-w input voltage.

14. Sensitivity with Balance Antenna Excitation. The overall sensitivities of both equipments with the balancers set at their maximum settings were measured by applying a c-w signal voltage at a given frequency from a standard signal generator to the antenna terminal and ground through the standard dummy antenna pad. Sensitivity measurements were made at maximum settings of the balancer (± 50 for the standard model DP and ± 80 for the special model DP) at each of the five frequency settings on each band at which sensitivity measurements with loop excitation were made. Similar measurements were made with the sense button depressed so as to cut out the balancer circuit and insert the sense circuit. For the latter measurements the sense resistor for each band was set for zero resistance.

15. Equality of Balance Effects at the Plus and Minus Maxima of the Balancer. This relation was determined from the sensitivity measurements as described in reference (e).

16. Variation of Quadrature Voltage with Respect to the Setting of the Balancer. The method of measurement for this test was the same as for determining the balancer sensitivity with balance antenna excitation, using c-w input voltage as described in paragraph 14, except that measurements were made at each 10 divisions of the balancer dial scale.

17. Ratio of Balancer Sensitivity to Loop Sensitivity. These ratios were calculated from the data obtained for loop sensitivity and corresponding balancer sensitivities at the maximum settings of the balancer. The sensitivity data in either case were converted into terms of microvolts per meter field strength required for standard output. An effective height of two meters for the balance antenna was assumed in accordance with reference (e).

18. Noise Output with Respect to Balancer Setting. The sensitivity of the special Model DP was adjusted to give 60 microwatts of noise output at a balancer setting of zero. The noise outputs at each 10 divisions of the balancer scale both plus and minus, were measured.

19. Balancer Gain with Respect to Line Voltage Variations. For this test the grid lead to the r-f amplifier tube was disconnected from the tube and connected by a short shielded lead to a Model 300 Ballantine electronic voltmeter. A 100 kc signal was delivered from the signal generator through a standard dummy antenna pad to the antenna circuit of the special model DP receiver the loop circuit being resonant. The signal generator output necessary to maintain an arbitrary value of 0.0003 volts on the electronic voltmeter was noted for each of five values of line voltage to the receiver.

20. Loop Balancer and Sense Sensitivity with Respect to Line Voltage Variations. Sensitivities were measured at 100 kc as described in paragraphs 13 and 14 for four values of line voltage.

21. Loop Circuit "Q". The "Q" of the loop alone was measured at 1200 kc on a Boonton Radio Corporation Model 160A "Q" meter and found to have a value of 108. The "Q" meter was then used to apply 0.02 volts at 100 kc to the loop center. The Ballantine Electronic Voltmeter was connected in place of the r-f amplifier grid and the voltage gain of the complete loop circuit determined to be 27.5. No change was indicated by removing the balance amplifier tubes or by disconnecting the balance amplifier coupling condensers from the tuned circuit.

DATA RECORDED DURING TEST

22. Information taken from the data recorded during the tests is contained in Tables I to III and plates 1-15 appended hereto.

PROBABLE ERRORS IN RESULTS

23. All tests were carefully conducted so as to maintain minimum errors in observations and in manipulation of the controls of the equipment under test or of the measuring apparatus. Tests involving the standard signal generator output voltage reading have an estimated overall accuracy of ± 10%. Width of minima are included with table of data to permit estimating the accuracy of the observations.

RESULTS OF TEST

24. Balancer variations on a number of observations over the frequency band produced no detectable shift of minimum. The balancing voltage supplied by the balance amplifier is, therefore, properly in quadrature to the loop voltage.

25. The noise introduced by the balance amplifier for different balance settings is shown on Plate 15.

26. The subject equipment in its present form is considered to be unsatisfactory as regards line voltage variation effect on the gain of the balance amplifier. Data are given on Plates 12, 13 and 19.

27. General Direction Finder Performance Tests. The operation of the equipment under simulated shipboard conditions is shown in Tables 1-3. The subject equipment gave normal balance on a number of stations with an antenna of such short length that the standard model DP-9 failed to give balance. Plate 11 gives the balancer gain of the subject equipment over the standard model DP-9. It was noted that small changes in line voltage seriously affected the balance when set on the minimum. Data were taken as shown on Plates 12, 13, and 14.

28. Sensitivity Measurements. Sensitivity measurements with either loop or balance antenna were made at five frequency settings for each band or both equipments. Sensitivities are given in Plates 1 and 2. The curves labeled "loop" were measured with loop excitation. Those labeled "sense" and "Bal" ± 50", "Bal -50", "Bal +80" and "Bal. -80" were measured with balance antenna excitation. Sense sensitivities were measured with the sense resistors reduced to zero.

29. Balancer sensitivities with respect to balancer settings are given on Plates 3 to 8. Because of the greater balance sensitivities of the special receiver the scale ordinates of plates 6 to 8 are different by a factor of 10 from those of Plates 3 to 5. Since the input of the balance amplifier is untuned, adjustment of the balancer away from zero (blocked grids) increase the noise level by as much as 10 decibels (Plate 15). This constitutes an actual decrease in the usable sensitivity of the receiver, and may, therefore, widen the observed minimum by a factor of about three, even though the balancer is perfectly adjusted. Since this is a function of balancer setting, rather than antenna voltage, best results require a large balance antenna in order to minimize the degree of balance amplification employed. Put another way, for a given size of balance antenna, if the Model DP-9 were unable to balance, the special model might balance successfully, but with an abnormally wide minimum. This noise difficulty could be overcome if a tuned antenna circuit with 90 degree phase shifter were used for the balance amplifier. However, the slightest mal-tracking between blance antenna and loop circuits would cause phasing errors leading to displaced minima. These phase errors appear to make such a design impracticable to manufacture and maintain in accurate alignment.

30. The ratios of balance sensitivity to loop sensitivity in percent of loop sensitivity for the two equipments are given on Plate 9. The ratios of sense sensitivity to loop sensitivity are given on Plate 10.

31. The ratios of the balance to loop sensitivities of the special model DP were divided by those of the standard model DP-9 and these values plotted on Plate 11 as "gain" of the special receiver over the standard receiver.

32. Balancer "gain" variations with respect to balancer setting at 5 values of line voltage are plotted on plate 12. The values indicated are the microvolts from the signal generator, applied through a standard dummy to the antenna terminal, necessary to produce the arbitrary value of 0.0003 volts at the grid terminal of the r-f amplifier tube as read on the electronic voltmeter and decade amplifier at 100 kc.

33. Balance, sense and loop sensitivity and their ratios in percent of loop sensitivity with respect to line voltage variation at (100 kc) are given in plate 13.

34. Comments on Subject Equipment. The special equipment furnished by the manufacturer was not intended to represent a finished mechanical product; therefore, the tests were confined to those having a direct bearing on the electrical performance of the balance amplifier. Attention is invited to several features that should be considered in any equipments that might be ordered.

35. The sense resistors are not connected so as to give the same direction of rotation for zero resistance as in the standard model DP's.

36. The time constant of the electronic eye is too great for good observation of the minimum.

37. The receiver output meter is subjected to a heavy electrical shock when the sense button is pressed.

38. The antenna grounding and sense relays require at least 105 volts a.c. for operation.

39. The frequency coverage of the high frequency band does not extend above 1325 kc.

40. The image response on the high frequency band is not within the specification limit.

41. The electrical and mechanical zeros of the balancer scale do not coincide.

42. The necessity for vernier control on the balancer detracts from simplified balancer operation.

43. If desirable, the scale of the balancer can be divided into 50 divisions plus and minus instead of 80 plus and minus as at present.

44. If desirable, 2 degrees of balance could be made available by switching or changing the balance resistor values.

CONCLUSIONS

45. It is concluded:

(a) The subject equipment produces good bearings with a shorter balance antenna than a standard model DP-9 direction finder.
(b) That the noise introduced by the balance amplifier increases with displacement from zero balance and has the effect of decreasing the useful sensitivity of the equipment at the increased balancer settings.
(c) That it is advantageous to use the best possible balance antenna.
(d) That variation of line voltage produces excissive instability in the balancer adjustment.
(e) That both electronic control and amplification of balance voltages are worthy of further study.

TABLE 1

Standard Model DP-9

(Total Balancer Divisions ±50)

Band	Station	Freq. (kc)	Min.	Bal.	Min.	Bal.	Width of Min.
1	NSS	113	180.0	+30	70	-27	1/4°
2	(WA)	338	108.5	+32	289.0	-32	1/5°
3	WCAO	600	41.2	-26	221.4	+26	2°
3	WMAL	630	152.5	- 5	332.2	+ 5	1/5°
3	WRC	980	50.0	-35	229.5	+35	1/10°
3	WBAL	1090	142.0	+45	322.0	-45	1°
3	WOL	1260	140.0	+38	320.0	-38	1/2°
3	WJSV	1500	48.5	- 5	228.5	+ 5	1/10°

TABLE 2

Special Model DP
(Total Balancer Divisions ±80)

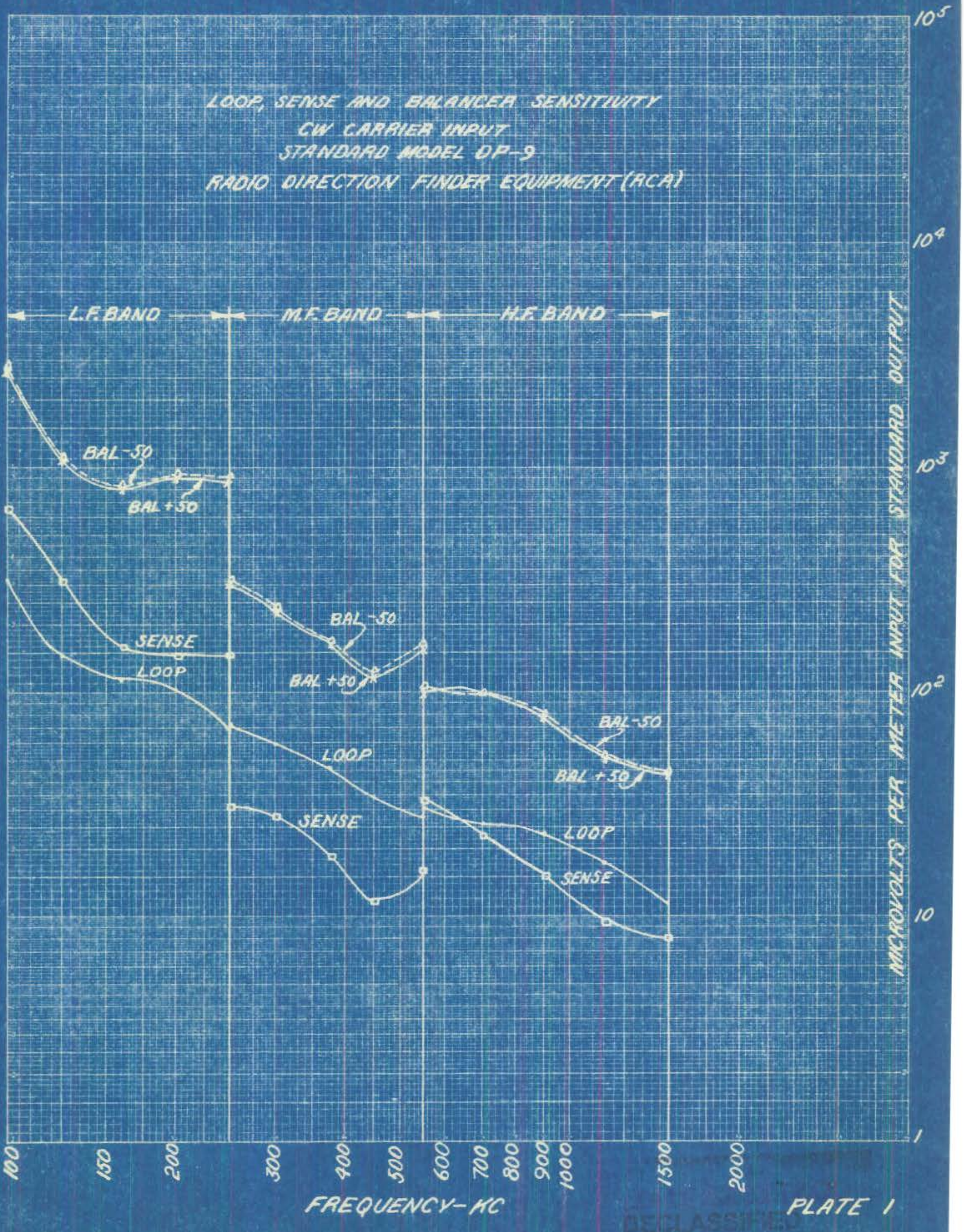
1	NSS	113	180.0	-21	0	+19	1/4°
2	(WA)	338	107.5	-22	288.2	+19.5	2°
3	WCAO	600	42.5	+20	221.8	-20	3°
3	WMAL	630	152.0	+ 2	332.0	- 5	1/10°
3	WRC	980	50.2	+20	230.0	-22	1/4°
3	WBAL	1090	143.5	-28	327.5	+29	1°
3	WOL	1260	169.5	-21	351.2	+18	1/2°
3	WJSV	1500					

TABLE 3

	DP-9		Special DP	
Station	Min.	Bal.	Min.	Bal.
WMAL	150.5	-22	151.0	+12
WRC	53.0	X	53.0	+39
WOL	X	X	141.5	-41.5

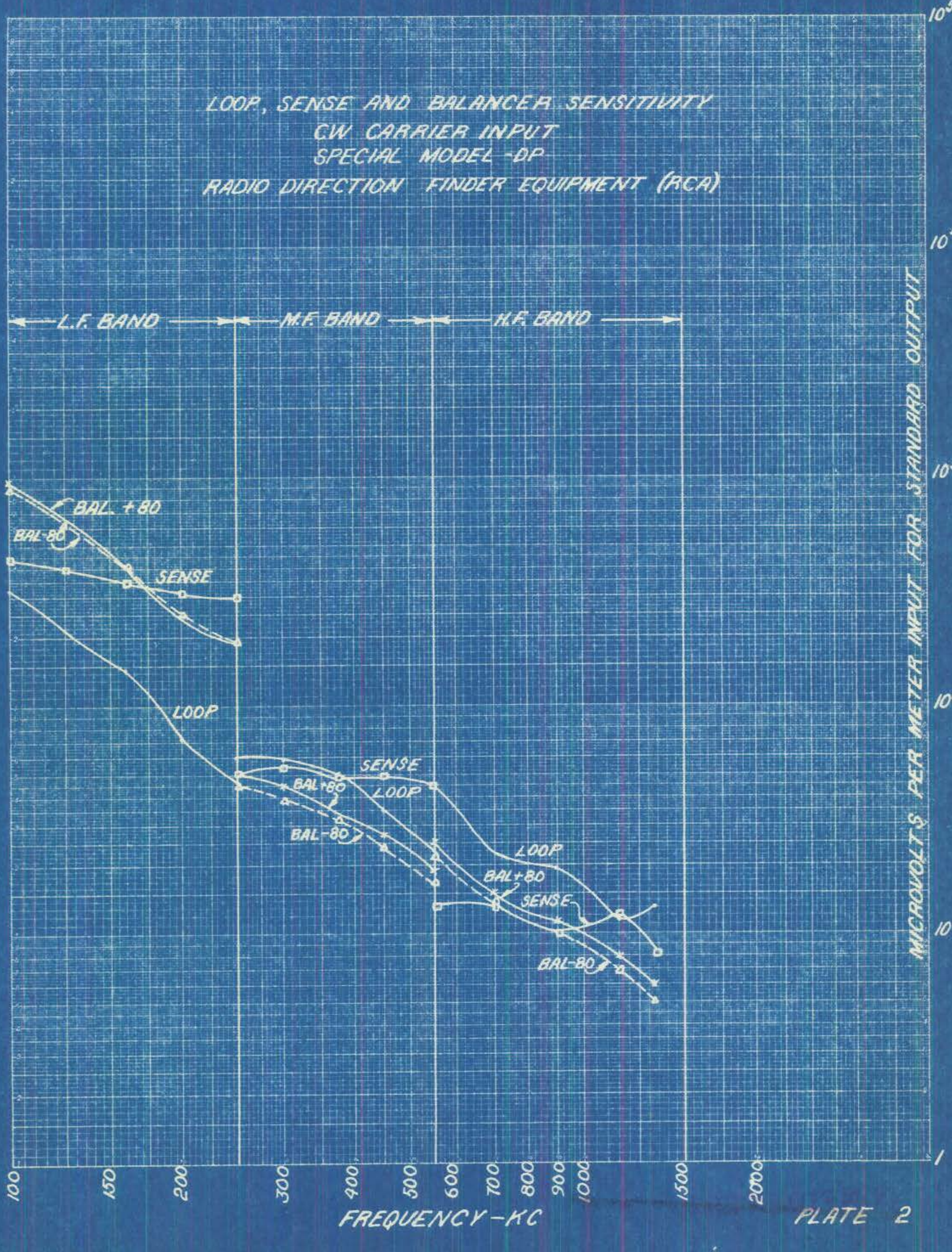
X Unable to balance.

Note: Data in Table 2 were taken several hours after that in Table 1. Data in Table 3 were all taken with a 15 minute period.



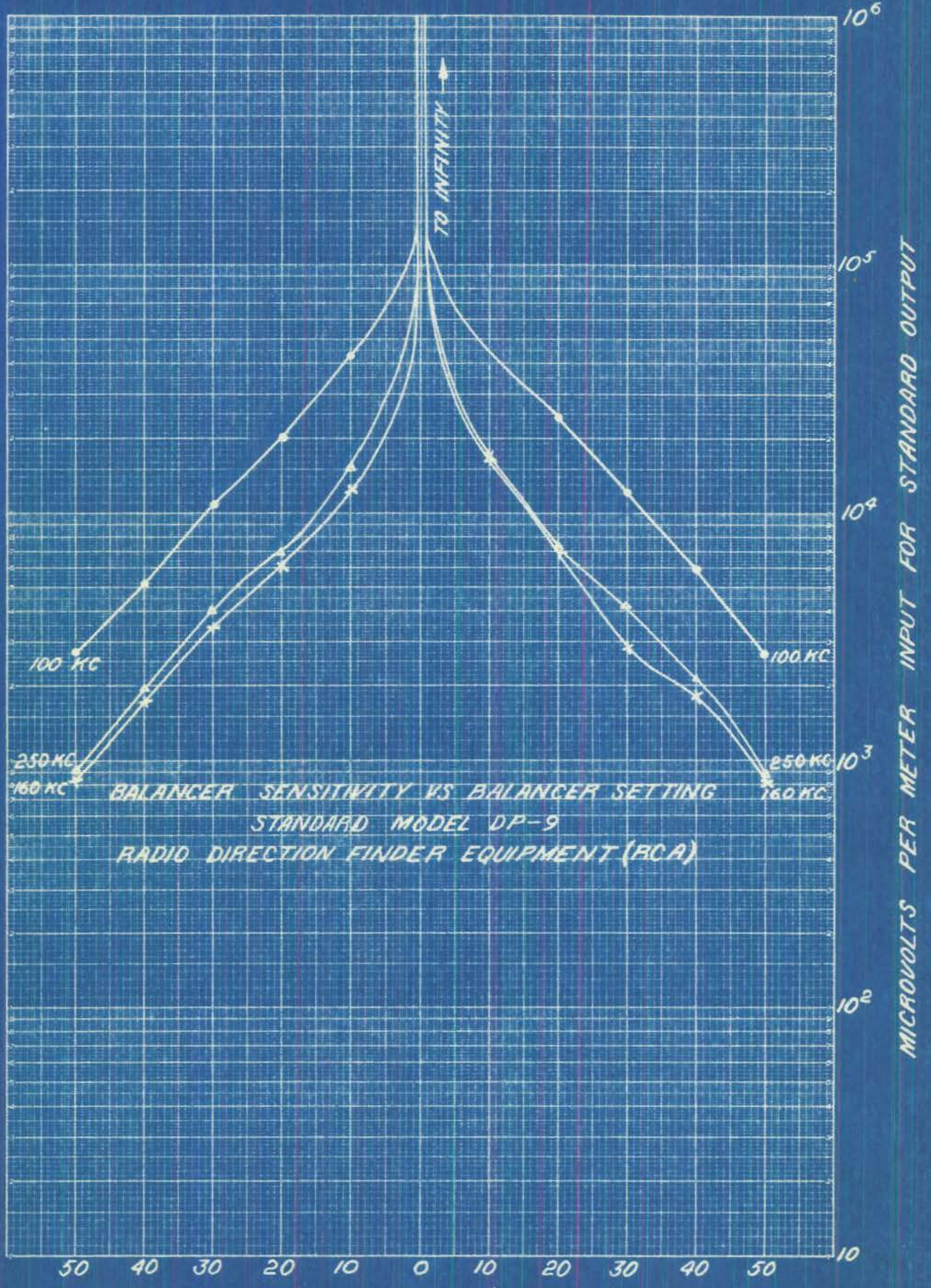
LOOP, SENSE AND BALANCER SENSITIVITY
CW CARRIER INPUT
STANDARD MODEL DP-9
RADIO DIRECTION FINDER EQUIPMENT (RCA)
L.F. BAND
M.F. BAND
H.F. BAND
BAL-50
BAL+50
SENSE
LOOP
BAL-50
BAL+50
LOOP
SENSE
BAL-50
BAL+50
LOOP
SENSE
10^5
10^4
10^3
10^2
10
1
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT
100
150
200
300
400
500
600
700
800
900
1000
1500
2000
FREQUENCY-KC

PLATE 1



LOOP, SENSE AND BALANCER SENSITIVITY
C.W. CARRIER INPUT
SPECIAL MODEL -DP
RADIO DIRECTION FINDER EQUIPMENT (RCA)
L.F. BAND
M.F. BAND
H.F. BAND
BAL. +80
BAL-80
SENSE
LOOP
SENSE
BAL+80
LOOP
BAL-80
LOOP
BAL+80
SENSE
BAL-80
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT
10^5
10^4
10^3
10^2
10
1
100
150
200
300
400
500
600
700
800
900
1000
1500
2000
FREQUENCY-KC

PLATE 2



TO INFINITY
100 KC
250 KC
160 KC
100 KC
250 KC
160 KC
BALANCER SENSITIVITY VS BALANCER SETTING
STANDARD MODEL DP-9
RADIO DIRECTION FINDER EQUIPMENT (RCA)
10^6
10^5
10^4
10^3
10^2
10
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT
50 40 30 20 10 0 10 20 30 40 50
− +
BALANCER DIAL SETTING-DIVISIONS

PLATE 3

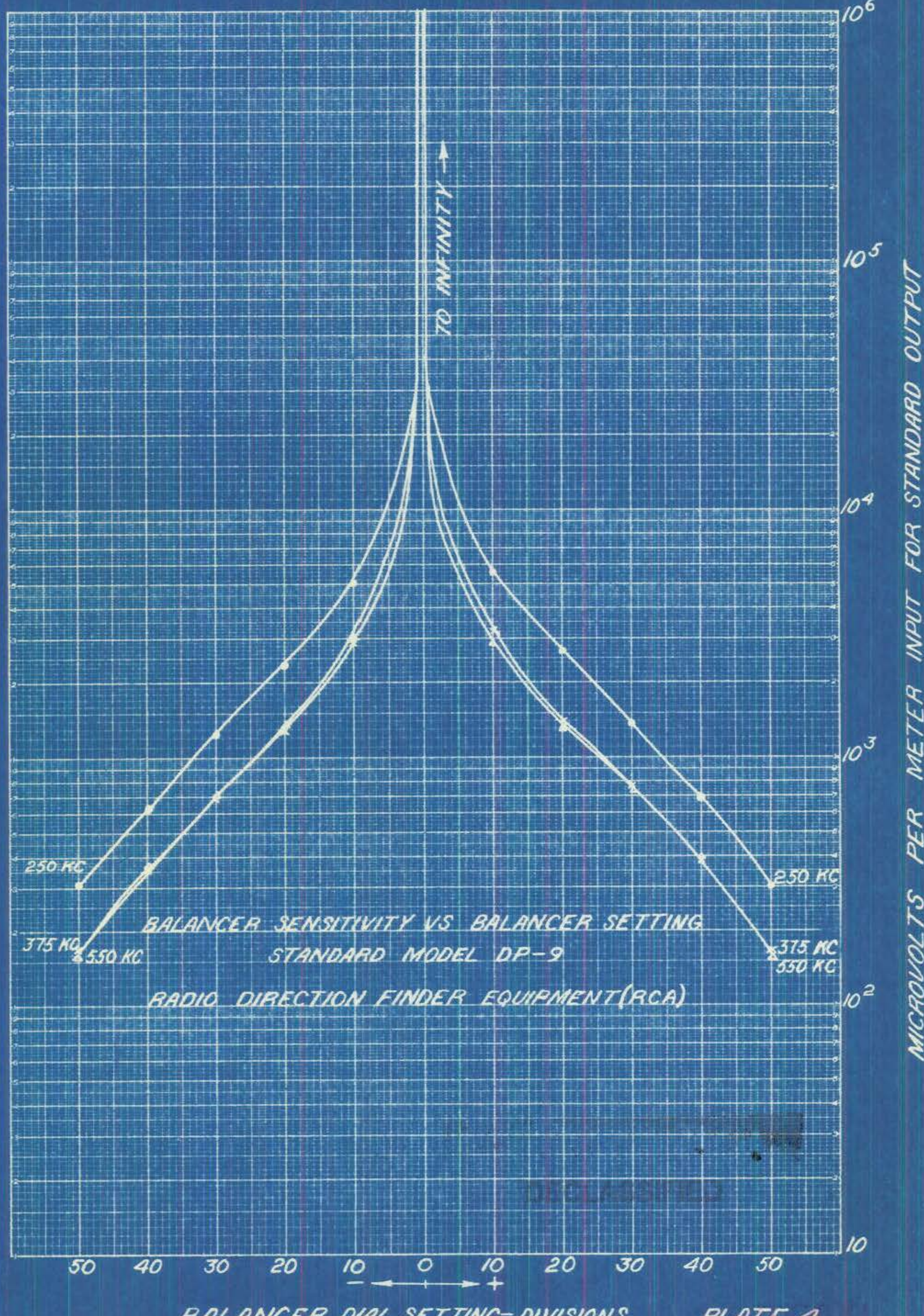

BALANCER SENSITIVITY VS BALANCER SETTING
STANDARD MODEL DP-9
RADIO DIRECTION FINDER EQUIPMENT (RCA)
TO INFINITY →
250 KC
375 KC
550 KC
250 KC
375 KC
550 KC
10^6
10^5
10^4
10^3
10^2
10
50 40 30 20 10 0 10 20 30 40 50
− ← → +
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT
BALANCER DIAL SETTING - DIVISIONS

PLATE 4

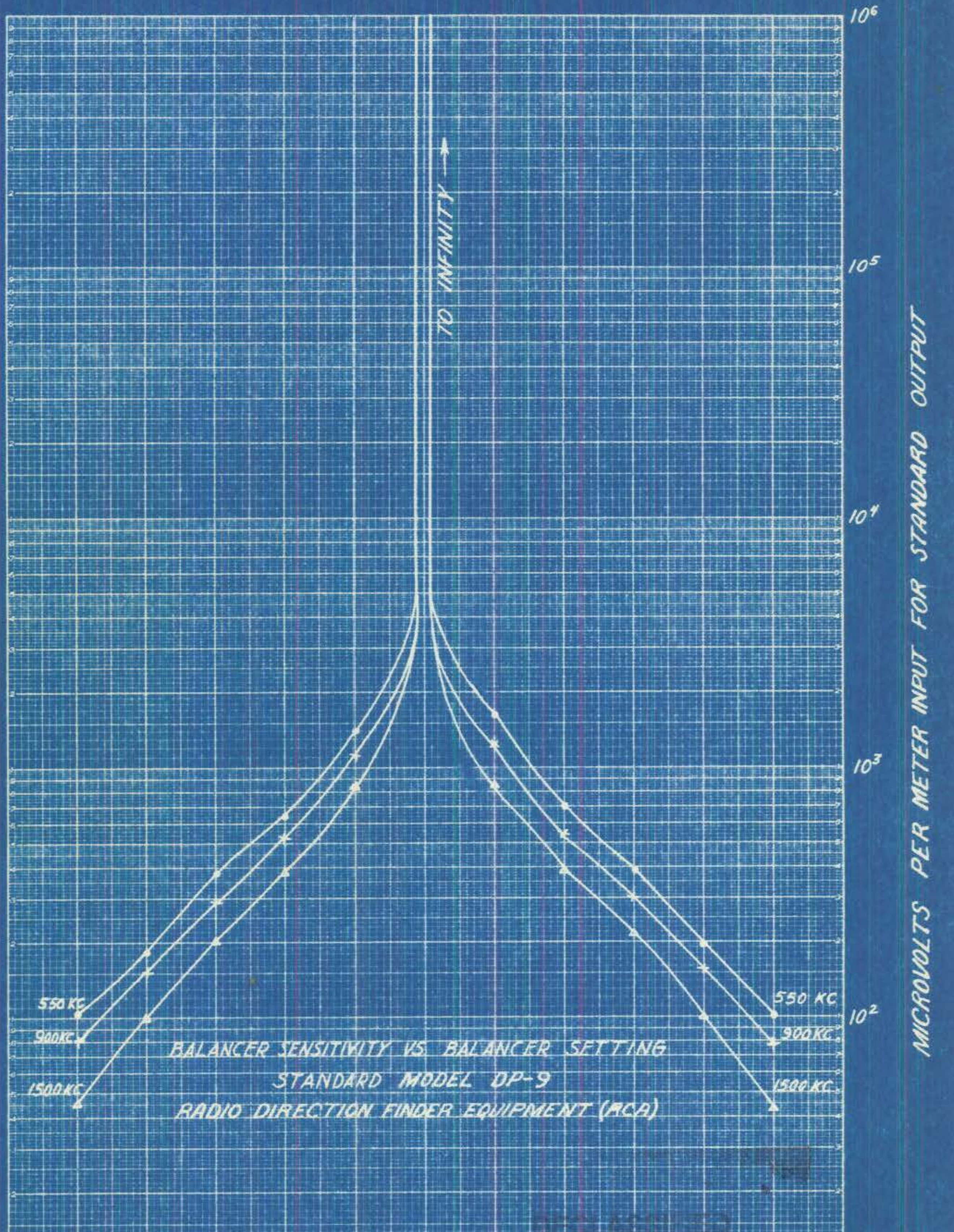

BALANCER SENSITIVITY VS. BALANCER SETTING
STANDARD MODEL DP-9
RADIO DIRECTION FINDER EQUIPMENT (RCA)
TO INFINITY
550 KC
900 KC
1500 KC
10^6
10^5
10^4
10^3
10^2
10
50
40
30
20
10
0
10
20
30
40
50
−
+
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT
BALANCER DIAL SETTING- DIVISIONS

PLATE 5

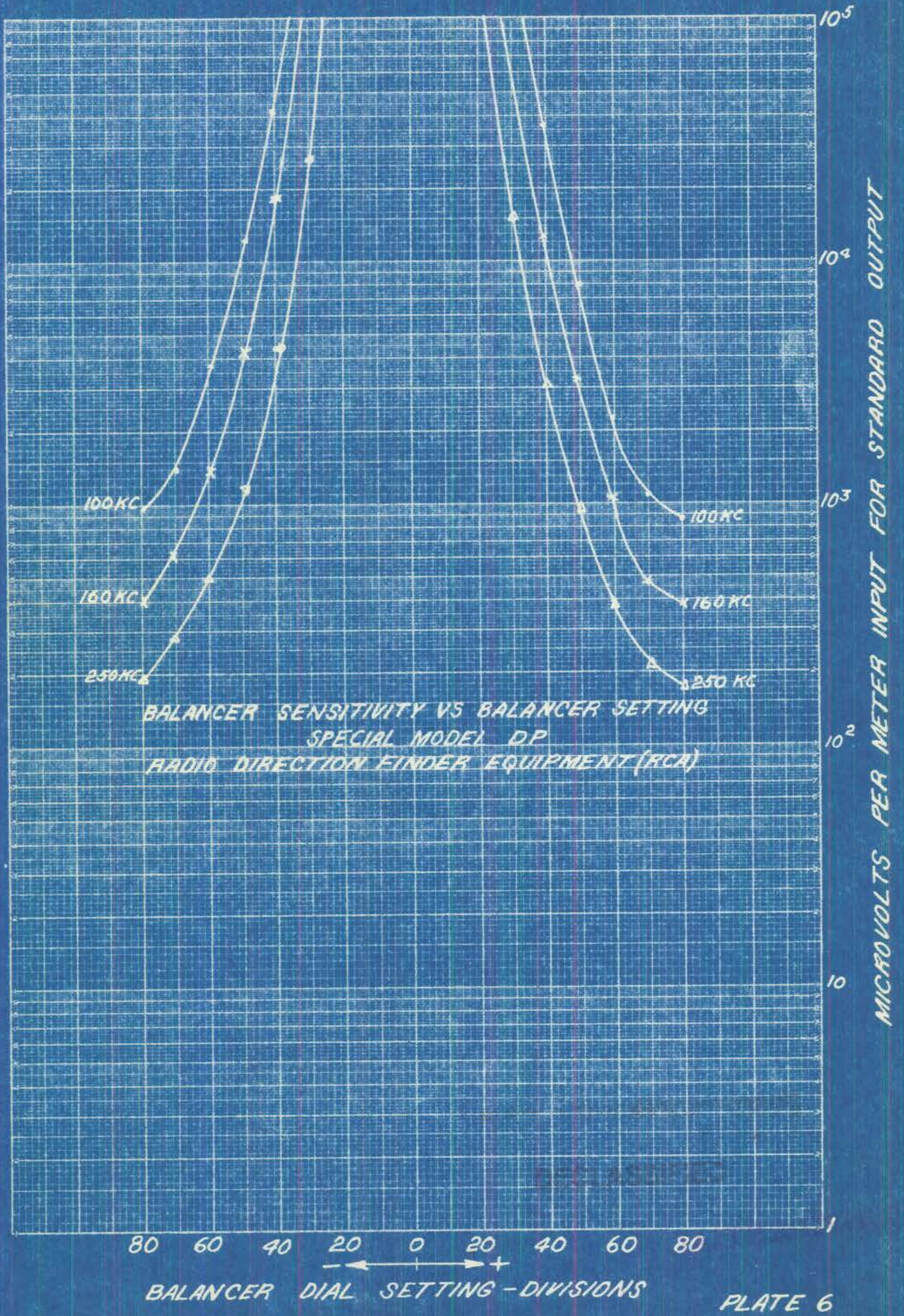

BALANCER SENSITIVITY VS BALANCER SETTING
SPECIAL MODEL DP
RADIO DIRECTION FINDER EQUIPMENT (RCA)
100 KC
160 KC
250 KC
100 KC
160 KC
250 KC
10^5
10^4
10^3
10^2
10
1
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT
80
60
40
20
0
20
40
60
80
−
+
BALANCER DIAL SETTING - DIVISIONS

PLATE 6

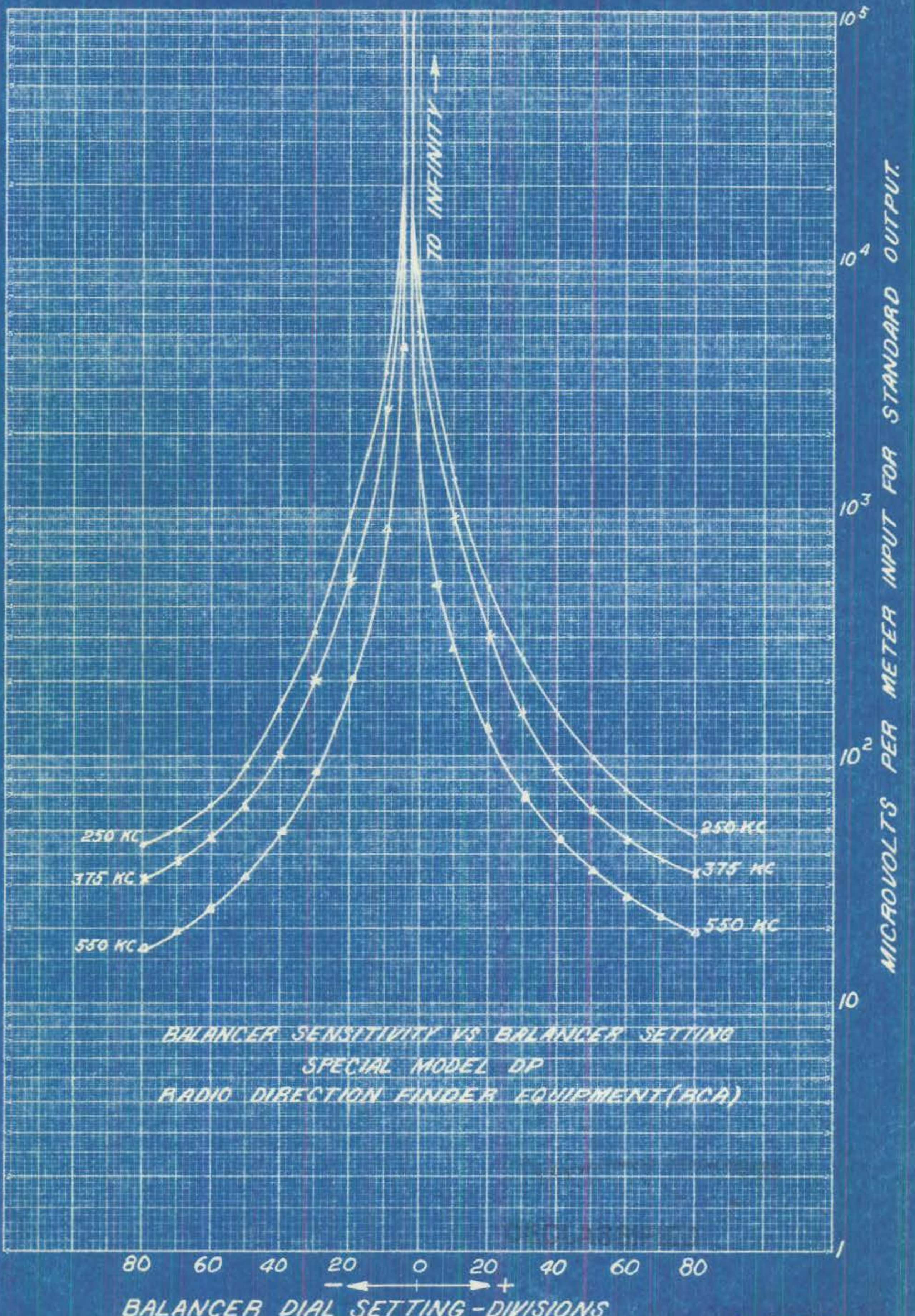

TO INFINITY
250 KC
375 KC
550 KC
250 KC
375 KC
550 KC
10^5
10^4
10^3
10^2
10
1
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT.
BALANCER SENSITIVITY VS BALANCER SETTING
SPECIAL MODEL DP
RADIO DIRECTION FINDER EQUIPMENT (RCA)
80 60 40 20 0 20 40 60 80
− +
BALANCER DIAL SETTING - DIVISIONS

PLATE 7

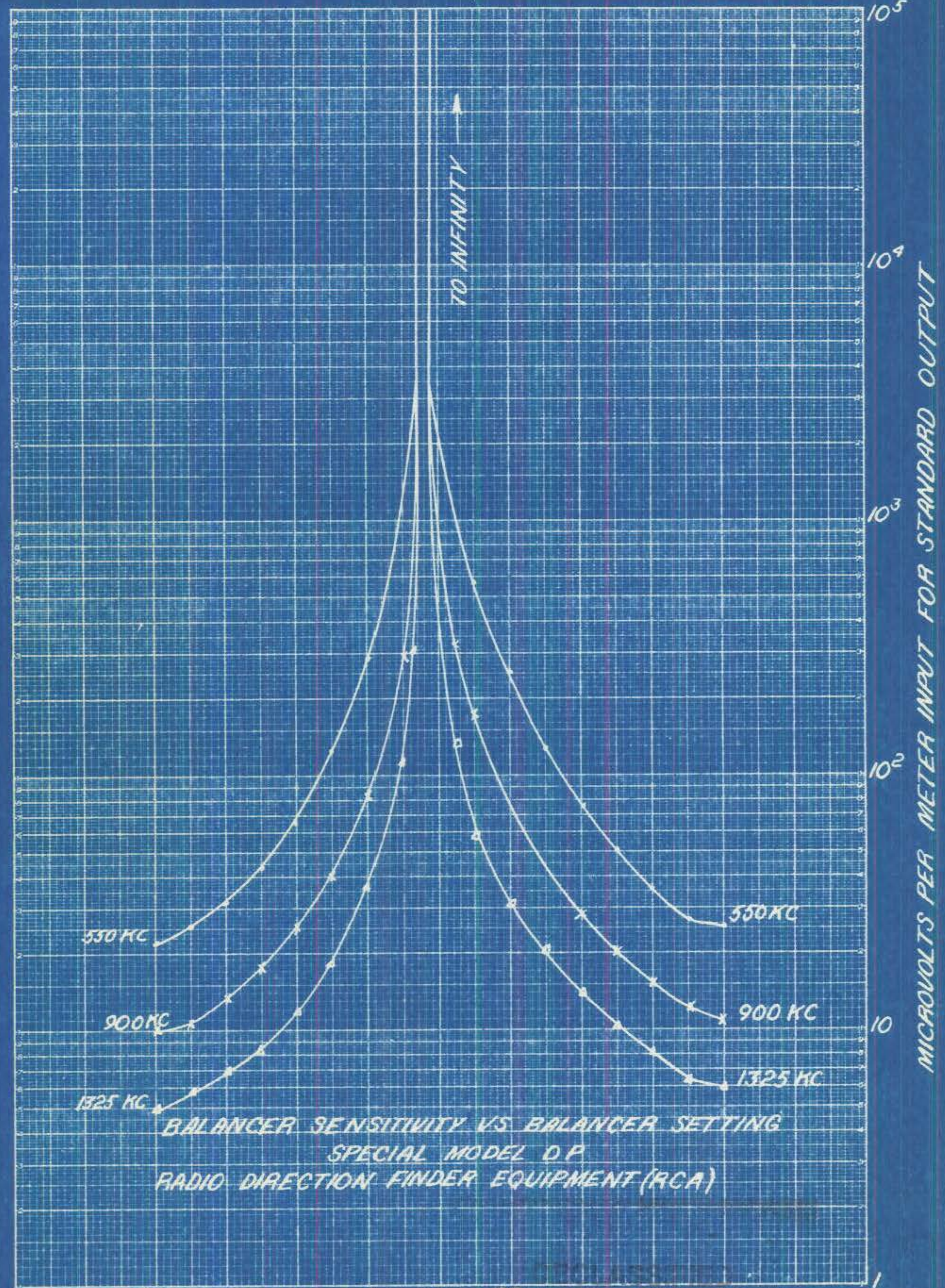
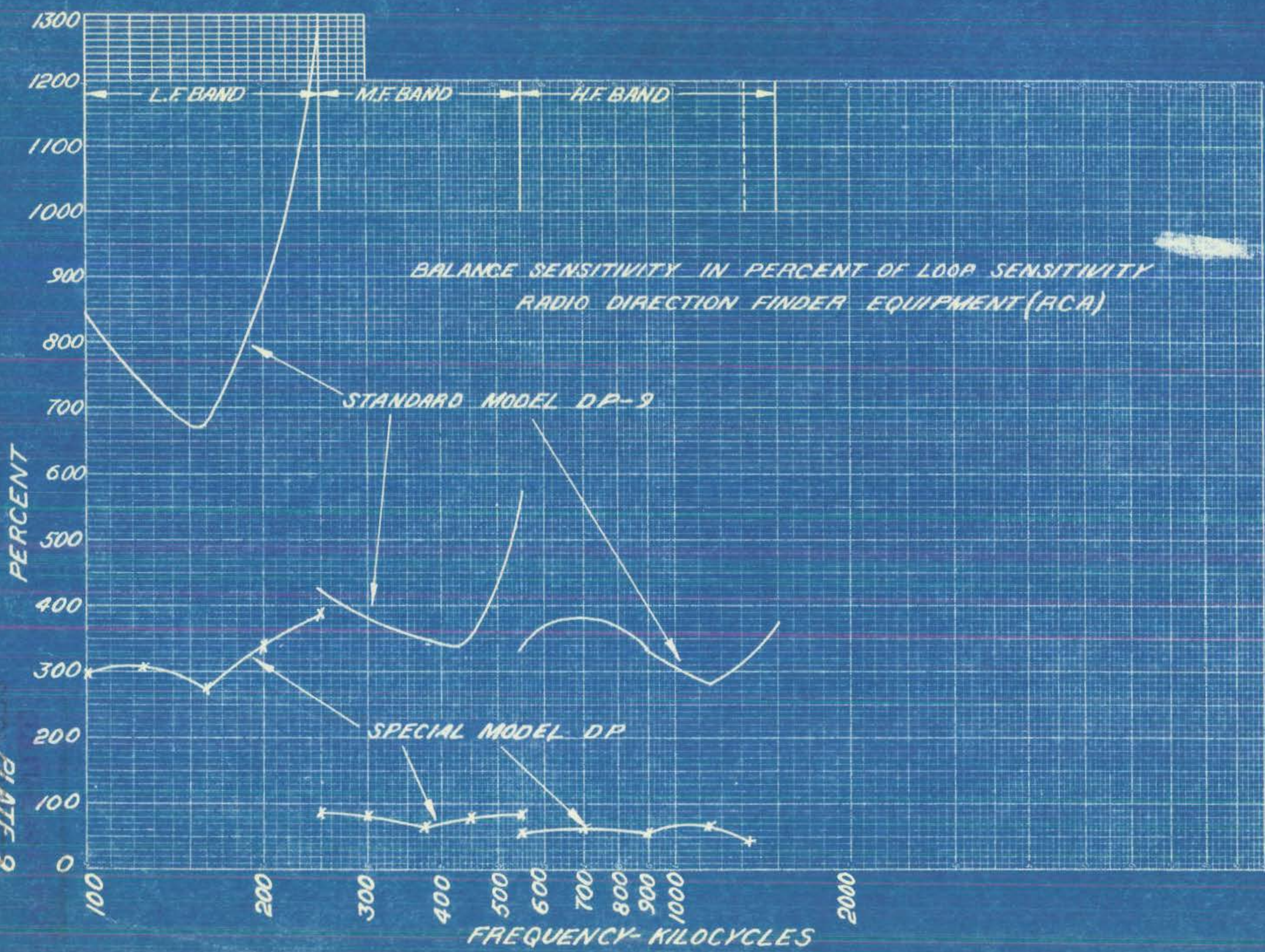

TO INFINITY
550 KC
900 KC
1325 KC
550 KC
900 KC
1325 KC
BALANCER SENSITIVITY VS BALANCER SETTING
SPECIAL MODEL DP
RADIO DIRECTION FINDER EQUIPMENT (RCA)
10^5
10^4
10^3
10^2
10
1
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT
80 60 40 20 0 20 40 60 80
− +
BALANCER DIAL SETTING - DIVISIONS

PLATE 8



BALANCE SENSITIVITY IN PERCENT OF LOOP SENSITIVITY
RADIO DIRECTION FINDER EQUIPMENT (RCA)
L.F. BAND
M.F. BAND
H.F. BAND
STANDARD MODEL DP-9
SPECIAL MODEL DP
PERCENT
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
100
200
300
400
500
600
700
800
900
1000
2000
FREQUENCY- KILOCYCLES

PLATE 9

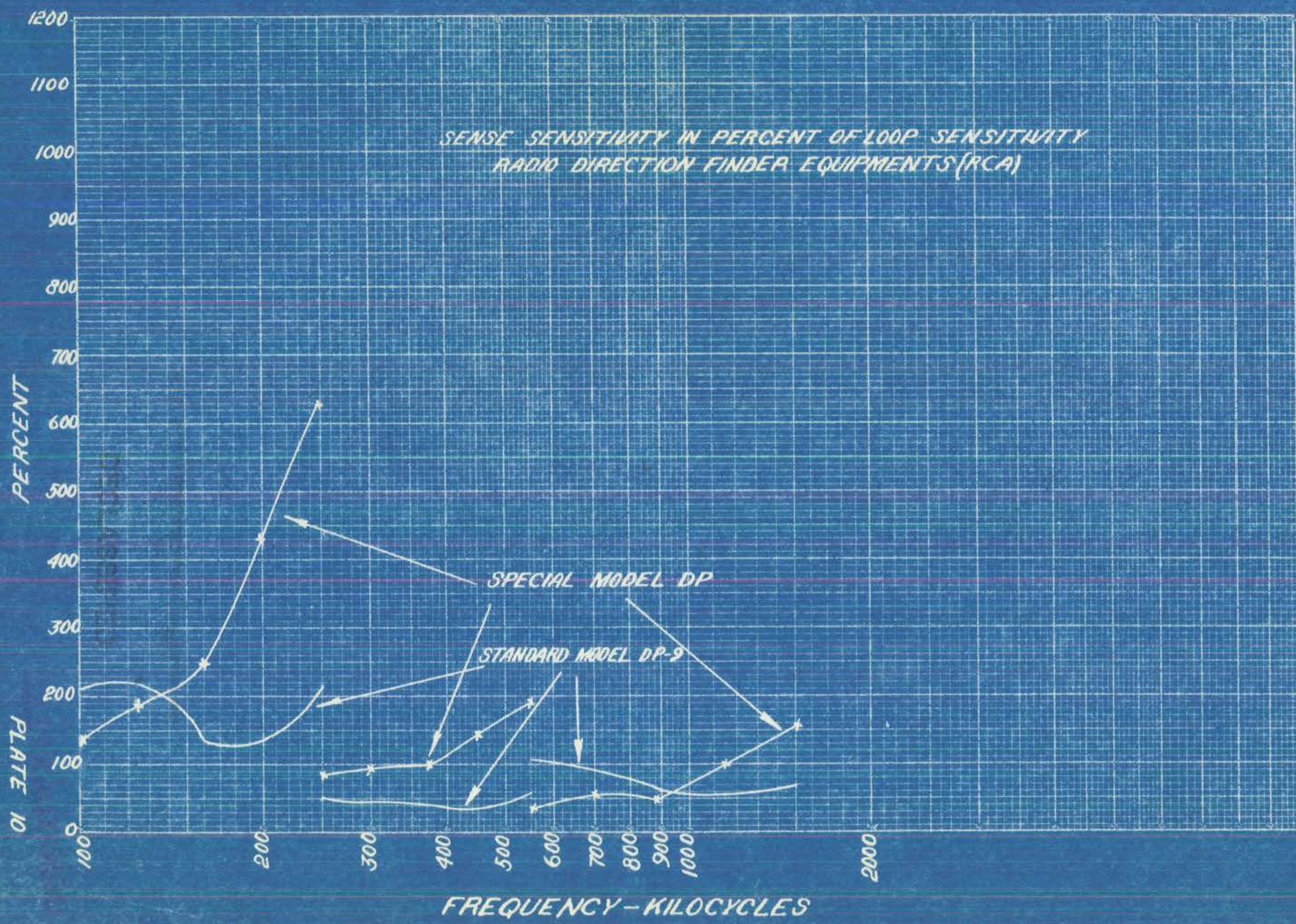

SENSE SENSITIVITY IN PERCENT OF LOOP SENSITIVITY
RADIO DIRECTION FINDER EQUIPMENTS (RCA)
SPECIAL MODEL DP
STANDARD MODEL DP-9
PERCENT
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
100
200
300
400
500
600
700
800
900
1000
2000
FREQUENCY - KILOCYCLES

PLATE 10

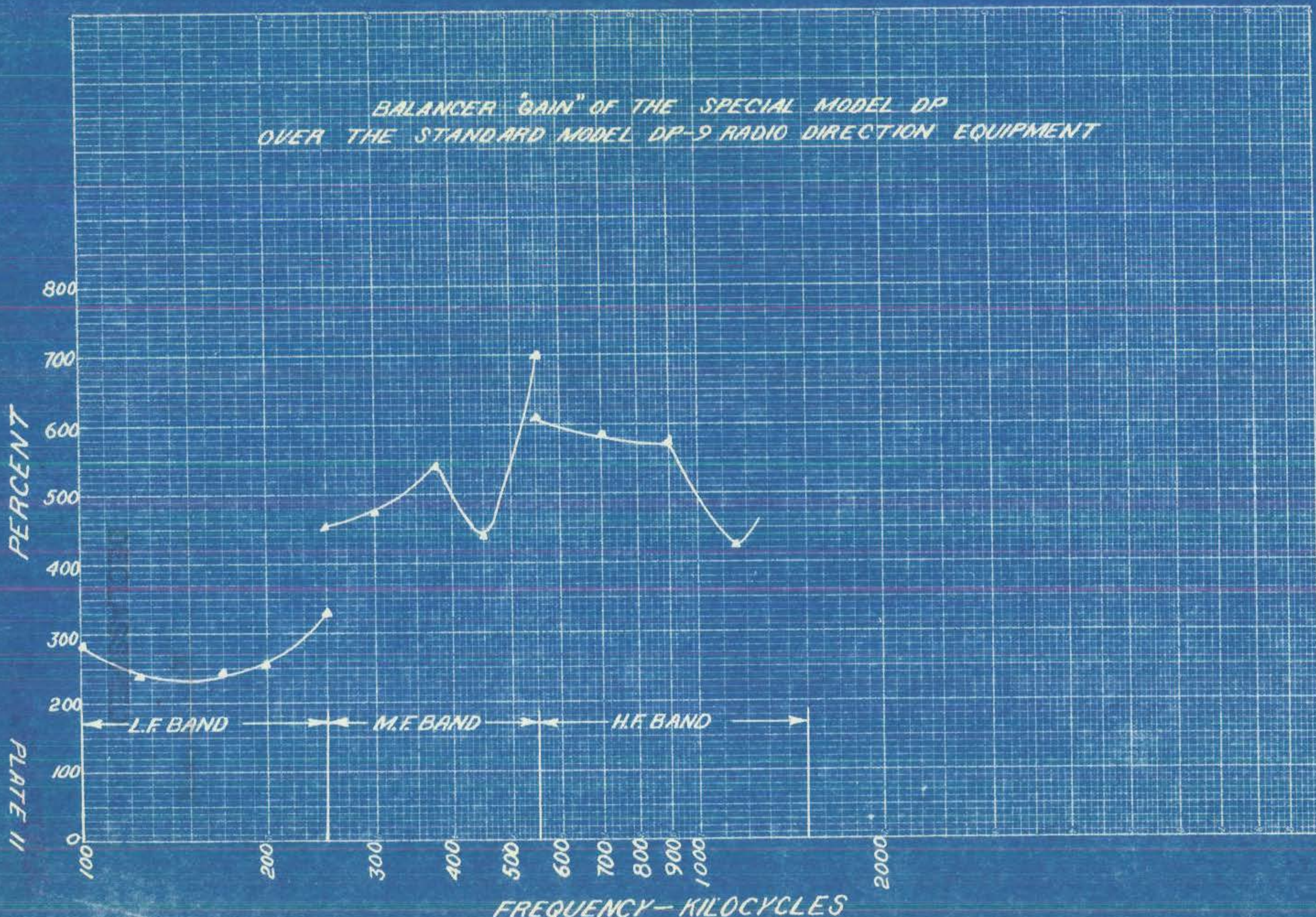
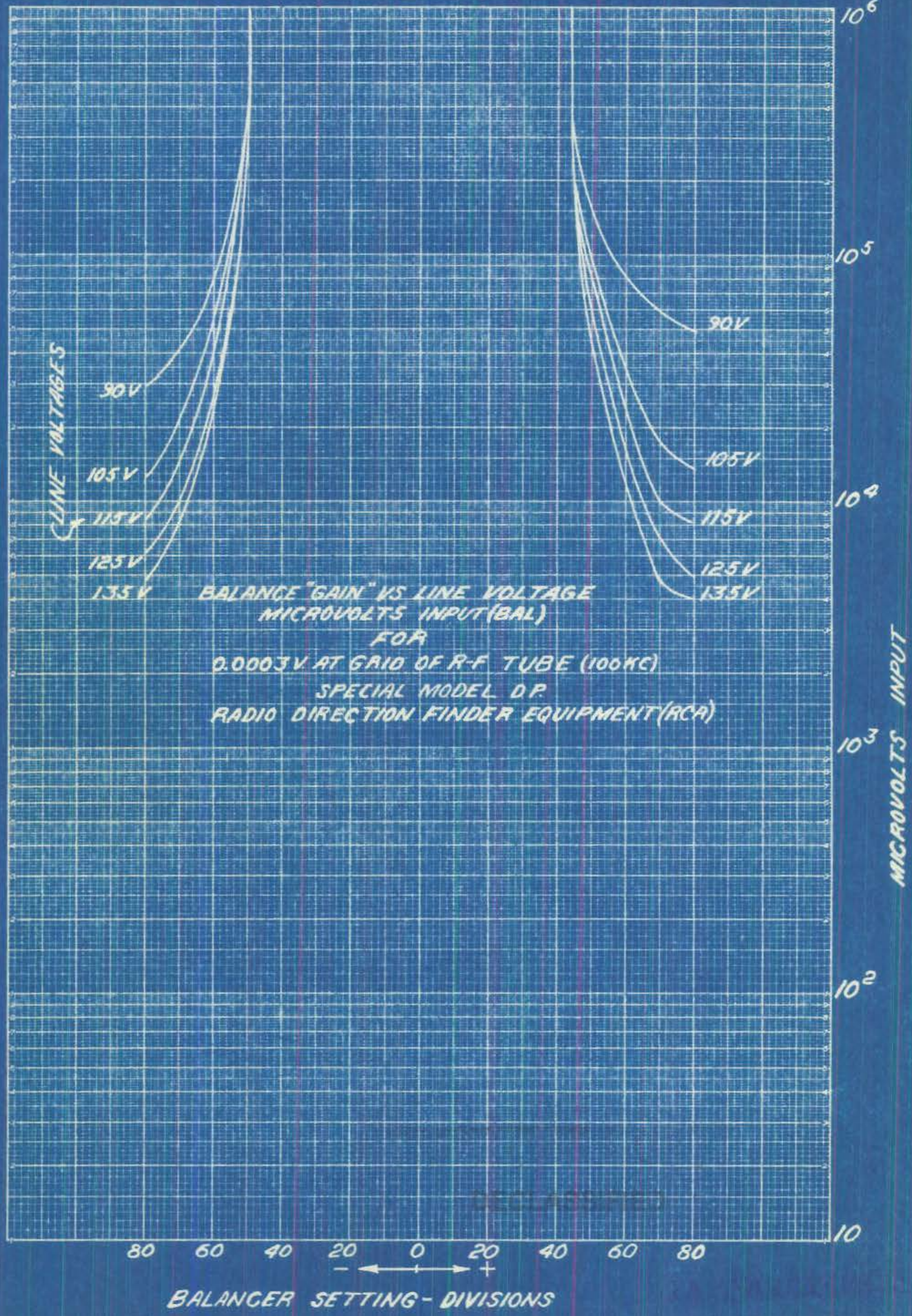

BALANCER "GAIN" OF THE SPECIAL MODEL DP
OVER THE STANDARD MODEL DP-9 RADIO DIRECTION EQUIPMENT
PERCENT
800
700
600
500
400
300
200
100
0
L.F BAND
M.F BAND
H.F BAND
100
200
300
400
500
600
700
800
900
1000
2000
FREQUENCY—KILOCYCLES

PLATE II



BALANCE "GAIN" VS LINE VOLTAGE
MICROVOLTS INPUT (BAL)
FOR
0.0003 V AT GRID OF R-F TUBE (100KC)
SPECIAL MODEL DP
RADIO DIRECTION FINDER EQUIPMENT (RCA)
LINE VOLTAGES
90V
105V
115V
125V
135V
MICROVOLTS INPUT
10^6
10^5
10^4
10^3
10^2
10
80 60 40 20 0 20 40 60 80
− +
BALANCER SETTING - DIVISIONS

PLATE 12

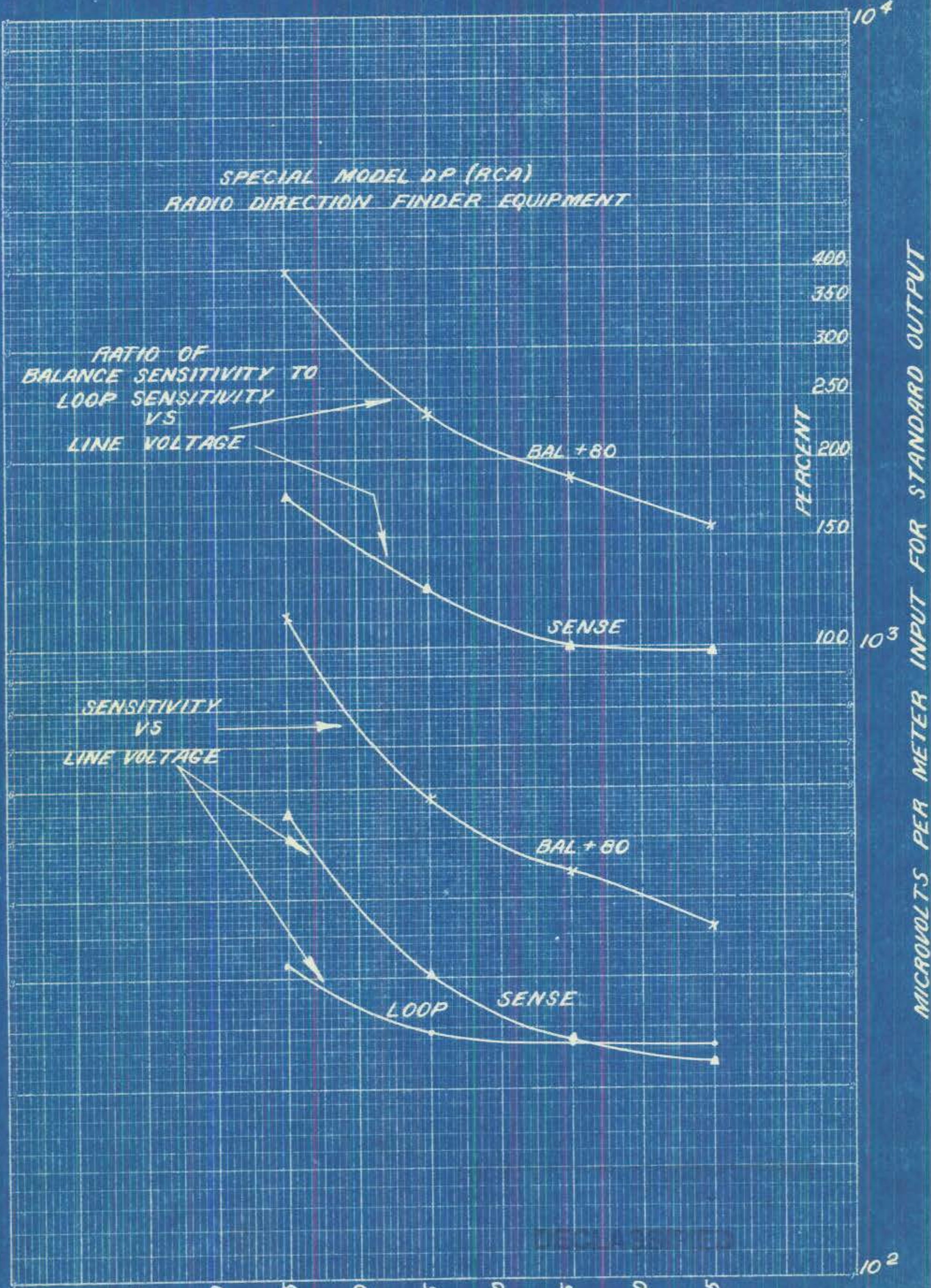

SPECIAL MODEL DP (RCA)
RADIO DIRECTION FINDER EQUIPMENT
RATIO OF BALANCE SENSITIVITY TO LOOP SENSITIVITY VS LINE VOLTAGE
BAL +80
SENSE
SENSITIVITY VS LINE VOLTAGE
BAL + 80
LOOP
SENSE
PERCENT
400
350
300
250
200
150
100
10^4
10^3
10^2
95
100
105
110
115
120
125
130
135
LINE VOLTAGE
MICROVOLTS PER METER INPUT FOR STANDARD OUTPUT
DECLASSIFIED

PLATE 13

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

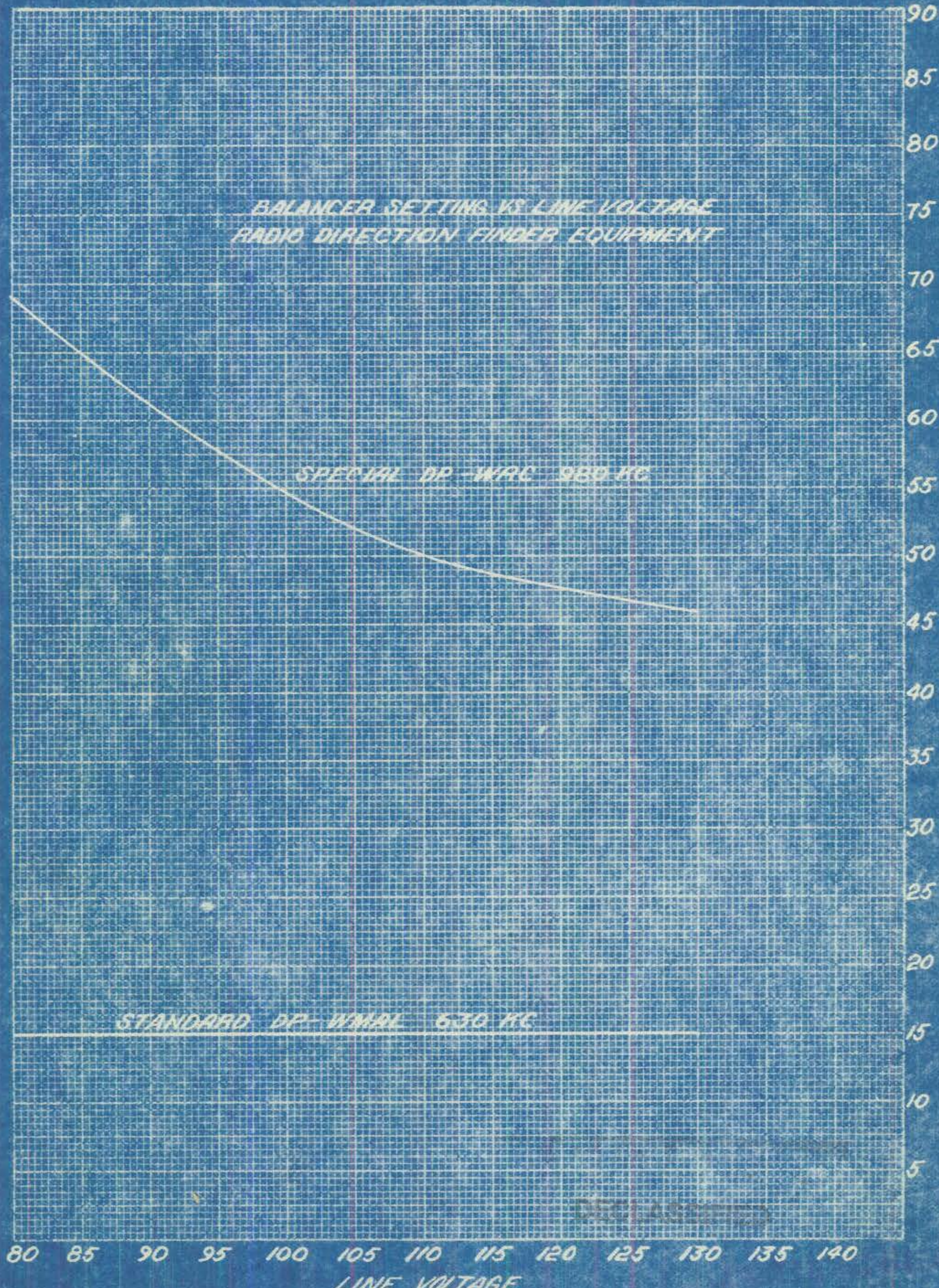


PLATE 14

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

N. R. L. 34A

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

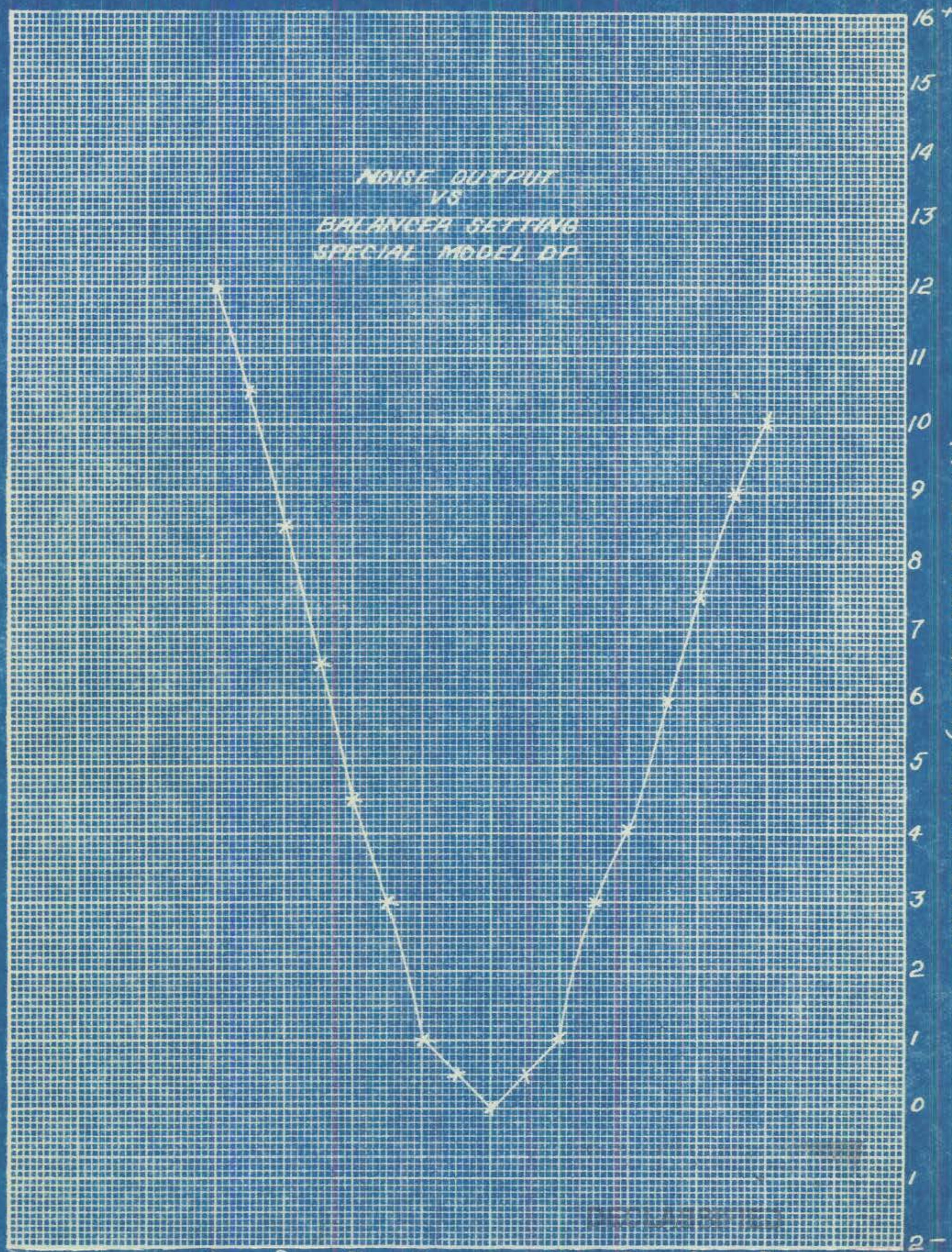


PLATE 15

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

N. R. L. 31A

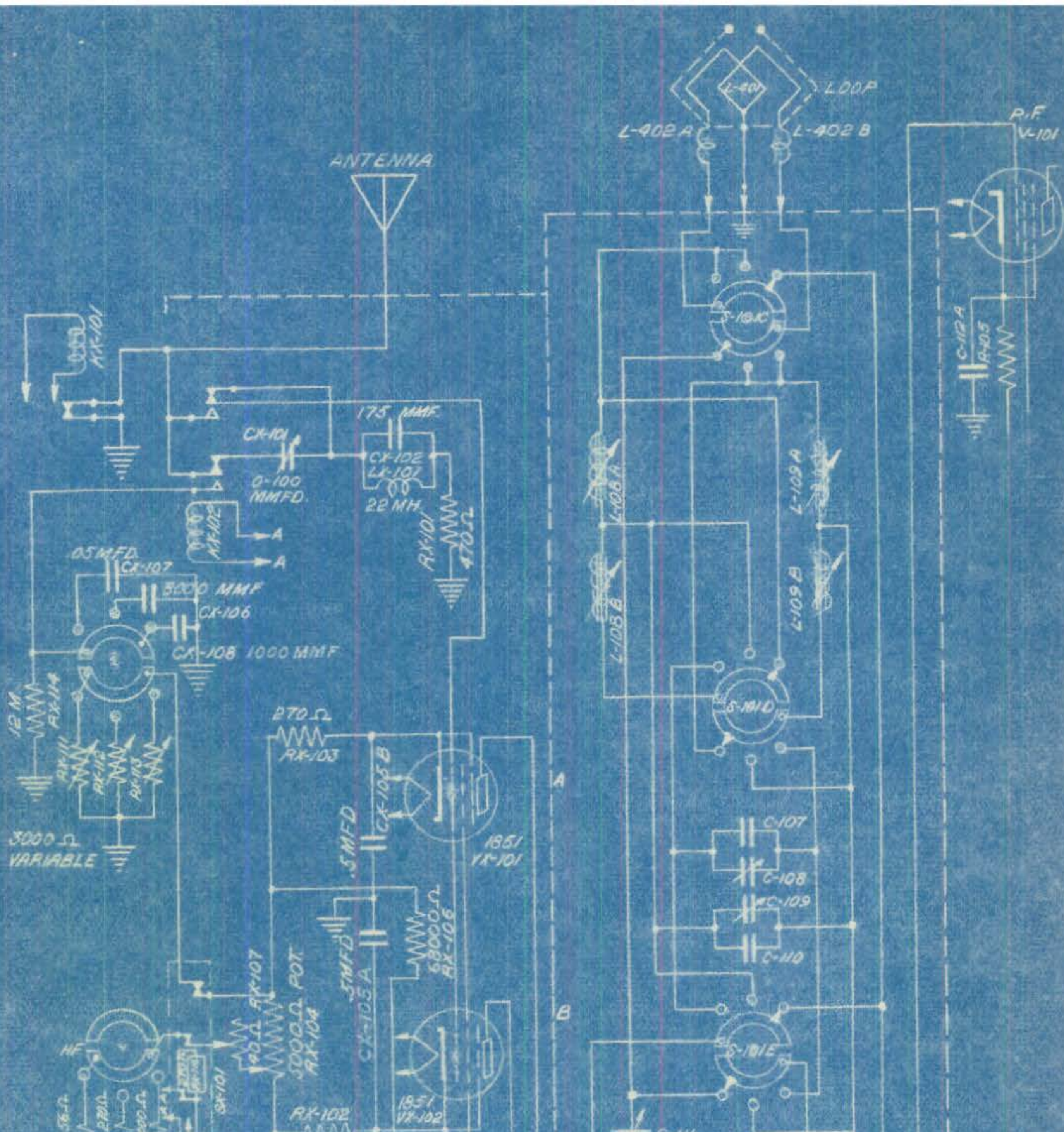
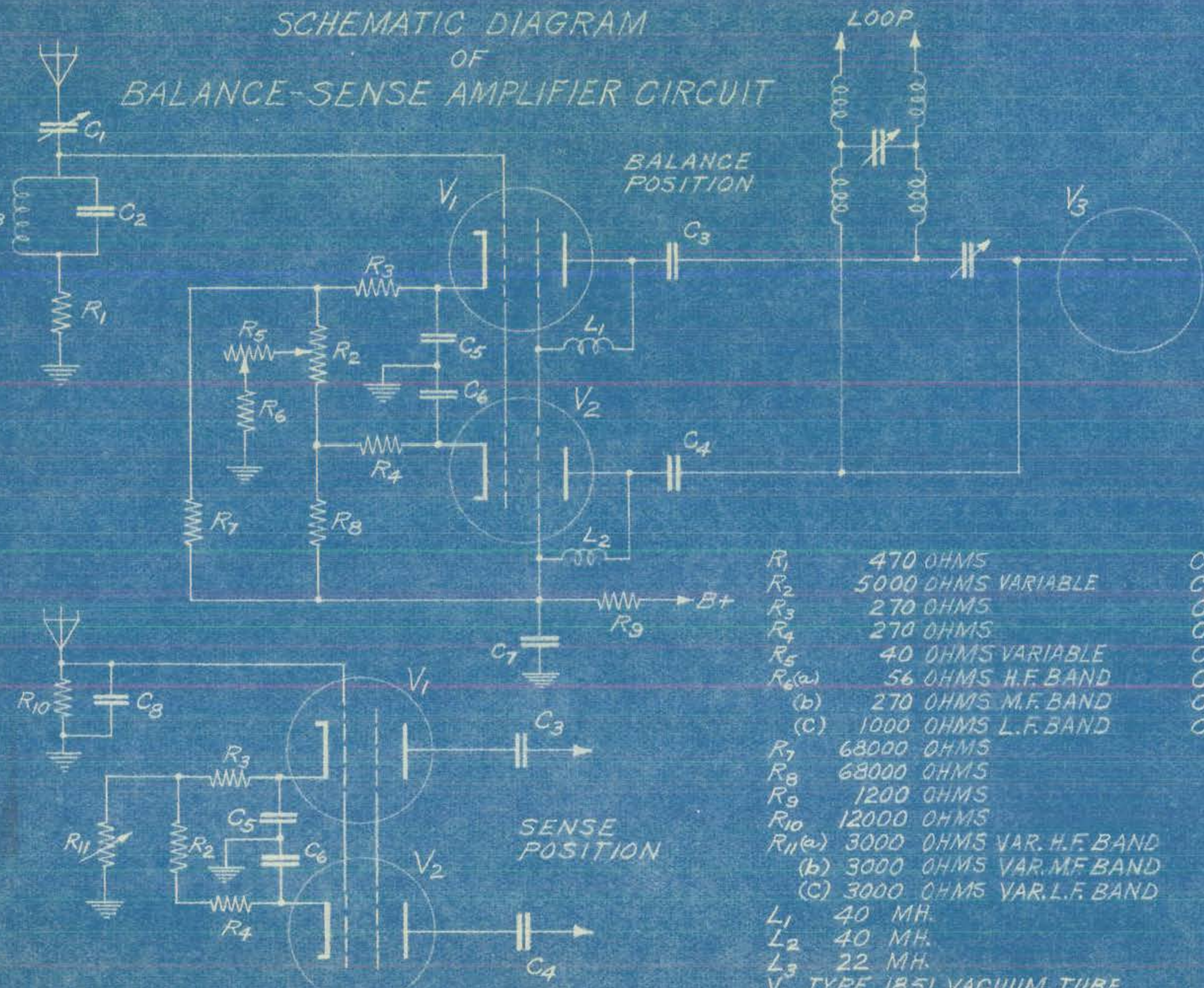


PLATE 16

DECLASSIFIED

SCHEMATIC DIAGRAM
OF
BALANCE-SENSE AMPLIFIER CIRCUIT



R_1	470	OHMS
R_2	5000	OHMS VARIABLE
R_3	270	OHMS
R_4	270	OHMS
R_5	40	OHMS VARIABLE
R_6 (a)	56	OHMS H.F. BAND
(b)	270	OHMS M.F. BAND
(C)	1000	OHMS L.F. BAND
R_7	68000	OHMS
R_8	68000	OHMS
R_9	1200	OHMS
R_{10}	12000	OHMS
R_{11} (a)	3000	OHMS VAR. H.F. BAND
(b)	3000	OHMS VAR. M.F. BAND
(C)	3000	OHMS VAR. L.F. BAND
L_1	40	MH.
L_2	40	MH.
L_3	22	MH.
V_1	TYPE 1851 VACUUM TUBE	
V_2	TYPE 1851 VACUUM TUBE	
V_3	1ST R-F TUBE	

C_1	0-100 µµf. VARIABLE
C_2	175 µµf.
C_3	0.02 µf.
C_4	0.02 µf.
C_5	0.5 µf.
C_6	0.5 µf.
C_7	1.0 µf.
C_8 (a)	1000 µµf. H.F. BAND
(b)	8000 µµf. M.F. BAND
(C)	0.05 µf. L.F. BAND

PLATE 17