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NRL Report No. R-1475
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FR-1475

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report of Test of Model DV Direction Finder Equipment Serial No. 5 (Bendix Radio Corporation)

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

Number of Pages: Text - 7 Tables - 9 Plates - 3
Photographs - 5

Authorized by: BuEng. ltr. C-NOs-59120(7-6-W3) of 8 July 1938.

Date of Test: 12 July 1938 to 24 August 1938.

Prepared by: R. A. Gordon, Associate Radio Engineer

Reviewed by: A. Hoyt Taylor, Prin. Physicist
Superintendent, Radio Division

Approved by: H. M. Cooley, Captain, USN, Director

Distribution:
BuEng. (5)

bms

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APPENDICES
(A)

(B)

[redacted]

AUTHORIZATION

1. The tests herein reported were authorized by Bureau of Engineering letter, reference (a). Other pertinent correspondence is listed as references (b), (c) and (d).

Reference:
- (a) BuEng. let. C-NOs-59120(7-6-W3) of 8 July 1938.
- (b) RINM, Balto. 2nd end. L4-3/59120 of 27 July 1938 to BuEng.
- (c) BuEng. let. C-NOs-59120(8-18-Rcl) of 20 August 1938.
- (d) BuEng. conf. Specifications RE 13A 546A.

OBJECT OF TESTS

2. The object of these tests was to determine the suitability of the Model DV direction finder for use in naval aircraft.

ABSTRACT OF TESTS

3. These tests include measurements of efficiency over a temperature range of -32 to +54° C. with a relative humidity of 100%, comparison of the sensitivity with the Model RDF-2-A equipment, and observations of its operation as a unilateral and bilateral direction finder. The report of the Naval Air Station covering the equipment's operation during flight is contained in the appendix to this report.

Conclusions

(a) The use of a low impedance loop greatly increases the useful range of the equipment and probably offers a more dependable operation over conditions of high relative humidity.

(b) The incorporation of flexible couplings in the hydraulic system allows a more flexible operation and minimizes breakage and leakage due to vibration.

(c) The fact that the equipment requires a sense antenna whose length is critical for practical unilateral operation limits the use of the equipment to airplane installation wherein a separate antenna may be installed for use as the sense antenna. If it is desired to use this equipment in aircraft where it will be necessary to use the combined transmitter-receiver antenna for the sense antenna, then it will be necessary to modify the equipments' antenna circuit to permit practical unilateral operation, as a usable cardioid pattern cannot be obtained with the use of large antennas, the loop gain control becoming ineffective.

Recommendations

For Present Equipment

(a) The Model DV radio direction finder will be satisfactory for naval aircraft providing all the equipment is modified to conform to the modifications as made to Serial No. 5, tested at this Laboratory. These modifications are listed as follows:

(1) Change radio frequency transformers T102 and T103 to provide frequency overlap between bands 1, 2, and 3.

(2) Change band spread condenser (C107) to a loop compensating condenser.

(3) Install a small capacitor in the sense antenna circuit and provide a switch for shorting out this condenser when using a small antenna; switch should be labelled "Long-Short".

(4) Remove cadmium plating from tuning condenser C108 and plate with copper and then nickel.

(5) Effect all changes in mechanical and electrical defects as contained in reference (b).

(6) Instruction books should contain information as of modifications in sub-paragraphs (2) and (3).

For Future Equipment

(b) The specifications should require the equipment to give practical unilateral operation with sense antennas ranging in length from 6 feet to the full "V" antenna as used on large aircraft.

(c) The specifications should require optimum unilateral operation without the additional manual operation of detuning the loop.

[redacted]

EQUIPMENT UNDER TEST

4. The Model DV radio direction finding equipment was manufactured for the U.S. Navy by the Bendix Radio Corporation of Baltimore, Maryland. The equipment is designed to provide unilateral and bilateral bearings when using the Model RU receivers over a frequency range 220 to 1500 kilocycles. It is intended to be used on the large patrol planes which are equipped with large antennas. The equipment provides for operation at a remote point from the actual loop location by means of a hydraulic control, and incorporates an auto-syn mechanism for indication of loop setting. The equipment utilizes the cardiod principle for unilateral operation which gives an indication of the station bearing and then reverts to the bilateral loop operation for actual determination of the bearing.

5. The equipment consists of the following major components:

1 Hydraulic make up pump, Navy Type CEA-23129			
1 Hydraulic loop control unit, Navy	Type		CEA-23129
1 Hydraulic loop rotator,	"	"	CEA-23127
1 Azimuth position indicator,	"	"	CPO-22261
1 Coupler unit,	"	"	CRR-55051
1 Plug-in loop,	"	"	CRR-69025
1 Vacuum tube,	"	"	CRC-38667

METHOD OF TEST

6. The equipment was set up in the field and bearings taken on known station locality. The accuracy of these bearings was noted. The operation of the equipment as a unilateral direction finder was noted with various size antennas. The equipment was operated under temperatures ranging from -32 to +54° C. with a relative humidity of 100%. During this test the sensitivity of the equipment was observed for moisture effect. The sensitivity was compared with the Model RDF-2-A direction finder by recording the field strength necessary to produce like outputs on each equipment. In conducting this test, the Model DV was tuned to the signal with the loop in position of maximum and the receiver output adjusted to 50 milliwatts output and the field strength recorded. The Model RDF-2-A was then tuned to the same signal and the loop set for maximum; the field strength was then varied until the receiver output regained the value of 50 milliwatts and the field strength recorded. These tests were made with both equipment installed in a Type XRE-1 airplane and located approximately 2 miles from the transmitter. The tests made on unilateral and bilateral operation were conducted in the field approximately 100 yards from any antennas or metal towers. A vertical, low capacity antenna was employed for the sense antenna. The equipment was thus operating under ideal conditions and the results of the tests should be regarded as the optimum performance of the equipment.

DATA RECORDED DURING TESTS

7. The data recorded during these tests include measurement of the loop distributed capacity and natural frequency, the power required to operate the equipment, the unilateral and bilateral ratios, the sensitivity compared to the Model RDF-2-A, frequency band overlap, accuracy of bearings and width of minima. Weights are also recorded. These data are presented under discussion of RESULTS.

DISCUSSION OF PROBABLE ERRORS

8. The accuracy of the field strength measurements is within 15%. All other measurements are accurate to 2%.

RESULTS

9. The results of these tests are discussed in accordance with Specification RE 13A 546A.

10. Effect of Temperature and Humidity. The equipment when subjected to temperature variations of from -32 to +54° C. showed the usual circuit detuning due to contraction and expansion of inductances and capacitors, the tuning being variable, however, permits the best performance of which the equipment is capable. The effect of humidity was to reduce the efficiency by 15% at a temperature of 54° C. and a relative humidity in excess of 95%. The efficiency was stable again after a drying out period of 90 minutes at 50° C. It is considered that this 15% loss in efficiency is not excessive and is not a serious detriment to the satisfactory operation of the equipment due to its ability in returning to a stable performance after passing through a condition of condensation. The results of this test are contained in Plate 1.

11. At temperatures from -20 to -32° C. the azimuth control unit developed a back lash of 3°. This does not affect the synchronizing or accuracy of the azimuth indicators and is purely a loss in movement of the mechanical control.

12. Power Consumption. The power consumed by the equipment is shown in Table 1. The azimuth control power consumption of 27 VA is 8% greater than specified in paragraph 5-16(3) of reference (d), but is not considered detrimental as the power supply is capable of handling this small increase.

13. Loop Distributed Capacity. The distributed capacity of the low impedance loop complies with that specified in reference (d), paragraph 4-4. The data are contained in Table 2.

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14. "Q" of the Loop. The "Q" of the loop was measured and found to be as specified by reference (d); the values are contained in Table 3.

15. Weight of Equipment. The weight of the equipment is as follows:

Loop, hydraulic controls and fluid	21.3 lbs.
Cables and junction boxes	8.3 lbs.
Coupler, base and azimuth indicator	5.9 lbs.
Total weight	35.5 lbs.

The extra 1/2 pound is compensated for by the incorporation of the manual loop rotating and locking control.

16. Continuous frequency range. The loop tuning circuit comprises a variable condenser and three radio frequency loop coupling transformers. These transformers are selected by a 3-position band switch located on the front panel of the coupling unit. The frequency ranges of these transformers provide sufficient overlap, the frequency range of each tap being contained in Table 4.

17. Unilateral Operation. When the equipment was initially tested, its operation as a unilateral direction finder was not considered satisfactory. In order to obtain unilateral maximum to minimum ratios of better than 2.5/1 it was necessary to detune the loop. The amount of loop detuning was considered excessive on account of the loss in efficiency when switching to bilateral without retuning the loop, the output being reduced from 32 to 51% over the band 200 to 1500 kilocycles.

18. A representative of the contractor, upon the request of the Naval Research Laboratory, remedied this objection by using the band spread condenser (C107) as a loop compensating capacity. This permits of efficient operation on bilateral after the usual tuning procedure of the T position and eliminates the added tuning operation.

19. Proper unilateral operation was obtained after the above circuit change was made when a suitable antenna was used. Vertical antennas ranging in length from 2 to 20 feet were tried. An 8 foot vertical antenna gave the best results, maximum to minimum ratios as high as 80/1 being obtained. Antennas longer than 8 feet necessitated the use of a series capacity in order to obtain effective loop gain control for positive unilateral indication while antennas under 8 feet in length gave insufficient ratios ranging from 1.6/1 to 2.5/1.

20. It is necessary to slightly detune the loop to obtain optimum unilateral performance; however, without detuning the loop, satisfactory operation is obtainable as is shown in Table 5.

21. Unilateral-Bilateral Maximum. Using the 8 foot vertical antenna, the unilateral and bilateral maximums were in accordance with reference (d) and the data obtained are contained in Table 6. The response curve of the loop with rotation is shown in Plate 2. The polar patterns on both unilateral and bilateral are shown in Plate 3.

22. Antenna circuit losses. When the equipment is operated in the R position, the sense antenna is connected through the coupler unit to the receiver input by means of a low capacity-low loss transmission line. The sensitivity of the equipment compared to that when the antenna is connected directly to the receiver complies with reference (d) and the data are contained in Table 7.

23. Bilateral operation. Operating on the bilateral position, the equipment's performance was excellent. Accurate beatings were observed over the frequency range with sharp, well defined minima and complete elimination of antenna effect as can be seen from the data obtained on the ambiguity of the bearings contained in Table 8.

24. Sensitivity Comparison. The sensitivity of the Model DV equipment was compared to that of the Model RDF-2-A direction finder. The sensitivity of the Model DV equipment was considerably greater than that of the Model RDF-2-A ranging from 45 to 200% greater over the frequency range 220 to 1500 kilocycles. The improvement of the low impedance loop and low loss matched transmission line coupling and r-f coupling transformers is clearly shown by the rapid increase in sensitivity over that of the RDF-2-A as the frequency increases. The values obtained are tabulated and contained in Table 9.

25. Mechanical and electrical inspection. Several features of this equipment, both mechanical and electrical, were objectionable to this Laboratory. These points were discussed with the Resident Inspector of Naval Material, Baltimore, at a conference at this Laboratory on 21 July 1938, the results of which are contained in reference (b) and in which the Laboratory concurs.

26. Subsequent to the above discussion, the Naval Aircraft Factory recommended that the coupler unit tuning condenser, having cadmium plated plates, was not considered satisfactory for Naval use as the cadmium plate tends to "grow" and eventually renders the condenser inoperative. The contractor furnished the Laboratory with two condensers to be tested in order to determine which type would be suitable for Naval use.

27. These condensers were given an accelerated test by subjection to hot salt water spray. One type consisted of having nickel plate upon the cadmium plate. This type proved to be unsatisfactory as the nickel plate flaked off due to the growing process of the cadmium and rendered the condenser unusable after a period of 2 hours.

The remaining condenser consisted of having the cadmium plate removed by acid treatment, then the clean brass plates were copper plated, followed by nickel plating. This successfully withstood the same treatment and showed no evidence of flaking or corrosion on plates after a period of 20 hours.

28. The Bureau of Engineering was advised of the acceptability of the copper-nickel process and the contractor was so notified by reference (c). A photograph of these condensers is attached to this report.

CONCLUSIONS

29. The use of a low impedance loop greatly increases the useful range of the equipment and probably offers a more dependable operation over conditions of high relative humidity.

30. The incorporation of flexible couplings in the hydraulic system allows a more flexible operation and minimizes breakage and leakage due to vibration.

31. The fact that the equipment requires a sense antenna whose length is critical for practical unilateral operation limits the use of the equipment to airplane installation wherein a separate antenna may be installed for use as the sense antenna. If it is desired to use this equipment in aircraft where it will be necessary to use the combined transmitter-receiver antenna for the sense antenna, then it will be necessary to modify the equipments' antenna circuit to permit practical unilateral operation, as a usable cardioid pattern cannot be obtained with the use of large antennas, the loop gain control becoming ineffective.

TABLE 1

Azimuth Control (800 Cycles)			Vacuum Tube (DC)		
Volts	Amperes	VA	Volts	Amperes	Watts
120	.225	27	12	.285	3.42
			200	.010	2.0

TABLE 2

Loop Distributed Capacity

Loop distributed capacity	18 mmf
Loop natural frequency	4900 kcs

TABLE 3

"Q" of Loop

Loop clear	2000 kcs	Q = 154
Loop to shield	2000 kcs	Q = 150

TABLE 4

Frequency Range

Tap 1	211 - 500 kilocycles
Tap 2	475 - 755 "
Tap 3	751 - 1586 "

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TABLE 5

Unilateral Operation

Sense Antenna 8 Ft. Vertical

Station	Freq. Kcs.	Receiver Volts Output Min.	Receiver Volts Output Max.	Max. to Min. Ratio	Max. to Min. Ratio (detuning loop)
WA	332	.1	3	30	37
WMAL	630	.1	4.5	45	49
WRC	950	.2	12	60	72
WBAL	1160	.1	1.4	14	19
WJSV	1460	.2	12.6	63	70

The width of the minima ranged from 3 to 5 degrees.

TABLE 6

Unilateral-Bilateral Maximum

Station	Freq. Kcs.	Receiver Volts Output Unilateral (D)	Bilateral (B)	D% of B Maximum
WA	332	2.5	10	25
WMAL	630	1.9	10	19
WRC	950	2.8	10	28
WBAL	1160	2.1	10	21
WJSV	1450	3.2	10	32

TABLE 7

Antenna Circuit Losses

Freq. Kcs.	Antenna to Coupler Unit Output Volts	Antenna to Recr. Output Volts	% of Coupler to Antenna
332	8.6	10	86
630	7.8	10	78
710	7.0	10	70
950	8.4	10	84
1060	7.3	10	73
1450	8.4	10	84

TABLE 8

Bilateral Bearing Accuracy

Station	Freq. Kcs.	DV Bearing	True Bearing	Error	Reciprocal Bearing	Width of Minima
WBAL	1060	21°	21°	0°	200° (1°)	2°
WCAU	1170	49	47	2°	229° (0°)	4°
WRC	950	18	17	0°	197° (0°)	2°
WLW	700	274°	276°	2°	92° (2°)	6°
WOR	710	46°	48°	2°	225° (1°)	4°
WPG	1100	71°	71.5°	.5°	253° (2°)	4°

The output on the above bearings was 50 milliwatts in the maximum position.

TABLE 9

Sensitivity Comparison

Freq. Kcs.	DV Field Strength for 50 mw microvolts/meter	RDF-2-A Field Strength for 50 mw microvolts/meter	Field Strength Increase for RDF-2-A
365	279	398	42%
700	447	646	44%
1000	292	742	152%
1200	209	668	220%

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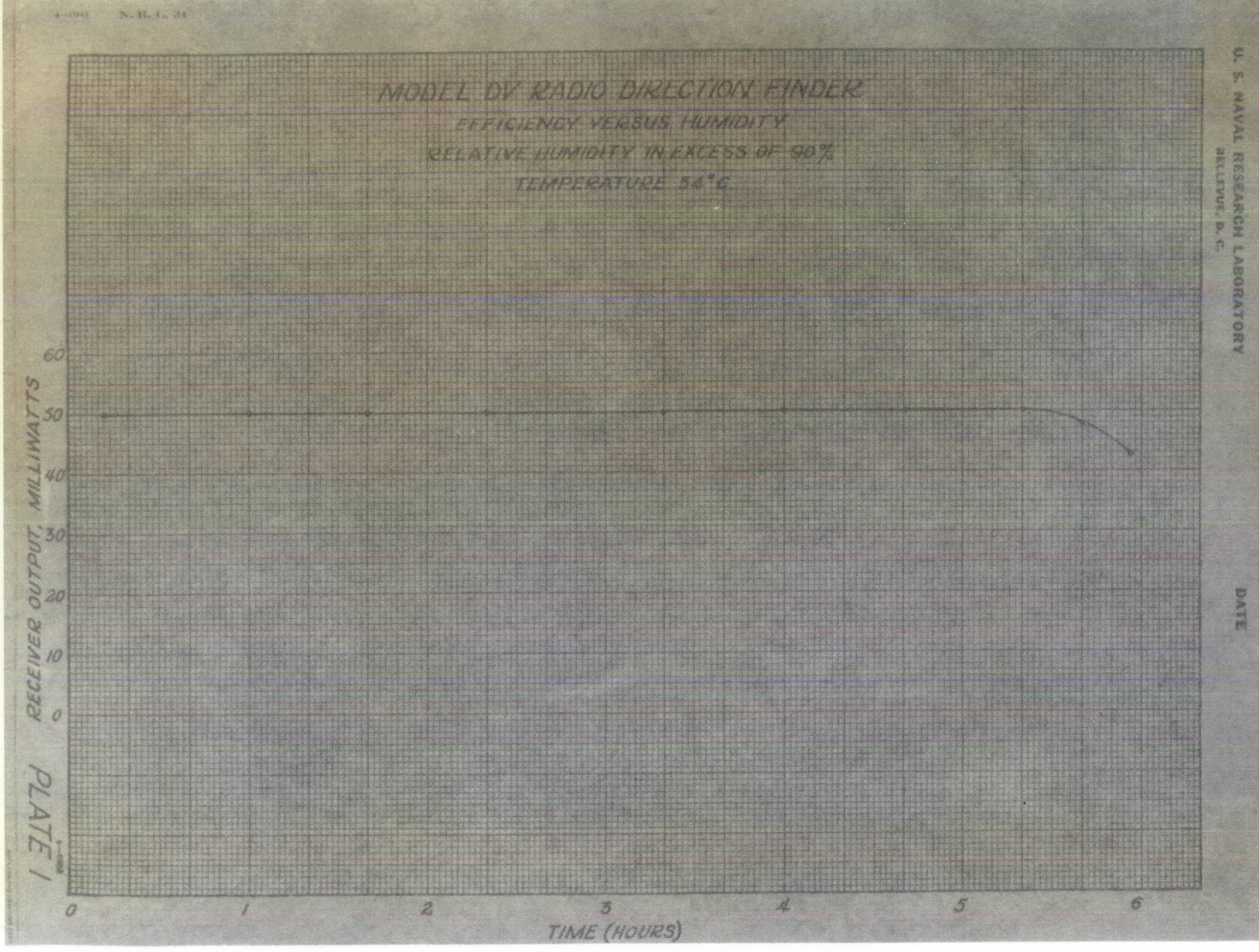

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.
DATE
N. R. L. 34
MODEL DV RADIO DIRECTION FINDER
EFFICIENCY VERSUS HUMIDITY
RELATIVE HUMIDITY IN EXCESS OF 90%
TEMPERATURE 34°C
RECEIVER OUTPUT, MILLIWATTS
60
50
40
30
20
10
0
TIME (HOURS)
0
1
2
3
4
5
6

PLATE I

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

DATE

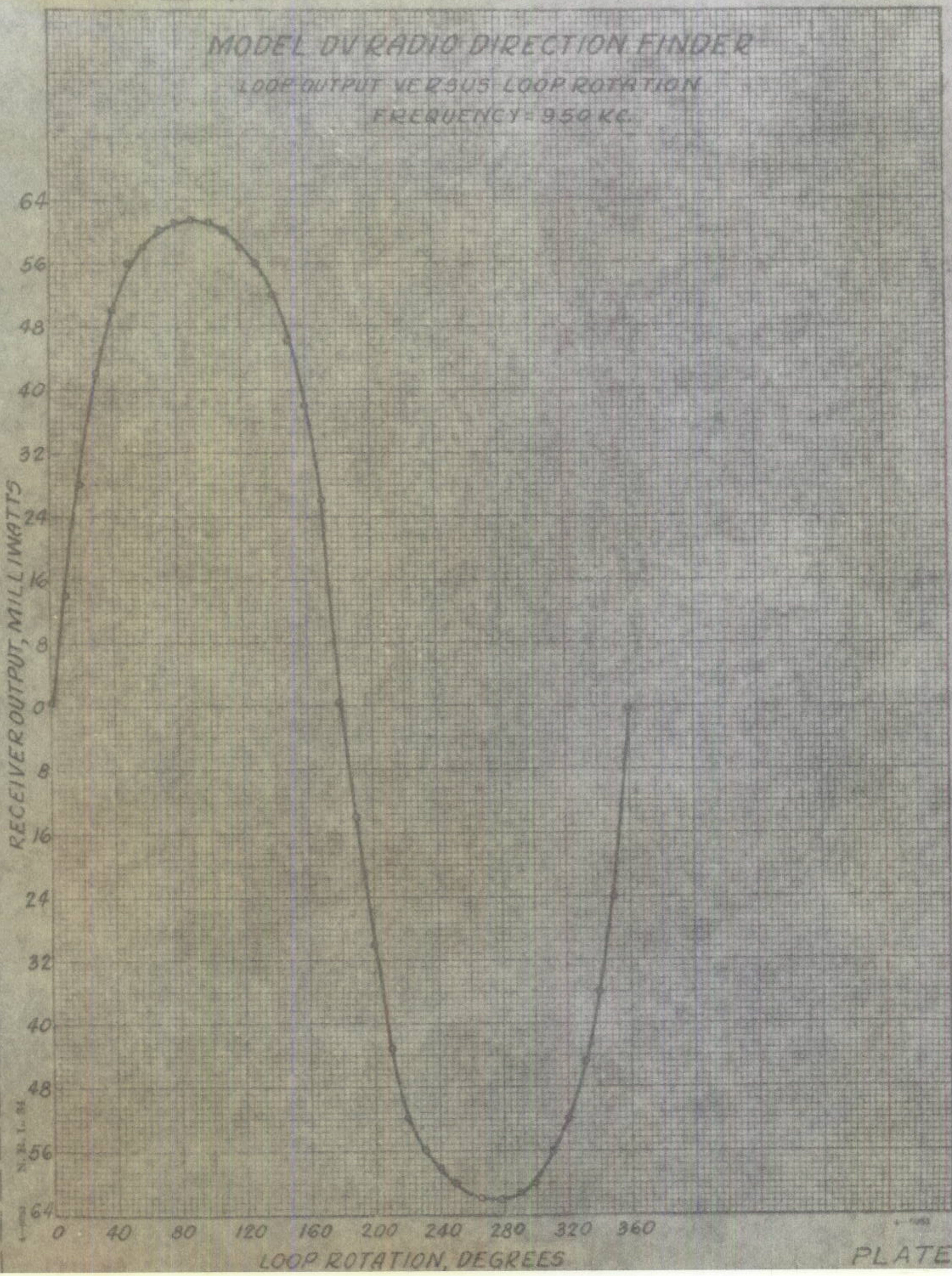


PLATE 2

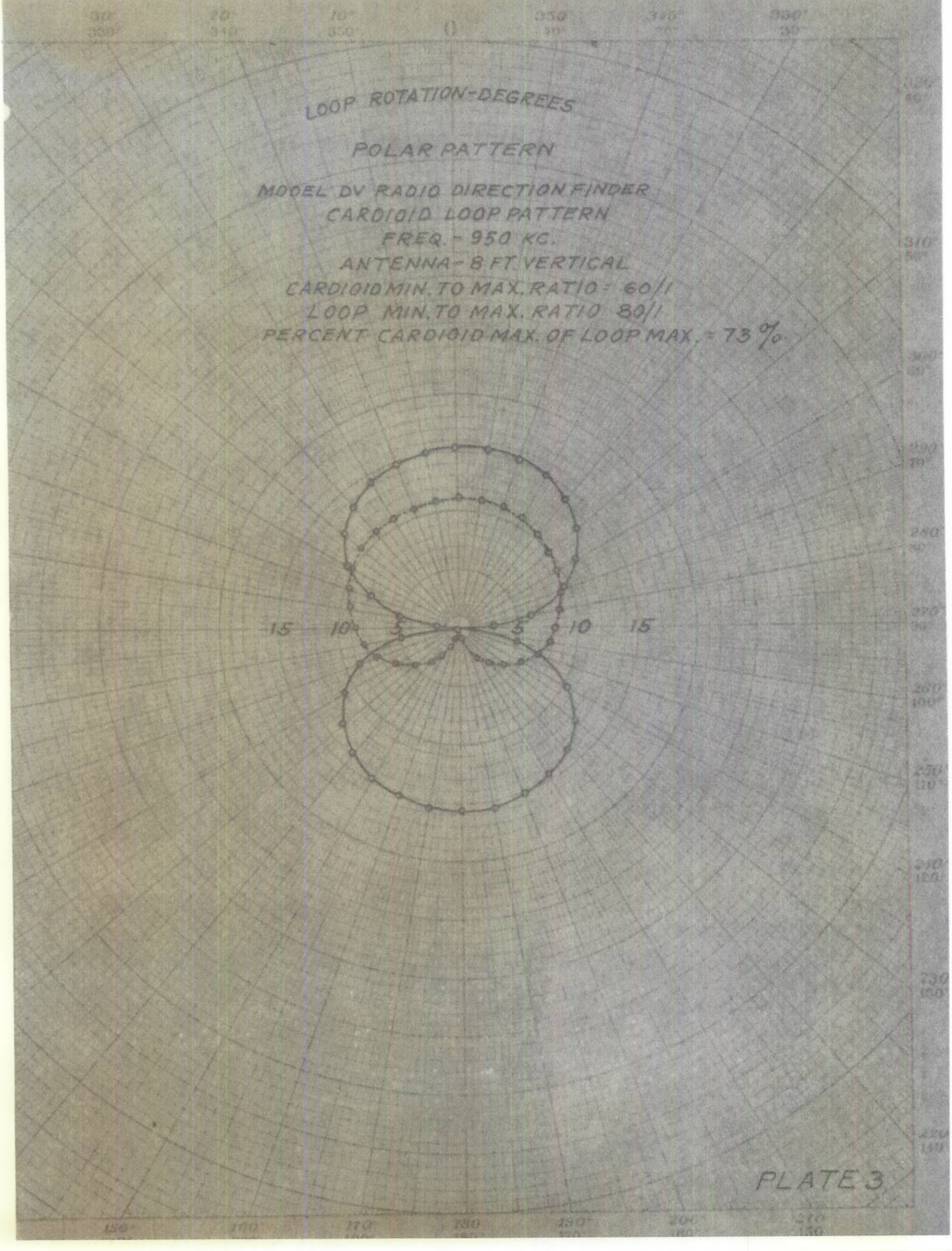
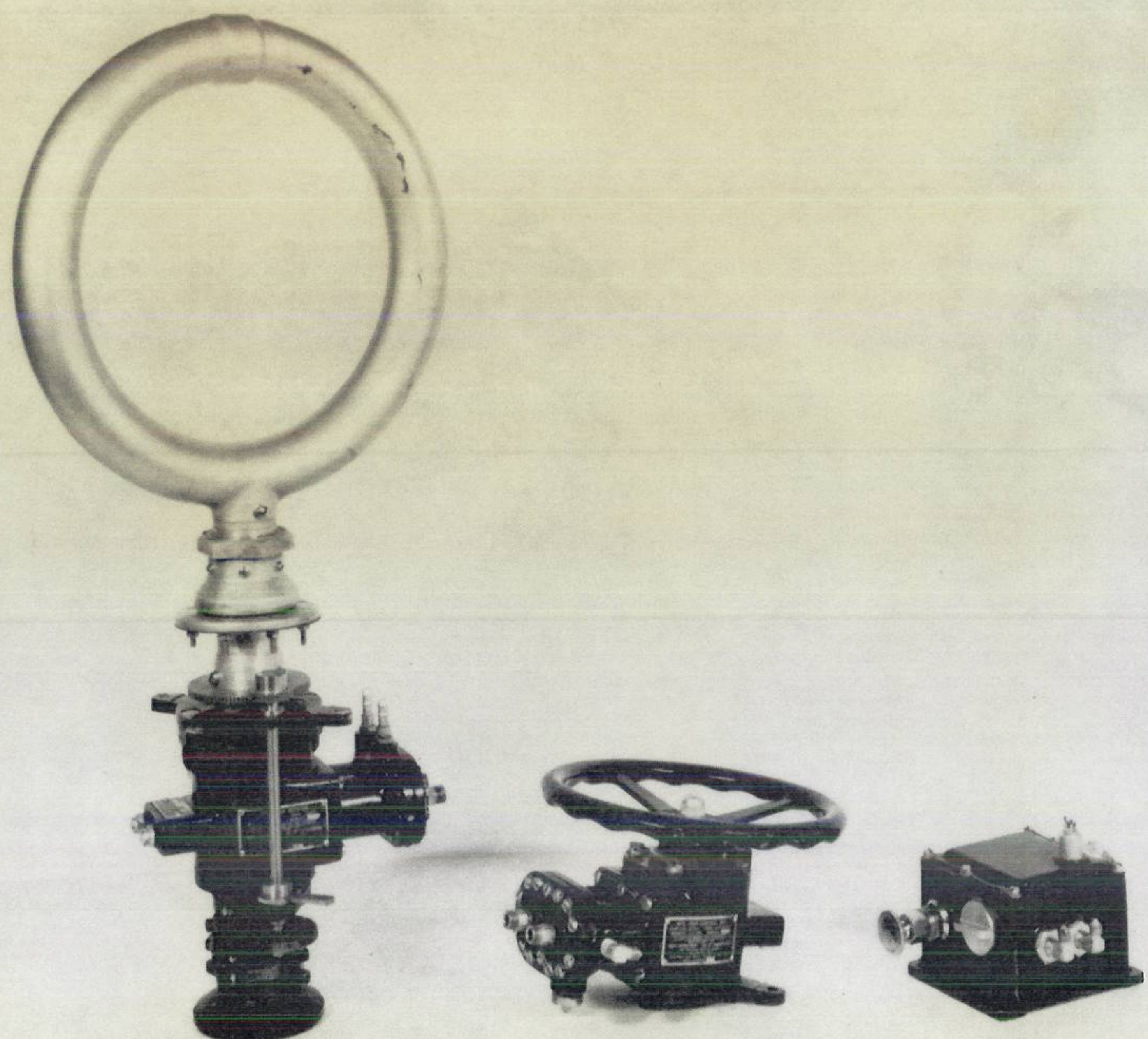
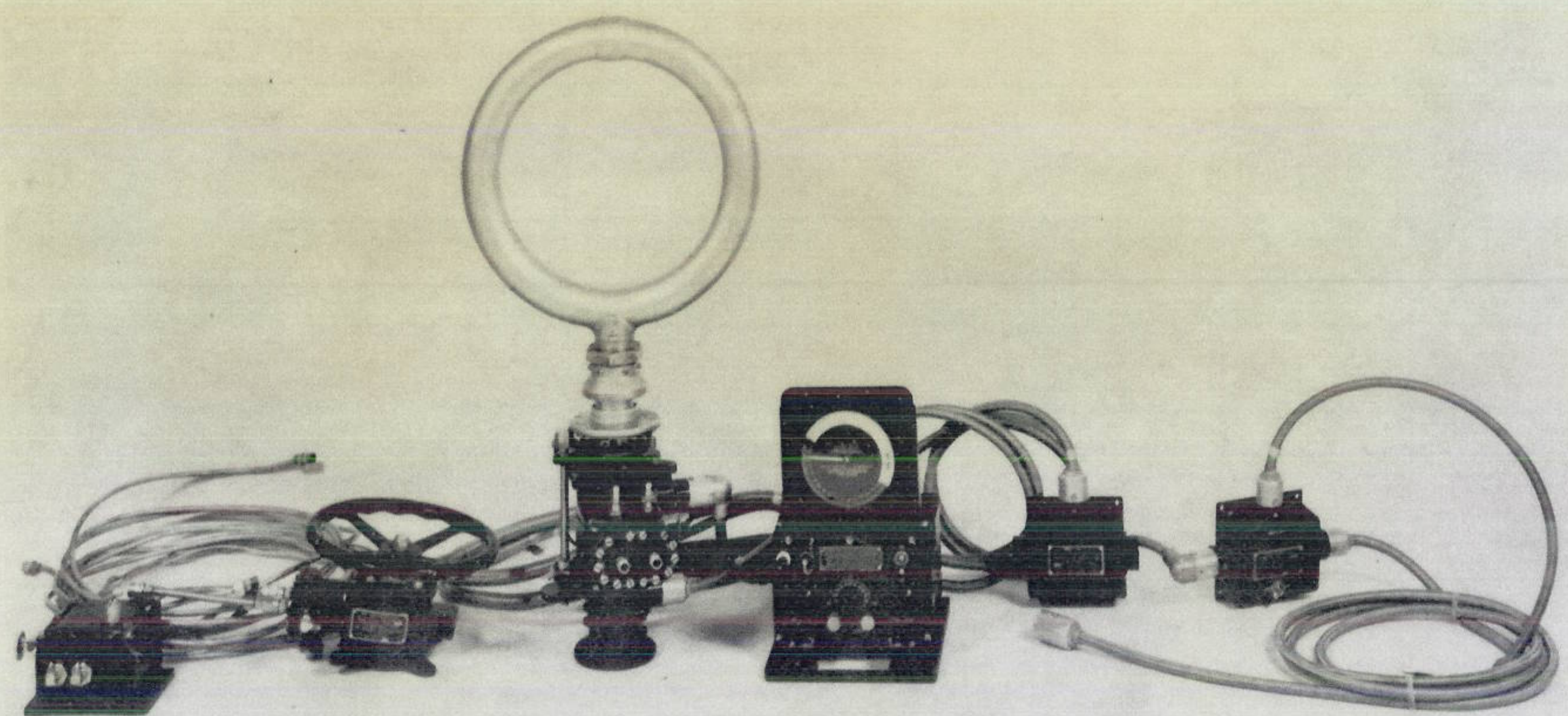

LOOP ROTATION-DEGREES
POLAR PATTERN
MODEL DV RADIO DIRECTION FINDER
CARDIOID LOOP PATTERN
FREQ. - 950 KC.
ANTENNA - 8 FT VERTICAL
CARDIOID MIN. TO MAX. RATIO = 60/1
LOOP MIN. TO MAX. RATIO 80/1
PERCENT CARDIOID MAX. OF LOOP MAX. = 73 %
15
10
5
5
10
15

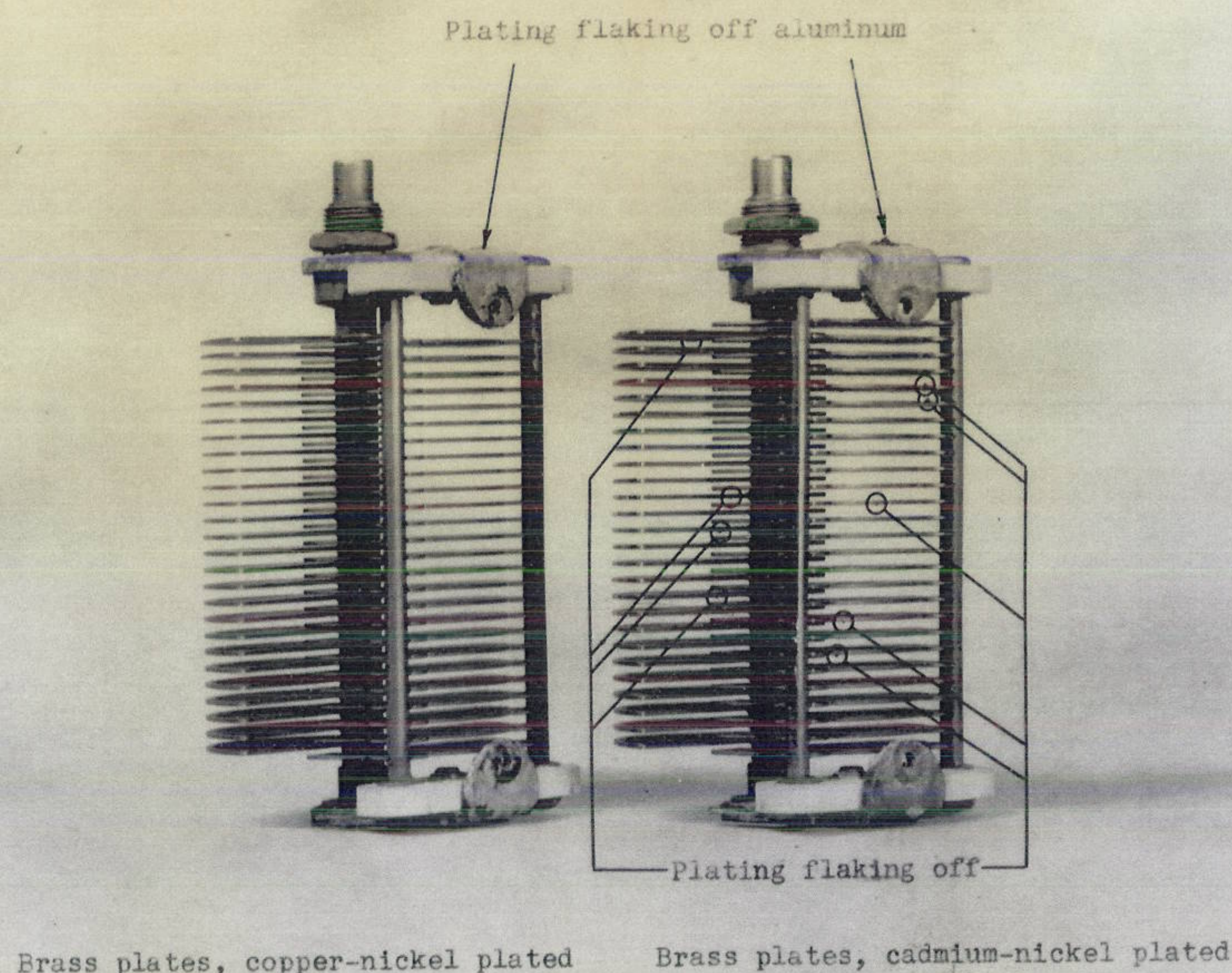
PLATE 3



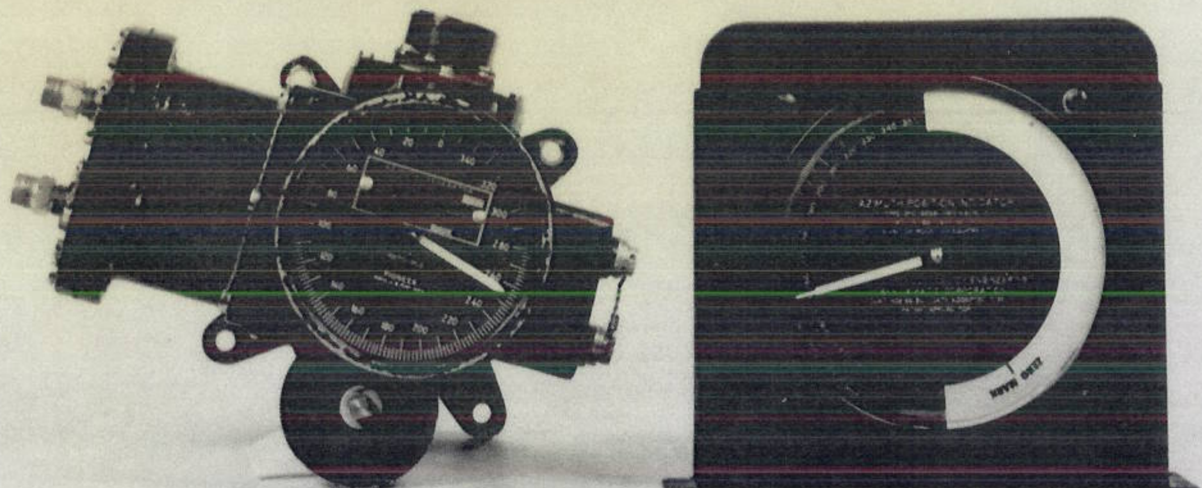
Model DV Direction Finder Equipment.
Hydraulic Control Units.



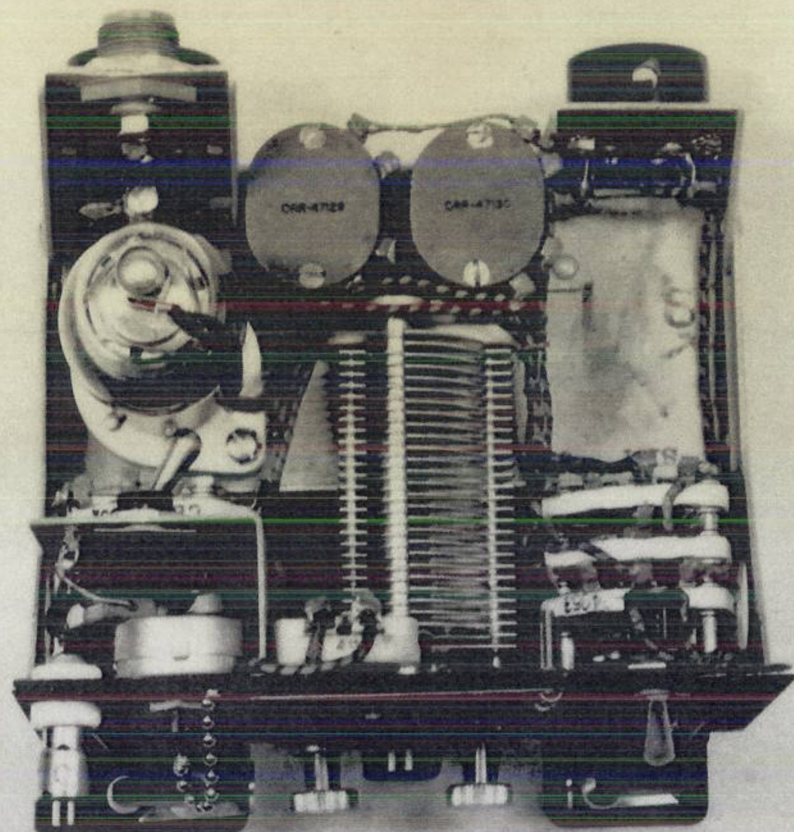
Model DV Direction Finder Equipment.
Complete Assembly.



Model DV Direction Finder Equipment.
Tuning Condenser.



Model DV Direction Finder Units.
Azimuth Indicators.



Model DV Direction Finder Equipment.
Coupler Unit.

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U. S. NAVAL AIR STATION
ANACOSTIA, D. C.

DV/F42-1/66/NA6
(623)
Serial #38111

JCL/BAG

30 August 1938

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From: Commanding Officer.
To: Director, Naval Research Laboratory, Bellevue, D. C.

SUBJECT: Aircraft Radio - Model DV Radio Direction Finding Equipment - Report on Tests of.

Reference: (a) Bureau of Engineering Confidential Specification RE 13A 546A.
(b) BuEng. Conf. Ltr. C-NOs-59120 (7-6-W3) of 8 July 1938, with enclosures (A) to (E).
(c) Comairscofor letr. F42-1/VP-7 of 26 February 1938.

Enclosure: (A) Photograph No. AN-52039-Schematic Circuit Diagram of Model DV Equipment.
(B) Photograph No. AN-52040-Outline Drawings of Model DV Equipment. Figs. 1,2,3,4 and 5.
(C) Photograph No. AN-52041-Outline Drawings of Model DV Equipment, Figs. 6 and 7.
(D) Photograph No. AN-52064-Loop Pattern and Cardioid Pattern of Model DV Equipment.

1. DESCRIPTION OF EQUIPMENT: The Model DV radio direction finding equipment has been designed to provide unilateral and bilateral bearings when used in conjunction with model RU receivers over the frequency range of 220 to 1500 kc. The equipment is intended for use in large airplanes where it is necessary to mount the loop at a remote point; a hydraulic control mechanism has been incorporated to provide for loop rotation and an auto-syn mechanism provides remote indication of loop setting. Unilateral directional indications are secured by combining suitable antenna and loop pickups to give the well known cardioid pattern and after the station direction had been roughly determined in this fashion, accurate bearings are secured by ordinary loop reception with the loop rotated to the correct minimum. The list of major units, with their Navy type description, which comprise the model DV radio direction finding equipment is as follows:

NAME	NAVY TYPE DESIGNATION
Azimuth Generator	CPO-21316
Azimuth Position Indicator	CPO-22261
Hydraulic Loop Rotator	CEA-23127
Hydraulic Loop Control Unit	CEA-23129
Hydraulic Make Up Pump	CEA-23128

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NAME	NAVY TYPE DESIGNATION
Coupler Unit	CRR-50051
Coupler Mounting Base	CRR-50054
Coupler Power Junction Box	CRR-62009
Azimuth Indicator Power Junction Box	CRR-62010
Plug in Loop	CRR-69025

2. COMPARISON OF MODEL DV RADIO DIRECTION FINDING EQUIPMENT WITH RDF-2 SERIES. The Model DV is intended to fulfill the same requirements as the RDF-2 series but differs from the RDF-2 series in the following manner.

(a) A low impedance loop with 120" flexible loop transmission cable is used in place of a high impedance loop with a large transmission loop cable.
(b) Chassis type construction has been employed.
(c) The Navy Type 38667 vacuum tube is used in place of Navy Type 38223.
(d) Hydraulic lines are made of annealed copper tubing instead of aluminum tubing. An eight inch flexible section has been supplied at the ends.
(e) Loop gain control has been provided in place of an antenna phasing control.
(f) A gear driven manual loop control mechanism has been incorporated in the structure of the hydraulic loop rotator.

3. HISTORY OF TESTS: Model DV radio direction finding equipment was delivered to this station on 1 August, 1938, by the Naval Research Laboratory. Tests were conducted by the Laboratory personnel until August 9th. During this period Naval Research Laboratory tests were interrupted for two days due to bad weather and the necessity of installing the equipment in the XRE-1 airplane No. 8938. Flight tests were begun on 10 August and completed on 15 August. Seven flights were made with a total of approximately 12 hours flying time. Careful mechanical inspection and miscellaneous tests were made after flight tests had been completed.

4. OUTLINE OF TESTS: The following tests were conducted by this station:

(a) Check of unilateral feature of equipment; range of suitable sense antennas; ratio of cardioid maximum

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to cardioid minimum; maximum and minimum cardioid bearings; sense reversals due to improper operation.

(b) Check of bilateral operation; ratio of bilateral maximum to bilateral minimum; ratio of bilateral maximum to unilateral maximum; width of bilateral bearings; 180° difference between true and reciprocal bearing.

(c) Complete check of performance including loss of receiver sensitivity on thirteen stations throughout the frequency range.

(d) Check of audio output at various loop settings both in the bilateral and unilateral positions.

(e) Use of various lengths of trailing antenna for sense purposes; effect of trailing antenna on operation of equipment.

(f) Location of airplane whose transmitter was delivering two watts of power to the antenna.

(g) Check of operation of azimuth indicator.

(h) Mechanical inspection including check of weights and dimensions.

(i) No tests were made at 230 miles per hour due to lack of facilities.

5. METHOD OF TEST: The following procedure was used to secure data which would give a good picture of the performance of this equipment and also provide a working basis for the comparison of future equipments. A desired station would be selected and the equipment would be tuned and the receiver sensitivity adjusted so that an output of 50 milliwatts would be obtained in the maximum bilateral position. Measurements were made on steady carriers with an oscillating receiver and after adjusting the maximum bilateral output to 50 milliwatts, no further change in receiver sensitivity was made for the particular test, except where so indicated. In this way the bilateral outputs, unilateral outputs, outputs in the "receive" position, and outputs with the direction finder out of the circuit entirely bear a direct relationship to each other, as long as the receiver is operated at low levels. In this way the cardioid maximum/minimum ratio, bilateral maximum/minimum ratio, cardioid maximum/bilateral maximum ratio can be determined under conditions approaching service conditions and furthermore a definite starting point is available for comparative tests of future equipments. Bearings were recorded for maximum cardioid, minimum cardioid, true radio bearing, and reciprocal bearing. These figures do not give the bearing accuracy of the equipment because the airplane's devia-

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SUBJECT: Aircraft Radio - Model DV Radio Direction Finding Equipment - Report on Tests of.

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tion is not taken into account and not all readings were made with the same airplane headings. However, for good operation the cardioid maximum bearing and cardioid minimum bearing should be 180° ± 10° apart and 90° ± 10° removed from the bilateral minima. The bilateral minima should be 180° apart and when this is the case the radio bearing is accurate after being corrected for deviation due to the airplane.

6. The following data was taken on the station compass rose using a half Vee sense antenna with the loop gain control turned to maximum value.

STATION	FREQ. KC	RU OUTPUT WITHOUT DV mw	RU OUTPUT WITH DV mw	MAX. CARDI. mw	MIN. CARDI. mw	MAX. CARDI. Degs.	MIN. CARGI. Degs.	MAX. BILAT. mw	MIN. BILAT. mw	RDO. BEAR. Degs.	RECIP. BEAR. Degs.	WIDTH OF BEARING Degrees
WFIL	560	120	100	25 30	2.0 0.5	316	145	50	0.4	52	232	6
WCAO	600	125	110	24 26	0.5 0.0	314	94	58	1.5	28	205	6
WMAL	630	100	75	13 15	0.5 0.0	250	65	50	0.0	342	161	5
WOR	710	120	95	15 17	1.0 0.5	303	115	50	1.0	52	232	8
WABC	860	190	95	9 14	1.0 0.8	318	142	50	1.5	43	222	6
WRNL	880	170	90	10 10	1.8 1.5	106	270	50	2.5	190	12	6
WFMD	900	130	65	8.0 8.0	0.4 0.2	243	72	50	0.1	331	151	4
WRC	950	170	75	6.0 7.0	0.7 0.1	278	92	50	0.1	12	191	4
WBAL	1060	150	85	6.0 7.0	0.9 0.1	302	115	50	0.0	23	202	1
WRVA	1110	140	75	4.0 4.5	0.4 0.1	98	280	50	0.6	192	12	6
WCAU	1170	175	125	6.0 7.0	1.3 0.6	318	141	50	0.3	48	228	5
WOL	1310	120	90	4.0 5.0	0.7 0.1	267	70	50	0.2	344	163	5
WJSV	1460	175	125	4.5 6.5	1.3 0.4	148	312	50	0.2	213	33	5

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Serial #38111
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Double figures are shown under the cardioid output headings. In each case the upper figure is obtained without retuning on the "D" position. This is normal operation. By retuning on the "D" position an improved cardioid is obtained as indicated by the lower figures. This procedure is described in the instruction book but it should not be necessary and in the subject equipment, as submitted to this station, it was not necessary to retune on the "D" position to obtain usable cardioids but it was necessary to retune on the "D" position to obtain optimum cardioids. It will be observed that measurements are expressed in milliwatts of receiver output whereas Specification 5-9(1) requires an 8:1 cardioid maximum/minimum ratio expressed in microvolts input to the receiver. Checking of this specification paragraph literally would occasion considerable difficulty with the equipment operatively mounted in the airplane, and measurement of milliwatt output ratios instead of microvolt input ratios accomplishes the same result as long as the receiver is operated at levels where output is proportional to input. This also applies to 5-9(2) of the governing specifications relating to the ratio of unilateral maximum to bilateral maximum. Converted to microvolt ratios at receiver input, the information in the preceding table together with the specification requirements, is as follows:

STATION	FREQ KC	LOSS OF RECEIVED SIGNAL DUE TO "DV" % uv	*CARDIOID MAX/MIN RATIO, uv	CARDIOID MAX/BILAT MAXIMUM % uv	DIFFERENCE BETWEEN TRUE & RECIP. BILATERAL BEARING	WIDTH OF BEARING
WFIL	560	9	3.5/1	71	180	6
WCAO	600	6	7.1	64	177	6
WMAL	630	14	5/1	51	179	5
WOR	710	11	4/1	55	180	8
WABC	860	29	3/1	42	179	6
WNRL	880	27	2.5/1	45	178	6
WFMD	900	29	4.5/1	40	180	4
WRC	950	34	3/1	35	179	4
WBAL	1060	25	2.6/1	35	179	1
WRVA	1110	27	3/1	28	180	6
WCAU	1170	15	2.3/1	35	180	5
WOL	1310	11	2.5/1	28	181	5
WJSV	1460	15	2/1	30	180	5
Specification requirement		not over 40%	8/1	15 to 60%	179 to 181°	6°

* Cardioid ratios secured without retuning in "D" position.

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7. PERFORMANCE OF MODEL DV IN FLIGHT. The following data on the performance of the Model DV was taken in flight.

STATION	FREQ. KC	SENSE ANT.	LOSS OF RECEIVED SIGNAL DUE TO DV % uv	*CARDIOID MAX/MIN RATIO uv	CARD.MAX/ BILAT/MAX % uv	DIFFER. BETWEEN TRUE & RECIP.BI-LAT.BEARS.	WIDTH OF BEARING
WFIL	560	5 ft.	43	5/1	26	180	6
WOR	710	fore	43	4/1	26	180	8
WBAL	1060	and	49	2.3/1	14	179	6
WFBR	1270	aft	52	2.6/1	14	181	5
WFIL	560	Half	37	2/1	49	186	6
WOR	710		39	3.5/1	39	183	8
WBAL	1060	Vee	37	2/1	28	181	7
WFBR	1270		41	2.3/1	26	187	5
WFIL	560	Full7	16	2.4/1	80	181	8
WOR	710		12	2.6/1	52	176	8
WBAL	1060	Vee	20	2.4/1	40	178	6
WFBR	1270		25	1.7/1	28	179	5
WRVA	1110	10 ft.		1.8/1	39	179	3
WBAL	1060	trail-		2.8/1	28	180	7
WFBR	1270	ing		1.4/1	26	180	4

*Cardioid ratios secured without retuning in "D" position.

8. LOSS OF RECEIVER SENSITIVITY DUE TO USE OF MODEL EV. The loss of receiver sensitivity when using the model DV direction finding equipment in the "R" position depends upon three factors, viz:

(a) <u>Frequency.</u> Loss of sensitivity increases with frequency.
(b) <u>Size of Antenna.</u> Loss of sensitivity increases as the receiving antenna becomes smaller.
(d) <u>Length of Antenna Coupling Cable.</u> Loss of received signal increases rapidly as length of antenna coupling cable is increased.

9. AUDIO OUTPUT Versus LOOP SETTING. Audio output versus loop setting was checked in both the bilateral and unilateral positions. See enclosure (D). Station used was WRC on 950 kc. Sensitivity was adjusted to give 50 milliwatts output in the maximum

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bilateral position and no further adjustment of sensitivity was made during the test. Full Vee sense antenna was used.

10. RANGE OF SENSE ANTENNAS. The Model DV equipment, as submitted to this station, would phase properly only with very small antennas. On the XRE-1 radio test airplane the only antenna which could be properly phased was the 7 foot fore and aft. The Half Vee antenna proved to have too much pickup for proper phasing as did also the Full Vee antenna. Although proper phasing could not be secured when using the Full Vee or Half Vee sense antenna, it was still possible to secure sufficiently good operation to secure useful unilateral indications in most cases. However, it is desirable to match antenna and loop pickups exactly whenever possible. Tests with trailing sense antenna indicated that useful unilateral operation could no longer be secured when the antenna length exceeded ten feet. On the basis of the above experience it is believed that the long trailing antennas or large fixed antennas on patrol planes will not prove satisfactory as sense antennas in conjunction with the Model DV equipment.

11. EFFECT OF TRAILING ANTENNA ON MODEL DV OPERATION. One flight was made to determine whether the performance of the model DV direction finder was adversely affected by the presence of long trailing antennas. Tests were made using the half Vee sense antenna and at the same time having varying lengths of trailing antennas either grounded to the fuselage direct, or grounded through a RU-2A receiver, or left open circuited. Results indicated that grounding of trailing antennas to the fuselage direct, destroyed the operation of the direction finder entirely; grounding trailing antennas to the fuselage through a receiver reduced the performance of the direction finder considerably especially on the unilateral position although it was possible to get bearings under favorable conditions; with the trailing antenna open circuited the bilateral bearings appeared satisfactory but the unilateral indications were not of the best. Good operation was secured only when no trailing antennas were reeled out.

12. LOCATION OF AIRPLANE USING TWO WATTS OF ANTENNA POWER. SU-2 airplane #9104 was sent out to a location 20 miles from the Air Station and flown at an altitude of 2000 feet with approximately two watts of power in a fixed antenna at 1510 kc. Attempts were made to locate the SU-2 airplane with the DV direction finding equipment in the XRE-1 airplane. The effort failed due to serious interference from two broadcast stations on the same frequency but the signal strength from the two watt source was easily adequate

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for securing a good bearing if no interference were present. The frequency of 1510 kc was chosen as being the least favorable for loop reception.

13. Dimensions are as shown in enclosures (B) and (C). There is one error on the azimuth position indicator drawing. The depth dimension shown as 5-3/4 inches should be 3-3/4 inches.

14. Weight of Model DV less hydraulic fluid is as follows:

	POUNDS	OUNCES
Azimuth Generator and Hydraulic Loop Rotator	7	0
Azimuth Position Indicator	1	12
Hydraulic Make Up Pump	3	4
Hydraulic Loop Control Unit	4	11
Coupler Unit	3	10
Coupler Mounting Base		9
Coupler Power Junction Box		9
Azimuth Indicator Power Junction Box		9
Plug-in Loop	2	1
Accessories consisting of Hydraulic Lines and Power Cables	10	4
TOTAL	34	5
SPECIFICATION	35	0

15. CABLE AND TUBING LENGTHS.

CABLES	LENGTHS
D.C. Power Cable	60"
D.C. Power Cable	60"
Receiver-Antenna Coupling Cable	60"
Loop Transmission Cable	120"
A.C. Power Cable	24"
A.C. Generator Cable	120"
Indicator Cable	70"
1/4" O.D. Copper Tubing	132"
1/8" O.D. Copper Tubing	75"

16. OPERATION OF A IMUTH INDICATOR. Satisfactory.

17. MECHANICAL INSPECTION: The following mechanical deficiencies were observed during tests at Anacostia;

(a) Insufficient clearance between soldered terminals and bottom of case in coupler unit.

(b) Adjusting screw loose on C107.
(c) Coupler terminal of antenna coupling cable loose.
(d) Receiver terminal of antenna coupling cable broke off.
(e) Leak developed in hydraulic system in flexible portion of tubing near loop. Braid covering on flexible portion of tubing frayed badly in two instances. More flexible braid appears necessary.
(f) Gasket should be provided between loop housing and loop mounting.
(g) Felt washer around loop shaft fits loosely and permits water to pass into the airplane. Operation of the equipment is not adversely affected.
(h) No slots have been provided for making dial on loop azimuth generator adjustable as requested by reference (c).
(i) Incorrect dimensions are shown on outline drawings of loop azimuth indicator.
(j) Steel safety wire used on loop rotator.

18. CONCLUSIONS.

(a) The use of the low impedance loop and smaller diameter transmission line, the chassis type of construction, and the flexible hydraulic lines are considered desirable features in the model DV equipment.
(b) The maximum/minimum cardioid ratios required by paragraph 5-9(1) of the governing specifications could not be obtained when using the fixed antennas on XRE-1 airplane although usable cardioids could be secured. The equipment, as submitted, required very small sense antennas for optimum cardioids and if it is desired to use the large fixed antennas on patrol planes for sense antennas, a circuit revision will probably be necessary.
(c) Retuning on "D" position improved the cardioid pattern but with properly matched sense antennas, this procedure should rarely be necessary.
(d) The presence of long trailing antennas has a serious adverse effect on the operation of the model DV equipment. This was particularly true of the unilateral indications and trouble may be encountered in service on this point.

DV/F42-1/66/NA6 (623)
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19. RECOMMENDATIONS FOR PRESENT EQUIPMENT.

(a) It is recommended that the mechanical deficiencies noted in paragraph 17 be carefully inspected and corrected as necessary.
(b) It is recommended that the circuit be revised to operate with larger sense antennas.
(c) It is recommended that the Model DV radio direction finding equipment be considered suitable for naval service when the preceding recommendations are carried out.

20. RECOMMENDATIONS FOR FUTURE EQUIPMENT.

(a) Reference (c), paragraph 5, mentions the desirability of having a separate receiver for direction finding purposes only. If this policy is to be followed it appears advisable to have the receiver built as an integral part of the direction finder. In this way it will be possible to eliminate the necessity of plug-in receiver coils; simplification of circuits and reduction of number of cables and component parts can be achieved by building the receiver, the receiver power supply, and the direction finder coupler unit as a single unit; the loss of received signal in the "R" position encountered in using a design similar to the model DV could be substantially reduced by the single unit design.
(b) Serious consideration should be given the advantages of enclosing the loop in a stream-lined housing. If this is done the troubles due to moisture and leakage should be greatly minimized.
(c) Eliminate the hydraulic control system entirely and provide a less complicated and sufficiently rugged mechanical system for rotating the loop.
(d) A remote indicating system operating from an 11-15 volt d.c. source would be preferable to a system operating from 800 cycle supply if the same performance were attainable.
(e) Rubber covered cables and flexible grounding tabs across shock mounts should be required throughout.
(f) Illumination on the indicator dials should be provided.
(g) Knife edge indicator pointers should be required throughout.
(h) Dials should be adjustable throughout 360°.

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(i) Specification cardioid performance should be required without retuning in the unilateral position.

(j) Approximate range of desired sense antennas should be stated in specifications.

(k) The method used to couple the plug in loop to the loop assembly should be such that any moisture passing inside the coupling nut will not enter the loop plug in assembly.

21. It is requested that two copies of the Naval Research Laboratory's report on the subject equipment be furnished this station.

/s/ J. D. PRICE

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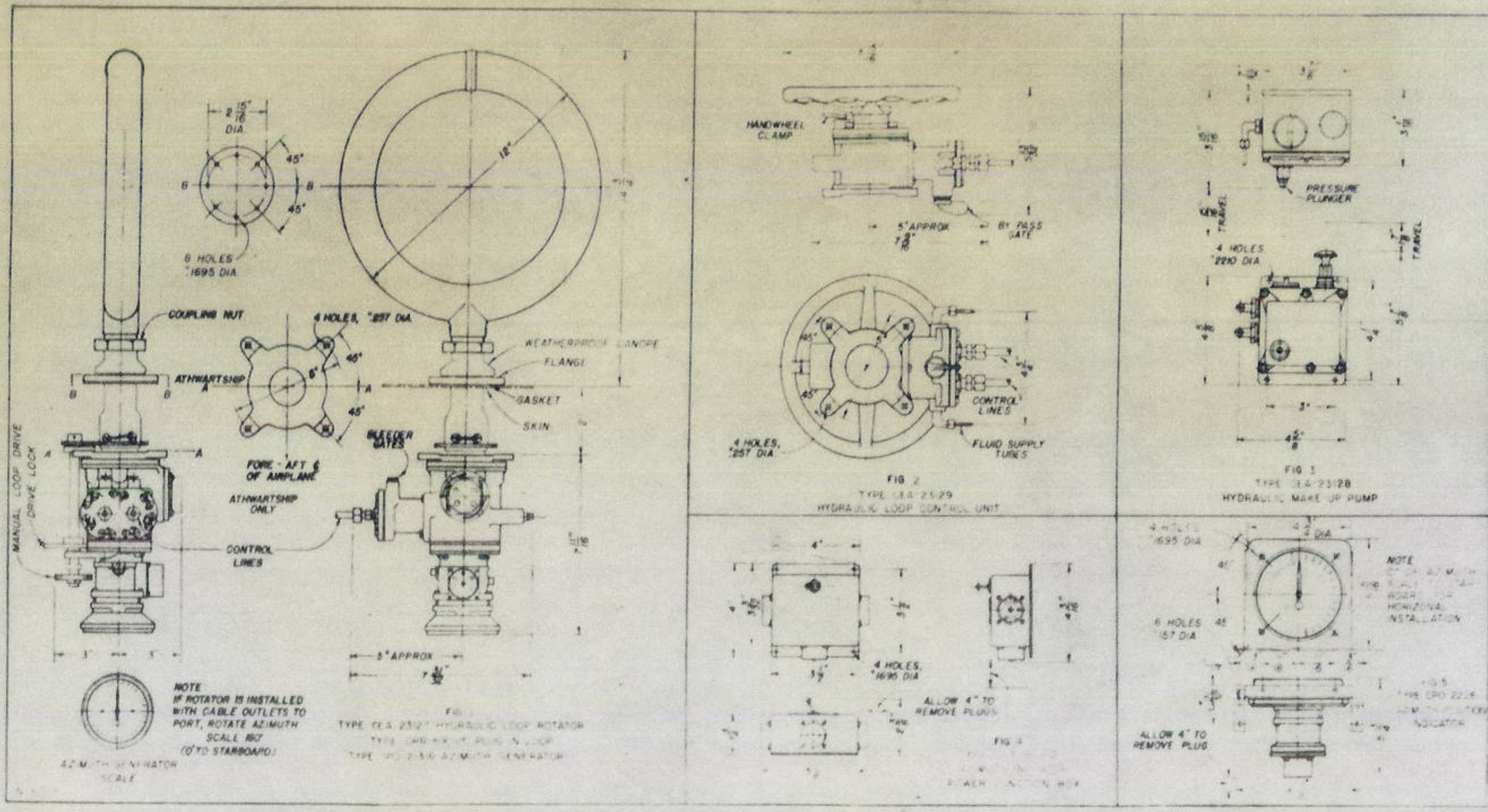
BuAero.
NAF, Phila., Pa.



FIGS. 1,2,3,4 & 5 - OUTLINE DRAWINGS

[illegible] of [illegible] Direction Finder AN-52060 7-20-38 OFFICIAL NAVY PHOTOGRAPH NOT TO BE USED FOR PUBLICATION ENCLOSURE (B)

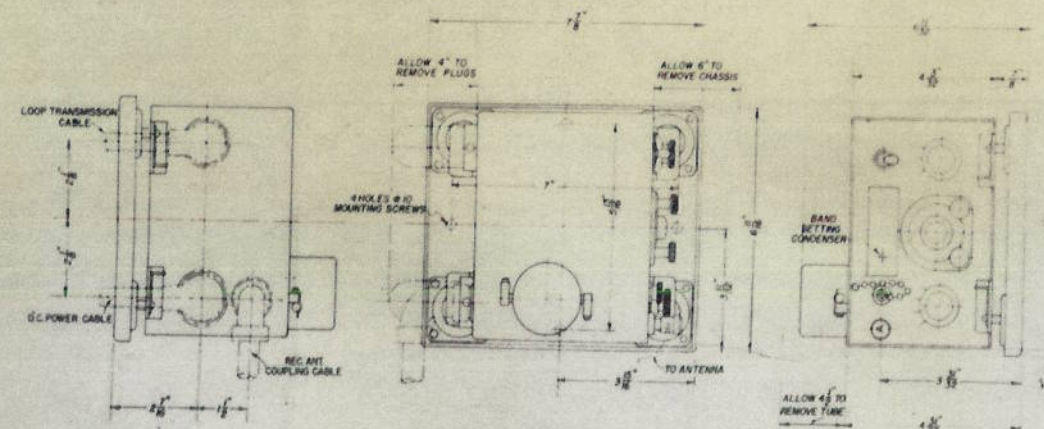


FIG. 6
TYPE CRR-50051 COUPLER UNIT & TYPE CRR-50054 COUPLER MOUNTING BASE

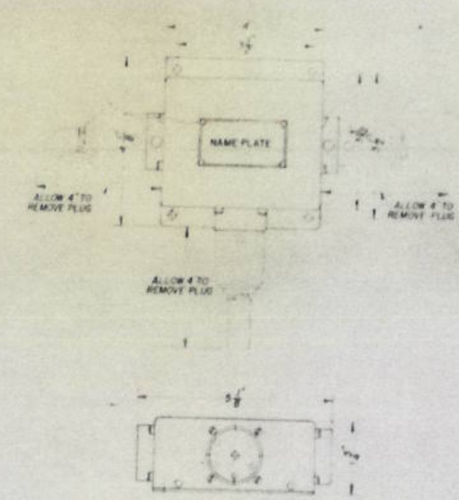


FIG. 7
TYPE CRR-62009 COUPLER POWER JUNCTION BOX

FIGS 6 & 7 - OUTLINE DRAWINGS

L 70610

Outline Drawing of
Model DV Direction Finder

AN-52041 7-20-38

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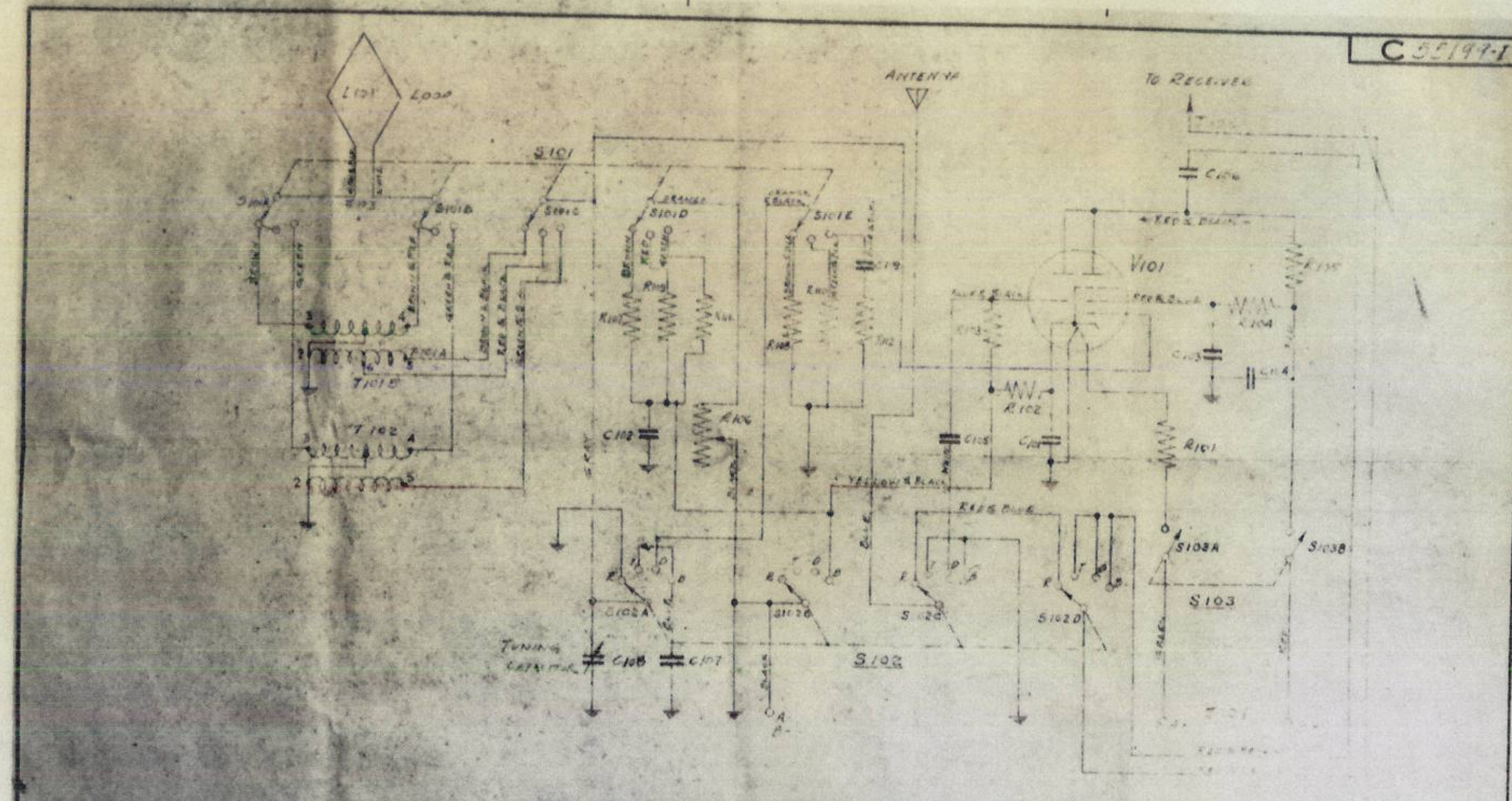
ENCLOSURE (C)



BENDIX RADIO CORPORATION BALTIMORE, MD.

ALTERATIONS	USED ON TYPE NO.	USED ON ASSEMBLY	REQ.	REQ.	REQ.	REQ.	DRAWING	ITEM	NAME
			A-C	A-C	A-C	A-C			

MATERIAL | SCALE | FINISH | QUANTITY | DRAWN | CHECKED | APPROVED | C

IMPORTANT
THIS PRINT, DATED JUL 20 1938 SUPERSEDES ALL PREVIOUS ISSUES

Schematic Diagram of Model DV Direction Finder. AN-52039 7-20-38

OFFICIAL NAVY PHOTOGRAPH
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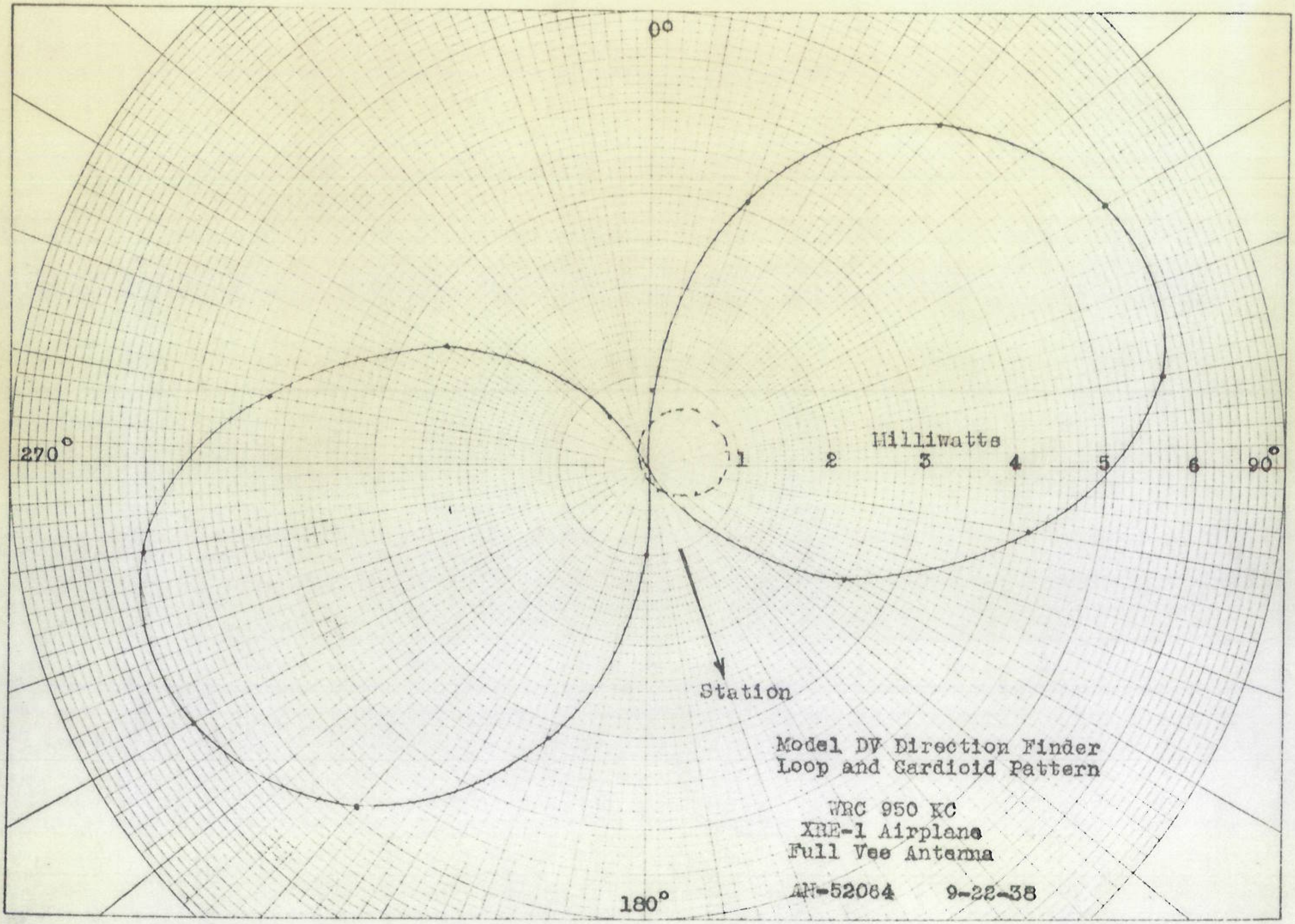
ENCLOSURE (A)


0°
90°
180°
270°
Milliwatts
1
2
3
4
5
6
Station
Model DV Direction Finder
Loop and Cardioid Pattern
WRC 950 KC
XRE-1 Airplane
Full Vee Antenna
AN-52064 9-22-38