REPORT NO. R-1285

DATE 6 July 1936

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SUBJECT

Test of CXN Direction Finder Adapter
Manufactured by
Radio Research Company, Inc.

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NAVAL RESEARCH LABORATORY

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Bu.Eng.Prob.No.D3-4

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report of Test of

Model CXN Direction Finder Adapter
Manufactured
by
Radio Research Company.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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AUTHORIZATION FOR TEST

1. The tests herein reported were authorized by reference (a). References (b) and (c) were used in conjunction with the tests made.

Reference: (a) Bu.Eng.ltr. C-43978(2-3-W8) of 6 February 1936.
(b) Instruction Book for Type RDF-1-A Direction Finder.
(c) Bu.Eng. ltr. NOs-41504(2-18-W9) of 20 Feb. 1936.

OBJECT OF TEST

2. The object of the tests was to determine the characteristics of the Model CXN-RAJ radio direction finder both as a portable and as a fixed equipment when operating from storage battery or alternating current power supply.

ABSTRACT OF TESTS

3. Specific tests of the following nature were conducted on the Model CXN-RAJ radio direction finder.

(a) Inspection of workmanship, construction and materials.
(b) Operation of the equipment with AC power supply.
(c) Operation of the equipment with DC power supply.
(d) Quality of the cardioid pattern.
(e) Effect of misadjustments on bearing, accuracy and sense indication.
(f) Accuracy of equipment.
(g) Range of the equipment, including approximate sensitivity.
(h) Selectivity.
(i) Operation with non-oscillating receiver.
(j) Operation at upper frequencies.

CONCLUSIONS

(a) The Model CXN Direction Finder is ruggedly constructed of good materials and shows good quality workmanship throughout.

(b) The circuit design is simple and straightforward.

(c) With a battery power supply the bearings are reliable throughout the broadcast range. At the higher frequencies where the radiation may not be coming from the transmitter in a direct path, the bearings are not as good, but when a definite sense indication is obtained, it is reliable. It is theoretically impossible to reverse sense by night effect, so the chance is small that a bearing with definite sense may be bad. Accuracy may at times be very low on broadcast even though the sense indication is reliable.

(d) With AC power supply the power lead acts as an antenna and destroys the sense whenever the pickup on the power lead exceeds the pickup on the sense antenna. The bearings become less reliable as the length of the power lead or the frequency of the received signal is increased. The use of a counterpoise and shielded power lead lessens the probability of sense error but does not remove it entirely.

(e) No change of bearings could be observed due to change of the loop tuning.

(f) Bearings could be taken on broadcast stations with the receiver in either the oscillating or non-oscillating condition, but the oscillating condition was the better position for taking a bearing.

(g) Good bearings could be taken on keyed CW signals wherever the keying was rapid enough and of sufficient duration to make the necessary adjustments.

(h) In cases where a steady carrier was available, the adjustments pertaining to sense could be made more accurately when an output meter was used instead of a pair of telephones. This is particularly true of the loop tuning and phasing resistor adjustments. The actual bilateral accuracy of bearing once the sense had been determined is as good with the telephones for indicators and it is possible to work with lower signal levels than it is with the output meter for an indicator.

(i) Two or three positions of the phasing resistor are sufficient for frequencies in the broadcast band, but for an ideal adjustment necessary for a true cardioid it is necessary to make separate adjustment at practically every frequency.

(j) Care in making adjustments and the use of a proper length sense antenna will give a cardioid whose ratio of maximum to minimum on any frequency in the broadcast band will be greater than 15 to 1 and in some cases the minimum phases out so well that the ratio of maximum to minimum is greater than 100 to 1.

(k) The dependable range of the equipment on frequencies above the broadcast band is only as great as the optical path, although at times it is possible to take a bearing on 6000 kc transmission at a distance of 250 miles.

[redacted]

(l) Bearings could be taken on a plane in flight as long as a line drawn from the direction finder to the plane does not make too large an angle with a horizontal plane. This angle is estimated roughly to be about 30°.

(m) No means has been provided in the Model CXN-RAJ circuit for balancing for sharp bilateral minima. However, it is possible, by placing the hand on the loop shield and sliding it along, to find a balance point resulting in a very sharp minimum at times. The equipment has a distinctly lower order of precision than the Model DP direction finder.

RECOMMENDATIONS

It is recommended:

(a) That the Model CXN-RAJ Radio Direction Finder be considered satisfactory for fixed installations for approximate results provided the installation is such that the power supply lead does not pick up enough radiated energy to destroy the correct sense indication. Due consideration must be given to the short comings of loop direction finders at high frequency.

(b) That the Model CXN-RAJ Radio Direction Finder be considered satisfactory for portable use when operated with a storage battery power supply. Where there is no danger of not recognizing 180° sense error, AC power supply could be used.

(c) That the portion of the range above 1500 kilocycles be used for experimental purposes. If dependable indications are necessary, the portion of the range below 1500 kc should be used. Due caution should be observed to avoid possible error due to night effect.

[redacted]

MATERIAL UNDER TEST

4. The Model CXN-RAJ direction finding equipment is a combination of the Model CXN loop collector and coupling unit operating with a Model RAJ receiver. The circuit design of the Model CXN radio direction finder is identical to that of the type RDF-1-A with the exception of minor modifications which are required to permit operation from a 6 volt battery supply or from the power pack of the Model RAJ receiving equipment which operates from 110 volts, 60 cycles, A.C. With these modifications, the direction finder will operate only with the Model RAJ receiver. The frequency range extends from 500 to 8000 kc. in seven steps.

5. The Model CXN radio direction finder adapter consists of the following units:

1 - Type L1130-B direction finder which consists of rotatable loop, associated circuits and mounting base.

1 - Receiver antenna coupling cable.

1 - Junction box.

2 - Power cables.

1 - Vacuum tube; Navy Type 38233, Commercial Type RK33.

6. The Type L1130-B direction finder consists of a shielded rotatable loop antenna mounted on a cabinet type base comprising bearings and indicators for the mechanical operation of the unit together with suitable switches, coupling devices and circuits for all of its electrical functions. This unit includes a separable mounting plate to which it is normally attached by means of four snap slides. The direction finder-receiver coupling cable is a low loss shielded transmission line provided for connecting the direction finder output to the antenna terminal of the receiver. The junction box provides a means for feeding power to the direction finder from the receiver power supply.

7. The only vacuum tube used in the Model CXN direction finder adapter is a Navy Type 38233, Commercial Type RK33. It includes two independent heater type triodes in a single envelope, one section being employed to couple the loop, and the other section to couple the sense antenna to the antenna terminal of the radio receiver.

8. The theory of operation of the equipment can be given briefly by describing the action of the equipment on each of the four positions of the selector switch. The four positions are lettered R, T, D, B and on position R the direction finder is in the circuit only inasmuch as the sense antenna is coupled to the receiver through one section of the RK-33 coupling tube. In the R position only non-directional reception is desired so the loop section of the tube is blocked by placing the 6 volt filament supply across its cathode resistor R_1, R_6 with its negative to ground. The output network, consisting of R_3, R_4 and C_5 remains in the circuit to retain the receiver trimmer adjustment. See Plate 1.

9. The T position of the selector switch unblocks the loop section and

blocks the antenna section of the tube through S_5, S_7. In addition, S_6 grounds the antenna section tube grid. At this point the loop is tuned by means of the frequency band switch and variable condenser C_1.

10. The pickup with the selector switch in the R position is non-directional and can therefore be represented by a circle. The pickup in the T position as the loop is rotated through 360° is the figure of eight characteristic of all loops. The zero points of the figure of eight comes when the plane of the loop is perpendicular to the path of the oncoming wave.

11. On the D position, the antenna and loop pickups are combined to form a cardioid which definitely establishes the bearing of the station being measured in a general manner. The antenna pickup is limited by the phasing resistor to a value which is the same as that of the loop pickup so that one side of the cardioid phases out to a complete zero, while the other side adds up to twice the value of the loop pickup or antenna pickup alone. This condition is fully realized only when conditions are ideal, but ordinarily they are approximated closely enough to give a cardioid which establishes the general direction of the bearing being observed. Exceptions to the above will be noted under results of tests.

12. The B position of the selector switch arranges the circuits to permit reading minimum bearings. The B position resembles the T position but with one important difference. The bias is lowered through the shorting out of R_6, raising the sensitivity of the loop section to a much higher value.

METHOD OF TEST

14. The loss of sensitivity due to the use of the loop tuner and connecting cable between the direction finder and the receiver antenna post was determined in two ways. The measurements were first made by using a General Radio Model LC-A Serial No. 2 standard signal generator as a voltage source and determining the number of microvolts necessary to produce a 10 milliwatt receiver output with and without the loop tuner and connecting cable. This was done at various points in the band and the ratio of inputs observed. The second method was to use a steady signal from a broadcast station as the antenna input and measuring the receiver output with and without the loop tuner in the circuit and observing the ratio of outputs. The selector switch of the loop tuner was in the R position so that the antenna phasing resistor would be shorted out. All the foregoing measurements were made with an oscillating receiver operating on manual volume control.

15. The equipment was set up in No. 1 Compass House and bearings were taken on stations thruout the frequency range. The ratio of cardioid maximum to cardioid minimum was determined by measuring receiver outputs on output meter 583-A, Serial No. 72. Selectivity and range of the equipment were measured in a general way by taking bearings on stations where a nearby powerful station was transmitting in an adjoining channel and by taking bearings on very weak stations.

16. The equipment was set up in the field near the compass house and the effect of shielding the power lead was observed. The effect of a counterpoise was observed and the reliability of sense indications was checked under various conditions. The equipment was taken to 20th Street and Alabama Avenue, S.E., and operated with both A.C. and D.C. power supply. Reliability, range and selectivity were again observed.

17. The approximate sensitivity of the equipment when using the loop for the collector was calculated since it was impossible to apply a signal to the center of the loop without destroying the equipment. The signal voltage at the grid of the coupling tube necessary for standard output was known from the tests described in par. 14. The voltage at the grid may be calculated from the formula

$$e = HEQ$$

where e = voltage at grid in microvolts

H = effective height of collectors in meters
E = field strength in microvolts per meter
Q = The "Q" or figure of merit of the input circuit

The effective height may be calculated from the formula $H = \frac{2\ AN}{\lambda}$

where A = area of the loop in square meters
N = number of turns
λ = wavelength in meters

The "Q" of the input circuit may be measured directly with a "Q" meter. Thus the value of E, the field strength in microvolts per meter, may be calculated. This value is of course the value for maximum pickup from the loop. To obtain a satisfactory minimum for taking a bearing requires a field strength some 50 to 100 times the value as calculated by the above method.

18. True bearings were obtained by drawing an azimuthal map centered on No. 1 Compass House and extending over a radius of about four hundred miles. The latitude and longitude of the stations observed were taken from the Berne list.

DATA RECORDED

19. Data were recorded on tests and the information is contained in Tables 1 to 8 inclusive.

PROBABLE ERRORS

20. Tests to determine loss of sensitivity of the receiver when the loop tuner is in the circuit are accurate to ±10% at the lower frequencies and ±15% at the higher frequencies. The approximate sensitivity of the equipment using the loop as a collector is probably accurate to only ±50% since this represents the results of calculations and measurements which in themselves are not highly accurate.

21. The bearings obtained can be read to ±1/2 degree. This does not represent the accuracy of the bearing but only the reading of the scale.

22. True bearings were calculated and should be accurate to ±1/2 degree provided the latitude and longitudagiven by the Berne list is correct.

RESULTS OF TEST

23. - Stowage and mounting boxes (3), as requested by reference (c),

[redacted]

were made at the Laboratory and one box with complete equipment is shown in Plate 2. The weight is shown in Table 1.

24. Workmanship and materials used are very good. No failures occurred during the entire test period. Switches are rugged and positive and the design throughout is liberal.

25. For the first tests made on the Model CXN-RAJ direction finder, the power supply used was A.C. The equipment was set up in No. 1 Compass House and bearings were taken on stations in the broadcast band. The sense indications were positive and correct and the loop minima were sharp. However, a bearing on the TBK transmitter located on the radio balcony operating on 3000 Kc showed a reversal of sense indication and consequently the bearings were 180° in error. When the CXN-RAJ was set up in the field near the Compass House and still operated with A.C. but with a considerably longer power supply lead, the first trouble encountered with proper sense occurred in bearings taken on WPG, Atlantic City. When the equipment was set up at 20th Street and Alabama Avenue, S.E., and the 60 cycles supplied by the truck alternator, the sense indications began to show 180° reversal in the case of WOR Newark on 710 kc and WRVA Richmond on 1110. A longer sense antenna (3 to 5 ft. had been used) corrected the indication on WOR but failed on WRVA. After many trials it was decided that the sense would be reversed whenever the energy picked up by the power supply lead exceeded the energy picked up by the sense antenna. Lengthening the sense antenna corrected the error in some cases; adjustment of phasing resistor helped in other cases. Shielding the power supply lead helped to eliminate the 180° error as did also the use of a counterpoise beneath the equipment but in spite of all precautions some reversals of sense would occur when using AC power supply. However, a long power supply lead made the equipment susceptible to error and as the frequency increased the danger of error became greater. The accuracy of the bilateral bearings was not affected by the pickup of energy on the power leads but the sense ambiguity sometimes caused an error of 180°. Weak stations were more susceptible to error than strong nearby stations.

26. All the difficulties in securing reliable sense indications disappeared when the long power supply lead was eliminated and a 6 volt storage battery with dynamotor substituted as a power supply. At the upper frequencies the sense indication occasionally became indefinite, but at no time was it distinctly reversed. Whatever sense indications were given by the equipment when using a storage battery power supply were correct.

27. The ratio of cardioid maximum to cardioid minimum was measured in terms of milliwatts output at the above mentioned points. In all cases the receiver was oscillating at such a frequency so that the beat note would be of a value suitable for maximum receiver output. In the broadcast band the cardioid minimum would phase out so well that the ratio of maximum to minimum in some case would exceed 100 to 1 and no difficulty was encountered in securing a 10 to 1 ratio on any station. As the frequency increased, the cardioid pattern became distorted and the ratio became lower. At the upper end of the band with strong steady signals (TBK, Radio Balcony) the maximum to minimum ratio would drop as low as 3 to 1. When upper frequency weak signals, particularly keyed signals, which came from beyond the optical range were observed, the sense indication became so indefinite as to be practically useless. Under these conditions the loop minima were equally indefinite.

28. Adjustment of loop tuning was critical when trying to secure a good cardioid, but once the sense had been determined the accuracy of bearing was not affected by a misadjustment of the tuning. Too great a misadjuetment of loop tuning would reduce the pickup to a point where no bearings could be taken. For obtaining the best possible cardioid, it was necessary to adjust the phasing resistor for each bearing, but satisfactory and definite cardioid patterns could be obtained throughout the broadcast band without about three settings of the phasing resistor. As the frequency of the observed bearing increases, the probability of a distorted cardioid becomes greater and the adjustments become more critical. None of these misadjustments was found to cause sense reversals or a shift in bearing when the equipment was operated from a battery power supply. One misadjuetment could cause an apparent sense reversal, but it is easily detected. If the receiver gain were too high on a powerful signal, the receiver would give a fair signal at the cardioid minimum and block entirely at the cardioid maximum, thus giving an apparent reversal of sense.

29. In Table 3 are given the results of a large number of observations selected at random and they give a good picture of the results to be expected when using the equipment as a portable direction finder. Numerous sources of error out of the equipment itself are to be considered, such as the error in establishing of a true north-south line from a sun bearing, and possible distortion of the radiation field due to neighboring objects, although this was avoided as much as possible. In all cases observed, the reciprocal bearing was within about 1^{o} of the true bearing $\pm 180^{o}$.

30. Range of the equipment is also given in Table 3. A nine-foot sense antenna was used and it was possible to take bearings on any station in the broadcast band which could be heard well enough to identify.

31. The selectivity was good enough to separate WPG Atlantic City operating on 1100 kc from WRVA Richmond, which operates on 1110 kc. No trouble was experienced in taking bearings on WCAO Baltimore, which is 30 kc removed from WMAL local.

32. Most bearings were taken with an oscillating receiver, but bearings could be taken on powerful broadcast stations with a non-oscillating receiver, provided the modulation was of a steady nature. Music was preferable to speaking. In the high frequency bands, only code stations were available and the oscillating receiver was used at all times. The stations observed were usually keyed and, if the keying were rapid and steady, it was possible to adjust the equipment for reasonably good bearings.

33. In Table 4 are recorded seven readings made at various frequencies throughout the band on the TBK transmitter, which was operating on the radio balcony about four hundred yards distant. It will be noted that the ratio of cardioid maximum to cardioid minimum tapers off very rapidly in the neighborhood of 5000 kc. The bearings appear to be inaccurate and erratic, but in all cases up to and including 6000 kc. the reciprocal bearing is exactly 180^{o} opposite from the true bearing and consequently the inaccuracies are not an inherent defect of the CXN-RAJ direction finder. Some of the error is due to center of radiation and some due to wired radio transmission along power lines.

34. The operation of the CXN-RAJ direction finder deteriorated very rapidly above 1500 kc. Above 2000 kc the dependable range was estimated to be

as low as 25 miles, although bearings were taken on WMZ operating on 5985 kc at a distance of 249 miles. However, as soon as the frequency exceeded 2000 kc or the distance exceeded 25 miles, the cardioid became indefinite, and the loop minima became broad and also shifted their position. All observations were made in daytime. No night observations were made.

35. In the case of a nearby powerful station such as WJSV located one mile away, it is possible to secure a 180° reversal of sense by tuning the receiver to the second harmonic and tuning the loop to the fundamental. However, such an obvious misadjustment is necessary to secure this condition that no trouble should be encountered in actual practice.

36. Observations on a plane in flight showed good results at 3475 kc, but at 6600 the cardioid became uncertain. At 6600 the loop still gave a fairly distinct minima and in both cases it was necessary for the plane to be abreast of the direction finder and not above. These observations were made on keyed signals which are inferior to a steady note.

37. Table 7 gives the approximate sensitivity of the equipment using the loop only as a collector. These values indicate a very satisfactory degree of sensitivity. Since these values are for the maximum position of the loop the field strength required for taking bearings is some 50 times the values shown in the table. Should the noise level be too high to permit the use of the maximum gain of the receiver still greater values of field strength would be required.

38. Due to the method of obtaining the sensitivity as described in par. 17 the probable error must be taken into account when comparing these results with measurements made on other equipments.

39. The power consumption of the equipment is shown in Table 8.

CONCLUSIONS

40. The Model CXN Direction Finder is ruggedly constructed of good materials and shows good quality workmanship throughout.

41. The circuit design is simple and straightforward.

42. With a battery power supply the bearings are reliable throughout the broadcast range. At the higher frequencies where the radiation may not be coming from the transmitter in a direct path, the bearings are not as good, but when a definite sense indication is obtained, it is reliable. It is theoretically impossible to reverse sense by night effect, so the chance is small that a bearing with definite sense may be bad. Accuracy may at times be very low on broadcast even though the sense indication is reliable.

43. With AC power supply the power lead acts as an antenna and destroys the sense whenever the pickup on the power lead exceeds the pickup on the sense antenna. The bearings become less reliable as the length of the power lead or the frequency of the received signal is increased. The use of a counterpoise and shielded power lead lessens the probability of sense error but does not remove it entirely.

44. No change of bearings could be observed due to change of the loop tuning.

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45. Bearings could be taken on broadcast stations with the receiver in either the oscillating or non-oscillating condition, but the oscillating condition was the better position for taking a bearing.

46. Good bearings could be taken on keyed CW signals wherever the keying was rapid enough and of sufficient duration to make the necessary adjustments.

47. In cases where a steady carrier was available, the adjustments pertaining to sense could be made more accurately when an output meter was used instead of a pair of telephones. This is particularly true of the loop tuning and phasing resistor adjustments. The actual bilateral accuracy of bearing once the sense had been determined is as good with the telephones for indicators and it is possible to work with lower signal levels than it is with the output meter for an indicator.

48. Two or three positions of the phasing resistor are sufficient for frequencies in the broadcast band, but for an ideal adjustment necessary for a true cardioid it is necessary to make separate adjustment at practically every frequency.

49. Care in making adjustments and the use of a proper length sense antenna will give a cardioid whose ratio of maximum to minimum on any frequency in the broadcast band will be greater than 15 to 1 and in some cases the minimum phases out so well that the ratio of maximum to minimum is greater than 100 to 1.

50. The dependable range of the equipment on frequencies above the broadcast band is only as great as the optical path, although at times it is possible to take a bearing on 6000 kc transmission at a distance of 250 miles.

51. Bearings could be taken on a plane in flight as long as a line drawn from the Direction Finder to the plane does not make too large an angle with a horizontal plane. This angle is estimated roughly to be about 30°.

52. No means has been provided in the Model CXN-RAJ circuit for balancing for sharp bilateral minima. However, it is possible, by placing the hand on the loop shield and sliding it along, to find a balance pointresulting in a very sharp minimum at times. The equipment has a distinctly lower order of precision than the Model DP direction finder.

[redacted]

TABLE 1

MODEL CXN DIRECTION FINDER ADAPTER

Weights and Dimensions (Overall)

	Weight (lbs.)
Direction finder adapter 5-3/8" x 5-3/4" x 7-1/4" (without loop)	
Loop diameter, inside 8-5/8", outside 11-3/4"	7.5
Maximum height overall 17-3/4"	
Coupling cable, 24" long, 3/8" diameter	0.32
Junction box 5-1/8" x 4-1/8" x 1-7/8"	0.5
2 Power cables, 60", 7/16" diameter	0.93
1 Vacuum tube, Navy Type 38233, Commercial RK-33	
Total weight of adapter	9.25
Weight of Model RAJ equipment	67.75
Weight of cabinet	52.00
Total	129.00 pounds

[redacted]

TABLE 2

MODEL CXN DIRECTION FINDER EQUIPMENT

Attenuation of antenna reception due to use of loop tuner and associated cable.

A
10 milliwatts output

Frequency (kc)	Input to Loop Tuner (Microvolts)	Input direct to receiver (Microvolts)	Ratio
400	0.97	0.73	1.33
800	1.1	0.62	1.78
1200	1.7	0.82	2.08
1800	3.4	1.1	3.09
2600	3.6	0.82	4.40
3750	10.0	2.0	5.0
4940	6.0	1.05	5.7
6750	7.0	1.0	7.0

B

Frequency	Receiver Output With Loop Tuner (Milliwatts)	Receiver Output Without Loop Tuner (Milliwatts)	Ratio
630	7	10	1.43
950	8	17	2.11
1060	6	12	2.0
1310	14	30	2.14
2910	4	30	7.5
4150	2.5	14	5.6
4375	5	25	5.0
5140	3	20	6.6
6060	5	25	5.0

The inputs used were radiated broadcast signals and were identical for the conditions with and without loop tuner but the inputs varied when different stations were tuned in.

[redacted]

TABLE 3

MODEL CXN DIRECTION FINDER

Bearings Taken at No. 1 Compass House

Station	Frequency (kcs)	True Bearing (Degrees)	Distance (Miles)	Error (Degrees) Trial 1	Trial II	Trial III
WFIL	560	51.0	128	+7	-1	-2
WCAO	600	34.1	40	-5.1	-3.1	-9
WMAL	630	359.0	5	-2.5	+1	-1
WEAF	660	53.6	228	+1.4	+3.4	+2.6
WOR	710	48.2	206	-4.7	-3.7	-7.2
WJZ	760	47.1	182	+5.1	+5.1	
WTAR	780	161.2	142	-1.7	-1.2	
WTBO	800	307.2	113	+1.8	+1.8	
WABC	860	44.1	209	+4.9	+4.4	+0.9
WRC	950	357.0	7	0	-1	-1
WBAL	1060	24.5	40	-2.5	-2.5	-3.5
WPG	1100	70.8	149	+2.2	+5.2	+7.2
WRVA	1110	195.0	86	-1	-7	-2.5
WCAU	1170	46.7	119	+0.8	+1.3	+1.3
WFBR	1270	38.6	41	-7.6	-3.6	
WOL	1310	359.0	5	+6	+6	+4

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TABLE 4

MODEL CXN DIRECTION FINDER HIGH FREQUENCY BEARINGS TAKEN AT NO.1 COMPASS HOUSE.

Station	Frequency (kcs)	True Bearing (Degrees)	Distance (Miles)	Error (Degrees) Trial I	Trial II	Trial III
WJSV	2920	278	1	-10	-3	0
NAA	4015	315	3	-7	0	-4
WOO	4752.5	68.4	222			+14.6
WQEN	5105	352.5	6	+15	-34	+11
WNEJ	5230	24	21	+14	-51	
WEU	5270	48	180	-20		
WMZ	5985	55.6	249	+7	+12	+2

Minima on above stations, with exception of WJSV and NAA, were so broad that the probable error of the readings was estimated at $\pm 25^{\circ}$. Readings on NAA and WJSV were definite within $\pm 5^{\circ}$.

TABLE 5

MODEL CXN-RAJ DIRECTION FINDER

Bearings taken on Model TBK transmitter on Radio Balcony with direction finder at No. 1 Compass House.

Frequency	Cardioid Max. / Cardioid Min.	Bearing	Reciprocal	Error
2000	250/1	167	347	-1
3000	250/1	147	327	-21
4000	100/1	156	336	-12
5000	20/1	153	333	-15
6000	3/1	162	342	-8
7000	5/1	150	326	-18
7500	8/1	142	323	-26

True Bearing - 168°
Distance - 400 yards

Minima on all the above readings could be read within $\pm 3^{\circ}$.

TABLE 6

MODEL CXN DIRECTION FINDER

Accuracy of Setting

WRC - 950 kcs.			WBAL - 1060 kcs.			WMAL - 630 kcs.		
Loop Setting Degrees	Milliwatts Output AC	Power Supply DC	Loop Setting Degrees	Milliwatts Output AC	Power Supply DC	Loop Setting Degrees	Milliwatts Output AC	Power Supply DC
260	42	42	280	50	50	280	41	42
270	37	38	290	46	45	290	32	34
280	31	32	300	41	40	300	22	23
290	22	23	310	33	33	310	13	13
300	14	15	320	24	23	320	5	6
310	8	8	330	15	14	330	1.5	1.2
320	4	4	340	8	8	332	0.5	0.6
330	0.4	0.4	350	2.5	2.5	334	0.3	0.4
331	0.15	0.2	358	0.3	0.25	336	0.2	0.2
332	0.1	0.1	359	0.2	0.15			
333	0.02	0.05	0	0.1	0.05	337	0.15	0.15
334	0.00	0.00	1	0.05	0.00			
335	0.01	0.02	2	0.04	0.02	340	0.4	0.4
336	0.08	0.08	3	0.05	0.08			
340	0.5	0.5	10	1.0	1.0	350	3.5	4
350	4	4	20	5	5			
360	9	9	30	12	12	360	10	10
10	16	15	40	19	20	10	18	20
20	24	23	50	28	28	20	28	32
30	32	30	60	37	37	30	36	41
40	37	36	70	44	42	40	45	48
50	42	40						
154°	Reciprocal Bearing	154°	182°	Reciprocal	182°	156°	Reciprocal	156.5°

The equipment was not set up on a true North South line for the above measurements.

[redacted]

TABLE 7

SENSITIVITY OF MODEL CXN-RAJ EQUIPMENT USING THE LOOP ONLY AS THE COLLECTOR.

Frequency kcs.	Effective Height of Loop	Q	Microvolts per Meter
500	0.0089 Meters	45	2.5
590	0.0105	43	2.4
700	0.0124	83	1.1
1050	0.0187	86	0.9
1450	0.0258	35	2.2
1570	0.0279	59	1.9
2750	0.0490	30	2.4
3000	0.0532	40	2.5
5000	0.0890	21	3.3
8000	0.147	15	3.7

TABLE 8

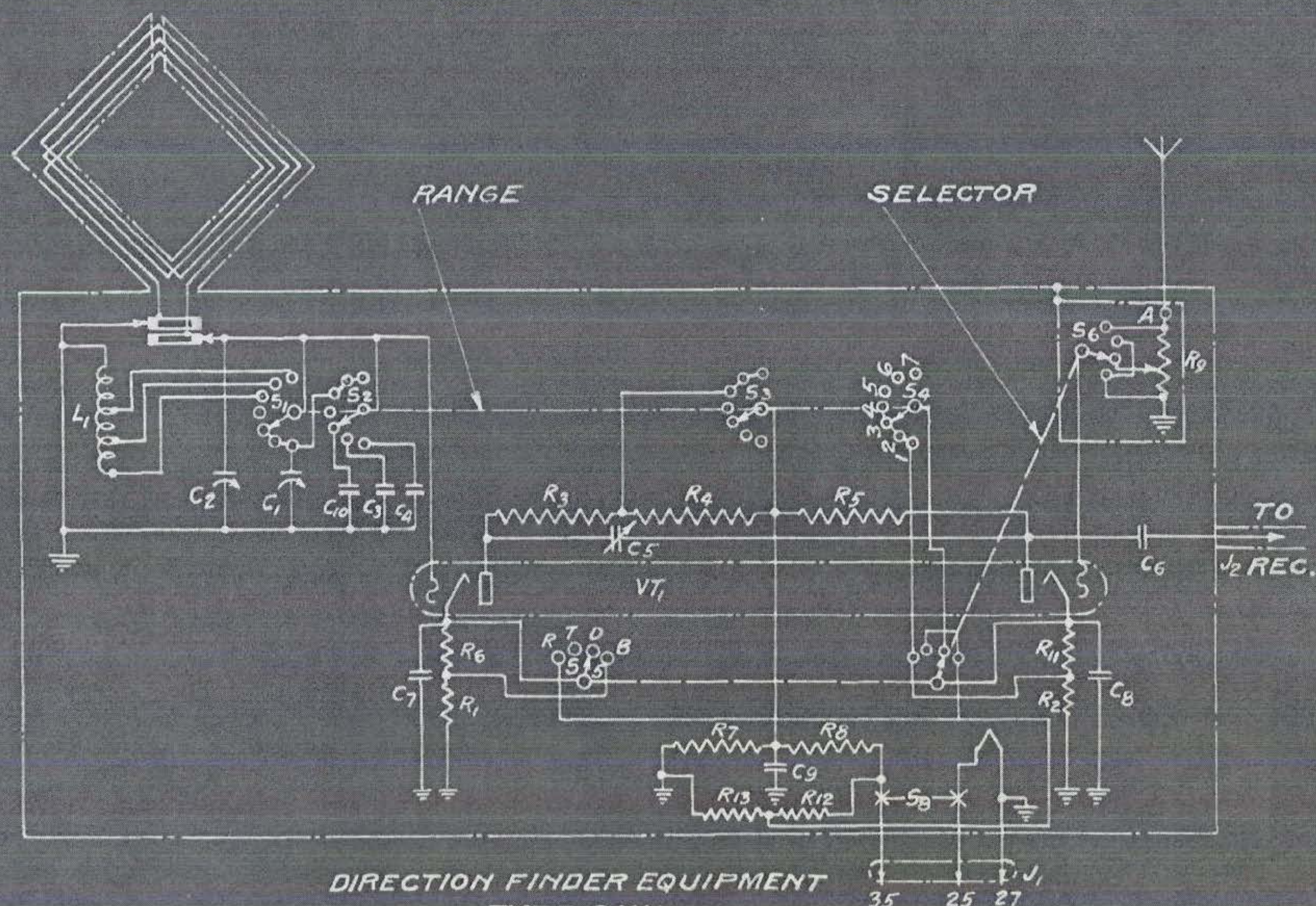
POWER CONSUMPTION

D.C.

	Volts	Amperes	Watts
Dynamotor alone	6.2	3.0	18.6
Dynamotor and Receiver	6.2	8.0	49.6
Dynamotor, Receiver and D.F. Unit	6.2	8.8	54.6

110 Volts A.C.

	Watts
Rectifier alone	29
Rectifier and Receiver	64
Rectifier, Receiver and D.F. Unit	69



DIRECTION FINDER EQUIPMENT
TYPE CXN
SCHEMATIC DIAGRAM.

PLATE 1

[redacted]

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

Plate 2

[redacted]

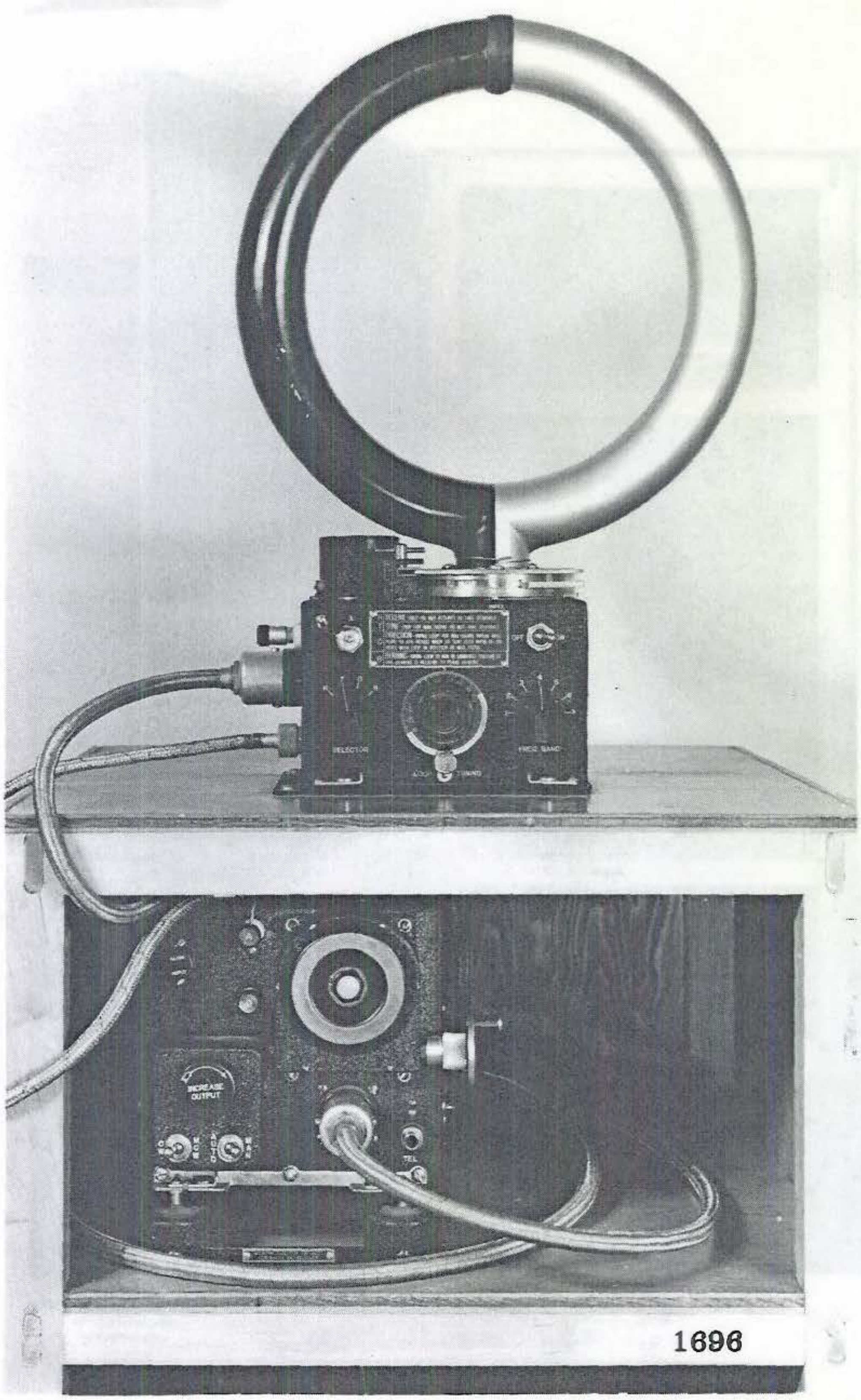


Plate 3