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Report on

Systems Test of the Models ASG and XASG Radar Equipments

Contractor - The Philco Company

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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SECTION 1

REPORT ON THE SYSTEMS TEST OF THE MODELS ASG AND XASG RADAR EQUIPMENTS

1-1. INTRODUCTION

1-1-1. During the period 16 October 1942 to 31 October 1942, the XASG equipment was given a systems test as described below. From 27 November 1942 to 18 December 1942, the ASG equipment was given similar tests. For convenience, the results of tests on both equipments are given here.

1-1-2. Contents (Section 1)

1-1-3. List of Plates

1-1-4. List of Tables

1-2. DESCRIPTION OF EQUIPMENT

1-2-1. The ASG Radar Equipment is an "S" band airborne radar system designed for use in lighter-than air-aircraft. It is relatively small in size weighing altogether 268.3 lbs. exclusive of cabling. There are two main units, the transmitter-converter-antenna assembly, and the receiver-indicator unit. In addition to this are the Remote PPI and the remote tuning control. The XASG is a preliminary model of the ASG and differs from it only in minor details.

1-2-2. The transmitter-converter-antenna assembly embodies the modulator, transmitter, antenna and RF to IF converter plus two stages of IF. The receiver indicator contains the rest of the receiver and the PPI and "A" Scope Indicator. The Remote PPI repeats the pattern at a spot remote from the receiver, presumably the pilot's station. The remote tuning unit controls the klystron tuning and is intended to be placed near the receiver within easy reach of the operator.

1-2-3. The individual weights of the unit are:

	ASG	XASG
Xmtr-conv-ant assembly------------	175.5 lbs.	178.5 lbs.
Recr-Ind unit including cradle----	75.	86.
Remote PPI-----------------------	7.0	8.1
Remote tuning head---------------	0.8	1.

1-3. DESCRIPTION OF TESTS

1-3-1. The systems tests included an investigation of:

(1) Maximum Range on
  (a) land targets
  (b) surface craft of various sizes
  (c) Type SBD airplane (XASG only)

(2) Minimum Range on
  (a) 44 ft. boat
  (b) Type SBD airplane (XASG only)

(3) Range accuracy
(4) Range resolution
(5) Bearing accuracy
(6) Bearing resolution
(7) Interference in other Radars from ASG and XASG
(8) Interference in ASG and XASG from outside sources
(9) Effect of ± 10% line voltage change
(10) Comparison with other "S" band Radar Equipments in sensitivity.
(11) Reliability of operation.
(12) Elevation accuracy.

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1-4. INSTALLATION

1-4-1. Installation instructions in the preliminary instruction book gave little or no data useful in setting up the equipment at the Chesapeake Bay Station other than the cabling diagram. For this reason, no comments on the instructions in the preliminary book are included except that they are inadequate. Since setting up the equipment, however, new instruction books have been received in which these points have been treated much more satisfactorily.

1-4-2. The power for the equipment was supplied from an NEB-2D generator between Nov. 27 and Dec. 8, and from an NEA-2D generator for the remainder of the tests. The generators were driven by a 220 volt 3 phase motor. The total power drain is listed as 863 watts.

1-5. TUNE-UP

1-5-1. The directions for tuning the equipment as given in the instruction book are quite complete except that nothing is mentioned about the line and T-R box. Readjustment of TR box and lines was found necessary after a new magnetron was installed.

1-5-2. The T-R box was found to tune to resonance beyond the point at which the plugs were stopped by the lock nuts they wear. It was found necessary to remove one of the lock nuts before the cavity was completely tuned. The receiver coupling loop is apparently too small, and must be inserted in the TR cavity as far as possible. Since there are no stops on the coupling loop, it would be possible to break the glass of the TR box by trying to insert this loop too far.

1-6. SYSTEM SENSITIVITY

1-6-1. A list of signal-to-noise ratios was compiled on various targets on two occasions and compared with a standard list against which sensitivity tests are checked. The equipment which is used in making up the standard list is the 271 equipment, also an S-band equipment. The list is given in Tables I and II.

1-6-2. In general, the ASG and the XASG were as good or better than the 271 on most of the targets. When they were working normally, their sensitivity was quite satisfactory.

1-6-3. The receiver, antenna and transmitter characteristics were measured, since all three contribute to the system sensitivity. The results of the measurements are given in the following paragraphs. (See page 4.)

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1-6-4. The signal-to-noise ratio of the ASG receiver was 21 db below theoretical on a 1 kt scale. The IF band width was 2.4 mc. at the half-energy point. The video response was 2.5 db down at 1 mc. and dropped off very sharply after this point.

1-6-5. The signal-to-noise ratio of the XASG receiver was 26 db below theoretical on a 1 kt scale. The IF band width was 2.2 mc. at the half-energy point. The video response was 2.0 db down at 1 mc., dropping off very sharply after this value.

1-6-6. The reason for the poor sensitivity is apparently due to the crystals furnished with the equipment. Recent measurements have shown that the impedance characteristics of the crystals furnished with the equipment are quite different from those of the 1N21 crystals now being furnished.

1-6-7. The antenna gain was 21 db over a dipole. The beam width was approximately 5 degrees half-energy, half angle, in both planes. These figures apply to both the ASG and the XASG.

1-6-8. The peak r.f. power output of the ASG transmitter was measured as 30 kilowatts. The same figure was obtained for the XASG transmitter. Preliminary measurements on these equipments indicated low power output, but this was traced to a defective magnetron.

1-7. MAXIMUM RANGE

1-7-1. The maximum consistent range on fixed targets was observed on the Annapolis Towers at a signal-to-noise ratio of from 3-1 to saturation. Under conditions of atmospheric inversion, echoes were received from as great a distance as 30 miles. This was seen about 9:00 p.m., and persisted for about ten minutes. It might be well to mention here that while testing the XASG, echoes were seen as far away as 65 miles south. There is little doubt but that under similar conditions the ASG would also register the same signal.

1-7-2. On a test with a 44' wooden boat, the echo was visible on the ASG to a distance of 7 miles on two different runs. The boat was followed out to 7 miles at which time the signal-to-noise ratio had fallen to 1-1/2. The signal was such at 7 miles that it is fair to believe that it would have been visible at 7-1/2 or 8 miles before disappearing. It was noticed that the boat put in better signals coming in than going out. A similar test on the 271 lost the boat at 10,000 yards, or about 5 miles. On a different occasion the XASG followed the boat to a distance of 12,000 yards when the 271 lost it at 10,000 yards.

1-7-3. Large boats, freighters, etc., were followed south down the bay to a maximum distance of 20 miles. In general, such craft were visible reliably to a range of 16 - 18 miles.

1-8. MINIMUM RANGE

1-8-1. Moving targets coming toward the equipment could be followed in to 1/10 mile before their identity was lost in the transmitter pulse.

1-9. RANGE ACCURACY

1-9-1. Absolute range accuracy was determined in two ways: by the use of an optical ranger and by measurement from a U. S. Geological Survey Map.

1-9-2. The first method was used on a 44' wooden boat; the second method was used on Sharp's Island Light and Annapolis Towers. The data collected is given below in tabular form.

Target	Range Estimate on PPI	Absolute Range	Method	Error
(1) 44' wooden boat	2200 yds.	2310 yds.	(1)	110
(2) Sharp's Island Light	14000 yds.	14700 yds.	(2)	700
(3) Annapolis Towers	39000 yds.	39000 yds.	(2)	___

The range accuracy will necessarily be poor because of the type of ranging used, but should be better than this.

1-9-3. No perceptible range drift was noticed within 1 hour of starting.

1-10. RANGE DISCRIMINATION

Range discrimination was estimated at 200 yds. on the 5-mile scale. That is to say, two signals of the same order of magnitude having the same approximate bearing and differing in range by 200 yds. on the 5-mile scale can be distinguished as two signals.

On the 20-mile range, signals as described above but differing in range by 1,000 yds. could be distinguished separately.

It is fair to assume that on the 50 mile range, echoes 1 mile apart could be seen as multiple and on the 90 mile range they would need to be separated by about 4000 yds.

1-11. BEARING ACCURACY

1-11-1. In both equipments the accuracy of the bearing indication on the PPI was acceptable on the whole. The error

1-11-1. (Cont'd.)

was measured by checking the angular displacement of the trace on the PPI tube against physical angular displacement of the spinner. The results are given in Tables III and IV.

1-12. BEARING DISCRIMINATION (See Tables V & VI)

1-12-1. The test for bearing discrimination was performed as follows. A signal was selected and data taken of signal-to-noise ratio vs. deviation from bearing for maximum signal. The ASG observations were made on three different steady targets of signal strengths from saturation to 4-1. The XASG observations were taken on only one target.

1-12-2. To summarize these tables, an average signal will appear at a signal-to-noise ratio of 1-1, reach a maximum within about 5°, and drop out of sight again after about 11°. This does not mean that two signals have to be separated by 11° to be seen as separate. Two echoes separated by 3° may be seen separately provided there is not too great disparity between their signal strengths. For instance, two pips whose signal-to-noise ratios are 10-1 and 2-1 may be distinguished at an azimuth difference of 3°.

1-12-3. No perceptible bearing drift was noticed.

1-13. ELEVATION ACCURACY

1-13-1. The accuracy of the tilt indicator on the ASG at 115 line volts varied from the true angle by a maximum of 1.5°. The data collected are given in Table VII. This test was not given the XASG.

1-14. LINE VOLTAGE CHANGE

1-14-1. Neither the ASG nor the XASG is excessively sensitive to line voltage change and in general, both operate satisfactorily over a $\pm$ 10% line voltage fluctuation, from 103.5 to 126.5.

1-14-2. At 103.5 volts, 800 c.p.s. the sensitivity is considerably lowered, the signal-to-noise ratio for a typical target noise ratio being about .75 times what it was at 115 volts.

1-14-3. At this voltage, the PPI and A scopes are dimmer, need to be refocussed and the A scope has a wider pattern. The tuning needs to be readjusted.

1-14-4. Although noticed at all voltages, the inaccuracy of the initiation of the sweep on the PPI was found most objectionable at this lowered voltage. This caused the outline of the edge of the circular pattern on the PPI to be ragged since all the sweeps were not of the same length. This is not a problem of inaccurate blanking which did not cut off each sweep at the same place since the range marks also showed this inaccuracy and caused a ragged circular pattern as the antenna rotated.

1-14-5. The trouble might be traced to a faulty delay tube circuit since the range marks as well as the transmitter pulse are triggered by the output of this tube.

At 126.5 v. 800 c.p.s., the sensitivity is better than at the mean normal operating voltage, the signal-to-noise ratio for a typical target being about 1.2 times what it was at 115 volts. The A scope was brighter, its maximum vertical displacement was greater, and both tubes remained in focus. The equipment did not require retuning, except for a small readjustment of Klystron voltage, to compensate for changed crystal current. The data are given in Table VIII.

1-15. <u>INTERFERENCE</u>

1-15-1. At no time did interference from sources outside the equipment cause disturbance sufficient to hinder the performance of the equipment to an extent worthy of mention. Other radars in the vicinity would cause moving pips to appear on the screen but their character was so transitory in nature that they could not be confused with those from a target and were not great enough in brilliance to cause trouble.

1-15-2. Some interference in the SN and SF radar equipments was noticed but it was transitory and weak and caused no trouble.

1-15-3. A continuous wave oscillator of the right frequency in any sector would probably cause this radar to be useless in that direction, but it is reasonable to expect that it would be inoperative over not more than a few degrees of its search.

1-15-4. Signals of the intermediate frequency were never observed on the indicators and there seems to be adequate shielding against this sort of interference.

1-15-5. Blocking of the receiver was not noticed and there was no trouble with delayed receiver recovery. When there were several adjacent saturated signals, they tended to merge into one another, but blocking was not observed.

1-15-6. Most of the internal noise in the ASG was caused by the fan motors. When these motors were disconnected, the main part of this noise vanished.

1-16. DEFECTS AND RECOMMENDATIONS

1-16-1. PPI.

1. During the warm-up period, the PPI sweep was noticed to jump to the right and left occasionally a distance of about 1/8 of an inch. This trouble was not observed after the equipment had been running for some time.

2. On the 90-mile range, putting the equipment in beacon operation results in cutting the physical length of the sweep approximately in half.

3. It is observed that the sweep is not exactly circular; this is particularly noticeable on the 5-mile range.

4. When there are no signals and the gain is turned up, the sweep looks very untidy. Part, but not all of this, is due to the noise from the fan motors. At times a whole line or a part of it will be intensified or erratic pips appear.

5. The intensity changes with range selection.

6. The focussing changes when the high voltage to the transmitter is turned off or on.

7. The blanking is incomplete and extraneous traces may be observed when the intensity is turned up or when the equipment is operating at a lowered voltage.

8. The range marks on the search are irregular, causing a ragged circle on the pattern. The edge of the pattern is also ragged as are the signals seen. This indicates that the initiation of the sweep is not precise due perhaps to poor triggering or poor delay circuit.

9. The center of the pattern is not anchored but described a small closed curve. This is most noticeable on the 5 and 90 mile ranges.

10. On the 5-mile range, there are only 4 markers; this is brought about by the fact that the tube blanks off too soon at the end of the sweep and the 5th marker does not appear in time to show.

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1-16-2. "A" Scope

1. There is considerable difference in the range discriminating ability of the PPI and the A Scope. The A Scope is the poorer of the two because of the shortness of the sweep. A longer sweep or better focus would help.

2. The centering changes with range selection.

3. The maximum vertical displacement is too small. A greater displacement would tend toward greater ease of operation and make smaller signals discernible.

4. The conducting coating (Aquadag?) is faulty and does not draw off the electrons fast enough to prevent their congregating and forming dead spots on the screen under certain conditions.

5. Position two on the A Scope on occasions has an erratic vertical displacement which indicates oscillation of some parts of the circuit.

6. There is a change of intensity with range selection.

7. The focussing is poor. It is impossible to focus both ends of the trace at the same time, and the focussing of vertical and horizontal do not occur at the same point.

1-16-3. Modulator

1. The plate current to the 715-A and the magnetron change with range selection. They increase with longer range.

2. The noise of the blowers is excessive and indicates excessive wear on the motors and is tiring to the operator.

3. The fan motors also cause considerable noise in the Indicators. This was discovered by disconnecting all three and noticing the effect. All were faulty in this respect as all made noise when connected separately.

4. The 829 tube failed on two occasions. The first tube became gassy, drew too much current and caused one RKR-72 to overheat. The next 829 was unsatisfactory because of poor triggering. The initial pulse jumped around considerably on all three positions of the A Scope.

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1-16-3 (Cont'd.)

5. The 715-A tube was replaced because of excessive arcing inside the envelope. In general, all 715-A tubes tended to arc inside the envelope, when used in this equipment.

6. Occasionally when the equipment was improperly tuned the D. C. High voltage supply would arc over.

7. A fuse blew when the spinner was reversed at the high speed.

8. There is no cover below the modulator unit to protect the magnetron, relays, and other equipment mounted below the chassis.

9. Service is extremely difficult because of the inaccessability of the parts.

10. The soldered connections of the resistor between the plate of the 715-A and the RF choke came loose and had to be resoldered. One, indeed, had no solder on it at all when delivered.

1-16-4. Receiver Indicator

1. There are holes in the PPI and repeater housing that let light in which falls on the screen.

2. The spin and tilt switches are unhandy and should be made more accessible and differentiated from the other controls.

3. The component parts of this unit are inaccessible and service is difficult.

1-16-5. Antenna Assembly

1. The gear drive on the antenna from the spinner motor is coupled too closely. The gears are so close that they do not turn smoothly and cause excessive vibration and wear, as well as a disturbing noise.

2. The tilt does not go a full 20° up and down. It goes up to $+17.2^{\circ}$ and down to -17°.

3. The coupling between the worm speed reduction and the selsyn motor has considerable play in certain positions. That is, the pin locking the two rotating shafts is not tight and allows one to rotate with respect to the other.

1-16-6. Converter and I.F.

1. The central conductor of the coaxial conductor between the klystron and the beacon wavemeter came out and caused this part of the unit to be inoperative. In general, the coaxial conductors used throughout the receiver caused much trouble from shorts or breakings.

2. The tuning of the T-R box was such that the plug tuned it to resonance at a point beyond where it was stopped by the lock nut. Complete tuning was possible only after removal of the lock nut.

1-16-7. Coaxial Plumbing

1. On several occasions the insulation broke down and shorted out the plumbing. So bad did this become that the central conductor had to be removed and polystyrene insulators put in to replace those that had been burned up in the arcing.

2. The coaxial conductor between the TR box and crystal converter shorted out and had to be repaired. The shielding got between the polystyrene beads and shorted to central conductor. The use of better cable (e.g. PT5 or its equivalent) is recommended.

3. One of the tuning stubs was found to become inoperative after the screw adjustment had been turned all the way to the left. This is because the threaded shorting plug came off the threaded portion of the stub and could only be re-engaged by pushing the stub back with a screw driver after unscrewing the plug from the vertical position of the line.

1-17. SUMMARY OF RECOMMENDATIONS

1. It is recommended that the sweep length on the A Scope be increased so as to fill the tube. This will facilitate its use, and make for greater range discrimination.

2. It is recommended that the maximum vertical displacement be increased on the A Scope. A greater displacement would make the pattern easier to watch and permit recognition of signals of lower S-N ratio.

3. It is recommended that the A Scope tube included with the equipment be one of such make that dead spots will not appear as mentioned before due to a faulty conducting coating on the screen.

1-17. (Cont'd.)

4. It is recommended that less noisy blower motors be included in the equipment.

5. It is also recommended that the blowers used be of a type which causes less electrical disturbance in the radar.

6. It is recommended that it be made impossible to reverse the spinner at high speed.

7. It is recommended that a cover be provided below the modulator unit to protect the magnetron and other parts mounted under the chassis.

8. It is recommended that those adjustments which require frequent changes during operation be provided with knobs.

9. It is recommended that the holes in the remote PPI housing be closed to keep out the light.

10. It is recommended that the spin and tilt switches be put in more accessible places and that the type of the spin switch be changed to one more easily operated.

11. It is recommended that the tuning plug on the TR Box be made longer or the length of the lock units decreased so as to permit tuning the unit without removing the lock unit.

12. It is recommended that the spacing on the coaxial line between the magnetron and the antenna be increased to prevent breakdown by the high voltages it carries. 7/8" line is recommended.

13. It is recommended that there be included in both tuning stubs a stop which would prevent the shorting plug from being unscrewed too far and coming off the end of the threaded portion of the tuning screw.

14. It is recommended that the manual brilliance control be limited in some way to prevent the intensity from growing too great and burning the screen.

15. An investigation of the functioning of this equipment under Beacon operation has been made using several TR boxes. A separate report is being made.

16. It is recommended that the modulator be redesigned to eliminate the overloading of the 715A tubes in particular, and to reduce the possibility of arc-overs from one component to another and to make it more accessible for servicing.

ASG SENSITIVITY, MEASURED ON STANDARD TARGETS

TABLE I

Location	Bearing (degrees)	Range (nautical miles)	Signal-to-Noise Ratio		
			271	ASG#1	ASG#2
---	24	12.5	3-1	4-1	4-1
Annapolis Towers	10.5	20	4-1	10-1	5-1
Poplar Island	40-55	9-10	6-1	Saturated	Saturated
Tilghman Island	73	8.5-10	8-1	"	9-1
Cook Point	103	12-13	5-1	10-1	10-1
Hill Point	95-117	11-13	2-1	8-1	Saturated
---	133	12.5	4-1	2-1	"
Sharp's Island Light	99	7.4	4-1	8-1	7-1

XASG SENSITIVITY, MEASURED ON STANDARD TARGETS

TABLE II

Location	Bearing (degrees)	Range (nautical miles)	Signal-to-Noise Ratio		
			271	XASG#1	XASG#2
---	24	12.5	3-1	2-1	1-1
Annapolis Towers	10.5	20	4-1	5-1	3-1
Poplar Island	40-55	9-10	6-1	Saturated	Saturated
Tilghman Island	73	8.5-10	8-1	"	"
Cook Point	103	12-13	5-1	"	"
Hill Point	95-117	11-13	2-1	Sat. to 4-1	Sat. to 4-1
--	133	12.5	4-1	Saturated	Saturated
Sharp's Island Light	99	7.4	4-1	10-1	10-1

Note: (1) The 271 signal-to-noise ratio data were observed at a different time from either run on the ASG or XASG.

(2) A signal-to-noise ratio of greater than 10 to 1 is considered saturation on the ASG and XASG. On the 271, saturation would correspond to a much larger signal-to-noise ratio.

AZIMUTH ACCURACY OF ASG

TABLE III

Actual Physical Degrees	Degrees on PPI Sweep Clockwise-Counter Clkws.		Error CW-CCW		Play
0	0	0	0	0	0
45	44	43	-1	-2	1
90	88	88	-2	-2	0
135	132	135	-3	0	3
180	181	182	1	2	1
225	225	226	0	1	0
270	272	272	2	2	0
315	316	316	1	1	0
360	360	360	0	0	0

AZIMUTH ACCURACY OF XASG

TABLE IV

Actual Physical Degrees	Degrees on PPI Sweep Clockwise-Counter Clkws.		Error CW-CCW		Play
0	0	0	0	0	0
60	59	61	-1	+1	2
120	121	124	+1	+4	3
180	182	184	+2	+4	2
240	238	242	-2	+2	4
300	305	306	+5	+6	1
360	360	360	0	0	0

AZIMUTH DISCRIMINATION OF ASG

TABLE V

Signal Bearing 75, range 1.7 miles S-N ratio 4-1

Bearing°	S-N Ratio	
80	indiscernible	
79	1-1	
78	1.5-1	
77	2-1	
76	3-1	Spread 9°
75	4-1	
74	3-1	
73	2.5-1	
72	2-1	
71	1.5-1	
70	1-1	
69	indiscernible	

Note: (Continued next page).

AZIMUTH DISCRIMINATION OF ASG

TABLE V (Cont'd.)

Signal, Sharp's Island Light, bearing 96°, range 7 miles, S-N ratio 8-1:

Bearing°	S-N Ratio	
105	indiscernible	
104	1-1	
102	4-1	
100	5-1	Spread 14°
98	7-1	
96	8-1	
94	4-1	
92	3-1	
90	1.5-1	
89	indiscernible	

Signal, Pier to the North, bearing 357°, range 1.7 miles, S-N ratio, saturated:

Bearing°	S-N Ratio	
357	S	
350	10-1	
349	7-1	Spread (2 x 5) = 10°
348	5-1	
347	3-1	
345	1-1	
344	indiscernible	

Average Spread - 11°

AZIMUTH DISCRIMINATION OF XASG

TABLE VI

Signal, Sharp's Island Light; bearing from maximum signal taken as 0°, range 7 miles, S-N ratio saturation.

Bearing°	S-N Ratio	
-8	1-1	
-6	2-1	
-5	5-1	
-3	Saturation	Spread 18°
+5	Saturation	
+7	5-1	
+9	2-1	
+10	1-1	

ELEVATION ACCURACY OF ASG

TABLE VII

Actual Elevation	Elevation read from meter	Error
17.2°	17.2°	0°
16	15	-1.00
10.8	10	-0.8
5	5	0
0	0	0
5	5	0
9.6	10	+0.4
14	15	+1.0
17	18.5	+1.5

EFFECT OF LINE VOLTAGE CHANGE ON ASG

TABLE VIII

At Rated Volts 115 volts, 800 c.p.s.

Annapolis Towers:
(1) Tilt - 2
(2) Bearing 13.5
(3) Range 19-20 miles
(4) S-N 5-1
(5) Xtal current .26 ma.
(6) Xmtr a) Rct. 12.1 ma.
b) Mod. 10.1 ma.
(7) Tuning 42.1

Below Rated Volts, at 103.5 volts, 800 cps.

PPI is dimmer, needs refocussing. Slight tendency toward poor blanking and extraneous traces. A scope much dimmer with wider pattern.

Annapolis Towers:
(1) Tilt- 4
(2) Bearing 14
(3) Range 19-20 mi.
(4) S-N = 3-1
(5) Xtal current .26 ma.
(6) Xmtr. a) Rct. 10 ma.
b) Mod. 8 ma.
(7) Tuning 40.7

Sharp's Island Light:
(1) Tilt 0
(2) Bearing 96
(3) Range 7 mi.
(4) S-N 7/1
(5) Xtal current .26 ma.
(6) XMTR a) Rct. 10 ma.
b) Mod. 8 ma.
(7) Tuning 40.7

Above Rated volts, at 126.5 volts, 800 c.p.s.

PPI no brighter than at 115, and in focus. A scope is brighter but still in focus.

Amplification is greater; higher peak signals are observed on the A scope and higher amplification on non-saturated signals.

Annapolis Towers:
(1) Tilt - 2
(2) Bearing 13
(3) Range 19-20 mi.
(4) S-N = 6-1
(5) Xtal current .32 ma.
(6) Xmtr a) Rct. 16. mas.

Note: (Continued next page)

EFFECT OF LINE VOLTAGE CHANGE ON ASG

TABLE VIII (Cont'd.)

Sharp's Island Light:

(1) Tilt 0

(2) Bearing 97°

(3) Range 7 miles

(4) S-N = 8-1

(5) Xtal current .32 ma.

(6) Xmtr. a) Rct. 16 ma.

(7) Tuning 42.1

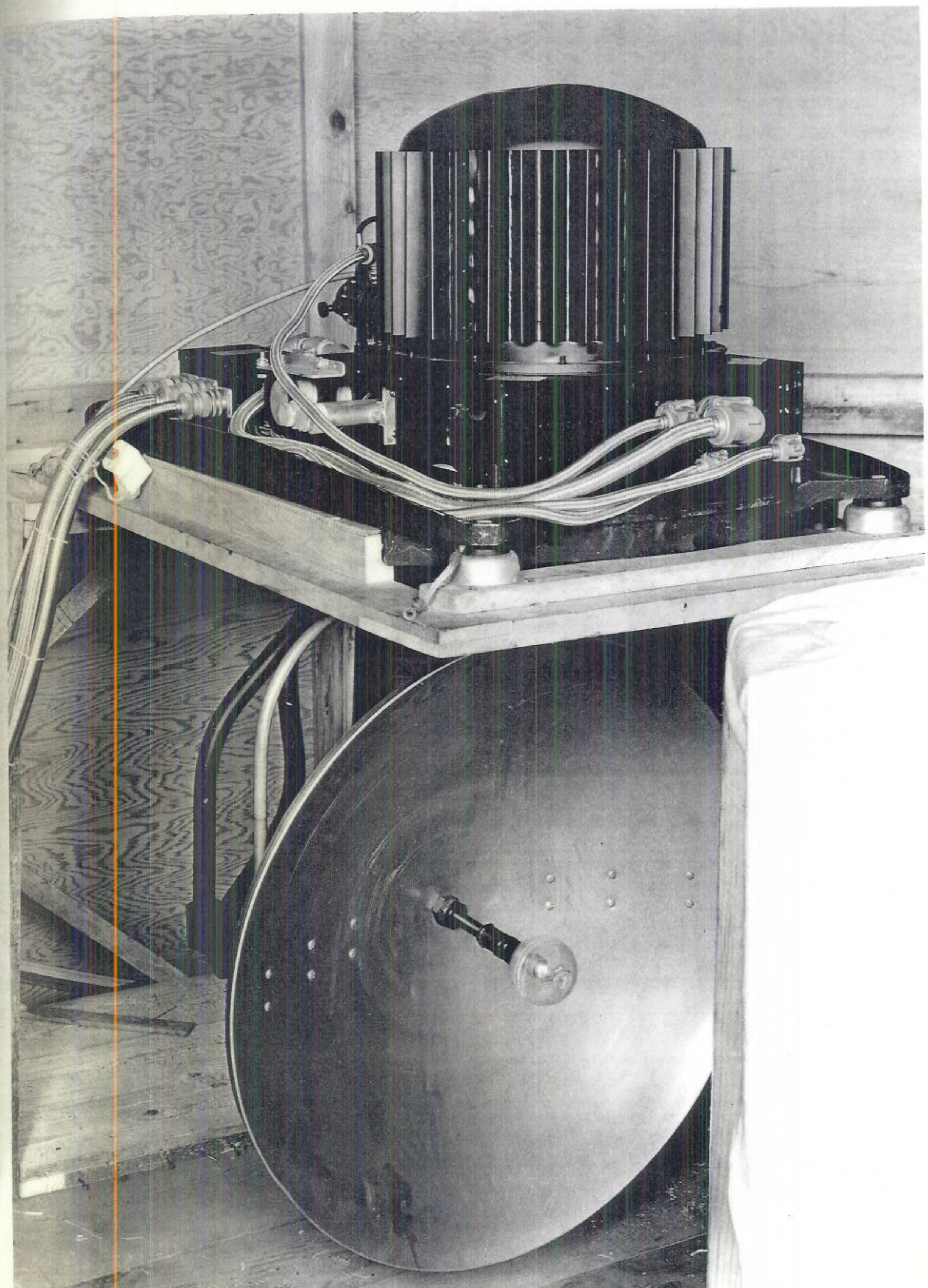


PLATE I SEC.I

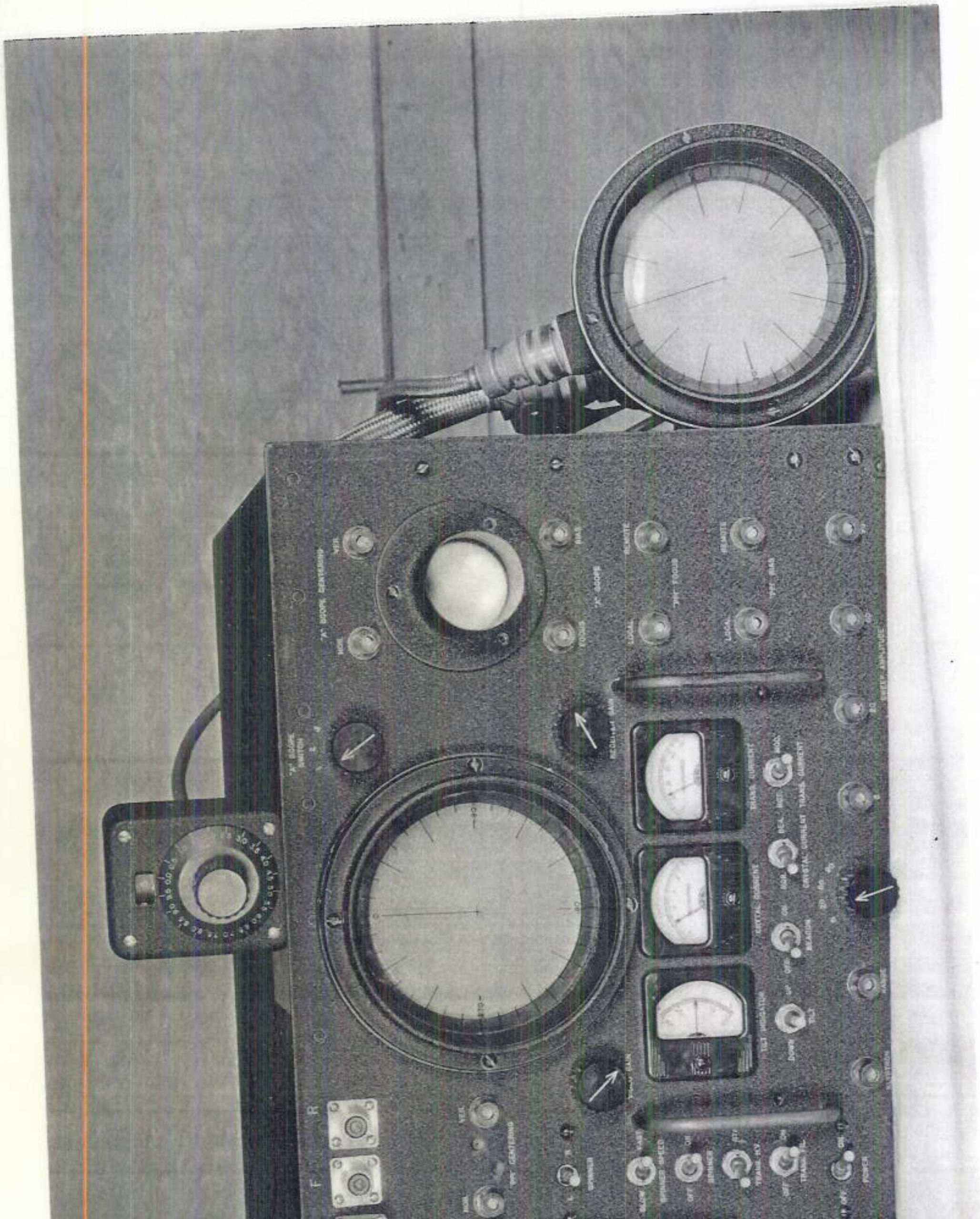
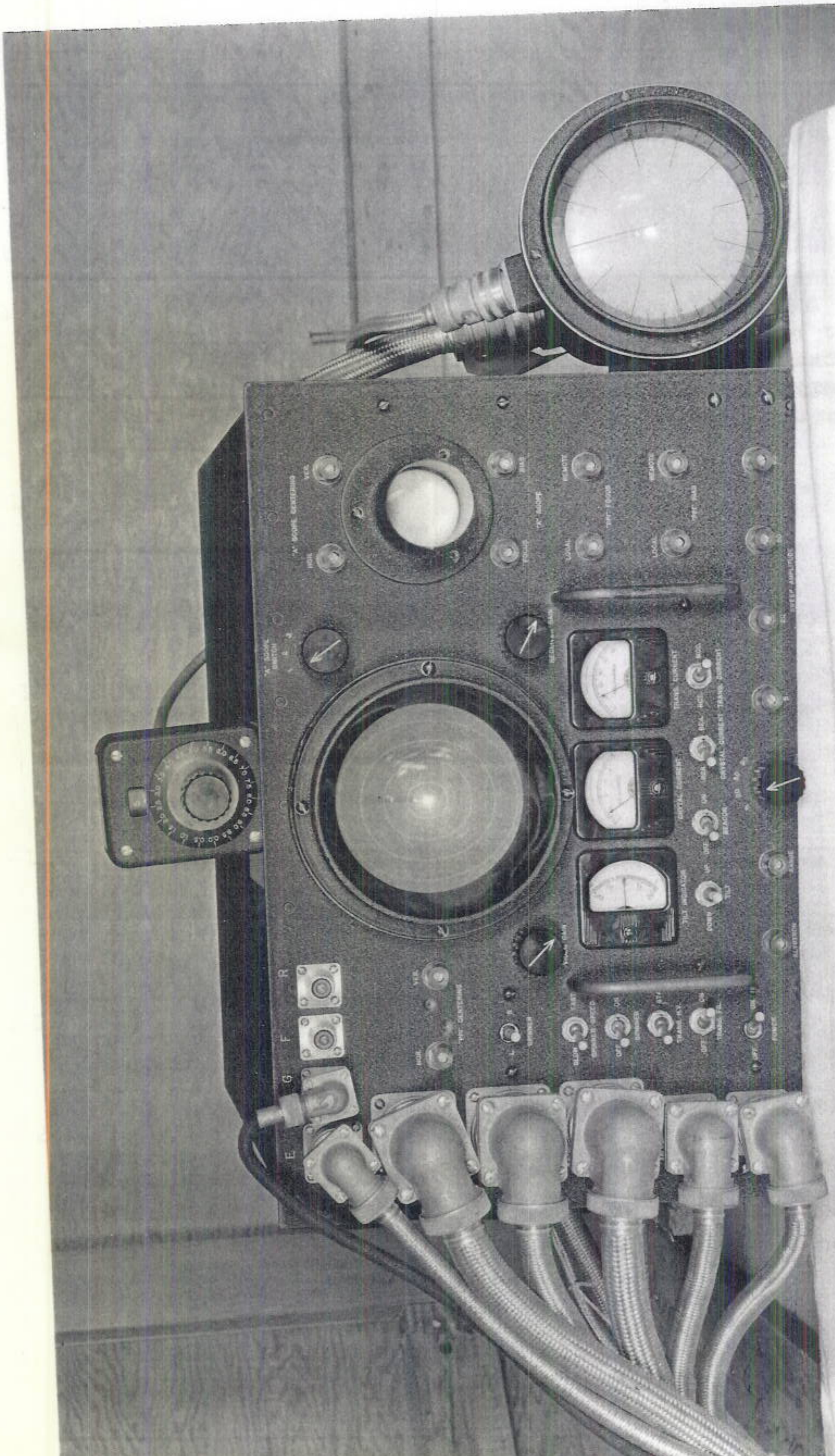


PLATE 2 SEC.I



SECTION 2

REPORT OF TEST ON MODEL ASG RADAR EQUIPMENT

2-1. INTRODUCTION

2-1-1. One Model ASG, Serial #2, airborne radar equipment manufactured by the Philco Radio Corporation was submitted to the Aircraft Section of the Naval Research Laboratory for test. Laboratory tests were conducted to determine performance characteristics and suitability for use in the naval aircraft service. The results of these tests are herein reported.

2-1-2. Contents (Section 2)

2-1-3. List of Plates

2-1-4. List of Tables

2-2. DESCRIPTION OF UNITS

General

2-2-1. The ASG radar is airborne equipment designed to detect surface vessels. Extremely short but intense pulses of high frequency energy are transmitted in a beam from a highly directive antenna. Objects within range of the equipment reflect energy that is received by the same antenna system. The amplified energy appears as video pulses recurring at the same rate as the outgoing train, but delayed in time in accordance with the distance to the object.

2-2-2. The distance and relative bearing of the objects is indicated on a cathode-ray tube. The azimuth direction of radial trace lines on the CRT is correlated with the azimuth direction of the radio beam. The starting time of each radial sweep coincides with the time of generation of each pulse by the transmitter. The video pulses derived from the received echoes are superimposed upon the oscilloscope trace so as to increase the intensity of the beam for that instant. The screen of the indicator is of the long persistance type so that a received echo gives rise to a bright spot on the screen. Because of the time delay between each transmitted pulse and its echo these spots appear at a distance outward from the center which gives a direct measure of the distance to the object. The relative bearing of the object is indicated by the angular position of the trace when the echo is received. To aid in estimating distances, range marks, bright concentric circles, spaced at regular intervals can be superimposed upon the pattern on the screen while scales marked on the face of the screen permit the angular position of the spots to be estimated with reasonable accuracy.

2-2-3. Means are provided for rotating the directive antenna by remote control from the operator's position. It is possible to control the beam so as to concentrate upon a particular target or to cause the beam to rotate continuously for searching. The maximum range of the equipment may be selected as 5, 20, 50, or 100 nautical miles.

2-2-4. A complete equipment comprises the following:

Antenna	On single mounting base Weight--175.5 lbs.
R.F. to I.F. Converter	
Transmitter	
T.R. Box	
Junction Box	

Receiver Indicator Unit and Mounting Base	85 lbs.
Remote Indicator	7.0 lbs.
Tuning Head (Remote)	0.8 lbs.

2-2-5. An external source of power is required to furnish 24 volts at 7 amperes and 115 volts 400 to 2400 cycles at 7 amperes. These current values are not likely to be exceeded under operating conditions.

2-2-6. Receiver Indicator unit is contained in a unit 19-1/2 x 22-3/16 x 13-3/8 inches. Plate voltage supplies for all units, except the Modulator, are contained in the Receiver Indicator unit. A timing oscillator is used to provide 800 cycles for Searching and 400 cycles for Beacon operation. This oscillator controls the Sweep Generator where the deflection voltage originates. A Selsyn Driver tube amplifies this voltage before it is applied to the selsyn rotor winding.

2-2-7. The stator of the selsyn is arranged to produce two signals that differ in amplitude depending upon the rotor position. After proper amplification these voltages are applied to deflecting coils that reproduce the sweep at the same relative bearing as that in which the antenna is pointing.

2-2-8. Blanking pulse and range mark generating circuits are provided from within this same unit.

2-2-9. Four stages of 30 Mc. I.F., a second detector, video amplifier and cathode follower are mounted on a chassis with a narrow band i.f. amplifier and detector. These latter tubes and a 2" scope with class A presentation comprise the receiver tuning system. The klystron is tuned for maximum output from this narrow band i.f. stage that is peaked in the center of receiver i.f. band.

2-2-10. The class A scope may also be used for monitoring reflected signals and the keyer pulse shape. A three position switch controls selection of its function.

<u>Transmitter, Converter and Antenna Assembly</u>

2-2-11. A heavy casting is the common supporting element for these three units and their interconnecting cables.

2-2-12. The transmitter is contained in a domelike structure that is made air-tight to allow proper operation at high altitudes. Timing pulses from the Receiver-Indicator unit control the operation of the pulse amplifier stages; the final amplifier allows discharge of a keyer condenser to a magnetron where the high frequency energy is generated.

2-2-13. A crystal mixer, klystron local oscillator, and two stages of i.f. comprise the converter box for radar operation. Proper frequency adjustment for "Beacon" operation is assured by including a pre-tuned wavemeter within this converter box. The frequency of the local oscillator is adjusted by varying the cavity size through a flexible shaft from the remote tuning head.

2-2-14. The parabolic antenna and its associated selsyn and driving motors are supported by the same casting that holds the transmitter and r.f. to i.f. converter unit. A lever arm system couples the antenna to the tilting motor and tilt indicating selsyn mounted in the base.

2-2-15. All r.f. coaxial lines are rigidly fastened to the equipment and to the supporting frame. They couple the magnetron output to the antenna.

Remote Indicator

2-2-16. The remote P.P.I. is similar to the scope in the Receiver-Indicator unit and the elements of the two scopes are connected in parallel. The remote indicator is enclosed in a cylindrical housing and occupies space 14-1/2" x 8-1/2" x 7-1/2" including Lord shock mounts.

2-3. TEMPERATURE TEST

Procedure

2-3-1. The complete ASG was set up in the temperature chamber with all the operators controls accessible to the observers. Meters in the Receiver-Indicator were used to monitor crystal, rectifier and modulator currents. A pyrometer was used in recording the temperature inside the modulator unit. Relative power output from the antenna was measured with a littlefuse-balanced bridge type indicator.

2-3-2. Power input to the equipment was read on metersexternal to the test chamber.

2-3-3. A normal set of readings were taken with the equipment stabilized at room temperature. In an hour, all units had reached their steady operating temperatures. Reference to these readings is made when comparing the operational data.

2-3-4. The temperature was then lowered to -30° C. and maintained until every piece of the ASG reached this temperature. Ordinarily three hours would suffice for this cooling period, but this model was left at -30° C. overnight and tests continued next morning.

2-3-5. At -30° C. readings were taken of the 800 cycle input voltage and current, d.c. voltage, direct current, power output reference, frequency of magnetron, temperature in transmitter, crystal, rectifier and modulator currents. The mechanical operation of the antenna system, blowers, relays, meters, control switches and remote tuner were checked for proper operation. Any excessive starting currents were noted. Functions and effects of klystron voltage, focus, centering, sweep amplitude, gain, brilliance adjustments were noted. A ten minute warm-up period was allowed before readings.

Observations

2-3-6. Variations of peak crystal current were very pronounced with the temperature changes encountered. Normally the klystron repeller voltage is adjusted for maximum crystal mixer current with a given setting of the tuning head. Coincident with this maximum, received signals occur when tuning head adjustment gives peak crystal current. During this run the lower temperatures produced a discrepancy between adjustment for best received signal and maximum crystal current. Maximum crystal current obtainable at room temperature was adjusted to 0.3 ma. Operation at -30° C. presented a maximum of 0.62 ma; but best signals as judged from the "Main-Bang" on the A scope in position 3 were obtained with a klystron tuning head setting that corresponded to a 0.5 ma. crystal current. Best signals do not correspond to maximum crystal current.

2-3-7. It was impossible to obtain correct focus on either the local or remote indicators at the lowest temperature. The misadjustment was not great enough to prevent interpretation of the pattern but most efficient presentation was not obtained. The run was limited to 10 minutes so that the warm-up of the equipment would not upset observations at the next operating point. It is probable that a longer period of operation would have allowed proper focus.

2-3-8. All functions of the antenna system were satisfactory. Search rotation at both speeds and sector operation by manipulation of the "L" and "R" toggle switch were at same speed as at room temperature. Tilting operation was entirely satisfactory. Complete tilt could be made from any starting position at normal speed.

2-3-9. Operation of all blowers, relays, meters, control switches and the remote tuning head were entirely normal and there was no indication of unreliability. Power output of the magnetron remained the same as indicated by the littlefuse-balanced bridge arrangement. Rectifier and modulator currents were normal and steady. Reference to the data sheet shows the 800 cycle power consumed remained the same; the load due to the d.c. circuits increased 30 watts. This is a 27.5% increase in load but all operation was entirely dependable. There was no evidence of motors failing to start or of reduction gear boxes freezing-up.

2-3-10. Operations at -10° C. was satisfactory in all respects except for the departure from normal crystal current. Maximum current was 0.52 ma. but it was necessary to detune to 0.4 ma. for best receiving conditions.

2-3-11. At room temperature and highest temperature encountered (50° C.) crystal current and oscillator tuning were normal. That is maximum current occurred with best received signal. This maximum was lower at 50° C. than at room temperature.

2-3-12. D.C. power consumed decreased with the increase in temperature. Some of the variation in the d.c. load was caused by fluctuations in the d.c. source. It will be noted from data sheets that higher currents correspond to higher input voltage.

Humidity Run

Procedure

2-3-13. ASG, Serial No. 2, was subjected to 97% humidity at 40 C. for five hours. Approximately one hour was required to reach the above conditions of temperature and humidity. The "hat" enclosing the modulator and high-voltage supplies was removed for this six hour period. It was necessary to replace the "hat" before completing the run. This will be discussed under observations. As in the temperature run readings were made of 800 cycles voltage and current, d.c. voltage, direct current, power output reference, frequency of magnetron, and crystal, rectifier and modulator currents. The mechanical operation of the antenna system, blowers, relays, meters, and control switches were checked for proper operation. Performance of high voltage supplies was particularly noted.

Observations

2-3-14. With the "hat" removed satisfactory operation at this humidity was impossible. Points of high potential had excessive corona and caused undue loading of the high-voltage supply system. Initially the "Rct" current was 35 ma. Over a 5 minute period this current gradually decreased to 20 ma. No further decrease was noted so the "hat" was replaced and the filaments and blowers allowed to operate. Steady high voltage was not applied until the rectifier current became normal. Twenty minutes of this warm-up operation was required to obtain normal current.

2-3-15. R.F. power under stable operating conditions as indicated by the littlefuse-balanced bridge device was down 20% from the standard of comparison at room temperature.

2-3-16. The d.c. power consumed remained practically the same, but current from the 800 cycle supply increased by 12 per cent.

Variable Voltage Run

Procedure

2-3-17. Before data was taken for this run ASG Serial #2 was operated at 28 volts d.c. and 112.5 volts a.c. and allowed to reach a stable operating point. The d.c. voltage was then increased to 30 volts and notation made of all currents, voltages, r.f. power and frequency. Similar data was obtained in successive 2 volt steps of decreasing voltage until erratic operation was observed.

Observations

2-3-18. Satisfactory operation was obtained in a range of 22-30 volts with power output varying in direct proportion to the input voltage. The primary tap and rheostat setting were unchanged for the above conditions. It is possible to maintain 14 kv in the high voltage system by manipulation of the taps and rheostat. At 20.5 volts input the sweep amplitude was less than that required to cover the face of the indicators. It was impossible to compensate for this with the sweep amplitude adjustment provided.

2-3-19. Antenna tilt angle indication was unreliable at 20.5 volts. Speed of tilt was much reduced and the drive motor was close to the stalling point.

2-3-20. Rotation in "Slow" search position was unduly reduced in speed. Operation was satisfactory in "Fast" position.

Vibration of ASG Serial #2

Procedure

2-3-21. The entire unit was firmly secured to the shake table in normal operating position through the Lord shock-mounts provided. Power output monitor and supply voltage meters were mounted free of the vibrating table. In preparation for the test the table vibration rate was varied throughout its operating range and all natural periods of vibration in the units recorded. Then operation was carried on with the table vibrating to hit these resonant periods. At least one hour's operation at these points was carried out, and more than one hour if there was any indication of failure.

Observations

2-3-22. The damping diode in the modulator, RKR73, tended to work out of its socket. No provision is made to clamp this RKR73 into its socket, a standard Amphenol Octal.

2-3-23. The supporting shelf on which are mounted the blower motor, magnetron coupling condenser, and 715-A keyer tube vibrated excessively. No damage was introduced by this vibration, but this unnecessary mechanical strain should be eliminated,

2-3-24. One of the coupling arms in the antenna tilt system continually rotated loose. This is a round threaded stud that transmits the motion to the longer arm connected to the parabola.

Pressure Chamber Tests

Procedure

2-3-25. The chamber was evacuated to simulate conditions at 15,000 feet. It took 1/2 hour to exhaust the chamber to the required pressure and it was held there for four hours then brought back to sea-level pressure in a half-hour. Attempts to pressurize the coaxial line before exhausting the chamber were futile. There was a major leak about the plastic ball that encloses the antenna and reflecting elements. The modulator housing was sealed with no greasing of the gasket.

Observations

2-3-26. There was no evidence of arcing in the modulator even though the pressure leaked to 11 lbs. per sq. inch in the exhausted chamber. Proper care in making the seal would have prevented this leakage.

2-4. CONCLUSIONS AND RECOMMENDATIONS

2-4-1. The r.f. mixer circuit is exceedingly critical to temperature changes. This is indicated in the Temperature Run by the variation of crystal current and klystron oscillator tuning. Plate IV of "Maximum Crystal Current versus Temperature" shows how severe a current change this is. It is apparent that best performance cannot be obtained at all times with the mixer circuit so critical to temperature changes.

2-4-2. The inability to focus the indicators at low temperatures can be corrected easily by applying a different voltage to the focusing circuit or changing the resistance range of the focusing potentiometer.

2-4-3. Plate V shows the variation of d.c. load with temperature changes. The increase in load was expected with more drag imposed by lubricants in the reduction gear boxes. All motors carried the additional load with no signs of failure.

2-4-4. It was impossible to get satisfactory operation of the high voltage circuits with 97% humidity at 40 C. An excessive amount of corona discharge overloaded the high voltage supply. Care must be taken to allow time for tubes and components to heat up after having had the modulator open in a humid atmosphere. The inclusion of a moisture absorbing chamber would be very appropriate.

2-4-5. Operation was reliable in a range from 22-30 volts. Compensation for the lower primary voltage could be made by adjustment of the taps and rheostat provided.

2-4-6. The vibration tests indicate the desirability of providing a clamp to hold the RKR73 damping diode in its socket. A more rigid supporting shelf for the blower motor and condenser assembly is necessary. The mycalex strip between the top of the blower and the condenser should be replaced by material capable of absorbing more bending and twisting stress.

2-4-7. A locking arrangement should be provided to prevent the antenna tilting stud from rotating out and making the equipment inoperative.

TEMPERATURE RUN ASG SERIAL #2

TABLE IX

Time	Temp.	Current 800 cycles	Voltage 800 cycles	Voltage DC	Current DC	Bolometer	Freq. Meter Reading
0 hrs.	Room	6.5	108	28	3.9	80	705
3.5 hrs.	-30° C.	6.5	108	29	4.8	80	705
5.5 hrs.	-10° C.	6.5	108	28.5	5.7	80	705
8.0 hrs.	$+50^{\circ}$ C.	6.5	110	27.5	3.6	80	699

At 3.5 hrs: unable to focus
crystal maximum = 0.62 ma.
tuning peak at 0.5 ma.

Time	Temp.	Pyrometer	Crystal Current	Rectifier Current	Modulator Current
0 hrs.	Room	43° C.	0.32	13	9
3.5 hrs.	-30° C.	-30° C.	See Report	10.5	9
5.5 hrs.	-10° C.	-10° C.	" "	13	10
8.0 hrs.	$+50^{\circ}$ C.	$+66^{\circ}$ C.	0.22	13	10

At 5.5 hrs: max. crystal 0.52 ma.
tuning peak at 0.40 ma.

HUMIDITY RUN ASG SERIAL #2

TABLE X

Time	Temp.	Humidity	Current 800 cycles	Voltage 800 cycles	Voltage DC	Current DC	Bolometer
0 hrs.	25° C.		6.5	113	28.5	3.9	51
5.2 hrs.	41° C.	97%	7.3	115	29.0	3.7	40

Crystal Current	Rectifier Current	Modulator Current	Frequency Meter Reading
0.32	14	11.5	701.5
0.23	15	12.0	701.2

VARIABLE VOLTAGE ASG SERIAL #2

TABLE XI

Voltage DC	Current DC	Voltage 800 cycles	Current 800 cycles	Crystal	Rct.	Mod.	Bolometer	Freq. Meter Reading
28	3.8	112.5	6.9	0.44	14	11	42	7.025
30	4.0	118.5	7.4	0.44	16	13	45	7.02
26	3.5	106.0	6.5	0.44	11.5	9	35	7.025
24	3.3	99.1	5.9	0.43	9	7.5	35	7.03
22	3.1	92.0	5.4	0.32	7.5	6	32	7.035
20.5	3.0	86.5	4.9	0.04	0.6	4	25	7.015

Sweep amplitude decreased.
Tilt indicator inaccurate.
Tilt motion very slow.
Rotation on "Fast" normal.
Rotation on "Slow" slow.
Position "3" on "A" scope unusable.
Power output can be made normal by manipulation of taps.
Freq. becomes normal.

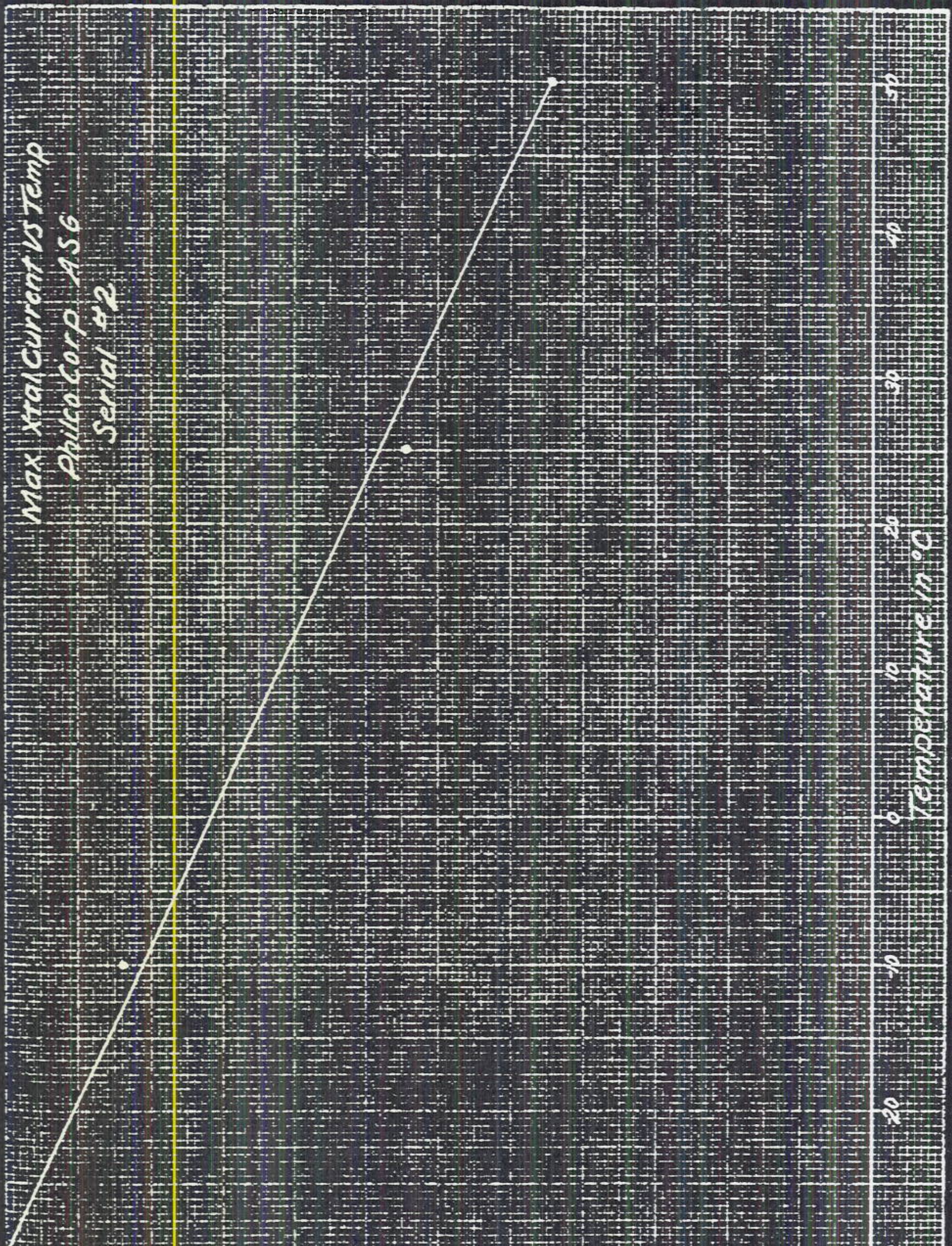

Max Xtal Current Vs Temp
Philco Corp A5G
Serial #2
Temperature in °C
Crystal Current in Ma
-30
-20
-10
0
10
20
30
40
50
0
.1
.2
.3
.4
.5
.6

PLATE 4

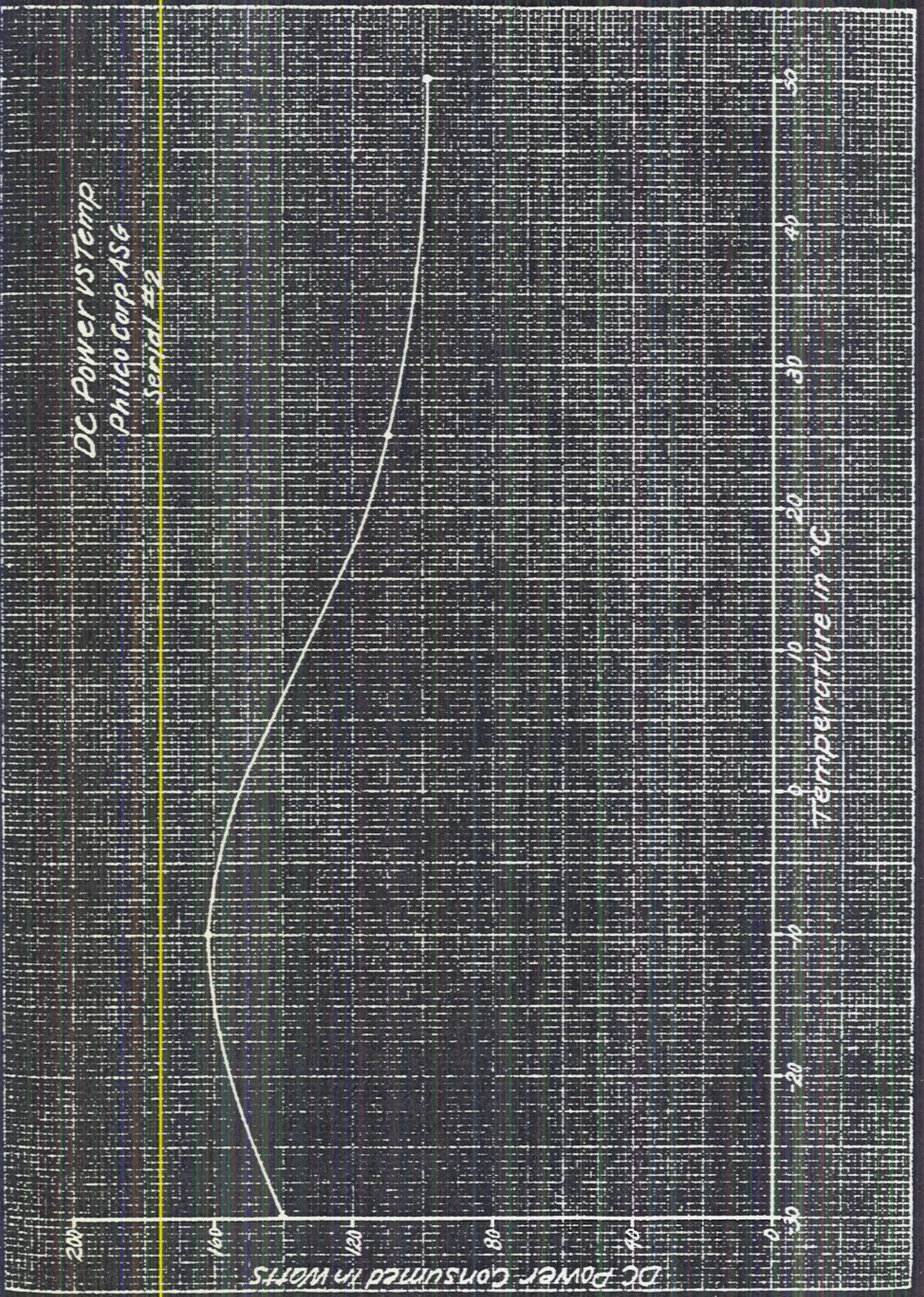

DC Power VS Temp
Philco Corp ASG
Serial #2
Temperature in °C
DC Power Consumed in Watts
-30
-20
-10
0
10
20
30
40
50
0
40
80
120
160
200

PLATE 5

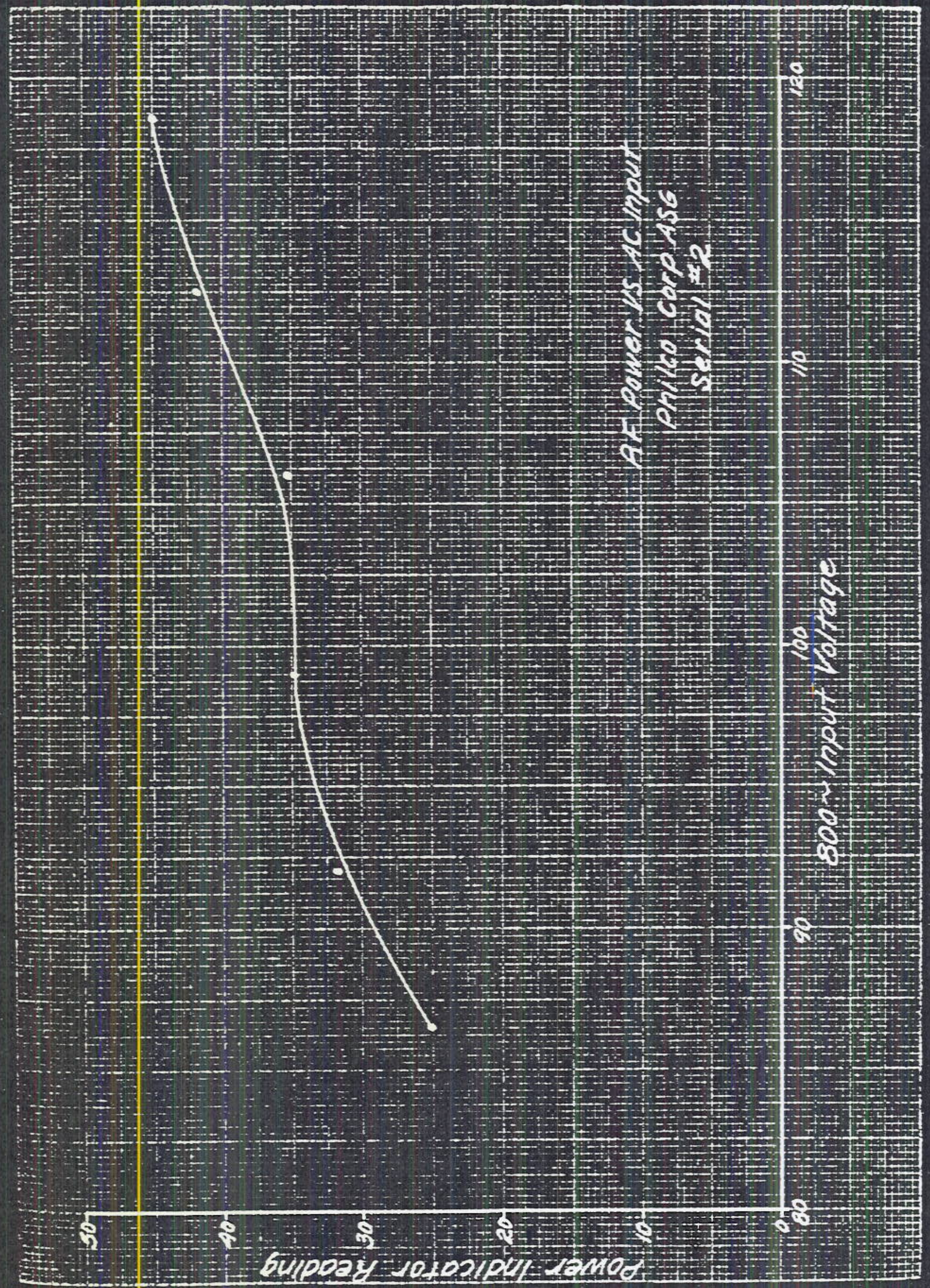

RF Power VS AC Input
Philco Corp ASG
Serial #2
800~ Input Voltage
80
90
100
110
120
Power Indicator Reading
0
10
20
30
40
50

PLATE 6