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NAVAL RESEARCH LABORATORY REPORT

TESTS FOR INFORMATION ON
SHAFT REVOLUTION INDICATORS,
MAGNETO-VOLTMETER TYPE,
WESTINGHOUSE ELECTRIC CO. - MFR.

By P.B. Clark and G. Pida

- Report B-2903 -

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Interior Communication Section

October 31, 1946

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MAGNETO-VOLTMETER TYPE,
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* * *

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ABSTRACT

A magneto-voltmeter type shaft revolution system was submitted to the Laboratory for an investigation of its performance and to permit obtaining information for specification development. The system included an induction-type generator and two indicators. Its functions and general design were investigated under simulated Service conditions and checked against applicable performance limitations and Service requirements of specification, reference (b). Performance of the system was investigated over the temperature range 40°F. to 130°F. The initial accuracy of the system under ordinary temperature conditions was not within the broadest limits allowed by the specification (for type "B" systems) even if the span of the errors were equally divided by adjusting the zero reference. Both the temporary and permanent effects on the system of the simulated Service conditions (except extreme temperatures) were relatively small. The higher extreme temperature condition had large permanent and very large temporary effects on the accuracy of the system. The permanent effects were of the order of 100 rpm decrease in indication. The low extreme of temperature had no appreciable permanent and only small temporary effects on the accuracy of the system. In addition to the major design deficiency of temperature compensation, the system even under ordinary conditions did not have the accuracy required. While the basic principles involved and the actual design of the transmitter are sound, considerable improvement would be necessary for satisfactory accuracy. Pending new developments in the design of instrument rectifiers, the feasibility of obtaining the desired accuracy is questionable as the limits of accuracy of rectifier-type indicators is of the order of 1% of full scale reading under favorable temperature conditions. The expected accuracy for the size indicator employed in this system is about 4%.

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INTRODUCTION

Authorization

1. This problem was authorized by BuShips ltr. JJ17-1-18(335) of 28 February 1946.

Purpose

2. The purpose of this work was to procure information on the subject magneto-voltmeter type shaft revolution equipment for specification development as well as to ascertain the suitability of the design for Naval use. In addition to the determination of performance with respect to the applicable requirements of specification, reference (b), the effects of temperature conditions, requested in reference (a), were investigated.

Description of Material

3. The shaft revolution system is of the magneto-voltmeter type consisting of a generator and two indicators. The tachometer generator is an ac type employing permanent magnets for excitation. The housing is a heavy cylindrical iron casing that appears to have been copper plated prior to the application of a black paint finish. Cork gaskets are used to make the seal between a cover plate at the end of the housing containing the terminal block and between the other end of the housing and the stator structure. No seal was provided between the shaft and the housing. The stator structure consists of two pairs of poles made of laminated steel and arranged with two permanent magnets between them to form a cylindrical structure. These are assembled between two brass rings and secured by through bolting. Each pole structure has two salient pole faces. This structure results in a total of eight salient poles in the stator. The magnetic circuit of one of the permanent magnets is provided with a shunt for adjusting the air gap flux and therefore the generated voltage. The stator winding consists of four coils each encircling a double pole face. The coils are connected in series, with the common terminals brought out to the terminal block. The rotor is a laminated steel core with ten salient pole faces and is mounted on a hollow rotor shaft which is supported by ball bearings that are mounted in the end plates that are bolted to the stator structure. A coupling shaft with a flat on one end and threads on the other fits inside the rotor shaft and is held in position by two washers and a nut. The speed of the generator is four times that indicated on the meter. All the screw heads of the bolts holding the bearing support plates and securing the generator in its housing were threaded with wires to secure them.

4. The indicators are rectifier type voltmeters housed in heavy enclosures of bronze, painted black. The full wave rectifier elements are probably copper-oxide piles. The cover assembly, consisting of a glass window, phenolic ring, and a gasket, screws on to the

INTRODUCTION (Contd.)

housing. The glass window is held between the cover flange and a phenolic ring. The phenolic ring is painted white on its inside surface. The gasket seal is located between the phenolic ring and the enclosure. A black sealing compound is used between the glass window and the cover flange. The dial markings indicate the scale range from 0 to 500 rpm with large division marks and numerals every 100 rpm, and division marks for each 50 rpm and 10 rpm. The dial face has a white background with black identification numerals, division marks, and pointer. The voltmeter has a D'Arsonval movement (a permanent magnet and a movable coil of approximately 850 ohms resistance). It is mounted on a phenolic plate together with the circuit resistors and rectifier. One resistor of 830 ohms is connected directly across the movable coil. The other resistors are in the rectifier circuit as shown in the schematic circuit diagram, Plate 1. The phenolic mounting plate is fastened to a metal plate by screws threaded into lead inserts (all other screws have lock washers). The metal plate is in turn mounted in the housing. The terminal block is in a separate chamber of the housing accessible from the outside by removing a small plate cover. A sheet of stiff paper under the cover plate is probably designed to serve as a gasket.

PROCEDURE

Method of Test

5. The subject equipment was most nearly similar to the type "B" shaft revolution system of specification, reference (b), and the tests performed were selected on this basis. Some of the specification requirements and conditions were not applicable as revolution counters and shaft rotation direction indicators were not provided with the subject equipment. Changes were also made in the speed limitations for various tests as the top range for the subject equipment is 500 rpm as compared to 400 rpm for the types noted in the specification. Both indicators (number one and number two) were tested concurrently as a switching arrangement allowed each indicator to be read separately or both together.

6. The accuracy of the indicators at various speeds was checked by means of a drive using various gear ratios. The power to this drive was supplied by a tuning-fork-controlled amplifier, accurate to one part in 26,000. As some difference was noted in the readings for clockwise and counter-clockwise shaft rotation during the first accuracy checks, the indicators were checked for rotation in both directions throughout the remainder of the tests. The accuracy of the indicators was checked during some of the tests and following completion of each at either ten speeds (every 50 rpm) or at three speeds (50, 250, and 500 rpm). Five consecutive readings were recorded at each speed.

7. Both indicators were initially checked for accuracy over the entire range. Then to determine if the additional line resistance

PROCEDURE (Contd.)

corresponding to approximately 750 feet of No. 16 copper wire would affect the indicators, a resistance of an equivalent value (2.98 ohms) was inserted in each indicator circuit and the accuracy checked. This was not required in the specification but was done for previous shaft revolution systems tested at the Laboratory and reported by reference (c).

8. A series of tests was conducted to determine the effect of various temperature conditions by allowing the indicators and generator to reach thermal equilibrium at ambient temperatures of 70, 40, 130, 200, and 0°F. and checking their accuracy. To determine which was affected by temperature the most, the generator or the indicators, two accuracy checks were made at the same ambient temperature, one with the indicators and generator at the ambient temperature and the other with the indicators at the ambient temperature and the generator at room temperature. The generator shaft was greased and oiled after the 0°F. temperature condition caused it to stick.

9. The indicators were next checked while operating in the four different positions of the inclination test: (1) 45° forward from vertical (2) 45° backward from vertical, (3) 45° to left of vertical and (4) 45° to right of vertical. Following this test, the indicators were subjected to fifty hours of continuous operation at 450 rpm. Accuracy was checked during the test and after the test.

10. All of the equipment was subjected to the specified 250 ft. lb. shock test of 20 blows and the shock-vibration test of six 30-minute periods at frequencies of 100 to 350 vibration/min. in steps of 50. The indicators were bulkhead mounted on the shock machine and on the vibration machine while the generator (mounted on a metal angle bracket furnished with the equipment) was mounted on a wooden angle bracket. Standard spacers were used for mounting. The indicators and generator were operating at 450 rpm while being shocked and vibrated. The accuracy of the indicators was noted after each shock blow, after each half hour of the shock-vibration test, and following completion of the shock test and the shock-vibration test. The inclination test described previously was repeated after the shock-vibration test.

11. Upon completion of these tests, both indicators and generator were continuously operated for 450 hours by using a drive varying from 60 rpm to 490 rpm at an average rate of 60 rpm. The accuracy of the indicators was checked several times per day throughout the test and a complete accuracy check at ten speeds followed the endurance test. This was also the final accuracy check recorded on graphs, Plates 2 to 5.

12. Following endurance and the final accuracy test, the system was operated continuously for four hours at an overspeed at 562 rpm (112.5% of full scale reading). Accuracy was noted at five speeds after this test. To check if speeds in excess of 112.5% of full scale reading would cause jamming or damage to the instruments, the system was operated at 585 rpm for five minutes and the accuracy recorded after test. The error was not checked at values of shaft acceleration or deceleration of or less than 80 rpm (paragraph E-11b of specification, reference (b)) or the damping time recorded (paragraph E-11c of specification, reference (b)) as the observed performance indicated that increase in error due

PROCEDURE (Contd.)

to lag or slow response was negligible as is usual in such a system.

13. A partial material inspection was made. The equipment was submitted to the specified dielectric test before and after the insulation test. At this point the generator was disassembled to determine if provisions were made to prevent entry of water. Due to the observed lack of shaft seals, the watertight test was omitted, however, both indicators were subjected to the specified splash-proof test and examined afterwards for leakage. Indicator No. 1 was then completely disassembled, reassembled, and rechecked for accuracy. There was some discrepancy in the indications noted before and after disassembly of the generator and indicator No. 1 so the magnetic shunt of the generator was adjusted to produce the previous generator voltage-output/speed values and the indications were found to be similar to those previously recorded, except in the case of the indicator No. 1. The rectifier unit of the latter was injured in disassembly.

Results of Test

14. The results of the initial accuracy check as given in the graphs, Plates 2 through 9, are used as a basis for comparison of performance under the various simulated Service conditions. The results of all tests are graphically presented in detail in Plates 2 through 9. The data presented are readings of indicators when only one indicator was connected to the generator-transmitter. As there was very little change in indication when two indicators were connected, (one rpm or less) data for this condition in combination with the simulated Service conditions are not presented. The same reason applies for not presenting the data when the indicators were under a particular ambient temperature condition and the generator-transmitter was at room temperature except for the one condition of 200°F. ambient temperature. In the selected data that are presented, the errors shown are the maximum of five consecutive readings at any one reference speed. (Deviation of the maximum from the average error of five readings was less than 3 rpm except under the temperature condition of 200°F. where deviations of about 6 rpm were recorded.) Because there was considerable difference (up to 4 rpm) in readings for clockwise and for counter-clockwise shaft rotation, data for both directions were included in the graphs and this difference can be especially noted by comparing Plates 4 and 5.

PROCEDURE (Contd.)

15. The following table contains selected data from the graphs for the purposes of comparison and discussion:

Test Conditions	Maximum Error (rpm)							
	*Indicator No. 1				*Indicator No. 2			
	CW		CCW		CW		CCW	
	Speed		Speed		Speed		Speed	
	Low	High	Low	High	Low	High	Low	High
Initial Accuracy	-10	-5	-10	-2	-12	-2	-13	0
Resistance Effect	-10	-4	-10	-2	-12	-2	-12	0
Temperature - 40°F.	-10	+7	-10	+8	-13	+10	-12	+10
Temperature - 130°F.	-13	-35	-13	-32	-18	-40	-18	-38
Temperature - 200°F.	-32	-128	-32	-130	-48	-170	-48	-172
Temperature - Room	-11	-9	-11	-8	-19	-10	-18	-9
Temperature - 0°F.	-12	-1	-13	0	-19	-1	-19	0
Temperature - Room	-10	-10	-10	-9	-20	-13	-20	-12
Temperature - 200°F.*	-30	-113	-30	-111	-49	-138	-49	-138
Temperature - Room	-10	-9	-10	-5	-19	-11	-19	-9
Inclination Position No. 1	-11	-9	-10	-8	-38	-13	-38	-13
Position No. 2	-10	-9	-9	-8	-19	-16	-19	-12
Position No. 3	-10	-9	-10	-7	-19	-13	-20	-11
Position No. 4	-11	-9	-11	-8	-19	-13	-18	-11
After Endurance (50 hrs.)	-9	-8	-9	-9	-19	-15	-19	-17
After Shock	-9	-3	-8	-1	-19	-11	-19	-10
After Vibration	-10	-9	-10	-4	-18	-10	-18	-5
Inclination Position No. 1	-10	-8	-10	-4	-18	-10	-18	-3
Position No. 2	-10	-7	-10	-3	-18	-10	-16	-9
Position No. 3	-10	-9	-10	-8	-15	-9	-15	-3
Position No. 4	-10	-8	-10	-3	-12	-10	-12	-2
After 450 hrs. Endurance (Final Accuracy)	-10	-4	-10	-2	-18	-4	-17	-1
After Overspeed at 552 rpm	-9	-5	-9	-2	-15	-3	-15	-1
After Overspeed at 585 rpm	-10	-8	-9	-2	-18	-9	-18	-6

Notes: * Both indicators at 200°F., generator at room temperature
 Low Speed - 50, 100, 150 rpm
 High Speed - 400, 450, 500 rpm
 Allowable Error -- ± 3 rpm

16. At the 0°F. ambient temperature some trouble was encountered with the generator when low temperatures caused the shaft to stick. This was remedied by oiling and greasing the shaft and bearings and by running the generator continuously for several hours before continuing the test.

17. Indicator No. 1 accumulated errors after the eleventh blow of the shock test with indicated errors changing from consistently negative values of the order of 7 rpm to positive values of the order of 10 rpm and then to +18 rpm after the twelfth. The indications.

PROCEDURE (Contd.)

in addition, were erratic, since out of five consecutive readings (reference speed, 450 rpm) taken immediately after the 11th blow, two were of nearly zero error and, after the 12th blow, four were of nearly zero error. Indications reverted back to normal after the succeeding blows until, after the 19th blow, when they again were in error by + 20 on the first two of five consecutive readings, changing back to normal for the succeeding three readings. No change was noted as a result of the 20th blow. The pointer of indicator No. 2 stuck below zero several times and would not register until a tap on the glass freed it.

18. Shortly after the vibration test began, the meter elements of indicator No. 2 became loose in the case. Investigation showed that the screws in the lead inserts securing the meter element phenolic mounting base to the metal mounting plate had become loose and entirely worked out. These were replaced and tightened. The zero position of the pointer was accidentally shifted during this process and was reset.

19. The electrical circuits of the indicators and the generator complied with the dielectric and insulation test requirements. During the splashproof test about 1 cc of water leaked into the housing and about the same amount into the terminal block chamber. The stiff paper gasket under the cover plate of the terminal block chamber was soaked around the edges. Water was found in the space between the phenolic ring and the windowed screw cover. Examination suggested the leak to have occurred between the flange of the screw cover and the glass window and since the black sealing compound was wetted, between the glass window and the phenolic ring.

20. A complete material inspection and check of the design details and workmanship were not made since, as indicated by many of the minor design details and materials of the subject equipment, the system was probably not initially designed for Naval use. The actual construction and arrangement of the components are not such as to make corrective modifications prohibitive. The following are a few of the deviations from the specification requirements that are indicative of their nature. The enclosure for the generator is cast iron or steel; some screws are not suitably protected against corrosion; lead inserts are used instead of lock washers; dial markings, the glass window and the nameplate are not in accordance with specification requirements; the terminal block is not of the approved type; no revolution counter is provided; no dial illumination is provided; the internal components of the indicator are not arranged so as to permit easy withdrawal as a single unit from the enclosure and operation while thus removed; no provision is made to indicate direction of shaft revolution; and the terminals are not of the approved type.

21. The overall dimensions and weights of the system are as follows:

	<u>Dimensions</u>	<u>Weights</u>
Generator	6-1/4" x 6-1/4" x 4-3/4"	18-1/4 lbs.
Indicator	6-3/4" x 5-3/4" x 3-5/8"	9-1/4 lbs.

PROCEDURE (Contd.)

Discussion of Results

22. Reference to the graphs of errors, plates 6 to 9 and to the summary of errors in the table in paragraph 16 will show that even under ordinary conditions the system did not have the accuracy required by specification, reference (b). The specification allows maximum errors of ± 3 rpm for the master repeater indicator in a type B system. The generator voltage is adjustable by means of the magnetic shunt and could probably be varied to shift the span of the indicated errors so as to dispose them symmetrically with respect to a zero reference. It will be noted from the initial accuracy data that indicator No. 1 has a span of errors of about 5 rpm and indicator No. 2 has a span of errors of about 13 rpm. Shifting the level of the 5 rpm span would at best give errors of ± 2.5 rpm, and ± 6.5 rpm for the 13 rpm span.

23. The recorded data show that the extremes of the temperature conditions, particularly the upper extreme of 200°F., had the greatest effects on the accuracy of indications of the subject equipment. In general, higher temperatures caused negative errors and lower temperatures caused positive errors of indication. Since the effects of the various temperature conditions were relatively small at the lower speeds (below 100 rpm), the graphs of the errors have steep slopes. Although data are not presented to show the separate effects on the generator-transmitter and the indicators, except at the temperature of 200°F., such data were taken and showed that the temperature effects on the generator-transmitter were relatively slight except at 200°F. Comparison of the two sets of accuracy data taken at 200°F. ambient temperature, Plates 6 to 9 and Table in paragraph 16 will show that the separate temperature effect on the generator-transmitter is of the order of minus 5 percent error of indications out of a total combined effect on the system of about minus 30 percent of the scale reading.

24. Comparison of the data of the initial accuracy check with the data taken after the first 200°F. temperature condition shows a permanent effect of the order of minus 2 percent error of indication. This permanent effect may explain to some extent the smaller effect of the 0°F. temperature condition as compared to the effect at 40°F. It was particularly noted that the second 200°F. temperature condition had, relatively, very slight permanent effects on the indications of the system. This observation suggests conditioning the indicator, or more specifically, the rectifier elements at the extremes of the service temperature conditions at the time of manufacture before the final calibration of the system.

25. The effects of the extremes of the temperature range 40°F. to 130°F. on the accuracy of indications of the system were excessive. The maximum error of indication at the 40°F. temperature condition was of the order of minus 10 rpm. This figure is the same as the maximum error recorded during the initial accuracy check indicating no effects. The graph of errors, Plate 6, however, shows that the effects of the 130°F. temperature condition became more apparent at the higher speeds.

PROCEDURE (Contd.)

For example, at 450 rpm reference speed on initial accuracy check (room temperature) the error was plus 6 rpm, a change of 11 rpm, which is excessive when compared to the specification requirement of ± 3 rpm for the master repeater indicators in the type B shaft revolution system. The effects of the temperature condition at the upper extreme of the range 40°F. to 130°F. were proportionally greater. On the basis of a room temperature of about 85°F., 40°F. is 45°F. lower, and 130°F. is higher by the same amount, but the effects of the higher temperature on indications were more than twice as great. The error at 450 rpm at 130°F. for indicator No. 1 was minus 32 rpm as compared to minus 5 rpm at room temperature or a change of minus 27 rpm.

26. The data presented in Plates 2 to 9 inclusive and in the summary table in paragraph 16 were obtained with one or the other indicator connected alone to the generator-transmitter. Data also were taken with both indicators as a load on the generator-transmitter and are available on request. The differences in indication produced by the additional load of one indicator were appreciable but small when compared to the total effects of the temperature conditions below and above room temperature. As an example of the relative effects, indicator No. 1 showed an error of minus 30 rpm at 400 rpm at 130°F. when connected alone and an error of minus 31 rpm when indicator No. 2 was also connected to the generator-transmitter.

27. The rectifier elements used in the indicators of the subject system appear to be of the copper-oxide type. Current literature on the subject of rectifiers for instruments indicates that the copper-oxide types still are superior for this application. This impression was emphasized in discussions on a paper on selenium rectifiers, reference (e). The stability of the copper-oxide rectifier is dependent on the frequency, current density and the ambient temperature, reference (d). The frequency and density effects at a given temperature can be calibrated out. Temperature effects, however, will require that other elements in the circuit have compensatory impedance - temperature characteristics. The upper limit of ambient temperatures for which compensatory elements could be employed is limited because the rectifier element characteristics became erratic above temperatures of 110°F.

28. The data of indicated errors, table in paragraph 16, taken during the tests for effects of inclination show that the movable element of indicator No. 2 did not maintain its deflection when inclined from the vertical. The maximum discrepancy was of the order of 5% when inclined forward from the normal position. No attempt was made to determine the cause except to note that the movable element including the pointer was in no way directly obstructed. It is probable that the movable element including the pointer was not in proper balance or alignment.

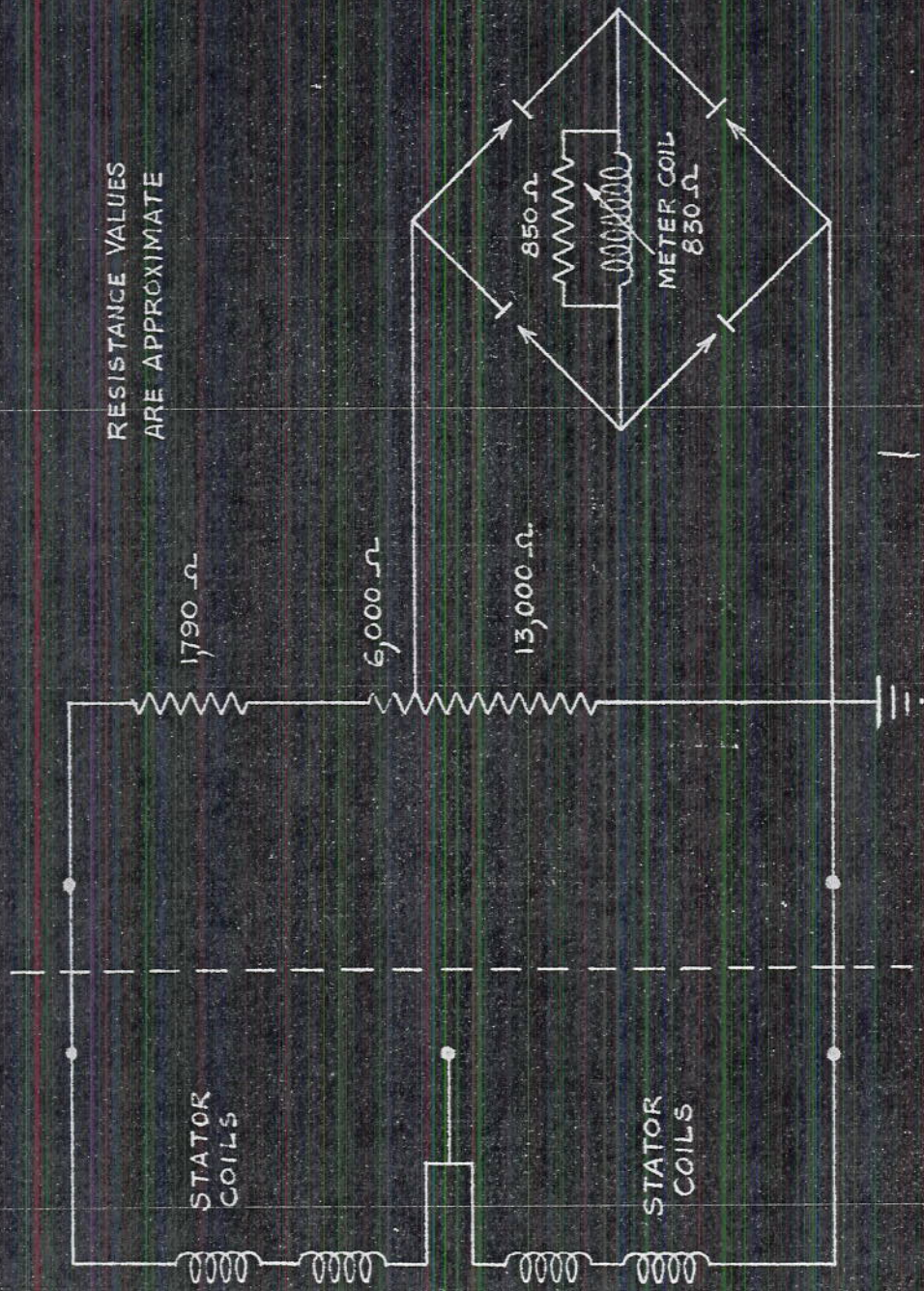
REFERENCES

- (a) BuShips ltr. JJ17-1-18(335) of 28 February 1946 to NRL.
- (b) Restricted Specification RL7-I-18(INT) of 1 May 1944 and Amendment 6 of 15 March 1945.
- (c) NRL Test Report No. 445 of 24 February 1944.
- (d) Henney, Keith, The Radio Engineering Hand Book, page 195, Third Edition, McGraw-Hill Book Company, Inc., New York, 1941.
- (e) E. A. Richards, "The Characteristics and Applications of the Selenium Rectifier", Journal I.E.E. Vol. 88, Part II, No. 5, Oct. 1941.

SCHEMATIC CIRCUIT DIAGRAM

FOR

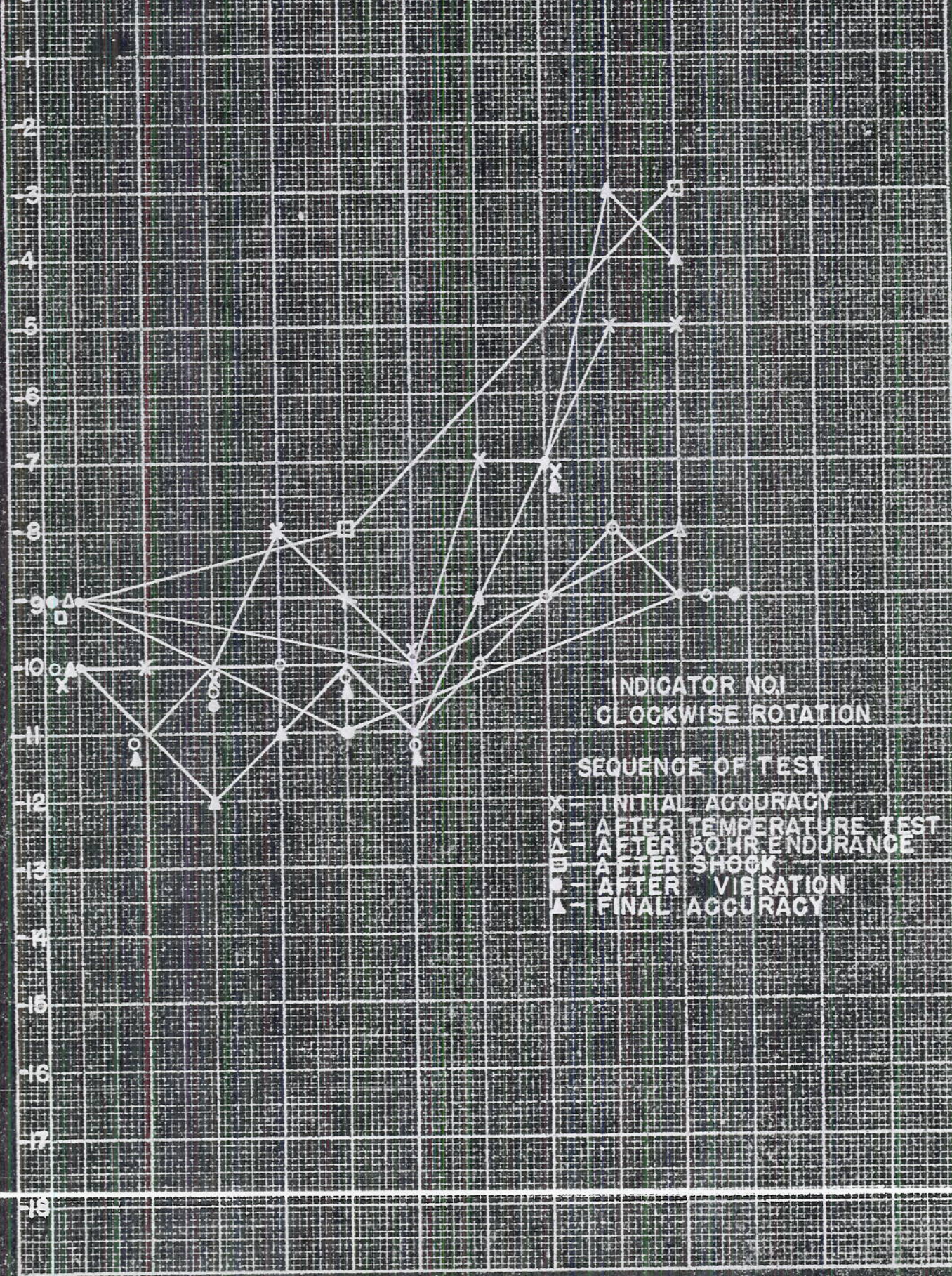
MAGNETO - VOLTMETER PROPELLER SHAFT REVOLUTION INDICATOR



MAXIMUM ERROR VS. DRIVEN RPM UNDER SPECIFIED TEST CONDITIONS

50 100 150 200 250 300 350 400 450 500 DRIVEN RPM

MAXIMUM ERROR OF FIVE READINGS (RPM)

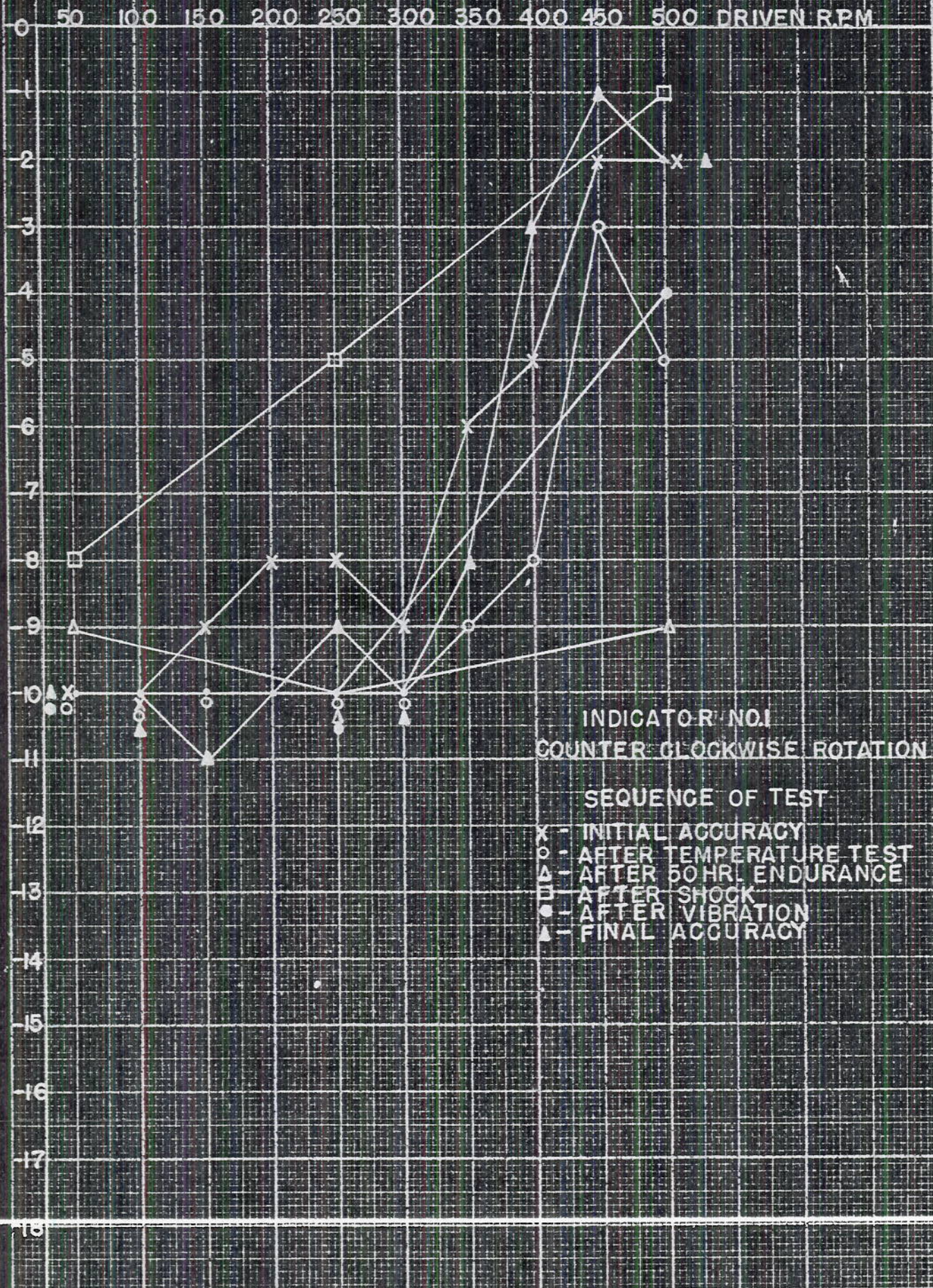


INDICATOR NO1
CLOCKWISE ROTATION

SEQUENCE OF TEST

- X - INITIAL ACCURACY
- O - AFTER TEMPERATURE TEST
- Δ - AFTER 50 HR ENDURANCE
- - AFTER SHOCK
- - AFTER VIBRATION
- ▲ - FINAL ACCURACY

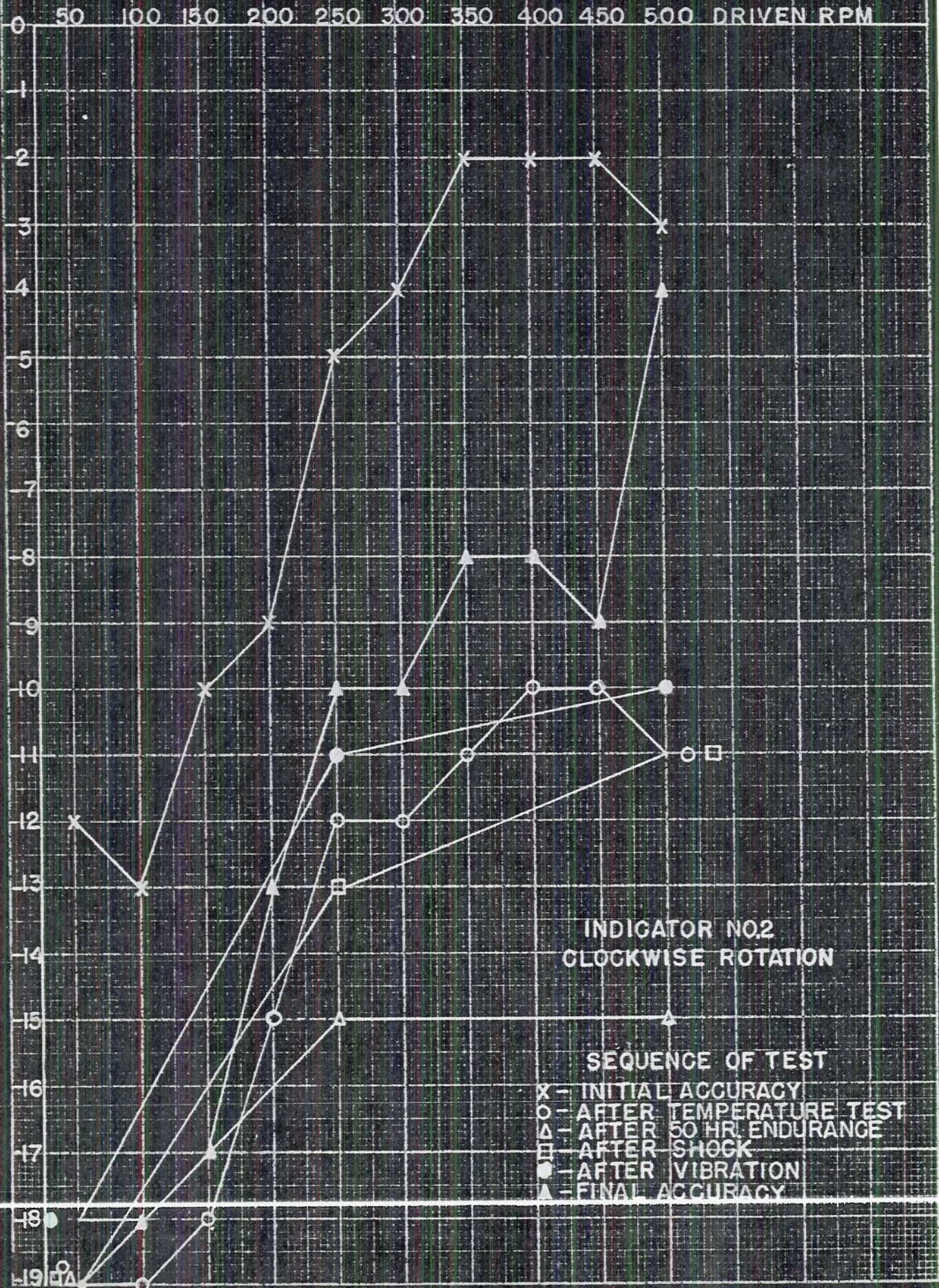
MAXIMUM ERROR VS. DRIVEN RPM UNDER SPECIFIED TEST CONDITIONS



MAXIMUM ERROR OF FIVE READINGS (RPM)

INDICATOR NO.1
 COUNTER CLOCKWISE ROTATION
 SEQUENCE OF TEST
 X - INITIAL ACCURACY
 O - AFTER TEMPERATURE TEST
 Δ - AFTER 50 HRS. ENDURANCE
 □ - AFTER SHOCK
 ● - AFTER VIBRATION
 ▲ - FINAL ACCURACY

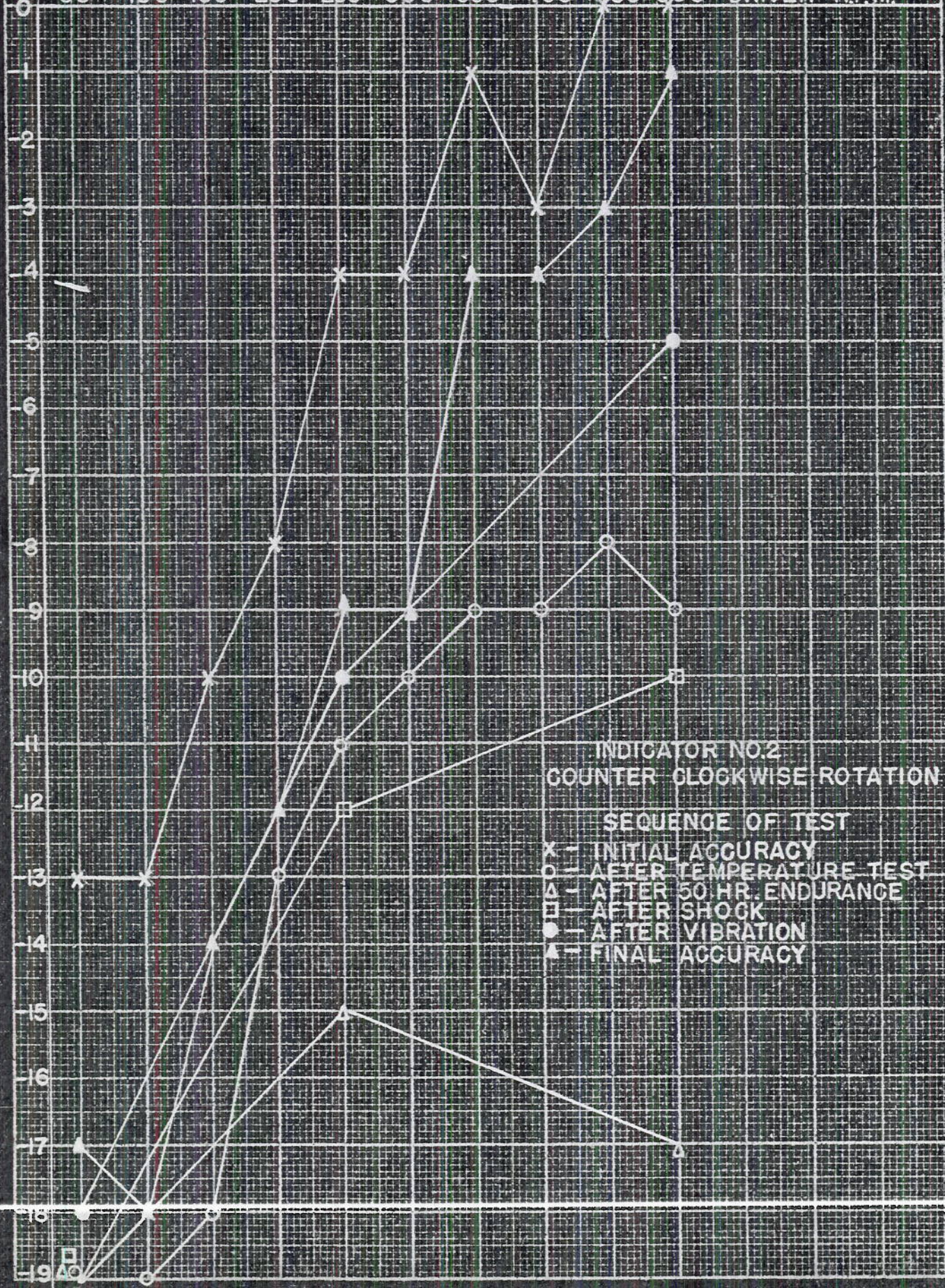
MAXIMUM ERROR VS. DRIVEN RPM UNDER SPECIFIED TEST CONDITIONS



MAXIMUM ERROR VS. DRIVEN RPM UNDER SPECIFIED TEST CONDITIONS

50 100 150 200 250 300 350 400 450 500 DRIVEN RPM

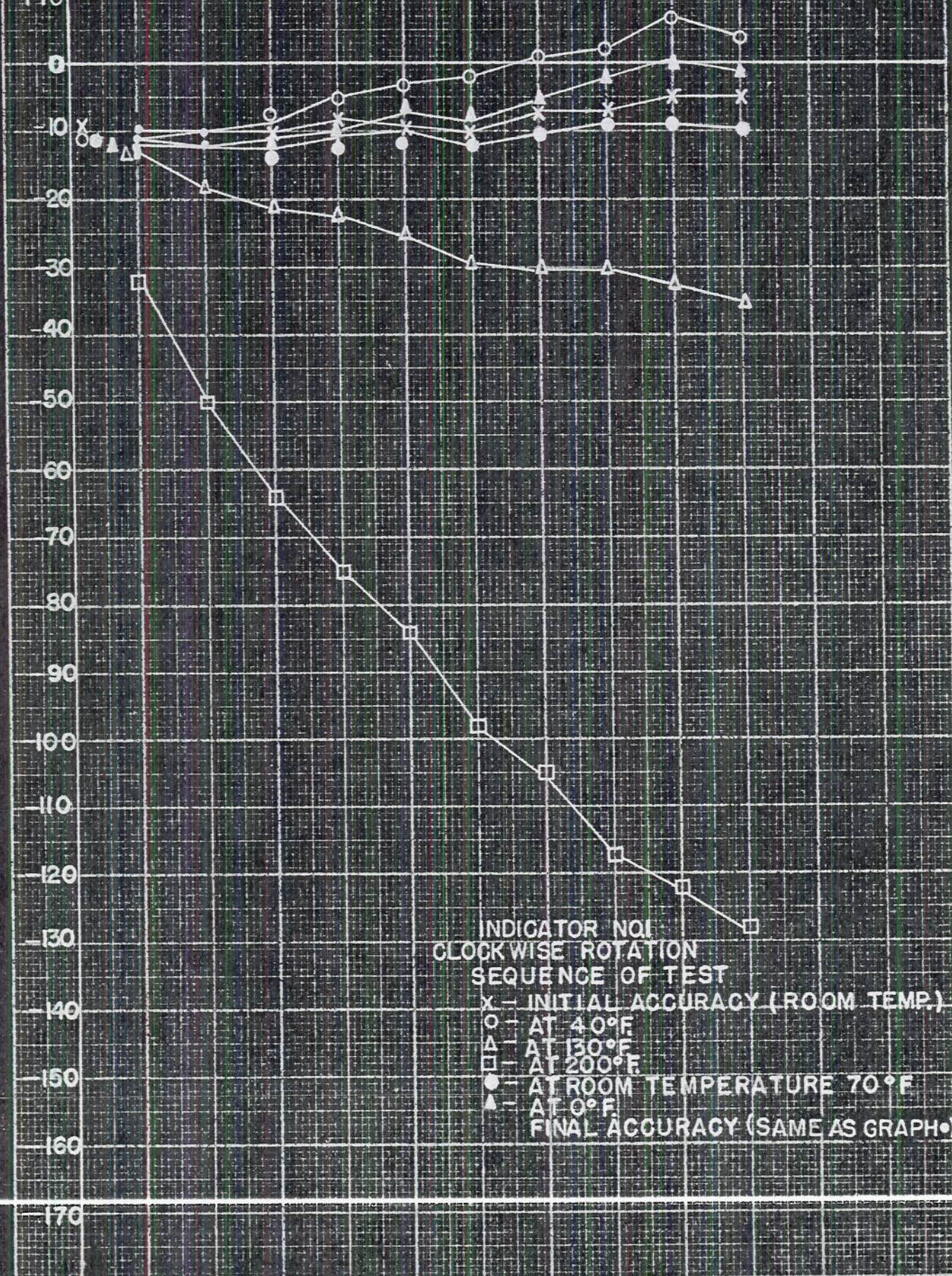
MAXIMUM ERROR OF FIVE READINGS (RPM)



MAXIMUM ERROR VS. DRIVEN RPM AT VARIOUS TEMP CONDITIONS

50 100 150 200 250 300 350 400 450 500 DRIVEN RPM

MAXIMUM ERROR OF FIVE READINGS (RPM)

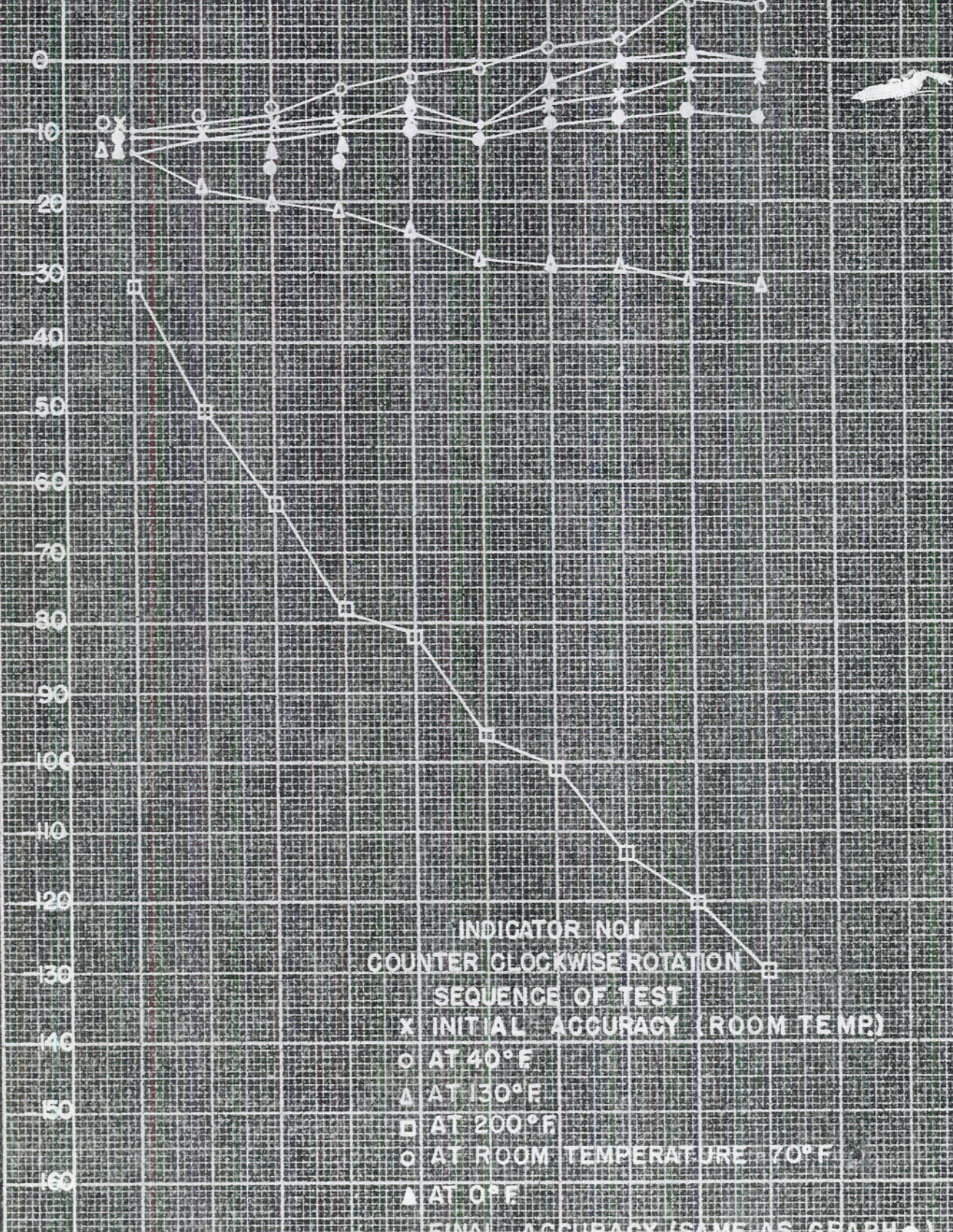


INDICATOR NO. 1
 CLOCK WISE ROTATION
 SEQUENCE OF TEST
 X - INITIAL ACCURACY (ROOM TEMP.)
 ○ - AT 40°F
 △ - AT 130°F
 □ - AT 200°F
 ● - AT ROOM TEMPERATURE 70°F
 ▲ - AT 0°F
 FINAL ACCURACY (SAME AS GRAPH)

MAXIMUM ERROR VS. DRIVEN RPM AT VARIOUS TEMPERATURE CONDITIONS

40 50 100 150 200 250 300 350 400 450 500 DRIVEN RPM

COUNTER CLOCKWISE READINGS (RPM)

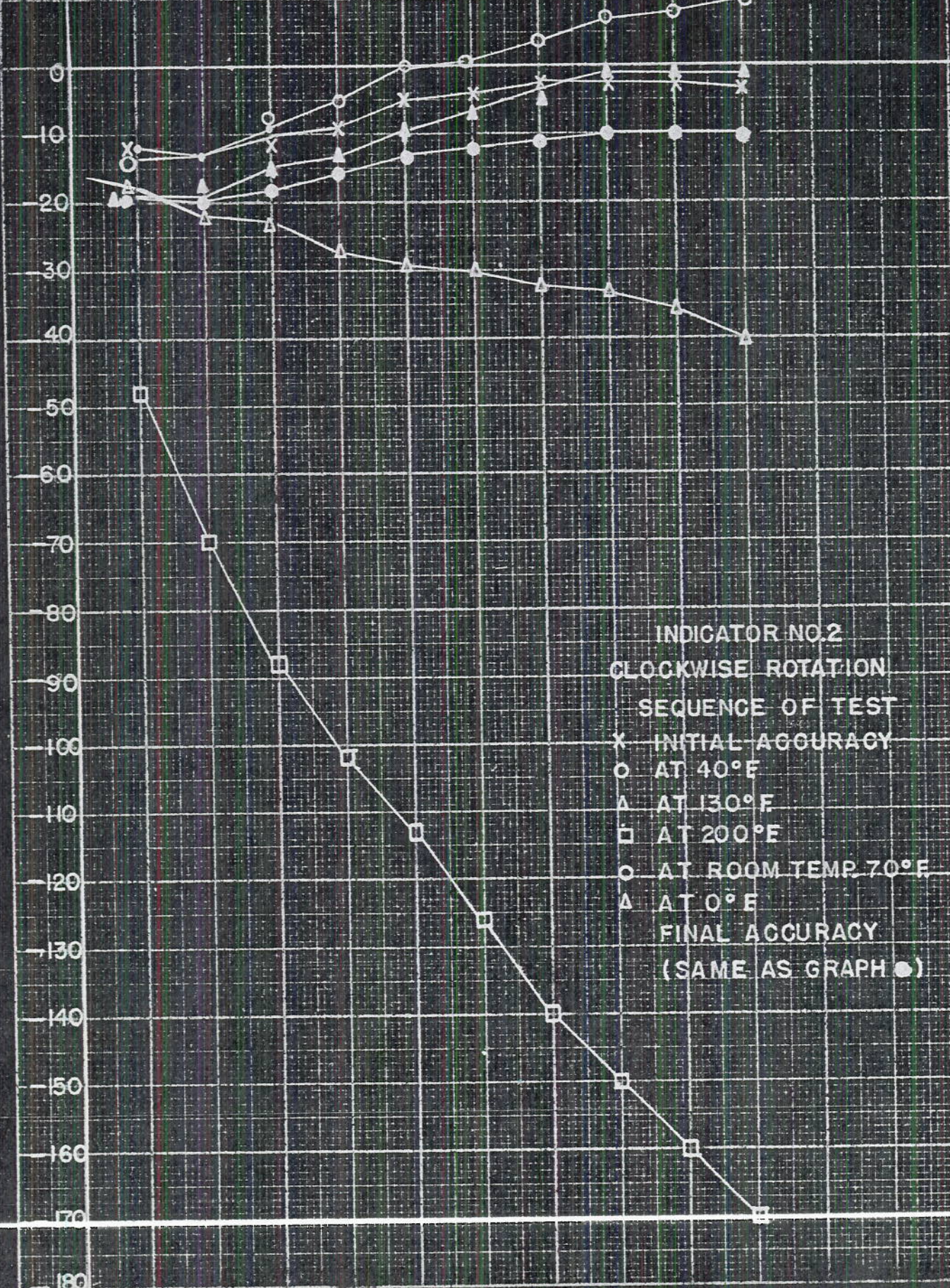


INDICATOR NO. 1
 COUNTER CLOCKWISE ROTATION
 SEQUENCE OF TEST
 X INITIAL ACCURACY (ROOM TEMP)
 O AT 40°F
 A AT 130°F
 B AT 200°F
 O AT ROOM TEMPERATURE 70°F
 A AT 0°F
 FINAL ACCURACY (SAME AS GRAPH)

MAXIMUM ERROR VS. DRIVEN R.P.M. AT VARIOUS TEMPERATURE CONDITIONS

+10 50 100 150 200 250 300 350 400 450 500 DRIVEN R.P.M.

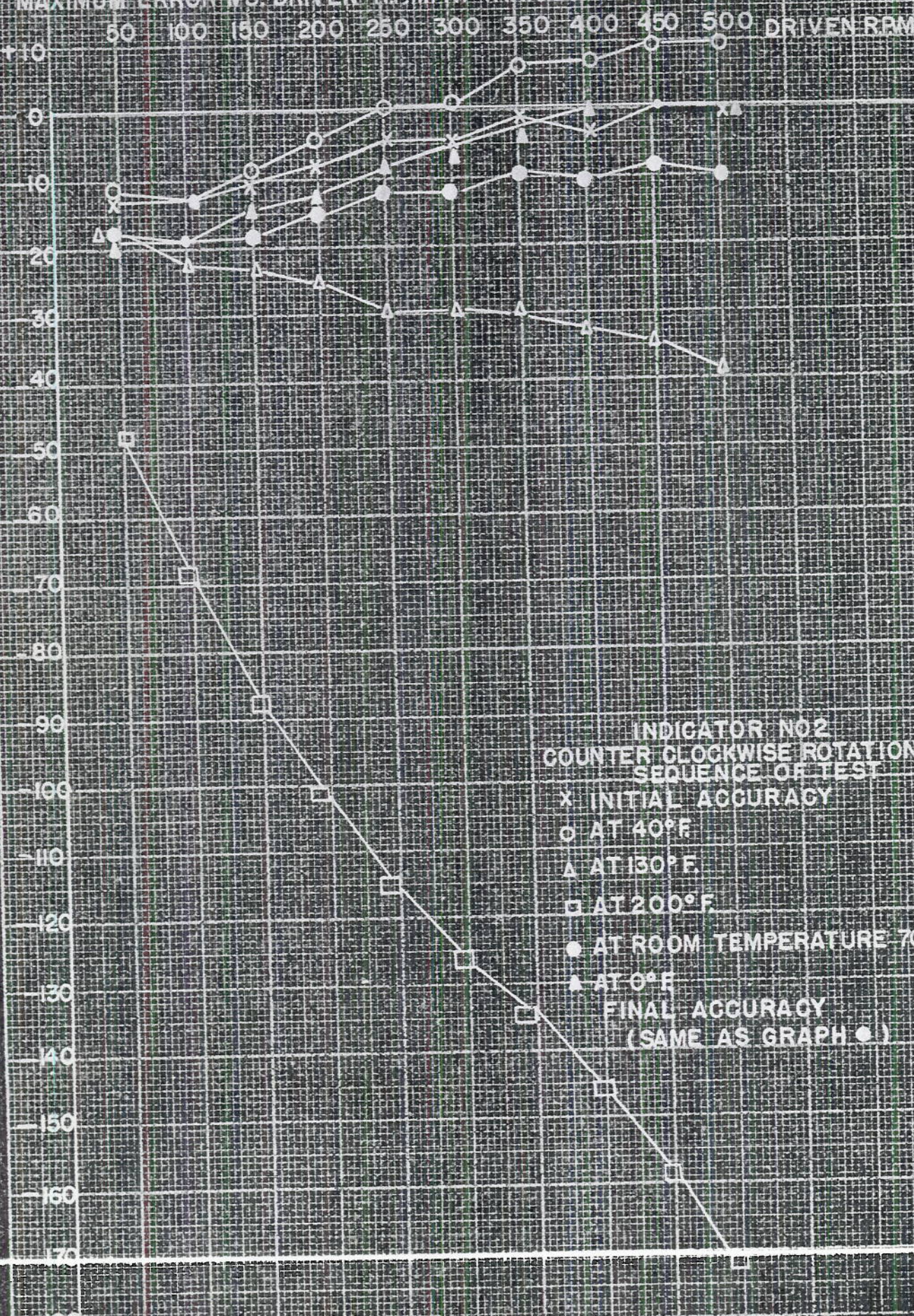
MAXIMUM ERROR OF FIVE READINGS (R.P.M.)

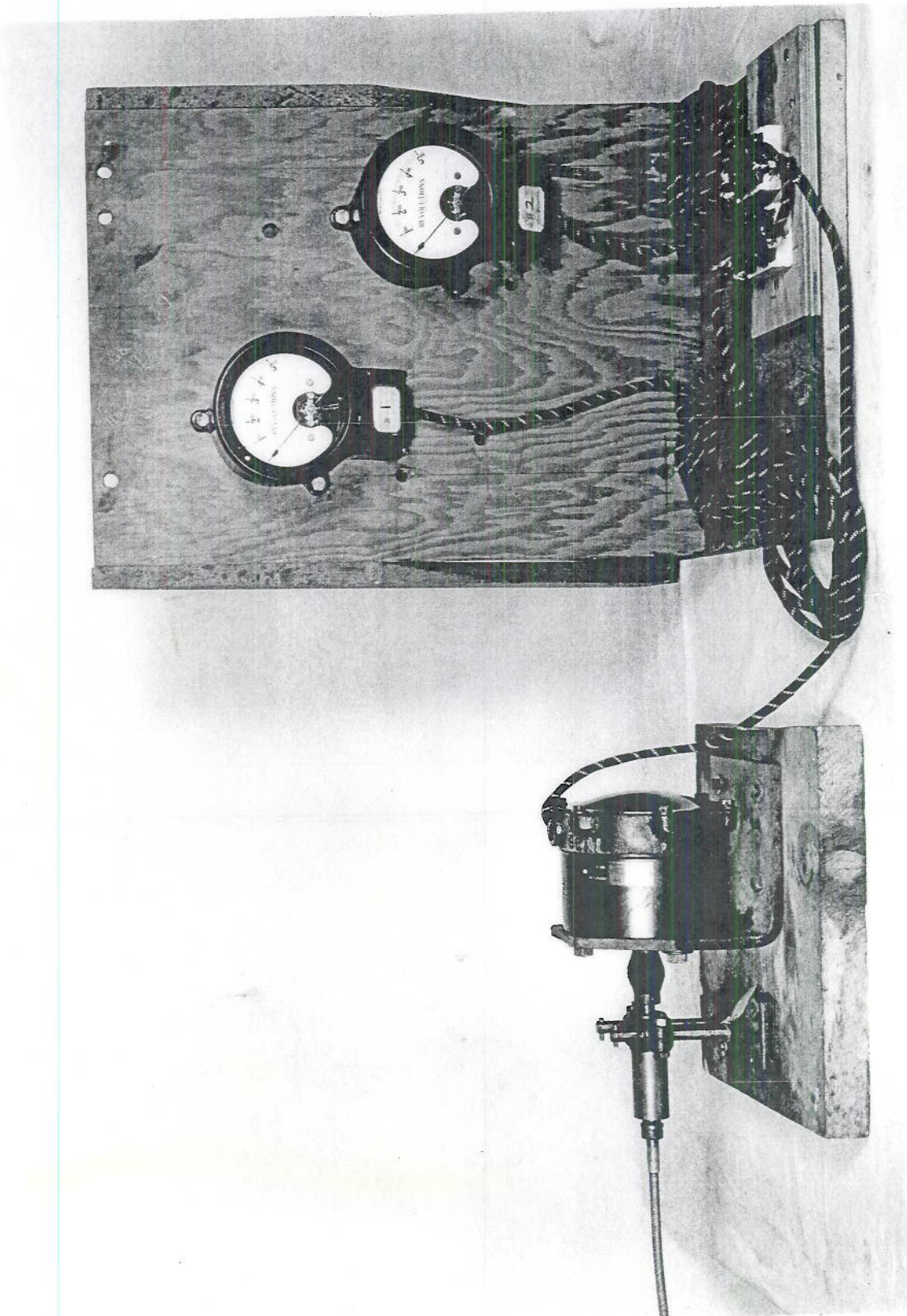


INDICATOR NO.2
 CLOCKWISE ROTATION
 SEQUENCE OF TEST
 X INITIAL ACCURACY
 O AT 40°F
 Δ AT 130°F
 □ AT 200°F
 ● AT ROOM TEMP. 70°F
 Δ AT 0°F
 FINAL ACCURACY
 (SAME AS GRAPH ●)

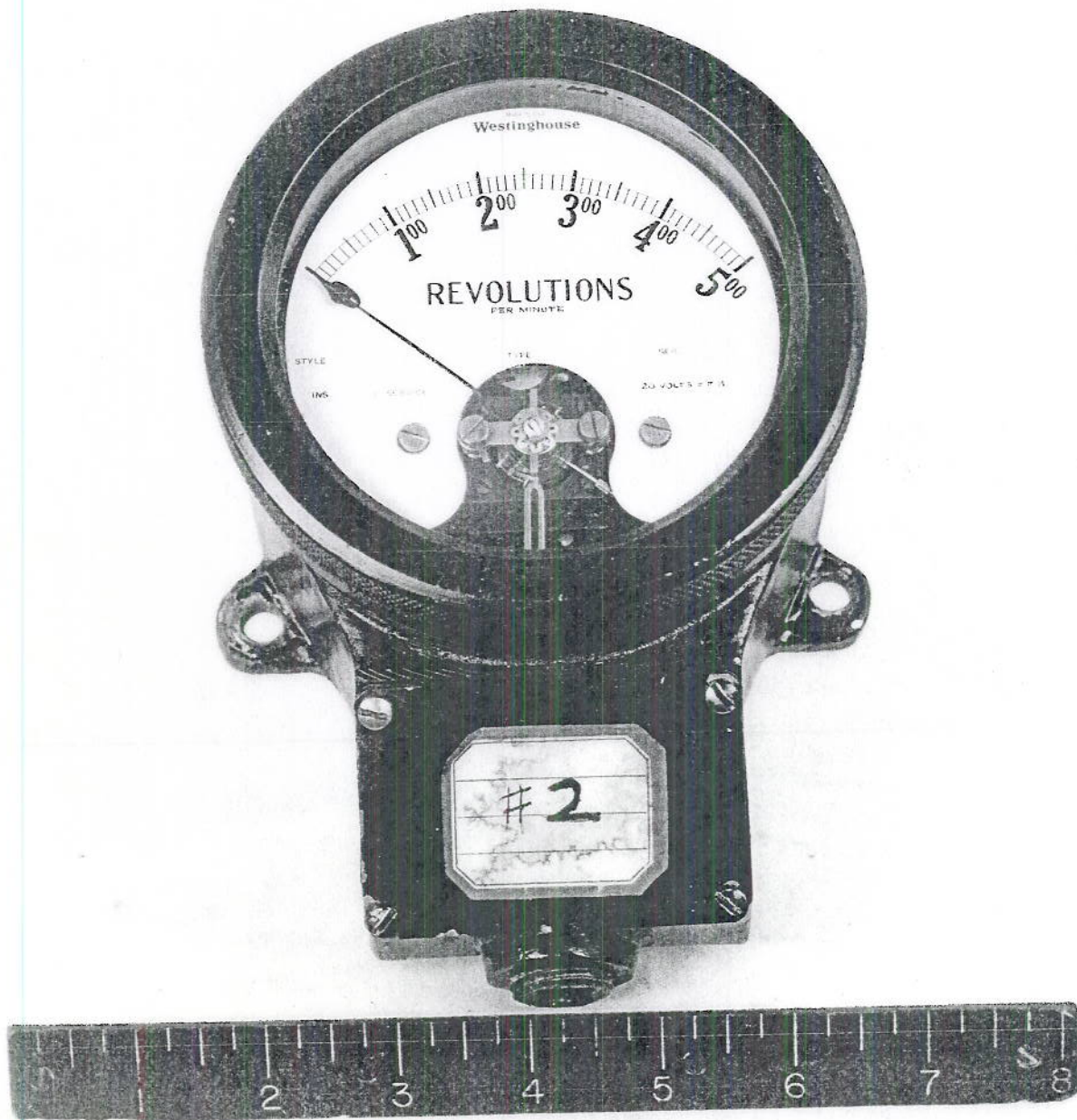
MAXIMUM ERROR MS. DRIVEN RPM AT VARIOUS TEMPERATURE CONDITIONS

MAXIMUM ERROR OF FIVE READINGS (RPM)

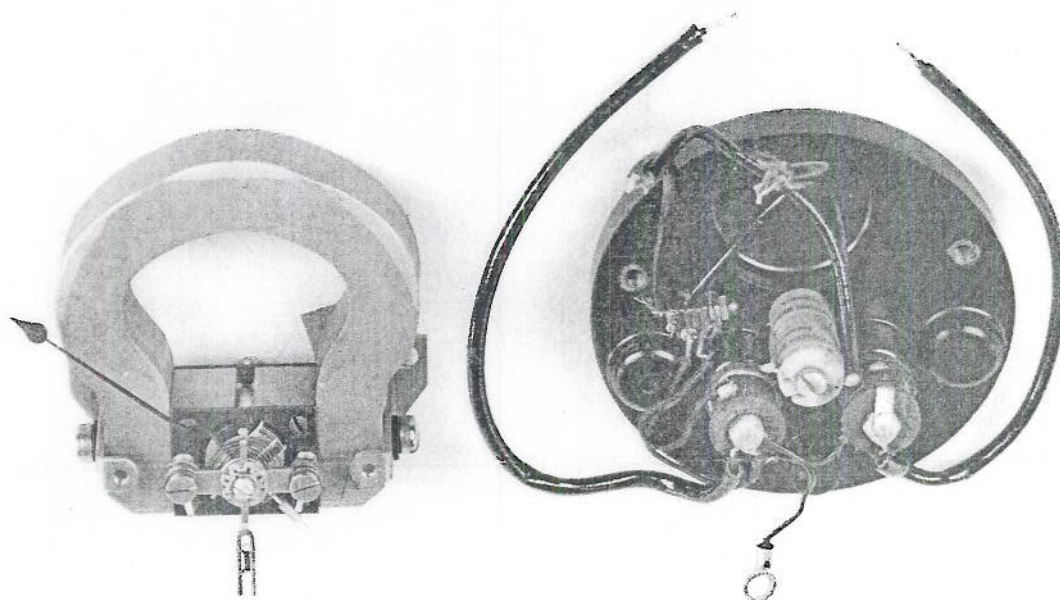




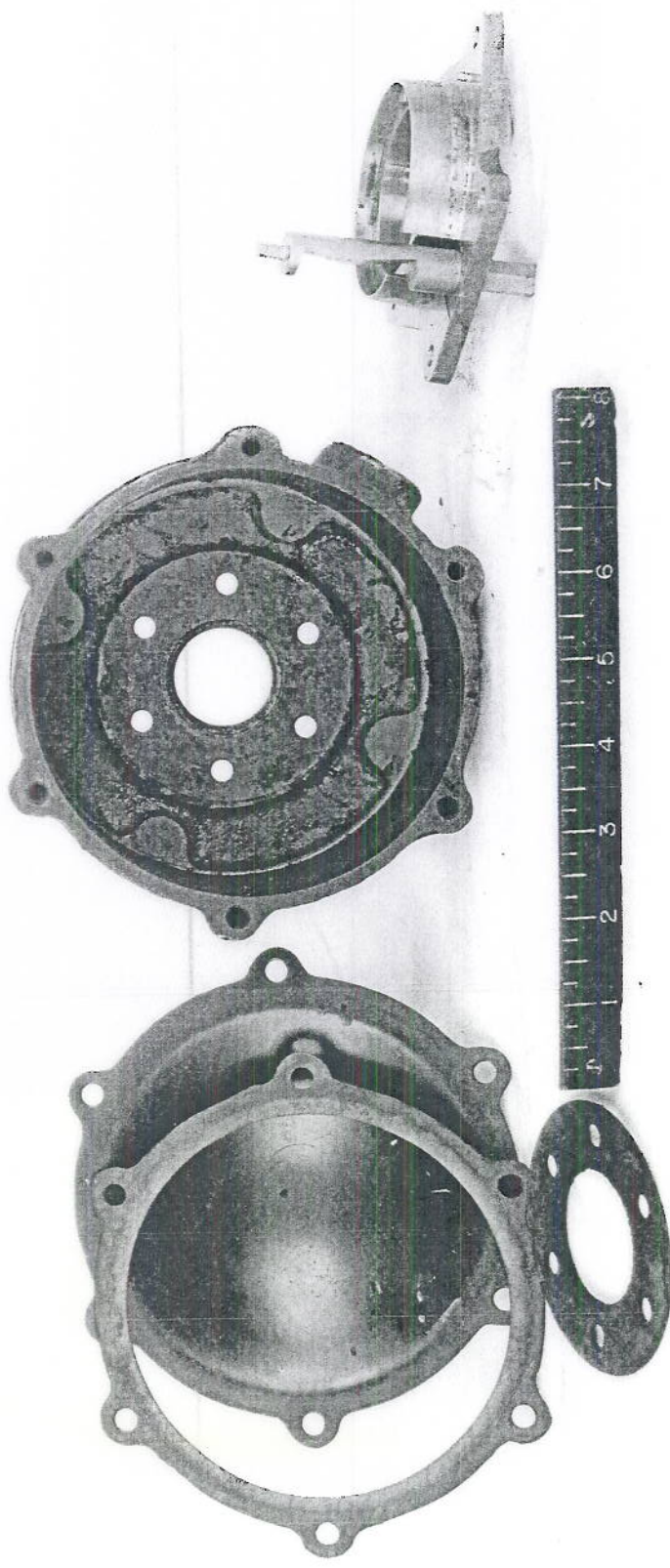
SHAFT REVOLUTION SYSTEM MOUNTED FOR TEST



INDICATION NO. 2



METER COMPONENTS OF INDICATOR NO. 1



GENERATOR HOUSING AND MAGNETIC SHUNT

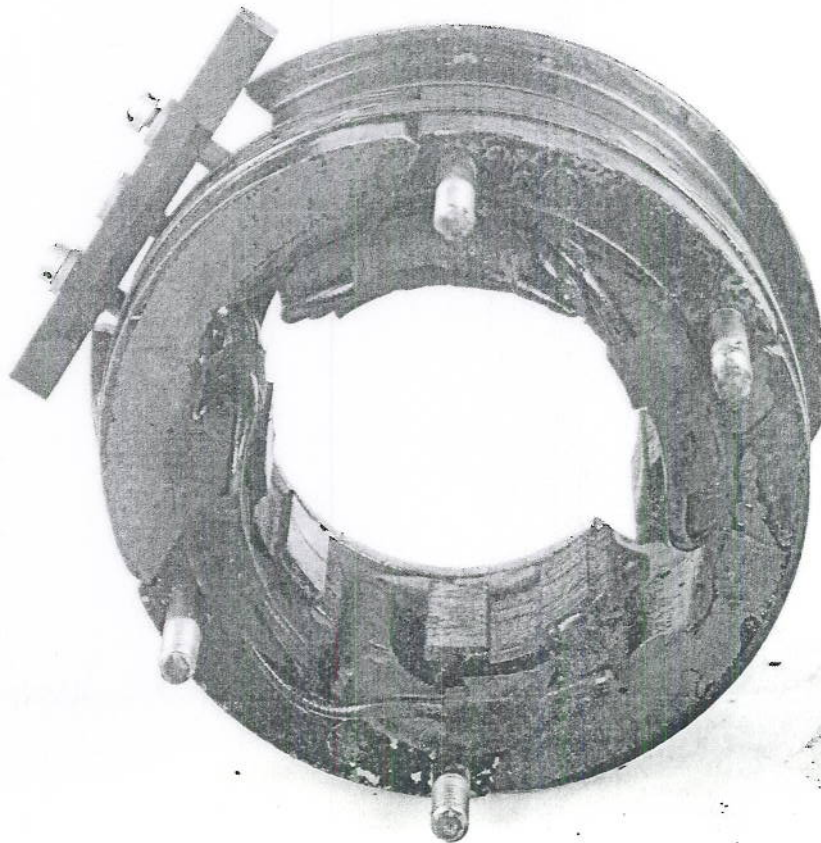
~~RESTRICTED~~

B-2903

PLATE 14



GENERATOR - DISASSEMBLED



GENERATOR STATOR