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NRL Report No. B-1823

FR-1823

NAVY DEPARTMENT

Report of Test

on

Indicator Motors, Type "N"

Submitted by

Henschel Corporation
Amesbury, Massachusetts

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text - 6 Tables -7 Plates -13

Authorization: BuShips ltr. S65-5(355) of 2 August 1941

Date of Test: September, October and November, 1941

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Distribution:
BuShips (6)
es

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APPENDICES

AUTHORIZATION FOR TEST

1. This problem was authorized by reference (a), and other references pertinent to this problem are listed as references (b), (c), (d), and (e).

References:
(a) BuShips ltr. S65-5(355) of 2 August 1941 to NRL.
(b) Specification SGS(65)-42a of 15 February 1937.
(c) NRL Test Report B-1587.
(d) NRL Test Report B-1587-A.
(e) BuShips ltr S65-5(7-30-SS) of 12 August 1940 to INM, Boston, copy to NRL.

OBJECT OF TEST

2. The object of this test was to determine conformance of the sample type "N" Indicator Motors with specification, reference (b), and their suitability for Naval use.

ABSTRACT OF TEST

3. The sample type "N" indicator motors were set up at this Laboratory in suitable test circuits where their performance was carefully observed for compliance with the specification. An inspection of the sample to determine compliance in the matter of materials, design, and workmanship, concluded the test.

CONCLUSIONS

(a). The sample type "N" indicator motors manufactured by the Henschel Corporation are of good design and workmanship and they comply with the specification in all of the major requirements; such as accuracy before and after endurance, shock, vibration, oscillation, torque, temperature rise when continuously operated, and materials of construction.

(b). During the course of the tests conducted on these motors, the following departures from the specification were noted:

(1). An insulation breakdown occurred between rotor and rotor windings in one out of six motors tested. This motor was one of two subjected to the shock and vibration tests.

(2). The bearings on the forward end of the rotor shaft are not dustproof.

(3). The outside shell diameter from the first flange to brush end of motor exceeds that allowed by approximately 0."080. This departure from the specifications was, however, waived under previous test, reference (d), by reference (e).

(4). All windings are of enameled instead of double silk or double cotton covered enameled copper wires as required by the specification. This departure was also waived under previous test, reference (d).

(5). Motor No. 1 failed after 24 hours on endurance. Its erratic performance at this point in the test is shown in Plates 2 and 10. This failure was traced to poor brush contacts and excessive end play in the rotor shaft. The end play, coupled with intermittent open circuit at the brushes, was sufficient to cause the damper to disengage from time to time. Because of this performance, which would seriously impair the operation of the remainder of the system on endurance and eventually destroy the faulty motor, motor No. 1 was eliminated from the endurance test.

RECOMMENDATIONS

(a). In view of the general satisfactory performance of the subject motors, it is recommended that they be approved for Naval use subject to correction or waiver of the departures from the specification listed under "Conclusions".

DESCRIPTION OF MATERIAL UNDER TEST

4. Six type "N" indicator motors and one type "A" transmitter generator were submitted for test.

5. This manufacturer submitted a generator positioning arm and index plate, six metal dials graduated in degrees and six indicator pointers, and 2 sheet metal plates each mounting 3 type "N" indicator motors, which materials were utilized in the present tests.

6. The motors submitted are of the bipolar stationary field type. The stator windings are connected directly to the external terminals S_1 and S_2 by insulated stranded wire. The rotor consists of three independent coils connected in Y and symmetrically disposed about the rotor axis. The rotor windings connect to the external terminals R_1, R_2, and R_3 through silver collector rings and brushes. All terminals for external connections are on insulating blocks.

7. The rotors are mounted in non-separable ball bearings which rest in the end bells and against end plates. Brass shims are inserted between the forward bearing and the end plate to limit end play. Through bolting is used to secure the end bells to the frame. Further details of design and construction are shown by photograph, Plate 1.

METHOD OF TEST

8. The type "N" motors were tested for accuracy while connected as a single system and positioned by the type "A" transmitter. Accuracy tests were made with the primaries or stator windings energized at 115 volts 60 cycles, 103.5 volts 65 cycles, and 126.5 volts 55 cycles.

9. The reflected light method of test was employed. For this method of test each motor was flange mounted concentrically in a cylindrical housing which was rigidly connected to the transmitter rotor through a shaft provided with a chuck for grasping the transmitter rotor. Electrical circuit was maintained between the transmitter and motor by means of slip rings and brushes in the motor mount.

10. Between static readings the shaft was rotated at 1/18 r.p.m. by means of an auxiliary driving motor which was also geared to the recording drum. The driving motor was controlled by means of a microswitch located on the type "N" motor housing, the periphery of which was notched at 3° intervals.

11. By connecting the leads R_1, R_2, R_3 of the transmitter to R_3, R_2, R_1 of the motor, the motor rotor should remain stationary while the transmitter rotor and motor housing are rotated by the common shaft. Any displacement of the rotor under these conditions constitutes an error when transmitter rotor and motor rotor start from a given fixed point, usually electrical zero.

12. When connected as in paragraph 11, both motor and transmitter were set to electrical zero by means of an electron oscillograph and a reference mark placed on the recording drum by means of a light beam reflected from a small mirror secured to the motor rotor shaft. This reference point was established at the beginning of each accuracy test. Each motor was tested for accuracy with both clockwise and counter-clockwise rotation when starting from electrical zero under conditions of primary supply given in paragraph 8. The system was brought to a standstill every 3° and errors were recorded by exposing the sensitive material on the recording drum to light reflected from the mirror on the motor rotor shaft. During each test the other five motors remained in the circuit as a load on the transmitter. The test equipment is shown by photograph, Plate 13.

13. In addition, "dynamic" tests were made with the same apparatus and in the same manner as the "static" tests conducted under reference (b), except that the motor housing and transmitter rotor were rotated continuously through 360° at a rate of 1 rpm while the light beam constantly fell on the reflecting mirror. Thus, a solid line is recorded representing a graph of the performance of the indicator motor while following the transmitter. Sufficient traces were obtained by this method under test conditions otherwise identical with those of the "static" runs to enable comparison of results obtained. Traces thus obtained are shown by Plates 6 to 12 inclusive. A summary of maximum errors is given in Table 2.

14. The "dynamic" test runs are submitted as additional information and were not conducted under specification, reference (b).

15. Following accuracy, torque tests were conducted as specified by paragraphs F-2c(3) to F-2c(3)c inclusive.

16. The oscillation characteristics of the motors were then obtained in accordance with paragraph F-2c(4), using an oscillographic timing method. Each motor was equipped with a standard pointer and only one motor was connected to the transmitter for each test.

17. The electrical characteristics of various combinations of motors and transmitter were then determined, followed by measurement of the maximum secondary voltages of all units, employing a vacuum tube voltmeter.

18. The six motors were then mounted on the metal plates submitted by the manufacturer and together with the transmitter placed in a thermostatically controlled oven at an ambient of 65°C. The transmitter and motors were wired as a single system and the transmitter driven at 100 rpm for 500 hours. The direction of rotation was reversed every 24 hours.

19. During the endurance test, the maximum temperature rise in all windings was determined by the resistance method.

20. After endurance all motors were inspected for mechanical and electrical defects and again tested for accuracy at 115 v. 60 cycles.

21. Two motors were selected and subjected to shock and vibration tests. These motors were again checked for accuracy at 115 v. 60 cycles. During all tests conducted in this report, no adjustments, repairs, cleaning nor oiling were made on any of the motors tested except motor no. 1 which failed on endurance.

22. All motors were given an insulation resistance test with a 1000 volt "megger" prior to subjecting them to dielectric. The dielectric test was conducted by applying 1500 volts 60 cycles between rotor and stator windings and windings and case for a period of one minute. This potential was built up slowly but continuously in small increments by means of a Variac transformer inserted in the input circuit.

23. Following the dielectric test, all motors were again tested for insulation resistance as in paragraph 22. An examination to determine compliance with the specifications in design, materials, construction and workmanship, concluded the test.

RESULTS OF TESTS

24. The results of tests conducted are as follows:

Requirements	Test Values
Accuracy: Para. F-2c(2)	Complied.
As modified to allow ± 1.5 degree error.	See Table 1 and Plates 2 to 7 inclusive.
Torque: Para. F-2c(3)	Complied - See Table 3.
Oscillation: Para. F-2c(4)	Complied - See Table 4.
Endurance: Para. F-2c(5)	*One motor failed as explained under "Conclusions".
Temperature rise during endurance: Para. F-2c(6)	Complied - See Table 7.
Accuracy following endurance: Para. F-2c(5)	Complied - See Table 1 and Plates 2 to 7 inclusive.

Requirements	Test Values
Shock and Vibration: Para. F-2c(8) and F-2c(9)	Complied.
Accuracy following endurance, shock and vibration: Para. F-2c(5), F-2c(8) and F-2c(9)	Complied - See Table 1 and Plate 6.
Electrical characteristics: Not specified.	See Tables 5 and 6.
Insulation Resistance before dielectric.	All motors greater than 200 megohms.
Dielectric: Para. F-2c(11) E-9p(1)	*One out of six motors broke down between rotor and rotor windings.
Insulation Resistance following dielectric: Para. F-2c(12) E-9p(3)	5 Motors greater than 200 megohms.
Check against drawings:	None submitted.
Dimensions: Para. E-3c	*Outside shell diameter 0."080 greater than 2."188 allowed.
Rotor Balance: Para. E-3n	Complied

* Denotes noncompliance with specifications.

CONCLUSIONS

25. (a). The sample type "N" indicator motors manufactured by the Henschel Corporation are of good design and workmanship and they comply with the specification in all of the major requirements; such as accuracy before and after endurance, shock, vibration, oscillation, torque, temperature rise when continuously operated, and materials of construction.

(b). During the course of the tests conducted on these motors, the following departures from the specifications were noted:

(1). An insulation breakdown occurred between rotor and rotor windings in one out of six motors tested. This motor was one of two subjected to the shock and vibration tests.

(2). The bearings on the forward end of the rotor shaft are not dustproof.

(3). The outside shell diameter from the first flange to brush end of motor exceeds that allowed by approximately 0."080. This departure from the specifications was, however, waived under previous test, reference (d), by reference (e).

(4.) All windings are of enameled instead of double silk or double cotton covered enameled copper wires as required by the specification. This departure was also waived under previous test, reference (d).

(5.) Motor No. 1 failed after 24 hours on endurance. Its erratic performance at this point in the test is shown by traces Plates 2 and 10. This failure was traced to poor brush contacts and excessive end play in the rotor shaft. The end play, coupled with intermittent open circuit at the brushes, was sufficient to cause the damper to disengage from time to time. Because of this performance, which would seriously impair the operation of the remainder of the system on endurance and eventually destroy the faulty motor, motor No. 1 was eliminated from the endurance test.

TABLE 1

Summary of Accuracy Tests - Maximum Errors in Degrees -
Plates 2 to 7, Inclusive.
Motors Connected to Generator
"Static" Tests

Test Conditions and Direction of Rotation		Direction of Error	Motor Numbers					
			1	2	3	4	5	6
Before endurance 115 v.a.c. 60 cycles	CW	+	.37	.17	.30	.25	.16	.32
		-	.58	.78	.40	.75	.59	.40
	CCW	+	.33	.72	.39	.72	.50	.35
		-	.52	.24	.24	.42	.43	.51
Before endurance 103.5 v.a.c. 65 cycles	CW	+	.20	0	0	.13	0	.08
		-	.83	.97	.67	1.03	.97	.85
	CCW	+	.65	.81	.51	.82	.66	.63
		-	.23	.03	.20	.35	.19	.32
Before endurance 126.5 v.a.c. 55 cycles	CW	+	.64	.44	.36	.48	.50	.72
		-	.44	.67	.48	.75	.52	.35
	CCW	+	.28	.52	.31	.54	.52	.28
		-	.79	.60	.57	.65	.52	.78
After endurance 115 v.a.c. 60 cycles	CW	+	.65	.25	.26	.47	.28	.20
		-	.65	.72	.57	.64	.68	.77
	CCW	+	-	.85	.48	.68	.62	.60
		-	-	.28	.24	.46	.25	.35
After shock and vibration test 115 v.a.c. 60 cycles	CW	+			.25			.58
		-			.37			.43
	CCW	+			.33			.48
		-			.15			.41
After endurance and adjustment 115 v.a.c. 60 cycles	CW	+	*.48					
		-	.95					
	CCW	+	.60					
		-	.67					

*See Plate 12.

TABLE 2

Summary of Accuracy Tests - Maximum Errors in Degrees -
Plates 8 to 12, Inclusive.
6 Motors Connected to Generator
"Dynamic" Tests

Test Conditions and Direction of Rotation		Direction of Error	Motor Numbers 1	2	3	4	5	6
Before endurance 115 v.a.c. 60 cycles	CW	+	.18	.03	0	.08	0	0
		-	.97	1.18	1.08	1.19	1.20	1.08
	CCW	+	0	.05	.28	.54	.25	.02
		-	1.03	.87	.61	.90	.86	1.16
Before endurance 103.5 v.a.c. 65 cycles	CW	+						0
		-						1.58
	CCW	+						.02
		-						1.17
Before endurance 126.5 v.a.c. 55 cycles	CW	+						.40
		-						.78
	CCW	+						.13
		-						1.20
After endurance 115 v.a.c. 60 cycles	CW	+	.27	.06	0	0	0	.30
		-	1.04	1.45	1.02	1.28	1.45	1.18
	CCW	+	-	.17	.27	.38	.45	.20
		-	-	1.07	.50	1.00	.87	.85
After shock and vibration 115 v.a.c. 60 cycles	CW	+			0			.13
		-			1.20			1.14
	CCW	+			.20			.32
		-			.60			.72
After endurance and adjustment 115 v.a.c. 60 cycles	CW	+	.12					
		-	1.15					
	CCW	+	.38					
		-	1.07					

TABLE 3

Torque and Torque-Gradient in Inch-Ounces with One Receiver Connected to Transmitter

Displacement in Degrees from Electrical Zero	Motor Numbers					
	1	2	3	4	5	6
CW						
1	.13	.14	.16	.14	.15	.14
2	.31	.29	.30	.29	.30	.29
3	.45	.43	.46	.44	.45	.44
4	.61	.56	.62	.59	.60	.58
5	.76	.72	.77	.73	.76	.72
6	.90	.87	.91	.89	.90	.87
7	1.05	1.00	1.06	1.03	1.05	1.02
8	1.19	1.15	1.22	1.19	1.21	1.15
9	1.34	1.28	1.36	1.34	1.36	1.30
10	1.50	1.43	1.50	1.48	1.52	1.44
CCW						
1	.15	.14	.13	.16	.16	.14
2	.31	.30	.29	.31	.31	.30
3	.46	.45	.44	.46	.45	.44
4	.61	.57	.59	.61	.61	.60
5	.75	.72	.73	.76	.76	.74
6	.91	.87	.89	.91	.92	.88
7	1.05	1.01	1.04	1.05	1.06	1.03
8	1.20	1.17	1.19	1.21	1.22	1.19
9	1.35	1.31	1.39	1.36	1.36	1.32
10	1.50	1.46	1.49	1.51	1.51	1.45
Torque Gradient	0.15	0.145	0.15	0.15	0.151	0.145
Maximum Torque						
CW	11.72	11.33	11.92	11.10	12.16	11.02
CCW	13.06	12.35	12.66	11.80	11.90	11.85

TABLE 4

Oscillation Test: Time (in seconds) for "Standard" indicator pointer to come to rest as determined by oscillograph method. One receiver connected to transmitter.

Motor No.	Pointer Displacement in Degrees	Time for Pointer to Come to Rest.
1	179	1.61
1	90	.89
1	20	.65
1	10	.41
1	5	.21
2	179	1.30
3	179	1.27
4	179	1.54
5	179	1.31
6	179	1.30

TABLE 5

Electrical Characteristics of Transmitter and Receiver Combinations on 115 v.a.c. 60 Cycles

System	Receivers Free to Indicate		Rotor of One Receiver Locked 180° Out of Position	
	Amps.	Watts	Amps.	Watts
1 Trans. - 6 Rec.	1.93	42.0	2.73*	158.0*
1 Trans. - 5 Rec.	1.72	36.5	2.25	144.0
1 Trans. - 4 Rec.	1.49	30.8	1.80	137.0
1 Trans. - 3 Rec.	1.25	24.4	1.54	132.0
1 Trans. - 2 Rec.	1.18	18.8	1.50	122.0
1 Trans. - 1 Rec.	.74	12.8	1.37	116.4
1 Trans. - - -	.51	7.0	-	-

*Values given are initial readings obtained on energizing system as windings of locked receiver heated rapidly and gave unstable values.

TABLE 6

Maximum Induced Voltages (r-m-s) as indicated by an Electronic Voltmeter. Units not interconnected.

Unit	Winding Measured		
	$R_1 - R_2$	$R_2 - R_3$	$R_1 - R_3$
No. 1 Motor	80.0	80.0	80.0
No. 2 Motor	79.5	79,5	79.5
No. 3 Motor	78.0	78.5	78.5
No. 4 Motor	79.0	79.5	78.5
No. 5 Motor	79.0	79.5	79.0
No. 6 Motor	78.5	79.0	78.5
Generator	89.5	89.5	89.5

TABLE 7

Maximum temperature rise in °C in windings - Resistance method above an ambient of 65° C as measured during endurance 35° C. allowed.

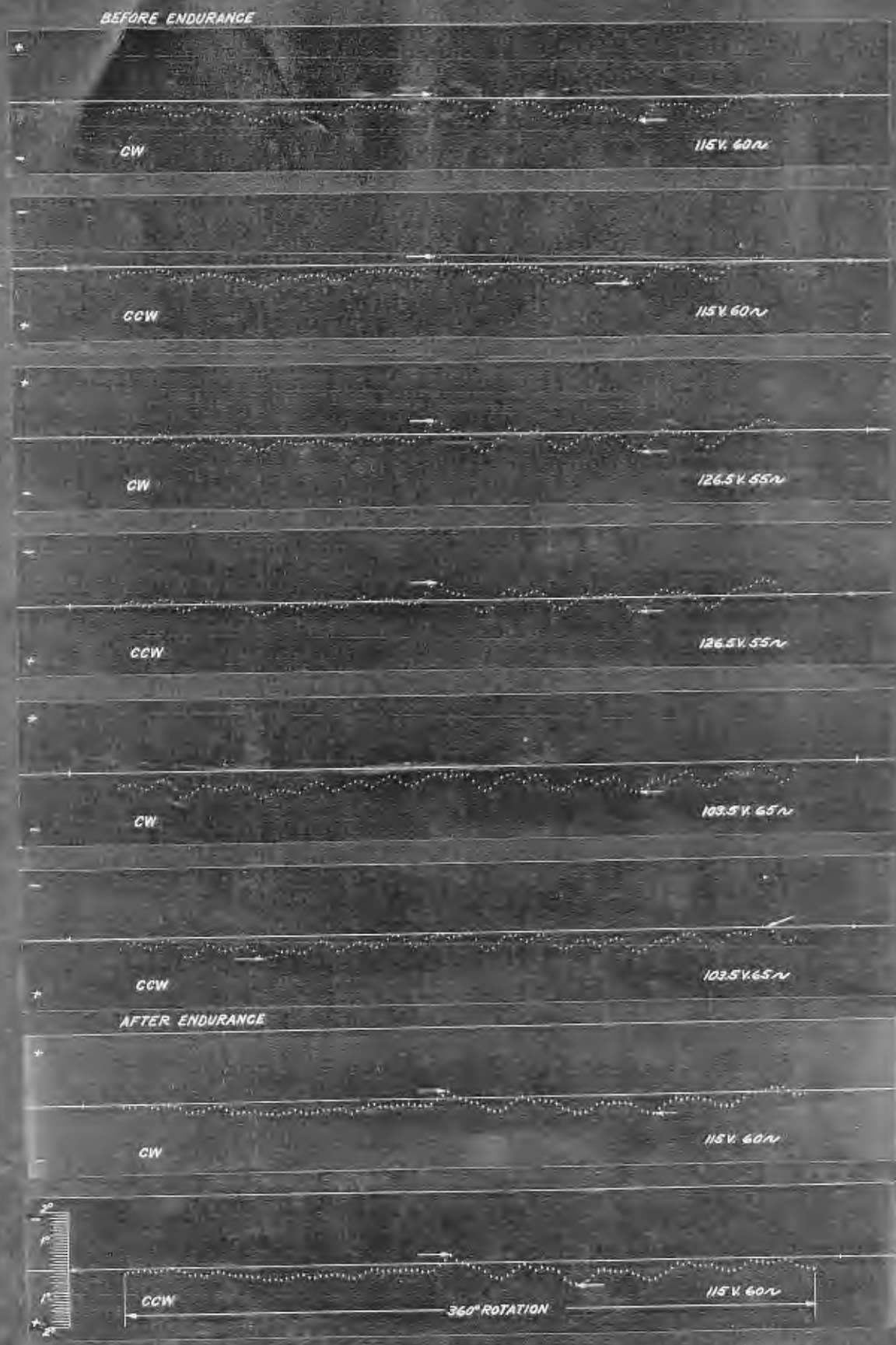
Unit	Winding Measured			
	$S_1 - S_2$	$R_1 - R_2$	$R_1 - R_3$	$R_2 - R_3$
No. 1 Motor	* -	-	-	-
No. 2 Motor	18.3	14.7	14.0	13.9
No. 3 Motor	22.7	18.3	18.2	17.8
No. 4 Motor	18.4	14.7	14.4	14.5
No. 5 Motor	25.1	20.2	14.3	20.4
No. 6 Motor	19.3	15.6	15.6	15.5
Generator	23.6	17.4	16.9	24.0

*Not used on endurance because of erratic behavior as explained under "Conclusions b-5" and shown in Plates 2 and 10.

PLATE I

RESULTS OF ACCURACY TESTS (STATIC METHOD)
MOTOR NO. 1
NOTE: ARROWS INDICATE MAXIMUM ERRORS

PLATE

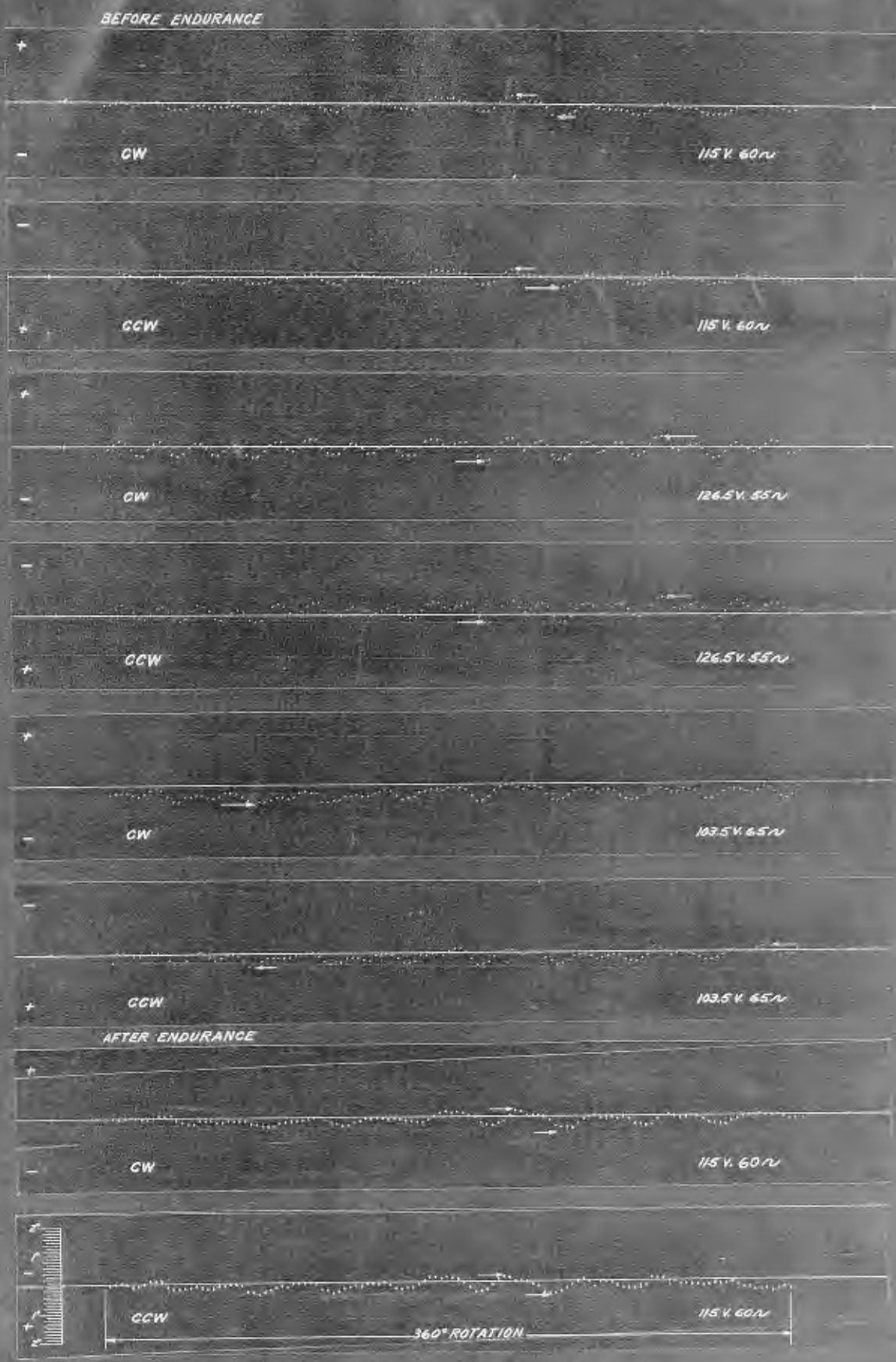


RESULTS OF ACCURACY TESTS (STATIC METHOD)

MOTOR NO. 2

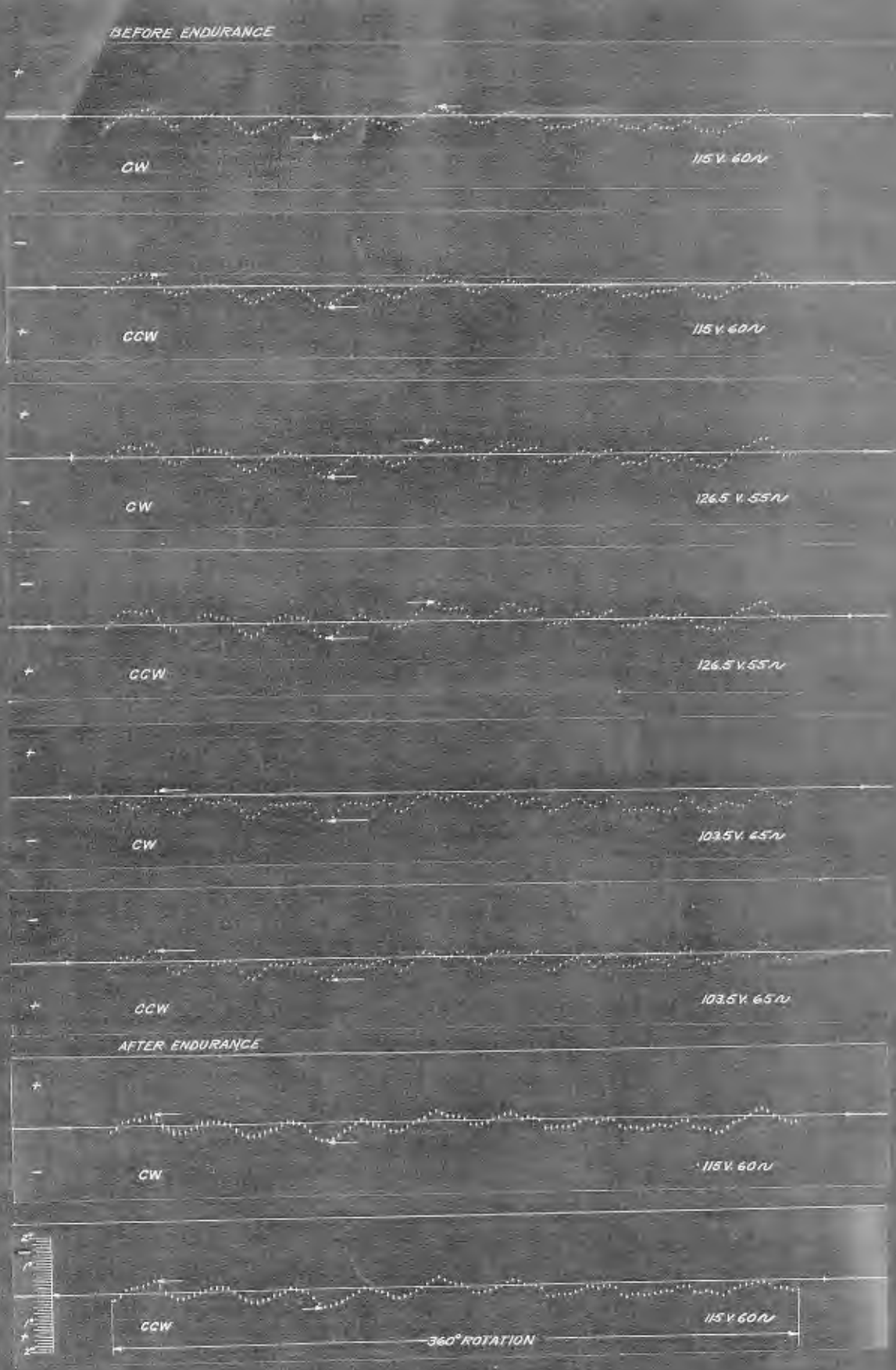
NOTE: ARROWS INDICATE MAXIMUM ERRORS

PLATE



RESULTS OF ACCURACY TESTS (STATIC METHOD)
MOTOR NO. 3
NOTE: ARROWS INDICATE MAXIMUM ERRORS

PLATE 4

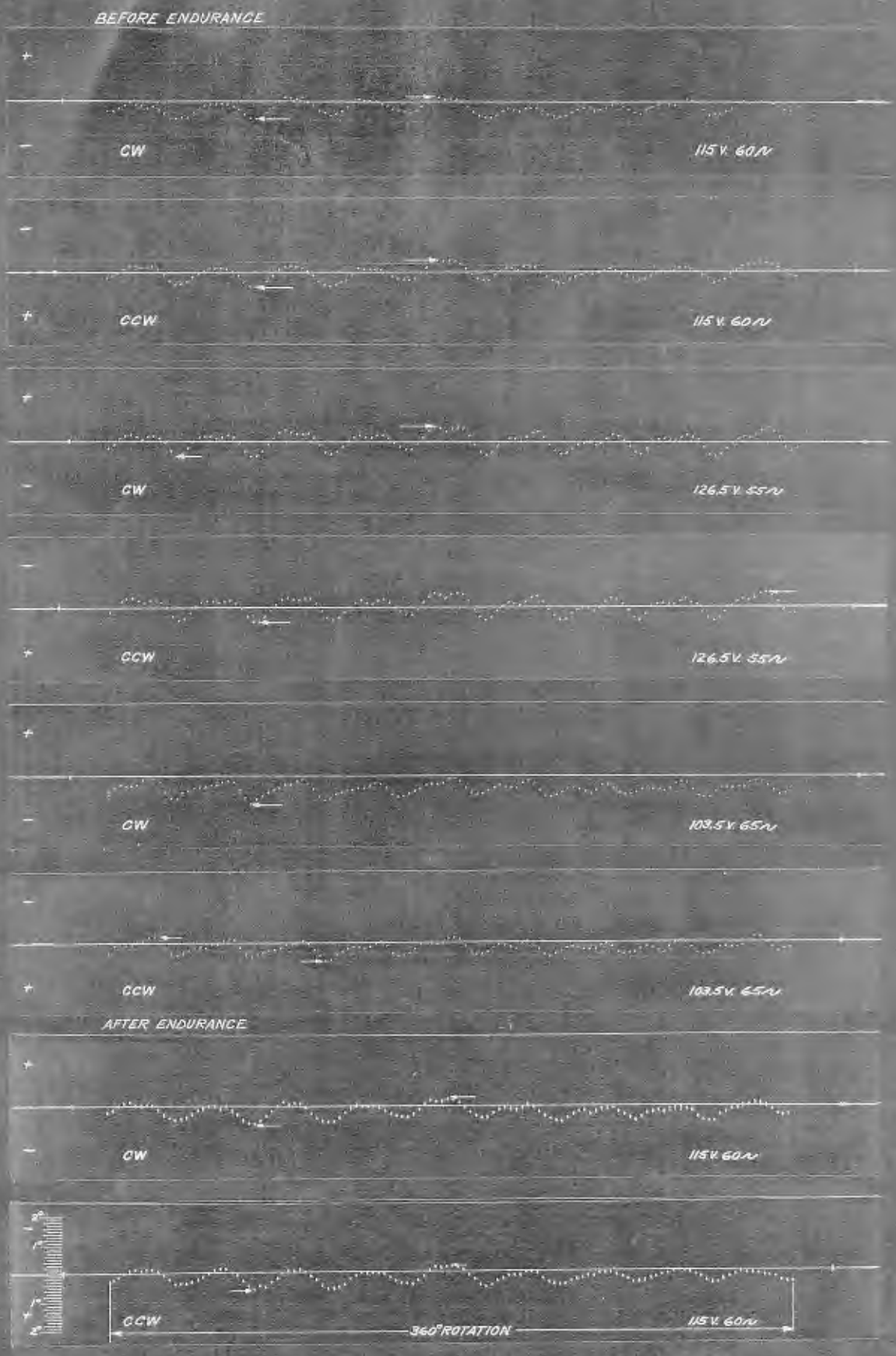


RESULTS OF ACCURACY TESTS (STATIC METHOD)

MOTOR NO. 4

NOTE: ARROWS INDICATE MAXIMUM ERRORS

PLATE 5

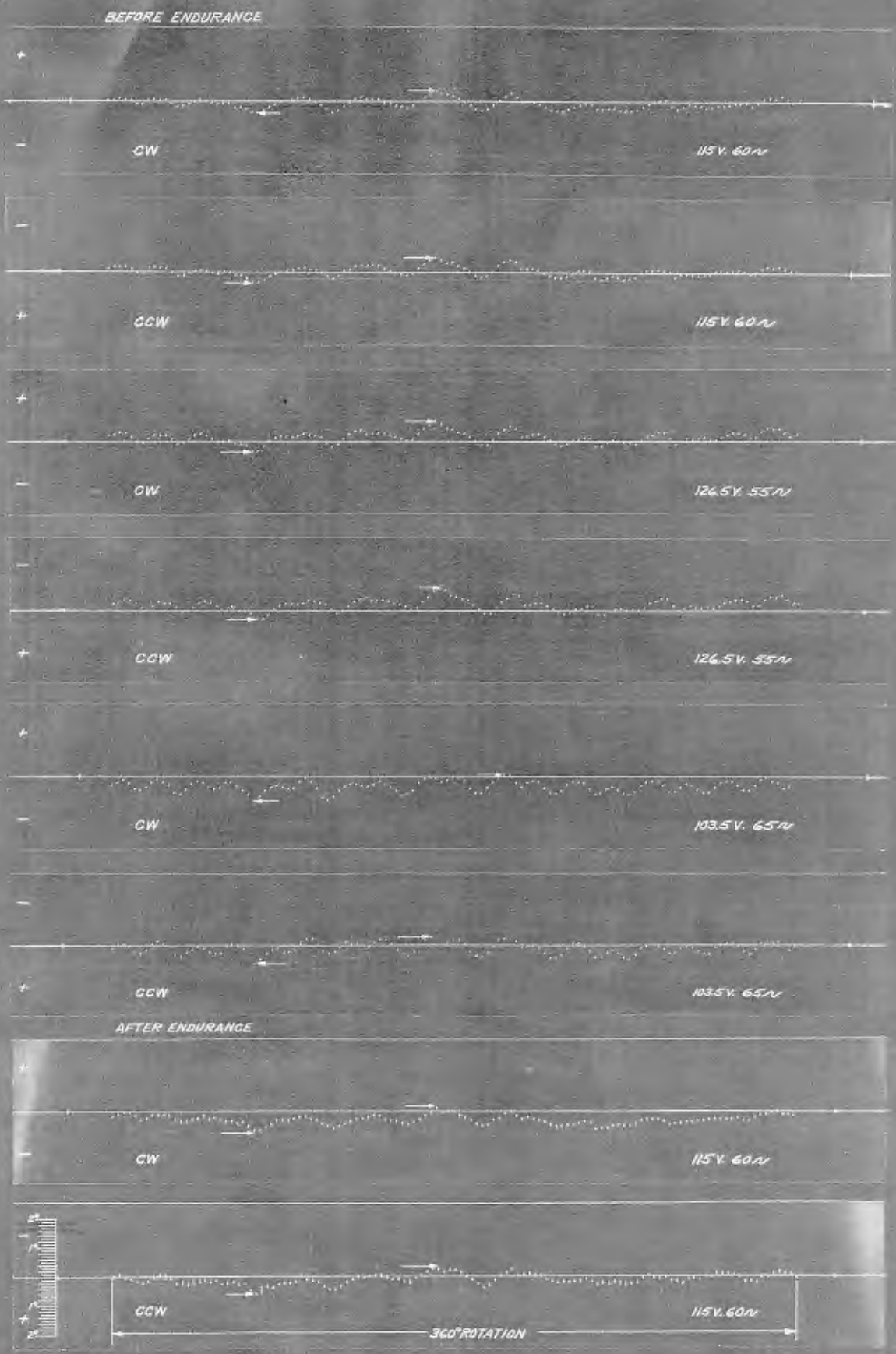


RESULTS OF ACCURACY TESTS (STATIC METHOD)

MOTOR NO. 5

NOTE: ARROWS INDICATE MAXIMUM ERRORS

PLATE 6

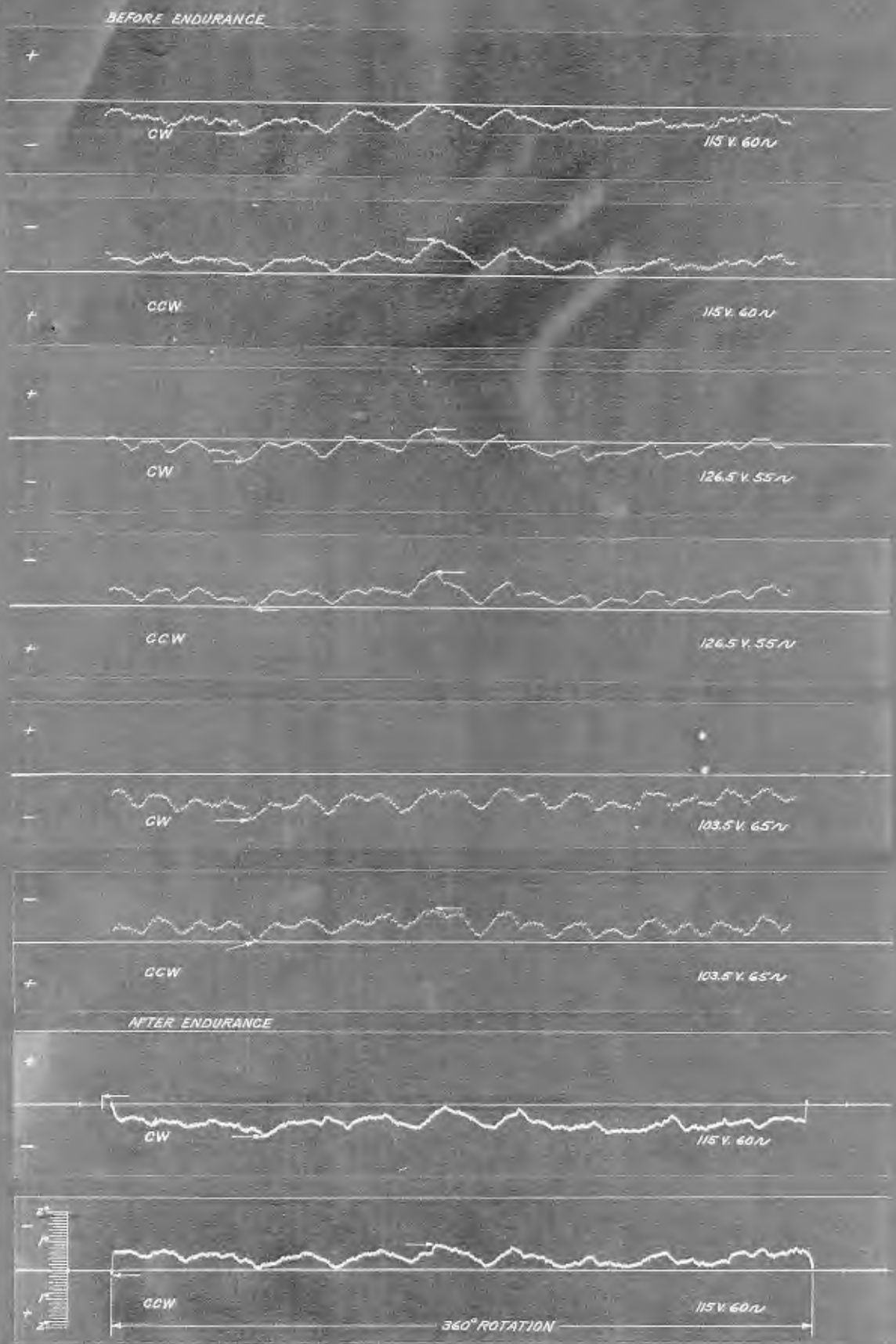


RESULTS OF ACCURACY TESTS (STATIC METHOD)

MOTOR NO. 6

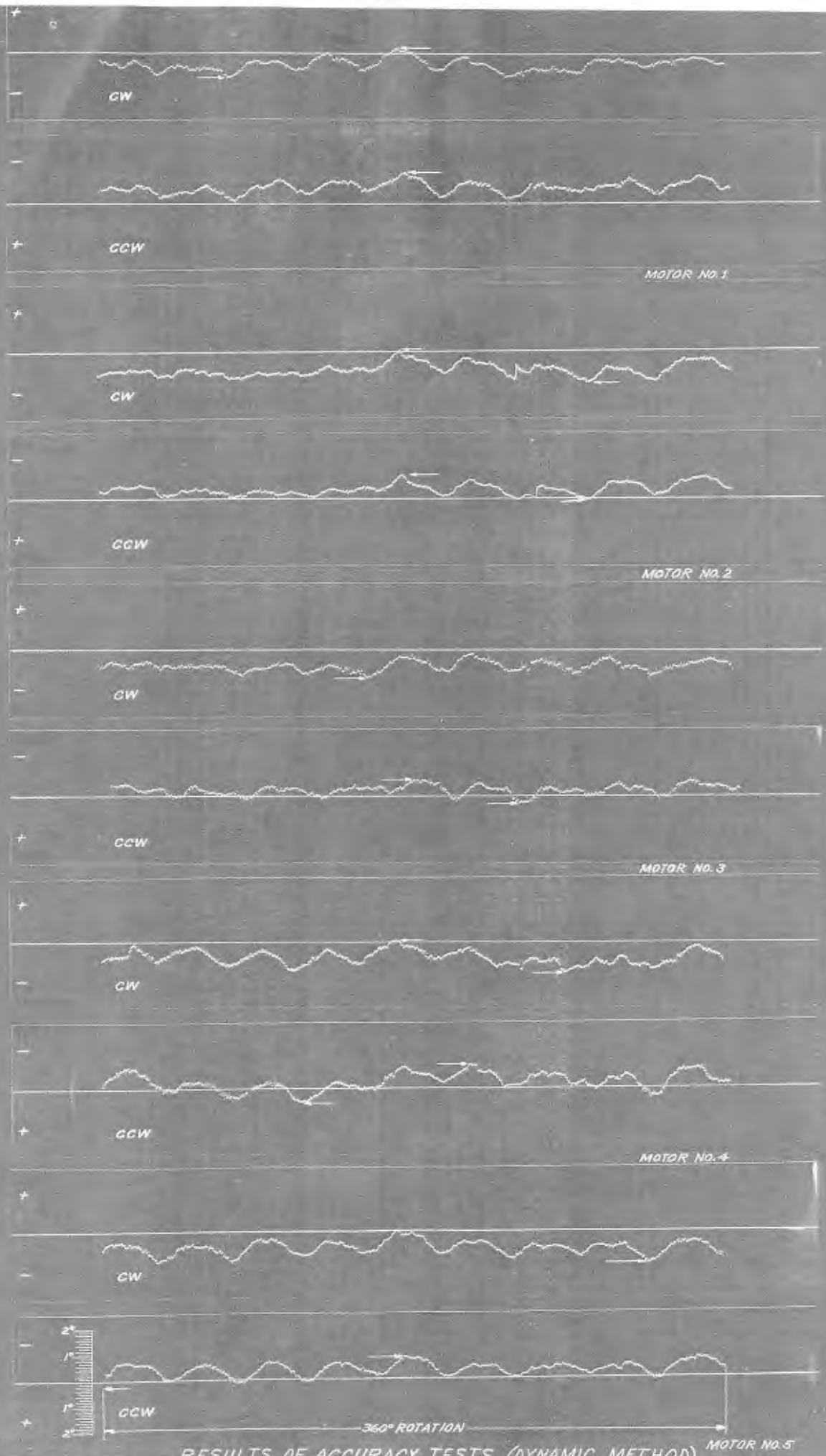
NOTE: ARROWS INDICATE MAXIMUM ERRORS

PLATE 7



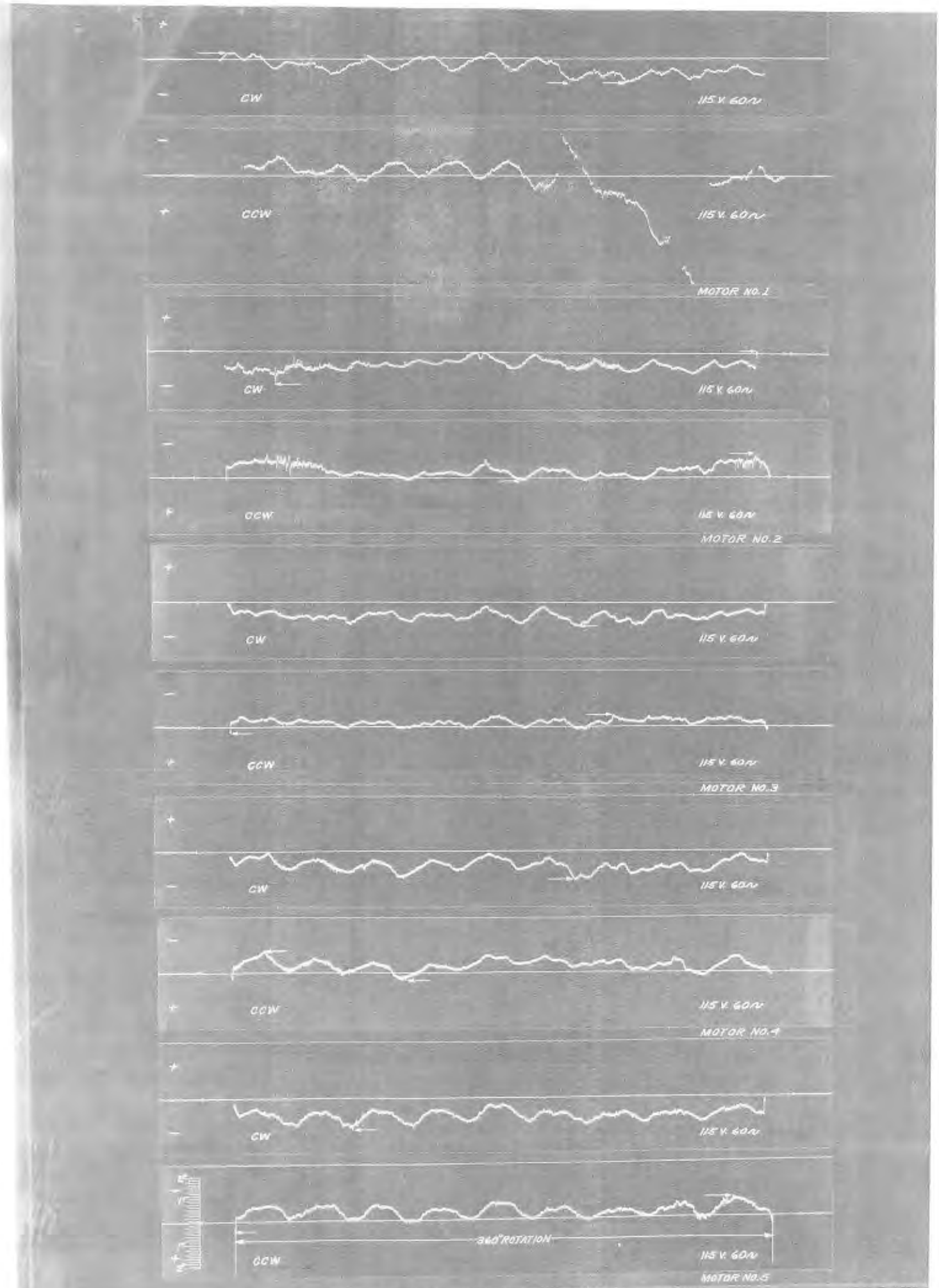
RESULTS OF ACCURACY TESTS (DYNAMIC METHOD)
MOTOR NO. 6
NOTE: ARROWS INDICATE MAXIMUM ERRORS

PLATE 8



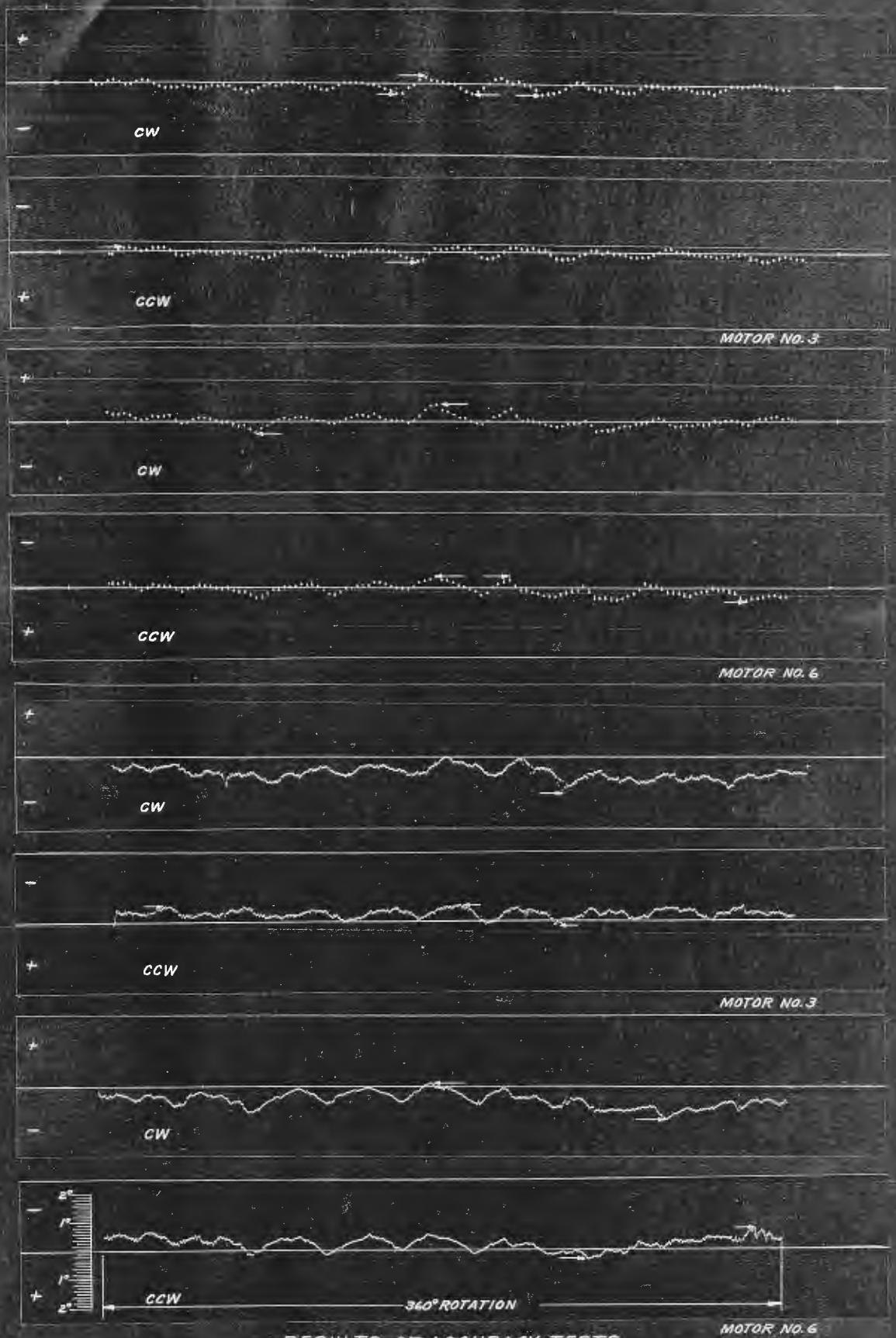
RESULTS OF ACCURACY TESTS (DYNAMIC METHOD)

PLATE



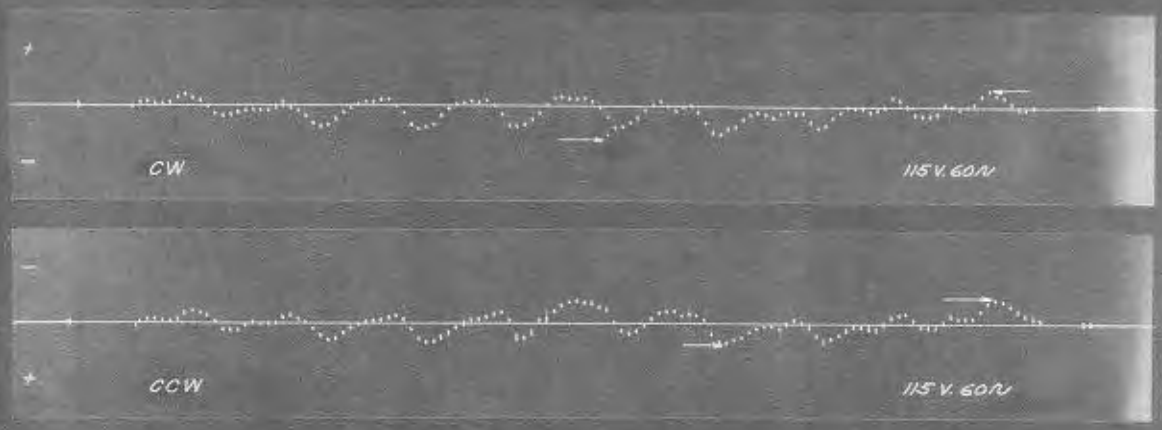
RESULTS OF ACCURACY TESTS (DYNAMIC METHOD)

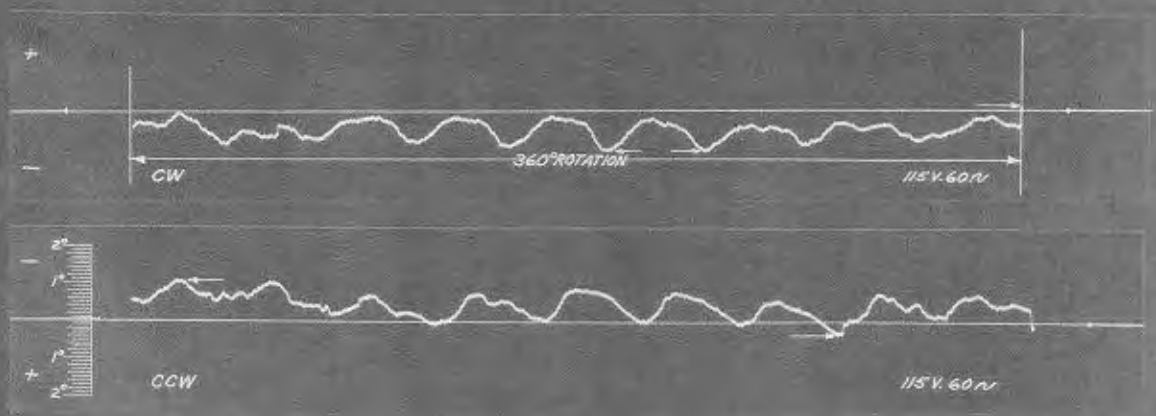
PLATE I



RESULTS OF ACCURACY TESTS
STATIC AND DYNAMIC METHODS
AFTER ENDURANCE, SHOCK AND VIBRATION
115 V. 60 ~

PLATE II





RESULTS OF ACCURACY TESTS (STATIC AND DYNAMIC METHODS)
MOTOR NO. 1
AFTER ENDURANCE AND ADJUSTMENT

PLATE 12

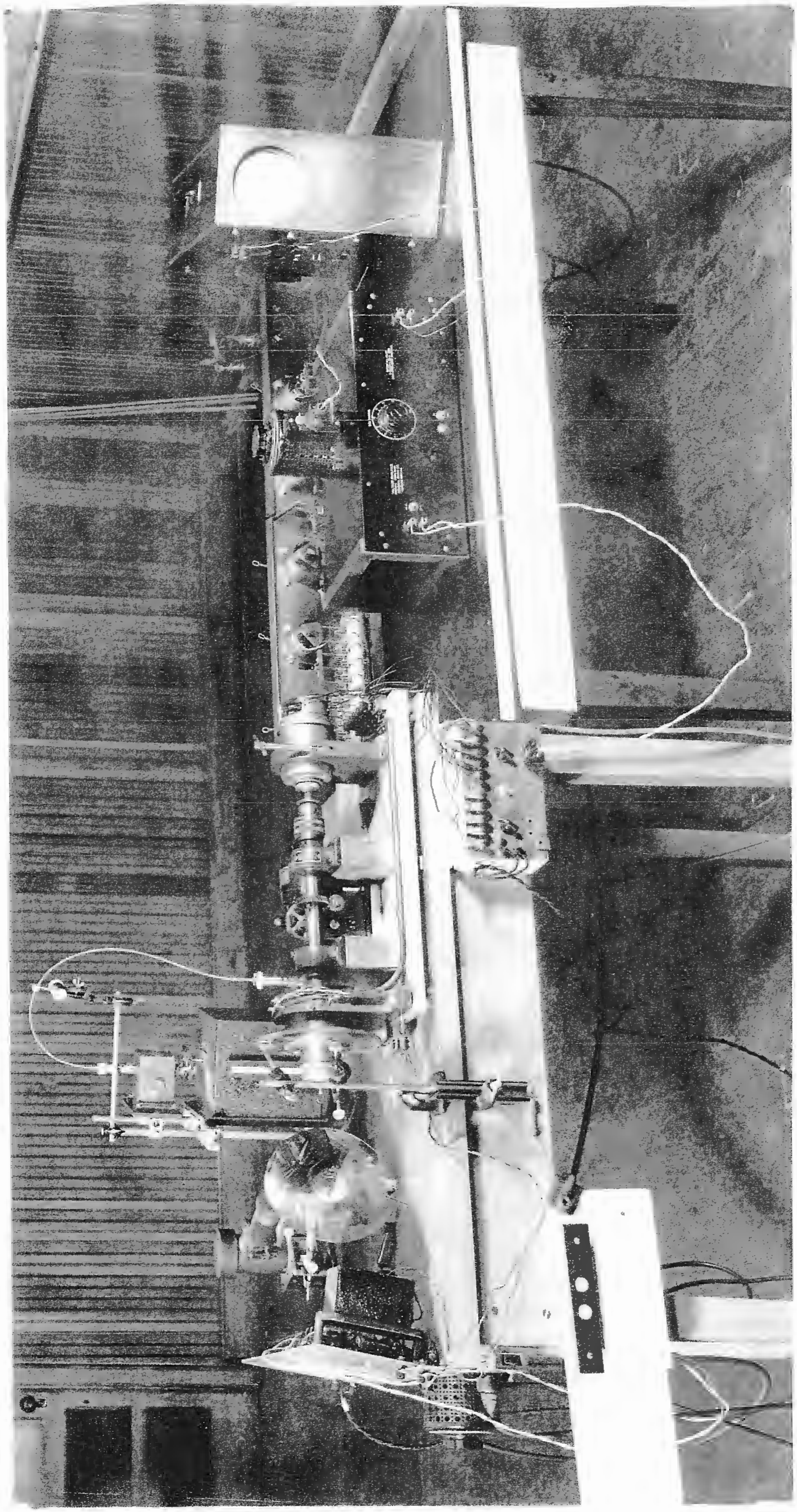


PLATE 13