May 24, 1937 NRL Report No. B-1368

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report of Test

on

Overload Transformers

Submitted by

Arma Engineering Company

Brooklyn, New York

FR-1368

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

Number of Pages: Text - 5 Tables -3 Plates - 15

Authorization: BuEng. ltr. S71-8(3-18-Ds) of 23 March 1937.

Date of Test: April and May, 1937.

Prepared by: _____
W. B. Roberts, Pr. Eng. Aide, Chief of Section.

Reviewed by: _____
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Approved by: _____
H. M. Cooley, Captain, U.S.N., Director.

Distribution:
BuEng. (5).

epc

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APPENDICES

AUTHORIZATION.

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

Reference: (a) BuEng. ltr. S71-8(3-18-Ds) of 23 March 1937.
(b) Specifications SGS(71)-119a.
(c) BuOrd. Specifications O.S. No. 671 - Synchro Transmission Systems- of 14 September 1933.
(d) Arma Engineering Drawing 20985 - BuEng. File No. 11-T-1225L-Alt. 0.
(e) BuEng. ltr. Nos-51703-(4-8-Ds) of 19 April 1937 to NRL.

OBJECT OF TEST.

2. The object of this test was to determine the conformance of the transformers with the specifications, references (b) and (c), and their suitability for the Naval service.

ABSTRACT OF TEST.

3. The subject transformers were set up at this Laboratory in suitable test circuits and their performance was carefully checked for conformance with the specifications. The test was concluded with an inspection of the sample transformers to determine their compliance with the specifications in the matter of materials and workmanship.

CONCLUSIONS.

(a) Under the accuracy test, the increase in the error caused by the insertion of a transformer in the synchro circuit appears to exceed the allowable 3 minute increase. However, an allowance should be made for the human error in setting the generator dial and reading the vernier off the motor dial. These errors are estimated to be ± 3 minutes in each case, or a possible total error of ± 6 minutes.

(b) Under the test for displacement necessary to operate the indicator trouble lamp, it was noted that the displacements ranged from $14^{o}42'$ to $21^{o}0'$. This exceeds the allowable range of 14^{o} to 20^{o} specified under reference (e).

(c) The results of the measurements of reduction in torque gradient give values in excess of the allowable 5 percent, the greatest reduction being 6.2%.

(d) The coefficient of stiffness of coupling was reduced by an average of 10.7% when a transformer was inserted in the synchro circuit. The allowable reduction is 10%, but the result given includes a possible error in determining the results from the oscillograms, Plates 12 to 15 inclusive.

(e) The temperature rise of the transformers, as determined by the resistance method, was within the specified limit.

(f) The case and terminal cover designs are exceptionally good. There is no possibility of the terminal turning and breaking an internal connection.

RECOMMENDATIONS.

(a) It is recommended that the subject overload transformers be given consideration of approval for Naval use in accordance with the importance of the torque and accuracy requirements which are slightly exceeded.

(b) It is further recommended that the results of the displacement test be considered as satisfactory as, at the values given, the glow of the indicator lamp appeared suddenly and had a useful value of illumination.

DESCRIPTION OF MATERIAL UNDER TEST.

4. The three sample transformers submitted are identical in design and each consists of two tapped primary windings and a divided tapped secondary winding on a laminated core. Housed in the same case are two fixed condensers and two fixed resistors connected across portions of the secondary and primary circuits respectively. Drawing, reference (d), gives diagram of internal connections.

5. All of the electrical components of the unit are located in a cast aluminum alloy case filled with an insulating compound. A terminal block of molded, fabric inserted, phenolic material forms the cover of the case. External connections are made by securing lugs with machine screws threaded into small brass plates embedded in the block. The bottom of the case is of sheet aluminum.

6. The purpose of the transformer is to operate a type VG-2 indicator lamp when the displacement between a synchro motor and its generator exceeds the specified number of degrees. The windings are tapped to allow for the installation of the transformer in the circuits of synchro motors of various ratings.

METHOD OF TEST.

7. The method used in conducting the test was to set up a circuit whereby the sample transformers could be connected in the rotor circuits (S1 and S3) between a type 5 synchro motor and generator. That is, primary winding M1-TT1 was connected in circuit S1 and primary winding M3-TT3 in circuit S3. A selected VG-2 lamp, consuming a current of 0.00165 amperes at 115 volts, A.C., 60 cycles, was connected across terminals L and L1. During this test, the transformers were located in a temperature controlled cabinet having a temperature of 54° C. Extension lead wires were provided for accurate measurement of temperature rise of the secondary windings, using the resistance method.

8. The accuracy test was made with the use of two test stands, each holding a synchro motor or generator. A dial graduated in degrees from 0 to 360 and a vernier graduated to permit readings of 3 minutes, were used with each stand. Both synchros were first set on electrical zero, after which the generator was slowly rotated in steps of 10 degrees and the errors in the positions of the motor dial recorded. This test was made without and with the transformers in the circuit and in both clockwise and counter-clockwise directions. The test equipment, as assembled for this test, is shown by Plate 10.

9. The displacement test was made with the same equipment by locking the generator dial at zero and displacing the motor dial until a point was reached where the trouble indicator lamp began to glow. This procedure was repeated in steps of 10 degrees in both clockwise and counter-clockwise directions without and with the transformers in the circuit.

10. The torque test was made by replacing the motor dial with a balanced pointer and a 3 inch drum, around which was passed a silk thread from which a container for holding shot was suspended. With the generator

locked as before, the weight was slowly varied until the pointer was displaced one degree. This was continued until the pointer had been displaced 10 degrees in steps of one degree, after which the shot were weighed and the torque computed in inch-ounces. This procedure was repeated in both clockwise and counter-clockwise directions without and with the transformers in the circuit.

11. The stiffness test was made by placing an aluminum dial 3.5 in. diameter and 0.015 in thickness on the synchro motor. With the system energized the generator was set to 36 degrees. After deenergizing the system, the generator was returned to zero and locked, thereby leaving the motor displaced by 36 degrees. An oscillograph was then connected across leads S1 and S3 and the circuit was closed, causing the motor dial to return to zero after several oscillations. The oscillograph was equipped with a film drive and a 60 cycle wave was used for timing. The oscillograms obtained were used in computing the coefficient of stiffness of coupling without and with a sample transformer connected in the circuit.

12. The temperature rises of the transformer windings were obtained using the resistance method, by removing them from the synchro circuits and setting up an equivalent circuit simulating a condition where a motor was displaced 180 degrees in relation to the generator. The current passed through the windings was the same value as was obtained with the motor and generator used on the previous tests. During this test, the transformer was located in a temperature controlled cabinet having a temperature of 54° C.

13. Unless otherwise noted, all tests reported herein were made at the rated voltage of 115 volts, a.c., 60 cycles.

RESULTS OF TEST.

14. Under test for accuracy, the maximum increase in the error introduced by the insertion of the transformer in the synchro circuit, was 12 minutes. This occurred in only one instance, being observed with No. 1 transformer in the circuit and the generator positioned 240 degrees from electrical zero. Errors of 9 minutes were observed in four instances, but the majority of errors were 3 minutes or less. The data obtained during the accuracy test are given as Table 2 and curves, Plates 2 and 3.

15. The maximum and minimum displacements required to operate the indicator lamp were as follows:

Transformer No.	Displacement required to operate lamp.			
	Maximum		Minimum	
	Clockwise	Counter-Clockwise	Clockwise	Counter-Clockwise
1	19°51'	19°54'	15°0'	14°42'
2	20°54'	20°6'	15°0'	14°45'
3	21°0'	20°3'	15°3'	14°48'

Note: These values are the points where the lamp first started to glow. Except in the instances where only one of the electrodes glowed at the displacement given, the illumination was of a useful

intensity. With an additional displacement of 1 degree, the illumination was suitable for trouble indicator use in all instances.

16. The results obtained from tests of reduction in indicator motor torque gradient resulting from the insertion of a transformer in the synchro circuit were as follows:

Reduction in Torque Gradient

	Clockwise	Counter-Clockwise
Transformer No. 1	4.4%	5.2%
Transformer No. 2	5.2%	5.4%
Transformer No. 3	5.4%	6.2%

17. The oscillograms, given as Plates 12 to 15 inclusive, were obtained from a normal synchro circuit and with Numbers 1, 2, and 3 transformers, successively placed in the circuit. From these a stiffness coefficient of 100 was obtained for the normal circuit and an average coefficient of 89.3 was obtained with a transformer in the circuit. This reduction in the stiffness of coupling is 10.7%. That allowed is 10%.

18. The average temperature rise of the secondary windings of the transformers was 16.5° C. at an ambient temperature of 54° C. when set up in a circuit simulating the maximum current obtainable with two type 5 synchros.

CONCLUSIONS.

19. Under the accuracy test, the increase in the error caused by the insertion of a transformer in the synchro circuit appears to exceed the allowable 3 minute increase. However, an allowance should be made for the human error in setting the generator dial and reading the vernier of the motor dial. These errors are estimated to be ± 3 minutes in each case, or a possible total error of ± 6 minutes.

20. Under the test for displacement necessary to operate the indicator trouble lamp, it was noted that the displacements ranged from $14^{\circ}42'$ to $21^{\circ}0'$. This exceeds the allowable range of 14° to 20° specified under reference (e).

21. The results of the measurements of reduction in torque gradient give values in excess of the allowable 5 percent, the greatest reduction being 6.2%.

22. The coefficient of stiffness of coupling was reduced by an average of 10.7% when a transformer was inserted in the synchro circuit. The allowable reduction is 10%, but the result given includes a possible error in determining the results from the oscillograms, Plates 12 to 15 inclusive.

23. The temperature rise of the transformers, as determined by the resistance method, was within the specified limit.

24. The case and terminal cover designs are exceptionally good. There is no possibility of the terminal turning and breaking an internal connection.

Table 1.

Motor displacement to light lamp.

Arma Synchro Overload Transformers

Generator setting in degrees from elect. zero (CW).	Trans. No. 1		Trans. No. 2		Trans. No. 3	
	CCW	CW	CCW	CW	CCW	CW
10	14°-51'	15°-45'	14°-54'	15°-1'	15°-0'	16°-0'
20	14°-57'	17°-3'	15°-3'	17°-9'	15°-3'	17°-9'
30	15°-48'	18°-51'	15°-48'	18°-48'	15°-57'	18°-51'
40	17°-9'	18°-54'	17°-9'	18°-51'	17°-15'	18°-57'
50	18°-54'	19°-30'	18°-51'	19°-45'	18°-51'	19°-51'
60	18°-9'	18°-45'	18°-57'	18°-18'	18°-57'	18°-30'
70	19°-45'	17°-12'	19°-54'	17°-24'	20°-0'	17°-42'
80	18°-3'	17°-45'	18°-42'	17°-9'	18°-33'	17°-30'
90	17°-12'	16°-45'	17°-30'	17°-18'	17°-45'	17°-42'
100	16°-42'	17°-6'	16°-54'	17°-54'	17°-12'	18°-3'
110	16°-45'	18°-9'	17°-3'	19°-3'	17°-15'	19°-6'
120	17°-3'	19°-42'	17°-12'	20°-45'	17°-45'	20°-43'
130	17°-54'	19°-33'	18°-21'	19°-30'	18°-33'	19°-39'
140	19°-9'	17°-48'	19°-45'	17°-51'	19°-45'	17°-45'
150	19°-47'	16°-12'	19°-54'	16°-21'	20°-0'	16°-15'
160	17°-6'	15°-30'	17°-15'	15°-24'	17°-27'	15°-33'
170	15°-33'	15°-0'	15°-45'	15°-6'	15°-45'	15°-6'
180	15°-0'	15°-12'	15°-6'	15°-6'	15°-9'	15°-6'
190	14°-42'	15°-51'	14°-45'	15°-48'	14°-48'	15°-51'
200	14°-54'	17°-12'	14°-51'	17°-6'	14°-54'	17°-9'
210	15°-39'	18°-51'	15°-36'	18°-48'	15°-30'	18°-45'
220	17°-6'	18°-57'	17°-0'	19°-0'	17°-12'	19°-0'
230	18°-45'	19°-30'	18°-33'	19°-48'	18°-39'	19°-54'
240	18°-45'	18°-9'	18°-57'	18°-39'	18°-51'	18°-39'
250	19°-36'	17°-9'	19°-45'	17°-24'	19°-45'	17°-45'
260	18°-9'	16°-39'	18°-18'	17°-15'	18°-33'	17°-30'
270	17°-3'	16°-51'	17°-12'	17°-27'	17°-33'	17°-48'
280	16°-36'	17°-3'	16°-51'	18°-3'	17°-3'	18°-6'
290	16°-45'	18°-9'	17°-6'	19°-0'	17°-15'	19°-9'
300	17°-0'	19°-45'	17°-15'	20°-54'	17°-33'	21°-0'
310	17°-51'	19°-51'	18°-15'	19°-42'	18°-30'	19°-27'
320	19°-3'	17°-30'	19°-36'	17°-30'	19°-45'	17°-42'
330	19°-54'	16°-9'	20°-6'	16°-27'	20°-3'	16°-3'
340	17°-6'	15°-18'	17°-30'	15°-21'	17°-33'	15°-18'
350	15°-45'	15°-9'	16°-0'	15°-9'	16°-0'	15°-3'
360	15°-0'	15°-9'	15°-12'	15°-0'	15°-12'	15°-9'

Table 2.

Accuracy Test - without and with transformers.

Generator setting in degrees from elect. zero	CW-Rotation-slip ring end error in motor reading				CCW-Rotation-slip ring end error in motor reading			
	No Transformer	Transformer No. 1	Transformer No. 2	Transformer No. 3	No Transformer	Transformer No. 1	Transformer No. 2	Transformer No. 3
10	0	0	-3	-3	-21	-24	-21	-27
20	+9	+6	+9	+6	-21	-18	-24	-21
30	-3	-3	0	-3	-15	-21	-21	-18
40	-6	-9	-9	-9	-21	-24	-24	-21
50	+12	+15	+9	+12	-12	-12	-12	-15
60	+9	+15	+15	+12	-9	-12	-15	-12
70	-3	-6	-9	-6	-21	-24	-24	-24
80	+3	+3	0	-3	-21	-18	-21	-21
90	-6	-3	-3	-3	-27	-27	-18	-18
100	-3	-3	-3	-6	-21	-24	-21	-24
110	-3	0	-3	-6	-21	-18	-18	-18
120	-3	-3	-3	-3	-21	-21	-24	-21
130	0	-3	-3	-3	-30	-33	-30	-30
140	+9	+9	+9	+9	-21	-21	-24	-21
150	+6	+6	+6	+3	-15	-18	-18	-21
160	+3	-3	-3	-3	-24	-27	-24	-30
170	+12	+9	+9	+9	-15	-15	-15	-18
180	+3	+3	+6	+3	-18	-18	-21	-21
190	0	0	-3	-3	-30	-30	-30	-27
200	+9	+9	+6	+9	-21	-24	-18	-24
210	+3	+3	+3	+6	-30	-27	-24	-30
220	+3	0	0	-3	-30	-30	-27	-33
230	+9	+12	+9	+9	-21	-21	-21	-21
240	0	-3	-3	-3	-18	-21	-18	-21
250	-6	-6	-3	-6	-24	-21	-21	-24
260	+6	+6	+6	+3	-15	-21	-21	-18
270	0	0	-3	-3	-24	-24	-24	-27
280	-3	-6	-6	-3	-24	-24	-27	-27
290	0	0	0	0	-18	-15	-18	-21
300	-3	-3	-6	-6	-21	-24	-21	-21
310	-6	-9	-6	-9	-24	-27	-24	-27
320	0	+3	0	+3	-21	-18	-18	-18
330	-9	0	0	-3	-21	-21	-21	-21
340	+3	-9	-6	-6	-30	-27	-30	-27
350	0	+3	0	0	-24	-24	-24	-24
360	-6	-6	-6	-6	-24	-24	-27	-24

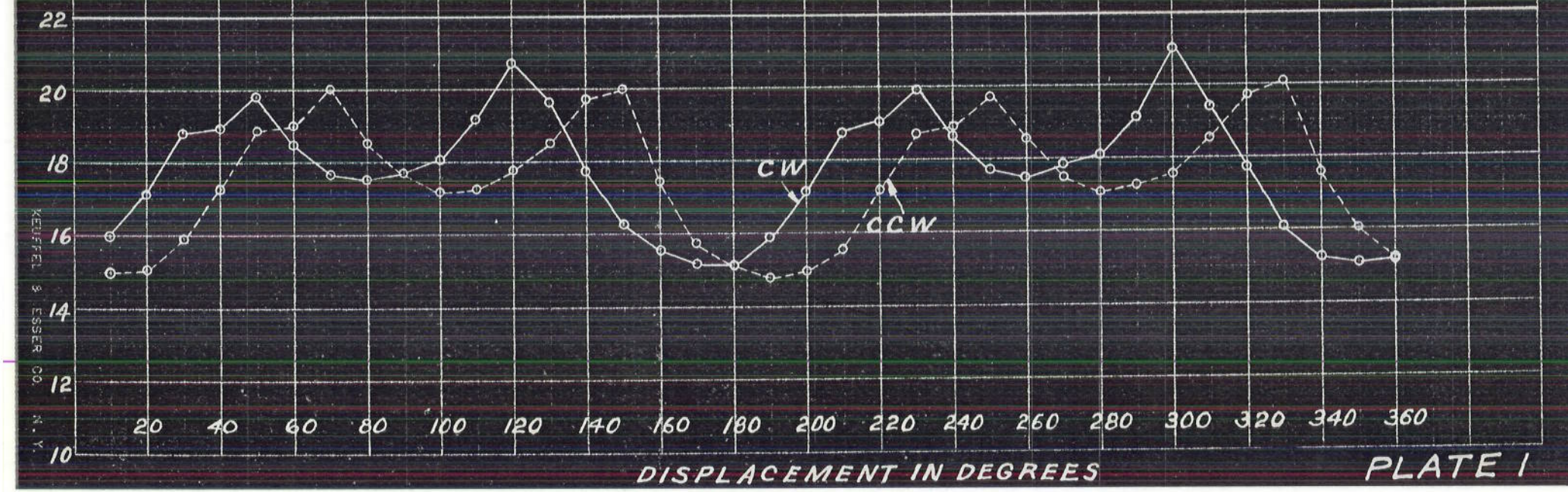
Table 3.

Torque Tests

	Gen. displacement in degrees	Without transformer: Weight to return motor to zero (Gms.)	Without transformer: Weight to return motor to zero (Ozs.)	Without transformer: Inch ounces (ozs. x 1.5)	With No. 1 Transformer: Weight to return motor to zero (Gms.)	With No. 1 Transformer: Weight to return motor to zero (Ozs.)	With No. 1 Transformer: Inch ounces (ozs. x 1.5)	With No. 2 Transformer: Weight to return motor to zero (Gms.)	With No. 2 Transformer: Weight to return motor to zero (Ozs.)	With No. 2 Transformer: Inch ounces (ozs. x 1.5)	With No. 3 Transformer: Weight to return motor to zero (Gms.)	With No. 3 Transformer: Weight to return motor to zero (Ozs.)	With No. 3 Transformer: Inch ounces (ozs. x 1.5)
Generator displaced CW (from slip ring end)	1	6.46	.228	.342	6.5	.229	.344	6.95	.245	.367	7.02	.247	.371
	2	13.83	.488	.732	13.21	.466	.699	13.31	.470	.705	14.4	.508	.762
	3	20.51	.724	1.085	19.77	.697	1.045	19.93	.703	1.055	20.02	.706	1.058
	4	27.06	.955	1.432	25.9	.914	1.37	26.08	.920	1.380	26.14	.922	1.38
	5	33.78	1.192	1.786	32.36	1.141	1.712	32.71	1.154	1.730	32.69	1.153	1.73
	6	40.86	1.442	2.160	39.35	1.387	2.081	38.70	1.365	2.047	39.19	1.382	2.07
	7	47.98	1.692	2.537	45.54	1.610	2.41	45.83	1.615	2.420	45.68	1.610	2.42
	8	54.99	1.939	2.910	52.14	1.838	2.72	52.33	1.845	2.768	52.88	1.865	2.80
	9	62.05	2.188	3.281	59.27	2.080	3.135	59.23	2.088	3.133	59.28	2.090	3.135
	10	69.69	2.458	3.685	65.66	2.315	3.473	66.13	2.330	3.506	65.47	2.310	3.46
Generator displaced CCW(from slip ring end)	1	8.47	.298	.448	8.7	.307	.460	8.27	.291	.437	8.39	.296	.444
	2	15.62	.552	.827	14.83	.524	.785	15.0	.529	.794	15.1	.532	.799
	3	22.61	.798	1.196	21.58	.762	1.141	21.52	.759	1.14	21.51	.760	1.138
	4	29.28	1.033	1.548	28.26	.996	1.495	28.3	.998	1.499	28.25	.997	1.495
	5	36.87	1.300	1.950	34.91	1.232	1.846	34.71	1.224	1.836	34.79	1.226	1.840
	6	43.66	1.539	2.310	41.91	1.478	2.22	41.44	1.460	2.192	41.15	1.450	2.176
	7	50.8	1.792	2.688	48.51	1.711	2.568	48.44	1.707	2.562	48.67	1.716	2.57
	8	57.76	2.034	3.045	55.33	1.95	2.925	55.06	1.940	2.915	55.42	1.955	2.93
	9	65.43	2.308	3.46	62.35	2.20	3.298	62.35	2.20	3.29	62.24	2.194	3.30
	10	72.82	2.568	3.85	69.17	2.444	3.656	69.29	2.443	3.665	69.13	2.440	3.65

MOTOR DISPLACEMENT
TO OPERATE TROUBLE SIGNAL
(USING L+L, CIRCUIT FOR LAMP)
ARMA SYNCHRO OVERLOAD TRANSFORMERS.

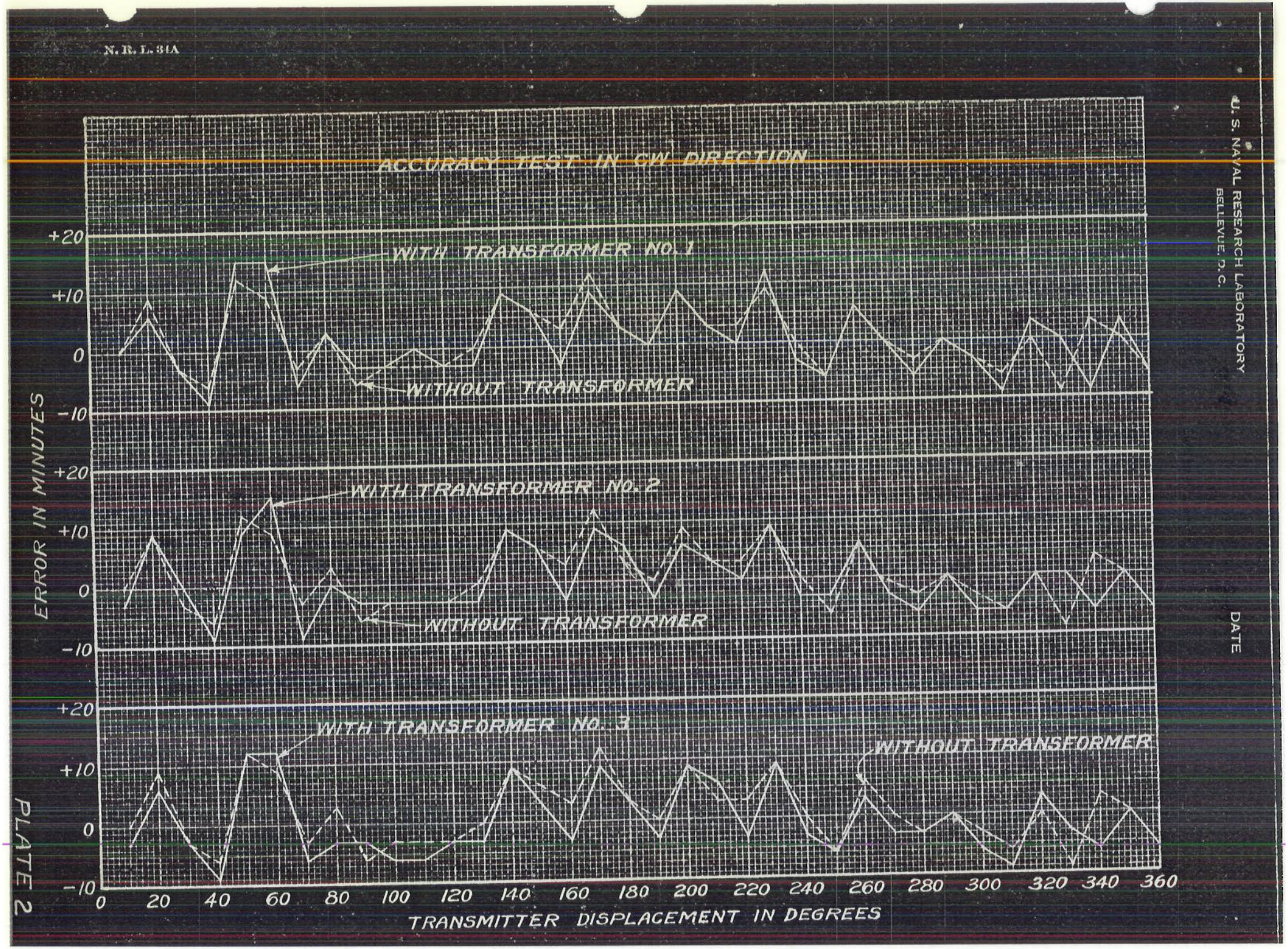
TRANSFORMER No. 1



KEUFFEL & ESSER CO. N. Y.

PLATE 1

N. R. L. 31A



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BELLEVUE, D.C.

DATE

PLATE 2

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DATE

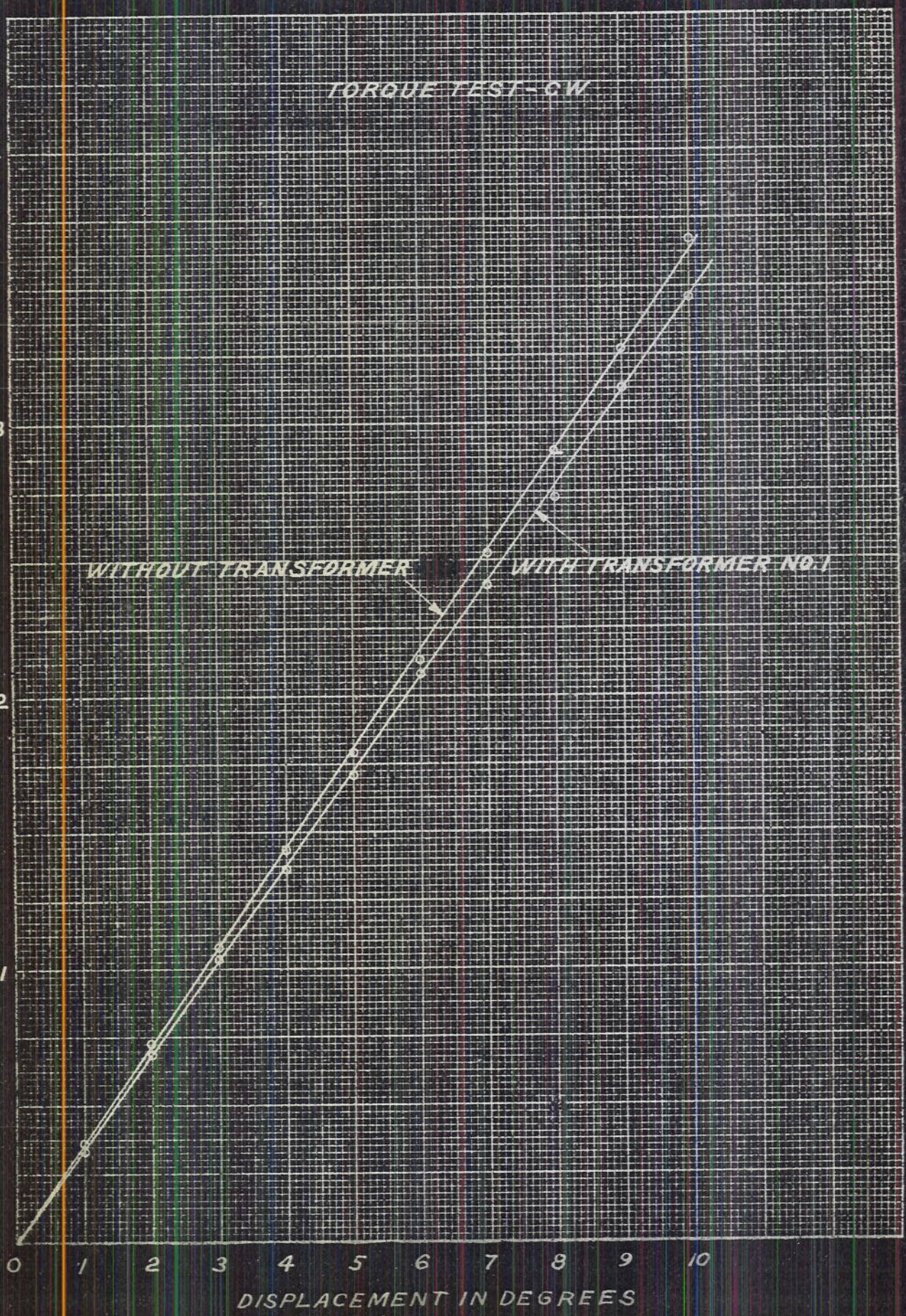

PLATE 4

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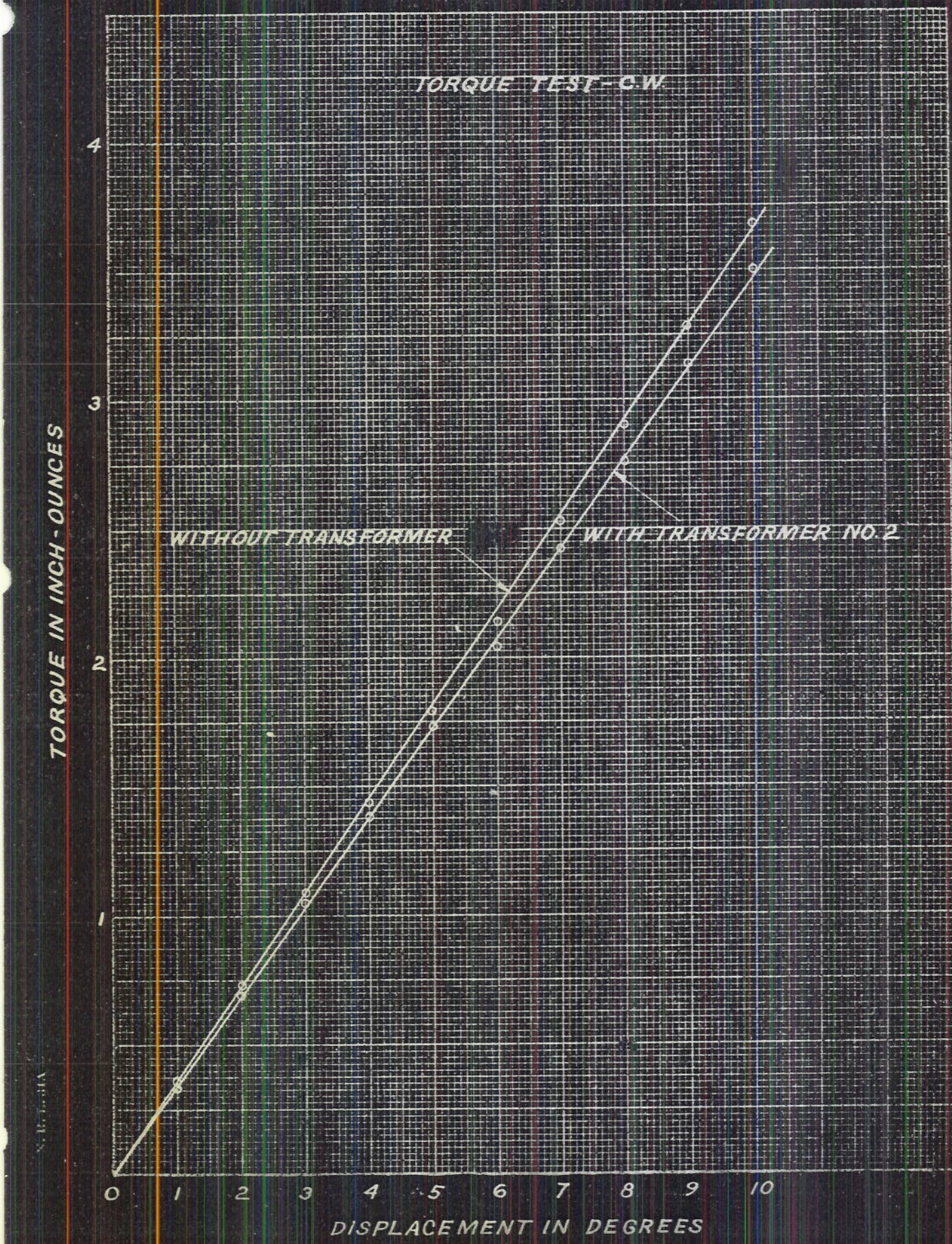

PLATE

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PLATE 6

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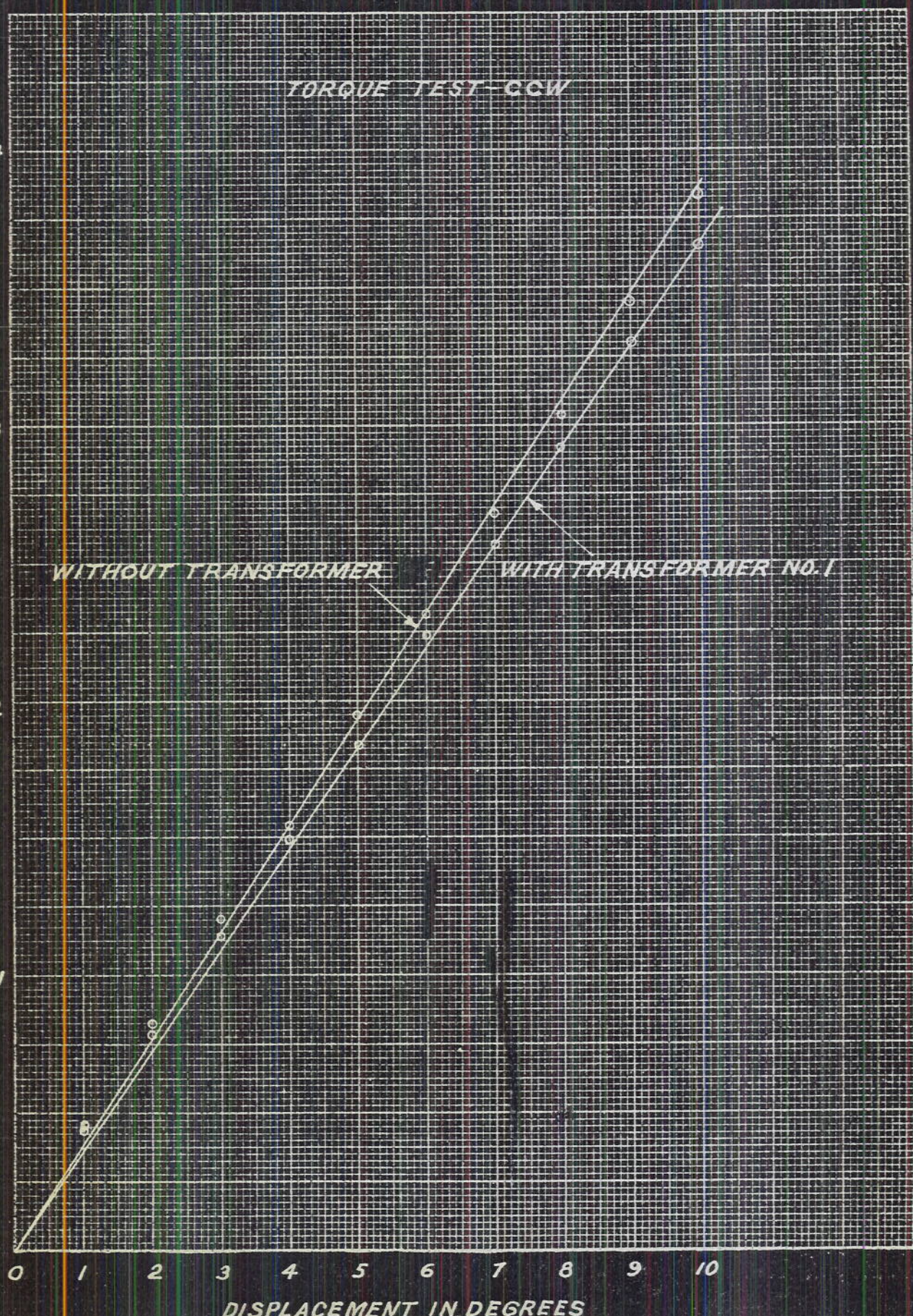

PLATE 7

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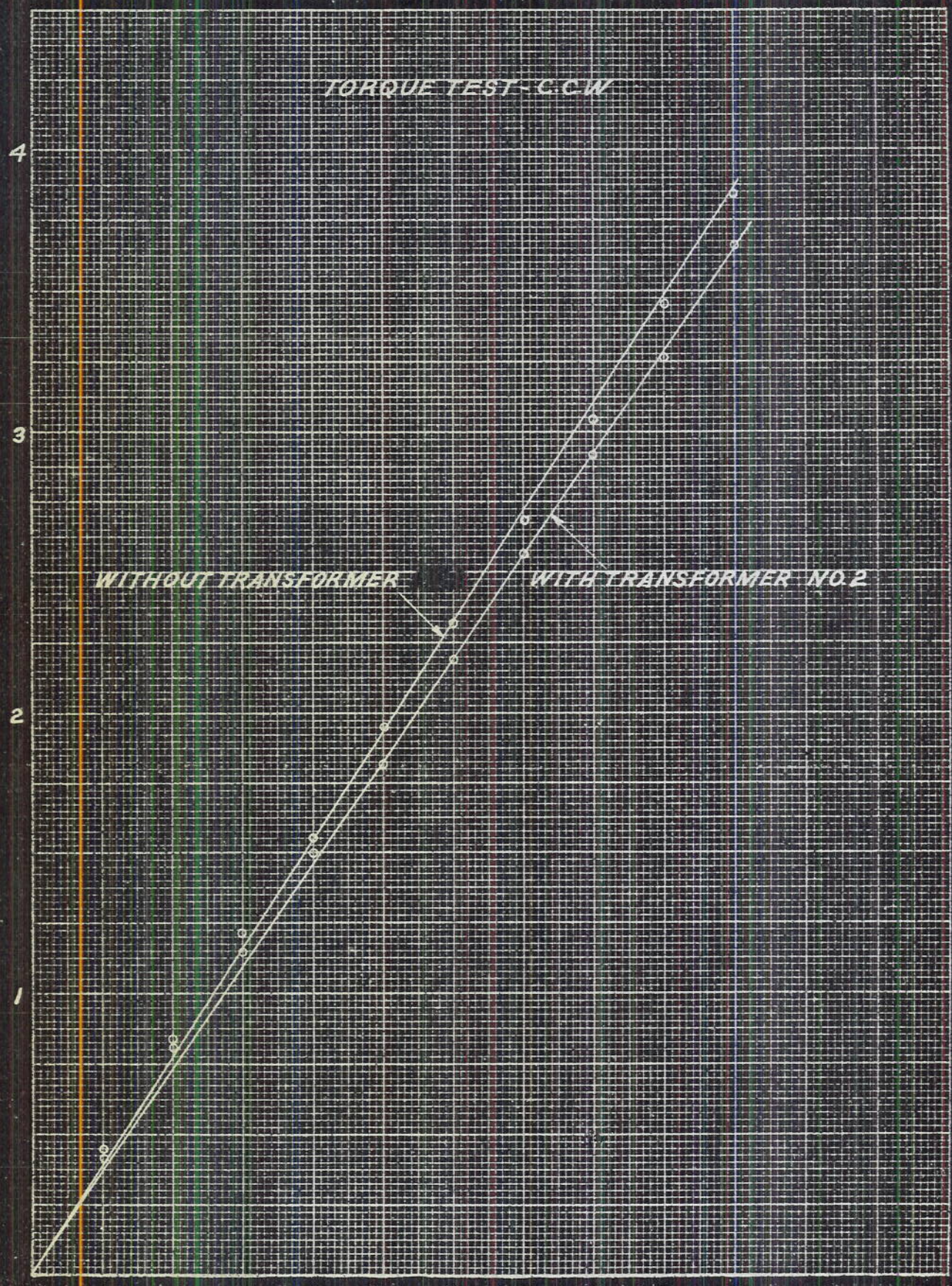

N. R. L. 31A

PLATE 8

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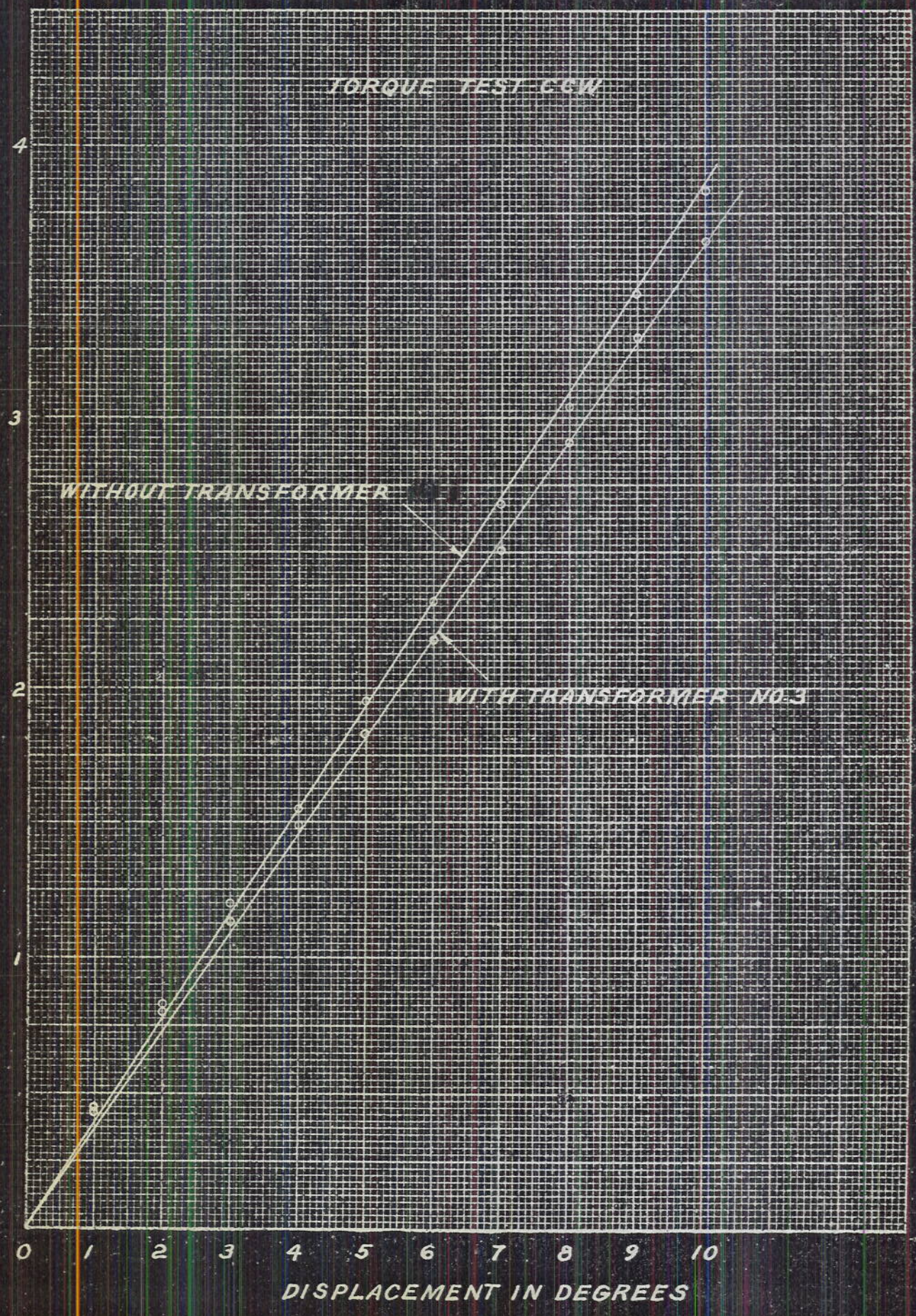


PLATE 9


M1
L1
S1
L2
S2
L
M3
TT1
T1
T3
TT3
SYNCHRO OVERLOAD RELAY
TYPE 2M4
SER. NO. 2X
INSP.
CONT. NO.
DATE
ARMA ENGINEERING CO., INC.
BROOKLYN, NEW YORK

Plate 11

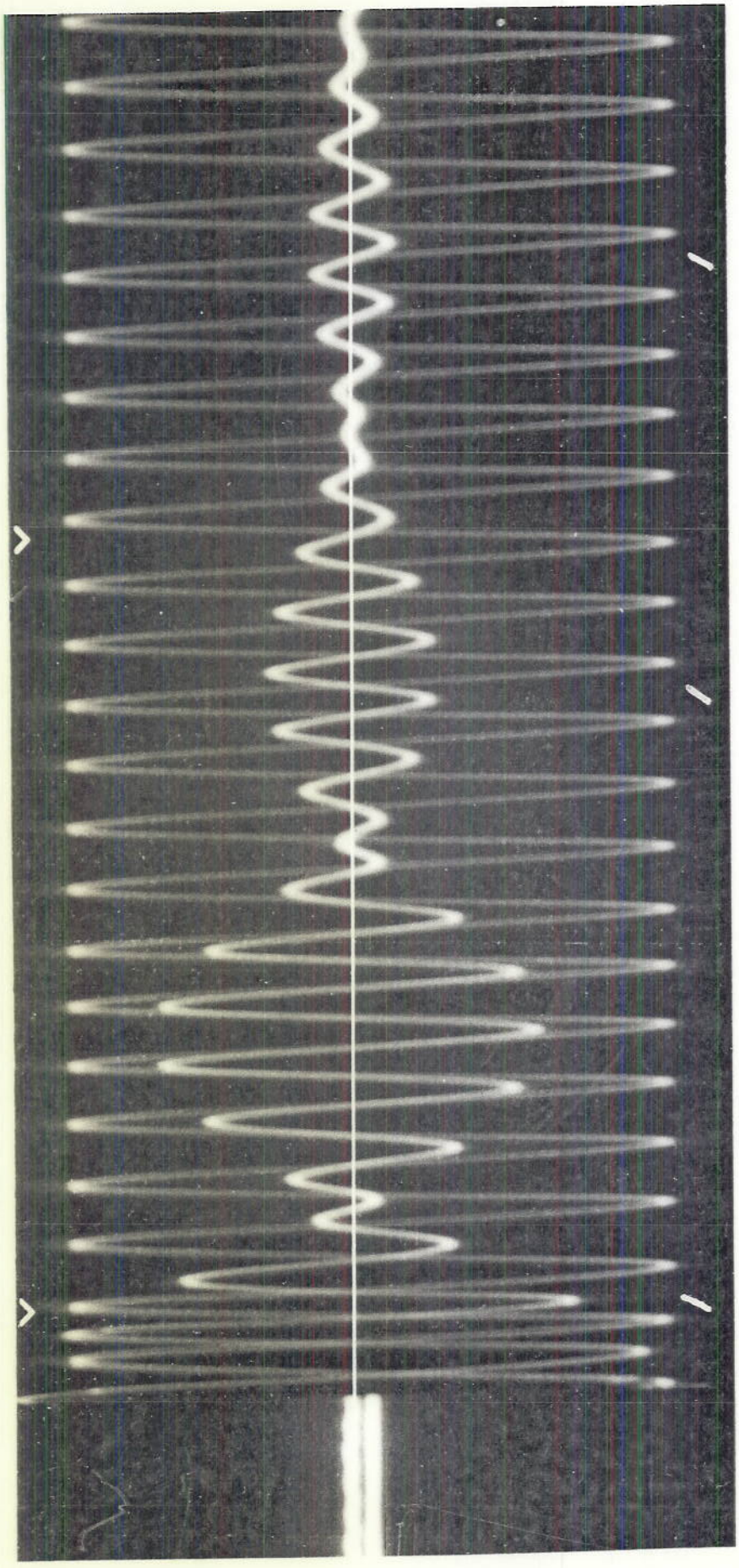


Plate 12

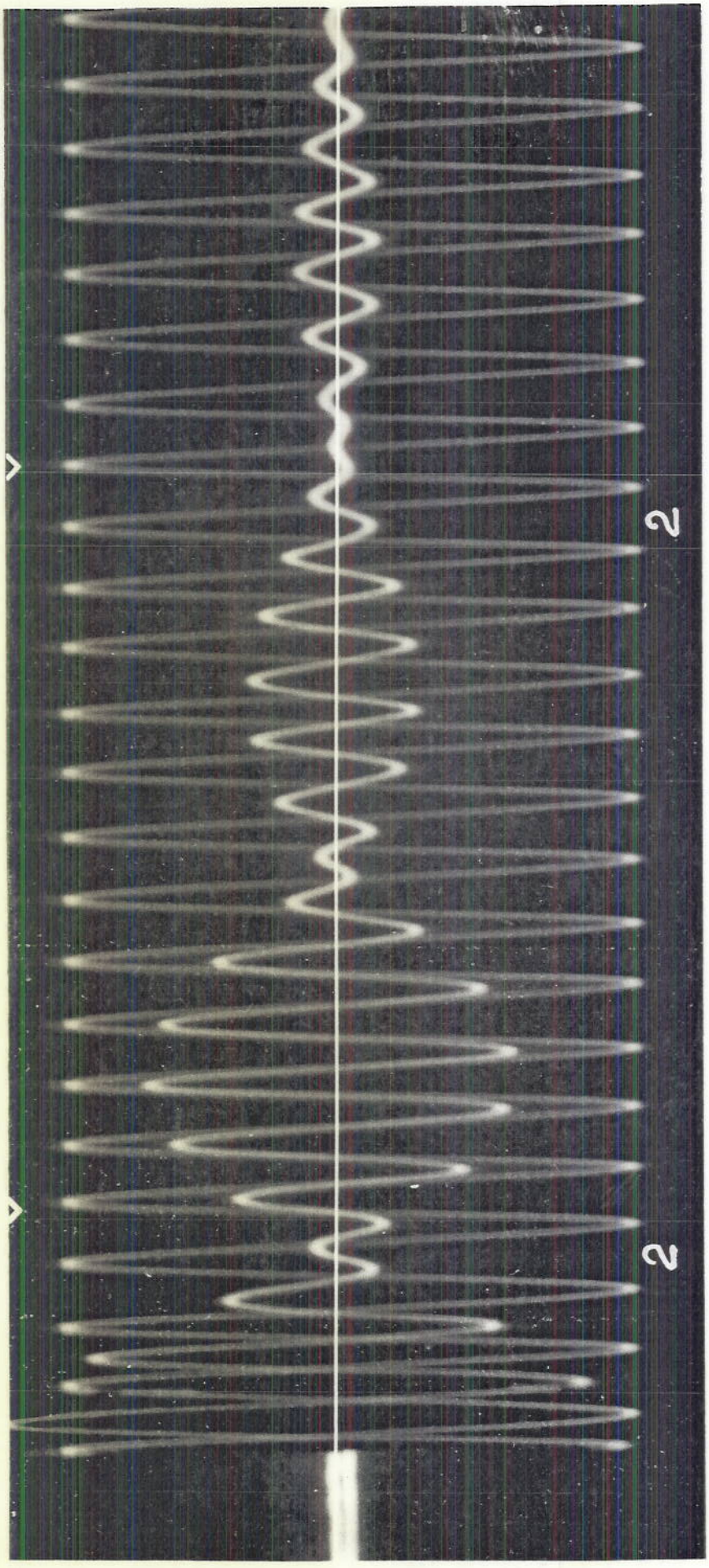


Plate 13

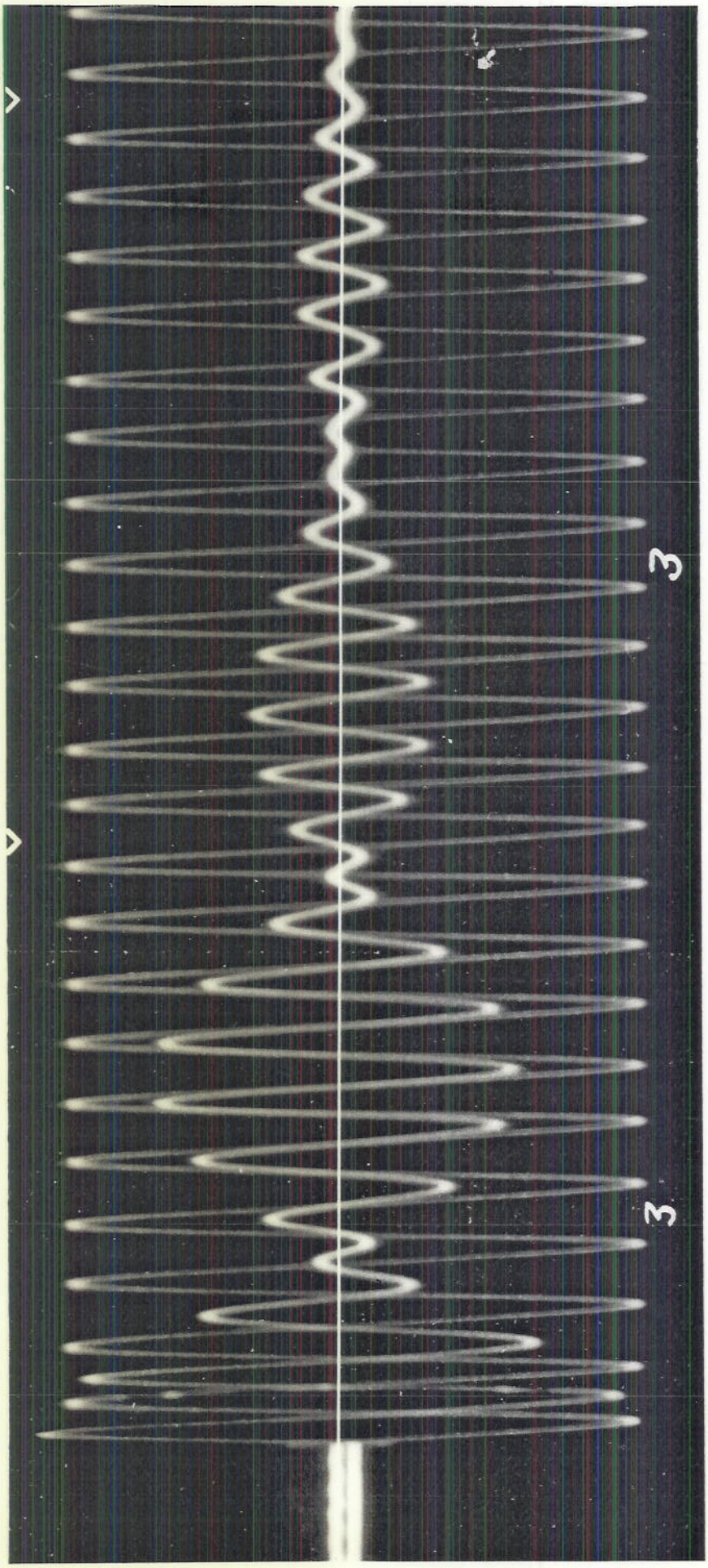


Plate 14

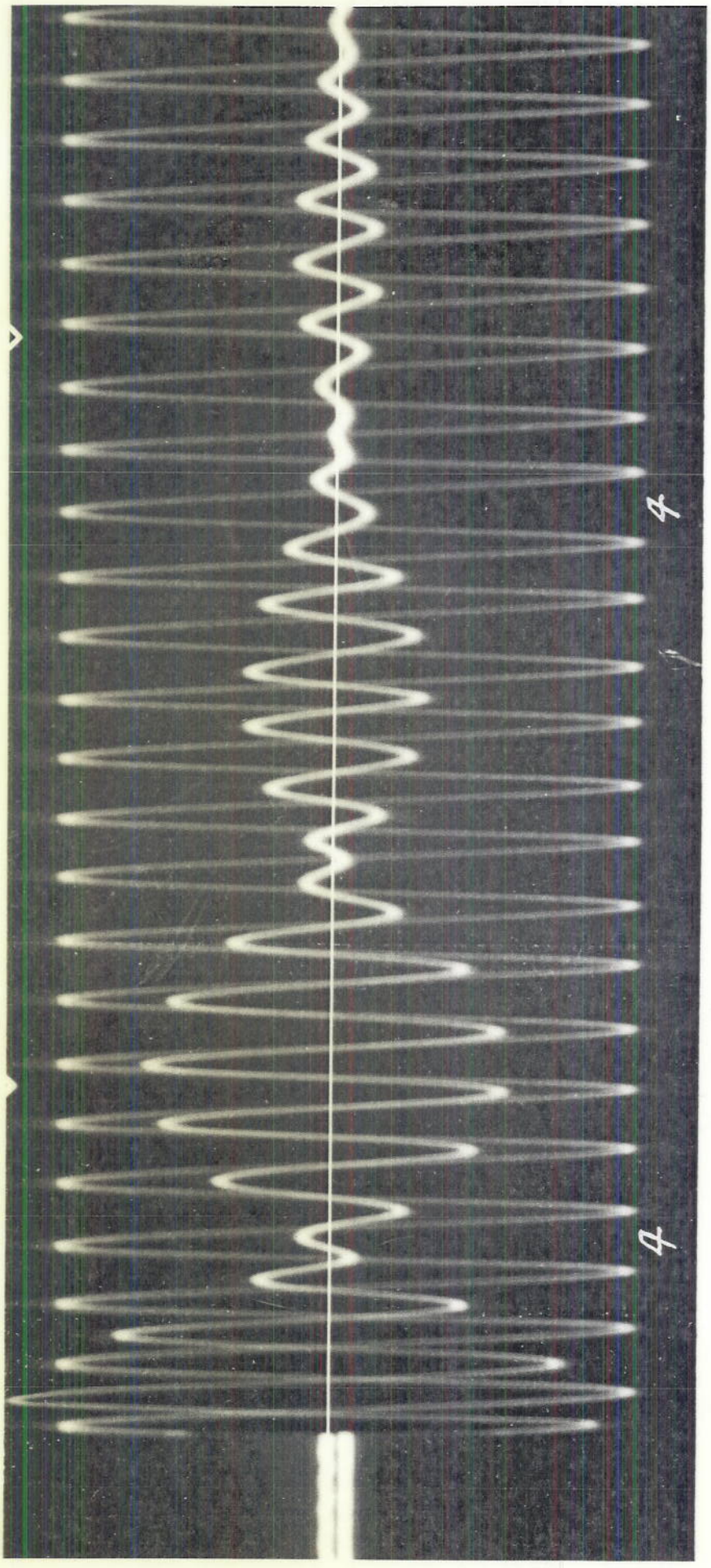


Plate 15

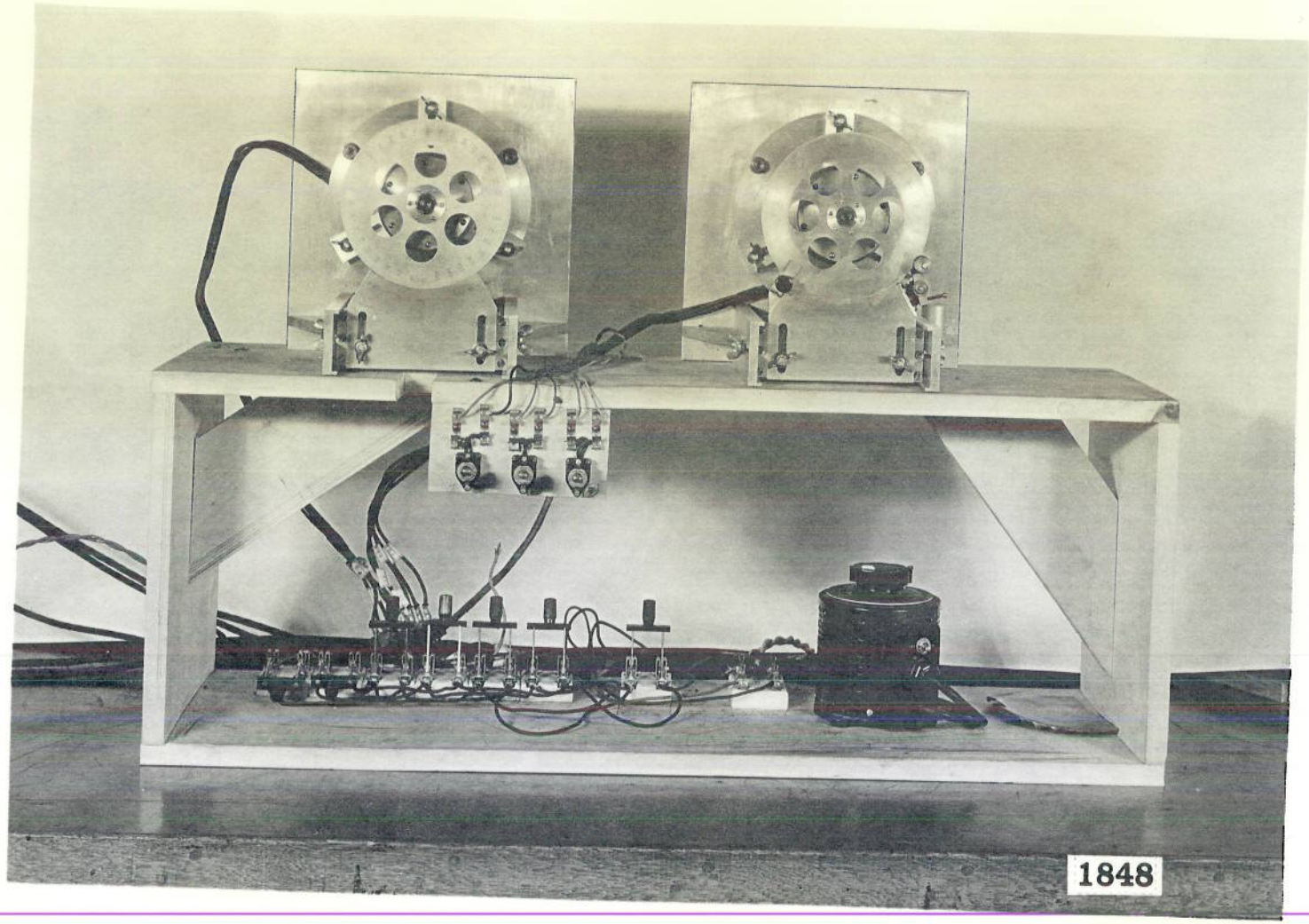
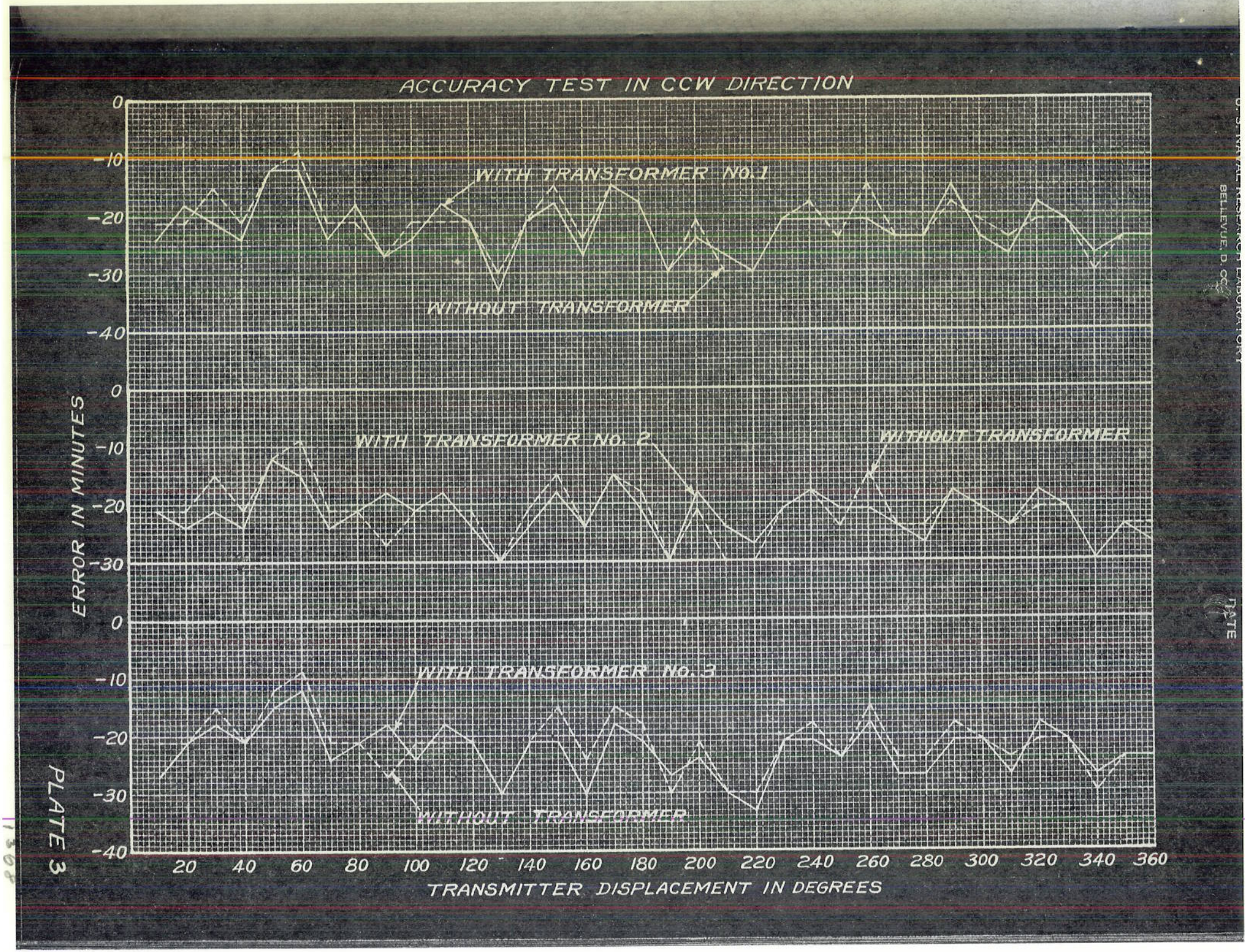
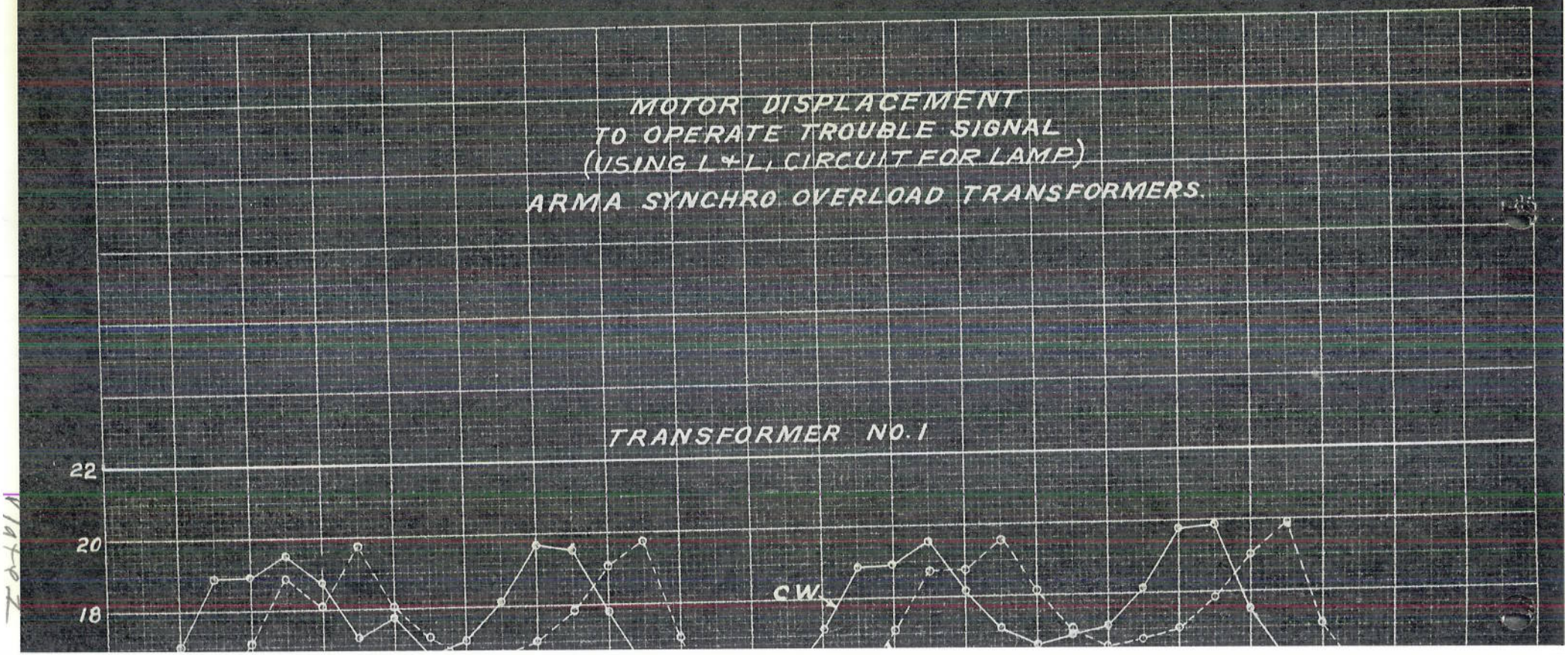


Plate 10

398


ACCURACY TEST IN CCW DIRECTION
WITH TRANSFORMER NO.1
WITHOUT TRANSFORMER
WITH TRANSFORMER NO. 2
WITHOUT TRANSFORMER
WITH TRANSFORMER NO. 3
WITHOUT TRANSFORMER
ERROR IN MINUTES
0
-10
-20
-30
-40
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
TRANSMITTER DISPLACEMENT IN DEGREES
PLATE 3

1368


MOTOR DISPLACEMENT
TO OPERATE TROUBLE SIGNAL
(USING L+L, CIRCUIT FOR LAMP)
ARMA SYNCHRO OVERLOAD TRANSFORMERS.
TRANSFORMER NO. 1
22
20
18
CW

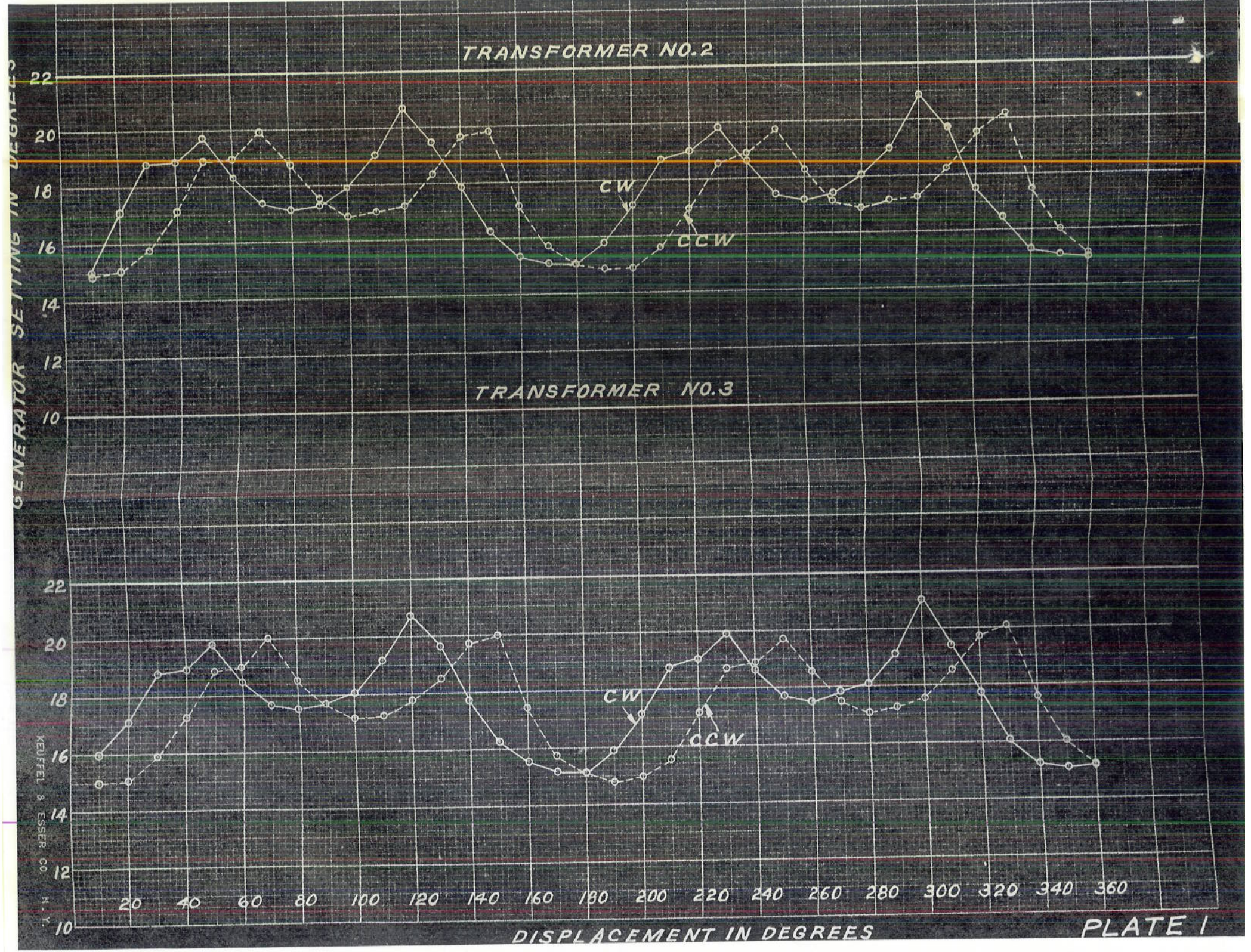

TRANSFORMER NO.2
GENERATOR SETTINGS IN DEGREES
22
20
18
16
14
12
10
CW
CCW
TRANSFORMER NO.3
22
20
18
16
14
12
10
CW
CCW
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
DISPLACEMENT IN DEGREES
KEUFFEL & ESSER CO. N. Y.

PLATE I