12 July 1937 NRL Report No.B-1377

NAVY DEPARTMENT

BUREAU OF ENGINEERING

PDF 73

FR-1377

Report of Test

on

Overload Transformers

Submitted by

Bendix Marine Products Company

Brooklyn, New York

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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

Authorization: BuEng.Ltr.NOs-51703 (4-8-Ds) of 19 April 1937.

Date of Test: May and June 1937.

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

Reviewed by: _____
R. A. Gano, Lieutenant, U.S.N.

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

Distribution:
BuEng. (5)

fk

TABLE OF CONTENTS

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. NOs-51703 (4-8-Ds) of 19 April 1937.
(b) Specifications SGS(71)-119a.
(c) BuOrd. Specifications O.S. No. 671-- Synchro Transmission Systems -- of 14 September 1933.
(d) Chas.Cory Corp. Drwg. No. CA-2030. BuEng. File No. DD364-S71-522-Alt.O.
(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 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 slightly exceed the allowable 3 minutes increase in two instances. 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.

(b) Under the test for displacement necessary to operate the indicator trouble lamp, it was noted that the displacements ranged from 15°54' to 19°42'. This is within the range of 14° to 20°, specified under reference (e).

(c) The results of the measurements of reduction in torque gradient give average values within the allowable 5 percent, the greatest reduction being 5.1 percent.

(d) The coefficient of stiffness of coupling was reduced 3.56 percent when a transformer was inserted in the synchro circuit. The allowable reduction is 10 percent, but the result given includes a possible error in interpreting the oscillograms.

(e) The temperature rise of the transformer, as determined by the resistance method, was within the specified limit of 80° F. (44.4° C.) above an ambient temperature of 130° F. (54.4° C.).

(f) The cases are of spot welded steel painted with aluminum and having covers of molded phenolic material. This construction is satisfactory but the terminal screws mounted on the covers have no device to prevent their turning.

(g) The insulating compound used in the transformer cases runs at some temperature between 130° F. and 190° F. A compound having a higher melting point should be substituted.

(h) The nameplates furnished are not in accordance with paragraph D-5 of the specifications.

Recommendations

(a) It is recommended that the subject overload transformers be approved for Naval use, subject to the correction of terminal and nameplate design and the use of a more suitable insulating compound.

DESCRIPTION OF MATERIAL UNDER TEST

4. The three (3) sample overload transformers submitted were manufactured by Bendix Marine Products Company, Incorporated, Brooklyn, New York. They are intended for use in self-synchronous motor circuits for operation of a trouble lamp when a motor is displaced from 15 to 18 degrees from the position of its generator.

5. The transformers are identical in design and each actually consists of two (2) transformers, No. 1 stacked with air gap, No. 2 stacked 100% interleaved. The primary windings of both transformers are tapped and the lead wires connect to terminals on the molded cover. The secondary windings are connected in series and are not tapped.

6. Connected across the primary of transformer No. 2 is a 4 ohm 10 watt resistor. Drawing, reference (d), gives the circuit and wiring diagram of the overload unit.

7. All of the electrical components of the unit are located in a steel case, aluminum finish, having a cover of phenolic material, on which are located line terminal connections. The transformer laminations are of silicon steel and flexible lead wires extend from each of the transformers to the machine screw connections on the terminal block. The case is filled with an insulating compound. A photograph of one of the sample transformers is given as Plate 11.

METHOD OF TEST

8. 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) of a motor and generator. That is, primary winding M1-T1 was connected in circuit S1 and primary winding M2-T2 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-L. During these tests, the transformers were located in a temperature controlled cabinet having a temperature of 54.4° C. Extension lead wires were provided for accurate measurements of temperature rise of the windings, using the resistance method.

9. The accuracy test was made with the use of two test stands, each holding a self-synchronous 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.

10. The displacement test was made with the use of 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.

11. The torque test was made by replacing the motor dial with a balanced pointer and 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 clock-wise and counter-clockwise directions without and with the transformers in the circuit.

12. 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 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.

13. 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 54.4° C.

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

RESULTS OF TEST

15. Under test for accuracy, the maximum increase in error introduced by inserting one of the transformers in the synchro circuit was six (6) minutes. This error occurred only in two instances. Data obtained during this test are given as Table 2 and curves, Plates 2 and 3.

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

TRANSFORMER NUMBER	DISPLACEMENT TO LIGHT LAMP			
	MAXIMUM		MINIMUM	
	CW	CCW	CW	CCW
1	19° 42'	19° 12'	17° 0'	16° 57'
2	18° 15'	18° 42'	16° 21'	16° 45'
3	17° 27'	18° 12'	15° 54'	16° 15'

NOTE: With one additional degree of displacement, the value of illumination was considered suitable for trouble indication.

17. 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

Transformer	Clockwise	Counter-Clockwise
No. 1	3.7%	5.1%
No. 2	4.0%	4.0%
No. 3	3.8%	5.1%

18. The oscillograms, given as Plates 12 to 15 inclusive, were obtained from a normal synchro circuit and with numbers 1, 2, and 3 transformer, successively placed in the circuit. From these a stiffness coefficient of 130.6 was obtained for the normal circuit and an average coefficient of 125.95 was obtained with a transformer in the circuit. This reduction in the stiffness of coupling is 3.56%. That allowed is 10%.

19. The average temperature rise of the winding M1-T1 of the transformers was 29° C. at an ambient temperature of 54.4° C. when set up in a circuit simulating the maximum current obtainable with two type 5 synchros.

20. No breakdowns occurred in any of the transformers when subjected to the required dielectric test of 1500 volts, a.c. 60 cycles, applied between windings and ground for one second.

21. The insulation resistance between the windings and ground was 100 megohms at 500 volts, following the dielectric test. A minimum of one megohm is allowed.

22. The transformers measure 2-3/8 inches in width, 4-9/16 inches in length, and 2-7/16 inches in depth, and weight 24 oz.

CONCLUSIONS

23. Under the accuracy test, the increase in the error caused by the insertion of a transformer in the synchro circuit appears to slightly exceed the allowable 3 minute increase in two instances. 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.

24. Under the test for displacement necessary to operate the indicator trouble lamp, it was noted that the displacements ranged from 15°54' to 19°42'. This is within the range of 14° to 20°, specified under reference (e).

25. The results of the measurements of reduction in torque gradient give average values within the allowable 5 percent, the greatest reduction being 5.1 percent.

26. The coefficient of stiffness of coupling was reduced 3.56 percent when a transformer was inserted in the synchro circuit. The allowable reduction is 10 percent, but the result given includes a possible error in interpreting the oscillograms.

27. The temperature rise of the transformer, as determined by the resistance method, was within the specified limit of 80° F. (44.4° C) above an ambient temperature of 130° F. (54.4°C.).

28. The cases are of spot welded steel painted with aluminum and having covers of molded phenolic material. This construction is satisfactory but the terminal screws mounted on the covers have no device to prevent their turning.

29. The insulating compound used in the transformer cases runs at some temporature between 130° F. and 190° F. A compound having a higher melting point should be substituted.

30. The nameplates furnished are not in accordance with paragraph D-5 of the specifications.

Table 1

MOTOR DISPLACEMENT TO LIGHT LAMP

Generator Setting in Degrees from Electrical Zero (CW)	TRANSFORMER #1		TRANSFORMER #2		TRANSFORMER #3	
	CCW	CW	CCW	CW	CCW	CW
10	18°-9'	17°-12'	17°-15'	16°-21'	17° -6'	16°-6'
20	16°-57'	17°-30'	16°-51'	16°-45'	16° -24'	16°-6'
30	17°-45'	17°-48'	16°-45'	16°-54'	16° -15'	16°-18'
40	17°-54'	17°-51'	17°-0'	16°-54'	16° -18'	16°-18'
50	17°-51'	18°-30'	17°-0'	17°-45'	16° -24'	17°-9'
60	17°-45'	18°-30'	17°-3'	18°-0'	16° -24'	17°-15'
70	18°-18'	19°-42'	17°-45'	18°-6'	17° -12'	17°-21'
80	18°-39'	18°-36'	18°-6'	18°-15'	17° -30'	17°-21'
90	18°-57'	18°-18'	18°-0'	17°-54'	17° -45'	17°-9'
100	19°-0'	18°-27'	18°-30'	18°-6'	17° -45'	17°-9'
110	18°-48'	18°-27'	18°-6'	18°-0'	17° -30'	17°-21'
120	18°-51'	18°-12'	18°-15'	18°-3'	17° -45'	17°-12'
130	18°-54'	18°-45'	18°-18'	18°-3'	17° -45'	17°-21'
140	19°-0'	18°-42'	18°-15'	18°-6'	17° -48'	17°-15'
150	19°-0'	18°-30'	18°-9'	17°-45'	17° -48'	16°-54'
160	19°-6'	18°-3'	18°-18'	17°-15'	17° -48'	16°-30'
170	19°-6'	17°-45'	18°-3'	17°-0'	17° -39'	16°-18'
180	18°-39'	17°-12'	17°-45'	16°-30'	17° -18'	16°-0'
190	18°-33'	17°-0'	17°-30'	16°-21'	17° -0'	15°-54'
200	18°-3'	17°-9'	17°-6'	16°-45'	16° -45'	16°-0'
210	18°-0'	17°-30'	17°-0'	16°-51'	16° -36'	16°-12'
220	18°-0'	17°-45'	17°-9'	17°-0'	16° -51'	16°-21'
230	17°-54'	18°-21'	17°-9'	17°-48'	16° -45'	17°-9'
240	17°-51'	18°-27'	17°-12'	18°-6'	16° -39'	17°-24'
250	18°-39'	18°-42'	18°-0'	18°-9'	17° -15'	17°-21'
260	18°-48'	18°-42'	18°-9'	18°-9'	17° -42'	17°-27'
270	18°-15'	18°-51'	18°-36'	17°-48'	18° -12'	17°-0'
280	18°-57'	18°-30'	18°-42'	18°-3'	17° -57'	17°-18'
290	18°-48'	18°-24'	18°-24'	18°-12'	17° -27'	17°-21'
300	18°-48'	18°-39'	18°-27'	18°-3'	17° -42'	17°-24'
310	18°-51'	18°-51'	18°-18'	18°-12'	17° -45'	17°-27'
320	19°-3'	18°-48'	18°-24'	18°-12'	17° -45'	17°-24'
330	19°-9'	18°-30'	18°-36'	18°-3'	17° -51'	17°-12'
340	19°-12'	18°-18'	18°-30'	17°-45'	17° -51'	17°-0'
350	19°-6'	17°-54'	18°-30'	17°-12'	17° -45'	16°-30'
360	18°-51'	17°-30'	17°-54'	16°-54'	17° -18'	16°-15'

Table 2

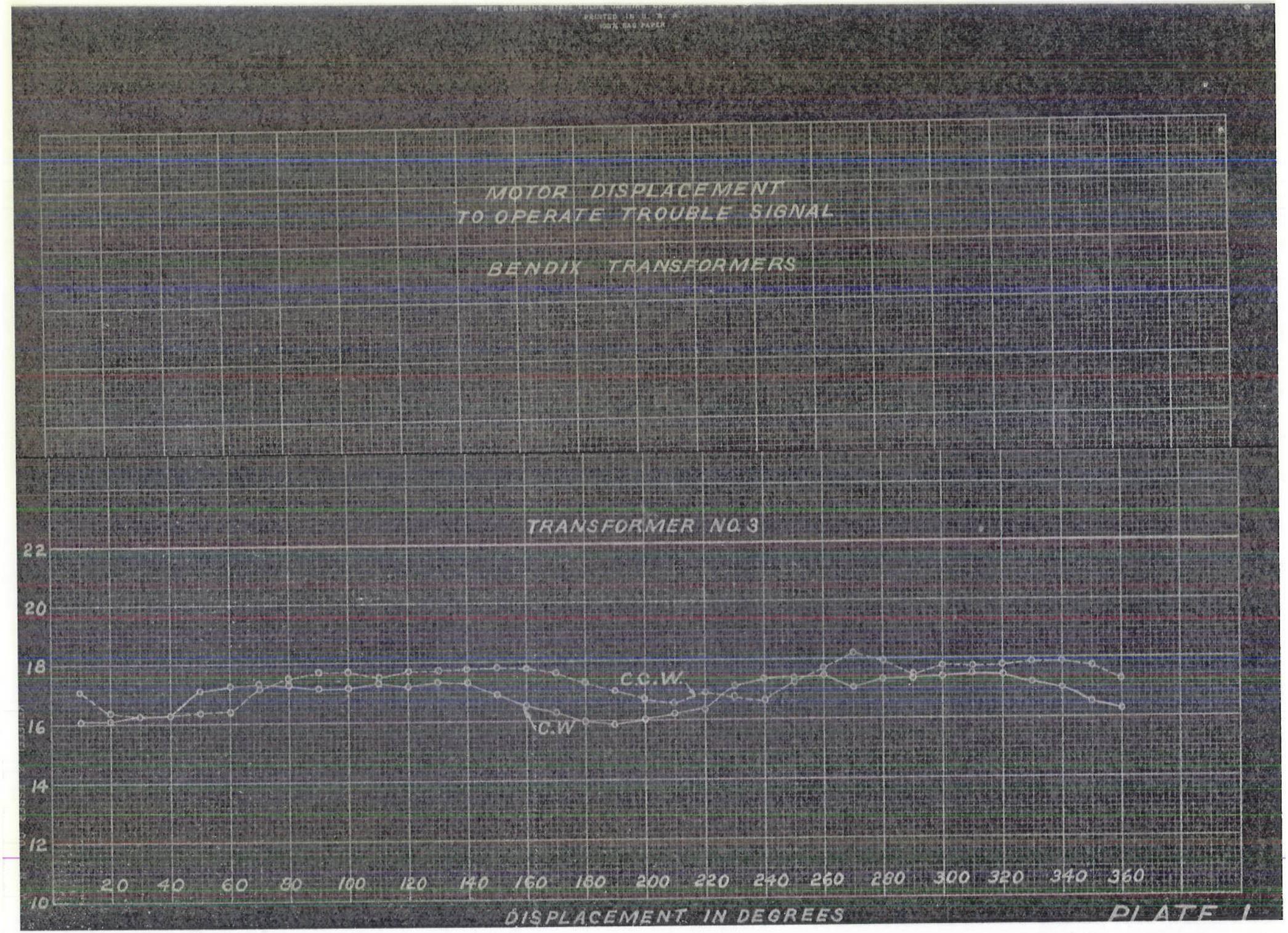
ACCURACY TEST - WITHOUT AND WITH TRANSFORMERS

Generator Setting in Degrees from Electrical Zero	CW - Rotation-Slip Ring End-Error in Motor Reading				CCW - Rotation - Slip Ring End-Error in Motor Reading.			
	No Transformer	Trans. #1	Trans. #2	Trans. #3	No Transformer	Trans. #1	Trans. #2	Trans. #3
10	-15	-15	-15	-15	-3	0	-3	0
20	-9	-9	-9	-9	+9	+6	+6	+6
30	-9	-9	-12	-9	+3	0	0	+3
40	-15	-15	-12	-15	0	0	+3	0
50	-9	-9	-9	-12	+6	+9	+6	+6
60	-9	-12	-9	-9	+3	0	0	0
70	-15	-15	-15	-15	0	0	-3	0
80	-9	-6	-9	-9	+6	+6	+6	+3
90	-6	-6	-6	-6	+3	+3	+3	+3
100	-12	-12	-12	-9	0	0	0	+3
110	-6	-6	-6	-6	+15	+9	+15	+15
120	-9	-9	-6	-9	+ 9	+9	+ 9	+9
130	-15	-18	-15	-15	+ 6	+6	+ 6	+6
140	-12	-12	-9	-9	+ 9	+12	+12	+12
150	-12	-12	-12	-15	+ 6	+9	+ 6	+6
160	-15	-18	-15	-15	+ 6	+6	+ 6	+6
170	-9	-9	-9	-9	+ 9	+12	+12	+12
180	-9	-12	-9	-12	+ 3	+3	+ 6	+6
190	-21	-21	-18	-21	0	+3	0	+3
200	-12	-12	-15	-12	+ 9	+9	+ 9	+9
210	-15	-15	-15	-15	+ 6	+3	+ 3	+3
220	-18	-18	-21	-18	0	+3	+ 3	0
230	-15	-15	-15	-15	+ 6	+6	+ 6	+9
240	-15	-15	-15	-15	0	+3	+ 3	+3
250	-12	-15	-15	-15	-3	0	-3	0
260	-9	-9	-6	-6	+ 6	+3	+ 6	+3
270	-12	-12	-12	-9	-6	-3	-3	-6
280	-12	-15	-12	-12	-3	-3	-3	-3
290	-12	-9	-9	-12	0	-3	+ 3	+3
300	-12	-12	-12	-12	-3	0	+ 3	0
310	-15	-15	-12	-15	-6	-3	-3	-6
320	-9	-6	-9	-9	0	+3	0	+3
330	-9	-9	-6	-9	-6	-6	-9	-6
340	-12	-12	-12	-9	-3	-6	-3	0
350	-6	-9	-9	-9	+ 3	0	+ 3	+3
360	-6	-6	-9	-6	0	-3	0	0

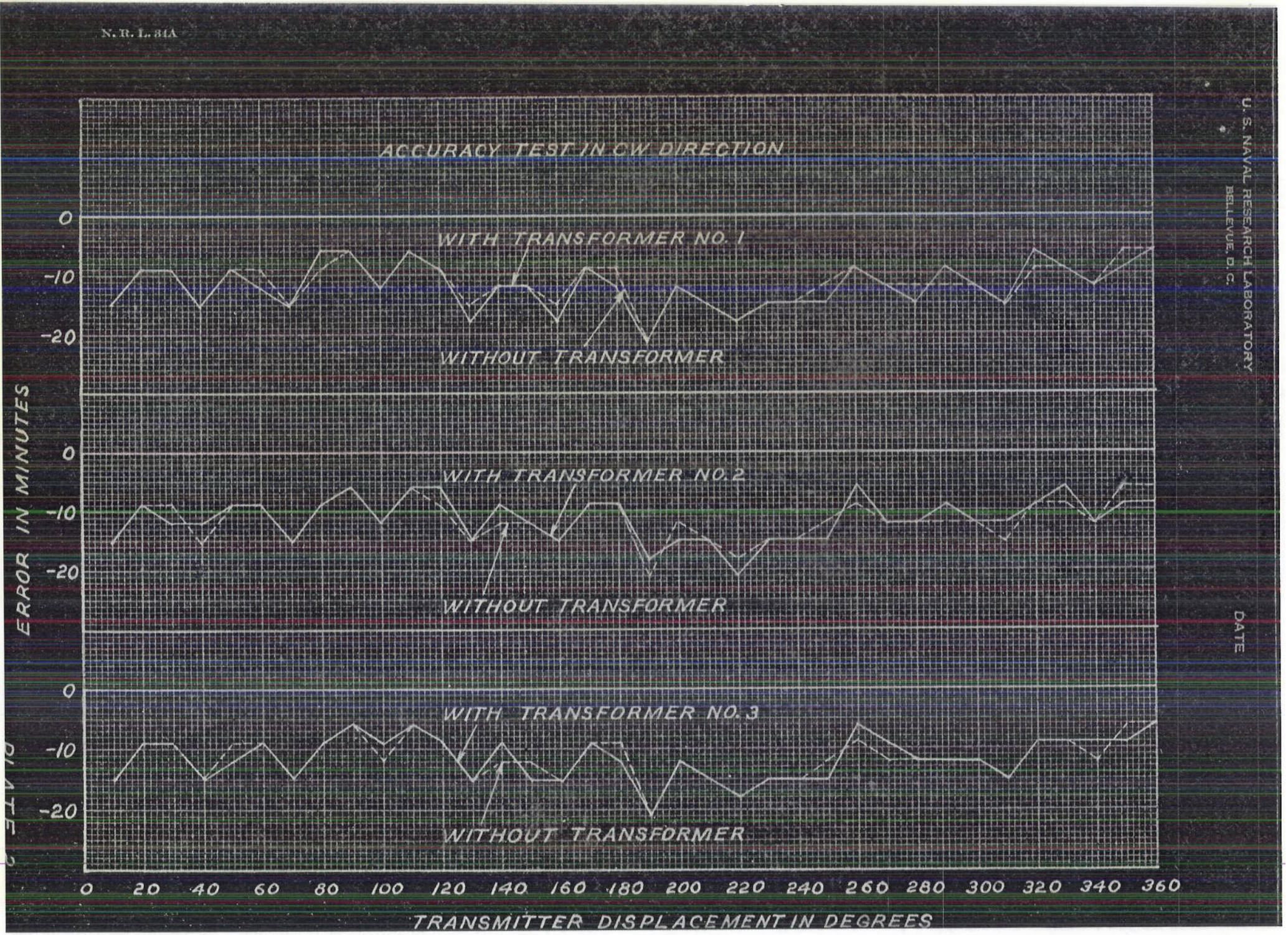
Table 3

TORQUE TESTS

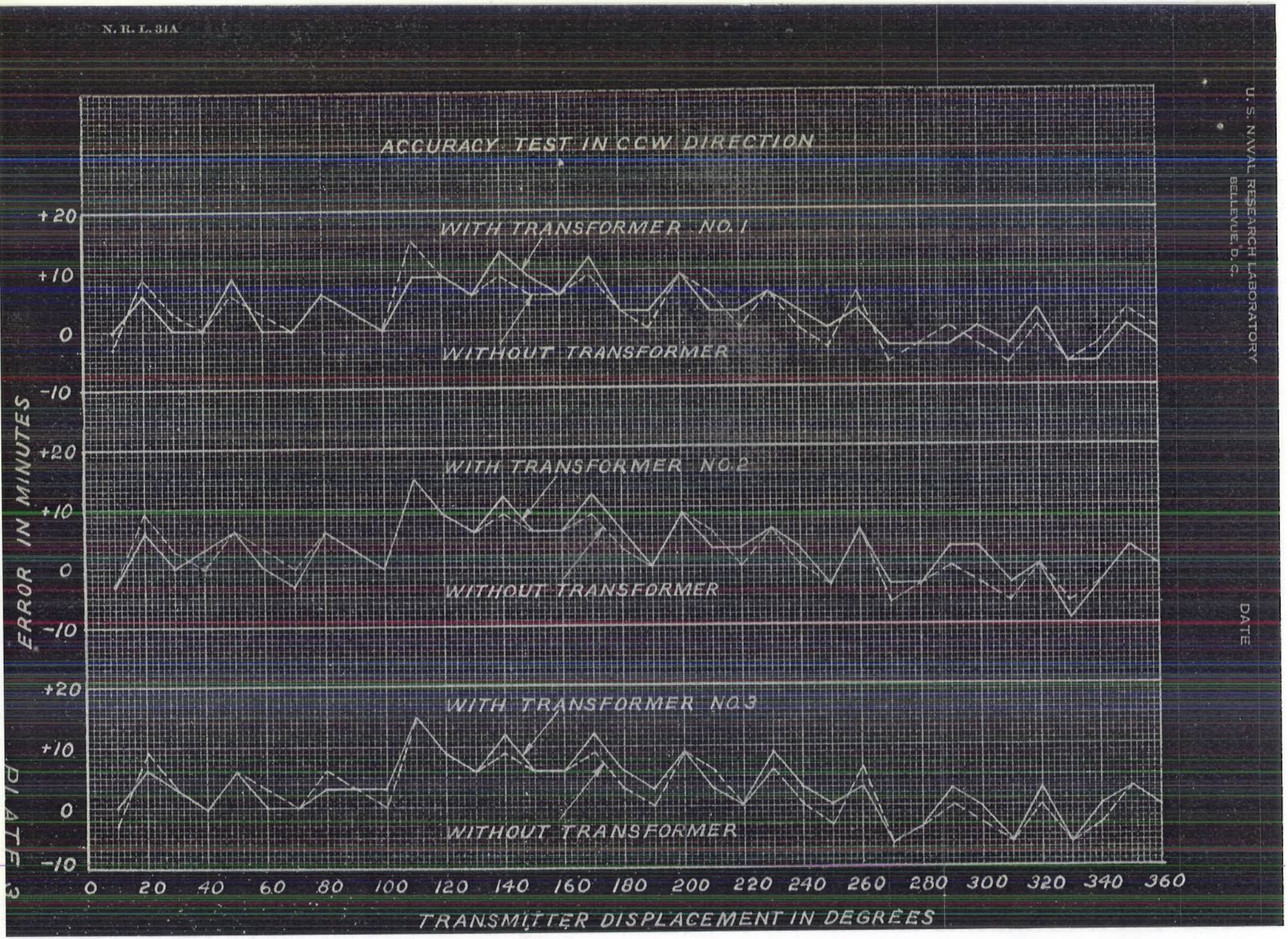
	Gen. Displacement in Degrees	Without Transformer: Weight to return Motor to Zero GMS.	Without Transformer: Weight to return Motor to Zero OZS.	Without Transformer: Inch Ounces (OZS. x 1.5)	With #1 Transformer: Weight to return Motor to Zero GMS.	With #1 Transformer: Weight to return Motor to Zero OZS.	With #1 Transformer: Inch Ounces (OZS. x 1.5)	With #2 Transformer: Weight to return Motor to Zero GMS.	With #2 Transformer: Weight to return Motor to Zero OZS.	With #2 Transformer: Inch Ounces (OZS. x 1.5)	With #3 Transformer: Weight to return Motor to Zero GMS.	With #3 Transformer: Weight to return Motor to Zero OZS.	With #3 Transformer: Inch Ounces (OZS. x 1.5)
Generator Displaced CW (From slip ring End)	1	7.85	.277	.415	6.88	.243	.364	7.64	.2695	.404	7.30	.257	.386
	2	14.78	.521	.782	13.89	.490	.735	14.10	.497	.746	14.07	.497	.745
	3	21.42	.755	1.134	20.83	.734	1.103	20.68	.729	1.094	20.51	.724	1.086
	4	28.61	1.1	1.515	27.55	.972	1.457	27.63	.975	1.462	27.38	.966	1.448
	5	35.49	1.25	1.877	34.05	1.20	1.802	33.82	1.193	1.789	33.79	1.191	1.787
	6	42.45	1.497	2.247	40.66	1.434	2.150	40.73	1.435	2.155	40.83	1.440	2.160
	7	49.27	1.738	2.607	47.50	1.675	2.513	46.94	1.655	2.483	47.51	1.675	2.514
	8	56.33	1.985	2.980	54.09	1.191	2.862	54.56	1.924	2.884	54.30	1.915	2.872
	9	63.50	2.240	3.360	61.13	2.157	3.227	60.70	2.14	3.212	61.30	2.162	3.245
	10	70.23	2.470	3.705	67.48	2.37	3.570	67.39	2.377	3.565	66.78	2.355	3.530
Generator Displaced CCW (From slip ring End)	1	6.65	.234	.353	6.55	.231	.346	6.16	.217	.326	6.24	.22	.330
	2	13.84	.488	.732	12.70	.448	.672	13.02	.459	.689	12.94	.456	.685
	3	21.13	.745	1.118	19.60	.691	1.037	19.84	.700	1.050	19.59	.691	1.036
	4	28.07	.99	1.485	26.00	.917	1.375	26.56	.937	1.405	26.5	.935	1.402
	5	35.21	1.241	1.864	33.17	1.17	1.754	33.37	1.176	1.765	33.07	1.165	1.750
	6	42.11	1.485	2.228	39.79	1.404	2.105	39.82	1.405	2.107	39.95	1.409	2.114
	7	49.38	1.741	2.610	46.68	1.645	2.470	46.85	1.652	2.479	46.41	1.636	2.456
	8	56.08	1.977	2.971	53.22	1.877	2.817	53.48	1.887	2.830	53.37	1.894	2.822
	9	62.77	2.21	3.320	60.25	2.125	3.178	60.0	2.116	3.176	59.55	2.100	3.150
	10	70.1	2.472	3.710	67.10	2.368	3.550	67.59	2.382	3.575	67.37	2.376	3.562


MOTOR DISPLACEMENT
TO OPERATE TROUBLE SIGNAL
BENDIX TRANSFORMERS
TRANSFORMER NO. 3
22
20
18
16
14
12
10
C.C.W.
C.W.
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
DISPLACEMENT IN DEGREES
PLATE 1

N. R. L. 31A


ACCURACY TEST IN CW DIRECTION
WITH TRANSFORMER NO. 1
WITHOUT TRANSFORMER
WITH TRANSFORMER NO. 2
WITHOUT TRANSFORMER
WITH TRANSFORMER NO. 3
WITHOUT TRANSFORMER
0
-10
-20
ERROR IN MINUTES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
TRANSMITTER DISPLACEMENT IN DEGREES
U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.
DATE

N. R. L. 31A


ACCURACY TEST IN CCW DIRECTION
WITH TRANSFORMER NO. 1
WITHOUT TRANSFORMER
WITH TRANSFORMER NO. 2
WITHOUT TRANSFORMER
WITH TRANSFORMER NO. 3
WITHOUT TRANSFORMER
+20
+10
0
-10
ERROR IN MINUTES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
TRANSMITTER DISPLACEMENT IN DEGREES
U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.
DATE
PLATE 3

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

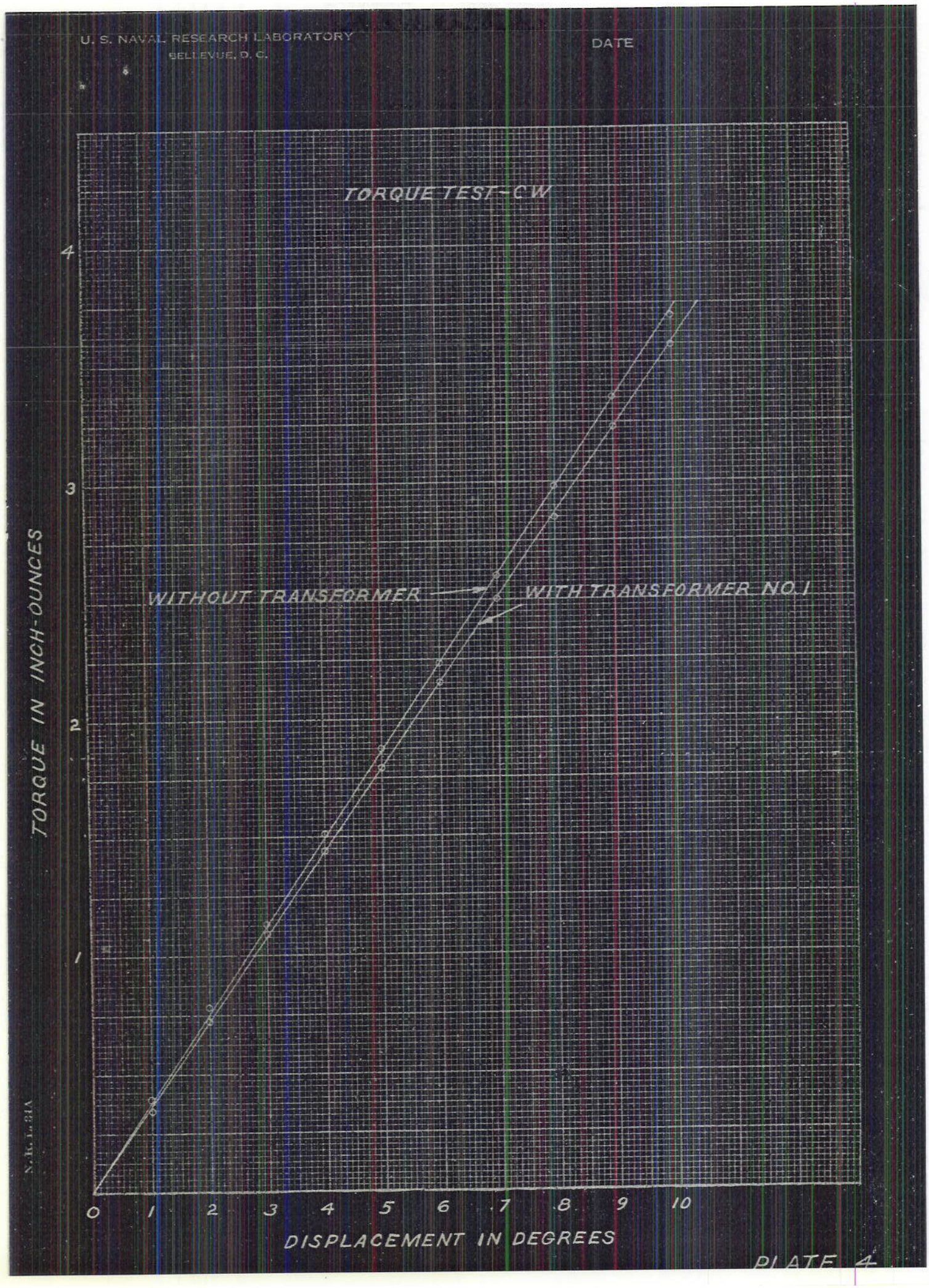


PLATE 4

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

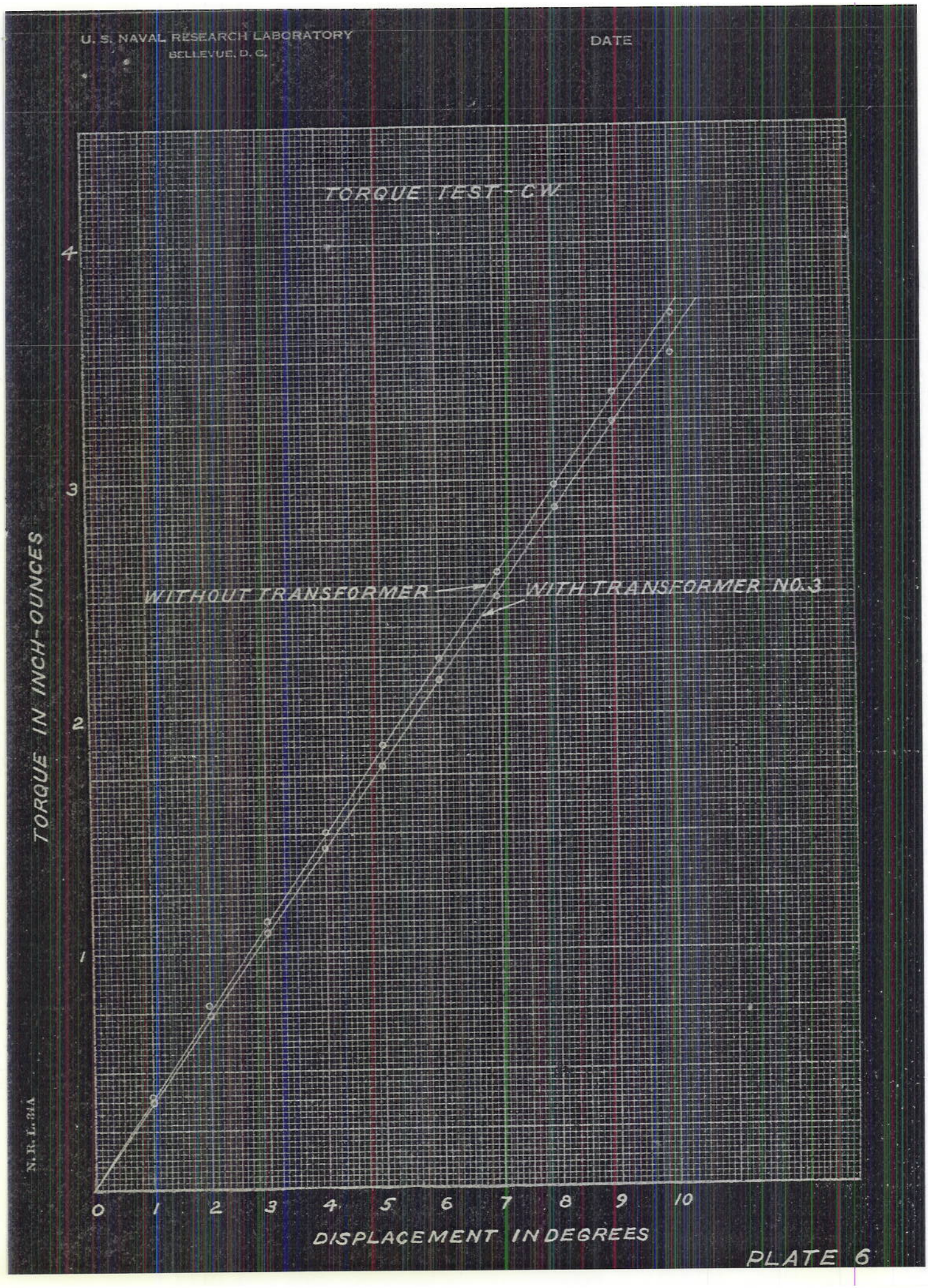
DATE

N. R. L. 31A.

PLATE 5

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

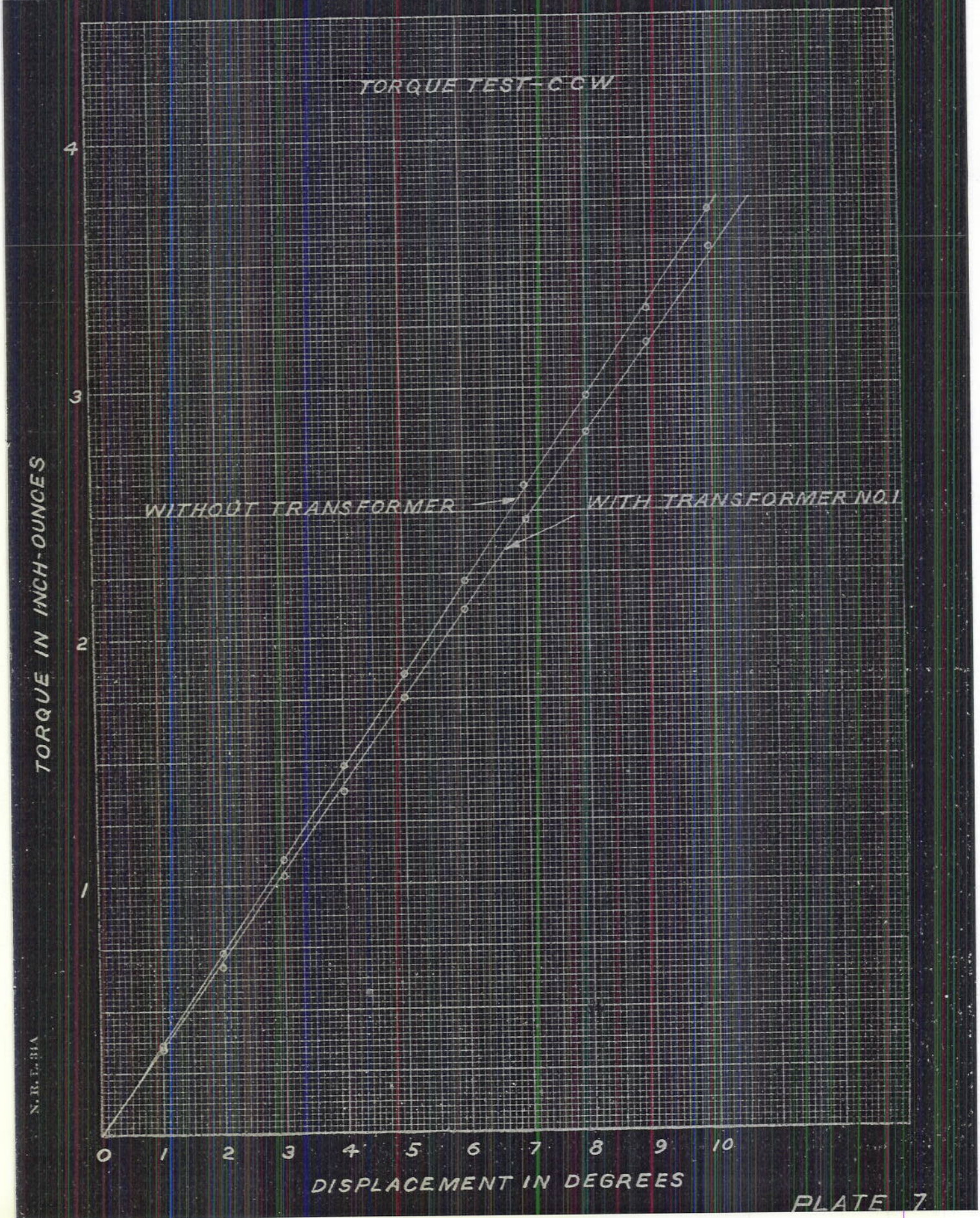


N. R. L. 31A

PLATE 6

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

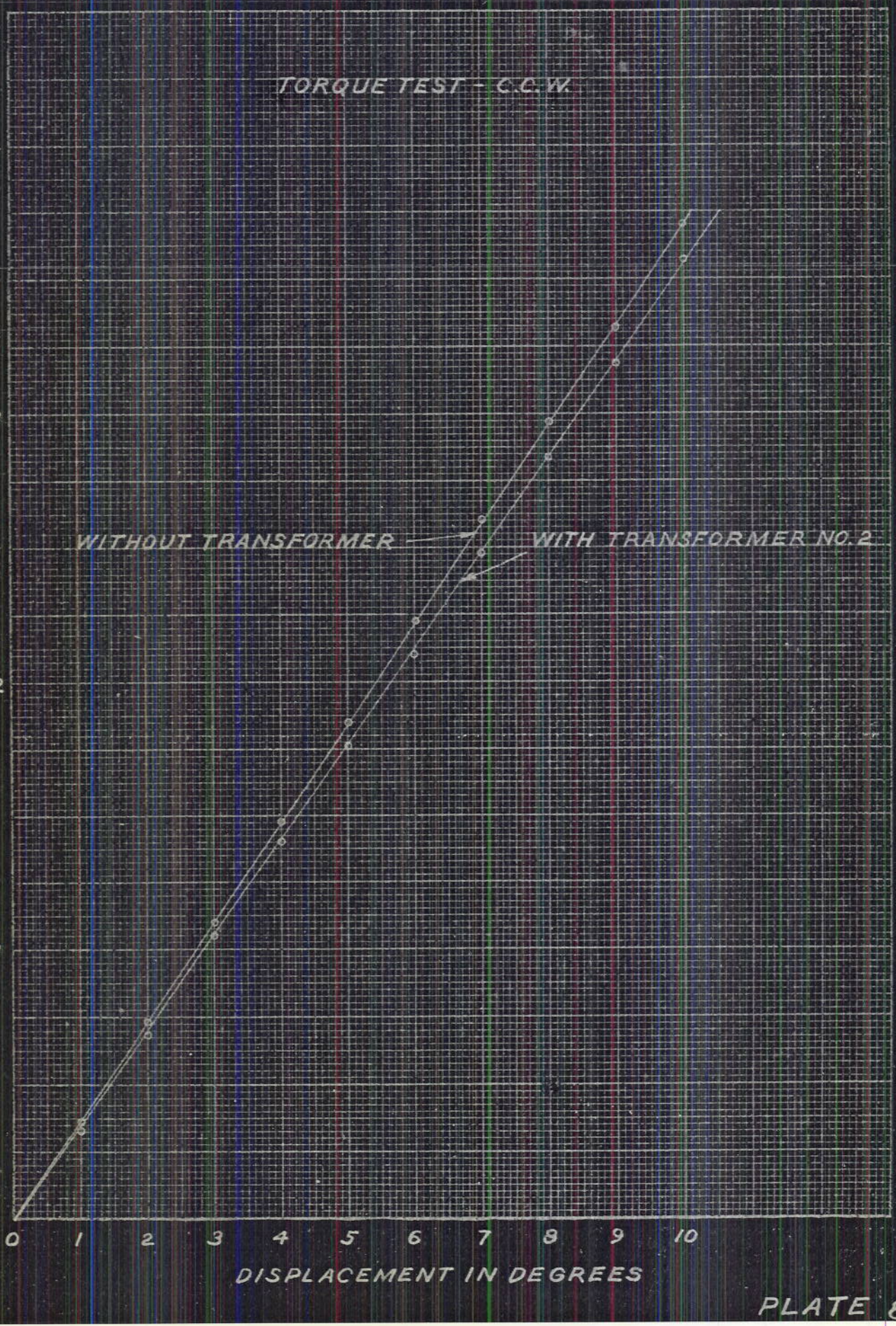


N.R.L. 31A

PLATE 7

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE



N. R. L. 31A

PLATE 8

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

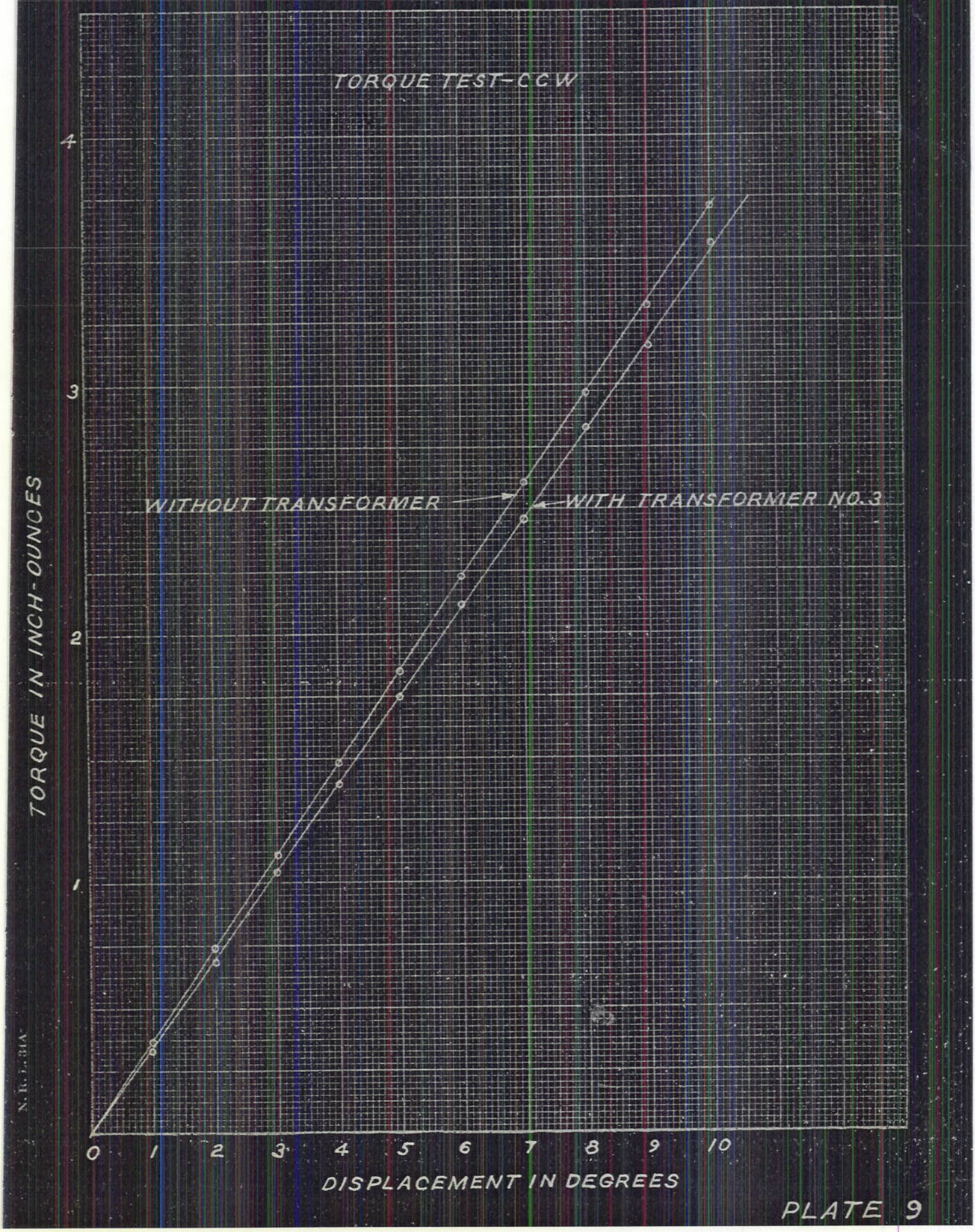


PLATE 9