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Report
of
Test on Transformers,
Overload and Blown Fuse Types.

Submitted by

General Electric Company.

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AUTHORIZATION

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

Reference: (a) BuEng.1tr. S62-2/L5(10-10-Ds) of 12 October 1936 and S62-2/L5(12-17-Ds) of 18 December 1936.

(b) Specifications SGS(71)-119a - Trouble Indicators for Self-synchronous Motors and Generators - of 15 July 1936.

(c) BuOrd. Specifications O.S. No. 671 - Synchro Transmission Systems - of 14 September 1933.

(d) General Electric Co. Drawing W-4979985 - Blown Fuse Transformer.

OBJECT OF TEST

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

ABSTRACT OF TEST

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

CONCLUSIONS

(a) Under the accuracy test, occasional errors appear to exceed by three minutes the allowable 3-minute increase in error with the transformer in the circuit. An allowance should be made, however, 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.

(b) The results of the test for displacement necessary to operate the indicator lamp are not within the required 15 to 18 degrees. Two or three degrees must be added to the values given in order to produce a perceptible glow as defined by the specifications.

(c) The results of the measurements of reduction in torque gradient are within the limits allowed by the specifications.

(d) The coefficient of stiffness of coupling was reduced less than the allowed 10 per cent by the insertion of a transformer in a Synchro circuit.

(e) The temperature rises of both types of transformers are within the limits allowed.

(f) The potentials across the indicator lamp of the blown fuse transformer were within the specified tolerances.

(g) Both types of transformers were satisfactory under the required dielectric and insulation resistance tests.

(h) Under inspection the following features were noted as being objectionable:

(1) In the overload transformer, the lead wires are too short, resulting in their breaking off where soldered to terminals. The construction of the internal brackets should be improved as they now require the use of nuts which have been filed to fit. In addition, provision should be made to prevent the terminals from turning.

(2) If the present type of case construction is retained for the overload transformer, the lining for the box should be of a more moisture-resistant material.

(3) Provision should be made to prevent the terminals from turning when making line connections to the blown fuse transformer.

(4) The paper insulator used in the end bells of the blown fuse transformer should be replaced with a non-hygroscopic material.

(5) The projecting corners of the nameplate on the blown fuse transformer should be rounded to prevent injury to personnel.

(6) Neither of the transformer cases is hermetically sealed as required by the specifications.

RECOMMENDATIONS

(a) It is recommended that both types of transformers be approved for Naval use subject to correction of the deficiencies noted herein.

DESCRIPTION OF MATERIAL UNDER TEST

4. The overload transformer consists of two primary windings and a tapped secondary winding on a laminated core. One primary is connected to terminals M2-T2, the other to terminals M1-T1, across which are also connected a fixed resistor of 2.25 ohms. The start of the secondary is connected to L1, but L2 is a dead terminal which may be connected to any one of the five taps.

5. The terminals are mounted on a phenolic block which forms one end of the case. The transformer is built into a pressed metal case.

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

7. One of the four sample transformers submitted is shown by Plate 10.

METHOD OF TEST ON OVERLOAD TRANSFORMERS

General Set-up.

8. The method employed in conducting all tests on the overload transformers was to set up a circuit whereby either one of the sample transformers could be connected in the rotor circuit (R1 and R3) between a Synchro motor and generator. That is, primary winding M1-T1 was connected in circuit R1 and primary winding M2-T2 in circuit R3. A selected VG-2 lamp, consuming a current of 0.00165 amperes at 115 volts, a.c., 60 cycles, was connected across the tapped secondary. The transformers were placed in a temperature-controlled cabinet having a temperature of 54°C. Extension lead wires were provided for accurate measurement of temperature rise of the windings by the resistance method.

Accuracy Test

9. This test was accomplished 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 were 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 9.

Displacement Test

10. With the same equipment used in the accuracy test, the Synchro generator dial was locked at zero and the motor dial was displaced 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.

Torque Test

11. For this test the motor dial was replaced with a balanced pointer and 380 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 was 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.

Stiffness Test

12. For this test the motor was fitted with an aluminum dial 385 in diameter and 0.015 in thickness. With the system energized the generator was set to 36 degrees. The system was then deenergized and the generator was returned to zero and locked, leaving the motor displaced 36 degrees. An oscillograph was then connected across leads R1 and R3 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 coefficient of stiffness of coupling without and with a sample transformer connected in the circuit.

Temperature Rise

13. The transformers were removed from the Synchro circuits and set up in 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. The resistance method was used for obtaining the rises at an ambient temperature of 54°C.

METHOD OF TEST ON BLOWN FUSE TRANSFORMERS

14. The procedure in this test was to set up a circuit simulating actual installation where the primary of the transformer would be connected to the load side of two fuses, and the secondary, with a VG-2 lamp in series, connected across the line side. The potential across the indicator lamp was measured with a vacuum tube voltmeter under the several conditions of over and under voltage and frequency, and with the fuses in and out.

15. The temperature rise of the transformers was determined by the resistance methods by placing them in a temperature controlled cabinet having a temperature of 54°C. The transformers were connected in the same circuits which were supplied with rated voltage and frequency.

16. The usual dielectric and insulation tests followed by an inspection of the construction, workmanship, and materials, concluded the test.

17. The blown fuse transformer is designed to operate a VG-2 indicator lamp when either or both fuses in a circuit blow. It consists of a primary winding and a secondary winding, ratio 1:1, mounted on a laminated core. The pressed case construction and nameplate and terminals are shown by Plate 10.

18. Four terminals are provided; two primary terminals for connection across the load side of the fuses, but with the indicator lamp in series, and two secondary terminals for connection across the line.

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

RESULTS OF TEST

Overload Transformers

20. The maximum increase in the error as determined during the accuracy test was six minutes when the generator was rotated clockwise and six minutes when rotated counter-clockwise. The error of six minutes occurred in several instances. The results of this test are given in Tables 4 and 5, and curves, Plates 4 and 5.

21. The maximum and minimum displacements required to operate the indicator lamp, using No. 5 tap on transformers 1, 3 and 4, are as follows:

Transformer No.	Displacement required to operate lamp			
	Maximum		Minimum	
	Clockwise	Counter-Clockwise	Clockwise	Counter-Clockwise
1	18° 48'	18° 51'	14° 51'	14° 30'
3	20 6	19 42	17 3	16 0.
4	18 51	18 45	16 9	15 15

Note: These values are the points where the lamp first started to glow and the intensity of the illumination was very low. In order to produce a useful indication it was necessary to increase the displacements by two or three degrees. This applies to all the results given for displacement tests in Tables 1, 2, and 3, and curves, Plates 1, 2, and 3. The specifications require that the lamp shall not glow at 15 degrees but shall glow at 18 degrees with sufficient brilliancy to be seen from a distance of 6 feet in a field of 30-foot candles.

22. The results obtained from tests of reduction in indicator motor torque gradient resulting from the insertion of the transformers in the circuit are as follows:

Reduction in Torque Gradient

Transformer No. 1 - 2.1% CW	4.2% CCW
Transformer No. 3 - 1.91% CW	1.94% CCW
Transformer No. 4 - 1.82% CW	2.08% CCW

Note: These values are within the 5% allowed by the specifications.

23. The oscillograms given as Plates 11 and 12 were obtained without and with No. 3 transformer in the circuit. From these, a stiffness coefficient of 130.7 was obtained without the transformer in the Synchro circuit and a coefficient of 123.45 with the transformer in the circuit. A complete description of this test and calculations are given in paragraphs 102 to 107, inclusive, of Ordnance specifications No. 671. The reduction of the stiffness of coupling is 5.54% and is within the allowable 10 per cent.

24. The maximum temperature rise of any winding in the overload transformer was 7.6°C. above an ambient of 54.4°C. The allowable rise is 44.4°C.

Blown Fuse Transformers

25. The potential across the indicator lamp associated with the blown fuse transformer under the various conditions of over and under voltage and frequency is given in Table 9. This table also gives the values obtained during the temperature rise tests.

26. Both types of transformers withstood the required dielectric test, 1500 volts, a.c., 60 cycles. Following this, the insulation resistance in each case was 100 megohms by 500 volt megger. The minimum allowable is 1 megohm.

CONCLUSIONS

27. Under the accuracy test, occasional errors appear to exceed by three minutes the allowable 3-minute increase in error with the transformer in the circuit. An allowance should be made, however, 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.

28. The results of the test for displacement necessary to operate the indicator lamp are not within the required 15 to 18 degrees. Two or three degrees must be added to the values given in order to produce a perceptible glow as defined by the specifications.

29. The results of the measurements of reduction in torque gradient are within the limits allowed by the specifications.

30. The coefficient of stiffness of coupling was reduced less than the allowed 10 per cent by the insertion of a transformer in a Synchro circuit.

31. The temperature rises of both types of transformers are within the limits allowed.

32. The potentials across the indicator lamp of the blown fuse transformers were within the specified tolerances.

33. Both types of transformers were satisfactory under the required dielectric and insulation resistance tests.

34. Under inspection, the following features were noted as being objectionable:

- (a) In the overload transformer, the lead wires are too short, resulting in their breaking off where soldered to terminals. The construction of the internal brackets should be improved as they now require the use of nuts which have been filed to fit. In addition, provision should be made to prevent the terminals from turning.
- (b) If the present type of case construction is retained for the overload transformer, the liner for the box should be of a more moisture-resistant material.
- (c) Provision should be made to prevent the terminals from turning when making line connections to the blown fuse transformer.
- (d) The paper insulator used in the end bells of the blown fuse transformer should be replaced with a non-hygroscopic material.

(e) The projecting corners of the nameplate on the blown fuse transformer should be rounded to prevent injury to personnel.

(f) Neither of the transformer cases is hermetically sealed as required by the specifications.

Table 1

No. 1 Overload Transformer
Motor Displacement to Light Lamp

Generator
Setting
in Degrees
from Elect.
Zero-(CW)

	Tap 1		Tap 2		Tap 3		Tap 4		Tap 5	
	CCW	CW	CCW	CW	CCW	CW	CCW	CW	CCW	CW
10	32°- 0'	26°-57'	26°-51'	23°-27'	22°-30'	20°-15'	18°-51'	17°-51'	15°-57'	15°-21'
20	32 30	26 9	26 3	22 51	21 33	19 45	18 0	17 9	15 21	15 9
30	28 12	25 51	24 3	22 30	20 18	19 15	17 24	17 3	15 24	14 51
40	26 57	27 6	23 15	23 27	19 51	20 9	17 6	17 24	14 57	15 15
50	26 15	28 21	23 3	24 3	19 15	20 30	16 48	17 54	14 39	15 30
60	25 51	30 15	22 33	25 51	19 36	21 51	16 51	18 51	14 45	16 15
70	26 45	32 6	22 57	27 30	19 48	23 30	17 12	20 12	14 51	17 21
80	27 15	33 18	23 45	28 51	20 24	24 27	17 54	21 9	15 30	18 18
90	28 9	33 39	25 30	29 12	21 57	25 15	19 6	21 45	16 30	18 45
100	31 3	34 15	26 51	29 18	23 6	25 9	20 0	21 30	17 6	18 48
110	32 18	34 6	28 9	29 51	24 12	25 30	20 54	21 51	18 0	18 45
120	33 24	32 48	29 3	28 48	25 3	24 48	21 39	21 30	18 39	18 30
130	33 6	31 54	29 0	27 51	25 0	23 51	21 45	20 24	18 39	17 39
140	34 12	31 12	29 45	27 12	25 36	23 18	21 30	20 12	18 12	17 21
150	32 51	31 36	28 3	26 57	23 48	22 54	20 6	19 36	17 6	16 51
160	32 0	33 0	27 39	27 45	23 12	23 12	19 45	19 45	16 54	16 51
170	31 0	31 12	26 45	27 15	22 18	23 16	19 0	19 54	16 9	16 51
180	30 51	28 51	26 12	25 6	22 9	21 27	19 3	18 45	16 3	16 6
190	31 30	27 12	27 3	23 54	22 18	20 45	18 48	18 9	15 54	15 51
200	32 15	26 15	26 9	22 57	21 12	19 57	18 3	17 21	15 15	15 18
210	28 30	26 15	24 9	22 57	20 30	19 48	17 39	17 12	15 15	15 6
220	26 45	27 15	22 51	23 30	19 45	20 15	17 0	17 45	14 45	15 30
230	25 45	27 57	22 12	24 12	19 6	20 45	16 42	18 3	14 30	15 30

Table 1 (Continued)

Generator
Setting
in Degrees
from Elect.
Zero-(CW)

	Tap 1		Tap 2		Tap 3		Tap 4		Tap 5	
	CCW	CW	CCW	CW	CCW	CW	CCW	CW	CCW	CW
240	25°-36'	30°-15'	22°-15'	25°-42'	19°- 9'	22°- 0'	16°-36'	19°- 3'	14°-30'	16°-24'
250	26 6	32 6	22 45	27 30	19 21	23 42	16 51	20 15	14 42	17 30
260	26 54	33 3	23 30	28 30	20 15	24 30	17 45	20 57	15 30	18 6
270	28 51	33 21	25 9	29 9	21 48	25 3	18 48	21 54	16 9	18 51
280	30 48	33 51	26 30	29 12	22 57	24 56	19 51	21 48	17 0	18 48
290	32 0	34 6	27 57	29 54	24 6	25 30	20 45	21 54	17 51	18 45
300	33 15	32 54	28 51	28 45	25 0	24 51	21 45	21 30	18 30	18 30
310	33 30	32 0	29 9	27 45	25 9	23 54	21 54	20 30	18 51	17 45
320	34 24	31 30	30 6	27 18	25 21	24 36	21 30	20 18	18 15	17 30
330	33 6	31 30	28 9	27 0	23 51	22 54	20 15	19 30	17 9	16 51
340	32 6	33 0	27 36	27 36	23 24	23 9	20 0	19 36	17 6	16 51
350	31 3	31 3	26 30	27 9	22 30	23 9	19 6	19 30	16 9	16 51
360	30 54	28 30	26 30	24 54	21 15	21 24	19 0	18 30	16 9	16 3

Table 2

No. 3 Overload Transformer
Motor Displacement to Light Lamp

Generator Setting in Degrees from Elect. Zero	Tap 1		Tap 2		Tap 3		Tap 4		Tap 5	
	CCW	CW	CCW	CW	CCW	CW	CCW	CW	CCW	CW
10	35°-30'	31°- 6'	30°-30'	27°- 0'	24°-54'	23°- 9'	20°-45'	20°- 9'	17°-18'	17°-36'
20	37 48	30 21	31 9	26 9	25 3	22 21	20 33	19 33	17 6	17 6
30	34 12	30 33	28 6	26 9	23 30	22 18	19 57	19 18	17 6	16 54
40	31 39	31 30	26 42	27 0	22 15	23 0	19 6	19 51	16 39	17 12
50	30 6	32 54	25 39	27 45	21 48	23 30	18 51	20 15	16 15	17 30
60	29 36	35 12	25 18	29 30	21 15	24 54	18 51	21 6	16 9	18 9
70	30 9	36 27	26 6	31 9	22 9	26 27	19 9	22 30	16 36	19 18
80	31 3	37 3	26 45	31 51	22 54	27 3	19 54	23 3	17 12	19 45
90	32 54	36 48	28 21	31 45	24 30	27 9	21 3	23 21	18 12	20 0
100	35 6	37 6	30 3	31 27	25 36	26 30	21 57	23 0	18 45	19 45
110	36 6	36 57	30 48	32 12	26 15	27 15	22 15	23 9	19 15	19 30
120	36 15	37 0	31 0	32 3	26 36	27 21	22 45	23 12	19 30	19 48
130	36 39	35 12	31 30	30 15	27 0	25 48	23 0	21 51	19 42	18 30
140	37 17	34 56	32 0	29 54	27 9	25 9	22 51	20 30	19 9	18 27
150	36 36	35 45	30 36	29 48	25 51	25 6	21 36	20 54	18 6	18 0
160	38 21	35 15	31 15	30 3	25 12	25 30	21 15	21 12	18 0	18 9
170	34 51	35 51	29 30	30 57	24 39	26 6	20 45	21 51	17 33	18 12
180	34 18	32 54	29 0	28 12	24 30	24 12	20 48	20 54	17 30	17 51
190	35 12	31 0	30 3	26 54	24 54	23 12	20 45	20 0	17 12	17 18
200	37 39	30 12	31 6	26 12	24 45	22 39	20 12	19 30	16 51	17 3
210	34 0	30 39	27 48	26 6	23 6	22 12	19 45	19 15	16 54	16 45
220	31 9	31 21	26 12	26 57	22 12	22 54	19 6	19 54	16 30	17 12
230	29 45	32 54	25 33	28 3	21 39	23 30	18 30	20 18	16 0	17 30

Table 2 (Continued)

Generator
Setting
in Degrees
from Elect.
Zero

	Tap 1		Tap 2		Tap 3		Tap 4		Tap 5	
	CCW	CW	CCW	CW	CCW	CW	CCW	CW	CCW	CW
240	29°-51'	35°-45'	25°-36'	30°- 0'	21°-45'	25°- 3'	18°-51'	21°-24'	16°-12'	18°-21'
250	30 6	36 38	26 3	31 9	22 6	26 21	19 0	22 30	16 36	19 21
260	31 0	37 0	26 45	31 30	22 48	26 54	19 45	23 9	17 3	19 51
270	33 0	36 30	28 45	31 51	24 15	27 15	21 9	23 12	18 6	20 6
280	35 3	37 3	30 3	31 24	25 36	26 48	21 51	23 3	18 45	19 54
290	36 6	36 51	30 51	32 3	26 36	27 18	22 48	23 15	19 18	19 51
300	37 3	35 30	31 45	30 48	26 51	26 15	23 3	22 45	19 39	19 30
310	36 51	35 9	31 45	30 6	26 54	25 30	23 3	21 54	19 45	18 30
320	37 9	34 12	31 57	29 18	26 57	24 54	22 45	21 15	19 0	18 9
330	36 0	35 9	30 39	29 30	25 39	24 48	21 36	21 0	18 3	17 56
340	35 12	37 45	28 54	30 48	25 9	25 9	21 15	21 6	18 3	17 51
350	34 35	35 30	29 15	30 54	24 21	26 0	20 45	21 24	17 12	17 54
360	34 9	32 54	29 0	28 12	24 30	24 3	20 24	20 39	17 18	17 45

Table 3

No. 4 Overload Transformer
Motor Displacement to Light Lamp

Generator
Setting
in Degrees
from Elect.
Zero.

	Tap 1		Tap 2		Tap 3		Tap 4		Tap 5	
	CCW	CW	CCW	CW	CCW	CW	CCW	CW	CCW	CW
10	32°-30'	28°-30'	27°-12'	24°-57'	22°-42'	21°-24'	19°-3'	18°-48'	16°-9'	16°-15'
20	33 42	27 48	27 3	24 12	22 3	21 3	18 30	18 30	15 45	16 15
30	29 45	27 30	25 3	23 57	21 9	20 51	18 12	18 9	16 0	15 51
40	28 9	28 42	24 6	24 54	20 45	21 30	17 57	18 48	15 45	16 15
50	27 6	29 30	23 30	25 27	20 9	22 3	17 39	19 6	15 15	16 30
60	27 6	31 54	23 45	27 18	20 36	23 12	17 51	20 0	15 30	17 18
70	27 51	33 9	24 6	27 48	20 51	24 30	18 6	21 9	15 45	18 12
80	28 33	33 54	24 51	29 21	21 30	25 6	18 48	21 48	16 9	18 42
90	30 30	33 48	26 30	29 30	22 57	25 30	19 57	22 0	17 9	19 0
100	31 57	33 30	28 36	29 6	23 45	25 3	20 30	21 45	17 45	18 51
110	32 54	34 0	28 36	29 39	24 42	25 21	21 9	21 30	18 9	18 45
120	33 45	32 51	29 6	28 30	25 3	24 30	21 36	21 18	18 45	18 30
130	33 48	32 0	29 6	27 57	25 3	23 48	21 30	20 24	18 36	17 30
140	34 9	31 30	29 54	27 24	25 15	23 30	21 30	20 12	18 30	17 21
150	32 51	31 54	28 3	27 15	23 51	23 9	20 6	19 48	17 0	17 0
160	32 0	33 39	27 36	28 0	23 21	23 15	20 0	19 54	17 0	17 6
170	32 9	31 9	26 15	28 6	22 36	23 45	19 9	19 57	16 9	17 0
180	30 54	29 54	26 30	25 54	22 6	22 15	19 0	19 12	16 6	16 30
190	32 9	28 30	27 15	25 3	22 48	21 45	19 0	18 54	16 6	16 30
200	32 54	27 30	26 45	24 3	22 0	20 57	18 12	18 21	15 45	16 9
210	29 30	27 45	24 54	24 6	21 9	20 51	18 6	18 9	15 45	15 54
220	28 15	28 30	24 9	24 54	20 51	21 30	17 51	18 39	15 24	16 12
230	27 3	29 45	23 15	24 45	20 0	21 54	17 33	18 54	15 16	16 30
240	27 0	31 51	23 30	27 21	20 9	23 6	17 45	20 6	15 18	17 15

Table 3 (Continued)

Generator
Setting
in Degrees
from Elect.
Zero

	Tap 1		Tap 2		Tap 3		Tap 4		Tap 5	
	CCW	CW	CCW	CW	CCW	CW	CCW	CW	CCW	CW
250	27°-45'	33°-9'	24°-3'	28°-45'	20°-48'	24°-30'	17°-57'	21°-12'	15°-36'	18°-12'
260	28 18	34 0	24 54	29 24	21 33	25 9	18 42	21 30	16 6	18 48
270	30 9	33 51	26 33	29 27	22 54	25 21	19 48	22 0	17 3	19 0
280	31 51	33 36	27 51	29 0	23 45	25 54	20 30	21 30	17 36	18 45
290	33 0	33 54	28 36	29 30	24 33	25 12	21 0	21 30	18 0	18 21
300	33 36	32 45	29 9	28 6	24 54	24 30	21 36	21 12	18 36	18 21
310	33 15	32 0	28 54	27 36	24 51	23 30	21 30	20 12	18 30	17 21
320	34 6	31 18	29 42	27 12	23 21	23 18	21 33	19 51	18 6	17 12
330	32 45	31 48	28 0	27 0	23 39	22 51	20 6	19 30	17 3	16 51
340	32 0	33 12	27 45	27 56	23 39	23 15	20 0	19 30	17 0	16 54
350	31 6	32 15	26 39	28 0	22 45	23 31	19 3	19 30	16 6	16 54
360	31 9	29 30	26 30	25 45	22 15	21 57	19 6	19 6	16 15	16 18

Table 4

Accuracy Test
With and Without Numbers 1, 3 and 4 Transformers
(CW Rotation - Slip Ring End)

<u>Generator Setting in Degrees from Elect. Zero</u>	<u>Error in Motor Reading, No Transformer</u>	<u>Error with No.1 Transformer</u>	<u>Error with No.4 Transformer</u>	<u>Error with No.3 Transformer</u>
10	+6	-3	-6	-3
20	+3	+3	-3	0
30	0	0	0	0
40	-3	-3	-6	-9
50	0	0	0	0
60	0	0	-3	0
70	+3	0	0	-3
80	+6	+6	+3	+3
90	+9	+9	+6	+6
100	0	0	+3	0
110	+9	+12	+9	+6
120	+6	+3	+9	+6
130	+3	+3	+6	+3
140	+3	+3	+3	+3
150	+3	+6	+3	+6
160	+3	0	0	-3
170	+3	+6	+6	+9
180	0	0	0	-3
190	-6	-3	-6	-3
200	-3	+3	+3	+3
210	0	0	-3	0
220	0	0	-3	-3
230	+9	+6	+6	+9
240	+3	+6	+6	+3
250	0	+3	0	+3
260	+6	+6	+6	+9
270	+3	0	0	+3
280	0	0	0	+3
290	+3	+6	+9	+6
300	+3	+3	+6	+3
310	-6	-6	-6	-6
320	-3	-3	0	-3
330	-6	-6	-6	-6
340	-9	-9	-9	-9
350	-6	-6	-9	-6
360	-6	-6	-6	-6

Table 5

Accuracy Test
With and Without Numbers 1, 3 and 4 Transformers
(CCW Rotation - Slip Ring End)

<u>Generator Setting in Degrees from Elect. Zero</u>	<u>Error in Motor Reading, No Transformer</u>	<u>Error with No.1 Transformer</u>	<u>Error with No.4 Transformer</u>	<u>Error with No.3 Transformer</u>
10	-18'	-21'	-18'	-18'
20	-18	-18	-18	-18
30	-21	-21	-24	-24
40	-24	-21	-24	-24
50	-21	-24	-21	-21
60	-27	-24	-18	-21
70	-24	-21	-24	-27
80	-27	-24	-27	-27
90	-24	-27	-27	-30
100	-27	-27	-30	-30
110	-27	-30	-24	-27
120	-30	-30	-30	-30
130	-30	-30	-30	-27
140	-24	-21	-24	-24
150	-24	-24	-21	-21
160	-21	-21	-24	-21
170	-18	-15	-15	-15
180	-21	-21	-21	-21
190	-21	-21	-21	-21
200	-21	-21	-21	-18
210	-21	-21	-21	-21
220	-27	-30	-27	-27
230	-24	-21	-21	-21
240	-24	-21	-24	-24
250	-30	-30	-30	-30
260	-27	-27	-30	-30
270	-24	-24	-24	-27
280	-24	-24	-27	-27
290	-21	-18	-18	-21
300	-21	-21	-21	-21
310	-21	-24	-24	-24
320	-18	-15	-18	-18
330	-15	-18	-15	-18
340	-15	-18	-12	-15
350	-15	-12	-12	-12
360	-18	-18	-18	-18

Table 6

Torque Tests
With and Without No. 1 Transformer

<u>No Transformer</u>				<u>With Transformer</u>		
<u>Generator Displacement in Degrees</u>	<u>Weight to Return Motor to Zero-Gms.</u>	<u>Weight in Ozs.</u>	<u>Inch Ozs. Oz.x1.5</u>	<u>Weight to Return Motor to Zero-Gms.</u>	<u>Weight in Ounces</u>	<u>Inch Ozs. Ozs.x 1.5</u>
Generator displaced - CW (from slip ring end)						
1	6.84	.2414	.3621	6.59	.2322	3.483
2	13.85	.4884	.7326	13.57	.4785	.7177
3	20.90	.7376	1.1064	19.98	.7052	1.058
4	27.53	.9706	1.456	27.46	.9694	1.454
5	34.68	1.223	1.834	33.65	1.188	1.782
6	41.57	1.466	2.199	40.56	1.432	2.148
7	49.05	1.73	2.595	47.77	1.685	2.527
8	55.42	1.954	2.931	54.99	1.94	2.91
9	62.61	2.208	3.312	61.35	2.162	3.243
10	70.18	2.475	3.712	68.80	2.426	3.639
Generator displaced - CCW (from slip ring end)						
1	7.24	.255	.3825	6.82	.2406	.3609
2	14.25	.5025	.7537	14.15	.4996	.7494
3	21.00	.7404	1.1106	21.08	.7444	1.1166
4	28.11	.992	1.488	27.67	.977	1.465
5	35.00	1.234	1.851	34.61	1.222	1.833
6	41.96	1.48	2.22	41.25	1.455	2.182
7	49.02	1.73	2.595	48.24	1.702	2.553
8	55.94	1.972	2.958	54.85	1.934	2.901
9	63.28	2.23	3.345	60.53	2.138	3.207
10	70.52	2.49	3.735	67.83	2.392	3.588

Table 7

Torque Tests
With and Without No. 3 Transformer in Circuit

Generator Displacement in Degrees	No Transformer			With Transformer		
	Weight to Return Motor to Zero-Gms.	Weight in Ozs.	Inch Ozs. Ozs.x 1.5	Weight to Return Motor to Zero-Gms.	Weight in Ozs.	Inch Ozs. Ozs.x 1.5
Generator displaced CW (from slip ring end)						
1	6.84	.241	.3615	6.41	.226	.339
2	13.50	.476	.714	13.09	.462	.693
3	21.09	.744	1.116	20.02	.7075	1.061
4	27.46	.968	1.452	26.50	.935	1.403
5	34.22	1.207	1.810	33.60	1.185	1.778
6	41.24	1.454	2.181	40.31	1.42	2.13
7	47.97	1.692	2.538	47.70	1.682	2.523
8	54.96	1.937	2.906	54.20	1.91	2.86
9	62.46	2.202	3.303	61.25	2.16	3.24
10	69.12	2.442	3.663	67.54	2.381	3.571
Generator displaced CCW (from slip ring end)						
1	7.67	.270	.405	7.50	.2645	3.967
2	14.44	.509	.764	13.83	.488	.732
3	21.46	.757	1.135	20.68	.729	1.094
4	27.92	.984	1.476	27.16	.958	1.437
5	35.90	1.266	1.899	34.00	1.198	1.797
6	42.19	1.488	2.232	40.78	1.437	2.156
7	48.71	1.718	2.577	47.90	1.688	2.532
8	55.36	1.952	2.928	54.74	1.931	2.896
9	62.31	2.197	3.296	61.05	2.155	3.232
10	68.75	2.425	3.338	68.09	2.404	3.606

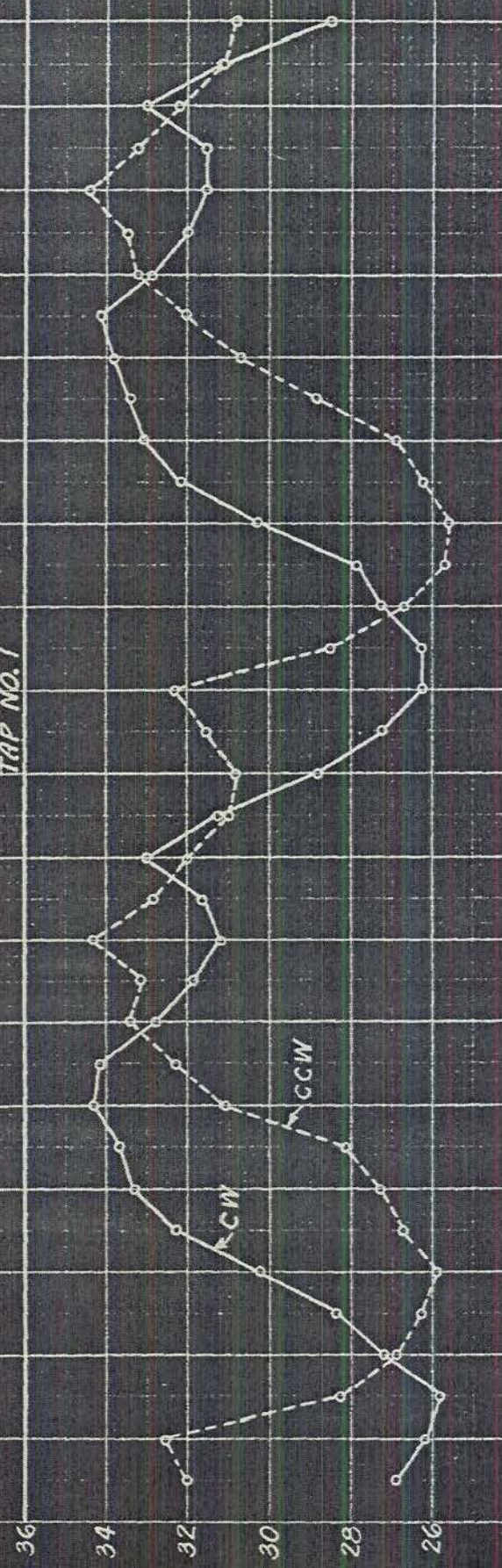
Table 8

Torque Tests
With and Without No. 4 Transformer in Circuit

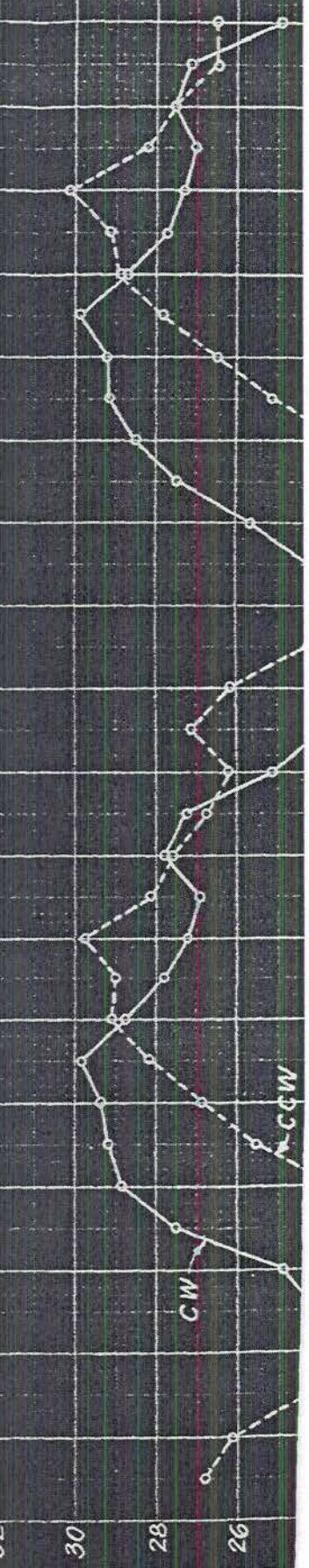
Generator Displacement in Degrees	Without Transformer			With Transformer		
	Weight to Return Motor to Zero-Gms.	Weight in Ozs.	Inch Ozs. Ozs.x 1.5	Weight to Return Motor to Zero-Gms.	Weight in Ozs.	Inch Ozs. Ozs.x 1.5
Generator displaced CW (from slip ring end)						
1	7.40	.261	.3915	6.61	.233	.3495
2	14.29	.504	.756	13.24	.467	.7005
3	21.16	.746	1.109	19.80	.6985	.748
4	28.14	.993	1.489	27.40	.967	1.45
5	35.21	1.242	1.863	33.89	1.195	1.792
6	42.27	1.49	2.24	41.57	1.469	2.204
7	49.52	1.75	2.625	48.48	1.708	2.562
8	55.13	1.94	2.91	54.77	1.932	2.898
9	62.92	2.22	3.33	61.76	2.18	3.27
10	70.30	2.48	3.72	69.0	2.435	3.65
Generator displaced CCW (from slip ring end)						
1	7.12	.251	.3765	6.59	2.32	3.48
2	13.90	.49	.735	14.21	.5015	.752
3	20.66	.7299	1.095	20.57	.725	1.0875
4	27.65	.976	1.464	26.57	.937	1.405
5	35.08	1.238	1.857	34.74	1.224	1.836
6	41.77	1.475	2.213	41.43	1.46	2.19
7	48.98	1.727	2.590	47.73	1.682	2.523
8	56.10	1.98	2.97	54.34	1.916	2.874
9	63.12	2.225	3.337	61.70	2.178	3.267
10	70.08	2.473	3.709	68.70	2.42	3.63

DISPLACEMENT OF INDICATOR
 TO OPERATE TROUBLE SIGNAL
 5 F & 5 G SYNCHROS
 OVERLOAD TRANSFORMER NO. 1

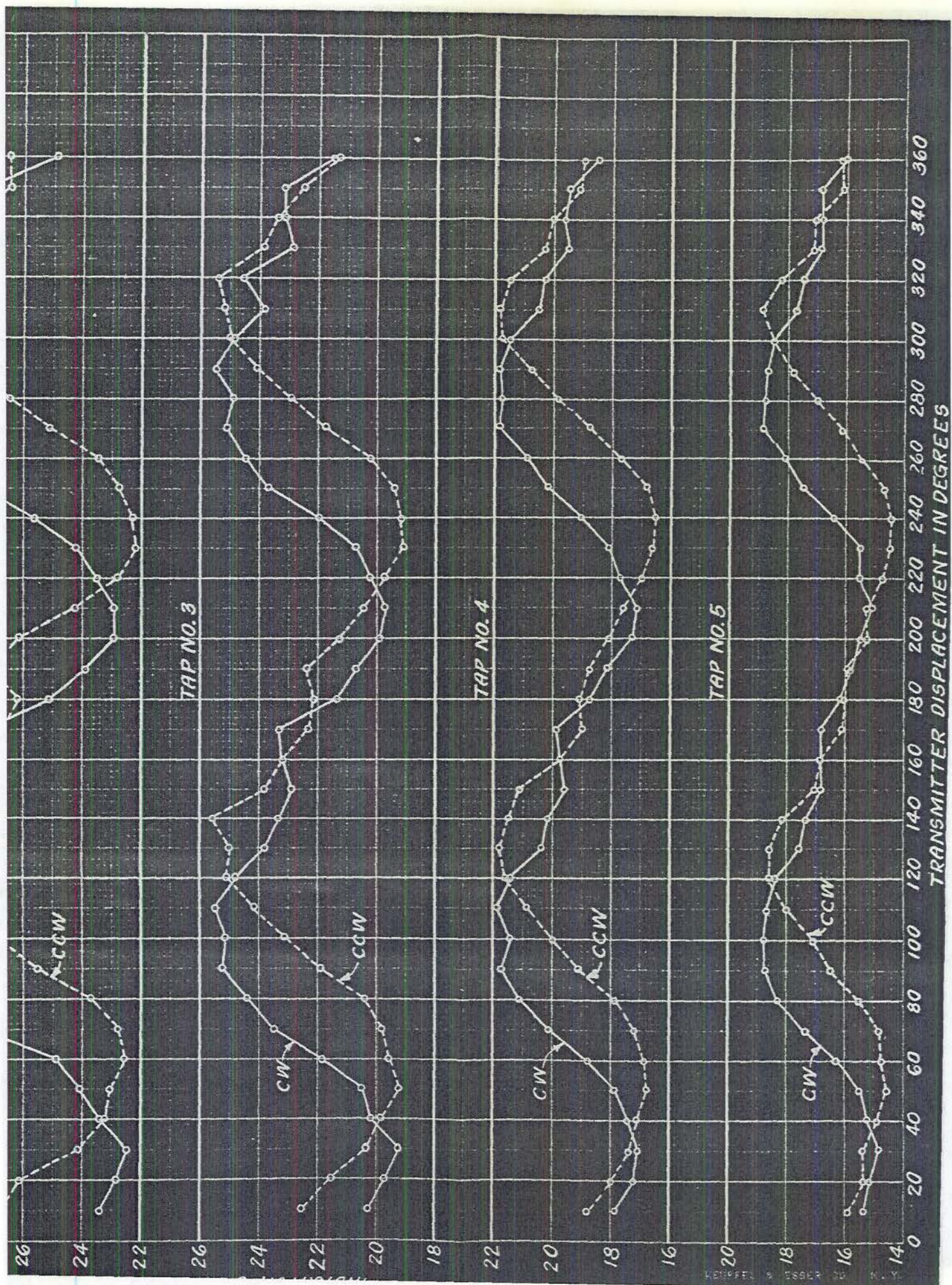
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TAP NO. 2

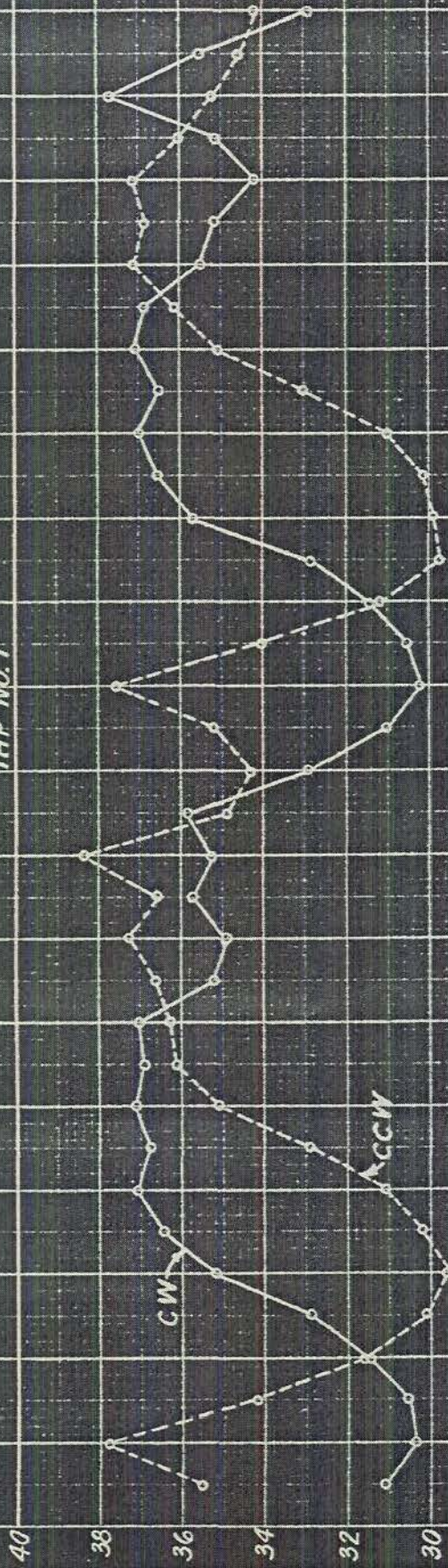


TO OPERATE LAMP - DEGREES



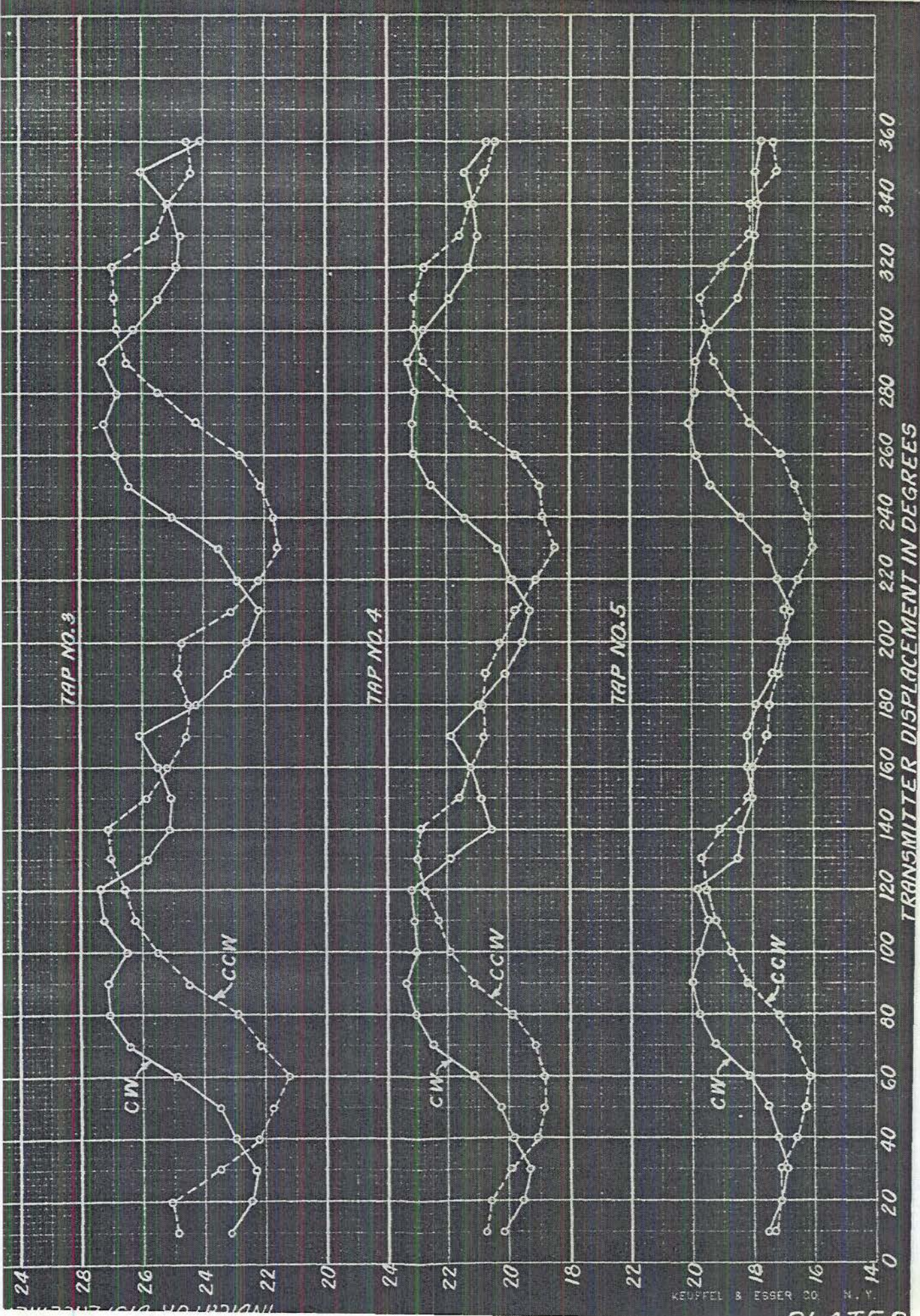
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TO OPERATE TROUBLE SIGNAL
5F & 5G SYNCHROS
OVERLOAD TRANSFORMER NO. 3

TAP NO. 1



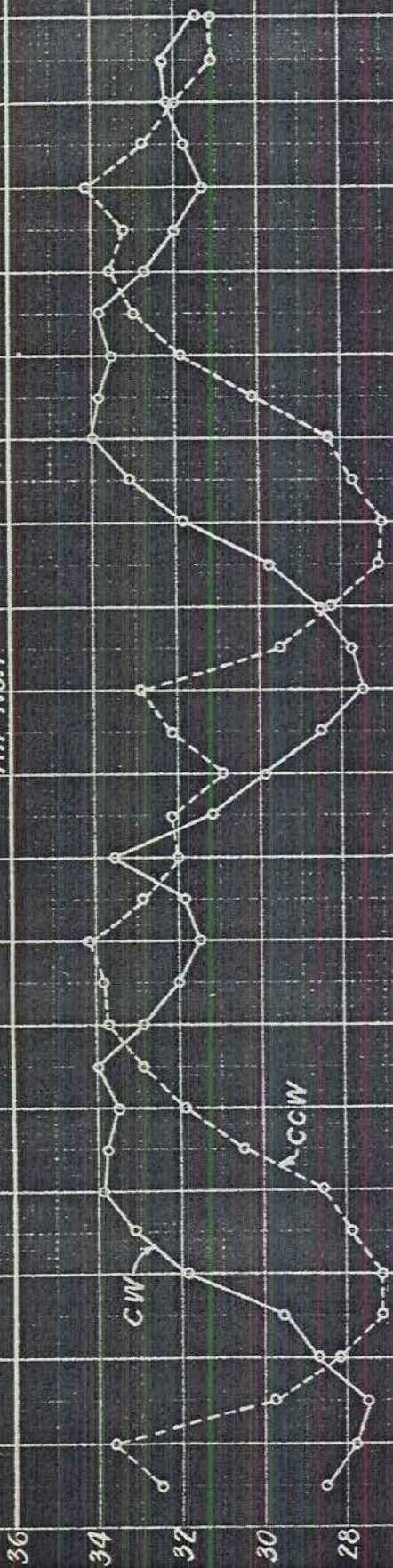
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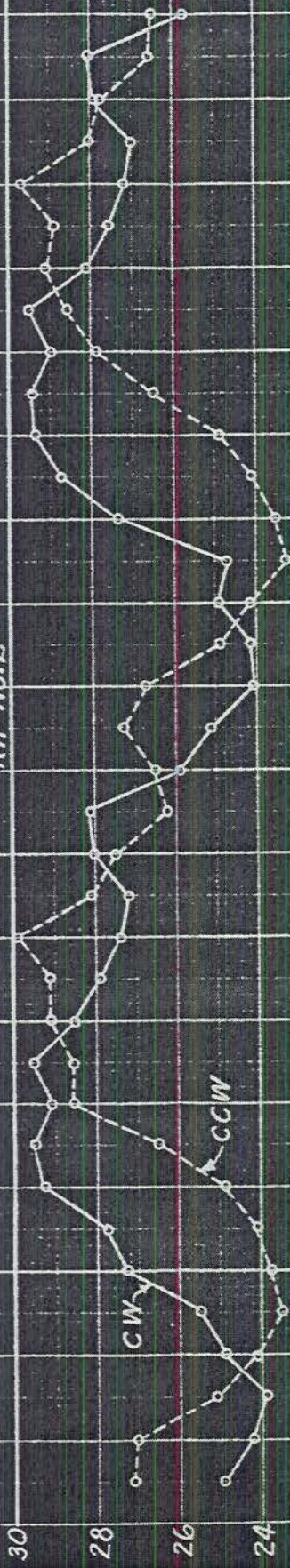


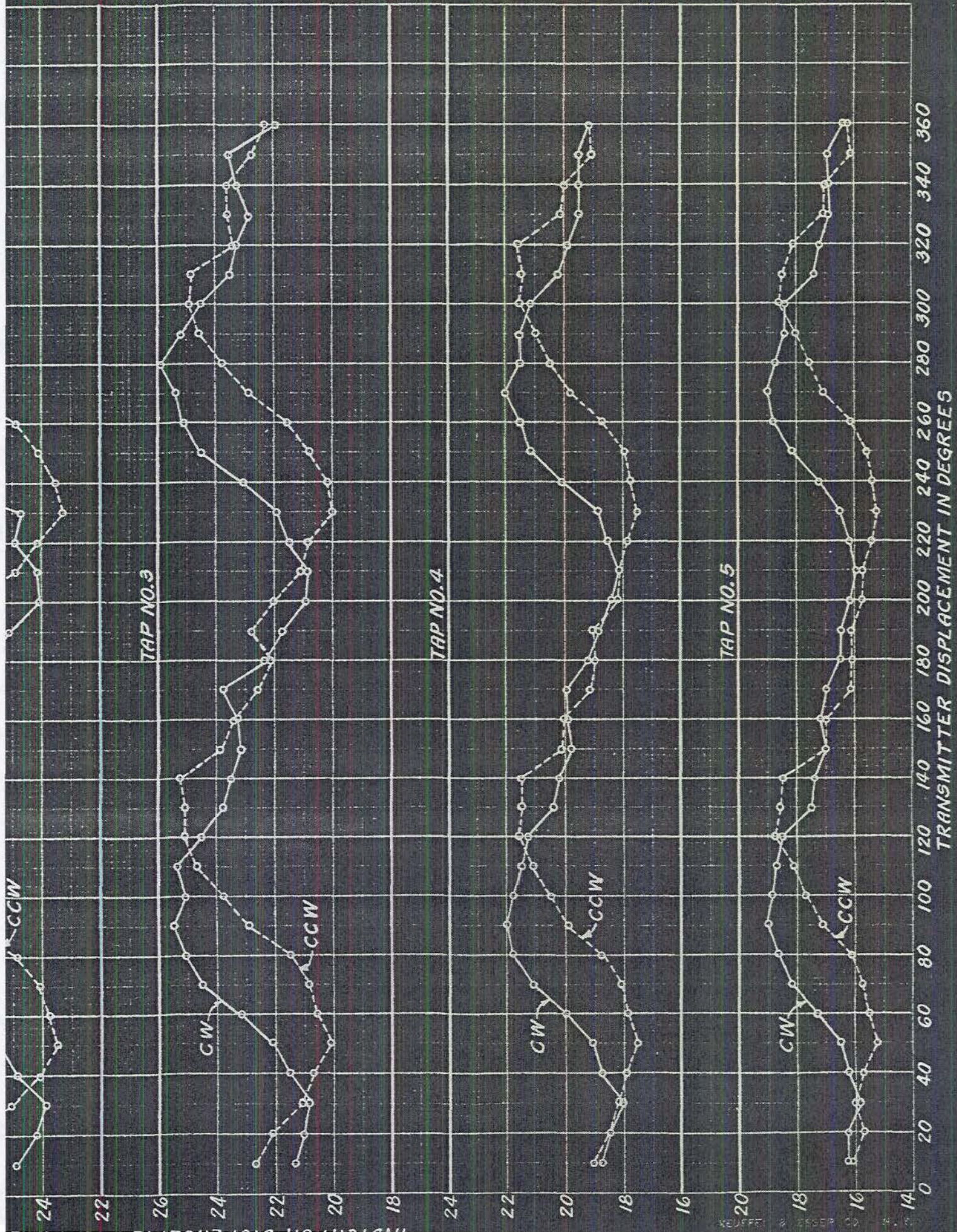
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TO OPERATE TROUBLE SIGNAL
5F & 5G SYNCHROS
OVERLOAD TRANSFORMER NO. 4

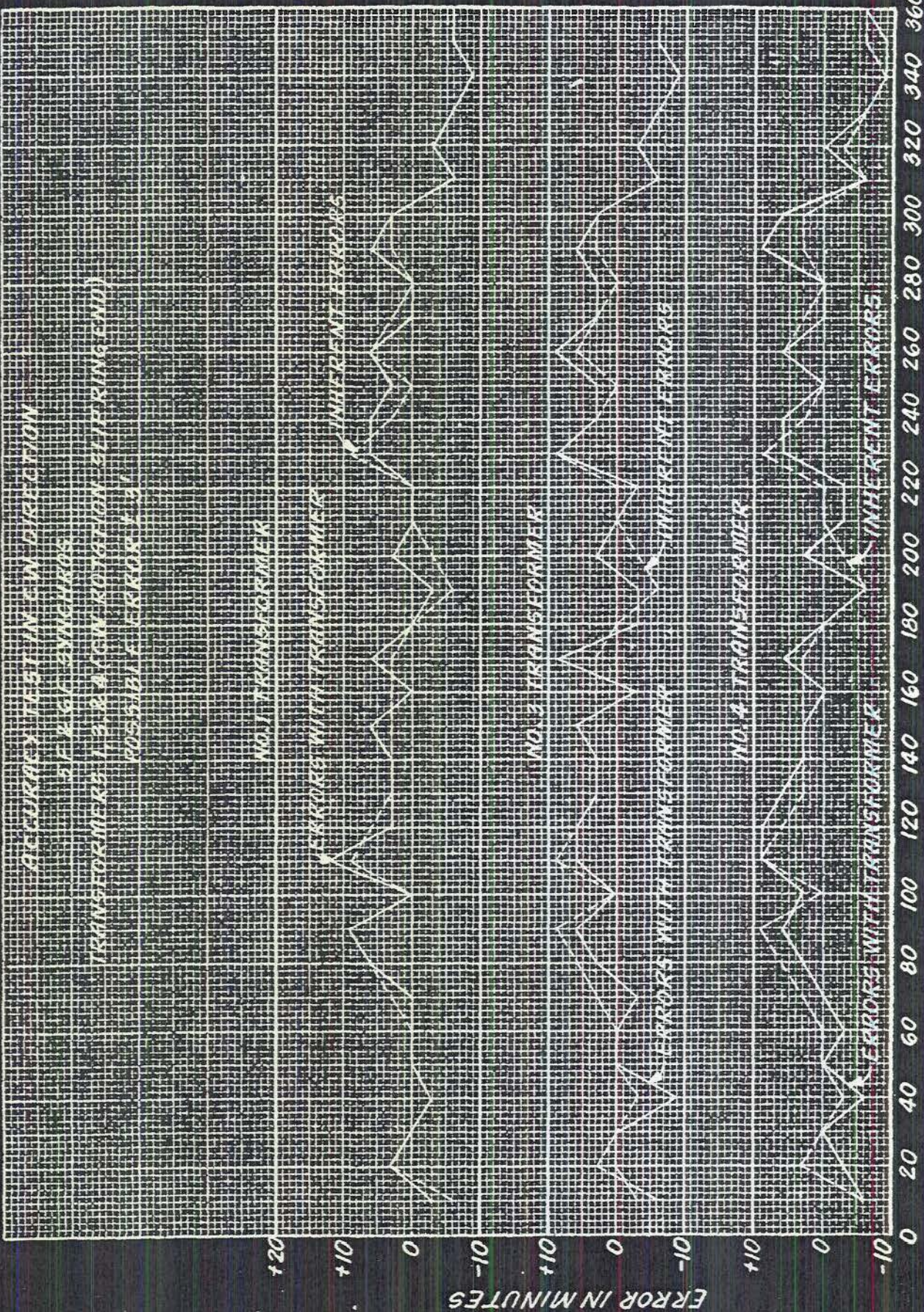
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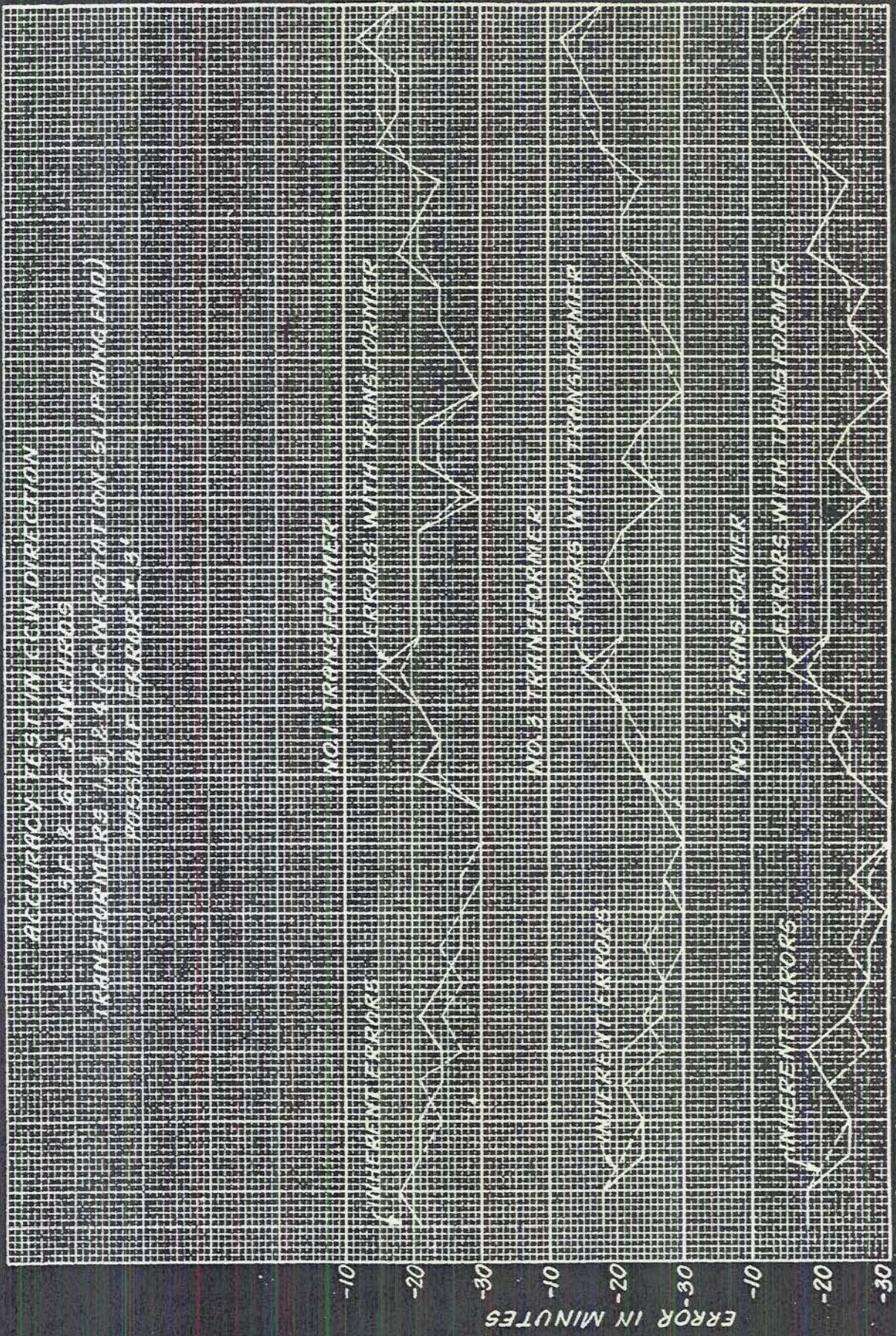
TAP NO. 2







ERRORS WITH TRANSFORMER INHERENT ERRORS



ACCURACY DATA IN DISCRETE
 POINTS FOR EACH TRANSFORMER
 (KNOXVILLE, TENN. (KNOXVILLE))
 (KNOXVILLE, TENN. (KNOXVILLE))
 (KNOXVILLE, TENN. (KNOXVILLE))

NO. 1 TRANSFORMER

NO. 2 TRANSFORMER

NO. 3 TRANSFORMER

TRANSMITTER DISPLACEMENT IN DEGREES

ERROR IN MINUTES



LATTICE

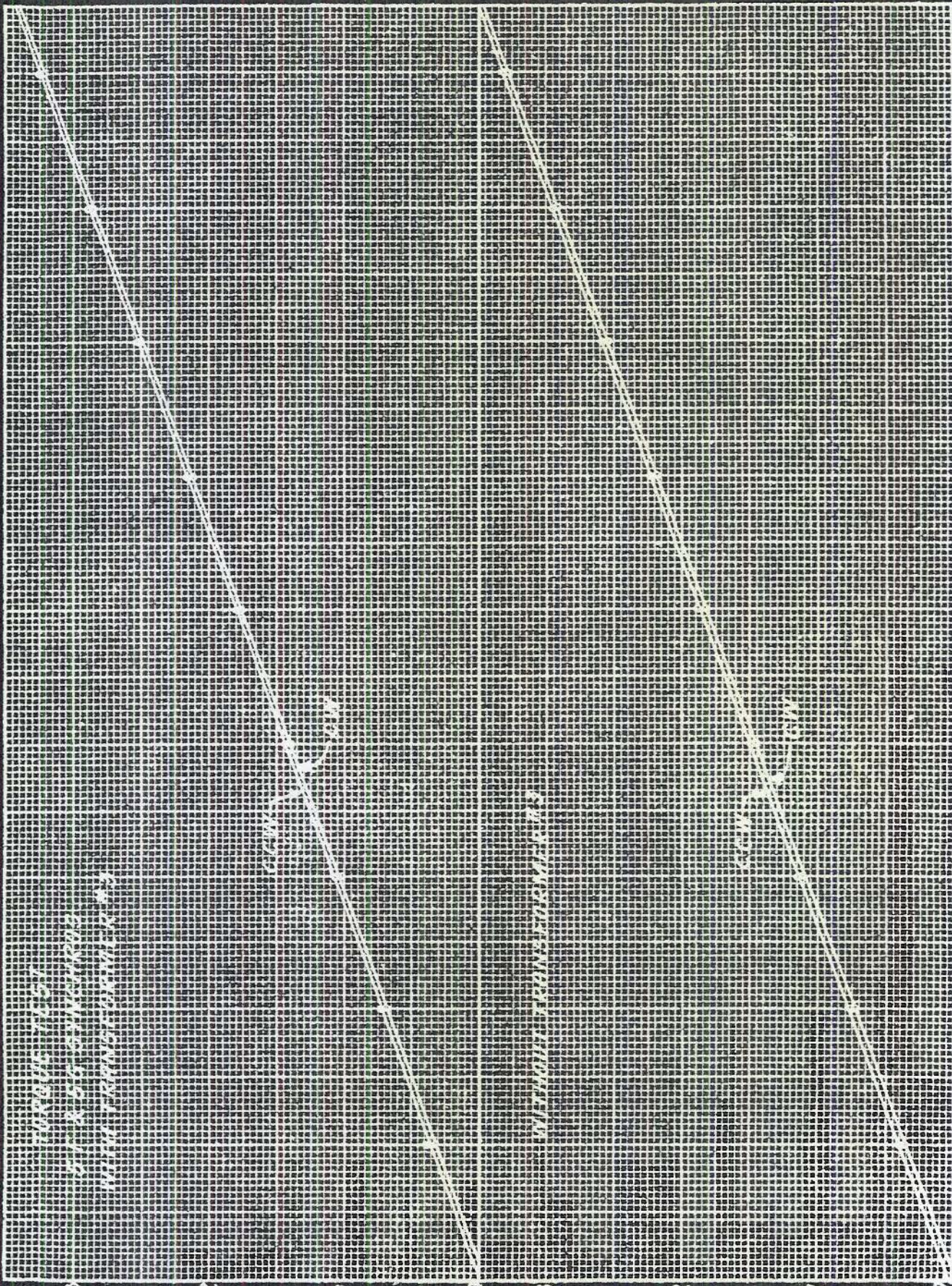
CELL

LATTICE

CELL

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0 1 2 3 4 5 6 7 8 9

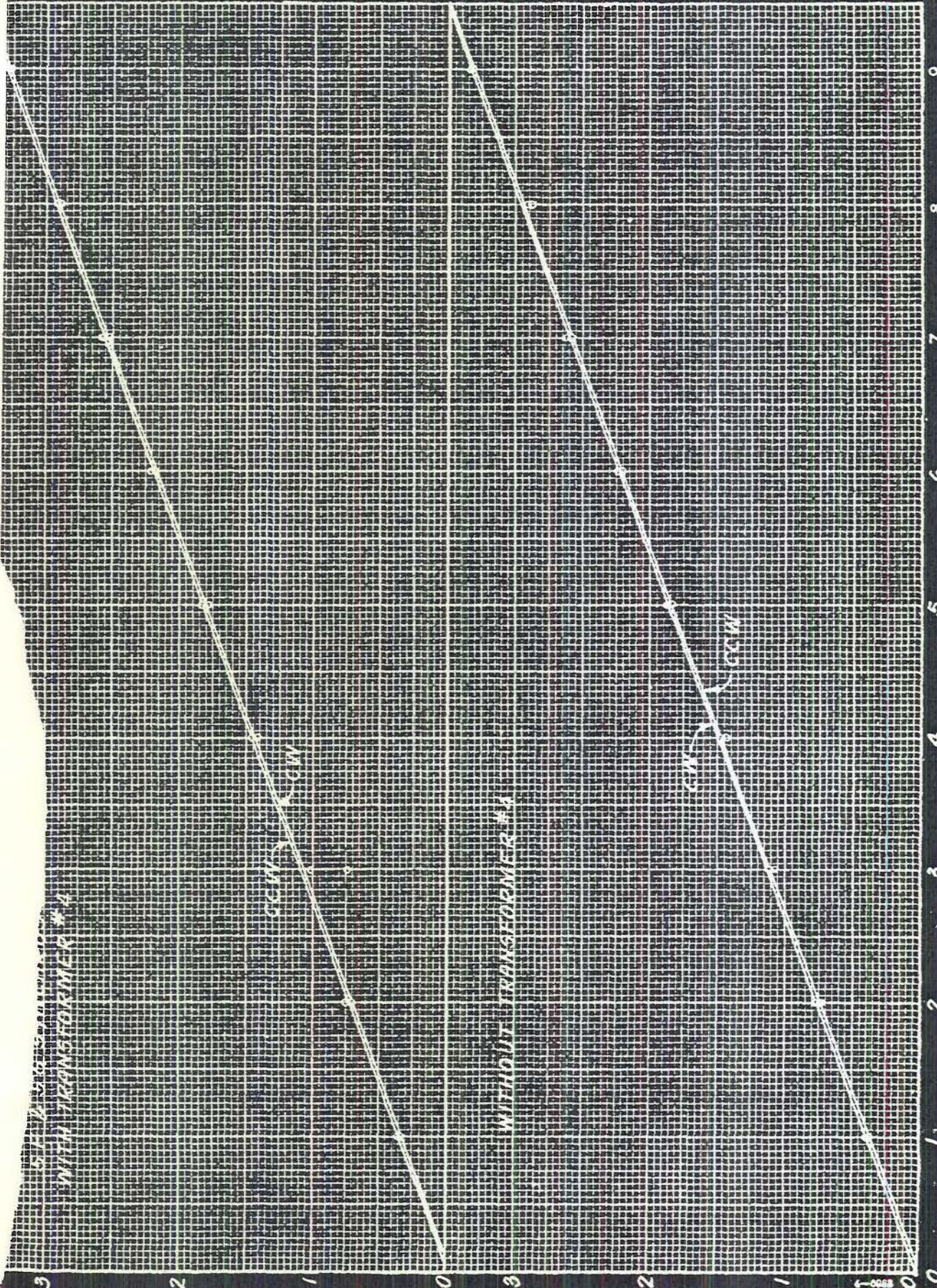


9
8
7
6
5
4
3
2
1

TORQUE IN INCH-OUNCES

PLATE 7

GOVERNMENT PRINTING OFFICE



WITH TRANSFORMER

WITHOUT TRANSFORMER

TORQUE IN INCH-OUNCES

PLATE

0 1 2 3 4 5 6 7 8 9

