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SUBJECT

Report of Instantaneous Type Shaft Revolution System.

BY

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

24 January 1935 NRL Report No.B-1118

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report of

Instantaneous Type Shaft Revolution System

manufactured and submitted by

Electric Tachometer Corporation,
Philadelphia, Pa.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
Washington, D.C.

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Authorization: BuEng.let. S65-5/L5(11-2-Ds) of 6 November 1934.

Dates of Test: November - December 1934 and January 1935.

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Bu.Eng.(5)

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APPENDICES

AUTHORIZATION FOR TEST

1. This test was authorized by reference (a) and other additional reference pertinent to this problem is listed as reference (b).

Reference : (a) BuEng.let. S65-5/L5(11-M-Js) of 6 November 1934.
(b) Navy Department specifications 56S(65)10 of 15 April 1934.

OBJECT OF TEST

2. The object of this test was to determine the suitability of the instantaneous type shaft revolution indicator system for the Naval Service and compliance with Navy Department specifications 5GS (65)10 of 15 April 1934.

ABSTRACT OF TEST

3. The system was set up at this Laboratory and its operation closely observed while under test for endurance, accuracy and shock integrity. At the start and finish of the 500 hours endurance test, the recorded revolutions on the port and starboard transmitter mechanical counters and the port and starboard and averaging counters were logged. While under endurance, the system was operated at an average speed of 317 RPM and the direction of rotation of the transmitter shafts was reversed for one hour in every twenty-four. At the conclusion of this test, the system was operated for accuracy. Then one of the shaft transmitters was subjected to shock and the system again operated for accuracy.

Conclusions

(a) The master transmitter under test proved to be rugged in design and accurate in operation. However, the equipment submitted is not a finished product and was submitted for preliminary tests to determine the suitability of the instrument design and its practicability.

(b) The system as submitted requires the master transmitter instruments to be located at the shafts and repeater instruments at all other stations. A system of this type depends entirely on the friction drive, as described in paragraphs 8 to 13 inclusive, for positioning the selsyn transmitter motor which drives the selsyn indicator motors in the repeater instruments.

(c) In the event that one or more of the selsyn indicator motors becomes sluggish or stuck, the accuracy of the entire system would be affected. False RPM indications would be given at the gauge board (throttle stations) where accuracy is most desired. Also, in a system of this type, should a minor repair on the master transmitter become necessary while the system is under operation, it would be necessary to de-energize the entire circuit from that transmitter. Furthermore, troubles such as sluggishness of motor, damage, high resistance grounds, etc., in any other repeater on the same circuit (and in some cases in any repeaters in the system) will immediately destroy the accuracy of the gauge board instruments. In order for the throttleman to be sure of the accuracy of the gauge board instruments, he would have to clock total revolutions frequently.

(d) A system with the master instrument installed on the gauge board will allow for better installation, accessibility and maintenance than a system, such as the subject system, having the master instruments located at their respective shafts where space is often limited.

(e) The master instruments should include two pointers, one indicating hundreds, the other units. This feature gives greater accuracy.

(f) The average RPM indicator, as described in paragraph 19, is not satisfactory due to the gearing of the differential motor to the pointer (1 to 2 ratio). It has the following disadvantage: If the system is set up properly and then de-energized and the average RPM indicator pointer displaced 180°, or one transmitter motor displaced 360°, the pointer will "lock in" 180° out of its proper position when the system is again energized.

(g) In order to overcome these faults in design and suitability, it is recommended that the Bureau advise the manufacturer to redesign the equipment, embodying the use of master transmitter instruments for location at the gauge boards. A description of such instruments is given in NRL Report 3-1082 of 10 October 1934.

Recommendations

(a) It is recommended that the manufacturer be given temporary approval and final approval be held in abeyance pending further tests on a complete system of finished equipment, including a constant frequency control unit and embodying the use of master transmitter indicator instruments for location at the gauge boards.

DESCRIPTION OF MATERIAL UNDER TEST

4. The subject system, as submitted, is incomplete and was submitted for a preliminary test in order to study the design and determine its ruggedness and accuracy of operation in conformance with Navy Department specifications SGS(65)10. The manufacturer submitted the following equipment:

- 1 starboard shaft transmitter
- 1 port shaft transmitter
- 1 RPM indicator with direction of rotation signal
- 1 average RPM indicator
- 1 two shaft average counter transmitter - indicator

5. The shaft transmitter is enclosed in a watertight case having an extended shaft provided with two ball bearings and a stuffing box. The case contains the following equipment:

- 1 constant speed motor
- 2 selsyn transmitters
- 1 mechanical six digit counter
- 1 uni-directional gear mechanism
- 1 positioning roller and friction disc assembly

6. The operation of the transmitter is as follows: The transmitter drive shaft is driven at three times the speed of the propeller shaft and drives, through uni-directional gearing having a total reduction ratio of 8:1, a master screw shaft.

The uni-directional gear arm operates backing signal contacts for operation of the backing signals located in the indicators.

7. The master screw shaft is fitted with a coarse pitch male thread which carries the friction roller carriage and, through a 2-1/2:1 gearing, operates a mechanical total revolution counter and total revolution selsyn transmitter motor.

8. The friction roller carriage which is positioned by the master screw carries the friction roller (3".141 diameter) and a finely pitched rack which engages a steel pinion and positions the RPM selsyn transmitter motor.

9. A Burgess micro-switch, normally closed, is mounted on one end of the carriage rack which is provided with a slot suitable for the ball bearing guide of the friction roller assembly. An adjustable device is provided on the carriage for operating the Burgess switch when the friction roller is at the center of the friction disc.

10. The friction roller is secured to the bronze nut, located in the carriage, by means of four screws, one of which extends approximately 5/16" so as to engage a mechanical stop on the master screw.

11. The synchronous motor (1800 RPM at exactly 60 cycles) drives the friction disc through suitable gearing at exactly 100 RPM.

12. As the friction disc is driven at a constant speed of 100 RPM, the master screw, operating at a variable speed, causes the friction roller to seek a position on the friction disc where: Variable RPM x 3"141 = 100 RPM x active diameter of the friction disc.

13. The transmitter is so designed that, with a propeller speed of 400 RPM, the transmitter shaft rotates at 1200 RPM and the master screw shaft 1200/8 or 150 RPM. Thus with the friction disc rotating at 100 RPM constant speed: 150 x 3"141 = 100 x 4"712. The active diameter of the friction disc is 4"712 and the displacement of the friction roller from zero is 2"356.

14. The RPM selsyn transmitter pinion has 36 teeth - 48 pitch and rotates 360° when the friction roller is displaced 2"356 from zero.

15. A mechanical device, in the form of a ratchet, is located in the gear assembly of the friction disc drive. This safety device is operated when the mechanical stop, secured to the master screw shaft, engages the projecting screw provided on the friction roller. When the shaft speed exceeds its maximum speed (450 RPM), with or without failure of the constant speed motor, the screw head on the friction roller engages the stop, causing the friction roller to drive the friction disc. The friction disc, which is normally driven through a ratchet mechanism, is then driven at a speed greater than normal speed and the friction roller takes control, causing the ratchet to function as a safety device.

16. An electrical device is provided, so that when the propeller shaft is stopped while the constant speed motor is energized, the friction roller will seek the center of the friction disc (zero) causing the adjustable device on the carriage to open the contacts of the Burgess micro-switch, thereby de-energizing the constant speed motor.

17. The synchronous motor is of the split phase type, and has a 3.75 MFD condenser connected in series with one of its stator windings.

18. The RPM indicator, enclosed in an aluminum alloy case, consists of one selsyn indicator motor with a suitable dial, pointer and a backing signal. The dial is marked from 0 to 400 RPM in one RPM graduations. Six argon lamps are provided for dial illumination.

19. The average RPM indicator is also enclosed in an aluminum alloy case and consists of one differential type selsyn motor provided with a dial and a pointer. The dial is marked from 0 to 400 RPM in graduations of one RPM. The windings of the differential selsyn motor are energized by the port and starboard transmitter motors and are so connected as to add the total RPM of the shafts. The pointer is connected to the differential selsyn motor through a gear reduction of 1:2 so that the resulting indication will show the average RPM of the two shafts.

20. The "two shaft revolution counter and average counter and average transmitter" consists of two selsyn indicator motors, one selsyn transmitter motor and three Veeder type counters. These counters record the port shaft total revolutions, starboard shaft total revolutions and average total revolutions. The total revolution counters are driven by their respective selsyn motors. The total average revolution counter is driven through a mechanical differential which also drives a total average selsyn transmitter motor. This instrument was submitted without an enclosing case.

21. No tell-tale indicator or constant frequency control unit was submitted with this equipment.

22. The selsyn motors submitted with the equipment are manufactured by the Arma Engineering Corporation; the constant speed (at exactly 60 cycles) motors by Holtzer Cabot.

METHOD OF TEST

23. The system as submitted was interconnected electrically to a 115 volt, a.c., 60 cycle frequency controlled supply. Two constant speed motors, connected to the same supply, were used to drive the shafts of the transmitters through reduction gears of suitable ratios.

24. The system was first tested for endurance by operating it for 500 hours at an average speed of 317 RPM; the direction of rotation of the transmitter shafts being reversed for one hour in every twenty-four. For the period of this test, the total revolutions on the port and starboard transmitter mechanical counters were compared with the total revolutions recorded by the two shaft revolution counter and averaging counter.

25. Next, the accuracy of the system was ascertained by operating the system at speeds corresponding to shaft speeds of 80, 133.33, 200, 266.66, 333.33 and 400 RPM for periods of two hours each. The total revolutions of the port and starboard mechanical counters and the transmitted total revolutions were compared to determine the accuracy of this part of the system. The RPM indicated on the RPM indicator and on the average RPM indicator were logged.

26. For determining the accuracy of the system, it was necessary to drive the port and starboard shaft transmitters at known speeds. For checking each speed, readings of the shaft transmitter counters were taken at intervals of two hours, while the system was under operation, using a chronometer as a standard. The speed was computed by dividing the total revolutions of each counter by the time elapsed between readings.

27. The shock integrity of the shaft transmitter was determined by placing the unit on a Navy standard shock machine in the horizontal position and subjecting it to 20 - 250 foot pound blows

while connected in the system and under operation. During this test, observers were stationed at each of the remaining instruments to note any change that might occur due to the shock.

28. At the conclusion of the shock test, the system was again checked for accuracy at a known shaft speed of 200 RPM. This test was the same as outlined in paragraph 25.

29. In view of the system not being submitted as a finished product, but for preliminary tests only, the temperature compensation test at ambient temperature of 135° F. and the insulation resistance, dielectric, and watertight integrity tests were omitted.

RESULTS OF TEST

Endurance Test

30. The total revolutions transmitted by the port and starboard shaft transmitters, during the endurance test, was 9,510,000 revolutions. This checked with the revolutions recorded on the two shaft revolution counter and average counter..

Accuracy Test

31. There was no difference between the transmitted revolutions and the recorded revolutions that could not be attributed to the human error in reading the counters while they were operating.

32. The maximum error in the RPM indicator and the average RPM indicator was plus 0.25 RPM and minus 2.13 RPM respectively. Data recorded during the accuracy test and explanation of table are given in paragraphs 34 and 35.

33. The maximum time required for the system to function properly and indicate true RPM was approximately 16 seconds. This value was obtained by checking the time interval between the starting of the transmitter shaft and the time the RPM pointer had indicated the correct shaft speed (400 RPM).

34. Accuracy Test.

Standard RPM	Actual RPM	Hours Time	Revolutions Duration of Test: Transmitted Rev.	Revolutions Duration of Test: Recorded Rev.	Selsyn Error	Indicated Revolutions per Minute: RPM Indicator: Average Readings	Indicated Revolutions per Minute: RPM Indicator: Error RPM	Indicated Revolutions per Minute: Average RPM Indicator: Average Readings	Indicated Revolutions per Minute: Average RPM Indicator: Error RPM
80.0	79.97	2	9,597	9,597	0	80.1	+.13	78.2	-1.77
133.3	133.40	2	16,008	16,008	0	133.5	+.10	131.7	-1.70
200.0	200.04	2	24,005	24,005	0	200.2	+.16	198.3	-1.74
266.6	266.62	2	31,994	31,994	0	266.8	+.18	265.4	-1.22
333.3	333.73	2	40,048	40,048	0	333.5	-.23	331.6	-2.13
400.0	400.20	2	48,024	48,024	0	400.2	0	398.5	-1.70
*200.0	200.05	2	24,006	24,006	0	200.3	+.25	198.5	-1.55
1	2	3	4	5	6	7	8	9	10

* Readings during shock test.

35. Explanation of Table (paragraph 34).

Column 1 - The speed at which it was desired to test system.

Column 2 - Actual speed as determined by dividing revolutions of shaft by number of minutes of test. The shaft transmitters were driven by synchronous motors, through proper gear ratios, connected to the commercial power supply. This gave for all practical purposes, a constant speed. An electric clock in parallel with synchronous motor drives was never observed to be more than one second out with the standard chronometer.

Column 3 - Duration of test.

Column 4 - Revolutions actually transmitted during test (mechanical counter at shaft).

Column 5 - Revolutions recorded on selsyn controlled revolution counters in instruments.

Column 6 - Selsyn error, zero in all cases. This shows that the selsyn transmitters at shaft and receivers in instruments were in step at all times. (Does not apply to selsyns connected to RPM pointers.)

Column 7 - Average of readings of RPM indicator, taken at intervals of 15 minutes during test. These readings were practically constant.

Column 8 - Average error in RPM indicator.

Column 9 - Average readings of average RPM indicator taken at intervals of 15 minutes during test.

Column 10- Same as Column 8.

36. The system was again checked for accuracy at the completion of the shock test on the shaft transmitter, but did not show any greater error than when previously tested at the same speed (200 RPM).

37. Weights and dimensions.

Instrument	Weight	Case Dimensions
Shaft transmitter.	185 lbs.	20-1/2" x 21-1/8" x 9-9/16"
RPM indicator.	20 lbs. 2 oz.	11" dia. x 9-1/8"
Average RPM indicator.	19 lbs. 7 oz.	11" dia. x 9-1/8"
Two shaft counter and average counter.	20 lbs. 12 oz.	No case submitted.

38. The current required to operate the system was as follows:

Constant speed motors	0.90 amperes
Selsyn motors	3.35 amperes

CONCLUSIONS

39. The master transmitter under test proved to be rugged in design and accurate in operation. However, the equipment submitted is not a finished product and was submitted for preliminary tests to determine the suitability of the instrument design and its practicability.

40. The system as submitted requires the master transmitter instruments to be located at the shafts and repeater instruments at all other stations. A system of this type depends entirely on the friction drive, as described in paragraphs 8 to 13 inclusive, for positioning the selsyn transmitter motor which drives the selsyn indicator motors in the repeater instruments.

41. In the event that one or more of the selsyn indicator motors becomes sluggish or stuck, the accuracy of the entire system would be affected. False RPM indications would be given at the gauge board (throttle stations) where accuracy is most desired. Also, in a system of this type, should a minor repair on the master transmitter become necessary while the system is under operation, it would be necessary to de-energize the entire circuit driven from that transmitter. Furthermore, troubles such as sluggishness of motor, damage, high resistance grounds, etc., in any other repeater on the same circuit (and in some cases in any repeaters in the system) will immediately destroy the accuracy of the gauge board instruments. In order for the throttleman to be sure of the accuracy of the gauge board instruments, he would have to clock total revolutions frequently.

42. A system with the master instrument installed on the gauge board will allow for better installation, accessibility and maintenance than a system, such as the subject system, having the master instruments located at their respective shafts, where space is often limited.

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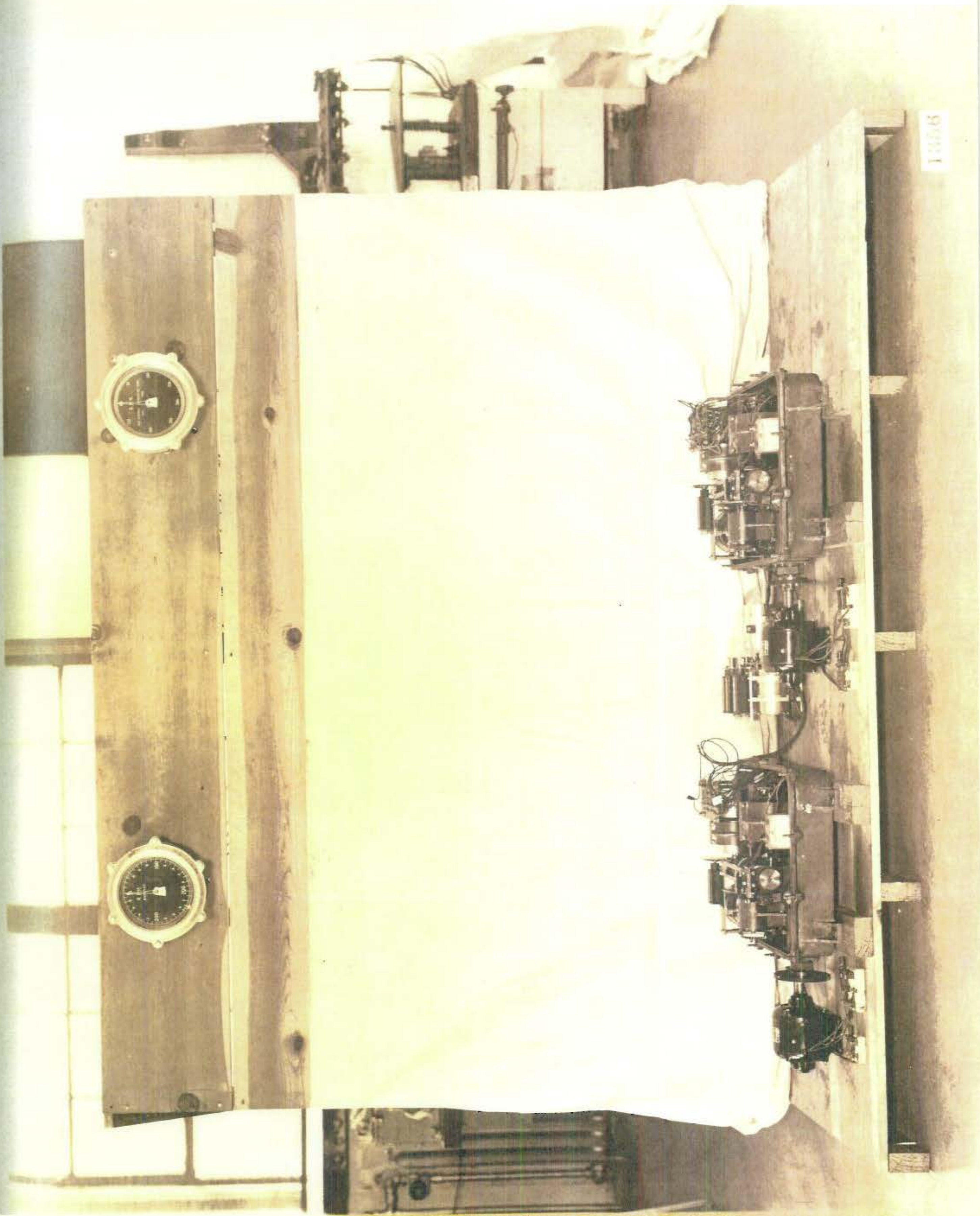

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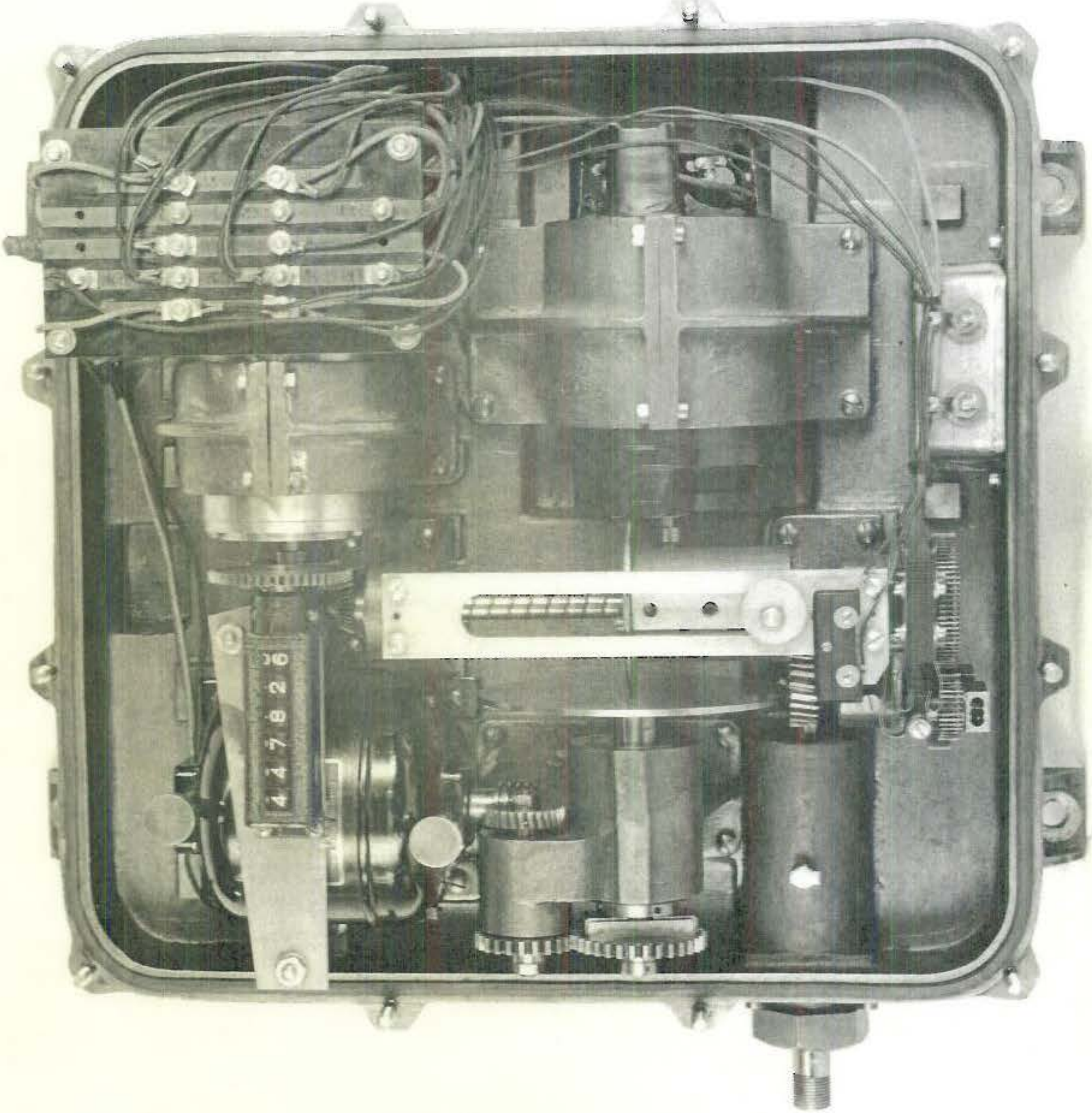

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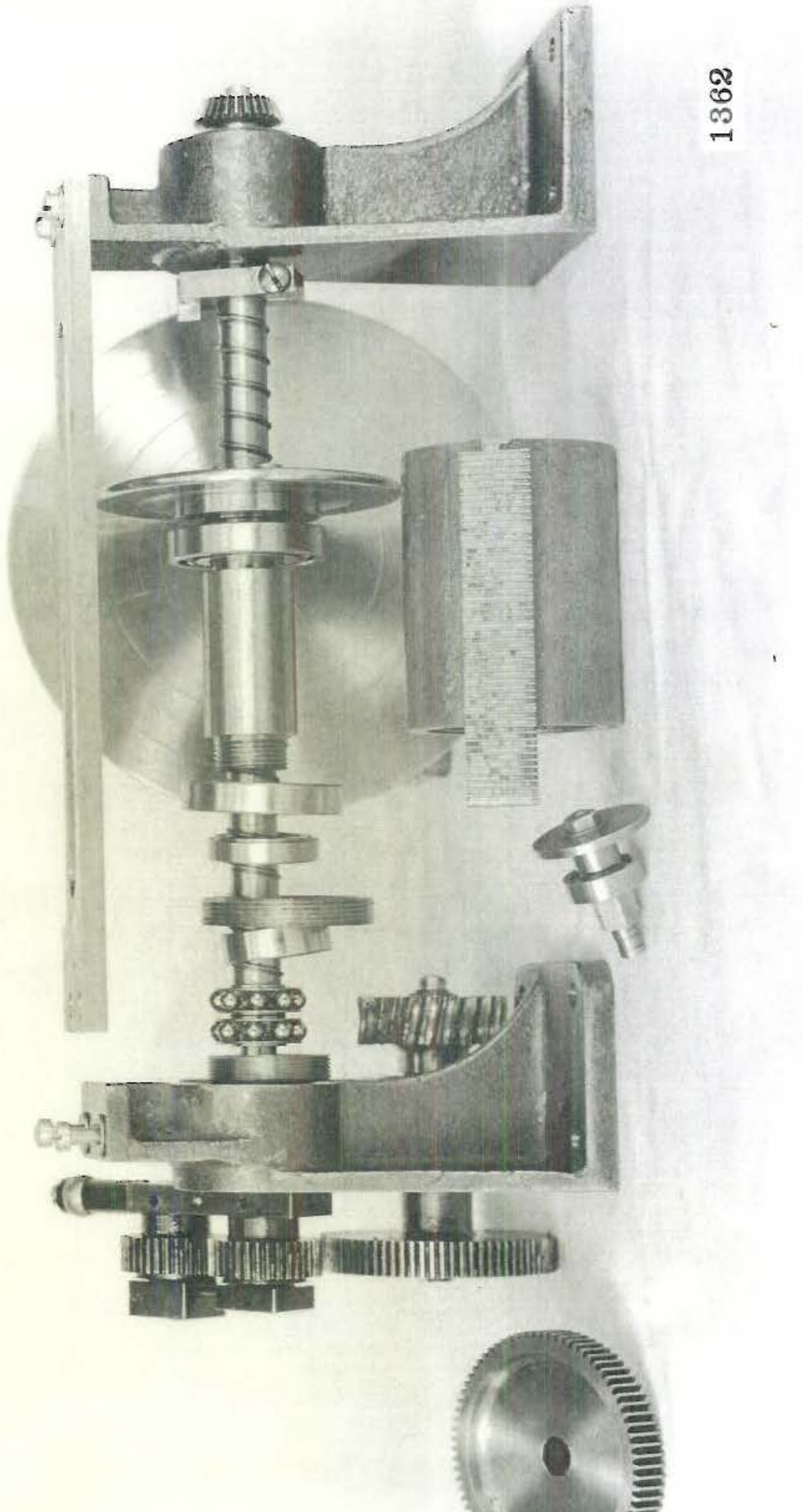

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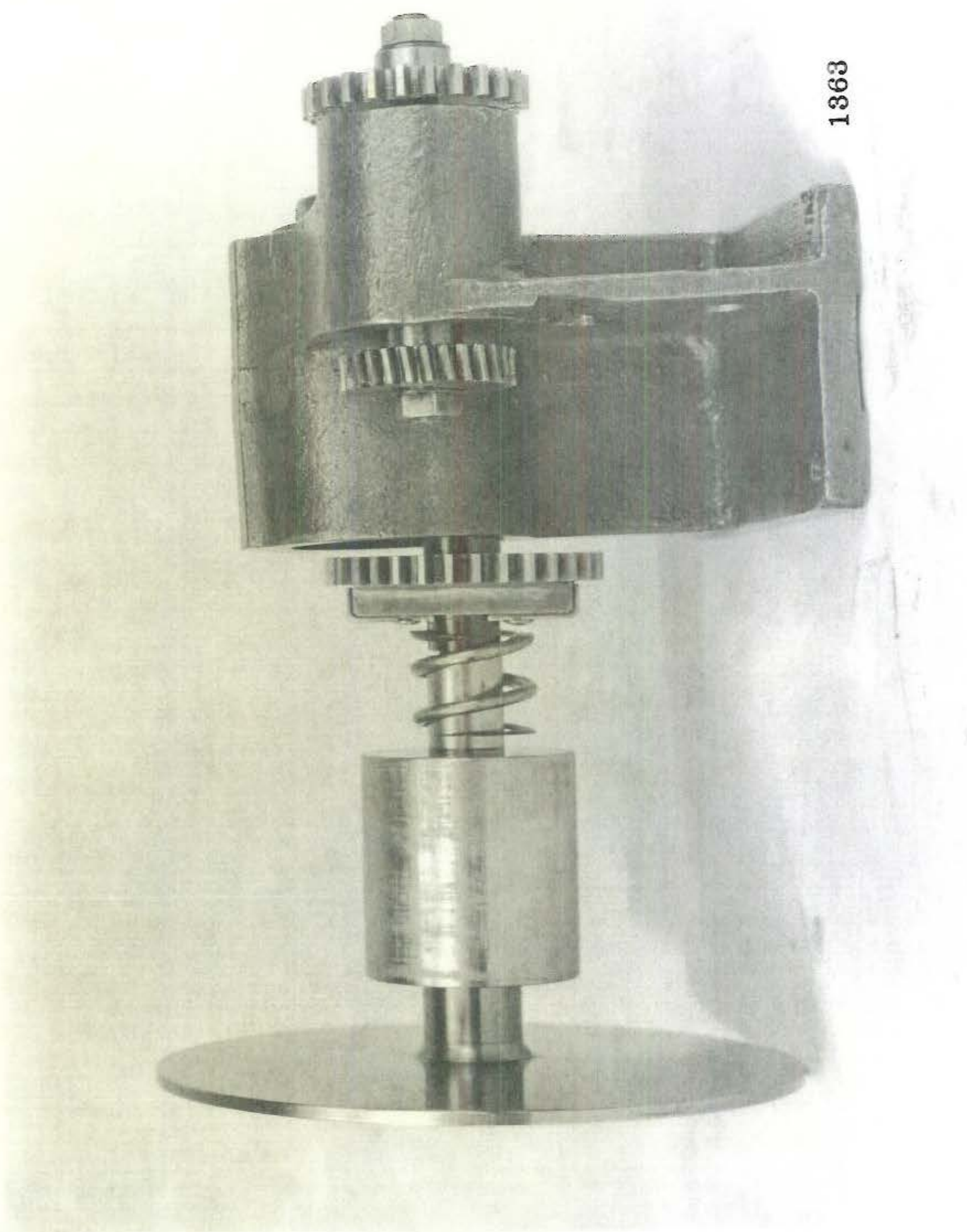

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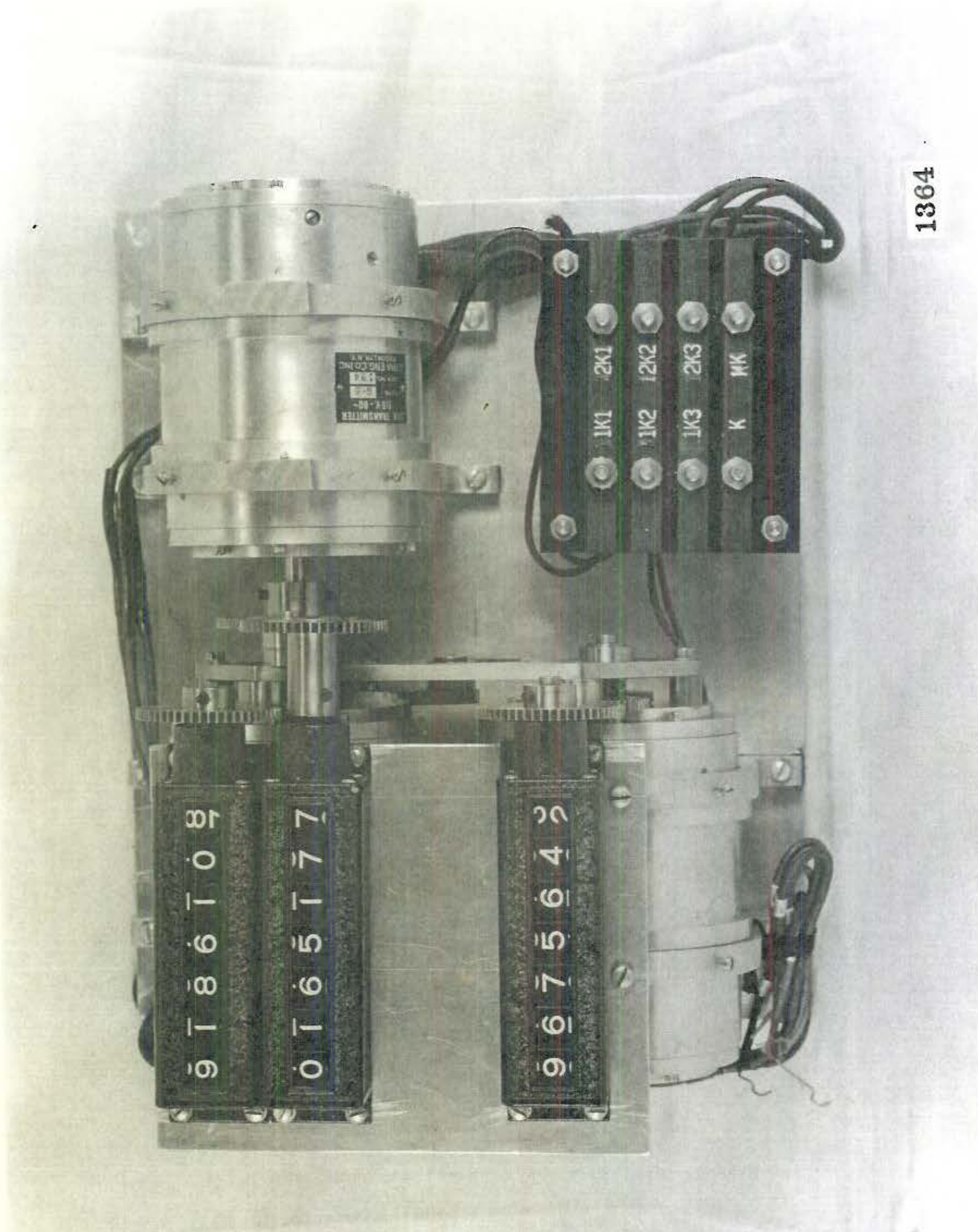

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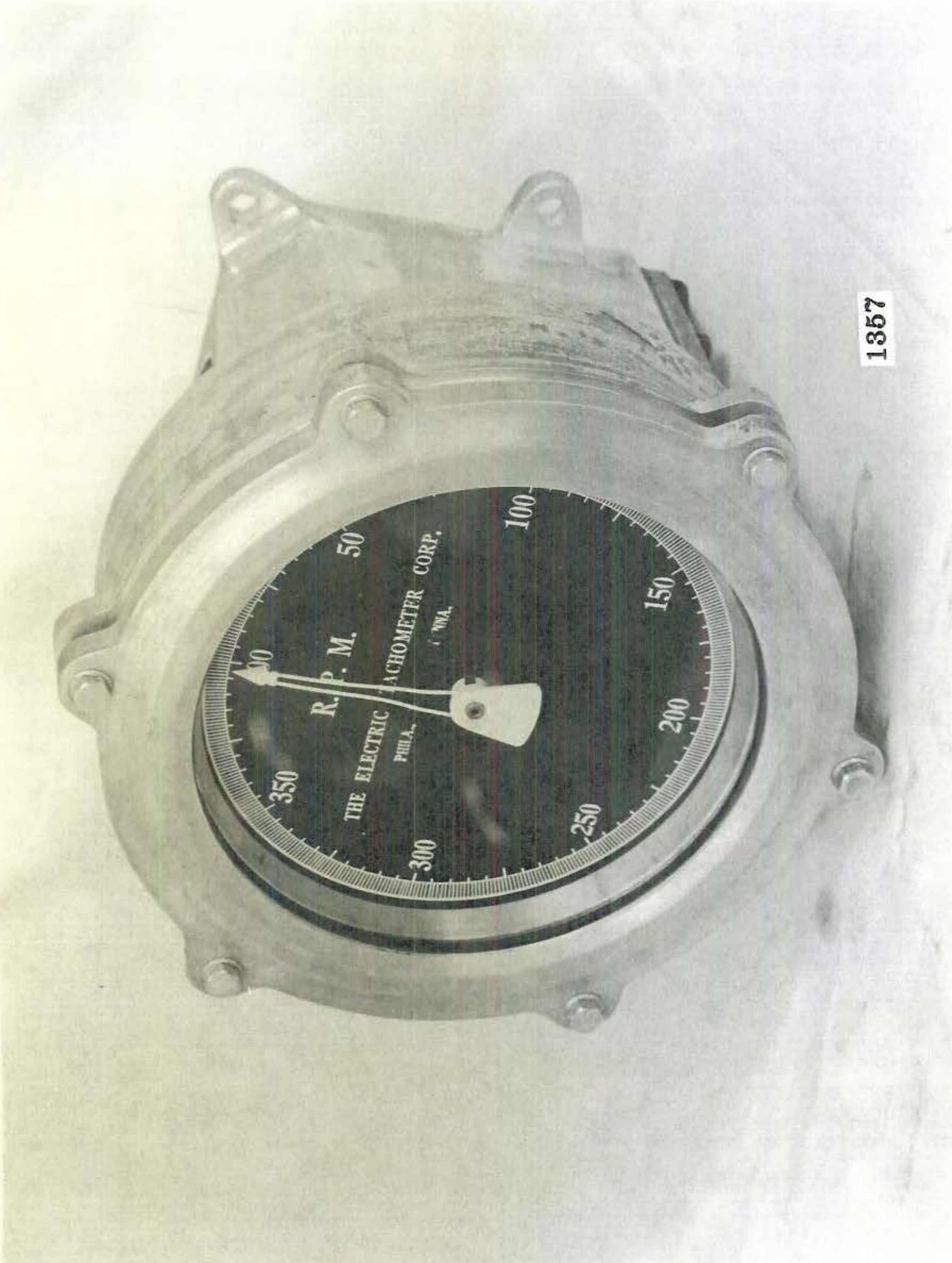

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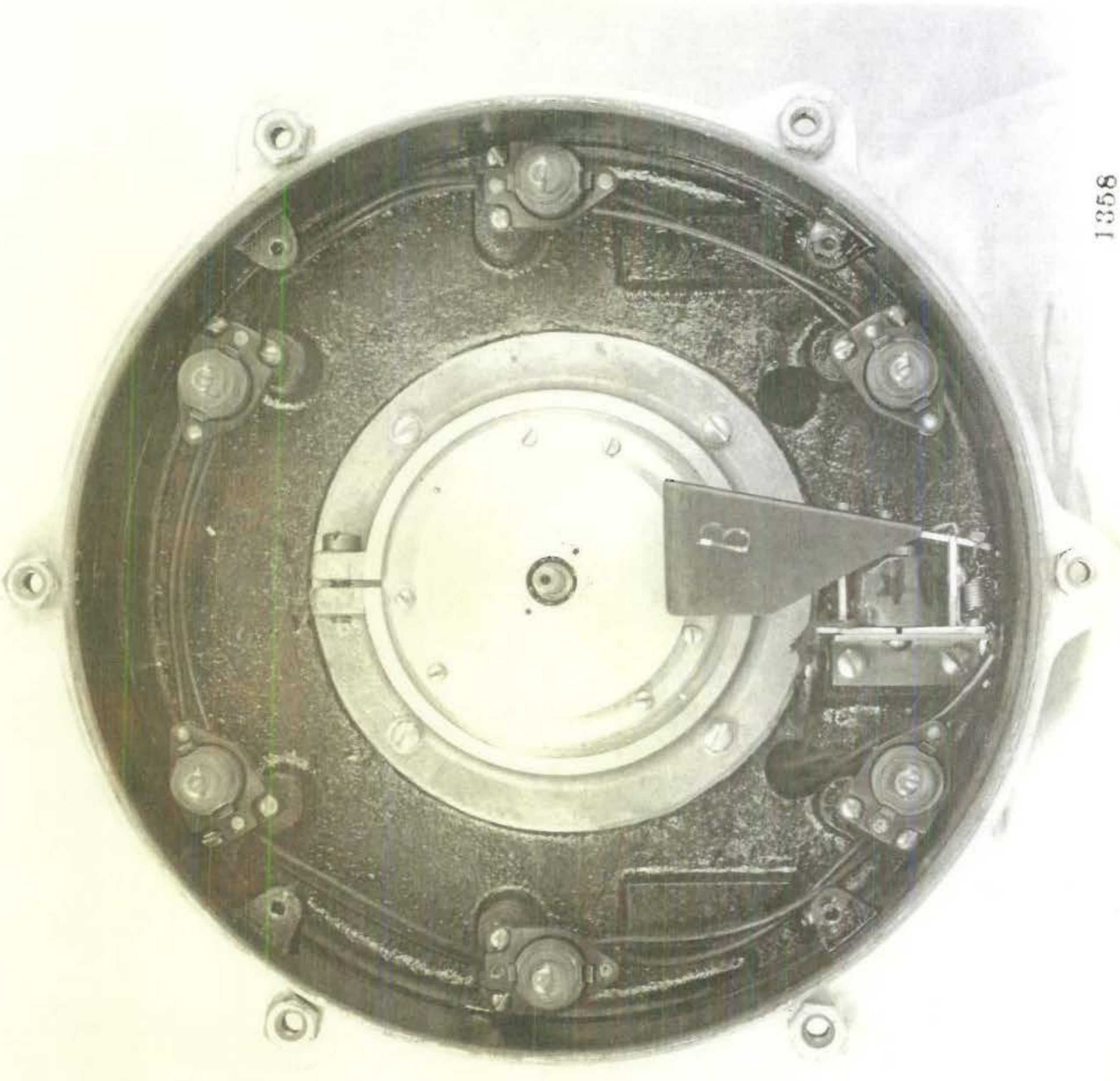

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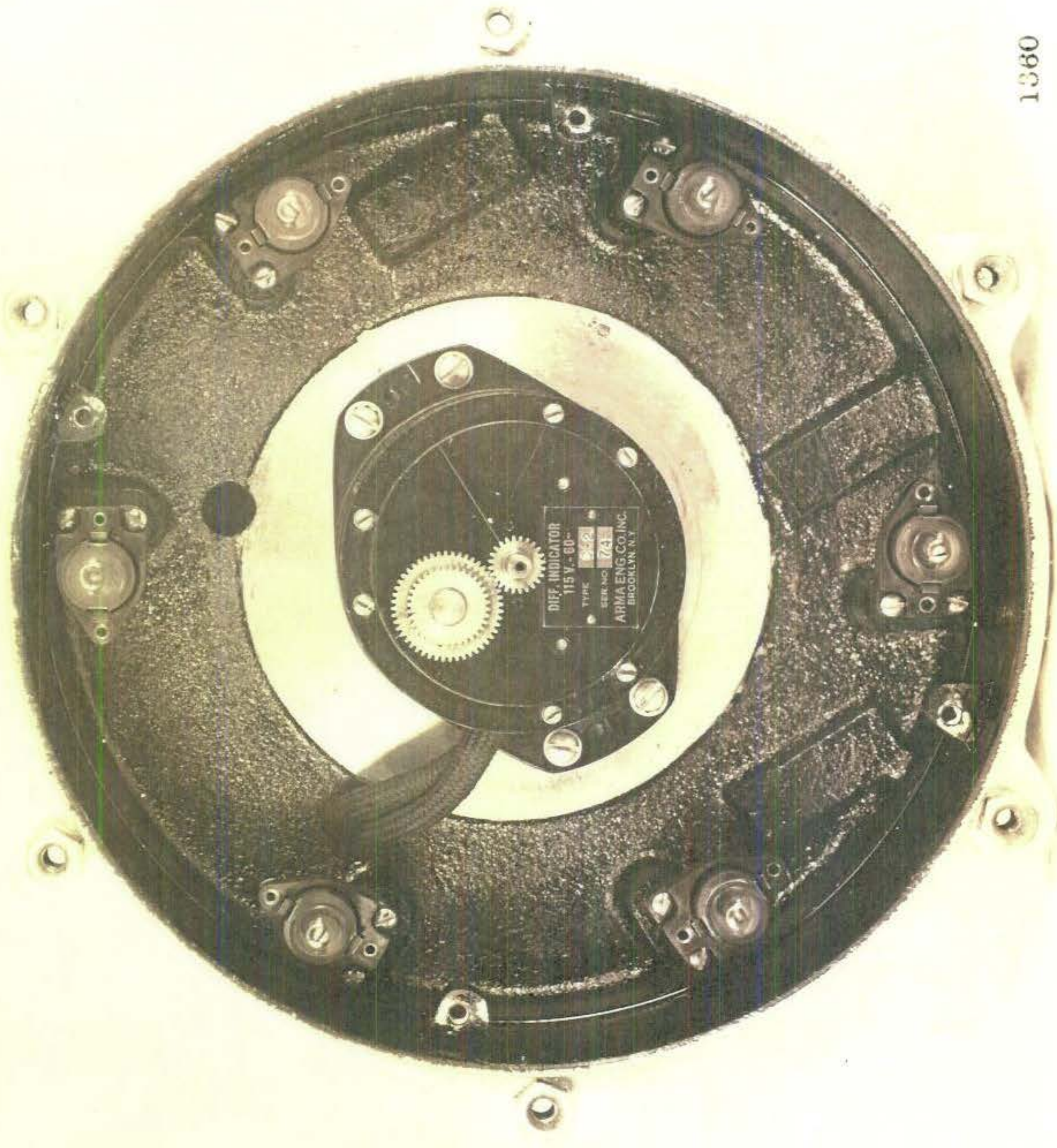
PLATE 8


DIFF. INDICATOR
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TYPE
SER. NO.
ARMA ENG. CO. INC.
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PLATE 9