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NAVY DEPARTMENT
BUREAU OF ENGINEERING

Report
on
Test of Propeller Shaft Revolution
Indicator System
Manufactured and Submitted
by the
Electric Tachometer Corporation
Philadelphia, Pa.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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AUTHORIZATION

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

Reference: (a) BuEng. ltr. NOs-42200(6-12-Ds) of 19 June 1935.
(b) Navy Dept. Specifications SGS(65)-10a of 1 March 1935.
(c) Navy Dept. Specifications SGS(65)-42 of 1 May 1934.
(d) Contract NOs-42200.

OBJECT OF TEST

2. The object of this test was to determine the suitability of this instantaneous type propeller shaft revolution indicator system for the Naval Service and its compliance with Navy Department Specifications, references (b) and (c).

ABSTRACT OF TEST

3. The system, shown by Plate 1, was set up at this Laboratory and closely observed while under test for conformance with specifications, reference (b). Both shaft transmitters were rotated ahead at a speed corresponding to shaft speeds of 400 r.p.m. for a period of 500 hours. The direction of rotation of both shafts was reversed for a period of one hour in every 24 hours. The total revolutions of the port and starboard shaft transmitters and the master indicator transmitters were compared daily and logged. All instruments were tested for shock integrity and examined to determine whether the material submitted was in strict accordance with the specifications.

Conclusions

This instantaneous type shaft revolution indicator system, manufactured and submitted by the Electric Tachometer Corporation, Philadelphia, Pennsylvania, for type approval under Contract N0s-42200, failed to comply with the specifications, reference (b), paragraphs F2c(2) and F2c(4)e as well as others outlined under "COMMENTS," paragraphs 57, 60, 61 and 63 of this report and is therefore unsuitable for Naval use.

Recommendations

(a) Inasmuch as this system failed to comply with the specifications, it is recommended that type approval be held in abeyance until the manufacturer corrects the defects, noted under "COMMENTS" of this report, and submits a complete system to this laboratory which satisfactorily meets the requirements of the specifications.

(b) It is also recommended that the manufacturer change the circuit of the argon lamps in the repeater indicator, so that every alternate lamp will be energized by the supply for No. 1 shaft and the remaining lamps for No. 2 shaft. This arrangement will permit dial illumination in case of failure of one of the shaft supplies.

(c) It is further recommended that the Bureau consider the advisability of requiring the manufacturer to embody in each of the master indicator transmitters, a ratchet protective device, allowing the friction wheel to drive the friction disc at shaft speeds exceeding 400 r.p.m. or in case of failure of the constant speed motor drive. Such a device was incorporated in the manufacturer's shaft revolution indicator system reported in NRL Report No. B-1118 of 24 January 1935. Under test, with the friction disc stopped, the friction wheel slipped against the disc and rotated occasionally. The remainder of the time the type M Selsyn motor was unable to overcome the friction between the wheel and disc. This caused both the transmitting and the receiving Selsyn to over-heat and if continued would undoubtedly have resulted in their failure.

(d) In addition, it is recommended that in future specifications for systems of this type the Bureau consider the advisability of eliminating the follow-up mechanism. In the subject system, the pointers of the master indicator transmitter are geared to the follow-up mechanism, rather than directly to the friction roller rack. The master instrument pointers will be affected if the interference torque of the Selsyn transmitter, caused by jamming one or more repeater indicators, exceeds the torque of the follow-up motor. Since a large percentage of the trouble encountered in the system has been due to erratic operation of the follow-up mechanism, and since it is believed that the self-positioning friction device can be built rugged enough to carry the load of the master instrument pointers and the Selsyn transmitter directly without error; the follow-up mechanism appears to be an unnecessary complication and a source of error rather than accuracy. However, if it is considered necessary to retain the follow-up mechanism in systems similar to the subject system, it is recommended that the master instrument pointers be geared directly to the rack of the self-positioning friction roller device, and that the follow-up mechanism be used only for positioning the Selsyn transmitter. The pointers will place but little load on the friction roller, and should there be a casualty in the Selsyn repeater circuits or to the follow-up mechanism, the indications of the repeater indicators only will be in error. The accuracy of the master instrument will be unaffected. This recommendation applies only to systems wherein the friction roller is positioned mechanically. In the system covered by

NRL Report No. B-1082 of 10 October 1934, the friction roller is positioned electrically by the same follow-up mechanism which moves the master instrument pointers and the Selsyn transmitter. The follow-up system cannot be eliminated in a system of this type, nor can the master instrument pointers be positioned independently of the follow-up mechanism.

(e) In conclusion, it is recommended that consideration be given the idea of transmitting propeller shaft motion to the master instrument by mechanical shafting rather than by a Selsyn system; or that they both be used, one acting as a stand-by to the other. It is believed that mechanical shafting would be dependable since it would be necessary to run only from each propeller shaft to its own master instrument.

DESCRIPTION OF MATERIAL UNDER TEST

4. The equipment, submitted under Contract NOs-42200, is designed for measuring the speeds of twin propeller shafts and operates from a supply of 115 volts, a.c., 60 cycles, with exception of the constant speed motors incorporated in the master indicator transmitter instruments, which must be energized from a 115 volt, a.c., 60 cycle, frequency controlled supply.

5. The following equipment was submitted:

	<u>Manufacturer's Drwg. No.</u>
2 Shaft transmitters	2100
2 Master indicator transmitters	2102
2 Repeater indicators	2103
1 Tell-tale indicator	2104

Shaft Transmitters

6. The shaft transmitters (Drawing No. 2100) are driven by means of bronze and phenolite spur gears from the propeller shafts through a ratio of 3:1, so that a speed of 400 r.p.m. of the propeller shaft produces a speed of 1200 r.p.m. at the main transmitter shaft.

7. The main transmitter shaft, which is housed in heavy ball-bearings and provided with a watertight stuffing gland, drives, through a reduction ratio of 15:1, a Selsyn transmitter, type A, manufactured by the Chas. Cory Corporation, Brooklyn, N. Y.

8. This drive is accomplished by means of a worm gear and a uni-directional gear, so that regardless of direction of rotation of the propeller shafts, the Selsyn transmitter always turns in the same direction. (Counter-clockwise when looking at its shaft end.)

9. A six figure revolution counter, counting unit revolutions of the propeller shaft, is driven independently through sprockets and a chain from the main transmitter shaft, so that the Selsyn motor may be removed from its housing without disturbing the functioning of the revolution counter.

10. With the uni-directional gear train is combined a contact switch which is connected to the direction of rotation signals located in the various indicators.

11. The transmitter case, cover, stuffing box and all internal brackets are made of composition BE. Standard square cross section rubber gaskets are used for watertightness. The counter is visible through a watertight glass window located in the top of the cover.

12. The function of the Selsyn motor in the shaft transmitter is to impart rotations of the propeller shaft to the motors located in

the master counter transmitter, master indicator transmitters and the tell-tale indicator. The speed of the Selsyn transmitter is 80 r.p.m. when the propeller shaft speed is 400 r.p.m.

Master Indicator Transmitter

13. In the master indicator transmitter is located a Selsyn motor connected to the Selsyn transmitter in the propeller shaft transmitter. This motor runs continuously in phase with the Selsyn transmitter, and is connected through a 1:1 spiral gear to a right-hand lead screw supported by double ball-bearings on which moves a rack and a hardened steel friction wheel approximately 2-3/8 inches in diameter.

14. The friction wheel engages a friction disc, driven at a constant speed of 60 r.p.m. by a Holtzer Cabot synchronous motor. A reduction drive between the 1800 r.p.m. synchronous motor and the friction disc is accomplished through a 30:1 worm gear. The friction disc is pressed against the friction wheel on the screw shaft by a steel spring located in its housing. When the propeller shaft is in motion, the friction wheel will assume a position on the friction disc where the surface speeds of the disc and wheel are equal. For any speed of the propeller shaft, there is a definite location for the friction wheel along the axis of the screw shaft. The displacement of the friction wheel along the screw shaft causes the rack to rotate a steel pinion located on a vertical ball-bearing mounted shaft. Attached to the rack is a lever arm which cuts off the constant speed motor driving the 60 r.p.m. disc, at zero shaft speed, by means of a "Burgess" micro switch. To prevent the rack from jamming against the screw shaft housing, when the shaft speed exceeds 450 r.p.m. (approximately), or the constant speed motor fails, a pin inserted in the shaft engages a pin projecting from the friction wheel. This causes the wheel to rotate with the shaft and slip where it contacts the friction disc.

15. The vertical shaft engages a contact making device, and a follow-up device, more fully described in paragraph 17.

16. From the screw shaft, which is running at a speed proportional to the speed of the propeller shaft, a six-figure counter is driven by means of a chain and sprockets. In this instrument is also located a red and black signal target to show "Back" or "Ahead" rotation of the propeller shaft through the operation of the contact switch located in the propeller shaft transmitter. The object of the follow-up contact mechanism is to actuate a reversible follow-up motor in order to set the indicating hands of the indicator to a position corresponding to the true r.p.m. of the propeller shaft. At the same time, the follow-up motor, through gearing, positions a Selsyn transmitter, type A, which positions the Selsyn motors, type M, located in the repeater indicators.

17. The action of the follow-up mechanism is as follows. On the end of the pinion shaft actuated by the rack on the screw shaft nut, is mounted a steel disc, approximately 1-3/4 inches in diameter, having a notch in its periphery. A follow-up switch or contactor is mounted

on a second (insulating) disc, parallel to and co-axial with, the notched operating discs. It normally shorts both forward and reverse shading coil circuits of the follow-up motor, but may open one or the other to give the desired direction of rotation. The contactor is operated by a small crank having a roller which normally engages the notch on the first disc. Displacement of the notch to a higher speed position turns the small crank out of its normal radial position and lifts the reverse contact arm from its contact. The other contact arm remains closed and allows the follow-up motor to operate and turn the hands (and the second disc carrying the contactor) up to the new position, the roller drops into the slot, the crank assuming its normal radial position, and the raised contact arm makes contact, renewing the short circuit on the reverse shading coils. This normal short on both forward and reverse shading coil circuits results in a strong inductive breaking effect on the rotor, which stops the follow-up system at a point corresponding to the new readings. Change to the lower speed indication is effected in the same way, the displacement opening the forward circuit until the new indication is duplicated by the follow-up system.

18. The case and cover of the master indicator transmitter are aluminum castings provided with square cross section rubber gaskets. The aluminum mounting plate for the various mechanisms is bolted in this case, and is provided with the necessary legs and lifting handles so that the complete assembly may be removed from the case and placed on a flat surface for inspection.

19. The dial diameter is 8" and the dial is divided into two concentric scales, one reading from 0 to 4 and denoting hundreds of r.p.m., the other reading from 0 to 100 and denoting units of r.p.m. A six-figure mechanical counter is located behind a slot in the dial. The dial is illuminated with VG2-N lamps.

Repeater Indicator

20. The repeater indicators consist mainly of two Selsyn motors, type M, responding to their respective Selsyn transmitters located in the port and starboard master indicator transmitters. The motors in the repeater indicator are geared to two concentric pointers, the starboard marked No. 1 and the port marked No. 2.

21. The dial is 7" in diameter and is graduated to read from 0 to 400 r.p.m. in divisions of 2 r.p.m. and is numbered every 20 r.p.m. It, as well as the pointers and the two direction targets, is to be painted with radium luminous material.

22. The case and cover of the repeater indicator are of cast aluminum, and the supporting plate for the motors, as well as most other parts, is of bronze. The case and cover are made watertight by means of standard square cross section rubber gasket.

Tell-tale Indicator

23. The tell-tale indicator contains two Selsyn motors, type M, which run continuously at the same speed as the Selsyn transmitters in

the propeller shaft transmitters. These motors are geared to a differential in such a way that a pointer fastened to the spindle rotates one complete revolution for a difference of twenty revolutions between the two propeller shafts.

24. When the leading shaft turns faster than the following shaft, the pointer turns in a counter-clockwise direction, but when the following shaft is faster than the leading shaft, the pointer turns in a clockwise direction. When the shafts are turning at the same speed, the pointer remains stationary. A direction target is provided to show the direction of rotation of No. 1, the leading shaft. In general design, the case and cover of the tell-tale indicator are identical with those of the repeater indicator.

METHOD OF TEST

25. The units submitted were first interconnected electrically and energized from a controlled frequency supply of 115 volts, a.c. 60 cycles. Two constant speed motors, connected to the same supply, were used to drive the shafts of the transmitters through reduction gears of suitable ratios.

26. The system was then tested for endurance by operating it at a speed of 400 r.p.m. for 500 hours, the direction of rotation of the transmitter shafts being reversed for one hour in every twenty-four. By direction of the Bureau, the endurance test was interrupted after 290 hours of operation in order to conduct shock tests. The test was then resumed until the system had operated for the remainder of the required 500 hours. During the endurance test, the total revolutions of the port and starboard shaft transmitter mechanical counters, and the port and starboard master indicator transmitter mechanical counters were compared daily.

27. The shock integrity of the system was ascertained by placing a representative unit of each type on a Bureau of Engineering shock machine, in the normal position, and subjecting it to 20 blows of 250-foot pounds each. During this test all instruments were connected in the system and operating at a speed of 400 r.p.m. All instruments were observed to note any change that might occur due to shock.

28. Next, the accuracy of the system was determined by operating it at speeds corresponding to shaft speeds of 60, 100, 150, 200, 250, 300 and 400 r.p.m., for periods of one hour clockwise and one hour counter-clockwise.

29. The system was then tested to determine whether the accuracy of the system would be effected by power supply variations of $\pm 10\%$ in voltage or of ± 5 cycles in frequency. During this test, the constant speed motors in the master indicator transmitters were separately energized from a controlled frequency supply.

30. A test was then made to determine whether the accuracy of the master indicator transmitters was effected by locking the pointers

of one repeater indicator instrument 90° out of phase with the indication of the master indicator transmitters. For example, the two repeater indicator pointers in one instrument were moved and locked at the 100 r.p.m. marking on the dial while the system was operating and the master instruments were indicating 400 r.p.m. shaft speed.

31. The system was then tested for its insulation resistance, dielectric strength and watertight integrity.

32. The test was concluded by observing the dial illumination in a dark room and inspecting the equipment for conformance with the specifications regarding material and workmanship.

RESULTS OF TEST

33. When the two pointers in one repeater indicator instrument were moved and locked at the 100 r.p.m. marking on the dial, while the shaft transmitter was being driven at a shaft speed of 400 r.p.m., No. 2 master transmitter indicator was effected and instead of indicating 400 r.p.m., there was an error of plus 4 r.p.m. No. 1 master indicator transmitter was unaffected.

Endurance Test

34. During the endurance test, with the system operating at 400 r.p.m., the master indicator transmitters, and consequently the repeater indicators, were frequently observed to be in error. The errors varied from -0.25 r.p.m. to +3.0 r.p.m. on the master indicator transmitters.

35. The latter part of the endurance test, conducted after application of shock, showed errors of approximately plus 0.5 to plus 2.5 r.p.m. on the master indicator transmitters. The application of 20 blows of 250-foot pounds each caused slight errors which were corrected by the system within 7 seconds after the blow was applied.

Accuracy Test

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

37. The maximum error of minus 4.25 r.p.m. occurred in No. 1 master indicator transmitter at a speed of 60 r.p.m. The data recorded during the test are given below.

Accuracy Test

<u>Shaft Speed</u> <u>r.p.m.</u>	<u>Master Instrument No. 1</u>		<u>Master Instrument No. 2</u>	
	<u>Indicated rpm</u>	<u>Error rpm</u>	<u>Indicated rpm</u>	<u>Error rpm</u>
60	55.75	-4.25	59.75	-0.25
100	96.25	-3.75	99.25	-0.75
150	146.5	-3.5	150.0	0.0
200	196.25	-3.75	199.25	-0.75
250	247.5	-2.50	249.5	-0.5
300	298.25	-1.75	299.75	-0.25
400	402.75	+2.75	400.5	+0.5

Note: The "Ahead" readings correspond exactly to those taken when the shafts rotated "Back."

38. The time required for the master transmitter indicator to indicate 400 r.p.m. starting from 0 was 34 seconds.

39. The minimum insulation resistance between all windings and ground was 200 megohms when measured with 1000 volt megger.

40. All instruments withstood the required dielectric test of 1500 volts, 60 cycle, alternating current, applied for one minute between each terminal and ground.

41. The current consumed by the constant speed motors in the master indicator transmitters was 0.5 amperes (total) at 115 volts, a.c., 60 cycles.

42. The current consumed by the remainder of the system was 5.4 amperes at 115 volts, a.c., 60 cycles.

43. The system was uneffected when its supply was varied from 103.5 to 126.5 volts and its frequency varied from 55 to 65 cycles.

44. The maximum distance from which any instrument dial could be clearly read was approximately three feet when viewed in a completely dark room.

45. No. 1 master indicator transmitter case leaked around the removable plate over the terminal strips. All other instruments were watertight when submerged in water to a depth of three feet for a period of one hour.

46. The 5 mfd. condenser used in conjunction with the capacitor type synchronous motor satisfactorily withstood 1000 volts, d.c., applied across the terminals for a period of one minute. Nothing leaked from the condenser can when subjected to a temperature of 150° F. for a period of four hours.

Weights and Dimensions

<u>Instrument</u>	<u>Weight</u>	<u>Dimensions</u>		
		<u>Height</u>	<u>Width</u>	<u>Depth</u>
Master indicator transmitter	70 lbs.	15"625	16"125	10"5625
Shaft transmitter	55 lbs.	12"75	10"9375	9"25
Repeater indicator	37.5 lbs.	12"875 dia.		8"875
Tell-tale indicator	40.5 lbs.	12"875 dia.		8"875

Material Inspection

Tell-tale Indicator

48. Bolts, piece 8, should be 5/16" - 18 instead of 1/4" - 20.

49. Provide steel inserts in instrument case for securing cap screws. Inserts should be raised slightly above the surface of the boss or steel shims should be provided to prevent piece 12, BE metal, from contacting aluminum. This instrument is for bulkhead mounting but should have been designed for gage board mounting, as required by paragraph E7, of SGS(65)10a.

50. Provide steel inserts in case for receiving screws for securing hand-hole cover, piece 4. Studs in aluminum alloy should be eliminated. The hand-hole cover should be located at the rear of the case as required by paragraph E-2c(3) of SGS(65)-42.

51. Bosses should be provided for nameplate securing screws.

Repeater Indicator

52. The present steel inserts in instrument case for securing cap screws should be raised slightly above the surface of the boss or steel shims should be provided to prevent piece 12, BE metal, from contacting aluminum.

53. The dial pointers and targets should be painted with radium paint (20 ML grade) having a coverage of two square inches per gram.

Master Indicator Transmitter

54. The hand-hole cover, piece 4, should be located at the rear of case, as required by paragraph E-2c(3) of SGS(65)-42. Steel inserts should be provided in the case for receiving screws for securing the cover.

55. Pieces 16, 17, 18, 19 and 39 are BE metal and are in contact with the aluminum support plate, piece 15. Where dissimilar metals, except steel, are in contact, the faying surfaces should be painted with bakelite varnish and baked or steel shims should be employed. Dowel pins should be provided in accordance with paragraph D-7 of SGS(65)-42.

56. It was observed that when the friction disc was pushed away from the friction wheel, the spring tension against the disc assembly was

insufficient to overcome the friction in the housing and return the disc to its normal position. The cast aluminum housing should embody a steel liner, as steel parts working in an aluminum cylinder are believed to be unsatisfactory.

COMMENTS ON RESULTS OF TEST

57. The system, in so far as the 500 hour endurance test was concerned, operated without breakdowns. However, there were errors in the r.p.m. indications throughout the test.

58. The accuracy test showed even greater errors in the r.p.m. indications of No. 1 master indicator transmitter, the greatest error occurring at the lowest shaft speed (60 r.p.m.). No. 2 master indicator transmitter had less than the allowable error throughout the endurance and accuracy tests.

59. The time required for the master indicator transmitters to correctly indicate a shaft speed of 400 r.p.m. starting from zero, was 34 seconds.

60. The dial illumination is unsatisfactory and the instruments cannot be read from a distance of six feet as required by the specifications.

61. The case of No. 1 master indicator transmitter was not watertight. No doubt this could be easily corrected.

62. When subjected to shock, the system showed no greater error than it did during the period of the endurance test, and there was no visible derangement or damage of parts.

63. The manufacturer has failed to comply with the specifications, relative to materials, as outlined in paragraphs 48 to 55, inclusive.

64. The Bureau's attention is invited to the fact that no frequency control equipment, master counter transmitter, or double intermittent counter accompanied this system.

CONCLUSIONS

65. This instantaneous type shaft revolution indicator system, manufactured and submitted by the Electric Tachometer Corporation, Philadelphia, Pennsylvania, for type approval, under Contract NOs-42200, failed to comply with the specifications, reference (b), paragraphs 2Fc(2) and F2c(4)e as well as others outlined under "COMMENTS," paragraphs 57, 60, 61 and 63 of this report and is therefore unsuitable for Naval use.

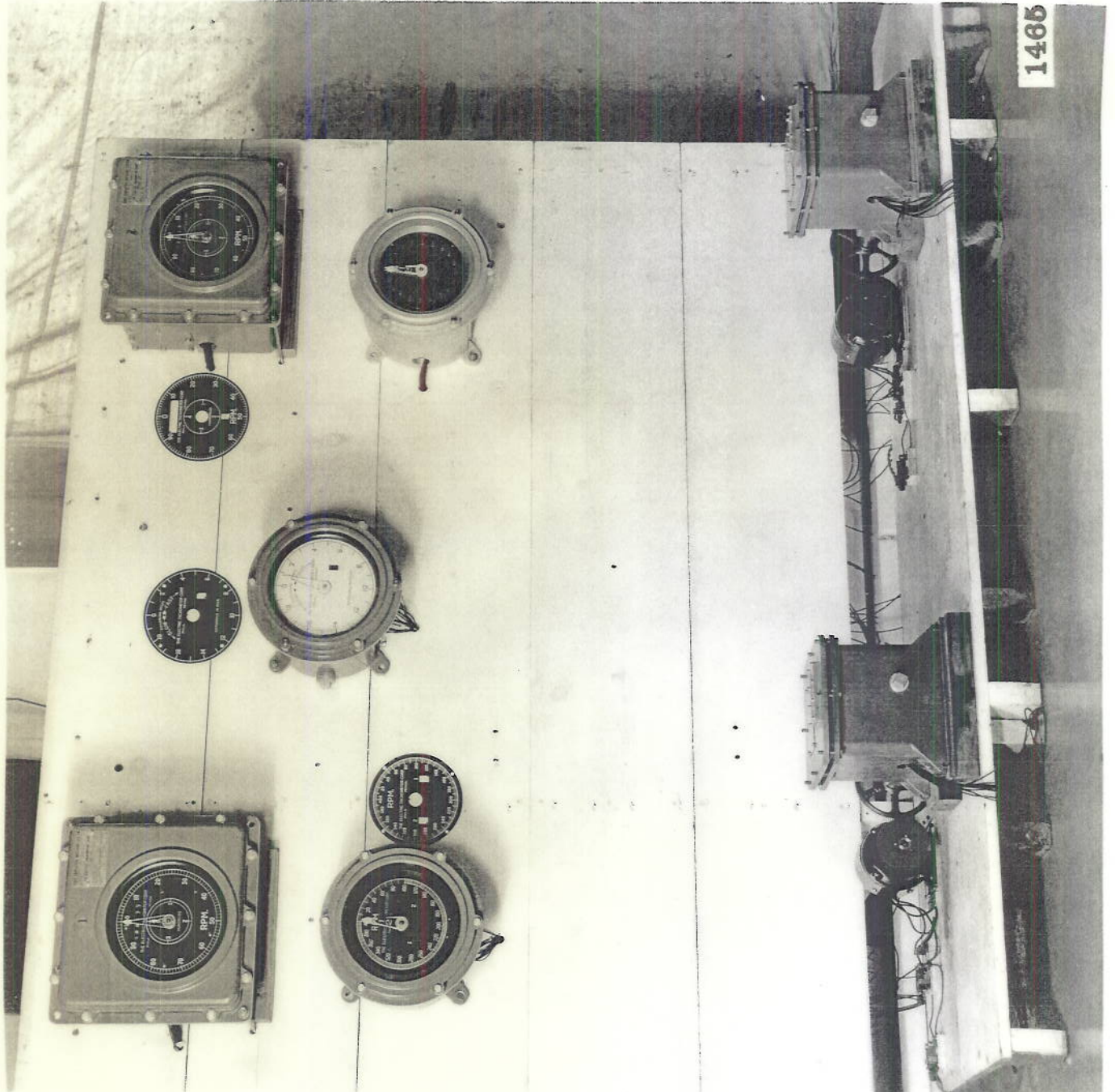
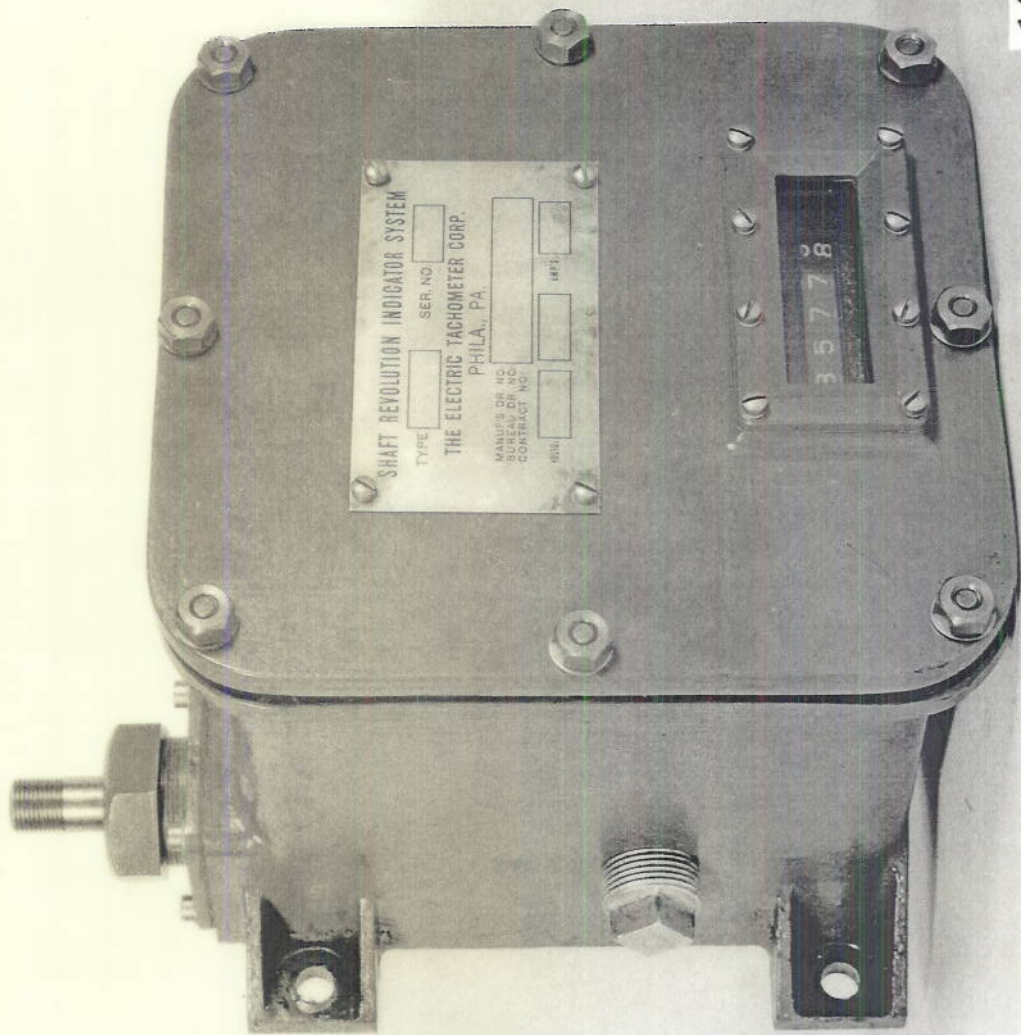
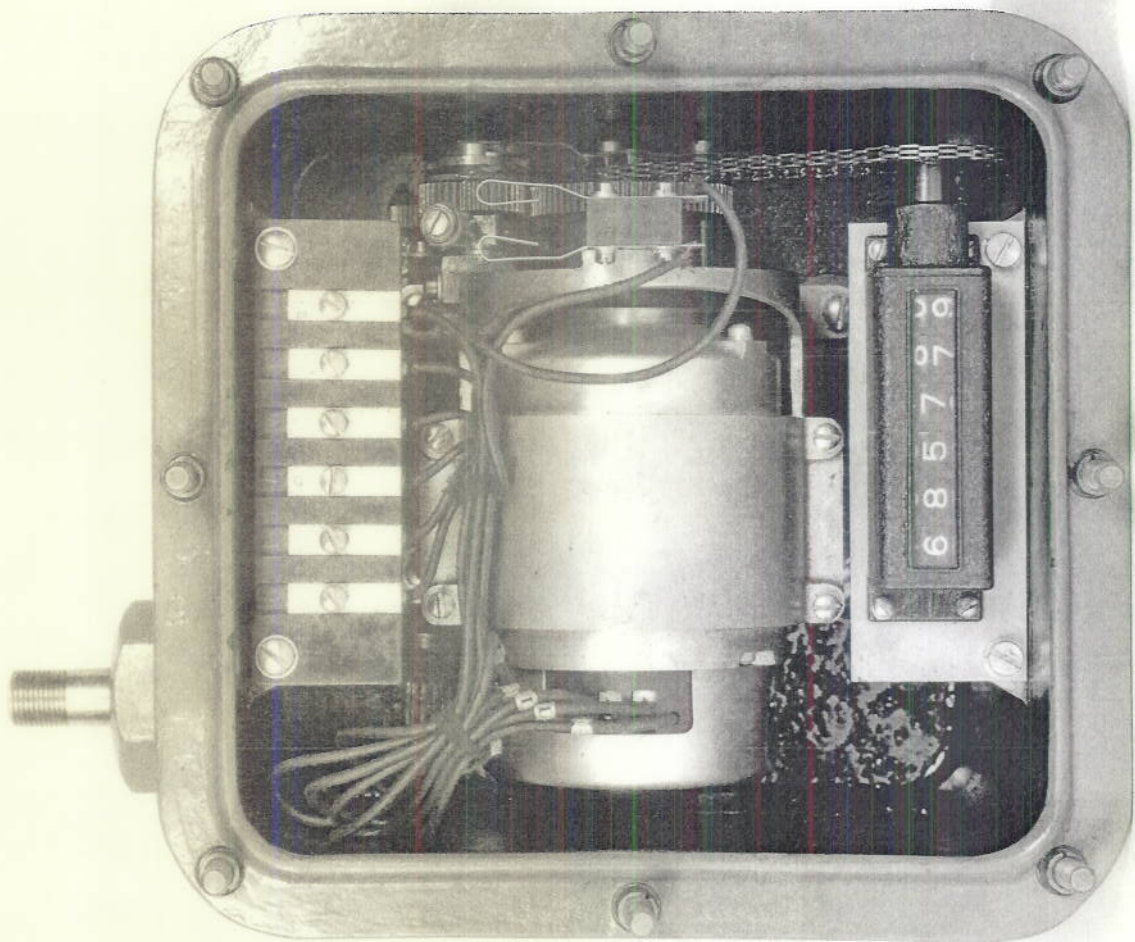


Plate 1



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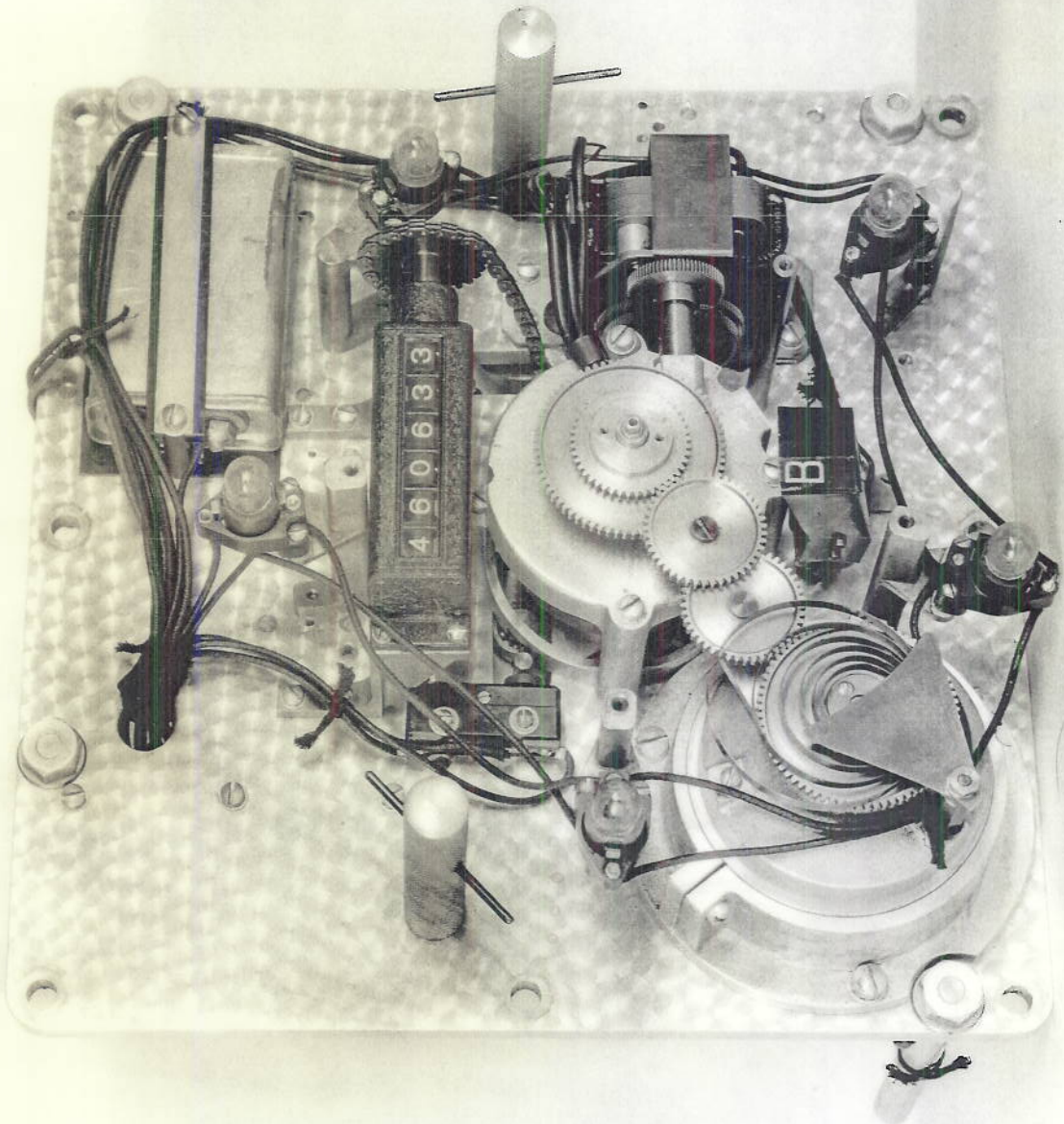


SHAFT REVOLUTION INDICATOR SYSTEM
 TYPE SER. NO.
 THE ELECTRIC TACHOMETER CORP.
 PHILA. PA.
 MANUFACTURED BY
 CONTRACTOR NO.
 DATE

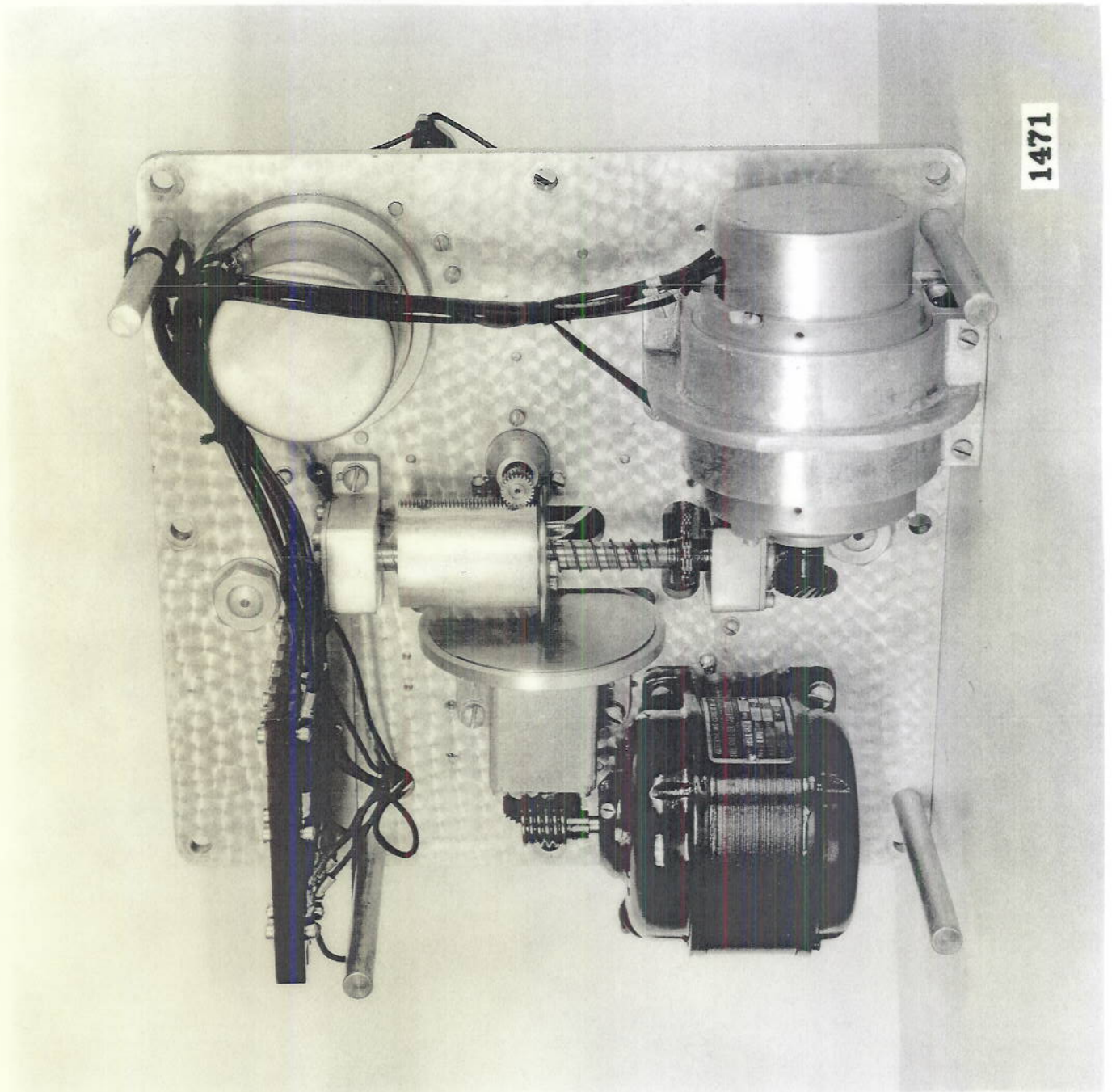
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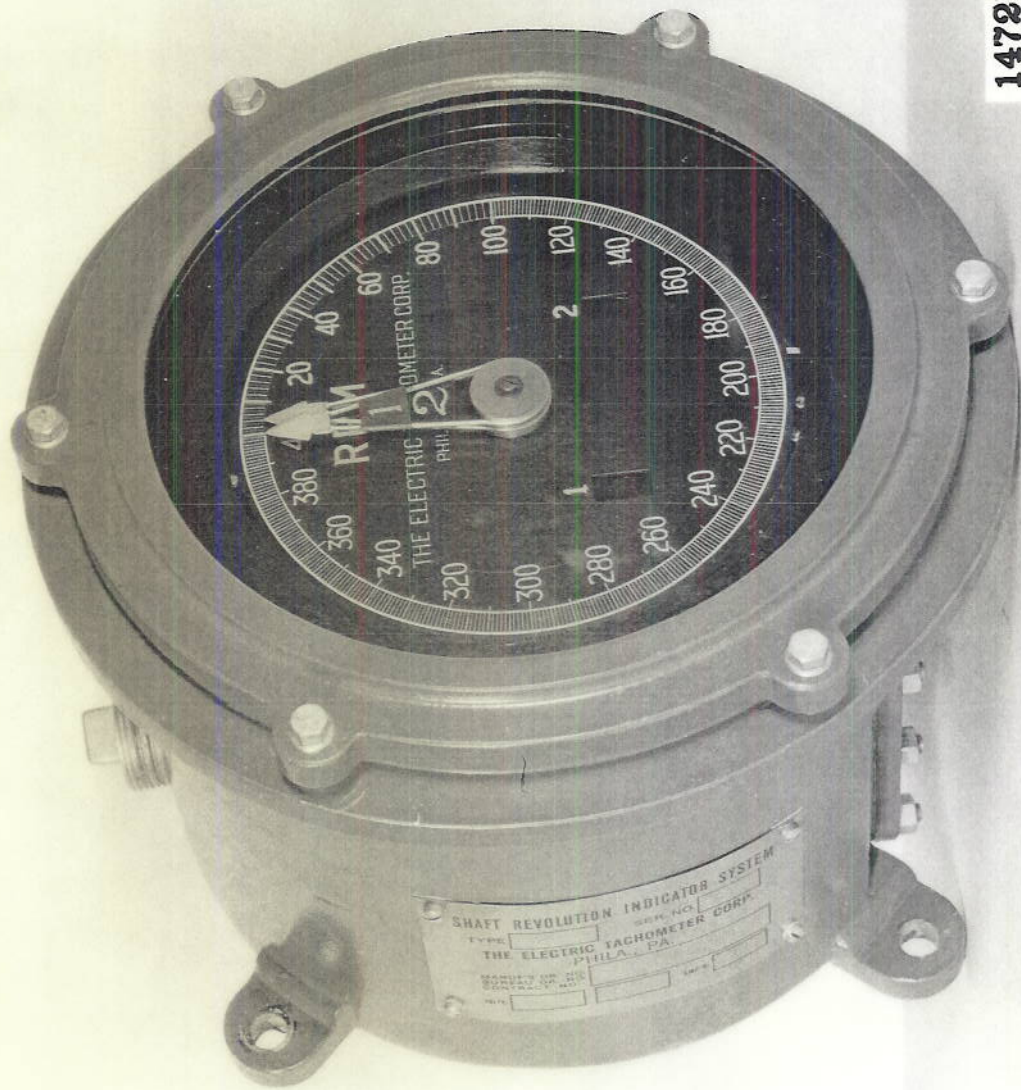
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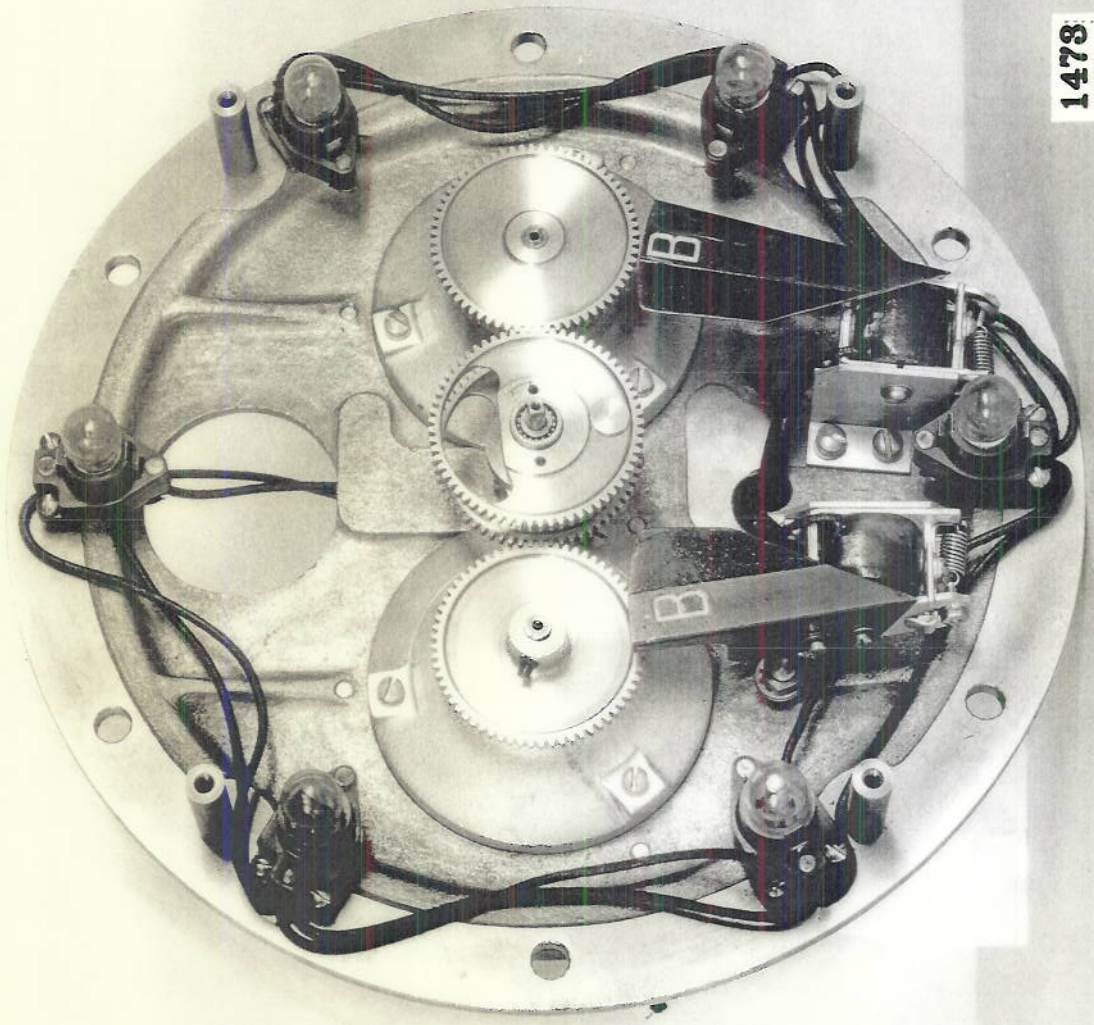
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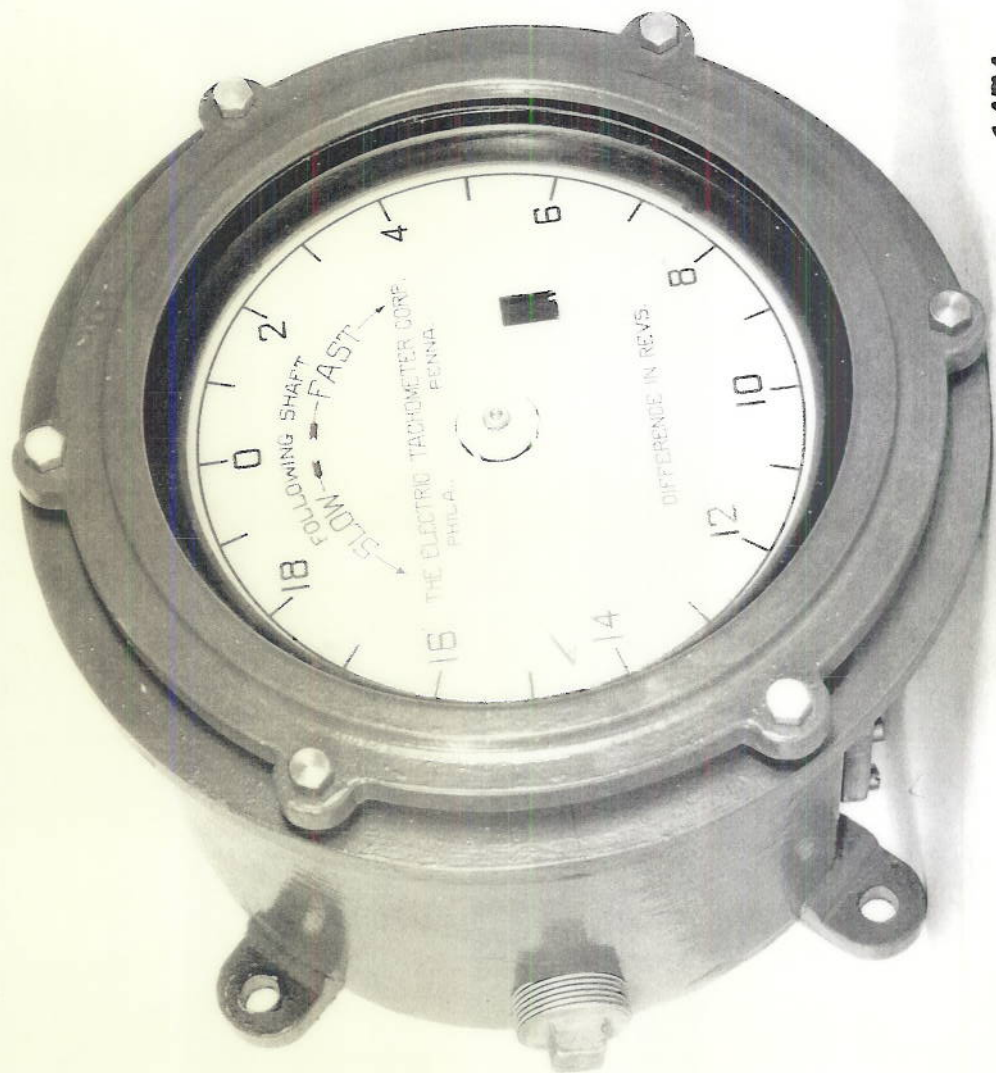
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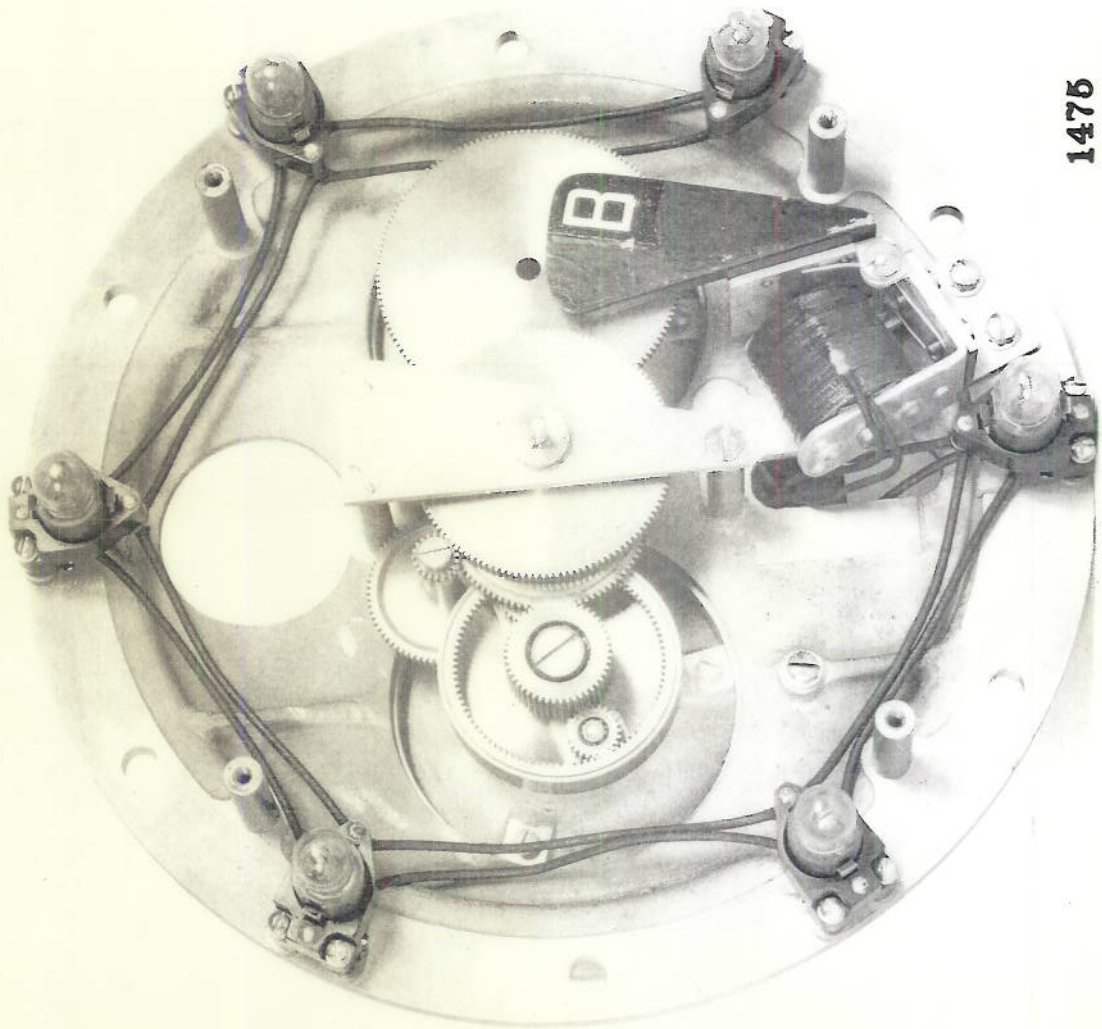
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