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SUBJECT

Report of Test

on

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Indicator-Motors, Navy Type "N"



by

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G. K. O. Hardesty



[redacted]

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NAVY DEPARTMENT

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on

# Indicator-Motors, Navy Type "N"

Henschel Corporation,

Manufacturer and Exhibitor

[redacted]

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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Date of Test: May, June, and July, 1940.

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## APPENDICES

AUTHORIZATION FOR TEST

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

Reference: (a) BuC&R and BuEng. ltr. BB57&9/S65 (4-12-SS) of 24 April 1940 to Director, NRL.
(b) Specifications SGS(65)42a of 15 February 1937.
(c) NRL Test Report B-1587.
(d) Henschel Drwg. No. 15-023 of Type "N" indicator-motor.
(e) BuEng. ltr. BB57&9/S65 (3-1-Df) of 22 March 1940 to INM, Boston, copy to NRL.

OBJECT OF TEST

2. The object of this test was to determine the conformity of the sample type "N" indicator-motors with the specifications, reference (b), and their suitability for Naval use in electrical telegraphs and indicating equipment.

ABSTRACT OF TEST

3. The sample motors were connected to a type "A" generator, furnished by the manufacturer, and tested for compliance with the specifications pertaining to accuracy, torque, and oscillation. The electrical characteristics were then determined and the motors and generator were subjected to the 500-hour endurance test.

4. Following endurance, the motors were again tested for accuracy. Then all bearings were cleaned and an accuracy test conducted on two of the motors. A final test of accuracy on these two motors followed a shock and vibration test. One motor was disassembled and checked against drawing, reference (d), and specification, reference (b).

Conclusions

(a) The subject type "N" indicator-motors comply with the specifications, as modified to permit a 1.5 degree error, except as follows:

(1) Following the endurance test, three motors had errors exceeding 1.5 degrees. The greatest error was 2.15 degrees. The two lower records of Plates 1 to 6, inclusive, show erratic response due to the condition of the bearings. The elongated traces on these records indicate that the motor shafts were creeping toward a position of less error during the exposure period. As shown by Plate 7, this loss of accuracy was not due to permanent damage, as the accuracy was greatly improved by cleaning and lubricating the bearings.

(2) An insulation breakdown occurred between the rotor and its windings in two of the five motors tested.

(3) The shell diameter exceeds the allowable value by 0".080.

(4) The bearings are not dustproof.

(5) The windings are of enameled instead of double silk or double cotton covered enameled wire, as required by the specification. However, this was waived by reference (e), subject to a satisfactory test.

(6) Following the endurance test, one of the ball bearings in No. 4 motor was found to have two balls in contact due to the failure of the ball retainer.

(b) The samples check with drawing, reference (d), except that the electrical characteristics given do not quite agree with the results of this test.

Recommendations

(a) It is recommended that the subject type "N" indicator-motors be approved for Naval use subject to correction of the deficiencies listed under "Conclusions," paragraphs (a)2 to (a)6, inclusive, and a satisfactory check test.

DESCRIPTION OF MATERIAL UNDER TEST

5. The following material was submitted:

6 - Type "N" indicator-motors
1 - Type "A" transmitter-generator

6. A generator positioning arm and index plate and six metal dials and pointers were also furnished for use in connection with the tests. Three motors were mounted on each of two sheet metal plates.

7. The motors are of the stationary field type. The terminals $R_1$, $R_2$ and $R_3$ connect to the rotor windings through silver slip rings and brushes. The terminals for all external connections are on insulating blocks.

8. The rotors are mounted in non-separable ball bearings. Brass shims are used to limit the end play. Further details of construction and design are given by drawing, reference (d), and photograph, Plate 8.

METHOD OF TEST

9. The type "N" motors were first tested to determine their accuracy, while all six were connected in a circuit and positioned by the type "A" generator. Tests were made while the circuit was supplied with current at 103.5 volts, 65 cycles, 115 volts, 60 cycles, and 126.5 volts, 55 cycles.

10. The equipment used for this test incorporated a shaft having a chuck on one end and a cylindrical housing on the other. The chuck grasped the shaft of the generator while the motor under test was mounted concentrically in the housing. By means of slip rings and brushes on the housing, a circuit was maintained between the generator and the motor.

11. By connecting leads $R_1$, $R_2$, and $R_3$ of the generator to $R_3$, $R_2$, and $R_1$ of the motor, the rotor of the motor should have remained stationary, while the work shaft and generator rotor were rotated. Movement of the motor shaft indicated an error which was measured by the reflected light method. This was accomplished through the use of a small mirror secured to the motor shaft.

12. By means of auxiliary test equipment, the work shaft was rotated through 3 degrees at a rate of 20 degrees per minute and the error in indication was recorded on sensitive paper mounted on a recording drum. As the light beam was blocked by a shutter except while the generator and motor were at rest, this was strictly a "static" test. The rotation was continued in 3-degree steps through 360 degrees in both clockwise and counter-clockwise directions. The five motors not being tested remained in the circuit as a load. Before starting each accuracy test, the generator and the motor under test were set to electrical zero and a zero reference mark was placed on the sensitive material.

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14. Torque tests were then conducted in the manner described by the specification. In addition, the maximum torque of each motor was determined.

15. The oscillation characteristics were ascertained by tests conducted in accordance with the specification, using an oscillographic method of timing. Only one motor was connected to the generator at a time in accordance with instructions received from Bureau of Ships personnel. The pointer was the one used for a previous test of this type motor reported by reference (c).

16. The electrical characteristics of several combinations of motors and generator were then measured. The maximum secondary voltages on all units were measured with a vacuum tube voltmeter.

17. The equipment was then subjected to an endurance test during which the motors and generator were placed in a compartment having an ambient temperature of 65 degrees centigrade. The generator was rotated for 500 hours at 100 r.p.m., the direction of rotation being reversed every 24 hours.

18. During the endurance test, the motors were mounted on a metal plate, as they were when received. The temperature rises of the windings were determined by resistance measurements made throughout this period.

19. Following this, all motors were again tested for accuracy at 115 volts, 60 cycles.

20. All motors were then disassembled and the bearings cleaned and lubricated with instrument oil. Due to a bearing failure, no further tests were conducted on No. 4 motor. Motor No. 1 was returned to the manufacturer at oral request of the Bureau. Motors Nos. 2 and 3 were then tested for accuracy with a total load of 4 motors connected to the generator. Two of these were shocked and vibrated and then checked for accuracy to determine whether the shock and vibration tests had damaged them.

21. The insulation resistances of the motors were measured with a 1000 volt "megger." The motors were then subjected to an alternating potential of 1500 volts, 60 cycles, applied between all windings and the case for a period of 1 minute. This potential was slowly built up in small steps with no interruption between steps.

22. Finally, an examination was made to determine compliance with the specifications pertaining to materials, design, dimensions, and workmanship and agreement with drawing, reference (d).

RESULTS OF TEST

23. The results of the test, and the order in which made, were as follows:

| Requirements | Test Values |
|---|---|
| Accuracy: Para. F-2c(2) modified to allow ± 1.5 degree error. | Complied before test for endurance. See Table 1 and Plates 1 to 6, incl. |
| Torque: Para. F-2c(3). | Complied. See Table 2. |
| Oscillation: Para. F-2c(4). | Complied. See Table 3. |
| Endurance: Para. F-2c(5). | No mechanical failures observed during test. |
| Accuracy following endurance: Para. F-2c(5). | *Three motors had errors greater than 1.5 degrees. Highest error 2.5 degrees. See Table 1 and Plates 1 to 6, inclusive. |
| Temperature rise during endurance run: Para. F-2c(6). | Complied. See Table 6. |
| Accuracy following cleaning and oiling of bearings: Not specified. | Complied. Two motors checked. See Table 1 and Plate 7. |
| Shock and Vibration: Paragraphs F-2c(8) and F-2c(9). | Complied. |
| Accuracy following shock and vibration: Not specified. | Complied. Two motors checked. See Table 1 and Plate 7. |
| Electrical characteristics: Not specified. | See Tables 4 and 5. |
| Dielectric and Insulation Tests: Paragraphs F-2c(11) and F-2c(12). | *Two out of 5 motors broke down between rotors and their windings. Insulation resistances of others satisfactory before and after dielectric test (above 200 megohms). |
| Compliance with drawing as requested by reference (a). | Complied. |
| Dimensions: Para. E-3c. | Outside shell diameter 2.268 between flanges. Max. allowed is 2.188. |

*Denotes non-compliance with specification.

CONCLUSIONS

24. The subject type "N" indicator-motors comply with the specifications, as modified to permit a 1.5 degree error, except as follows:

(a) Following the endurance test, three motors had errors exceeding 1.5 degrees. The greatest error was 2.15 degrees. The two lower records of Plates 1 to 6, inclusive, show erratic response due to the condition of the bearings. The elongated traces on these records indicate that the motor shafts were creeping toward a position of less error during the exposure period. As shown by Plate 7, this loss of accuracy was not due to permanent damage, as the accuracy was greatly improved by cleaning and lubricating the bearings.

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(f) Following the endurance test, one of the ball bearings in No. 4 motor was found to have two balls in contact due to the failure of the ball retainer.

25. The samples check with drawing, reference (d), except that the electrical characteristics given do not quite agree with the results of this test.

TABLE 1

Summary of Accuracy Tests - Maximum Errors in Degrees -
From Tables 1 to 7, Inclusive.
All 6 motors connected to generator.

| Test Conditions and Direction of Rotation | | Direction of Error | Motor Numbers 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|
| Before endurance 115 volts 60 cycles | CW | + | .32 | .75 | 1.10 | .40 | .60 | .44 |
| | | - | .77 | .70 | .78 | .72 | .80 | .76 |
| | CCW | + | .73 | .55 | .79 | .68 | .81 | .90 |
| | | - | .30 | .98 | 1.00 | .44 | .51 | .38 |
| Before endurance 126.5 volts 55 cycles | CW | + | .46 | .80 | 1.24 | .50 | .65 | .80 |
| | | - | .91 | 1.22 | 1.05 | .80 | 1.17 | .90 |
| | CCW | + | 1.15 | 1.30 | 1.20 | 1.06 | 1.08 | 1.02 |
| | | - | .39 | .68 | 1.10 | .30 | .60 | .68 |
| Before endurance 103.5 volts 65 cycles | CW | + | .30 | .54 | .75 | .40 | .48 | .38 |
| | | - | .92 | 1.25 | .55 | .90 | .82 | .74 |
| | CCW | + | .60 | .80 | .77 | .74 | .45 | .40 |
| | | - | .22 | 1.06 | .68 | .40 | .45 | .52 |
| After endurance 115 volts 60 cycles | CW | + | .56 | .88 | .69 | 0 | .30 | .56 |
| | | - | 1.87 | 1.43 | 2.15 | 1.60 | 1.33 | .96 |
| | CCW | + | 1.27 | .80 | 1.03 | 1.11 | .78 | .60 |
| | | - | 1.10 | 1.23 | 1.56 | 1.10 | .77 | 1.00 |
| After* endurance and cleaning bearings 115 volts 60 cycles | CW | + | | .66 | .80 | | | |
| | | - | | .73 | .67 | | | |
| | CCW | + | | .68 | 1.00 | | | |
| | | - | | 1.22 | .77 | | | |
| Final test* after shock and vibration 115 volts 60 cycles | CW | + | | .74 | 1.08 | | | |
| | | - | | .53 | .45 | | | |
| | CCW | + | | .50 | .88 | | | |
| | | - | | .86 | .62 | | | |

*Note: Only 4 motors connected to generator during these tests.

TABLE 2

Torque and Torque-Gradient in Inch-Ounces -
Single Motor Connected to Generator

| Displacement in Degrees from Electrical Zero | Motor Numbers | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| CW | | | | | | |
| 1 | .166 | .158 | .108 | .116 | .129 | .166 |
| 2 | .306 | .317 | .258 | .269 | .297 | .335 |
| 3 | .474 | .467 | .412 | .452 | .442 | .487 |
| 4 | .624 | .634 | .578 | .596 | .604 | .644 |
| 5 | .776 | .807 | .722 | .762 | .766 | .810 |
| 6 | .941 | .952 | .896 | .914 | .920 | .971 |
| 7 | 1.093 | 1.108 | 1.032 | 1.057 | 1.059 | 1.112 |
| 8 | 1.243 | 1.269 | 1.192 | 1.219 | 1.211 | 1.285 |
| 9 | 1.395 | 1.428 | 1.330 | 1.394 | 1.370 | 1.439 |
| 10 | 1.544 | 1.584 | 1.492 | 1.566 | 1.524 | 1.611 |
| CCW | | | | | | |
| 1 | .145 | .137 | .195 | .195 | .150 | .129 |
| 2 | .300 | .362 | .352 | .343 | .330 | .297 |
| 3 | .446 | .454 | .498 | .514 | .473 | .447 |
| 4 | .602 | .603 | .649 | .677 | .615 | .605 |
| 5 | .748 | .750 | .813 | .836 | .785 | .773 |
| 6 | .910 | .909 | .966 | 1.005 | .919 | .926 |
| 7 | 1.060 | 1.155 | 1.106 | 1.142 | 1.086 | 1.076 |
| 8 | 1.239 | 1.211 | 1.269 | 1.313 | 1.225 | 1.234 |
| 9 | 1.383 | 1.344 | 1.423 | 1.446 | 1.391 | 1.396 |
| 10 | 1.530 | 1.515 | 1.561 | 1.630 | 1.518 | 1.544 |
| Torque Gradient | .154 | .155 | .152 | .160 | .152 | .157 |
| Maximum Torque | | | | | | |
| CW | 12.10 | 12.58 | 12.79 | 12.35 | 12.54 | 12.46 |
| CCW | 11.65 | 11.90 | 11.36 | 11.53 | 11.72 | 11.59 |

Note: Maximum torque at approximately 98°.

TABLE 3

Oscillation Test: Time (in seconds) required for "Standard" indicator pointer to come to rest as determined by the oscillograph method. One motor connected to generator.

| Motor No. | Degrees Displacement | Time for Pointer to Come to Rest |
|---|---|---|
| 1 | 180 | 1.03 |
| 2 | 180 | 1.33 |
| 3 | 180 | .93 |
| 4 | 180 | 1.18 |
| 5 | 180 | 1.01 |
| 6 | 180 | 1.31 |
| 6 | 90 | 1.10 |
| 6 | 20 | .92 |
| 6 | 10 | .65 |
| 6 | 5 | .40 |

TABLE 4

Electrical Characteristics of Generator and Motor Combinations Tested at 115 Volts, 60 Cycles.

| Equipment | Motors Free to Indicate | | One Motor Rotor Locked 180° Out of Position | |
|---|---|---|---|---|
| | Amps. | Watts | Amps. | Watts |
| 1 Gen. - 6 Motors | 1.84 | 40.4 | 2.35 | 167.0 |
| 1 Gen. - 5 Motors | 1.63 | 35.6 | 2.15 | 160.0 |
| 1 Gen. - 4 Motors | 1.42 | 29.8 | 1.93 | 150.0 |
| 1 Gen. - 3 Motors | 1.16 | 23.8 | 1.70 | 140.0 |
| 1 Gen. - 2 Motors | 0.95 | 18.4 | 1.57 | 132.0 |
| 1 Gen. - 1 Motor | 0.75 | 12.2 | 1.40 | 122.0 |
| 1 Gen. Alone | 0.48 | 7.0 | -- | -- |

Note: Values given in last two columns are approximate as windings heat rapidly and produce unstable readings.

TABLE 5

Maximum induced voltages (r-m-s) as indicated by a vacuum tube voltmeter. Units not inter-connected.

| Equipment | Winding Measured | | |
|---|---|---|---|
| | $R_1 - R_2$ | $R_2 - R_3$ | $R_1 - R_3$ |
| No. 1 Motor | 92 | 92 | 92 |
| No. 2 Motor | 92 | 92 | 92 |
| No. 3 Motor | 92 | 92 | 92 |
| No. 4 Motor | 92 | 92 | 92 |
| No. 5 Motor | 92 | 92 | 92 |
| No. 6 Motor | 92 | 92 | 92 |
| Generator | 91 | 91 | 91 |

TABLE 6

Maximum temperature rise of windings in degrees Centigrade as measured during endurance test at 65 degrees Centigrade.

| Equipment | Winding Measured | | | |
|---|---|---|---|---|
| | $S_1 - S_2$ | $R_1 - R_2$ | $R_2 - R_3$ | $R_1 - R_3$ |
| No. 1 Motor | 16.0 | 10.8 | 10.8 | 10.5 |
| No. 2 Motor | 17.2 | 12.0 | 13.7 | 12.0 |
| No. 3 Motor | 19.0 | 14.8 | 13.8 | 13.7 |
| No. 4 Motor | 22.6 | 16.4 | 15.2 | 15.7 |
| No. 5 Motor | 21.2 | 15.7 | 15.6 | 16.0 |
| No. 6 Motor | 23.5 | 17.6 | 16.4 | 17.2 |
| Generator | 29.9 | 18.2 | 17.9 | 17.9 |