Electric Motor Repairing Specification – 2012

Rewind/Repair Processes for Electric Motor Efficiency Retention

Green Motors Practices Group
A Non-Profit Corporation

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1.0 INTRODUCTION

This Specification covers Green Motors Practices Group's (GMPG) repair and rewind efficiency retention protocol for low and medium-voltage random-wound and form-coil three-phase AC squirrel cage induction motors and describes minimum requirements for repair and overhaul of such machines. Note: Motors used in hazardous environments shall have all explosion-proof features maintained and recertified in accordance with UL674 or CSA required equivalent.

2.0 INITIAL INSPECTION and DISASSEMBLY

2.0.1 Initial inspection of machinery shall, within practical limits, include, but not be limited to, testing and digital imaging to document each motor's as-received condition and configuration. If tests and inspection indicate defects of a potentially catastrophic nature, the service provider shall contact the machine's owner or the owner's designated representative, and give a description of the defects. The description may include digital pictures and an estimate of the potential effect of the defects on the motor's reliability and energy consumption, and on the expected time and cost to complete the repair.

2.0.2 Disassembly minimum process shall include:

- Perform match-mark to identify external and internal component configuration for correct reassembly;
- Perform insulation resistance test of insulated stationary and rotating components;
- Identify and locate needed equivalent replacement components;
- Store disassembled machinery protected and isolated from unrelated components.

2.1 WINDING REMOVAL

2.1.1 Winding Data – Precisely record winding data prior to winding removal to permit replication of the original configuration. If the motor is more than two-pole, replacing a concentric configuration with a lap winding configuration is preferred when appropriate, and is permissible if: (1) the replacement does not affect the winding's magnetic densities, harmonic content, or current densities by more than 2% , and (2) the replacement reduces current density (increases wire cross sectional area per ampere). Otherwise, the total cross sectional area of a turn, the turns per coil, the span and connection of the coils shall not change. Where practicable, repairer may reduce end turn extensions, but may not increase them.

2.1.2 Core Loss – Conduct core-loss tests on all stators. Compare both before and after stripping and iron repair to check for damaged inter-laminar insulation. The tests shall be at a flux density of 85,000 lines per square inch RMS[1]. Repairer shall record exciting current and watts loss each time, as well as carry out a temperature check for hot spots and overall core heating. If data from previous core tests are available, repairer shall compare the results at a similar magnetic flux density. If hot spots exceed 15° C[2] above the ambient temperature after 15 minutes, or losses are excessive overall after stripping, repairer shall remedy and/or discuss with the customer before proceeding. For a core with less than 15° C hot spots, the losses after stripping shall not be more than four watts per pound, and not more than 20% higher than the pre-strip losses[3]. To avoid misleading comparison of results, repairer must not conduct the second core loss test with post-stripping measurement adjustments (i.e., use initial test core dimensions), or until the cleaning and drying of the core is complete. If the initial and post-stripping core measurements vary,

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[1] IEEE 112 Segregated no-load saturation test, EASA Tech Note 17
[2] CSA392-11, Testing of three-phase squirrel cage motors during refurbishment pg. 12
[3] CSA C392.11, Testing of three-phase squirrel cage motors during refurbishment pg. 12

repairer shall perform a second post-stripping core test, using the corrected dimensions; the watts loss per pound and temperature-rise shall comply with the criteria given above.

2.1.3 Burn Out – Prior to each operation of a heat-cleaning (burn-off) oven, repairer shall verify by visual inspection that the water mist temperature control system is operational. Repairer shall strip the winding clean in a controlled temperature burnout oven where (1) the part temperature is monitored by a fixed location sensing probe attached to the upper half of the stator bore, and; (2) the calibrated temperature is limited by means of fuel control and supplementary (water spray) cooling to 370°C (700°F). If a higher temperature becomes necessary, the repairer shall reference manufacturer communication or documentation indicating that the core iron can safely withstand the temperature, and shall confirm this by the core loss test. It is acceptable to chemically or mechanically strip windings provided that, (1) no open flame contacts or overheats the laminations, and; (2) no core plate is flared or teeth splayed (bent).

2.1.4 Winding Extraction – Avoid lamination damage due to coil cutoff, coil extraction, or splaying of teeth.

2.2 CORE PREPARATION

2.2.1 Iron Damage – Before proceeding with the repair, correct and report to the machine's owner all obvious iron damage and significant frame damage, plus any defects indicated by a core loss test as defined in section 2.1.2.

2.2.2 Method of Repair – Select the most appropriate method based on the following information:

2.2.2.1 Grinding – Limited grinding and de-burring of the lamination core-plate may be acceptable provided dimensional integrity of the slots and/or bore remains unchanged, and lamination insulation integrity is maintained. Correct any smeared bore tooth-tops before proceeding.

2.2.2.2 Removal of lamination(s) –It is unacceptable to remove individual lamination(s) without replacing them with an equivalent material. However, it is acceptable to restack part or all of the assembly with the same number of de-burred, undamaged laminations if they have the same material composition, dimensions, and inter-laminar insulation characteristics as the original core-plate assembly.

2.2.2.3 Chemical inter-laminar re-insulation process – A re-insulation solution capable of withstanding future burn-off oven processing is permitted provided core-plate integrity remains uncompromised and core-loss test results remain within the parameters of section 2.1.2.

2.2.2.4 Mica between lamination – Inserting split mica between the laminations is permitted provided the lamination assembly dimensions remain unchanged.

2.3 WINDING

2.3.1 Insulation system shall be equal to or better than the insulation classification temperature rating of the original system installed by the manufacturer. Individual insulation system components shall be compatible as a group, and suitable for the intended operational environment.

2.3.2 Conductors and conductor cross sectional area shall be equal to or greater than the area (of total conductors per turn) and conductivity of the original materials supplied by the manufacturer. Magnet wire shall be spike resistant and variable frequency drive rated.

2.3.3 Stator coil(s) extension shall not be greater than original extension from core-plate, nor can the extension increase I^2R losses. Repairer shall pay particular attention to this action to minimize crossed slot conductors.

2.3.4 Coil-to-coil connections shall be equal to or greater than the conductivity of the winding conductors and nameplate insulation class rating. Before proceeding, neutralize any/all connection compounds and/or chemicals as per manufacturer's instructions.

2.3.5 Impregnation method shall include preheating, treatment, and curing of stator with materials suitable to the operating temperature and environment in which the equipment is to operate[4], or per the machine's owner requirements, whichever is more stringent.
2.3.6 Winding D.C. resistance tests using a DC resistance bridge or equivalent. Conduct the test to determine unbalanced winding coil groups or high resistance connections. Lead-to-lead or phase resistance temperature corrected measured results should be less than 2% unbalance for random, and less than 1% unbalance for form wound stators.[5]

2.4 ROTOR TEST AND REPAIR

2.4.1 Testing shall be conducted for damaged bars and end rings, whether the motor-rotor is suspect or not. This test shall apply a stable single-phase voltage to the stator of the assembled motor, while a slowly rotated shaft makes (at least) one revolution. Variation of stator current in excess of 3% is an indication of a rotor defect. When repairer suspects electrical or mechanical defects with the rotor, or if the stator winding is defective, repairer may conduct one or more of the following additional tests[6]:

- Growler test
- Current analysis or vibration analysis of a loaded motor
- Physical examination
- Ultrasonic or magnetic impression examination of the bars and end rings
- Core loss tests (axial current thorough shaft)

2.4.2 Repair of rotor squirrel cages can be excessively expensive and difficult; further work may be unwarranted. Repairer may not use GMPG compliant identification if they determine that a rotor has failed or may be defective and un-repairable. However, this does not preclude repairer from re-barring and/or replacing rotor bars and end rings if performed to the original design using equivalent materials.

2.5 SHAFT AND BEARING FITS

2.5.1 Shaft extension – shall be checked for straightness and size. If dimensional tolerances are unavailable reference ANSI/EASA AR100-2010, Tables 2-1 through 2-6[7]. If defective, repairer must notify the machine's owner.
2.5.2 Bearing fits – shall be measurement verified at both the shaft and end bracket contact points against bearing manufacturer published tolerances. If dimensional tolerances are unavailable, reference ANSI/EASA AR100-2010, Tables 2-13 and 2-14[8]. If defective, repairer must notify the machine's owner.
2.5.3 Repairs to shaft and end bracket bearing housings shall be by building up the metal and machining to size concentric and parallel to component original manufactured machined surfaces. Welding, plating and sleeving are the accepted and preferred methods. Wear resistant high strength epoxy products designed for use on bearing housings shall be acceptable. It is unacceptable to use general epoxies or other compounds, or to knurl and/or peen to lock or seat bearings.

2.6 FANS

2.6.1 Fan inspections shall focus on cracks and measurements for tolerance fit to the shaft or rotor. Fans are to fit firmly to the shaft or rotor by the original factory method unless there has been fretting corrosion between dissimilar metals. In this case, the service provider shall provide an alternative method to the customer. It is not permissible to weld the fan to the shaft. It is permissible to make repairs to fans after receiving permission from the machine's owner. Replacement fans shall have the same number of blades, be of the same or superior (i.e. more suitable for the environment or application) material, and be

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[4] EASA/ANSI AR100-2010, Recommended Practice For The Repair of Rotating Electrical Apparatus, pg. 13
[5] CSA C392.11, Testing of three-phase squirrel cage motors during refurbishment pg. 8
[6] CSA C392.11, Testing of three-phase squirrel cage motors during refurbishment pg. 15
[7] EASA/ANSI AR100- 2012 Recommended Practice For The Repair of Rotating Electrical Apparatus pgs. 5, 6
[8] EASA/ANSI AR100- 2012 Recommended Practice For The Repair of Rotating Electrical Apparatus pgs. 10, 11

dimensionally and structurally equivalent to the original manufacturer supplied fan. It is preferable to replace fans with an original equipment component supplied by the manufacturer, and specifically designed for the applicable motor. Variation of a fan's air velocity or flow from original characteristics is unacceptable.

2.7 BALANCING

Conduct a dynamic balance check of each motor rotor. In the event rotor unbalance exceeds manufacturer's original specifications, repairer shall dynamically balance the rotor. The balancing work must meet the following criteria:

Half key – Balance with a half key in the keyway is necessary to offset weight added when installed on driven equipment.

Tolerance G2.5 (ISO 1940-1) – Generally, the permitted total imbalance is 7.5W/N = oz. in/plane where W is weight of rotor in pounds and N is operating speed in RPM (213 W/N gm. in/plane).

Tolerance G1.0 (ISO 1940-1) – Two pole rotors should be balanced to 3W/N = oz. inch/plane (85 W/N gm. in/plane).

Material removal shall maintain electrical and structural integrity of the rotor and flow capacity of the fan.

Added material shall maintain structural integrity of rotor and fan. Positioning shall be adequate to withstand the centrifugal forces either in the manufacturer's designated positions and locked in place, or positioned in a location where centrifugal force will tend to keep the material in place. Attach weights to metallic parts only.

2.8 REASSEMBLY

The re-assembly of the motor is generally the reverse of the disassembly process observing the following points:

- Match marks shall line up.
- On reinsertion of the rotor, take care not to damage the journals or the stator windings and laminations.
- Dowels and fitted bolts shall go back into the same holes that they came from.
- On motors with insulated bearings, document insulation resistance tests.
- Bearing type (open, shielded or sealed), internal fit, and lubricant shall be equivalent to the original.
- On vertical motors, the endplay shall be the same as the original manufacturer's setting, unless the machine's owner and the repairer agree that a modified setting would deliver better performance.

2.9 FINAL TESTS

2.9.1 Insulation winding resistance to ground required tests conducted at 500 volts DC prior to running the motor. The minimum value shall be 5 meg-ohms for random windings, or 100 meg-ohms for form coil windings, corrected to 40° C. If acceptable, the repairer shall hi-pot test the winding in the following manner:

- Rewound motor tests shall be one time only, for one minute at 1700VDC plus 3.4 times the machine's voltage rating, e.g. 3264VDC for a 460VAC machine.
- Repaired motors not rewound shall be hi-pot tested to 65% of the new winding value.

2.9.2 Motor run test the motor at no load and rated terminal voltage. The test shall determine the presence of the following conditions and the required action:

No Load Ampere Unbalance – Repairer shall investigate and correct this condition if the unbalance does not follow line leads when exchanged, and exceeds six to ten times voltage unbalance.

Vibration – Repairer shall take horizontal, vertical and axial readings at each bearing and record the results. Tolerance shall not exceed ANSI/*EASA AR100-2010, Table 4-5*, or another more rigid standard provided by the machine's owner.

3.0 QUALITY CONTROL

3.1 MEASURING INSTRUMENTS

3.1.1 Calibration of all measuring instruments shall be regular, including burn off oven temperature control[9] and electrical measuring devices used by the repairer in motor and motor component testing. The calibration records shall be available for machine owners and GMPG inspection. Minimum frequency of calibration shall be annual, with the following exceptions:
Bore Gauges checked for conformance with measurement standards traceable to international or national standards before and after each use per section 6.1.
Machinist's Gauge Blocks calibrated at a minimum requirement of every five (5) years.
Micrometers checked for conformance with measurement standards (per section 6.1) traceable to international or national standards before and after each use.
Core Loss Test Equipment calibrated per manufacturer's instruction if available and documentation shall be on file and available for review. Alternatively, if core loss testing calibration is unavailable or impractical, repairer may temporarily (six months or as approved by GMPG) follow sections 5.2.2 through 5.2.4 until remediation by a third party calibration.

3.2 TESTS AND INSPECTION DURING WORK

3.2.1 Record documentation of all tests, measurements, and inspections carried out during motor repair work. Repairer shall ship supervisor-signed, original copies of these records, at the same time as the motor, to the machine owner or designated representative contact person.
3.2.2 Final Inspection. Repairer will inform the machine owner or their designated representative of the time and place of final tests on any of their motors, and they will have the right to witness the tests. In emergency cases, provided the repairer made every effort to inform machine owner or their representative of test scheduling and they were unable to attend, the repairer shall not postpone the final tests.
3.2.3 Test Results and Documentation. The repairer will deliver final inspection and test results, in their original form, to the machine owner or their designated representative. A stainless-steel GMPG compliant tag shall include the test completion date, GMPG account number, and a unique identifier attached to qualifying repair and or rewound motors.

4.0 PROCEDURE: BURN-OFF OVEN TEMPERATURE VERIFICATION

4.1 Objective: To outline a procedure determining the temperature of a typical motor service center burn-off oven. This procedure verifies or reveals necessary compensation of existing oven temperature control and/or gauge read-out.

4.2 Procedure:

4.2.1 Obtain a suitable, removable temperature indicating device using a calibrated temperature indicating device of known accuracy. In conjunction with a calibrated meter, this device determines part (stator) temperature for verification purposes and identified as such. Annual calibration and certification of the meter output shall be traceable to national or international standards.

[9] ATTACHMENT—Instrumentation and Equipment Quality Procedures, page 6 for a minimal alternative

4.2.2 Verification operation shall require placing the temperature indicating device into the stator bore or adjacent to the temperature sensing device, ensuring that the leads are accessible. When the part/oven temperature gauge readout stabilizes at a pre-selected temperature (e.g. 700° F or 370° C) repairer will compare that reading to the reading from the verification device. If the oven temperature does not stabilize, a lower temperature selection is acceptable provided calculated adjustments reflect an appropriate offset at 700° F or 370 °C. A qualified technician records, notes variations dates, and archives the readings including notations on or near the gauge.

5.0 PROCEDURE: CORE-LOSS TESTER VERIFICATION

5.1 Objective: To outline a procedure for an "in house" ongoing verification program establishing a baseline to determine the accuracy of core-loss test equipment watts loss per pound.

5.2 Procedure:

5.2.1 Calibrate the core-loss equipment instrumentation to the manufacturer's instructions or specification[10]. Apply a sticker to the core-loss equipment indicating the date of re-calibration and initial by the responsible qualified technician. Archive all documentation with regard to the initial re-calibration of the instrumentation.

5.2.2 Re-calibrate core loss equipment immediately conducting a core test on a suitable surplus stator. Archive the documented watts loss per pound results and label the surplus stator as a "baseline core-loss reference tool," including date and initials of the responsible qualified technician.[11]

5.2.3 Reference tool stator shall then be re-tested annually (at a minimum) and/or as needed, with the results compared to the original baseline test. Test results within 5% of the original baseline test indicate the core-loss equipment resulting watts loss per pound is verified and accurate. Record each subsequent test and label tested core-loss equipment with the test date, initialed by the qualified technician.

5.2.4 Obtain a manufacturer's calibration certificate when purchasing instruments for calibration. Keep this certificate on file for GMPG evaluation requirements.

6.0 PROCEDURE: MICROMETER AND MICROMETER REFERENCE/CALIBRATION

6.1 Objective: To outline a procedure for an "in house" calibration of micrometer and micrometer reference standards. Note: The indicated read-out on an inside micrometer is not (considered) accurate and therefore not calibrated. Measure the inside micrometer itself with a calibrated outside micrometer for an accurate reading.

6.2 Procedure:

6.2.1 The first step in the verification process shall be to obtain a set of machinist's gauge blocks, complete with a traceable calibration certificate. The dimension range of the blocks shall be appropriate for the range and capability of instruments calibrated. It is permissible to "wring" (together) several gauge blocks in order to achieve the appropriate size to be calibrated. These identified gauge blocks, used at a minimum annually (preferably monthly) for calibration of micrometers and micrometer standards are stored in an appropriately safe, secure location. To maintain calibration, it is necessary to re-certify the

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[10] It may be necessary to return instrumentation to the equipment manufacturer for calibration or exchange instrumentation for calibrated units. Other instrumentation calibration sources may also be used.

[11] The condition of the reference stator core is not important, but it must be stored in a safe dry place to prevent any change in the core stack insulation system between test procedures.

gauge block set by the original manufacturer or a qualified independent calibrator or replace them with a new calibrated set at least every five (5) years.

6.2.2 Record measurements on an appropriate calibration record form, dated and initialed by the responsible technician.

6.2.3 All instruments involved in the calibration process shall reach ambient temperature before and during the calibration process. In order to calibrate micrometers check the instrument(s) against the appropriate gauge blocks at 0.2500” increments over the range of the instrument, and compare results to the fourth decimal place. Repeat the measurement to verify that it is accurate. Record this reading on a calibration form as the “as found” measurement.

6.2.4 If the micrometer and gauge block measurements match within the micrometer manufacturer’s tolerance it is (considered) calibrated and record the “as found” measurement in an “as left” column. Any variance between the gauge block and the micrometer should be corrected by adjusting the micrometer to match the gauge block, and record in the “as left” column.

6.2.5 The micrometer is now considered calibrated, and may be used annually (preferably monthly) to verify the size of its’ corresponding reference standard. If not, replace the standard as it has become “worn” and unreliable.

6.2.6 Standard measuring practice require that a micrometer be “zeroed” to its’ appropriate reference standard before any measurement is taken. This principle applies not only to calibration but with each use of the instrument.

6.2.7 Purchase instruments capable of the tolerance and calibration required with a manufacturer’s certificate traceable to a National Standard for calibration. Archive this certificate for GMPG verification evaluations.

SPECIFICATION REFERENCES

AEMT	Good Practices Guide—The Repair of Induction Motors Best Practices to Maintain Energy Efficiency
CSA	C390-10 Test Methods, Marking Requirements and Energy Efficiency Levels for Three-Phase Induction Motors
	C392-11 Testing of Three-Phase Squirrel Cage Induction Motors during Refurbishment
EASA	ANSI/EASA AR 100-2010 Recommended Practice for the Repair of Rotating Electrical Apparatus
	The Effect of Repair/Rewinding on Motor Efficiency – EASA/AEMT Rewind Study and Good Practice Guide to Maintain Motor Efficiency (2003)
	Guidelines for Maintaining Motor Efficiency during Rebuilding (Tech Note 16)
	Stator Core Testing (Tech Note 17)
IEEE	Standard 43-2000, Recommended Practices for Testing Insulation Resistance of Rotating Machinery
	Standard 112-2004, Standard Test Procedure for Polyphase Induction Motors and Generators
	Standard 1068-2009, Standard for the Repair and Rewinding of AC Electric Motors in the Petroleum, Chemical and Process Industries
NEMA	Standard MG-1:2009, Motors and Generators
USDOE	Office of Industrial Technology, Model Repair Specification for Low Voltage Induction Motors