Appendix

Glossary

Absorption The process by which pollutants enter the bloodstream or other body components from the site of exposure.

Alternator A synchronous machine used to convert mechanical power into alternating current electric power.

Ambient temperature [AMB] This is the temperature of the surrounding cooling medium, commonly known as room temperature, and is the maximum temperature the equipment may operate without damage.

ANSI American National Standards Institute

Amperes A measure of current flow in an electrical circuit.

Baseline A reading taken when a machine is in good operating condition and then used as a reference for monitoring and analysis.

Breakdown torque The maximum torque that an AC motor will develop when applying rated voltage, at rated frequency without an abrupt drop in speed, also termed as pull-out torque or maximum torque.

Bearing A device that supports, guides, and reduces the friction of motion between fixed and moving machine parts.

Code letter A letter which appears on the nameplates of ac motors to show their locked-rotor kilovolt amperes per horsepower at rated voltage and frequency.

Constant horsepower motor A term used to describe a multi-speed motor in which the rated horsepower is the same for all operating speeds. When applied to a solid state drive unit, it refers to the ability of the drive to deliver constant horsepower over a predetermined speed range.

Constant torque motor A multi-speed motor for which the rated horsepower varies in direct ratio to the synchronous speeds. The output torque is essentially the same at all speeds.

Current rating Equipment amperage consumption when delivering rated output power at nameplate rated voltage.

Delta connection A three-phase winding connection in which the connected phases form a triangularly closed circuit

Design NEMA design letters A, B, C. D, and E define certain starting and running characteristics of poly-phase squirrel cage induction motors. These characteristics include locked-rotor torque, locked-rotor current, pull-up torque, breakdown torque, slip at rated load, and the ability to withstand full-voltage starting.

Direct current Type of power supply available from batteries, generators or a rectified source used for special-purpose applications.

Duty A continuous or short-term rating of a machine. Continuous-duty machines reach an equilibrium temperature within the temperature limits of the insulation system. Machines that do not, or cannot, reach an equilibrium temperature have a short-term or intermittent-duty rating. Short-time ratings are usually one hour or less for motors. Intermittent duty motors are available with maximum operating times of 5, 15, 30, or 60 minute duties or times.

EASA Electrical Apparatus Service Association is an international trade organization with nearly 2,400 electro-mechanical member firms in 56 countries.

Efficiency The ratio between useful work performed and the energy expended in producing it. It is the ratio of output power divided by the input power.

Enclosure Housing of the motor. Common acronyms:

ODP – Open Drip Proof, operates with dripping liquids up to 15^0 from vertical

ODP Splash Proof – Operates with splashing liquids up to 100^0 from vertical

TENV – Totally Enclosed Non-Ventilated, has no external cooling

TEFC – Totally Enclosed Fan Cooled, cooled by an external integral fan

TEAO – Totally Enclosed Air Over, intended for auxiliary external cooling

TEXP Totally Enclosed Explosion Proof, withstands internal explosion preventing external ignition, gases and dust are rated separately.

Foot-pound The amount of work, in the English system, required to raise a one-pound weight a distance of one foot.

Frame The NEMA standardized motor mountings and shaft dimensions. If the nameplate displays a two digit frame number, the number is the distance from the center of the drive shaft to the center bottom of the mount in sixteenths of an inch (e.g. 56 frame divided by 16 = 3.5 inches from the shaft to mount). For three digit frame sizes, divide the first two digits by four to calculate the distance from the center of the drive shaft to the center bottom of the mount in fourths of an inch (e.g. 145T frame, 14 divided by 4 = 3.5 inches from shaft to mount)

Frame size suffix examples – For NEMA motors that have a letter following the frame numbering system:

T – Indicates a motor manufactured meeting 1964 dimensional standards;

S – Is a standard “short shaft”, the shaft is not only shorter but a smaller diameter intended for belt driven loads;

U - Indicates a motor manufactured either prior to or meeting 1964 dimensional standards;

Y - Indicates a non-standard mount or body configuration;

Z - Indicates a non-standard shaft configuration;

C - Is a standard face mount with a flat machined mounting surface on the driven end with tapped holes to allow mounting to driven equipment;

D - Is a standard flange mount with a flat mounting machined surface on the drive-end with holes for mounting to driven equipment;

H - Indicates a frame with a rigid base having an "F" dimension larger than that of the same frame designation without the suffix;

J - This frame has a "C" face mount with a threaded shaft for integral pump mounting;

JM - Indicates the frame is suitable for close-coupled mechanical seal pump mounting;

JP - Indicates the frame is suitable for close-coupled packing seal pump mounting.

Frequency The number of cycles in a time-period (usually one second) 50 cycles metric and 60 cycles base twelve (English) system. Alternating current frequency expression in cycles per second, termed Hertz (Hz).

Full load amperes Line current (amperage or FLA) drawn by a motor when operating fully loaded with voltage as indicated on the motor nameplate

Full-load current The current required an electrical machine to produce its rated output or full work performance.

Full-load speed The speed at which any rotating machine operates when fully loaded.

Full-load torque The torque produced when operated at full-load.

GMPG [Green Motors Practices Group] A non-profit organization of motor service centers who have committed to quality rewinding saving energy and improving electric motor reliability. In addition, the group promotes continuous energy improvement and motor driven system optimization.

Harmonic A multiple of the fundamental electrical frequency. Harmonics are present whenever the electrical power waveforms (voltage and current) are not pure sine waves.

Hertz (hz) The preferred terminology for cycles per second (frequency).

Horsepower	A unit for measuring the output power of a machine. One horsepower equals 33,000 foot-pounds of work per minute (550ft-lbs per second) or 746 watts.
IEC	International Electromechanical Commission,
IEEE	Institute of Electrical and Electronics Engineers
Insulation	Non-conducting material used to electrically separate conducting material.
Insulation class	A letter or number that designates the temperature design characteristics of an insulation material or system with respect to thermal capacity. The letter designation may represent the anticipated temperature rise of a machine as the insulation system material may well exceed the designation indicated.
Kilowatt	A unit of electrical power, also the output rating of motors manufactured for metric application.
Locked-rotor current	Steady-state current taken from the line with the rotor of a motor at standstill and at rated voltage and frequency.
Locked-rotor torque	The minimum torque that a motor will develop at standstill for all angular positions of the rotor, with rated voltage applied at rated frequency.
Megohmmeter	Is an instrument that utilizes DC voltage for measuring insulation resistance.
Motor	A rotating machine that converts electrical power (either alternating current or direct current) into mechanical power.
NEC	[National Electrical Code] A code developed for the proper use of electricity and electrical equipment.
NEEA	[Northwest Energy Efficiency Alliance] A non-profit consortium of Northwest electric utilities and government entities whose mission is to make affordable energy efficient products and services available in the market place.

NEMA — [National Electrical Manufacturers Association] An organization that establishes voluntary industry standards relating to electrical equipment.

Newton-meter — Unit of torque, in the metric system, that is a force of one Newton, applied at a radius of one meter and in a direction perpendicular to the radius arm.

Nominal efficiency — This efficiency represents the average efficiency for a large population of motors of the same size and design. In addition, a minimum efficiency established for each level of nominal efficiency. The minimum level is the lowest level of efficiency expected when a motor is marked with the nominal efficiency value in accordance with the NEMA standards.

Part-winding start — A part-winding start poly-phase motor is one arranged for starling by first energizing part of its primary winding and, subsequently energizing the remainder of the primary winding. The leads are normally numbered 1, 2, 3 (starting) and 7, 8, 9 (running).

Phase — This indicates the equipment's configuration to accept alternating current.

Poles — The magnetic poles set up inside an electric machine by the placement and connection of the windings.

Pound-foot — Unit of torque, in the English system, that is a force of one pound, applied at a radius of one foot, and in a direction perpendicular to the radius arm.

Power factor — This is the ratio of watts to volt-amperes of an ac electric circuit. (see reactive power)

Reactive power — This is the power required by inductive devices to develop magnetic fields of force. Reactive power does not provide any useful mechanical work but is required to make inductive devices operate.

Resistance temp detector — [RTD] A device used for temperature sensing consisting of a wire coil or deposited film of pure metal for which the change in resistance is a known function of temperature. The most common type is nickel, with other types being copper, platinum, and nickel-iron.

Rotor The rotating element of an ac motor or generator.

R.P.M. [Revolutions Per Minute] This is the rated operating speed of a motor at full load. Normal operating speeds for 60 hertz and 50 hertz motors vary depending on the number of poles in the motor stator. (See synchronous speed and slip)

Service factor This is a multiplier which, when applied to the rated power, ambient temperature, voltage, or installation elevation indicates the extent a short-term excessive condition may exist without equipment damage (may be longer-term if no other extenuating circumstances occur).

Single phase This term indicates the electrical equipment has one winding or element to accept alternating current. Power supplied may have one energized leg and one neutral leg or there may be two energized legs to complete the circuit.

Slip The difference between synchronous and operating speeds, compared to synchronous speed, expressed as a percentage. Slip is the difference between synchronous and operating speeds, expressed in rpm.

Starting torque The torque produced by an at rest motor when power is applied, also known as locked-rotor torque.

Stator The stationary part of a rotating electric machine commonly used to describe the stationary part of an ac machine that contains the power windings.

Synchronous speed The speed of the rotating machine element of an ac motor that matches the speed of the rotating magnetic field created by the armature winding. Synchronous speed = (Frequency x 120) / (Number of Poles)

Temperature rise The amount by which a motor, operating under rated conditions is hotter than its surrounding ambient temperature. The ambient temperature plus the temperature rise is the maximum temperature the motor should operate at full load.

Thermal Protection This indicates if a motor has internal automatic or manual thermal overload protection.

Three phase This term indicates the electrical equipment has three windings or elements to accept alternating current. In most instances power supplied will have three energized legs.

Torque The rotating force produced by a motor. The units of torque may be expressed as pound-foot, pound-inch (English system), or Newton meter (metric system).

Trending Analysis of the change in measured data over at least three data measurement intervals.

UL Underwriters Laboratories, Inc. is an independent testing organization that sets safety standards for motors and other electrical equipment.

Variable- torque motor A multi-speed motor in which the rated horsepower varies as the square of the synchronous speeds.

Voltage Is the designed electrical supply pressure at which electrical equipment operates.

Watts A unit of electrical power equal to current times voltage

WYE connection A three-phase winding connection formed by joining one end of each phase to make a "Y" point. The other ends of each phase connect to power to complete the circuit, also termed a star connection.

WYE-delta starting Wye-delta is a connection which reduces the inrush current and torque of a poly-phase motor during starting. A Wye-start (star), delta run motor is one arranged for starting by connecting to the line with the winding initially connected wye (star). The winding is reconnected delta after a predetermined time for continued operation. The lead numbers for a single run voltage are normally 1, 2, 3, 4, 5, and 6.

Exercise 1A: Answers

20 HP, 7200 hrs, $0.10 (cents) per kWh

Year	Efficiency	Operation Cost	Efficiency	Operation Cost
1945	88%	$ 12,207		
1955	90%	$ 11,936		
1965	88.5%	$ 12,138		
1975	87.5%	$ 12,277		
1985	87.5%	$ **12,277**	92%	$ 11,677
1995	89%	$ 12,070	93%	$ 11,551
2000/2010	91% Epact	$ **11,805**	93%	$ **11,551**

New Motor 2010 Epact Price: **$ 1,200**
New 2012 NEMA Premium Price: **$ 1,515**
Complete Rewind (approx.) Price: **$ 896**

10 year life power cost of 1997 Epact: **$118,050**
10 year life power cost of NEMA Premium: **$115,510**

Here's a table containing calculation results and associated costs. Did you get the same answers? Notice the insignificance of prices associated with purchase or repair of this 20 HP motor in comparison to ten-year costs. If you have an older motor, is it better to buy new or rewind it?

Exercise 1B: Answers

20 HP, 2400 hrs, $0.10 per kWh full load

Year	Efficiency	Operation Cost	Efficiency	Operation Cost
1945	88%	$ 4,069		
1955	90%	$ 3,979		
1965	88.5%	$ 4,046		
1975	87.5%	$ 4,092		
1985	87.5%	**$ 4,092**	92%	$ 3,892
1995	89%	$ 4,023	93%	**$ 3,850**
2001	91% Epact	**$ 3,935**	93%	**$ 3,850**

New Motor 2010 Epact Price: **$ 1,200**
New 2012 NEMA Premium Price: **$ 1,515**
Complete Rewind (approx.) Price: **$ 896**

10 year life power cost of 1997 Epact: **$39,350**
10 year life power cost of NEMA Premium: **$38,350**

Here's a table containing the various associated costs. At 2,400 hours, is it better to buy new or rewind? If the failed motor is NEMA Premium, is it better to rewind or replace it?

Electric Motor Repairing Specification – 2012

Rewind/Repair Processes for Electric Motor Efficiency Retention

Green Motors Practices Group
A Non-Profit Corporation

Table of Contents

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

[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