

Model Repair Specifications For Low Voltage Induction Motors

These Model Repair Specifications are intended to cover routine repair and rewind of low-voltage random-wound three-phase AC squirrel cage induction motors. For motors falling outside this description, the more comprehensive model specifications below are recommended.

Electric Motor Model Repair Specifications
DOE/BP-2748

Available from the USDOE Motor Challenge Program or the Bonneville Power Administration.

The following Model Repair Specifications contain:

- 1. Introduction** (Introduction and General Requirements)
- 2. Repair Procedures** (Required procedures)
- 3. Quality Control** (Requirements for Calibration, Materials, and Documentation)
- 4. Motor Repair Form** (For purchaser to describe the motor's condition, operating environment, and desired service)
- 5. Glossary**

Sections 1-4 are part of the package that accompanies the motor to the service center. The glossary (Section 5) is intended for the purchaser's benefit and is not necessary as part of the documentation accompanying the motor.

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INTRODUCTION

1.1 SCOPE

These Model Repair Specifications lists the suggested minimum requirements for the repair and overhaul of low voltage random wound three phase AC squirrel cage induction motors, which are sent for repair. It pertains to motors with anti-friction bearings (ball and roller) only.

1.2 INTENT

The intent of these Model Repair Specifications is to achieve a consistent, high quality diagnosis, repair and/or overhaul of a motor, and to return it to good operating condition with a minimum of delay and cost.

Not all repair situations can be covered in these Model Repair Specifications. In the absence of specific instructions, the requirement shall be to restore the motor to as-manufactured condition.

1.3 REFERENCE DOCUMENTS

The references to be used in conjunction with these Model Repair Specifications are the latest editions of the following:

UL	UL674 Electric Motors and Generators For Use In Hazardous Locations
EASA	AR100-1998 Recommended Practice For The Repair of Rotating Electrical Apparatus
IEEE	IEEE Std. 43, Recommended Practice for Testing Insulation Resistance of Rotating Machinery IEEE Std. 112, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators
ISO	ISO Std 1940-1, Mechanical Vibration – Balance Quality Requirements of Rigid Rotors
NEMA	NEMA Std. MG-1, Motors and Generators
ABMA	ANSI/ABMA Std. 7, Shaft and Housing Fits for Metric Radial Ball and Roller Bearings

1.4 HAZARDOUS LOCATIONS

Motors intended for use in hazardous locations will have a nameplate to that effect. The repair work shall be done in a facility which has been certified by the Underwriters Laboratories to meet the requirements of UL674 Qualification of Facilities Engaged in the Repair of Electric Motors and

Generators for use in Hazardous Locations. If the explosion-proof characteristics of the motor are not to be maintained, then the nameplate shall be altered to reflect this, and the motor will no longer be considered suitable for use in hazardous areas.

1.5 GENERAL

1.5.1 Unavoidable Degradation

During the course of repair, if any damage is found which cannot be fully repaired, the purchaser's approval is required before proceeding. Likewise, if any repair is indicated which may result in a permanent degradation of efficiency or other performance parameters, the purchaser's approval is required before proceeding.

1.5.2 Operating Environment

If this motor operates in severe environmental conditions, it will be indicated on the accompanying motor repair form. No repair methods or materials may be used which make the motor more vulnerable to these conditions than it was as originally built.

1.5.3 If Powered by an Inverter

If "Powered by ASD" is checked on the accompanying Motor Repair Form, this motor is powered by a pulse-width-modulated inverter. The windings shall be sufficiently insulated and supported to withstand this type of power supply. Magnet wire must be of a design intended for inverter duty. The wire manufacturer and specification shall be reported to the customer.

1.5.4 Subcontracted Work

If any work is to be subcontracted (e.g., rotor balancing) or any subassemblies (e.g., formed coils) are to be provided by outside sources, the purchaser shall be advised of the providers of these parts/services as soon as it is known they are required.

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REPAIR PROCEDURES

2.1 DOCUMENTATION

2.1.1 Repair Forms

The motor will be accompanied by a Motor Repair Form from the purchaser which will list the perceived problems, the operating environment, the urgency of the repair, past problems where applicable, the required repair, cost constraints, missing parts and the person within the purchaser's organization to be contacted about the repair. This form shall be used as a guide for the repair. A sample is included in Section 4 of these specifications.

During repair, actions and findings will be recorded on a Repairer's Tracking Form. It shall contain records of all the work done, problems noted, checks and measurements taken during the work, repairs carried out and the final tests conducted prior to shipping. Requirements for the work, checks and tests are listed in following sections. A sample of a Repairer's Tracking Form developed by EASA is included after the Motor Repair form.

2.1.2 Expanded Work Scope

If tests and inspection indicate problems beyond the initial scope of the listed repair, then the designated person shall be contacted and given a description of the problems, plus an estimate of their effect on delivery and costs.

2.1.3 File

The repairer will keep a copy of the Motor Repair Form and the Repairer's Tracking Form in the file for the particular job.

2.2 INCOMING INSPECTION

On receipt of the motor and after reading the Motor Repair Form, the repairer shall do the initial tests set out below, plus any other tests indicated by the form.

2.2.1 Intent

The intent of the initial tests shall be to determine and record the probable cause of failure, if any, to document certain pre-repair parameters, and to determine what work is required.

2.2.2 Visual

A visual inspection shall be made to assess the general condition of the outside of the motor for cracks, broken welds and missing parts.

2.2.3 Insulation to Ground

An insulation resistance test to ground shall be performed, at a voltage suitable for the motor's voltage rating and the apparent condition of the motor. The testing shall be as follows:

- The initial test voltage shall be 500 volts DC.
- For motors where there is more than one winding, the insulation shall also be tested between windings, at the test voltage appropriate to the lower voltage winding, with other windings grounded.
- The duration of the insulation test shall be one minute. The temperature shall be recorded.

2.2.4 Bearings

The shaft shall be manually rotated to check for any obvious problems with the bearings or shaft.

2.2.5 No Load Run

If possible, the motor shall be run on no load, at nameplate voltage and checked for balanced currents and vibration. The readings shall be noted on the Repairer's Tracking Form.

2.3 DISMANTLING

2.3.1 Identify Problem

After the incoming inspection, the motor shall be dismantled to the extent needed to either fully identify or repair the problem, or to do the specified overhaul.

2.3.2 Markings

End brackets and frames shall be clearly match-marked with numerals or letters.

2.3.3 Parts Storage

Bolts and small parts shall be stored in dedicated containers and parts from other jobs shall not be kept with them.

2.3.4 Insulated Bearings

If the motor has insulated bearings, note which, if any have the insulation deliberately bridged. The insulation resistance of each insulated bearing shall be at least 10 megohms with a 500 volt DC test.

2.3.5 Dowels

If dowels or fitted bolts are used to ensure accurate fits, the location of these pieces shall be identified.

2.3.6 Explosion Proof

Repairer must be certified by UL for repair of explosion-proof motors. For motors certified for hazardous locations, extra care shall be taken to ensure that joints and flame paths are not damaged during the work. If damage requiring other than normal repair is found, purchaser shall be notified before proceeding with repair.

2.3.7 Rotor Removal

For horizontal motors where the shaft rotor assembly is too heavy to be removed easily by hand, one or two cranes shall be used to move the shaft, with a close fitting pipe installed over one end of the shaft to act as a shaft extension. Attention shall be paid to the following:

- Care shall be taken that the slings do not damage the bearing surfaces or the rotor.
- Under no circumstances shall the stator windings be touched by any of the parts being moved.

2.4 VERTICAL MOTORS

Vertical motors shall be dismantled according to the manufacturer's instruction book. The assembly of vertical motors is critical. Particular attention shall be paid to, and records kept of:

- The amount of rotor lift (end play);
- The make and types of bearings, particularly the thrust bearings including orientation of thrust bearings;
- The arrangement of the thrust and guide bearings, including specially ground mating surfaces;
- The axial and radial clearances (fit) to the shaft and housing;
- The method of lubrication of both upper and lower bearings;
- The method of bearing insulation, if any, and
- Any other particular features of the motor configuration.

2.5 WINDING REMOVAL

2.5.1 General

For motors that are to be rewound, the core shall be stripped, cleaned, tested and repaired.

2.5.2 Take Data

Winding data shall be recorded so as to permit replicating original configuration.

2.5.3 Core Loss

A core loss test shall be done on all stators both before and after stripping and iron repair, to check for damaged interlaminar insulation. The tests shall be done at a flux density of 85,000 lines per square inch rms. Exciting current and watts loss shall be recorded each time, as well as a physical check carried out for hot spots. If data from previous tests are available, the results shall be compared. Testing at other flux densities may be done if previous data is available.

If hot spots exceed 15°C above the average temperature after 10 minutes, or losses are excessive overall either before or after stripping, the situation shall be discussed with the purchaser before proceeding further. For a core without any hot spots, the losses after stripping shall not be more than 10% higher than the pre-strip losses. To avoid misleading results, the second core loss test should not be done until the core has been cleaned and dried.

2.5.4 Burn Out

The winding shall be burned out in a controlled temperature burnout oven where the part temperature is limited by means of fuel control and supplementary (water spray) cooling to 360°C (680°F) for organic (C3) or 400°C (750°F) for inorganic (C5) interlaminar insulation. If a higher temperature is deemed necessary, repairer shall reference communication or documentation from the motor manufacturer indicating that the core iron can safely withstand the temperature.

2.5.5 Aluminum Frame

Frames may be chemically stripped if burnout facilities are not available. Other methods of stripping may only be used with purchaser approval.

2.6 CORE PREPARATION

2.6.1 Cleaning

The stripped core shall be cleaned of all foreign material, such as insulation debris, and dried.

2.6.2 Iron Damage

All obvious iron damage, plus any problems indicated by the core loss tests, and significant frame damage, shall be reported to the purchaser before proceeding further.

2.6.3 Method of Repair

The method of repair to damaged cores shall be discussed with purchaser and shall be chosen from the following:

- **Grinding.** Selective grinding with a small sharp power tool.
- **Spray between laminates.** Separating laminations and reinsulating with spray-on interlaminar insulation.
- **Mica between laminations.** Inserting split mica between the laminations.
- **Restacking.** Restacking, with deburred laminations and new interlaminar insulation.

2.6.4 Core Loss Test

A final core loss test shall be done as described in sub-section 2.5.3.

2.7 REWINDS

2.7.1 Winding Details

The total cross sectional area of a turn, the turns per coil, the span and connection of the coils shall not be changed without authorization from the purchaser.

2.7.2 Thermal Class

Class F or higher system materials shall be used throughout. Windings which were originally Class H shall be replaced with a Class H rewind.

2.7.3 Sensors

Temperature sensing devices shall be replaced with devices comparable to those previously used.

2.7.4 Explosion Proof

If the temperature class of the insulation of an explosion-proof motor has been increased, a temperature sensor shall be installed to monitor and limit the motor surface temperature to the original maximum external temperature. The motor shall be tagged with a warning to the operator that to maintain the hazardous area classification, the sensor must be connected to shut down the motor.

2.7.5 Insulation Materials

Insulation shall include, as a minimum, the following components:

- **Turn insulation.** Multiple build coating turn insulation of polyamide, polyimide or a combination of both over polyester, or equivalent;
- **Slot Liner.** Slot liner extending at least one quarter inch past each end of the slot;

- **Separator.** Center strip or separator between the top and bottom coil sides in a slot;
- **Wedge.** A top piece to hold the coils in the slot (where needed, a bottom filling piece shall be used to make up any extra space in the slot); and,
- **Phase Barriers.** Phase barriers between end turns of different phases (these shall be trimmed to permit clear airflow).

2.7.6 End Turns

The end turns shall be fully compacted so that there are no loose wires. Both sets of end turns, plus leads and jumpers, shall be laced tightly together so that each coil is tied securely to the two adjacent coils.

2.7.7 Connections

All connections shall be brazed with materials that will not be subject to corrosion in the specified operating environment. They shall have no sharp edges and shall be insulated.

2.7.8 Winding Test

Before impregnation, the winding shall be tested to verify that there are no wrong connections or shorted turns. This may include a surge comparison test, a high potential test, and winding resistance test. Voltage used shall be as indicated in EASA Recommended Practices for the Repair of Rotating Electrical Apparatus or other standards approved by purchaser. Any defects shall be corrected and retested before impregnating. Test results shall be recorded in the Repairer's Tracking Form.

2.7.9 Impregnation

The rewound stator shall be impregnated in one of the following ways:

- **Dip-and-Bake.** Double dip-and-bake cycle using resin or varnish and a temperature controlled bake oven (baking times and temperatures shall be recorded in the Repairer's Tracking Form.)
- **Trickle.** A trickle epoxy or polyester treatment where the resin is poured into the end turns and slots of a vertically inclined stator, which has been heated with controlled electric current to assist in curing the resin.
- **VPI.** Vacuum Pressure Impregnation (VPI) treatment.

2.8 ROUTINE OVERHAULS

2.8.1 Testing

After dismantling, the following procedure shall be followed:

- Winding and cooling ducts shall be cleaned, dried and inspected.
- Winding insulation resistance shall be tested at 500 volts DC.
- The duration of the test shall be one minute. The minimum acceptable level after one minute, corrected to a 40°C reference temperature per IEEE 43, is 20 megohms. Levels less than 20 megohms shall be discussed with the purchaser.
- If satisfactory levels are not attained, the winding shall be recleaned and dried thoroughly at a temperature not exceeding 90°C (195°F), and then retested.
- After successful insulation resistance to ground has been achieved, the winding shall be given a high potential or surge comparison test. Voltage level used shall be as indicated in EASA Recommended Practice for the Repair of Rotating Electrical Apparatus or other standards approved by purchaser.

2.8.2 Cleaning

The components, including the stator windings, shall be cleaned with hot water and a suitable detergent after heavy deposits of dirt and grease have been removed by scraping and wiping.

If necessary, brushes shall be used to clean small passages in components.

Solvents shall not be used to clean insulation, but may be used on mechanical components of the motor.

All components shall be thoroughly dried at a temperature less than 90°C (195°F), for as long as it takes to remove all signs of moisture. For windings, this will be indicated by the insulation resistance stabilizing after some hours of drying.

2.8.3 Repairs

After satisfactory insulation resistance has been attained, all loose or damaged wedges, slot sticks, coil supports etc., shall be replaced or repaired.

The winding shall then be given a dip-and-bake using a Class F or higher grade varnish. Immersion and baking times shall be sufficient to penetrate any cracks and give a sealed durable finish to the insulation. The repairer shall notify the purchaser if a dip-and-bake is undesirable.

2.8.4 Other

The routine overhaul of other parts of the motor shall return the parts to good condition.

2.8.5 Reassembly

The assembly of the motor after overhaul is covered in sub-section 2.15.

2. 9 ROTOR TEST AND REPAIR

2.9.1 Testing

All rotors shall be given a test for damaged bars, whether the motor is suspect in this area or not. This test shall apply a stable single-phase voltage to the stator of the assembled motor while the shaft is slowly turned through at least one revolution. Any fluctuations of stator current in excess of 3 percent shall be investigated further.

Other methods may be used if the stator winding is faulty and it can be shown that they have a good record of detecting faults.

For motors where electrical or mechanical problems with the rotor are suspected, more sophisticated tests shall be used. These include one or more of the following:

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

2.9.2 Fabricated Cage Repair

Since repair of squirrel cages can be expensive, no work shall be done in this area without purchaser approval.

2.9.3 Cage Replacement

For cage replacement, the conductive, metallurgical and strength characteristics of both the bar and end ring materials shall be determined and duplicated. Since changing the rotor resistance or density has major effects on the motor performance, no change in these is permitted without purchaser approval.

Any parts that are to be reused shall be cleaned and examined for defects.

2.9.4 Testing

After fabrication, the joints shall be examined and tested by ultrasonic or comparable means.

2.9.5 Balance

The rotor shall be dynamically balanced to the tolerances listed in sub-section 2.14 of these specifications.

2.9.6 Cast Rotor Repair

A defective cast cage shall not be repaired without prior authorization from the purchaser.

The method of repair shall be to remove the old cage by chemical means, without damaging the laminations, followed by rebarring with extruded, aluminum bars and duplicate cast aluminum end rings to give the same cage resistance as before.

2.9.7 Iron Repairs

Because of the costs involved, this work shall not be done without prior purchaser approval. If tests or observation indicate that the laminations have been damaged, they shall be repaired or replaced with new laminations. Care shall be taken to ensure a consistent air gap.

2.10 SHAFT REPAIR

2.10.1 General

If information on the Motor Repair Form or any tests indicate that there may be a shaft problem, it shall be tested and repaired or replaced. If there is any risk or uncertainty in the proposed repair method, this shall be discussed with the purchaser prior to proceeding.

2.10.2 Requirements

When the work is completed, the shaft shall meet the following criteria:

- **Total Indicated Runout.** It shall be straight, with a Total Indicated Runout (TIR) when measured in V blocks, of no more than 0.051 mm (0.002 inch) for up to 41.3 mm (1.625 inch) shaft diameter and no more than 0.003 inch for larger diameters.
- **No Cracks.** The shaft shall have no cracks. If ultrasonic, magnetic particle, dye penetrant or other testing methods are needed to verify this, they shall be documented in repair records.
- **Straightness.** The shaft shall be straight, parallel and undamaged at the bearing areas. If any measurable but acceptable deviation from this is noted, it shall be documented in repair records.
- **Journal Repairs.** Make journal repairs by welding or plating, followed by machining and grinding, with fit as specified in section 2.11.4.
- **Fit To Rotor.** The shaft shall be a tight fit to the rotor iron. If there is looseness, the shaft shall be built up and turned for proper interference fit, or shall be replaced.
- **Shaft Material.** New shafts shall be machined from AISI Gr. C1045 hot rolled steel or better. For special applications, the service center shall consult with the manufacturer and report recommendations to purchaser.
- **Tolerances.** Shaft extension dimension tolerances shall be within the limits specified in NEMA MG-1, Motors and Generators sections.

2.11 ANTI-FRICTION BEARINGS

2.11.1 New Bearings

Anti-friction bearings shall always be replaced. New bearings shall be the same type as originally used, unless otherwise approved by the purchaser. If the bearing type, size, sealing, shielding or configuration is changed, this shall be noted on a supplemental nameplate. If the original bearing race showed pitting from shaft current, the causes and remedy for this shall be discussed with purchaser.

2.11.2 Shielding, Sealing

If the method of shielding, sealing or lubricating is to be changed, it shall be approved by the purchaser.

2.11.3 Clearance

Unless otherwise specified by the manufacturer or purchaser, C3 clearance bearings shall be used for all bearings.

2.11.4 Tolerances

Fitting tolerances to the journals and housings shall be per manufacturer's specifications. Out of tolerance fits shall be restored. (Reference ANSI/ABMA Std. 7-1995 as a guide.)

2.11.5 Heating

The bearing shall be heated, without use of direct flame, to approximately 94°C (200°F) to permit it to be slid easily onto the shaft up to the shoulder. Bearings with bores under 45mm may be press fit.

2.11.6 Grease

Greasable bearings shall be lubricated as specified in the EASA Recommended Practice for the Repair of Rotating Electrical Apparatus or other standards approved by the purchaser.

Lubrication shall be in accordance with the motor manufacturer's recommendations if available. Otherwise fill the cavity to 1/3 capacity. The lubricant shall be compatible with both the customer's lubricant and the lubricant packed by the bearing manufacturer.

2.11.7 Insulated Bearings

Insulated bearing resistance shall be at least 10 megohms. Voltage applied from the megohmmeter should not exceed 500 VDC. Alternately a 115VAC test lamp may be used. No light should be visible from the lamp filament. (Reference IEEE 112-1996, section 9.4.3. or EASA AR100-1998)

2.12 END BRACKETS

2.12.1 Requirements

End brackets shall fit snugly to the stator frame. Worn dowel holes and rabbet fits shall be repaired.

2.12.2 Tolerances

See section 2.11.4 for the fit of the outer diameter of anti-friction bearings to housings.

2.12.3 Repairs

Repairs to end bracket bearing housings shall be by building up the metal and machining to size. Welding, plating and sleeving are the accepted methods.

Epoxies and other compounds shall not be used for locking bearings.

2.13 OTHER DEVICES

2.13.1 Fans

Fans shall be checked for cracks and fit to the shaft or rotor.

Fans shall be firmly fixed to the shaft or rotor by the original factory method, unless there has been corrosion between dissimilar metals, in which case a new method shall be proposed to the purchaser. Welding to the shaft is not permitted.

Repairs to fans shall only be done after discussion with purchaser.

New fans shall be as supplied by the original manufacturer if available.

Fans used in motors for use in hazardous locations shall be made of material that will not cause sparking, either by impact or by build up of static electricity.

2.13.2 Temperature Sensors

Temperature sensors shall be installed in the motor as originally found or as otherwise specified by the purchaser.

- **Bearing.** Bearing sensors shall be of the same type as those removed and shall be located to sense, as nearly as possible, the highest bearing temperature. If the original bearing sensor was insulated, the replacement shall also be insulated.
- **Winding.** Sensor type shall be the same as the original and will usually be located in the end turns.

2.13.3 Leads

Leads shall be flexible and multistranded, and have at least the same cross sectional area as the original leads. Temperature class must be the same as original or better.

Main power and accessory leads shall be indelibly marked using the same marking systems as the incoming motor. If this is illegible, then the system described in NEMA MG-1, Motors and Generators, Section 2 shall be used and a notice describing the system attached to the terminal box. Every effort shall be made to keep the original direction of rotation.

Lugs, if used, shall be suited for the application and have all cable strands in the lug. No cable strands may be cut off or bent back to facilitate insertion in the lug.

If crimp lugs are used, the correct make and style of die shall be used for the particular lug, and the correct compression applied.

2.13.4 Terminal Boxes

Terminal boxes shall be returned to original condition. In particular, the following items must be confirmed.

- Missing bolts and gaskets for both the cover and the motor-to-box joint shall be replaced.
- On motors certified for hazardous environments, the junction boxes shall be sealed off from the main body of the motor by a sealing compound approved by UL for this application.
- Damaged flanges shall be repaired. No paint or gaskets shall be left on the flanges of boxes for explosion-proof motors.

2.13.5 Space Heaters

Space heaters shall be tested for insulation resistance for one minute at 500 volts. A 10 megohm minimum resistance is acceptable.

They shall be tested for correct functioning.

2.13.6 Vibration Sensors

Vibration sensors shall be replaced in their original locations.

2.14 BALANCING

The motor rotor shall be dynamically balanced in a balance stand before assembly of the motor. Balance criteria include the following:

- **Half key.** It shall be balanced with a half key in the keyway.
- **Tolerance G2.5 (ISO 1940-1).** Generally, the permitted total imbalance is $15W/N/2 = \text{oz in/plane}$ where W is weight of rotor in pounds and N is operating speed in RPM. (426 W/N/2 gm. in/plane)
- **Tolerance G1.0 (ISO 1940-1).** Two Pole rotors should be balanced to $6W/n/2 = \text{oz.in./plane}$. (170.4 W/n/2 gm. in/plane)

- **Material removal.** If material is removed, structural integrity and fan capacity shall be maintained.
- **Added material.** Added material shall be able to withstand the centrifugal forces and be positioned 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. Weights may be attached to metallic parts only.

2.15 REASSEMBLY

The assembly of the motor is the reverse of the disassembly process and the following points shall be observed:

- Match marks shall line up.
- On reinsertion of the rotor, take care not to damage the journals or the stator windings. Cranes, slings and extension pipes shall be used on heavy rotors. Check axial alignment of stator and rotor cores.
- Dowels and fitted bolts shall go back into the same holes that they came from.
- Where they can be measured, all air gaps shall be within 10 percent of the average.
- On motors with insulated bearings, the insulation shall be checked and noted. (See 2.11.7)
- On vertical motors, the lift on the shaft shall be the same as the original manufacturer's setting, unless purchaser and the repairer agree that a modified setting would give better performance.
- Motors for use in hazardous environments shall have all the explosion-proof features maintained and verified in accord with UL674.

2.16 FINAL TESTS

2.16.1 Insulation

Prior to running, the motor shall be given an insulation resistance test to ground in the following manner:

For rewound motors, a DC high potential test shall be conducted at 1700 VDC for motors to be powered by less than 250VAC service voltage. Motors to be powered between 250VAC and 600VAC service voltage shall be tested at 1700VDC plus 3.4 times the machine's voltage rating, e.g. 3264VDC for a 460VAC machine. Readings corrected to 40°C, which are less than 20 megohms, shall be discussed with purchaser.

2.16.2 Running Test

After the insulation tests, the motor shall be run at no load at full terminal voltage, with either a half key or a half coupling, on the shaft. If the motor uses an external oil supply and removal system in normal use, a similar system shall be arranged for the test. The test shall determine that:

- **No Load Amps.** No load current unbalance at balanced rated voltage shall be less than 2 percent.
- **Vibration.** Horizontal, vertical and axial readings shall be taken at each bearing and results recorded for purchaser's review. Tolerance shall not exceed EASA Recommended Practices, Table 4-5, or other standard provided by purchaser.
- **Temperature Rise.** Temperature rise after levels stabilize shall be within normal limits on the frame and bearings.
- **Shipment.** At the completion of the test, the motor shall be painted as specified by the purchaser, and prepared for shipment. Any lubricant and coolant inlets and outlets shall be plugged and masked before painting and shipping. Any special precautions or preparations that should be noted before powering the motor shall be indicated on a tag.

3.0

QUALITY CONTROL

3.1 MEASURING INSTRUMENTS

3.1.1 Calibration

All measuring instruments shall be calibrated regularly. The calibration records shall be available for purchaser inspection. Minimum frequency of calibration shall be annually, except:

- **Insulation Testers.** Insulation resistance testers - every six months to a known resistance;
- **Dimension Meters.** Micrometers, vernier calipers and other dimension measuring devices - every six months against a minimum grade AA gauge block set; and,
- **Bore Gauges.** Bore gauges shall be calibrated to a certified standard before and after each use.

3.1.2 Storage

All measuring equipment shall be stored in a clean dry environment.

3.2 MATERIALS

3.2.1 Anti-Friction Bearings

Anti-friction bearings shall be replaced. They shall be the same type as originally used, unless otherwise specified by purchaser.

Bearings shall be stored in their factory packaging in a clean, dry, location. The location shall be isolated from any vibration strong enough to be felt by hand.

3.2.2 Solid Insulation

Insulating materials such as slot liners, tapes and phase insulation shall meet or exceed the temperature class of the motor and shall be compatible with the resins used.

Specifications for the materials shall be obtained from the material supplier and kept for checking their suitability for the application.

The materials shall be stored in a clean, dry location. Material such as B stage tape that degrades with time at room temperature, shall be kept refrigerated.

3.2.3 Resins And Varnishes

The manufacturer's material specifications for resins and varnishes shall be kept on file, to permit checking for correct storage, handling and usage.

A sample shall have been taken and analyzed to be satisfactory within three months of its being used on a motor.

3.2.4 Other Materials

Other materials shall be new and of good quality. In particular the following shall be confirmed:

- **Lead Wires.** Lead wires shall be multi-stranded and flexible with insulation meeting or exceeding the temperature and voltage class of the motor.
- **Magnet Wire.** Magnet wire for random-wound motors shall be compatible with the other insulation system components and shall be insulated with a polyamide, polyimide or a combination of both, over a polyester base coat, or equivalent. Any wire damaged in storage or working shall be replaced. The manufacturer's specifications for the insulation shall be kept on file for reference. Inverter grade wire shall be used on any motor that purchaser advises is powered by a pulse-width modulated inverter.

3.3 TESTS AND INSPECTION DURING WORK

3.3.1 Records

Records shall be kept of all tests and inspections carried out during the work. Signed copies of these records shall be shipped in original form, at the same time as the motor, to the designated contact person.

3.3.2 Access

Purchaser shall have access to the repair facilities at all times that work is being done, for the purposes of checking progress and inspecting the work.

3.4 FINAL INSPECTION AND TEST

For all motors over 200 HP, or when purchaser specifies, purchaser shall be informed when the final inspection and testing of the motor is to take place. Purchaser shall have the right to be present for tests on any motors.

In emergency cases, tests will not be held up waiting for purchaser representatives, but every effort shall be made to keep purchaser informed so that they can be present if possible.

All final inspection and test results shall be sent, in their original form, to the designated contact person.

4 Motor Repair Form

Repairer:				Date:		
Motor Designation:	Facility	Dept.	Process	Description	MM+ I.D.	
Manufacturer:		Type:		Power:		
Volts:	Amperes:	Speed:		Frame:		
Serial #:		Bearings: Replace w/bearing by (mfg.):		Lubricant Grade:		
Other:						
Service: Explain:			<input type="checkbox"/> Powered by ASD	<input type="checkbox"/> Contamination		
			<input type="checkbox"/> High Altitude	<input type="checkbox"/> High Ambient Temperature		
Reason sent for repair:						
Required work:						
Past problems with machine:						
Missing parts:						
Urgency: (check one)			Cost limitations:			
<input type="checkbox"/> Rush, full O.T.			<input type="checkbox"/> Contact with price before work			
<input type="checkbox"/> Rush, limited O.T.			<input type="checkbox"/> Go ahead, advise price			
<input type="checkbox"/> ASAP, no O.T.			<input type="checkbox"/> Other _____			
<input type="checkbox"/> Routine (specify time)						
<input type="checkbox"/> Hold points if required						
Special instructions						
Contact:				Phone:		
Reference:						

5

GLOSSARY

Air Gap. The radial clearance between the rotor and stator. The size and symmetry of the air gap is important for maintaining motor efficiency.

Bars. Axial conductors in a rotor cage.

Burnout Oven. Heat cleaning oven used for stripping windings from a core. These are sometimes called roasting ovens. They operate at temperatures up to 750°F and may have water spray systems to control temperature transients and secondary combustion to control emissions. They are distinguished from lower temperature baking ovens, which are used to cure varnish.

Cage. See “Squirrel Cage” .

Coil. One or more turns of wire that insert into a single pair of core slots.

Coil supports. Ring-like structures or individual blocking between coils to which a motor's end turns are tied to add rigidity. Sometimes called “surge rings”.

Core. The magnetic iron structure of a motor's rotor or stator. It is comprised of stacked sheet iron.

End bracket. Structure at each end of the motor enclosure that supports the bearing. These are sometimes called end “bells” because of their bell-like shape.

End ring. Circular metal structure that shorts the rotor bars together at each end of the rotor, forming the squirrel cage. End rings may be cast integral with the bars or connected during rotor fabrication.

End Turns. Portion of a coil outside the slots at each end of the core.

Exciting Current. Component of electric current used to induce a magnetic field.

Flux density. Measure of magnetic field strength. Calculated measure of magnetic field strength of the core iron or how hard the core iron is being utilized magnetically.

Form wound. Winding method in which preformed coils are wound in orderly layers of rectangular cross-section wire. This is most common in medium and high voltage machines over 500 HP. It is distinguished from “random wound” in which windings of round wire are inserted into stator slots before any varnishing is done.

Growler. A vee-shaped AC electromagnet used to test rotors. Placing a rotor or armature across the open iron and inducing a secondary voltage into the rotor bars or armature coils completes the magnetic circuit.

High Potential Test. Test of insulation integrity by application of a higher than nameplate rated AC or DC voltage between electrically winding or circuit elements and ground. Also called “hi pot test”.

Hot spots. Regions of high temperature in an iron core. These are typically caused by shorts between the sheet iron laminations due to surface damage or failure of interlaminar insulation. Service personnel feel for hot spots during core loss testing to determine if core repair or replacement is necessary.

Induction Motor. The simplest and, by far, most commonplace AC motor design. The induction motor rotor is simple, having neither permanent magnets, externally excited electro-magnets, nor salient (projecting) poles. The rotor contains a conducting structure, which is excited by magnetic induction from the stator without necessity of brushes or other direct contact.

Interlaminar Insulation. The thin insulating coating between the sheets of iron in a core. This is necessary to reduce circulating electric currents (known as eddy currents) within the core iron.

Inverter Duty. Intended for being powered by a DC to AC inverter. An inverter comprises the output stage of all electronic adjustable speed drives, which are also known as variable speed drives or variable frequency drives. Part 31 of NEMA MG-1 provides recommended standards for Inverter Duty motors.

Journal. Region on a shaft where a bearing is located. The journal must be precisely machined for a correct fit to the bearing bore. With sleeve bearings, the journal is the actual bearing surface on the shaft.

Jumper. Crossover connection from pole group to pole group. Internal connection by which coil groups of a given phase are connected in series.

Leads. Conductors running from the motor coils out to the terminal box. These are typically flexible stranded wires with tough flexible insulation. They must be correctly labeled to facilitate connection to the power cable.

Losses. Motor input power that is lost rather than being converted to shaft power. The lost power manifests as heat in various parts of the motor structure.

Low Voltage. Voltage ratings not exceeding 600 VAC.

Magnet Wire. Wire used for winding motors and transformers. It is non-stranded wire of round or rectangular cross-section with factory applied turn insulation. It is manufactured in many size increments. Care must be taken that rewinding replicates the original winding size.

Phase Barrier. Insulating film material placed in the end turns to ensure good electrical isolation between the end turns of different coils.

Pitch. The number of slots encompassed or surrounded by a coil. It is expressed as 1-n where n is the number of the encompassed slots including the ones in which the coil is inserted. See also “Span” below.

Poles. Poles are the total number of magnetic north/south poles produced in the rotating magnetic field of a motor. The number of poles is determined by the winding design and the motor speed is inversely related to the number of poles.

Purchaser. Purchaser shall mean the customer requesting services to which these Specifications are applicable.

Random Wound. Windings of round wire not preformed into layers. Also known as mush wound, this is the type of winding used in nearly all low voltage machines under 600 HP. It is distinguished from “form wound” in which preformed coils are wound in orderly layers of rectangular cross-section wire.

Records. Records shall mean information recorded and maintained in the shop's files/computer for ten years or as otherwise agreed. A copy shall be provided to the client with the repaired or inspected motor.

Repairer. Repairer shall mean the person(s) or company(ies) carrying out the work as specified in these Specifications.

Resistance, Insulation. Resistance between points that are supposed to be electrically isolated. Higher is better.

Resistance, Winding. Resistance of the winding measured between each pair of line connections. Rewinding should replicate original resistance. Changed resistance after rewinding may indicate altered winding pattern, incorrect wire gauge, or a turn miscount.

Restacking. Rebuilding and reinsulation of a core with new and/or reconditioned laminations.

Rotor. The rotating part of an AC induction motor that includes the shaft, the laminated iron, and the squirrel cage.

Separators. Insulating spacers used to separate coils of separate phases within a slot. Also called “slot sticks”.

Slots. Cutouts in core iron for the insertion of coils.

Slot Liner. Film inserts in core iron slots. They protect the coil wire from damage and provide an extra measure of electrical insulation between the wire and core iron.

Slot sticks. See “separators”.

Space heaters. Electrically powered device in a motor enclosure, which keeps the internal air above the dew point to prevent condensation from forming on winding insulation.

Span. Another word for “Pitch” (See above). An earlier definition was the number of teeth encompassed by a coil, which is 1 less than pitch. To avoid confusion with the older meaning, the value of pitch or span should always be expressed as 1-n or 1 to n.

Squirrel Cage. This is the current conducting assembly used in most induction motor rotors. Sometimes called a rotor cage. It is typically cast aluminum in smaller motors and fabricated of copper alloy in larger motors.

Stator. The stationary part of a motor's magnetic circuit. In induction motors it is the outer annular iron structure containing the power windings.

Strand. Smallest component of a wire. Some wire is compounded of multiple smaller wires for flexibility. The smaller wires are strands. Strand is a term also used in a motor to refer to multiple wires in parallel within the same coil. Multiple strands are sometimes used in a motor to improve flexibility for coil insertion or to obtain a desired wire cross-sectional area not available in a single wire size.

Stripping. Process of removing old windings from a core. The biggest challenge is unsticking the varnish. Various combinations of cutting, mechanical pulling, heat, or chemical softening may be used in stripping. The most common method involves heating in an oven to break down the varnish.

Surge Comparison Test. Test of winding integrity and symmetry, using a specially designed instrument. Also called "surge test". This test imposes a voltage transient simultaneously on all three phases. A decaying wave form appears on a scope. Failure of the three phases to overlay (i.e. have the same shape) indicates phase impedance asymmetry, thus a fault condition or winding error.

Teeth. The core iron material between the slots.

Temperature Rise. Temperature increase above ambient. National Electrical Manufacturers Association provides standards for temperature rise of fully loaded motors based upon insulation class and other motor parameters. Ensuring that temperature rise remains within these limits during no-load running is a worthwhile safeguard though it does not prove that temperature rise will remain within limits at rated load.

Three Phase. Commonplace AC electrical service involving three conductors offset in phase from each other. The concept eliminates torque pulsation and accommodates creation of rotating magnetic fields, within motors, to facilitate starting and running torque.

TIR. Total Indicated Runout. This is a measure of bend, warp, or out-of-round in a rotating structure like a disk or shaft. It is the total deflection as measured by a dial indicator.

Turn. A single wire loop within a coil comprised of multiple loops.

Turn Insulation. Enamel insulating coating on the winding wire. This thin, but important, coating is applied to the wire by the wire manufacturer. Most wire manufacturers offer wire product lines with more robust turn insulation for use in inverter fed motors.

Vacuum Pressure Impregnation (VPI). Method of applying varnish to ensure maximum penetration and minimum voids. The wound core is placed in an air-tight tank. A vacuum is applied to remove the air, and moisture. While still under vacuum, varnish is introduced to submerge the core. Finally, pressure is applied to force the varnish into all spaces.

Varnish. Substance to secure windings into the core, provide an extra measure of insulation integrity, and stabilize wires and coils against abrasion from movement. Varnish is applied as a liquid by various methods and is cured or hardened to a solid, usually by heating.

Wedge. Insulating material that is slid into the top of each slot. It may vary from a flexible arched film to a straight rigid strip, sometimes called a top-stick. The wedge serves to tighten the coils in the slot and hold them in place.

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