ANSI/EASA Standard AR100-1998

Recommended Practice For the Repair of Rotating Electrical Apparatus

Table Of Contents

Back to top.

Back to top.

Back to top.

Note: Sections pertaining to the repair of liquid-filled and dry-type distribution transformers were withdrawn from this edition of *EASA Recommended Practice for the Repair of Rotating Electrical Apparatus*.
Back to top.

Section 1 General

1.1 PURPOSE
The purpose of this document is to establish guidelines in each step of electrical apparatus rewinding and rebuilding.

1.2 SCOPE
This document describes record keeping, tests, analysis, and general guidelines for the repair of electrical motors and generators. It is not intended to take the place of the customer's or the machine manufacturer's specific instructions or specifications.
Excluded from the scope of this document are specific requirements, certification, and inspection required for listed explosion proof, dust-ignition-proof, and other listed machines for hazardous locations; and specific or additional requirements for hermetic motors, hydrogen-cooled machines, submersible motors, traction motors, or Class 1E nuclear service motors.

1.3 IDENTIFICATION
1.3.1 Service Center Labeling
Machines received for repair should have the repair company's name or identifying logo and shop order number permanently embossed or inscribed adjacent to the nameplate on the frame for future reference. This shop order number should be listed on the repair invoice.

1.3.2 Records
A record of each machine received for repair should be established at the time of receipt and kept on file for at least 3 years. The record should include the nameplate data, electrical test data (both before and after repair), mechanical measurements (both before and after repair), original winding data, final winding data, and details of replaced parts. This record should be made available to the customer for review if requested. The primary cause of failure should be determined, if possible, and should be recorded on the apparatus repair record.

1.3.3 Nameplate
An electrical machine should have a permanent nameplate containing the principal information needed to put the machine into service. The original nameplate is preferred. If a machine is redesigned, the original nameplate should remain on the unit and a new nameplate mounted adjacent to it with the word "redesigned" and the new rating and date of redesign shown. The original nameplate may be reversed (blank side out) to prevent misinterpretation, but it should
remain with the frame.

1.4 CLEANING
All windings and parts should be cleaned. Dirt, grit, grease, oil, and cleaning agents should be removed. Windings and parts should then be dried.

1.5 TERMINAL LEADS
All apparatus should be equipped with lead wire of rated temperature and voltage insulation and of sufficient current carrying capacity. The temperature rating should be appropriate for the duty and any oven curing process, and allow for the effect of heat transfer to the terminals.
All leads should be suitably marked or colored where necessary to indicate correct connection. Lead markings should conform to original manufacturer markings, NEMA Stds. MG 1 or IEC Std. 34-8, whichever is applicable.
Leads and markings should be of sufficient durability to withstand the environment involved and be of sufficient length for ease of connecting to power supply at the terminal box or to terminal blocks. Leads on totally enclosed apparatus should be properly sealed to meet environmental operating conditions.
A print or plate should be furnished, where necessary, indicating correct connections.

1.6 TERMINAL CONNECTORS
The recommended method of attaching terminal connectors (lugs) to lead wire is by crimping or pressure indenting the lug barrel, using a lug sized to suit the particular cable stranding provided, in accordance with recommendations of the lug manufacturer.
Damaged or missing lugs should be repaired or replaced.

1.7 TERMINAL BOXES
Terminal boxes should accommodate the connections without crowding. Missing terminal boxes should be replaced, and
damaged terminal boxes should be repaired or replaced.
Gaskets and seals should be replaced where necessary.

1.8 COOLING SYSTEM
The fans and cooling ducts should be clean and operational. Cover plates and air baffles should be in place. Damaged or missing parts of the cooling system should be repaired or replaced.

1.9 EXTERIOR FINISH
Apparatus should be externally cleaned and painted. Shaft extensions should be treated to prevent corrosion.

1.10 PACKAGING AND TRANSPORTATION
After completion of the repair and testing, the machine should be packed in a manner suitable for the form of transport to be used. Packing and transport should be as arranged with the customer. Blocking of the shaft is recommended, depending on the type of machine, mode of transport and the distance to be traveled. Where blocking is used, it should be clearly identified. Oil-lubricated machines should be shipped without oil, and the need for lubricant clearly identified.
Back to top.

Section 2 Mechanical Repair

2.1 SHAFTS
Shafts should be checked for wear, cracks, scoring and straightness.

2.1.1 Shaft Extensions
Shaft extensions should be smooth, polished and concentric with the shaft center. Shaft extension dimensions should be checked.
2.1.1.1 Diameter Tolerances
· NEMA frame size machines: See Table 2-1.
· IEC frame size machines: See Table 2-2.
2.1.1.2 Permissible Runout
· NEMA frame size machines: See Table 2-3.
· IEC frame size machines: See Table 2-4.
2.1.1.3 Keyseat (Keyway) Width Tolerances
· NEMA frame size machines: See Table 2-5.
· IEC frame size machines: See Table 2-6.
Keyseats should be true and accommodate keys to a tap fit.

2.2 BEARINGS
2.2.1 Ball or Roller Bearings
Bearing housing and shaft bearing fits should be measured and compared to manufacturer's specifications (Reference: ANSI/ABMA Std. 7 as a guide). Any fits that are not within tolerance should be restored.

2.2.2 Sleeve Bearings
Sleeve bearings should be uniform in diameter, of proper fit in the housing, smooth internally, and suitably grooved for adequate distribution of lubricant.
When sleeve bearings are remanufactured or replaced by new bearings, the diametral clearance should be set to original equipment manufacturer's specifications if available. Otherwise, the values in Table 2-7 are provided as a

guide. Measure the new bearing dimensions.
2.2.2.1 Sleeve Bearing End-Thrust
Bearings of horizontal machines should be positioned on the shaft to eliminate end-thrust against either bearing.
2.2.2.2 Oil Rings
Oil rings should be true and rotate freely. Retainers, when provided, should be inspected and replaced if necessary.
2.2.2.3 Seals
Seal clearance should be set to original equipment manufacturer's specifications if available. Otherwise, the values in Table 2-8 are provided as a guide. Measure the final seal dimensions.

2.3 LUBRICATION
2.3.1 Grease
Grease passages and pipes should be clean. Grease inlets should be equipped with fittings. Grease should be compatible with the customer's lubricant. Open bearings should be filled with grease during assembly.
In the absence of the machine manufacturer's lubrication instructions, the grease reservoir should be filled to approximately 1/3 capacity.

2.3.2 Oil
Oil should be compatible with the customer's lubricant. There should be a means to determine oil level, such as an oil sight gauge.

2.4 FRAME AND BEARING HOUSINGS
2.4.1 General
Frame and bearing housings should be examined for defects. Cracks and breaks should be repaired and fits restored to manufacturer's specifications.

2.4.2 Mounting Surface Tolerances, Eccentricity and Face Runout
· NEMA Type C face-mounting motors and Type D flange-mounting motors: See Table 2-9.
· NEMA Type P flange-mounting motors: See Table 2-10.
· IEC flange-mounted machines: See Table 2-11 and Table 2-12.

2.5 LAMINATIONS
The rotor laminations should not be loose on the shaft, sleeve or spider on which the lamination stack is assembled. The fit should be restored if it is found to be loose. The outer diameter of the rotor laminations should be true and concentric with the bearing journals.
The stator laminations should not be loose in the frame. The bore of the stator laminations should be true and concentric with the rabbet (spigot) diameter of the frame.

2.6 BALANCING
Dynamic balancing should be to the level specified by the customer. In the absence of a requested level, dynamic balancing to balance quality grade G2.5 (ISO 1940/1) should enable the machine to meet final vibration limits as defined in Paragraph 4.5.6.
Note: Locate balance weights so that they do not interfere with other components.

2.7 SLIP RINGS
The slip rings should be turned to concentricity with the shaft bearing seats.
The surface of the finished rings should be smooth and polished.
Slip rings should have sufficient stock to ensure proper brush performance. Manufacturer's limits should apply.

2.8 COMMUTATORS
2.8.1 Machining
The commutator should be turned to concentricity with the shaft bearing seats.
The surface of the machined commutator should be smooth and burnished. No flat spots or high, low or loose segments should exist.
Commutators should have sufficient stock to ensure proper brush performance. Manufacturer's limits should apply.

2.8.2 Undercutting

The mica should be undercut, or left flush, as required by the application. When undercut, the mica should be removed along the sides of the bar for at least the complete length up to the riser or dust groove and to a depth of approximately the width of the slot. Undercut areas should be free of foreign material and high mica.

Beveling may be required for those commutators that have rough segment edges resulting from work-hardening of the copper during the undercutting process.

2.9 BRUSHHOLDERS

Brushholders should be clean and free of any grit, oil, or dirt. Movable brushholder parts should be free working. The brush fit in the brushholder box should be inspected for excessive clearance, and worn brushholders should be replaced. Clearances should be as specified in Table 2-13.

Brush stud insulation should be free of cracks and should not be charred or have pieces missing.

In the final assembly of the machine, brushholders should be adjusted for clearance to the commutator or slip rings of 0.060 inch (1.5 mm) to 0.125 inch (3 mm), depending on the size of the unit. Manufacturer's specifications should apply.

For commutator machines, it should be verified that the brushholders align the brushes with the commutator bars and maintain equal radial spacing between brushes.

Spring pressure should be measured and adjusted to a range recommended by the original equipment manufacturer or the brush manufacturer for the specific application and brush type. For commutator machines, brush springs should provide the required brush pressure for successful commutation.

Brushholders and jumpers should be high-potential tested to the machine frame at the test voltage specified for the corresponding winding circuit (see Subsection 4.4).

2.10 BRUSHES

Brush shunts should be tight in the brush and connections to the holder should be clean and tight and clear of other items.

The face of the brush should be seated, or contoured, to make full contact with the commutator surface or slip rings.

The brush fit in the brushholder box should be inspected for side clearance (see Table 2-13) and for excessively worn brushes. Brushes worn beyond useful length should be replaced.

Brushes in the same circuit of a machine should be of the same grade unless otherwise specified by the original equipment manufacturer. For DC machines, brushes should be the size and grade to give successful commutation in normal service.

2.11 BRUSH SETTING FOR DC MACHINES

In the final assembly, the brush rigging should be positioned so that the brushes are set for brush neutral, with brush position clearly marked. Accepted methods of determining this position vary widely, and no single standard procedure applies.

Note: In an assembled DC machine, each brush must contact at least two commutator bars at a time. Then, the brush short-circuits the armature coil connected to these bars. The brushes are considered to be set for brush neutral when the armature coils shorted by the brushes are midway between main poles.

2.12 AIR GAP MEASUREMENT OF DC MACHINES

In a DC machine, the radial length of all main and interpole air gaps should be uniform and to original manufacturer specification.

2.13 ACCESSORIES

Capacitors should be tested for rated capacitance and subjected to a high-potential test (see Paragraph 4.4.4). Capacitors should be replaced if damaged.

Short circuit devices, centrifugal mechanisms, switches, and starting relays should be verified for electrical and mechanical operation at correct speed and voltage. These items should be replaced if damaged.

Terminal boards should be replaced if damaged.

Space heaters should be tested for rated current or power and subjected to a high-potential test (see Paragraph 4.4.4). They should be replaced if damaged.

Bearing temperature sensors or protectors should be identical with or equivalent to the original devices in electrical and thermal characteristics.

Back to top.

Section 3 Rewinding

3.1 INSPECTION

3.1.1 Windings

The condition of the windings and the extent of repairs should be determined by inspection and, as necessary, by

tests (see Section 4).
Bars and end rings for amortisseur and squirrel cage windings should be examined for evidence of defects. Testing may be needed (see Paragraph 4.3.2).
Winding data should be reviewed for accuracy.

3.1.2 Core Laminations
Cores should be examined for evidence of shorting or lamination hot spots. Testing may be needed (see Paragraph 4.2.7).

3.1.3 Thermal Protectors or Sensors
Thermostats, resistance temperature detectors (RTDs), thermocouples and thermistors should be checked for electrical and physical defects.

3.2 REWIND SPECIFICATION
The winding should maintain the same electrical characteristics as the original unless redesigned by agreement with, or at the instruction of, the customer. Any rating change should be indicated on a new nameplate (see Paragraph 1.3.3).

3.3 STRIPPING OF WINDINGS
Defective windings should be removed from the core in a manner that will not damage the laminations or other components. Oven temperature should be controlled to avoid degradation of the interlaminar insulation and distortion of any parts. Core slots should be clean and free of sharp edges or particles.

3.4 INSULATION SYSTEM
The entire insulation system, materials, and methods of application should be equal to or better than that used by the original machine manufacturer. All components of the insulation system must be compatible with each other with respect to electrical,
mechanical, and thermal characteristics. The insulation system should withstand the high-potential tests described in Subsection 4.4 and the normal operation of the machine.

3.5 CONDUCTORS
The current-carrying capacity, insulation, and mechanical qualities of the conductors should be suitable for the environment in which the machine is to operate. The temperature rating of the conductor insulation should be equal to or higher than that of the insulation system. If the conductor material is changed, it should be equal to or better than the original material in all aspects of performance and application.

3.6 STATOR, ROTOR, AND ARMATURE COILS
Coil extensions should not be longer than the originals.

3.6.1 Random-Wound Coils
Coils should be wound and inserted in the core slots with a minimum of crossed conductors. Care should be taken not to damage the insulation or conductors. Coils should be wedged with full-length top sticks to hold them securely in the slots. Inter-phase insulation should be used (where applicable).

3.6.2 Form-Wound Coils
The fabricating of coil loops and the forming of these loops into the coil shape should be accomplished without damage to the conductor insulation. Each layer of coil insulation should be uniformly and tightly applied to minimize stress points and air voids.
Coils should be placed in the core slots without damaging the coil insulation. Coils should tightly fit slots. Coils should be wedged to hold them securely in the slots. Surge rings or similar supports should be secured to the coils and laced to one another as necessary to diminish distortion.

3.7 FIELD COILS
Where high rigidity and a complete bonding of all the components is required, a high bond strength varnish or a thixotropic resin should be applied to the ground insulation and to each layer of the coil during winding of the coil; otherwise, vacuum pressure impregnation may be utilized when a complete bond between insulation and conductors

can be ensured.

3.7.1 Stationary Coils
Varnish treatment of shunt, series and interpole coils is acceptable for coils originally manufactured by this method. The insulation of the outer coil layer should be sufficient to withstand surges or inductive voltage spikes.

3.7.2 Rotating Coils
Coils and pole pieces should be securely wedged and braced when installed.

3.8 AMORTISSEUR AND SQUIRREL CAGE WINDINGS
Bars for amortisseur and squirrel cage windings should fit tightly in the core slots. End rings should be secured to the bars by welding or brazing, as appropriate for materials used. The winding should maintain the same electrical characteristics as the original unless redesigned by agreement with, or at the instruction of, the customer.
The winding should withstand thermal and mechanical forces that occur during normal operation of the machine.
For balancing, see Subsection 2.6.

3.9 THERMAL PROTECTORS OR SENSORS
Thermostats, resistance temperature detectors (RTDs), thermocouples and thermistors should be identical with or equivalent to the original devices in electrical and thermal characteristics. Thermal protectors or sensors should be removed or omitted only with customer consent.

3.10 SHAPING AND LACING OF STATOR WINDINGS
End windings should be shaped and laced as needed to provide the necessary clearance to the rotor, stator, frame, bearing housings, air deflectors and frame hardware. End windings should be able to endure starting currents. On larger machines where surge rings (coil supports) are used, the rings should be suitably insulated, accurately fitted and laced to the coils to insure adequate support for the winding. Blocking between coils on end windings of formed coils should equal or exceed the original in strength against end winding movement.
Restrictions to air flow should be avoided.

3.11 COIL CONNECTIONS
3.11.1 Making Connections
Connections which are made by crimping, soldering, brazing, or welding should use materials that have adequate conductivity and are mechanically strong enough to withstand the normal operating conditions. Materials such as solder paste, fluxes, inhibitors and compounds, where employed, should be neutralized after using. These materials should be suitable for the intended use and of a type that will not adversely affect the conductors. Soldered joints should not be used in place of brazed or welded joints.
Connections and splices should be so constructed as to have conductivity equal to or greater than the conductors of the winding.

3.11.2 Insulating Connections
Connections should be adequately insulated to withstand the temperature and voltage ratings of the machine and be mechanically adequate to withstand normal operation. Connections and leads should be laced, tied, or otherwise securely fastened to prevent movement.
The insulation should be applied so as to allow the varnish/resin to penetrate.

3.12 WEDGES
Wedges for stators, armatures and rotors should have adequate mechanical strength and thermal rating to withstand normal operation of the machine.
Wedges should fit tightly in the slots.

3.13 BANDING OF ROTORS AND ARMATURES
Bandings should be secured, tied, or laced and be mechanically strong enough to withstand the centrifugal force, current surges, and vibrations of normal operation of the machine, including overspeed (where applicable).
Resin-filled glass banding tape may be applied directly to the winding. It should be applied at the manufacturer's recommended tension and method of curing. The banding should be of sufficient thickness and width to restrain the

coils.
When wire banding is used, it should be applied to the winding over banding insulation. The banding should match the original in location, material (magnetic or non-magnetic), wire size and number of turns. The wire should be applied with sufficient tension to hold the coils in place without distorting them.
Caution: Replacing wire banding with resin-filled glass banding may change the magnetic circuit configuration, affecting commutation and thermal rating of the winding. Similar effects may result from replacing glass banding with wire banding.

3.14 IMPREGNATION OF WINDINGS
Windings of rewound machines should be pre-heated, varnish/resin treated and cured using a method of application and a material of sufficient thermal rating to withstand the normal operation of the machine. The treatment should be compatible with the entire insulation system and suitable for the environment in which the machine is to operate.
Back to top.

Section 4 Testing

4.1 SAFETY CONSIDERATIONS
See Appendix for safety considerations.

4.2 INSULATION CONDITION TESTS
Tests should be performed to indicate the suitability of the insulation for continued operation. Inspection and insulation resistance tests should be performed before the high-potential tests. Other tests, indicated below, may also be applied. All test results should be retained. Trends in results are often better condition indicators than the absolute values (Reference: IEEE Std. 95).

4.2.1 Inspection
Insulation should be examined for evidence of degradation or damage, such as:
(1) Puffiness, cracking, separation or discoloration as indication of thermal aging.
(2) Contamination of coil and connection surfaces.
(3) Abrasion or other mechanical stresses.
(4) Evidence of partial discharges (corona).
(5) Loose wedges, fillers, ties, banding, or surge rings.
(6) Fretting at supports, bracing or crossings (an indication of looseness or movement).
(Reference: IEEE Std. 432, Sec. 5.)

4.2.2 Insulation Resistance Test
The recommended minimum insulation resistance to ground,
R_{Min}, when measured at or corrected to 40° C is given by:

$R_{Min} = n + 1$, in Megohms

where
n is the rated machine potential in kilovolts. A 500V megohmmeter is suitable for testing of machines rated up to 2400V. Above that voltage, a 1000V megohmmeter is recommended. Test voltage should be applied for one minute (Reference: IEEE Std. 43).

4.2.3 Polarization Index (P-I) Test
The polarization index test should be performed at the same voltage as the test in Paragraph 4.2.2 for ten minutes. The recommended minimum value of polarization index for windings rated Class B and higher is 2.0 (References: IEEE Std. 43, Sec. 9.2; and IEEE Std. 432, App. A2).

4.2.4 Insulation Power Factor Tests
Insulation power factor, dissipation factor, and tip-up tests may be performed on large machines. Interpretation of results is by comparison with results of tests on similar machines. No standard interpretation of results has been established (Reference: IEEE Std. 432, Sec. 8.1).

4.2.5 Step Voltage Test
Step voltage tests are useful if performed at regular maintenance intervals. Changes in results may indicate insulation degradation (Reference: IEEE Std. 95).

4.2.6 Turn-To-Turn Test
Accepted methods of testing turn-to-turn insulation vary widely. No single standard procedure applies, although several standards touch on the subject (IEEE Stds. 432, 522, and 792; and NEMA Stds. MG 1-12.05). The most often used procedure is the surge comparison test, using a test voltage of twice the circuit rating plus 1000 volts. This test may be applied to all types of windings.

4.2.7 Interlaminar Insulation Test
Defects in laminated cores can be detected by loop or core tests (Reference: IEEE Std. 432, Sec. 9.1, App. A4).

4.2.8 Bearing Insulation Test
Bearing insulation should be tested with a 500V megohmmeter. Insulation resistance should be 10 megohms or greater.

4.3 RECOMMENDED WINDING TESTS
Windings should be tested to ensure that there are no grounds, short circuits, open circuits, incorrect connections or high resistance connections.

4.3.1 Stator and Wound-Rotor Windings
One or more of the following tests should be performed:
(1) Insulation resistance test.
(2) Winding resistance test.
(3) Growler test.
(4) Phase-balance test.
(5) Surge comparison test.
(6) Polarity test.
(7) Ball rotation test (low voltage energization).

4.3.2 Squirrel Cage Windings
One or both of these tests should be performed:
(1) Growler test.
(2) Single-phase test.

4.3.3 Armature Windings
One or more of the following tests should be performed:
(1) Insulation resistance test.
(2) Growler test.
(3) Surge comparison test.
(4) Bar-to-bar resistance or voltage drop test.

4.3.4 Shunt, Series, Interpole, Compensating and Synchronous Rotor Windings
One or more of the following tests should be performed:
(1) Insulation resistance test.
(2) Winding resistance test.
(3) Surge comparison test.
(4) Voltage drop test (DC or AC voltage), coils in series.
The variation in DC voltage drops should not be greater than 5% between coils of same field circuit.
10% variation in AC test results is acceptable if the DC test is within limit.

4.3.5 Interconnection of Windings
Shunt, series, interpole, compensating, and synchronous rotor windings should be tested to ensure that the polarities and connections are correct. Terminal and lead markings should comply with Subsection 1.5.

4.4 HIGH-POTENTIAL TESTS

High-potential tests should be performed on windings and some accessories of electrical machines at a specified voltage. To avoid excessive stressing of the insulation, repeated application of the high-potential test voltage is not recommended.

Machines to be tested must be clean and dry. Inspection and insulation resistance tests with acceptable results should be performed before the high-potential tests. Insulation resistance tests should be repeated at the completion of the high-potential tests.

When a high-potential test is conducted on an assembled brushless exciter and synchronous machine field winding, the brushless circuit components (diodes, thyristors, etc.) should be short-circuited (not grounded) during the test.

High-potential tests should be successively applied between each winding or electric circuit under test and the frame (or core) of the machine. All other windings or electric circuits not under test should be connected to the frame (or core).

Capacitors of capacitor-type motors must be left connected to the winding in the normal manner for machine operation (running or starting).

Electrical machines may be tested using AC or DC high-potential test equipment. The DC high-potential test is recommended instead of the AC test because of its non-destructive nature. Multiply the AC test voltage by 1.7 to obtain the equivalent DC test voltage.

AC high-potential testing should be performed by applying specified voltage at 50-60 Hz continuously for one minute.

DC high-potential testing should be performed by applying specified voltage for a duration of one minute after test voltage is reached. The DC potential should be increased gradually to the desired test voltage in order to limit the charging current.

Caution: After completion of a DC high-potential test, the winding must be grounded to the frame (or core) until the charge has decayed to zero. (References: IEEE Stds. 4 and 95; and NEMA Stds. MG 1-3.01.)

4.4.1 Windings

4.4.1.1 New Windings

High-potential tests should be applied as specified in Table 4-1 for AC voltage and Table 4-2 for DC voltage. The tests should be applied once only at the specified voltage. Subsequent tests (such as acceptance tests) should be at 85% of these values (Reference: NEMA Stds. MG 1-12.03).

4.4.1.2 Reconditioned Windings

High-potential tests for reconditioned windings should be performed at 65% of the new winding test value.

4.4.1.3 Windings Not Reconditioned

Machines with windings not reconditioned should have an insulation resistance test instead of a high-potential test.

4.4.2 Accessories

4.4.2.1 New Accessories

Accessories such as surge capacitors, lightning arresters, current transformers, etc., which have leads connected to the machine terminals should be disconnected during the test, with the leads connected together and to the frame or core. These accessories should have been subjected to the high-potential test applicable to the class of machine at their point of manufacture. Capacitors of capacitor-type motors must be left connected to the winding in the normal manner for machine operation (running or starting).

Component devices and their circuits, such as space heaters and temperature sensing devices in contact with the winding (thermostats, thermocouples, thermistors, resistance temperature detectors, etc.), connected other than in the line circuit, should be connected to the frame or core during machine winding high-potential tests. Each of these component device circuits, with leads connected together, should then be tested by applying a voltage between the circuit and the frame or core. The high-potential tests should be applied as specified in Table 4-3 for AC voltage and Table 4-4 for DC voltage. During each device circuit test, all other machine windings and components should be connected together and to the frame or core. (Reference: NEMA Stds. MG 1- 3.01.8).

4.4.2.2 Accessories of Machines
with Reconditioned Windings

The high-potential test for accessory circuits of reconditioned machines should be performed at 65% of the new device test value.

4.4.2.3 Accessories of Machines with Windings Not Reconditioned

Accessory circuits of machines which have not had their windings reconditioned should have an insulation resistance test instead of a high-potential test.

4.5 NO-LOAD TESTS

4.5.1 Speed

For AC motors, no-load running tests should be made at rated voltage and rated frequency. The speed should be measured and compared with name-plate speed.

Shunt-wound and compound-wound DC motors should be run with rated voltage applied to the armature, and rated current applied to the shunt field. The speed should be measured and compared with nameplate speed.

Series-wound motors should be separately excited when tested due to danger of run-away.

DC generators should be driven at rated speed with rated current applied to the shunt field. The output voltage should be measured and compared with rated voltage.

4.5.2 Current

No-load current should be compared with full-load current.

4.5.3 Cooling System

The cooling system should be verified as being operational.

4.5.4 Sound Level

Tests may be made for sound level as an indication of fault or as an irritation to those in the machine ambient (Reference: NEMA Stds. MG 1-12.53, 1-12.81 and 1-20.50).

4.5.5 Bearing Temperature

Ambient and bearing housing temperatures may be measured periodically until temperatures are stabilized.

4.5.6 Vibration Tests

The vibration tests should be in accordance with NEMA Stds. MG 1-7 for standard machines, as arranged with the customer, or as necessary to check the operating characteristics of the machine. When there are special requirements, i.e., lower than standard levels of vibration for a machine, NEMA Stds. MG 1-7 for special machines is recommended.

The unfiltered vibration limits for resiliently mounted standard machines (having no special vibration requirements), based on rotational speed, are shown in Table 4-5. Vibration levels for speeds above 1200 rpm are based on the peak velocity of 0.15 inch per second (3.8 mm/s). Vibration levels for speeds below about 1200 rpm are based on the peak velocity equivalent of 0.0025 inch (0.0635 mm) peak-to-peak displacement. For machines with rigid mounting, multiply the limiting values by 0.8.

Note: International standards specify vibration velocity as rms in mm/s. To obtain an approximate metric rms equivalent, multiply the peak vibration in in/s by 18. (Reference: NEMA Stds. MG 1-7.08.)

4.6 PERFORMANCE TESTS

Full-load tests may be made as arranged with the customer or as necessary to check the operating characteristics of the machine (References: IEEE Stds. 112 and 115 and NEMA Stds. MG-1).

4.7 INSTRUMENT CALIBRATION

Each instrument required for test results should be calibrated at least annually against standards traceable to the National Institute of Standards and Technology (NIST) or equivalent standards laboratories (References: ANSI/NCSL Z540-1-1994 and ISO 10012).

Each instrument should bear record of recent calibration and, if extreme importance is attached to the test results, the instrument should be calibrated immediately before and after the completion of the test procedure.

[Back to top.]

Appendix Electrical Testing Safety Considerations

(This Appendix is not a part of EASA AR100-1998, *Recommended Practice for the Repair of Rotating Electrical Apparatus*.)

A.1 PERSONAL SAFETY

A.1.1 Training
Employees should be trained in safe operation of all electrical equipment within their responsibility. Training should be provided by
use of relevant equipment operational manuals, hands-on training and/or training video tapes. Employees should be informed of the relevant safety rules, and employers should enforce compliance.

A.1.2 Clothing
Clothing should be suitable for the work to be performed. Flame-retardant material is recommended. The wearing of exposed jewelry should be avoided. Safety glasses should be worn at all times.

A.1.3 Supervision
Employees should work under the direction of an experienced and qualified person within the test area. At least two persons should be within the test area at all times.

A.1.4 First Aid
Personnel should be trained in the procedure for securing emergency medical aid.

A.2 TEST AREA
A.2.1 Enclosure
Test area should be enclosed with a fence or colored rope, preferably yellow. Red or yellow strobe lights may be placed at test corner areas for additional warning.

A.2.2 Gates
When a metallic fence or cage is used, it should be grounded. Gates provided for entry of equipment and personnel should be equipped with interlocks so power to test area is interrupted if gate is opened.

A.2.3 Signs
Signs should be posted concerning the electrical hazards, warning unauthorized personnel to stay out of the test area.

A.2.4 Lighting
Test areas should be well illuminated.

A.2.5 Safety Equipment
Fire extinguishers and first aid equipment should be readily available and personnel should be trained in their use. Operating personnel should stand on an insulated mat.

A.2.6 Test Unit Clearance
Clearance should be provided between the test unit and test area boundaries to allow ease of movement for personnel. Lead length should allow a minimum of ten feet (3 meters) between test center operator and test unit. Exposed shafts and couplings/sheaves should be guarded.

A.3 UNIT UNDER TEST
A.3.1 Suitability For Test
Test personnel should verify that the unit is mechanically and electrically suitable to undergo the proposed test procedures.

A.3.2 Exclusive Attention
Only the unit under test should be in the test area.

A.3.3 Grounding
An equipment ground should be installed on all apparatus under test.

A.3.4 Base
Units under test should be secured to prevent rolling or tipping during testing.

A.4 TEST PANELS
A.4.1 Construction
Construction should be of the "dead front" type. Instantaneous over-current trips or fuses should limit fault currents in the main power supply to the panel capacity.

A.4.2 Voltages
Output voltages should be clearly marked. Voltages above 600V should require special selection procedures to prevent inadvertent application.

A.4.3 Warning Lights
A warning light should indicate when the panel is energized. An additional warning light should indicate when power leads to a unit under test are energized.

A.4.4 Disconnect
A means for disconnecting the lines to the panel should be located within sight from the test panel.

A.4.5 Safety Switch
An emergency hand or foot operated switch or push button to de-energize the power source should be located in the test area. A remote emergency safety switch adjacent to the test area also is recommended.

A.4.6 Leads
Test leads and insulated clips should be of adequate ampacity and voltage class for the machine being tested.

A.4.7 High-Potential Ground Test
AC or DC high-potential testing current should be limited by impedance or instantaneous trips to limit damage when breakdown occurs.
Back to top.

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29CFR1910.331 - .335 OSHA: Electrical Safety-Related Work Practices. Occupational Safety And Health Administration. Washington, DC; revised 1994.

Standards Organizations & Other Resources

The following organizations produce documents and standards, some of which are referenced in the *EASA Recommended Practice for the Repair of Rotating Electrical Apparatus*.

ABMA
American Bearing Manufacturers Association
1200 19th St., NW, Suite 300
Washington, DC 20036
(202) 429-5155
Fax: (202) 223-4579

ANSI
American National
Standards Institute
11 West 42nd St., 13th Floor
New York, NY 10036
(212) 642-4900
Fax: (212) 302-1286

IEC
International
Electrotechnical Commission *

3 rue de Varembe
CH 1211 Geneva 20, Switzerland

IEEE
Institute of Electrical and Electronics Engineers, Inc.
345 East 47th St.
New York, NY 10017
(212) 705-7900
Fax: (212) 752-4929
For Publications:
445 Hoes Lane
P. O. Box 1331
Piscataway, NJ 08855-1331
(800) 678-4333
Fax: (908) 981-9667

ISO
International Organization
of Standardization *
1 rue de Varembe
CH 1211 Geneva 20, Switzerland

MIL-STD
United States Government Printing Office
710 North Capitol St.
Washington, DC 20420
(202) 512-1800
Fax: (202) 512-2250

NEMA
National Electrical
Manufacturers Association
1300 N. 17th St., Suite 1847
Rosslyn, VA 22209
(703) 841-3200
For Publications:
(703) 841-3201
Fax: (703) 841-3300

NFPA
National Fire
Protection Association
One Batterymarch Park
Quincy, MA 02269
(617) 770-3000
Fax: (617) 770-0700
For Publications:
P. O. Box 9146
Quincy, MA 02269
(800) 344-3555
Fax: (617) 984-7057

NIST
National Institute of
Standards and Technology
Route 270

Gaithersburg, MD 20899
(301) 975-2000

UL
Underwriters' Laboratories, Inc.
333 Pfingsten Rd.
Northbrook, IL 60062
(847) 272-8800, Ext. 42612
Fax: (708) 272-8129

* IEC and ISO standards are available through ANSI, which is the American representative to all international standards groups.