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IEEE Recommended Practice for the Repair and Rewinding of Motors for the Petroleum and Chemical Industry

Sponsor

Petroleum and Chemical Industry Committee
of the IEEE Industry Applications Society

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IEEE Standards Board

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American National Standards Institute

Abstract: General recommendations are provided for users of motors that need repair as well as owners and operators of establishments that offer motor repair services. The use of this recommended practice is expected to result in higher quality, more cost-effective, and timely repairs. Guidelines are also provided for evaluating repairs and facilities.
Keywords: horizontal motors; motors, repair and rewinding of; vertical motors

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Introduction

(This introduction is not part of IEEE Std 1068-1996, IEEE Recommended Practice for the Repair and Rewinding of Motors for the Petroleum and Chemical Industry.)

This recommended practice was conceived at the Petroleum and Chemical Industry Conference held in September 1984 in San Francisco, following a panel discussion on motor repair. The Project Authorization Request was submitted 26 September 1984, and was approved by the IEEE Standards Board on 13 December 1984. The project was sponsored jointly by the Petroleum and Chemical Industry Committee (PCIC) of the Industry Applications Society and the Electric Machinery Committee (EMC)* of the Power Engineering Society. The first ballot was mailed out in June 1989. Although the required affirmative votes were received and negative ballots were resolved, it was felt that a reballot was in order, and the second ballot was mailed in November 1989. This recommended practice was put back in the revision cycle in 1991 in anticipation of a need for an early revision. The revised document was balloted in 1995, reballoted in May 1996, and submitted to the IEEE Standards Board in June 1996.

The IEEE Motor Repair and Rewind Working Group, which had members from both the PCIC and the EMC, had the following membership:

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The committee that balloted and approved this recommended practice for submission to the IEEE Standards Board consisted of members of the PCIC and the EMC, and had the following membership:

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*Formerly the Rotating Machinery Committee

When the IEEE Standards Board approved this recommended practice on 19 September 1996, it had the following membership:

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IEEE Recommended Practice for the Repair and Rewinding of Motors for the Petroleum and Chemical Industry

1. Overview

1.1 Scope

This recommended practice covers general recommendations for the repair of electric motors and includes recommendations for both the user and the repair facility. It is not intended to supplant specific instructions contained in the manufacturer's instruction book or in any contractual agreement between a manufacturer and a purchaser of a given machine.

These recommendations apply to horizontal and vertical motors, NEMA frame size 140 and above, having a voltage rating of 15 kV or less. These recommendations apply only to the repair of motors and are not intended to cover major modifications.

Excluded from the scope of this recommended practice are the following:

— Specific requirements, certification, and inspection required for listed explosion-proof and dust-ignition-proof machines.

— Any specific or additional requirements for hermetic motors, hydrogen-cooled machines, submersible motors, or Class 1E nuclear service motors.

1.2 Purpose

This recommended practice is intended to be a basic or primary document that can be utilized and referenced by owners of motors that need repair as well as by owners and operators of establishments that offer motor repair services. It has been developed primarily for the needs of the Petroleum and Chemical Industry but can be adapted to other applications.

The use of this recommended practice by users and repair facilities is expected to result in higher-quality, more cost-effective, and timely repairs. It also provides a means of evaluating repairs and facilities.

2. References

2.1 General

Definitions, construction, and test methods not specifically covered in this recommended practice should comply with the following standards insofar as they are applicable. When the following standards are superseded by an approved revision, the revision shall apply.

API 541-1995, Form-Wound Squirrel-Cage Induction Motors 250 hp and Larger.[1]

IEEE Std 1-1986 (Reaff 1992), IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation (ANSI).[2]

IEEE Std 100-1996, IEEE Standard Dictionary of Electrical and Electronics Terms.

IEEE Std 112-1991, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators (ANSI).

IEEE Std 115-1983 (Reaff 1991), IEEE Guide: Test Procedures for Synchronous Machines (ANSI).

IEEE Std 432-1992, IEEE Guide for Insulation Maintenance for Rotating Electrical Machinery (5 hp to less than 10 000 hp) (ANSI).

IEEE Std 841-1994, IEEE Standard for the Petroleum and Chemical Industry–Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up to and Including 500 hp (ANSI).

NEMA MG 1-1993, Motors and Generators.[3]

2.2 Insulation tests

Where appropriate to the construction, tests should be made in accordance with the following IEEE test procedures:

IEEE Std 43-1974 (Reaff 1991), IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery (ANSI).

IEEE Std 117-1974 (Reaff 1991), IEEE Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery (ANSI).

IEEE Std 275-1992, IEEE Recommended Practice for Thermal Evaluation of Insulation Systems for Alternating-Current Electric Machinery Employing Form-Wound Preinsulated Stator Coils for Machines Rated 6900 V and Below (ANSI).

IEEE Std 429-1994, IEEE Recommended Practice for Thermal Evaluation of Sealed Insulation Systems for AC Electric Machinery Employing Form-Wound Preinsulated Stator Coils for Machines Rated 6900 V and Below (ANSI).

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[1]API publications are available from the Publications Section, American Petroleum Institute, 1200 L Street NW, Washington, DC 20005, USA.

[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[3]NEMA publications are available from the National Electrical Manufacturers Association, 1300 N. 17th St., Ste. 1847, Rosslyn, VA 22209, USA.

2.3 Other insulation systems

For other insulation systems that do not have established test procedures, similar procedures may be used if it is shown that they properly discriminate between service-proven systems known to be different.

When being evaluated by an established test, a new or modified insulation system should be compared to an insulation system on which there have been two years of service experience. If a comparison is made to a system of the same temperature class, the new system should have equal or longer thermal endurance under the same test conditions; if a comparison is made to a system of a lower temperature class, the new system should have equal or longer thermal endurance at an appropriately higher temperature. When comparing systems of different classes, an appropriate higher temperature should be considered to be 25 °C per class higher than the temperature for the base insulation system class.

3. Definitions

Definitions in this recommended practice are in accordance with the definitions in IEEE Std 100-1996.[4] Definitions that are unique to this recommended practice are as follows:

3.1 accepted test: A test on a system or model system that simulates the electrical, thermal, and mechanical stresses occurring in service.

3.2 experience: Successful operation for a long time under actual operating conditions of machines designed with temperature rise at or near the temperature rating limit.

3.3 insulation system: An assembly of insulating materials in association with the conductors and the supporting structural parts. All of the components described below that are associated with the stationary winding constitute one insulation system, and all of the components that are associated with the rotating winding constitute another insulation system.

- *Coil insulation with its accessories.* All of the insulating materials that envelop and separate the current-carrying conductors and their component turns and strands, and form the insulation between them and the machine structure; includes wire coatings, varnish, encapsulants, slot insulation, slot fillers, tapes, phase insulation, pole-body insulation, and retaining ring insulation when present.
- *Connection and winding support insulation.* All of the insulation materials that envelop the connections that carry current from coil to coil, and from stationary or rotating coil terminals to the points of external circuit attachment; and the insulation of any metallic supports for the winding.
- *Associated structural parts (insulation system).* Items such as slot wedges, space blocks, and ties that are used to position the coil ends and connections; any nonmetallic supports for the winding; and field-coil flanges.
- *Insulation class.* Divided into classes according to the thermal endurance of the system for temperature rating purposes. NEMA classes of insulation systems used in motors include Classes A, B, F, and H. These classes have been established in accordance with IEEE Std 1-1986. Other classes of insulation are constantly being developed for such use.

[4]Information on references can be found in Clause 2.

Insulation systems shall be classified as follows:

— *NEMA Class A.* An insulation system (105 °C temperature limit including a 40 °C ambient or 65 °C rise) that by experience or accepted test can be shown to have suitable thermal endurance when operating at the limiting Class A temperature specified in the temperature rise standard for the machine under consideration.

— *NEMA Class B.* An insulation system (130 °C temperature limit including a 40 °C ambient or 90 °C rise) that by experience or accepted test can be shown to have suitable thermal endurance when operating at the limiting Class B temperature specified in the temperature rise standard for the machine under consideration.

— *NEMA Class F.* An insulation system (155 °C temperature limit including a 40 °C ambient or 115 °C rise) that by experience or accepted test can be shown to have suitable thermal endurance when operating at the limiting Class F temperature specified in the temperature rise standard for the machine under consideration.

— *NEMA Class H.* An insulation system (180 °C temperature limit including a 40 °C ambient or 140 °C rise) that by experience or accepted test can be shown to have suitable thermal endurance when operating at the limiting Class H temperature specified in the temperature rise standard for the machine under consideration.

3.4 major modification: Includes conversion from one type of machine to another type of machine, conversion from one type of enclosure to another type of enclosure, or conversion from one rating to another rating.

3.5 motor: A rotating machine that converts electrical energy into mechanical energy. As used in this recommended practice, the term can also be used to mean a generator.

3.6 repair: Includes incoming inspection and test, damage appraisal, cleaning, replacement or fixing of damaged part(s) or both, assembly, postrepair inspection and test, and refinishing.

3.7 repair facility: The entity contracted to make repairs; includes the "on site" repair(s) made by employees of that entity in addition to repair(s) made at a shop operated by or under the supervision of that entity.

3.8 user: The owner of the motor or an authorized agent of the owner.

4. Prerepair activity and responsibility

Several items should be considered and documented prior to repairs. Indeed, some prequalification activities should be finished prior to failure or shipment to a repair facility. Some of these activities are the responsibility of the user, while others are assigned to the repair facility.

4.1 User responsibility

In order for the repair operation to be high quality and cost-effective, the user should make advance preparation.

4.1.1 Records

Obviously, the more information the owner can furnish to the repair shop, the better the repair will be. For example, at times the nameplate will not be readily readable after several years in service, and pertinent data must be obtained largely by measurements. It would be ideal if the owner would keep a record of the nameplate and other motor information in a file along with any data such as failure history, bearing replacement, and other problems and repairs. This record would then be furnished to the repair facility.

4.1.2 Facility

The owner should take the time to prequalify several local repair facilities. The following are possible check items:

a) *Crane equipment capacity.* The capacity and condition of lifting equipment should be adequate to handle large motors safely and smoothly.

b) *Cleanliness.* Facilities should be clean and orderly, and tools and equipment should be in good repair. The area, especially winding areas and bearing installation areas, containers, and equipment used to apply the insulation system should be checked.

c) *Insulation requirements.* The facility should have the necessary equipment to adequately install and test the integrity of the insulation system.

d) *Instrumentation.* The shop should have adequate instrumentation and measurement equipment that is calibrated yearly to properly perform all tests. Records are necessary on all testing. Backup instruments are recommended for data verification.

e) *Pricing structure.* Agreement on costs, inspection, rewinding, or reconditioning motors should be established in advance.

f) *Warranty.* All warranty items and conditions should be in writing and clearly understood by both parties before repairs are begun.

g) *Removal of windings.* Facilities for removing windings safely and without damaging machine laminations should be available.

h) *Rotor balancing.* Rotor balancing and vibration analysis equipment should be available.

i) *Quality assurance program.* Does the shop have a formal Quality Assurance (QA) program in place and does the program, if any, meet with your company standards for QA?

4.2 Repair facility responsibility

4.2.1 Incoming inspection

Prior to unloading the machine, the shipment should be inspected with the shipper representative for obvious damage that may have occurred during shipment.

a) A receiving report should be filled out and include broken or missing parts and/or any unusual problem(s).

b) For conditions that cannot be adequately described, pictures should be taken for clarity.

c) Record all motor nameplate information available. The following data should be obtained:

    1) Type of apparatus
    2) Manufacturer
    3) Style
    4) Serial number
    5) HP/kVA/kW/power factor
    6) r/min
    7) Phase
    8) Frequency
    9) Volts
    10) Full-load amps
    11) Temperature rise/insulation class/ambient base
    12) Type of bearing and manufacturer

13) Code or locked rotor amps
14) Service factor
15) Enclosure

4.2.2 Incoming tests

Prior to incoming running, perform the following and record information where appropriate:

a) Verify that there is no shaft or bearing damage.

b) Verify that bearings are lubricated.

c) Insulation resistance tests should be performed. See 4.3.1 items i) through l) for minimum insulation resistance values, temperature compensation requirements, and test voltages. See Annex A for a motor data insulation resistance record form.

d) Hipot to ground in accordance with IEEE Std 432-1992 as appropriate to the winding being tested.

e) Other tests required before energizing the motor are as follows:

   1) Continuity of field coils and stator windings.
   2) Condition and installation of brushes.
   3) Single-phase, low-voltage (approximately 10–20% of rated voltage) test on ac squirrel-cage rotor to find defective rotor bars. Maximum accepted line current variation < 3%, as the shaft is rotated with full-load current applied.
   4) Core loss test.
   5) Polarization index (where appropriate).
   6) Surge test (where appropriate).

If conditions permit, the motor should be run at reduced voltage initially (25–50% of rated voltage). If the test is successful, complete the data sheets in Annexes A and B, and then run the motor at full voltage, if possible.

4.2.3 Disassembly procedures and instructions

a) Before any disassembly is begun, parts should be marked (i.e., brackets, frame, covers, and brush holders).

b) Brackets and bearings should be identified as pairs.

c) Frame-mounted devices should be identified and recorded.

d) Wiring should be recorded, sketched, and marked before disconnecting.

e) Before removing the coupling or other shaft-mounted components, measure and record their position with respect to the end of the shaft (flush, past flush, or from flush). Critical components may need to be match marked for reassembly.

f) Check fan blades for damage and cracks using a penetrating dye system.

g) As parts are removed, record all noted damage or special markings.

h) Check shaft extension runout compliance with original motor specifications. If other information is not available, use the following:

   1) AC motor runout = 0.001 in total indicator reading
   2) DC motor runout = 0.002 in total indicator reading

i) Visually check for evidence of rubbing at outside diameters (fan, shrouds, end rings, armature laminations, etc.).

j) If possible, check for tightness of the core on its shaft. Visually inspect for signs of axial and radial movement.

k) Visually check rotating components for excessive heating and other abnormalities.

4.2.3.1 DC machines

Check condition of commutator, core laminations, windings, connections, bands, keyway, support rings, wedges, ties, threaded fits, etc.

4.2.3.2 AC machines

Inspect condition of bar joints, end rings, windings, slip rings, key ways, threaded fits, synchronous pole pieces, etc.

a) Measure and record dimensions of the following:

    1) Shaft extension
    2) Journal and bearing fits
    3) Shaft extension runout
    4) Shaft seal fits
    5) Commutator/collector ring diameter
    6) Commutator riser and brush surface length

b) Visually inspect the condition of nonrotating components (brackets, baffles, shrouds, brush holders, brushes, gasket, spacers, shims, threaded fits, machine fits, etc.).

c) Measure and record bracket fits for housings, cartridges, and bearings.

d) Visually inspect the condition of ball or roller bearing housing or cartridges (wear, grooving, seal fits, fretting, grease fitting, insulation, oil gages, etc.).

e) Visually inspect the condition of sleeve bearings while still in brackets (wear, oil grooves, oil rings, seals, dowels, parts, etc.).

f) Visually inspect field frame poles, iron, mounting blocks, welds, machined fits, brush rigging, space heaters, etc.

4.2.4 Removal of field coils—synchronous rotors

a) A diagram showing field pole location orientation and wiring connections should be made before attempting to remove poles.

b) Field poles should be marked according to frame and or rotor location.

c) The axial position for rotating field poles should be measured and recorded before removal to ensure that they are reinstalled at correct electrical center.

4.2.5 Removal of field poles on dc machines

a) A wiring diagram of field pole connections should be made facing connection end. Show main poles and interpoles with relation to some permanent frame-mounted device such as conduit box, etc. Clearly identify connecting leads from interpole to brush holders in order to ensure correct commutating polarity when reconnecting.

b) Follow standard practice of identifying shunt pole leads with F1-F2, series pole leads with S1-S2, and interpole/armature leads with A1–A2.

4.2.6 Rotors/rotating poles inspection

a) Prior to disconnecting the wiring, make an accurate drawing showing the location of all poles, wiring, fan blades, and associated hardware. Shaft keyway can be used as a reference indicating relationship of collector rings, brush exciter, leads, and wiring cleats.

b) Each pole piece should be match marked with respect to the rotor spider to ensure that they are reassembled in the same location and in the same orientation. General practice is to number the poles in a clockwise sequence while facing the collector ring or exciter end.

c) Measure and record the axial location of the pole pieces with respect to the rotor core and shaft. (Generally, this is best accomplished by identifying Pole #1, placing a center punch mark at its midpoint, and measuring the distance from the center punch mark to the shaft reference. Then using this dimension and shaft reference, place a center punch mark on each of the remaining poles. Locating the poles in this manner will allow the rotor to be returned to its correct magnetic center. An alternate method is to measure the distance between each pole piece dovetail and its outside rotor slot edge.)

d) When inspecting collector rings, if the rings must be removed in order to dismantle the poles, all orientations for the rings should be recorded on a drawing.

e) When inspecting squirrel-cage rotor bars (synchronous and induction), rotor bars and their connecting end rings should be inspected for cracks, arcing in slots, and for cage migration. All cracks and evidence of arcing should be recorded and, if possible, pictures should be taken showing the location of damaged bars. A drawing should be made showing the defective bar location, and all connecting parts between poles and end rings should be identified and recorded on the drawing.

4.2.7 Other mechanical inspection

a) Motor parts should be inspected for presence of cracks, signs of wear, or rubbing.

b) The keyway should be inspected for wear.

c) Ball, roller, and sleeve bearing tolerances, including bearing cap clearance, should meet the motor manufacturer's or bearing manufacturer's specifications.

d) Dimensions of bracket fits for housing, cartridge, and bearings should be measured and recorded.

4.3 Damage appraisal

A thorough appraisal of the motor's condition, as received, is essential for the following purposes:

— To determine what specific repairs are needed (The motor may have been sent to the repair center with limited external evidence as to the nature and location of trouble. What seems wrong may be correctable in several ways.)

— To find unsuspected trouble, perhaps unrelated to the obvious defect

— To diagnose cause and effect to help prevent a recurrence

This appraisal should include a complete review of the following conditions of each part of the motor:

— General cleanliness

— Cracked or broken welds or castings

— Missing hardware
— Wear or rub marks, including fretting
— Discoloration, charring, or other evidence of overheating
— Looseness at mating fits
— Corrosion, moisture, or oil inside the machine
— Mounting feet flatness (motor frame feet are to be flat within 0.005 in when placed on a flat reference surface)

Photographs of any abnormal conditions found are strongly recommended as part of the appraisal process and inspection report. In the absence of clear photographs, any drawings, diagrams, or descriptions should allow no uncertainty as to the location of the conditions described. If references are made to "clock position" or to ends of the machine (e.g., "inboard" or "outboard"), some explanatory note or sketch should make clear the location being described. The terms "drive end" and "opposite drive end" are recommended for horizontal shaft machines; "top" and "bottom" for vertical shaft units.

Damage appraisal of motor components is divided into two categories, electrical and mechanical (see 4.3.1 and 4.3.2).

4.3.1 Electrical

The stator winding comes first. Look for the following:

a) Slot wedges ("top sticks") that are loose, damaged, or have shifted in position.

b) Ties or lashings that are loose or broken.

c) Dirt, oil, or moisture deposited on coil surfaces.

d) Coil damage. Besides obvious burning, tracking, or charring, look for loose or cracked tape, coils that have moved within the slot, deposits of dirt or chemicals, and insulation pitted or worn away by airborne abrasive particles. If severe arcing or burning has taken place, inspect the entire unit interior carefully for globules or fragments of molten copper that may have been projected from the failed winding. Windings of motors rated 5 kV and above that have slot partial discharges will evidence white or grey powder on the surface.

e) On lead cables or straps, look for cracked, overheated, or frayed insulation; and loose or burned terminal lugs.

f) When a winding shows clear evidence of destructive arcing or overheating, observe and record carefully the location and nature of the damage. If all coils appear equally overheated, ventilation failure, undervoltage, stalling, or prolonged overload are likely causes. If coils within one phase are largely undamaged, the likely causes are single-phase operation or serious voltage unbalance. If only certain coils adjacent to line leads have been damaged, especially with relatively little heating, the likely cause is a transient surge voltage on the feeder circuit. These and many other failure modes, with the probable contributing factors, are reviewed in the bibliography (Clause 8).

g) Be alert also for evidence of insulation damage caused by flying objects such as broken fan blades within the motor. The impact will typically gouge down to bare copper without any burning unless adjacent turns become short-circuited and failure progresses.

h) Pay close attention, whether or not winding damage is apparent, to all stator ventilating passages. These can be blocked by varnish or contaminants even when a winding looks fairly clean on the surface.

i) If no stator winding damage is apparent, test the insulation resistance for windings using a megohmmeter in accordance with IEEE Std 43-1974. Record the value of insulation resistance (IR) between the winding (all leads connected together) and the stator core. Test voltage, applied for 1 min, should be as follows:

Rated motor voltage	Megohmmeter test voltage, dc
240–2400	500
3000–4800	2500
5200–13 800	2500 or 5000

j) If the measured insulation resistance corrected to a reference of 40 °C is not at least equal to 1 MΩ per 1000 V of motor nameplate rating plus 1 MΩ, the winding should be thoroughly dried and the test then repeated. Drying out temperature of the winding should not exceed 80 °C as measured by thermometer.

k) To correct IR readings to the reference temperature, use the formula found in IEEE Std 43-1974.

$$R_c = K_t \times R_t$$

where

R_c = Insulation resistance (in megohms) corrected to 40 °C
R_t = Measured insulation resistance (in megohms) at temperature t
K_t = Insulation resistance temperature coefficient at temperature t

Obtain K from figure 1 in IEEE Std 43-1974.

l) Windings in apparently good condition should receive a dc overpotential (hipot) test for 1 min at a voltage T calculated as follows:

$$T = 0.65\ (2E_m + 1000\ \text{V})(1.7)\ \text{Volts}$$

where

E_m = Rated motor nameplate voltage

m) If these tests are not passed, the repair center should discuss the results with the owner to arrive at a decision to rewind or to attempt further reconditioning and retesting (e.g., by reimpregnating the winding).

n) Inspect the stator core structure itself carefully for evidence of severe corrosion, local overheating of laminations, loose or broken slot teeth, loose or shifted vent spacers, or rub marks from contact by the rotor or material caught in the air gap. A core loss test should be performed to evaluate the condition of the laminations.

o) The rotor is the second major electrical component to be appraised. Cleanliness, laminations, vent spacers, slot tooth condition, and rub marks are checked as in the stator. Rotor laminations should be checked for "coning" (separation of laminations, causing the length of the rotor to be greater at the outer diameter than it is at the shaft).

p) A squirrel-cage rotor will be the type most often encountered. It may use a cage-bar and end ring structure that is cast in place using aluminum alloy, a fabricated aluminum bar or ring assembly, or a fabricated copper alloy cage. Whichever the type, using a dental mirror if necessary, inspect all accessible surfaces of bars and end rings, looking for "blued" (overheated) areas, cracks, missing pieces, bar movement in the slots, porous or deteriorated brazed or welded joints, and bars that have "lifted" outwards in the slots under centrifugal force. Record the location and nature of all defects found.

q) When overheated or melted bars are present, the most severe damage will typically be at the ends of the rotor, outside the core stack, when starting duty is the source of trouble. If running overload or blocked ventilation is the problem, rotor damage is more likely to be within the core stack itself.

r) Look for evidence of arcing or burning along the edges of bars adjacent to slots. This generally indicates bar looseness.

s) One or more cracked or broken cage bars normally dictates replacement of the entire cage. If the rotor cage requires replacement, aluminum or aluminum alloy cages should be of low copper content (0.2% or less). Copper or copper alloy cages should use metal joining material that is phosphorus free. If bars are loose but undamaged, swaging (with a properly radiused tool) of the bars near each end of the core stack and at one or more locations along the stack length may expand the bar material sufficiently to tighten the fit. However, this will not work if the bars are of the T-shape (narrow top, wide bottom) designed for a loose fit of the upper portion. Varnish treatment of a rotor containing a loose cage, even if vacuum-pressure impregnation is used, will not permanently lock loose bars in position and should not be used to repair a loose cage. Unless the bars can be mechanically tightened, they should be replaced.

t) The entire rotor should be tested in one of two ways to locate broken cage bars that are not otherwise apparent. If the stator and bearings are in usable condition, a single-phase test may be performed [applying typically 10% rated voltage to only two leads of the stator winding, turn the rotor slowly by hand and observe for current variations indicating the possible presence of cage defects; see 4.2.2 item e) 3)]. Otherwise, the removed rotor can be similarly tested on a "growler." Neither test, unfortunately, is either infallible or procedurally standardized. A typical difficulty is that the halves of a broken bar may separate only when the rotor is hot, the gap closing again when the rotor cools off. Oven-heating the rotor for a short time prior to a growler test may be helpful.

u) Examine steel retention caps or "shrink rings" (usually attached to the ends of high-speed rotor cages to restrain centrifugal expansion) for signs of distortion, looseness, or fretting. End rings themselves in such rotors may sometimes fail by being expanded outward into a somewhat conical shape by high centrifugal forces—a condition that must be corrected by replacement rather than remachining.

4.3.2 Mechanical

The mechanical condition appraisal should give particular attention to the following:

a) *Antifriction bearings.* Condition of lubricant; dirt, rust, or moisture; fretting corrosion; thermal discoloration; pitting or spalling of balls, rollers, or races; broken or missing retainers.

b) *Sleeve bearings.* Scoring or wiping of babbitt; integrity of any insulation furnished to block passage of bearing current (50 MΩ minimum IR is recommended; no temperature correction is needed; use megohmmeter with less than 50 V output); oil leakage; oil ring wear. Check forced-oil lubrication systems for blockage inside piping; presence of proper metering orifices in the system; proper pump operation.

c) *Shafts.* Straightness (NEMA MG 1-1993, Section 1, Part 4); cracks, corrosion; scoring or galling.

d) *Seals.* Rubbing or wear; leakage; glazing or hardening of felt or elastomeric materials.

e) *Gaskets.* Hardened, broken, or shifted parts; missing gaskets; evidence of lubricant or contaminant leakage past a gasket.

f) *Fasteners and dowels.* Loose, missing, or broken parts.

g) *Frame or housing.* Corrosion; structural weld integrity; blocked drains, breathers, or ventilating air passages.

h) *Condition of accessories.* Space heaters, thermostats, etc.

i) *Bearing replacement versus reuse.* Many users and repair facilities consider it good practice to replace antifriction bearings on any unit sent in for overhaul regardless of what other repair work is done. When large and expensive components are involved, such as spherical roller thrust bearings, financial constraints dictate keeping existing bearings in service if at all possible. That requires careful appraisal of bearing condition. To do that, the repair facility should use illustrated guidelines published by most bearing manufacturers and readily available through suppliers of power transmission equipment. The symptoms of shaft current flow, improper thrust loading, fatigue, lubrication failure, or other defects are well defined in such literature.

5. Recondition without damage repair

There are occasions when motors will be in a condition that requires only that the ventilation passages be cleared or the exterior be cleaned and painted, sometimes even reusing the same bearings, although this is not normally recommended for antifriction bearings. Perhaps the insulation is in good enough condition that a varnish and rebake (dip and bake) may restore the serviceability of the motor. When the motor is only to be cleaned and revarnished or possibly have the bearings changed, the repair facility must ensure that any method and solvents used for cleaning must be compatible with both the winding insulation (including slot liners and caps) and the enamel on the iron and any paint on the surfaces of the motor. Similarly, if motors are to be dried out, care must be exercised to avoid any possibility of overheating windings or insulation. It is recommended that drying temperatures be kept below 80 °C. See the appendix in IEEE Std 43-1974 for suggested drying procedure.

6. Repair period

6.1 Repair facility

6.1.1 Receiving

In most cases, the repair facility will have already received the unit and been involved with the decision to rewind. On some occasions, the initial damage evaluation will have been made at another location. In any case, there are steps covered in 4.3 that need to be performed and should be reviewed before damage repair or reconditioning is started.

6.1.2 Stripping and cleaning

One of the most potentially damaging procedures in the rewinding operation is the removal of the old, failed, electrical windings. There are several ways to remove these. Three of the ways will be addressed in this recommended practice.

6.1.2.1 Oven burnout

Some types of interlaminar insulation are severely damaged by exposure of laminations to temperatures above 650 °F during this process of "burning out" a winding preparatory to rewinding. Tests show that this may result in increased core loss (with resulting reduction in efficiency) or overheating of the new winding after it has been installed, or both.

Holding the oven chamber temperature below 650 °F will not necessarily eliminate the damage. Lamination temperature is not necessarily the same. Conventional oven temperature controls are often too slow in response to maintain the safe limit. Furthermore, shutting down the oven heat source does not necessarily limit the core temperature to a safe value. Some epoxy insulations, for example, will release large amounts of heat (even in the absence of oxygen) as they break down, even if the oven burners have been shut off.

It has been demonstrated that even with ovens set at 650 °F, the iron temperature can exceed 800 °F. The use of an embedded thermocouple or resistance temperature detector (RTD) is recommended to monitor the actual iron temperature. A properly calibrated recorder is preferred for recording both oven and motor temperatures. The oven temperature *must* be capable of being automatically controlled.

Therefore, oven burnout is only recommended if core temperature does not exceed 650 °F through use of a water or steam injection system in the oven for rapid suppression of "flaming" from burning insulation.

NOTE—The use of hand-held torches or direct flame is not recommended.

6.1.2.2 Water blasting

When water blasting is the procedure used for insulation removal, the following should be observed:

Extra care should be exercised when directing the cutting stream around the laminations so that moisture is not forced between the laminations. In conjunction with that, the motors should not be allowed to set overnight immediately after water blasting without removal of the windings and commencement of some form of artificial drying at a low temperature (less than 500 °F). Any cleaning solutions added to the high-pressure water must be compatible with the materials used in the motor construction. User and repair facility should be aware that there are significant safety hazards in using this method, and proper precautions should be taken.

6.1.2.3 Mechanical

When using mechanical removal techniques, extra care should be exercised so as to not cause separation of the laminations while pulling the windings. When heat is used to soften insulation (as opposed to burning out in an oven), the flame must not be allowed to impinge on the motor laminations.

6.1.3 Replacement of coils

The designations "random-wound" and "mush-wound" are interchangeable and, for replacement coils, refer to windings that are wound on a winding lathe and inserted into slots that are usually semiclosed. Form-wound coils are wound with rectangular wire, also on a winding lathe, and are usually used in slots that are "open." These windings rely on sheet material for insulation to ground and between coils. Conductor and turn insulation is usually enamel for random-wound coils. Form-wound coils utilize enamel, glass, synthetic aramid polymer, or mica tape for conductor and turn insulation. For hermetic motors with random- or form-wound coils, the insulation material must be compatible with the refrigerant.

a) After removal of the old coils, but prior to replacement of the coils, the laminations should be cleaned, inspected, repaired if necessary, and repainted.

b) Slot liners are recommended for all motors.

c) Coils should be formed from continuous lengths of properly sized and insulated magnet wire (to match nameplate criteria). Splices are not recommended in individual coils under normal circumstances.

d) Insertion of coils in slots should be done with care to avoid damage to the insulation or magnet wire.

e) Crossings of magnet wire within the slots should be held to a minimum on random-wound coils.

f) RTDs or thermocouples should be placed within the windings if they were part of the original design or requested to be added by the customer. Special care should be taken to ensure that the proper type RTD is used, and that the temperature/resistance values are in calibration.

g) Extra insulation material should be added between wedges and coils, and as fillers to obtain a snug fit against slot teeth. Form-wound coils should be insulated with a turn insulation of a minimum of one 1/2-lapped layer of at least 5 mil (0.005 in) mica paper, mica flake, or mica splitting supported by glass cloth, synthetic aramid polymer, polyester mat, polyester floc, or a combination of these in either tape or wrapper form. Tapes utilizing one or more layers of polyethylene terephthalate (PET) are unacceptable. Turn insulation should be used on all stators that have a core length greater than 0.64 m (25 in). Also, turn-to-turn insulation should be used according to the following turn-to-turn voltage schedule:

 > 50 V peak—one 1/2-lapped layer
 > 80 V peak—two 1/2-lapped layers
 > 120 V peak—three 1/2-lapped layers

 NOTE—Designs with one conductor per turn should have both strand and turn insulation.

h) Shape and secure end turns with proper bracing as required for particular coil design.

6.1.4 Replacement of bearings and restoration of fits and seals

a) *Removal of bearings.* Roller and ball bearings should be removed by using hydraulic presses or screw-drive bearing pulling equipment. Removal by hammering is not acceptable. If heat must be applied for removal, precautions are to be used to ensure that heating is concentric and that the shaft will not be heated unevenly, and the bearing should not be reinstalled.

b) *Reassembly of bearings.* Split sleeve bearings that are either new replacements or have been rebuilt should be fitted to journals by "bluing and scraping" as in the following:

 1) Using a bearing scraping tool (typically a triangular file with the teeth ground off), scrape any side reliefs and lands to the clearances and contours recommended by the motor manufacturer. Apply a small amount of nondrying bluing compound to the shaft journal, spreading it out to form a uniform coating 1–2 in wide over the full length of the bottom of the journal. Lift the shaft slightly, roll the lower bearing half into place, then lower the shaft onto it, ensuring that the normal rotor weight is applied to the bearing. Turn shaft 1/2 to 1 revolution. Lift the shaft again, and roll the lower bearing half out. A pattern of very light blue and dark blue areas will be seen on the bearing surface. These correspond to "high" and "low" portions of the bearing surface, respectively. Scrape the high spots to make the light/dark pattern uniform; the fitting process should be repeated with bluing as required until at least 80% contact has been achieved. When this is complete, leave the lower bearing half in place with the rotor weight resting on it.

 2) Lay two or three pieces of lead wire or other calibrated deformable gage material on the journal, perpendicular to the shaft centerline; their ends within 1/2 in of the horizontal split line. Make sure the upper and lower bearing halves are clean. If shims are used between the halves, make sure they are clean also. Place the upper bearing half over the journal on the wires or gage. Install the upper bearing cap or housing and tighten its bolts to specification. Then unbolt and remove the upper bearing housing and upper bearing half carefully. Measure the thickness of the lead wire or the clearance of the deformed material as instructed on the package. If the clearance is within limits, remove the wires or gage and proceed with reassembly. If it is not within limits, both bearing halves must be rebabbitted if too loose, or top half of bearing must be scraped if too tight.

 3) Reassembly of horizontal or vertical tilting-pad or shoe bearings should follow whatever procedures the manufacturer prescribes. Unless supplied by the owner, details of that procedure should be given to the owner as part of the final repair report (see 7.1 and Annex B).

4) Ball or roller bearings should be fitted to shafts by heat-expanding the inner bearing race in accordance with the bearing manufacturer's recommendations, using an oil-bath heater or an induction heater. Care must be exercised when using an induction heater to ensure that heat is evenly applied to bearings. Bearings must not be allowed to seize onto the shaft in a cocked position or before being fully seated up to the locating shaft shoulder or retaining ring. For those motors in which the outer bearing race is the "tight-fitted" member (e.g., vibrating screen drives), the bearing chamber is to be heat-expanded: the inner bearing race will be a slip fit on the shaft. Any pressure used to seat a tight-fitting bearing race shall be equally applied all around the race.

5) Sealants should not be used to secure a bearing race against rotation. If the metal-to-metal fit between races and the shaft or bearing housing is not within design limits, parts should be either bushed, sleeved, remachined, metal sprayed and machined to size, or otherwise restored to acceptable dimensions.

6) Grease-lubricated bearing housings or chambers should be packed no more than 1/3 full, using a grease suited to the motor's operating environment and bearing grease.

7) Either sleeve or antifriction bearings may be electrically insulated in some way to block the passage of damaging shaft currents originating within the machine's electromagnetic dissymmetries. The integrity of this insulation, as applied to the bearings themselves, should be tested during the reassembly process. [See 4.3.2 item b).]

8) All accessories fitted to bearing assemblies shall be replaced so that bearing insulation is not short-circuited and so that no protective system sensitivity is lost. Such accessories include lubrication system piping and fittings as well as temperature or vibration sensing devices.

9) Bearing assemblies should be adjusted to provide total shaft end play in accordance with the machine's design limits. For horizontal shaft antifriction bearing motors, the end play must allow for thermal expansion of the shaft without damage to bearings. For vertical motors, locknut adjustments, spacer rings, and installation of thrust bearing, support springs must be in accordance with manufacturer's instructions (or owner specifications). Sleeve-bearing machines must be assembled—by adjustment of bearing or rotor positions—such that the rotating assembly will "float" at its magnetic center position within the normal end play limits. This natural rest position will be indicated by a magnetic center indicator supplied on the motor, which should be carefully checked at reassembly. Any change in the magnetic center position, although it may be acceptable, must be marked on the shaft so as not to mislead the installer into positioning the coupling inappropriately.

10) Check sleeve-bearing assemblies for oil leaks as follows: With all piping, seals, probes, etc., in place, coat the exterior surfaces of all joints, splits, or threaded-in fittings with whiting and allow it to dry. Fill the bearing chamber to its normal oil level. Observe the whiting for any signs of darkening indicating an oil leak, and seal any leaks that may appear with original sealing gasket or other original sealing material. Repeat this process following final running tests.

6.1.5 Rotor/stator

6.1.5.1 Stator and rotor lamination repair

a) Eliminate laminations with mechanical or electrical damage. The following four methods of repairing laminations in a motor stator or rotor are dependent on the degree of damage. Selection of a method is based on the inspector's experience and judgment as to which repair method will eliminate core hot spots.

   1) *Method one.* (Stator is slightly rubbed by the rotor, fusing the edges of the laminations together.) The effectiveness of this method depends on the depth of the slot and the extent to which the winding fills the slot. The fused laminations may be vibrated apart with an air-driven

hammer placed against the end of the core section. Vibrations of the lamination fingers will break the metal fusion. While vibrating the damaged section, spray a high-quality insulation varnish in the damaged area. As the fingers vibrate, the varnish will penetrate the air gaps caused by the vibration and reinsulate the fingers. This method assumes the damage is near the end of the stator core section and the damage is on the tips of the fingers. Alternately, the laminations can be separated and the interlaminar insulation can be restored by the insertion of varnished mica splittings followed by an overall varnish treatment.

2) *Method two.* (Coil has failed in the slot, thereby melting the laminations, or the stator is moderately rubbed by the rotor.) With a pencil metal grinder, grind away fused metal until a definition of core laminations can be seen. Small, high-speed (25 000 r/min) hand grinders equipped with carbide-tipped, cone-shaped rotary files work best. Grind with light, intermittent pressure (rather than continuously) with movement in the same plane as the laminations until the fused metal is removed. Repaint the ground area and test the core for hot spot in the damaged area. Do not grind an area that will damage the mechanical integrity of the slot. If the damaged area is more than 10% of the total surface area of the core, then go to Method three.

3) *Method three.* (Damage is greater than 10% of total core-surface area or hot spot cannot be eliminated by Method two.) If the damaged area cannot be repaired by one of the first two methods, then a partial or total restacking of the stator or rotor core must be considered. The laminations will need to be disassembled and replaced or repaired by hammering and sanding away the damaged metal. The laminations must then be reinsulated by dipping in an organic insulating material with at least 300 °C temperature rating and air drying before reassembly. Inorganic insulation with higher temperature ratings is preferred, if available. The damaged area can be redistributed in the core by rotation of each damaged lamination by one slot. This may require rekeying the lamination in the frame.

4) *Method four.* Coning of end laminations on rotors should be fixed by welding to rigid laminations, installation of rigid finger plates, undercutting and banding, or lamination replacement. Excessive coning of the end laminations will often require replacement of the rotor to achieve a satisfactory result. Vacuum pressure impregnation (VPI) or varnish treatment is a temporary solution to this problem as indicated in 4.3.1 item s).

b) Rotor/shaft assemblies should be lifted and handled carefully so as not to transmit any lifting or other stresses to any part of the rotor cage or other motor windings. Lifting equipment must not cause abrasion or other physical damage to journal surfaces or seal fits. Do not allow the rotor to drag against the inner diameter of the stator when inserting the rotor into the stator.

c) Centering of the rotor within the stator should be checked, whenever permitted by the machine construction, by both "stationary gap" and "rotating gap" feeler gage readings at both ends of the motor. Readings should be taken at not less than three points 90° apart around the rotor periphery. In the "stationary" check, feeler gages are inserted successively at the separate points and the values are recorded. In the "rotating" check, the gages are left at one location and the rotor is turned in 90° steps, noting the reading at each step. This test can reveal an eccentric rotor that may go undetected by the "stationary" test. Readings shall not exceed a 10% deviation from the average at each end. (See API 541-1995, Section 2.4.7.16.)

6.1.5.2 Balancing

Rotor/shaft assemblies should be dynamically balanced at the largest fraction of maximum operating speed possible on the repair center balancing machine. Balancing should be done with the rotor supported on its shaft-bearing journals. The amount of unbalance should be measured in ounce-inches. The amount and location of balance weights added in the process, including their relative phase angle, should be recorded. Available manufacturer's recommendations should be followed concerning the acceptable limit of residual unbalance, but in any event, the degree of balance must be whatever is required to meet final vibration limits as given in tables 1, 2, and 3. The following information on shaft vibration is extracted with permission from NEMA MG 1–1993, Rev. 1, section 7.09.

"Shaft vibration limits are measured by non-contacting proximity probes. These probes are sensitive to mechanical and magnetic anomalies of the shaft or on the surface of the shaft to which it responds. This is commonly referred to as "electrical and mechanical probe-track runout." The combined electrical and mechanical runout of the shaft shall not exceed 0.0005 inch peak-to-peak (6.4 μm peak-to-peak) or 25% of the vibration displacement limit, whichever is greater. The probe-track runout is measured with the rotor at a slow-roll (100–400 rpm) speed, where the mechanical unbalance forces on the rotor are negligible. It is preferred that the shaft be rotating on the machine bearings, positioned at running axial center (magnetic center), when the runout determinations are made.

NOTES
1—Special shaft surface preparation (burnishing and degaussing) may be necessary to obtain the required peak-to-peak runout readings.
2—Shaft vibration measurements require special provisions for the installation of the measurement probes and shall therefore be a subject of prior agreement between manufacturer and purchaser.

When specified, the limits for the relative shaft vibration of rigidly mounted, standard machines with sleeve bearings, inclusive of electrical and mechanical runout, shall not exceed the limits in Table 7-2 (table 2 in this recommended practice).

Special machines requiring lower relative shaft vibrations levels than shown in Table 7-2 (table 2 in this recommended practice) shall not exceed the limits in Table 7-3 (table 3 in this recommended practice)."

CAUTION—Induction two-pole machines or synchronous two-pole machines may require special balance techniques, sometimes at rated speed. The balance of these rotors should not be changed without express written owner instructions or approval.

After complete motor reassembly, final balancing at maximum operating speed should be carried out to achieve NEMA standard vibration limits, as shown in Table 1, 2, or 3 of this recommended practice.

Table 1—Unfiltered bearing housing vibration limits, measured in any direction, with the machine on rigid mounting or resilient mounting per NEMA MG 1-1993, Rev. 1, section 7.06.1 or 7.06.2 (rigid mounting preferred)

Speed (r/min)	Rotational frequency (Hz)	Standard machine limits, velocity in/s peak (mm/s peak)	Special machine limits, velocity in/s peak (mm/s peak)
3600	60	0.15 (3.8)	0.08 (2.0)
1800	30	0.15 (3.8)	0.08 (2.0)
1200	20	0.15 (3.8)	0.08 (2.0)
900	15	0.12 (3.0)	0.06 (1.5)
720	12	0.09 (2.3)	0.05 (1.2)
600	10	0.08 (2.0)	0.04 (1.0)

Table 2—Limits for the unfiltered maximum relative shaft displacement (Sp-p) for standard machines

Maximum speed (r/min)	Relative shaft displacement (peak-to-peak)
3600	0.0028 in (70 μm)
≤1800	0.0035 in (90 μm)

Table 3—Limits for the unfiltered maximum relative shaft displacement (Sp-p) for special machines

Maximum speed (r/min)	Relative shaft displacement (peak-to-peak)
3600	0.0020 in (50 μm)
1800	0.0028 in (70 μm)
≤1200	0.0030 in (76 μm)

6.1.6 Electrical connections

a) Where any cables pass across or against metal edges of motor structural parts in the assembled machine, cable should be appropriately sleeved or taped for mechanical protection of the insulation against abrasion.

b) All leads should be given permanent markings adjacent to the terminal lugs in the form of indented metal bands (unless permanently die-stamped into the cable insulation). Lead identification should be in accordance with NEMA MG 1-1993.

c) Lead cables should not be brazed or welded to terminal lugs. The preferred method of attachment 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. No split barrel lugs are to be used. The crimping tool used should have ratchet pressure control such that the tool cannot be opened and released from the lug until the minimum recommended crimping force has been applied. No more than one cable should be crimped within the barrel of any one lug. In no case shall any strands of cable be cut or bent back out of the lug barrel so as to more easily fit the cable into the barrel. All strands must be fully attached to the lug.

d) Any bolted joints in the lead connections, such as where two or more lugs are permanently joined together or where bus bars are interconnected in some large machines, should be tightened to the following minimum torque values (based on heat-treated, Grade 5.0 steel bolts having unlubricated threads):

Bolt size (in)	Minimum dry tightening torque (lb-ft)
1/4	11
5/16	21
3/8	38
1/2	85
5/8	175

6.1.7 Fits

a) All parts containing machined fits—bearing brackets, frame structures, bearing capsules or holders, etc.—should be handled in such a way as to avoid distorting or scarring any of the machined surfaces. Any such fits should be thoroughly cleaned before being reassembled to a mating part. Take care to avoid getting a fit "cocked," and be sure parts are fully seated against any locating shoulders.

b) Gaskets should be replaced with materials appropriate to the motor's in-service environment. Sealing compounds used in lieu of gasketing should be applied in adequate thicknesses to fully seal the opening and should be of a consistency such as to remain in place after assembly.

c) Any dowel pins supplied between mating parts are to be properly replaced. Tightness of mounting bolts, or any sort of sealing compound, is not to be relied upon to maintain part alignment.

d) Some large motors may require shims to adjust stator position for correct air gap or to control bearing pedestal position. Shims used for that purpose must be flat, clean, free from burrs, and either stepped or tapered as necessary to accommodate surfaces that may not be parallel.

6.1.8 Painting

a) All accessible bare metal surfaces (including weld beads applied during repair) should be thoroughly cleaned and prime painted. Unless the owner specifies otherwise, finish paint can be chosen by the repair facility.

b) Exposed machined surfaces (such as shaft extensions) should be coated with a rust-preventive coating unless the machine is to be returned to service immediately.

6.1.9 Shipping precautions

a) For either railcar or highway truck transportation, rotor/shaft assemblies of sleeve-bearing motors should be blocked for shipment. The shaft should be restrained against either endwise, sidewise, or up-and-down movement caused by impact. Screws, clamps, plates, or other blocking means should be clearly identified for removal before the motor is started.

b) Vertical-shaft motors or motors having antifriction bearings need not be blocked for shipment provided one bearing is "locked" as part of the normal assembly. Vertical motors are to be shipped in the vertical position.

6.2 Field repairs

Although this recommended practice is intended to apply to repairs that are accomplished in a repair facility, it is recognized that repairs can and will be made at the installation location. For those cases, not all of the clauses of this document will apply. Others, however, should still be required. These can be handled on a job-by-job basis through communication between the owner and repair facility.

7. Post repair

7.1 Repair facility

Upon completion of motor repairs, the repair facility should submit a written report including the following:

a) Condition of the motor upon receipt
b) A detailed description of the work performed

c) Condition of the motor (both electrical and mechanical) when returned
d) Sufficient test data demonstrating that the motor was appropriately repaired
e) Photographs as deemed necessary for clarity

The motor repair report (Annex B) is intended to demonstrate the information that should be supplied as a minimum. This report should be protected by a water-resistant envelope, attached to the motor when it is returned.

7.2 User

After repairs have been completed and the motor is returned to the owner, a few precautions need to be taken to ensure that the repairs will have the desired result—a motor restored to a condition that will perform with the same or better characteristics as the original motor.

If the motor is to be put in stock, it should be stored in such a manner as to preserve the integrity of the repairs. If it is left outdoors, some method of low-level heating should be employed to avoid moisture condensation within the enclosure and deterioration of unpainted surfaces.

When the motor is reinstalled, the mechanical placement and alignment should be carefully checked to ensure that the motor is securely fastened to the foundation and that the shaft is properly lined up with the shaft of the driven equipment. Proper shaft alignment is critical whether the shafts are parallel or in line.

The electrical connections should be carefully made to ensure that they are tight and properly insulated. When the motor is first energized, a check should be made of the running currents and these currents should be compared with both the nameplate and historical data. It is helpful if the motor is run uncoupled until bearing temperature stabilizes to rule out any major problems and to locate the magnetic center for proper coupling installation. After the motor is coupled to the load but before energizing, the shaft should be rotated by hand, if possible, to be sure that no problems have occurred in the driven load or the coupling installation.

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Annex A

(informative)

Motor data insulation resistance record

Motor Number ____________________ Date received ____________________

Serial Number ____________________ Shop ID number ____________________

Temperature ________________ Humidity ______________

Surge test ________________ passed ______________ failed ________________

	Before	After
Voltage		
Megohms		
Microamperes		

	Before	After
Series field		
Shunt field		
Armature field		

Bearings

	Drive-end bearing	
	Found	**Left**
Bearing size		
Shaft size		

Opposite drive-end bearing	
Found	**Left**

Rotor air gap

	Before	
	Opp. Drive end	**Drive end**
Vertical		
Horizontal		
Diagonal		

After	
Opp. drive end	**Drive end**

Vibration analysis

Location	Opposite Drive-end bearing housing			Shaft V H	Drive-end bearing housing			Shaft V H
Units	**V**	**H**	**A**		**V**	**H**	**A**	
(Mils)								
(IPS)								

Note—Values entered shall include initials of tester.

Cause of Failure/Notes/Comments: ____

____

____

Annex B

(informative)

Motor repair report form

Motor Number ____________________ Date____________________Vertical?__________

Serial Number ____________________ Service ____________________ Horiz.?__________

MFG	hp/kW	Voltage	Amps	Phase	Hz	r/min	Enclosure

Frame	Insulation class	Form/random wound	Model

Type	Style	Design	Code	Service factor

Power factor	Exciter A	Exciter V	Secondary A Secondary V	Temperature rise		Ambient temperature	

Work Performed: Circle the appropriate items below or fill in as necessary.

STATOR: Rewind Retreat Clean and Paint

STATOR SHORTED IRON: Yes No

If found shorted, action taken: ____

ROTOR SINGLE-PHASE TEST: Good Bad

If bad, action taken: ____

ROTOR: Rebuild Rewind Retreat Clean and Paint

ARMATURE OR FIELDS: Rewind Retreat Clean and Paint

LEADS: Repair Replace Seal

BRUSH HOLDERS: Reinsulate Repair Replace Clean

COMMUTATOR: Repair Rebuild Replace Turn Undercut

METAL WORK: Housing Journal Other:

ANTIFRICTION BEARINGS: (Indicate type:) Sealed Shielded Open

SLEEVE BEARINGS: Rebuild Replace Scrape Reinsulate

BEARING SEAL: Rebuild Replace Remachine Reset

FLAME SEAL: Rebuild Replace Remachine Reset