A Guide To AC Motor Repair And Replacement

ELECTRICAL APPARATUS SERVICE ASSOCIATION

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Introduction

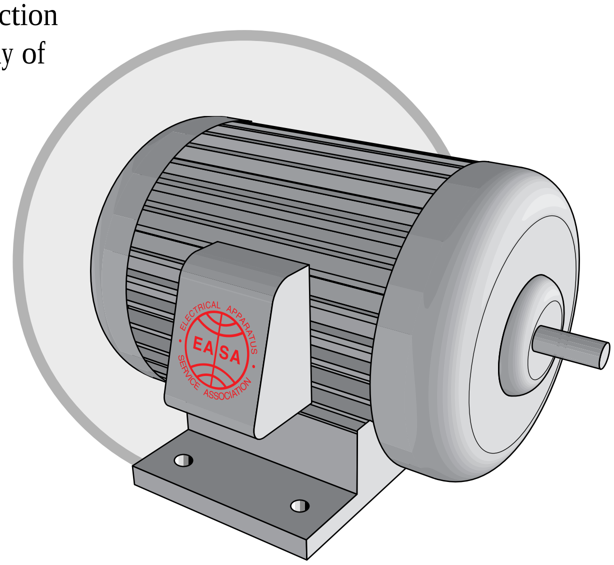
Motors never fail at a "good" time. Production stops; workers stand idle; deliveries are missed. The pressure to get back in operation quickly often leads to snap decisions to repair or replace the failed motor. But the best time to make such decisions is before a breakdown occurs—not during a crisis. That's why it's so important to plan ahead and take a proactive approach to motor system management.

A good first step is to make a list of all the motors at your facility. This should include the type, size and application of each motor, as well as its age, maintenance and repair history, operating conditions and environment, and annual energy cost (or hours of operation). By examining this information, it's often possible to determine ahead of time which motors to repair or replace when a failure occurs. It can even help in spotting application problems that may be contributing to or causing failures.

Taking a proactive approach to motor system management can also suggest opportunities for improving performance or reducing energy costs, whether by redesigning a motor to better suit its application or replacing it with a more energy efficient model. It's also beneficial for identifying critical applications for which it makes sense to replace a failed motor but then have it repaired for use as a spare.

The purpose of this booklet is to encourage end users to take a more proactive approach to motor system management. It provides helpful information for making informed repair or replace decisions—before the next motor fails. Included, too, are guidelines for selecting a qualified vendor to repair or replace failed equipment, tips on how to specify repairs, and explanations of typical repair procedures.

The booklet focuses on the "workhorses" of industry—1 to 200 horsepower, three-phase, squirrel-cage induction motors, rated at 600 volts or less. Although many of the principles also pertain to larger motors, the rebuilding procedures described may not apply for machines used in hazardous locations.



Plan Ahead

Proactive motor system management is the key to making a cost-effective decision when a motor fails. Start by making a complete list of the motors at your facility—e.g., types, sizes, applications, operating conditions, and so forth. Helpful software called *MotorMaster* is available for this purpose from the U.S. Department of Energy (DOE) and Allied Partners in its Motor Challenge Program.[1] EASA service centers and other qualified vendors also may be able to assist in this area of motor management.

Next, based on this information, develop and implement a motor repair/replacement policy. This will ensure that everyone who makes repair/replace decisions will know what to do in almost every situation.

A good motor repair/replacement policy should factor in motor type and size, age, repair history, any special mechanical and electrical features, the application, and the operating conditions and environment. It also should consider energy costs, the cost of downtime, and the cost and availability of repairs and replacements.

Once a motor repair/replacement policy has been established, it frequently is possible to take the next step toward more effective motor management. Analysis of the motor inventory data, for example, may indicate that spares should be on hand for certain key motors. Performance trending and close monitoring of maintenance functions also may help minimize costly, unexpected downtime by targeting motors for repair or replacement before they fail. In other words, taking a proactive approach to motor management can lead to fewer crises, better decisions, and reduced costs.

Why Motors Fail

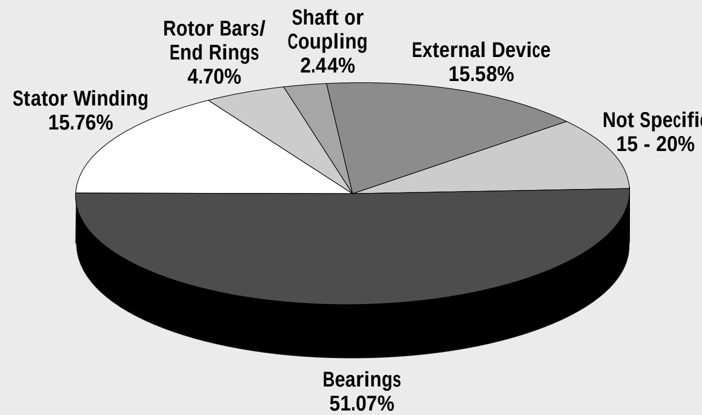
Most motor failures are due to mechanical causes, the largest percentage of which are associated with bearing failures. The easiest way to prevent premature failures and maximize motor life is to perform simple maintenance procedures and inspections regularly.

Recommended Maintenance Procedures [2]

- ✔ Follow the manufacturer's recommended lubricant and lubrication requirements.
- ✔ Clean accumulated dust and dirt from the motor and ventilation passages.
- ✔ Identify and correct excessive vibration.
- ✔ Install properly sized overload protection.
- ✔ Detect and dry moisture in the windings.

Even with regular maintenance, motors eventually will fail. When this occurs, an EASA service center or other qualified vendor can provide quality service and repairs or replacement motors. EASA service centers also can diagnose the cause of the failure to help prevent a recurrence and advise whether it's best to repair/rewind the motor or replace it with a more efficient model that is also better suited to the operating conditions and environment of the application. Many also offer ongoing motor system management and maintenance programs to ensure long, efficient operation and to minimize unexpected shutdowns.

Distribution Of Failures On Failed Components [3]



Making The Decision To Repair Or Replace

As mentioned earlier, the best way to avoid making hurried decisions when a motor fails is to plan ahead. Analyze the economics of repair and replacement for the motors in your facility and develop a comprehensive motor repair/replacement policy. Again, *MotorMaster* software that's available from the U.S. Department of Energy (DOE) and Allied Partners in its Motor Challenge Program can be helpful here.

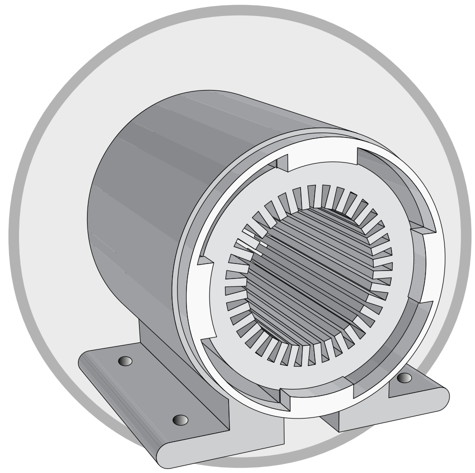
Whether you are developing a repair/replace policy or deciding whether to repair or replace a failed motor, the most important factor usually is downtime. But other variables are notable, too, including the type, size, age and maintenance history of the motor, special electrical or mechanical features, the cost to repair or replace the motor, and operating costs.

Sometimes the best decision is fairly obvious, based on the cost of a new motor versus that of repair. At other times, it makes sense to perform a simple payback analysis, factoring in all the costs, variables, and other considerations discussed below. The important thing to remember is that an investment in repair or replacement is not just a one-time cost. Other expenses should also be considered, including installation, maintenance, and energy costs for the life of the motor.

■ **Downtime**. Production downtime generally is THE key factor considered when a motor system breaks down. Lost production means idle workers, missed deadlines, and disappointed customers.

The only way to deal with the reality of motor failure effectively is to plan ahead. Develop information on the types and sizes of motors that operate your most crucial applications. If possible, build an inventory of spare motors that can serve as replacements for these critical production applications.

Many companies cannot afford to keep an inventory of spare motors. Even so, it is important to maintain detailed information about all the motors in the facility. Such information is useful when contacting service centers and other motor vendors about repair services or to determine if they commonly stock particular models.



Whether repair or replacement will be faster will depend upon the size and type of motor, stock availability, and the service center's production schedule. It usually takes three to five work days to repair a motor in the 1 to 200 hp range, but on fast turnaround jobs the time often can be shortened.

Replacements for most general-purpose open dripproof (ODP) and totally enclosed fan-cooled (TEFC) motors under 100 hp are stock items at many EASA service centers and other vendors. Rush orders for general-purpose motors in larger sizes (100 to 500 hp) can often be delivered within two to four days, whereas special motors and motors over 500 hp could take several weeks to obtain.

When time is critical—as it almost always is—check with the service center to determine a realistic delivery schedule for repair and replacement. Keep in mind that work loads at service centers may vary with the season and other business factors. Above all, let the service center know when fast turnaround is essential. Most are sensitive to customer needs and will work hard to get the repair completed as quickly as possible. Most also pride themselves on doing the job right the first time, so avoid asking them to "cut corners" to get the motor running sooner. Remember, any compromises made in the quality of the repair could lead to higher operating costs or even premature failure.

■ **Reliability Of Repaired/Rewound Motors**. Before deciding to have a motor repaired or rewound, it's reasonable to ask if the repaired motor will be as reliable as a new one. While no studies to date directly address this issue, the quality of the materials and workmanship that go into properly repaired/rewound motors often surpass manufacturers' design specifications.

As an example, to improve reliability of rewound motors many service centers routinely upgrade insulation system components to a higher temperature class than that used by the original manufacturer (e.g., from Class B to Class F or H). This significantly improves the motor's ability to withstand higher temperatures, thereby reducing the possibility of premature failure. Insulation upgrades of this kind often equal or exceed the temperature class of even today's highly reliable energy efficient motors.

Many service centers also offer a range of other repair options aimed at improving reliability, including use of premium grades of magnet wire, improved methods of applying insulating varnish, epoxy treatments, precision balancing of rotating elements, proper bearings, and higher temperature lubricant. Of course, well documented quality assurance systems, repair practices designed to maintain motor efficiency, and extensive testing protocols are among the other ways that many service centers ensure that the repaired motor will operate as efficiently and at least as reliably as it did before it failed. EASA service centers also repair motors according to EASA's *Recommended Practice* [4] and, at a minimum, back their work with EASA's *Limited Warranties* [5].

■ **Efficiency Of Repaired/Rewound Motors**. Does repairing or rewinding affect motor efficiency? Studies show that motors that are rewound or repaired using industry best practices maintain their original operating efficiencies [6].

To assure that the repaired motor will retain its original efficiency, use a service center that adheres to EASA's *Recommended Practice* (or equivalent repair specifications) and follows the repair procedures from *EASA Tech Notes 16 & 17* that are summarized on Page 11 [7].

■ **Application Considerations**. To assure proper performance, analyze the speed/torque requirements of the application before replacing a motor. Generally speaking, the replacement should have torque equivalent to that of the old motor. For centrifugal applications, the replacement should also have a full-load speed equal to or less than that of the original motor. Finally, be sure to consider whether any special couplings, mounts or adaptors will be needed for a new replacement motor or a spare from inventory. Application issues can be complex, and EASA sales and service centers usually can help.

■ **Repair And Replacement Costs**. Motor failures often result in seized bearings, burned out windings, or both. EASA and other qualified service centers routinely repair such damage, so repair estimates are relatively straightforward. For more complex repairs (e.g., a bent or broken shaft or a cracked frame), get a repair quote before going further—especially if the economics of the repair/replace decision are in doubt.

This is also the time to check on the cost and availability of a replacement and to reevaluate the application and operating conditions. In some cases, there may be opportunities to improve performance or reduce operating costs.

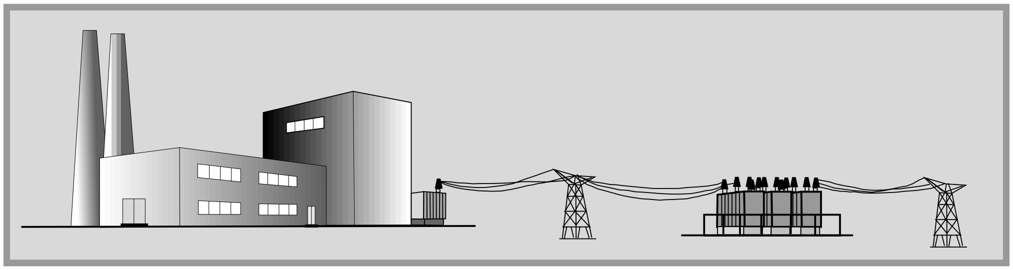
Of course, if the failed motor has special electrical or mechanical features, repair frequently is the best option. Such motors normally are well suited for their applications and will continue to give good service after repair or rewinding.

■ **Operating Costs And Motor Efficiency**. When making a repair/replace decision, consider the energy efficiency of the present and replacement models, the utility rates and the hours of operation. Where utility rates and usage are low, the payback may be longer. Be sure to calculate payback based on the difference between repair and replacement costs, taking into account any modification costs associated with the new motor.

■ **Be Proactive**. As mentioned throughout this booklet, it makes sense to know as much as possible about your motor system application requirements and operating environments. Communicate this information when shopping for a service center or other motor supplier. Learn as much as possible about the services and products offered by prospective vendors. Develop a motor repair/replacement policy. By planning ahead, you will be assured of making the right repair/replacement decision each time.

Calculating Energy Cost Savings

To determine the payback for buying an energy-efficient replacement instead of repairing a failed motor, first calculate the energy cost savings and the demand cost savings for the two motors [8].



Energy Cost Saving*

$$S = 0.746 \text{ x Hp x C x N} \left(\frac{100}{E_b} - \frac{100}{E_a}\right)$$

Demand Cost Saving

$$S = 0.746 \text{ x Hp} \left(\frac{100}{E_b} - \frac{100}{E_a}\right) \text{x MDC x NM}$$

Where:

S	Savings in dollars per year
Hp	Horsepower rating of the specified load (hard to measure in the field; .75 load is a reasonable substitute)
C	Energy costs in dollars per kilowatt hour
N	Running time in hours per year (how long the motor runs, not process time)
E_a	Efficiency (%) of Motor "A" (new replacement) at the specified load (or from motor nameplate, DOE's *MotorMaster* software, or average motor efficiency from 1994—i.e., not meeting NEMA Standard 12-10.)
E_b	Efficiency (%) of Motor "B" (repaired motor) at the specified load (or from NEMA MG 1, Table 12-10, on Page 7, or DOE's *MotorMaster* software)
MDC	Monthly demand charge
NM	Number of months per year demand charge applied

* Applies to motors operating at specified constant load. For varying loads, apply to each portion of the cycle where load is relatively constant for an appreciable period of time. Total savings is the sum of the savings for each load period. (The equations do not apply to motors on pulsating loads or on loads that cycle at rapidly repeating intervals.)

Calculating Simple Payback

Calculate the simple payback for an energy-efficient replacement over repairing the failed motor as follows [9].

$$SPB = \frac{NC + IC - RWC - UR}{ECS + DCS}$$

Where:

SPB — Simple payback—i.e., number of years required to pay back the difference in cost

NC — New motor cost

IC — Incremental installation costs, if any (motor of different hp, speed, or frame size may require new wiring, mounts, sheaves, pulleys, belts, modifications, etc.)

RWC — Rewind/repair cost (from quote or *Vaughen's Price Guide*)

UR — Utility rebate (if available)

ECS — Energy charge reduction (from Energy Cost Saving equation).

DCS — Demand charge savings (from Demand Cost Saving equation)

The higher the SPB, the longer the payback of replacing the motor.

Efficiency Ratings

Nominal Full-Load Efficiencies
Energy Efficient 1800 Rpm Motors

HP	TEFC	ODP
1 hp	82.5%	82.5%
1.5-2 hp	84.0%	84.0%
3 hp	87.5%	86.5%
5 hp	87.5%	87.5%
7.5 hp	89.5%	88.5%
10 hp	89.5%	89.5%
15-20 hp	91.0%	91.0%
25 hp	92.4%	91.7%
30 hp	92.4%	92.4%
40-50 hp	93.0%	93.0%
60 hp	93.6%	93.6%
75 hp	94.1%	94.1%
100 hp	94.5%	94.1%
125 hp	94.5%	94.5%
150-200 hp	95.0%	95.0%

Reference: NEMA MG 1, Table 12-10.

An EASA service center or qualified motor supplier can assist in determining efficiency values for speeds other than 1800 rpm.

Summary

The best repair/replace decisions are made beforehand, not during a crisis. Be proactive. Learn as much as possible about your motor system application requirements.

Then:

- ✔ Compile complete information about all the motors at your facility—e.g., types, sizes, maintenance and repair histories, ages, applications, operating conditions, special electrical and mechanical features, and annual energy costs.
- ✔ Communicate this information when shopping for a service center or other motor supplier.
- ✔ Reevaluate each motor and application to identify opportunities for improving performance and reducing operating costs.
- ✔ Identify critical applications and, if possible, inventory spare motors for them.
- ✔ Develop and implement a motor repair/replacement policy.

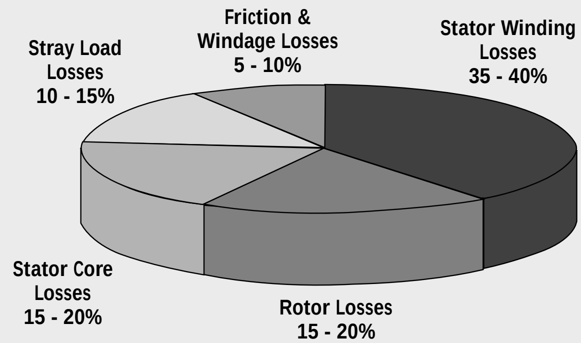
Some factors that may inform the decision to repair or replace include:

- Importance of having the motor back in service immediately.
- Type and size of motor (e.g., hp, efficiency rating)
- Application (speed/torque requirements).
- Special features (electrical and mechanical).
- Electrical operating costs and hours operated annually.
- Simple payback analysis.
- Cost and availability of repair service as compared with those of a new motor.
- Age and repair history of the motor.
- Maintenance and capital budgets.

Obtaining Quality Motor Repairs

When repair is the best option, quality is important. Select a service center that adheres to EASA's *Recommended Practice* (or comparable repair standards) and uses industry best practices to maintain motor efficiency and reliability (see Page 11).

Motor Loss Distribution (100% Full Load) [10]



Motor Losses and Efficiency

To understand how repair procedures (good and bad) affect motor efficiency, it helps to know something about motor losses.

Whether new or rewound, all motors give off (or lose) a portion of the input electrical power as heat—called motor losses. If the losses increase, the motor will run hotter and therefore less efficiently, using more energy to do the same work as before. The added heat due to increased losses also will speed the rate at which the insulation system will deteriorate, thereby shortening the life of the motor. In fact, every increase of 10° C in the temperature of the winding can reduce thermal insulation life by half.

Motor losses are either "fixed" or "variable," both of which can be affected by poor repair practices. Fixed or "no-load" losses remain constant over the full operating range of the machine. They include stator core losses as well as friction and windage losses.

Motor Losses

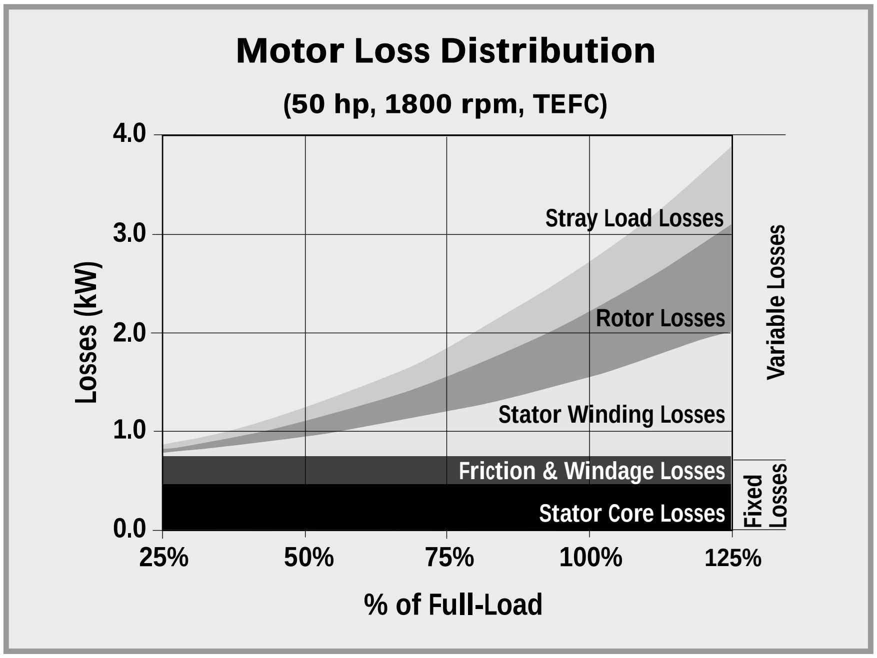
Type Of Loss	Cause	Can Be Increased By
Stator Core Losses	• Energy used to magnetize core material (hysteresis) • Losses due to magnetically induced circulating currents in the stator core (eddy currents)	• Overheating the stator core during winding removal • Grinding or filing the stator slots • Sandblasting the core
Friction And Windage Losses	• Energy used to overcome bearing friction • Energy used to overcome air movement from the rotor and cooling fan	• Installing bearings of incorrect type or size • Damaging or improperly installing the bearings • Using the wrong size or type of fan
Stator Winding Losses (Variable I^2R Losses)	• Heating that occurs as current flows through the resistance of the stator winding	• Installing the wrong type of seals • Changing the design of the winding
Rotor Losses (Variable I^2R Losses)	• Heating that occurs as current flows through the resistance of the rotor bars and end rings	• Machining the stator or rotor • Damaged rotor cage • Poor connections between bars and end rings • Wrong or improperly installed bars
Stray Load Losses	• All residual losses not fully accounted for by other types of variable losses	(Not applicable)

Variable losses change with the load. They occur because the flow of current must overcome the resistance (R) of the windings. Variable losses are proportional to motor current (I) squared and often are called I^2R losses.

The graph on Page 10 shows how motor losses (and efficiency) vary with load for a typical 50 hp energy efficient motor. Fixed losses (core, friction and windage) have a greater effect in lightly loaded conditions; I^2R losses dominate as the load increases.

Importantly, increased core losses are not the only, nor necessarily the main reason that motor losses sometimes increase due to poor repair practices. Studies have shown that motor efficiency can decrease in rewound motors even if core losses actually decrease or increase only marginally. Improper bearing replacements, for example, can increase friction and windage losses, and substituting smaller wire sizes for those used in the original winding can increase I^2R losses [11].

Likewise, procedures that change losses in one area can alter motor performance in another. Increasing the air gap by machining the rotor, for example, will reduce stray load losses but also will increase magnetizing current and therefore increase winding losses while lowering the power factor.

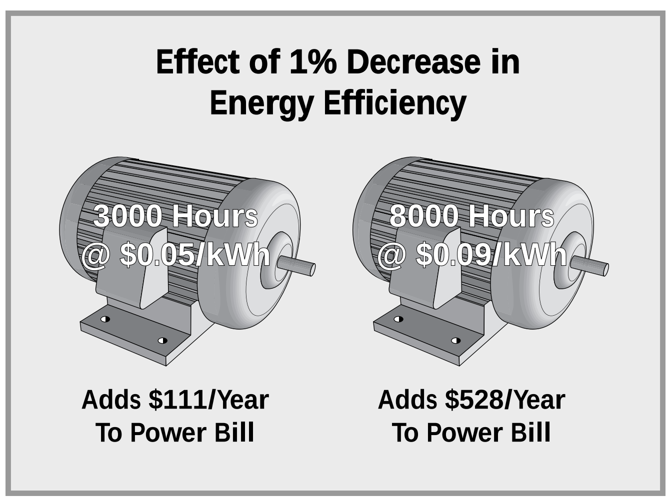


The Cost of Poor Repair Practices

It is clear that poor repair practices may increase motor losses and reduce the energy efficiency of repaired motors. The economic significance of this change will depend upon the size of the motor, how much it is used, and local utility rates.

As an example, if a 100 hp motor runs 3,000 hours per year (about average) and electricity costs $0.05 per kWh, a decrease in efficiency of 1% would increase the power bill by about $111 for the year. If the motor is used more or utility rates are higher, the additional cost for electricity would be higher. For instance, if it runs 8,000 hours per year and utility rates are $.09 per kWh, a decrease in efficiency of 1% would add about $44 per month to the electric bill, or around $528 annually.

Because repair procedures and materials can affect motor losses and operating efficiency, they should be carefully monitored and controlled. Check with the service center that will do the work to be sure they are familiar with recommendations in *EASA Tech Notes 16 & 17* and use the following procedures.



Rewind Procedures That Maintain Motor Efficiency

Motor Loss	Increased By	Suggestions To Control Or Quantify Loss
Stator Core Losses	• Overheating core steel during stripping • Damaging core insulation during winding removal • Excessive abrasion or grinding during core cleaning	• Conduct "loop" or core loss test before and after winding removal • Follow procedures in *EASA Tech Notes 16 & 17* • Calibrated oven temperature control • No-load test with three-phase wattmeter
Friction And Windage Losses	• Bearings and/or cooling fan not replaced to original manufacturer's specifications • Incorrect bearing fits • Incorrect bearing preload • Under/over fill of lubricant	• No-load test at rated voltage with three-phase wattmeter • Correct bearing fits and tolerances (from ABMA Standards) • Use correct lubrication • Use correct type of seals • Follow manufacturer's recommendations
Stator Winding Losses (Variable I^2R Losses)	• Reducing conductor cross-sectional area • Changing the number of turns • Using incorrect winding configuration • Machining rotor	• Accurately record winding data and verify with manufacturer's data or *EASA Rewind Data* • Perform winding resistance tests with milliohmmeter
Rotor Losses (Variable I^2R Losses)	• Altering rotor bars and end rings • Changing cage design	• Repair to original specifications • Balance rotor
Stray Load Losses	• Change in air gap symmetry and air gap eccentricities • Bent motor shaft or damaged end shields	• Make sure shaft is straight and check end shields for wear; repair or replace defective parts • Perform final vibration analysis

Specifying A Motor Rewind

Efficiency changes identified in most studies result from increased motor losses that are linked to inadequate quality control measures during repair or rewinding—e.g., shortcuts, errors, and substitutions of parts and materials [12]. When buying motor repair and rewind services, make sure all work will meet expectations by providing written repair/rewind specifications for each motor. Service centers also find this helpful and usually can do a better job if they know exactly what the customer wants.

What should a repair or rewind specification include? Although it may be patterned after EASA's *Recommended Practice* or other published motor repair and rewinding guidelines, its purpose is to communicate the customer's repair requirements and expectations to the service center. At a minimum, it also should require the repair to be performed by qualified, properly trained personnel in a facility that is adequately equipped to handle the size and type of motor to be repaired.

Additionally, a good repair specification should incorporate procedures that will ensure reliability and help maintain the efficiency of the repaired equipment. *EASA Tech Notes 16 & 17* provide a series of recommended practices to assure that these goals will be met. Some of the most important ones are shown in the chart “Rewind Procedures That Maintain Energy Efficiency” on Page 11.

EASA also is continuing to work with service centers, the DOE, utilities, and independent laboratories to identify other “best practices” and to educate both service centers and end-users of their importance.

■ **Basic Repair Specifications**. Every repair specification should include these procedures:

- Inspect and test for mechanical and electrical defects.
- Dismantle and test stator and rotor as appropriate (e.g., continuity, insulation resistance, high potential, surge comparison, loop or core loss, and growler tests).
- Determine cause of failure.
- Provide repair estimate and consult with customer regarding repair/replace options.
- Check winding data against manufacturer’s original data or EASA’s *Motor Rewind Data*, making corrections if necessary.
- Remove old windings and clean stator.
- Repeat loop or core loss test.
- Install new insulation.
- Make and insert new coils.
- Perform surge comparison test on new coils.
- Connect coils and leads; test all windings.
- Test thermal protectors and similar devices; replace if necessary.
- Impregnate stator windings with insulating varnish and cure in baking oven.
- Install new bearings and seals of proper size and type.
- Assemble the motor, perform final tests (including high-potential test), and paint.
- Report cause of failure, results of key tests, and measurements.
- Document all additional services and specifications for quality assurance.

Note: More information about the various steps involved in repairing/rewinding motors is provided in the Appendix.

■ **Repair Options**. Many rewind specifications also request input from the service center about repair options that could increase reliability or maximize the efficiency of the motor. These might include:

- Making the new coils from wire having greater cross-sectional area, if this can be done without reducing the number of turns.
- Optimizing motor efficiency by redesigning the winding to match constant, nonstandard plant voltage conditions.
- Providing a higher temperature insulation system (typically Class H).
- Repairing previous core damage by insulating and restacking the core or by other methods.

- Identifying and correcting poor mechanical repairs or incorrect bearing sizes or types.
- Repairing other mechanical problems (e.g., restoring the shaft or housing surface, boring and bushing the end-brackets, or correcting a "soft foot" condition).
- Analyzing the pattern of failures and the application to identify and correct unfavorable operating conditions; may require redesigning the motor or replacing it with one that is better suited to the application.

Additional Services That Are Often Required Or Specified

To assure maximum life for motors that operate in harsh environments or unusual service conditions, rewind specifications may require additional repair services. These may include:

Additional Services

- Mechanical modifications
- High-temperature bearings and grease
- Electrical redesign
- Insulation upgrade
- Multiple dip-and-bake varnish cycles
- Vacuum pressure impregnation (VPI)
- Epoxy treatment
- Dynamic balance
- Dynamometer test

Note that some of these services may be part of a service center's basic repair—e.g., upgraded insulation system or dynamic balance. Discuss the value and benefits of such services with your service center.

Evaluating And Selecting A Motor Service Center

When evaluating and selecting a motor service center, consider the firm's business reputation and professionalism, as well as its experience, reliability, responsiveness and past performance. Request a list of customers and call them for their opinions. Perhaps most importantly, visit prospective service centers and ask questions.

■ **Knowledge and experience**. Do their personnel have the required knowledge, experience and training? Are they abreast of industry developments? Do they use the latest technologies? How do they verify winding data? If necessary, can they access outside engineering consulting services and databases?

■ **Equipment**. The types and quality of equipment may vary widely from one service center to another. Make sure the equipment is appropriate for the range of motor sizes to be rebuilt, and that it is used properly. Test instruments and equipment, for instance, should have the capabilities and accuracy required for the size of motor being repaired. Test instruments should also be calibrated at least annually.

■ **Other services**. Do they routinely determine the cause of failures to help prevent recurrence? Can they help with repair/replace decisions and supply new replacement motors? Do they offer preventive/predictive maintenance services or motor system application assistance? Can they redesign motors for new applications or to maximize energy efficiency? Is their work backed by a written warranty like the *EASA Limited Warranties*? Are they a factory-authorized service center for one or more motor manufacturers?

Some Specific Items To Consider When Evaluating A Motor Repair Facility

- Electrical repair capabilities
- Mechanical repair and machining capabilities
- Lifting capacity—i.e., crane and hoist capacities
- Technical capabilities and backup
- Test facilities and test equipment capabilities
- Accuracy of test instruments
- Availability of field assistance
- Adherence to EASA's *Recommended Practice* or other published repair standards
- Documentation
- Quality assurance measures
- Communications
- Housekeeping and safety
- Current financial stability and future prospects
- Liability insurance and workers' compensation coverage

Obtaining Motor Repairs Of The Highest Quality

Follow these steps to find a service center that can consistently provide motor repairs and rewinding services of the "highest quality."

To Obtain The "Highest Quality" Repairs And Rewinding Services

- ✔ Ask EASA for a list of area service centers.
- ✔ Prequalify and select a motor service center that can:
  - Assist in failure assessment.
  - Recommend whether to repair or replace the motor.
  - Provide new replacement motors, if that's the best option.
  - Consistently deliver quality motor repairs.
  - Support motor maintenance.
- ✔ Learn more about motor repair and maintenance.
- ✔ Develop a motor repair/replace policy to use when motors fail.
- ✔ Establish a motor inventory system to track the maintenance and repair history of each motor. (*MotorMaster* software available from the U.S. Department of Energy and Motor Challenge Allied Partners can be helpful here, as can many sales and service centers.)
- ✔ Work with an EASA service center or other vendor to develop motor rebuilding specifications that meet your needs. (EASA's *Recommended Practice* is a good place to start.) Require conformance to those specifications by inspecting new and rebuilt motors when they are received.
- ✔ Require a detailed repair report for each repaired motor.

How Service Centers Can Assure Quality Repairs

Service centers that implement quality assurance programs can consistently deliver reliable motor repairs that maintain motor efficiency and reduce rework. By documenting quality procedures, such service centers "say what they do" and "do what they say" for quality.

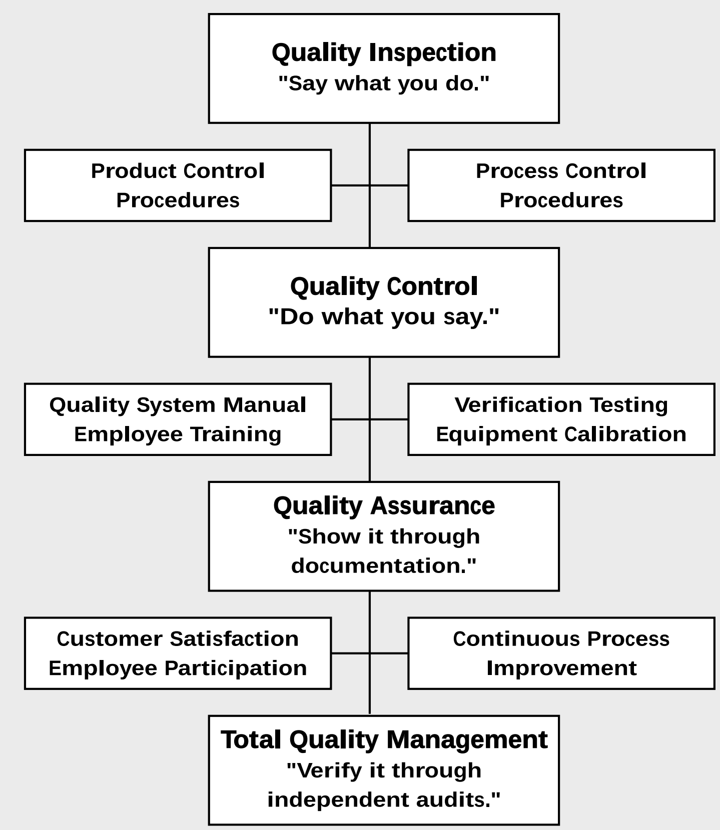
Formalized quality assurance programs like the *EASA-Q Quality Management System* and ISO 9000-1994 can also verify stated quality through internal and third-party audits. Programs like these require less effort on your part to ensure consistent quality in repaired motors.

EASA's Quality Initiatives

This booklet was produced by the Electrical Apparatus Service Association (EASA) in cooperation with the U.S. Department of Energy's Motor Challenge Program as one of EASA's quality initiatives. EASA service centers provide "Reliable Solutions Today" that will help you get the longest life and most efficient operation from your electric motors.

EASA also has developed the *EASA-Q Quality Management System* for electrical apparatus service centers. *EASA-Q* is a comprehensive guide for developing a quality system that exceeds all requirements for ISO 9000-1994 while presenting a recognized level of quality management in the motor repair industry.

EASA-Q is written specifically for the motor repair industry to provide you with the best service quality available in the industry.



Steps To Quality Management

About EASA

EASA is an international trade organization of electromechanical sales and service firms throughout the world. Through its many engineering and educational programs and publications, EASA provides members with a means of keeping up to date on materials, equipment, and state-of-the-art technology.

When it comes to sales, application, service and maintenance of motors, generators, drives, controls and other electromechanical equipment, look to EASA and EASA members for "Reliable Solutions Today." EASA members have the experience and professionalism to provide energy-efficient solutions for your complete motor system. To be assured of quality workmanship and performance, always look for the EASA logo.

Comments or questions about this publication may be directed to the Electrical Apparatus Service Association, Inc. at 1331 Baur Blvd., St. Louis, MO 63132 U.S.A., or e-mailed to easainfo@easa.com.

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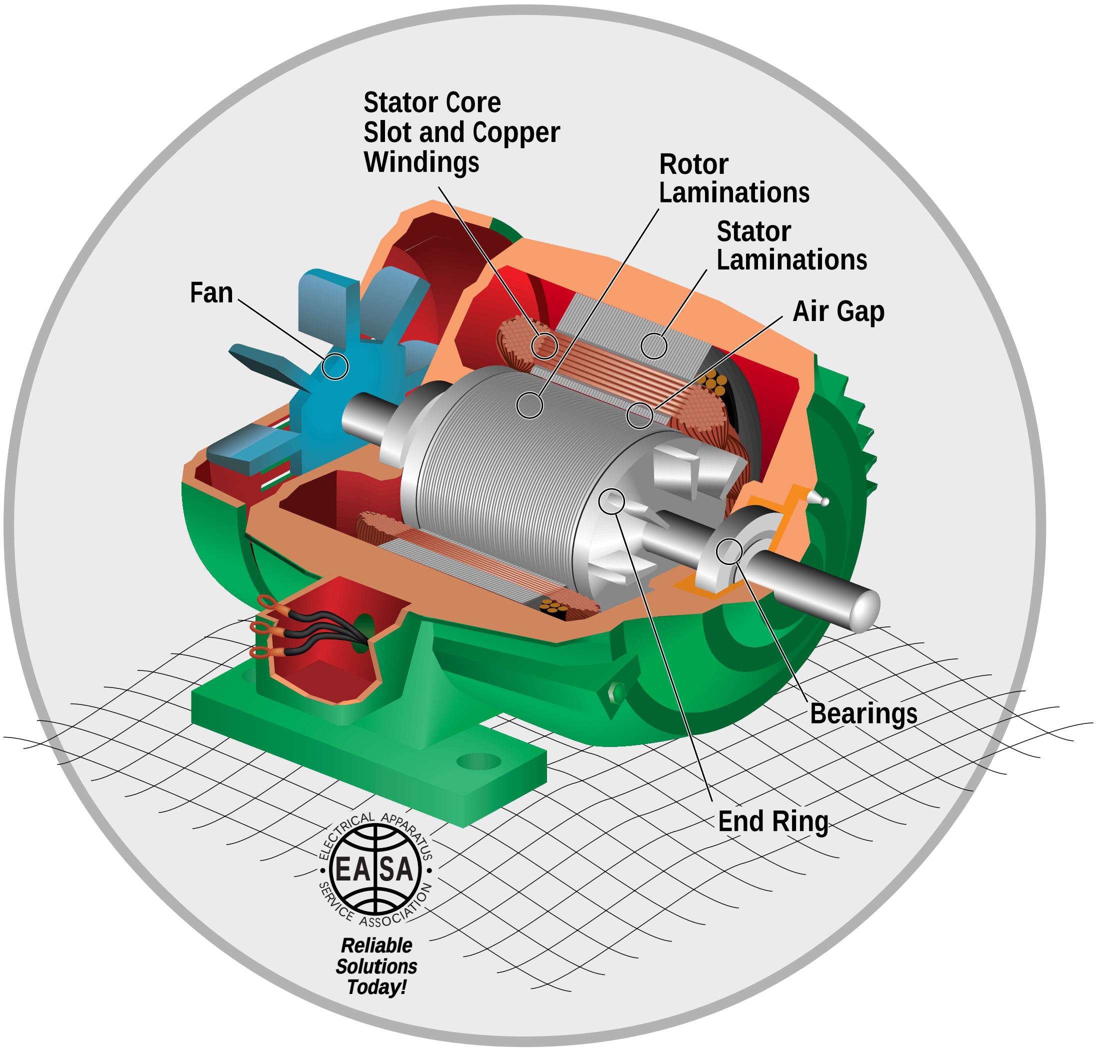
Appendix: Motor Repair Procedures

The following overview summarizes what happens during a typical motor repair—i.e., stator rewind that requires no mechanical repair. It also explains the effects that poor repair and rewinding procedures can have on motor efficiency and reliability.

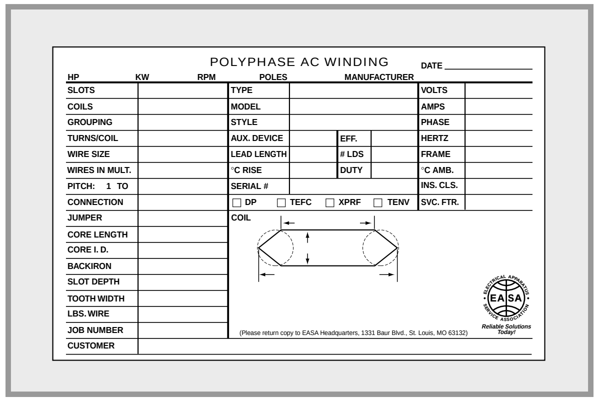


■ **Incoming Inspection & Testing**. When the motor arrives at the service center, it is carefully inspected for mechanical defects. This includes evaluating the general condition of the frame, end shields, and bearings, as well as the exposed shaft and keyway. Any cracked, defective or worn parts are noted on the job card or data sheet, along with nameplate data and important physical details (e.g., lead length and conduit box orientation). This information will ensure that the motor can be reassembled in its original configuration.

If the cause of failure is not apparent, the motor may undergo a number of electrical tests to diagnose the problem and determine the kinds of repairs needed. These may include continuity, single-phase, and insulation resistance tests.

If the shaft turns freely and the motor is operational, a no-load test may be run at rated voltage and frequency. Any unusual noises, vibrations or significant deviations from synchronous speed at nameplate voltage are noted on the data sheet.

■ **Dismantling & Inspection**. As the motor is dismantled, it is examined for any internal mechanical or electrical defects—e.g., signs of wear, rubbing or abrasion, mechanical stress, thermal aging, loose connections, contamination, or arcing. Any defects are recorded on the data sheet so that a detailed repair estimate can be prepared.


POLYPHASE AC WINDING DATE ____________

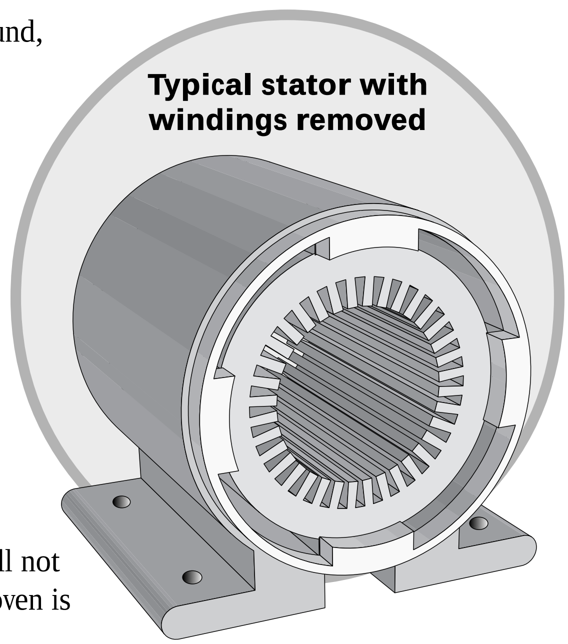
HP KW RPM POLES MANUFACTURER

SLOTS		TYPE				VOLTS	
COILS		MODEL				AMPS	
GROUPING		STYLE				PHASE	
TURNS/COIL		AUX. DEVICE		EFF.		HERTZ	
WIRE SIZE		LEAD LENGTH		# LDS		FRAME	
WIRES IN MULT.		°C RISE		DUTY		°C AMB.	
PITCH: 1 TO		SERIAL #				INS. CLS.	
CONNECTION		☐ DP ☐ TEFC		☐ XPRF ☐ TENV		SVC. FTR.	
JUMPER		COIL					
CORE LENGTH							
CORE I. D.							
BACKIRON							
SLOT DEPTH							
TOOTH WIDTH							
LBS. WIRE							
JOB NUMBER		(Please return copy to EASA Headquarters, 1331 Baur Blvd., St. Louis, MO 63132)				Reliable Solutions Today!	
CUSTOMER							

Additional electrical tests, performed on the stator windings as appropriate, may include continuity, insulation resistance, high potential, and surge comparison tests. The rotor is also checked carefully for cracked or broken bars, tested using growler, and cleaned thoroughly. Test results are recorded on the data sheet, together with important mechanical dimensions and measurements—e.g., bearing sizes and fits and shaft run-out. Each part is also positively identified to ensure control throughout the repair process.

Note: If moisture is detected but the stator windings are otherwise undamaged, they often can be reconditioned without rewinding the stator.

■ **Core Processing**. If the motor is to be rewound, the old winding must be removed and the stator core must be thoroughly cleaned. First, however, the core dimensions are measured and recorded so that new slot insulation can be fabricated. The length of the coil extensions is also measured and recorded.


Typical stator with windings removed

At this point an initial "loop" test or core loss test should be performed to check the condition of the interlaminar insulation for shorts or other damage. Any suspected problems are noted on the data sheet to be checked or repaired after the winding has been removed.

In order to remove the old winding, the stator core must be processed using acceptable practices that will not damage it. For example, if a controlled-temperature oven is used, the temperature of the core must be monitored closely. Allowing it to get too hot could damage the interlaminar insulation, degrading its electrical and magnetic properties [13].

As the winding is being removed winding details are accurately recorded. These include the size and shape of the coils, the wire size(s), the number of conductors, the number of turns, the coil groupings, and the connection pattern.

To assure that the new winding will be identical to the original, the data is checked for accuracy against the manufacturer's design specifications or a database like EASA's *Motor Rewind Data.* Reverse engineering techniques and computer programs may also be used to verify the accuracy of winding data.

Next, the stator core is cleaned thoroughly, examined for evidence of shorts between laminations or electrical arcing and, if necessary, repaired. A second "loop" test or core loss test should then be performed to ensure that the core is in good condition before the new insulation and winding are installed.

■ **Winding**. Accurate winding data and precise manufacturing techniques are used to produce exact duplicates of the original coils—i.e., the same dimensions, wire size(s), number of turns, and cross-sectional area. The new coils and appropriate insulation are then inserted into the stator slots.

Next, the electrical connections are made, after which the winding is tested. Insulation resistance and surge comparison tests are commonly performed at this stage. For added stability, the end turns of the winding usually are laced together.

Typical stator with new windings installed

■ **Insulating Varnish**. The rewound stator is now impregnated with an insulating varnish and placed in a low-temperature curing oven. Depending upon the repair specifications and the application, some service centers use a vacuum pressure impregnation (VPI) or a trickle process instead of a dip tank to saturate the windings with varnish. Excess varnish is carefully removed from the stator bore and mechanical mating surfaces. (Depending upon the method used, the entire process is usually repeated.)

■ **Reassembly & Final Testing**. The motor is then reassembled with new bearings of the original size and type. This is important because using the wrong type of bearings can affect motor efficiency. Bearings should also be installed carefully in accordance with recommended fits and tolerances as specified in the American Bearing Manufacturers Association Standards [14].

The assembled motor is now tested as specified in EASA's *Recommended Practice* or other written repair specifications. Tests may include surge comparison, high potential and no-load tests, as well as any performance tests required by the customer. After being inspected a final time, the motor is painted and prepared for shipping.

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[11] Vince Schueler, Paul Leistner and Johnny Douglass, *Industrial Motor Repair In The United State*s (Washington State Energy Office, Olympia, WA, November 1995).

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Notes