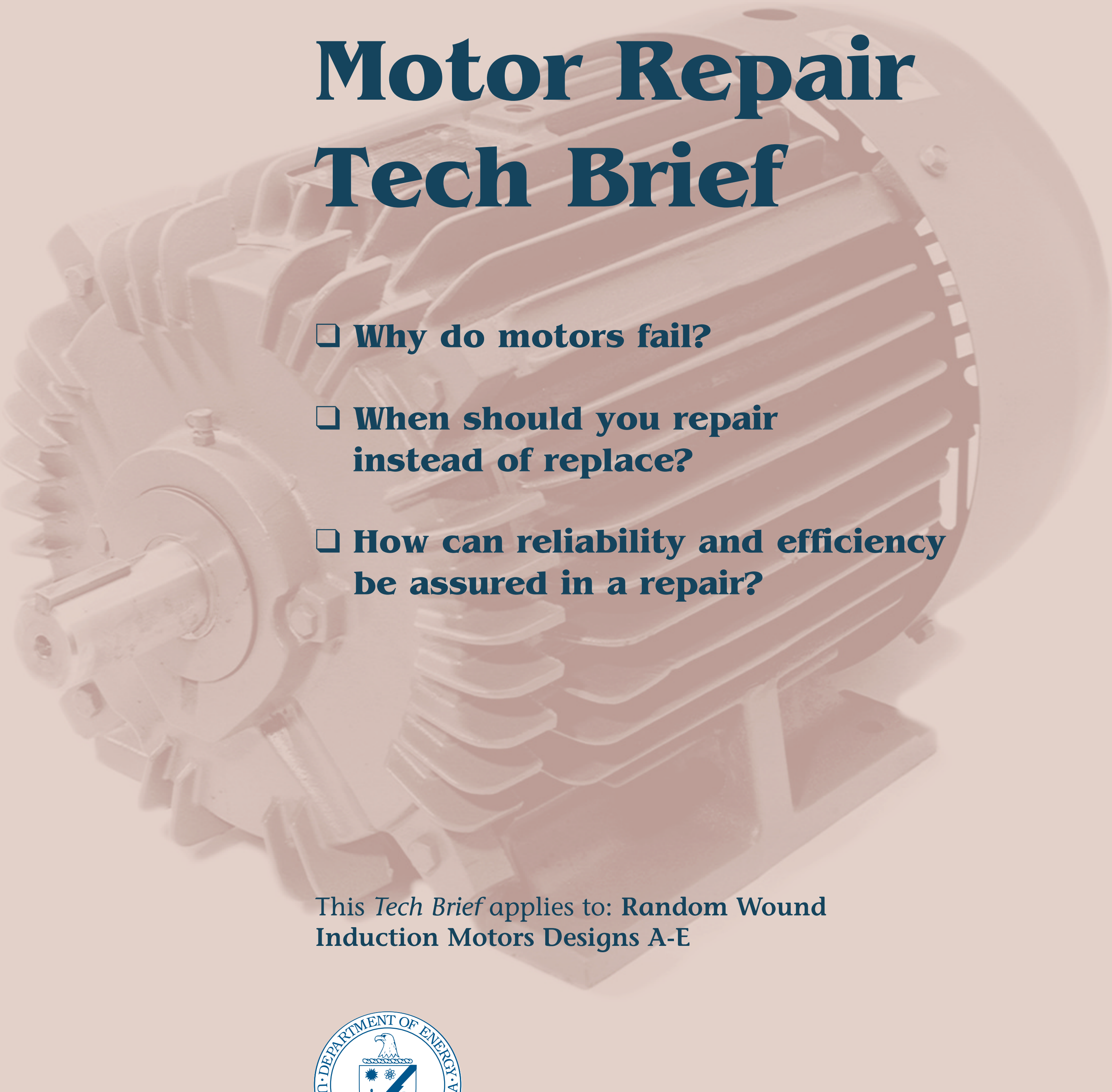
# Motor Repair Tech Brief



- ❑ Why do motors fail?
- ❑ When should you repair instead of replace?
- ❑ How can reliability and efficiency be assured in a repair?

This *Tech Brief* applies to: **Random Wound Induction Motors Designs A-E**

OFFICE OF INDUSTRIAL TECHNOLOGIES
ENERGY EFFICIENCY AND RENEWABLE ENERGY • U.S. DEPARTMENT OF ENERGY

## Acknowledgements

The following series of Repair Documents—*The Service Center Evaluation Guide, Selected Bibliography on Electric Motor Repair, Model Repair Specifications for Low Voltage Motors,* and *Motor Repair Tech Brief*— were produced by the U.S. Department of Energy's Office of Industrial Technologies (OIT) with input from trade associations, consulting companies, manufacturers, non-profit corporations, and others.

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# Why do motors fail?

Motors don't fail **just** because of age or operating hours. Stresses from heat, power supply anomalies, humidity, contamination, improper lubrication, and unusual mechanical loads work in conjunction with time to degrade components. Motors have survived for several hundred thousand operating hours when these stresses are minimized.

## Heat

Temperatures over the design rating take their toll in various ways. Electrical insulation deteriorates at a rate that may double for every 10°C. Excessive temperature also causes separation of greases and breakdown of oils to cause bearing failure. Primary causes of overheating are:

- Overloading
- Too frequent starts
- High ambient temperatures
- Low or unbalanced voltage
- High altitude operation
- Inadequate ventilation

## Power Supply Anomalies

Ideal power is a perfect sine wave on each phase at the motor's rated voltage and frequency. This is rarely achieved. The following problems occur:

- *Harmonics.* Cause overheating and decreased efficiency.
- *Overvoltage.* At moderate levels is usually not damaging, but can reduce efficiency and power factor. (NEMA limit 110% of rated.)
- *Undervoltage.* Increases current and causes overheating and reduced efficiency in fully loaded motors. It is relatively harmless in underloaded motors. (NEMA limit 90% of rated.)
- *Voltage unbalance.* Causes overheating and reduced efficiency. Unbalance greater than 1% requires motor derating and motors should never be powered by a system with more than 5% unbalance.
- *Voltage spikes.* Commonly caused by capacitor switching, lightning, or cable standing waves from a variable frequency drive (VFD). These tend to cause turn-to-turn insulation failures.
- *Frequencies under 60 Hz from VFDs.* This generally requires reduced torque demand or supplemental cooling.
- *Bearing damage from shaft currents.* This usually originates from VFDs. Consult the drive provider for information on strategies such as an insulated bearing sleeve, electroconductive grease, or a shaft grounding system.

## Humidity

Humidity becomes a problem when the motor is de-energized long enough to drop near the dew point temperature. Moisture weakens the dielectric strength of electrical varnish and other insulating materials. It also contributes to corrosion of bearings and other mechanical components. Moisture from the air can mix with certain particulate contaminants to create highly electroconductive solutions.

Insulation moisture can be significantly reduced if the motor is kept warm. If possible, motors stored in humid environments should be pre-warmed several hours or even days before start-up to drive out insulation moisture. Then conduct an insulation (megger) test to ensure a safe start. Humidity control strategies are:

- By heating or dehumidification, keep the environment of unpowered motors below 80% relative humidity.
- Specify new or rewound motors with heating elements for the windings and use these when unpowered.
- Periodically rotate the shaft of stored motors to keep lubricant on the bearing surfaces.

## Contamination

Contamination cannot be completely excluded by total enclosure or even an explosion proof enclosure.

Contamination destroys motors in three ways:

- Abrasion
- Corrosion
- Overheating

Some airborne particulates are very abrasive. Motor coils flex when in use, and contamination with abrasive particles can eat away the wire enamel. Some substances such as salts or coal dust are electrically conductive and can exploit any weakness in the insulation, especially when assisted by moisture. Heavy accumulation of contaminants typically obstructs cooling passages either internally in open motors or externally in closed motors. This leads to overheating.

## Improper Lubrication

Unfortunately, there are more ways to get it wrong than right. One can over lubricate as well as under lubricate. Grease itself can introduce contaminants into bearings if careful control is not practiced in loading grease into guns and protecting the injector tip from dirt. Mixing greases with different bases can cause grease constituents to separate and run out. Refer to the "Grease Compatibility" table below. Different motors pose different requirements for the introduction of lubricant and removal of old lubricant.

Consult with motor and bearing manufacturers and colleagues with similar contaminants and operating environment. Maintain records of lubrication. This will assist in optimizing lubrication for your own operating circumstances.

## Unusual Mechanical Loads

A variety of mechanical conditions can either overstress bearings, leading to early failure, or distort the motor frame causing asymmetric air gap, which in turn can cause vibration and bearing failure or winding overheating. Conditions to avoid are:

- Misaligned couplings.
- Over tightened belt, or sheaves out of alignment.
- Overly compliant base or poor shimming of mounting feet.
- "Soft foot," i.e. motor feet not in the same plane.
- Dynamic imbalance of load or internal imbalance of motor rotor.
- Failure to bypass resonant speed points in VFD powered motors.
- Mis-application of bearings.

### Grease Compatibility

| | Aluminum Complex | Barium | Calcium | Calcium12-hydroxy | Calcium Complex | Clay | Lithium | Lithium 12-hydroxy | Lithium Complex | Polyurea |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum Complex | X | I | I | C | I | I | I | I | C | I |
| Barium | I | X | I | C | I | I | I | I | I | I |
| Calcium | I | I | X | C | I | C | C | B | C | I |
| Calcium12-hydroxy | C | C | C | X | B | C | C | C | C | I |
| Calcium Complex | I | I | I | B | X | I | I | I | C | C |
| Clay | I | I | C | C | I | X | I | I | I | I |
| Lithium | I | I | C | C | I | I | X | C | C | I |
| Lithium 12-hydroxy | I | I | B | C | I | I | C | X | C | I |
| Lithium Complex | C | I | C | C | C | I | C | C | X | I |
| Polyurea | I | I | I | I | C | I | I | I | I | X |

**I** = Incompatible **C** = Compatible **B** = Borderline

# When should you repair instead of replace?

The answer is simple in principle. Rewind or otherwise repair a motor when it is cheaper than buying a new motor. Implementing this is a little more difficult because you need to consider the total cost of ownership. Ideally, you have to consider:

- First cost of repair and new purchase
- Efficiency of existing and proposed new motor
- Availability of a new motor
- Lifetime discounted cost of electric energy for each scenario
- Salvage value of existing motor
- Possible modifications to the mounting
- Cost in downtime and repairs from a possible early failure in either scenario

The key calculation for your decision is the annual energy savings from replacing the motor. This can be calculated by the following formula:

$$kW_{saved} = hp \times L \times 0.746 \times (1/E_{ex} - 1/E_n)$$

where:

**hp** = Motor nameplate horsepower

**L** = Load as percent of full rated load

$E_{ex}$ = Efficiency in percent of existing motor after repair

$E_n$ = Efficiency in percent of replacement motor

**Total Electric Dollar Savings =**

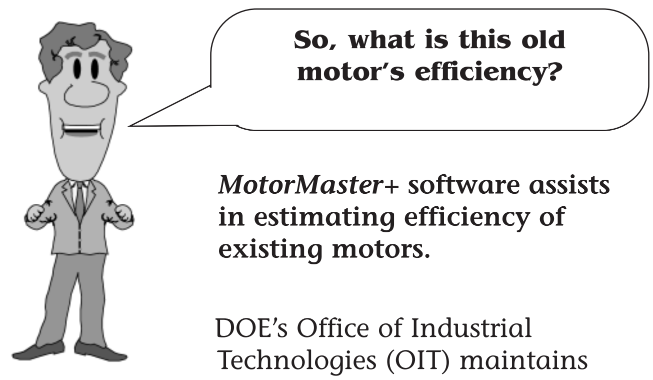
**($kW_{saved}$ x12 x Monthly demand charge)**

**+**

**($kW_{saved}$ x annual operating hrs x kWh rate)**

*MotorMaster+* is an excellent software tool in this process. It provides default costs of repair and new purchase and performs simple payback or life cycle cost comparisons. If needed, precision can be sharpened by using estimates from a current edition of Vaughen's Price Publishing's *Complete Price Guide®*. This guide provides costs of new motor purchases and repairs, by region, based upon annual market surveys. Best of all, obtain a firm quote from your motor service center.

For standard off-the-shelf motors, the repair scenario can rarely prevail unless the user is assured that the original efficiency is high, that it is maintained through repair, and the repaired motor is as reliable as a new one. These are possible, but not guaranteed.




***MotorMaster+* software assists in estimating efficiency of existing motors.**

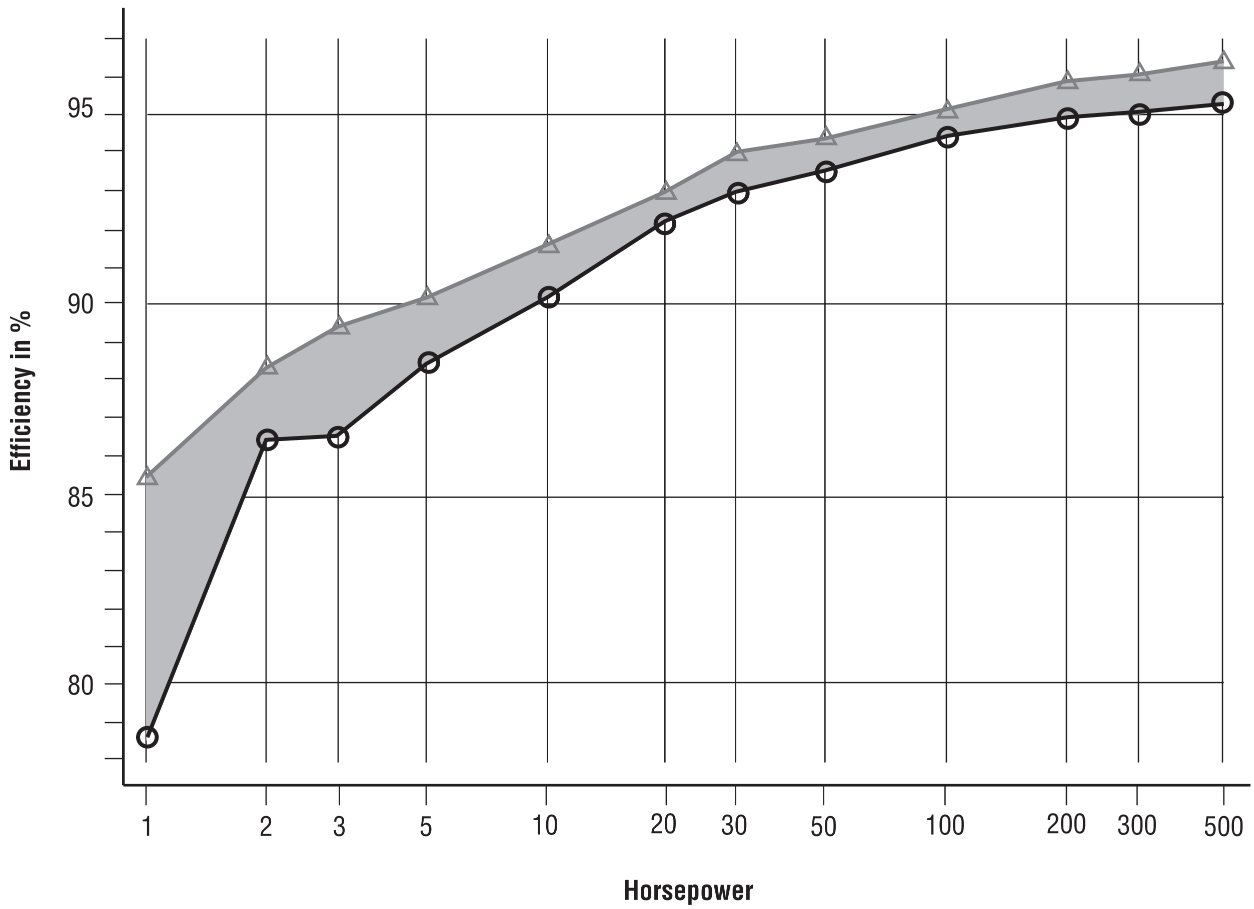
DOE's Office of Industrial Technologies (OIT) maintains current information on new methods and devices for assessing motor efficiency in the field. Contact the OIT Information Clearinghouse for further details.

## What Efficiency Can I Get In a New Replacement Motor?

Today's motors are more efficient. The National Electric Manufacturers' Association (NEMA) has established labeling standards for energy-efficient motors from 1 to 500 horsepower. The Energy Policy and Conservation Act of 1992 (EPCA) has mandated minimum efficiency standards in the 1 to 200 horsepower range. Many premium motors substantially exceed these efficiency standards.

The best premium motors tend to have efficiency within the shaded band shown in the chart on the next page. Your distributor should be able to provide a motor with efficiency in the band. For more common enclosures and speeds, such as TEFC–1800 RPM, you may find a motor near or even beyond the top of the band. Use *MotorMaster+* to identify models and catalog numbers.

## Premium Efficiency Target Range



# How can reliability and efficiency be assured?

To help assure a quality repair, you can:

1. Evaluate prospective motor repair service providers.
2. Not pressure the provider for an unrealistic turn-around time.
3. Communicate your requirements to the provider.

Two companion documents to this Tech Brief can assist in these tasks:

- *Service Center Evaluation Guide*
- *Model Repair Specifications for Low Voltage Induction Motors*

**Efficiency**

**How can a repair cause your efficiency to diminish?**

- ❑ Heat damage to stator core
- ❑ Wrong wire size or turn count
- ❑ Higher friction bearings/seals
- ❑ Bad re-design of winding pattern

**These DON'T have to happen!**

## Evaluate Motor Repair Service Providers

Use the *Service Center Evaluation Guide*. Make an appointment to spend adequate time evaluating each provider's service center.

- Look for indicators of a quality control program such as evidence of participation in an ISO 9000 program, membership in Electrical Apparatus Service Association (EASA), and participation in EASA's EASA-Q program. The EASA-Q program covers all the elements of ISO 9000 and requires a service center audit and customer survey.
- Inquire about staff morale, training, turnover, etc.
- Determine whether the service center has sufficient facilities and materials to handle the size and type of motors you will bring.
- Note what test equipment the service center owns and routinely uses to verify successful repair. Examples are:

  — Core loss tester or EASA loop test setup

  — Surge comparison tester

  — Voltage regulated power supply for running at rated voltage

  — Vibration testing equipment
- Ask to see the record keeping system by which the service center maintains records on repaired motors.
- Inquire about the method of insulation removal, e.g., burn off, mechanical pulling, etc. For burn off, ask about methods for preventing flames or hot spots and ensuring uniform temperature when roasting multiple motors.
- Take note of the overall cleanliness and orderliness of the service center.

A disappointing showing on one of these items is no guarantee of a poor service center, but if several items are questionable, the service center may be a poor choice. Detailed service center evaluation guidance, including a questionnaire for the service center supervisor, is provided in the *Service Center Evaluation Guide*.

## Avoid the fast turnaround quandary

The best way to do this is to implement a comprehensive motor systems management plan. Assistance in setting up a plan can be found in *Energy Management Guide for Motor-Driven Systems* and in the *MotorMaster+* motor management software package.

A motor systems management plan helps to ensure that sufficient spares are available for immediate replacement of critical motors. This will not preclude the repair option because the repaired motors can be re-inventoried as spares. A motor systems management plan also helps to determine in advance whether any given motor should be repaired or replaced, reducing the chance of a hasty bad decision. Finally, a plan provides for maintaining a motor's repair history as well as tracking and ensuring proper maintenance. This helps identify and correct causes of motor failure and reduce its future incidence.

Some service centers offer creative assistance for your motor systems management. Some examples are:

- Completely managing your motor tracking system
- Guaranteeing on-the-shelf spares for specified motors
- Preventative/Predictive Maintenance services

## Communicate your repair requirements

Provide a repair specification with each motor to be repaired. This should clearly outline your requirements for before and after testing, varnish application method, record keeping, etc. The *Model Repair Specifications for Low Voltage Induction Motors* provides a model from which you can customize your own specifications. Supply the service center with the motor's "medical history." Items in the medical history can include:

- History of past repair
- History of predictive testing, vibration, insulation resistance, etc.
- History of lubrication and other maintenance
- Methods for starting and frequency of starting
- Load; percent of rated, stability, starting inertia
- Power source information, e.g. VFD

Motor systems management software like *MotorMaster+* is an excellent way to maintain your motors' medical history. You may also be able to contract with your motor repair service provider to provide on-site predictive/preventative maintenance and records maintenance.

## More Tools

- ❑ *Energy Management Guide for Motor-Driven Systems*
- ❑ *Service Center Evaluation Guide*
- ❑ *Model Repair Specifications for Low Voltage Induction Motors*
- ❑ *Selected Bibliography on Electric Motor Repair*
- ❑ *MotorMaster+* Software

Contact the DOE OIT Information Clearinghouse to get these tools to assist with motor management, maintenance, and repair.

**1-800-862-2086**
**www.motor.doe.gov**

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