# Long-Term Costs and Savings of Properly Rewound Motors

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**ABSTRACT**

Industrial facilities send thousands of motors to motor service centers to be rewound every year with little knowledge of the motor's true condition after rewinding. As long as the motor operates as required and does not fail prematurely, the quality of the motor core and rewind may never be known. Was a damaged core rewound resulting in a sub-standard rewind reducing motor efficiency or was a healthy core rewound and reassembled using proper techniques resulting in a truly reliable motor that maintains its original nominal efficiency?

Often facilities consider the affects in quality that motor rewinds have on its reliability. The efficiency of a motor after servicing or rewinding is rarely considered, or is considered to be lower and a penalty of having a motor rewound. This paper discusses how motor reliability and efficiency are interconnected and how the Green Motor Initiative (GMI) is influencing the efficiency and reliability of motor rewinds.

## The Relationship of Reliability and Efficiency

Motor and motor system reliability is often one of the most important factors in an industrial facility. A single motor failure can cost significantly more in lost production than the cost of a motor rewind, or a new motor for that matter. Because of the impact motor reliability has, many consider it one of the most important factors when making motor repair/replace decisions. Unfortunately, half of that equation is overlooked by many facilities because they lack the resources or experience to verify the quality of a motor service center's process or do not consider it cost-effective. As long as motors are not failing, many facilities assume there is no reasonable return on their investment to verify a motor service center's quality standards and controls.

Often, facilities understand the costs associated with an unreliable motor; but fail to understand the energy costs associated with an unreliable, less efficient motor. They do not realize the affect small decreases in motor efficiency can have on increasing their energy costs and reducing the life expectancy associated with that motor. The reduced life expectancy is a consequence of the efficiency loss which increases the heat generated in the windings and core. For every 10°C rise in temperature, motor winding life is reduced by half and bearing life is greatly reduced.

Facilities often assume that motor efficiency will decrease after each rewind and it is a cost of having a motor rewound. Table 1 below shows the affect decreases in efficiency can have on various motor sizes.

Table 1. Increases in Energy & Cost for Decrease in Motor Efficiency

| | 0.5% Decrease | | 1% Decrease | | 2% Decrease | | 3% Decrease | |
|---|---|---|---|---|---|---|---|---|
| HP | kWh/yr | $/yr | kWh/yr | $/yr | kWh/yr | $/yr | kWh/yr | $/yr |
| 20 | 324 | $ 23 | 652 | $ 46 | 1,319 | $ 92 | 2,001 | $ 140 |
| 50 | 810 | $ 57 | 1,630 | $ 114 | 3,297 | $ 231 | 5,002 | $ 350 |
| 250 | 4,052 | $ 284 | 8,149 | $ 570 | 16,484 | $ 1,154 | 25,010 | $ 1,751 |
| 500 | 8,104 | $ 567 | 16,298 | $ 1,141 | 32,967 | $ 2,308 | 50,019 | $ 3,501 |

- Assumed 5,000 hours/yr
- Assumed 70 percent motor load
- Calculated as (HP*.746*.7*5000/(.900-%decrease)) –(HP*.746*5000/.900)
- Cost based on $0.07/kWh and no demand savings

The U.S. Department of Energy's (DOE) February 2000 report on motors stated, "You should generally subtract two points from motor efficiency on smaller motors (<40 HP) and one point for larger motors" in reference to motor rewinds. The same report went on to state "Shops with the best quality-control practices can often rewind with no significant efficiency degradation." This information was reinforced by a 2003 EASA/AEMT report which stated, "No losses in motor efficiency provided processes are controlled," and "if processes are not controlled, larger motors (75-150 HP) lost on average 0.6 percent efficiency." Washington State University's Cooperative Energy Program updated the Motor Master+ User's Guide in 2005 to lower the default rewind efficiency reduction to 1 percent for smaller motors and 0.5 percent efficiency for larger motors.

The previously cited DOE report provides the key reason why reliability and efficiency are directly related. The "best quality-control practices" and "process controls" referred to in this report is typically the same practices and controls that maintain motor reliability. When a facility evaluates a motor service center's quality-control procedures for motor reliability, a secondary benefit is maintained, motor efficiency.

## Poor Rewind Practices that Effect Reliability and Efficiency

There are a number of rewind practices that effect motor reliability and motor efficiency. The issues described below do not highlight everything that can affect motor reliability, but what affects a motor's reliability *and* efficiency.

### Core Damage

Core damage is a primary cause of reduced motor efficiency and will affect motor reliability by generating heat and a reduction in torque. The damage can result from a failure event causing physical damage that increases the air gap, smears or deforms laminations, or welds lamination that may require a hole be left in the core once the shorted laminations are removed. There are repair techniques to replace or reposition the damaged material so it has less localized heating; these techniques typically do not improve a motor's efficiency. There exists a technique that replaces damaged laminations to return a motor to its original nominal efficiency values, provided the stack height has not been altered.

Core damage can also be in the form of overheating the core during the burnout process to remove the old windings. The core material should not exceed 680°F for organic core laminations and 750°F for inorganic core materials and should never be exposed to an open flame [EASA 2003]. Higher temperatures damage the inner-laminar insulation which results in increased core loss which lowers motor efficiency and reduces its life expectancy.

### Improper Winding Length

Improper coil extension length can result in either increased winding resistance for longer windings or potential winding ground fault if the length is too short [EASA 2003]. When the coil extension length is longer than originally installed in the motor, additional resistance of the windings occurs resulting in increased heat generation. This can reduce the thermal life of the winding insulation. If coil extension length is reduced, it can decrease winding resistance and therefore may increase motor efficiency. The reduced length does reduce the heat transfer by reducing the exposed length of the wire; however this affect is much smaller than the affect from reducing the resistance of the winding. For example, a 100 HP motor with a 10 percent reduction in coil extension length could cause a 2.6 percent reduction in total motor loss. If the coil extension length is to short, the insulated wire and slot insulation may wear against the lamination slot cell and eventually lead to a ground fault.

### Bearing Installation and Lubrication

Improper bearing lubrication, incorrect bearing type, and improper fits can have significant affects on a motor's efficiency and reliability. These issues typically result from improper repairs or handling of the bearings during the motor repair process. The affect can range from a slight increase in motor load to rapid, catastrophic failure of the bearings causing permanent damage to the motor.

### Insufficient Air Flow or Incorrect Fan Sizing

Insufficient airflow through the motor can increase motor operating temperature which may slightly increase winding resistance resulting in reduced thermal life of the insulation and elevated temperatures that adversely affect lubrication and bearing life. Some general causes of insufficient air flow are incorrect fan size, an incorrect or damaged fan cover, or removing internal air deflectors. Incorrect fan sizing can cause insufficient or excessive air flow that may or may not improve cooling capacity. A small increase in fan size can result in a significant increase in motor load with only a small increase in air flow. The motor load is the cubic of the size increase so a 2 percent increase in fan size results in an 8 percent increase in motor load from the fan [EASA 2003].

### Preventing or Correcting These Issues

There are various methods industrial facilities can use to help ensure the issues previously discussed are prevented or corrected during the motor repair/rewind process. Facilities can conduct run-in and load test of each motor after rewind or of a random sampling, the facility can have a quality assurance monitor in each motor service center while work is being conducted, or the facility can conduct random inspection and verifications of the motor service centers. Con ducting run-in and load testing requires a significant investment in equipment and operator training to test the motors and provide a quality assurance inspector to the motor service center would not be a cost effective use of personnel.

**Green Motors Initiative**

The random inspection of the motor service center is the approach Green Motors Practices Group (GMPG) and the Bonneville Power Administration (BPA) have taken to implement the Green Motors Initiative (GMI). The GMI provides ongoing 3rd party certification of motor service centers to verify they follow the consistent set of standards developed by the GMPG and based on EASA's best practices and technical notes.

These standards help ensure:

- The motor is properly tested before and after the rewind in accordance with EASA Tech Notes #16 and 17;
- The shop maintains all equipment properly calibrated or verified against known standards;
- Recommends replacement or repair/rewind on the basis of total cost of ownership;
- Motor repair/rewind procedures are in accordance with the **"**Guidelines for Maintaining Motor Efficiency During Rebuilding**"** EASA/AEMT Study and GMPG's "Electric Motor Repairing Specification," April, 2008; and
- When failure event damage may impact motor efficiencies, customers are made aware of the economic consequences.

The GMPG conducts inspections and verifications of the participating motor service centers at a minimum annually. Each shop must agree in writing to follow the standards set by the GMPG and to provide information from each motor that qualifies as a Green Motor Rewind (Green Rewind). The GMPG provides each shop with a set of standard tables for estimating the increased energy costs based on the reduced motor efficiency and the facilities power rate ($/kWh). The estimated reduction in motor efficiency is based on the shop's experience and EASA technical publications.

Based on the shop following these standards, the Region Technical Forum (RTF), a part of the Northwest Planning and Conservation Council (NWPCC), has recognized the energy savings that can result from following the GMPG standards and have approved a deemed energy savings table for induction motors sized 15 to 5,000 horsepower (HP). Based on these deemed energy savings, BPA provides $2 per HP incentive to the motor service centers for each Green Rewind and the motor service center credits $1 per HP to the repair invoice and acknowledges the facility's serving utility has provided the incentive.

In support of the initiative, the GMPG and BPA are conducting a series of 8-hour classes focused on total life cycle cost evaluation, motor and driven system efficiency, the relationship between efficiency and reliability, and how end-user's can evaluate and make quality repair/replace decision based on practical facts. Motor service centers are encouraged to attend and participate with the expectation that they may forge a new business niche by embracing motor efficiency and eventually, with encouragement, branch into driven system efficiency and reliability issues.

## Green Motors Initiative in Action

One GMI certified motor service center recently received three motors (two were 300 HP and the other was 350 HP in size) for rewinding. The motors were from rotary screw compressors in a lumber mill, operating 24-hours per day, 7 days per week, and exposed to high concentrations of saw dust. The motors were approximately 25 years old, rewound at least five times previously with a history of failure every two to three years. All three motors had core damage that was repaired during previous rewinds and appeared to have been repaired correctly. When the motors were evaluated in accordance with the GMI standards, the core tests revealed significant damage to their core that was not apparent during the previous rewinds. Each core test result showed a core loss of 9 to 13 watts per pound. The recommended core loss should not exceed 4 watts per pound [EASA Currents 2008]. The core tests also indicated damage to the inner-laminar insulation which caused a significant increase in core temperature and breakdown of the winding insulation which resulted in premature motor failure.

The motors were previously rewound as the cost of rewind was only 50 to 60 percent of the cost of a new motor and the lumber mill manager assumed the motor failures were due to the operating environment, not the previous damage done to the core. When presented the results of the core tests and comparisons to new motors, the facility replaced all three motors with new NEMA® Premium motors. The energy savings from the new motors resulted in an 18-month simple payback and increased motor reliability when compared to rewinding costs.

## Conclusion

The reliability and the efficiency of a motor are directly related. Many of the same issues that affect a motor's reliability also affect the motor's efficiency. By working with the motor service centers to verify they have and follow quality-control practices, an industrial facility not only helps ensure the reliability of a motor but the efficiency as well. Even if the industrial facility is not experiencing motor failures, it does not mean the motor reliability or efficiency is maintained. By using a motor service center that has quality-control practices in place and being followed, the industrial facility improves motor reliability and maintains their motor's efficiency.

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