Rewinding Energy Efficient Motors

Understand the process and work with your service center to make sure you get the motor performance you need.

By Chuck Yung, Electrical Apparatus Service Association (EASA)

You spent a lot of money replacing those standard efficiency electric motors with energy efficient models, and now one has failed. Do you rewind it or replace it? Sure, the rewind will save money, but can an energy efficient motor be rewound without reducing its efficiency?

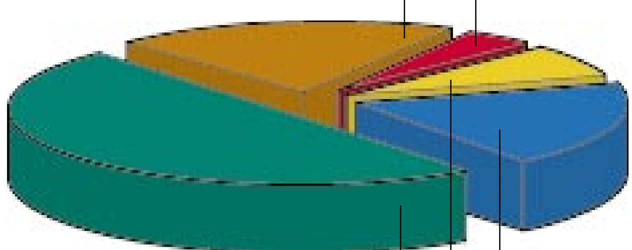
The answer is probably yes, if the service center follows some basic guidelines.

By dealing with a qualified service center, and verifying a few simple things, you can be reasonably sure that your rewound energy efficient motor will maintain its original efficiency. A savvy end-user will be prepared to discuss specific procedures with the service center before sending an energy efficient motor out for rewind.

There is really no magic in an energy efficient motor. When power input is converted to power output, some energy is always lost. By addressing the areas where power is loss—to heat, friction, and windage—motor manufacturers have increased the efficiency of their products. They use longer stator cores and correspondingly longer rotors, for example, to reduce losses in the core. They also use more copper than usual in the windings to reduce copper losses.

The external fan on totally enclosed, fan-cooled (TEFC) models is also as small as possible to do the job, minimizing the horsepower diverted to cooling the motor. Manufacturers of energy efficient motors use open or shielded bearings and are careful to install only a specified quantity of grease during assembly. Over-packed bearings increase friction, which lowers motor efficiency.

TYPICAL MOTOR LOSSES



Stator losses account for about half of total motor losses at full load.

Core burnout and testing

The stator core is composed of laminations—thin pieces of steel, coated with an insulation to reduce eddy currents in the core. Assuming the failure did not blow a hole in the core (thereby reducing the mass), the next concern is whether the windings are burned out at an appropriate temperature.

To facilitate removal of the old windings, most service centers first process stators in special burnout ovens to incinerate insulating varnishes and epoxies. Care must be taken to maintain the appropriate core temperature in order to preserve the inter-laminar insulation of the core.

The insulating coating (organic, chemical, or oxide) on each thin piece of laminated steel in the core reduces efficiency-sapping eddy currents. Newer motors tend to have lamination insulation capable of withstanding higher temperatures than do older motors. Because winding insulation materials (varnishes and epoxies) burn at lower temperatures than the inter-laminar insulation, the burnout process—properly done—will not harm the inter-laminar insulation.

Some manufacturers of burnout ovens state that temperatures below 750 F are safe. A recent study conducted in the United Kingdom also settled on 750 F for standard laminations, and found that oxide-coated newer steel laminations could withstand temperatures in excess of 900 F with no loss of efficiency. Ideally, an oven with a chart recorder will provide documentation that your motor was not burned out at an excessive temperature.

CONCENTRIC WINDING GROUP

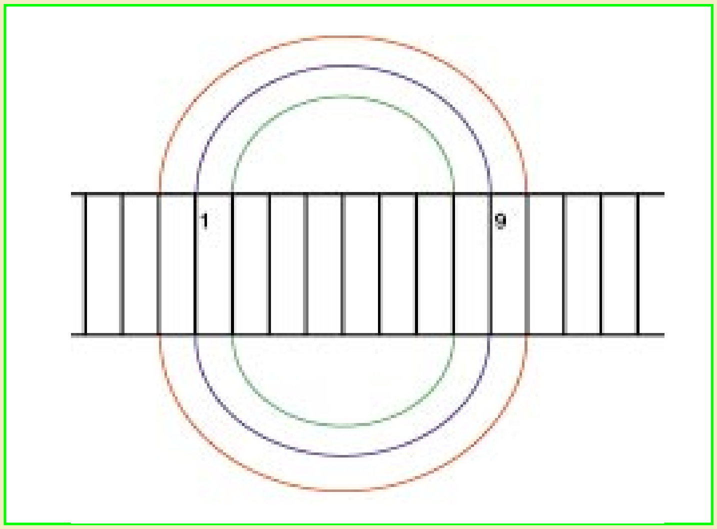


Fig. 1. Concentric windings, used in smaller motors, are well suited for mass production. Coil spans differ, so mean turn length and effectiveness of the turns also vary.

LAP WINDING GROUP

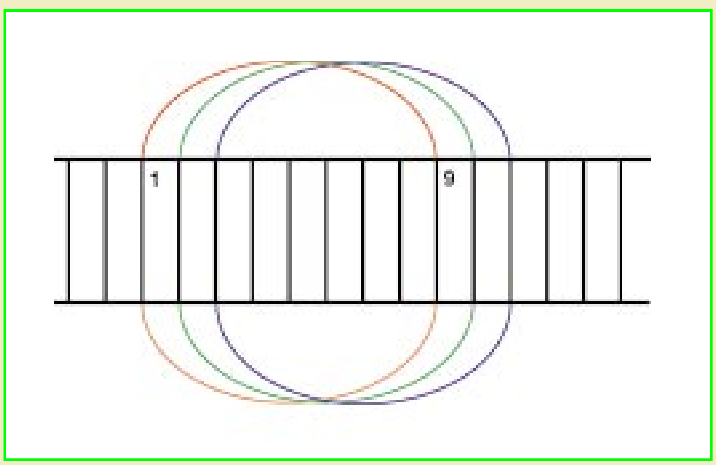


Fig. 2. All coils in a lap winding have the same span and mean turn length, and are as easy as concentric windings for a service center to install.

A core-loss test should be performed before and after the old windings are removed. The watts per pound readings help determine if the core is still good and safeguard against burnout-related problems.

Commercially available core testers simplify the process for the service center and usually provide neat printouts documenting the core's condition. Core loss also can be measured with a wattmeter if an adequate voltage supply is available. The calculations are done manually, so it takes a bit longer.

Winding wire size

When current passes through a conductor, heat is generated. For a given current, a larger conductor will heat up less than a smaller conductor will. To maintain the motor's original efficiency, it makes sense that the wire in the new winding must be no smaller than that in the original winding.

Looking at it another way, the cross-sectional area of the conductors determines the amount of copper in a motor. A larger cross-sectional area reduces copper losses (heating due to resistance) and increases efficiency.

Based on current density, this is usually reported as circular mils per amp (CM/A). The CM/A for the new winding must not be less than that of the original winding or efficiency will suffer.

Motors manufactured prior to 1964 generally had at least 550 CM/A. From 1964 until the advent of the energy efficient motor, T-frame TEFC motors usually were designed with lower current densities (350 to 450 CM/A) to meet industry demands for lower cost, lighter weight motors. Today's high-efficiency models may have current densities of 600 to 1000 CM/A.

Make sure the service center you deal with understands that changing current density affects efficiency, and that it does not reduce wire size just to make a particular motor easier to rewind. Assuming no damage to the stator core, and no reduction in the circular mils/amp, the potential efficiency of a rewound energy efficient motor should remain pretty much the same.

Type of winding

Random-wound motors may have either concentric or lap windings. Manufacturers use concentric windings (Fig. 1) in smaller motors, because they are well suited for automated production of thousands of identical motors. This keeps new motors economical, which benefits the buyer. The downside is that not every turn in a concentric coil is equally effective.

Viewed from the end of a stator core, the concentric winding has coils with two, three, or more different slot spans. Each span has a different angle (chord factor), which determines the effectiveness of the turns within that coil. Depending on the chord factor, 10 turns in a coil spanned at 1-9 will not have the same strength as 10 turns of a coil spanned at 1-10 or 1-8. If the turns in one span are half as effective as the turns in another, twice as many turns would be required. That would double the resistance of that coil.

The distance around the coil also changes with the span, so a larger span for the same 10 turns would require a longer conductor. Because a longer conductor has greater resistance, the total winding resistance depends partly on the coil span(s) selected.

The distance that the coil ends extend beyond the core also affects the length of conductors. Keeping these coil extensions to the minimum by careful fitting helps control the mean turn length (the average distance around each coil). The shorter this length, the lower the total winding resistance, which in turn reduces copper losses and improves efficiency.

Service centers have an advantage over manufacturers in winding because they can use lap windings (Fig. 2). All coils in a lap winding have the same span and mean turn length. Although it takes a little longer to insert a lap winding, this is not a major drawback for service centers. They install both lap and concentric windings manually because automated production is not practical given the wide variety of equipment they repair.

Grease intervals, quantity, and viscosity also will impact the efficiency of an energy efficient motor.

Winding resistance

Because all coils in a lap winding have the same mean turn length, it is often possible, by careful fitting, to produce a winding with a lower resistance than the original winding. Lower resistance means less efficiency is lost in the windings. All else being equal, a carefully fitted rewound motor can be more efficient than the original. As a general practice, the service center should replace the stator winding with exactly the type of winding removed from it. This means the same wire size, winding type, turns, span, and coil extension.

For energy efficient motors, conversion from concentric winding to lap winding should be done only if mean-turn-length calculations for both windings prove that total winding resistance can be reduced. It is often possible to improve the efficiency of a two-layer concentric winding, while a three-layer concentric winding is always more efficient than its lap-wound counterpart.

No matter which type of winding is used, winders must carefully fit the coils and avoid lengthening coil extensions to ease insertion. As noted previously, lengthening coil extensions increases total winding resistance, reducing efficiency. Worse still, the portion of the coil projecting from the iron is very inefficient.

Bearings

Quality bearings of C-3 internal clearance are the standard for electric motors (except for some specialty applications such as vibrators). Sealed bearings prevent contamination and require no periodic lubrication; unfortunately, they also create more friction than shielded or open bearings, resulting in a slight drop in efficiency. When efficiency is a concern, the best bet is to remain with the open or shielded bearing style installed by the manufacturer.

For greater reliability in some applications or environments, it may be worthwhile to install sealed bearings, despite the expected drop in efficiency. A better alternative is to consider installing non–contact seals, which exclude contaminants without causing friction.

Grease intervals, quantity, and viscosity also will impact the efficiency of an energy efficient motor. Follow the manufacturer's guidelines for each motor to maintain optimum efficiency.

Windage /Fans

External fans are often overlooked as a cause of efficiency loss. Windage varies among fan designs, depending on such factors as fan diameter (by far the most significant variable), the number and size of blades, the material, and surface finish. Replacing a damaged fan with one that is not identical will impact motor efficiency. Even painting a fan could affect efficiency.

Most fans today are plastic or aluminum. Replacements should be identical to the originals whenever possible. If your chemical processes make aluminum impractical, be sure that you (or your service center) discuss alternatives with the motor manufacturer to avoid adversely affecting efficiency.

Service center procedures

Core-loss tests are extremely important for verifying the condition of the stator core. Before- and after-burnout watts per pound readings allow the service center to document core condition. Tests can be made with a commercially available core tester or with a wattmeter and a power supply.

The service center should have an adequate test panel, instruments, and power supply to perform no-load tests on motors it repairs. This should include an accurate bridge to measure extremely low winding resistance. Digital equipment is generally better for measuring the extremely low resistance encountered with ac windings. The winding temperature at the time of measurement should be recorded and corrected to a standard temperature (usually 25 C).

The temperature control on the burnout oven should be accurately calibrated. The burnout process also should be monitored closely to ensure that temperatures do not exceed appropriate safe levels. Ideally, the oven should have a chart recorder to document temperatures during the burnout cycle.

Dynamometer testing of large electric motors is expensive because of the set–up time, test time, and power consumption. With smaller motors, the expense is difficult to justify. Very large motors require a substantial investment in switchgear and power supply. Most end-users make the load-test decision based on how critical the application is, as well as local energy costs and the operating cost of the individual motor. A utility producing its own electricity is less concerned about energy efficiency than a paper mill paying 12 cents per kWh.

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Several manufacturers of electrical test equipment are developing instrumentation to test motor efficiency without applying full-load tests, using sum-of-losses measurements. For the narrow focus of rewinding electric motors, the pie chart illustrates the relative importance of these factors.

Deal with a knowledgeable center

Energy efficient motors can be rewound without a loss of efficiency. It is in your best interest to deal with a knowledgeable service center. If your company requires a repair report, build some guidelines into it to ensure that you are getting the best possible repair with the highest possible efficiency. Documentation is of key importance. Winding resistance (corrected to standard ambient) serves as a good quick-check of the finished job, and core-loss test results confirm that no damage resulted from the motor failure or the burnout process.

One final point: It is seldom practical to increase the efficiency of motors not originally built as energy efficient. The stator core and rotor losses depend upon the core length and type of steel used in the laminations. The frame is usually sized to fit the existing core. Adding laminations to the stator and rotor, then rewinding the stator and rebuilding the rotor are rarely feasible, much less cost effective. The slot configuration was designed to hold a specific amount of copper, so increasing the cross–sectional area of the conductors in order to reduce copper losses is seldom possible.

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