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This article is adapted from the U.S. Department of Energy's tip sheet "Extend the Operating Life of Your Motor," originally prepared by the Washington State University Energy Program and Lawrence Berkeley National Laboratory.

When it comes to the operation of industrial processes, life cycle cost (LCC) analysis is an often-ignored methodology that can lead to significantly reduced facility operating costs. This is not a new concept—it has been standard practice in the development and procurement of complex military systems for many years. Federal government guidelines require life cycle analysis for federal agencies considering energy and water conservation projects and renewable energy projects in all federal buildings. Even the Hydraulic Institute (a manufacturers' trade association) has published a handbook on the subject, to help lead facilities personnel through the analysis for pumping systems.

LCC analysis need not always be a time-consuming and expensive en-deavor, however. Such analysis is essentially a methodology for calculating and comparing the installation and operating costs of alternative proposed projects over the life of the equipment, process or facility. Experience has shown that for motor-driven systems in general, energy and maintenance costs tend to dominate operating costs. Thus, quantifying these costs over the life of the system goes a long way in identifying opportunities for savings.

U.S. Department of Energy's Best Practices

Best Practices is part of DOE's Industrial Technologies Program, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together emerging technologies and best energy-management practices to help companies begin improving energy efficiency, environmental performance, and productivity.

Best Practices emphasizes plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to materials focused on near-term and long-term solutions for improving the performance of motor, steam, compressed air, and process heating systems. In addition, the Industrial Assessment Centers provide comprehensive industrial energy evaluations to small- and medium-size manufacturers. For more information and materials such as tip sheets, case studies, and the MotorMaster+ software, contact the EERE Information Center at 877-337-3463 or visit www.eere.energy.gov/

industry/bestpractices .

Alliance to Save Energy

The Alliance to Save Energy (www.ase.org) is a non-profit coalition of business, government, environmental and consumer leaders. It supports energy efficiency as a cost-effective energy resource under existing market conditions and advocates energy-efficiency policies that minimize costs to society and individual consumers, as well as lessen greenhouse gas emissions and their impact on the global climate. To carry out its mission, the Alliance to Save Energy undertakes research, educational programs, and policy advocacy, designs and implements energy-efficiency projects, promotes technology development and deployment, and builds public-private partnerships, in the U.S. and other countries.

Motor Decisions Matter

Motor Decisions Matter is a national campaign encouraging the use of sound motor management and planning as a tool to cut motor energy costs and increase productivity. The campaign is sponsored by a consortium of motor industry manufacturers and service centers, trade associations, electric utilities and government agencies.

The campaign encourages commercial and industrial customers to develop a motor plan, with the assistance of their local distributor, repair center or utility representative. A motor plan addresses common motor decisions before they become a crisis and ensures motor availability, enhanced productivity, and lower energy costs.

The Department of Energy estimates that greater attention to motor system management can reduce energy costs by a dramatic 18 percent. More information is available at www.motorsmatter.org

While many organizations do not regularly conduct LCC analyses, most do have some form of an asset management program. Understanding and maximizing the life of electric motors should be a part of asset management for any organization with significant quantities of electric

motors.

The Industrial Technologies Program within the U.S. Department of Energy (DOE) has a variety of materials addressing potential opportunities to reduce energy and maintenance costs in industrial process systems. This includes software tools, a series of guidebooks, case studies, tip sheets and other materials. Many of these materials relate to motors and motor systems, including a specific series of tip sheets on energy and maintenance opportunities. The following information comes from the tip sheet on how to extend motor operating life.

Why care about motors?
Over 1.2 million integral horsepower motors are sold each year in the United States, and about 3 million motors are repaired annually.

On average, motors account for almost 70 percent of the total electricity consumption for manufacturing facilities, and 23 percent of total U.S. electricity consumption—equal to about 680 billion kWh/year.

Even small improvements in motor operating life or efficiencies can result in significant cost savings at energy-intensive facilities.

Why do motors fail?
Certain components of motors degrade with time and operating stress.

- Electrical insulation weakens over time with exposure to voltage unbalance, over and under-voltage, voltage disturbances and temperature.
- Contact between moving surfaces causes wear. Wear is affected by dirt, moisture and corrosive fumes, and is greatly accelerated when lubricant is misapplied, becomes overheated or contaminated, or is not replaced at regular intervals.
- When any components are degraded beyond the point of economical repair, the motor's economic life is ended.

For the smallest and least expensive motors, the motor is put out of service when a component such as a bearing fails. Depending upon type and replacement cost, larger motors—up to 20 or

50 horsepower (hp)—may be refurbished and get new bearings, but are usually scrapped after a winding burnout. Still larger and more expensive motors may be refurbished and rewound to extend life indefinitely.

An economic analysis should always be completed prior to a motor's failure so as to ensure that the appropriate repair/replace decision is made.

How long do motors last?
Answers vary, with some manufacturers stating 30,000 hours, others 40,000 hours, and still others saying "It depends." The useful answer is "probably a lot longer with a conscientious motor systems maintenance plan than without one."

Motor life can range from less than two years to several decades under varying circumstances. In the best circumstances, degradation still proceeds, and a failure can occur if it is not detected. Much of this progressive deterioration can be detected by modern predictive maintenance techniques in time for life-extending intervention.

Even with excellent selection and care, motors still can suffer short lifetimes in unavoidably severe environments. In some industries, motors are exposed to contaminants that are severely corrosive, abrasive and/or electrically conductive. In such cases, motor life can be extended by purchasing special motors, such as those conforming to the Institute of Electrical and Electronic Engineers (IEEE) 841 specifications, or other severe-duty or corrosion-resistant models.

The operating environment, conditions of use (or misuse) and quality of preventive maintenance determine how quickly motor parts degrade. Higher temperatures shorten motor life. For every 10 ¡ C rise in operating temperature, the insulation life is cut in half. This can mislead one into thinking that purchasing new motors with higher insulation temperature ratings will significantly increase motor life. This is not always true, because new motors designed with higher insulation thermal ratings may actually operate at higher internal temperatures (as permitted by the higher thermal rating). Increasing the thermal rating during rewinding, for example, from Class B (130¡ C) to Class H (180¡ C), does increase the winding life.

Maximizing motor life
The best safeguard against thermal damage is avoiding conditions that contribute to

overheating. These include dirt, under and over-voltage, voltage unbalance, harmonics, high ambient temperature, poor ventilation and overload operation (even within the service factor).

Bearing failures account for nearly one-half of all motor failures. If not detected in time, the failing bearing can cause overheating and damage insulation, or can fail drastically and do irreparable mechanical damage to the motor. Vibration trending is a good way to detect bearing problems in time to intervene.

With bearings often implicated in motor failures, the L10 rating of a bearing may be cause for concern. The L10 rating is the number of shaft revolutions until 10 percent of a large batch of bearings fails under a very specific test regimen. It does not follow that simply having a large L10 rating will significantly extend motor bearing life. Wrong replacement bearings, incorrect lubricant, excessive lubricant, incorrect lubrication interval, contaminated lubricant, excessive vibration, misaligned couplings, excessive belt tension and even power-quality problems can all destroy a bearing. Always follow the manufacturer's lubrication instructions and intervals.

Make sure that motors are not exposed to loading or operating conditions in excess of limitations defined in manufacturer specifications and the National Electrical Manufacturers Association (NEMA) standard MG-1-2003. This NEMA standard defines limits for ambient temperature, voltage variation, voltage unbalance and frequency of starts.

Motor couplings should not be ignored, either. For direct drive applications, correct shaft alignment ensures the smooth, efficient transmission of power from the motor to the driven equipment and to protect the operating life of the equipment. Incorrect alignment occurs when the centerlines of the motor and the driven equipment shafts are not in line with each other.

Misalignment produces excessive vibration, noise, coupling and bearing temperatures, leading to premature bearing or coupling failure.

Motor management

When an electric motor does fail, you must decide whether to repair or replace. DOE's resources include tips on developing a repair vs. replace policy, a "Guidelines to a Good Motor Repair" document and other related materials.

When the decision is made to repair, use a respected service center and be prepared to ask questions to ensure quality repair. A good motor service center can often pinpoint failure modes and indicate optional features or rebuild methods to strengthen new and rewound motors against critical stresses. DOE's "Service Center Evaluation Guide" offers guidance in selecting a quality service center. The Electrical Apparatus Service Association (www.easa.org) is another good source of guidance on motor repair.

Developing a repair vs. replace policy for various sizes and applications is the first step in establishing a Motor Management Program. Other motor management strategies can include purchasing policies (considering premium efficiency motors), establishing a motor inventory, tracking motor life, creating a spares inventory, and scheduled maintenance. The U.S. Department of Energy's MotorMaster+ software program is a free, straightforward tool used by many organizations to implement motor management programs. Putting such a program in place can be part of a larger plant operations asset management program.

References:

1. "Extend the Operating Life of Your Motor," U.S. Department of Energy, September 2005.
2. NEMA Standard MG-1-2003, "Motors and Generators."

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