Energy Tips – Motor Systems

Motor Systems Tip Sheet #2 • September 2005

Industrial Technologies Program

Suggested Actions

- Conduct predictive maintenance tests to reveal whether efficiency is below the original or nameplate level. Decreased efficiency may be due to:
  - Higher winding resistance compared to manufacturer specifications or an earlier measurement. This may be caused by winding being at a higher temperature than that of the manufacturer's resistance specifications or by rewinding with smaller diameter wire. A low resistance ohmmeter is often required for winding resistance tests.
- Increase in no-load power or core losses. Core loss testing requires motor disassembly and is performed in a motor service center.
- Significant current unbalance when voltage is balanced.
- Evidence of cage damage.

Resources

U.S. Department of Energy—For additional information on motor and motor-driven system efficiency measures, to obtain the DOE's *MotorMaster+* software, or learn more about training, visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices.

Estimating Motor Efficiency in the Field

Some utility companies and public agencies have rebate programs in place to encourage customers to upgrade their existing standard-efficiency motors to NEMA Premium™ efficiency motors. Yet, to accurately estimate energy savings and determine annual dollar savings requires knowing the efficiency of the existing motor.

Efficiency is output power divided by input power, yet most of the methods and devices attempt to assess losses to circumvent the difficult task of measuring shaft output power. Efficiency needs to be measured accurately because, as shown in Table 1, a single percentage point of improved efficiency is worth significant dollar savings—even for motors as small as 25 horsepower (hp). A good electric power meter can provide an accuracy of 1%, but an inexpensive, portable way to measure shaft output power of a coupled motor does not exist. A further complication is that motor efficiency is dependent upon loading, power quality, and ambient temperature.

Table 1. What is an extra point of motor efficiency improvement worth?

Horsepower	Full-load Motor Efficiency (%)		Annual Savings	
	Original Efficiency	Final Efficiency	Annual Energy Savings, kWh	Dollar Savings $/year
10	89.5	90.5	605	$30
25	92.4	93.4	1,420	71
50	93.0	94.0	2,803	140
100	94.5	95.5	5,431	272
200	95.0	96.0	10,748	537

Note: Based on purchase of a 1,800 rpm totally enclosed fan-cooled motor with 8,760 hours per year of operation, 75% load, and an electrical rate of $0.05/kWh.

Credible efficiency ratings are normally obtained in a laboratory, following carefully controlled dynamometer testing procedures as described in IEEE Standard 112(b). Field measurements for determining motor efficiency pose challenges that require developing various methods and devices.

Motor losses fall into several categories that can be measured in various ways.

- Stator electric power (I^2R) losses
- Rotor electric power (I^2R) losses
- Friction and windage losses (including bearing losses, wind resistance, and cooling fan load)
- Stator and rotor core losses
- Stray load losses (miscellaneous other losses).

The most direct and credible methods of measuring these losses involve considerable labor, equipment, and the availability of electrical power. Power readings must be taken with the motor running under load, then uncoupled and running unloaded. Winding resistance must be measured. Temperature corrections must be performed.

Some of the available field motor-efficiency estimation methods include:

- **Loss accounting methods.** These measure most of the above losses using either special dedicated “lab-in-a-box” devices or very accurate conventional instruments, for example, power meters, thermometers, and micro-ohmmeters. These methods have the potential of being accurate within 1% to 3% if carefully applied. The necessary instruments are costly and the process is very time and labor consumptive. Power meters must be accurate at very low power factors that occur when motors operate unloaded.
- **Slip method.** The slip method has largely been discredited as a viable technique for estimating motor efficiency. This method computes shaft output power as the rated horsepower multiplied by the ratio of measured slip to the slip implied by the nameplate. Slip is the difference between synchronous and shaft speed.
- **Current signature predictive maintenance devices.** A number of sophisticated devices are marketed for analyzing motor condition, particularly current harmonics, based upon electrical measurements of an operating motor. While the accuracy of these devices has not been verified, the marginal cost and labor of using these devices is small if they are already deployed for predictive maintenance uses.
- **MotorMaster+ 4.0.** The *MotorMaster+ 4.0* software incorporates several methods for determining motor load. These involve the use of motor nameplate data in conjunction with selected combinations of input power, voltage, current, and/or operating speed. With the percent load known, the software determines as-loaded efficiency from default tables based on the motor type, condition, and horsepower. *MotorMaster+* automatically chooses the best available method based upon the data it is given.

About DOE’s Industrial Technologies Program

The Industrial Technologies Program, through partnerships with industry, government, and non-governmental organizations, develops and delivers advanced energy efficiency, renewable energy, and pollution prevention technologies for industrial applications. The Industrial Technologies Program is part of the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy.

The Industrial Technologies Program encourages industry-wide efforts to boost resource productivity through a strategy called Industries of the Future (IOF). IOF focuses on the following eight energy and resource intensive industries:

- Aluminum
- Forest Products
- Metal Casting
- Petroleum
- Chemicals
- Glass
- Mining
- Steel

The Industrial Technologies Program and its BestPractices activities offer a wide variety of resources to industrial partners that cover motor, steam, compressed air, and process heating systems. For example, BestPractices software can help you decide whether to replace or rewind motors (MotorMaster+), assess the efficiency of pumping systems (PSAT), compressed air systems (AirMaster+), steam systems (Steam Scoping Tool), or determine optimal insulation thickness for pipes and pressure vessels (3E Plus). Training is available to help you or your staff learn how to use these software programs and learn more about industrial systems. Workshops are held around the country on topics such as “Capturing the Value of Steam Efficiency,” “Fundamentals and Advanced Management of Compressed Air Systems,” and “Motor System Management.” Available technical publications range from case studies and tip sheets to sourcebooks and market assessments. The Energy Matters newsletter, for example, provides timely articles and information on comprehensive energy systems for industry. You can access these resources and more by visiting the BestPractices Web site at **www.eere.energy.gov/ industry/bestpractices** or by contacting the EERE Information Center at **877-337-3463** or via email at **www.eere.energy.gov/informationcenter/.**

BestPractices is part of the Industrial Technologies Program Industries of the Future strategy, 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 right now.

BestPractices emphasizes plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to 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 ADDITIONAL INFORMATION, PLEASE CONTACT:

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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