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?

<table>
<thead>
<tr>
<th>Horsepower</th>
<th>Full-load Motor Efficiency (%)</th>
<th>Annual Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original Efficiency</td>
<td>Final Efficiency</td>
</tr>
<tr>
<td>10</td>
<td>89.5</td>
<td>90.5</td>
</tr>
<tr>
<td>25</td>
<td>92.4</td>
<td>93.4</td>
</tr>
<tr>
<td>50</td>
<td>93.0</td>
<td>94.0</td>
</tr>
<tr>
<td>100</td>
<td>94.5</td>
<td>95.5</td>
</tr>
<tr>
<td>200</td>
<td>95.0</td>
<td>96.0</td>
</tr>
</tbody>
</table>

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.

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- Aluminum
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- 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](http://www.eere.energy.gov/industry/bestpractices) or by contacting the EERE Information Center at [877-337-3463](tel:877-337-3463) or via email at [www.eere.energy.gov/informationcenter/](mailto:www.eere.energy.gov/informationcenter/).