HORSEPOWER BULLETIN

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Advanced ENERGY

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A guide for implementing a simple, cost-effective policy for industrial induction motor repair or replacement*

*For AC Induction Motors, NEMA Designs A & B, 1Hp to 500Hp, 1200, 1800 and 3600 RPM

THIS BULLETIN WILL HELP YOU

- **Choose between repairing or replacing a motor before the motor fails**
  - Determine your horsepower breakpoint [above which to repair, below which to replace].
  - Communicate with purchasing officers and other signatories about motor economics.
- **Get the replacement motors you need**
  - Establish a motor inventory.
  - Create a motor specification.
  - Develop a relationship with motor suppliers.
- **Work with repair shops to maintain quality**
  - Select and audit quality shops.
  - Specify repair criteria.
  - Reduce emergency motor repairs.

Annual operating cost of a motor is often many times the initial cost. Consequently, a motor replacement policy based on purchase price and operating cost can improve your company's cash flow by reducing annual operating and maintenance costs.

First, determine your current policy and discuss the changes recommended in this bulletin with all affected parties. This will help refine and coordinate implementation of this policy. With this policy in place, better economic choices for your facility can be achieved.

A COMMON-SENSE APPROACH

A sound motor repair or replacement policy is simple, clear and does not require a lot of additional work. The basics of a successful motor management policy include:

- Conduct a motor inventory and survey critical motors.
- Ensure that motor purchasing procedures account for life-cycle costs.
- Make available the correct new motors.
- Identify your preferred motor service providers, and communicate expectations.

This bulletin provides information about each of these topics as well as additional Web sites and references that can assist you in developing your own successful motor policy.

[Special cases not covered: non-NEMA[1], multi-speed, DC, 900RPM, NEMA Designs C & D, and special purpose motors.]

CONDUCT A MOTOR INVENTORY AND SURVEY CRITICAL MOTORS

See Advanced Energy's Motor Survey How-To-Guide for more information and instruction on how to complete these critical first steps to a sound motor management policy.

ENSURE THAT MOTOR PURCHASING PROCEDURES ACCOUNT FOR LIFE-CYCLE COSTS

It is important to understand how much your motors cost to operate throughout their life cycle. By understanding these costs, you will make better decisions about motor repair or replacement.

Operating versus life-cycle costs

The first thing most people consider in any type of purchase is the initial cost. For a 75Hp, 1,800RPM motor that amount is just over $4,000[2]. By comparison, a car costs nearly $17,000.

If that motor operates 50 percent of the year [4,000 hours is two shifts, five days per week] and has a nameplate efficiency of 94.1 percent, at the current national average of $0.0702 per kWh, the motor will cost more than $16,000 to operate each year — that is four times more than the initial cost in the first year, and electricity costs are only expected to increase in the future.

Now consider the cost over the entire lifetime of these two investment scenarios. For the electric motor, invest only 2.5 percent of the life-cycle costs of the motor initially and pay 97.5 percent of the life-cycle costs as operating costs. See Table 1. By comparison, the car's initial cost is more than 65 percent of the life-cycle costs, and fuel costs a mere 35 percent of the life-cycle costs.

Purchase price should not be your only consideration when making your decision to purchase or repair. Efficiency also has a great impact on the life-cycle cost of an electric motor, which is the prime driver of motor economics.

Using life-cycle costs to make your decision

Operating costs account for the largest portion of of a motor's life-cycle costs. It is important to consider the savings potential between two options, such as purchasing two new motors or repair versus replacement in comparison to the initial investment. The incremental cost of selecting a particular option, such as purchasing a new NEMA Premium® motor, divided by the annual savings from selecting that option over a competing option, such as repairing an old motor, is called the payback period.

Table 1: Investment Comparison Summary

	75Hp Electric Motor	Car
Initial cost	$4,249	$17,200
Annual usage	4,000 hours	15,000 miles
Efficiency	94.1%	30 mpg
Fuel costs	$0.058/kWh	$2.599/gallon
Lifetime	10 years	7 years
Annual operating cost	$16,695	$1,300
Life-cycle cost	$171,199	$26,296
Operating cost as percent of life-cycle costs	97.0%	34.6%

The payback equation for motors can be rearranged to show when costs break even at a given payback period and electric rate. When plotted over time, this graph is called the horsepower breakpoint curve [as shown in Graph 1, page 3]. At given annual operating hours, the curve produces a facility's horsepower breakpoint, the horsepower rating above which motors should be repaired, and below which motors should be replaced with a new motor. This concept, as well as the curve's dependence on each facility's operating condition, is illustrated in the example on page 3. Create a custom curve online at:

http://www.advancedenergy.org/md/hp_breakpoint_tool.html

The following information is needed to produce the most accurate curve for your facility:

1. Average electric rate [$ per kWh]

Add your electric bills [energy, demand and fees] for the most recent 12 months. Add the total energy [kWh] used during the same period and divide the total cost by the total kWh to find the average electric rate. Contact your electric utility company for assistance if needed.

2. Maximum acceptable payback period

Many companies require a payback period of less than two years; however, some allow as much as 10 years for energy-efficiency or reliability projects. Check your company's payback requirements. Life-cycle costs should also be considered for how much money will be lost by not replacing with a NEMA Premium® motor.

3. Motor supplier discount

You will be asked to estimate a discount applied to new motor purchases by your motor supplier since many companies have negotiated lower costs than motor list price. Contact your purchasing department or your motor supplier for assistance.

4. Average motor load

This is the average load on the motor as a percent of the rated [nameplate] load. The average load is often assumed to be 75 percent, but may range from less than 25 percent to 125 percent. Since this varies by motor it may be necessary to check amp readings and compare them to the nameplate amps, or use readings from the motor's history record. For a more accurate watt measurement, see page 3 of our Motor Survey.

Example

A corporate engineer decides to find the horsepower breakpoint for two facilities, one in North Carolina with an average electric rate of $0.04 per kWh, and one in New Hampshire with an average electric rate of $0.12 per kWh. These facilities operate two shifts, five days a week [6,240 hours]. The company requires a two-year payback period. A contract with a motor supplier that provides a 40-percent discount from list price is in place, and the engineer determines the average motor load to be 75 percent.

Using the online tool at Advanced Energy's Web site [**http://www.advancedenergy.org/md/hp_breakpoint_tool.html**], the engineer produced the curves in Graph 1 showing that in North Carolina, 1,800RPM motors 25Hp and lower for open drip proof [ODP] enclosures and 10Hp and lower totally-enclosed, fan-cooled [TEFC] motors should be replaced with NEMA Premium® motors upon failure. In New Hampshire, replace 1800RPM motors 250Hp and lower for ODP enclosures and 60Hp and lower TEFC motors with NEMA Premium® motors upon failure.

MAKE THE RIGHT NEW MOTORS AVAILABLE

Planning and creating a motor inventory and motor specification will ensure availability of motors.

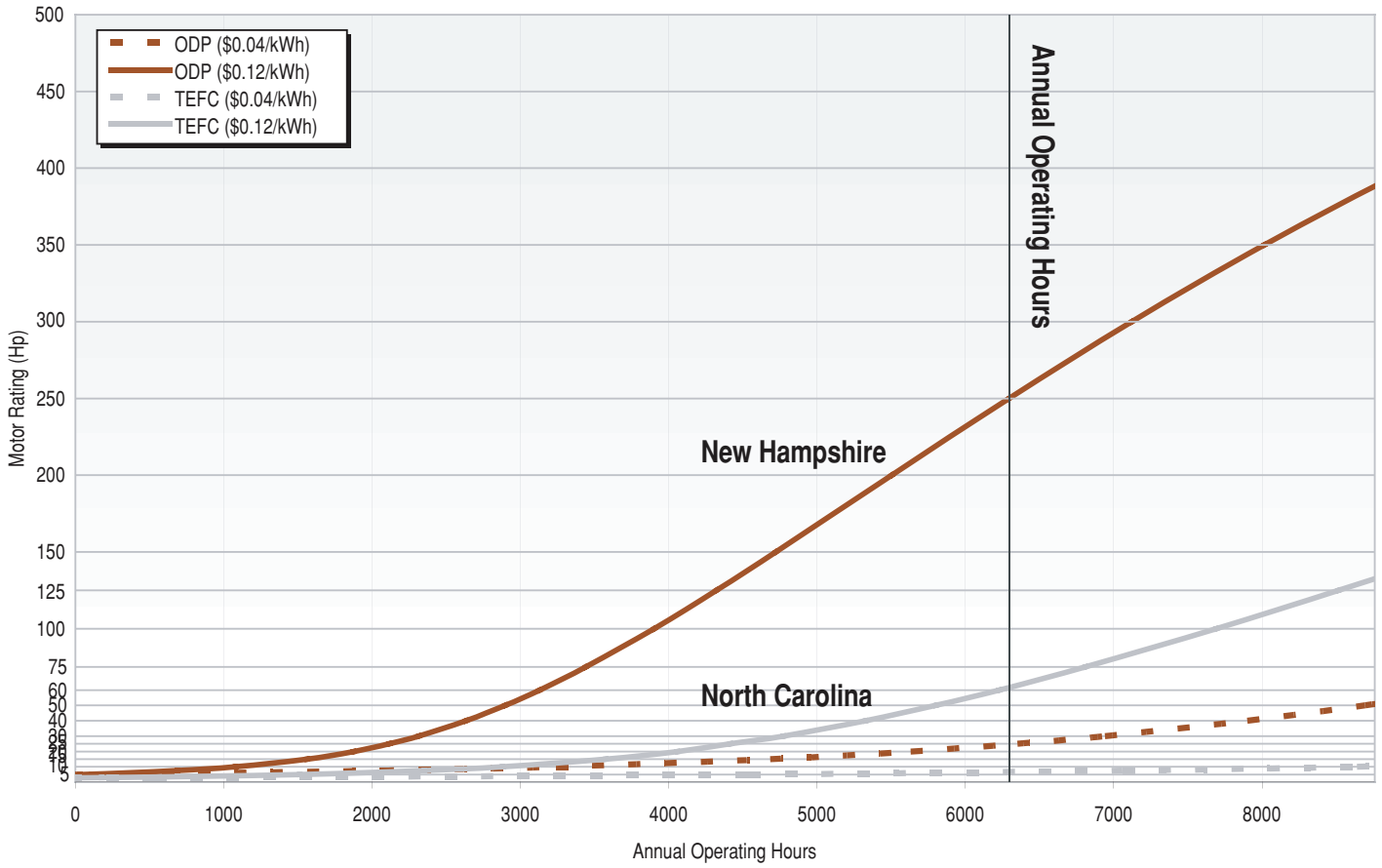
Establish an inventory system

An established inventory system systematically increases the efficiency of motor populations, which cuts costs by avoiding emergency motor repairs and statistically increasing the time between failure.

- Take care of critical motors first

  If the cost of downtime per hour is greater than the purchase price for a new motor in any application, a new motor should be purchased and installed at the earliest scheduled downtime. These motors should be replaced on a regular basis [i.e. every two to five years] to prevent unscheduled shutdowns, and a dedicated new motor should be kept as a spare in inventory. Where possible, build in-line redundancy into your most critical processes.

Graph 1: Breakpoint for Replacing a Failed Motor with a NEMA Premium® Motor



■ Keep inventory and records

Knowing which spares are available and how to locate them quickly will save time during unplanned motor downtime. Keeping records will also identify problematic motors or applications. Tools such as MotorMaster+, available for free through the U.S. Department of Energy, provide a management system for these motor records. One person should be responsible for maintaining these records if this service is not available through your motor suppliers.

■ Make records available to maintenance and the purchasing department

Use the inventory and records [especially failure and repair history] to reveal premature failures and identify good candidates for replacement as part of the budget cycle. This will help appropriately allocate funds for accounting and maintenance, and further streamline motor replacement at the time of failure.

Once the motors that require spares are identified, this inventory list can be used to negotiate cost and availability of replacement motors with your motor supplier. Make arrangements in the following order of preference: [a.] CONSIGNED INVENTORY: motors kept in your plant but owned by your supplier and billed when installed, [b.] GUARANTEED INVENTORY DELIVERED WITHIN FOUR HOURS: inventory maintained by supplier and [c.] OWNED INVENTORY: motors you purchase and store for your spares inventory.

Create a motor specification

Motor specifications ease the process of purchasing new motors. A motor specification lists basic standards for new motor purchases, and a more detailed specification addresses performance characteristics and specific applications.

At a minimum, a basic specification should include:

1. NEMA Premium® motors for new motor or equipment purchases. Also, note whether IEEE841 specifications are required for motors in harsh conditions. At a minimum, motors purchased should meet the energy-efficiency standard set forth by the United States government as part of the Energy Independence and Security Act of 2007 [EISA].
2. Same voltage and frequency as the plant where the motor will operate.
3. NEMA frame sizes [in feet and inches] on new equipment for future replacement flexibility.
4. Any necessary replacements for specialty motors, such as non-NEMA motors [i.e. metric, DC, etc.] in operation with NEMA Premium® motors and drives.
5. Speed equal to the motor being replaced.

Reducing Obstacles

Many facilities have an annual maintenance budget that accounts for motor repair but not new motor purchase. Using the tools provided in this bulletin simplifies the process. [and online at **http://www.advancedenergy.org/md/hp_breakpoint_tool.html**] simplifies the process.

Table 2: Motor Efficiencies

Hp	NEMA Premium®	Energy Efficient
1	85.5	82.5
1.5	86.5	84.0
2	86.5	84.0
3	89.5	86.5
5	89.5	87.5
7.5	91.7	88.5
10	91.7	89.5
15	92.4	91.0
20	93.0	91.0
25	93.6	91.7
30	93.6	92.4
40	94.1	93.0
50	94.5	93.6
60	95.0	94.1
75	95.4	94.1
100	95.4	94.5
125	95.4	95.0
150	95.8	95.0
200	96.2	95.4
250	96.2	95.4
300	96.2	95.4
350	96.2	95.4
400	96.2	95.4
450	96.2	95.8
500	96.2	95.8

Table values are for 1800RPM TEFC motors.
Efficiency values for other speeds and enclosures are available at http://www.advancedenergy.org/md/hp_breakpoint_tool.html

AUDITING YOUR MOTOR REPAIR FACILITY

- Is the facility's equipment in good condition?
- Is the facility in compliance with safety requirements, neatness and housekeeping?
- Are records and files well organized?
- Are employees knowledgeable and satisfied at work?
- Does the facility keep a variety of wire sizes and shapes in stock? [Look for half and full sizes if you have foreign motors.]
- What is the test equipment purpose and frequency of use?
- Does the facility comply with the motor repair quality standards or specifications supplied?
- Check the facility's compliance with standards and procedures published by EASA*. [Membership in EASA is a bonus.]
- Does the facility have an active quality assurance program?

MOTOR REPAIR QUALITY STANDARDS*

- Require repair to duplicate the original motor in:
  - Number of turns.
  - Winding design and coil configuration [lap or concentric].
  - Wire cross sectional area.
  - Rolling bearing size, type and specification including seals and/or shielding.
- Always replace bearings when rewinding. One-third to one-half of all motor failures involve bearing failures.
- Ask your repair facility to:
  - Record core loss before and after stripping.
  - Repair or replace defective laminations.
  - Calibrate instruments at least annually.
  - Measure and record winding resistance.
  - Measure and record no-load amps and voltage during final test.
  - Have a quality assurance program.
  - Have and use the following equipment: ammeter, voltmeter, wattmeter, ohmmeter, megohmmeter, high potential tester.
- Ask your repair facility NOT to:
  - Heat stators above 650°F.
  - Sandblast the iron core.
  - Knurl, peen or paint bearing fits.
  - Use an open flame for stripping.
  - Grind the laminations or file the slots.
  - Increase the air gap.
  - Increase stator winding resistance.
  - Make mechanical modifications without your approval.
  - Change the winding design.
- Ask if the repair facility will maintain records as part of your inventory system to help identify root causes of failures.
- Avoid rush rewinds if possible. Speeding certain processes [such as stator burn-out] can cause damage.

* Electrical Apparatus Service Association [EASA]

* From EASA Technical Note 16. Electrical Apparatus Service Association, 314-993-2220, www.easa.com

IDENTIFY PREFERRED MOTOR SERVICE PROVIDERS AND COMMUNICATE EXPECTATIONS

In order to make this policy work for you, several entities must be involved and aware of their role. When implementing your policy, specify one or two preferred motor service centers and negotiate a contract with a single motor supplier to ensure best pricing. This ensures expectations are communicated to those who are critical to the success of your motor policy.

Ensure quality repairs

The selected repair facilities should be researched, visited and have the right equipment and skill to meet motor repair criteria. Since ensuring they can meet specific criteria requires specific knowledge about motor repair, look for shops that have outside certification. EASA Q applies ISO9001 principles of documentation to standardize repair quality.

Proven Efficiency Verification [PEV] is the only motor repair certification program that requires annual before and after repair motor testing. The program also includes a site audit and inspection of equipment at least every five years. These measurements ensure the shops can repair motors to meet the undamaged performance characteristics. For more information about this program and the PEV repair facility nearest you, call Advanced Energy. If your repair facility has not been assessed by Advanced Energy, you can evaluate it qualitatively for characteristics consistent with quality work using the guidelines provided in this bulletin.

Build a relationship with motor suppliers

Providing a supplier with motor specification allows for an open and specific discussion about motor pricing and other services that may be beneficial [such as maintaining inventory and records]. Include in the motor specification the general criteria for all new motors, such as minimum efficiency level, NEMA frames and your facility's operating voltage and frequency.

IMPORTANT CONSIDERATIONS FOR MOTOR REPLACEMENT

Fan and Pump Applications

If energy savings are the reason for motor replacement, the replacement motor should have a nameplate full load RPM equal to or slightly less than the motor being replaced. If this is not an option, select the motor with the lowest full load speed [but same synchronous speed] available that meets the efficiency of Table 2.

This is important because a motor that runs faster will increase its power consumption as it delivers a greater process output, and can decrease the savings estimated by efficiency difference alone.

Sizing Replacement Motors

Be careful when considering downsizing. Motors may be oversized for many reasons, including high-starting loads or occasional short-duration, high-peak loads. Modern energy-efficient motor designs are efficient over a wider range of loads compared to older models. This allows motors that are slightly oversized to handle less than ideal operating conditions without sacrificing efficiency.

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[1]National Electric Manufacturers' Association, 202.457.8400, www.nema.org
[2]Pricing from MotorMaster+4.0, free download available at www.oit.doe.gov

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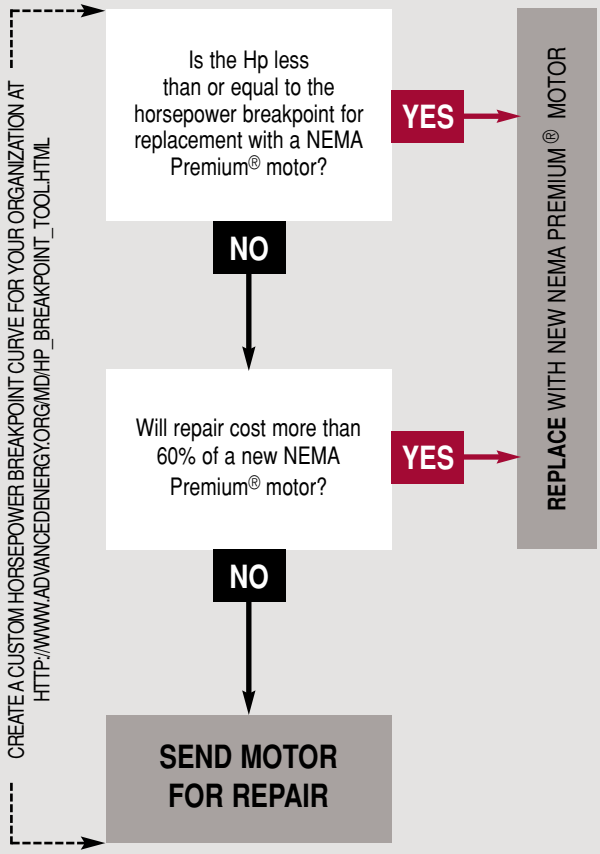
REPAIR OR REPLACE A MOTOR WHEN IT FAILS?



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