EFFICIENT, INEXPENSIVE MOTORS: A NEW TREND IN THE MOTORS MARKET

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ABSTRACT

The Consortium for Energy Efficiency (CEE) has established criteria for premium-efficiency motors above the EPACT standard. CEE has set a uniform efficiency benchmark that all market players (manufacturers, utilities, and end-users) can use. Some end-users however, have been reluctant to specify these motors because they think they are too expensive, or are not readily available.

Besides confirming that many motors that meet the CEE Premium-Efficiency criteria are available, recent research using MotorMaster software reveals a startling new reality in the motor market. Some motors that have the low lifetime energy cost associated with the CEE Premium-Efficiency level cost less than EPACT motors.

This is good news for corporate energy managers who need efficient, reliable and inexpensive motors. The paper includes a sample motor purchase and repair policy and presents a business case to show how adopting a similar motor policy can save money and boost productivity.

BACKGROUND

In days past, many utilities offered rebates for energy-efficient motors, because they cost about 15 to 20% more than standard motors. This strategy developed a strong market for energy-efficient motors. Now in the USA, you can no longer legally buy what was then called a "standard efficiency" motor (except for definite purpose motors). This is because the federal regulation, known as the Energy Policy Act (EPACT) was adopted from the National Electrical Manufacturers Association's (NEMA) energy-efficient motor criteria. The Consortium for Energy Efficiency (CEE) has established criteria for premium-efficiency motors above the EPACT standard. CEE and its member utilities have set a uniform efficiency benchmark that all market players (manufacturers, utilities, and facility managers) can use.

Every facility that relies on motors should have a written motor repair/replace policy. A premium-efficiency motor specification is an important part of this policy. However, some facility mangers have been reluctant to specify these motors, because they think they are too expensive or are not readily available. Recent research conducted by PRODUCTIVE ENERGY SOLUTIONS for a major Midwestern utility using the MotorMaster software database shows that these motors are widely available through a number of manufacturers in a wide range of sizes.

WHO SHOULD NOT READ THIS PAPER

Industrial facilities that subject their motors to harsh, abusive environments should not be wasting money buying inexpensive motors. When motors go down, profits go down with them. Companies that are surviving on thin margins in the face of global competition cannot afford the reduced productivity associated with downtime from failed motors.

Instead of looking for the least expensive motors, these facilities should consider specifying severe-duty motors that meet the IEEE 841 motor specification (2).

The lifetime cost of motors consists of three primary components: first cost, energy cost and downtime cost. Misguided attempts to reduce motor costs usually focus on the first cost of the motor. However, usually the lifetime energy cost is much larger than the first cost (30 to 60 times or more, depending on hours of usage, electric rate, and load fraction)[1]. Also, the downtime cost of lost production can sometimes be much larger than the energy cost if it is a critical motor. This would suggest that the motor purchase price is between 2 and 5% of the lifecycle cost of owning and operating the motor. It stands to reason that spending a little more on an IEEE 841 motor makes sense, when the potential savings in energy cost and downtime losses are so much larger than the first cost.

Ironically, some facilities think that because they are buying a lot of motors, they need to cut costs by buying low priced motors. However, buying based on low price alone increases costs more in the long run because of the reduced reliability and increased energy costs.

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[1] Various resources are available to help calculate the annual operating costs of a motor system, including MotorMaster software(6), the MotoRater calculator wheel (1), and an on-line interactive tool at www.ProductiveEnergy.com (5). See Bibliography.

REDUCE COSTS BY IMPLEMENTING A PROACTIVE MOTOR POLICY

Good maintenance managers can fix broken down motors and get production back up and running quickly. Great maintenance managers do all they can to avoid motor breakdowns in the first place. Along with a good preventive maintenance policy, one of the most important steps to take to eliminate motor breakdowns is to implement a proactive motor purchase and repair policy. A proactive policy reduces costs by reducing breakdowns and minimizing downtime when a motor does fail. In their "Motor Insight" booklet (3), Advanced Energy in North Carolina cites an example of a plant that found that repaired motors lasted only about half as long until breakdown as new motors. The booklet also suggests that on average, new motors are about 5% more efficient than the old rewound motors. This difference is mainly attributable to the energy-efficient design of the new motors. Performance degradation due rewind is possible, but not likely if the work is done according to repair standards published by the Electrical Apparatus Service Association (EASA).

METHODOLOGY

All NEMA frame Totally Enclosed Fan Cooled (TEFC), 460-volt, three phase, 1800-rpm motors between one and 200 hp were considered for the analysis. The original intent of the research effort was to establish an average price and average efficiency level for motors that do and do not meet the CEE criteria. This paper builds upon that effort. The author has no financial interest in any motor vendor or manufacturer. The unbiased results presented here are based on the following methodology:

1. First, the MotorMaster V3.01.04 database was queried to yield all 1800-rpm, 460-volt, TEFC motors, and these results were sorted by horsepower size.
2. Next, for each size, the motors were divided into three categories:
   a. Those that do not meet the EPACT criteria
   b. Those that do meet the EPACT criteria, but not CEE
   c. Those that meet the CEE criteria
3. Those that did not meet the EPACT criteria were removed from the analysis.
4. For each size, the average price and average efficiency was calculated for motors that meet the EPACT criteria and the CEE criteria.
5. For each size, the data for the motors that met the CEE criteria was queried to find those that were priced less than the average EPACT motor for that size.

All prices in the analysis are the list prices from MotorMaster. Street price is 30 to 40% less than list. Many fine motors that meet the CEE criteria are not listed here, because their list price is not less than the average list price for the EPACT motors. The author does not in any way mean to imply that these higher priced motors are not also a good value. Many of them in fact are excellent investments in increased productivity and energy efficiency.

INTEPRETING THE RESULTS

Table 1 is a comparison of the EPACT and CEE efficiency criteria for 1800-rpm TEFC motors. The CEE criteria raises the bar for energy efficiency by a percentage point or two above the federal EPACT standard. The savings from using motors that meet the CEE criteria will depend upon the actual operating hours, electric rate, and motor load.

Table 1. 1800-rpm TEFC Motors Efficiency Criteria Comparison

NEMA size hp	CEE Premium Efficiency	EPACT Minimum Efficiency
1	85.5	82.5
1.5	86.5	84
2	86.5	84
3	89.5	87.5
5	89.5	87.5
7.5	91.7	89.5
10	91.7	89.5
15	92.4	91
20	93	91
25	93.6	92.4
30	93.6	92.4
40	94.1	93
50	94.5	93
60	95	93.6
75	95.4	94.1
100	95.4	94.5
125	95.4	94.5
150	95.8	95
200	96.2	95

Facilities who have studied the costs of operating their motors usually find that the premium-efficiency motors have a two-year payback or less, so they decide to simplify the decision by adopting a motor purchase policy such as this one:

"All motors that operate more than 4 hours per day should meet the CEE criteria. Other

motors should meet the EPACT criteria. If no motor that meets the EPACT criteria is available, purchase a standard motor."

A simple policy such as this frees plant staff from doing a calculation every time they buy a motor, yet guides them in the proper direction to reduce long-term motor systems costs.

For all the major motor manufacturers, table 2 shows what percentage of their premium-efficiency line meets or exceeds the CEE criteria. Clearly some manufacturers have decided to embrace the standard, while others have not. Table 2 is adapted from the CEE web site. The Romans said "Caveat Emptor" or let the buyer beware! Just because the catalog says premium efficiency, doesn't mean it meets the CEE criteria. Savvy buyers know to verify that the NEMA Nameplate Nominal Efficiency meets or exceeds the efficiency criteria before the motor is ordered.

Table 2. Manufacturers' Adoption of CEE Criteria

Motor manufacturer	% of premium-efficiency line meeting CEE criteria
ABB	0
Baldor	100
GE	50
Grainger/Dayton	83
Leeson	Part of Marathon
Lincoln	81
Magnetek	67
Marathon	46
Reliance	78
Siemens	12
Sterling	24
Tatung	51
Teco/Westinghouse	60
Toshiba	67
U.S. Motors	62
WEG	54

Table 3 is a list of motor manufacturers that sell inexpensive premium-efficiency motors that meet the CEE criteria, but cost less than the average price of all EPACT motors their size. There are many fine motors made by nearly all the major domestic manufacturers that meet the CEE criteria that are not listed here because they may be more durable or have some other features that make them more expensive than the average EPACT motor. There are no 7-1/2 or 30-hp motors on the list. The data shows that some manufacturers are clearly zeroing in on the low-priced premium-efficiency motors market. Of course you should always review the specifications carefully before purchasing any motor.

Table 3. Low-Cost Premium-Efficiency Motors

Hp	Manufacturer	Efficiency	List
1	US Motors	86.5	$300
1	Dayton	86.5	$300
1	Toshiba	85.5	$286
1	Avg. EPACT		$303
1.5	US Motors	86.5	$315
1.5	Toshiba	86.5	$315
1.5	Avg. EPACT		$320
2	Sterling	86.5	$330
2	Toshiba	86.5	$342
2	US Motors	86.5	$342
2	Avg. EPACT		$352
3	US Motors	89.5	$393
3	Toshiba	89.5	$393
3	Lincoln	89.5	$397
3	Avg. EPACT		$417
5	US Motors	90.2	$448
5	Toshiba	89.5	$448
5	Avg. EPACT		$458
10	Sterling	91.7	$735
10	Avg. EPACT		$747
15	Lincoln	92.4	$975
15	Sterling	92.4	$1,000
15	Avg. EPACT		$1,040
20	Lincoln	93	$1,224
20	Avg. EPACT		$1,262
25	Sterling	93.6	$1,540
25	Dayton	93.6	$1,542
25	Toshiba	93.6	$1,542
25	Avg. EPACT		$1,562
40	Toshiba	94.1	$2,340
40	Dayton	94.1	$2,340
40	Avg. EPACT		$2,383
50	Lincoln	95	$2,993
50	Avg. EPACT		$3,006
60	Lincoln	95	$3,991
60	Toshiba	95	$4,284
60	Avg. EPACT		$4,542
75	Toshiba	95.4	$5,520
75	Avg. EPACT		$5,537
100	Lincoln	95.4	$6,576
100	Toshiba	95.4	$6,775
100	Avg. EPACT		$7,018
125	Lincoln	96.2	$8,780
125	Sterling	95.4	$8,818
125	Avg. EPACT		$9,079
150	Lincoln	96.2	$10,277
150	Avg. EPACT		$10,829
200	Lincoln	96.5	$12,990
200	Avg. EPACT	96.2	$13,265

SAMPLE REPAIR/REPLACE POLICY
(for a facility that pays 5 cents per kWh for electricity)

ABC MANUFACTURING
MOTOR PURCHASE AND REPAIR POLICY

This policy was developed for ABC Manufacturing, by Productive Energy Solutions, LLC using information provided by Tom Smith on 04 Feb 2001. The methodology has been adapted by Productive Energy Solutions from information published by the Electrical Apparatus and Service Association (EASA), the US Department of Energy's Motor Challenge program, and Advanced Energy's Horsepower Bulletin. Research has shown that besides being more reliable, new premium-efficiency motors are typically 5% or more efficient than older standard efficiency motors. This policy will yield a two-year payback (or less) for the new premium-efficiency motor, based on a $0.05/kWh average cost of electricity.

This policy covers all new and failed three-phase, 1800-rpm and 3600-rpm Open Drip Proof (ODP) or Totally Enclosed Fan Cooled (TEFC) motors in our facility. Use the policy below to determine whether a motor should be repaired. Exceptions and special cases are noted at the end of the memo. All new and replacement motors should meet the efficiency criteria defined in the table below if they will operate more than 4 hours per day.

Premium Efficiency Criteria

	1200 rpm		1800 rpm		3600 Rpm	
HP	ODP	TEFC	ODP	TEFC	ODP	TEFC
1	82.5	82.5	85.5	85.5	80.0	78.5
1.5	86.5	87.5	86.5	86.5	85.5	85.5
2	87.5	88.5	86.5	86.5	86.5	86.5
3	89.5	89.5	89.5	89.5	86.5	88.5
5	89.5	89.5	89.5	89.5	89.5	89.5
7.5	91.7	91.7	91.0	91.7	89.5	91.0
10	91.7	91.7	91.7	91.7	90.2	91.7
15	92.4	92.4	93.0	92.4	91.0	91.7
20	92.4	92.4	93.0	93.0	92.4	92.4
25	93.0	93.0	93.6	93.6	93.0	93.0
30	93.6	93.6	94.1	93.6	93.0	93.0
40	94.1	94.1	94.1	94.1	93.6	93.6
50	94.1	94.1	94.5	94.5	93.6	94.1
60	95.0	94.5	95.0	95.0	94.1	94.1
75	95.0	95.0	95.0	95.4	94.5	94.5
100	95.0	95.4	95.4	95.4	94.5	95.0
125	95.4	95.4	95.4	95.4	95.0	95.4
150	95.8	95.8	95.8	95.8	95.4	95.4
200	95.4	95.8	95.8	96.2	95.4	95.8

<u>Energy-efficient ODP and TEFC motors 1 to 200 hp</u>
(see table above)
If the motor already meets the efficiency criteria in the table above, repair the motor only if the repair cost is less than 60% of a new energy-efficient motor. Replace if the repair cost is greater than 60%.

<u>Standard efficiency ODP motors 1 to 200 hp</u>
If the efficiency does not meet the efficiency criteria in the table above, replace it with a new energy efficient motor that does. If it is driving a fan or pump, make sure that the full-load speed of the new motor closely matches the full-load speed of the old motor.

Standard efficiency TEFC motors 1 to 200 hp

Motor operating hours (or higher)	Replace motors this size (and smaller)
One shift 8 hours/day, 5 days/week, 2,000/year	**10 hp**
Two shifts 16 hours/day, 5 days/week, 4,000/year	**30 hp**
Three shifts, five days / week 24 hours/day, 5 days/week, 6,000/year	**60 hp**
Three shifts 7 days / week 24 hours/day, 7 days/week, 8,000/year	**100 hp**

If the motor is the same size or smaller than the size shown in the table above, then replace it with a new energy-efficient motor.
If the motor is larger than the size shown in the table above, repair it only if the repair is less than 60% of the cost of a new energy-efficient motor.

<u>Fans and pumps:</u> make sure that the full-load speed of the new motor closely matches the full-load speed of the old motor (no more than 5 rpm faster than the old motor for 1800-rpm motors, no more than 10 rpm faster for 3600-rpm motors). On belt driven fans, if only faster motors can be found, the pulleys and belts should be adjusted to maintain the fan speed.

<u>Exceptions:</u> Special motors such as 900-rpm, 1200-rpm, multi-speed, inverter duty, or wash-down duty motors usually would be repaired unless the cost of the repair exceeds 60% of the cost of a new energy-efficient motor.

<u>Beyond repair motor failures:</u> Temperatures above 650°F cause permanent damage to the magnetic properties of the stator core. Motors that have been on fire, involved in a fire, or sustained temperatures hot enough to blister the paint should not be repaired. Likewise, a motor with a bent or broken shaft, cracked rotor bars, or a hole melted in the stator core from a catastrophic electrical failure should not be repaired.

SUMMARY AND CONCLUSIONS

Motor users who drive critical loads, and/or subject their motors to harsh, abusive environments should consider purchasing the most expensive motors available (IEEE 841) in order to reduce motor system lifetime costs.

Motor users who want to reduce motor costs *and* buy inexpensive motors can consider the new breed of efficient, inexpensive motors that meet the CEE criteria. Use MotorMaster software so you understand the options before you pick up the phone, or better yet, use MotorMaster before the motor breaks down.

All facilities that purchase and repair motors should have a written motor purchase and repair policy in order to reduce downtime, maintenance and energy costs.

Readers who would like more information, or who would like to calculate the cost of operating a motor or to develop a customized repair/replace policy for their facility can do so for free, on-line at www.ProductiveEnergy.com.

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