Baldor Motor Basics: Premium Efficiency Motors

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Former Baldor motors expert Edward Cowern PE, is a name known and respected by many in the electric motor industry. During his tenure at Baldor, Cowern — now enjoying his retirement — was tasked with producing a number of motor- and basics-related tutorials. The tutorials were primarily in response to a steady flow of customer questions regarding motors and applications. Today's customers continue asking questions and seeking answers to address their various motor-related concerns. We hope you find these articles useful and would appreciate any comments or thoughts you might have for future improvements, corrections or topics.

(Following is Part 8 of Baldor Motor Basics — a continuing series of articles — courtesy of the Baldor Electric Co. — dedicated primarily to motor basics; e.g. — how to specify them; how to operate them; how — and when — to repair or replace them, and considerably more.)
Please note that while current regulations for the U.S. only allow production of premium efficient three-phase motors in the1–500 hp range, the information in this article is still relevant when comparing to older motors which may be installed in plant equipment — E. Cowern

Introduction

Conservation through lighting alterations using different bulbs, ballasts and light sources is well understood and easy to achieve. The use of improved efficiency three phase induction motors has not been as accepted. There are a number of reasons why conservation efforts with motors have not been as popular.

Light bulbs are sold by input ratings or watts. With the input rating being so prominent, it's easy to understand that if a 40-watt bulb is replaced by a 34 watt bulb, there will be savings. But, unlike light bulbs, electric motors are sold by output rating (horsepower) rather than input wattage. As a result, the measure used to evaluate differences in motors is the efficiency rating and efficiency shows up in the fine print and is not as easily understood as the wattage of bulbs.

The second reason lighting is different from motors is that lights are usually on or off — not in between. But motors can be running at full load, half load, quarter load, or no load. Frequently when motors are coupled through clutches to an intermittent motion system the motor may spend a lot of the time operating with no load. Similarly, air compressors may run unloaded much of the time. As a result of varying load levels and intermittent loading, projected savings based on full load efficiencies may not materialize.

That's the bad news.

The good news is that premium efficiency motors, with their enhanced designs, result in lower operating costs at any level of loading including no load. For example, the no load losses of a five horsepower premium efficiency motor might be 215 watts. The no load losses of a standard motor of the same type might be 330 watts. Figure 1 shows a plot of watts loss for various load levels on a conventional motor versus the premium efficiency motor of the same type. Curves of this type change dramatically with motor size, but trends are the same.

The Basics

The process of converting electrical energy to mechanical energy is never perfect. As much as we would like to have a 100% efficient motor, it is impossible to build a machine that will take 746 watts of electricity (the equivalent of 1 hp) and convert it to 1 hp of mechanical output. It always takes somewhat more than 746 watts to yield 1 hp's worth of output. It does become easier to approach 100% perfection with large motors than with small. For example, if the conversion process were only 50% efficient, then it would take 1,492 watts of electricity to get 1 hp's worth of output. Luckily, in industrial motors the conversion process is usually more efficient than this. The efficiency of standard industrial three phase motors usually runs from a level of approximately 75% at 1 hp up to 94% at 200 hp. The curve shown in Figure 2 illustrates the general trend of motor efficiency versus motor size for standard and premium efficiency motors.

A reasonable question might be, "Where does the extra

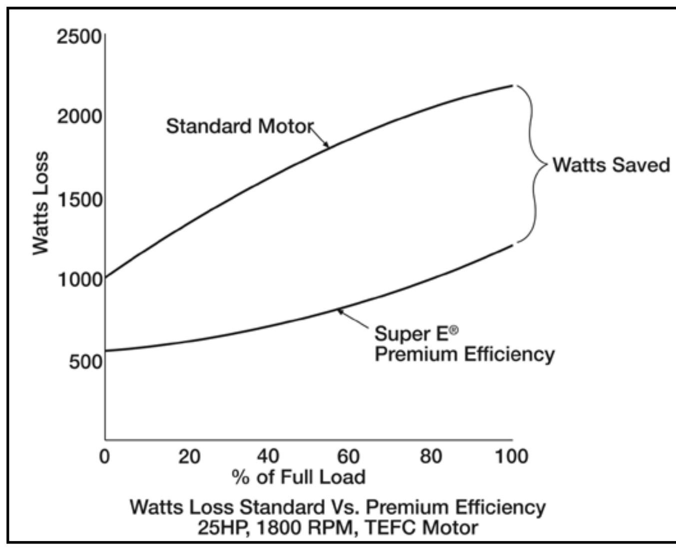


Figure 1 **Plot of watts loss for various load levels on conventional motor versus premium efficiency motor of same type.**

energy go?" In all cases, energy not delivered to the shaft becomes heat that must be carried away from the outside surface and internal parts of the motor.

As an additional complication, the efficiency of electric motors varies depending on the amount of load on the motor. Figure 3 shows the general trend of motor efficiency based on motor loading. For example, when a motor is running idle (no load on the output shaft), energy is being used by the motor to excite the magnetic field and overcome the friction of the bearings and the so-called windage of the rotating portion of the motor. Thus the efficiency at no load is 0%. The efficiency climbs as torque is applied to the motor shaft up to the point where the efficiency levels out and ultimately drops from its highest level. In most motors the peak efficiency will occur somewhere between 50 and 100% of rated load. The point at which it peaks is determined by the specific motor design.

To show where the losses occur in a fully loaded motor, Figure 4 gives a general outline of the flow of power through the motor. The flow is shown as 100% electrical power going to the motor on the left side and the various losses involved in converting the power until it ends up as mechanical power at the output shaft. In this case, the major losses are stator resistance loss (so-called Stator I2R). This is the largest single loss in the motor. It is followed by rotor resistance loss (Rotor I2R). Next come losses that are described as the core losses. These are losses resulting from the cycling magnetic forces within the motor. The more specific terms used for these losses are hysteresis and eddy current losses. Hysteresis loss is a result of the constant re-orientation of the magnetic field within the motor's steel laminations. Eddy current losses occur because the re-orientation of magnetic forces within the steel produces small electrical currents in the steel. These electric currents circulate on themselves and produce heat without contributing to the output of the motor. Hysteresis and eddy current losses occur in both the stationary and the rotating portion of the motor, but the largest share occur in the stationary portion.

15 Hp, 4-Pole, 3-Phase Phase Motor Typical Energy Flow

Next come the so called friction and windage losses. In this case the friction is the friction of the bearings. Ball bearings are extremely efficient, but still there are some losses generated as a result of the rolling of the ball bearings. Windage loss is a combination of things. First, the rotor spinning in the air creates some drag. The faster it spins, the more drag it creates with the surrounding air. In addition, there has to be air flow through or over the motor to carry away heat being generated by the losses. In most cases a fan is either incorporated on the shaft of the motor or designed in to the ends of the motor's rotor to provide air flow for cooling. This requires energy and uses input without developing output.

Finally, there is a category called stray load losses. These are losses that cannot be accounted for in the previous four categories. Generally, stray load losses are dependent on motor loading and increase as load is applied.

The accepted domestic test for electric motor efficiency is the one defined by IEEE Standard 112 Method B. This test method

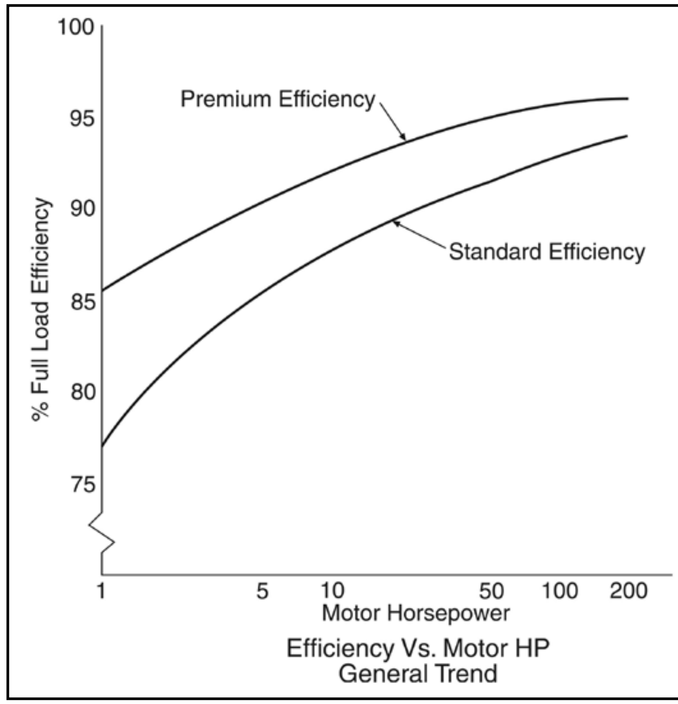


Figure 2 Curve shown illustrates general trend of motor efficiency versus motor size for standard and premium efficiency motors.

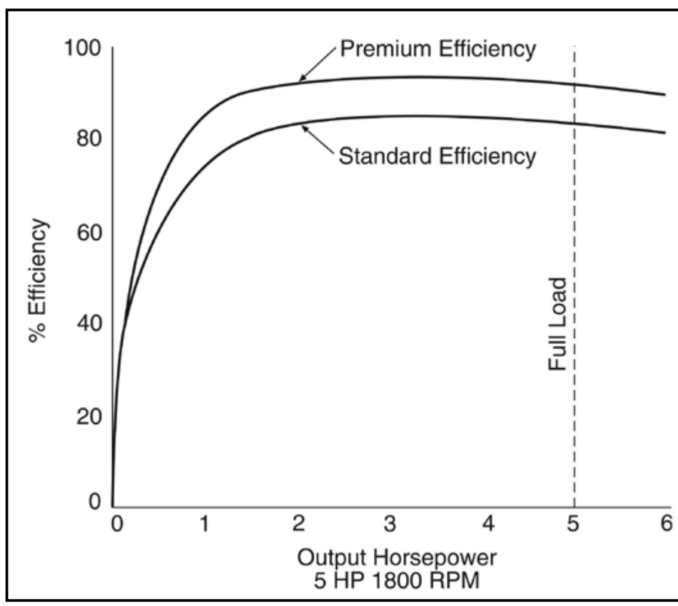
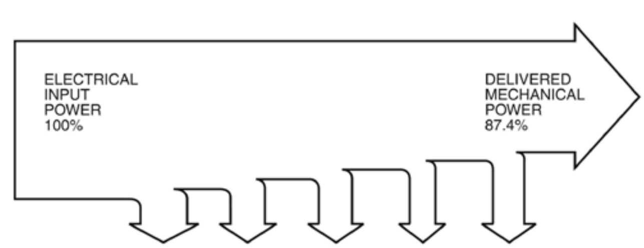


Figure 3 General trend of motor efficiency based on motor loading.



	STATOR RES. LOSS	ROTOR RES. LOSS	CORE LOSS	FRICTION & WINDAGE LOSS	STRAY LOAD LOSS	TOTAL
PERCENT OF LOSSES	30%	20%	19%	13%	18%	100%
PERCENT OF INPUT	3.8%	2.5%	2.4%	1.6%	2.3%	12.6%

Figure 4 General outline of flow of power through motor shows where losses occur in fully loaded motor.

accounts for all of these losses when the motor's performance is measured on a dynamometer. More about this later.

The energy flow diagram shown in Figure 4 would be typical for a standard motor of 15 hp. The mix of losses will vary somewhat based on motor size, but the diagram shows the overall trend of where the energy goes. It is important to note that many of the core losses and friction and windage losses are independent of the amount of load on the motor, whereas stator resistance loss, rotor resistance loss and stray load losses get larger as torque is applied to the motor shaft. It is the combination of these losses that produces the result of efficiency versus load shown in Figure 5.

Efficiency Improvement

To improve efficiency of a motor the five categories of losses mentioned previously are worked on one at a time. Reducing the stator resistance loss involves both magnetic and electric modifications that allow for more copper wire to be inserted in the slots of the stator of the motor. In general, the stator lamination design has to have slots large enough to accept more copper wire. For example, in household wiring #12 gauge wire has higher ampacity than #14 gauge wire. The same is the case in motors. But increasing the wire's size without increasing the amperage load results in less loss. In addition, the best reasonably priced conductor material must be used. In the case of electric motors, the best reasonably priced conductor material is copper.

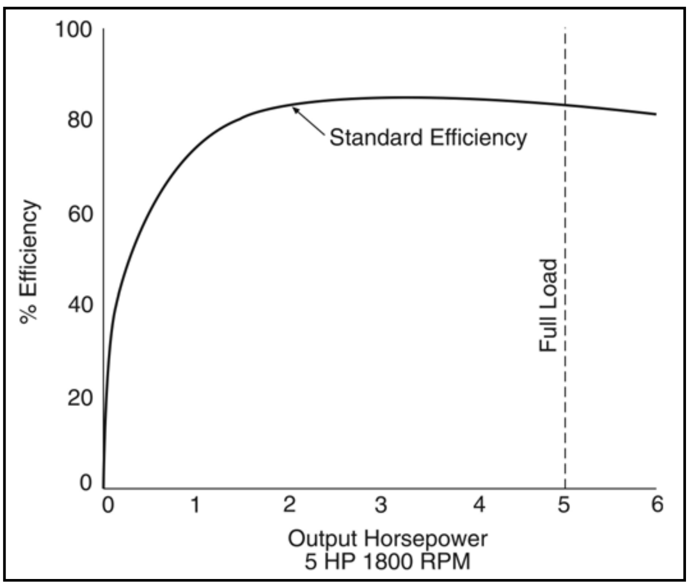


Figure 5 While many core, friction and windage losses are independent of motor load, stator resistance, rotor resistance, and stray load losses grow as torque is applied to motor shaft.

The second largest loss, rotor resistance, is reduced by using special rotor designs with larger areas of aluminum conductor. Using larger "rotor bars" results in lower rotor resistance and less rotor energy loss.

Hysteresis and eddy currents are reduced in many different ways. Hysteresis loss can be reduced by using improved steels and by reducing the intensity of the magnetic field. Eddy current losses are lowered by making the individual laminations that comprise the stator (and rotor) thinner and insulating them more effectively from each other.

In the case of friction and windage — there is little that can be done to improve the efficiency of bearings, but if the previously outlined steps have been effective in reducing total losses, the size of the cooling fan can be reduced — which helps increase motor efficiency.

The last component of losses is stray load loss. In this case, various manufacturing techniques are used to reduce stray load losses. With each of the five elements being worked individually and collectively, substantial improvements in motor efficiencies can be achieved.

Basis of Comparison

There are many different terms used to compare efficiencies of one motor to another. The two most often heard are nominal efficiency and guaranteed minimum efficiency. It is easy to get confused as to what basis should be used for determining potential savings from efficiency upgrades. The basis for nominal efficiency ratings can be explained in the following manner. If a large batch of identical motors were to be made and tested, the nominal efficiency would be the average efficiency of the batch. Due to manufacturing tolerances, some units might be less efficient and others more efficient. However, the nominal is the predictable average of the lot.

The second term used is guaranteed minimum efficiency. The guaranteed minimum recognizes the variations from one motor to the next and sets an arbitrary low limit. It says in essence, none of the motors in the batch will be less efficient than this.

With these two choices, what should be the basis of comparison?

If you had to stake your life on the result and it involved a single motor, then guaranteed minimum efficiency would be the one to use. However, if you're considering a number of motors in a range of sizes, and you're not held precisely to what the final minimum result would be, then nominal efficiency is the proper basis of comparison. Nominal efficiency also makes it easier because nominal efficiency is stamped on the nameplate of the motor. In addition, nominal and minimum guaranteed are related to each other by a formula established by the National Electrical Manufacturers Association (NEMA). So comparing different motors on the basis of "nominal" is really equivalent to comparing on the basis of minimum guaranteed.

Of more importance is the standard by which the efficiency is going to be determined. The standard should *always* be IEEE 112, Method B; of all standards developed for determining efficiency of motors, this is one of the most rigorous.

Other standards that are used, particularly some international standards, do not demand such rigorous testing. In some cases efficiency is merely calculated, rather than measured. In virtually all cases the "other" standards will give efficiencies higher than the tougher IEEE 112 standard. The correct basis of comparison should be that all motors be compared on the same standard. The IEEE method also measures the efficiency in the hot running condition. This makes it more accurate because the efficiency of the motor will fall slightly as operating temperature rises.

A Few Precautions

The result of using premium efficiency motors is not necessarily without some pitfalls. For example, premium efficiency motors run somewhat faster (have less slip) than their less-efficient counterparts. A premium efficiency motor might run at a full load speed of 1,760 rpm. The motor it replaces might be running at 1,740 rpm. This can help or hurt conservation efforts, depending on the type of load the motor is driving. For example, if it is driving a conveyor handling bulk materials, the higher speed will result in getting the job done faster. Also, if the conveyor has periods of light load, the reduced losses of the motor will save energy during that period of time.

The same situation exists on many pumping applications, where a specific amount of fluid is going to be used to fill a tank. If the motor runs faster, the work is completed sooner and the motor is shut down earlier. In these cases the consequence of the increased speed does not result in increased energy use. But there are applications such as chilled water circulating pumps where the extra speed can reduce expected savings.

The reason this can happen is that centrifugal pumps, along with other types of variable torque loads such as blowers and fans, require horsepower proportional to speed cubed. As a result a slight increase in speed can result in a sharper increase in horsepower and energy used. A typical example might be where the original motor is directly connected to a centrifugal pump. The original motor's full load speed is 1,740 rpm. The replacement premium efficiency motor, driving the same pump, has a higher speed of 1,757 rpm. The resulting difference of 1% will increase the horsepower required by the pump by $1.01 \times 1.01 \times 1.01 = 1.03$. Thus the horsepower required by the load is increased by 3% above what it would be if the pump speed had remained the same. Even with increased speed there remains, in most cases, some improvement in efficiency and reduction in energy usage, although it may not be what you hoped to achieve.

For fans and blowers the same thing would hold true if no changes take place to bring the equipment speed back to the original value. For example, if a motor drives a fan with a belt drive and the fan speed is 650 rpm, hanging the motor and using the same exact pulley and belt would increase the fan's speed and the horsepower required. This could reflect back as extra energy drawn from the power system. However, if an adjustment is made in the ratio between the pulleys to restore the fan speed to the original value, then the anticipated savings will materialize. These types of challenges make it desirable to look at efficiency upgrading as a "system" rather than strictly a motor consideration.

Driven Equipment Efficiency

As consumers, we are faced with energy efficient ratings on new refrigerators, air conditioners, hot water heaters, etc. The same type of data is usually not nearly as available on machinery purchased for industrial and commercial installations. For example, not all pumps with the same performance specifications have the same efficiency. Similarly not all air compressors have the same efficiencies. Some air compressors have dramatically better efficiencies than others — especially when operated at less than full load. At first glance it looks like a problem of evaluating one versus the other could be insurmountable. However, a good vendor should be willing to share certified performance information.

Proper Sizing

In addition to the challenge of different efficiencies from different equipment manufacturers there is also the matter of selecting properly sized equipment. For example, a pump oversized for the job may be much less efficient than a pump properly sized. Similarly, an air compressor oversized for the job may be much less efficient than one selected to more closely match actual requirements.

Evaluation

There are a great many ways to approach capital investment and determine rates of return, payback periods, present worth, etc. Most of these are good for large capital investments where there may be risk involved if the project doesn't work out or if the product changes or is affected by market dynamics. Electric motors and other conservation measures tend to be a simpler problem and usually do not need the rigorous mathematical treatment found in these more complicated analysis approaches**. Formulas to determine savings are found in the appendix of this paper.**

Ideal Motor Loading

In the process of upgrading efficiency a question comes up as to what the ideal load conditions should be for replacement motors. A motor that is overloaded will have short life. In the opposite situation, a motor that is grossly oversized for the job it is asked to do is inefficient. Figure 6 shows a typical load versus efficiency curve for a 10 hp motor. This curve shows that in the upper half of the load range (50% - 100%) the efficiency stays fairly constant at a high level. At loads below 50% the efficiency drops dramatically. In most situations, once the motor is in operation and running, the load doesn't vary. This is especially true on heating, ventilating and air conditioning applications such as circulator pumps and air handling equipment. On other types of machinery, such as air compressors and machine tools, the load may cycle on and off, heavily loaded for some periods and lightly loaded at other times. Obviously on cycling loads it is important to size the motor so that it can handle the worst-case condition. However, on continuously loaded motors it is desirable to load motors at somewhere between 50 and 100% and most preferably in the range of 75 to 80%. By selecting a motor to be loaded in this range, high efficiency is available and motor life will be long. Also, by loading at somewhat less than 100% the motors can more easily tolerate such things as low voltage and high ambient temperatures that can occur simultaneously in summer. This approach will get somewhere closer to optimum efficiency while preserving motor life.

Existing Motor Efficiency Upgrades

In a commercial or large industrial situation the question comes up: "Should motors be replaced on a wholesale basis

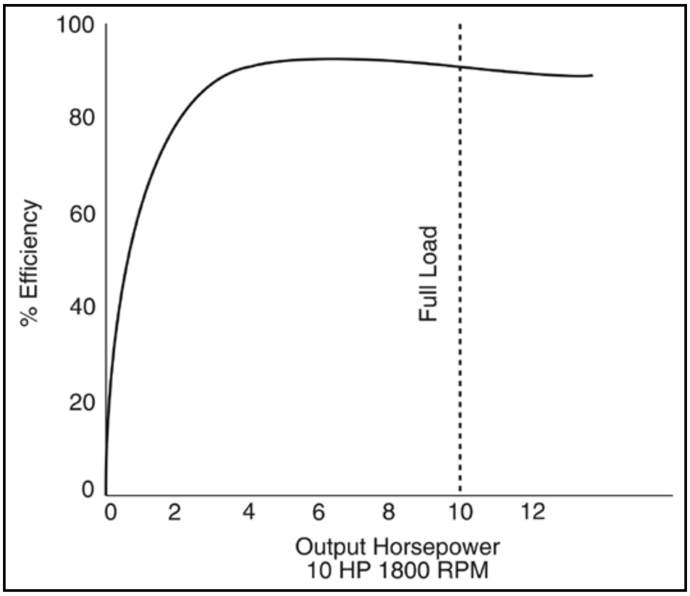


Figure 6 Typical load versus efficiency curve for a 10 HP motor; this curve shows that in the upper half of the load range (50% - 100%), the efficiency stays fairly constant at a high level.

throughout the plant, or selectively changed?" There is probably no hard rule for this, but here are some ideas. The wholesale change-out of all motors in a plant or commercial building generally cannot be justified on a cost basis. The reason for this is that some of the motors may be used only intermittently. Such things as test equipment, trash compactors and other similar situations support the case for not changing everything. There can also be other complications such as specialized motors found on some types of pumps and machine tools and old motors (where direct interchanges are not readily available). These fall into a cloudy area where change-out may not be justified.

Motors having the greatest potential for savings are those that run on an extended basis with near full load conditions. These are the logical candidates for any change-out program.

Utility Rebate Programs

A major breakthrough occurred a short time ago when court rulings were passed down so utilities could offer their customers financial help for conservation efforts. Prior to this change, utility companies were in a dilemma. If they financed and promoted conservation, the cost of the effort, personnel, equipment, etc., was an expense that reduced their sales and income. This set up a double disincentive for utility support of conservation measures.

Under the new rules utility money expended on conservation can be considered as a capital investment. Put differently, this means that financing the "buy back" of one kilowatt of capacity through conservation efforts is equivalent, for accounting purposes, to investing money to build a generating plant capable of generating that extra kilowatt. This new accounting approach has unleashed money that utilities are now willing (in some cases mandated) to invest in their customers' conservation efforts. A statement made by one utility indicated it was now possible to "buy back" a kilowatt of capacity for roughly two-thirds of the cost of installing a new kilowatt of capacity. This new approach has turned a losing situation into a win-win situation for utilities and their customers.

The result of this has been a great flurry of activity in utility rebate programs to finance various types of conservation efforts. Again, as with individual initiatives on conservation, lighting has received major attention because it is easy to understand and large gains can be quickly achieved. Electric motors and variable speed drive systems now receive more attention because they represent the equipment that utilizes almost two-thirds of the power generated in the country.

Rebate programs usually handle motors in two different ways. One is a rebate allowed for standard motors that fail in service. This rebate recognizes that the expense involved to remove the old motor and install a new one is going to be necessary. In the "failed motor" programs the rebate is usually reduced, but is based on making it economically feasible to buy the premium efficiency motor to replace the old standard efficiency motor. In this case, only the extra cost difference for the purchase of the premium efficiency motor is recognized and offset.

A second approach is used for operating motors where a higher rebate incentive is offered to cover some of the cost of removal and replacement of an operable motor.

In the case of the operating motors, the rebate is aggressive enough to encourage wholesale change-out of operating motors. In this particular case, in addition to the rebate, the benefits of reduced energy costs are enjoyed by the customer — with few strings attached.

There are many other rebate programs based on different concepts including some where the utility invests in the conservation project and the resulting savings are shared by the utility and the customer over a period of time. Utility rebates in whatever form are a great incentive.

Perhaps the most important aspect is that utility rebates have aroused the commercial and industrial consumer's interest in conservation with motors.

In all rebate programs, minimum efficiency standards for the new motors must be met and usually there is a qualifier regarding the number of hours per year the motor must operate to be considered. In situations where rebate programs are offered, especially the aggressive ones, there can be few excuses for not using premium efficiency motors.

Getting Involved

The steps for getting involved in upgrading your motor efficiency situation should be as follows:

New equipment. When purchasing new equipment that will operate for substantial periods of time, ask for the premium efficiency motor option. Written into your request for quotation on air compressors, pumps, HVAC equipment, process machinery, etc., should be a specification that reads something like this:

Bidder should quote with his choice of standard induction motors and as an alternative, quote on the same machine equipped with premium efficiency motors. Bidder will separate the incremental cost for the addition of the premium efficiency motor(s) and provide the nominal efficiencies of both the standard and the premium efficiency motors offered.

By using a specification similar to this, the ultimate owner of the equipment will be in the position to make logical decisions on new motors being installed in the facility. In most cases the incremental cost for a more energy efficient motor will be relatively small — especially when compared with the cost of the equipment it drives.

In-service failures. If a motor operates at a high level of load and runs reasonably long hours, replace it with a premium efficiency motor at time of failure.

Motors will normally last for many years if they are operated within reasonable limits and cared for properly. When they do fail it can be almost as expensive to get them repaired as it is to buy a new unit. Also, when a failure occurs, the labor to get the old motor removed and a rebuilt or new replacement in place is the same. In some cases labor can cost more than the motor. This makes time of failure the ideal time to make the change to get a more efficient motor in place.

Motor change-outs. Changing operating motors is the most difficult procedure to justify. It becomes feasible if the motors operate at high levels of load, have long hours of service, and especially if a utility rebate is involved.

If these three conditions are met, then you can start moving toward realizing bottom line savings available with premium efficiency motors.

Don't ignore the other possibilities. Some great energy saving possibilities, in addition to or in conjunction with premium efficiency motors, are the use of variable frequency drives. These are great energy savers, especially on variable torque loads such as centrifugal pumps, fans and blowers. On these types of loads the horsepower required varies as a cubic function of speed, and the energy varies almost in direct relationship to the horsepower.

Thus slowing a fan by 15% can yield energy savings of over 35%. Electronic variable frequency drives (VFDs) are extremely reliable and have become relatively inexpensive.

Two-speed motors also offer a simple and economical way to reduce energy costs. The speeds are not infinitely adjustable, as they are with adjustable frequency drives, but in those situations where that degree of adjustment is not necessary, the simplicity and economy of the two-speed motor and its control can yield great savings.

Don't ignore the opportunities with small motors. Many motor users in "light industry" and commercial facilities do not recognize the opportunity to save energy because they are of the opinion that their motors are "too small" to be viable candidates for efficiency upgrades. That thought process couldn't be more wrong! The degree of efficiency improvement on motors less than 10 hp is substantially more than it is on larger units. For example, the efficiency improvement between a standard 3 hp motor and a premium efficiency 3 hp motor might be 7 or 8%.

Comparing it in the same way with a 100 hp motor, the efficiency gain might be only 2%. The net result is that small motors have the potential for paying off their differential cost faster than large motors.

Operating Costs and Savings

Rule of thumb. To get some perspective on the costs to operate motors and some possible savings, here is a good rule of thumb:

At 5 cents per kilowatt hour, it costs $1 per horsepower per day to operate a motor at full load. (At 10 cents per kilowatt hour, this doubles to $2 per day.) In some parts of the country, such as Hawaii and Alaska, energy costs run between 20 and 40 cents per kilowatt hour. This value can be ratioed to reflect less than full load or less than continuous operation, etc.

Consider a 100 hp motor operating continuously in a 10 cents per kilowatt hour area. The annual cost of operation comes out to be approximately $70,000. This can represent about 11 times the first cost of the motor. By spending an extra 30% ($1,200) to get a premium efficiency unit (2.4% more efficient) the annual operating cost could be reduced by approximately $1,800.

In the case of a small 3 hp motor at 10 cents per kilowatt hour, the annual operating cost would be over $2,300 per year and an extra 40% spent on the motor could reduce the operating cost by $140 per year. In both cases mentioned, the extra cost of the motor would be paid off by energy savings in a few months.

When motors are running continuously at or near full load the initial cost of the motor is usually of little consequence compared with the annual operating cost.

Other Benefits

Because of their reduced losses, premium efficiency motors run at lower temperatures than equivalent standard motors. This results in longer insulation and lubricant life and less downtime. Inherent in their design is the ability to tolerate wider voltage variations and, when necessary, higher ambient temperatures.

An additional benefit is that by generating less waste heat in the space around the motor, building ventilation and/or air conditioning requirements are reduced. This can result in additional savings.

Summary

At the present time electric energy costs are high, but stable. Conservation has reduced the need for new generating facilities and the prices of fuels have been relatively constant. However, many nuclear plants are approaching the end of their useful life. As they are retired and their capacity has to be replaced, capital costs will certainly rise. Also, as the demand for clean-burning gas, liquid and solid fuels increases, the cost of these fuels is certain to rise. Thus it is important to seize every reasonable opportunity to conserve now. Adoption of premium efficiency three-phase induction motors is an easy and cost effective way to conserve.

OPERATING COST FORMULAS: MOTORS

$$\text{Kilowatt Hours} = \frac{\text{HP}^{**} \times .746 \times \text{Hours of Operation}}{\text{Motor Efficiency}}$$

*** Average Load hp (May be lower than motor nameplate hp)*

Useful Constants

Average hours per month = 730
Hours per year = 8,760
Average hours of darkness per year = 4,000
Approximate average hours per month (single shift operation) = 200

Annual Savings Formula

$$S = 0.746 \times HP \times C \times N \left[\frac{1}{E_S} - \frac{1}{E_{PE}} \right]$$

S = Dollars saved per year
HP = Horsepower required by load
C = Energy cost in dollars per kilowatt hour
N = Annual running hours
E_S = Efficiency of standard motor (decimal)
E_{PE} = Efficiency of premium motor (decimal)

General Formula — All Loads

$$\text{Kilowatt Hours} = \frac{\text{Watts} \times \text{Hours of Operation}}{1000}$$

Approximate Operating Cost = Kilowatt Hours × Average Cost per Kilowatt Hour
(*Does not include power factor penalty or demand charges which may be applicable in some areas.*)

PREMIUM EFFICIENCY MOTORS – (Q & A)

(Please note that while current regulations for the U.S. only allow production of premium efficient three-phase motors in the 1–500 hp range, the information in this article remains relevant when comparing to older motors that may be installed in plant equipment.)

In spite of the great money and energy saving potential available by using premium efficiency motors, it is surprising that many motor users are not specifying these motors. Some reasons for not using them are misunderstandings about the energy saving potential. The following information is presented in a question and answer format to address some of the myths and questions related to premium efficiency motors.

Can I save money even when I only have relatively small motors in my plant?

The energy saving potential of small premium efficiency motors is actually greater percentage-wise than the savings on large motors. The reason is that on small motors, the percentage difference in efficiency between the standard motor and the premium efficiency motor is actually much greater than it is on larger motors. For example, the difference between a standard motor at 3 hp and the premium efficiency motor could easily be 9 or more percentage points. Compare this to a 100 hp motor where the difference between the standard and premium efficiency motors might only be 2%.

Do my motors have to be fully loaded to realize the savings available in premium efficiency motors?

It is usually advantageous to have motors loaded to more than 50% of rated load for optimum efficiency. Thus, it is usually best to resize a motor at the same time it is upgraded to premium efficiency. However, even if this is not done and the motor is oversized, there is still substantial savings to be gained by utilizing a premium efficiency motor. For example, at 25% of rated load, the difference in efficiency between a standard motor and a premium efficiency motor (of 10 hp) would be 89.5% vs. 92.4%. Thus, the premium efficiency motor is still substantially better even at low load levels than a non-premium efficiency motor. Even without resizing, a substantial efficiency improvement can be made.

How much more do premium efficiency motors cost?

Generally, premium efficiency motors cost 20 to 30% more depending upon the size and speed of the motor.

Why do premium efficiency motors cost more than standard motors?

Premium efficiency motors use more and better materials. For example, the lamination material is a higher grade, higher cost steel. In addition, the rotor and stator are generally longer in a premium efficiency motor than in a standard motor. The laminations are thinner compared to a standard efficiency motor. This means there are more laminations. In addition, the lamination slots are larger so more copper can be used in the windings. Finally, premium efficiency motors are manufactured in smaller production lots which also tends to make them more expensive.

If premium efficiency motors can save lots of money, why don't more people use them?

This is a tough question but is probably related to the fact that many people buy on first cost rather than considering operating costs. Also, there seems to be skepticism about manufacturer's claims on performance of these motors. Many power users that have been very active in other energy conserving programs such as lighting, insulating etc., have ignored the energy-saving potential of premium efficiency motors.

Why can't motor manufacturers make it more obvious that we are going to save money with these motors?

Unlike light bulbs that are sold by wattage consumption (input), electric motors are sold by horsepower (output). Thus, subtle differences in efficiency usually appear in the fine print and get overlooked. For example, it is obvious when you buy a 34 watt fluorescent light bulb to replace a 40 watt bulb, that some savings are available. It is less obvious when you buy a 5 hp motor of one design versus a 5 hp motor of a premium efficiency design, that there will be savings on the electric bill. Also, the vagaries of electric bills and the complications involved in the electric billing process with demand charges, energy charges, fuel cost adjustments and occasionally, power factor penalties, create enough confusion so savings are not obvious. But they exist.

How can I evaluate the dollar savings on premium efficiency motors?

There are three items needed to conduct an evaluation. First and most important, is the average cost per kilowatt hour of electricity. The simplest and most direct way to get this is to take the bottom line cost on a monthly electric bill and divide it by the total kilowatt hours used. This gives a net cost per kilowatt hour which is generally the best cost to use in evaluating energy saving equipment. The reason this works is that equipment designed for better efficiency will in general, reduce the demand, kilowatt hours, and fuel cost adjustments in equal proportions. Thus, using the average cost per kilowatt hour is the easiest way of making an evaluation. Next would be the hp size of the motor that is operating and, finally, the number of hours per month or year that it operates. With these three items and the efficiency difference between one motor and the other, it is easy to figure the cost savings. (*The formulas for doing this appear at the end of this chapter.*)

How quickly will these motors pay for themselves?

This is impossible to answer without all the facts from the previous question but motors operating twenty-four hours a day at or near full load, can be expected to pay for themselves in less than two years. The difference between a standard motor's cost and a premium efficiency motor's cost can be paid off in a few months. One thing is certain: regardless of the operating details, premium efficiency motors will always save money versus lower efficiency units and savings go on for as long as the motor is in operation. In many cases this could be twenty to thirty years. Also, as power costs rise, savings will rise in proportion. The old rule of "pay me now or pay me later" has a corollary when applied to premium efficiency motors which might be "pay a little more now and save some now and more later."

Are there any other advantages to premium efficiency motors?

Yes, because of the superior designs and better materials used in them, premium efficiency motors tend to run at lower operating temperatures resulting in longer life for lubricants, bearings and motor insulation. Another advantage is that, by generating less waste and less heat in the space around the motor, air conditioning and ventilation requirements are reduced, resulting in additional energy savings.

What is the best way to take advantage of premium efficiency savings potential?

Specify motors that meet the NEMA Premium efficiency requirements on new equipment and as replacement units for failures. Some judgement should be used on blanket specifications. For example, it may be impractical to try to specify premium efficiency motors for single phase, fractional horsepower, and specialized motor requirements or where the motor is an integral part of the equipment. Also, on motor installations where infrequent service is required, the extra cost may not be justified. Examples of this would be trash compactors, batch mixers and other equipment that only operate for short periods of time. It might also be difficult to justify the added cost of premium efficiency motors on equipment that operates on a seasonal basis, especially if the season is short.

In summary, it is important to seize the opportunity to move into premium efficiency motor use as soon as possible. **PTE**