# AMPS, WATTS, POWER FACTOR AND EFFICIENCY
# WHAT DO YOU REALLY PAY FOR?

## INTRODUCTION

There seems to be a great deal of confusion among the users of electric motors regarding the relative importance of power factor, efficiency and amperage, as related to operating cost. The following information should help to put these terms into proper perspective.

At the risk of treating these items in reverse order, it might be helpful to understand that in an electric bill, commercial, industrial or residential, the basic unit of measurement is the kilowatt hour. This is a measure of the amount of energy that is delivered. In many respects, the kilowatt hour could be compared to a ton of coal, a cubic foot of natural gas, or a gallon of gasoline, in that it is a basic energy unit. The kilowatt hour is not directly related to amperes, and at no place on an electric bill will you find any reference to the amperes that have been utilized. It is vitally important to note this distinction. You are billed for kilowatt hours: you do not necessarily pay for amperes.

## POWER FACTOR

Perhaps the greatest confusion arises due to the fact that early in our science educations, we were told that the formula for watts was amps times volts. This formula, watts = amps x volts, is perfectly true for direct current circuits. It also works on some AC loads such as incandescent light bulbs, quartz heaters, electric range heating elements, and other equipment of this general nature. However, when the loads involve a characteristic called inductance, the formula has to be altered to include a new term called power factor. Thus, the new formula for single phase loads becomes, watts are equal to amps x volts x power factor. The new term, power factor, is always involved in applications where AC power is used and inductive magnetic elements exist in the circuit. Inductive elements are magnetic devices such as solenoid coils, motor windings, transformer windings, fluorescent lamp ballasts, and similar equipment that have magnetic components as part of their design.

Looking at the electrical flow into this type of device, we would find that there are, in essence, two components. One portion is absorbed and utilized to do useful work. This portion is called the real power. The second portion is literally borrowed from the power company and used to magnetize the magnetic portion of the circuit. Due to the reversing nature of AC power, this borrowed power is subsequently returned to the power system when the AC cycle reverses. This borrowing and returning occurs on a continuous basis. Power factor then becomes a measurement of the amount of real power that is used, divided by the total amount of power, both borrowed and used. Values for power factor will range from zero to 1.0. If all the power is borrowed and returned with none being used, the power factor would be zero. If on the other hand, all of the power drawn from the power line is utilized and none is returned, the power factor becomes 1.0. In the case of electric heating elements, incandescent light bulbs, etc., the power factor is 1.0. In the case of electric motors, the power factor is variable and changes with the amount of load that is applied to the motor. Thus, a motor running on a work bench, with no load applied to the shaft, will have a low power factor (perhaps .1 or 10%), and a motor running at full load, connected to a pump or a fan might have a relatively high power factor (perhaps .88 or 88%). Between the no load point and the full load point, the power factor increases steadily with the horsepower loading that is applied to the motor. These trends can be seen on the typical motor performance data plots which are shown in figure 1.

## EFFICIENCY

Now, let's consider one of the most critical elements involved in motor operating cost. This is efficiency. Efficiency is the measure of how well the electric motor converts the power that is purchased into useful work. For example, an electric heater such as the element in an electric stove, converts 100% of the power delivered into heat. In other devices such as motors, not all of the purchased energy is converted into usable energy. A certain portion is lost and is not recoverable because it is expended in the losses associated with operating the device. In an electric motor, these typical losses are the copper losses, the iron losses, and the so-called friction and windage losses associated with spinning the rotor and the bearings and moving the cooling air through the motor.

In an energy efficient motor, the losses are reduced by using designs that employ better grades of material, more material and better designs, to minimize the various items that contribute to the losses in the motor.

For example, on a 10 HP motor, a Super E energy efficient design might have a full load efficiency of 91.7%, meaning that, at full load (10 HP), it converts 91.7% of the energy it receives into useful work. A less efficient motor might have an efficiency of 82%, which would indicate that it only converts 82% of the power into useful work.

In general, the efficiency of motors will be relatively constant from 50% to 100% of rated load.

## AMPERES

Now, let's discuss amperes. Amperes are an indication of the flow of electric current into the motor. This flow includes both the borrowed as well as the used power. At low load levels, the borrowed power is a high percentage of the total power. As the load increases on the motor, the borrowed power becomes less and less of a factor and the used power becomes greater. Thus, there is an increase in the power factor as the load on the motor increases. As the load continues to increase beyond 50% of the rating of the motor, the amperage starts to increase in a nearly straight line relationship. This can be seen in figure 1.

## SUMMARY

Figure 1 shows significant items that have been discussed as plots of efficiency, power factor and watts, as they relate to horsepower. The most significant factor of all these is the watts requirement of the motor for the various load levels because it is the watts that will determine the operating cost of the motor, not the amperage.

The customer that has an extremely low power factor in the total plant electrical system, may be penalized by his utility company because he is effectively borrowing a great deal of power without paying for it. When this type of charge is levied on the customer, it is generally called a power factor penalty. In general, power factor penalties are levied only on large industrial customers and rarely on smaller customers regardless of their power factor. In addition, there are a great many types of power customers such as commercial establishments, hospitals, and some industrial plants that inherently run at very high power factors. Thus, the power factor of individual small motors that are added to the system, will not have any significant effect on the total plant power factor.

It is for this reasons that the blanket statement can be made, that increasing motor efficiency will reduce the kilowatt hour consumption and the power cost for all classes of power users, regardless of their particular rate structure or power factor situation. This same type of statement cannot be made relative to power factor.

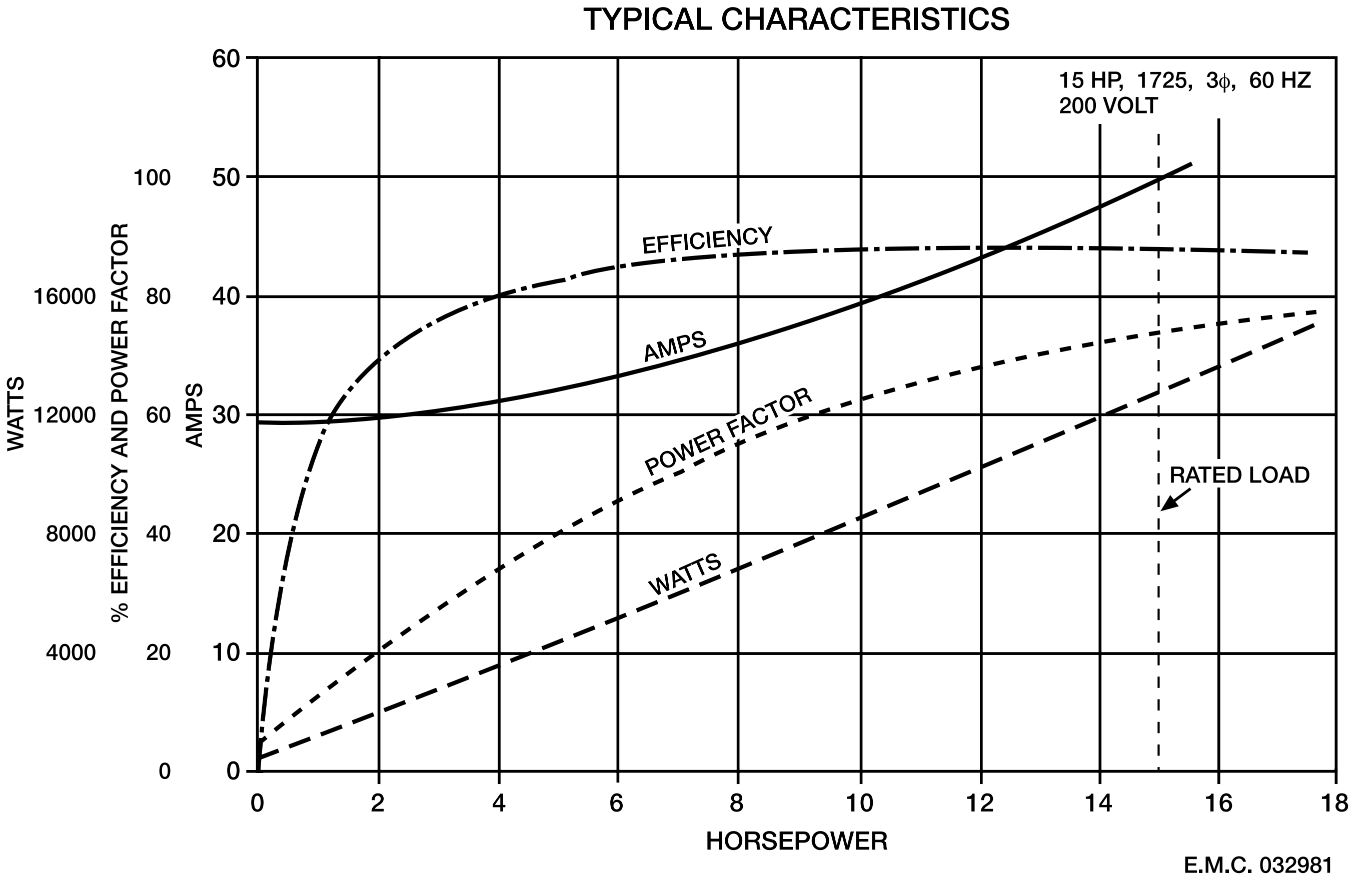
TYPICAL CHARACTERISTICS
15 HP, 1725, 3ϕ, 60 HZ
200 VOLT
EFFICIENCY
AMPS
POWER FACTOR
WATTS
RATED LOAD
WATTS
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Figure 1

The following basic equations are useful in understanding and calculating the factors that determine the operating costs of motors and other types of electrical equipment.

## OPERATING COST CALCULATIONS

### 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)

### General Formula All Loads

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

Approximate Operating Cost* = Kilowatt hours x Average Cost per Kilowatt Hour

* Does not include power factor penalty or demand charges which may be applicable in some areas.

### Useful Constants

| | | |
|---|---|---|
| Average Hours per Month | = | 730 |
| Average Hours per Year | = | 8760 |
| Average Hours of Darkness per Year | = | 4000 |
| Approximate Average Hours per Month (Single Shift Operation) | = | 200 |