# Motor Fundamentals

By Eric A. Woodroof, Ph.D., CEM, CRM
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Motors use more energy than any other single appliance type in the world. In addition- the annual electric cost to operate a heavily used motor can be 5 to 10 times the purchase price of the motor, so it is important to evaluate the "total cost of ownership" when buying a motor. When you consider that motors are on pumps, fans, compressors and many other devices, it is worth understanding the fundamentals, which can lead to big energy savings.

> *If you would rather watch a short webinar on this topic… You can access one here:* [https://www.profitablegreensolutions.com/special-samples](https://www.profitablegreensolutions.com/special-samples)

A motor is <u>not</u> a smart device. It is only a construction of magnets and wires… there is no computer or ability to make decisions. The motor simply converts electricity into magnetic energy, which is used to induce a rotation of the shaft. When a motor turns on, it spins as fast as it can, although the speed (rotations per minute or "RPM") is governed by the "no load" RPM equation below:

$$\text{SPEED} = \frac{60\,\dfrac{\text{cycles}}{\text{sec}} \times 60\,\dfrac{\text{sec}}{\text{min}}}{\text{number of pole pairs}}$$

Because most of the variables on the right-hand side of this equation cannot be easily changed, motors have "no load" RPM's that are predictable if you know how many magnet pole pairs were installed within the motor. In the USA (where the electric grid operates at 60 Hz), the "no load" RPM intervals are 900, 1800, 3600, etc.

When you look on the name plate of a motor (see sample below) it will have an RPM listed, which is the "full load" RPM. This RPM is usually slightly less than the predictable "no load" rpm intervals.

| | | | |
|---|---|---|---|
| Manufacturer Information | | AMPS 163. | VOLTS 460 |
| | | PH 3 | HZ 60 |
| NEMA NOM. EFFICIENCY | 96.2 | HP 150 | RPM 1785 |
| GUARANTEED EFFICIENCY | 95.8 | S. F. 1.15 | DUTY CONT |
| POWER FACTOR | 89.7 | Other Information | |
| MAX. CORR. KVAR. | 20.0 | | |

**Figure 1 - Typical Motor Nameplate Information (Google)**

*"No load" RPM and "full load" RPM can be explained with a bicycle analogy. When you are riding a bicycle on flat ground, you will reach a speed at which your legs cannot rotate the foot pedals any faster. That speed would be analogous to the "no load" rpm. However, if your bike goes up a hill, you would experience "load" and the rotations of the pedals will slow down.*

By measuring the RPM of a motor (how much it slows down when under a load), you can estimate the load on the motor. You can also estimate the load on a motor by measuring the amp draw of a motor and comparing it to the "full load" amp draw, which is often listed on the nameplate as "FLA" (full load amps). For example, if you measure 70 amps on an operating motor with a capability of 100 amps, then the motor is about 70% loaded.

Another important piece of information to get from the nameplate (or catalog) is the "locked rotor amps", which is the "inrush current" when the motor starts up under full load. *Referring back to the bicycle analogy, this is similar to when you're halfway up a hill and you stop... when you start again you have to put all of your weight and muscle onto one pedal to get the bike to roll and gain momentum. This very short period of pain in your leg would be analogous to inrush current that a motor experiences when starting on full load.* Inrush current can be 20 times higher than the full load amp draw of the motor, although it only lasts for a second or so. It is possible to set a new peak electric demand if you turn on a bunch of motors at the same time. One way to reduce the risk of setting a new peak is to stager the starting times of large motors, and/or install "soft starters" on motors, which slowly increase the amp draw.

Because there is a lot of torque required to start a large motor, most use 3 phase power. *3 phase power is analogous to having 3 pedals on a bicycle. Separated by an angle of 120 degrees, you would always have one pedal positioned to provide maximum torque (down stroke on a bike).*

AC induction motors cause the electrical supply's power factor to "lag". If your facility has a lot of motors (or other devices that convert AC electricity into magnetic fields), your power factor may become low enough that the utility will charge you a "power factor penalty". Many utilities world-wide will assess a penalty if your power factor drops below 85%. Some utilities charge you when you go below 100%. A relatively easy solution is to install capacitors (upstream electrically from the motor), which will help you maintain high power factor. On most motor nameplates, you will find "maximum kVAR", which indicates the size of the capacitor needed to correct the power factor lag of the motor. However, before buying a capacitor, consult an engineer or someone who regularly designs/installs/services capacitor systems. An expert may also give advice about installing a series of capacitors to automatically maintain your power factor for your whole facility.

"Service factor" could be retitled as "overload factor". It tells you how much you can overload a motor without consequence. For example- a service factor of 1.15 means you could overload a 100 hp motor to 115 hp without any significant damage to the motor.

Motors are interesting devices because they maintain high efficiency even when under a partial load (efficiency stays high all the way down to about 20% load). The figure below illustrates how a motor's efficiency is related to load. Most motors you will encounter in the working world might have an average load of 50%. If it's an HVAC motor, you could expect this load would be a little higher in the summer and a little lower in non-peak periods of the year. However, if you find that a motor is operating at less than 20% load (most of the time), you will want to "right-size" the motor to increase efficiency.

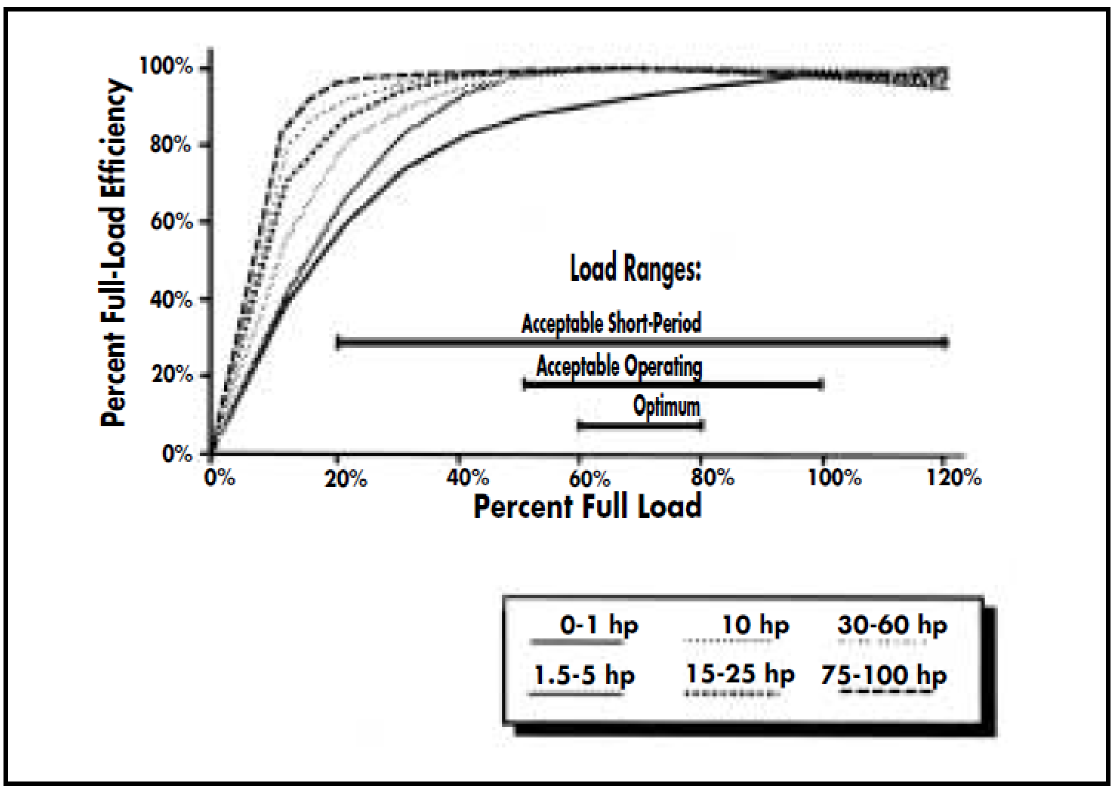


**Figure 2 - Motor Efficiency vs Load (Google)**

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Although there is no significant efficiency advantage to "right-sizing" a motor that is only 50% loaded, there is an advantage to installing a variable speed drive on any motor that is part loaded for a significant portion of the year.  The variable speed drive would allow the flow (air, water or any fluid) to be adjusted to match the load.

Historically, variable flow has been achieved via a number of approaches.  You may already have an outlet damper installed (this device looks like shutters on a window) to basically choke off the airflow after it exits the fan ("throttling" in pumps).  An "inlet vane damper" basically does the same by choking off the flow entering the fan.  *These devices are not very efficient because it is analogous to driving your car with your foot "pedal to the metal" on the accelerator and controlling your speed with the break.* If you see these devices on fans or pumps, it's probably best to replace them with a variable frequency drive which will adjust the speed of the motor by manipulating the frequency of the electrical current going into the motor.  As many readers know, the savings from VSDs can be 50% or more… so that is really worth knowing!

More information about the savings associated with variable speed drives can be found in this earlier article: [https://www.profitablegreensolutions.com/single-post/Energy-Savings-of-Variable-Speed-Drives](https://www.profitablegreensolutions.com/single-post/Energy-Savings-of-Variable-Speed-Drives)
However, I would consult an expert before implementing a VSD solution… you want to be sure everything is compatible and will operate well.

Hopefully, with this basic understanding of motor fundamentals, you can more easily spot opportunities for optimization in your facility, while saving energy and $$.